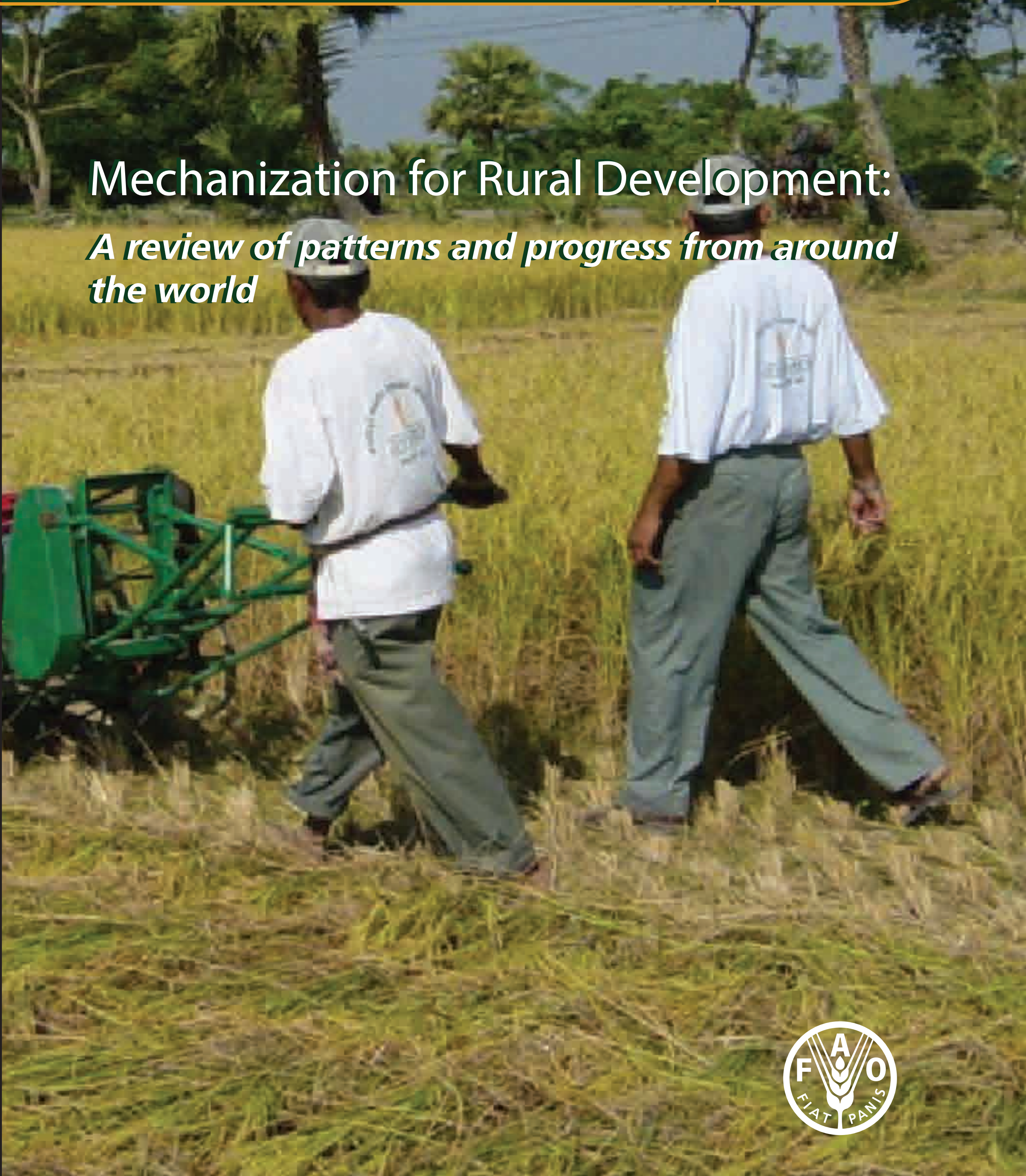
Integrated Crop Management Vol. 20–2013

ISSN 1020-4555



Mechanization for Rural Development:

A review of patterns and progress from around the world

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Mechanization for Rural Development:
A review of patterns and progress from around the world

Editors

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PLANT PRODUCTION AND PROTECTION DIVISION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2013

ISBN 978-92-5-107605-7 (print)
E-ISBN 978-92-5-107606-4 (PDF)

FOREWORD

Agricultural mechanization is a crucial input to agricultural crop production. It is frequently very capital intensive, compared to other (usually annual) inputs and it has repercussions on the efficiency of all other inputs used in crop production, including seeds, fertilizer, water, and time/labour. It is also much more complex in its application, requiring not only correct use, but also a service infrastructure for maintenance and repair. For this reason it is essential for FAO's Plant Production and Protection Division (AGP) to embrace the agricultural mechanization sector in the context of Sustainable Crop Production Intensification.

Whilst agricultural mechanization is indispensible for production, it can also have very detrimental effects on the environmental sustainability of farming (soil compaction and erosion, tillage, chemical pollution). However if the correct technologies are applied, for example: climate smart agriculture such as conservation agriculture; safe and efficient application of pesticides; precision application of fertilizers; soil compaction management; efficient harvesting; and natural resource conservation, then sustainable intensification can ensue.

The services provided to member countries will include the policies and infrastructures required by them to establish or expand their capacities to facilitate environmentally friendly mechanization in a socio-economically sustainable way. This includes roles for cooperatives, for the public sector, as well as for the commercial private sector, from financing and operational arrangements for the use of agricultural mechanization, to training in the use of machines, their maintenance and the related commercial supply infrastructure for sales, and after sales services.

This publication presents a kaleidoscopic view of agricultural mechanization experiences from around the globe and, as such, provides a solid launching pad for the promotion of sustainable mechanization technologies that are so vital if we are to feed, with due regard to the planet's natural capital, the burgeoning world population both now and into the future.

Clayton Campanhola
Director
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ACKNOWLEDGEMENTS

This compilation of agricultural mechanization experiences from around the world is the culmination of an activity initiated by Geoffrey C. Mrema when he was Director of the Rural Infrastructure and Agro-Industries Division (AGS) of FAO. The papers that became the 16 Chapters were commissioned by FAO and have been subjected to initial edition and revision by a team of editors including: John E. Ashburner, Reynaldo Lantin, Josef Kienzle, Brian G. Sims, Geoffrey C. Mrema, Divine Njie and Lawrence J. Clarke. Dmitry Prikhodko of FAO's Investment Centre Division contributed useful comments, especially on Chapter 9. Final editing of the complete set was undertaken by Brian G. Sims in August and September 2012. Magda Morales formatted the document for printing and we express our appreciation of her efforts. Proof reading was undertaken by John E. Ashburner and Brian Jackson.

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ABBREVIATIONS AND ACRONYMS

ADBN	Agricultural Development Bank, Nepal
ADLI	Agricultural Development Led Industrialization
ADMA	Agricultural Dealers and Manufacturers Association
AFMIC	Agricultural and Fishery Mechanization and Infrastructure Committee
AGCO	Allis-Gleaner Corporation
AGRISHOW	International agriculture in action trade fair (Brazil)
AGS	Rural Infrastructure-and Agro-Industries Division (of FAO)
AGSE	Agricultural Engineering Branch (of FAO)
AICRP	All India Coordinated Research Project
AIT	Asian Institute of Technology
AMS	Agricultural Mechanization Strategy. Agricultural Mechanization Stations China)
ANFAVEA	National association of motor vehicle manufacturers (Brazil)
ARCEDEM	African Regional Centre for Engineering, Design and Manufacture
ARDA	Agricultural and Rural Development Authority (Zimbabwe)
AREX	Department of Agricultural Research and Extension (Zimbabwe)
ASEAN	Association of South-East Asian Nations
BIS	Bureau of Indian Standards
BRRI	Bangladesh Rice Research Institute
CA	conservation agriculture
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology (Tanzania)
CAR	Central African Republic
CARD	Coalition for African Rice Development
CAT	Conservation Agriculture Technology Database
CDA	controlled droplet application
CGIAR	Consortium (formerly Consultative Group) of International Agricultural Research Centers
CIAE	Central Institute of Agricultural Engineering (India)
CIFEMA-SAM	Bolivian small-scale agricultural machinery manufacturing company
CIGR	International Commission of Agricultural and Biosystems Engineering

CIMMYT	International Maize and Wheat Improvement Centre
CIPHET	Central Institute of Post Harvest Engineering and Technology (India)
CIS	Commonwealth of Independent States
CKD	completely knocked down
COMECON	Council for Mutual Economic Assistance
CNH	Case New Holland
DA	Department of Agriculture
DAP	draught animal power
DDF	District Development Fund (Zimbabwe)
DEES	Directorate of Extension and Engineering Services (Namibia)
DFID	Department for International Development
DGPS	differential global positioning systems
DRC	Democratic Republic of Congo
EAC	East African Community
ECA	Europe and Central Asia
EIMA	International agricultural and gardening exhibition (Italy)
ENTAM	European Network for Testing of Agricultural Machines
ESCAP	Economic and Social Commission for Asia and the Pacific
EXPOINTER	Rio Grande do Sul agricultural fair (Brazil)
EU	European Union
FANR	Faculty of Agriculture and Natural Resources (Namibia)
FAO	Food and Agriculture Organization of the United Nations
FEBRAPDP	Brazilian federation for no-tillage farming
FFS	Farmer Field School
FMP	Farm Mechanization Programme (Zimbabwe)
FSU	Former Soviet Union
FTLRP	Fast Track Land Reform Programme (Zimbabwe)
FY	Financial Year
GB	Governing Body
GDP	Gross Domestic Product
GFCF	Gross fixed capital formation
GIS	Geographic information systems
GPS	Global Positioning System
GW	Gigawatt
HIV/AIDS	human immunodeficiency virus infection / acquired immunodeficiency syndrome
HYV	high yielding variety
IAE	Institute of Agricultural Engineering (Zimbabwe)
IAPAR	Parana State Agricultural Research Institute (Brazil)
IBGE	Brazilian institute of geography and statistics
ICAR	Indian Council for Agricultural Research

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDE	International Development Enterprises
IFAD	International Fund for Agricultural Development
IIT	Indian Institute of Technology
IITA	International Institute of Tropical Agriculture
ILO	International Labour Organization
InPhO	Information Network on Post-Harvest Operations
INTDIR	International Directory of Agricultural Engineering Institutions
IPAM	Environmental research institute of Amazonia (Brazil)
IRRI	International Rice Research Institute
ISO	International Organization for Standardization
ITINTEC	Institute for research into industrial technology and technical standards (Peru)
ITMCO	Iran Tractor Manufacturing Company
JECF	Japan-ESCAP Co-operation Fund
JICA	Japan International Cooperation Agency
KR	Kennedy Round
kW	Kilowatt
LIDAR	light detection and ranging
MADI	Mashare Agricultural and Rural Development Institute (Namibia)
MAPA	Ministry of agriculture, livestock and supply (Brazil)
MDA	Ministry of agrarian development (Brazil)
MDG	Millennium Development Goal
MECI	Morogoro Engineering Cluster Initiative
MOAC	Ministry of Agriculture and Cooperatives (Swaziland)
MODERFROTA	Programme of modernization of the agricultural tractor fleet, implements and harvesters (Brazil)
M&M	Mahindra & Mahindra
MTS	Machine Tractor Stations (China)
NABARD	National Bank for Agriculture and Rural Development
NAEF	National Agricultural Engineering Forum (Nepal)
NAIP	National Agricultural Innovative Project (India)
NAMTA	National Agricultural Machinery Traders Association (South Africa)
NARC	Nepal Agricultural Research Council
NAREGA	Mahatma Gandhi National Rural Employment Guarantee Scheme (India)
NARS	National Agricultural Research System
NATMIRC	National Marine Information and Research Centre (Namibia)
NATP	National Agricultural Technology Programme (India)

NAWIC	Namibia Agricultural Water and Information Centre
NCD	North Central Division (Namibia)
NED	North Eastern Division (Namibia)
NEPAD	The New Partnership for Africa's Development
NFMC	National Farm Mechanization Committee
NHB	National Horticulture Board (India)
NHM	National Horticulture Mission (India)
NGO	Non-Governmental Organization
NI	National Institute
NN	National Network
NNFU	Namibia National Farmers Union
NT	No till
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
PPP	Public Private Partnerships
PRONAF	National programme to strengthen family agriculture (Brazil)
PUMP	Productivity Upliftment Micro-projects Project (Namibia)
REFPI	Research and Extension in Farm Power Issues (Bangladesh)
RNAM	Regional Network for Agricultural Machinery
RO	Regional Office
RS	remote sensing
SAAMA	South African Agricultural Machinery Association
SAU	State agricultural universities (India)
SCMP	Smallholder Credit and Marketing Project (of IFAD)
SCPI	Sustainable Crop Production Intensification
SDSB	Swaziland Development and Savings Bank
SIL	Systematics International Limited
SKD	semi-knocked down
SME	small and medium-scale enterprises
SNL	Swazi National Land
SP	sub-programme
SSA	sub-Saharan Africa
STP	Sâo Tomé and Príncipe
STW	shallow tube well
TAC	Technical Advisory Committee
TAFE	Tractors and Farm Equipment Ltd.
TCDC	Technical Cooperation between Developing Countries)
THS	Tractor Hire Services
UK	United Kingdom
UN	United Nations
UNAPCAEM	UN Asian and Pacific Centre for Agricultural Engineering and Machinery
UNDP	United Nations Development Programme

UNIDO	United Nations Industrial Development Organization
USD	United States dollars
USSR	Union of Soviet Socialist Republics
VDMA	German association of mechanical and plant engineering
WAMED	Worldwide Agricultural Machinery Directory
WARDA	West African Rice Development Association
WT	Wheeled Tractor (as in 2WT and 4WT)

SUMMARY

Farm mechanization seems to have become, to a certain extent, the neglected waif of agricultural and rural development. As an essential input, mechanization can transform farm family economies by facilitating increased output and reducing the drudgery of hand-powered production. Mechanization, when carefully selected and appropriate to the task, is also capable of protecting natural capital and the environment whilst boosting food production.

However we have seen in recent years that consideration of mechanization as a vital input, in need of research and development, has been frequently neglected. Indeed, and as an example, the UK Government's 2011 Foresight Report (Foresight: The Future of Food and Farming: Challenges and choices for global sustainability[1]) barely mentioned the role of agricultural engineering. Following a meeting with the Government Chief Scientist, the UK's Institution of Agricultural Engineering was invited to respond to this deficiency and, as a result, produced, in 2012, the document 'Agricultural Engineering: a key discipline enabling agriculture to deliver global food security'[2].

Agricultural engineering departments in the CGIAR'[3]s international research centres have been wound down and closed and the availability of world-class undergraduate training is also in serious decline. Why this should be the case is not clear when careful studies have made it abundantly clear just how crucial an input mechanization is in the pursuit of global sustainable crop production intensification and improved rural livelihoods (for example see the deliberations of the 2009 FAO, Rome forum on how to feed the world in 2050[4]). In FAO itself the resources invested in the selection of appropriate mechanization options have been declining, although the vital role of rural mechanization is recognized as a vehicle for raising rural incomes through high quality service provision on the farm, for road transport and in the development of entrepreneurial enterprise in the agricultural product value addition chain[5].

However, following the recent food scarcity and price hike and the subsequent financial crisis with spiking prices for food stocks such as maize, wheat and soya, the focus of the world returned to a realization of the important role of agricultural production and productivity. When looking at the resources required for increased and sustained agricultural production (land, water and

1 http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf.
2 http://www.iagre.org/sites/iagre.org/files/repository/IAgrEGlobal_Food_Security_WEB.pdf
3 Consortium on International Agricultural Research
4 http://www.fao.org/wsfs/forum2050/wsfs-background-documents/hlef-issues-briefs/en/
5 See FAO's recent Diversification Booklet 19: Hire services by farmers for farmers. http://www.fao.org/docrep/015/i2475e/i2475e00.pdf

farm power for mechanization) it is clear that Africa has comparatively the most abundant land resources; however, the continent has the lowest farm power base with less than 10 percent of mechanization services provided by engine-powered sources. At the same time approximately 25 percent of farm power is provided by draught animals and over 70 percent comes from people's muscles (mostly from women, the elderly and children). This human power source often only has rudimentary tools and equipment at its disposal for soil preparation, crop care, transport of goods and bucket irrigation.

The 2009 high level FAO expert forum already referred to has made it very clear what the challenge ahead is: how to feed approximately 9 billion people in the year 2050. We have learnt lessons and now we must take care that the past mistakes of trying to achieve intensification only through mechanization is adapted to ensure its sustainability. FAO has coined the term "Sustainable Crop Production Intensification (SCPI)". In other words we need to produce more food with fewer inputs. One could also say that the goal is to produce food more efficiently in terms of energy inputs compared to the food outputs. FAO has summarized this vision in a guide for policy makers called Save and Grow[6]. In parallel with this guide, we must also ensure that mechanization initiatives are sustainable. Mechanization should not only be seen as the employment of heavy duty, high horse power equipment to clear the remaining virgin lands and forests, which would be extremely undesirable. Sustainable mechanization means the use of intelligent, lean and efficient engineering technology solutions to minimize the impact of heavy machinery on the natural resource base – the soil and the landscape.

Modern engineering technology does not necessarily require the genetic modification of crop plants (although this can be one more tool in the toolbox needed to achieve SCPI). It can be applied through simple solutions at the available farm power level (hand/human, draught animal and mechanical/motorized). One good example of this approach comprises the simple forms of precision farming that make efficient use of available seeds and fertilizer and inputs for crop protection. Other positive examples would include: the multi-use of expensive machinery for transport and for irrigation pumps besides farm mechanization only; conservation agriculture (with specialized mechanization) to arrive at energy efficient and lean soil management in line and accompanied by the protection of natural processes; and drudgery reduction. In the same way that FAO and the world have an obligation to eliminate hunger from the globe, FAO and partner agencies in development also have an obligation to appreciate that the poorest and most vulnerable people (women, elderly, children) are often undertaking the bulk of the farm work with simple or rudimentary tools; and this should no longer be tolerated. Inputs of mechanization and related services at the appropriate technology level can have a tremendous impact on

[6] http://www.fao.org/ag/save-and-grow/

reducing drudgery which is in itself already a major, socially driven, motivation and reason for increasing support to agricultural mechanization[7].

This present set of 16 discussion papers provides a world-wide kaleidoscope of farm mechanization issues for developing countries and brings out many site-specific (or rather region-specific) issues which should be of vital interest to policy makers globally.

The full list of papers, as they appear in the Chapters of this book, is as follows:

Africa

1. Investing in Agricultural Mechanization for Development in **East Africa**. Nuhu Hatibu
2. Agricultural Mechanization in **Southern African Countries**. Timothy E Simalenga
3. Agricultural Mechanization in **West and Central Africa**. Mathias Fonteh

Asia

4. Rural and Agricultural Mechanization in **Bangladesh and Nepal**: Status, processes and outcomes. Scott Justice and Stephen Biggs
5. Agricultural Mechanization in **India**. Gajendra Singh
6. **China**: Development of Farm Mechanization and the Agricultural Machinery Industry. Maohua Wang

Near East

7. The **Near East** Region. Bassam A Snobar and El Hassane Bourarach

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8. The Development of Farm Mechanization in **Brazil**. Francisco de Assis de Carvalho Pinto, Daniel Marçal de Queiroz and Ricardo Capúcio de Resende

Transition Countries of Eastern Europe and Asia

9. Agricultural Mechanization in **Countries in Transition in Eastern Europe and Central Asia**. Lawrence Clarke

Cross-cutting themes

10. Agricultural Mechanization and the **Environment**. Theodor Friedrich
11. **Agricultural Mechanization Strategies**. John Ashburner and Reynaldo Lantin
12. Agricultural mechanization in development: **A donor's view**. Tokida Kunihiro

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[7] FAO. 2006. Farm power and mechanization in sub-Saharan Africa. Rome. FAO. Agriculture and Food Engineering Technical Report 3. pp67.

Information Exchange

Some conclusions and pointers for the future

Lawrence Clarke has drawn out some general pointers for successful mechanization strategies. These include:

Interventions to assist the farmers (the demand side)

- Remove policies and regulations which restrict the choice of farm machinery by the purchaser;
- Any state supported leasing or credit programmes should allow the farmers to purchase or lease imported machinery as well as domestically produced machines;
- Consumer protection legislation should be introduced particularly for contracts and credit and to protect consumers against being sold faulty or inappropriate machines;
- Government programmes should concentrate on providing information for farmers and farm businesses to enable better choices to be made that consider both technical and business issues.

Approaches to improve the supply side

- Removal of policies which protect local industries. Such policies include subsidized finance, removal of favourable tax exemptions for domestically manufactured machinery, removal of protective tariffs on imported machinery and the removal of barriers to foreign investment.
- Free up the market for the importation of foreign machinery, including removal of unreasonable testing and certification requirements.
- Privatize state owned and operated machinery stations.
- Reduce bureaucracy and barriers to business development; create an environment which eases the development of businesses including such measures as easing import restrictions, creating a level playing field for foreign businesses, reducing taxation and easing restrictions on leasing of property and capital equipment.
- Any subsidized programme operated by the state should have a predefined period of operation after which it would be privatized.
- Introduce training and education programmes for commercial development as well as technician training (scope for donor support).

- Lending for the purchase of farm machinery as well as for emerging service providers can be a risky business for private banks and it is for this reason that credit from private banks is often unobtainable or expensive. Donors should consider supporting the farming and agricultural machinery sector by underwriting credit for these purposes. Such programmes could include business and technical training elements.

Interventions to support efficient, lean and environmentally sound mechanization

- Introduce so-called smart subsidies for mechanization inputs that are in line with sustainable mechanization and concepts such as 'Save and Grow' as described above.
- Develop precision agriculture applications as an integrated tool within the sustainable agricultural intensification concept or within the 'Save and Grow' concept.
- At global policy level: work on global agreements for good practices in the procurement and supply of agricultural equipment and mechanization inputs. Good practices means avoiding short-sighted politically-motivated arrangements with no after-sales support and with equipment levels that are not appropriate to the level of training of the recipient countries.
- Accept FAO together with other bodies such as UNIDO and OECD as international bodies that can provide a neutral platform for private and public sectors to work in harmony to develop and **implement** sustainable mechanization strategies for the benefit of farmers and rural enterprises in developing regions.

CHAPTER 1

Investing in agricultural mechanization for development in East Africa

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ABSTRACT

This chapter is a review of the agricultural mechanization situation in seven East African countries (Uganda, Tanzania, Rwanda, Kenya, Burundi, Ethiopia and Sudan). Hand tools continue to be the norm throughout the region despite attempts at large scale mechanization in the past. The importance of agriculture as a component of GDP is discussed and is generally less than 50 percent despite the high labour force involved. The history of mechanization from the mid 1950s to the present is reviewed from the perspectives of smallholder and large-scale agriculture. The crucial importance of mechanization is slowly being realized by national planners and there is now increasing political will to develop the sector's primary production and value addition chains through appropriate mechanization policies and strategies.

1.1 INTRODUCTION

This chapter covers seven countries of East Africa: the five countries of the East African Community (EAC) – Uganda, Tanzania, Rwanda, Kenya and Burundi; and Ethiopia and Sudan. Given the historical perspectives and drivers of agricultural mechanization in these countries, it is useful to divide the assessment into three historical periods of 20 years each:

- Period 1: the mid 1950s to mid 1970s. These were the boom years immediately before and/or after independence for most of the countries, with agriculture and mechanization driven by export cash crops.
- Period 2: the mid 1970s to mid 1990s. The height of cold war with socialist experimentation, civil wars, World Bank structural adjustment impositions, and general economic deterioration. Each country experienced at least one "lost" decade, and some two or even three. The rural areas, and thus agricultural development, were often the most seriously affected by these upheavals.

[1] Supported by Fildah Ayaa, Workineh Abebe, Habtamu Admassu and Yitayal Abebe

- Period 3: from the mid 1990s to the present. Dominated by globalization, return of relative peace, market economy experimentation, and accelerated growth of the service sector.

It was realized during the assessment reported here that there is very limited data and information on mechanization in all the countries. This must be constraining the planning and development of agricultural mechanization.

However, in general the review shows that manually operated implements are the norm rather than the exception in the region. At the same time many poor people in rural areas (some very remote) who previously did not even know what a telephone was, are now taking the mobile telephone for granted. Why is the same progress and adoption not taking place in the case of agricultural mechanization? This chapter tries to find answers to this question by discussing the history of mechanization in the region, factors that seem to have accelerated agricultural mechanization and those that seem to have hindered it, and the roles of the public and private sectors.

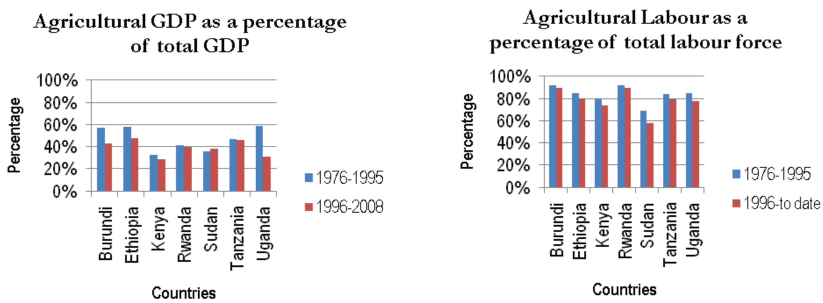
1.2 OVERVIEW OF AGRICULTURAL SECTOR IN EAST AFRICA

The seven countries covered in this review have a combined area of 5.2 million km^2 and a population of 246 million. The countries range from the largest country in Africa (Sudan – 2.5 million km^2) to one of the smallest (Rwanda – 0.263 million km^2). The land that is suitable for cultivation of both annual and perennial crops is estimated at 343 million hectares. However, the proportion of suitable land that is actually cultivated is on average very low at 18 percent, with the highest 80 percent utilization recorded in Burundi (FAOSTAT).

The seven countries are together endowed with ample water resources. For example, the Nile Basin, which is the main source of water for the EAC countries and Ethiopia, receives about 2000 billion cubic metres of precipitation each year. It is only in Sudan that more than 25 percent of cultivated land is irrigated. The low level of mechanization in the region is one of the most serious obstacles to expanded and sustainable utilization of the ample land and water resources for agriculture.

Although agriculture currently accounts for less than 50 percent of the GDP in all the seven countries, the region remains mainly rural and agricultural on account of the high proportion of the population living in the rural areas and/or employed in agricultural (crops and livestock) production (Figure 1.1). This mismatch, of the proportion of the GDP that is agricultural and the proportion of labour that is agricultural, means that poverty is concentrated on those living in rural areas and producing crop and livestock products mainly for family consumption.

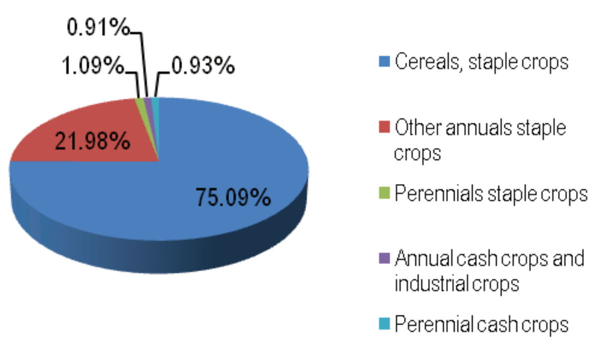
FIGURE 1.1
Contribution of agriculture to GDP and to employment



Source: (WRI, 2010)

The agricultural sector can be divided into several categories with different characteristics and factors that hinder or facilitate mechanization. Food crops that are generally staples occupy the bulk (98 percent) of cultivated land in the region, and the most dominant are cereals which occupy 75 percent of the area (Figure 1.2). The most dominant perennial crop in the region is bananas but it is cultivated on only 1.1 percent of the cropped area. Productivity is very low especially in small-scale and subsistence agriculture. Consequently, productivity has always lagged behind that recorded in other parts of the world with the gap widening over the years.

FIGURE 1.2
Area cultivated with selected crops in East Africa ('000 ha)



Source: FAOSTAT

1.3 GENERAL HISTORY AND STATUS OF ADOPTION OF AGRICULTURAL MECHANIZATION IN EAST AFRICA

There is arguably no other economic activity where sub-Saharan Africa has been more comprehensively by-passed by technological development, than in agricultural field operations — particularly in crop production. Just as it has been a matter of human sweat and drudgery for centuries, so it remains today for the majority. Many people in rural sub-Saharan Africa use mobile telephones, travel by bus, own at least a radio, and most own television including satellite television, and yet most do not own, have access to, or use even oxen or mules (let alone tractors) for agricultural field operations. Over 90 percent of the transportation of agricultural produce from field to home and/or local markets is done on the heads of women and children.

Food production for many continues to be through backbreaking manual labour. This leads to very low yields per unit of labour to the extent that often the food produced is just enough to recover the calories expended in its production. We hasten to point out that Ethiopia was among the first countries in the world to adopt the use of animal power for tillage operations. However, the technology used in Ethiopia has remained unchanged with the centuries-old tillage tool known as the *maresha*, which is still used to till more than 95 percent of the land under cultivation for annual crops (Goe, 1987 and Ehret, 1997) .

1.3.1 Trends of agricultural mechanization for different scales of farming

There is very limited mechanization of **smallholder agriculture** in the region. There is generally only one operation in smallholder food production that is almost fully mechanized, and that is grain milling (Box 1). The same trend is now being observed with small motorized pumps for lifting water. The main factors behind the successful mechanization of milling and the recent accelerated adoption of mobile motorized pumps, include the following:

a) Low capital requirement.
b) Sharing among many users, with clear and fair distribution of costs, and
c) Scalability – mainly the ability to be used under any set of conditions with very little prior preparation.

BOX 1

Hammer mills drove adoption of maize in Eastern Africa

African maize production received a boost with the introduction of the hammer mill in the 1920s. Hammer mills gave a processing cost advantage to maize over small grains, since maize could be dumped into the hopper for grinding, while millet and sorghum grains required de-husking first. The smallest hammer mill with a 3 kW diesel engine will produce about 150 kg of coarse flour per hour – a revolutionary advance compared to manual grinding.

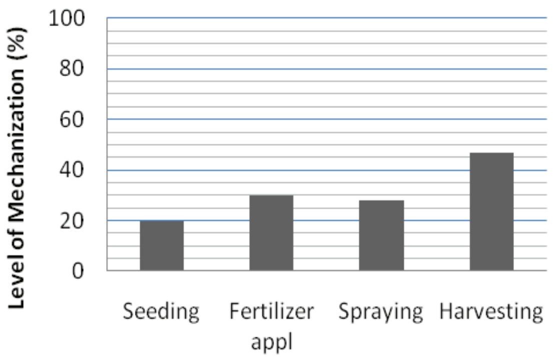
Source: Smale and Jayne, 2003

Large scale farming whether public or private has seen higher levels of mechanization at all stages of production. The following large scale farming scenarios illustrate this trend:

a) **Irrigated agriculture** – large scale irrigation schemes such as the Gezira and Managil in the Sudan, sugar cane estate farming in nearly all the seven countries reviewed, and the recent investments in irrigated paddy rice production, have played a significant role in expanding agricultural mechanization, since the 1940s. For example, the Sudan with the highest levels of irrigation in the region also has the highest levels of mechanization at about 35 percent of the cultivated land. In Kenya and Tanzania, the production of sugarcane is mainly under irrigation schemes which are also highly mechanized. The major mechanized operations include land preparation, cane loading, and cane transport. At the same time, in nearly all the irrigation schemes in the Sudan, Tanzania and Kenya, operations such as planting, spraying, fertilizer application, weeding and harvesting are still largely carried out manually (Figure 1.3). The most important aspects of irrigated agriculture that have supported mechanization and vice versa are as follows:

i) The need for heavy equipment for land clearing and levelling.
ii) Once cleared and levelled for irrigation, the cultivated land then becomes more suitable for mechanized operations.
iii) The good market linkages associated with irrigated schemes have provided better financial returns to the costs of mechanization.

FIGURE 1.3
Level of mechanization of secondary agricultural operations in the Gezira, Sudan



b) **State farms** – state farms both irrigated and rain-fed have played a very big role in nurturing agricultural mechanization, especially during the second period of "socialist experimentation" in Ethiopia and Tanzania. In Ethiopia for example, the Derg regime established large mechanized state farms totalling about 200 000 hectares, out of which about 47 000 hectares were irrigated. In Tanzania most of the mechanized and/or irrigated farming was developed under state farms, during the socialist period. Examples include:

i) The 30-40 000 ha of wheat cultivation in the Hanang Wheat Complex, and West Kilimanjaro in Northern Tanzania. The production on these farms is fully mechanized and about 75 percent of Tanzania's commercial wheat production comes from them.

ii) The rice state farms, including the 6 000 ha Mbarali Rice Farms, developed in the Southern Highlands.

The main factors driving mechanization were similar to those mentioned above under irrigated agriculture, but there was also the political thrust as these state farms were considered by policy makers to be key elements of agricultural modernization in the country.

1.3.2 Trends with respect to access to markets

Guaranteed markets - have been the driver of agricultural mechanization in all the countries through all the three periods of agricultural development. For instance, cotton production was the main driver of mechanization with draught animal power (DAP) and tractors in Tanzania, Uganda and Ethiopia. For example:

a) In Ethiopia, the Tendaho Cotton Plantation Share Company and Setit Humera large scale commercial farms (growing mainly sesame) were some of the large mechanization schemes started in the 1950s. By around 1966 it was estimated that there were about 250 farmers in Setit Humera schemes, owning more than 400 55-60 hp tractors with 19 different models from 12 different manufacturers in 8 different countries. The farms were established on 5 000 hectares at Dubte, Det Bahire and Logghia.
b) In Tanzania and Uganda there was a clear symbiotic relationship between the expansion of cotton production and the expansion of mechanization of field operations. For example, it is for this reason that DAP is universally used in the cotton growing Sukumaland of Tanzania and the cotton growing areas of Uganda (Starkey, 2000).

Therefore, in general sub-sectors with good access to markets such as the traditional cash crops (tea, cotton and sugarcane) – especially under estate farming conditions have been the drivers of mechanization. Small and medium-scale farmers have limited access and/or capability to purchase new machinery, and are thus heavily dependent on ageing second-hand machinery bought from the large scale estate farms (MAAIF, 2005).

1.3.3 Trends in relation to agro-ecological zones

Agro-ecology is a physical determinant of mechanization in East Africa. So that, for example, the flatlands of Sudan have been amenable to extensive mechanization of at least primary land preparation, while the hilly topography in Burundi, Ethiopia, Rwanda and Uganda has largely restricted expansion of engine-powered mechanization. The hand hoe is still predominantly used for land preparation on small-scale farms in Uganda – where 90 percent of the farmers depend exclusively on hand tools with only 8 percent using animal drawn technology for field operations and partly for transport, and 2 percent using mechanical power and to a small extent electrical power (MAAIF, 2005). Given the fact that the hilly areas of the region are also the ones with the highest production potential, there is an urgent need to develop specialized mechanization systems for these areas.

1.3.4 Trends with respect to agricultural development programmes of governments and donors

Historically most efforts to accelerate mechanization in the region, starting with the disastrous "Groundnut Scheme" in Tanzania after the Second World War, have been driven by politics, rather than being sound commercial propositions. For example, the hike in fuel prices in 1973 lead to politically driven efforts to develop "appropriate mechanization technologies" in the form of DAP and small tractors such as the Kabanyolo, Tinkabi and Snail. The success with these technologies was elusive leading to reduced support for mechanization during the 1980s. Throughout the 1990s, mechanization was nowhere near the top-level of policy priorities in the region.

Another mechanization approach tried in the 70s to 90s period was government operated tractor hire schemes. These were later abandoned partly due to the heavy financial burden on the government as a result of subsidizing the service (Sims, 2006). Furthermore, timeliness of agricultural operations was difficult to achieve because of conflicts among users of the service (Box 2). Studies on the economic benefits of these schemes were also carried out during this period and it was concluded, based on the various shortfalls identified, that government-managed and operated tractor hire schemes were not successful and were consequently largely abandoned in the late 1990s.

BOX 2

Failure of Tractor Hire Services

The government of Uganda had 489 tractors in the government tractor hire scheme by 1965. However in subsequent years, the service was abandoned partly due to the heavy financial burden on the government as a result of subsidizing the service. The timeliness of agricultural operations was difficult to perform because of timing conflicts among users of the service (Kibalama, 1993)

Therefore, although mechanization is an important factor in enhancing farm productivity, and the priorities of most policies and programmes of donors focus on enhancing productivity, mechanization has generally not been supported by the programmes with respect to smallholder production systems. What is not always acknowledged by agricultural development planners is that there is a serious shortage of a young and energetic labour force in rural Africa, due to the out-migration of youth to urban centres. The combination of low levels of agricultural mechanization and declining labour force has led to underperformance of many of the programmes designed to enhance productivity through input supply and extension.

It is therefore, refreshing to note that the current (post 2005) policies prioritize mechanization of agricultural operations in the region. For example:

a) **Ethiopia** - the Agricultural Development Led Industrialization (ADLI) framework encourages adoption of improved farm power and implements (GoE, 2007). It promises to invest in the adaptive research and development of improved farm implements and to strengthen the production capacity of rural technology centres in implement manufacturing.

b) **Tanzania** - the Kilimo Kwanza[2] initiative which calls for increased "supply of agricultural machinery and implements" by:
   i) Reviving privatized manufacturing plants for farm implement.
   ii) Embarking on local manufacturing of agricultural machinery and implements, and:
   iii) Ensuring that industrial strategies address the needs of agricultural mechanization.

c) **Uganda** – where the government has adopted a mechanization policy to promote the utilization of appropriate farm machinery and equipment, with the following elements (MAAIF, 2005):
   i) Provision of a conducive environment for the private sector to acquire, maintain and repair agricultural machinery.
   ii) Promotion of agricultural machinery hire service units in different agro-ecological zones, and:
   iii) Re-establishment of animal traction development centres in traditional and non-traditional areas.

1.3.5 Trends in the machinery supply chain

The machinery and equipment supply system in the region has historically depended on importation, first from Europe, then from North America, and recently from China, India and Vietnam. The importation of agricultural tractors is generally a good indicator of the rate at which mechanization is taking place. Records captured by FAOSTAT show that all the countries have imported very few numbers of tractors per year since the 1960s. Only Kenya has imported tractors in numbers above a thousand per year – and this only for the period 1971- 1990, with a peak of about 2 500 tractors imported in 1981. Importation to Tanzania was for sometime boosted by a local assembly plant for Valmet (Finland) and CNH (Italy) tractors.

However, local manufacturing especially of equipment has become an important element of mechanization in the region (Shetto, 2005). Local manufacturers largely fabricate implements and post-harvest equipment. This includes maize hulling and milling, shelling, rice threshing and hulling, coffee pulping, cassava grating, chipping and oil expelling machines, based

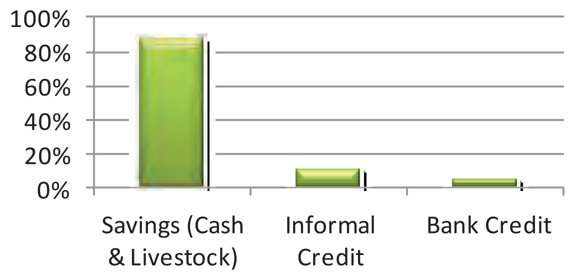
[2] Agriculture first in Kiswahili

on prototypes from local universities or research institutes. In fact although data are hard to come by these post harvest primary processes are rapidly being mechanized, and many young people are establishing and operating hire services for this kind of equipment. In areas where animal traction is important, many small workshops are in the business of producing animal drawn carts for rural transportation. As part of the effort to create youth employment, governments in the region are also supporting the development of this smallholder manufacturing sector, known as the "jua kali" or blacksmithing sector.

There are very few local formal manufacturers of agricultural equipment in East Africa and most of them manufacture to order. The Ndume factory, one of the largest players in Kenya, manufactures equipment ranging from airport cargo handling equipment to pneumatic seeders and cultivation machinery. However, recently machinery manufacturers from China, India and Iran have established local manufacturing plants in East Africa. For example, a company known as the Ugiran (Uganda-Iran) Company has been established as joint venture with the Ugandan National Enterprises Corporation (which has a 40 percent stake) and the Iran Tractor Machinery Company (ITMCO) (a 60 percent stake). ITMCO assembles tractors using components imported from Iran. The company with an invested share capital of US$1.5m will assemble 64 tractors per year in the first phase of the project growing to 285 tractors per year in its second phase. Similar enterprises are being set up in other countries while many other equipment manufacturers from Asia are establishing importation and distribution operations especially for power tillers, water pumps, and post harvest processing equipment.

It is clear that the opportunities for growth in agricultural mechanization in the East African region have been recognized by the private sector. The most interesting aspect is the extent to which private investors are investing their own money to purchase equipment for establishing hire services (Figure 1.4). Governments and donors should, therefore, accelerate this process by supporting 'technology and innovation into business' programmes.

FIGURE 1.4
Private sector investment sources for agricultural equipment



1.4 CONCLUSIONS: KEY FACTORS THAT HAVE FACILITATED OR HINDERED AGRICULTURAL MECHANIZATION IN EAST AFRICA

Agricultural mechanization is at a very low level in the region and this leads to the following consequences with respect to agriculture for development:

a) The very low levels of mechanization coupled with equally low utilization of other productivity-enhancing inputs such as improved seed, fertilizers and improved water management for agriculture, makes small- and medium-scale farming unattractive to the youth who make up the bulk of the population in the region.
b) Consequently, agriculture is not attracting the most enterprising members of the population and it thus has a tendency to remain at subsistence level.
c) For those who remain behind in the rural areas, the extremely low productivity makes farming a "poverty trap" in which the majority can hardly produce enough food to meet their minimum calorie needs.
d) The greatest consequence of low input - low output farming, of which low mechanization is one factor, is the serious logjam it creates. To adopt high input – high output strategies including mechanization; farmers require outlets for any surplus they produce as an incentive to undertake the necessary investment in high-cost inputs such as mechanization. At the same time, because of the low outputs, agro-industries and agribusinesses are not willing to invest to provide the necessary outlets because the volumes produced are too small to support optimum facilities. The circle is completed as the limited trade operations in the rural areas reduce the justification for public investment in rural infrastructure.

The most important factors that have driven agricultural mechanization in the past 60-70 years in the region, have been the following:

a) Politically driven desire to modernize agriculture in a particular country;
b) Development of large scale state, irrigated, and/or estate farms; and
c) Market-driven need for output growth where the scarcity of labour drives mechanization.

The most important factors that have reduced the success of efforts and programmes to promote agricultural mechanization have been the following:

a) High capital and operational costs of mechanization (for example mechanization accounts for 60 percent of the costs of sugar production in Kenya) coupled with low commodity prices of especially food crops which were targeted by the bulk of mechanization initiatives.
b) Given the fact that political decisions have been responsible for initiating most of the drives towards agricultural mechanization, lack of consistency in policy has been a major cause of failure of these initiatives.
c) Difficult topography in the high potential areas where mechanization would potentially pay, has been another major obstacle to accelerated mechanization.

d) Poorly articulated value proposition for private sector investment in agricultural mechanization due to poor linkages to profitable markets for most commodities produced in the region.

There are three main factors that would drive opportunities to invest in agricultural mechanization in the region. These are:

a) High global demand and prices for staple food commodities coupled with the increasing desire by rich but food deficit countries especially in the Middle East to secure food supplies from Sub-Saharan Africa (SSA).
b) The fact that land ownership in the region puts the largest proportion of arable land in the hands of smallholders through traditional tenure – one of the factors which has made 'land grabbing' more difficult.
c) The increased availability of efficient but small and low cost engines that can be adapted and used to operate machinery and equipment from two-wheel tractors for field operations, to equipment for high quality production of value-enhanced products.

Therefore, for the first time since the collapse of international commodity prices in the early 1970s, the three factors elaborated above come together to create real commercial opportunities for accelerated mechanization of small-scale agriculture. This is enhanced by the fact that the East and Southern Africa regions are highly favoured by the new crop of equity investors eyeing SSA as a destination for investment because of the sluggish economies of the developed world.

1.5 RECOMMENDATIONS

1. Integrate agricultural mechanization into agricultural value chains to improve adoption and adaptation. The current focus on the development of agricultural value chains offers real opportunities for accelerating agricultural mechanization. As the experiences with grain milling, and recently shelling have shown, a key entry point for mechanization in a particular value chain would be in post-harvest handling and value addition processing. Once these processes are fully mechanized, a profit-driven pull is created for mechanizing field operations.
2. Make agricultural development and food security policies, strategies and programmes "mechanization smart". Efforts are required to convince public and private sectors of the value proposition of agricultural mechanization so that they can make their current and planned agricultural programmes and business plans 'mechanization smart' – that is to include appropriate mechanization along the value chain the start. The opportunities that mechanization could open for the private sector – including primary producers and their associations, suppliers, financial services providers, and post-harvest handling and marketing agribusinesses – are not currently

apparent. This situation needs to be changed through public research and business development services on agricultural mechanization. Furthermore, private mechanization service providers using small tractors and equipment should be emphasized since outright ownership of equipment is out of reach for most smallholders.

3. Establish a comprehensive assessment of mechanization to update obsolete data. There is a serious paucity of up-to-date data and information about agricultural mechanization to guide serious planning and business development. There is therefore a need for an intensive and extensive assessment of the current state of agricultural mechanization supply and utilization. This should be followed by projections of the levels of agricultural mechanization which would be required in the future in relation to changing demographics, and demand for agricultural commodities and products.

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CHAPTER 2

Agricultural mechanization in Southern African countries

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ABSTRACT

This chapter reviews the status of agricultural mechanization in six southern African countries: Zimbabwe, Zambia, South Africa, Namibia, Swaziland and Mozambique. Generally there is a lack of a coordinated and holistic approach to agricultural and agri-business mechanization issues. Hand tools are still predominantly used in sub-Saharan African agriculture and support is needed to promote draught animal and tractor power. Challenges and opportunities for increasing the level of mechanization as an essential agricultural input are discussed. These include: creating an enabling environment for mechanization; the application of precision farming and conservation agriculture; and the analysis of investment opportunities. Several strategic action areas are identified for the promotion of sustainable agricultural mechanization. These are: improving private-public sector partnerships; enhancing access to mechanization services for the range of end-user groups; institutional capacity building; fiscal strategies and policy environment; and the services necessary to increase investment in mechanization. The chapter concludes that, while the commercial sector should be encouraged and supported, emphasis is needed to develop small-scale farmers to become more commercial. Training and capacity building are vital development tools and a mechanization strategy should be developed for each country.

2.1 INTRODUCTION

Agriculture in most developing countries and indeed overwhelmingly in sub-Saharan Africa (SSA) is characterized by small holdings due to high population density and nearly two-thirds of the population residing in the rural areas. Major sources of farm power include both animate (humans and draught animals) as well as inanimate sources such as diesel engines, tractors and electric motors. Agriculture in most of SSA contributes over 80 percent of trade in value, more than 50 percent of raw materials to industries and provides employment for the majority of its people (Rukuni, 1995).

Despite its economic contribution, often backed by good policy documents and statements, agriculture in most of SSA countries is still neglected and underdeveloped. Furthermore, over 30 - 40 percent of agricultural produce is still lost due to poor processing and storage methods (Hatibu and Simalenga, 1993). There is therefore a high potential for lateral expansion of the agricultural sector at all levels. The low level of engineering technology inputs (especially power) into agriculture, associated with a lack of targeted investments have been cited as major constraints hindering the modernization of agriculture and food production systems in Africa.

One of the major reasons for the disappointing performance and low contribution of agricultural mechanization to agricultural development has been the fragmented approach to mechanization issues (Bishop and Morris 1992; Mrema and Odigboh, 1993). This often arises from poor (or no) planning and over-reliance on unpredictable or unsuitable aid-in-kind for many mechanization inputs and limited co-ordination within and between government and private sector agencies dealing with mechanization.

Formulation of national agricultural mechanization strategic and investment plans is therefore necessary where a holistic or systems analysis approach is used in the planning process and in which all key players in the economic and cultural environment are considered. In most of sub-Saharan African countries, insufficient serious planning for sustainable mechanization has taken place. In many cases where mechanization has made a positive contribution to agricultural development, it has been by chance and not by design (Muchiri *et al.,* 1994). Africa needs to set its target for long term sustainable agricultural growth of not less than 4 percent a year. This will not be an easy task as during the last 30 years agricultural production in SSA has risen by only 2 percent annually. Agricultural exports have declined, and food imports are increasing at about 7 percent a year. Despite the rapid growth in food imports, severe food shortages are widespread; drought has also led to famine over the years as the effects of environmental degradation and climate change are increasingly felt.

One way of enhancing agricultural production and productivity is to encourage the use of mechanization technologies in agriculture and the associated agri-processing industries. Despite the worldwide developments of agricultural machinery and implements and the increasing use of draught animal power (DAP), agriculture in SSA is still predominantly carried out with old hand tool technology (Table 2.1). Enhancing the use of agricultural mechanization technologies in agricultural operations is therefore a crucial factor for increasing both the production and productivity of agriculture in the region.

TABLE 2.1
Sources of Power of Primary Land Preparation in some countries in SSA and Asia (% of cultivated land)

	Human Power	Draught Animal Power	Mechanical Power
Sub Saharan Africa	**80**	**16**	**4**
Botswana	20	40	40
Kenya	84	12	4
Tanzania	80	14	6
Zimbabwe	15	30	55
South Africa*	10 (20)*	20 (60)*	70 (20)*
India	**18**	**21**	**61**
China	**22**	**26**	**52**

Source: COMSEC (1992). * Estimated values under small holder farming communities

It is also interesting to note that similar statements on the need for promoting the use of agricultural mechanized inputs in order to modernize agriculture have been repeated over and over again for a number of years. For example, de Wilde (1967) emphasized the urgency of increasing the utilization of equipment in African agriculture. Almost 25 years later, 60 African mechanization experts, meeting in Zaria, Nigeria recommended the same and stated that: "If agricultural mechanization is to succeed in Africa, then there is a need for all concerned from policy makers, planners, donors and farmers to understand the role and consequences of agricultural mechanization in the entire farming system" (COMSEC, 1992).

This chapter provides an overview of mechanization and its challenges for transforming SSA agriculture and discusses the critical issues to be considered to achieve sustainable agricultural mechanization and processing operations. Six Southern African countries viz. Namibia, South Africa, Mozambique, Zambia, Swaziland and Zimbabwe have been selected as case studies to illustrate the challenges faced when promoting agricultural mechanization inputs, investments and transforming agriculture for agriculture-led industrialization.

2.2 OVERVIEW: STATUS OF AGRICULTURAL MECHANIZATION IN THE SOUTHERN AFRICAN REGION

2.2.1 Zimbabwe

Agriculture is the dominant sector of the Zimbabwean economy contributing an average of about 18 percent of the GDP. The sector:

- Employs and is the main source of livelihoods for up to 70 percent of the population.
- Is the main source of the domestic food supply, thus playing a critical role in national and household food security.
- Accounts for about 40–50 percent of exports and so is an important source of foreign exchange.
- Supplies 60 percent of industrial raw materials.

As of 1999 and prior to the launch of the third phase of the Land and Agrarian Reform Programmes in 2000, the level of farm mechanization in Zimbabwe was dominated by the historical background of the various farming sub-sectors namely the communal, old resettled, small scale commercial and large scale commercial farming sectors. The large scale commercial farm sub-sector practises mechanized, high-input high-output farming and is characterized by being in receipt of private and public resources of agricultural finance and credit. In contrast, the communal farming sector, consisting of roughly 1.8 million households, has limited access to productive resources and infrastructure. These smallholder farming communities practise rainfed agriculture using low-input low-output technologies. Approximately 90 percent of draught power for agricultural production in this sector is from animals, mainly oxen and occasionally donkeys and cows. The current average size of cultivated land is 3 hectares per household, which is usually split into separate parcels of land of less than 0.5 hectares each.

The A1 farming sector (small-scale farmers) was established in 1980 as part of the relocation of families displaced during the pre-independence liberation war. To date, up to 300 000 households have been resettled on land acquired by the government from former large-scale commercial farmers. Each household is allocated an average of 5 hectares of arable land and grazing land from 6-20 hectares depending on the agro-ecological region. The main source of farm power for agricultural production is provided by draught animals, but since many settlers do not own any animals or have insufficient numbers, farmers also hire District Development Fund (DDF) tractors for tillage services (ploughing, discing, rolling and planting). Recent studies have shown that A1 farmers invest most in animal drawn implements such as ploughs, cultivators, harrows and scotch-carts (Mlambo, 2004; Simalenga, 2005).

DDF is the major tillage service provider to A1 farmers, with a fleet of 768 tractors, of which only 45 percent are normally in working condition. The available fleet is grossly insufficient to meet the national demand for tillage of approximately 2 million hectares in the communal farming areas, plus the 3 million hectares farmed by A1 farmers. DDF tillage capacity is further strained by the shortage of ploughs, disc harrows, planters and spare parts. Analyses of the present and future scenarios have been articulated by other studies and reports (e.g. Simalenga, 2005).

The implementation of the third phase of the Land Reform Programme ushered in a new breed of farmer, the A2 farmer – small scale commercial farmers. Some of these new players purchased second-hand farm machinery from former large-scale commercial farmers. Evidence has shown that despite possessing these second-hand machines, most A2 farmers lack the financial resources to maintain them as they constantly break down. To alleviate tillage shortages on A2 farms, government directed the Agricultural and Rural Development Authority (ARDA) to assist them with tillage and harvesting services.

Since 2003, ARDA have been able to import over 450 tractors from Iran, Malaysia and South Korea. Another 250 units of tractors and farm machinery have been imported. This is in addition to an existing tractor fleet of 126 operational and 130 requiring repair, and 12 combine harvesters. A further 133 tractors and 13 combine harvesters were procured from former large-scale commercial farmers using resources from the Reserve Bank of Zimbabwe.

In 2004, ARDA had a total fleet of 709 operating tractors and 63 combines. Additional initiatives (500 more tractors to be purchased from Iran during 2006) are also being made by ARDA to import farm machinery. ARDA imports of farm machinery and equipment have resulted in increasing the country's mechanization capacity. However, the inefficiencies of ARDA may lead to poor service and so the country may fail to achieve the potential of ARDA's mechanization capacity.

Due to the size of their farming operations, A2 farmers depend on tractor power. However, the country's tractor capacity is not enough to service the farmers. Currently there are less than 10 000 tractors in the country (both in the private and public sectors), while the optimal national tractor fleet requirements have been estimated at over 40 000 units (Nhau, 2006). Studies undertaken under the FAO project, "Strengthening Mechanization Support Services in Zimbabwe" have shown that there is limited capacity of the two main public service providers (DDF and ARDA) to properly manage and make full utilization of the inputs under their control (Mlambo, 2004; Mfote, 2005; Nazare and Koza, 2005).

Tables 2.2, 2.3 and 2.4 give numbers of animal drawn and other equipment owned by communal farmers since 1996 while Tables 2.5 – 2.8 indicate numbers of motorized farm machinery and equipment. The increase in farm machinery numbers in the late 1990s is mainly attributed to donor-supported programmes especially the Japanese 2KR Programme[3].

Hand Tools and Implements in Zimbabwe

Hand tools and implements are currently being used in all the farming sectors. Typical examples of commonly used hand tools that have become symbols of specific farming systems include the use of hand hoes in communal farming areas, the use of knapsack sprayers in small-scale farming areas, and the use of cutters in large scale commercial tea and coffee estates. However, hand tool use is associated with communal farmers who cannot afford motorized implements and/or the small size of their cultivated areas makes it uneconomic to acquire expensive implements.

The range of hand tools that are used mainly by smallholder farmers includes hand hoes, axes, adzes, rakes, slashers, bonnets/cutters, sickles, picks, mattocks, hole diggers, shovels and watering cans. Of these, the most common hand tools that are found on a typical communal farm are hand

[3] Japanese grant aid programme as part of the Second Kennedy Round (2KR)

hoes, axes, hand picks and watering cans. There are other manually operated implements such as wheel barrows and knapsack sprayers that are commonly used without the need for DAP.

Local manufacturing sources of these tools include both the formal and informal sectors. The Institute of Agricultural Engineering, (IAE), Danhiko, Silveira House, Hlekweni and Glen Forest Training Centres have all developed training courses to broaden the product range and quality control aspects of blacksmithing. The IAE through its rural technology centre has also developed manufacturing tools for use by blacksmiths including improved forges. Practical Action[4] has designed prototypes that have been passed on to rural artisans and blacksmiths for commercial production.

Animal drawn tools and implements in Zimbabwe

Animal drawn implements form the major source of mechanized inputs in small landholdings. These include mouldboard ploughs, scotch carts, rippers, ridgers, cultivators, harrows and planters. Approximately 90 percent of the power for agricultural production in the smallholder farming sector (A1, old resettlement, communal and small scale commercial) is from animals, mainly oxen and occasionally donkeys and cows. The major producers of animal drawn equipment in the country have been Hästt Zimbabwe, Bain and Zimplow Limited, but several SMEs and individual producers have recently entered the industry since the launch of the farm mechanization programme.

TABLE 2.2

Zimbabwe: Estimates of numbers of animal-drawn implements. Distribution by farming sector

Implements	Communal farmers	Old Resettlement	SSCFs	A1 farmers	Total
Ox-drawn ploughs	1 260 400	49 200	13 213	126 000	**1 448 813**
Cultivators	640 364	37 000	11 000	66 000	**754 364**
Harrows	576 000	20 000	8 000	25 000	**629 000**
Scotch carts	775 297	38 000	10 000	70 000	**893 297**
Water carts	100 000	5 000	1 000	6 000	**112 000**
Ridgers	16 577	1 000	1 000	4 000	**22 577**
Planters	92 332	4 000	2 000	5 000	**103 332**

Source: MAEMI (2007). SSCF = small-scale commercial farmer

Table 2.2 shows more concentration of animal drawn implements in the smallholder sector where more sophisticated motorized machinery and equipment are not affordable.

[4] A UK-based NGO (http://practicalaction.org)

TABLE 2.3
Zimbabwe: Distribution of numbers of animal-drawn implements by province before the Farm Mechanization Programme (FMP)

Province	Implements				
	Ploughs	Cultivators	Planters	Ridgers	Scotch carts
Manicaland	251 232	130 811	17 918	3 915	154 902
Mash Central	171 545	89 319	12 235	2 673	105 770
Mash East	190 388	99 131	13 579	2 967	117 388
Mash West	171 057	89 066	12 200	2 666	105 469
Masvingo	114 138	59 429	8 141	1 779	70 374
Mat North	111 246	57 923	7 934	1 734	68 591
Mat South	212 646	110 720	15 166	3 314	131 112
Midlands	226 561	117 965	16 159	3 530	139 691
Total	**1 448 813**	**754 364**	**103 332**	**22 577**	**893 297**

Source: MAEMI (2007). Mash = Mashonaland; Mat = Matebeleland

The distribution of animal-drawn implements follows the distribution of smallholder farmers in the provinces with more implements in the more extensive provinces such as Midlands and Matebeleland South. Ownership of the ox-drawn plough is very common among smallholder farmers. The numbers of animal drawn implements distributed by the FMP are shown in Tables 2.3 and 2.4.

TABLE 2.4
Zimbabwe: Animal-drawn equipment acquired and distributed under the FMP

Sub-Programme	Target Group	Equipment or Implement	Phase 1	Phase 2	Phase 3	Total
Farm Mechanization	Smallholder Farmers (Communal Small-scale and A1)	Scotch Carts	0	45 000	33 000	**78 000**
		Cultivators	0	20 000	26 200	**46 200**
		Planters	0	1 000	1 000	**2 000**
		Ploughs	0	50 000	50 000	**100 000**
		Harrows	0	70 000	60 000	**130 000**
		Knapsack Sprayers	0	70 000	47 000	**117 000**
		Chains	0	200 000		**200 000**

Tractor Drawn Equipment

Zimbabwe does not manufacture tractors but relies on imports from the region and the international community. Tractors are imported into the country in complete form, semi-knocked down (SKD) kits or as completely knocked down (CKD) kit forms. There are dealers in the private sector with capacity to assemble over 10 000 units annually through the use of facilities owned by the Agricultural Dealers and Manufacturers Association (ADMA) such as Tanaka Power, Farmec, Bain New Holland, Willowvale Mazda Motor Industries and Hästt Zimbabwe.

Tractor-drawn equipment such as ploughs, disc harrows, ridgers and rippers are manufactured locally by private companies such as Farmec, Bain New Holland and Hästt Zimbabwe. Some of the private firms such as Farmec and Tanaka Power also import specialized equipment such as pneumatic planters, seed drills, boom sprayers, hay balers and combine harvesters on request from clients.

The numbers of tractors, implements and combine harvesters in the country have not been adequate to meet the requirements in the post independence era. The situation was exacerbated by the smuggling of whole or SKD tractors to neighbouring countries by the former commercial farmers during the Fast Track Land Reform Programme (FTLRP) and also due to non-replacement of the ageing fleet. Agricultural equipment and machinery ownership is vested both in the state and private hands. The state owns agricultural equipment and machinery through the District Development Fund (DDF) and the Agricultural and Rural Development Authority (ARDA).

Through these institutions, the state hires out mechanization services to farmers. The state machinery hire services operated by these institutions has consistently failed to meet the national tractor and combine harvester requirements owing to the small size of the respective fleets. DDF is the government institution mandated to supplement tillage services to communal, small-scale and resettled farmers and it offers services such as ploughing, discing, ripping and ridging. Apart from this it also offers other services such as borehole drilling and maintenance, construction and maintenance of small dams, irrigation schemes, dip tanks and roads particularly in resettlement and communal areas. ARDA is mandated to spearhead the commercialization of agriculture and rural development through increased support to smallholder farmers. ARDA provides tillage services (ploughing, ripping and discing), planting, harvesting, transport, repair and maintenance of machinery and equipment as well as land clearance to out-growers close to its estates.

Table 2.5 shows the distribution of tractors and combine harvesters in the country. These are however, not enough to serve all farmers in need of tillage services.

TABLE 2.5
Tractors and combine harvesters available in Zimbabwe

Organization/Institution	Total number of tractors	Total number of combine harvesters
ZFU (Zimbabwe Farmers Union)	1 500*	0
ZCFU (Zimbabwe Commercial Farmers' Union)	3 300*	203
Private Contractors/ Individual farmers	5 403	0
ZIADA (Zim Agric. Dev. Authority)	268	0
MAEMI	2 725	85
ARDA	801	59
DDF	603	2
Total	**14 600**	**349**

Source: MAEMI (2007) *Estimates by the ministry

In total there are currently about 14 600 tractors and 349 combine harvesters nationally. The total number of tractors and combine harvesters currently in the country fall below the national requirements of 40 000 to 50 000 tractor units and 400 units of combine harvesters required[5] to meet agricultural production targets. Besides field operations some of the machinery and equipment will be allocated towards livestock based farm operations.

In terms of capacity the majority of tractors in the country (70 percent) are of medium engine capacity (between 70 and 90 hp) as shown in Table 2.6.

TABLE 2.6
Zimbabwe: Current tractor population by capacity

Engine Capacity	Population	Percentage
Less than 70 hp	2 800	20%
70 – 90 hp	9 800	70%
More than 90 hp	1 400	10%
Total	**14 000**	**100%**

Source: MAEMI (2007)

The distribution of agricultural machinery and equipment across the farming sectors is shown in Table 2.7.

TABLE 2.7
Zimbabwe: Estimates of machinery and equipment distribution by farming sector

Machinery and Equipment[6]	Farming Sector				Total
	Communal	A1	Small Scale	A2	
Tractors	1 400	1 120	560	10 920	**14 000**
Ploughs	784	627	314	6 115	**7 840**
Disc Harrows	0	370	185	4 065	**4 620**
Planters	0	134	67	1 479	**1 680**
Combines	0	0	0	349	**349**
Fertilizer Spreaders	0	78	39	863	**980**
Rollers	0	100	350	1 200	**1 650**
Boom Sprayers	0	202	101	2 117	**2 420**
Rippers	0	50	250	1000	**1 300**
Trailers	630	504	252	4 914	**6 300**

Source: MAEMI (2007).

Motorized and tractor-drawn equipment is mainly found in the large-scale commercial farming sector where landholdings are larger and ideal for sophisticated machinery and equipment. Table 2.8 shows the distribution of machinery and equipment by province.

5 400 combines are required to harvest a maximum of 120 000 ha targeted in 30 days at a work rate of 300 ha/combine/month.
A medium-size tractor would be expected to plough at most 200 ha/year at a work rate of 2ha/day giving a potential 8 – 10 million ha.

6 This does not necessarily refer to ownership but to equipment operating or providing services within the respective farming sector.

TABLE 2.8
Zimbabwe: Distribution of machinery and equipment by province

Machinery and Equipment	Province								Total
	Manicaland	Mash Central	Mash East	Mash West	Masvingo	Matebele North	Mat South	Midlands	
Tractors	1 183	2 292	2 240	2 693	1 496	1 054	1 420	1 622	**14 000**
Ploughs	663	1 284	1 254	1 508	838	590	795	908	**7 840**
Disc Harrows	390	756	739	889	494	348	469	535	**4 620**
Planters	142	275	269	323	180	126	170	195	**1 680**
Combines	42	62	55	93	29	13	12	17	**323**
Spreaders	83	160	157	189	105	74	98	114	**980**
Trailers	532	1 031	1 008	1 212	674	474	639	730	**6 300**
Boom Sprayers	213	413	403	485	268	190	256	292	**2 520**

Mash = Mashonaland, Mat = Matebeleland

The distribution of machinery and tractor-drawn equipment follows the pattern of farming systems according to provinces with more machinery and equipment in the agriculture-favourable Mashonaland provinces.

2.2.2 Zambia

The agriculture sector employs about two-thirds of the labour force although most of them fall under the small-scale sector. The sector contributes about 18 percent to the Gross Domestic Product (GDP). Despite the decline in the mining industry, its share of the export earnings is set at a meagre 2 percent. Zambia has not quite attained household food security because there are still cases of malnutrition and people going without food, and this situation is being worsened by the rural-urban migration.

In the light of the decline of the mining sector, agriculture is now being regarded as the leading sector of the Zambian economy because of its large reserve of unutilized arable land. Zambia has a total area of about 75 million hectares but only 25 million hectares are suitable for crop or livestock production. Out of that, about 16 million hectares are suitable for rough grazing while the remaining 9 million hectares are considered to be arable with a good potential for crop production. However only about 1.3 million hectares are used for crops (nearly 15 percent of the total arable land available). Low usage of land is attributed to the low level of crop production technology, credit squeeze and land tenure problems (DHV, 1992).

The agricultural sector in Zambia can be differentiated into three categories, namely small-scale (smallholder) farmers, emergent farmers and commercial farmers. Smallholder and emergent farmers constitute about 76 percent and 20 percent of the farming community respectively while the commercial farmers make up the remaining 4 percent. For each of these categories of farmers to achieve their potential, it is important that agricultural mechanization appropriate to each group is encouraged and supported.

Major concerns raised by most commercial farmers at the moment include the high cost of agricultural machinery and implements and the high interest rates on loans to invest in mechanization inputs. Both factors are linked to the high inflation rate the country has been experiencing. They are equally anxious about subsidized imported agricultural produce which appears to be cheaper to consumers. Another problem faced by commercial farmers is lack of well trained operators.

Maize is the predominant smallholder crop but the traditional maize growing areas except for the Northern Province are experiencing increasingly erratic production due to drought and soil deterioration. Over the past decade maize production in Zambia has declined and commercial farmers are increasingly replacing it with high-value export-oriented crops.

Impact of Tractor Mechanization

Although the government tractor hire schemes were not viable *per se*, tractor mechanization in general was not a complete failure. Statistics show that between 1970 and 1988, the number of commercial farmers increased by 38 percent. A good number of African farmers entered commercial farming as a result of the government subsidy scheme. Subsistence farmers decreased in number by an average of 0.5 percent per annum during the period from 1969 to 1980, while emergent farmers increased by over 13 percent. The area cultivated by commercial farmers increased by almost 48 percent between 1965 and 1988 (GRZ/CSO, 1990). Large parastatal estates producing a variety of crops such as sugar, coffee, wheat, and tea using highly mechanized methods were started during this period. These schemes are still operating today.

However, the removal of subsidies on agricultural machinery for the private sector and the government's control of the producer price for maize (which remained so low), meant that it became uneconomic for commercial farmers to continue producing maize. Many of them switched to growing high value crops such as soya beans and wheat.

Present Status of Agricultural Machinery Dealerships in Zambia

The response to questionnaires sent to agricultural machinery dealers indicates that a few of them provide a limited warranty while the rest only provide back-up spares (Kwendakwema *et al.*, 2002). Industrial distributors for example provide warranties covering the first 600 hours of operation covering spares maintenance and labour. Farmers' responses reveal that their major constraints in mechanizing their farm operations are the high cost of machinery and the prevailing high interest rates on loans. A number of farmers expressed concern about the lack of farm-tailored training in the education curricula at all stages of learning in the country. However they would be willing to send some of their workers for training within the country at a fee if they felt that the training would be beneficial to their farm operations.

Tractor Supply and Demand Situation

There is scanty information to determine exactly how many tractors there are in Zambia and let alone how many are still fully functional because there has never been a systematic survey done on the subject. FAO estimates that a total of 5 990 tractors were imported into the country between 1971 and 1975 and further estimates the total number of tractors to be over 13 000 (FAO, 1990). This number does not however include tractors that came into the country through aid packages. The yearly supply of agricultural tractors to Zambia fluctuates between 150 units to 325 units.

Taking into account the FAO estimates of the tractors imported into the country between 1971 and 1975 and the annual tractor supply from 1976 and 1990, it is estimated that 9 737 tractors (excluding those that came through the aid programmes) were imported into the country. Out of this figure, 7 954 (nearly 82 percent of the total considered) were bought in the first decade, between 1971 and 1980. This means that only 1 783 tractors were bought between 1981 and 1990 to replace those imported over the previous 10 years and indicates a drop in the demand for tractors.

Decrease in the tractor demand is an indication that farmers are either moving back to lower levels of mechanization or that they are keeping their machinery for longer than its normal useful life. The implication of the former is that their capacity to expand the acreage under cultivation is impaired, while the latter implies increased maintenance and repair costs.

Future demand for agricultural tractors can be estimated from two main factors, namely the need to replace the tractors after they have reached the end of their economic life and the need for additional power following opening up of new land. The economic life of agricultural tractors as indicated by most machinery dealers interviewed is in the range of 8 to 10 years, assuming an average annual use of 1 200 hours.

In an effort to ensure national and household food security, the government in 2002 designed an agricultural commercialization programme (ACP) to raise the living standards of different categories of farmers and those who are unable to take advantage of the opportunities emerging from the liberalized economic environment.

The ACP has been implemented as a component of the Poverty Reduction Strategy Programme, aimed at achieving "poverty reduction and economic growth". The focus of ACP is on promoting the development of small and large-scale commercial agriculture, whose overall goal is to achieve "sustainable and broad-based agricultural growth" as a basis for poverty reduction.

The Zambia Agricultural Commercialization Programme aimed to facilitate sustainable and broad-based agriculture sector growth over the period 2002-05 by focusing on increasing income generation from farming through improved access to marketing, trade, agro-processing opportunities, agricultural finance services, improved agriculture infrastructure, appropriate technology, and information. The programme focuses on promoting development of small-and large-scale commercial agriculture in order to achieve the overall goal of sustainable and broad-based agricultural growth as a basis for poverty reduction and economic growth.

The smallholder mechanization support programme under 2KR has been designed to address the inadequate farm power and mechanization which currently is one of the limitations to increased agricultural production especially among the small-scale farmers. The majority of small and medium-scale farmers are still dependent on hand labour for agricultural operations, a few using DAP. As a result land utilization and productivity are low.

The objective of the 2KR programme is to provide farm machinery and equipment to the Zambian Government which would be used to support the small scale farmers engaged in agricultural production. The programme is aimed at improving rural livelihoods through effective facilitation of farm mechanization technologies. The proposed 2KR programme is expected to provide 45 units of assorted capacities of agricultural tractors and 100 power tillers which would be available to viable farmers' cooperatives throughout the country.

2.2.3 South Africa

In South Africa, the agricultural production environment is dualistic and has the features highlighted below. The two main sectors can be further subdivided. In the case of the commercial sector into: field cropping, horticulture, livestock production, mixed farming and forestry. In the case of the communal farming sector into: small scale farming and subsistence farming.

(i) Commercial agriculture

- Made up of less than 40 000 predominantly white-owned farming units.
- Covers a production area of approximately 82 million hectares.
- Is responsible for more than 99 percent of South Africa's formally marketed agricultural output.
- Despite the decrease in the number of farming units (i.e. from 50 000 to 40 000) output from commercial agriculture has continued to grow implying an increase in land productivity.
- Export growth has exploded, especially in the horticultural sector. Trade figures show farm exports of South Africa increased from R45 billion in 2008 to R46 billion in 2009 while imports decreased by 8.5 percent to R35 billion in 2009.

(ii) Smallholder agriculture

- Consists of 300 000 – 400 000 predominantly black farmers; there is however a lack of sufficient data regarding the smallholder sector.
- Farm an estimated 14 million hectares of agricultural land.
- Is concentrated principally in the former homeland areas of the country thus marginalized into regions of poor productive land with little or no infrastructural support, or water resources.

- The smallholder farmers thus typically have low levels of production efficiency and engage in agricultural production to supplement their household food requirements with surplus sold at local markets.
- This is further exacerbated by poor support services directed at smallholder farmers e.g. financial services, technical support, access to transport and other support infrastructure.

(iii) Subsistence agriculture

- Consists of an estimated 4 million households practising agriculture for subsistence purposes.
- Subsistence farmers practise agriculture mainly for household consumption. However recent studies have shown an increase in dependence on market purchases by both urban and rural households, in some cases reaching 90 percent of the food supplies.
- Subsistence and smallholder agriculture can however play an important role in reducing the vulnerability of rural and urban food-insecure households, improving livelihoods and helping to mitigate high food price inflation.

(iv) Production

- Between 1990 and 2009, field crop production increased by 13 percent, horticultural production by 62 percent, and animal production by 29 percent.
- The largest component of agricultural production currently is animal production.
- Data reflect the increasing importance of horticultural exports as a share of total agricultural output.
- Variations in crop production are largely derived from the variability in maize production, which is in turn influenced by climatic conditions, producers' willingness to plant, and in industry average yields.
- Farmers' willingness to produce, is influenced by the profitability of production i.e. price offers, both domestically and internationally, and the suitability of the natural resource base. The tradeoffs between these factors influence the affordability and availability of food. Self-sufficiency levels are currently below domestic consumption requirements for most principle food commodities and are supplemented by increasing import levels.

(v) Contribution to the economy

- Agriculture's share of GDP amounted to 3 percent in 2005-2007 (down from 9.1 percent in 1965). Its small contribution tends to overshadow the many other positive contributions this sector makes to the economy.
- Agriculture has some of the strongest backward, forward and employment multipliers in the economy. It is estimated that the sector creates secondary or related jobs equivalent to 20-30 percent of those of the sector itself.
- Agriculture provides a social welfare net to the most vulnerable in society, especially in rural areas.

- Eight percent of total employment is in primary agriculture. It is however of concern that agriculture has lost 50 percent of its employment during the period 1970-95, especially in light of the fact that it has one of the strongest employment multipliers in the economy.
- The sector as a whole is a net earner of foreign exchange. However, it should be noted that the processed food sector is a net importer.

(vi) Support to the sector

- The commercial, smallholder, and subsistence farmers currently receive less support from the state than most of their counterparts in other industrial countries in the world; these are also the markets where South African agricultural exports must compete.
- Measured in terms of the internationally accepted benchmark, namely the producer support estimate or PSE as calculated by the OECD, direct support provided to the agricultural sector in South Africa is similar to countries like Chile and Brazil. There is furthermore clear indication that these two countries are making efforts to increase support to their agricultural sectors in various ways. The level of support offered to these producers including South Africa is considerably lower than the OECD average.
- The total cost of support to the agricultural sector, measured as a percentage of the GDP, decreased from 1 percent between 1995 and 1997, to 0.59 percent between 2005 and 2007. This is considerably lower than the average of 0.97 percent for developed countries. The difference in the total cost of support measured in value terms is significant if one considers the enormous difference between the GDPs of developed countries and that of a country like South Africa.
- A salient feature of the period prior to the 1970s was that the level of agricultural R&D investment in South Africa exceeded that of Australia and the United States, but began to consistently lag behind the United States since 1980.

The South African agricultural equipment market is estimated at R1.2 billion (USD171 million) as of 2010. About 80 percent of the equipment is imported and this is mainly high-tech items. Tractor sales constitute the bulk (60 percent) of the total agricultural equipment market.

A study carried out during 2003 has estimated that there are over 325 000 tractors in the country with over 80 percent owned by commercial farmers (Simalenga *et al*., 2003). The annual sales for the past 5 years have averaged 3 575 units per annum. During 2005, tractor sales were 4 677 units (down 602 units from 2004) while the combine sales were 180 units. The study also estimated that there are about 900 000 working cattle (mainly oxen but also some cows) 190 000 working donkeys, 70 000 working horses as well as about 1 500 working mules. The annual sales of animal drawn equipment has been estimated at 5 000 units per year.

Out of a total land surface area of 121 909 000 ha, 100 665 792 ha is available for agricultural production (16 737 672 ha is potentially arable, 83 928 120 ha is suitable for livestock production and 1 433 964 is currently under timber production). Of the potentially arable area 77 percent is currently under production. Optimizing farm mechanization inputs has a crucial role to play in this expansion as well as in optimizing the use of existing farm lands and future developments.

There is limited knowledge or appreciation of the important role that DAP plays in the small scale farming communities amongst both the policy/decision makers and extension staff. Training, access to information, equipment spares and harnesses, lack of research and development in DAP as well as access to capital are among the key constraints, which appear to contribute to the current low levels of mechanization under small holder farming conditions.

2.2.4 Namibia

Despite its current low (approximately 5 percent) contribution to the GDP, agriculture is one of Namibia's most important sectors. The contribution of agriculture to GDP has dropped from 10 percent during the early 90s to 5 percent in 2007 due mainly to advancement in the mining sector and secondary (e.g. manufacturing sub-sector) and tertiary industries (e.g. financial sub-sector). The agricultural sector plays an enormous role in the development and the economy of the country and currently it supports, directly or indirectly, about 70 percent of the population. Most of these people reside in rural areas and are involved in subsistence farming. Generally the sector can be categorized into subsistence, commercial and urban agriculture. The sector faces many challenges in order to address the issues of hunger and poverty alleviation through productivity and food security.

Depending on the affordability of technology, a combination of tractors and DAP (oxen and donkeys) are used in ploughing and weeding of crop fields. Similarly, limited mechanized post-harvest technologies are used in activities such as transport, threshing and winnowing. It has been estimated that there is a total of 182 tractors in eight communal regions of Namibia (NRC, 2003).

The government initiative undertaken in the latter part of the 1990s, culminating in the privatization of its ploughing services, and the sale of tractors and equipment, was one of the most significant achievements of the Namibian Ministry of Agriculture since independence.

DAP in Namibia is mainly concentrated in communal areas in nine regions which are mainly crop growing areas and these i.e. North Central Division (NCD): Oshana, Ohangwena, Omusati and Oshikoto; and North Eastern Division (NED): Caprivi and Kavango, Erongo, Omaheke, Ojtozondjupa and Kunene regions. A total of 4088 animal drawn implements (ploughs and cultivators) have been subsidized to farmers by the Productivity Upliftment Micro-projects Project (PUMP) during 2004 /2005.

Surveys done in recent years estimate that 120 500 donkeys are in the northern communal areas of Namibia, with the NCD having more than 90 percent of the total. It is estimated that the Kavango Region has more than 500 donkeys. Fewer than 100 donkeys are found in the Caprivi Strip (Mwenya *et al.*, 2002). Farmers in these two regions prefer cattle to donkeys. The majority of farmers (60-70 percent) in Kavango use DAP to grow their staple crop, pearl millet.

In the four regions of the NCD, a survey was conducted and a total of 10 202 farmers were interviewed (Mudamburi *et al.*, 2003). It was found that 59 percent of the farmers use donkeys 21.7 percent oxen, 19 percent a combination of donkeys and oxen, 5 percent a combination of donkeys and tractors, 16.1 percent use tractors and 6.9 percent use hand hoes as a source of draught power while other farmers either hire or borrow any of the forms of power sources mentioned above (Tables 2.9 and 2.10).

TABLE 2.9

Namibia: Distribution of draught power sources in North Central Division

Source of farm power	Households using farm power	Proportion of respondents (%)
Donkey	6 019	59.0
Oxen	2 214	21.7
Donkey and Oxen	1 939	19.0
Tractor	1 641	16.1
Hand	703	6.9
Donkeys and tractors	505	5.0

Source: Mudamburi *et al.*, 2003

TABLE 2.10

Namibia: Distribution of transport sources in North Central Division (numbers of respondents)

Transport Category	Regions of NCD				
	Oshana	Omusati	Ohangwena	Oshikoto	Total
Donkey	533	802	396	1 824	3 555
Oxen	7	55	25	142	229
Tractor	4	7	3	45	59
Vehicle	239	334	62	133	768
Head loading	466	405	770	854	2 495
Wheelbarrow	151	64	102	31	348
Bicycle	154	139	21	12	326
Hiring	14	77	0	0	91
No response	541	931	578	336	2 386

Source: Mudamburi *et al.*, 2003

In Namibia access to reliable and timely agricultural information by farmers, local communities and service providers is limited. It is evident that data aimed at providing farm decision support have been receiving a minimum of effort and attention in the last two decades. Promotion of farm data utilization and access to farm management information for smallholder producers is not mainstreamed in most agricultural advisory and extension services in the sub-region.

There are many institutions in Namibia that are playing an important role in agricultural and rural development information (e.g. DEES - Directorate of Extension and Engineering Services; FANR Library - Faculty of Agriculture and Natural Resources; MADI - Mashare Agricultural and Rural Development Institute; NATMIRC - National Marine Information and Research Centre; NAWIC - Namibia Agricultural Water and Information Centre; NNFU - Namibia National Farmers Union, etc.). The majority of these institutions are found in the urban areas and their target audiences have a relatively high level of education. In contrast the few agricultural institutions found in rural areas serve the majority of the farming community and are ill equipped with limited information resources, have limited or no access to internet, lack infrastructure and are often staffed by semi-qualified personnel.

2.2.5 Swaziland

Swaziland, with an area of 17 364 km² has land which is highly valued and is a strategic natural resource for development. Over 75 percent of the population derive their livelihoods from agriculture and its allied industries. Most of people live in rural areas comprising about 75 percent of the total land (CSO, 2002). Out of the total land area the arable land constitutes about 10 percent while the rest is shared between grazing, settlement, forestry, urban dwellings and other uses. Subsistence and commercial farming constitutes 12 percent and 6 percent of the arable land respectively.

The agricultural sector is important to the economy of the country. It employs over 70 percent of the labour force and in 2002 agriculture contributed 10 percent of the country's GDP. The contribution of agriculture is marginally smaller compared to the manufacturing sector and the annual growth rate is around 1.5 percent. Crop production on Swazi National Land (SNL) accounts for about 1.9 percent of the GDP since production is highly dependent on rainfall (GoS, 2003). The principle crops grown on SNL are maize, beans, vegetables and cotton.

Farm power in Swaziland is mainly provided by the government by leasing tractors. However, most smallholder farmers fail to get the services early enough and resort to use of animal power. Some 55 percent of the smallholder farmers are estimated to be still relying on animal power for land preparation and other less power demanding operations such as planting and cultivation.

Despite the leasing of tractors by the government, small-scale farmers and many SNL farmers still use DAP. DAP is very important in Swaziland and some 55 percent of rural households are estimated to use animals for land cultivation. More than 88 percent of draught animals found on the SNL are cattle – mainly oxen which are used for primary and secondary tillage, weeding and transport. In the case of transport, oxen drag a sledge for carrying firewood, timber and kraal manure.

Tractor use is also widespread but lack of timely access to tractor hire services usually delays planting. Most farmers interviewed indicated that in 2006/07 the delayed rains prompted long queues for hiring the services of government tractors (which are cheaper) as farmers rushed to cultivate before the end of the planting season. This was exacerbated by the late deployment of government tractors.

Current access to mechanization services has been reported to be poor in the SNL although the demand seems to be high. The numbers of privately owned tractors in SNL have been growing steadily from 2 700 in 1990 to the current estimated 4 000 tractors (Table 2.11). On the other hand, it is uneconomical to work with tractors in small plots which is the predominant mode of production in the SNL. Given that the objective is to increase mechanized services among smallholder users, demand needs to be organized and aggregated. The models of 'block farming' and 'farmers' associations', whereby farmers' fields are amalgamated for mechanized operations, which are currently being followed by the Swazi-Taiwan Smallholder maize project and the Mahlangatsha Community Development Association are one way of strengthening the demand side while giving the ownership of accessing mechanized inputs to the community (TTM, 2002).

TABLE 2.11

Swaziland: Trend in tractor use (private owned) in SNL

Year	1976	1983	1990	1997	2000	2003*
Tractors in use	884	2 100	2 700	2 920	3 805	4 000

Source: IFAD (1993); CSO, 2000; *Dlamini, personal communication[7].

The Swazi-Taiwan project which started in 1980 with 69 homesteads (75 ha) had by 2003 been able to reach over 6 570 farmers with a total area of 6 618 ha. The main objective of the project was to accelerate maize production on SNL by:

- Bringing together financial assistance, supply and marketing services.
- Mechanizing maize growing operations through joint efforts on the purchase and utilization of farm machinery and equipment.
- Adopting integrated improved farming techniques through group action and joint farming systems.
- Strengthening the organization of SNL smallholder farmers through the establishment of economically viable block farming groups and maize producers associations.

As of 2003 the project is introducing block farming by recruiting farmers covering 50 ha in each of the four regions.

[7] A.M. Dlamini. Department of Animal Production and Health, University of Swaziland.

Various lessons have been learnt through this block farming project. The average maize yield for 2002/03 season was 3 041 kg/ha against the national average of 875 kg/ha. Most farmers interviewed under the scheme reported that it was profitable and the best for improved farming in the country. They reported that it was easier to access tractor services and other farm input supplies since they were grouped together. The farmers were also willing to pay for services rendered (TTM, 2002 & 2003).

In Swaziland, the demand for the use of tractors has been rising since the early seventies when the government embarked on its policy of encouraging tractor mechanization. These tractor numbers have not, unfortunately, met the demands of farmers despite the increase in the government backed Tractor Hire Services (THS) pool tractors. Since the inception of the THS in 1974, tractor numbers have increased from 9 units to 179 units and the number of tractor pools/centres from 3 to 21 (Table 2.12). The demand for tractors has been reported to be very high meeting 40 percent of the total need (Nathi, personal communication) although the demand is mainly restricted to the ploughing season and secondary tillage in maize which is for only three to four months (i.e. between October and January).

TABLE 2.12
Swaziland: THS numbers of tractors and pools/centres

Year	1974	1990	2001	2003
No. of tractors	9	32	160	179
No. of pools/centres	3	10	21	21

Source: MOAC (2002)

The THS could not be transferred to the private sector in 1980 since it was concluded that neither the private sector nor the cooperative movement had the capacity to take over the tractor hire pools and consequently they were retained within an expanded project, the number of pools being increased to ten and later to twenty one.

Operational efficiencies of the THS began to decline and subsidies had to be intensified in the system. Through the IFAD Smallholder Credit and Marketing Project (SCMP) and later through a Japanese grant, tractors were purchased to expand the hiring services throughout the country under a government subsidy to farmers.

Some of the operational deficiencies which have been reported are:

a) A decline in performance due to poor management, which included inadequate record keeping and costing as well as insufficient supervision. (On average a THS tractor ploughs only 8 ha per month.)
b) Repairs and maintenance were highly centralized and required stringent conditions of ordering spares. Ordering spare parts was dependent upon a single order book, which when full had to await all invoices from suppliers before a new one was issued.

c) Low level of preventative and routine maintenance. There was no system in place to diagnose faults before they developed into a major repair need.
d) The operators were not motivated to perform and improve their skills since they were on full employment even if they worked or not.
e) Individual tractor pools were not easily monitored and annual targets were not clearly set per tractor as a motivating measure for each pool to manage its tractors efficiently.

To foster the private sector ownership of farm power in 1985 the GoS, through the MOAC, stood as a guarantor for the lease of 11 tractors to farmers and farmers' associations, financed by the Swaziland Development and Savings Bank (SDSB). The recipients of the tractors were intended to provide privately managed tractor hire services. The scheme met with limited success due to technical and managerial shortcomings and some of the tractors were repossessed.

The major strengths of the THS as observed by the stakeholders are:
(i) Relatively cheap service (due to the subsidized costs) to Swazi farmers and serves as a token of social responsibility by the government to its people.
(ii) Availability of a tractor hire service to farmers in remote areas through Regional Development Authorities.

However, the THS has the following major weaknesses:
(i) The subsidy costs are uneconomical and therefore not sustainable.
(ii) Some of the tractors imported under THS do not have readily available spares locally.
(iii) Competition of donated tractors with local dealers.
(iv) The created demand has not benefited all farmers (i.e. the service is not accessible by all).

Opportunities for its improvement are two-fold. Firstly most farmers and MOAC officials as well as traders believe that THS has an opportunity to be efficient and serve the country effectively. Currently, THS meets only 25-40 percent of tractor demand in the country. The services could also charge at cost without affecting demand since there is willingness from farmers to pay for good services. Secondly, THS has the opportunity to train entrepreneurs and individual farmers on better tractor selection, management and maintenance and thus encourage tractor ownership under farmers' associations.

In Swaziland, oxen are the main animals used for agricultural work; bulls, cows and donkeys are also used though to a much lesser extent. The total numbers of animals used for draught purposes on SNL land are shown in Table 2.13. It has been estimated that 164 600 animals are in use of which 29 percent are in the Highveld, 37 percent in the Middleveld, 22 percent in the Lowveld and 12 percent in the Lubombo plateau. The percentage of land cultivated by oxen and tractors on SNL is difficult to estimate since no formal study has been carried out. However, Table 2.14 indicates the values extrapolated from different survey reports.

TABLE 2.13
Estimated number of working animals in Swaziland

	1994	1995	1996	2003*
Bulls	25 000	28 385	33 296	35 000
Oxen	116 207	102 776	115 099	118 000
Horses	1 300	1 291	5 969	7 000
Mules	72	226	1 069	2 000
Donkeys	14 560	11 810	13 678	15 000

Source: CSP, 2000; CSO (2002); *Author's estimate

TABLE 2.14
Swaziland: Estimated use of DAP, Tractors and Human labour on SNL

	Tractor	Draught Animal Power	Human Power
Figures based on no. of households using the farm power*	33	34	32
Based on RRA survey carried out in 1995**	37	32	31
Based on Hiring costs for the different services*	55	27	18
Own estimates	50	30	20

* CSO, 2002.
** Ogwang and Dlamini, 1995
*** In another study conducted by the National Emergency Response Council on HIV/Aids in 2003 (where 495 households were interviewed), 69 percent of respondents indicated they use human labour, 21 percent farm machinery and only 10 percent used DAP

2.2.6 Mozambique

Generally the smallholder agriculture sector in Mozambique is advancing well after the end of hostilities in the 1990s. Smallholder farming predominates and over 70 percent of the population lives in rural areas in approximately 3.2 million households (World Bank, 2006). The use of technology is low but on the increase as can be seen by the data in Table 2.15.

TABLE 2.15
Mozambique: Key characteristics of the agricultural sector

	2000	2003
No. of Households (millions)	3.06	3.17
Use of Technology (% of households)		
Fertilizer	2.7	4.3
Pesticide	4.5	5.2
Animal Traction	11.0	11.2
Irrigation	3.7	11.0
Access to credit	-	2.9
Basic Agro-processing	-	46.4

Source: World Bank, 2006

Use of Animal and mechanical traction and chemical Inputs

The use of animal and/or mechanical traction, improved seeds, and chemical inputs (fertilizers and agro-chemicals) is one of the possible avenues to turn low technology agriculture into an intensive – high productivity – system in rural areas of Mozambique. Access to capital to acquire assets like draught power and/or machinery is seriously constrained. Lack of financial resources also constrains smallholder access to agro-chemical inputs. In addition to that, availability of such inputs through open markets is virtually nonexistent. To have an idea about the use of such technologies among smallholders in the Zambezi Valley, the results of the survey concerning the use of animal and mechanical traction, the use of pesticides and fertilizers in selected crops, and the sources of those inputs among users is summarized in Table 2.16.

TABLE 2.16
Mozambique: Zambezi Valley smallholder use of DAP and chemical inputs. % of households

	Tobacco growers	Cotton growers	Non-growers
Traction			
Animal Traction	7.7	5.7	3.1
Mechanical Traction	0	1.2	4.7
Use of Pesticides			
Tobacco growers	95.4	-	-
Cotton growers	-	95	-
Use of fertilizer			
Tobacco	100	0	-
Cotton	0	0	-
Maize	29.2	28.1	-

Source: Benfica *et al*., 2005

As expected, the use of animal and mechanical traction is not very common among smallholder farmers in the region. In tobacco areas, over a quarter of the farmers report having cows, but only 7.7 percent (among tobacco growers) use DAP and no-one uses mechanical traction. No use of either source of traction is reported among non-growers in those areas. In cotton growing areas, animal traction is used by 5.7 percent of the growers and 3.1 percent of the non-grower farmers.

Study results indicate that 1.2 percent of growers use mechanical traction, compared with 4.4 percent of non-growers. The use of pesticides in the region is almost exclusively confined to growers of cash crops integrated in contract farming schemes. Indeed, among tobacco growers, 97.4 percent report using pesticides in tobacco fields, while 2.1 percent use them in vegetable fields. Among non-tobacco growers, about 3.1 percent reported using pesticides in vegetables. In cotton areas, about 95.0 percent of cotton growers do apply pesticides in cotton fields and 0.9 percent apply in vegetable fields. There is no application of pesticides among non-growers in cotton areas.

2.3 CHALLENGES TRENDS AND OPPORTUNITIES

2.3.1 Enabling environment for agricultural mechanization

The enabling environment for an agricultural mechanization development strategy includes the macroeconomic framework, rural infrastructure, other rural services, policies, agricultural statistics, public expenditures, and research and extension. Rural infrastructure is a key ingredient and priority for growth of the rural and agriculture sectors.

All the Southern African countries have diversified support structures consisting of public, private, parastatal, donor communities and non-governmental institutions that service the agricultural sector.

For example in Zimbabwe there are technical departments within the Ministry of Agriculture and Mechanization that have a critical role in promoting mechanization. These include: IAE – Institute for Agricultural Engineering, AREX - Dept of Agricultural Research and Extension, DDF - District Development Fund and ARDA.

In Zambia a comprehensive Agricultural Commercialization Support Programme has been developed and recently development partners such as JICA have developed a Smallholder Mechanization Support Programme under 2KR designed to address the inadequate farm power and mechanization situation.

In South Africa a well developed farm machinery distribution network has been established over the years. Farmers can access machinery, spares and repairs through these well established networks (Simalenga *et al.*, 2003). Almost all international makes of tractors and farm machinery such as MF Landini, New Holland etc. are available to farmers in the region via strong well establish distribution networks.

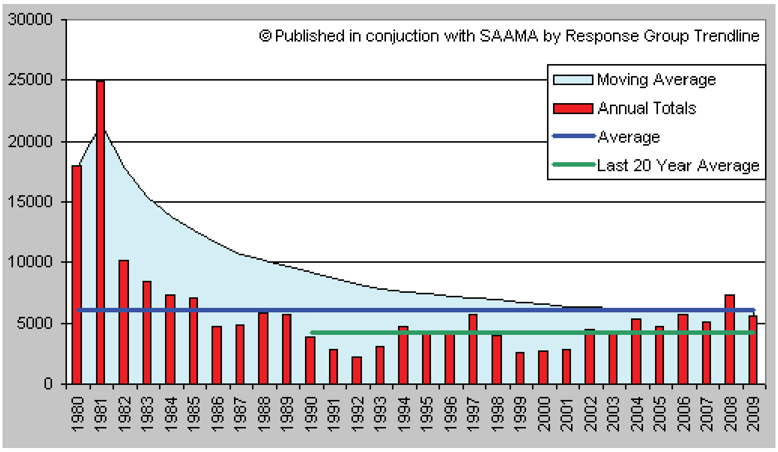
Various umbrella associations exist to support farm machinery manufacturers, dealers and end users. These include: The SA Agricultural Machinery Association (SAAMA); The SA Society for Agricultural Mechanization and The National Agricultural Machinery Traders Association (NAMTA). They provide information on sales and trends and economic indicators to their members and to the general public. Figure 2.1 shows how the information can be retrieved from the SAAMA website:

A number of lessons have emerged from partnerships which have been developed between governments and various donors in the implementation of mechanization projects and these include:

- Government agencies have a limited financial and human resource capacity to implement and sustain the activities. To ensure institutional sustainability of mechanization development initiatives, existing agencies and structures should be used to the extent possible, roles and responsibilities should be clearly defined; recurrent costs should be minimized and cost recovery or sharing be promoted where feasible.

FIGURE 2.1
Annual tractor sales information as provided by SAAMA

Total Market - By Year - Since 1980
http://www.saama.za/stats/



- There is need for beneficiary participation in project planning, design and implementation so as to instill a sense of ownership from a very early stage of a project cycle.
- Projects that involve agricultural production with potential for surpluses for the market should build sustainable marketing mechanisms within them.
- The smallholder Green Revolution experiences in Asia as a result of heavy government intervention in infrastructure development and input supply services demonstrate that sustained investment in the supply-side of agriculture through institutional capacity development is a critical ingredient to agricultural transformation.

2.3.2 Precision farming and conservation agriculture

The effect of labour shortages on agricultural productivity is often overlooked in the analysis of mechanization and agricultural production models. The HIV/AIDS pandemic has wreaked havoc in many households that now occupy new farms. Increasing labour costs under the harsh economic conditions that now prevail makes it difficult to engage in activities with high labour demand such as ploughing, planting and harvesting.

Conservation agriculture (CA) is seen by many as one of the ways to sustain eco-production systems but it also presents itself as a labour saving option that should be considered. The system has been promoted in South Africa under large scale commercial farmers supported by no-till clubs which have been very successful in Kwa Zulu Natal province. In Zimbabwe various NGOs and programmes are in place to promote CA. In other countries such as Namibia and Mozambique there is lack of drivers to promote the CA systems to farmers. Any future investment and interventions in mechanization should promote CA equipment as a means of protecting the environment / natural resource base as well as meeting the demands of labour saving and reducing the use of inputs in agricultural production.

2.3.3 Investment opportunities

Major investment opportunities exist in the region which include the following:

- The region has an agro-ecological environment with high potential to support diversified and productive cropping systems.
- Investing in technologies that can contribute to increased crop production in the small holder sector.
- Establishment of input and output markets and urban demand for agricultural produce.
- Contract farming arrangements for a number of crops such as cotton that can be accessed by smallholder farmers.
- Investing in farmer training and development of farming skills.
- Establishment of vibrant farmer cooperatives and networks linking farmers with financiers, input suppliers, technical and marketing services.

2.4 POSSIBLE AREAS FOR INTERVENTION AND INVESTMENT FOR SUSTAINABLE AGRICULTURAL MECHANIZATION AND AGRO-BUSINESS

It is generally agreed that agriculture will continue to be the most important sector in the economy of most of Southern African countries. Therefore it is logical to re-direct efforts towards this sector. One way of promoting sustainable agricultural development is to promote private sector participation through entrepreneurs in agricultural mechanized operations and agri-businesses.

The following are some broad strategic action areas for intervention with a view to strengthening and developing activities for the advancement of mechanization in the region.

STRATEGIC ACTION AREA # 1:

IMPROVING THE PRIVATE AND PUBLIC SECTOR PARTNERSHIP

Goal: To provide support to the private sector in order to improve the efficiency and quality of service providers. Two main areas for investment can be identified under this strategic goal:

(a) Manufacturing agricultural machinery, implements and parts.
(b) Agricultural processing industries and food technology systems.

The main objective here is to promote the manufacturing base on agricultural operations and processing technologies. The aim is to increase availability of agricultural machinery and equipment for both tillage and agro-processing.

STRATEGIC ACTION AREA # 2:

ENHANCING THE ACCESS TO MECHANIZATION INPUTS AND SERVICES FOR DIFFERENT FARMER GROUPS/END USERS

The goal for this action area is to enable farmers as well as processors to access viable and sustainable mechanization inputs and services. Investments can be directed towards:

(a) Farming and provision of services to farmers and agro-industries.
(b) Marketing of technology-oriented hardware, inputs and services.

The main objective in this area is to develop scientific commercial and profitable farming for both local and external markets. Here the aim is to increase supply of technologies, spares and services to farmers and agri-industries. This will include:

- Trading, importation and distribution of farm machinery and other technologies;
- Provision of maintenance and repair services and supply of inputs and spares (dealerships).

STRATEGIC ACTION AREA # 3:

INSTITUTIONAL CAPACITY BUILDING

Goal: Research, training and extension services are required to support mechanization initiatives. Investing in various training programmes for farmers, artisans, entrepreneurship, extension staff and students in colleges will form part of this strategic area.

STRATEGIC ACTION AREA # 4:

FISCAL STRATEGIES AND POLICY ENVIRONMENT

The goal for this action is to improve funding opportunities, coordination and to remove communication and collaborative bottlenecks which are major impediments to achieving greater mechanization of agricultural activities.

Financial services are important in any development activities. Studies have shown that farmers and agri-processors as well as manufacturers will require funds to enable them to carry out the proposed activities. Policy instruments to create an enabling environment and other complementary services or programmes which have direct impact in mechanization will need to be identified and implemented.

STRATEGIC ACTION AREA # 5:

STRENGTHENING OF COMPLEMENTARY INFRASTRUCTURE AND SERVICES NECESSARY FOR SUCCESSFUL MECHANIZATION INVESTMENTS

Mechanization efforts cannot succeed if they are promoted in isolation from other rural development efforts. Issues related to rural transport, natural resource management, irrigation development, access to markets, livestock improvement programmes are crucial to effective development of mechanization services.

Therefore identification of complementary services / programmes which support mechanization and investment directed towards such targeted services will be crucial under this strategic goal.

2.5 CONCLUSION

The following have been identified as main issues and challenges facing mechanization in the region:

- Inadequate financial resources including shortage of foreign currency to support procurement of machinery and spare-part kits. Overall there are limited importation incentives.
- Shortage of skilled and experienced staff in mechanization.
- Poor coordination and collaboration in programme strategy implementation and planning among stakeholders.
- Lack of capital at farm level for procuring mechanization implements and equipment especially small holder farmers.
- Inadequate access to appropriate mechanization technologies and services.

As stated in previous sections, the problems for starting and sustaining mechanized technology-oriented enterprises do not have a magic formula to solve them. They require both re-orientation of donor assistance towards micro-enterprises, deliberate government intervention in creating an enabling environment and a strong mechanism to take follow-up actions and support the entrepreneurs through targeted investments.

Financial markets need major reform in order to provide the required finance to support mechanization oriented entrepreneurs. This can be achieved by setting up special loan funds or by the provision of accessible credit facilities.

A comprehensive policy framework such as National Agricultural Mechanization Strategy needs to be in place to ensure that the enabling environment is created and sustained to run the business profitably. The strategy will also assist to identify the required infrastructure and other sectors of the national economy to be developed to support agricultural development (see Chapter 11: Agricultural Mechanization Strategies).

Education and training will need to be reviewed in-line with the changing economic environment. Courses such as business and capital management and application of information technology in agribusiness will have to be incorporated as well as entrepreneurship training in universities and colleges.

A mechanism for information for business and market (networking) will need to be established for regional collaboration, promotion and publicity. The mechanism will also initiate the formation of a data bank especially for regional trade and tariffs and market opportunities. This will greatly assist regional networking for a one-stop-information acquisition system (see Chapter 16: Information Exchange and Networking).

The chapter recommends the following actions to be put in place to enhance the quality and relevance of mechanization inputs in Southern African agriculture:

- Support and encourage the existing advanced and successful commercial farming sector.
- Place more emphasis on the development of small-scale farmers particularly in the following areas: The use of appropriate and affordable power options, credit acquisition, effective supply of agricultural inputs (including machinery spares) and marketing systems.
- Encourage the use of DAP whenever it is appropriate and where it can result in economic efficiency and reduction in drudgery.
- Provide in-service training for extension officers to improve their understanding of the different power and mechanization options available to farmers and to expose them to new technologies and opportunities.
- Develop a comprehensive agricultural mechanization strategy for the countries involving tractor and draught animal powered programmes as well as programmes which incorporate tractors and DAP complementing each other.

Agricultural mechanization is an economic activity which can enhance quality of life and bring added value from the use of natural resources. It thus deserves support in terms of investment. Development and modernization of Africa’s agriculture and its agri-industries will depend to a large extent on the transformation of policies and educational and entrepreneurship thrusts. It is argued that for sustainable agricultural growth to take place in the medium and long term, there is a need to change policy from emphasis on small-scale peasant farmers to medium-scale African commercial farmers. Entrepreneurship and professionalism in agricultural mechanization are likely to be one of the main keys to the sustainable development of African agriculture.

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CHAPTER 3

Agricultural mechanization in West and Central Africa

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ABSTRACT

The chapter covers farm mechanization issues in the 25 countries comprising the West and Central African regions. Socio-economic indicators are presented for each country together with the importance of the agricultural sector to national economies. Although tractors have been imported to the region since the late 1940s, the region today only has a total of 11 percent of the tractor population of SSA. This means that tractor use intensity is low in the two regions as is the total power input into agriculture. Mainly for political motives, tractors are now being imported into the region to address the crisis in food security and sovereignty. There are also initiatives being taken for local assembly of tractors. These are generally partnerships between governments and Indian and Chinese manufacturers; although some European manufacturers are also investing in local assembly. Growth in the agricultural sector is perceived as a necessary prerequisite for growth in GDP and this, coupled with the rural-urban population migration and low farmer productivity, means that mechanization is imperative. The elaboration of national agricultural mechanization strategies (AMS) is advisable, within national development plans, to achieve coherent organic growth of the agricultural mechanization industry. A regional, rather than national, perspective may be advisable to achieve economies of scale in local manufacture. Economies of scale will also be achieved by encouraging the emergence of larger-scale commercial farming.

3.1 INTRODUCTION

The regions West and Central Africa, as used in this chapter are those defined by the FAO in its statistical database FAOSTAT. There are 16 countries in West Africa namely: Nigeria, Côte d'Ivoire, Guinea, Burkina Faso, Ghana, Mali, Senegal, Mauritania, Liberia, Benin, Niger, Gambia, Sierra Leone, Togo, Cape Verde, and Guinea-Bissau. Central Africa comprises the following nine countries: Angola, Democratic Republic of Congo (DRC), Gabon, Congo, Cameroon, Chad, Equatorial Guinea, Sâo Tomé and Príncipe (STP), and the Central African Republic (CAR).

Table 3.1 presents some socio-economic indicators of the two regions and the importance of agriculture in their economies. The total population in 2008 was about 414 million for both regions. The population of Central Africa was 122 million with about half of this in the DRC. West Africa was home to about 291 million with about half of this population in Nigeria. The regions are relatively poor with a Gross Domestic Product (GDP) per capita in 2008 of 1 423 USD in Central Africa and about 1 045 USD for West Africa. There are islands of prosperity with small states like Gabon and Equatorial Guinea having the highest GDP per capita in the region. Within the period 2004-2008, all the economies of both regions experienced positive growth in their per capita GDP with three countries having double digit growth rates. These were, Angola with the highest growth rate (16.8 percent) closely followed by Equatorial Guinea (16.3 percent), and Chad with 10.2 percent.

Table 3.1 also shows the direct contribution of the agricultural sector to the economies of the various countries in the regions in the year 2008. Most countries have economies strongly dominated by the agricultural sector. In Liberia, agriculture generates up to 66 percent of the GDP; whilst in the oil rich states of Angola, Congo, Gabon and Equatorial Guinea, the contribution is less than 10 percent. The agricultural sector is the dominant employer with over 90 percent of the total work force engaged in agriculture in some countries. In Central Africa, during the period 2004-2006, about 61 percent of the workforce was employed by the agricultural sector, while in West Africa, this was about 49 percent.

The road infrastructure in the region is poor as it is in many developing countries. For example in 1999 the road density in sub-Saharan Africa (SSA) stood at about 2.5 km/1000 persons while it was 3.29 km/1 000 in Central America and the Caribbean, and in South America it was 7.13. In 2004 Nigeria had the worst road density in the region, followed by Niger and Mali. The highest densities were found in Burkina Faso followed by Gabon and the Republic of Congo.

3.2 STATUS OF AGRICULTURAL MECHANIZATION

Tractors were introduced in many countries in West and Central Africa as far back as 1948 in Ghana and 1949 in Sierra Leone (Ashburner and Kienzle, 2009). More than 60 years on their use is still very small compared to other regions in Africa. Table 3.2 indicates that in 2007, only about 37 percent of tractors in Africa were found in SSA while the bulk (63 percent) was located in North Africa. West & Central Africa had the lowest proportion on the continent with 9 and 2 percent respectively.

TABLE 3.1
Some socio-economic indicators and importance of agriculture in West and Central Africa

Country/Region	Total Pop in 2008, (1 000)	GDP/ capita in 2008, (current USD)	Average GDP/ capita growth rate 2004-2008	Agricultural workforce, % of total workforce in 2004-06	Percentage contribution to GDP from Agriculture in 2008	Road density in 2004, (km/ 1 000 persons)
Angola	18 020	4 714	16.8	70.5	7.7	-
Cameroon	19 088	1 226	3.3	53.4	19.5	2.95
CAR	4 339	458	2.6	68.2	54.4	-
Chad	10 913	770	10.2	70.3	12.3	-
Congo, DR	64 256	182	6.1	60.8	45.5	2.68
Congo, Rep	3 615	2 966	4.3	36.4	4.5	5.17
Equatorial Guinea	659	28 103	16.3		2.6	-
Gabon	1 448	10 037	2.7	31.6	4.9	6.83
STP	160	1 090	6.1	61.3	16.8	-
Central Africa	**122 501**	**1 423**		**61.2**		
Benin	8 662	771	4.0	49.1	32.2	2.50
Burkina Faso	15 233	522	4.9	92.1	34.1	6.96
Cape Verde	498	3 193	5.2	19.8	9.2	-
Côte d'Ivoire	20 591	1 137	1.5	43.7	22.8	4.25
Gambia	1 660	489	6.2	77.2	32.1	2.53
Ghana	23 350	713	6.2	55.7	37.5	2.53
Guinea	9 833	386	2.9	81.9	24.2	-
Guinea-Bissau	1 575	273	2.4	81.5	54.9	-
Liberia	3 793	222	6.4	64.9	65.8	-
Mali	12 705	688	4.3	78.1	36.6	1.62
Mauritania	3 215	889	6.1	51.4	23.7	-
Niger	14 704	364	5.0	96.2	-	1.46
Nigeria	151 212	1 370	6.9	28.9	32.8	1.40
Senegal	12 211	1 087	4.4	72.0	16.7	-
Sierra Leone	5 559	352	6.8	59.4	51.6	-
Togo	6 458	449	2.2	56.6	43.7	-
West Africa	**291 265**	**1 045**		**49.2**		

Source: Adapted from The World Bank Group, (2010), FAO (2009) and WRI (2007)
Note: regional data were calculated by the author from weighted values as required.

Figures 3.1 and 3.2 show the proportion of the number of tractors in the various countries in West Africa, and in Central Africa. Based on the available data, in West Africa, Nigeria has the greatest number of tractors and accounts for about 45 percent of the tractors in the region. In Central Africa, Angola by far dominates the tractor market and accounts for about 63 percent of the tractors found in the region.

TABLE 3.2
Percentage of tractors in various regions in Africa in 2007

Region	Number	Percentage
Northern Africa	397 415	63
Eastern Africa	87 486	14
Southern Africa	71 385	11
West Africa	55 841	9
Central Africa	14 150	2
Sub Saharan Africa	228 862	37
Africa- Total	626 277	

Source: Adapted from FAOSTAT (2010)

Table 3.3 shows the evolution of the number of tractors in Africa and in its various regions from the year 2000 and 2008. On average, about 13 500 tractors are bought annually with the bulk of this in North Africa. The net number of tractors in western Africa has been increasing annually at about 1 400 tractors, while in Central Africa this is about 16 tractors per year. However, this may not accurately reflect the situation on the ground because the latest data suggest that the number of tractors in a number of countries like Angola, Cameroon, Congo, Benin, CAR and Gabon has been constant during this period. This is mainly due to lack of data. In addition, accurate up to date data on the number of tractors in use in Africa are very difficult to come by and there is usually a discrepancy between data published by the FAO, which in principle is provided by member countries, and what prevails on the ground. For example, Fonteh (2010) reports that a census of agricultural tractors in Ghana in 2004 revealed that there were only 1 736 functional tractors whereas the government thought there were 4 000 tractors. The higher number had been previously widely reported as the tractor population in Ghana.

FIGURE 3.1
Distribution of tractors in various countries in West Africa in 2007

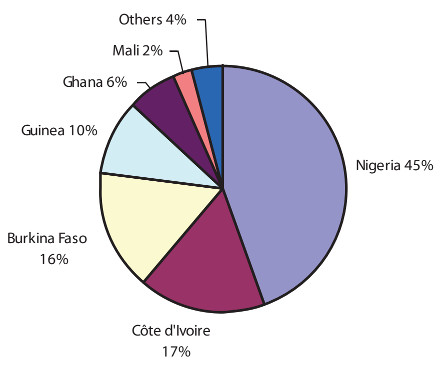


FIGURE 3.2
Distribution of tractors in various countries in Central Africa in 2007

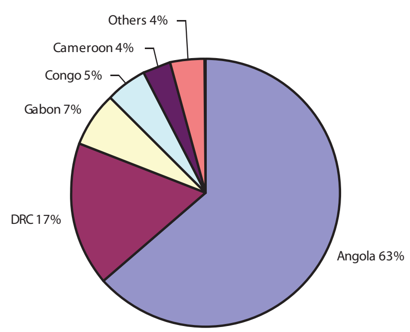


TABLE 3.3
Average annual change in the number of tractors in use between the period 2000 and 2007 in various regions of Africa

Year	Africa	Northern Africa	Eastern Africa	Central Africa	Southern Africa	Western Africa
2000	535 497	314 498	78 266	14 040	82 901	45 792
2001	544 149	323 066	80 853	14 060	78 582	47 588
2002	549 895	325 727	84 415	14 060	76 328	49 365
2003	550 791	327 649	85 141	14 060	73 931	50 010
2004	556 250	332 500	86 130	14 090	71 767	51 763
2005	593 048	368 428	86 581	14 100	71 435	52 504
2006	618 008	390 605	87 301	14 150	71 338	54 614
2007	626 277	397 415	87 486	14 150	71 385	55 841
Average change in # of tractors/year	13 568	12 513	1 241	16	-1 591	1 389

Source: Adapted from The World Bank (2010).

3.2.1 Tractor use intensity

Tractor use intensity is defined as the number of tractors in use per 1 000 ha of agricultural land (arable + permanent crops). Table 3.4 indicates that West and Central Africa are the two regions with the lowest levels of mechanization with tractor intensities of about 0.6 and 0.54 tractors per 1 000 ha respectively in the year 2007. These values are about 50 percent of the values obtained for SSA and for Eastern Africa. When compared to Southern Africa, they are about seven times smaller. In West Africa, the intensity has increased slightly within the past eight years, while in the Central African region it has dropped slightly. The latter may be due to the fact that official numbers of tractors in Angola, which dominates the Central African region, have remained unchanged during this period as a result of lack of data.

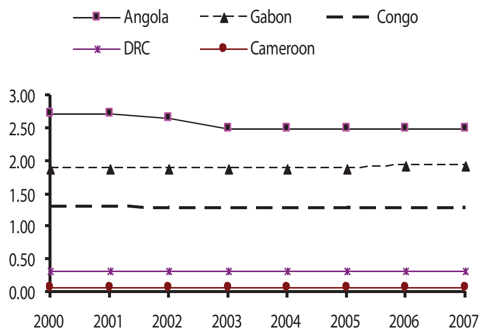
TABLE 3.4
Tractor use intensities of various regions in Africa from 2000 to 2007 (tractors/1 000 ha)

Country/Region	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Africa	2.38	2.40	2.39	2.34	2.34	2.44	2.52	2.54
Northern Africa	7.05	7.27	7.30	7.00	7.23	7.75	8.25	8.38
Eastern Africa	1.38	1.39	1.45	1.41	1.38	1.38	1.38	1.38
Central Africa	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54
Southern Africa	4.76	4.55	4.42	4.29	4.17	4.14	4.19	4.20
West Africa	0.57	0.58	0.58	0.59	0.60	0.59	0.60	0.60
Sub Saharan Africa	1.23	1.21	1.21	1.18	1.17	1.15	1.15	1.15

Source: Adapted from FAOSTAT (2010)

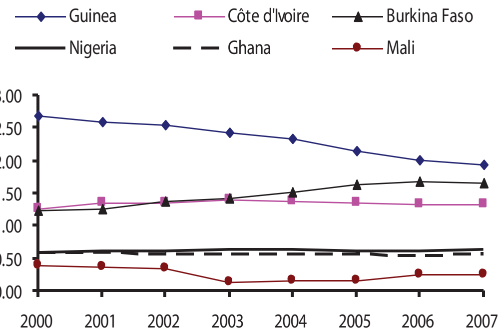
Figures 3.3 and 3.4 show the evolution of the tractor use intensities in countries with the highest number of tractors in use in West Africa and in Central Africa. Angola and Guinea have the highest tractor intensities in West and Central Africa but the available data indicate that the intensity has

FIGURE 3.3
Changes in tractor use intensities in major countries in Central Africa



Source: Adapted from FAOSTAT, 2010

FIGURE 3.4
Changes in tractor use intensities in major countries in West Africa



Source: Adapted from FAOSTAT, 2010

been dropping during the last decade. Burkina Faso and Gabon seem to have made the most significant improvement in tractor intensity. Although Nigeria has witnessed the greatest increase in the number of tractors of about 5 400 tractors during the period in question, the increase in the arable + permanent cropped land has meant that the tractor use intensity only increased slightly from about 0.59 to 0.63. However, during this same period, the arable land + permanent land increased by about 5.5 million ha. The situation in Burkina Faso is worth exploring in greater detail to appreciate why the level of mechanization has been increasing steadily especially after 2003. Despite the war in Côte d'Ivoire, mechanization there has improved noticeably since 2003. The tractor intensity in most Central African states has remained constant or even dropped with the exception of Gabon. This may be partly due to the fact that the reported number of tractors in use during this period has remained constant (perhaps because of a lack of updated data). On the other hand the total area of arable and permanently cropped land has increased.

3.2.2 Power sources used in region

Table 3.5 shows that agriculture in West and Central African regions is characterized by very low power input with greater than 90 percent of the farmers using human labour and hand tool technologies in some countries. Compared to other sub-regions in Africa, Central Africa uses the lowest amount of mechanical power as well as draught animal power.

TABLE 3.5
Proportion of farmers in some countries in West and Central Africa using different sources of power in agriculture

Country/Region	Percentage use of different power sources in Agriculture			
	Hand Tools	Draught Animal Power (DAP)	Mechanical	Partly manual and DAP
Nigeria	90	7	3	
Cameroon (small-scale farmers)	91.2	4.5	3.9	
Cameroon (large -scale farmers)	72	Not available	Not available	
Ghana	50	42	8	
Mali	17	72	0.9	9.3
Central Africa	85	11	4	
West Africa	70	22	8	
Eastern Africa	50	32	17	
Southern Africa	54	21	25	

Source: Adapted from Asoegwu and Asoegwu, (2007), FAO and CENEEMA, (2007), Fonteh, (2010), FAO, (2001) as cited by Shetto, (2007)

3.2.3 Importation of tractors in the region

In some countries in West and Central Africa, politicians have taken the lead to look for immediate solutions to address the food crisis with the importation and assembly of tractors. To be successful these initiatives need to be implemented within the context of a long-term concerted effort to transform subsistence smallholder agriculture to medium to large-scale commercial agriculture and bring about food security and generation of revenue from exports. Unfortunately, it seems many of these initiatives were hastily implemented for political reasons and were not preceded by well thought out plans on required support infrastructure like roads, provision of essential repairs and maintenance. These call into question the sustainability of some of these projects. The following are some examples of tractor importation initiatives in the region.

- 400 tractors imported from India to Mali in 2006, had problems of availability of spare parts and were not initially accompanied by the appropriate farm machinery.
- The DRC recently imported 920 tractors and a range of farm equipment (Ashburner and Kienzle, 2009). Issues have been raised about the appropriateness of the choice of equipment and the proposed mechanization scheme and advice has been solicited from the FAO. Issues relate to the absence of after sales services, and poor road infrastructure in the zone to be mechanized.
- Cameroon is in the process of importing 1 000 tractors from India. There are concerns about the choice of tractors, lack of accompanying implements and the lack of an enabling environment of the zone planned to be mechanized.
- According to Ashburner and Kienzle (2009) Sierra Leone ordered tractors and equipment without a clear plan on how these would be used or a comprehensive study of the sustainability of the project.

- In Ghana, in the period 2004-2009, the government planned to import 4 000 tractors. From 2004-2006, about 1000 tractors were imported and the target was that about 3 000 additional tractors would be imported by end of 2009 (Figures 3.5 and 3.6). This is an example in which the tractors were ordered with a good plan on how they would be used and with the involvement of the private sector in the supply of the tractors, and the provision of after sales services and also as service providers to small-scale farmers.

FIGURE 3.5
shows tractors at the Agricultural Engineering Services Directorate (AESD) awaiting distribution to farmers

FIGURE 3.6
is the parking lot of a Farmtrac tractor dealer. Both in Accra, Ghana

3.2.4 Constraints to Enhancing Agricultural Mechanization

Analyses of agricultural mechanization in Mali and Ghana by Fonteh (2010) concluded that the major constraint in both countries is the poor access of farmers to mechanization technologies. This is as a result of: the high cost of mechanization inputs, the low purchasing power of the majority of farmers to acquire them and the poor access to loans by farmers. Other studies in Cameroon (MINADER & FAO-AGS, 2010a) and analysis of the situation in Nigeria by Asoegwu & Asoegwu, (2007), and ICARRD *(*2006), suggest that this is in general the major constraint in the two regions.

The above results in a vicious circle because, the high costs of mechanization limit the demand by farmers and hence the supply is consequently very low and does not allow for economies of scale to reduce prices. This leads to little competition because of very few suppliers. In addition, the turnover period is very long. Table 3.6 illustrates the cost of acquiring tractors and tractor hire services in some countries in West and Central Africa. With the high costs of tractors in Cameroon for example, only major corporations, timber companies, airports and state funded projects can afford to pay for tractors sold locally. Small to medium scale farmers usually go for imported used equipment.

TABLE 3.6
Sample cost of tractors sold in the region and the cost of hiring farm machinery

Country	Description of equipment of service	Dealer Prices
Cameroon	MF440 tractor, 82 hp, 4WD	23 million fcfa
	4WD Mahindra tractor, 80hp	25 million fcfa
	2WD Mahindra tractor, 60hp	18 million fcfa
	4WD Chinese tractor model DFH-654, 65 hp	13.5 million fcfa
	4WD Chinese tractor model TS-304, 30hp	5.95 million fcfa
	Hiring of 324 hp bull dozer for land clearing	85 000 frs/hour
	Hiring of 120 hp bull dozer for land clearing	60 000 frs/hour
	Hiring 65-70 hp tractor for ploughing by CENEEMA	9-30 000 frs/hour
Mali	70 hp Mahindra tractor	7 million fcfa
	29 hp Mahindra tractor	6 million fcfa
	Power tiller with accessories for rice cultivation	2.8 million fcfa
Ghana	John Deere tractors imported from India, 60 hp	14 000 USD to individuals and sold in bulk to the state at 12 000 USD.
	Ploughing services by private Agricultural mechanization centres	30 Ghanaian Cedes per acre.

Source: Adapted from MINADER & FAO-AGS (2010b), Fonteh (2010)

In Mali with subsidies and preferential terms of payment, a 70 hp tractor is sold to farmers at 5.7 million fcfa[8]; a 50 hp tractor at 4.9 million fcfa while a 39 hp tractor is distributed at 2.8 million fcfa. Through the initiatives of the state, the cost of tractors has been significantly reduced in Mali. In Ghana, the tractor price quoted is based on tractors imported duty free and the state paying all charges which amount to about 33 percent reduction. The prices in Mali and Ghana with government interventions are about 2.5 times cheaper than those in Cameroon sold in a free market.

3.2.5 Assembly of tractors in the region

According to Fonteh (2010) in Mali a partnership between the government and an Indian company started assembling tractors in the year 2008 with a planned capacity of 50 tractors per month. A Chinese private company was also reported to have started assembling tractors in Mali. In Ghana two assembly plants by the Indians and Chinese were planned to take off in 2009. Yisa (2002) reports that Fiat and Steyr tractors were being assembled in Nigeria. It is not known if these are still in operation. However Trade Invest Nigeria (2008) reported that a Nigerian firm, called Afprint plc was going to construct two tractor assembly plants in Enugu and Kaduna States for the assembly of Mahindra tractors. The company already had an assembly plant in Ibadan. It is certain that with the current wave of installation of tractor assembly plants in the region, the Chinese probably also have plants in Nigeria. Plans are underway for the establishment of two tractor assembly plants in Cameroon; one by the Indians and the other by the Chinese. Mahindra Tractors (2010) report that they are also planning to set up assembly plants in Chad and in

[8] 520 fcfa = 1.00 USD. 1.93 Ghanaian Cedi (GHS) = 1.00 USD

Gambia. The former would be a public-private partnership, while the latter would be a private venture. The above approaches seem to be born out of political considerations alone. This approach may resolve the problems of spares but with the limited demands in the region, the economic justifications of many countries having a tractor assembly plant with very small production capacities is difficult to ascertain. Regional cooperation to assemble tractors or other agricultural machinery would, perhaps, have been more desirable.

FIGURE 3.7
The Mahindra tractor assembly plant in Mali

3.3 NEED FOR INCREASED AGRICULTURAL MECHANIZATION

Agriculture is particularly important in West and Central African countries because it is the backbone of most of their economies. In the period 2004-06, about 61 percent of the work force in Central Africa was employed in the agricultural sector while in West Africa; the percentage was about 49 percent. For this reason, growth in the agricultural sector in the region is perceived by many as a pre-requisite for economic development. As the population continues to increase and as the trend of rural exodus continues due to the drudgery and low productivity of agriculture in the region, the rate of urbanization will continue to be high. The consequence is that the percentage of the workforce employed in agriculture will continue to decrease.

FIGURE 3.8
The trend in the rural and urban populations in Central Africa

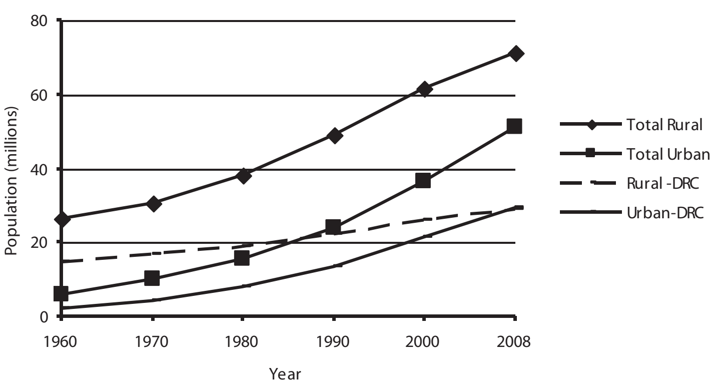
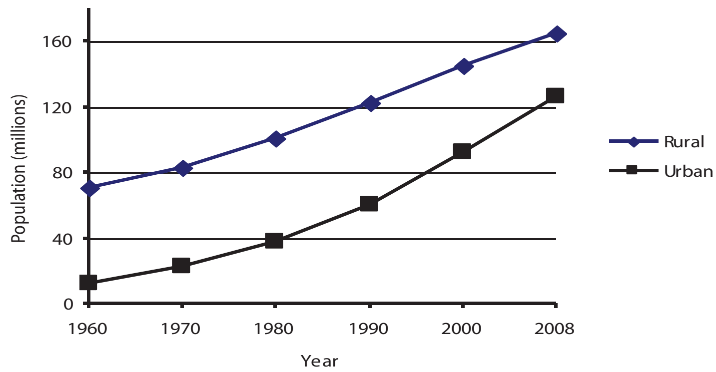


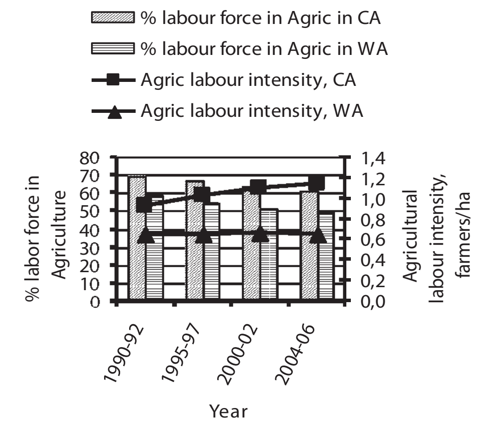
FIGURE 3.9
The trend in the rural and urban populations in West Africa



Figures 3.8 and 3.9 adapted from data by The World Bank (2010) show the evolution of the rural and urban populations in Central and West Africa from 1960 to 2008. In both regions, the rural population is still greater than the urban population but the urban population is increasing at a faster rate. This trend is likely to continue and hence, before long the urban population will be greater than the rural population. This implies that for agricultural production to keep pace with the increasing population, the productivity of farmers must increase. The situation in Central Africa is distorted by the data from the DRC which constitutes 52 percent of the population of the region and which still has only about a third of its population in urban areas. In Angola, Cameroon, Congo Republic, Gabon and STP, the urban populations in 2008 were greater than the rural population. When the population in the Central African region is considered without the DRC, Figure 3.8 indicates that there are more people in the region in urban areas than in rural areas. In West Africa, the population is still predominately rural. In the year 2008 only two small nations; Cape Verde and Liberia had urban populations greater than the rural. Ghana and Côte d'Ivoire had about 50 percent of their populations in urban areas.

Figure 3.10 shows the evolution of the agricultural labour force as a percentage of the total labour force in West and Central Africa as well as the evolution of the agricultural labour intensity. A higher percentage

FIGURE 3.10
Changes in the agricultural labour force and agricultural labour intensity in West Africa (WA) and in Central Africa (CA)



of the work force is engaged in agriculture in Central Africa compared to West Africa. However, both have been reducing steadily during the period considered. The agricultural labour intensity has been essentially constant in West Africa during the period in question. In Central Africa, however, the intensity showed a steady increase between 1992 and 2006. This seems to suggest that the level of mechanization in Central Africa has been declining as there are more persons/ha.

FIGURE 3.11
The trend of urban populations in West and Central Africa from 1960 to 2008

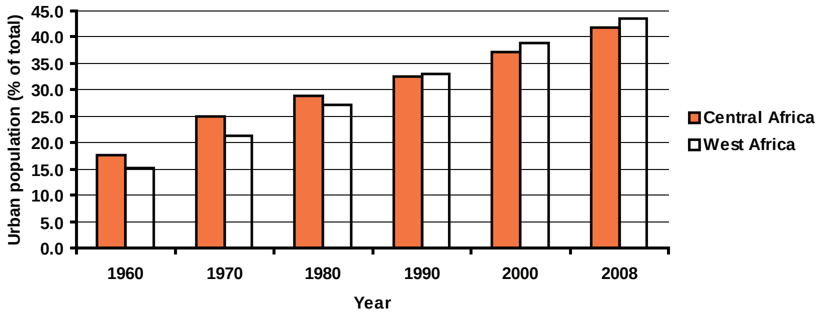


Figure 3.11 shows the trend in urbanization of both regions. In 2008, the urban population in Central Africa was about 42 percent while in West Africa it was about 44 percent.

In addition to the increasing urbanization in the regions, the productivity of the farmers is very low. Table 3.7 shows some indicators of this low level. The average per hectare yield of cereals is about 1 156 kg in Central Africa and 1 111 kg in West Africa. Sâo Tomé Príncipe (STP) has the highest yield of 2 270 kg/ha followed by Côte d'Ivoire and Gabon. The agricultural labour intensity i.e. the number of farmers cultivating a hectare is almost twice as high in Central Africa compared to West Africa. This suggests that the level of mechanization is higher in West Africa. In Central Africa, Gabon has the lowest labour intensity followed by Cameroon. The highest intensity is the DRC with 1.91 farmers/ha. In West Africa, Niger, Nigeria and Côte d'Ivoire have the lowest intensities while the highest is Gambia with 1.83. The added value per worker is also very low. Cape Verde and Gabon have the highest values of 1 986 USD and 1 835 USD respectively. The DRC has the lowest added value.

Based on all the above, the agricultural sector can only grow if the cultivated area per farmer increases as well as the productivity per unit area. It is only with sustained increases in production and productivity that agro-industries can develop to process the surpluses for sale in urban centres and for exports. For this to happen, it is crucial that the level of agricultural mechanization should increase.

TABLE 3.7
indicators of the low level of agricultural production in West and Central Africa

Country	Added value/worker in 2007, constant USD	Agricultural labour intensity in 2004-06, farmers/ha	Average cereal yield of 2004-2008, kg/ha
Angola	251	1.47	510
Cameroon	730	0.56	1 401
CAR	-	0.67	1 116
Chad	-	0.79	751
Congo, DR	164	1.91	772
Congo, Rep.	-	1.06	778
Equatorial Guinea	1 025		
Gabon	1 835	0.40	1 650
STP		0.77	2 270
Central Africa		**1.15**	**1 156**
Benin	-	0.64	1 205
Burkina Faso	-	1.25	1 084
Cape Verde	1 986	0.79	243
Cote d'Ivoire	888	0.49	1 766
Gambia, The	266	1.83	1 003
Ghana	390	0.98	1 359
Guinea	316	1.42	1 473
Guinea-Bissau	320	1.01	1 438
Liberia	-	1.41	1 294
Mali	523	0.92	1 070
Mauritania	424	1.52	839
Niger	-	0.43	433
Nigeria		0.43	1 460
Senegal	202	1.21	970
Sierra Leone		1.49	1 013
Togo	-	0.58	1 123
West Africa		**0.64**	**1 111**

Source: Adapted from The World Bank (2010), FAO (2009)

3.4 ENABLING ENVIRONMENT FOR AGRICULTURAL MECHANIZATION

FAO and UNIDO (2008) concluded that one of the major reasons for the disappointing performance and low contribution of mechanization to agricultural development in Africa has been the fragmented approach to mechanization issues. This was attributed to poor planning by government agencies and over-reliance on unpredictable or unsuitable, one-off, aid-in-kind or other external mechanization inputs. Lack of teamwork or coordination within and between government departments and inherent competition with private sector business initiatives in mechanization services have not helped the situation. Formulation of national agricultural mechanization strategic (AMS) and implementation plans is now seen as the solution, where a holistic approach is used and specifically includes private sector involvement, economic profitability and creation of an enabling environment with clear roles for both public and private sector stakeholders.

A number of countries with the support of the FAO have embarked on the elaboration of an AMS in order to create the environment for the development of agricultural mechanization. The AMS itself would only be successful, if it is developed and implemented within a broad framework of national development. Some countries like Ghana and Nigeria have not developed an AMS *per se*, but have placed agriculture at the centre of their development policies and identified the various constraints to enhancing agricultural productivity with mechanization as one component. Such countries can still make significant improvements in developing their agricultural sector because key aspects of an AMS like the involvement of the private sector, clearly defined roles of public and private sector stakeholders, are included in their approach to agricultural and rural development. DRC, Mali, Cameroon and Niger have developed, or are developing, AMS and in all cases the development of agriculture is planned to lead the industrialization process within the national development strategies.

3.4.1 Enabling Environment in Nigeria

Nigeria has done much to create an enabling environment for agricultural mechanization although it does not have an AMS. The various actions carried out will be used to illustrate the thinking of many states in the region on actions required to enhance agricultural mechanization. According to Asoegwu & Asoegwu (2007) between 1999-2007 the Nigerian government implemented a number of strategic reforms in the area of privatization, commercialization, deregulation, anti-corruption and reduction in financial crimes. The resulting initiatives and programmes contributed to creating an enabling environment to enhance agricultural mechanization. In 2001, a new agricultural policy and the National Integrated Rural Development Policy and Strategy were initiated. These two policies were implemented within the framework of the National Economic Empowerment and Development Strategy.

As concerns agricultural mechanization, the relevant highlights of the 2001 Agricultural Policy are that it defined the role of the state to be the creation of an enabling environment, while investments should be by the private sector. Agriculture was also recognized to be a business and not just a way of life. To complement the agricultural policy, a number of programmes were launched. According to Asoegwu and Asoegwu (2007) and ICARRD (2006) these were:

- Presidential Initiatives in Agriculture (PIA) in 2004: these focused on increasing the production, processing and commercialization of cassava, rice, tree crops and vegetable oil for consumption and as raw materials for industry. The PIA also included training of local producers of equipment, strengthening the research capacity of the nation, improved extension services, provision of subsidies, and enacting legislation to encourage the use of local materials e.g. the mandatory inclusion of at least 10 percent of cassava flour in all bakery products in the country.

- Nigeria Market Information System in 2004: this was established as a public-private partnership to facilitate the commercialization of agricultural produce.
- National Special Food Security Programme (NSFSP) in 2005: targeted resource poor farmers and was aimed at enhancing food security through the development of irrigated land, digging of wells and boreholes, provision of water pumps to farmers, and the creation of training and demonstration centres.
- FADAMA II programme in 2005. The aim was to increase the income of all stakeholders in Fadama areas. Under this project, power tillers were introduced.
- Restructuring and recapitalization of the Nigerian Agricultural Cooperative and Rural Development Bank to address the problem of inadequate funding of the agricultural sector. In 2006, N50 billion[9] was injected into the bank. The Bank has also been supporting the promotion of animal traction technology and the development of hand tools.

Other important existing measures were:

1. Nigerian Agricultural Insurance Scheme, established in 1987 with the aim of securing agricultural investments and encouraging financial institutions to lend more to farmers. According to NAIC (2008) it is also the only existing insurance company owned by the Federal Government of Nigeria due to its unique socio-economic benefits for the populace. The need for a specialized Agricultural Insurance Company to provide insurance cover to farmers came about because of the Government's concern over the vacuum created due to the unwillingness of conventional insurers to accept agricultural risks which they considered too great. The scheme has achieved one of the main objectives for which it was established, namely that of encouraging lending institutions to lend more to the agricultural sector, especially to the small and medium scale farmers (NAIC, 2008).
2. Land Use Act: Land tenure and the development of land is often a constraint in many countries. This however does not seem to be a major problem in Nigeria. The access to farm land by rural farmers is guaranteed through the provision of the Land Use Act, which vests the ownership of land in the Federal and State governments (ICARRD, 2006). The state governments have the responsibility to develop and allocate farm land to rural farmers for agricultural activities. This therefore greatly reduces the cost of mechanization especially as concerns land clearing in forest zones.

[9] In 2006 the exchange rate was NGN 128 = 1.00 USD

The Nigeria government recognizes that agricultural mechanization can only result in increase in agricultural productivity and production if it is carried out within the framework of an integrated agricultural and rural development programme. Agricultural and rural development policies and strategies in turn have to be integrated into a broader framework of national development policies which provides accompanying measures to ensure success e.g. development of infrastructure, creation of markets, financing, education etc. It is in this light that the National Integrated Rural Development Policy and Strategy was launched in 2001. The aims were to coordinate the development of the rural sector and promote rural industrialization. Four areas were targeted namely: improvement in rural infrastructure especially roads, promotion of agro-based rural industries, human resources development and finally special programmes for disadvantaged groups and areas.

ICARRD (2006) reports that the Nigerian government also instituted a number of measures to stimulate and encourage local and foreign investors in the agricultural sector. These include:

- Zero tariff rate on the importation of agricultural chemicals
- Duty free importation of spares for processing machinery
- Tax free dividends for 5 years for agricultural production and processing in Nigeria
- Tax relief for 5 years for pioneer industries, manufacture of fertilizers, and large scale farming of wheat, maize, rice and sorghum
- Removal of import and export restriction on agricultural products

In the light of all the above initiatives to create an enabling environment to stimulate investment by local and foreign investors in agriculture and rural development and consequently agricultural mechanization, it is therefore to be expected that agricultural production and productivity should have increased significantly in Nigeria between 2004 and the present.

3.5 INVESTMENT OPPORTUNITIES AND CHALLENGES FROM THE CURRENT STATUS

3.5.1 Opportunities

Recent hikes in world food prices due to environmental disasters, and the increasing use of food crops and agricultural land for the production of bio-fuels leading to the resulting food riots in many developing nations, have led many policy makers to start thinking of food sovereignty and not just food security. This calls for increasing the productivity of farmers. In addition, many countries in the region have now concluded that to stimulate growth and reduce poverty, the business environment needs to be improved for agriculture led growth. Cameroon, Mali, Ghana, Nigeria and others now have national development policies which call for mechanizing or intensifying agricultural production, as well as using agricultural products as raw materials for industries.

To achieve this goal, it is now widely recognized in the region that agriculture should be promoted as a business and not just for subsistence. This calls for the development of medium to large scale farmers who will need a lot of agricultural engineering technologies to improve their effectiveness and be profitable. It is also recognized that agricultural mechanization will not be sustainable if it is not developed within a broad framework of national development in which accompanying measures such as improved infrastructure, provision of credits, and access to markets are provided. It is with this in mind that a number of countries like Nigeria have developed strategies to create an enabling environment to increase private investment in the sector.

Because of the low productivity of farmers in the region, the low level of mechanization, the desire to ensure food sovereignty and intensify agricultural production to stimulate economic growth and development, there is a very high potential for expansion of the agricultural sector at all levels. This constitutes an investment opportunity in the following domains:

- Storage, processing, packaging and marketing of agricultural products not only for national consumption but for regional and international markets. Since it is widely documented that 30-40 percent of agricultural produce in Africa is lost due to poor post harvest handling, storage and processing methods, this is a great opportunity to buy products in season for storage and commercialization during the off season with higher prices. This will also stimulate agricultural production because in many instances, post harvest constraints hinder production.
- Medium or large scale agricultural production within the region of some strategic crops. The Chinese are already investing in this aspect to produce rice and mushrooms for export to China.
- Sale of agricultural machinery for all aspects of the value chain. The fear of many governments in the region of political instability resulting from the hikes in food prices has led many to import large numbers of tractors with a view to increasing agricultural production. For example about 4 000 tractors are to be imported by Ghana, 400 tractors to Mali, 920 to DRC and 1 000 to be imported by the government of Cameroon from India. Dealerships in farm machinery therefore are possible attractive areas for investment. In Ghana, John Deere and Farmtrac dealerships have been established and have been supplying tractors to the government as well as selling to individual farmers who do not qualify to obtain tractors from the government run scheme.
- Service providers:
  - The importation of large quantities of tractors by the state provides an opportunity to provide a number of services like spare parts, repairs of agricultural machinery, training equipment operators etc.
  - While waiting for medium and large scale farms to emerge, mechanization services could be provided to small scale farmers who cannot afford to

buy their own equipment. This has worked very well in Ghana with the creation of private agricultural mechanization centres in various parts of the country. These centres offer various services for ploughing, harvesting and transportation of produce.
    - The development of medium and large scale farms would require land clearing which requires heavy equipment like bulldozers, the construction of roads. This is therefore another investment opportunity.
    - As professional farmers develop, consulting services will be required to carry out feasibility studies to, for example, assist banks to provide loans.
- Local assembly of imported agricultural machinery.
- Research, development and production of equipment for the processing of indigenous crops.

3.5.2 Challenges

The major challenge which results from the current status is for governments in the region to develop and implement AMS to create the enabling environment for agricultural mechanization to flourish. This requires:

- Stimulating the development of medium and large scale farms and hence creating a bigger market. They should be able to obtain loans from banks and be profitable in order to repay the loans.
- Breaking the vicious circle of low level of mechanization due to high cost of inputs which leads to low demand, low supply and hence high cost.
- Provision by the state of accompanying measures like infrastructure, research and training facilities, markets etc. to ensure mechanization is viable.

3.6 THE WAY FORWARD

In order to enhance agricultural mechanization in West and Central Africa, the way forward is that the government should intervene to counteract the conflicting issues of high prices, low demand, low supply and high prices. For this to happen, demand must be stimulated through the emergence of professional medium to large scale farmers. The elaboration of an AMS would provide an opportunity to identify the various factors which result in the high cost of agricultural machinery in the region. This will then be followed by providing incentives to stimulate demand for agricultural machinery as well as local production. These incentives could be smart subsidies, loan guarantees, agricultural insurance, tax breaks etc.

With respect to the local assembly of farm machinery like tractors, the regional economic groups in the two regions should take the lead to coordinate activities based on a regional rather than a national perspective to ensure sustainability. Based on the data on Table 3.3, the tractor market in SSA is still very small and it's even smaller in West and Central Africa. However, there is a lot of potential for rapid growth. Many countries are embarking on the assembly of imported tractors mainly driven by political interests and not by economics. Most of these plants have very small capacities and hence it is difficult to see how they will be sustained unless the state supports them. MINADER & FAO-AGS (2010b) report that on the average, only about 40 tractors of different makes are imported into Cameroon annually. This makes the provision of spares very difficult due to the small volumes involved. In addition, a Chinese assembly plant that went operational in the year 2000 to produce power tillers quickly went out of business due to the very small market. Despite, this about two tractor assembly plants are planned to be constructed in Cameroon by the Chinese and the Indians. For economies of scale, there should be regional cooperation to develop a sustainable agricultural machinery industry based on a regional market.

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CHAPTER 4

Rural and agricultural mechanization in Bangladesh and Nepal: Status, processes and outcomes

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ABSTRACT

The development of farm mechanization in Bangladesh and Nepal is analyzed and discussed. In both countries emphasis is on two and four-wheel tractors, but other equipment such as transport, crop protection, harvesting and processing machinery is also included. The outstanding success story is the use of Chinese-made equipment (two-wheel tractors and diesel engines for irrigation pumps) that has transformed Bangladeshi agriculture. This success has not yet been repeated in Nepal's terai region. The impact of mechanization on local manufacturing, value addition and service provision has been very positive. Some common themes are drawn out of the comparative study to serve as a guide for future policy making. The need for research and analysis of mechanization options and issues is highlighted.

4.1 INTRODUCTION

In the 1970s there were many policy debates concerning the best choice of techniques for promoting equitable economic growth, and agricultural and rural mechanization was central to these policy debates. However, since then, while processes of agricultural and rural mechanization have taken place, there have been few studies that look at the nature and outcomes of these mechanization processes, or debates concerning future policy. Because patterns of rural mechanization so affect the use of rural resources, economic efficiency, rural employment and the distribution of benefits up and down local and global value addition chains, such policy debates are now long overdue. This chapter takes Bangladesh and Nepal as two case studies to illustrate some of the issues involved.

The chapter is written from a public policy perspective, i.e. what role government can play in encouraging sustainable and equitable economic growth. We concentrate on growth and poverty reduction; especially in rural areas. There are no general economic or engineering panaceas that can be scaled out and generally applied in this area of policy. At one time it was thought that increasing agricultural production, especially in food crops, was the major issue to be addressed in ensuring that poor people had adequate food to eat. However, the limitations of this approach are now well illustrated by experiences over the last 30 years, where globally and within countries there has been more than enough food available but still large numbers of rural poor people and marginalized groups, especially children, are malnourished and are a long way from being "food secure". The persistence and sometimes increases of such inequalities indicate that these are not just temporary, unusual, or unexpected outcomes of economic growth, but are structural issues that are related to the policies that gave rise to the specific patterns of economic growth and social change. Also in the past there were some in policy circles promoting a type of "one size fits all" rural mechanization process, with the promotion, in the name of efficiency, of large scale equipment, such as 4 wheel tractors, combine harvesters and high capacity irrigation pumps for groundwater extraction. The evidence of a totally different pattern of mechanization in Bangladesh's agricultural growth shows that alternative patterns were, and still are available (Biggs and Justice, 2010).

The cases of Bangladesh and Nepal illustrate well the need for location-specific policy analysis. A conceptualization of policy analysis is required where the specifics of the local contexts play the central role; whether these be local agro-climatic conditions, local agrarian structures, local trade conditions, or the local political and economic contexts.

4.2 BANGLADESH

4.2.1 Recent history of rural mechanization

In the early 1970s, when some influential people in policy circles characterized Bangladesh as a "basket case", no one could have foreseen that the country would, in 2010, have one of the most mechanized agricultural economies in South Asia (Mandal, 2002, Islam, 2009). Significantly, about 80 percent of all land preparation and other primary tillage operations are mechanized. This is performed mainly by 300 000 small 2-wheel tractors (2WTs) and the rest by a few (15 000) 4-wheel tractors (4WTs). Additionally, 60 percent of land is irrigated by over 1 million small diesel powered pump-sets and most of the wheat and much of the rice crop is threshed by small machines. There is a small number of combine harvesters in Bangladesh[10]. While some

[10] 4WTs have been promoted at different times in Bangladesh. For example, in the 1960s at Bangladesh Academy of Rural Development, Comilla (Lewis, 1996). 2WTS were promoted in Bangladesh in the early 1970s by a Japanese aid programme, which amongst other things established a training and service centre just outside Dhaka.

commentators might describe this as a situation where farmers on their own small farms use small-scale equipment, this is not the case. While the average size of land holding is small (less than 2 ha) there is a high degree of inequality in ownership. Small scale equipment is owned by rural entrepreneurs, who may use the equipment on their own holdings, but rent out and hire in services. There are highly developed markets for tractor, thresher, pump-set and other services derived from the spread of small diesel engines.

Bangladesh has a remarkable history of mechanization, in which the Bangladesh Government and the Bangladesh private sector both played important roles. Furthermore, for as yet not well-understood reasons the Bangladesh private sector[11] (as compared to the private sector in Nepal and India) focused on the import of cheap, low-hp engines and other machinery from China.

While there had been various experiments with Japanese and other 2WTs and pump-sets during the 1970s and early 1980s, perhaps the main reason for the rapid spread of 2WTs in the 1990s was a major change in policy in the late 1980s as a result of a national food crisis. After a cyclone hit Bangladesh in 1988 within two and half years of a previous one, taking not only a major toll on human life, but also on the draught oxen population, President Ershad asked what machinery would be most appropriate for their quick replacement. He was told that the Chinese 2WTs could do this, but due to the standards committee they could not be imported. To overcome this problem Ershad disbanded the committee. This action combined with market liberalization policy and the lowering of tariffs resulted in the massive import of small pump-set engines for irrigation and later 2WTs and other equipment. These developments coupled with the more recent spread of tens of thousands of small scale mechanized rice, wheat, and maize threshers - mainly powered by the Chinese diesel pump-set engines makes Bangladesh possibly the most mechanized and labour intensive agricultural sector in South Asia, with substantial employment and other growth linkages to other rural and urban sectors.

4.2.2 The spread of select rural and agricultural machinery

Shallow tube well and low-lift pump-sets

In Bangladesh 55 percent of cultivated land is under irrigation. Most of this is from ground water and surface water sources using small low-lift pumps. In 2006 it was estimated that of the 4.62 million hectares (mha) irrigated from groundwater sources, 3.12 mha (68 percent) was from shallow tube wells (STWs), 0.80 mha (17 percent) from low-lift pumps and, 0.7 mha (15 percent) from deep tubewells (Singh and Roy, 2008)[12].

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[11] Sri Lanka also went down the route of importing cheap Chinese engines, although a British aid programme has promoted 4WTs in the 1970s.

[12] Engines also replaced gangs of labourers for pulling sail boats upstream.

The spread of STWs on such a scale would not have been possible without a low-hp, affordable power source. The convergence of the technical specifications of these two technologies represents, so to speak, an alignment of the stars propitious for their scaling out.

Both the STWs and the low-lift pumps use the same engine and centrifugal pumps and cover 85 percent of the total irrigated area. These air or water-cooled single-cylinder diesel engines' horsepower ranges from 2.5 to 7 (average 5 hp) and now over 100 000 are imported from China every year. The compatible centrifugal pumps originally also came from China, but since the end of the 1990s nearly all centrifugal pumps are now manufactured in the Bogra industrial area, a good example of import substitution. This industrial area in the west of the country has a long history of manufacturing agricultural equipment going back to government and donor programmes in the late 1960s.

A more recent and little documented phenomenon is the spread of inexpensive locally manufactured lay-flat hosepipe for use with these pump-sets (see Figure 4.1). These are flexible, easy to move plastic pipes that take water from the pump-set to where it is needed in the field. Sometimes these pipes conduct irrigation water over hundreds of metres. They can be rolled up for transport when not in use. It is estimated that there is a 30 to 50 percent saving in water use as compared with conventional field canals - as there is

FIGURE 4.1
Chinese 4.5 hp diesel engine with Bangladeshi made centrifugal pump and 100 m plastic lay-flat hosepipe near Dinajpur, Bangladesh

no canal infiltration loss and with a 'fire hose' approach in the field, the new water management system can bring further savings as well as provide more even irrigation compared with traditional flood irrigation. As there is no need to dig tertiary delivery ditches in the fields, many hours of work can be saved. Alongside the spread of pump-sets and lay-flat hose pipes, have been the spread of market institutions for buying and selling water, threshing, transport and other services, arising from the spread of the low power diesel engines.

Two and four-wheel tractors

What had started with the import of small Chinese irrigation (diesel) pump-sets in the 1970s and 1980s was quickly followed by the major imports of Chinese 2WTs in the mid-1990s. The 2WT population is made up of about half Dongfeng and half Sifeng tractors. Earlier only 12 hp models were imported but in the last five years the engine size has increased to an average of 15 hp with even 18 hp models now available. The main attachment is the rotary cultivator (Figure 4.2). As engine size increased, the cultivator width has also increased from 60 cm (18 blades) to 80 cm (24 blades).

FIGURE 4.2

One of perhaps 350 000 Chinese 2-wheel tractors preparing land near Chuadunga

Trailers are popular for both 2WTs and 4WTs but little research has investigated their numbers and the variety of ways they are used for transporting people, agricultural inputs and outputs and other goods and services. From the authors' knowledge of Bangladesh we estimate that 40 percent of the 2WTs (120 000 tractor-trailers) have locally manufactured trailers of 1.5 – 2 tonnes capacity. The trailers are an important off-season and complementary income earner for owners where they transport a range of agricultural and non-agricultural goods in rural and peri-urban areas.

Current estimates of the numbers of 2WTs range between 3 to 400 000. Ahmed (2001) estimated that by 1996, 28 percent of land was cultivated by 2WTs. Meisner, *et al*. (2003) noted that by 2002 over 75 percent of wheat was cultivated by 2WTs. Current estimates are that over 80 percent of all the cultivated area is prepared by 2WTs with rotary cultivators (Singh and Roy, 2008). Perhaps 1 in 30 farmers owns a tractor so that nearly every tractor owner is a tillage service provider for their surrounding farmers. Singh and Roy mention that even the poorest farmers hire in 2WTs as they are cheaper than hiring oxen or 4WTs.

It is estimated that there are about 15 000 4WTs in Bangladesh. As shown in Table 4.1, that is only 8 percent of the combined horsepower of all 2 and 4 wheel tractors. They are mainly used in tea estates and sugarcane farming, however there have been programmes going back to the 1960s to promote 4WTs for general agricultural use (Lewis, 1996) and their promotion continues today. It is possible that in the north-west of the country, where there are more large farms, a pattern of larger-scale equipment use will start to emerge. It remains to be seen whether such a pattern of mechanization will be effective and equitable and efficient in the use of scarce national resources.

TABLE 4.1
Horsepower availability in agriculture by size of engine for Nepal and Bangladesh (Estimates for 2010)

	Nepal			Bangladesh		
Energy Source	**No. units (‘000s)**	**Total hp (‘000)**	**% of total hp**	**No. units (‘000s)**	**Total hp (‘000)**	**% of total hp**
2WTs*	12	168	10	400	5 600	46
4WTs**	30	900	53	15	460	4
Irrigation shallow tube well pump Diesel ***	120	600	36	1 200	6 000	49
Irrigation pump-sets Electric****	10	20	1	100	200	1
Total Available Horsepower		1688,			1 260	

Estimates are of the numbers of power sources (and their hp ratings) used primarily in agriculture and processing, including groundwater irrigation pumps. They do not, for example, include the many engines used in Bangladesh to power riverboats, rice mills, processing, etc., although these are a vital part of the Bangladeshi agricultural and rural economy.

*Average of 14 hp per 2-wheel tractor (2WT)

** Average of 30 hp per 4-wheel tractor (4WT)

***Diesel / petrol irrigation pump-sets average 5 hp. 5 – 10% of the pump-sets are petrol/kerosene.

****Electric irrigation pump-sets average 2 hp

Crop Protection Machinery

Manually operated weeders and sprayers are used widely and, according to Singh and Roy (2008), number about 200 000 and 1 000 000, respectively.

There are many types of manually pushed inter-row weeders; the majority are used in puddled rice cultivation and where many farmers transplant rice by hand in rows specifically to be able to use the pushed inter-row weeders (Figure 4.3).

FIGURE 4.3
Row weeder in use in Bangladesh

Harvesting and Threshers

Although the use of reapers and combine harvesters is growing, their overall numbers are still quite small. Beginning around 2001 a series of programmes launched by the project Research and Extension in Farm Power Issues (REFPI) under Bangladesh Agricultural University's Agricultural Engineering Department sparked great interest in 2WT-mounted and self-propelled reapers amongst other projects and with manufacturers.

- **Reaper**

  Though the Chinese 2WTs came with a reaper attachment, work in the late 1990s showed that they had maneuverability problems in small plots as well as being too expensive. Still, many engineers and manufacturers felt that the time for small reapers had come and fitted well with Bangladesh's small but highly differentiated and fragmented holdings. At one time (about 2002) perhaps 12 different programmes and manufacturers were designing and manufacturing self-propelled reapers using Chinese diesel engines of under 6 hp. The new "walk behind" reapers were much more maneuverable in smaller fields as compared to the longer 2WT reapers (Figure 4.4). However, many suffered quality as well as design limitations and their price was higher than other extensively used simpler machines. The result was that walk behind reapers did not spread much and it is estimated that there might only be a few hundred still in use.

FIGURE 4.4
Bangladesh-developed walk-behind reaper circa 2002

- **Combine Harvester**
  Combine harvester use is growing but still limited. Reconditioned Korean combines are being imported and sold at less than 10 000 USD (Enamul Haque 2009 and M.I. Hossain 2010)[13]. The authors reckon that less than 50 have been imported, many of which are only used by institutions and research farms.
- **Threshers**
  The spread of small horsepower, belt-driven threshers and maize shellers has been very rapid indeed. Prior to the mid 1990s Bangladesh had little mechanized threshing of any crops. Then much of the rice and wheat was being threshed by hand or by trampling (treading) with 2WTs or animals. Islam (2009) reports that currently 100 percent of maize is being shelled by powered maize shellers and over 80 percent of wheat and a large percentage of rice is being threshed by machines. There is also widespread use of the less expensive hold-on type open drum threshers for rice. All threshers and maize shellers are powered by the Chinese diesel engines that are identical to the ones used on pump-sets (Figure 4.5) and in some cases by the larger diesel engines of 2WTs.

While open drum threshing of rice represents cost savings over traditional threshing and does not have negative effects on women's work (as compared to traditional threshing) there is no grain cleaning mechanism and so the rice grain is still winnowed by hand (Kabir, 2004). The spread of open drum threshers to over 120 000 in 2006 can be attributed to the small-scale private sector as the simple designs easily lend themselves to manufacturing in local

[13] Personal communications, 16 June and 7 May respectively.

FIGURE 4.5
Diesel engine powered open-drum thresher at a Bangladesh agriculture fair

village workshops. In 2000 several government programmes began promoting rice and multi-crop (rice-wheat-lentil) closed drum threshers and by 2006 the numbers of these threshers was estimated to be at 45 000 (Singh and Roy, 2008). A few hundred pedal and power operated winnowers are also being used in the country.

Milling

Before the 1980s much of Bangladeshi rice was processed by rural women at home with the traditional foot powered *dheki*. The dhekis have almost totally disappeared from the rural households due to the spread of mechanized milling systems of many different types. In the 1980s and 1990s the mill was the old Engelberg type huller-polisher but by 2000 nearly all rural and urban based mills have converted to the rubber roller huller as they can save 10-20 percent of milled 'white' rice, decrease broken grain from 20 to less than 5 percent, and also save energy.

Change in milling machinery has been one of the biggest technological changes in the agricultural sector in recent years. This is not just a move to a concentration of milling in large-scale operations, but involves other methods as well. Currently there are economically viable mobile door-to-door rice hullers (transported and powered by 2-wheel tractor-trailer combinations or motorized three-wheelers). There are also more modern small and medium sized rubber roller mills, and there are the large modern and fully automatic mills of Dinajpur, Bogra, Ishwardi, and other big towns, that are using modern continuous batch driers. These are locally referred to as LSU dryers. Much of this equipment (new and used) is sourced from West Bengal. Nearly

100 percent of Bangladesh's rice is now milled in one of these four ways and the total number of mills large and small, is estimated at over 100 000 (Kabir, 2004).

Agro-machinery Industry

According to F.H. Ansarey in Parvez (2010) the agro-machinery industry in Bangladesh is worth over 400 million USD and sales of small single-cylinder diesel engines and 2WTs make up over half of this total. The other half comprises products fabricated by small and medium manufacturers who make threshers, trailers, centrifugal pumps, and diesel engine and tractor spare parts. For the latter there are over 40 foundries around Bogra that produce 80 percent of the cylinder liners and pistons and nearly all the centrifugal pumps for irrigation pump-sets.

Today, there are perhaps more than 10 000 small and medium sized local metal working workshops manufacturing agricultural machinery in Bangladesh. These range from small 'one welder' workshops employing 2-3 individuals to larger concerns employing much higher numbers of staff. In general, very few of them use jigs and fixtures and they produce machines to local standards that are low cost and "good enough" for local use. This is often perceived as a problem by the professional agricultural engineering community who would like to see more regulations and the promotion of technology of "higher technical standard".

The evidence suggests that there has been a rapid development of the ago-machinery sector, which is characterized by the rapid spread and high sales of local non-standardized but again, "good enough" equipment.

Many analysts have suggested that it would be good developmentally and there have been several initiatives to backstop and expand this industrial development. For example, by broadening the spare parts industry to fully manufacture the lucrative single diesel engines and 2WTs. Parvez (2008) documents an attempt to manufacture tractors under Chinese licensing.

It is important to note that while agro-machinery importers and Bangladeshi manufacturers are lumped into a single economic sub-sector, their commercial aims are sometimes diametrically opposed to each another. For example manufacturers (and many agricultural engineers) want higher tariffs on imported machinery so as to promote infant indigenous industries, inculcate higher technical standards, and develop local manufacturing capability. On the other hand importers work to reduce import taxes and other formal and informal trade regulations and barriers.

Bangladesh has for many years followed market liberalization policies and this has favoured importers. The decentralized nature of the small manufacturing workshops has not helped their abilities to organize themselves. On the other hand the centralizing of importers in urban centres in Bangladesh has meant that the Bangladesh Agricultural Machinery ***Merchants*** Association with large offices in Nawalpur has been able to keep an importer-friendly regime of minimal tariffs; while the less well organized and much smaller membership Bangladesh Agricultural Machinery ***Manufacturers*** Association has had little impact in getting support for their businesses.

Bangladeshi importers

Considering the impact that Bangladesh's local agro-machinery importers have had with pump-sets, tractors, etc., they might be regarded as the epitome of agricultural importers in the developing world. Not being landlocked as well as being a much less India-centric trading nation (as compared to Nepal) has probably allowed their merchants to travel further afield internationally to source more appropriate consumer goods including agricultural machinery.

We argue that the dramatic growth in the machinery import sector, has not led to any decrease in manufacturing. But instead has greatly contributed to the growth in rural engineering and industrial capacity and capability, where the imported diesel engines are added to hundreds of thousands of locally manufactured country boats, and tens of thousands locally made three-wheelers. The spare parts industry in Bogra has expanded to supply pistons, liners and whole centrifugal pumps for use with these diesel engines.

Bangladeshi local manufacturing

Much of the relevant literature on Bangladesh focuses on the opportunities for local manufacturing of agricultural machinery and highlights the deficiencies in quality control rather than celebrating the successes such as the volume of production and widespread dissemination of threshers, irrigation pumps, spare parts, trailers, etc.

The huge increase in maize cultivation from about 7 000 ha in the 1970s to over 75 000 ha was a concomitant to growth in the allied commercial poultry industry for feed production. The feed industry, particularly in recent years, has been highly mechanized and much of the milling and feed equipment is made locally.

4.3 NEPAL

4.3.1 Recent History of Rural Mechanization

As compared to Bangladesh, Nepal has a great diversity of agro-climatic conditions, the more obvious represented by the flat lands of the terai (Gangetic plains), valleys of the hills, and the lands of the high Himalayan mountains (Figure 4.7). The country also has an incredible diversity of cultures, ethnic groups, inequalities in ownership of land and other resources, and other economic conditions that influence the spread of different forms of mechanization. Although Nepal has a long open border with China to the north its main cultural and economic linkages have been in the past along its equally long border along the terai with India. A general timeline of the spread of these technologies is given in Figure 4.6.

FIGURE 4.6
Timeline of the spread of selected agro-machinery in Nepal

1960 1970 1980 1990 2000 2010
Traditional water mills (ghattas)-- Improved water mills-------
4-wheel tractor/trailers---
Low hp Indian irrigation pumpsets -------------------------------- Chinese diesel pumpsets
Two-wheel tractors/trailers Kathmandu & Pokhara Valleys--------------------------
Wheat threshers (powered by pumpset's diesel engine)--------------
Hand-cranked winnowing fans------------
Combine harvesters----------------
Two-wheel tractors (rest of Nepal)
Rice threshers (eastern Nepal only)
Reapers, 2 and 4 wheel tractors

Before the 1970s there was little mechanization in Nepal except for such things as traditional methods for using the power of falling water for energy. There are thousands of traditional water mills.

Since the 1970s the mechanization picture[14] has changed significantly and it is now estimated, for instance, that most of the wheat in the terai is threshed by machines, generally powered by the engines of first Indian and now, increasingly, Chinese diesel engine pump-sets. Rice threshers are beginning to spread in Nepal's eastern terai. Fifteen to twenty percent of tillage is mechanized, and there are at least 100 000 small-scale irrigation pump-sets[15]. In addition, the rapidly growing horticultural, poultry, dairy and animal feed industries and other "value addition chains", based on agricultural and other rural resources, are using engine powered equipment of one type or another in production, processing, transport and marketing activities.

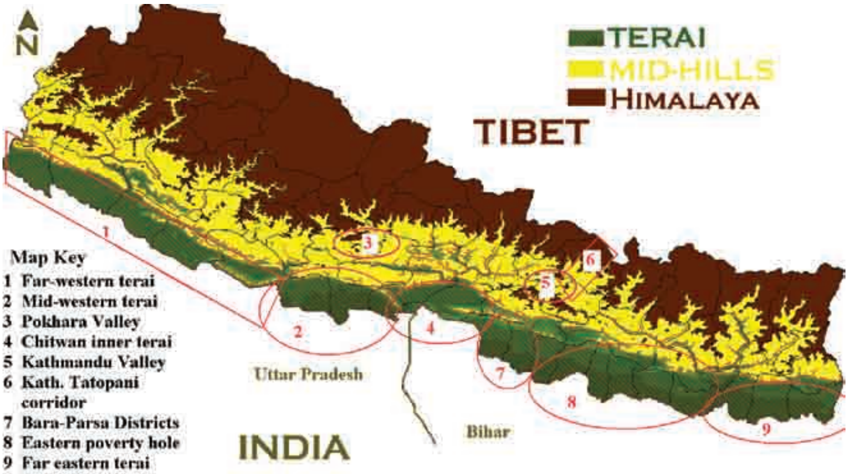
In addition to the diversity of patterns that are found between countries we find that there can be just as great diversity within a country. Regional diversity within Nepal is more pronounced than in Bangladesh for many reasons including that it has far more varied agro-ecological areas but also for different social, economic, and political reasons. In the past the Himalayas have been a barrier to deeper cultural and economic relations with China (although that is changing) but as it is landlocked, it has meant that Nepal is highly dependent on its only other neighbour, India, as a source of trade and agricultural technologies. Whereas Bangladesh being a littoral nation has, since independence, had much latitude with regard to its trading partners.

As compared to Bangladesh, Nepal's differing external influences and greater internal agro-ecological and cultural diversity, have meant that its mechanization processes show the higher levels of variation that we outline

[14] This paper is concerned with a small set of agricultural engineering and mechanization issues and not with covering the recent spread of equipment associated with the growth of the horticultural, poultry and dairy industries and other rural based value addition chains; nor are we looking at the spread of other rural engineering equipment such as mini and meso-hydropower, household solar water heaters, biogas plants, ropeways, rural road and bridges and other technologies with an engineering component.

[15] This figure does not include the very small manual treadle pump-sets that are spreading fast.

FIGURE 4.7
Socio-economic zones of different agricultural and rural mechanization patterns



in Figure 4.6. As mentioned above, due to proximity and the resulting economic and cultural ties, the mechanization patterns of Nepal's terai are highly influenced by what is found in adjacent areas of India. Therefore, we have extended the zones on the map far into India. For instance in the far and mid-western terai (Zones 1 and 2) the use of Indian combine harvesters reflects that these machines also spread (some years earlier) down India's border with the terai from their origins in the states of Punjab and Haryana. Despite some use of combines and many 4WTs, Zone 1 is considered much less mechanized than Zone 2 due to its higher levels of poverty and inequality, low levels of infrastructure, and development spending[16]. And although the terai extends all the way to West Bengal, this 'mechanization' corridor for combine harvesters ends half way down Nepal's terai at the conjunction of the borders with the Indian states of Uttar Pradesh and Bihar. There is little or no combine harvester use in Zones 4, 7 and 9 as they border with Bihar, whose own Naxalite movement has not allowed the free movement of Punjabi combine harvesters into Bihar due to perceived social and economic inequalities associated with combine harvesters.

Nepal's far eastern terai region in Zone 9, with it higher levels of industrialization also has high levels of use of rice threshers due to their spread from the neighbouring and more developed areas of Purnia and Kishanganj of eastern Bihar.

Similar to Zone 1, Zone 8's low level of economic development means that it is considered a region of high poverty in Nepal and perhaps has the least use of any agricultural machinery in Nepal's terai.

[16] Tractors and larger scaled equipment may be part of a process of the concentration of land and rural assets into fewer hands. Research is needed on this subject.

In the mid-hills there is higher ethnic diversity, therefore the topographical determinants are also overlain by social cultural and economic traditions that give rise to diversity in agricultural mechanization within the hills. For instance, in the mid-hills, Zone 5 (Pokhara Valley) which has a population of relatively wealthy retirees of the British and Indian Gurkhas, drawn from the Gurung and Magar ethnic groups of that zone, has a high level of use of 2WTs and threshers. The Nawari farmer/traders of Kathmandu valley in Zone 3 were some of the first to adopt 2WTs in the early 1970s. Their use of 2WTs along with the highest levels of use of fertilizers and chemicals in Nepal continues today.

Lastly, Zone 6 is a corridor that runs along the main highway from Kathmandu up to the Tatpani border crossing with Tibet in the high Himalayas. This corridor has relatively higher concentrations of the Newari ethnic group, with its long tradition of trading with Tibet. It is also one of the most economically developed areas in the mid-hills of Nepal, due in part to its proximity to Kathmandu and international donor agency offices and consequently has a high level of use of 2WTs.

4.3.2 The spread of selected rural and agricultural machinery

Four-wheel tractors

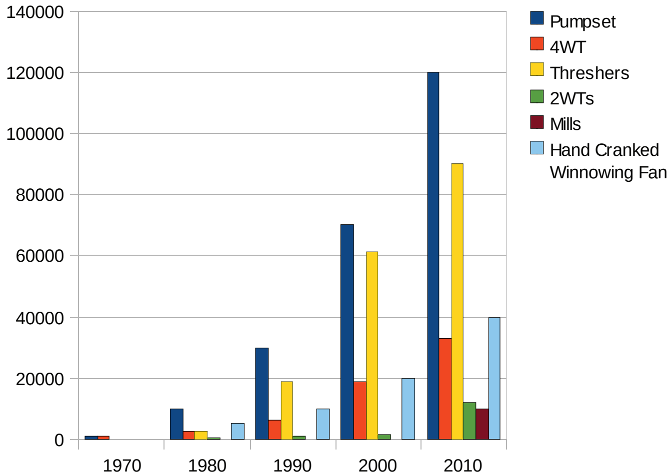
The earliest agricultural mechanization in Nepal was the introduction and promotion of 4WTs, on the terai, in the 1960s and 1970s (Pudasaini, 1976). This came about, not only as a result of government and donor support policies but also because of the long open border with India, where 4WTs and combine harvesters were being promoted as “the” symbol of a modern, commercial and efficient agriculture. From the 1970s onwards all the major Indian tractor companies established sales agencies across Nepal, the latest including multinational companies such as John Deere and New Holland, with manufacturing bases now in India. Current estimates of the total number of 4WTs in Nepal, with an average hp of over 30, are thought to be in the range of 30 000.

While the sale of 4WTs continues to grow steadily, several authors have noted that the relevance and potential for them in Nepal is quite low. This is due to the widespread fragmentation of holdings, and the low average holding size (national average of 0.98 hectare). One of the reasons for the continued sales of 4WTs is because all tractors are multifunctional and their engines can be used for a wide range of activities. In Nepal, a large number of 4WTs are used as road transport vehicles and this is partly due to the tractor import tariffs being only a small fraction of those for transport trucks. Their use in transport is also high in areas where the rural roads are poor and bridges across rivers are nonexistent. An understanding of the spread of 4WTs in Nepal would require an analysis of the ownership of tractors (on both sides of the border), the way tariffs and other regulations in Nepal and India are actually implemented, and the various uses of tractors and transport vehicles on the Indian and Nepali terai.

Combine Harvesters

From the mid-1990s onwards large Indian made combine harvesters with Uttar Pradesh (India) license plates began entering Nepal and, today there might be up to 50 Indian and Nepali owned machines operating on a contract basis in Zones 1 and 2 in Figure 4.8.

FIGURE 4.8
Spread of agricultural machinery, Nepal 1970 – 2010



Source: CBS, 2005; Pariyar *et al.*, 2002; Authors' estimates

Two-Wheel Tractors

In the mid-1970s and early 1980s there were concerted efforts to promote 2WTs. The Japanese International Co-operation Agency began first with the promotion of Japanese 2WTs. This promotion, along with subsidies through Nepal's Agricultural Development Bank in the 1980s, led to the private sector importing approximately 2 000 Japanese, South Korean and occasionally Indian and Chinese 2WTs by the early 1990s. Once the subsidies for the Japanese 2WTs were stopped they were rarely imported and, gradually, the less expensive Chinese ones became more popular. While there was a high seasonal demand for the 2WTs in agriculture they were particularly able to negotiate the very narrow and winding streets of Nepal's urban areas and so were also used in the construction and urban transport industry. However, due in part to a steady or even increasing sale of 2WTs, in 1993 the city governments of Kathmandu and Pokhara banned further registration in the valleys, as city administrations perceived that the tractors were being used primarily for construction haulage and not for agriculture, and were aggravating growing traffic congestion. Although not the intent, the "urban" ban on 2WTs resulted in importers being reluctant to continue importation and so the spread of 2WTs in the agricultural regions surrounding Kathmandu and Pokhara ceased. What happened was that the old stock of Japanese, Korean and other Chinese 2WTs were rehabilitated and maintained and even after 30 years some of the Japanese 2WTs are still in use. This has led to the strengthening of a local repair and spare parts industry.

By 2000, the only 2WTs in Nepal, more or less, were the aging populations in the Pokhara and Kathmandu valleys, which had been imported before the 1993 municipality bans. However, by this time there had been a number of small donor supported R&D projects in the mid 1990s that had promoted the cheaper Chinese 2WTs on Nepal's terai. The programmes succeeded in getting Nepal's agro-machinery merchants to re-start the importation of 2WTs and to market them in the areas where the projects were operating on the terai. Since the 2000s, there has been an increase in 2WT sales, with numbers approaching 1 200 in 2009. Sales during the Maoist insurgency dropped to 500 per year. The national 2WT total in 2009 was estimated to be 11 000 2WTs (NAEF, 2009) and many businessmen and engineers feel the demand will continue to eventually reach a population as high as 40 000 to 50 000. And despite the ban still in place in the Kathmandu and Pokhara the growth in these urban areas grows as farmers and other rural entrepreneurs who own them evade the bans by registering their tractors in other places.

Trailers constitute an important source of the income earning capability of tractors. While the tractors are used for only 3-6 months a year in agricultural field operations, they are employed much of the time for haulage in the transport industries of both rural and peri-urban areas. Farmers and other rural entrepreneurs see tractors as multipurpose productive investments to earn an income[17]. There are no available statistics but we estimate that nearly 80 percent of the owners of 2WTs in Nepal also own trailers (9 600 tractor-trailers). Though 2WT trailers are available from China, all the trailers in Nepal and Bangladesh are manufactured in local workshops. One reason that trailer ownership per tractor is higher in Nepal than Bangladesh is probably due to Bangladesh having a very high (and relatively undocumented) number of other forms of local transport- hundreds of thousands of rural, flat-bed rickshaws and tens of thousands of locally made motorized three-wheelers (Justice, 2004).

Like Bangladesh the financial economic rates of return (even without government subsidies) on 2WTs have always been very high in Nepal. Many farmers/rural entrepreneurs have become providers of tractor services to surrounding villages. They sell a range of tillage, haulage and other services.

[17] In Sri Lanka 2WTs are also used in these multiple ways and agricultural uses are just part of a mixture of operations and services provided by the rural entrepreneurial activities of farmers and others in the rural and agricultural industries (Biggs *et al*., 1993).

Shallow tube wells, pump-sets and flexible pipes

Subsidized programmes for pump-sets and STWs involving the Agricultural Development Bank, Nepal (ADBN) were introduced by the government in the late 1970s. They were designed to promote and expand year-round irrigation for farmers, mainly on the terai. The sole source of the pump-sets was India which still manufactures very heavy, expensive diesel engine pump-sets. In 2000, the spread of pump-sets was nearly halted for a few years due to the loss of subsidies that had been removed with the introduction of neoliberal policies; but by 2005 sales were strengthening again. While some argue that the present spread of pump-sets has come about as a result of the earlier ADBN programmes, others argue that the largest change in shallow tubewell irrigation, in recent years, is the appearance of the smaller, light-weight, inexpensive Chinese diesel pump-sets combined with the locally manufactured "lay flat" irrigation delivery pipe (NAEF, 2009). The use of these pipes has greatly increased the efficiency of field level water management (NSAE, 2010).

This recent spread of groundwater irrigation technology came about in part due to the activities, starting in 2003, of two separate but semi-coordinated efforts by two NGOs[18] to promote the Chinese pump-sets. Both NGOs had extensive experience in Bangladesh and had seen the huge impact that these Chinese irrigation pump-sets had had there. The Chinese engines were nearly half the weight of older Indian (Kiloskar type) design and cost 1/3 to 1/2 the price of the Indian diesel pump-sets. The lower cost equaled or even exceeded the earlier subsidies. The lower prices also brought them into the price range of some poorer farmers[19]. Both NGOs gave advice to separate Nepalese importers who, by 2004, had begun importing and selling the cheaper Chinese and lighter-weight pump-sets in Nepal[20].

Estimating the current number of pump-sets in Nepal is difficult. The official estimate of shallow tubewells (with a pump-set) in 2001 was close to 80 000[21]. However, the statistics do not include pump-sets that were bought outside official government programmes. If we take all purchases into account, plus the promotional activities of NGOs, it is likely that by the end of 2009 there were over 120 000 working pump-sets in Nepal with a continuing larger share of the market going to the Chinese. In most cases, as in Bangladesh, the pump-set engines are also used for driving wheat and rice threshers, mills and other rural engine-powered equipment. Interestingly, by 2009, the main supply of these Chinese pump-sets switched from Nepalese

[18] National Agricultural Engineering Forum (NAEF) and the International Development Enterprises (IDE), Nepal.

[19] See Bringing Pumps to the People (IWMI, *et al*., 2004) that discusses how these cheaper Chinese pump-sets provide pro-poor options for mechanization of irrigation.

[20] By the early to mid 2000s these low cost pump-sets were also becoming popular in India.

[21] The figure is based on a calculation of the estimated area irrigated by STWs and using an assumption that on average 2.5 hectares is irrigated by a STW.

importing direct from China to Nepalese importing Chinese pump-sets from India, as the Indian supplied and mostly rebranded Chinese pump-sets sell at a lower price. This may change as the Nepalese import market matures (Justice and Chaudhary, 2009).

Harvesting and threshing

- **Threshers**

  In Nepal the spread of threshing technologies has been mixed. Wheat threshers came to the terai via India in the late 1970s and like India spread quickly through the 1990s. By the 2000s nearly all wheat threshing in Nepal's terai was mechanized[22]. Yet, most other crops but especially rice have seen little in the way of mechanized threshing. Here we will place threshers into four categories, rice, multi-crop, wheat/winter crops, and maize/other crops shellers.

- **Treading**

  A variation of the traditional treading-threshing (*die garne*) of all grains by oxen is the widespread adoption of 'treading' of rice by 2 and 4-wheel tractors. Once tractors became available they were immediately put to this use. It is accomplished by stacking rice evenly in a circle on the threshing floor and then driving the tractor round and round in circles over it. Once the batch is considered to be threshed (up to 30 minutes or more of driving) 4-5 labourers will come and collect the straw and sweep up the rice which must then be winnowed. The hourly capacity is reported to be about 600-800 kgs. There are no statistics available on this but we estimate that 50 percent or more of the 2 and 4-wheel tractors in Nepal (20 000) are utilized for treading/threshing after rice harvest.

- **Wheat/winter crop threshers**

  The small horsepower (5-8 hp) spike-tooth thresher used by Nepalese farmers was developed for wheat in the late 1960s and early 70s at the G B Pant Agricultural University at Pantnagar and the Punjab Agricultural University. Though mainly for wheat they are also used for crops like lentil, gram, and pea. By the 1990s one could go into any terai village and see scores of farmers with their stacks of wheat surrounding a 'community' threshing floor awaiting their turn for the landlord's thresher (being powered by the landlords 7 hp diesel pump-set engine). As they spread further, there has been a move away from community threshing to mobile threshers being rented to individual households removing the need to transport the wheat and straw to and from the community threshing floor. Nepal's Central Bureau of Statistics (2006) indicates that the number of threshers from 1991/92 grew from 19 200 to 57 100 units in 2001/02. We estimate that currently there are

[22] Hand threshing of wheat and barley is still common in the mid hills and mountains, but this makes up a small percentage of the total Nepalese output. However, it is a very important percentage as these are important food crops for small farmers in those regions.

over 90 000 wheat and rice threshers. The spike-tooth threshers provide the further benefit of cutting and processing the wheat straw into small pieces (busa) for animal fodder. Though many wheat threshers are imported from India we estimate that the small and medium fabricating workshops of Nepal supply over 50 percent of the demand. Also, since 2000, large 4WT, PTO powered spike-tooth wheat threshers (18 – 25 hp), imported from India are gaining in popularity for wheat and winter crops.

- **Pedal driven open drum rice threshers**
  These open drum, hold on, wire loop type threshers are foot powered via a simple gear system (like foot-powered sewing machines). A single individual can operate the machine while threshing but usually the machine will have two or more people, with one or two persons pedaling and others threshing and after some minutes switching places to even out the work load. Numbers of pedal threshers in 2 000 were 3 000 (Pariyar *et al*., 2001) and their numbers are higher in the hills especially near motorable roads, the large towns of Kathmandu and Pokhara valleys, and even in Chitwan. They are seldom seen in the rest of the terai. The main manufacturer in the 1970s, 80s and 90s was the agricultural tools factory of Birganj but since its closure over 15 years ago the supply of these threshers is from small factories in Kathmandu valley who report very low sales. Imports from India are also reported. A recent trend in the Kathmandu valley and elsewhere is the conversion of these small pedal threshers to be powered via a belt and pulley by small 1-2 hp electric motors. In doing so higher revolutions can be attained so that that wheat can be threshed as well (rice needs drum speeds of up to 500 rev/min which can be obtained by the foot powered mechanism, whereas wheat needs speeds above 700 rev/min which can be provided by electric motors).
- **Axial flow rice threshers**
  Axial flow type threshers for rice have not spread widely in Nepal. In 2001 a few farmers in the three far eastern terai districts of Sunsari, Morang and Jhappa were using 8 hp axial flow threshers. Key informants there reported that a few years earlier Punjab and Haryana-made threshers started coming across the Indian border from one of Bihar's eastern districts of Kishanganj where these rice threshers were popular. The majority of Sunsari District farmers that we came into contact with reported hiring the threshers from service providers there, (mostly from the Tharu ethnic group) who would mount the thresher and 7-8 hp shallow tube well diesel engine on traditional bullock carts and pull them from household to household and collect between 10 and 15 percent of the threshed rice as service charge (Figure 4.9). It is interesting to note that just west of the very large Koshi barrage there are few or no rice threshers used. The reasons for this are unclear.

FIGURE 4.9
Mobile rice thresher in far eastern Nepal

In the early 2000s it was estimated that axial thresher numbers could be approaching 1 000. In the last 8 years larger horsepower, PTO-driven rice threshers have been imported from India but they have not spread widely. The total number of rice threshers, again in Zone 9 (Figure 4.7) might now be 5 000. Comparing the 7000 rice threshers (rice being the largest crop in Nepal) to the 90 000 wheat threshers (wheat covering one third the area of rice) gives some idea of the potential demand remaining (if one is a sales promoter for "mechanization"). Also, we note here that there are none of the inexpensive open drum, powered rice threshers in Nepal that are so popular in Bangladesh.

- **Maize shellers**
  Maize sheller production has been on the increase since 2000. Like wheat threshers the maize shellers are powered by the shallow tube well pump-set's engine. Pariyar *et al*. (2001) estimated that there were 2 000 shellers in 2000 and the current number could be double that. Maize being the second largest crop in Nepal, that is twice the area under wheat, indicates the potential demand remaining.
- **Multi-crop threshers**
  Multicrop threshers of 6-8 hp have been promoted by government researchers and also the Agricultural Tools Factory, Birganj for the last two decades. Despite their reported popularity in India, elsewhere its low threshing capacity, especially for wheat, might be a reason why it is not spreading in Nepal.
- **Hand-cranked Winnowing Fans**
  When thinking of mechanization and drudgery alleviation, this is a very important machine, yet often overlooked. These very simple hand-cranked fans (*pankha)* clean up to 300 kgs of grain per hour with the use of three labourers. It is a surprise to find that in Bangladesh there are none of these machines and that women and men farmers there spend an enormous amount

of time standing and waiting for the wind to blow to winnow their threshed crops. No data exist on the numbers in Nepal but we note that there are many winnowing fans in nearly every terai village. They are produced in Nepal but also imported from India. We estimate their numbers to be 40 000 or more.

Milling

Although there are few figures on the number and types of mills in Nepal, most of the commercial rice mills have switched to rubber roller mills. In the last decade local workshops have begun fabrication of not only the rubber roller de-huskers (rollers are still supplied from China and India), but also polishers, graders, and elevators for small and medium size mills. Rural mill owners are extremely interested in getting electricity for their mills but in many rural areas still rely on diesel engines.

There are estimated to be 20 000 or more traditional water mills (*ghattas*) in the mountains whose use is primarily for grinding grain. In recent years the technical efficiency of over 5 000 of these mills has been improved greatly by fitting new and locally manufactured cup type (Pelton) turbine blades. These new mills yield 2-3 times more power for the same volume of falling water, and are not only grinding more gain but also being connected with simple generators for local electricity production. With faster milling, village women's time spent waiting at the mill has been reduced by half (Centre for Rural Technology, undated).

4.3.3 Agro-machinery Industry

Compared to Bangladesh, Nepal's historical, cultural and even political connections along with a long and open border with India have led to different patterns for investments in agricultural mechanization, whether it is farmers buying machinery, establishing import and export businesses, or local manufacturing capability. Though the border and the connections have allowed for some cross border spread of 4WTs, threshers and combines, Nepal's merchant importers have only recently looked beyond India for possible technologies that might be more suitable for Nepalese farmers.

Nepal's burgeoning manufacturing sector has even more challenges with electricity shortages of up to 16 hours per day in the winter months, forced donation drives, and strengthening of unions.

Nepalese Importers

Until the late 1990s the importers of agricultural machinery were simply a few authorized Indian 4WT tractor dealers, many in established merchant houses/ families. Since then there have been many others entering business due to: 1) the huge expansion of the Indian 4WT manufacturing from 3-4 manufacturers to over 20, thereby greatly increasing the scope and the number of importers in Nepal; and 2) a similar expansion of traditional Kathmandu and other urban trader merchants into Chinese two-wheel tractor and pump-set engines.

There have been several attempts to organize these tractor merchants (NAEF, 2005) in the past with only small success. With the growth in this industry further attempts should be made.

Chinese traders came to Nepal in growing numbers around 2 000 bringing in everything from cheap consumer goods to construction machinery and even attending agro-machinery fairs in Nepal. Interestingly, over the last five years the numbers of Chinese traders have declined noticeably. Several experienced Nepalese traders wryly remarked that as the margins were small and that Nepalese were historically adept at trading, the Chinese could not compete.

Nepalese Local Manufacturing

Presently, there are perhaps 2 000 – 3 000 small and medium sized local metal working workshops manufacturing agricultural machinery in Nepal. Like Bangladesh these small workshops, in general, do not use jigs and fixtures and produce machines to local standards for local markets.

Besides power outages and having passed through a civil war, Nepal's manufacturers face many other obstacles such as continued civil unrest, national strikes, donation drives, and newly established trades unions. These particular 'political' problems have adversely affected larger industries more than the less organized smaller-scale sector which due to their smallness, escape under the radar and continue to supply much of the demand for small horsepower wheat and rice threshers and maize shellers as well as their servicing and maintenance.

In various meetings sponsored by Nepal's Ministry of Agriculture and National Agricultural and Environmental Forum, the agro-machinery manufacturers have lamented the lack of support for their sector and in particular the policy of tariffs on imported raw material (sheet metal, angle iron, etc.) for making agricultural machinery with anomalously little or no tariff on finished imported machinery (Karki, 2005).

There have been several attempts to form agricultural machinery manufacturers' associations which have met with even less success than the formation of the importers' association[23]. Recently the Agricultural Engineering Division of the National Agricultural Research Institute published a directory of agricultural machinery manufacturers in Nepal that could be valuable in future programmes to strengthen this part of the broader Nepalese economy. As in Bangladesh, an area of growth in agricultural machinery manufacturing has been the fabrication of feed mills (mills, batch mixers, etc.) for the burgeoning poultry industry.

[23] Shrestha, K.B. 2009. Personal communication. In the fall of 2009 the author organized a series of meetings with Kathmandu based agricultural tools and machinery producers.

4.4 RECURRING THEMES IN THE SPREAD OF RURAL MECHANIZATION IN BANGLADESH AND NEPAL

In this review we have not attempted a comprehensive appraisal of the available data and studies on rural mechanization. This would have been a major undertaking well beyond the scope of this exercise. However, we have tried to paint a broad picture of the current status of rural mechanization in Nepal and Bangladesh and give some explanations of how and why the spread of mechanization came about. The following are some recurring themes that emerge:

4.4.1 Lack of data and macro-economic policy analysis

There is a serious lack of data on the current numbers of different types of equipment and their use. Not only does this pose a problem for any empirically based policy analysis, but there is also a problem when different actors and interest groups in academic, political and commercial arenas make assertions about the current status of equipment and its use. The very way that agricultural mechanization is defined often reflects biases towards one type of mechanization rather than another[24]. For example, the FAO definition of tractors is a four-wheel tractor. Two wheel tractors are not counted as "tractors". Consequently, if we were to take the FAO definition of a tractor as an indicator of agricultural mechanization, we would say that Bangladesh's agricultural tillage operations are hardly mechanized as the country has only 15 000 4WTs. However, this would be a major misrepresentation, as in fact over 80 percent of tillage operations are mechanized and 90 percent are performed by the 300 000 plus 2WTs which make up over 40 percent of the total available mechanical horse power in agriculture (versus 4 percent for 4WTs- again, refer to Table 4.1).

Bangladesh is a flat country with very high "rural-urban" integration. Consequently it has suffered less from the problems of policy and agricultural "sector" policy analysis that has separated the agricultural sector from the rest of the economy in other countries.

4.4.2 Diversity of national and regional patterns of rural mechanization

What comes over clearly from these two historical case studies of the spread of mechanical equipment is the location specificity of rural mechanization transformations. While the history of mechanization in Bangladesh is longer than that in Nepal, we do not find in any way that Nepal is "following" Bangladesh. This is not only due to: 1) more obvious agro climatic and environmental reasons such as much of Nepal being mountainous, while Bangladesh is mainly flat, but also due to other significant factors such as: 2)

[24] For a longer discussion of these data collection and associated analysis problems see Biggs, *et al.*, 2010.

the history of technical introduction and macro economic policy; 3) the global trade regimes at different moments in history; and 4) the dominant choice of technique paradigms prevalent at the time. The history of rural mechanization in Bangladesh goes back long before independence from Pakistan in 1971. Even in the 1960s there were projects to promote 4WTs as the primary way of promoting modern commercial agriculture at the Academy of Rural Development in Comilla. Also the dominant government irrigation policy was to promote canal irrigation and deep tubewells. In Bogra there were plans to establish a substantial engineering and metal work capacity. Whether or not these were "good or bad" ideas or projects is another matter; the point we are making here is that there has been a long history of different types of mechanical interventions.

The history of such activities in Nepal is more recent, and until recently policy and interventions concerning agricultural mechanization have been minimal or laissez-faire with donor funded projects promoting what they thought was best, or with commercial entrepreneurs, mainly from India promoting their equipment. As recently as 1997, laissez-faire markets were promoted for rural mechanization, as reflected by the absence of any coverage of agricultural and rural mechanization in the Nepal Agricultural Perspective Plan (JMA and APROSC, 1997). The absence of past projects and the lack of past public and private investments in engineering capacities in Nepal mean that the history and broader economic contextual issues are important. The long open border between Nepal and India has also meant that agricultural mechanization in Nepal has been influenced by Indian farmers and Indian policy and practice in this area.

The various patterns of rural mechanization in Bangladesh and Nepal also show that some general engineering and social science theories of mechanization that suggest that there are ladders or a sequencing of mechanization, or that large scale equipment is inherently more "efficient" than small equipment are to be viewed with great skepticism in the light of the empirical evidence gathered over the last thirty years. Some such theories suggest that animal draught power is mechanized first, and that is followed by other operations. And that is not borne out in Bangladesh, where irrigation was mechanized long before animal draught operations. In large areas of Nepal threshing has been mechanized long before tillage operations. The Bangladeshi and Nepalese cases also show that increased mechanization can only take place by progressing up a ladder from first mechanizing operations with small scale equipment, and then getting to the top with 4WTs and combined harvesters. Bangladesh's highly mechanized agriculture has only 4 percent of the horsepower coming from 4WTs and the rest mainly coming from 2WTs, small pump-sets and the like. Whether small or large scale equipment, and what type of equipment will be relevant to or disseminated in different regions in the future will depend on, amongst other things, national and international energy and other policies, and the ability of different interest groups to promote technologies and/or have fair access to information, credit, etc. Some theories also suggest that electrical power is only used after mechanization goes through a fossil fuel stage. In this context, one cannot help reflect that Nepal could have far more electrically powered low lift pumps, if the big aid donors and the banks had been interested in funding decentralized medium and smaller hydro-electric stations over the past 20-30 years and the decentralized sale of electricity used for production, instead of being primarily interested in large schemes and centralized sales of electricity. These issues reinforce the idea that agricultural and rural mechanization and development are most usefully analyzed in the broader context of the politics of national and international energy policy arenas, trade policy and other sectors.

4.4.3 Central role of local engine services markets in mechanization processes

Central to an understanding of the spread of rural mechanization in Bangladesh has been the role of local markets for selling the services of 2WTs, low lift pumps and groundwater pumps. The spread of small-scale engine-driven equipment for pumping, tillage, threshing, transport etc., has not been as a result of "small farmers" using small-scale equipment mainly on their "stand alone" farms. The institutional forms in the market for selling and buying water, tillage services, etc. are very great, with some institutions being more fair and equitable than others[25]. In Nepal, the spread of rural market services arising from the spread of tractors, pump-sets and threshers are less pronounced, but they are occurring. This may be due to a more recent tradition where those with productive assets, such as land and equipment could hold them out of production, for a range of reasons. In addition, attitudes in rural and agricultural engineering professional communities that promoted the idea that 2WTs should only be used for tillage operations on the farm have proven to be misplaced. Hiring out the tractor for transport purposes, etc. was seen as bad, or to be stopped and regulated. A surprising attitude, especially in the light of the multiple uses (and markets in services) of small and large scale diesel engines world-wide and, in Nepal, the long term productive use and maintenance of 2WTs in the Katmandu valley going back at least 25 years.

4.4.4 Importance of global and national trade in rural engine-powered equipment

The Bangladesh case clearly illustrates the importance of global trade in engineering equipment. Without the large-scale import of cheap "good

[25] In this brief review we have not looked at the income, land and other assets (such as rural equipment) distribution and equity dimensions of the spread of rural mechanization. Nor have we looked at the processes of changes in these variables. That requires other much needed analysis to inform people in policy arenas.

enough" small scale diesel engines from China over the last 30 years Bangladesh's agricultural and rural economic growth would not have occurred. While much attention is often given to the importance of, for example, improved seeds for contributing to agricultural growth, the contributions of rural mechanization are equally, if not more important. One of the reasons why the groundwater irrigation potential on the Nepal terai has not been developed is partly due to the domination in Nepal of an irrigation policy and aid circle of knowledge that is not based on the irrigation experiences gained in Bangladesh over the last 30 years.

4.4.5 Role of public policy

The important role of public trade policy is well illustrated in both case studies. In Bangladesh, the import of small Chinese 2WTs was made possible by General Ershad's decision in the late 1980s to dissolve the standards committee which was preventing the import of this equipment. In Nepal the lack of imports of Chinese 2WTs was due in part to the local government 'traffic' restrictions in 1993, including no new registrations of 2WTs in the regions where they were spreading (Zones 3 and 5 in Figure 4.7). It was only when a combination of projects proved to the importers the 2WTs' usefulness and potential demand outside these two zones that Nepali traders started to import Chinese equipment again (Gurung, *et al*., 2008).

There are also observations with regard to the role of public research and development policy. On the whole the spread of rural mechanization technology that has occurred does not appear to be the result of the work of of public sector R&D institutions. While this is a broad generalization, it does not appear that there are many pieces of useful technology that have come out of Universities and research institutes. While in recent years agricultural engineering research departments and centres have been closed we do not have much evidence of public sector institutions producing useful technology that has spread (Biggs, *et al*., 2010). There does appear to have been some substantial public sector social science research that reviewed current rural engineering issues, and influenced public policy in Bangladesh[26]. In Nepal, almost the opposite appears to be the case with the main pillar of agricultural policy and planning in Nepal, the Agricultural Perspective Plan, totally ignoring an analysis of issues of agricultural and rural mechanization. This might be one of the reasons why medium and smaller scaled hydro-electricity investments have not been a higher priority in Nepal. One of Nepal's resources is hydro capacity and electricity for powering small-scale low lift irrigation pumps might have been encouraged earlier, if macro economic policy analysis had looked at these issues. The role of public sector regulatory policy has also been clear, not only as regards energy efficiency standards, but also as regards health and safety. In this review we have not touched on these issues, but

[26] For example see Mandal 2002

note that in many high and low income countries the agricultural and rural sectors are often some of the worst in relation to the health and safety of rural workers, not withstanding any regulations concerning the issues.

The activities, projects, and communications networks (web-based or published brochures, papers, journals) of NARS based and regional professional societies of agricultural engineers unfortunately appear to have played little role in the spread and use of agricultural engineering ideas and technologies in Bangladesh and Nepal. Exceptions could be made in the promotion of rice threshers in Bangladesh (BRRI, Agricultural Engineering) or post harvest technologies like coffee pulpers, rice husk stoves in Nepal (NARC, Agricultural Engineering Division). There are other instances but as agricultural engineering as a discipline (both nationally and internationally) has rarely been good about communicating its success stories, this may well have been a reason for the closure of departments at international agricultural research institutes e.g. ICRISAT's Engineering Group 1994, IRRI's Agricultural Engineering Division in 1996 and in the UK the Silsoe Research Institute's Agricultural Engineering International Development Group in 2003.

4.4.6 Promises of some rural mechanization theories, policies, plans and projects

Alongside the spread of a range of rural mechanization equipment over the last 30 years, there has also been other equipment promoted by governments and donors, by NGOs, and by the small scale and the large-scale corporate sectors that has not spread. In all of this there is the promise that certain types of equipment would be good for the economy, and good for poor farmers and labourers. The way that academic, commercial and aid donor interest groups influence technology choice on to paths that cannot be justified as being in the public good are numerous. Interestingly, a classic study by John Thomas (1975) illustrates how Bangladesh inherited a policy where major government support for irrigation went to deep tubewells and canal irrigation, when by any technical and economic analysis using national goals as criteria, major support should have been going to decentralized groundwater development. In Nepal, some of the policy and rural engineering lessons of Bangladesh, learnt 30 years ago appear not to have been used by recent donor supported irrigation projects in Nepal, and information from Bangladesh is only emerging slowly.

Another feature is the claims made by some members of the agricultural engineering community that large-scale equipment is more efficient, than small-scale equipment. This is often accompanied by illustrations of large-scale holdings with four-wheel tractors and combine harvesters and/or calls for large-scale land consolidation projects. The history of the development of agricultural and rural industries in Bangladesh shows there are many paths of mechanization and that large-scale equipment is neither necessary nor sufficient. It is important to note there are interest groups actively promoting this strategy, with promises of the way it will give rise to achieving national goals, and that benefits will be equitably shared. In Nepal, the promotional activities of dealers for large-scale Indian made equipment have been actively promoting their products on the terai for many years. It is only recently that farmers and officials in donor agencies and the government are taking into account the wide range of cheap engines and equipment that has been spreading for years in Bangladesh. The suggestion by some agricultural engineers that there is a theory that supports the assertion that large-scale equipment is more "efficient" particularly in smallholdings is hard to dislodge, even in the face of empirical evidence. The promises of large-scale equipment therefore need to be treated with caution.

4.4.7 Investment patterns in rural mechanization

Data on the spread of rural mechanization in Nepal and Bangladesh show that international and local investments have been taking place. Chinese made equipment has spread in Bangladesh and is now spreading in Nepal. Indian entrepreneurs have been selling Indian made (and now, with small diesel pump-sets, Indian labeled but Chinese made equipment in Nepal). In Bangladesh, there is a strong local engineering and manufacturing sector that links strongly with agriculture and other rural industries. It appears that global and local corporate and smaller scale private organizations are mobilizing private capital to take advantage of market and investment opportunities in these countries. While it is beyond the scope of this study, some personal knowledge of Bangladesh and Nepal would indicate that Bangladesh has more examples of how investment opportunities have been opened up more to poor people in Bangladesh than in Nepal. Over many years there have been micro and meso-credit schemes that have enabled poorer households to obtain loans, some of which have included loans for small pump-sets, threshers, etc. There is also a history of loans to landless labourer groups for low lift pumps for selling irrigation water. In Nepal, to date there is little evidence that the banking sector is developing methods to make loans to poor households for mechanical equipment. Recent attempts by the Planning Commission to find banks that would extend credit to 2WT operators, met with no success. This was even when the past record on 2WTs show that they were highly profitable and gave a full payback within two years. Experiments with collective ownership or management of equipment have not done well. There is clearly plenty of scope for public policy to support an equitable investment policy in this area.

4.5 FUTURE RURAL MECHANIZATION RESEARCH AND ANALYSIS

In this chapter we have discussed the past spread of the equipment of rural mechanization processes. We have drawn out some themes that the data appear to indicate, in this final section we point to some areas where research and analysis is needed in order to inform actors of policy options that are available in national and international policy arenas.

4.5.1 Rural poverty reduction, productivity and equity effects of rural mechanization

It was beyond the terms of reference of this study to search out data and analysize the income distribution, and other effects that rural mechanization has had on rural poverty, economic growth, equity etc. Studies are clearly needed before any empirically based policy recommendations could be made for either country, or for different parts of each country.

4.5.2 Investment opportunities for rural labourers and small farmers in rural mechanization

If rural poverty reduction and rural development are seen as high national development goals in Bangladesh, then existing technical and social science studies and ongoing experiences need to be reviewed in order to make this information available in policy arenas.

4.5.3 Ongoing monitoring of rural mechanization processes in regional, national and in global economic arenas

One of the issues this study has shown is the lack of information on current rural mechanization processes. This can be looked at on different levels; for example, in the Nepalese terai, the lack of local monitoring of the rapidly spreading cheap Chinese pump-sets and their associated cheap plastic piping. The plastic pipes are increasing the efficiency of water use by perhaps 30-40 percent over open canals. In some government and donor circles concerned with irrigation technology, this technology is not known about. There is a case then for cost effective information and analysis systems to gather and use this information. At the national and global levels there is a role for monitoring the business and promotional activities of different promoters of rural engineering technology. Further research should look at the role of foreign investment in the equipment manufacturing industry and the implications of changing ownerships patterns of land, capital equipment and other assets in rural areas.

The history of Bangladesh would appear to indicate that over the years the government has been able to take up options, such as cheap small-scale engines from China, quite easily. However, in Nepal with the laissez faire policies of the government, dominant donors and large tractor companies have been able to promote some mechanization options more heavily than others.

4.5.4 Rural mechanization and national energy and trade policy

Finally, perhaps the most important area where research is needed is on the relationships between rural mechanization and national energy policy. The pattern of mechanization in Bangladesh was a result of the cheap energy policy for agriculture. If relative fuel prices had been different, the pattern of mechanization and spread of different engineering technologies would have been different. We have already noted that one of Nepal's national assets is the energy of falling water, not to mention the potential of the massive supplies of surface and groundwater irrigation water from the monsoon each year. However, it is only recently that medium and smaller scale hydro schemes for local electricity production are being looked at more seriously. Whatever the past may have been, research is needed on the future relationships between the harnessing of usable energy, particularly for its use in agriculture and linked input and processing industries. Central to this will be rural engineering issues.

4.6 CONCLUSION

During the last 30 years in Bangladesh and Nepal there have been great transformations in rural mechanization. The productivity, employment and equity implications of this have yet to be studied. However, what can be said is that Bangladesh has achieved considerable increases in agricultural productivity, based on a labour-intensive form of rural mechanization. Growth linkages to other rural activities and the rest of the economy have been considerable. There has also been a strong private sector capacity to import relevant equipment, especially from China. In Nepal, mechanized equipment has also spread, but this does not appear to be so focused on rural poverty reduction, rural employment and productivity increasing. In both countries future patterns of mechanization will depend in large part on the energy policy, and globally the interest of major players in the regional agriculture and food industries.

4.7 ACKNOWLEDGMENT

We would like to thank Harriet Matsaert for her editorial help with the original draft.

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CHAPTER 5
Agricultural mechanization in India

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ABSTRACT
The chapter outlines the remarkable history of agricultural mechanization in India. Since independence in 1947, the country has changed from a machinery importer to the world's leading tractor manufacturing nation. And this has been achieved in parallel with a four-fold increase in food production and an annual, population growth of 1.5 percent. Mechanization patterns in different regions are described as is the idea that private sector contractors are a driving force in the mechanization revolution. Power input in agriculture is forecast to rise from less than 2 kW/ha now to 4.5 kW/ha by 2050 when there will be 7 million tractors in use in the country (compared with fewer than 8 thousand at independence). The agricultural engineering manufacturing industry is growing and maturing although traditional draught animal technology is expected to decline as draught animal numbers continue to fall. The importance of emphasizing and expanding agricultural engineering training and R&D is underlined.

5.1 INTRODUCTION

The story of the development of agricultural mechanization in India is both fascinating and in many ways, quite remarkable. The country has moved forward over the past six decades from one in which it then faced severe food shortages to where today it has become an exporter of some food commodities and a major exporter of other industrial products, including agricultural tractors. This has been achieved despite a three-fold increase in its population and barely a seven percent increase to the arable land area.

India is the second most populous country in the world with an estimated population of 1.21 billion in 2011 and an annual growth rate of 1.5 percent or 18 million. About 70 percent of the population live in rural areas with about 52 percent still depending on agriculture for their livelihood.

The per capita income in 2010 is estimated at US $1 200 and about 250 million people are still living below the poverty line. The literacy rate is

74 percent but there is higher illiteracy among women due to inadequate schools particularly in the rural areas. The gross enrolment ratio in higher education is just 16 percent which is much less than the world average of 23 percent (NKC, 2009). Other limitations include shortage of drinking water, poor sanitation, poor housing, inadequate hospitals and low per capita energy consumption.

The total land area of the country is 297 million hectares of which 142 million ha is classed as agricultural land. A total of 120 million ha constituted land holdings in 2001 (Table 5.1). Whilst it has basically an agrarian economy with a Gross Domestic Product (GDP) growing at a rate of 7 to 9 percent annually from 1990 to 2010, the share of agriculture has now declined to 16 percent from a level of 56 percent in 1950. The manufacturing and service sectors presently constitute 28 percent and 56 percent of the economy, respectively. The biggest challenge which the agricultural sector is facing is to meet the growing demand for food to feed the ever growing population of the country.

Since independence in 1947, there has been more than a four-fold increase in grain production due to the introduction of improved technologies and practices. However, the population has increased at a similar pace and there are still challenges to attaining full food and nutritional security. The country has a very diverse form of agriculture particularly due to varying soil and climatic conditions. Its climate is full of extremities; the temperature conditions vary from arctic cold to equatorial hot and rainfall from extreme aridity with less than 100 mm in the Thar Desert of Western India to the site of the world's maximum rainfall of 11 200 mm at Mowsinram in the northeast.

The available rainfall has large spatial and temporal variations. Although there has been a significant increase in the area under irrigation, still more than 65 percent cent is devoid of assured irrigation and the agricultural productivity in the rain fed areas is low.

5.2 SIZE OF LAND HOLDINGS AND MECHANIZATION

The average size of land holdings in 2001 was 1.33 ha with only 1 percent (1.2 million) consisting of farms of more than 10 ha but constituting over 13 percent of the cultivated land while the farms of less than 1 ha (over 62 percent) constitute about 18.7 percent of the cultivated land – the rest of the farms are in the intermediate range with the largest proportion being medium farms (4 to 10 ha) and semi-medium farms (2 to 4 ha) which cultivated 24 percent each of the total cultivated land in 2001. Thus the three categories comprising large, medium; and semi-medium farms (22 million farm holdings) cultivate between them 61 percent of the cultivated land – it is apparent that these three categories of farmers have been instrumental not only for the success of agricultural mechanization in India but for the overall success of the Green Revolution and the remarkable transformation of the food security situation over the past 50 years.

TABLE 5.1
Land Holdings in India

Category	Percentage Number of Holdings in each Category			Percentage Area Under each Category	
	1971	1991	2001	1991	2001
Marginal (<1 ha)	50.6	59.4	62.3	15.0	18.7
Small (1-2 ha)	19.0	18.8	19.0	17.4	20.2
Semi-Medium (2-4 ha)	15.2	13.7	11.8	23.2	24.0
Medium (4-10 ha)	11.3	7.1	5.5	27.1	24.0
Large (>10 ha)	3.9	1.6	1.0	17.3	13.2
Average holding size (ha)	2.28	1.57	1.33		
Total holding area (million ha)	**70.5**	**106.6**	**119.9**		

Source: FAO (2011)

Due to the laws of inheritance the number of holdings is increasing in many states, however, the situation in Punjab, the state with the highest level of mechanization and the highest productivity, a reverse trend has been witnessed with the marginal holdings declining from 38 percent in 1971 to 27 percent in 1991 and only 12 percent in 2001, cultivating less than 2 percent of the area. The area under holdings in the semi-medium, medium and large categories in Punjab in 2001, were 22, 43, and 27 percent, respectively thus cultivating over 92 percent of the total area. Similar trends are occurring in Haryana and in other parts of the country.

Many rural people owning land have moved to cities for jobs and other opportunities although they are still counted as owners of the land holdings. Their land is cultivated by other family members or rented by other farmers. Thus the actual number of operational holdings is much less than the number reported based on ownership of land. Also, many marginal and small holders work as labourers, away from their villages, renting out their land to other farmers. This has further reduced the number of actual operational holdings. In most cases such land is rented to tractor owners making their operational holdings bigger than their owned land, thus making the ownership of tractors more economically viable.

Banks, when sanctioning a loan to a farmer for the purchase of a tractor, take income from custom work into consideration. Due to implementation of the Mahatma Gandhi National Rural Employment Guarantee Scheme (previously known as NAREGA), wages for labour throughout India have gone up leading to a scarcity of farm labourers. This has provided a tremendous boost to mechanization, especially through opportunities for custom hire work. The President of India in her address to the Nation on the eve of Republic Day on 25th January 2011 said:

> *"...small farmers are leaving farming, because of poor returns and scarcity of agricultural labour. In such a situation, it would be advantageous to think of modernization and mechanized farming..."*

5.3 AGRICULTURAL GROWTH AND DEVELOPMENT PLANNING

India adopted a five yearly planned growth strategy after independence. Agriculture received particular attention from the very first plan (1951-56) when its situation was critical and the total annual grain production amounted to only 50 million tons in 1951. Concerted efforts were made in the late 1960s through the introduction of high yielding cereal varieties (HYVs), fertilizers, agro-chemicals for plant protection, agricultural machinery and above all agricultural technologies resulting from research and development. This led to the ushering in of the Green Revolution. Grain production attained a three-fold increase by the mid eighties and in 2010-11 a record harvest of over 241 million tonnes was achieved.

Presently a number of government departments are engaged in agriculture and rural development work in the country. At federal level, agricultural development is under the Ministry of Agriculture and Cooperation. The body responsible for controlling the national agricultural research system is the Department of Agricultural Research and Education, which works under the aegis of this Ministry. At state level, each has its own Ministry of Agriculture. Other ministries contributing to rural and agricultural development programmes are: Food and Agro-Processing; Rural Development; Water Resources; New and Renewable Energy Resources; Commerce and Industries; and Finance. The overall planning of the country's development of all sectors is done by the Planning Commission of India which is headed by the Prime Minister.

Focus of policy support for food and nutritional security

1. Fixing of minimum support prices (MSP) and buffer stocking of food grains
2. Major agrarian reforms including fixing of ceilings and consolidation of land holdings
3. Investment in rural infrastructure such as rural roads, markets, major irrigation systems, rural electrification, water conservation and watershed development
4. Building a strong agricultural research and education system coupled with an extensive extension system
5. Ensuring availability of inputs such as seeds, fertilizers, pesticides and farm machinery
6. Ensuring availability of credit and subsidies.

5.4 MECHANIZATION AND PRODUCTIVITY

During the period 1960-1980, more than 90 percent of public investment in agriculture was for the development of irrigation facilities including medium and major irrigation projects. The result was a significant increase in the area under irrigation, particularly in the states of Punjab, Haryana and Uttar Pradesh. During the era of the Green Revolution, provision of a range of inputs such as agro-chemicals and farm machinery contributed towards increasing agricultural productivity. The availability of farm power registered a significant increase due to enhanced contributions from electrical and mechanical sources. The apparent nexus between irrigation and power availability is seen in states such as Punjab, Haryana and Uttar Pradesh and as shown in Table 5.2.

In a seminal paper Binswanger (1978) concluded:

"*....The tractor surveys fail to provide evidence that tractors are responsible for substantial increases in intensity, yields, timeliness, and gross returns on farms in India, Pakistan, and Nepal. At best, such benefits may exist but are so small that they cannot be detected and statistically supported, even with very massive survey research efforts. Indeed, the fairly consistent picture emerging from the surveys largely supports the view that tractors are substitutes for labour and bullock power, and thus implies that, at existing and constant wages and bullock costs, tractors fail to be a strong engine of growth. In view of this finding, many of the benefit-cost studies reported may have overestimated the benefits, both social and private which arise out of the agricultural uses of tractors. Except in situations where area effects are possible—or by renting or buying from others—private returns to tractors from agricultural operations must be close to zero, or even negative at current fuel prices...*"

TABLE 5.2
Comparison of Farm Power, Irrigation and Yield (2001)

State	Farm Power (kW/ha)	Grain Yield (kg/ha)	Irrigated Area (%)	State	Farm Power (kW/ha)	Grain Yield (kg/ha)	Irrigated Area (%)
Punjab	3.5	4 030	84	Bihar	0.8	1 660	49
Haryana	2.3	3 090	84	Gujarat	0.8	1 170	32
Uttar Pradesh	1.8	2 110	73	Madhya Pradesh	0.8	910	28
Andhra Pradesh	1.6	2 000	41	Himachal Pradesh	0.7	1 500	23
Uttarakhand	1.6	1 710	-	Maharashtra	0.7	760	17
West Bengal	1.3	2 220	43	Rajasthan	0.7	880	31
Tamil Nadu	0.9	2 260	55	Jharkhand	0.6	1 100	-
Karnataka	0.9	1 410	25	Jammu& Kashmir	0.6	1 050	42
Kerala	0.8	2 160	17	Orissa	0.6	800	33
Assam	0.8	1 440	6	Chhattisgarh	0.6	800	21

Source: FAO (2011)

In another paper Binswanger (1986) stated,

"*....In general, mechanization will contribute little to growth in countries without a land frontier and with densely populated farmland — such as Bangladesh, most of India, and China. Given the fact that a high proportion of the work forces in these countries are still engaged* *in farming, even very rapid growth in the rest of the economy will not lead to rapid wage increases. Labor scarcity cannot be expected to arise from non-agricultural growth in the near future as a driving force for mechanization....*"

In a major ILO commissioned study Raj (1973) reported similar findings. Such findings created doubts about the agricultural development model based on the use of motorized agricultural mechanization inputs and led to reduced support for mechanization by governments in many developing countries and also by international development organizations.

However, Singh and Chancellor (1975), based on a year long survey, found that agricultural output for categories of farms was related to energy inputs, irrespective of ownership of farm power sources (owned or rented) and the size of land holding had no effect on yield. Farmers with better management (i.e. timely operations, like sowing, irrigation, weeding, fertilizer and pesticide application; and proper amounts and right techniques of application) had higher yields than those with poor management.

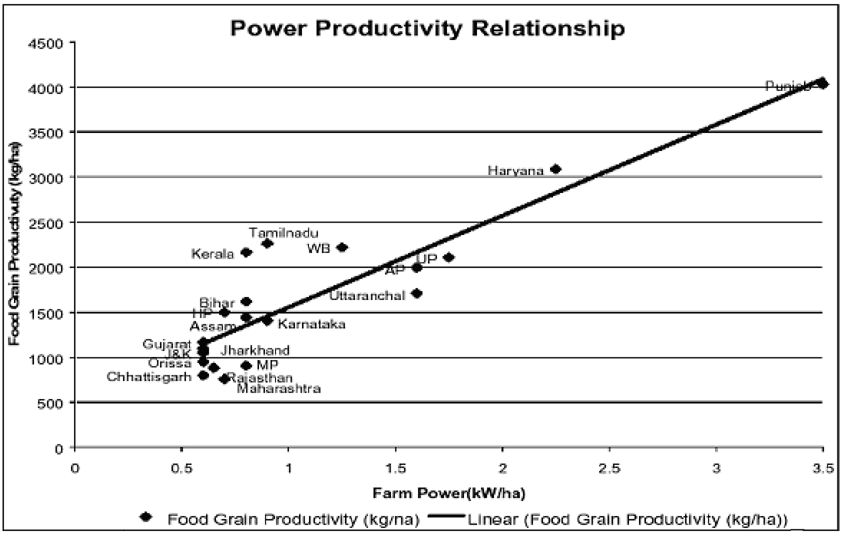
Further, Singh (2001) reported that the economics of ownership of most tractors in India had been justified by custom hiring for on-farm work as well as for off-farm transport and construction activities. The use of tractors in transport activities accounted for about 60 percent of average annual use of 600 hours. Many small farmers also started purchasing tractors due to the opportunity of custom hiring. Similarly, the ownership of many other farm machines and equipment, like pumps for tube-wells, seed-drills and planters became economically viable due to renting out to other farmers. However, ownership of large threshers, laser land levellers and combine harvesters is mainly justified by custom work.

5.5 DEVELOPMENT OF AGRICULTURAL MECHANIZATION

The state of agricultural mechanization in the country is characterized by large variations in power availability which in 2001 varied from 0.6 kW/ha of agricultural land in some states to 3.5 kW/ha in Punjab. The average farm power available country-wide was about 1.46 kW/ha which comprised about 84 percent from mechanical and electrical sources and 16 percent from animal power and human labour (IASRI, 2006). There is a strong linear relationship between the farm power available and agricultural output per ha (Figure 5.1). This underscores the emphasis on the growth and development of power machinery systems in Indian agriculture.

FIGURE 5.1

Relationship between farm power and productivity in different states of India



Source: NAAS (2009): State of Indian Agriculture

Farm operations requiring high power inputs and low control are generally the first to be mechanized (tillage, transport, water pumping, milling, threshing, etc.). The power intensive work can be done faster and normally at a lower cost. Those operations requiring medium levels of power and control tend to be mechanized next (seeding, spraying, inter-row operations, etc.) whereas those requiring a high degree of control and low power inputs are mechanized last (transplanting, planting of vegetables, harvesting and grading of fruits and vegetables, etc.); see Table 5.3. The growth in agricultural mechanization in India has followed this general pattern.

TABLE 5.3

Sequence of Mechanization

	Operation		
Sequence	**First Stage**	**Second Stage**	**Third Stage**
Type of Operation	High Power Low Skill	Medium Power Medium Skill	Low Power High Skill
Stationary	Grinding, milling, crushing, pumping, threshing	Grinding by size, cleaning	Grinding by quality
Mobile	Land preparation, Transport	Seeding of grain, harvesting of grain	Transplanting, Harvesting of Cotton, Fruits & Vegetables, Sugarcane

Source: NAAS (2009)

The growth in farm mechanization and investments in machinery and equipment are presented in Table 5.4 and can be divided into two broad periods; (a) The initial period covering the three decades 1942 to 1970 and (b) the four decades from 1971 to 2010.

TABLE 5.4
Aspects of Indian Agriculture (1960-2010)

Item	1960	1970	1980	1990	2000	2010
Agricultural land (million ha)	133	140	140	143	143	142
Irrigation pumps (million)	0.4	3.3	6.2	12.9	19.5	28*
Irrigated area (percent)	19	22	28	33	34	35
Cropping intensity	1.15	1.18	1.23	1.30	1.33	1.36
Fertilizer use (kg/ha)	2	15	39	88	125	160
Grain yield (kg/ha)	700	860	1 000	1 300	1 600	1 950
Tractors (thousands)	37	146	531	1 200	2 600	4 000
Area per tractor (ha)	3 600	960	260	120	55	36
Power tillers (thousand)	0	9.5	16	31	100	200
Draught animals (million)	80.4	82.6	73.4	70.9	60.3	50*

*Estimated

(i) Initial period 1942 to 1970

In 1942, the first degree programme in Agricultural Engineering was started at Allahabad Agriculture Institute and this marked the first formal training and education in the field of agricultural mechanization/engineering in India. During the mid-1940s a few tractors and bulldozers were imported and the Central Tractor Organization and State Tractor Organizations were established. The first Indian Institute of Technology (IIT) at Kharagpur was established in 1952 and its agricultural engineering programme started from the very beginning, indicating its importance alongside other engineering disciplines. During this period tractors were not manufactured in India and all tractors were imported. The number of tractors in use grew from 8 000 in 1950 to 20 000 in 1955 and 37 000 units by 1960. These were used mainly on larger government and private farms. Up to 1960, most farm operations and transport work was done using draught animals.

During the decade 1961 to 1970 India moved on to the second stage in agricultural mechanization with tractor production having started in 1961 with an annual output of 880 tractors by Eicher Tractor Ltd. During this decade five units were licensed to manufacture tractors while production of power tillers started in 1965. In the field of agricultural engineering education this was the most important period. The first College of Agricultural Engineering based on the US Land Grant pattern was established in 1962 at Pantnagar with the help of the University of Illinois followed by six more colleges and two degree granting departments at institutes under the Indian Council for Agricultural Research (ICAR).

During this period, 96 percent of the tractors were owned by big farmers having land holdings of more than 10 ha. Another major development was the creation of credit facilities to purchase farm equipment. In the later half of this decade, the Green Revolution started and a large quantity of HYV wheat seed was imported from Mexico to be disseminated to farmers after thorough research trials.

The development of irrigation facilities using water lifting devices was another hallmark of this period. Traditional water lifting devices could provide only 2-3 irrigations for wheat whereas high yielding varieties needed 6-8 irrigations per cropping cycle. Large and medium scale farmers purchased diesel engines to power irrigation pumps; renting of pumps also started. Rural electrification to power irrigation pumps expanded during this decade. The tractor population increased about four fold during the decade 1960-70.

(ii) Four decades of significant progress in agricultural mechanization 1971 to 2010

The four decades from 1971 to 2010 are the most important in so far as mechanization is concerned as it is during this period when there was significant progress in agricultural mechanization in India. During the period 1970 to 2000 the number of power tillers and tractors in use increased from 9 500 and 146 000 to 100 000 and 2.6 million respectively while the number of draught animals in use declined from 82.6 to 60.3 million thus demonstrating a significant increase and shift in the sources of farm power in India.

The first decade (1971-80) of these four decades was a period of growth of agriculture in India and there was increased demand for mechanization services. Six new tractor manufacturing units were established although three which existed prior to this period were closed. In addition six new units were licensed to manufacture power tillers; however two older units were closed. Rural credit became a reality as banks opened branches in the rural areas. The availability of credit to farmers increased and the tractor market expanded rapidly. A concerted effort was initiated to provide incentives to farmers through appropriate price support mechanisms. Minimum support prices for food grains, and sugarcane were declared hence ensuring the profitability of farming. Rural electrification expanded significantly leading to increased power availability to agriculture particularly for irrigation. One more new College of Agricultural Engineering was also established during this decade.

Manufacturing of irrigation pumps and threshers expanded leading to farmers installing electric motor and diesel engine driven irrigation pumps as well as purchasing threshers to handle the increased volumes of produce. During this period, custom hiring of threshers and pump sets increased as many farmers were unable to afford to buy these machines. Custom hiring of tractor implement systems and tractor-trailer units grew rapidly for tillage and transportation respectively. In fact, about 60 percent of the annual use of the tractors was for custom hiring. However, draught animals remained the main source of power and their numbers peaked at 83.4 million in 1975.

The second decade (1981-90) was the period which saw a quantum leap in food production and a rapid increase in the rate of agricultural mechanization. Four new tractor manufacturing units were established but four older units were closed. One new power tiller manufacturing unit started but four older units were closed. The Government of India undertook a concerted effort to popularize tractors and to make them affordable to more farmers. Power tillers and tractors with engine capacity above 1 800 cc were exempted from excise duty to encourage mechanization. India, which had been an importer of tractors up to the 1970s, started exporting them in the 1980s.

There was significant expansion of capacity for agricultural engineering education and seven new agricultural engineering colleges were established. A separate agricultural engineering division was created at the ICAR with responsibility for coordinating R&D projects related to agricultural mechanization and post harvest processing at its institutes and state agricultural universities.

Rural electrification expanded and farmers installed more pumps and purchased threshers. Medium farmers and small entrepreneur farmers bought tractors to meet the demand of custom work. Tractor pto-driven threshers gained popularity. The minimum support price was enhanced annually and grain bulk storage facilities expanded significantly. The use of power tillers almost doubled during the decade 1980-90.

By the third decade (1991-2000) agricultural mechanization had spread widely and policy decisions were taken to allow mechanization to grow on its own merit and strength. In 1992, the need for a license to manufacture tractors was abolished and during this period, two new tractor units started production. In the field of education eight new Colleges of Agricultural Engineering were established. Custom hiring of machinery and implements became popular in a big way. The majority of the farmers custom-hired threshers (driven by tractors through the pto) provided by entrepreneur-operators who were not necessarily farmers. Use of combine harvesters provided through custom-hire gained wider acceptability.

During the fourth decade (2001-10), an appreciable improvement in the agricultural situation in India has occurred which has led to a major boom in agricultural machinery manufacturing. Three major international manufacturers have now established plants in India: John Deere, New Holland and Same. Due to mergers, Mahindra & Mahindra (M&M) and Tractors and Farm Equipment (TAFE) have become huge conglomerates with international operations. Three new Colleges of Agricultural Engineering were started and the total number of colleges as of 2010 was 30. The annual admission capacity at bachelor level has reached 1200 places, at masters level the intake reached 300 and at doctoral level 100.

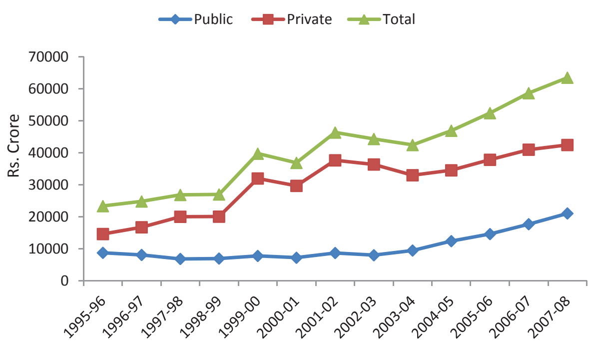
The minimum support price for farm produce increased significantly during 2008-2011. The high food prices both in India and globally at this time led to increased attention to energy and water saving technologies. The zero till drilling of wheat after rice in North India is becoming popular, mainly due to savings both in cost and time. The use of laser land levellers on custom-hire is growing as it saves irrigation water by up to 30 percent and helps increase productivity. Combine harvesters on custom-hire gained popularity (Mani *et* *al.* 2008). In contrast, the number of draught animals is rapidly declining. The grain yield reached 1 950 kg/ha and total grain production achieved an all-time record in 2010-11.

5.6 INVESTMENTS IN AGRICULTURAL MECHANIZATION

Over 90 percent of the public investment in agriculture during 1960-1980 went towards the development of medium and major irrigation projects. In the later period, other aspects such as rural roads, rural electrification and warehouse development received emphasis. In fact, the aim of investments is to generate capital in the form of infrastructure, improvement in the quality of natural resources and assets, and creation of productive assets.

The public investment has been used mainly to create infrastructure, whereas private investment has been helpful mainly in asset formation and in bringing about improvements to the quality of existing assets. The gross fixed capital formation (GFCF) measures the value of additions to fixed assets purchased by business, government and households *less* disposals of fixed assets sold off or scrapped. There has been a sizeable increase in gross fixed capital formation in agriculture both from the public and private sectors (Figure 5.2).

FIGURE 5.2
Gross fixed capital formation in agriculture from public and private investments



(At 1999-2000 prices; 10 000 Rs. Crore[27] = US$ 220 billion)
Source: ICAR (2008)

An increase in public investment definitely induces a rise in private investment, while a decline compels farmers to cope with this adverse impact by further increasing private investment (Chand and Kumar, 2004). The GDP is affected by capital formation as well as subsidies and terms of trade. For example the instant return to one rupee spent in subsidy is much higher than

[27] Crore = 10 million

the instant return on one rupee spent for public sector capital formation. In contrast, the long term return from capital formation is more than double the return from subsidies. In fact, diverting one percent of resources from subsidies to public investment raises output by more than two percent. So it becomes necessary to enhance public investment for long term returns. The effects of various forms of investment in mechanization are discussed below.

(a) Research and Development

Agricultural research and education has been a major consideration in agricultural development in India. The Indian Council of Agricultural Research (ICAR) institutes and state agricultural universities (SAUs) are located in several states.

Two institutes of the ICAR conduct research and development exclusively in the areas of farm machinery and post harvest engineering and technology. These are the Central Institute of Agricultural Engineering (CIAE), Bhopal and the Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana.

Research on mechanization is also conducted by commodity institutes (for sugarcane, cotton, rice, fodder and horticulture) and several national institutes (for fish, dairy, dry-land agriculture and others). Most of the state universities have agricultural engineering programmes with agricultural mechanization as a major component. The All India Coordinated Research Projects (AICRPs) are implemented under the aegis of ICAR and these currently include:

- Farm Implements and Machinery,
- Renewable Energy Sources,
- Utilization of Animal Energy,
- Ergonomics and Safety in Agriculture,
- Post Harvest Technology, and
- Application of Plastics in Agriculture.

All these AICRPs have cooperating centres located in different states so as to cater for the mechanization needs of the different agro-climatic zones.

(b) Efforts in improving Extension Services

Facilitation of the extension services concerning agricultural technologies in general and agricultural mechanization in particular have been focused on the following areas:

- Provision of institutional arrangements to make the extension system farmer driven and farmer accountable.
- Encouragement of Public Private Partnerships (PPPs).
- Strengthening of Mass Media Support by providing location-specific broadcasts through FM and AM stations of All India Radio and the Doordarshan (DD) National TV Channel.

- Provision of fee-based advisory services by graduates in agri-business development and through the establishment of agri-clinics.
- Operation of Kisan (Farmer) Call Centres through toll-free lines.

In addition, seventeen State Agro-Industries Corporations and Joint Sector Companies have been promoted by the Federal and State Governments. The objectives of these corporations are to manufacture and distribute agricultural machinery together with other inputs to promote agro-based industries and to provide technical services and guidance to farmers and others.

The Ministry of Agriculture carries out planning and activities at federal level to promote mechanization in the country through various schemes and programmes. In the recent past, the government launched a major extension programme with financial aid from the World Bank in which mechanization was an important component. Similarly, the National Agricultural Innovative Project (NAIP) is being implemented in different parts of the country under the aegis of ICAR to improve agricultural productivity and rural livelihoods. Mechanization and value addition to agricultural produce have also been given major emphasis in this programme.

Similar investments were made in a recently concluded National Agricultural Technology Programme (NATP). In addition, promotion of mechanization is an important component of the National Horticulture Mission (NHM) being implemented by National Horticulture Board (NHB).

(c) Quality of Farm Machinery and Training

Standardization and quality of implement manufacturing has been ensured mainly by the Bureau of Indian Standards (BIS) which has formulated more than 540 standards on agricultural machinery. However, there is still scope to improve the quality of agricultural implements, particularly in the case of small-scale manufacturers.

A wide network of farm equipment manufacturers exists in India with over 1 000 established manufacturers, millers and rural artisans being engaged in implement manufacturing and repair. The R&D institutions together with the farm machinery industry constitute two important pillars of agricultural mechanization and need to collaborate closely for their mutual benefit and that of the farmers. Manufacturers need training in terms of manufacturing processes, marketing and quality control. Although there is a sizeable network of training and testing institutes, this is insufficient to satisfy the numerous needs.

Four Farm Machinery Training & Testing Institutes have been established in Central, North, South and Northeast India respectively and these have now tested about 2 280 machines. In addition, various State Agricultural Universities (SAUs), Agricultural Engineering Colleges and Polytechnics, together with others have organized training in specific aspects of agricultural technologies for the benefit of thousands of artisans and professionals involved in the agricultural mechanization effort.

(d) Credit and Subsidies for Agricultural Machinery

Long-term credit is usually available for the purchase of tractors and farm machines and short-term credit for the purchase of seeds, fertilizer and similar inputs. The Reserve Bank of India has mandated both public and private sector banks to provide 18 percent of their total credit available to the agriculture sector. Public and private sector banks failing to reach this mandatory level are required to remit the shortfall at a nominal rate to the National Bank for Agriculture and Rural Development (NABARD). This incentive for financial loans is encouraging farmers to purchase tractors.

The purchasing power of the farmers is low. The government provides subsidy and credit at a reduced interest rate to those farmers who are economically and socially disadvantaged, so encouraging them to adopt modern technologies. For instance, loans for tractors may now be obtained for those who own 4 acres (1.6 ha) of irrigated land and the deposit has been lowered to 5 percent of the tractor cost. Loans are also available for second-hand tractors provided these are less than three years old (Das, 2009). These loans have an upper limit of Rs. 200 000 (US$ 4 000).

The credit flow to agriculture in 2007-08 registered a positive growth of 11 percent, although mechanization and minor irrigation suffered cut-backs (Table 5.5).

TABLE 5.5
Credit Flow for Agriculture and Allied Activities (in million US$)

Particulars	Year				Growth Rate (%)	
	2004-05	2005-06	2006-07	2007-08	2004-08	2007-08
Total Credit to Agriculture	27 850	40 110	50 980	56 590	25.8	11.0
Farm Mechanisation	1 010	2 150	2 250	1 850	20.6	-17.9
Minor Irrigation	930	1 930	1 900	630	-8.0	-66.8

Source: NABARD, Annual report 2008-09

The rate of subsidy on different farm machines ranges up to 25 percent although there is a ceiling on the upper limit. For example, the upper limit for tractors is Rs 40 000 and for combine harvesters Rs 150 000 (US$ 880 and US$ 3 300 respectively in March 2010).

The subsidy on tractors and power tillers is restricted to those which have been tested at the Central Farm Machinery Training and Testing Institute, Budni (MP) and fulfil the government guidelines issued in this regard. Subsidy on power tillers is allowed on those fitted with a rotary tiller and in the 8 to 15 hp range. The different states may select the items according to their specific local requirements.

In order to qualify for a subsidy, irrigation and plant protection equipment must bear the certification mark issued by the Bureau of Indian Standards (BIS). Regarding other equipment, this must have been tested in accordance with the Test Codes published by the BIS, by an authorized test station of the central or state government.

A list of farm machinery subsidized during from 2002 to 2006 under the Macro Management Scheme is presented in Table 5.6. This scheme allowed the states to use up to 10 percent of their total allocations for innovations (MOAC, 2007).

It is however evident that the number of machines sold under various subsidy schemes is only a very small fraction of total number of machines purchased by farmers and it has been observed that only influential farmers normally benefit from these schemes.

TABLE 5.6
Number of Farm Machines Subsidized from 2002 to 2006 under the Macro Management Scheme

Item	Number of farm machines subsidized			
	2002-03	2003-04	2004-05	2005-06
Power tillers	4 825	4 884	3 724	16 500
Manually operated equipment/tools	155 509	140 339	105 424	64 610
Bullock driven implements	74 372	69 168	32 788	41 854
Tractor drawn implements	17 863	796	5 804	15 236
Self-propelled equipment	4 631	3 698	1 236	6 080
Plant protection equipment	86 542	35 500	23 772	81 496
Irrigation equipment	10 500	9 666	18 484	6 587
Gender friendly equipment	-	-	-	66 464
New initiatives	-	-	-	1 556

Source: MOAC (2007)

5.7 RECENT PATTERN OF TRACTOR- MACHINERY PRODUCTION AND DISTRIBUTION

The success story of the production of tractors and farm equipment in India is unique. Starting from 880 tractors made in 1961, India has become the largest producer of tractors in the world manufacturing in 2011 about 630 000 tractors (Table 5.7).

As already shown in Table 2 above, there are wide variations in agricultural productivity and in the level of mechanization in the various states of India. In fact, there is a linkage between rural infrastructure, farmers' economic health, yield and mechanization. As a result, a large spatial variation in tractor density is also observed both within and between states. The highest concentration of tractors is in northern India mainly for dry land preparation. The last decade has witnessed increasing tractor density in southern and western India and to some extent in eastern India also.

TABLE 5.7
Tractor Sales by Various Manufacturers during 2004-05 to 2008-09

	Manufacturer	2004-05	2005-06	2006-07	2007-08	2008-09	Total of 5 Years	% of Total
1	M & M	65 394	85 028	102 528	98 714	133 514	485 178	30.7
2	TAFE Group	52 851	66 667	80 134	78 847	76 609	355 108	22.4
3	Escorts	31 696	28 297	50 256	47 213	43 286	200 748	12.7
4	John Deere	16 020	19 951	19 718	28 528	78 938	163 155	10.3
5	Sonalika	26 364	32 017	36 223	30 920	29 520	155 044	9.8
6	Punjab Tractors	30 330	31 396	30 045	28 045	*	119 816	7.8
7	NHI	10 445	13 214	19 369	23 240	21 002	87 270	5.5
8	HMT	7 032	7 900	6 522	4 687	4 109	30 250	1.9
9	Force Motors	4 016	4 461	3 858	2 092	1 065	15 492	1.0
10	MGTL	2 448	2 749	2 653	2 501	*	10 351	0.7
11	VST	935	1 228	1 495	1 714	2 329	7 701	0.5
	Totals	**247 531**	**292 908**	**352 801**	**346 501**	**342 836**	**1 582 577**	

Source: TMA (2005 to 2009)
* Merged with Mahindra & Mahindra (M&M).

An average of over 400 000 tractors per annum have been sold in India during the past five years. The average size of tractor is presently about 36 hp but is slowly increasing and is expected to rise to 45 hp by the year 2020. The export market of tractors is growing and increased from 8 000 in 2000-01 to 57 000 in 2011.

Power tillers are becoming popular in lowland flooded rice fields and hilly terrains and it is estimated that about 200 000 are currently in use. There are only two major manufacturers, namely, VST Tillers & Tractors Ltd., Bangalore and Kerala Agro Machinery Corporation, Ernakulam. The annual sale of power tillers has been between 20 000 and 25 000 units over the last five years and this figure includes some power tillers which were imported from China.

Diesel engines and electric motors are the main stationary power sources with a total estimated population of above 6.8 million and 21 million units, respectively. The engines cover different power ranges and they are mainly used for pumping but also to some extent for threshing, milling of flour and *dal* and for oil extraction.

Details about numbers of manually operated tools and animal operated implements available in India are given in Table 5.8. The number of sprayers almost doubled during 1992 to 2003. Similarly the number of wheeled hand hoes also increased significantly. In the case of animal drawn implements the number of steel ploughs almost doubled whilst the number of seed-fertilizer drills increased significantly.

The healthy growth in the tractor population has resulted in a corresponding growth in implement manufacturing particularly of disc harrows, seed drills, potato diggers and trailers (Table 5.9). The population of power operated sprayers, diesel and electric powered pump sets, paddy threshers, maize shellers and chaff cutters also increased significantly.

TABLE 5.8
Inventory of Manual and Animal Drawn Equipment in India (2003)

Farm Machines Available ('000)					
Manual			Animal Powered		
	1992	2003		1992	2003
Seed-fertilizer drill	876	2 494	Wooden plough	39 581	43 975
Seed drill	949	19 136	Steel plough	9 397	17 066
Chaff cutter	11 833	10 404	Disc harrow	2 257	2 650
Wheeled hand hoe	1 470	2 142	Cultivator	5 325	6 698
Sprayer	2 606	5 052	Seed-fertilizer drill	2 815	5 103
Thresher	900	910	Seed drill	4 535	4 700
			Leveller	9 610	11 971
			Wet land puddler	2 375	3 547
			Animal-drawn cart	13 386	10 101

Source: MOAC (2003)

TABLE 5.9
Inventory of Powered Farm Machinery in India (2003)

Tractor/Power Operated Machines Available ('000)					
	1992	2003		1992	2003
Power operated sprayers/dusters	306	608	Levellers	590	878
Diesel engine pump sets	4 577	7 237	Potato diggers	98	296
Electric pump sets	6 403	8 446	Trailers	462	1 117
Mouldboard plough	499	172	Paddy threshers	35	161
Cultivators	684	965	Wheat threshers	1 076	726
Disc harrows	646	1 772	Maize shellers	62	119
Seed-fertilizer drills	390	1 011	Chaff cutters	977	2 274
Planters	96	114	Combines (both tractor-drawn and self-propelled)	8.5	20

Source: MOAC (2003): Livestock Census

After liberalization and with the development of research prototypes of machines, manufacturing was boosted particularly in Haryana, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh. Combine harvester manufacturing is concentrated mainly in Punjab and more than 3 000 are sold annually. Combine harvesting of wheat, paddy and soybean is well accepted by farmers. Tractor-powered combine harvesters cost only 25-30 percent of the price of self-propelled combines and have proved to be a real innovation of the manufacturers of Punjab and this machine can be owned by individual farmers. In contrast, self propelled combines are normally owned by custom-hiring contractors. At present, 13 models of self-propelled combine are being manufactured with cutter bar widths ranging from 2.06 m to 4.85 m (IASRI, 2006).

5.8 ESTIMATES OF INVESTMENTS BY FARMERS IN FARM MACHINERY

Investment in machinery is long term in contrast to investment in other inputs such as seeds, fertilizer and chemicals. Investment in hand operated tools is growing very slowly with the increase in the population of agricultural workers.

Investment in the animal operated implements is decreasing gradually due to the decrease in the number of draught animals. However, investment in power operated farm equipment is increasing rapidly (Table 5.10).

TABLE 5.10
Number of farm machines subsidized under the macro management scheme (2002 to 2006)

Item	Number of farm machines subsidized			
	2002-03	2003-04	2004-05	2005-06
Power tillers	4 825	4 884	3 724	16 500
Manually operated equipment/tools	155 509	140 339	105 424	64 610
Bullock driven implements	74 372	69 168	32 788	41 854
Tractor drawn implements	17 863	796	5 804	15 236
Self-propelled equipment	4 631	3 698	1 236	6 080
Plant protection equipment	86 542	35 500	23 772	81 496
Irrigation equipment	10 500	9 666	18 484	6 587
Gender friendly equipment	-	-	-	66 464
New initiatives	-	-	-	1 556

Source: MOAC (2007)

The total investment in the farm machines in 2005 (Table 5.11) was estimated to be around Rs 273 billion (US$ 6 billion). This compares to an annual investment in 1997 of some Rs 180 billion (US$ 5 billion) (Singh and Doharey, 1999). Annual investment in 2005 in agro-processing and post-harvest equipment was estimated to be around Rs 200 billion, bringing the total annual investment to Rs 453 billion or US$ 10 billion (IASRI, 2006).

In 2010, the author has estimated that investment in farm machinery has risen to about Rs 450 billion with a further Rs 300 billion invested in agro-processing and post harvest equipment, bringing the total annual investment to Rs 750 billion or US $ 15 billion.

5.9 FUTURE INVESTMENTS

The future investment in agriculture will be guided by a number of factors. Sales data gathered over the past eight years indicate a growing preference for tractors in the 41 to 50 hp range. High capacity machines will also be preferred in future, including rotary tillers, harrows, laser levellers, high clearance sprayers, planters, high capacity threshers and self-propelled and tractor drawn combines.

The custom hiring of mechanical power for tillage, irrigation, harvesting and threshing will be preferred by those farmers who cannot afford, or prefer not to own machines. The present trend in agricultural mechanization is for the high capacity machines to be used for custom hiring and for contractual field operations. Numbers of hand operated tools and implements will only grow very slowly as the number of agricultural workers increases. Animal operated implements will decrease due to the continued decrease in the number of draught animals. In contrast, the use of power operated farm equipment will increase rapidly.

TABLE 5.11
Estimated Investment in Farm Machinery during 2005

	Type of the equipment	Annual sales (Number)	Unit cost (Rs)	Total cost (million Rs)
1.	Tractors with minimum equipment	250 000	500 000	**125 000**
2.	Bulldozers and other earth moving machinery	500	2 000 000	**1 000**
3.	Power tillers	15 000	100 000	**1 500**
4.	Pump sets / submersible pumps	1 000 000	20 000	**20 000**
5.	Diesel engines	500 000	20 000	**10 000**
6.	Sprayers & duster (manual and powered)	NA	LS	**20 000**
7.	Power threshers	400 000	30 000	**12 000**
8.	Combines	2 500	800 000	**2 000**
9.	Reapers	3 000	50 000	**150**
10.	Straw combine	10 000	80 000	**800**
11.	Different types of tractor drawn equipment (ploughs, harrows, cultivators, rotary tillers, seed drills/planters, etc)	NA	LS	**35 000**
12.	Different types of animal drawn equipment / carts	NA	LS	**25 000**
13.	Hand tools and garden tools; manually operated equipment	NA	LS	**10 000**
14.	Sprinklers and drip irrigation equipment	NA	LS	**2 000**
15.	Other agricultural equipment (stubble shavers, shrub masters, water tankers, land levellers, land planes, forage harvesting equipment, manure spreaders, etc.)	NA	LS	**8 550**
	Total investment for 2005			**273 000**

NA- Not available, LS- Lump sum basis; ***Source:*** IASRI (2006)

The projections for mechanization in India are given in Table 5.12. The tractor population is expected to stabilize at around 7 million units by 2050 and available farm power will then stabilize at around 4.5 kW/ha. The draught animal population will decrease drastically whereas power tillers, diesel engines and electric motors are expected to register significant increases during the period 2005 to 2050.

TABLE 5.12
Projections for mechanization in India

Item	2005	2015	2030	2050
Agricultural workers (millions)	**230**	**280**	**340**	**350**
Draught animals (millions)	**53**	**37**	**18**	**8**
Tractors (millions)	**3.0**	**4.5**	**6.0**	**7.0**
Power tillers (thousands)	**152**	**250**	**400**	**500**
Diesel engines (millions)	**6.4**	**7.3**	**7.8**	**8.5**
Electric motors (millions)	**17**	**25**	**35**	**40**
Power (kW/ha)	**1.5**	**2.2**	**3.5**	**4.5**

5.10 CONCLUSIONS

There is no doubt that India has achieved considerable progress in the field of agricultural mechanization over the past four decades. While the success of the Green Revolution in the 1970s was largely attributed to three major inputs – the increased utilization of fertilizers and improved seeds (of HYVs) as well as irrigation, it is apparent that mechanization as the fourth input also played a key role. Further, the development and dissemination of the mechanization technologies was largely dominated by the private sector – machinery and implement manufacturers and distributors as well as the farmers themselves who were ready to invest in agricultural machinery and implements.

The following facts and lessons demonstrate the pace of adoption and impact of agricultural mechanization in India:

- Tractor use has increased by about 28 times between 1970 and 2010 while the number of draught animals in use has declined from 82.6 million to about 50 million. Statistics on other machinery and implements show similar trends. The states with high rates of available power per hectare are also the ones which have the highest yields. Four wheel tractors dominated the farm power sector in India with much less use of two wheel power tillers compared to other Asian countries.
- Mechanization technologies were first adopted by the large farmers (over 10 ha farm size) followed by medium scale farmers (with 4 to 10 ha farm size). The large numbers of such farmers in states like Punjab and Haryana played a critical role in facilitating the creation of a viable agricultural machinery and implement distribution and services sector. Such farmers were also the ones who were able to provide mechanization and other services to the more numerous semi-medium (2 to 4 ha farm size) and small holder farmers (1 to 2 ha) farmers.
- The availability of credit at subsidized rates has been catalytic to the rate at which farmers – especially the small and medium scale ones – were able to procure agricultural machinery and implements. In addition, assured support prices for the farmers' produce, as well as the availability of off and on farm custom hire possibilities where agricultural machinery could be used, further enhanced the profitability of acquiring agricultural mechanization inputs by farmers.
- The high level of effective demand for agricultural machinery and equipment led to the creation of a competitive and viable manufacturing industry such that India became globally a leading player in this sector including becoming a net exporter.
- The Government of India provided support services for research and development; testing and standards; as well as for human resources development in support of agricultural mechanization. The agricultural engineering programmes established in the numerous state agricultural universities were instrumental for the success of agricultural mechanization in India.
- Business and enterprise friendly policies, laws, and regulations as well as physical and institutional infrastructures which encourage commercial activities and entrepreneurship in farming, input supply, produce handling, processing and marketing as well as in manufacturing were, and remain, the key factors to success of agricultural mechanization in the different states of India.

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CHAPTER 6

China: Development of farm mechanization and the agricultural machinery industry

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ABSTRACT

The development of agricultural mechanization in China from 1949 to the present is described, as are the underlying policy decisions and preconditions. With a population likely to rise to 1.6 billion within the next 30 years, China has had to take firm developmental steps to ensure food security. Agricultural mechanization has played a key role together with concomitant factors such as plant breeding and improved agricultural practices with ecosystems approaches. Mechanization has developed in tandem with decentralized local agricultural machinery manufacture which has absorbed the rural labour force freed up as a result of increased labour productivity. To close the technology gap with the most developed international agricultural machinery manufacturers, China has developed an open door policy which 'exchanges the market for technology'. This means that multinational companies are welcome to set up joint venture companies with Chinese counterparts and enjoy access to the vast Chinese market so long as they bring advanced technology with them. Phasing out the commune system and encouraging private investment in agricultural machinery has made the market even more attractive for such ventures.

6.1 INTRODUCTION

The development of agricultural mechanization and the farm machinery manufacturing industry in China has made significant contributions to the transformation of the country's traditional farming into modern agriculture (Stavis, 1978). The impact of science and technological innovations and experiences from international and regional exchange and cooperation on the promotion of agricultural mechanization and the development of the manufacturing industry have played important roles in this transformation.

The following discussions are based on China's recent strategic research projects on mid- and long-term agricultural mechanization, on her research and development programmes as well as on the experiences gained and lessons learned during the 60 years from 1949 to 2008. In 2004, China passed the "National Law on Promotion of Agricultural Mechanization", which provided for enhancement of regional and international cooperation on agricultural mechanization, technology transfer, information dissemination and beneficial marketing development.

After the founding of the People's Republic of China in 1949, the government encouraged the development of the agricultural sector, which it regarded as fundamental to national economic and social development and as the cornerstone of China's industrialization, social stability and further prosperity.

During the 60 years since then, China's population has increased from 450 million to 1.33 billion, while the per capita arable farmland has decreased from 0.18 ha to less than 0.10 ha. Agricultural productivity however, has improved during the same period. Total grain output has increased about 4.7 fold while per capita grain output has increased from 209 kg to 398 kg. The agricultural sector's rapid growth had resulted in steadily increasing food supplies and has ensured sufficient food and other agricultural products for the large population.

During the late 1990s, China declared the end of its historic deficit in agricultural produce. The country has successfully used seven percent of the world's arable land to feed 20 percent of global population. The rural economic system reform since 1978 has made China confident of its continued ability to feed its population, which is forecast to reach 1.6 billion by 2030.

Starting as an economically underdeveloped agricultural country in 1949, China had been able to increase its total farm power and rural electricity consumption from almost nil to 822 million kW and 571 billion kWh, respectively by 2008. The government had also gradually established and improved agricultural mechanization, rural electrification, water conservation and storage and other engineering infrastructure. The development of agricultural mechanization and farm machinery manufacturing industries has made significant contributions in modernizing agriculture and in building a fairly well-off society in a comprehensive way (Tam, 1985).

6.2 OVERVIEW OF THE STATUS OF AGRICULTURAL MECHANIZATION DEVELOPMENT IN CHINA

Since its founding in 1949, New China's agricultural mechanization has developed through four stages consonant with economic development, namely: (i) preliminary stage (1950–1980); (ii) national economic system reform stage (1980–2003); (iii) transformation of traditional farming into modern agriculture stage (2004–2009) and (iv) development of agricultural machinery manufacturing industries and investment opportunities and challenges stage

(2010–present). Table 6.1 shows a summary of the chronology of significant events during those stages.

TABLE 6.1
Chronology of significant events in the development of Chinese agricultural mechanization

Period		Events/Milestones
Stage I Preliminary Stage (1950–1980)	1950-1980	Tractors and agricultural implements are introduced from the former USSR and Eastern European countries. Local industries produce primarily medium- and small-sized machinery.
	1949-1956	First Five Year Plan commences in 1953; investment priority put on industry and agricultural mechanization is experimented with on a limited scale and only state farms are planned to acquire 5145 standard tractors of 15 hp each by 1957. First tractor factory is constructed in Luoyang City, Henan Province with Soviet assistance and planned capacity of 15 000 units of 54 hp tractor (Tam, 1985).
	1950-1957	Government disseminates improved farm tools into the rural areas to increase agricultural productivity and to upgrade the rural economy from a weak economic base and low level of technological and institutional development.
	1958-1965	Initial national economy adjustment period; government lays down guiding principles and strategies for agricultural mechanization; reforms farm tools and establishes state-owned tractor stations aimed at replacing human- or animal-powered tillage in certain areas with engine-powered tillage.
	Before 1975	As a policy issue, agricultural mechanization is not considered a priority of real national significance although discussed more than once after the land reform of the early 1950s (Tam, 1985).
	1966 to 1980	There is rapid development of agricultural mechanization for the first time; government promulgates the goal of "achieving national agricultural mechanization by the year 1980." Government adopts administrative and other measures to speed up the agricultural mechanization process; by 1980, the total farm power had reached 147 5 GW[28] and about 42.4 percent of cultivated land had been mechanized.
	October 1975	After the convention of the Fourth National People's Congress, the First National Conference on "Learning from Dazhai in Agriculture," Mao Zedong's slogan emulating the development works of Dazhai villagers in North China, resolves to make basic mechanization the basis for achieving modernization of the agricultural sector and of the whole economy (Tam, 1985).
	December 1976	Second National Conference on "Learning from Dazhai in Agriculture," which was urgently advanced four years ahead of schedule, affirms the priority of rapid mechanization as the focus for rural development (Tam, 1985).
	October 1978	Start of transformation of economy from centrally planned to market-oriented; government plans to abolish the rural people's commune system. Government promotes international science and technology exchange and import-export trade of farm machinery along with the reforms and opening up the economy to the outside world; holds the first international farm machinery exhibition in Beijing; which attracted 12 foreign machinery companies and created interest among local firms and technical circles and awareness of mechanization in government bodies. Government buys most of the equipment exhibited at the fair; technology exchanges and cooperation between the Chinese farm machinery industry and its global counterparts begin. Chinese people learn about the latest developments in global farm machinery technology and recognize the technology gap between China and the developed world. China imports a complete set of large tractors and matching farm implements for the first time.

[28] Giga (G) is 10^9, so that 147.5 GW = 147.5 million kW.

Period		Events/Milestones
Stage II National Economic System Reform (1980–2003)	1980–2003	Government implements the farmland management system reform that results in scattered and small parcels of land cultivated by rural households. Only small farm machinery is feasible for individual farmers to use.
	1983	Government abolishes the commune system and implements the farmland household contract responsibility system in connection with production.
	Mid-1980s to early 1990s	Government implements abolition of the commune system. Government encourages the improvement and innovation of two-wheel tractors (2WTs) and four-wheel tractors (4WTs), paddy tillage machines and small tractor back-pack combines.
	Mid-1990s	Central Government issues the document on "Decisions on promoting the advancement of science and technology." Efforts focused on basic and high-technology research activities, while giving full support to research and development institutions that directly enhance economic development and convert research outputs into commercial applications. Mechanization of rice production creates a huge market opportunity and presents a challenge for technology transfer by foreign firms. Socialized agricultural mechanization services begin in rural areas using cereal combines for trans-regional mobile harvesting services from the south to the north; such services increase utilization hours of large- and medium-sized machinery and hence improve viability and profitability. International farm machinery firms see opportunities to enter the Chinese market, especially those for crop establishment, inter-cultivation and harvesting of corn (maize), the third most important crop in China. Production capability for large and medium-sized machinery lower than 200 horsepower steadily matures to meet the market demands for tillage, seeding and harvesting of 30 million hectares of paddy fields.
	1999	Rural industry contributes one-fourth of the gross domestic product (GDP), one-fifth of national income, one-third of farmers' income, one-half of the increase in industrial production and two-fifths of export value. Village and township enterprises provide more than US$100 billion in agricultural development funds and employ 130 million rural laborers. Total grain yield has risen to a historic high of 512 million tonnes (412 kg per capita in 1998) from 305 million tonnes in 1978.
Stage III Transformation from Traditional Farming to Modern Agriculture (2004–2009)		It becomes clear that transforming traditional farming into modern agriculture needs the application of agricultural mechanization, agricultural equipment design and manufacture, post-harvest technology and product processing. Government enacts the first State Law on "Promotion of Agricultural Mechanization," effective on 1 November 2004, requiring all government bodies above the county level to include the promotion of agricultural mechanization to the national and social development plans and to increase financial support for its development. China's increased annual GDP increase to an average of 9.8 percent from 1979 to 2008 has created a favorable national economic situation to balance the economic gap between urban and rural areas. China starts a new period characterized by industry supporting agriculture and the urban economy supporting rural development. Skilled farmers learn modes of operation for the commercialization and socialization of farm machinery services, which create an increasing market for large and medium-sized farm machinery. Development of large- and medium-sized tractors and combines revitalizes the agricultural sector; domestic market grows rapidly; old machines are replaced. Market opportunities for large tractors and combines open; domestic production capability for medium- and large-sized tractors increases.

Period	Events/Milestones
Stage IV: Development of Agricultural Machinery Manufacturing Industries, Investment Opportunities and Challenges (2010–present)	Industries shift from fabrication of simple hand-tools and animal-driven implements to manufacture of various types of modern agricultural equipment; China's agricultural machinery industries can already supply many kinds of farm power and implements to meet the requirements of domestic agricultural production. Industries enhance the competitiveness of their small- and medium agricultural machinery in the world market; however, cotton, oil-seed rape, sugarcane and sugar beet harvesting operations, which are still manual, present challenges in technological innovations.

(i) The preliminary stage of agricultural mechanization development (1950–1980)

China initially practised agricultural mechanization in state-owned farms with assistance from the former USSR which equated mechanization with "tractorization", following the classic route of transfer of technology, which in this case was probably considered as appropriate because of similarity of conditions. Experts and technicians from the former USSR and Eastern European countries provided technical services and staff training. The government established state-owned mechanized farms through land reclamation and managed state-owned tractor stations (Machine Tractor Stations [MTS] and Agricultural Mechanization Stations [AMS]) by trial and error. The first generation of Chinese technicians, engineers and managers for agricultural mechanization developed their knowledge and skills through practical experiences in mechanized farming. Subsequently, they contributed significantly to the development of farm mechanization in China.

Experiences during the 30-year period from 1950 to 1980 enabled the government to better chart the roadmap for its development and to create a viable national farm machinery manufacturing industry. By the end of 1980, there were 1 829 farm machinery manufacturers and 2 366 local-level manufacture and repair workshops. The local industries contributed to the improvement and production of farm tools and machinery and served as incubators for the establishment of rural manufacturing enterprises during the 1980s. The government established a comprehensive central-to-county level system of management including the organization and provision of services as well as research and educational institutions devoted to agricultural mechanization.

Management had also learned lessons in identifying and solving problems, which included a lack of understanding of the local natural and socio-economic conditions that had led to impractical, over-ambitious and arbitrary forecasts, violations of natural and economic laws, abuse of administrative measures as well as extensive mass movements of people. It realized that the implementation of a planned economy only permitted unified management by the state and collectives but did not empower individual farmers in management. The result was an agricultural mechanization system that has been perceived as not having greatly benefited the farmers.

By 1980, the structure of farm power changed significantly along with the system reforms. The distribution ratio of farm power had changed from 100:18:4.6 (manual:animal:mechanical) in 1965 to 100:16:47 in 1980. The total farm power had reached 147.5 GW and total farm-used tractor power had reached 35.4 GW. There were 670 000 units of large- and medium-sized and 1.67 million units of small-sized tractors. The mechanization levels had reached 42.4 percent for tillage, 10.4 percent for sowing, 0.7 percent for paddy transplanting and 2.6 percent for rice harvesting.

China's agricultural machinery manufacturing industry had the following annual production capacity: farm power machinery, 23.23 GW; tractors for farm use, 138 000 units; walking tractors, 350 000 units; and combine harvesters, 6 000 units. Table 6.2 shows the increase in agricultural tractor power and units of power tillers and combine harvesters over a 30-year period.

TABLE 6.2
Basic statistics of agricultural mechanization development, 1950–1980

Year	1949	1959	1969	1979
Total power of tractors in use (million kW)	0.074	2.35	13.69	35.38
Boat-based (floating type) power tillers for paddy field (unit)	13	4 908	8 000	—
Combine harvesters (unit)	13	4 908	8 000	23 026
Total power for irrigation and drainage (million kW)	0.065	2.345	13.69	—

Source: Anon. 2009.(a) Scientific and technical development report on China's agricultural mechanization (1949-2009). China Agricultural Science and Technology Press (in Chinese).

(ii) Agricultural mechanization development in the national economic system reform stage (1980–2003)

During the early 1980s, China's rural economy diversified. Rural industries and village and township enterprises boomed in the rural areas. By 1986, the production value of rural industries as well as village and township enterprises had exceeded the total value of agriculture. By 1999, the rural industrial sector had contributed one-fourth of the GDP, one-fifth of national income, one-third of farmers' income, half of the increase in industrial production and two-fifths of the value of exports. The village and township enterprises had also provided more than US$100 billion in agricultural development funds and employed 130 million rural laborers.

The reconstruction of the rural economic system led to the re-evaluation of the policy of agricultural mechanization. Since 1982, the State has allowed farm machines to enter the market as commodities and has given farmers the right to purchase and manage farm machinery. Thus a multi-ownership economy that primarily relied on the state, the collectives and individual farmers for the purchase and management of agricultural machinery had generally formed. In 1997, farm households ran 97 percent of the tractors in use. The number of small tractors increased rapidly, while the number of large- and medium-sized tractors declined. In fact, the mechanization level of cultivated land in the country as a whole decreased to a certain extent. By

1986, it had been restored to the level of 1978. Following the reconstruction period, agricultural mechanization and farm industries developed smoothly. The total farm power and mechanization levels of cultivated land developed rapidly in line with the actual conditions of the country. Some data about the development are given in Table 6.3.

TABLE 6.3
Major agricultural machinery and electricity consumed in rural areas at year-end, 1980–2003

Year	Total Power of Agricultural Machinery (10^6 kW)	Large and Medium-sized Agricultural Tractors		Small Tractors		Diesel Engines for Field Irrigation and Drainage		Electricity Consumed in Rural Areas (10^9 kWh)
		Number (10^3 units)	Capacity (10^6 kW)	Number (10^3 units)	Capacity (10^6 kW)	Number (10^3 units)	Capacity (10^6 kW)	
1980	147.457	744.865	23.693	1 874.000	16.155	2 899	27.177	32.08
1985	209.125	852.357	27.436	3 824.000	33.670	2 865	25.660	50.89
1990	287.077	813.521	27.455	6 981.000	62.314	4 111	33.485	84.45
1995	361.181	671.846	24.041	8 646.356	78.481	4 912	38.390	165.57
2000	525.736	974.547	31.611	12 643.70	116.639	6 881	52.326	242.13
2001	551.721	829.900	29.017	13 050.84	122.579	7 286	55.800	261.08
2002	579.299	911.670	30.734	13 393.88	126.950	7 506	58.042	299.34
2003	603.865	980.560	32.298	13 777.06	130.602	7 496	55.928	343.29

Source: Anon 2009(b). China Statistical Yearbook.

Since the implementation of the open-door economic policy in 1978, the agricultural machinery technology advances in developed countries have made an impact on the management of local agro-industries. It has become clear that transforming traditional farming into modern agriculture needed the promotion of agricultural mechanization, agricultural equipment design and manufacture, post-harvest technology and product processing.

Although the farmland household contract responsibility system succeeded in increasing agricultural productivity and in stimulating the enthusiasm of farmers, agricultural mechanization development faced new challenges in small-scale farming under the market-oriented system. The government gradually reduced state investments in agricultural mechanization and eased up the government control in the planning of agricultural machinery production. It allowed farmers to buy and operate machinery. The efficiency and economic benefit of machinery utilization in the small-scale farming sector became critical. The manufacture of machinery and power units for small farms dominated the agricultural machinery industry. Most agricultural power and machinery owned by cooperatives or state farms was transferred to private ownership or contract responsibility management.

The percentages of privately owned agricultural machinery in the total machinery inventory in 1994 were the following:

Type of Machinery	Percent
Large-and medium-sized tractors	70.5
Small-sized tractors	97
Rural vehicles	80.6
Irrigation power equipment	77.7
Power threshers	86.9
Farm-use pumps	77.8
Total original value of all agricultural machinery	>79

The government adopted the following principles in promoting the improved farming technologies: (1) the simultaneous development of full and partial mechanization and the application of improved hand tools technology; (2) an equal emphasis on manual, animal and electro-mechanical power; and (3) the combination of engineering, agricultural and biological technologies. Farmers gradually became the main beneficiaries of investments for agricultural mechanization and improvement of farming tools.

Agricultural machinery research and development efforts aimed to meet the needs of farmers by transforming scientific research results into farming practices and developing mechanization technologies in key rural areas for critical farming operations to reduce production costs and increase benefits. Engineering services provided for horticulture, intensive livestock production and aquaculture as well as processing agricultural products. Technology development was required to keep in mind aspects of ecological and environmental friendliness. Crop harvesting, paddy field mechanization and conservation tillage technologies for arid farming became major issues.

Socialized contract services were recognized as a solution to promote agricultural mechanization and resource-conservation approaches for the small-scale farming system. Macro-planning, policy and regulation formulation services for the promotion of agricultural mechanization replaced the administrative and management functions of government organizations.

Rapid national industrialization has created favourable conditions for the transfer of the rural labour force into city or township industries. The comparative economic benefits between industrial and agricultural production emerged and created the challenge to sustain the increases in cereal production and to ensure grain security. This trend emerged particularly during 1998–2003 and resulted in a reduction of grain production, decreased grain production area and sluggish improvement of farmers' net income. It led to the recognition of the urgent need to modernize agriculture with increased agricultural machinery input. The Standing Committee of the National People's Congress gave priority to the creation of a legal guarantee system to promote agricultural mechanization.

(iii) The transformation of conventional farming into modern agriculture (2004-2009)

Since 1978, China's economic reform and adoption of opening up to globalization have accelerated the development of the country's national economy. China's annual GDP has increased by an average of 9.8 percent from 1979 to 2008 and reform has created a favourable national economic situation to balance the economic gap between urban and rural areas. China has commenced a new period characterized by industry supporting agriculture and the urban economy supporting rural development.

Based on the trend towards industrialization and aiming at building an equitably prosperous society, the National Social and Economic Development Programme has, since 2004, given priority to solving problems facing agriculture, rural areas and farmers. It adopted a series of measures to enhance the agricultural sector, such as reducing the burden on farmers by withdrawing agricultural tax and adopting subsidy policies directed to producers. In 2004, farmers' taxes were reduced by US$36 billion and subsidies for grain producers, seeds and farm machinery reached US$18 billion. Investments in agriculture from the Central Government increased 37.5 percent compared with those in 2003. The market demand for agricultural equipment shifted toward the mechanization of production processing. The central government has established a financial subsidy policy to encourage farmers and cooperative organizations to buy agricultural machinery. The financial subsidies increased from 70 million Yuan in 2004 to 155 x 100 million Yuan in 2010 (i.e. from 8.45 million USD to over 2 billion USD).

Table 6.4 gives indicative figures of the progress of agricultural mechanization in China in the period 2004-2008.

TABLE 6.4
Farm power, agricultural machinery and electricity consumed in rural areas from 2004 to 2008

Year	Total Power Agricultural Machinery (10^6 kW)	Large and Medium-sized Tractors		Small Tractors		Diesel Engines for Irrigation and Drainage		Electricity Consumed in Rural Areas (10^9 kWh)
		Number (10^3 unit)	Capacity (10^6 kW)	Number (10^3 unit)	Capacity (10^6 kW)	Number (10^3 unit)	Capacity (10^6 kW)	
2004	640.279	1 118.636	37.131	14 549.28	138.554	7 775	58.042	393.30
2005	683.978	1 395.981	42.935	15 268.92	146.609	8 099	60.340	437.57
2006	725.221	1 718.247	52.453	15 679.00	152.291	8 364	61.488	489.58
2007	765.896	2 062.731	61.011	16 191.15	166.477	8 615	62.828	550.99
2008	821.904	2 995.214	81.865	17 224.10	116.639	8 984	65.617	571.32

Source: Anon. 2009(b). China Statistics Yearbook

(iv) Development of agricultural machinery manufacturing industries, investment opportunities and challenges stage (2010–present)

Since the founding of the new China, its agricultural machinery manufacturing industries have gradually developed from a status characterized by scattered small workshops to one characterized by local enterprises and large industries. The industries shifted from fabrication of simple hand-tools and animal-powered implements to the manufacture of various types of modern agricultural equipment. China's agricultural machinery industries can already supply many kinds of farm power and implements to meet the requirements of agricultural production based on domestic conditions and have enhanced the competitiveness of their medium- and small-sized agricultural machinery in the world market. Some basic information on the industry is given in Tables 6.5 and 6.6.

TABLE 6.5
Number of agricultural machinery manufacturers and total annual output values, 1949–2008

Year	Number of Agricultural Machinery Manufacturers with Annual Sales over 5 Million Yuan (unit)	Total Annual Output Values (million Yuan)
1949	36	0.03
1957	276	3.84
1965	1 598	14.50
1970	1 621	32.42
1975	1 882	62.37
1980	1 829	70.76
1985	2 290	123.98
1990	2 513	285.58
1995	2 122	696.23
1998	1 641	741.22
2000	1 484	726.18
2002	1 484	483.46
2004	1 617	854.00
2006	1 757	1 273.28
2008	2 021	1 914.92

Source: Anon. 2009(a). Scientific and technical development report on China's agricultural mechanization (1949-2009). China Agricultural Science and Technology Press (In Chinese).

TABLE 6.6
Production capacity of China's agricultural machinery industry in 1977–2008

Year	Tractors			Combine Harvesters (10^3 unit)	Internal Combustion Engines (million. kW)
	Large- and Medium-sized (10^3 unit)	Small-sized (10^3 unit)	Total (10^3 unit)		
1977	99.3	230.5	329.8	2.5	20.1544
1978	113.5	324.4	437.8	4.9	20.7206
1986	32.6	747.4	780	2.0	51.33
1996	64.7	1 941.4	2 025.1	24.3	180.47
2000	51.0	1 526.7	1 578.6	31.5	173.164
2002	39.3	789.0	852.9	45.3	132.39
2004	98.3	1 794.2	1 970.4	50.0	434.01
2006	197.8	1 916.8	2 114.6	108.0	452.17
2008	217.1	1 879.9	2 097.0	70.0	549.77

Source: Anon. 2009(a)

The domestic market for large- and medium-sized farm machinery began to grow rapidly. It opened the market opportunities for advanced large tractors and combines and stimulated the agro-machinery manufacturers to adjust their product structure. The domestic production capability for medium- and large-sized tractors also increased.

In terms of the agricultural machinery product structure, the domestic production capability for large and medium-sized machinery under 200 hp has steadily matured to meet the market demands for tillage, seeding and harvesting in recent years. China has a total of about 30 million hectares of paddy fields, and since the mid-1990s, the mechanization of rice production has created a huge market opportunity in China and has presented a challenge for technology transfer by foreign firms.

Since 1978, the international science and technology exchange and import-export trade of farm machinery have been promoted along with the reforms and opening up the economy to the outside world. The farm machinery exhibition held in October 1978 in Beijing was the first large-scale international farm machinery fair since the founding of new China. The Chinese government purchased most of the equipment exhibited at the fair. Such equipment had an extensive and far-reaching impact on China's farm machinery industry and the fair marked the beginning of the exchange and cooperation between the Chinese farm machinery industry and its global counterparts. China imported a complete set of large tractors and matching farming implements for the first time.

From a long-term perspective, the cooperation between Chinese and foreign firms for manufacturing agricultural machinery in China and for local placement of products has been successful for exploring the Chinese market. The Chinese agricultural machinery industry requires not only an open door policy for technology, but more importantly also a willingness to learn the development strategy ideas and advanced industrial management methods from developed countries.

The mode of technology transfer from John Deere to the Jiamusi Combine Harvester Factory in the 1980s was different from John Deere's holding the majority of the shares of Deere-Jialian joint venture in the 1990s. The latter type of Chinese-foreign joint venture, in which the foreign company holds the majority of the shares, essentially created a subsidiary company of the foreign multinational company, entitling it to adopt any new technology from its foreign principals while enabling the Chinese and foreign partners to jointly explore the Chinese market. Moreover, China has the advantage of lower cost of labour and raw materials. Thus, the advantageous features of the two partners are complementary and the successful joint venture between John Deere and Jialian is an example of Chinese-foreign mutually beneficial cooperation in the farm machinery sector.

Foreign firms commonly encounter difficulties due to a lack of understanding of the Chinese conditions and so joint ventures have superior management

TABLE 6.7
Joint venture and other collaborative activities of Chinese industries with international manufacturers of large tractors and combines

Year	Collaborative Activities between Chinese Industries and International Manufacturers
1978	China holds first international machinery exhibition in Beijing; 12 foreign companies participated; China buys nearly all machines exhibited. Exhibition marks the beginning of opening China's machinery market to the outside world; attracts business from leading agricultural machinery manufacturers. This first promotion of the large-scale technology transfer of farm machinery manufacturing from developed countries into China lays the foundation for further international cooperation in the field.
1981	John Deere (JD) Company/US, which has explored the Chinese market for last 20 years, starts joint ventures with Jiamusi Combine Factory in Heilongjang Province, Northeast China and Kaifeng Combine Factory in Henan Province, Central China to take advantage of low production costs and favorable marketing opportunities. China imports the design and manufacturing technology of JD's 1000 series grain combines in August 1981; JD introduces production technology making the two joint-venture projects the first and largest farm machinery manufacturing entity. JD provides training programs for design and manufacturing engineers and technicians on production technology for 160 hp and medium-sized tractors; demonstrates Model 7810 185 hp tractor, Model 726 double harrowing machine and Model 450 seed drill in a state-owned reclamation farm in Xinjiang Autonomous Region; also demonstrates in Friendship Farm in Heilongjiang province modern machinery for completely mechanizing the entire farm production process from tillage, irrigation and harvesting to product storage; negotiates with state-owned farms in Xinjiang concerning the possible order of up to 1000 extra-large tractors and farm machinery; JD expects to play a significant role in the development of western China.
1984	FIAT/Italy forms joint venture with China First Tractor Factory with import and introduction of the production technology for FIAT 90 series tractors.
1990s	Case Company/US starts joint venture with Sipping Combine Factory in Jilin Province; sets up assembly factory for engineering machinery in Shanghai; negotiates the cooperative production of Model 515 combines; partnership has ranked third in tractor sales.
1997	JD demonstrates machinery for animal husbandry at Inner Mongolia Autonomous Region; forms joint venture with Jialian Harvesting Machinery (JDJL).for manufacture of combines. Yanmar Company/Japan sets up joint venture with Wuxi City, Jiangsu Province to produce 3000 "People Brand" semi-fed type rice combines per year, with 30 percent of the parts manufactured in China. Kubota Company/Japan sets up a mono-capital firm in Suzhou City, Jiangsu Province; Kubota competes with Yanmar for the semi-fed type rice combine market in southeast China. Sanjiu Company/Taiwan sets up a mono-capital factory in Shanghai; manufactures low-temperature grain dryers for mechanized post-harvest rice drying; markets them mainly in the coastal provinces of south-east China. Jinzi Company/Japan sets up mono-capital firm in Wuxi City, Jiangsu Province; competes with Sanjiu for market demand of paddy post harvest treatment equipment in the coastal provinces of south-east China. Farm machinery companies/South Korea set up trading in South-east China, Shandong Province, Zhejiang Province and some other areas; explore markets for combines, rice transplanters, powered tillage machinery and agricultural vehicles; seek market opportunities by providing competitive price and technology levels. Massey Ferguson/UK and Hege/Germany market their tractors and combines.
1998	JDJL has annual output of 3000 units combine, including 500 units of Model 3060 with 5 kg/s output and 2500 units of Model 1075 with 2.5 kg/s output.
1999	New Holland Company/USA starts joint venture, the Harbin New Holland Beidahuang Tractor Company Limited; partnership sells 363 units of 175 hp tractors to Heilongjiang Province and starts with the installation of 100–180 hp tractors for the domestic and overseas markets.

and a higher rate of success. This is a lesson that has been learned by foreign companies following the initial stages of the reform. With respect to international cooperation, China has invented a phrase called "exchange of market for technology," meaning that China is willing to open up part of the market, facilitating the entry of foreign firms in terms of policies, taxes and relaxation of restrictions on share-holding by foreign firms; whilst at the same time benefiting from new technology.

The Chinese government encourages foreign firms to supply farm machinery products which are urgently needed by the Chinese agricultural sector and cannot yet be manufactured by the Chinese enterprises, e.g. 200 hp or larger tractors with complete sets of advanced implements and fittings as well as complex combine harvesters. The trend in export and import of China's agricultural machinery is shown in Table 6.8.

TABLE 6.8
China's import and export status of agricultural machinery

Year	Import Value (million US$)	Export			Combine Harvesters (unit)
		Value (million. US$)	Large Tractors (unit)	Walking Tractors (unit)	
1977	0.15	0.21	631	1 603	—
1978	0.20	0.16	481	358	—
1986	0.25	0.36	225	4 566	—
1996	15.17	0.41	8 144	48 876	51
2000	18.84	9.18	6 607	59 702	117
2002	31.40	15.21	8 068	54 306	163
2004	64.39	36.64	18 806	65 765	305
2006	67.40	69.00	125 432	—	1 513
2008	13.45	64.88	180 000	—	—

Source: Anon. 2009(a). Scientific and technical development report on China's agricultural mechanization (1949-2009). China agricultural science and technology press (in chinese).

Since the turn of the 21st Century, China's farm machinery manufacturers have encountered a favourable market environment that accelerated the development of the machinery industry. China is currently not only self-sufficient in tractors and mid-sized cereal combines powered by 200 hp diesel engines, but also has the production capability of over 200 000 medium and large-sized agricultural tractors, more than 2 000 000 small tractors and more than 100 000 medium-sized combine harvesters annually.

The production of small farm machinery is on a large-scale and highly intensive and is thus able to offer remarkably competitive prices in the international market. The Chinese market has proven the reliability and the capability of China in the manufacture of medium-sized and small farm machinery. Together with the introduction and absorption of large and extra-large advanced farm machinery from developed countries, China has contributed a production value of about 15 percent of global agricultural machinery manufacture in recent years. Since 2006, China's agricultural machinery export value has exceeded the import value and China has increased its competitiveness in South America, Africa and Asia. Table 6.9 shows the statistics of trading of agricultural machinery with Asia and Africa.

TABLE 6.9
Share of China's agricultural machinery export and Import with Asia and Africa

Year	Trade Share with Asian Region		Trade share with African Region	
	Proportion of Export, Percent	Proportion of Import, Percent	Proportion of Export, Percent	Proportion of Import, Percent
2003	46.7	40.5	8.7	0.17
2004	52.2	39.0	9.1	0.1
2006	41.1	43.2	10.0	0
2007	41.0	—	10.5	—
2008	38.2	—	10.7	3

Source: Anon. 2009(c). China agricultural machinery yearbook 2009.

The agricultural machinery manufacturing industry still faces challenges such as searching for technological innovations for harvesting of cotton, oil-seed rape, sugarcane and sugar beet, which are still basically done by hand and makes it difficult for China to improve labour productivity and improve social conditions (especially through the elimination of drudgery).

China is still far behind the world's technological frontier in terms of sophisticated technologies like intelligent, green, flexible manufacturing, digitalized design, electronic and intelligent control equipment and instruments, complex electro-hydraulic servo-control systems and component standardization. To catch up and compete better, China needs continuous promotion of the model of international technological joint ventures and mutual trade cooperation.

6.3 VISION FOR THE FUTURE ON THE AGRICULTURAL MECHANIZATION DEVELOPMENT STRATEGIES AND NEW TRENDS OF TECHNOLOGICAL PROGRESS FOR CHINA'S FARM MACHINERY

By the end of the first decade of the 21st Century, China is still at an intermediate stage in its industrialization development. Chinese agriculture has long been guided by a policy of food self-sufficiency that reflects the government's view of food security as "basic and essential." China's agriculture is transforming from the mode of high-input, high-output, low efficiency and unsustainable development towards high yield, good quality, high efficiency, ecosystem friendly and food security based on a new agricultural technology revolution. Diversification, expanding industrialized operations, sustainable development and new agricultural technology and mechanization are the four engines driving this transformation.

During 2008–2010 China had overcome annual natural disasters and had faced challenges of global financial crises and globally increasing demand for food supply and safety. Based on its experiences and lessons learnt during 30 years of economic reform and opening up to the outside world (1978–2008) China has drawn up a further sustainable agricultural development strategy stressing transformation of the development paradigm, improving development quality and sustainability, reconstructing agro-industry, increasing scientific and technological innovation capability and pursuing coordinated urban and rural economic development.

Expanding rural demand to boost the internal commodity market and developing modern agriculture to transform China's economic growth pattern are set directions even as limited agricultural expansion area and resources, together with the impacts of climate change, constrain increasing grain production and satisfying the growing demand for animal product consumption (meat, milk and eggs). The new Scientific Development Outlook stresses that helping agriculture, rural areas and farmers is paramount for supporting national industrialization and the development of a modern economy.

Developing modern agriculture needs improvements in soil fertility and environmental protection, resource utilization, cropping area and labour productivity as well as increasing agricultural infrastructure construction, improving standardization and quality control of agricultural products and speeding up promotion of agricultural mechanization.

The acceleration of industrialization and urbanization requires transferring large numbers from the rural labour force into secondary and tertiary industries. Recently, the rural labour cost has increased progressively and speeding up agricultural mechanization has become an essential component of rural economic and social development. The increasing labour cost has enhanced the understanding by farmers of the role of agricultural mechanization in modern farming. Accelerating agricultural mechanization development requires innovation in agronomic technologies, developing farmers' cooperative organizations, strengthening rural science and technology capacities and the extension of new agro-technologies.

The State agricultural comprehensive mechanization level is estimated to reach 70 percent by 2020 and rise to 85 percent by 2030. A key issue relating to realizing the long-term strategy is to work on the eastern and mid-western regional economic and social development policy, to ensure a balanced and coordinated urban and rural development. Innovative technology is still needed to produce new machinery and equipment for key bottleneck areas in crops such as cotton, oil-seed rape, sugar cane, sugar beet, fruits and vegetables.

In the new development programme the government should give urgent and greater attention to expanding agricultural mechanization for production and post-harvest processing of cash crops, fruits and vegetables, livestock (including poultry), particularly in hilly and mountainous areas. Urgent areas for research and development include improving agricultural machinery that is environmentally friendly, energy efficient as well as for developing advanced technology for on-farm collection, transport, primary treatment and processing of straw, biomass and farm waste.

China is still an economically developing country and although it can rely on local R&D and production capabilities to meet the domestic requirements for agricultural machinery, it still lags behind developed countries in terms of advanced manufacturing technologies, intelligent equipment and system management of the farm machinery industry supply chain. China needs to strengthen its cooperation with the farm machinery R&D and manufacturing partners of developed countries.

The Chinese government has confirmed that an overall improvement in the level of agricultural mechanization is essential for seizing opportunities and meeting further challenges. The technology of farm machinery in China lags 10 to 15 years behind that of the developed countries, although in the early 21st Century, this gap was narrowed at a relatively rapid rate. China's farm machinery industry will be restructured in terms of scale and consolidation with a view to expanding cooperation with international agricultural machinery manufacturing companies.

Information technology support plays a big role in raising the modernization level of China's farm machinery in terms of R&D, manufacturing technology, enterprise management, quality control and after-scales service. The management of agricultural mechanization in China aims at speeding up the socialization of the service provision by developing towards leasing and contracting systems.

The government anticipates a huge potential market for advanced large and medium-sized farm machinery equipment spurred by domestic demand. China will develop a variety of innovative farm machines and equipment, participate in the international market and make contributions to the agricultural modernization of developing countries.

Agricultural mechanization in China aims at quickly absorbing the results of the science and information technology revolution thereby accelerating the development of new information- and knowledge-based farm machinery products. For example, since 2000, China has conducted trial and demonstration projects on precision farming. The infrastructures for differential global positioning systems (DGPS), geographic information systems (GIS) and remote sensing (RS) have been improved and applied to investigate site-specific crop management and intelligent technology innovation for farm equipment.

Based on the principles of equality and mutual benefit, China will strengthen the technical exchange and cooperation with its partners in the global farm machinery industry for assistance in the modernization of its agriculture, promotion of mutual understanding, and developing the world's farm machinery technology.

Agricultural mechanization has shifted millions of workers from the farms to the manufacturing and service industries in developed countries and has enriched the industrial revolution process. Accelerating agricultural modernization in the less developed world will give humankind better working and living conditions, allow the rural economy to flourish, liberate farmers from drudgery and help to alleviate poverty.

Entering into the new century, Asian countries have recently appeared on the horizon of global economic development. Promotion of regional cooperation between agricultural communities and manufacturing industries will be mutually beneficial to speeding up agricultural modernization, contributing to the global economy and promoting common efforts to face new challenges. Chinese agriculture is on the verge of a new era in the next 10 to 20 years.

6.4 ANALYSIS AND LEARNING FROM CHINA[29]

Although much can be learned from the history and experiences of China's development and promotion of agricultural mechanization, developing countries cannot always fully adopt the strategies because of China's distinctive system of government. In China, although farmers are now given a free hand in individual decisions on their farming activities, they still have to strictly follow implementing guidelines from the central or county level planning authorities for agricultural and national development. Thus, there was no absolute devolution of decision-making in planning for development of agricultural mechanization in support of certain objectives of grain production and food security. The government workers as well as the private industry supplying the machinery and other inputs to agriculture must also follow the guidelines issued by the central government. It is not clear however, how the central government formulates these guidelines, that is, whether it follows the principles of strategy formulation (such as those suggested by FAO) or whether they are established by consultation with those affected by, or followers of, such guidelines.

The significant feature of China's development approach is that in spite of the impetus in industrial development, it never neglected agriculture or relegated it to the background and in fact devoted attention to it to maintain a balance in rural and urban progress. It gave priority to producing food and providing food security for its very large population. A remarkable decree is that industry is to be developed firstly in support of agriculture and mechanization is one of the inputs needing support from the government.

The abolition of the commune system in 1983 triggered the renewed interest of farmers in pursuing mechanization probably because they have become more effective economic decision-making units than in the collective system of ownership, management and financing. The leadership has now put emphasis on the development of outputs in agriculture based on the general principle of economic rationality. In the commune system the farmers were restricted to diversifying production away from grain which was not as profitable as other crops (Tam, 1985).

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Because they do not yet have well-developed industrial and commercial sectors, most developing countries do not have the revenue resources to support agricultural mechanization. The industrially developed situation in China, particularly the machinery manufacturing industry, is similar to what occurred in the more developed smaller countries like South Korea, Thailand and Taiwan where mechanization has achieved such positive progress.

The similarity between China, Korea and Thailand is that all have promulgated their mechanization promotion laws which serve as documents providing the guidelines for implementation and development of agricultural mechanization with due allocation of resources to implement the guidelines and pursue the direction for development.

China's quest for a developed agricultural mechanization is approaching a climactic conclusion. By design China has reached a point where it is only a matter of time and continued sustained effort that mechanization and industrialization will be on a par with the developed countries.

There have been two basic driving factors that eventually led to this conclusion, namely: (i) the resolve to develop agriculture through mechanization; and (ii) the resolve to develop the farm machinery manufacturing industry to support rural development. However, these two simplified approach doctrines are not by any means complete. The resolve to develop mechanization is driven by the resolve to have self-sufficiency at least in food and be food secure for the burgeoning population, estimated to reach 1.6 billion in 30 years even under the present one child per couple policy. The extensive efforts of agricultural research and development in the pursuit of high rice yields ran parallel with the mechanization approach.

Perhaps the idea of regional or world-wide cooperation in mechanization has been a result of China's collaboration with research institutions in agriculture worldwide. For example, as early as 1978, China's agricultural research institutions began collaboration with the International Rice Research Institute in the Philippines. China was a pioneer in the production of rice through hybrid technology which has enabled the yield barrier of 15 tonnes per hectare to be broken. Consequently, the lesson learned is that while mechanization has been the proclaimed goal there are other parallel developments that China also pursued by mobilizing other teams possessing expertise and technology. Complex as it is, mechanization is not a stand-alone goal. An agricultural mechanization strategy is needed to achieve rational mechanization but there are other requirements outside of the machinery technology that must be explored. China appears to have met those requirements.

China developed its machinery manufacturing industry in parallel with mechanization development to support the latter and as a strategy to advance the country's economic development. This strategy seems to have emanated from the policy of supporting agriculture with the goal of increasing yields and providing for food security. There may be other hidden aspects which explain the willingness of farmers to adopt mechanization technology. There is the social aspect which impinges on cooperation and discipline which may have taken root during the Cultural Revolution era.

The present positive outcome of mechanization development in China has not been without difficulties. Even during the days of the centrally planned economy, there were conflicts that had to be overcome and the idea of the leader prevailed in the past with little consultation. The next leader will have his say when his turn comes. The system of governance may have its shortcomings but it invoked enthusiasm when the decision to open the economy prevailed and the population responded with enthusiasm to the market-oriented approach. The difference is that the experience of the Cultural Revolution was a prerequisite leading to the success of mechanization; some other developing countries have not gone through this path and most of them have had an open market economy since the beginning.

In this regard, although the path that China has followed may be difficult for other countries to emulate, there are other models, and these are now the developed countries which did not have to go through a revolution. For example, Japan did not have to go through a revolution to achieve the same end and neither did the Republic of Korea, Thailand, Taiwan and Malaysia which now have a progressive agricultural sector propelled by agricultural mechanization which in turn is supported by a robust farm machinery manufacturing industry, commerce, tourism and exports.

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CHAPTER 7

The Near East Region

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ABSTRACT

The Near East – a UN term – comprises a group of countries in North Africa and the Middle East. The area is typified by containing large tracts of arid and semi-arid terrain and irrigation is usually needed for agriculture. The oil production economy dwarfs the agricultural sector in several countries; however agriculture does play an important role in the economy employing 20 percent of the 300 million population. Small farm size and lack of training constrain mechanization but there are modern mechanized farms in the region, and custom hiring is an attractive option. The chapter estimates tractor numbers and describes national manufacture of tractors, engines and implements where this occurs. The production and export of Massey-Ferguson tractors in Iran is an outstanding example. The agricultural mechanization situation is described for the majority of the countries in the region.

7.1 BACKGROUND

The Near East is a descriptive name adopted by the United Nations and refers to the countries located in North Africa and the Middle East. The region includes Iran and also the drier areas of Northern Sudan although this country is discussed separately in Chapter 1 by Nuhu Hatibu *et al.* (Investing in agricultural mechanization for development in East Africa). Table 7.1 provides some basic data on the constituent countries.

The Near East is a unique region, typified by vast areas of arid or semi-arid terrain and where in several countries, heavy dependence has to be made on irrigation. Even this can be restricted to drip irrigation systems or water harvesting techniques in countries where total water resources are extremely scarce, such as Palestine, Jordan and parts of Lebanon. In other countries, reliance is made on the rivers such as in Iraq, parts of Syria and in Egypt where experts tend to discuss the total volume of water available rather than the prevailing levels of rainfall (Aboufreika and Elehery, 2008). Egyptian agriculture is almost entirely irrigated.

TABLE 7.1
Basic data for the Near East – projected for 2010

	Total Population (million)	Agricultural population (million)	Total area (million ha)	Arable area (million ha)
North Africa				
Morocco	32.4	8.4	44.7	8.1
Algeria	35.4	7.4	238.2	7.5
Tunisia	10.4	2.1	16.4	2.8
Libya	6.5	0.2	176.0	1.8
Egypt	84.5	23.6	100.1	2.8
Sub-total	169	42	575	23
Middle East				
Jordan	6.5	0.4	8.9	0.1
Lebanon	4.2	0.08	1.0	0.1
Syria	22.5	4.5	18.5	4.7
Iraq	31.4	1.7	43.8	5.2
Iran	75.1	16.2	174.5	17.0
Sub-total	140	23	247	27
TOTAL	**309**	**65**	**822**	**50**

Source FAOSTAT, 2010

Much of the region is rich in petroleum resources, the oil economy far exceeding that of the agricultural sector in several countries. These resources have facilitated the considerable investments that have been made in irrigation schemes in some of these countries. In others such as Egypt, it is the pure necessity that has forced the issue, indeed since ancient times.

The discovery of a vast aquifer in Southern Libya during oil exploration work in the 1950s led to the eventual construction of the largest irrigation project in the world, the Great Man Made River project which started in 1984. Construction work is likely to continue until 2015 but water is already being supplied from the Nubian sandstone aquifer system to the populated regions in the North with some 30 percent being used for domestic and industrial supplies and 70 percent for agricultural projects (Zidan, 2007). The proportion for agriculture will eventually rise to about 80 percent when the project is completed.

There are many other important irrigation projects in the region, some new and others implanted many years ago. A common problem with some of the older schemes has been salinity build up, a particularly acute problem in Iraq (Rahi and Halihan, 2010).

Rainfed agriculture is also practised in some areas, particularly in the coastal regions, on the extensive high plateaux of North Africa in Morocco and Algeria and in the various mountainous regions. Some of the agricultural areas are remote, including the many isolated oases where intensive but traditional agriculture is practised using manual techniques or employing work animals, particularly for soil tillage, general transport tasks and for water lifting.

7.2 THE RURAL ENVIRONMENT IN THE NEAR EAST

Agriculture plays an important role in the economy of the Near East where it engages about one fifth of the population of 300 million, although this proportion is considerably less in Libya (3 percent), Jordan (6 percent), Lebanon (2 percent) and Iraq (5 percent).

The total area of arable land is approximately 50 million ha, distributed almost equally between North Africa and the Middle East. The physical size of the individual countries is however widely different, ranging from 238 million ha in Algeria to only 1 million ha in Lebanon. However, most of the countries have vast tracts of arid or semi-arid areas, Morocco, Lebanon and Palestine being the few exceptions.

Agriculture however does not figure strongly as a proportion of the GDP in most of the countries, being some 20 percent in Syria but much less in the other countries. The influence of the oil economy is important in Algeria, Libya, Iraq and Iran whilst tourism and diverse business interests play a strong part in the economies of several of the other countries.

Labour availability, the levels of research, extension and training and the availability of resources are important factors that have influenced past investment in agriculture and in the levels of mechanization that have been achieved.

The present status of mechanization in the region is described below.

7.3 THE STATUS OF AGRICULTURAL MECHANIZATION IN NORTH AFRICA

One constraint facing increased agricultural mechanization in North Africa concerns the size of holdings. For instance, over 90 percent of farms in the Nile Delta of Egypt are of less than 0.8 ha (Aboufreikha and Elehery, 2009). In Tunisia, the national census conducted in 1994-95 showed that although the average farm size was 11.2 ha, the number of farms of less than 5 ha had almost doubled between 1962 and 1995 (Jouili, 2009). In Morocco and Algeria too there are appreciable numbers of smaller farms, often with scattered land holdings (MADR, 1998; République Tunisienne, 1996).

Another influencing factor regarding the success of mechanization concerns the general lack of training of operators and farmers leading to poor equipment operation and maintenance and the adoption of inadequate cropping practices (Bourarach, 1989; Kheyar *et al.*, 2007). This discourages the farmer from investing in more appropriate machinery, or from calling upon the services of a qualified equipment hiring contractor, if indeed one is available under the local business climate. But despite this constraint, some highly mechanized farms do exist throughout the region in both the irrigated and the dryland areas.

Average annual tractor usage tends to be in the range of 400 to 800 hours and transport constitutes a high proportion of the usage. The build up of a strong service support infrastructure can be hindered in some countries due to a plethora of tractor makes and models on offer. For instance, more than 20 tractor makes were identified in Tunisia in 2004 (UNIDO, 2005).

The North African tractor fleet is difficult to estimate but has been variously quoted as being between 230 000 and 300 000 units. This may be compared with a possible total of some 220 000 active units in the whole of sub-Saharan Africa but perhaps 470 000 in the Middle East. This would indicate perhaps 800 000 tractors in use in the Near East (FAOSTAT, 2010).

It is reported that over 6 500 new tractors were sold in Morocco in 2009, but this represented a huge increase over normal figures and was mainly influenced by a combination of new subsidies and credit facilities (Ashburner, *et al.,* 2010).

Egypt deploys the highest concentration of tractors in North Africa, estimated in 2005 at over 27 per 1 000 ha, followed by Libya (19) and Algeria (12). By way of comparison, the figures for Lebanon are surprisingly high at 30 per 1 000 ha with an overall average of 16 tractors per 1 000 ha throughout the Middle East.

State-owned manufacturing plants for tractors, diesel engines and agricultural equipment were established in Algeria in the 1970s under joint venture agreements. The diesel engines were destined not only for use with agricultural tractors and combine harvesters but also for transport and industrial applications. However, the production and particularly the export markets for this equipment have considerably declined in recent years. Efforts are presently underway to attract private-sector partners for the agricultural machinery industry, which is currently operating well below its installed capacity. For instance, the manufacture of combine harvesters was suspended in 2006, together with that of most of the forage harvesting equipment undertaken at Sidi Bel Abbes, shortly afterwards.

Libya has manufactured tractors since the same period, originally under a joint venture. It also manufactures some other agricultural equipment. Apart from supplying the significant local market, it frequently exports packages within its bi-lateral aid programme, particularly to sub-Saharan Africa.

Morocco, Tunisia and Egypt rely on imports for their supplies of tractors and combines. A significant market of second-hand equipment has existed, although somewhat sporadically. Much other equipment is now locally assembled or fabricated in these countries. Although this is typically undertaken by small-scale enterprises, many are well equipped and produce equipment of high quality. Transport equipment and land preparation implements predominate in this local industry, together with some fabrication of sprayers and other equipment.

Mechanized dryland agriculture as practised in Morocco, Algeria and Tunisia has traditionally relied upon disc equipment, the seed being broadcast before being covered by passing a disc harrow. The use of conventional seed-drills remains low and that of direct drills for conservation agriculture in

2008-09 was reported for only 4 000 ha in Morocco and 6 000 ha in Tunisia – this technique remains very much within the research field with which the practitioners tend to be closely associated.

7.4 THE STATUS OF AGRICULTURAL MECHANIZATION IN THE MIDDLE EAST

The level of agricultural mechanization in the Middle Eastern countries varies from country to country depending mainly on the political, social and economic situations. Labour availability, the level of research and extension, education and training, the size of the agricultural sector and the availability of resources and size of the rural population among others are very important factors that play a role in influencing the level of agricultural mechanization needed.

The present status of agricultural mechanization in some of the Middle Eastern countries is summarized below.

7.4.1 Agricultural Mechanization in Iran

Iran is the largest country in the Middle East, with an area of about 165 million ha. It has a population of over 70 million of which one quarter or 17 million constitute the agricultural labour force. It is one of the major oil producing countries of the world.

The area of arable land is some 12 million ha of which about one half is irrigated; about one third of the farms comprise holdings of less than 2 ha (Tabatabaeefar and Hajeiahmad, 2006).

A major situation facing Iran is the decrease in the rural population which fell from 68 percent in 1956 to 38 percent in 1996 and continues to fall. This reduction increased the burden on the rural population and encouraged the introduction of various measures to mechanize the agricultural sector.

A Department of Agricultural Engineering was established at the University of Tehran, Karaj back in 1963 and the Faculty of Agricultural Engineering and Technology is now firmly established. The Ministry of Agriculture has also established a Centre for the Development of Agricultural Mechanization in Tehran which is promoting mechanization and machinery producers at national level.

The total number of conventional tractors in use in 2005 is indicated as almost 290 000 (FAOSTAT, 2010) together with an additional 120 000 single-axle models. The majority of conventional tractors are of about 75 hp.

The local manufacture and/or assembly of Massey Ferguson models have been undertaken by the Iran Tractor Manufacturing Company (ITMCO) since 1975. This same company has recently established a local assembly plant in Uganda, is also setting one up in Tajikistan and has signed a similar agreement with Zimbabwe in early 2010. A joint venture was set up in Venezuela in 2005. ITMCO acquired another Iranian company in 2003 which had been assembling Goldoni garden tractors.

The harvest is also mechanized in some areas and for instance, a strong Shiraz-based union organizes fleets of combine harvesters to gradually work from southern to northern Iran as the season develops, an excellent example of multi-farm use of high-value equipment. Much of this particular fleet comprises old machines but new combines with cutterbars up to 4.20m are now manufactured in a joint venture based in Tabriz.

Many other farm implements such as the tillers, planters, cultivators, harvesters, trailers, sprayers and threshers are produced locally by small and medium scale production workshops. Much other equipment is imported directly.

7.4.2 Agricultural Mechanization in Iraq

Iraq is another major oil producing country in the Middle East but it is also rich in agricultural resources, including both land and water. Although there has been heavy reliance upon agricultural machinery, this was formerly organized almost entirely by the state sector. It is only after the emergence of the new regime that efforts have been made to strengthen the service sector and significant tractor repair programmes have been accomplished, rehabilitating several thousand tractors and other equipment. Just recently, a major international tractor manufacturer has been contracted to supply assembly kits for over 1 000 tractors – this follows a programme whereby over 3 000 tractors were rehabilitated from 2006-2007 (CNH, 2009).

Nowadays, the economic system in Iraq has become an open system and the private sector has access to foreign currency, although the exchange rate is still very high. Dealership networks will need to be re-established and there are considerable training needs in order to restore a serviceable support sector.

As the economic sectors undergo major restructuring in the country, the agricultural sector is one of the most promising to be developed and operated by private businesses. With the high revenues generated from oil production, Iraq can now afford to invest again in major agricultural projects.

7.4.3 Agricultural mechanization in Jordan, Lebanon and Palestine

Jordan, Lebanon and Palestine are all small countries with no oil resources. Their income is partially generated from the agricultural sector but a high proportion of the skilled and highly educated people work abroad. These three countries receive sizable financial aid from the richer Arab countries and from several developed countries.

The agricultural sector faces several problems, including shortages of both labour and water. The first issue can be addressed through mechanization whilst drip irrigation together with water harvesting techniques is being used to address the second. Indeed it has now been shown that drip irrigation has allowed the limited water available to irrigate three to five times the area that was formerly irrigated by surface irrigation methods.

Mechanized production of poultry, eggs, milk and cattle together with sheep farms are on the increase in all three countries and they have become major exporters of fresh vegetables and fruit.

There is a strong cadre of skilled farm machinery operators, mechanics and agricultural engineers with university degrees. In addition, the economic, social and political systems continue to encourage the private sector to invest and become involved in activities and businesses that support the agricultural sector. For instance, most of the components, except the pumps and engines for drip irrigation systems are locally manufactured satisfying both the domestic market and enabling significant exports.

Because of the large number of small holdings and the high cost of agricultural machinery, contractor hire services have become popular. These are run either by owner operators or through cooperatives which can provide multiple operations. However, the services provided are generally limited to land preparation, transport, spraying and combine harvesting.

7.4.4 Agricultural Mechanization in Syria

Syria has a lot of similarity with Jordan, Lebanon and Palestine except that it is much larger in area and population. It is also an oil producing country although exports are modest and declining. It is generally self sufficient in food production.

The Syrian economic system is closely controlled by the government. Banking and foreign currency exchange is subject to strict regulations and foreign currency is not easily accessible to the public. But the government has invested heavily in the infrastructure and projects needed for the development of agriculture. This has led to Syria having now become a major producer of fruit and vegetables for both local consumption and for export.

Despite this situation, agricultural mechanization in Syria has remained modest with approximately 14 tractors per 1 000 ha (FAOSTAT, 2010). There are a number of both public and private sector industries for food processing and farm implement fabrication and distribution. Small-scale workshops and blacksmiths provide service support to both the rural and urban areas.

The agricultural cooperative movement in Syria is strong and helpful. Some agricultural cooperatives were mandatory for land reform, but the majority are voluntary organizations formed by established landowners and designed so as to enjoy the benefits of collective farming. These cooperatives are active in providing farm machinery contracting services.

The private sector in Syria is the most active investor when it comes to small businesses; therefore, they will have a large role to play in the farm mechanization field once they are given the logistic support regarding access to the hard currency and open banking system. The widespread disruption caused by internal strife in 2012 will have to be settled through political stabilization before development of the agricultural sector can flourish.

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CHAPTER 8

The development of farm mechanization in Brazil

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ABSTRACT

This chapter first provides an overview of mechanization in South America. It then describes the evolution of agricultural mechanization and the farm machinery industry in Brazil from the 1950s to the present. In that time agricultural production has risen sharply and the machinery industry has developed from being a net importer to a world–class exporter. Mechanization for smallholder farmers was encouraged by national plans such as PRONAF specifically targeted at family farms, and at the same time greatly helping the development of the domestic machinery manufacturing sector. Programmes such as MODERFROTA assist in the modernization of the farm machinery fleet and have positively influenced the growth of mechanization and the manufacturing sector. New land is available for exploitation, especially in the *Cerrado* savannah region where large mechanized farms dominate. Rapid mechanization is likely to result in some rural labour displacement in the first instance. Future investigation areas will include mechanizing tropical crops suitable for bio-fuel production.

SOUTH AMERICA – BACKGROUND INFORMATION[30]

The South American sub-continent is dominated by two important features – the almost uninterrupted Andes mountain chain running from North to South and the vast catchment basin of the river Amazon, including the world's largest rainforest. Brazil is by far the largest country, covering about half the total surface area. Chile stretches from the driest region in the world, the Atacama Desert down to the most southerly and permanently inhabited community.

Whilst there is tremendous diversity amongst the crops grown, two major farming systems can be identified. Firstly there are the many small farm holdings known as *minifundios* which comprise over three quarters of the

[30] The Background section is contributed by John Ashburner

farm households. In the Andean regions the farmers cultivate temperate crops (such as tubers – principally potatoes – and cereals), often on steeply sloping land and working soils which are frequently degraded. Animal traction (with oxen) is commonly used for soil cultivation. In the lowland, tropical areas, shifting cultivation is still practised in some regions whilst in others, sedentary farming allows subsistence crops to be tended on the small areas that can be managed with manual techniques. Maize, cassava, fruit together with some limited domestic livestock production are common subsistence crops but production is very diverse indeed.

Whilst the smallholder farmers in many countries of South America generally use little mechanical equipment, some recourse is made to threshing and primary processing equipment, these services often being supplied by contractors or community-based entrepreneurs. There are exceptions to this situation, the largest being Brazil where the small farmers manage much bigger farms and recourse is often made to mechanized techniques although animal traction can constitute an important power source. Generally speaking, a smallholder in Brazil is usually thought of as having some 18 ha. Although animal traction and manual technologies continue to be used, tractor power is now increasingly employed on smallholder farms in most South American countries.

Whilst the number of small farmers remains significant, the landholding areas of the large scale farmers in South America are much greater and despite widespread land reform programmes in many of the countries, there remains a tremendous cultural and technological divide between their production systems and those of the smaller farmers. Many of these large holdings were traditionally the *latifundios* owned by the aristocracy although today they also include much of the land which has been opened up only over the past half century, often by large agricultural enterprises.

These farms are nowadays highly mechanized, the traditional labour-intensive systems having become too expensive to accommodate. Some of the large scale farms are dedicated to livestock production, particularly cattle; others focus on export crops which, depending on the climatic region include banana, rice, sugar, fruit, coffee, cocoa, oil palm and many others. Some of the plantations are owned and managed by large agricultural enterprises, the largest often operating on a multi-national scale. There are now instances where individual landholdings amount to one million hectares.

Equipment supplies for these markets have developed in different ways in the various countries. Brazil being the largest country by far is clearly a case apart and is described in more detail below. Argentina also has a significant area of arable land, estimated at some 32 million ha or roughly half that of Brazil. It too has developed an important manufacturing industry for agricultural equipment including tractors, harvesters and a full range of equipment for crop husbandry, handling, primary processing and agro-industries. The only other country where tractor manufacture has developed is in Venezuela but this is an assembly plant only established in 2005 and set up in collaboration with the Iran Tractor Manufacturing Company (see Chapter 7: The Near East Region).

Supplies of agricultural machinery and equipment to the other South American countries rely almost entirely upon imports, there being well-established dealers throughout the region. Most of these trade representatives also have well-equipped workshops and carry out not only minor repairs but also major overhauls of the sophisticated imported equipment that they represent. In addition, there are many smaller workshops, often in the more rural areas where good support service is offered which allows some fully depreciated machinery to be kept running, often for twenty years or even much longer.

Several efforts have been made in the past to promote the local manufacture of animal traction equipment, particularly in Ecuador, Peru and Bolivia but only the Centre based at Cochabamba, Bolivia continues fabrication (see Box 14.3, Chapter 14: Agricultural Machinery Manufacturing and Supply). It also undertakes training and works in collaboration with the local university. Other animal traction equipment is made in a traditional manner by some of the rural artisans and blacksmiths in the Andean region.

Some primary processing equipment is locally manufactured, most notably for rice, maize, coffee and forage (choppers). Stationary threshers for wheat and barley have been made in Pasto, southern Colombia for several decades. There is also local manufacture of hammer mills and grain cleaners in several countries. Niche markets have been seized upon in other parts such as a range of equipment for feed preparation, forage harvesting, fertilizer and manure spreading, cattle crushers and other livestock production equipment in Temuco, Chile. But none of these enterprises compare with the much larger equipment manufacturers now well established in Brazil and Argentina.

A number of public sector initiatives have been attempted in order to promote agricultural mechanization schemes. A network of machinery hire centres was set up in Ecuador in the 1980s with the aim to provide services to resource poor farmers in both the coastal and mountain regions. As with some similar schemes in Africa, it proved un-economic and difficult to manage and the machinery fleet was sold off only a decade later, the equipment being acquired mainly by the original tractor operators consequently retrenched from this government service.

A vast hydro-electric and irrigation scheme has been constructed in the Ayacucho region of southern Peru and this includes a scheme which has now resettled Andean farmers on some 15 000 ha of irrigated plots in part of the arid high plateau region known as the Pampa de Majes. Limited state and donor-supported machinery hire services were introduced during the 1990s to assist with field clearance and land levelling on the new plots, the machinery being utilized at very high intensity (often over 1 200 tractor hours annually).

It would appear that this service has now been completely absorbed by the farmers themselves or by private sector service providers in the region, now that the farms have been fully established.

There are several other examples of public sector interventions to promote agricultural mechanization in South America but many of these date back to the 1970s or earlier. There were large-scale schemes in Chile, Peru, Colombia and Venezuela but in all cases the focus has firmly reverted to private sector operations. Bolivia is a special case having benefited from huge aid packages involving donations of agricultural machinery in the 1980s and 1990s which tended to completely distort possibilities for the private sector to develop. This situation too is also now changing although, apart from in the lowland tropical and highly productive region near Santa Cruz, the machinery support infrastructure remains weak throughout the highland and inter-Andean valley regions of the country.

8.1 INTRODUCTION TO AGRICULTURAL MECHANIZATION IN BRAZIL

Agricultural mechanization started to be introduced to Brazil just after World War II. Initially, Brazil imported tractors and farm implements mainly from the United States and European countries. In a survey completed in 1958, it was found that Brazil had 50 thousand tractors in operation with 143 different brands. This large number of tractor models created a huge problem regarding service support and the maintenance of stocks of spare parts. The result was increased tractor and farm machinery maintenance costs which became a limiting factor in the development of Brazilian agriculture.

For these reasons from 1959 to 1969, the Brazilian government decided to encourage the domestic development of agricultural tractor factories by launching a series of national plans to promote the industrial production of tractors, power tillers and tracklayers. Since the 1970s, Brazilian agriculture has undergone a long period of profound expansion; and the farm implement industry has developed in parallel with the tractor industry. Today in the Brazilian agricultural machinery industry, not only are the most important multinational companies represented, but there are also many national companies which design, develop and export their own technology.

Brazil has a land area of 851 million hectares and covers about half the total area of South America. Of this land, according to a study by the Environmental Research Institute of Amazonia (IPAM, 2009) and in agreement with Brazilian environmental legislation, between 36 and 43 percent is suitable for agricultural production (304 to 367 million hectares). According to FAO (2010) the agricultural area of Brazil in 2008 was 264 million ha, including 61 million ha of arable land and 196 million ha of permanent crops and pastures. Consequently, one might be tempted to suppose that considerable additional land is potentially available for agricultural production but this of course raises additional issues which need to be considered such as land clearance, deforestation and protection of the rainforest and savannah ecosystems. Despite these reservations, Brazil has substantial potential for increasing agricultural production over the coming decades.

In 2008, the total production of major crops (bean, cassava, coffee, corn, cotton, orange, rice, soybean, sugar cane and wheat) in Brazil was 837 million tons. This represents a 93 percent increase in the level of production since 1990, whilst the cultivated area has only increased by 24 percent. These figures represent annual average growth rates of almost 9 percent and 3 percent, respectively.

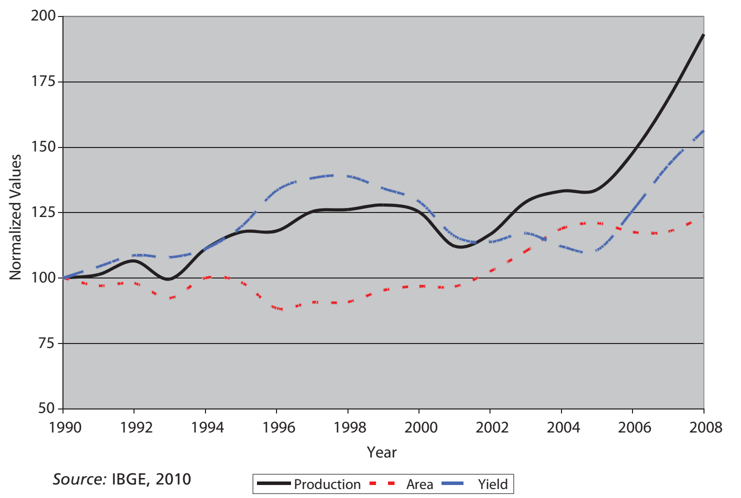
The systematic increase in Brazilian production of major crops was more influenced by increased yield over the period 1990 to 1998, but by an expansion to the cultivated area from 1998 to 2005. Both these factors have subsequently come into play since 2005 (see Figure 8.1).

The new agricultural frontier in Brazil is concentrated in the centre-west region (Figure 8.2) where about 70 percent of the area comprises farm holdings in excess of 1000 ha and agricultural mechanization is an essential input. In contrast, nearly 90 percent of landholdings in the northeast, south and southeast are of less than 100 ha.

During the last 20 years, a double cropping production system has been introduced in which two crops are grown and harvested on the same land during each year. This change in cultural practice particularly in the states of Paraná and Mato Grosso, located respectively in the southern and central-western parts of the country, was made possible by the introduction of short cycle crop varieties and has played an important role in increasing grain production in Brazil. The system requires that the timing of farming

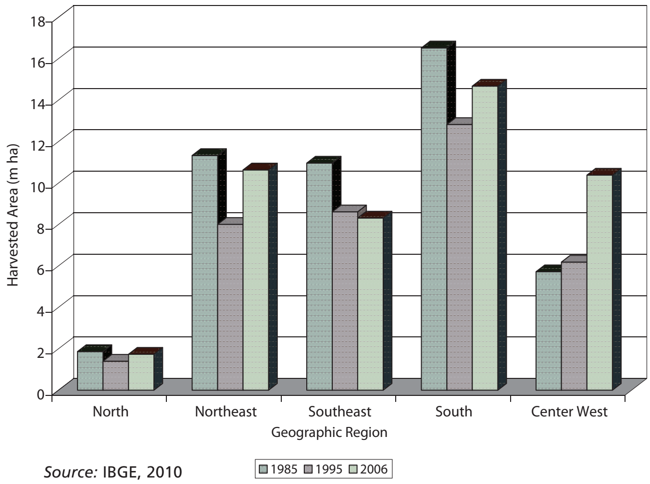
FIGURE 8.1

Brazilian agricultural production and cultivated area for the most important crops: cassava root, coffee, common bean, corn, cotton, orange, rice, soybean, sugar-cane. The data were normalized and set to a value of 100 in 1990 for purposes of comparison



Source: IBGE, 2010

FIGURE 8.2
The harvested area for each Brazilian geographic region in the last three agricultural censuses: 1985, 1995 and 2006



Source: IBGE, 2010

operations be optimized and performed on specific dates; achieving these requirements has been through mechanization.

8.2 THE BRAZILIAN SAVANNAH OR *CERRADO*

The Brazilian savannah zone is a vast region in the centre of the country stretching over to the western border with Bolivia and Paraguay, towards the north and also to the south, including parts of São Paulo State. It comprises about 205 million ha and covers over 20 percent of the country. The gentle topography is characterized by acid soils of poor natural fertility, an aspect that initially deterred farmers from settling on all but small areas of the better soils where subsistence crops could be grown (The Economist, 2010). But in the 1960s a research team managed to identify ways of redressing the severe acidity problems with copious applications of locally available lime at rates of 5 ton/ha or more. This was later combined with techniques of direct seeding and the use of nitrogen-fixing cover crops which not only reduced dependency on organic fertilizers but also protected the fragile soils from the erosive forces of nature.

The result has been an explosion in land development in the region and the development of some of the largest and most extensively mechanized farms in the world. The land development has not been undertaken without criticism as this also is one of the richest and biodiverse savannah regions in the world. But in a situation where the world population is expected to increase to 9 billion by 2050, the region still represents one of the largest potential food production areas still available.

Only 40 years ago Brazil was barely self-sufficient in food and was importing some meat, rice and beans, amongst other products. Today it is the prime world exporter of orange juice, sugar, soybeans, poultry and beef. The total area under production has increased by about one third since 1996, most of this in the *Cerrado* (The Economist, 2010).

A recent study has been undertaken of the remarkable development that has taken place in the *Cerrado*, comparing it with changes that have taken place in northeast Thailand and posing the question as to whether the vast regions of the Guinea savannah zone in Africa, particularly in Nigeria, Mozambique and Zambia could not be converted into another major food production resource (World Bank, 2009). It is estimated that some 400 million ha of savannah could be used for agriculture in Africa whereas only 10 percent are currently being cropped. It was concluded that the role of the state was vital for stimulating a stable and conducive enabling environment to allow private sector development of commercial agriculture, this being led by the large farmers in the *Cerrado* region but by smallholder farmers in northeast Thailand. An approach through smallholder farmers would seem preferable but there will be a need to ensure diversification opportunities for the producers of low-value staples.

8.3 BRAZILIAN AGRICULTURAL MACHINERY MARKET

Looking at the number of wheeled tractors and combines that have been sold annually over the past 20 years in Brazil (Figure 8.3), the market has seen considerable variation from year-to-year. The market had shrunk appreciably during the 1980s but began to recover in the 1990s. There has been a significant increase in numbers of units sold from the year 2000 which coincides with the launch of MODERFROTA[31], a finance scheme introduced by the Brazilian government. The sales of combine harvesters have also varied but have averaged some 3000 units annually over the past 20 years.

The Programme for the Modernization of the Fleet of Agricultural Tractors, Implements and Harvesters (MODERFROTA) is a rural credit scheme designed to finance the renovation of the agricultural machinery fleet. The annual investment in the scheme has not been uniform since its conception (Figure 8.4) but it has certainly influenced the rate of growth of agricultural mechanization.

The average power of the tractors used in Brazilian agriculture has remained fairly stable at between about 65 and 75 hp although there is a gradual trend to use increasingly powerful tractors of over 100 hp since the mid 1990s (Figure 8.5). The relative decline of the small tractor market share does not necessarily represent a decrease in the number of units sold, since the market is in a period of expansion. The system of farming with income coming predominantly from agricultural activities and using family labour is defined by Brazilian legislation as Family Agriculture. These family farmers are the potential users of lower horsepower tractors.

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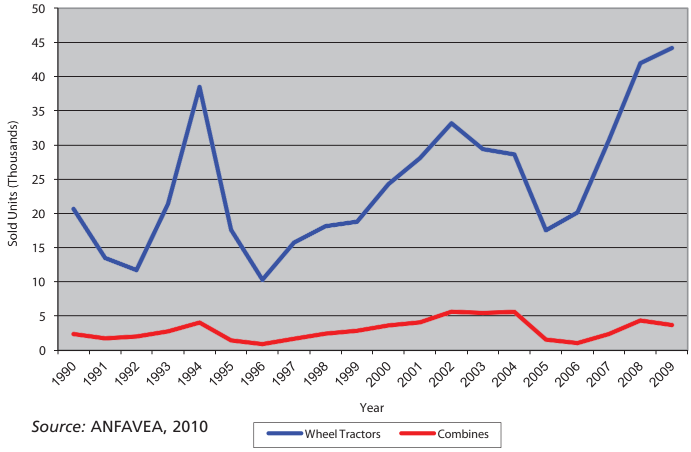
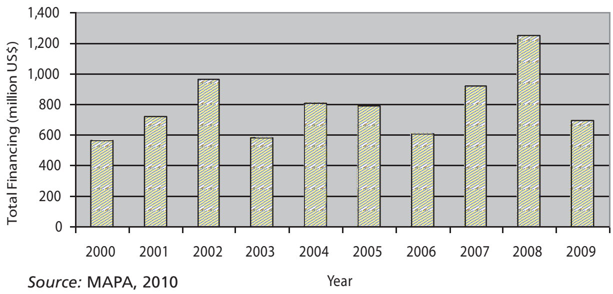
[31] Modernização da Frota de Tratores e Implementos Associados e Colheitadoras

FIGURE 8.3
Number of wheeled tractors and combines sold on the Brazilian domestic market from 1980 to 2009



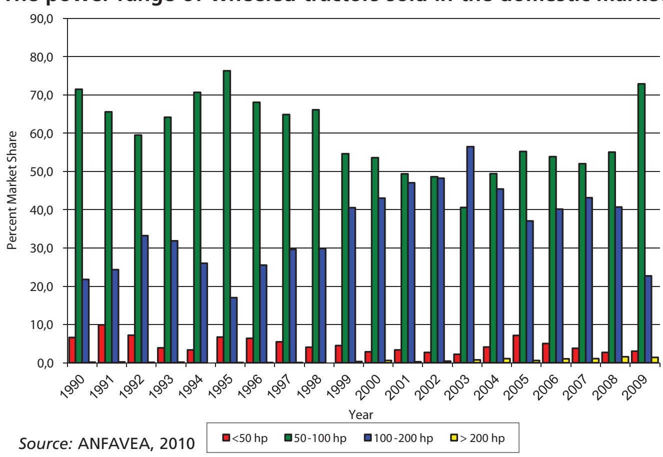
Source: ANFAVEA, 2010

FIGURE 8.4
The annual financing used by farmers from the programme for the modernization of the fleet of agricultural tractors, implements and harvesters – MODERFROTA



Source: MAPA, 2010

FIGURE 8.5
The power range of wheeled tractors sold in the domestic market



Source: ANFAVEA, 2010

Family Agriculture plays an important role in ensuring food security in Brazil. It supplies the domestic market with the crops which make up the majority of people's diets. In the last agricultural census undertaken in 2006, Family Agriculture was practised on 85 percent of Brazilian farms and occupied 24 percent of the land area. Although only 22 percent of these farms were involved in the production of food crops, they accounted for 87 percent of the national production of cassava, 70 percent of beans, 46 percent of corn, 38 percent of coffee, 34 percent of rice and 21 percent of wheat (IBGE, 2006). The average land area of the Family Agriculture farms was 18.4 hectares.

It may be concluded that the development of agricultural machinery for small farmers in Brazil is a great opportunity for both private and public investment.

From the start, agricultural mechanization worldwide has been the driving force for labour productivity, improved production techniques and the development of new cropping technology (Vian and Andrade Junior, 2010). In Brazil, demand for machinery has been created and maintained through public policies for agricultural credit and investment, so that, in 50 years, the country changed from being a net importer into an exporter of agricultural machinery.

Vian and Grin (2009) identified five periods with different credit policies during this transformation of the Brazilian agricultural machinery industry:

- **1950-1960 - Tractor Import Policy:** The government encouraged the importation of tractors in this period, increasing their numbers at an annual rate of 22 percent. The increased number of tractors was the catalyst for the development of a national industry of agricultural implements and, at the end of this period, the Brazilian tractor manufacturing industry was initiated.
- **1960-1980 - Modernization of Farming:** Mechanization was a key factor for the adoption of modern farming practices, including greater use of agro-chemicals. The national farm machinery industry was encouraged by the market protection policies put in place, and the farmers were extended credit lines and exempt from taxes and interest on machinery purchases. Consequently the production of tractors increased, reaching a peak of 64 175 units sold in one year in 1976.
- **1980-1989:** Largely due to the oil crisis in the late 1970s, the machinery sector, along with the rest of the economy was in crisis. The government prepared a plan to assist the agricultural machinery industry with the goal of improving the sector's ability to adapt its technology to the real needs of national agriculture. The industry recovery happened after 1984, mainly due to a price guarantee policy coupled with good harvests, restoring the purchasing power of farmers.
- **1990-1999 - Recession:** The Brazilian economy went through a process of structural reform, deregulation and open trade. Rural credit was drastically reduced, and government actions were aimed at cutting spending to control inflation. The tractor and harvester industries were obliged to adapt to

the new market rules. Government actions such as facilitating external funding resources for the agricultural sector had no immediate effect on the machinery industry, given the high level of farmer indebtedness. Thus, a return to rural credit lines had to be preceded by a rescheduling of the producer debts. In 1996 the National Programme to Strengthen Family Agriculture (PRONAF) was launched and offered credit interest rates below current market rates. According to the Ministry of Agrarian Development (MDA), PRONAF has the lowest interest rates among the rural credit systems in the country. PRONAF may finance the investment in machinery, equipment and production infrastructure, as well as agricultural services. The loans contracted by farmers within PRONAF have grown every year in the last decade, in 1999/2000 this amount was US$ 1.19 billion (R$ 2.15 billion) and, in 2007/2008, was US$ 5.07 billion (R$ 9.00 billion) (MDA, 2010).

- **1999-2007 - Present:** The year 1999 marked the return of a specific policy to develop the agricultural machinery manufacturing sector with the launch of the Programme of Modernization of the Farm Tractor Implements and Harvesters (MODERFROTA), with the revitalization of credit policies that had previously been drastically reduced. Agricultural machinery and implement production and exportation increased quantitatively and qualitatively as a result, increasing the range of products and adapting them to the specifics of each crop and region.

Vian and Grin (2009) showed that 70 percent of the agricultural machinery sales could be explained by the availability of credit. Thus, the public policy of extending credit has had a key role in the modernization of agriculture in Brazil. The most recent example of public policy to increase the credit available for the modernization of the Brazilian agriculture was the launch in 2008 of the programme "*Mais Alimento*" (More Food). This allows family farmers to invest in modernization and acquisition of new machinery and equipment, correction and remediation of soil, milk coolers, genetic improvement, irrigation, establishment of orchards and greenhouses and storage. In this programme, the farmer can finance tractors up 74 hp and, according to ANFAVEA (2010), in its first year of operation was responsible for a 45 percent increase in the number of units sold of tractors in this power range.

While public credit policies have stimulated the demand for agricultural machinery, trade fairs have been the site for the dissemination of new agricultural technologies and equipment. The largest of these fairs is the International Agriculture in Action Trade Fair (AGRISHOW), held annually since 1994 in the city of Ribeirao Preto, São Paulo state. The numbers of visitors and value of business generated during AGRISHOW have been increasing every year, indicating the importance of such events within for Brazilian agribusiness. In 2010, 140 000 people visited the five days of AGRISHOW, where there were 800 practical field demonstrations, and approximately US$ 500 million (R$ 860 million) of orders were placed (AGRISHOW, 2010). Although it is not just dedicated to machinery but to all sectors of agriculture, the EXPOINTER fair that has been an annual event for more than a century in the state of Rio Grande do Sul, is another example of the importance of these events in the dissemination of new technologies. In 2010, EXPOINTER received 560 000 visitors and generated orders for agricultural machinery at a level similar to that achieved by AGRISHOW (R$ 830 million) (EXPOINTER, 2010).

TABLE 8.1
Brazilian crop production and yield in world rankings

Crop	Total Production - World Ranking	Yield (kg/ha)		
		Maximum Average in the World	Brazil	World Average
Bean, dry	2nd	1 982	915	729
Cassava	3rd	33 545	14 070	12 460
Green Coffee	1st	1 989	1 259	847
Maize	3rd	9 658	4 086	5 109
Rice, paddy	9th	6 556	4 228	4 309
Soybean	2nd	2 822	2 816	2 384

Source: FAO (2010)

8.4 BRAZILIAN CROP PRODUCTION AND INFLUENCING FACTORS

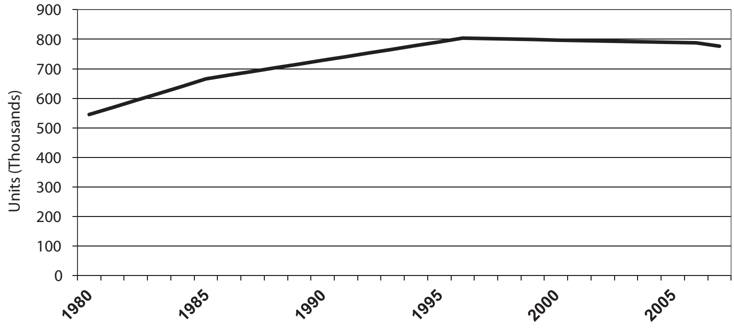
Brazil has been experiencing major advances in overall food production, but still has much to gain in improving crop yields (Table 8.1).

Higher yields are achieved with technological developments in agriculture, often achieved with the development and adoption of technologies for saving land and manpower (fertilizers, pesticides, seeds and mechanization). In recent decades, the country has made substantial progress in making more efficient use of fertilizers, the development of seeds adapted to the tropical climate and short growing period, which enable more than one crop per year in the same field. Variable Rate Application of nutrients has been used on millions of hectares. Thus, mechanization, combined with these other technologies, may be the factor driving agricultural productivity to new levels, helping to comply with tight timeliness schedules, with optimum doses and specific dates for soil amendments, planting and pest and disease control as well as harvesting. Mechanization plays an important role in all these aspects.

8.5 AGRICULTURAL MACHINERY FLEET

The rapid growth in domestic market of agricultural machinery sales from 2000 did not increase the fleet of agricultural tractors (Figure 8.6) indicating a largely replacement market. This has a positive impact on Brazilian agriculture because it indicates that there is a tendency to progressively scrap older machinery in the fleet, replacing it with newer, more efficient machines with better embedded technology and thus contributing towards achieving greater operational efficiency.

FIGURE 8.6
Brazilian wheel tractor fleet



Source: FAO, 2010

This situation also reinforces the hypothesis that an aggressive policy to facilitate the purchase of machinery such as through MODERFROTA can lead Brazil to a new level of agricultural productivity.

8.6 MECHANIZATION OF SPECIALIST CROPS IN BRAZIL

The manufacturing industry for tractors and combines is dominated by multinational companies. But in parallel, Brazil has been developing and delivering technological products primarily developed for tropical crops, for example for mechanization of the production of beans (*Phaseolus* and *Vigna* spp.), sugar cane and coffee.

Bean production had been traditionally focused in the small farm sector but the development of mechanized harvesting technology aroused the interest of large producers, especially those with irrigation systems. These legumes are a great ally in fighting hunger in Brazil and although the planted area has generally decreased, the consequent loss in overall production has been partly offset by increased yield.

The production of sugar cane traditionally involved considerable and arduous labour inputs, the crop leaves being burnt before the cane is cut by hand. Mechanical sugar cane harvesting is now practised on about 35 percent of the cropped area and for instance, in the state of São Paulo, crop burning will be eliminated on all mechanized farms by 2014 and on all other sugar production areas by 2017. Already, cane burning has been prohibited on all new cane production areas throughout Brazil since 2009. Thus, a huge increase is expected in mechanical sugar cane harvesting over the next decade.

Mechanization of coffee harvesting is strategic for Brazil to maintain its world leadership in coffee growing whilst still providing competitiveness in price and quality. Manual harvesting is becoming increasingly difficult due to labour shortages and costs and a whole range of mechanical coffee harvesting machines and equipment has now been developed. This varies from the use of large self-propelled harvesters on some of the larger estates to the provision of portable and pneumatic machines which facilitate a more selective berry detachment. But coffee mechanization does not merely rely upon innovative machine design – it also requires the research support of plant breeders, for instance to improve the uniformity of ripening of the beans to permit the use of the larger but non-selective mechanical harvesters so that the harvested beans are of similar maturity.

According to the Brazilian Federation for No-Tillage Farming (FEBRAPDP, 2009), Brazil is the world's second leading country in area with no-tillage system with approximately 25 million hectares, behind only the United States of America (26 million ha)[32]. This conservation technique has been vital to the financial and environmental sustainability of food production not only for the large flat farms of the *Cerrado*, but also for the medium and small farms in the south and southeast, with more hilly landscapes. One of the limiting factors in the adoption of this system has been mechanization, especially with regard to mechanized planting through heavy crop residues. But the Brazilian agricultural machinery industry has been very active in developing suitable technologies for no-tillage planting for all levels of production ranging from manual planting through to mechanical multi-row tractor-drawn planters. These aspects are dealt with in more detail in other chapters and by Casão Junior *et al*. (2012).

Despite the great development Brazilian agriculture faced in the last two decades, there are still unlimited opportunities for machinery development for tropical crops. For example, with the exception of sugar cane, there is no machinery available for harvesting tropical energy crops. Brazil wants to maintain its leadership position in bio-fuel production, not only with sugar cane, but also with other crops that do not compete with food production such as babassu palm (*Attalea speciosa*), physic nut (*Jatropha curcas)*, and macaúba or macaw palm (*Acrocomia aculeata*). However, in order for the energy produced from these crops to help the country to be self-sufficient and a leading exporter of bio-fuels without harming food production, development of mechanization options needs to continue to constitute part of the research and investment policy in Brazil.

8.7 THE PROBLEM OF LABOUR DISPLACEMENT

It is well known that when agriculture is not mechanized, farmers depend on the workforce, and the requirement is seasonal depending on the operations to be performed, e.g. soil preparation, planting, weeding and harvesting. Therefore, the labour used in agriculture is not permanent and is date dependent. By adopting agricultural mechanization, producers are less dependent on temporary manpower ensuring them greater financial sustainability for their business. However, employment levels may decrease if there is no public policy for absorption of the available manpower that is

[32] Up to date worldwide figures can be found on FAO's Conservation Agriculture site: www.fao.org/ag/ca/6c.html

no longer needed in the field. This challenge is even greater if we consider that the manpower released as a result of agricultural mechanization will often have relatively low qualifications. See the case studied by Ortega and Mouro (2007) on coffee plantations in the *Cerrado* region of Minas Gerais state. Coffee is a manual labour-intensive crop and harvesting is the operation that requires most input. With a favourable topography for mechanization, the use of mechanical harvesters in the plantations of the Minas Gerais *Cerrado* has been increasing significantly in recent decades, reducing production costs. However, this change has a negative effect on the employment level due to the reduction of jobs in the coffee production areas. Based on the last agricultural censuses, the authors identified an increase of 175 percent in the numbers of coffee harvesters from 1980 to 1995/96. Regarding the level of employment in coffee production areas in the period 1970-1985, there was a positive growth following the expansion of the coffee activity in the region. However in the period 1985-1995, there was a decrease due to mechanization. This reduction was greater in temporary compared with permanent jobs (Table 8.2). According to Rezende (2008) the release of semi-skilled labour

TABLE 8.2
Workforce used in the coffee plantation of Minas Gerais Cerrado

Job status	Agricultural Census				Average Rate of change (%)		
	1970	1980	1985	1995/96	70-80	80-85	85-95
Permanent	18 351	53 696	62 097	52 503	11,3	2,9	-1,7
Temporary	22 902	43 860	65 963	29 592	6,7	8,5	-7,7

Source: Ortega and Mouro, 2007

in agricultural regions may have contributed to increasing poverty in both rural and urban sectors of Brazil. Therefore, a policy of increasing the rate of agricultural mechanization in countries that present low levels of education must be accompanied by a policy of improvement of education and training qualifications and development of new possibilities for the labour released.

Ortega and Mouro (2007) concluded that the problem of unemployment in coffee production is more pronounced due to the presence of labour-intensive family farming in the same region. By reducing the availability of temporary employment in plantation agriculture there was a negative impact on the family farms since many small farmers offer temporary jobs at key seasons. With the decline in their incomes and without access to rural credit, the family farms did not follow the modernization of agriculture started in the 1970s (Rezende, 2006). The formulation of specific governmental programmes to improve the financial situation of family farming is relatively new (PRONAF was launched in 1996 and *Mais Alimento* in 2008). Since the 2006 Census was the first time that the activity of Family Agriculture was evaluated, the consequences of this specific policy for family farming can only be adequately analyzed after the coming agricultural census of 2016.

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CHAPTER 9

Agricultural mechanization in countries in transition in Eastern Europe and Central Asia

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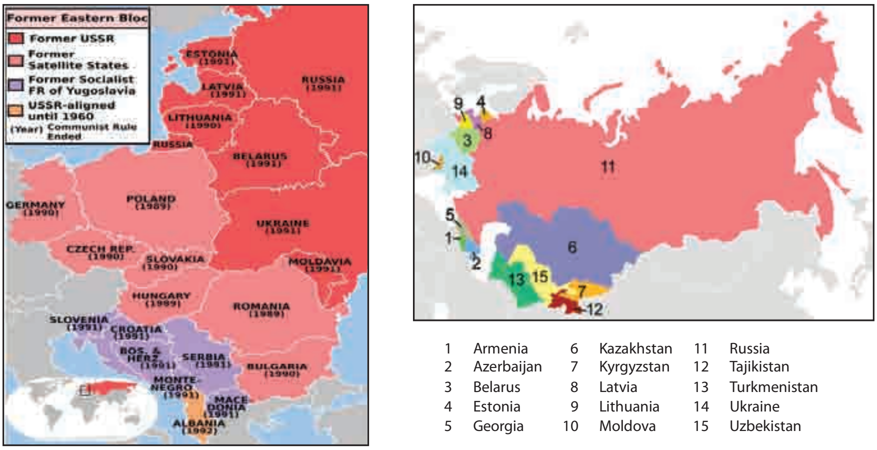
ABSTRACT

The collapse of the Soviet Union and the Council for Mutual Economic Assistance (COMECON) in the early 1990s severely impacted the economies of 15 countries of the former USSR as well as seven countries of the formerly centrally planned economies of Eastern Europe. Agricultural machinery manufacture and distribution had been centrally planned, leading to (deliberate) economic inter-dependence between countries. This situation ceased very rapidly and has been replaced by a situation of re-privatized farms, largely independent machinery manufacturers and the incursion of multinational companies into the region. Membership of the European Union has been beneficial to some Eastern European countries. Tractor imports are rising and agricultural output, which suffered an initial decline, is recovering well. Private enterprise needs to be encouraged and supported to produce farm machinery input supply chains similar to the free market model.

9.1 INTRODUCTION

This chapter covers the 15 countries of the former Soviet Union (Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan) as well as the former centrally planned economy countries of Eastern Europe (Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Romania, Yugoslavia). The former German Democratic Republic (East Germany) is not included here as it was re-united with the Federal Republic of Germany in 1990 and its agriculture has subsequently developed in a completely different manner.

FIGURE 9.1
The countries in transition in Eastern Europe and Central Asia (ECA)



Source: Wikipedia

9.2 HISTORICAL PERSPECTIVE

In December 1991 the Union of Soviet Socialist Republics (USSR) was officially dissolved and the countries of Eastern Europe separated themselves into newly independent nations. From the USSR emerged Russia (the Russian Federation) and a number of independent countries in Central Asia and Eastern Europe. In Central Asia, eight countries emerged: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan and Tajikistan. In Eastern Europe six others were formed; Belarus, Estonia, Latvia, Lithuania, Moldova and Ukraine.

Seven Eastern European countries that had previously been under the Soviet sphere of influence although not part of the USSR also then became fully independent, these were: Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and Yugoslavia.

Albania had remained outside the Soviet Bloc, holding on to its independence but was never-the-less governed by a totalitarian communist regime which only released its grasp on power in 1990. East Germany has re-united with the Federal Republic of Germany; Czechoslovakia has split into the Czech Republic and Slovakia; and Yugoslavia has disaggregated, creating Slovenia, Croatia, Bosnia Herzegovina, Montenegro, Macedonia and most recently Kosovo, leaving the remainder as Serbia.

In order to understand the present situation regarding the status of agricultural mechanization and in particular the investment opportunities in this region, it is useful to have an overview on how agriculture and, in particular, mechanization was organized and practised prior to the political transformation.

In most of the countries, agriculture was organized on the basis of either collectives (cooperatives) or as state farms (Table 9.1). The collectives were

TABLE 9.1
Farm structure by ownership in % with average areas in use (ha)

Country	Cooperatives		State farms		Private farms	
	Pre-transition	Post -transition (1995)	Pre-transition	Post-transition (1995)	Pre-transition	Post-transition (1995)
Poland	4 (335)	4 (400)	19 (3 140)	18 (2 000)	77 (6.6)	78 (6.7)
Hungary	80 (4 179)	55 (1 702)	14 (7 138)	7 (1 976)	6 (0.3)	38 (1.9)
Czech Rep.	61 (2 561)	48 (1 430)	38 (6 261)	3 (498)	1 (4.0)	49 (16.0)
Slovak Rep.	68 (2 654)	63 (1 665)	26 (5 162)	16 (2 455)	6 (0.3)	13 (1.0)
Slovenia			8 (470)	7 (303)	92 (3.2)	93 (4.1)
Romania	61 (2 374)	35 (170)	14 (5 001)	14 (2 002)	25 (1.5)	51 (1.8)
Bulgaria		41 (750)	90 (13 000)	40 (1 100)	10 (0.4)	19 (0.6)
Lithuania		35 (450)	91 (2 773)	1 (124)	9 (0.5)	64 (2.6)
Latvia		17 (706)	96 (3 000)	2 (547)	4 (0.5)	81 (5.8)
Estonia		33 (567)	96 (3 500)		4 (0.5)	67 (2.1)
	Former-style Kolkhoz/ Sovkhoz (collectives and state farms)		New types of organization (cooperatives, corporations etc)		Private farms (and household plots)	
Russia	95	28	-	43	0.05 (2.0)	5.0 (5.0)
Russia	95 (73% of prod'n)	28 (23% of prod'n)	-	43 (39% of prod'n)	0.05 (2.0) (24% prod'n)	5.0 (5.0) (43% prod'n)

Sources: European Commission, 1995 and Nazarenko, 1995

made up of formerly private farms, their owners having then become part of the labour force of the new cooperatives. The state farms were established on state owned land and were worked by an employed farm labour force. The continued existence of private farms was however permitted in some countries. Poland and Yugoslavia maintained the largest areas of privately farmed holdings with 77 percent and 92 percent respectively of their cultivated land still remaining in private ownership at the time of transition.

The break-up of the collectives and the general re-privatization of farming differed greatly from country to country and the method and extent of this in individual countries has had a great influence on the subsequent development of mechanization. This has had, and still has, a great influence on investment opportunities in mechanization. It was not only industry that was centrally planned in these economies, but agriculture too, including mechanization and all other input supplies. Farm production plans were prepared and from these the inputs and resources required to implement the plans were determined.

Farm machinery utilization rates were an important input to these plans with the numbers and types of machinery being precisely calculated and allocated to each farm or cooperative. Prior to the initial socialist reforms, most farm operations had been carried out with high inputs of human labour, either by labourers for the large estate owners or as smallholder farmers. Animal power, mainly with horses, was used for field operations such as ploughing and transport. In contrast, the socialist reforms emphasized the need to "modernize" farming and to reduce the then heavy burden of physical labour.

All aspects of farm mechanization were planned from calculations of the actual numbers and types of machinery needed at farm level through to the supply chain and manufacturing. Data inputs included the farm size, cropping patterns, seasonal factors and machine life. The forecast requirements were then fed into a central supply company and channelled up to the ministry responsible for import/manufacture. A consolidated manufacturing plan was then prepared for the factories designated to supply the region throughout the various countries of COMECON (the Council for Mutual Economic Assistance).

The operation of farm machinery on the various farms was carried out by specialized machinery units composed of drivers, mechanics and engineers. The maintenance and service calendars for the tractors were established by monitoring fuel usage. Machinery maintenance and repair was undertaken in the large workshops which existed on the farms. These were well equipped and it was quite normal for full overhauls, including the machining of parts, to be undertaken in these workshops.

One of the results of this system was that, at the time of the political change in 1990, much of the machinery currently in use had been kept going for a very long time. Judged by Western standards it would have been considered already as fully depreciated and hence due for replacement.

Such a system of manufacture, distribution, operation and repair was fundamentally different from the farm machinery supply and support chain that had developed in Western Europe and North America. In these regions, emphasis had been placed on technical machine performance together with economic factors such as the associated running costs, depreciation rates, the costs of preventive maintenance and of replacement parts. In the former centrally planned economy countries, the concept of a linked supply chain of manufacturers, distributors, dealers and service providers competing for clients amongst the farmers through improved designs and services did not exist.

9.3 QUALITY OF CONSTRUCTION AND PERFORMANCE OF THE MACHINERY

The years of protected markets and lack of investment inevitably impeded improvements to the design and construction techniques and thus to the overall performance of the machinery. Access by the farm machinery factories to high specification steels and other materials was limited and hence farm machines in general were heavy with a greater reliance on cast iron and heavier low specification steels than those being developed by Western manufacturers. The resulting greater machine weight, low levels of engine technology and high sulphur content fuels resulted in poor technical performance and poor fuel economy as well as high levels of engine wear.

The goal of the former central-planners was to standardize farm machinery to an extreme degree, giving emphasis to the needs of the larger state and collective farms with their larger field sizes. Tractor design and production technology was not well advanced and severe design limitations of the hydraulic systems led to the general use of track laying or extremely heavy four wheel drive tractors in order to be able to accomplish high draught operations such as ploughing.

Combine-harvesters suffered from high grain losses, that have been quoted at some 10 percent or more (FAO, 1995). This compares with a loss of 2 percent or less normally considered acceptable amongst Western countries. Machine reliability was also a major problem leading to delays to the sowing and harvesting operations and to consequent increased production losses. The reliability problem was in part due to poor design and construction but also due to the prevailing general old age of the machinery fleet. In the decade following the political changes of 1990, the number of operational machines comprising the farm machinery park soon dipped to critically low levels.

Despite the technical deficiencies of the machinery, the careful planning of the number of machines needed to undertake the work to be carried out meant that the overall efficiency of utilization was mostly much higher than that found on small and medium sized West European farms. For example, an FAO study of the "AGROMECS" in Romania found that there was one 65 hp tractor per 80 hectares of cultivated land (FAO, 1995); a surprisingly extensive area. In overall terms up to 1990, the system functioned well with the technical levels of all the individual components matching each other. However, once the centrally planned system collapsed it led to extreme difficulties.

9.4 MANUFACTURE OF FARM MACHINERY

A number of the countries had established a significant agricultural machinery manufacturing industry, including Poland, the Czech Republic, the former Yugoslavia, Romania, Belarus, Kazakhstan and the Russian Federation (see Table 9.2). In the former Soviet Union (FSU), trade in farm machinery and its components was governed to a large extent by COMECON and led to a high degree of inter-dependence between the manufacturing states. Russia and its satellites exchanged some fifty percent of their component production. Similar proportions applied to inter-state deliveries of farm machinery where production of certain machines was allocated to certain countries so that, in general, the park in any one country could have been made up of agricultural machines produced in a number of different countries.

The central planning of this trade was tied in with that of other goods, leading to an intentional economic inter-dependence between the different countries. With the break-up and subsequent decline in inter-CIS (Commonwealth of Independent States) trade in the early 1990s, this inter-state trade virtually collapsed and the factories languished for want of specialized steels, materials and imported components. Their markets also declined due to the prevailing domestic economic circumstances. At the beginning of the 1990s the universal

TABLE 9.2
Origin of tractors and agricultural machinery manufactured within the FSU (% of total production)

Item /	Russia	Ukraine	Belarus	Kazakhstan	Uzbekistan	Others
Tractors	5	25	60	-	-	10
Harvesters - grain	100	-	-	-	-	-
- corn	-	100	-	-	-	-
- sugar beet	-	100	-	-	-	-
- forage	32	34	35	-	-	-
- potatoes	100	-	-	-	-	-
Potato - planters	24	-	76	-	-	-
- diggers	-	-	100	-	-	-
Ploughs	52	46	-	2	-	-
Cultivators	52	13	-	21	14	-
Drills	29	59	-	9	3	-
Mowers	43	-	-	57	-	-
Pick-up balers	-	-	10	-	-	90 (Kyrgyz)
Windrowers	-	100	-	-	-	-
Irrigating machines	50	50	-	-	-	-
Post-harvest equipment	100	-	-	-	-	-
Sprayers	-	77	-	-	8	15
Fertiliser spreaders	62	38	-	-	-	-
Equipment for animal production	32	30	33	5.3	0.6	10

Source: Marchenko, 2008

picture was one of rapid decline due to low farm purchasing power but also due to severe production problems associated with the structure of trade in the COMECON countries.

Poland, Czechoslovakia, Yugoslavia and Albania differed from this production and trading pattern. Poland had looked towards Western Europe and, in the 1970s, the Ursus tractor company signed a joint venture agreement with Massey Ferguson to develop and produce modern tractors in Poland. In Czechoslovakia, the Zetor Company had produced relatively modern tractors since 1945 and this development continued throughout the following decades. Tractors were exported all over the world and competed on near to level terms with tractors manufactured in the West.

Yugoslavia was not part of the communist trading block; private farms still predominated and the country developed its own agricultural machinery industry. At the core of this was the IMT Company which purchased the license to manufacture Massey Ferguson tractors and combine harvesters in the 1970s. Another company, Rakovica, also produced tractors. In addition there was a comprehensive farm machinery manufacturing industry in Yugoslavia including combine harvesters. Similarly, Albania mainly adopted Chinese technology and established a tractor manufacturing plant together with manufacturing facilities for other agricultural machinery.

9.5 OTHER INFLUENCING FACTORS

Land tenure was another major factor contributing towards the outlook for the farm machinery market. In many of the newly emerged countries, it took a long time for the question of ownership of agricultural land and property to be resolved. In most countries, apart from small garden plots, all of the agricultural land was owned by the state. During the political changes that occurred in the early nineties, the general principal that was applied was that ownership of land should revert back to the previous title holders (Box 9.1).

In those countries which had developed a large industrial sector, many of the previous owners of agricultural holdings, particularly smallholdings, did not have the desire, the knowledge or the skills to revert back to farming for a living. At the same time they did not wish to relinquish their title to the land. This created a major cadastral farm structure problem in many countries and delayed the restructuring of agriculture. Indeed in many cases this situation still has not been resolved.

An essential part of modern farming is access to finance and credit. These facilities did not exist in ECA countries as all financial issues were handled by the State. Another challenge during the transition and which was often overlooked or minimized was the question of a culture of entrepreneurship. In 1989 and 1990, the generation of managers and operators involved in the manufacture, distribution, operation and support of farm machinery had grown up and been educated and trained in the centrally planned economy; a culture of entrepreneurship did not exist and the management skills required to run small and medium farm businesses had never been assimilated.

BOX 9.1

The restructuring of land tenure in Albania

The re-privatization of farms in Albania was relatively straightforward. When farms were collectivized the farmers placed deeply buried stones on the boundaries of their farms. After the change of regime in 1990 they simply reclaimed their land by digging up the stones and then reverted again to smallholder farming. The assets of the cooperatives were also split up amongst the farmers – even buildings were knocked down and the resulting building materials divided out. It was a common sight at the time to see numerous small piles of bricks on the sites that were previously cooperatives. If there were trees on the cooperative these too were divided amongst the individual farmers. There is now little trace of the physical infrastructure of the cooperatives. The resulting structure of agriculture has influenced the type of mechanization that has emerged over the past 20 years.

9.6 TRENDS IN AGRICULTURAL MECHANIZATION

Since 1990-2, the status of farm mechanization can be broadly split into two ten-year periods. During the decade of 1990 to about 2000, the effect of the major political upheavals both on agriculture and agricultural mechanization was quite catastrophic with declining production in all countries. For instance, in the Russian Federation the total sown area declined by about a third (Table 9.3); average yields also dropped dramatically although after 1999 they started to climb again. The 1998 gross production of grain was only about half of that achieved in 1991. In the Eastern European countries (Figure 9.2) agricultural production also fell. In the period 1994 to 2007 production was on average only about sixty percent of the pre-1990 levels, although after 2000 the trend was one of a gradual recovery of production levels.

TABLE 9.3
Main indices of agricultural production in the Russian Federation 1991 and 1997-2005

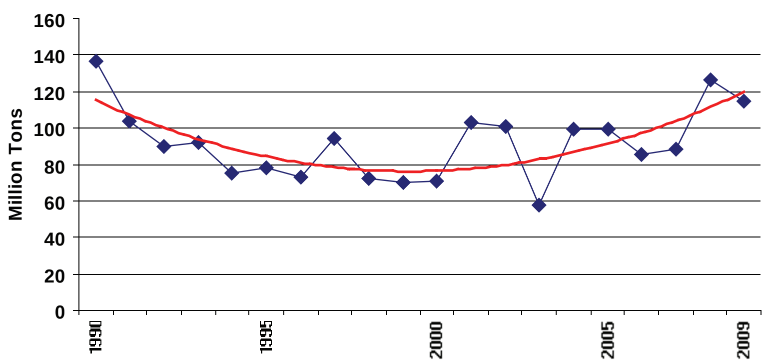
YEAR	1991	1997	1998	1999	2000	2001	2002	2003	2004	2005
Sown area – million ha	115.50	96.60	91.66	88.30	85.40	84.70	84.58	79.60	78.76	77.48
Sown Area of grains and grain-legumes – million ha	61.80	53.60	50.70	46.60	45.60	47.20	47.47	42.20	43.75	43.79
Average yield of grain – t/ha	1.50	1.65	0.94	1.17	1.44	1.80	1.96	1.78	1.88	1.85
Gross grain output – million tons	89.10	88.55	47.56	54.71	65.51	82.50	86.60	67.20	78.10	78.20

Source: Marchenko, 2008.

One of the major causes of this fall in agricultural production (particularly the reductions in sown area) was almost certainly the lack of agricultural machinery to carry out field operations. In all countries, domestic production of agricultural machinery had dropped dramatically (Figure 9.3) but this shortfall was not filled by an importation of machinery (Figure 9.4). In addition to this in 1990, it has already been described that the average age condition of the machinery park was already very high. As supplies of spare parts and the availability of repair services dried up, and as machines became more difficult to repair, the number of machines in operation rapidly declined.

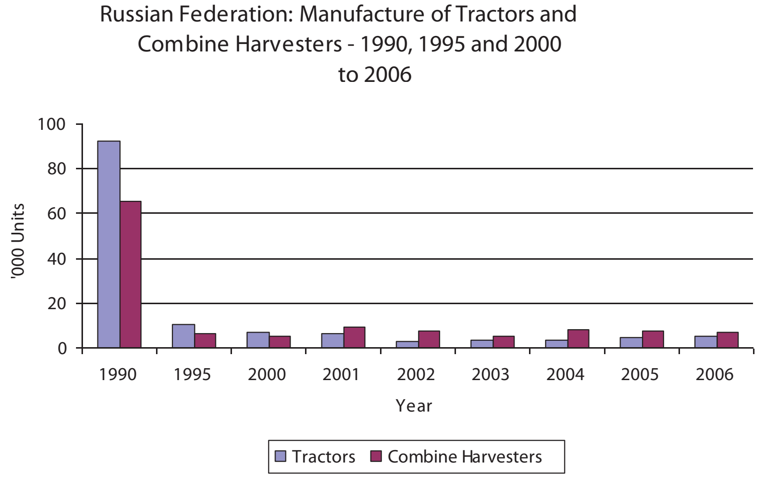
Tractor manufacturing in Belarus was not quite so badly affected during the transition period. This was probably due to the fact that the Minsk Tractor Plant (Belarus Tractors), which was the biggest producer of tractors in the ECA countries, had already built up a world wide export market. The plant

FIGURE 9.2
Wheat production in Eastern Europe



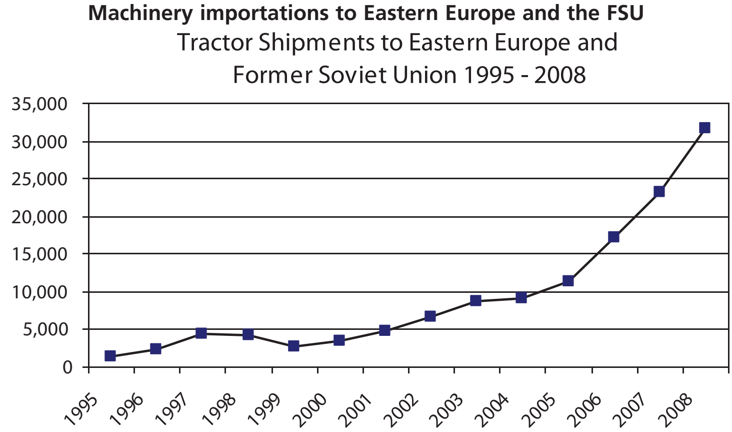
Source: (FAO, 2010)

FIGURE 9.3
Machinery manufacture in the Russian Federation



Source: (Rosstat, 2010)

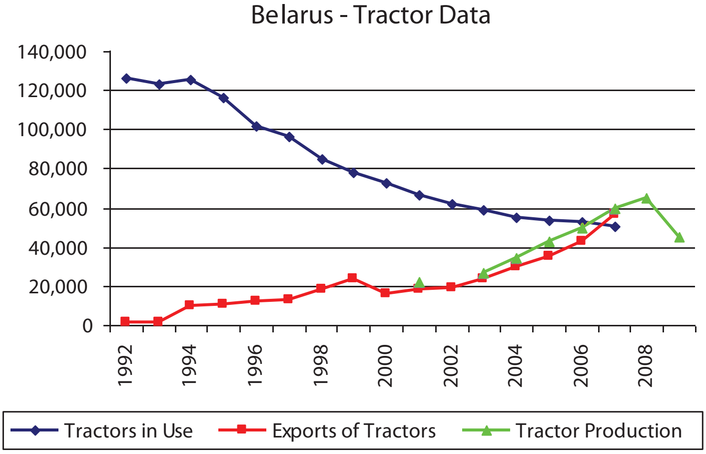
FIGURE 9.4
Machinery importations to Eastern Europe and the FSU



Source: (SIL, 2010)

also remained under state ownership. Although machine production data for the Minsk Tractor Plant are difficult to find, some indicators of the situation are shown in Figure 9.5. It can be seen that the domestic market had almost completely collapsed with the number of tractors in use dropping from over 120 000 units in 1992 to about 50 000 units in 2007. During the same period, however, tractor exports increased from a very low base in 1992 to nearly 60 000 units in 2007 (FAOSTAT). Production data (source: VDMA) for the period 2005 to 2008 shows a substantial increase which drops off rapidly in 2009, probably as a result of the global financial crisis. It is interesting to note the small difference in production numbers and exports, indicating a very low domestic demand for Belarus tractors during that period.

FIGURE 9.5
Tractor data for Belarus



Source: (FAO, 2010 and VDMA, 2010))

9.7 THE PRESENT STATUS OF AGRICULTURAL MECHANIZATION IN ECA COUNTRIES

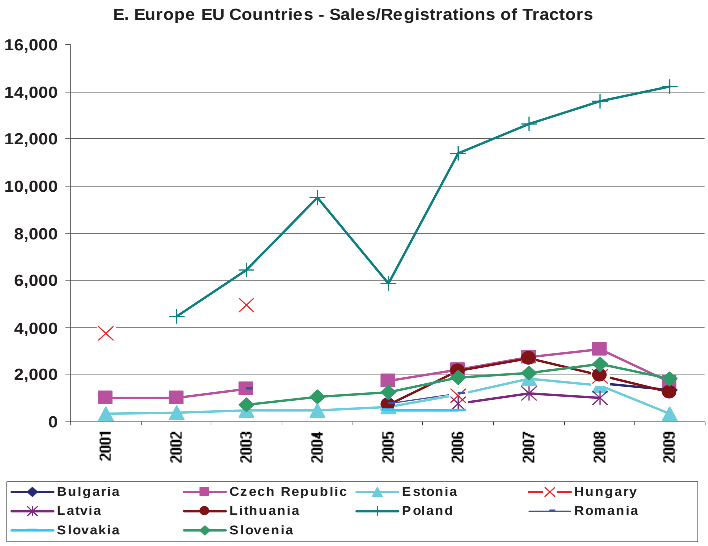
Individual countries in the region have followed different policies of restructuring over the past two decades (for further details see FAO, 2008; World Bank, 2008 and World Bank, 2010). Accession into the European Union (EU) of one group of countries had a major influence on their development of mechanization due to their consequent assimilation of the EU agricultural policy. A second group comprises countries with similar histories and which were formerly within the Soviet Union; Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. A third group comprises Albania and the countries of the former Yugoslav Republic (Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Montenegro and Serbia).

9.7.1 The ECA countries that are members of the European Union

Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Estonia, Latvia and Lithuania became members of the European Union (EU) in 2004, followed by Romania and Bulgaria in 2007. This has had a major impact on the development of the agricultural sectors and the development of the associated farm machinery industries in these countries (Figure 9.6).

Access to EU markets at EU pricing levels has given a major boost to agriculture in these countries. A significant factor was the fact that, apart from Poland and Slovenia, farms were already organized in large units with very large field sizes. Although the land may have had a large number of owners the potential was there for the field sizes to remain large and to provide an opportunity for extremely efficient use of farm machinery. But even in

FIGURE 9.6
Tractor sales in ECA countries which are now in the EU



Source: (VDMA, 2010)

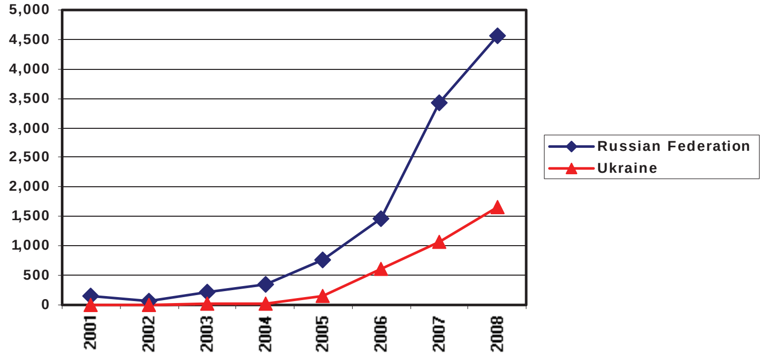
Poland and Slovenia, where farm size is generally on a par with some other EU countries, the stability and price advantages of the EU have meant that investment in agriculture has increased.

As can be seen from Figure 9.6, the levels of tractor sales illustrate that there has been significant investment in farm machinery. Between 2001 and 2009, sales of tractors increased significantly in Poland, Hungary, Slovenia, Lithuania, and Estonia. In Hungary there was a big spurt in tractor sales in 2001 to 2003 but this seems to have tailed off in 2006 to 2008. Apart from Poland, there was a general decline in sales in 2009, probably due to the global financial crisis which started in 2008.

9.7.2 Countries of the Former Soviet Union

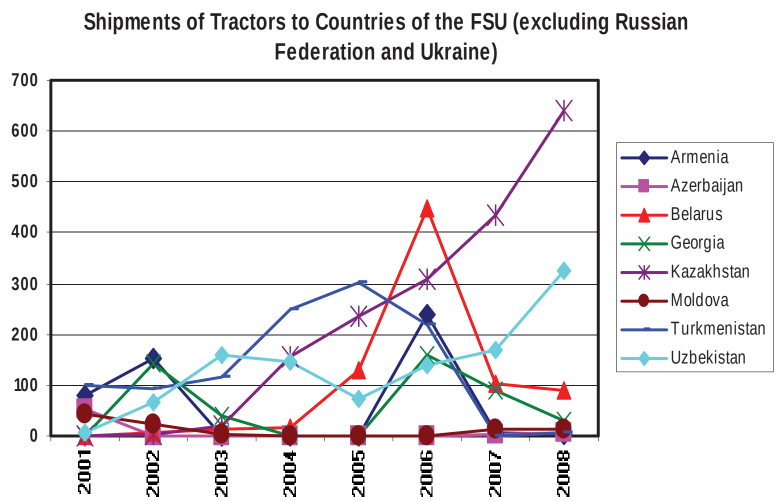
Agriculture in the countries of the former Soviet Union is taking longer to recover than in those countries that have acceded to the EU. For example, in the Russian Federation Table 9.3 indicates that the total sown area consistently declined between 1991 and 2005 from 115 to 77 million ha and gross grain output fell from 89 to 78 million tons. A major contributory factor to this was the lack of investment in new farm machinery, an aspect which has only begun to recover in recent years. Tractor imports from the major western manufacturers to the Russian Federation in the period 2005 to 2008, show an increase from about 750 to 4 500 units annually (SIL, 2010). A similar increase has occurred in the Ukraine (Figure 9.7).

FIGURE 9.7
Tractor imports to the Russian Federation and Ukraine



Source: (SIL, 2010))

FIGURE 9.8
Tractor imports to other countries of the Former Soviet Union



Source: (SIL, 2010))

The pattern emerging for the other FSU countries is similar (Figure 9.8) where increases in the imports of tractors only started to occur in 2004/05. Exceptions to this were Belarus and Kazakhstan where, in both countries, tractor sales started to pick up in 2003. However, whereas sales have continued to climb in Kazakhstan, in Belarus there was a slump in sales in 2007 and 2008.

9.7.3 Albania and Countries of Former Yugoslavia (excluding the EU Member, Slovenia)

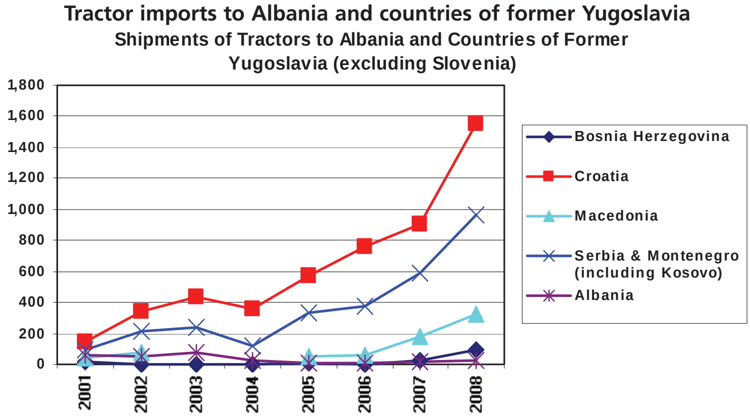
Privately owned farms continued to exist in the former Yugoslavia. Many of these were small and thus investment possibilities were limited, in particular as far as this concerned farm machinery. This meant that, following the split up of Yugoslavia into the individual countries, little changed in agriculture for the following decade.

A further de-stabilizing factor in the region was the armed conflict. In the last ten years, however, investment in farm machinery in Croatia, Serbia, and Macedonia has surged ahead as is illustrated in Figure 9.9.

Although not part of the former Yugoslavia, Albania has a similar agricultural sector as it has now also reverted back to smallholder private farming (see Box 1 above). Albania is one of the poorest countries in Europe and investment in farm machinery has remained persistently low over the last two decades.

FIGURE 9.9

Tractor imports to Albania and countries of former Yugoslavia



Source: (SIL, 2010))

9.8 CHALLENGES AND OPPORTUNITIES FOR FUTURE INVESTMENT IN MECHANIZATION

Farm mechanization in the previously centrally planned economies was organized in a completely different way from the system that had developed in Western Europe and North America. During the period of transition from 1989 to 1991, the central planning system ceased to operate and, with one or two exceptions, virtually the whole of the manufacturing and supply side of the mechanization sector came to a halt.

In economies that are not centrally planned and where a free market prevails, the agricultural machinery market is determined by the demands of farmers or farming companies. These potential clients may choose the type, size and make of machine they will purchase, based on which best suits their personal and business needs. The manufacturers respond by developing, and marketing machines that they consider will be sought after by the farmers. The farmers will also seek ready availability of spare parts and servicing support for their machinery. Such service is often provided by independent companies who establish a franchise with the manufacturer of the machinery they sell - these are the "dealers". Often, there are also many other independent workshops and retailers who provide maintenance services and who sell spare parts.

The biggest single challenge facing the farm mechanization sub-sector in the former centrally planned economies has been the development of an alternative to the rigid centrally planned system that previously governed the manufacture, distribution and operation of farm machinery. There is a need to stimulate the emergence of individual private service-provider companies as well as private entrepreneurship regarding farming in general and the operation and management of the necessary farm machinery.

For individual countries, mechanization needs to be viewed in the context of the industry it serves, which has been and in many cases still is in a period of unprecedented transition. The farm machinery manufacturing industries are only just recently re-launching their activities and major international manufacturing companies are starting to invest in the ECA countries either directly or through joint ventures (for further details see World Bank, 2010).

For instance, John Deere has invested in manufacturing and distribution in Russia, CNH is investing in Uzbekistan and Poland; AGCO is investing in Russia and Kazakhstan, Same-Deutz-Fahr in Russia, Poland and Croatia, CLAAS in Russia, Hungary and the Ukraine, Caterpillar in Poland, Hungary and Russia. Other companies which are investing in ECA countries are ARGO (Russia), Kverneland (Russia), Mahindra and Mahindra (Serbia, Croatia, Bosnia, Macedonia); Escort Group (Poland); Hozo-SK (Romania); Iran Tractor Manufacturer (Tajikistan); Uzel (Poland); Zetor (Poland, Czech Republic, Slovakia). In addition, the previous ECA manufacturers (Tractor Concern Plants, New Community, MTW) which have now been privatized are expanding production and distribution in other countries.

These large multi-national companies are mainly targeting the newly emerging large farms and farming businesses and interest in marketing farm machinery to the smallholder farmers has been largely lacking. Now however, Indian manufacturing companies are leading an increased interest in the small farm sector led by Mahindra and Mahindra, the Escort Group and TAFE. These companies are experienced in designing and producing low cost tractors and machinery suited to low income, small scale farmers. The private sector is therefore increasingly able to meet the demands of both individual farmers as well as the agro-industrial companies either through importations or local manufacture. Furthermore, the companies that are now investing in local manufacture are very large and it is probable that the remaining constraints affecting future investments will decrease.

In contrast, the situation for the service supply sector is different. In many countries there are generally a multitude of small companies emerging which offer services for essential maintenance and repairs and the supply of spare parts. But these companies very often struggle to obtain credit for business development and to finance their cash flow. Whereas farmers often can access funds through agricultural banks and benefit from other government agricultural development programmes, the service providers are rarely considered in national agricultural development plans. However, these service providers are very important and their needs should be taken into account during planning the development of the agricultural sector. Failure to do this will reduce the efficiency of the ownership and operation of farm machinery and put a brake on the resurgence of agricultural production.

Figures 9.7, 9.8 and 9.9 indicate that for the past five years most countries have experienced an increase in demand for farm machinery. This has dramatically increased in some (e.g. the Russian Federation, Poland, Ukraine, Kazakhstan, Croatia), whereas in others increases have been only slight, if at all (e.g. Albania, Bosnia, Azerbaijan, Georgia).

The question arises as to what can be done further to reinforce these positive trends and to improve farmers' access to and choice of farm machinery. Two approaches are available, both of which are worthy of serious attention: through the stimulation of the demand side (targeting the farmers) and through improving the offer or supply side (focusing on alleviating constraints within the farm machinery industry).

With regard to the farmers, access to a wide and competitive range of equipment needs to be made available. If credit or leases are required, these should be equally applicable to domestic or imported equipment. State support programmes should provide sound technical and financial advice to farmers concerning the investment in and management of farm machinery.

The restructured supply network will only operate competitively if any remaining government restrictions are removed. Hence local industries should no longer receive special protective measures nor should foreign investment be impeded. Unreasonable testing and certification requirements fall within this category. The previously state-operated farm machinery hire services need to be fully privatized.

Whilst the public sector now withdraws from the daily management of farming enterprises, it has an increasingly important role to play in support through research, training and education. It can also play an important role in supporting credit programmes for the farming sector – as can potential donors.

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CHAPTER 10

Agricultural mechanization and the environment

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ABSTRACT

Conservation agriculture is likely to become the standard agricultural production system in the future. The world cannot feed itself and protect its natural resource base otherwise. This chapter explains the impact of current, tillage-based, agricultural practices and discusses the salient points and relevance of conservation agriculture, with a particular emphasis on mechanization issues. The most significant change will be in no-till planting practices where seeders need to penetrate surface organic mulch and deposit the seed and fertilizer at the correct depth. But other important areas analyzed include environmentally safe agro-chemical application, precision farming and controlled traffic farming. Local manufacture of CA machinery should be encouraged, but international cooperation may be needed in the short term. CA is a knowledge intensive concept and adoption is eased through mentoring of newcomers by experienced practitioners who can reduce the machinery investment burden through leasing arrangements at the outset. Government enabling policies have been seen to be crucial if we are to continue the exponential rise in CA adoption from the present 125 million hectares.

10.1 INTRODUCTION

10.1.1 The need for considering the environmental footprint of agriculture

There is no alternative but to increase agricultural productivity (i.e. crop yield per unit area) and the associated total and individual factor productivities (i.e. biological output per unit of total production input, and output per unit of individual factors of production such as energy, nutrients, water, labour, land and capital) to meet the global food, feed and biofuel demand and to alleviate hunger and poverty. However, until now, agricultural intensification generally has had a negative effect on the quality of many of the essential resources such as soil, water, land, biodiversity and ecosystem services which has caused yield and some factor productivity growth rates to decline. Another challenge for agriculture is its environmental footprint and the effects of climate change.

Agriculture is responsible for about 30 percent of the total greenhouse gas emissions of CO_2, N_2O and CH_4 while being directly affected by the consequences of a changing climate.

The new paradigm of "sustainable production intensification" recognizes the need for a productive and remunerative agriculture which at the same time conserves and enhances the natural resource base and environment, and positively contributes to harnessing environmental services. Sustainable crop production intensification must not only reduce the impact of climate change on crop production but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in crop production systems above and below the ground to improve ecosystem services for better productivity and a healthier environment. A set of soil-crop-nutrient-water-landscape system management practices known as Conservation Agriculture (CA) contributes to all of these goals. CA saves on energy and mineral nitrogen use in farming and thus reduces emissions; it enhances biological activity in soils, resulting in long term yield and factor productivity increases. While not tilling the soil is a necessary, but not sufficient, condition for truly sustainable agriculture, CA has to be complemented with other techniques, such as integrated pest management, plant nutrient management, and weed and water management. The functionality of these environmentally friendly agricultural management practices in modern productive farming depends mostly on the availability of suitable mechanization technologies, which allow, for example, seed to be placed accurately in a not-tilled soil, to apply agrochemicals and plant nutrients exactly where they are required without contaminating non-target areas, and to save resources such as water and energy to the greatest extent possible.

10.1.2 Definition and Description of Conservation Agriculture

According to FAO, CA is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely:

1. Continuous zero or minimal mechanical soil disturbance (i.e. no-tillage and direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil; minimum soil disturbance from cultivation, harvest operations or farm traffic; in extreme cases limited strip tillage).
2. Permanent organic matter soil cover, especially by crop residues, crops and cover crops. And:
3. Diversification of crop species grown in sequence or associations through rotations or, in the case of perennial crops, associations of plants, including a balanced mix of legume and non-legume crops.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical tillage are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves the quality of land husbandry both for rainfed and irrigated production. Complemented by other known good practices, such as the use of quality seeds, and integrated pest, nutrient, weed and water management, CA is a base for sustainable agricultural production intensification. The yield levels of CA systems are comparable with conventional intensive tillage systems, which mean that CA does not lead to yield penalties, although there may be some initial depression after a changeover while the soil recuperates. At the same time, CA complies with the generally accepted ideas of sustainability. As a result of the increased system diversity and the stimulation of biological processes in the soil and above the surface as well as due to reduced erosion and leaching, the use of chemical fertilizers and pesticides, including herbicides, is reduced in the long term. Ground water resources are replenished through better water infiltration and reduced surface runoff. Water quality is improved due to reduced contamination levels from agrochemicals and soil erosion. CA further helps to sequester carbon in soil at a rate of about 0.5 t/ha/year. Labour and energy requirements are reduced by about 50 percent, which allows farmers to save on labour, fuel and machinery costs.

In 2010 CA was being applied on about 117 million ha around the world with some farms practising it for over 30 years. Over the past 20 years, the rate of transformation from tillage-based farming to CA has been some 5.3 million hectares per annum increasing in the last decade to 6 million ha. Several countries have adoption levels of more than 50 percent of their arable land, which permits the observation of the longer-term and large scale effects of CA on the environment at a landscape scale, for example, at watershed or river basin level. CA is now practised by farmers around the world under the most diverse agro-ecological conditions, soil types and farm sizes.

10.2 ENVIRONMENTAL ASPECTS OF AGRICULTURAL MECHANIZATION

Agricultural mechanization is usually about addressing issues of delivery of farm power and increasing the efficiency of agricultural labour. However, there are two areas within the agricultural crop production sector where mechanization has a particular impact on the environment, in both senses: it can accelerate environmental degradation, or it can help to reduce the environmental footprint of agriculture considerably. Those areas are soil tillage and pesticide application. Mechanized soil tillage along with the use of heavy machinery can accentuate and accelerate soil degradation, while modern technologies allow the implementation of farming concepts like CA and the very site specific application of agrochemical inputs with minimum contamination of non target areas.

When a tillage-based production system is to be transformed into a CA-based system, it involves a shift in the prevailing on-farm mix of mechanical technologies. Some will remain, but with only marginal use in future, and there will be the development of a completely new set of mechanical technologies, changes in farm power requirements, and in land use suitability for sustainable intensification as elaborated in the following sections.

10.2.1 Specific features of mechanization under CA

The most significant change when switching from tillage-based farming to CA is in the land preparation and seeding practices. The use of tillage as a standard periodic operation is completely eliminated in a fully functioning CA system and remains only for very specific tasks, such as creating the conditions for changing over to CA by breaking up compacted soil or levelling the soil surface. Breaking compacted soil horizons may also become necessary within CA systems under mechanized farming, particularly in humid climates (Figure 10.1). In surface irrigated systems the maintenance of the irrigation furrows between permanent raised beds is a regular operation requiring tillage equipment; and in cold moist climates strip tillage before or together with the planting operation may be deemed appropriate.

FIGURE 10.1
Paraplow for subsoiling with minimum soil movement, Nicaragua

Source: (Photo: T. Friedrich)

Another area of significant change is the seeding and planting operation. Equipment for seeding and planting must be able to deposit the seed with an accuracy similar to that of conventional seed drills into an untilled soil which ideally will be covered with a heavy mulch of crop residues (Figure 10.2). For

FIGURE 10.2
No-till direct seeding into heavy residue mulch, Nicaragua

Source: (Photo: T. Friedrich)

FIGURE 10.3
Low disturbance double disk furrow opener (left) next to a hoe opener (right), which creates considerably more soil disturbance despite this particular opener being designed for low disturbance, Kazakhstan

Source: (Photo: T. Friedrich)

this reason the equipment must have specially designed furrow openers which can penetrate the mulch without accumulating it or pushing it into the soil and deliver the seed into the undisturbed soil at the desired depth. In order to do this, no-till direct seeding equipment needs to be strong enough to resist the higher soil forces, and heavier than a conventional seed drill, particularly when disk type furrow openers are used. There are different furrow opener types available for different conditions. They also come with different costs attached and create more or less soil disturbance (Figure 10.3). As no-tillage

FIGURE 10.4
Hand jab planter for no-till planting, Zambia

Source: (Photo: J. Kienzle)

systems such as CA mature and are optimized over a period of time, the trend is clearly towards minimum disturbance no-till furrow openers, such as double disk, cross slot or star-wheel type tools, which also facilitate weed management; and away from higher disturbance tine openers.

At the manual technology level, besides using a planting stick or the hoe, the most common planting tool for row crops is the jab planter (Figure 10.4). Simple row crop precision planters exist for animal traction, often with fertilizer application, using ripper tines or double disks as furrow openers. The designs range from simple lightweight long-beam type ripper-planters (Figure 10.5) to self suspended one or two row animal drawn planters, eventually even with a ride-on option (Figure 10.6).

FIGURE 10.5
Simple long beam animal traction no-till planter, Tanzania

Source: (Photo: J. Kienzle)

For single axle tractors one- or two-row precision planter attachments are available, similar to the ones used on four wheel tractor no-till planters (e.g. in Brazil) (Figure 10.7). In addition to those, there are low cost no-till planters available, however with a limited residue handling capacity (e.g. in Bangladesh – Figure 10.8; and Kenya – Figure 10.9).

FIGURE 10.6
Animal traction no-till planters, Cuba

Source: (Photo: T. Friedrich)

FIGURE 10.7
Single axle tractor with two row no-till planter, DPR Korea

Source: (Photo: Kim Kyong Il)

FIGURE 10.8
Multicrop no-till seeder for single axle tractor, Bangladesh

Source: (Photo: M. Hossain)

FIGURE 10.9
Multicrop no-till seeder for single axle tractor, Kenya

Source: (Photo: B. Sims)

For four wheel tractors the full range of no-till seeders and planters, starting with small tractors of 30 hp (Figure 10.10) up to the large tractors of 400 hp,

FIGURE 10.10
28 hp Cholima tractor with 7-row no-till seeder, DPR Korea

Source: (Photo: T. Friedrich)

is available (Figure 10.11). Among the equipment operating with double disk furrow openers, the versions with offset disks of different diameters (Figure 10.12), which is particularly popular in Brazil, is very suited for smaller tractors, since it can cut through residues and into soil with equipment weights of less than 100 kg/row, depending on the moisture conditions, while other double disk seeders often require weights of 150 to 250 kg/row.

For weed management under CA, conventional cultivators and hoe type equipment lose importance. Slashers, cutters or crimper-rollers are used for

FIGURE 10.11
Large scale no-till seeding equipment, Kazakhstan

Source: (Photo: T. Friedrich)

FIGURE 10.12
Double disk furrow opener with offset disks of different diameter from Brazil, Uzbekistan

Source: (Photo: T. Friedrich)

mechanical surface weed management. Chemical herbicide application plays a significant role, and sprayers remain the main tool for this.

The harvest operation in CA is part of the land preparation for seeding the next crop. The management of crop residues during the harvest has a direct influence on the ease, problems and quality of the subsequent planting operation. Standing residues, anchored in the soil, or at least a tall standing stubble can facilitate seeding particularly in heavy or difficult residue situations, such as in the case of high yielding rice. In semi-arid continental climates with winter precipitation and extremely low winter temperatures, a standing residue or high stubble facilitates snow trapping and hence water retention. Another important aspect is the treatment of the residues. Farmers practising CA often use simple residue spreaders on their combine harvesters, rather than choppers, this has the additional benefit of a lower energy requirement (Figure 10.13).

FIGURE 10.13
Homemade residue spreader for combine harvester, Costa Rica

Source: (Photo: T. Friedrich)

One of the most important tools specific to CA, and which is used for residue, cover crop and weed management especially in sub-humid or humid climates, is the knife roller, crop crimper or vegetation crusher. It is also used in organic no-till farming, which essentially is CA without the use of synthetic agro-chemicals (Figure 10.14). Knife rollers are available for animal traction and for tractor use, as trailed or 3-point mounted equipment.

FIGURE 10.14
Knife roller or crop crimper, Brazil

Source: (Photo: T. Friedrich)

For the harvest operation under CA the shift from a two step harvest, with stationary threshing at the field side or at the farm yard, towards a one stage harvest with combine harvesting is desirable, preferably even with a stripper header. If windrowing is necessary under specific crop and climatic conditions then mobile pick-up threshing in the field will be required. These methods facilitate the retention, return and spreading of as much crop residue as possible.

Another significant change that is taking place is in farm power requirements. Without the heavy tillage operation, the required peak farm power requirement is roughly halved. Small scale farmers using animal traction or single axle tractors, who in tillage-based systems would hire four wheel tractors for ploughing, or farmers who consider that their actual mechanization level is in transition to a four-wheel tractor, under CA systems can continue farming without acquiring additional farm power. In mechanized systems the overall power requirement for tractors decreases by about 50 percent with an additional shift towards lower horsepower by about 40 percent.

10.2.2 Application of pesticides

The use of agrochemicals for pest, disease and weed management can have a significant impact on the environment. In many cases the handling of these products and the equipment used for their application are unsuitable, leading to the generally known negative consequences for human health and the environment. It is estimated that about 50 percent of all pesticides applied do not reach their intended target. Even if the use of pesticides is guided by a general understanding of environmental processes within a strategy of integrated pest management, their actual application is a very complex matter, requiring knowledge and proficiency and the use of appropriate and safe equipment. Modern technology facilitates the reduction of non target contamination, for example with low drift nozzles and other technical means to reduce spray drift, such as air curtains, spray shields or the use of wick-type touch-on applicators, for example for systemic herbicide weed control. This technology is also available at manual level at a very affordable cost for small farmers (for example the Zamwipe – Figure 10.15).

FIGURE 10.15
Zamwipe wick-type herbicide applicator, Zambia

Source: (Photo: T. Friedrich)

Atomizers which produce a narrower droplet spectrum allow for the creation of the specific droplet size required for a particular type of application. At the same time this allows a reduction in application volumes as for example with low volume applicators with rotary nozzles (controlled droplet application

- CDA). But also modern hydraulic nozzles, such as air-induction nozzles, have come a long way to create narrow, specific droplet spectra or to produce coarse sprays with low drift potential, yet providing good coverage and biological efficacy at low application volumes.

The use of electronics to control the application process is further improving accuracy and target specificity of pesticide application and reducing off target contamination. Detection of green plants allows the application of pesticides for spot spraying of actually existing weeds, with a potential to reduce the use of herbicides for weed control in arid lands by up to 90 percent (Figure 10.16). LIDAR[33] and similar sensor technologies facilitate the detection of existing plants and their canopy density, controlling for example orchard sprayers so that they only apply spray in the presence of a bush or tree and regulate the application volume and airflow according to the canopy density, while switching off automatically between target plants.

FIGURE 10.16
Weed Seeker spray boom for herbicide application only on green weed spots, South Africa

Source: (Photo: T. Friedrich)

However, while these technologies exist, their actual use is still limited and the enforcement of not only latest technologies for pesticide application, but also the correct and safe use of pesticide application equipment as well has to be under-pinned by legislation. So far only a few countries address these aspects with legislation, such as the requirements for proficiency of pesticide application operators (for example in the EU, Brazil, Belize), the safety of new pesticide application equipment, as for example increasingly described by ISO[34] standards (for example EU, Brazil, Cameroon, China) or the regular mandatory inspection of spray equipment (for example EU, parts of Brazil).

33 Light Detection and Ranging
34 International Organization for Standardization

All of these aspects are addressed in the FAO code of conduct on distribution and use of pesticides (FAO, 2003).

10.2.3 Precision farming

Precision farming describes the very site specific use of modern technologies to control crop management interventions and has been partly addressed in Section 10.2.2. However, precision farming, particularly using satellite and land based global positioning systems in addition to direct crop sensors, is also increasingly being applied in other areas of mechanized farming besides pesticide application, increasing efficiency and reducing waste, for example with fertilizer application or field traffic.

Global positioning systems allow the creation of detailed soil nutrient or yield maps, by assigning soil samples and yield values recorded by onboard yield sensors, for example in modern combine harvesters, to specific locations. These maps can then be used to apply fertilizers or seed rates precisely and specifically at predetermined sites.

Other applications of precision agriculture measure actual crop parameters, as described for pesticide application. For example the "green seeker" technology detects the colour of crop leaves and correlates this with the nitrogen supply situation, which can then be directly used to control top dressing application of nitrogen (see Sims, 2011). This technology is available fully automatically for tractor level mechanization, but also manually with simple colour cards, allowing a more target oriented application of nitrogen as opposed to broadcasting. For herbicide application, besides the above mentioned use of colour sensors reacting to green plants, there are technologies based on image recognition technology which allow crops to be distinguished from weeds to trigger herbicide sprays only and directly onto the weed plants, and so avoiding off target areas.

A very important area of precision farming is the satellite guidance of farm vehicles, either by simple indicators like light bars or screens, or combined with a fully automatic steering. This technology, first used in aerial application to better guide aircraft, is now available for tractors and combines, allowing accuracies in the centimetre-range. This is helpful particularly in large scale farming with more accurate spacing of equipment passes, avoiding wasteful overlap or equally harmful untreated strips. It also allows the introduction of controlled traffic farming, in which all farm equipment always uses exactly the same tramlines every year, even when they are invisible. This is of particular importance in mechanized no-tillage based farming systems, and also in large-scale mechanized farming, which increasingly can lead to dangerous compaction not only of the soil surface, but also in the soil profile. With controlled traffic farming, most of the cropped land is never affected by traffic compaction, leading to significant yield increases, while the permanent tramlines become so heavily compacted that they actually facilitate the trafficability in the field even under difficult conditions. Besides using satellite guidance technology, controlled traffic farming is also possible at lower mechanization levels, including animal traction and manual levels, using for example permanent bed and furrow systems.

The application of controlled traffic concepts will eventually lead to completely different generations of farm machinery, from tractors through seeders to sprayers and spreaders to harvesters and transport equipment (Figure 10.17). General design features would be track spacing as wide as possible, eventually standardized, while the tracks themselves would be as narrow as possible. Machinery weight, rather than being spread evenly across the surface, as is the case with actual wide and multiple tyres, will be concentrated in the track and spread along it with multiple axles or rubber tracks. The working width for each item of farm equipment would have to be standardized according to the track spacing as multiples of the same.

FIGURE 10.17

Cotton picker adapted for Controlled Traffic Farming with 3 m track and single tyres; additional front support wheels to distribute the header weight along the track, Australia

Source: (Photo: T. Friedrich)

10.2.4 Other areas of pollution reduction

Agricultural engineering is increasingly addressing the aspects of pollution from agricultural machinery. The OECD[35] tractor codes for standardizing tractor performances address issues such as noise levels and also the emissions from modern engines driving agricultural machines are increasingly under scrutiny. Another aspect is the development of lubricants and fuels based on biodegradable vegetable oils and the development of engine technologies which can be operated by biofuels, including biogas. This can further contribute not only to reducing the environmental footprint of mechanized agriculture, but can also help the mechanization of agricultural operations in remote areas which are disconnected from conventional energy and fuel supplies.

[35] Organisation for Economic Cooperation and Development

Advances in the area of bioenergy have made the use of fuels from organic origin (other than fossil sources) ecologically and economically feasible, regardless of whether the fuel is solid, liquid or a gas. Efficient technologies for using the different types of fuels exist at all scales. Besides the burning of fuel wood, the use of vegetable oil as fuel in remote areas can be adapted with relatively simple, small scale technologies for remote poor communities, as is done for example in the north of Brazil. Another fairly scale independent technology, particularly in tropical climates, is the production of biogas from animal excrements. This can be applied to directly supply farm households with cooking and lighting fuel, applied at community level it could also be used for electricity generation with gas-engine driven generators and at large semi-industrial scale even for bottling biogas as transport fuel or feeding into gas grids. This would not only offset fossil fuel emissions, but also reduce green house gas emissions resulting from animal manures or slurries.

10.2.5 Irrigation

Agricultural irrigation is actually one of the largest water consumers worldwide: about 70 percent of global freshwater resources are used for agricultural crop production. Since other consumers are increasing the pressure on water use, the availability of water for agriculture will be reduced and so water saving technologies are paramount to sustain irrigated farming which, due to its higher production levels, is contributing a much higher proportion of global food production than its actual share of cropping land would suggest.

One aspect of water economy in irrigation is the general crop and land management under CA. Particularly for rice, the highest consumer of irrigation water, new cropping methods combining CA and the System of Rice Intensification (SRI) allow significant water savings by avoiding permanent flooding and creating an aerobic soil environment.

But besides the agronomy, direct water management has a major influence on water use in agriculture. Surface irrigation schemes are probably the most widespread form of irrigation. Among them basin type flood irrigation can be considered the most wasteful due to the large evaporation surface. Bed and furrow systems, which can be used even for crops like rice and wheat, allow a significant reduction of the open water surfaces and the consequent evaporation losses. Technical irrigation, using pressurized pumping systems to irrigate the crops from the top also have a wide range of water efficiencies, with evaporation losses in high pressure systems using rain guns reaching levels above 70 percent. In general, regardless of whether stand alone sprinklers or moving sprinkler installations in centre pivots or similar irrigation machines are concerned, the finer the droplets of the spray and the farther the distance they travel through the air before hitting the soil, the higher are the evaporation losses. Technologies using droplegs with drag hoses, micro sprinklers or drip irrigation are the options which save most water and also consume least power.

With these technologies the water is not atomized into small droplets and does not travel a long way through the air, but is applied directly to the soil without even wetting the crop canopy.

Irrigation management is another important aspect. More than 10 percent of worldwide irrigated land is irreversibly damaged by salinity problems. Over irrigation combined with inadequate drainage is usually the cause of this. However, drainage in irrigation schemes is water which is unproductively returned to the catchment, often loaded with leached soil nutrients, leading to eutrophication or other environmental downstream problems. Ideally irrigation management should control the water supply exactly to the point where plants do not suffer stress, but where there is no surplus water in the soil dissolving soil nutrients and evaporating at the surface or leaching down to the groundwater or drainage system. Such soil moisture monitoring can best be done with capacitance probes, allowing real time soil moisture profiles to be recorded, but there are also simpler and cheaper measurement options available for irrigation management.

10.3 INVESTMENT OPPORTUNITIES FOR ENVIRONMENTALLY FRIENDLY MECHANIZATION

10.3.1 Development of environmentally friendly equipment

Environmentally friendly agriculture cannot easily be developed without the commercial availability of suitable equipment, while on the other hand the equipment industry will not develop such equipment without perceiving a significant market. In many countries this can be an impediment to introducing CA and to achieving its adoption and upscaling. But it also applies to other environmentally friendly technologies, for example in the areas of pesticide application and precision farming. The respective equipment is usually more expensive and cannot in all cases be justified by immediate savings in inputs, for example expensive pesticides. In most situations farmers are not sufficiently rewarded for supplying environmental services as they are also not charged with the costs resulting from pollution and degradation; hence there is little incentive for a farmer to spend the extra cost for environmentally friendly equipment.

In the case of Brazil, CA was initially promoted and spread by progressive farmers, using imported no-till equipment and increasingly modifying their old equipment to adapt it for the new way of farming. In the early years commercial workshops offered conversion kits for conventional seeders to convert them into no-till seeders. As the demand for equipment increased, equipment manufacturers picked it up and started to develop specific CA equipment. Many of these manufacturers were independent, small with a very local market and close contact with their clients. Most of them had already been producing a range of implements, mainly tillage and seeding equipment. The close contact with the farmers and the competition within the industry have led to a steady improvement of the technology. The result is a set of equipment which is very well suited to the specific requirements of CA, i.e. facilitating direct seeding into not-tilled soil with minimum disturbance and the highest possible amounts of mulch cover. Public research and projects assisted in this process and also facilitated the introduction and development of special equipment for smallholder farmers at manual, animal traction and single axle tractor levels, allowing the same performance levels as the larger tractor equipment (Casão Junior *et al*., 2012). As the market developed, most of these equipment manufacturers specialized in CA equipment, phasing out the manufacture of tillage tools and promoting specifically conservation agriculture. Similar developments took place in Argentina mostly for large scale equipment and in Paraguay for small scale equipment.

Most of the other markets, where no-till equipment was developed, mainly focussed on zero tillage, but not on the full CA package including the residue handling. This accounts for the zero tillage planters being produced in South Asia, namely Pakistan and India, mostly for irrigated, levelled lands. An exception is the so called "Happy Seeder", which includes a residue handling capacity, but is still not perfect for un-levelled rainfed land (Figure 10.18).

FIGURE 10.18
No-till seeder with residue chopper and chisel furrow openers, Indian "Happy Seeder"

Source: (Photo: T. Friedrich)

Another example is China, where the equipment manufacturing industry has started to produce CA equipment in large numbers following a government policy. In this case the residue handling capacity is being addressed in some of the equipment (Figure 10.19). Yet, as they are aiming at very low equipment costs, the use of high quality steel as is needed for the disk openers used in Brazil, is not common in China.

In terms of precision farming particularly, the guidance technologies as well as advanced equipment for pesticide application are becoming increasingly popular in countries with a higher education level in the farming community.

FIGURE 10.19
No-till seeder with residue chopper, chisel type fertilizer and double disk seed furrow opener, China

Source: (Photo: T. Friedrich)

The incentive here is the reduction of waste and the direct saving of expensive agricultural inputs, particularly pesticides. However, in most countries where low levels of education prevail, farmers are still selecting the equipment, for example knapsack sprayers, by the purchase price, and not considering the long term savings in products they could have achieved by investing in better and safer technologies.

10.3.2 Implications of CA on investment in agricultural mechanization

Since CA still has, in most parts of the world, relatively low adoption levels, two different scenarios have to be distinguished: the fully equipped mechanized farmer with an up to date operational set of equipment not yet fully depreciated; and the non-mechanized farmer, or the farmer with an obsolete set of machinery considering full renovation of the machinery fleet.

For the first kind of farmer the shift to CA can require a considerable additional investment in machinery, particularly the fairly expensive no-till seeders and planters. On the other hand the conventional set of machinery will still be required until the conversion is completed, while the market value of the old equipment will not be high. This additional investment can be a significant hurdle to adoption, particularly if it is accompanied by uncertainty about the success of the new cropping system. This uncertainty can be significantly reduced with a mentoring programme between advanced CA farmers and newcomers. A study in the Pacific Northwest of the USA showed that new CA adopters would usually save about 10 percent of their operation costs and generally the profitability of farming improved in all cases (Meyer, 2010). Yet, while new adopters left on their own often experienced a yield decline in the first year, others, who had an experienced CA farmer as mentor had on average an immediate yield increase of up to 40 percent in addition to the reduced operation costs. In those cases the mentor also often leased out the expensive no-till equipment to the newcomer to facilitate the transition. This helped to overcome the cash flow problem caused by the investment into new no-till equipment.

For a farmer starting a new operation or mechanizing or switching completely to a CA system, there would be a significantly lower amount of capital tied up in farm machinery, compared to a conventional operation. Considering the other savings, for example in tillage equipment, the overall investment requirements for complete replacement or new mechanization programmes can be reduced by 50 percent compared to tillage-based systems. This is relevant, for example, in the former Soviet Union states which after independence were left with mostly obsolete machinery in need of complete replacement. In Africa, where new agricultural mechanization programmes are under way in many countries, the improved economics of CA mechanization could also increase the feasibility and viability of such programmes. The reduced requirement for farm power, i.e. tractors, considered a threat by the tractor manufacturers, can also be an opportunity. It could facilitate opening up new markets which so far have been ignored by farm mechanization by making farming more profitable and the investment in machinery more accessible. In this scenario, service provision by well trained and equipped CA mechanization providers could play an important role.

10.4 OUTLOOK AND PROJECTION

10.4.1 Enabling policies

Due to the benefits of CA in combining a high output intensive production with sustainability and improved environmental services, policy makers are becoming increasingly interested in harnessing the potential of sustainable farming systems such as CA. Yet, for its successful introduction and up-scaling in a country, the availability and accessibility of equipment and machinery for CA is often one of the biggest impediments. Suitable policies are needed to facilitate farmers' access to capital and even directly subsidize the cost of the equipment and machinery to reduce the investment risk for early adopters. This "subsidy" could be justified as payment for environmental services, considering the reduced impact on the environment from safe pesticide sprayers or CA compared to tillage-based farming. But even with adequate capital, farmers in many countries would not be able to source suitable equipment. To address this problem the market needs to be stimulated, import taxes on equipment and raw material need to be adjusted to facilitate the import and eventually national manufacture of CA equipment. As long as no national producer of equipment is servicing the farmers, existing suppliers from other countries need to be proactively brought into the country, including facilitating building up dealership and service networks.

In the area of pesticide application legislation, for example in Europe and the USA, is obliging farmers to phase out obsolete equipment and to adopt environmentally friendly technologies, for example for drift reduction or for avoiding point source pollution resulting from handling of spray equipment. Also tractor emissions are coming increasingly under scrutiny with emission regulations in the EU for example.

Mechanization policies, especially in those countries which start from a low mechanization level, as is the case for most African countries, need to be coherent with policies addressing the sustainable intensification of crop production, such as CA for example. This would mean that the standard equipment supplied with a tractor would not be the plough or the disk harrow but a no-till seeder. Also the reduced farm power requirements under CA need to be considered when planning a national mechanization strategy and the associated investment cost.

Ultimately, it must be recognized that a behavioural change in all stakeholders will need to be encouraged and facilitated to help the changeover to sustainable and environmentally friendly farming systems. This includes the roles and competences of the key national extension, research and education institutions, the government departments, development agencies and donors that support them, as well as the private sector including farmers and farm managers who have an important role to play in innovation processes, and input supply markets including for equipment and machinery.

Farming concepts like CA are knowledge intensive and include many new aspects and those who promote or practise them require training and practical experience. In the case of farmers, an opportunity to test, learn and adapt is necessary. Government supported mentoring programmes can facilitate the uptake of CA significantly. For extension and NGO staff, practical training is necessary in alternative mechanization technologies. Similarly, in universities and national and international research institutions, there is a need to include training and research not only on CA-related agronomy and cropping system management at the field, farm and landscape level, but also for pesticide application technologies which, despite its importance, is a frequently neglected issue.

10.4.2 Scenarios for future development

CA adoption in annual crops around the world has grown from some few hectares in 1970 to 110 million hectares in 2009[36], which represents about 7 percent of the total global cropland. Although the distribution and dynamics of adoption are different in different countries, the general pattern of adoption is always an S-shaped curve with a long, slow start, followed by an exponential adoption up to levels of 70-90 percent, after which the adoption rate slows down again. Brazil took about 20 years between the mid

[36] And has grown to nearly 125 million ha in 2012 (http://www.fao.org/ag/ca/6c.html)

1970s and the mid 1990s to reach 1 million ha and increased the adoption in the next decade to about 26 million ha. CA adoption levels in Argentina, Brazil and Paraguay have reached 70 to 75 percent. It is expected that by 2020 the adoption levels will exceed 85 percent in these countries. Western Australia has already reached 90 percent adoption and the adoption wave in Australia is moving east. Likewise adoption levels of over 50 percent have been reached in the Canadian prairies. Adoption in the USA, actually the first country to have significant adoption of no-tillage farming, remains low at 25 percent, mainly as result of non supportive policies. A very steep increase in CA adoption over the last few years has taken place in Kazakhstan, where in only 4 years more than 1.2 million hectares under CA were reached and about 3 million hectares under conservation tillage. Also China has already reached adoption levels of more than 1.3 million hectares and is committed to further expand this area as a priority. Due to the clear government support for CA a rapid expansion in both countries can be expected. A further rapid expansion of CA can be expected in Africa. Although at this point not yet highly visible or supported by statistics of adoption, many African countries as well as regional organizations such as NEPAD[37] have adopted CA as a priority policy issue. Pilot projects have been established and experience gained, from which up-scaling of CA is expected in the next few years. Europe so far has significant adoption in only a few countries, mainly resulting from strong farmers' organizations and local champions or supportive national policies. Overall the policies in Europe are not yet supportive of CA. Nevertheless the global trend of CA adoption is following the national trends observed so far. Also at global level the exponential growth has started with adoption levels increasing over the last decade at rates of 5.5 million hectares per year. A further acceleration of this growth rate can be expected, depending mainly on supportive policy environments. If the global adoption trend would further follow the national trends observed to date, it can be expected that CA in the next 20 years would become the standard way of farming with adoption levels beyond 50 percent.

In the area of pesticide application, to date only the EU has strict legislation which directly addresses the characteristics of spray equipment. In the rest of the world there are a few countries with voluntary standards or regulations, but the vast majority have no clear functional legislation regarding sprayer quality, safety and environmentally friendly use.

10.5 CONCLUSIONS

Considering the current world challenges posed by the increasing demand for food, feed, fibre and biofuel from crop production, ecological and economic sustainability have to be considered in any intensification and productivity enhancement strategy. Hence, innovations for sustainable agricultural

[37] The New Partnership for Africa's Development

mechanization can only be meaningful and effective within the context of sustainable crop production systems, and not in isolation. Conservation Agriculture includes the basic elements of such a sustainable production system, increasing productivity and production while reducing the need for external inputs and the environmental footprint of farming. CA improves the delivery of ecosystem services by agriculture such as water resources, biodiversity and the mitigation of climate change while strengthening the ecological foundation of cropping systems to also adapt to changing climates. CA requires appropriate and very specific mechanization inputs which could be described as "innovations for sustainable agricultural mechanization". Some of the currently used and promoted technologies, especially for soil tillage, will have to be reduced due to their negative impact on the environment and society. The policy support for CA worldwide is increasing which is reflected in the exponential increase of worldwide adoption. Besides CA, agricultural mechanization can address a number of other issues related mostly to the application of agricultural inputs, to reduce or even avoid the negative environmental impacts of intensive agriculture.

This move from conventional tillage based agriculture to no-tillage based CA requires significant changes in agricultural mechanization, which are increasingly recognized also by the industry. Yet, to become fully sustainable, the socioeconomic component of the production system as well as the mechanization structure has to be considered. Improved profitability of farming and farmers' livelihoods form an economic base that allows the mechanization sector to develop and prosper in a sustainable way. In many developing countries, especially in Africa, supportive and guiding policies are required to attract and encourage the agricultural machinery sector to open up and develop markets for agricultural mechanization in general and for CA equipment in particular and to establish the required commercial and service infrastructures. Without this change in the machinery sector, the future agricultural development needs of developing countries for food security, poverty alleviation, economic growth and environmental services cannot be achieved.

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CHAPTER 11

Agricultural mechanization strategies

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ABSTRACT

The need for formulating and implementing agricultural mechanization strategies (AMS) for the development of both the agricultural and industrial sectors of developing countries is discussed. Experiences gained in Africa in various countries since the early 1990s are described. The development of the Regional Network for Agricultural Machinery (RNAM) from the 1970s in Asia is detailed. Its impact on the development of agricultural mechanization and the agricultural machinery industries in its member countries has been widespread and profound because of the timely formulation and applications of AMS.

11.1 THE NEED FOR THE FORMULATION EXERCISE

Other chapters have described a widely diverse range of ways in which agricultural mechanization is being utilized to facilitate agricultural production. It has been observed that in some parts of the world there have been few major changes to the local availability of motorized farm power whilst in other countries, the number of tractors deployed on the farms has risen dramatically over the past few decades. Thus the use of agricultural mechanization as a development tool varies considerably from country to country, a situation which was true not only in the past but is also the case in many countries today.

For change in the use of agricultural mechanization to take place consistently and coherently requires a plan, the implementation of which will normally need certain resources. The manner in which these resources are handled is referred to as a strategy and it is generally recognized that a carefully prepared strategy will normally provide the best chance of success for the resulting plans.

This logic is nothing new and the formulation of appropriate strategies constitutes an important step in the development process. FAO has advocated for several decades the importance of formulating strategies at national level concerning agricultural mechanization in order to avoid costly mistakes in the use of this resource. Although not referred to directly as a mechanization strategy, a specially commissioned study in the late 1970s underscored "*the importance of policy and planning to ensure that mechanization develops in harmony with overall national development objectives*" (FAO, 1979a & FAO, 1979b).

For many years the process was guided by a publication which first appeared shortly afterwards – Agricultural mechanization in development: guidelines for strategy formulation (FAO, 1988). Whilst these guidelines strongly justified the need for the formulation process, they left the *modus operandi* for the exercise very much to the implementers.

Considerable expertise has since been accumulated through the formulation of agricultural mechanization strategies in a number of countries worldwide and in 2010 for instance, such a process was being undertaken by four separate countries in Africa (Cameroon, Niger, Morocco and the Democratic Republic of Congo).

11.2 FORMULATION METHODOLOGY

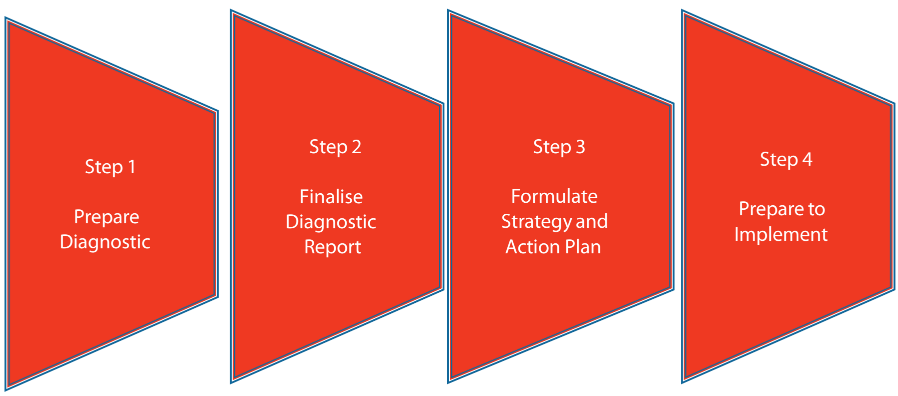
It is suggested that two fundamental and important approaches be adopted during the formulation process. Firstly a fully participatory approach is recommended in order for the views of the multiplicity of concerned actors to be considered. Where possible, these should participate in a series of workshops which will be held throughout the strategy formulation exercise. In some cases this may not prove possible (e.g. some private sector actors may not have the necessary time available for a workshop) and so they should be interviewed separately on another occasion so that their views can be duly considered. This would constitute one of the important activities of the formulation team of specialists who will prepare the bulk of the documentation needed for the exercise.

Secondly, a systematic approach is important given the complexity of agricultural mechanization and its effect on many sectors which themselves are very diverse. The formulation and implementation of an agricultural mechanization strategy does not depend only upon technical aspects but also upon socio-economic, institutional and cultural factors, amongst others. The composition of the formulation team should be designed to ensure that these factors are taken into consideration and typically this will be made up of a highly experienced team leader, supported by specialists in agricultural mechanization, post-harvest technology, agro-economics and institutional arrangements. There may also be a need to enlist the assistance of other specialists such as perhaps in legal matters, cultural affairs, sociology, statistics or other specializations.

There may well be considerable discussion at the start of the exercise as to what should be included in the study and what should be omitted. This can best be resolved by firstly clearly defining (for the purposes of the exercise) the meaning of agricultural mechanization. In most cases this could be described as "*any agricultural operation carried out with the aid of a machine*", be this by hand (such as a hoe or spade), with work animals (a seed drill or cart) or powered by a tractor (a plough) or an engine (a grain mill). It would also normally be advisable to further stipulate some other limits. For instance it might be considered convenient to **include** pump sets and irrigation equipment but to **exclude** pumping stations and their equipment on typical large-scale irrigation schemes. One might also **include** grain mills, graders and storage equipment on or near the farm but **exclude** the equipment at large-scale storage and processing centres. One might further **include** all tractors used for agricultural purposes but **exclude** those used for other purposes such as for refuse collection or civil engineering works. Agricultural mechanization will also encompass the equipment itself, including its fabrication and distribution to the farmer. The precise definition could well be country specific and should be decided at the outset of the formulation process.

The methodology for the formulation process comprises four major steps as shown in Figure 11.1. Once the exercise has been launched at the inaugural workshop, the first phase is undertaken by the formulation team who, each within their particular specialization, perform a thorough analysis of the situation. A second, fully participatory workshop is then held to gather the views of the participants regarding the current situation. This can conveniently be conducted by three discussion groups working in parallel. The group members may be conveniently chosen as representing "**the offer**" comprising the manufacturers, dealers, blacksmiths, repair mechanics, "**the demand**" represented mainly by the farmers and "**the institutional support**" with members drawn from the respective ministries, development partners and non-governmental organizations.

FIGURE 11.1
The progressive steps in the formulation of an agricultural mechanization strategy



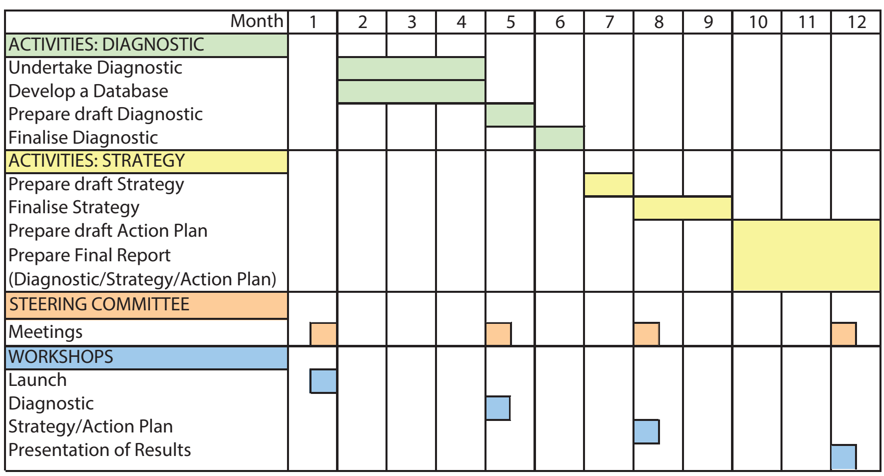
The results of these discussion groups and the reports of the formulation team are then consolidated during the second phase to prepare a comprehensive report describing the diagnostic of the current situation.

The third step comprises the formulation of the agricultural mechanization strategy and corresponding action plan. For a strategy to be successful, it is essential that it provides a response to a clearly expressed need and as confirmed by political will. It must accordingly be aligned with national development policies and goals. The strategy will very much depend upon the desired objectives and the definition of these forms the basis for study during the third participatory workshop. Inputs and advice offered by the project Steering Committee can also be very valuable at this stage.

Once the objectives become clear, the agricultural mechanization strategy can be formulated and an action plan outlined. The plan can be further developed during the fourth and final step of the process when a portfolio of project profiles can be prepared. It may also be possible to prepare more detailed project documents under some circumstances hence the importance of close interaction with potential donors, institutional personnel and other potential collaborators during the eventual and later implementation phases. The step is completed with the presentation of the results at the final participatory workshop.

The overall programming for these four steps, the workshop and the Steering Committee meetings are illustrated in Figure 11.2. An overall timeframe of between 12 and 18 months for the complete formulation exercise will normally be sufficient.

FIGURE 11.2
Typical Work Plan for formulating an agricultural mechanization strategy



11.3 FORMULATION EXPERIENCES

11.3.1 Africa

The first country in Africa where an agricultural mechanization strategy (AMS) was formulated with FAO assistance was Lesotho, a small mountainous country where much of the male farmer population tended to be absent for long periods while working in the mines of neighbouring South Africa ("retrenchment" however reversed this situation in the 1990s). It was a very special case, but a country where a comparatively high percentage of the farmers used the government-provided mechanized services for soil preparation. It is one of the few countries where public sector mechanization services are still available, although on a reduced scale and indeed the mechanization scene continues to be a source of concern.

A very detailed mechanization study was undertaken in Malawi in 1992 (Morris and Bishop, 1992), and in the same year the Ministry of Agriculture in Kenya undertook a strategy formulation exercise. Other formulations were conducted in Sudan (1995), Guinea (1996), the Democratic Republic of the Congo (1997) and Burkina Faso (1998). A start was also made in Ghana in 1994, although this only reached the stage of a diagnostic of the current situation and a preliminary discussion workshop (FAO, 2009).

In all of these countries the agricultural mechanization scenario has since changed considerably; however, it is less clear if this has been influenced to any significant extent by the mechanization strategies that were then formulated.

The cumulative experiences of this work were brought together in two concisely written papers published by the Agricultural Engineering Branch (AGSE) of FAO. The first of these lays emphasis on the important but separate roles that need to be identified for the government on the one hand and the private sector on the other (FAO, 1997a). This emphasizes that in order for the agricultural machinery sub-sector to be sustainable, the strategy and action plan must ensure that all actors are subsequently able to make a livelihood from their businesses, be they farmers, retailers, fabricators or importers.

The second paper outlines the steps that can be taken during the formulation process (FAO, 1997(b)). Once the idea is expressed that a mechanization strategy formulation exercise might be beneficial to the agricultural sector, the process will normally commence with a workshop to ensure that the principle actors and interested parties are able to express their views concerning this perceived need. Funds will need to be allocated and this initial workshop could be invited to propose members for a steering committee to oversee the subsequent activities. A thorough diagnostic will then need to be undertaken and on the basis of this, a strategy outlined and prepared as a draft report for presentation at a second national workshop. The final strategy document would then be prepared, incorporating a proposed plan of action.

11.3.2 Asian regional and country experiences

The Regional Network for Agricultural Machinery (RNAM) was organized in 1977 with UNDP assistance and was executed by the Economic and Social Commission for Asia and the Pacific (ESCAP). It was a networking project of eight Asian countries for regional cooperation and exchange of hard technologies or prototypes, experiences, design, development, testing, evaluation, local manufacture and popularization of agricultural machinery as well as technical information on formulation of AMS. RNAM primarily aimed at increasing the level of mechanization in each participating country to improve farmers' income through a national network of public institutions and private sector organizations including the associations of agricultural machinery manufacturers and distributors as well as cooperatives and other farmer groups.

The original country members were India, Indonesia, Islamic Republic of Iran (Iran), Pakistan, Philippines, Sri Lanka, Republic of Korea (Korea) and Thailand. Other Asian countries including Bangladesh and Nepal joined RNAM in 1987; the People's Republic of China (China) in 1990 and Vietnam in 1994. Each member country had a designated focal point institution, called the National Institute (NI) involved in mechanization activities of the country, including AMS formulation.

RNAM had been advocating to its member countries through their respective NIs and assisting them in AMS formulation since the first phase (1977-1981) as well as providing catalytic assistance in impact studies up to the fourth phase (1987-1991) and beyond until ESCAP expanded RNAM into the UN Asian and Pacific Centre for Agricultural Engineering and Machinery (UNAPCAEM) in 2003. ESCAP/RNAM published the member countries' AMS statements in 1987 and an update in 1993.

One of RNAM's initial sub-programmes was the formulation of the national AMS, which was designed to be implemented through a National Network (NN) of institutions and organizations under the coordination of the NI. RNAM encouraged the establishment of a national committee, which was generically called the National Farm Mechanization Committee (NFMC) as an advisory body to the national planning authority pertaining to agricultural mechanization. The NFMC was to be headed by a senior officer in the agriculture ministry. Called by a different name in some of the member countries, the NFMC was composed of representatives from government agencies with activities related to agricultural mechanization and from private sector organizations, particularly those of farmers and machinery manufacturers and distributors. The three elements, namely, NFMC, which had advisory function, the NI which served as the secretariat of NFMC and the NN, which implemented the approved strategies in coordination with the NI, together comprised the country institutional infrastructure for coherent formulation and implementation of its national AMS as approved by the national economic development planning body.

In 1980, ESCAP commissioned a review of the existing policies and strategies in seven of the original participating countries by two experts, one from FAO and another from the Asian Development Bank. The survey resulted in the publication of "Guidelines for Agricultural Mechanization Strategy and Development," which became the principal reference for each NFMC in formulating its own country strategies (Gifford & Rijk, 1980).

RNAM emphasized the strengthening of the NFMC as it had a key role in formulating AMS. It organized three regional workshops on policies and strategies, two of which were held in Korea, the first in 1983 and the second, a training workshop, in 1986. The third workshop was held in China in 1990.

RNAM chose Korea as an ideal venue because it served as a successful model for formulating pragmatic policies and strategies and in effectively implementing them. Korea started doing so during the mid-1960s when it was still using manual labour and animal power in agriculture and has sustained its efforts through the 1970s when it started industrializing its economy. Realizing the emergence of second-generation problems of labour shortage brought about by rapid industrialization, Korea further intensified its efforts in AMS formulation and implementation. In 1979, it promulgated the Mechanization Promotion Law which embodied well-defined policies and strategies not only to cope with possible food insecurity but also to make agriculture more productive and less stressful for the older generation who were left behind to attend to farming. The youth migrated to the urban areas for better-paying jobs than farming. The Mechanization Promotion Law enabled Korea to fully integrate its agricultural machinery research and development activities with private sector machinery manufacturing and commercialization, institutional training and extension programmes, supply and after-sales services, inspection and notification (machinery testing) and funding in its development plans.

The first regional workshop in 1983 enabled the participants to take stock of the existing policies and strategies in their own countries and to draft suitable proposals to their respective NFMCs using the RNAM guidelines in AMS formulation and learning from the Korean experience.

The second regional workshop in 1986 enabled the participants to exchange country experiences in AMS formulation and implementation during the three years since the first workshop even as RNAM had been reminding the NIs of the need for follow-up activities and including in their country reports the status and problems encountered for presentation at the Technical Advisory Committee (TAC) meetings. The reporting responsibility motivated the country participants in the workshop to take stock of the status of the AMS formulation, the impact of any of the strategies in increasing the level of agricultural mechanization and the lessons learned from the experiences of other member-countries for adaptation in their own exercises. Korean resource persons and a consultant whom ESCAP/RNAM commissioned assisted the participants in that training-workshop to further polish their knowledge in AMS formulation and implementation. Back in their respective countries, the workshop participants would be playing a major role in AMS formulation or becoming resource persons themselves in the exercises.

Apart from the presentation of country progress reports, the workshop activities consisted of drafting strategies for certain aspects of mechanization under the guidance of resource persons from FAO and the host country. Participants learned first hand from visits to government planning bodies at various levels, research institutions, mechanized farming areas, machinery factories and farmers' organizations, particularly the cooperatives and group farming schemes that have worked effectively in Korea.

The country draft proposals and the reports were in turn used as working papers for national workshops organized by the NFMC in each country. Participants and observers in such national workshops varied from country to country but generally included representatives from the national players in agricultural mechanization such as academic and research institutions, lawmaking bodies, ministries of agriculture, trade and industry, public works, education and training, budget and finance and economic development planning body, associations of banks and agricultural credit facilities, machinery manufacturers and distributors and farmers. The NFMC also invited consultants in related programmes and projects especially those with assistance from FAO and other relevant international development agencies. RNAM also provided catalytic assistance to the NIs in undertaking impact studies as follow-up actions after the formulation and implementation of their AMS.

The NFMC then presented the results of national workshops to the policy and decision makers for action and implementation in the form of programmes and projects and possibly supporting policies as well as declarations and, as in the case of China and Korea, promulgation of mechanization laws. In effect the national workshops provided opportunities for those whose interests would be affected by any final decisions to state their views. After the strategy document became official, the NFMC instigated a periodic review and evaluation mechanism for updating the strategies. Thus, AMS formulation was a continuous and dynamic process, of which the roles of the NI as catalyst and initiator and the NFMC as the intended formulating, recommending and monitoring body, were critical for the effectiveness of the exercise.

The NFMCs in China, India, Korea and Thailand had been among the more active ones. Their enthusiastic pursuit of AMS probably contributed to their progress in mechanization. Some of the critical and conflicting issues that hindered AMS formulation were about subsidies proposed by farmers and suppliers of machinery, which economic planners tended not to support as a matter of policy, reduction in tariffs and duties on imported parts and raw materials, which the finance body tended to block perhaps because of revenue contractions, and the promotion of local manufacture of machinery with corresponding protective tariffs and incentives, which machinery importers and traders tended to oppose. Similarly, academic and research institutions tended to veer away from adaptive design of simple and low-cost machinery proposed by farmers because of the lack of creative challenges for graduate students to use as thesis research material. Debates on these issues and on the fundamental question of whether to mechanize or not by the decision makers have been hindering the progress of mechanization development in some of the member countries. Strong political will resulting from awareness by the decision makers of the advantages of agricultural mechanization is crucial to the success of AMS formulation and implementation and RNAM considered that a dynamic NFMC, supported technically by the NI was crucial to making progress. China, Iran, Korea and Thailand have advanced well because their NFMCs addressed such issues.

One year after the second workshop, RNAM compiled the outputs of AMS formulation and the relevant policies of the participating countries along the following lines: (1) general mechanization policy directions, (2) R&D, (3) manufacturing, supply and marketing, (4) financing and credit and (5) education, training and extension (ESCAP/RNAM, 1987).

The third workshop in 1990 enabled first hand observation of the effects of the transformation of China from a centrally planned to a market-oriented economy. China served as a perfect venue for the workshop in the light of its dramatic developments brought about by systematic planning (after the Cultural Revolution) to achieve certain milestones in technological development, trade and utilization of agricultural machinery. China was eager to share its experiences with the RNAM member countries. Notable was China's resolute development of its agricultural machinery manufacturing industry along with fertilizer and seed production to support agricultural production. Just like the other member countries China, since 1949, has aimed at self-sufficiency in food as a primary concern owing to its burgeoning population and frequent natural calamities. It has felt an urgency to improve agricultural inputs, increase output and improve household income. China had trial and error experiences in terms of its mechanization development which underwent a tumultuous process of decision making for lack of experience during the early period. Without the benefit of systematic AMS formulation, it had made costly mistakes (Tam, 1985 and Stavis, 1978).

In the China workshop, the participants and resource persons from the Department of Construction and Agricultural Machinery (NI in China), a tractor research institute, a university and a diesel engine manufacturer, discussed issues affecting agricultural mechanization policies and strategies. Topics included the following: (1) import-export regulations, (2) local machinery manufacture, (3) availability of credit facilities to farmers and manufacturers, (4) affordability of agricultural machinery, (5) after-sales services by machinery traders, (5) labour and employment, (6) farm gate prices of agricultural produce, (7) energy costs, (8) socio-economic and technological issues and (9) prevailing social systems/institutions. They also had one-on-one discussions that were helpful to them in getting ideas for proposed provisions in their country AMS. Then they presented their proposed revised AMS to the other workshop participants for further exchange of related ideas and experiences.

FAO and RNAM have emphasized that the NFMC is not a policy-making body; rather, it bases its recommendations on the national policies, usually pertaining to economic planning by a high-level body attached to the office of the executive branch of government. However, the NFMC may recommend certain policy statements in support of the strategies formulated for effectiveness in achieving certain objectives. India, Indonesia and the Philippines had policies of selective mechanization, that is, its introduction should result in no net labour displacement or be coupled with livelihood-generating projects or activities.

Member countries with viable mechanization strategies generally had an economic environment characterized by shortage of farm labour, fairly high farmer or rural family income due to high farm gate prices of produce and reduced costs of inputs like seeds and fertilizers. They also had, among other industries, a generally viable and highly competitive local machinery manufacturing industry that supplies quality machinery to farmers at affordable prices. They also have a well-informed farmer population regarding modern methods of farming.

The formulation of AMS is dynamic and should be reviewed periodically to assess its relevance or applicability to current situations. Table11. 1 summarizes the general policy and strategy directions in the RNAM participating countries in 1987 which they updated in 1989/91.

During the four phases of RNAM with UNDP assistance (1977-1991) the foundation and institutional infrastructure for AMS formulation was laid. During the period 1992-2002 when RNAM operated at ESCAP because of limited funds, the member countries had continued to review their AMS statements and determine their impact on the mechanization of crop production and processing along with its contribution to economic progress and development. There was discernible impact in India, Korea, Pakistan and Thailand (ESCAP/RNAM, 1993). The mechanization of rice production, the staple food in Asia, has been the subject of AMS formulation by the RNAM-member countries. In Korea, rice production is 100 percent mechanized using engines. Thailand is approaching the same status propelled by its exportation of rice.

While the trend in the increase of agricultural machinery in the member countries varied from country to country, a part of that trend may be attributed to the impact of the NI and the NFMC. It can be discerned that

TABLE 11.1
General agricultural mechanization policy and strategy directions in RNAM participating countries, 1987 vis-à-vis 1989/91

Country	1987	1989/91
Bangladesh	Not applicable, Bangladesh joined RNAM in 1987	Expansion of minor irrigation prior to gradual introduction of mechanized tillage equipment No import duties payable on agricultural machinery and equipment, including diesel engines for pumps Increase in public investments
India	Use of higher levels of mechanization (mechanical power technology) which would increase cropping intensity to increase farmers' income	Selective mechanization of agriculture; use of higher levels of mechanization for timeliness of operations Promote liberal use of agricultural machinery which does not displace labour and create serious problems of unemployment Granting of tax rebates and exemption public and private investments in research Complete "Indianization" of locally manufactured tractors, power tillers and self-propelled combines Compulsory testing of tractors, combines, power tillers and engines prior to large-scale manufacture Government subsidy for the purchase of tractors, implements, pumpsets, sprinklers, drip irrigation systems, for electricity for agricultural purposes; for the installation of biogas plants, and for the rectification of pump sets for irrigation purposes
Indonesia	Mechanization to be supported by making available appropriate, efficient, and low cost machinery Introduction of higher levels of production technology in transmigration areas Mechanization requirement in Java to focus on post-harvest handling, processing, irrigation and pest control.	Selective policy of agricultural development in specific/well defined areas and considering the various levels of mechanization needed Efficient utilization of agricultural machinery Requiring local manufacturers to utilize local components for assembling diesel engines, single-axle hand tractors, mini-tractors, rice polishers and pumps Control on importation of spare parts, inputs and machinery
Iran	Shift from oil-based to diversified economy; agriculture to play a major role to achieve the goal Promote appropriate levels of mechanization to enhance productivity, production and farmers' income Encourage local manufacture to achieve self-sufficiency to the maximum extent possible; importing only those components which cannot be locally produced. Increase mechanization power level to 0.9 hp/ha during the next 10 years	Increase the level of farm mechanization with the objective of attaining an economy that is based on agricultural business Increase the utilization capacity of tractors from the current 450 h/y to 700 h/y considering the country's favourable climatic conditions for crop production Self-reliance in the local manufacture of tractors, other agricultural machinery and implements; utilization of locally available raw materials, especially steels

Country	1987	1989/91
Nepal	Not applicable; Nepal joined RNAM in 1987	Emphasis on achieving self-sufficiency in the production of agricultural tools and implements appropriate to local conditions Identification of appropriate machinery to increase agricultural productivity and cropping intensity without displacing labour Exempting farmers from duties and taxes on imported and locally produced agricultural machinery
Pakistan	Phasing out of bullock based farming in favour of mechanical powered farming using tractors which will be manufactured locally Encourage greater participation by private sector in development Encourage custom-hiring of all types of machinery	Enhance large-scale modernization and mechanization using tractors to speed up cultivation, sowing, spraying, harvesting and post-harvest operations Enhance the use of machines for the commercialization of farming, i.e., not as a tradition but as a form of business enterprise Privatization of all tractor manufacturing firms thereby enhancing local manufacture of tractors Exempting imported raw manufacturing materials from duties Extending subsidies for the installation of diesel/ electric tube wells; subsidy for hiring earth moving machines for reclamation and development of waste lands and crop protection machinery; subsidy for deep tillage implements and newly developed machines by research institutions during their introduction period
China	Not applicable; China joined RNAM in 1990	Encourage private ownership of agricultural machinery Constant readjustment of rural industrial structure, developing trade services in rural areas and improving agricultural enterprises in towns and villages to avoid labour displacement due to mechanization and in order to utilize existing/available labour, especially in the rural areas Strict limitation on the importation of goods, raw materials and technology Enhance local manufacture of agricultural machinery for export
Philippines	Encourage mechanization and develop related programmes that promote optimum use of labour or increase productivity rather than displace labour Support local production of appropriate farm tools and equipment Create/increase agro-based employment in the rural population, particularly the landless workers; encourage the creation of agro-industries Further development and dissemination of post-harvest technology	Equal governmental support for all levels of mechanization, i.e., mechanical, manual and draught animals Extending credit and financial assistance to farmers and resettlers for the purchase of agricultural machinery Development and extension of agricultural machines and equipment appropriate for small farms and which could be locally fabricated.

Country	1987	1989/91
Korea	Promote mechanization to alleviate farm labour shortage while ensuring maximum and economic utilization of agricultural machinery Extend the supply of good quality agricultural machines Strengthen after-sales services Expand training facilities and programmes	Restructuring of the agricultural machinery industry. Develop and promote use of more efficient and high level/automated machines Organize more mechanized farming groups(MFGs) and entrusted farming corporations (EFCs) Improve and strengthen after-sales services of tractors, rice transplanters and combines as well as extension. Training programs for farmers and other users of agricultural machinery Emphasis on balancing the volume of exports of agricultural machines
Sri Lanka	Emphasis on mechanization of non-irrigated and rainfed area for increased crop production and productivity Exclude undesirable imports of agricultural machinery Promote the use of labour-saving devices which will not displace labour	Increasing cropping intensity and extending areas under cultivation using inputs like agricultural machinery Extension of special credit schemes to newly resettled farmers for the purchase of agricultural machines Introduction of appropriate agricultural mechanization technologies provided no labour displacement problems are created Protecting locally manufactured machinery by taxing imported equivalent items like pumps and sprayers
Thailand	Increase efficiency in agricultural production Make the unit production cost competitive in foreign markets Inclusion of farm mechanization policy in the 6th Plan for National Economic and Social Development, 1987-91 Mechanization system to be rationalized; prepare master plan	Increase efficiency in agricultural production and decrease production cost of agricultural commodities in order to be competitive in foreign markets Promote free trade among private entrepreneurs of agricultural machinery to encourage competition and to discourage monopolies and importation. Further strengthen the NFMC, i.e. the NCAM

the trend is greater in countries where the NFMC is active. Table 11.2 shows such trends in the member countries during the recent past as compiled by RNAM (Rahman, 1994).

TABLE 11.2

Average yearly increase in use of agricultural machinery for selected Asian countries as reported by the NIs in the RNAM-member countries, %

Machine	Period	India	Indonesia	Pakistan	Philippines	Korea	Sri Lanka	Thailand
4-wheel Tractors	1971-1980	10	170	11	10	60	30	22
	1981-1990	10	15	18	26	64	2	10
2-wheel Tractors	1971-1980	11	30	90	25	70	n.a.	14
	1981-1990	17	10	9	66	13	n.a.	14
Pumps	1971-1980	15	25	6	33	12	30	8
	1981-1990	17	n.a.	6	21	15	16	7
Sprayers	1971-1980	9	74	95	26.8	17	24	2
	1981-1990	36	11	60	86	227	36	4
Reapers and Harvesters	1971-1980	30	-	50	-	n.a.	n.a.	n.a.
	1981-1990	26	-	33	12	n.a.	n.a.	n.a.
Shellers	1971-1980	15	75	106	28	38	n.a.	30
and Threshers	1981-1990	23	23	19	4.3	5	n.a.	13

n.a. = information not available

Shortage of farm labour is related to industrialization, which is usually the outcome of sound and effective economic development policies encouraging agro-industrial processing and non-agricultural development programmes and projects. Manufacturing and processing, small-and medium-scale enterprises (SMEs), tourism, health and education services, exports, trade and commerce, etc., result in wealth generation for the country and provide attractive remuneration to workers. Indirectly, such policies support AMS and their implementation. Young to middle-aged and able-bodied labour resources tend to migrate from the farm to the urban areas or where factories, commerce and other off-farm work stations have been established, leaving the farm to the production efforts of the older generation that would demand minimal drudgery as well as fast and productive operations. That phenomenon happened in Korea where farm operation requirements could only be satisfied with mechanical-powered agricultural machinery.

Apart from Korea, the parallel and balanced development of industry for wealth generation and agriculture for food production had taken place in Japan and Taiwan and also in some industrialized zones in China, India, Malaysia and Thailand. They belong to the group of countries which have well-developed or progressive mechanization systems and, apart from Japan, they are newly industrializing countries.

Within a country, there may be agricultural zones where farmers have abandoned the production of labour-intensive food crops because of shortages of labour. The farm workers are hesitant because of low economic returns from their labour inputs or lack of competitiveness against other income-generating activities. Yet, with modern agricultural technologies such as improved varieties, organic, conservation and precision farming and biotechnologies such zones can cater to niche markets by using mechanization technologies. Farmers may convert a currently non-financially viable production of a crop into a viable one.

11.4 ANALYSIS

In developed economies, government intervention is usually limited to providing an environment conducive for the private sector to invest in agricultural mechanization technologies. Formal AMS formulation by a public institution is rarely necessary, if at all. The farmers' and manufacturers' associations lobby for their interests to decision makers and legislators. Manufacturers sell their machinery products through advertisements and marketing networks. Public agricultural research and extension institutions incidentally disseminate information about their new developments in agricultural machinery and mechanization in publications, conferences, meetings, demonstrations and exhibitions. In contrast, because of the less developed machinery industry and lower purchasing power of farmers, governments in the developing countries are constrained to focus rural and agricultural development on agriculture with mechanization as a means of achieving the objectives of development strategies.

The general status of agricultural mechanization in developing countries may be defined on the basis of sustained sources of supply of quality agricultural power and machinery and popular use by farmers of such mechanization technologies.

The common indicators of progressive and sustainable mechanization systems comprising elements of engine power and renewable energy sources and their driven machines consist of the following: (1) presence of robust and competitive private local machinery manufacturing industries, (2) active machinery marketing activities with before-sales efforts such as promotions, field demonstrations and operator training (3) available after-sales services particularly those for repair, maintenance, readily available supply of spare parts and training of operators by the machinery manufacturers or distributors and (4) effective public mechanization training and extension programme for farmers and other users of power and machinery in collaboration with local machinery manufacturers.

In the initial stages, industrial and agricultural extension by the public agricultural machinery research and development institutions is usually necessary to disseminate information on new technology developments that have promise as shown by public institutions for testing and evaluation of agricultural machinery. Their activities in technology promotion to farmers help the small- and medium-scale machinery manufacturers market their products.

Korea has the aforementioned characteristics of a developing country mechanization system. Other developing countries may adapt the Korean model considering the salient similarities of small farm size, crops, level of industry development, etc. but their policy and decision makers may have an indifferent attitude toward mechanization. A major deterrent is the issue of displacement of labour which is quite the opposite in Korea because it has a shortage of agricultural labour resulting from its industrialization. Some government policy makers compromise by agreeing to promote selective mechanization or that which results in net labour employment or generation of livelihood activities. After years of such policies, mechanization has barely moved forward and farmers as well as landless farm labourers have remained poor because government decision makers have not had effective policy instruments or incentives that would encourage the private sector to invest in non-agricultural industries or small-scale or medium-scale enterprises and agro-industries to create jobs in the rural areas. While mechanization is not an end in itself, the efficient production of crops is somehow compromised and economic development slowed down. But in spite of the social concern caused by inhibiting mechanization, a preponderance of poor people in rural areas is still the reality. Uplifting the quality of life needs a strategy that should be coordinated with AMS but not necessarily restricting the latter wherever possible.

As shown in Table 11.1, selective mechanization has been a standing policy in India, Indonesia, Nepal, the Philippines and Sri Lanka. In Bangladesh, the Planning Commission, which was responsible for drafting the Five-Year Plans, formulated the mechanization policies and strategies for 1990-1995 without an established NFMC. Although the Commission believed that mechanization was labour displacing, the plans included activities that would encourage selective mechanization such as providing waivers on duties for import of small engines (1-20 hp) to rapidly expand minor irrigation coverage (Wicks, 1993). That strategy was a reaction to the two natural calamities in 1986 and 1988 that killed thousands of people, destroyed properties and infrastructures and decimated the number of work animals. It included also the waiver on quality standards for imported machinery in favour of affordability by farmers[38]. Somewhat unexpectedly, as it was not so planned, the emergency action sparked the development of the indigenous foundry industry and resulted in the local manufacture of diesel engine spare parts with subsequent quality improvements owing to competition and further development of skills by farmers in the repair of engines and power tillers which replaced the draught animals. The success shows that a decisive policy statement may lead to something better but monitoring mechanisms should be in place to get feedback and do mid-course readjustments if necessary or to yet further improve the system that naturally emerged. (For further details of the Bangladesh situation, see Chapter 4 by Scott Justice and Stephen Biggs: Rural and Agricultural Mechanization in Bangladesh and Nepal: Status, processes and outcomes).

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[38] This is a case of overruling the recommendation of the national committee on machinery standards, which the Planning Commission probably saw as impractical or not applicable to the emergency situation. It confirms the observations of Adrianus Rijk (e.g. Rijk, undated) regarding the irrelevance and counterproductive nature of procedures followed by government-established **testing and evaluation** centres and minimum **quality standards** in developing countries. He stated that prescribed standards are difficult to achieve given the level of manufacturing technology or raw material domestically available; they only lead to unnecessary expense and are not required from the perspective of the end-user. In the case of testing and evaluation, the requirements of the different clients are very different and therefore, when a testing and evaluation program is being proposed, it is crucial to establish the purpose of it and understand the requirements of the different clients consisting of (1) suppliers: manufacturers, importers, agents, and dealers who see testing and evaluation as part of the marketing effort for their product; (2) regulators: policy makers who restrict the free supply of machinery through legislation on importation, standards, health and safety, etc.; (3) finance institutions: banks and lenders who have an interest in repayments of loans resulting from adequate quality to ensure that the investment generates the expected cash flow; (4) advisers: extension officers, consultants, journalists of technical magazines who are concerned about the quality and performance of the machinery they recommend and (5) users: farmers, contractors, managers of agricultural enterprises who have to make investment decisions but have little need for technical engineering parameters; for them, it is more pragmatic to evaluate the performance of machinery under realistic field conditions and have its performance, suitability, and (financial) benefits judged by the user himself.

China, in spite of an abundance of labour resources, had a positive attitude towards mechanization as gauged by its deliberate plan of "constant readjustment of rural industrial structure, developing trade services in rural areas and improving agricultural enterprises in towns and villages to avoid labour displacement due to mechanization and in order to utilize existing/available labour, especially in the rural areas".

The introduction of mechanization had been debated in China during the late 1950s with Mao Tse-tung issuing arguments that multiple cropping and intensification of agricultural production would generate labour. Such debates pre-date those that raged among economists and engineers in other developing countries and international agricultural development assistance organizations during the 1970s and early 1980s. By 1958, the strategy for developing China's agriculture stressed intensification of cultivation through increased labour inputs, selective mechanization and tool reform supported by the manufacture of improved farm tools and machinery in local factories. As a general policy, agriculture was organized according to the principles of collective ownership coupled with mechanization, which was low-level as only few standard 15 hp tractors were used (Stavis,1978).

China's mechanization strategy accounts for what in reality results in labour displacement no matter how euphemistically stated (as in the policy of selective mechanization in other developing countries) because the purpose is to save for the farmer the high costs of manual labour with low productivity when using only hand-tool or animal draught technologies. Rather than put a barrier to mechanization, which policy makers agree as beneficial, the decision makers may issue certain other policy instruments and strategies to encourage the private sector to create jobs. A pro-active rather than a laissez faire attitude of planners and decision makers aiming for labour scarcity in the farm will increase farmers' demand for mechanization technologies. They may well formulate strategies and focus efforts in planning for the deliberate creation of off-farm jobs. The planners in Korea resolutely pursued rapid industrialization with an ambitious start of rehabilitating the massive basic steel industry built during the 1960s through grants-in-aid from a consortium of industrialized countries. The move to transform what was then considered to be a white elephant amidst poverty and an agrarian economy spurred economic development through activities in heavy industries like ship building, engine and vehicle manufacturing, construction, agricultural machinery manufacturing with technical assistance and collaboration from Japanese manufacturers. Other metal industries which demanded plenty of labour and employment also in the ancillary and downstream industries created labour shortages in the rural sector.

While the selective mechanization policy may have noble intentions it in effect pre-destines the poor farmer to be the poor employer of the poor landless rural labourer. Both of them are stuck in the rut of poverty with little hope of getting out as has been the case in developing countries for several decades. The promise of the Green Revolution, multiple cropping, increased inputs of fertilizers, irrigation, improved varieties and hybrid seeds have had little impact on absorbing excess labour in the farm probably because of the higher rate of labour entry resulting from high population growth rate. Thus, creation of jobs in labour-saturated agriculture except during seasonal peak labour demands of planting, weeding and harvesting operations has not coped with the faster rate of labour influx.

Perhaps, because the situation is untenable, it is time for excess labour to move on and engage in other endeavours which government agencies concerned may plan on training them for. This could include technical and business skills training for non-agriculture jobs or assisting them with seed capital loans to engage in SMEs. Economic planners may encourage the domestic private sector and foreign investors to set up industries in the rural areas by planning on building suitable rural road or rail links and power facility infrastructures as well as security. Such plans could be part of the AMS.

Sometimes, the implementing agency or body creates self-imposed barriers or restrictions because the solution to their problems is outside their mandate. Creativity in finding solutions, which sparked the development of advanced countries, is fundamental and in many cases may better supersede rigid bureaucratic procedures.

In contrast with the five Asian countries mentioned above, which have selective mechanization policies, Iran, Pakistan, Korea, Thailand and Vietnam do not and appear to have progressed faster in mechanization development. Bearing in mind that their common ultimate goal is food security, they are achieving it without, or in spite of, controversial social displacement issues. Thailand and Vietnam have developed capacities to export rice through mechanization in spite of labour surpluses.

Emulating China's attitude as an example, the NFMC in each country may consider coordinating or collaborating with efforts to promote and develop the tourism industry in areas of good potential. The NFMC may include it in the AMS formulation and even assist in implementation through information on how to access credit capital. A successful strategy for employment and livelihood generation in the tourism sector in rural areas may also mean that mechanization will move forward.

Like the other developing countries, Korea was at the hand tool and animal-draught mechanization technology level during the 1960s but has advanced to engine-powered mechanization technologies since the 1970s because of the political will to pursue industrialization, which created some shortages in agricultural labour supply. Yet it continues to pursue breakaway advancements in mechanization technologies through sustained research and development of high-technology mechanization using electronic controls, computers and global positioning systems (GPS) for automation of farming operations and precision agriculture. Such modern technologies applied to agriculture are aimed at more efficient, productive and profitable farm operations (even undertaken by aging farm workers) than before.

Part of the progress of Korea may be attributed to its systematic planning and pursuit of the goal of achieving annual increases in numbers of mechanized farms and farming operations with further outlook for the long-term programme. The private sector industries responded to the favourable environment primed by government subsidies for the purchase of machinery as recommended by the pro-active NI. The mechanization progress of Korea, which may be attributed to a sound AMS and well-organized institutional infrastructure, is documented in various country reports presented in the annual TAC meetings and workshops of RNAM as well as in the subsequent Technical Committee meetings and workshops of the UNAPCAEM (Choe, 2003 and Kil, 2003).

Thailand is another RNAM-member country that has benefited from systematic AMS formulation under its own environment of economic development. There has been continuity of well thought out institutional programmes in spite of changes in administration officials.

The pattern of mechanization progress of China appears to follow that of Korea. Although China had years of head-start in terms of local manufacture of agricultural machinery, only when it opened its market to the outside world did it start progressing the way that Korea did. The recent policy of China's government toward increased privatization of the state-owned agricultural machinery and ancillary industries is a further indicator of following Korea's path of development. Even before China formally joined RNAM in 1990, it was already an active and enthusiastic learner of RNAM activities through attendance as invited observer in the TAC and GB meetings as well as through participation in some RNAM activities like providing the prototypes of machines as early as in 1978 for the testing, evaluation and adaptation of rice transplanters. While learning from RNAM, China also shared its experiences in AMS formulation in 1990 when it hosted the third workshop on policy and strategies. Having been a keen observer of the activities of RNAM in AMS formulation and an eager implementer of its own formulated strategies, China progressed fast in its own mechanization technologies.

India with its mix of mechanization levels and the industries to support each level also has the potential of advancing fast towards the path followed by China and Korea. As one of the largest producers of 4-wheeled tractors in the world it has a high degree of industrialization in machinery manufacturing. Perhaps it is hindered by a large farming population cultivating a small area for crop production and for livelihoods. There is no shortage of labour in the highly populated and less industrialized states of India. It has a standing policy of selective mechanization to avoid the negative impact on labour and employment.

In the RNAM member-countries as well as in other developing economies, the relevant body in charge of mechanization in the ministry of agriculture plays a significant role in establishing and sustaining an industrial extension system characterized by widespread machinery demonstrations to farmers in collaboration with machinery manufacturers and distributors. The increased awareness and demand by farmers have been imperative and the situation is in contrast to that in advanced countries where the private manufacturers promote their machinery according to the prevailing marketing system and each have their own marketing strategies. In such advanced countries the role of public institutions is mainly safeguarding the quality of machinery through accredited power machinery or tractor testing centres which release test results of random samples from manufacturers or their dealers' inventory and let users evaluate the merits of the machine based on the centre's published data. Large-scale manufacturers therefore become protective of their quality and ensure it by having in-house testing facilities. In developing countries however, the small- and medium-scale manufacturing enterprises do not have elaborate testing facilities but would only roughly test their machines in the field usually for reliability and workability to impress farmers and for durability for competitiveness. This culture has not developed in labour-rich developing countries where farmers or landowners do not have the kind of awareness of the large farmers in the developed countries.

Since its inception in 1977 RNAM has advocated AMS formulation and implementation to its member countries. One of the difficulties in some member countries had been that periodic changes in government decision makers disrupt the continuity of previous programmes and in some cases the NI must start all over again in making the new government and set of decision makers aware of the merits of agricultural mechanization and its role in economic development, particularly in agriculture and industry. Policies could change either way depending on their priorities and in some cases even the country's membership in the RNAM had been questioned because of still inadequate institutional memory in the new leadership. The Agricultural Mechanization Promotion Law, which Korea promulgated in 1979, has been effective in institutionalizing agricultural mechanization, thus providing continuity and defining the relevant mandates of each institution concerned (Choe, 2003).

It appeared that the passage of that organic law was also a key factor in Korea's success because it enshrined the general provisions and guidelines which provided continuity or were not affected by changes in government administration and even those in the NI. The law has resulted in sustained support and improvement of existing mechanization programmes. China also has a mechanization law passed in 2004 and Thailand has a long-established Agricultural Engineering Division of the Department of Agriculture and Cooperatives with continuity of programmes supported in spite of changes in the political environment.

As of 1994, only half of the RNAM member countries (China, India, Iran, Pakistan and Korea) had well thought out plans, though of varying qualities. The other member countries had either not completed the process or had their plans pending endorsement by their legislature or the highest executive office (Rahman, 1994(b)). Some member countries had vague or generalized statements in their plans which might have resulted in ineffective implementation because of a lack of a database with accurate and updated facts and figures.

The AMS document was considered as dynamic and needed periodic review and evaluation as well as adjustments and updating based on current developments. Some NIs had found difficulty or had not been able to convene even an initial NFMC meeting because of inadequate moral and material support from the mother organization. Other NFMCs had only one-time initial or organizational meetings and thereafter had been inactive. Sometimes the reported strategies were more the results of what was going on in the agricultural, industrial or agricultural mechanization system and not really the forward-looking plans which were the intention of the strategy.

Assuming that strategies were well thought out in some aspects of the complicated mechanization system, they might not have worked out because the other aspects lacked the same treatment or were unwittingly made incompatible with the correct ones. The NI might not have detected early warning of failure or incompatibility because of a lack of an effective monitoring system. The periodic meetings of the NFMC would have detected bottlenecks early in their development. Having played the key role in shaping the approval, adoption and implementation of the strategy for agricultural mechanization based on the policy, the NFMC could have also functioned ideally as an oversight body to monitor and report the progress of implementation and achievements obtained against set targets to the higher planning body. If in the course of implementation, some impediments had been encountered, the NFMC could recommend policy instruments, if necessary, to make effective mid-course corrections or adjustments to put the activities on track. Point persons, one in the NI and one in the NFMC, might ensure full attention to the liaison activities relevant to AMS activities.

A reverse-direction planning similar to making a battle plan could be incorporated as part of the AMS reformulation of the strategies as a result of continuous monitoring activities. Like a battle plan, the reverse strategy formulation starts at the end result desired and proceeds toward the starting point for each critical path, each time identifying actual parallel or serial bottlenecks or barriers that may occur. Once identified, the bottleneck becomes the target of another strategy or challenge for creative solutions. In some cases, a proactive attitude is needed especially if the formulated solution may require revision, elimination or replacement of the policy itself. Thus, the NI can focus efforts on finding ways to overcome impediments. The battle plan may then have several critical paths that lead to the start of the unsolved bottleneck. That bottleneck may be critical in the sense that activities in other paths cannot move unless the critical path is solved. In reviewing the forward-direction AMS process, the NFMC may find it necessary to make changes and adjustments. It may help also if the strategists could learn from the principles by Sun Tzu[39] whose book is a required reading in business management courses offered by many advanced universities.

The following are usually the bottlenecks or impediments to mechanization: (1) low purchasing power of farmers, (2) abundance of unemployed or under-paid rural labour, (3) small landholdings or farm sizes, (4) high cost of imported machines, (5) substandard quality of locally manufactured machines and (6) government policies that create an environment not conducive to the private sector for investing in mechanizing agriculture in terms of local machinery manufacture and providing goods and custom hire services of machines.

Korea and Thailand became ready to implement their respective strategies for agricultural mechanization given their prevailing progressive economy. It just shows that to attain progressive mechanization, the country concerned must have the economic environment, particularly a robust machinery local manufacturing and machinery supply industry, among other indicators. It does not mean however, that AMS formulation is an exercise in futility when such an environment is absent in the country. It can be that the environment is present at least in some areas or sectors of a country but because there is no coherent AMS, development can only proceed by trial and error. For example, before 1978, China had a fast developing machinery manufacturing industry resulting from the efforts of its leaders with resolve to develop it to achieve progress in mechanization, which in turn would support agriculture to the point of achieving self-sufficiency in food. Only after it opened its economy did the manufacturing industry make an impact on mechanization and agriculture. The socio-economic environment changed after 1978 (see Chapter 6 on China by Maohua Wang: China: Development of Farm Mechanization and the Agricultural Machinery Industry).

Although not an end in itself, the establishment and active work of the NFMC in each country as recommended by RNAM was among the intermediate impacts that RNAM made in each member country. Although the intensity of impact varied and was in proportion to the response of the decision makers in a country, the NI as focal point and spearheaded by the activities of the NFMC, has been instrumental in developing national policies related to mechanization. Such activities which were sanctioned or were deemed to be in conformity with national policies, dealt with industrial extension to locally manufacture small-sized machinery, to popularize machines among farmers and to promote regional information exchange. In these activities, the NIs collaborated with varying degrees of intensity with

[39] Sun Tzu, who lived about the late sixth century B.C., was an icon in Chinese military strategy formulation. His book, "The Art of War," although a military treatise, contains principles applicable to everyday living conflicts, business tactics and national development problems like "wars" against hunger and food insecurity, poverty, HIV, drug abuse, health abuse, environmental degradation, etc.

the private sector. According to Schantz, 1988, it is the government decision makers that elaborate the mechanization strategy but the private sector initiative is vital for success.

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CHAPTER 12
Agricultural mechanization in development: A donor's view

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ABSTRACT

Farm mechanization can be a major driver of development of the agricultural sector in many countries. This chapter reviews patterns of mechanization in many parts of the world and maps out possible development scenarios. Stimulation of local markets and local machinery manufacture is important and both the private and public sectors have critical roles to fulfil. The activities of JICA (Japan International Cooperation Agency) in farm mechanization are reviewed. They cover countries at various levels of development in Asia, Africa, Latin America and CIS nations in Europe. The chapter reflects on the needs for training and other elements of technical cooperation at all levels, and the opportunities and obstacles facing the promotion of agricultural mechanization in developing countries. Public sector policy on mechanization needs to be well founded and flexible to adapt to the changing needs and growth of the sector in developing agricultural situations.

12.1 THE ECONOMIC ENVIRONMENT AFFECTING AGRICULTURAL MECHANIZATION

The record-high agricultural commodity prices in the first decade in the 21st Century had significant impacts on agricultural production throughout the world. One of the major causes of food price rises is food shortage due to high demand in developing economy giants, namely China and India. These countries share about one third of the world population, and their food self sufficiency is critical for the food security situation in Asia, if not in the rest of the world. In addition, price rises were exacerbated by escalating oil prices that accelerated the demand for bio-fuel as a renewable energy source to supplement fossil energy; and that required changes in land use from food crops to energy source. The situation jeopardized supplies in some food exporting countries and they halted exportation to reserve the products for their own food security. This created a crisis in food importing developing countries which were required to pay more to meet their domestic food demands. There is a critical need to effectively and efficiently produce more food to meet the future demand to feed the increasing world population. However, at the same time, it is important to realize that more equitable distribution of current food supplies will go a long way to alleviating world hunger.

Another effect of high food prices is that they generated more income for farmers and producers, and they have been a driving force to investing more in agriculture, especially in agricultural mechanization. The increases in food prices have also tended to increase labour costs and this led to more rapid agricultural mechanization, while the increase in oil prices accelerated costs of some agricultural inputs and farming operations. A rapid increase in machinery population was observed in many Asian food exporting countries including China and India. In order to reduce labour costs, bigger machinery is employed in many countries where a certain level of mechanization has been achieved. In addition, energy saving technology to reduce the cost of farming operations became more popular in mechanized countries especially in South America. The question we now ask is: what are the impacts of high oil prices and food prices in food importing countries particularly Sub-Saharan Africa (SSA) ?

The trends in agricultural mechanization development have followed a certain pattern in both developed and developing countries. As an indication of the level of mechanization, the numbers of tractors used in selected countries is shown in Table 12.1. The mechanization situation of selected countries is reviewed below.

TABLE 12.1
Tractors in use in selected countries ('000 Units)

Country	1965	1970	1975	1980	1985	1990	1995	2000	2005	2007
Japan	60	278	721.09	1 471.4	1 853.6	2 142.2	2 123	2 027.67	1 910.7	1 877
China	73	126.4	346.8	747.9	861.4	824.1	685.2	989.1	1 410.6	2 063.5
Thailand	5	7	7	18	31.4	57.7	148.8	439.1	780	830
India	48	100	227.7	382.9	607.8	988.1	1 354.9	2091	2 789	3 149
Kazakhstan	-	-	-	-	-	-	170.1	52.1	44.1	40.2
Egypt	14.5	17.3	21.5	36	51.9	57	89.1	86.3	98.1	102.6
Côte d'Ivoire	0.7	1.4	2.2	3.7	4.3	4.8	5.3	8.4	9.3	9.4
Nigeria	1	2.9	5.7	8.4	11.1	13.9	16.7	19.4	23	24.8
Kenya	5.7	7.3	6	6.5	9	10	11.2	12.2	13.4	14
Tanzania	16.8	17	13.6	10	8	7.4	7.5	16.3	21.5	21.5
U S A	4 800	5 270	5 120	4 726	4 670	4 426.7	4 344.1	4 503.6	4 470.9	4 389.8
Honduras	0.4	1.7	2.8	3.3	3.9	4.5	5	5.2	5.3	5.3
Brazil	114	165.9	323.1	545.2	666.3	728.8	791.2	797.5	789.6	776.9

Source: FAOSTAT-Agriculture website

Japanese agricultural mechanization, observed historically, is unique because the majority of small-scale family farming units were completely mechanized within 15 years (from 1955 to1970) mainly by two-wheel tractors (2WTs). Since about 1970, walk-behind 2WT farming has been shifted gradually to ride-on tractor farming (Sakai, *et al*. 1986). One of the causes of reduction of tractor use after the 1990s is the increased farm size made possible by the larger sized tractors used by hire services in order to reduce their own machinery costs and those of their clients. Following the appreciation of the Yen, Japanese tractors have lost their competitiveness in foreign markets. However, second-hand power tillers and small tractors in good condition are exported to Southeast Asian countries, because the tractors are frequently replaced with new models in Japan. The Japanese law to promote high performance machinery made to high standards helped this process.

The USA has the most intensively mechanized agriculture. The tractor population has been gradually reduced to 4.39 million units in 2007 from a high of 5.47 million units in 1966. The total arable land reached a peak of 189 million ha in 1969 and maintained this level until the early '90s before it declined to 170 million ha after 2000. One of the main causes of the reduction in numbers is the use of high horsepower tractors employed to increase labour productivity. A similar trend is observed in Brazil although its arable land area is still increasing. In addition, the zero tillage method using cover crops has been mainstreamed in South America and this allows a vastly increased efficiency of machinery use.

Asian countries such as China, Thailand and India are increasing tractor use and numbers; in fact these three countries started tractor production and exportation in collaboration with foreign manufacturers as early as the 1970s. There are about 8 000 farm machinery factories in China, and more than three quarters are small in size and capacity. It is expected that the number of factories or manufacturers will be reduced by competition, because the tractor size is rapidly increasing, and machine quality is improving. The number of tractors manufactured in India is increasing and the market is expanding to other countries and continents following the aim of China. The market for four wheel tractors is growing in Thailand, and 2WTs are exported to neighbouring markets such as Cambodia, competing against Japanese second-hand machines.

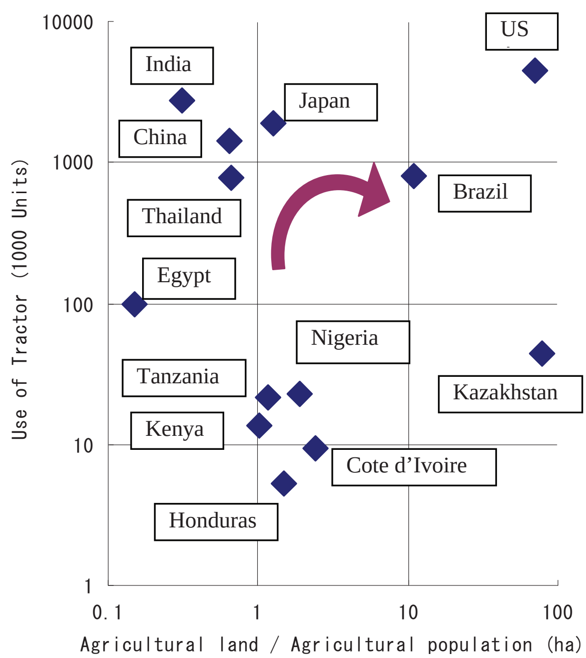
Kazakhstan is one of the Commonwealth of Independent States (CIS) countries which exports agricultural products to other CIS member states. After independence from the USSR, *sovkhoz* and *kolkhoz*[40] were disbanded and consequently cereal production plummeted to less than half of its previous level. Subsidies for purchasing agricultural inputs were removed and there was less price incentive offered to farmers when commodity prices fell after dissolution of socialist production organizations. The number of tractors in use was also immediately reduced. What is required now is a reform of farming organizations as well as the mechanization strategy.

[40] State and collective farms under the Soviet regime. See: http://en.wikipedia.org/wiki/Sovkhoz

SSA countries have generally had very low tractor numbers and this remains the case. During the period of colonization, a certain (limited) number of tractors were imported for the commercial farming sector. After independence, farming was 'Africanized', and animal power was very popular as an intermediate technology in those countries not affected by trypanosomiasis. As a part of structural adjustment programmes, state tractor hiring services were generally privatized (e.g in Kenya in the 1990s).

Taking these points into consideration, Figure 12.1 attempts to indicate the state of mechanization, and its movement, in several countries. One way could be the replacement of human muscle power by draught animal or engine power. Initially heavy work like soil tillage was usually the first to be mechanized, and tractor use was increased where mechanization was profitable. For smallholder farmers, it is not always easy to acquire machinery and it may not be profitable to use machines unless they can be accessed through a hire service provider. As the economy grows, tractor power tends to increase, because labour costs tend to remain high if small tractors (or draught animals) are used. As the tractor size rises, the area covered will also need to increase to retain the profitability of mechanized farming operations; and so the mechanization tendency is from left to right as indicated by the arrow in Figure 12.1.

FIGURE 12.1
The movement of agricultural mechanization from small to large scale



12.2 INTEGRATED MARKET OF AGRICULTURAL MACHINERY

12.2.1 Globalization of the agricultural machinery industry

The globalization of the world economy has had a significant influence on production of agricultural machinery, including tractors. The tractor manufacturing companies of developed countries had established factories or companies in their countries of origin; then they started to shift to Eastern Europe, Latin American and Asian countries to capture global markets. For example, Japanese manufacturers started production of 2WTs and other equipment in Southeast Asian countries. At the end of 20th Century, China and India were mass producing agricultural machinery with both domestic and foreign manufacturers (operating under licensing arrangements) for domestic use and for export. Agricultural machinery production and usage is expanding to include emerging countries. If these countries with rapidly expanding economies continue to supply cheap machines, the market for agricultural machinery will be expanded to less developed countries and this means that less developed countries will be required to import tractors and machinery from emerging countries unless and until their own production capability is built with comparatively lower production costs.

12.2.2 Local needs of agricultural machinery

Agricultural products are irregular unlike industrial products. Except for plant factories and controlled environment greenhouses, agriculture is, in principle, carried out under natural conditions. It is necessary to overcome the difficulties of working with the natural and irregular aspects of farming when agricultural mechanization is considered. Equally important aspects are the economic viability and farm management challenges that are incurred when agricultural mechanization is planned by and for individual farmers. Different groups of people create diverse types and models of farm tools and machines to meet the perceived needs. Standardization may not always be useful for end users if off-standard equipment is regulated and denied access to the market. In a market economy standards may need to be applied to protect users and so, to improve the reliability, safety and compatibility of farm machinery, it may be necessary for the government to apply regulatory actions to standardize the design of machine elements and the materials used in their manufacture. However standards should not inhibit innovation and adaptation to users' needs; it is the manufacturers' responsibility to reflect farmers' needs in their machinery products.

Many countries have research and development institutions for agricultural mechanization to respond to the demand of local farmers. These institutions are the major recipients of machine designs developed by international organizations such as International Rice Research Institute (IRRI) and Africa Rice Center (AfricaRice, formerly known as West African Rice Development Association or WARDA). They have developed relatively simple machines designed for smallholder farmers. These machines have not always been appropriate for some situations because the spare parts and support services supply chains are weak in some countries. Farm mechanization research activities have ceased at IRRI while FAO has scaled down agricultural mechanization as one of the core services of the Rural Infrastructure-and Agro-Industries Division (AGS). The international community is in danger of jeopardizing the future of agricultural mechanization by giving less priority to this vital input.

12.2.3 Utilization of agricultural machinery

The utilization of agricultural machinery is in the agricultural sector while its production is in the industrial sector. Replacing current farming practices with mechanized production is not always the right answer for all farmers. The promotion of agricultural mechanization should be associated with the improvement of those farming practices that are suitable for mechanized farming. The provision of agricultural machinery should reduce production costs, and this is especially true for less developed countries. However this may mean that farmers have to change their farming practices to accommodate mechanization, and this could cause conflicts with conservative farmers. There is a progressive development in South America (and other regions) where conservation agriculture is widely practised to reduce machinery operating costs and soil degradation at the same time. This development is a good example of adapting farming practice to reduce machinery costs, and is now observed in both developed and developing countries where it is applicable. It is always necessary to consider any negative impacts of mechanization when considering its application, economic viability and protection of agro-ecosystems are two vital aspects in this regard.

Historically the farmer-owner-operator has proved to be the key for successful mechanization. However, tractors are expensive for the majority of smallholder farmers and are not affordable unless their use can be shared. In the past it seems that group ownership has failed in most cases if not all. Government-run hiring services were not economically viable or technical successful in many countries. Following the imposition of structural adjustment reforms, many countries terminated their government hire services and in some cases the private sector has taken up the initiative. It is, however, not easy to rapidly shift machinery management from the government to the private sector or farmers' groups. Collective farms in Central Asia are facing difficulties in maintaining farm machinery by themselves. The support from the governments to ensure smooth transition is not always adequately provided.

When agricultural engineers design agricultural machinery they often place too much emphasis on technical issues and work performance. From the farmer's view point, a more important issue is the multi-purpose use of agricultural machinery, increased machine utilization can be a critical factor in better farm management. In Bhutan, most farmers use power tillers not only for soil cultivation but also as means of transportation. The economic performance of power tillers has not been adequately analysed for the Bhutanese farmers to see if future diffusion is viable or not. Research on farm machinery management in developing countries is frequently ignored.

12.3 IMPLICATIONS OF MECHANIZATION FOR JAPANESE COOPERATION

Japan joined the Colombo Plan[41] in 1954 and started its Official Development Assistance (ODA) as a part of its compensation for World War II. Agriculture is one of the major themes of Japanese international cooperation since the beginning of Japan's ODA. The Japan International Cooperation Agency (JICA[42]) was established in 1974 by merging agencies concerned with international development. Since 2008, when it was reorganized, JICA provides integrated programmes using various forms of support such as loan assistance, grant aid and technical cooperation.

12.3.1 Technical cooperation projects related to agricultural mechanization

Agricultural mechanization is recognized as one of the most important factors contributing to the success of the 'Green Revolution'. From the beginning, increased food production was the main purpose of agricultural development cooperation to improve food security. Japan assisted many Asian, African and Latin American countries in the field of agricultural mechanization as shown in Table 12.2. In the last decade, agricultural mechanization projects were implemented at a minimum level, because rural development is more

TABLE 12.2

Japanese technical cooperation projects on agricultural mechanization

Project title	Country	Period	Major contents
Padi Mechanization Training	Malaysia	1970-1975	Training
Central Extension Development Institute	Bangladesh	1975-1983	Mechanization
Jomo Kenyatta College of Agriculture and Technology	Kenya	1980-2000	Education, Research
Agricultural Extension and Mechanization in Kasetsart University	Thailand	1981-1991	R&D, Education
Rice Mechanization Pilot Project	Egypt	1981-1992	Rice mechanization
Centre for Development of Appropriate Agricultural Engineering Technology	Indonesia	1987-1994	R&D, T&E
Academic Development of Graduate Program at the Faculty of Agricultural Engineering and Technology, Institut Pertanian Bogor	Indonesia	1988-1993	Education, Research
Agricultural Machinery Repair & Maintenance Technology and Training	China	1992-1998	R&M, Training
Agricultural Machinery Training Project for Irrigated Rice Cultivation	Cote d'Ivoire	1992-1997	Training
Agricultural Machinery Test and Evaluation	Mexico	1999-2004	T&E
Training Centre Project for Agricultural Mechanization	Morocco	2000-2005	Training
Strengthening of Farm Mechanization	Bhutan	2008-2011	R&D, T&E, Training

R&D: Research and Development, T&E: Test & Evaluation, R&M: Repair & Maintenance
Source: Author, data derived from JICA database

41 http://www.colombo-plan.org/
42 http://www.jica.go.jp/english/

emphasized than agricultural development when the goals are poverty reduction and human security in rural areas.

The projects in Malaysia, Bangladesh and Egypt focused on training and extension activities to improve utilization of agricultural machinery, whilst improving food security through increases in agricultural production remained the highest priority. In Indonesia, an integrated agricultural machinery institute was established through the technical cooperation programme. Capacity for machinery testing and evaluation was installed in addition to the research and development functions of the project. Its design aimed to emulate the Institute of Agricultural Machinery of Japan. A testing and standardization project was implemented in Mexico to improve the regulatory system. A project in China is specifically for training in repair and maintenance due to the high demand from the private sector for maintenance work after the switch to a market economy.

There were several projects implemented with universities in developing countries such as Kenya, Thailand, Indonesia and China. Universities are one of the most reliable organizations in developing countries, and can be effective vehicles for implementing projects on research and development as well as human resource development.

12.3.2 Training courses related to agricultural mechanization

Since Japanese technical cooperation started, Japan has provided training programmes in Japan. Training on farm mechanization was initially aimed at ASEAN[43] countries although the training was eventually for all developing countries. After 1990 the number of training participants from Korea and China were significantly reduced especially for the farm machinery design course due to the unwillingness of Japanese agricultural machinery manufacturing companies to invite them to visit their factories to observe after these countries increase their industrial competitiveness.

After JICA's organizational change in 2003, more people were invited from SSA countries with courses emphasizing human safety. Some training courses are specifically implemented for Central Asia because of the increased demand resulting from the disintegration of socialist forms of production. Recently JICA gives priority to specific regions and provides technical training in specific fields to maximize the limited financial resources as shown in Table 12.3. Training courses are periodically reviewed to suit the changing demand of developing countries.

To maximize the resources, JICA is also encouraging more advanced developing countries to assist less developed countries with the provision of more training opportunities; this is known as 'South-South cooperation'. All of the implementing organizations of this type of training have experience of hosting Japanese technical cooperation projects. The training on agricultural

[43] Association of South-East Asian Nations

TABLE 12.3

Training courses related to agricultural mechanization

Training Course	Period	Target Countries
Rice Mechanization	1981-1987	All developing countries
Farm Mechanization	1988-1989	All developing countries
Farm Mechanization II	1990-1999	All developing countries
Agricultural Mechanization System for Sustainable Agriculture	2001-2005	All developing countries
Farm Machinery Design	1983-2000	All developing countries
Appropriate Farm Machinery Development for Small Scale Farmers	2006-2010	All developing countries
Automation Technology for Agricultural Mechanization	1996-1999	All developing countries
Upland Mechanization Method	2000-2004	All developing countries
Agricultural Machinery Testing and Evaluation	1990-1999	All developing countries
Agricultural Machinery Testing and Evaluation II	2000-2004	All developing countries
Agricultural Machinery Testing and Evaluation for Agricultural Mechanization	2005-2009	All developing countries
Farm Machinery Repair and Maintenance	1976-1989	All developing countries
Farm Machinery Management	1990-1999	All developing countries
Farm Mechanization Planning for Increased Food Production	1997-1998	Sub-Saharan Countries
Farm Machinery Management Using Computers	2000-2002	All developing countries
Rice Postharvest Technology	1989-1995	All developing countries
Rice Postharvest Processing Technology	1996-2002	All developing countries
Rice Postharvest Processing Technology II	2003-2006	All developing countries
Rice Postharvest Technology	2007-2010	African countries
Appropriate Farm Machinery Development for Small Scale Farmers	2006-2010	All developing countries
Agricultural Machinery Improvement Technology	2006-2008	Morocco
Agricultural Mechanization System	2008-2010	Central Asia and Caucasus

Note: Data available after 1981 after JICA Tsukuba started agricultural trainings
Source: Author derived from JICA database

TABLE 12.4

JICA's training programme on agricultural mechanization for developing countries

Training Course	Period	Target Countries	Implementing Organization
Agricultural Engineering Technology in developing countries	1998-2002	SSA countries	Bogor University of Agriculture, Indonesia
Farm Machinery Management	1999-2003	SSA countries	Jomo Kenyatta University of Agriculture and Technology, Kenya
Rice Processing Technology	1999-2003	SSA countries	Rice Technology Training Center, Egypt
Rice Processing Technology	2004-2009	SSA countries	Rice Technology Training Center, Egypt
Agricultural Machinery Improvement Technology	2009-2011	SSA countries	Hassan II University, Morocco

Source: Author derived from JICA database

mechanization is targeted at SSA countries as shown in Table 12.4. Along with the training in more advanced developing countries, the third country experts are assigned mainly from these institutes to maximize the effectiveness of available resources with JICA's experience.

12.3.3 Grant aid related to agricultural mechanization

Japan has provided food aid consistently since FY1968, as short-term efforts toward ensuring food security. In addition, as a mid- to long-term effort, since FY1977 Japan has implemented a Grant Aid programme for 'Underprivileged Farmers' (known as 2KR) out of the belief that it is important to support self-help efforts toward the expansion of food production in developing countries. It provides agricultural inputs such as fertilizer, agro-chemicals and agricultural machinery. However, the total amount of 2KR has been significantly reduced and the agricultural machinery component also reduced in the last decade as shown in Table 12.5.

The major target region of the 2KR programme is SSA, while Central Asia has been a focus after the disintegration of Soviet Union, as shown in Table 12.5. The region of "Europe" in Table 12.5 represents countries of the Caucasus.

TABLE 12.5
Disbursement of 2KR grant aid

Regional area	No. of target countries	Frequency of disbursement for five-year periods						
		83-85	86-90	91-95	96-00	01-05	06-10	Total
Southeast Asia	6	4	5	15	12	1	0	37
East Asia	2	1	1	7	7	1	0	17
Central Asia	5	0	0	1	25	10	3	39
South Asia	6	0	6	16	14	5	4	45
Oceania	1	0	2	2	1	0	0	5
Middle America	6	2	9	16	14	2	0	43
South America	4	3	10	9	10	0	0	32
Sub-Saharan Africa	37	10	74	105	95	24	5	313
Middle East & North Africa	5	0	6	12	20	7	5	50
Europe	4	0	0	0	10	8	3	21

Source: Author derived from JICA database

Japanese grant aid projects on agricultural mechanization (Table 12.6) are closely related to the application of 2KR programmes and to the establishment of technical cooperation projects. All targeted countries in Table 12.6 are also target countries of 2KR. Technical cooperation projects were implemented in Bhutan, Egypt, Indonesia, Madagascar, Cote d'Ivoire and Tanzania utilizing the facilities established by the grant aid.

12.4 THE IMPORTANCE OF AGRICULTURAL DEVELOPMENT IN SSA

As discussed in the previous section, JICA has focused on agricultural mechanization in SSA with some of the most unfavourable and restricted conditions in the world. If we can find a solution to promote agricultural mechanization in SSA, it should not be a difficult task to mechanize agriculture in other places.

TABLE 12.6

Japanese grant aid project on agricultural mechanization

Project Title	Country	Year	Category
Agricultural Mechanization	Bhutan	1981	Equipment
Rice Mechanization Center	Egypt	1982	Facility
Agricultural Mechanization Center	Bhutan	1983	Facility
Agricultural Machinery Hiring Center	Egypt	1984-1985	Facility
Appropriate Farm Machinery Technology Development Center	Indonesia	1986	Facility
Agricultural Machinery Inspection & Extension Center	India	2006-2010	Equipment
Agricultural Machinery Training Center	Cote d'Ivoire	1988-1989	F&E
Nile Valley Mechanized Wheat Production Increase	Egypt	1992	Equipment
Damanhul Agricultural Mechanization Center	Egypt	2007	F&E
Antsirabe Agricultural Mechanization Training Center	Madagascar	2007	F&E
Agricultural Mechinery Training Center	Moldova	2007	Equipment
Postharvest Processing Technology Development Center	Myanmar	1983	Facility
Rice Technology Training Center	Egypt	1983	Facility
Kilimanjaro Postharvest Processing	Tanzania	1987	Facility
Renewal of Rice Processing Equipment	Egypt	1990	Equipment

F&E: Facility & Equipment   Source: Author derived from JICA database

12.4.1 Food security and agricultural productivity

Food is an issue for all. It is contradictory that over 200 million people go hungry while Africa has the potential to feed its nearly one billion people. The paradox is due to domestic conflicts, political instability, limited human resources, a lack of infrastructure, climate change, the uneven distribution of arable land and water, among other factors. In addition, the situation is exacerbated by existing international trade rules and agricultural export subsidies in the industrialized countries. World food supply is estimated to be enough to meet the demand based on an average adequate diet. Food shortages, however, not only at regional but also at household level occur all over the world. Africa imports a significant amount of wheat and rice, but exporting countries place a higher priority on large importers rather than small ones. The staple foods in Africa are diverse and include crops such as: banana, potato, cassava, millet, sorghum, in addition to the major grains. African people in rural areas try to be self-sufficient in food, because purchased food is costly even if the rural market is integrated to the world market.

The major cereals traded in the world markets are wheat, corn (maize), and rice. Wheat and corn are widely traded and the annual trading amounts are estimated at 130 million tonnes and 90 million tonnes respectively, while rice is mainly produced and consumed in Asia with a smaller market of 30 million tonnes per year. African countries are major importers of rice and the consumption and importation is rapidly increasing and has reached levels of 14 million tonnes and 6 million tonnes in milled rice respectively. JICA has joined with other donors and organizations in the Coalition for African Rice Development (CARD), which aims to double Africa's rice production to 28 million tons by 2018.

In Asia increased rice production has been achieved through an increase in the yield per unit of land, whereas in Africa the expansion in cultivated land is the primary factor in the increase in the total output. It can be said that among staple food crops, rice represents Africa's best opportunity for reduction of imports. It is believed that the price of rice and other grains in the international markets will stay at high levels in the foreseeable future through a combination of factors such as increased demand and changing consumption patterns in countries with growing economies, competition from production of bio-fuels from grains, and the possible effects of climate change. Hence, innovative plans are called for that will contribute to improving self-sufficiency in staple food grains, including rice, as an important challenge for African countries. Increases in rice yield will be required if there are constraints to shifting the land use from traditional crops to rice. Any increases in local production will replace rice imports purchased with foreign exchange.

12.4.2 Smallholder agricultural development

To extract Africa from its situation of stagnated agricultural production and food scarcity, will require the transformation of African agriculture. The major actions needed to make a rapid change are the expansion of sustainable agricultural land, improvement and stabilization of productivity, and improvement of agricultural infrastructure including farm to market roads. However, in practice these actions are more easily provided to relatively larger farms, because they provide more immediate visible impacts and more advanced farmers have better leverage to acquire these actions and investments.

Though most rural development projects emphasize the role of smallholder farmers, their beneficial effects can be offset as a consequence of distorted mechanization policies which usually benefit the capital intensive large scale farmers (Kaul, 1991). Most agricultural engineering imports are intended for modern farming such as state farms, plantations and, agro-food complexes. The low purchasing power and generally poor economic status of smallholder farmers have been seen as serious constraints to their adoption of innovations. Similarly it is also necessary to identify the farmers' needs and wishes which may not always be the same. Small scale farmers face a lot of problems in so far as agricultural mechanization is concerned.

12.4.3 Gender and agricultural mechanization

Gender issues in agriculture have rarely been recognized as a mainstream concern, because women are not afforded high status in agricultural policy making or development planning. It is well understood that a majority of the agricultural work force are women in developing countries, but the influence of mechanization on gender is not often discussed in development. There is little quantitative information on gender in agricultural mechanization, thus the issue is ignored. It is necessary for development practitioners to pay more attention to gender statistics in order to reflect the real situation.

It has been observed that the labour sharing pattern of weeding was changed after introducing rotary-weeders in a joint training programme as shown in Box 12.1. If we can involve more women in machine design, machine utilization may have different options such as reduction of excessive work load, power requirement and handle size. Rural women are disadvantaged in accessing engineering design due to limited education, information and services. Engineers should be encouraged to consult women farmers as a major target beneficiary of farm mechanization.

BOX 12.1

Work sharing in Tanzania by using rotary-weeder

Weeding has been done by women as it is seen as a 'woman's job' in the Kilimanjaro agricultural development project area. The project introduced a rotary-weeder to save weeding operation time for women, and conducted training on the weeding operation. The operation was interesting for some husbands and they started to help with weeding operation – treating it as 'man's work'. It was clear that the women saved time when weeding using a rotary-weeder and some women saved even more by handing over weeding work to men.

The project invited an equal number of men and women for the training. It was not easy for women to speak out about farm planning and operation in their home. The training, however, made it much easier to discuss with men about farming issues in front of other women participants. Male participants understand the role of women and recognized its importance in agriculture by participating in the training with women.

12.4.4 Agricultural mechanization policy in SSA

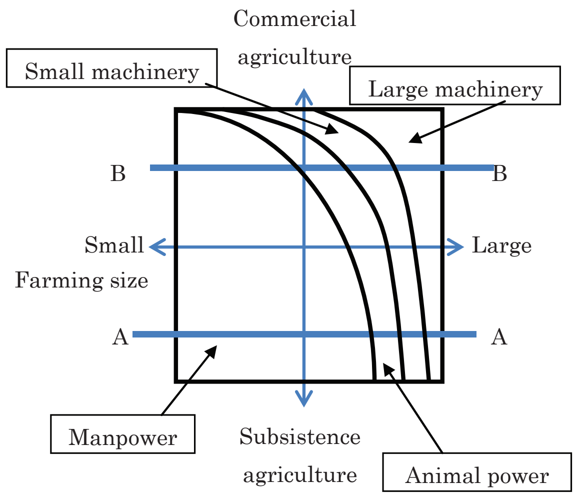
Many countries in SSA have an agricultural mechanization policy or strategy (e.g. URT, 2006). They are not, however, always implemented very well. This can be due to weak commitment of the government which is manifested in terms of limited budgetary allocation, limited human resources to implement, poor monitoring systems, among other factors. A more critical constraint is the difficulty of investment in agricultural mechanization caused by the low profitability of smallholder farming in SSA. It is not easy to sell small amounts of cash crops in rural areas, and the price is reduced by having a surfeit in the market when the crops are harvested at the peak of the season.

Agricultural mechanization development has not always been supported by a number of agricultural economists who worry about the unemployment of farm labourers who have no other income sources in rural areas. This myth has delayed and stagnated the advance of agricultural mechanization in developing countries. There is now ample evidence and general agreement that mechanization provides more opportunities of employment in the supply and value addition chains. In fact, the recent hike of farm labour costs gives more reasons for mechanization.

Most developing countries are aiming at levels of mechanization that have been reached in developed countries and where economic growth has been achieved. This approach requires a country's own research and development institutes focussing on: agricultural mechanization; standards for agricultural machinery; policy guidelines for the provision of subsidies and tax exemptions; and training centres for extension workers, technicians and farmers. This approach may well be correct under certain circumstances, but the natural and human resources and socio-economic situation should be well incorporated when the policy and strategy are formulated.

Within a country, farming systems are diversified and the mechanization level is not uniform. National policy planners are required to consider the situation of smallholder farmers although large-scale commercial farming is the main driving force for agricultural mechanization if we are aiming at a reduction of rural poverty.

FIGURE 12.2
Patterns of agricultural mechanization



12.4.5 Tractorization vs. draught animal power

When commercial agriculture is promoted, farmers are able to invest in agricultural machinery that is the start of a positive cycle leading to mechanization. Animal power is an appropriate technology at the initial stage of mechanization when farmers have small areas to cultivate under subsistence agriculture regimes.

When farming is commercialized (moving from line A-A to line B-B in Figure 12.2) powered agricultural mechanization is promoted. When farm size is increased to reduce machinery costs, larger sized machinery can be justified. Draught animal power is sustainable and viable under certain circumstances, especially for smallholder farmers.

At the beginning of the mechanization development process machines are basically owned by individual farmers. In order to increase utilization rates of privately owned machinery, custom hiring services can be provided to neighbouring farmers even with animal power or small machinery at an early stage. If the custom hiring service provides more opportunity as a profitable business, then it is viable to invest in larger machinery to cover larger areas. The key issue is the profitability of mechanized farming. In order to promote sound mechanization, all stakeholders such as manufacturers, distributors, service providers, operators and farmers need to gain profits from mechanized farming. Reducing machinery costs is an important issue that all stakeholders should always seek. A minimum input of machinery to a unit area, as in conservation agriculture, is one of the alternatives to reduce machinery cost.

12.4.6 Imports vs. Local manufacture

Kaul (1991) estimated that investment in agricultural equipment equates to about 1 percent of agricultural production. Outlay on fertilizers and the agro-chemicals consumed in one growing season is far greater than that for equipment which may have a working life of up to 15 to 20 years in SSA. Eighty percent of the agricultural equipment imported is used in the modern farming sector and it is appreciated that this sector produces some key crops which are vital to the economies of many African countries and provides an important linkage between industry and agriculture. An apparent neglect of the local manufacturing sector is observed in most SSA countries.

With regard to more sophisticated machines like tractors and combines, there is less advantage to manufacture in less developed countries where there is no steel industry. Multinational corporations have supported machinery assembly in developing countries to reduce costs and create employment, but little attention is made to provide support services. Unless the market size is large enough to start up a production line, multinational corporations cannot usually justify investment in factories in these countries. Furthermore, the stability of the government is another factor to be considered to ensure confidence in earning a return on the investment. The reality is that many SSA countries are required to continue to import assembled machines.

The predominant equipment used and made in most developing countries comprises hand tools and simple machines. It is a business opportunity for small scale factories, but one of the difficulties of local manufacture is the dependency on high cost imported raw material. This results in an inability to compete with low cost hand tools from countries such as China and India which have their own steel factories. On the other hand local manufacturers have the capacity to develop machines better suited to local contexts.

Many small scale manufacturers and fabricators exist all over Africa. They should not be ignored because they dominate the industry even in the more developed countries by integrating the small factories with the industrial sector. *Jua-kali* artisans in Kenya are recognized as being an important sector for self-employed innovative entrepreneurs in small businesses supplying small-scale technology products. They have established their foundation in Kenyan society by forming a specialized sector, and this creates more business opportunities and develops the industrial sector.

12.5 INTERNATIONAL OPPORTUNITIES TO SUPPORT AGRICULTURAL MECHANIZATION

12.5.1 Can farmers own tractors in SSA?

Can individual African smallholder farmers own tractors within a decade? The answer is 'No, it is almost impossible'. It is, however, possible to mechanize agriculture in Africa, but this requires a precondition, a drastic change that Africa be converted from importing to exporting food.

Many projects and pilot activities have been implemented to mobilize agricultural mechanization in SSA. These past actions and experiences include:

- Importation of agricultural tools, implements and powered machines with tax exemptions
- Promotion of tractor hire services
- Repair and maintenance by machinery dealers and entrepreneurs
- Research and development of machines with locally available materials
- Development and production of simple tools and machines
- Education and training of engineers, technicians, extension workers, operators and farmers
- Provision of commercial financing and soft loans
- Regulatory work and standardization

12.5.2 Preconditions for agricultural mechanization in SSA

As previously mentioned, agricultural mechanization in SSA confronts plenty of constraints (FAO, 2007). Even if the price of agricultural commodities is attractive to farmers, it is not an advantage unless African farmers can earn more from selling extra products. Many African farmers are at or near subsistence level producing various kinds of plants for food in small rainfed holdings, and this restricts African farmers from earning a good income from agriculture.

The main preconditions to promote agricultural mechanizations are:

- Stable economic growth that is ahead of the population growth rate
- Continuous reduction of the rural population
- Maintenance of a reasonable price level of major food crops
- Increase in crop production and markets for cash income

African farmers and entrepreneurs are investing heavily in the sector, although it may not be at an adequate level to generate sustained growth in productivity and income. The incentive for private investment in agricultural innovations is greatly enhanced by two factors, namely, secured output markets and the low level of costs incurred while investing in innovations. Smallholder farmers often lack market access and they are often forced to practise low-input and low-output subsistence agriculture. Technological success in Africa depends on assured output markets.

12.5.3 Technology options

Custom hiring services are an alternative to promote mechanization as a profitable business as shown in Box 12.2. It is necessary to have entrepreneurs like Mr. Kingangi with good management skills and the capacity to operate businesses.

Mechanization options may be selected by considering the farmers' situation based on two major criteria i.e. commercial vs. subsistence agriculture, and farm size as shown in Figure 12.2. For mechanized farming, there are four options for ownership, i.e. individual ownership, group ownership, commercial custom hiring service, and community hiring service if government ownership and hire services are excluded.

Individual ownership is the foundation of mechanization to form a farmer-owner-operator situation. If the machine has extra capacity and when it is not needed for work on the owner's farm, it can be utilized on neighbouring farms to generate income. If the farmer increases the service provision the operation could be considered to be a community hiring service. Group ownership is not an option unless all the group members have a strong sense of cohesion or clear responsibilities under their own rules and regulations. Empirical data show that the timing of farm operations frequently occurs simultaneously for all members and so it is not easy to share a machine used for the same purpose.

There is no single scenario that can be applied to all SSA countries. Thus a set of different scenarios should be considered for different socio-economic conditions as well as ecosystem and technical conditions. There are basically two major approaches to promote mechanization: one is the importation of powered machinery, and the other is local manufacture of simple machines and implements.

As the main driving force of farm mechanization, large-scale commercial farms are encouraged to have a programme of regular machinery replacement to reduce down time and ensure continuity in the production process. This scenario would be expected to provide more business opportunities for local importers and distributors. In addition, the second-hand machinery market will be stimulated, and more opportunities are open to maintenance services. This is an agricultural supply chain approach that makes more investment possible in agriculture.

BOX 12.2

Efficient tractor hire service in Kenya

Mr. Gideon Gitungo Kingangi is a very talented provider of tractor hire services, and he is also a 9-seater van tour operator. His home is located in Kabete near Nairobi in Kenya where he owns a field of about 2 acres. He purchased a new 80 hp 4WD tractor with a disc plough (3 x 660 mm) and a harrow (24 x 560 mm) using credit provided by a tractor distributor in April 2009. The total cost was about 42 000 USD and a 30 percent down payment was required. The remainder to be paid back in 2 years at an annual interest rate of 15 percent.

The hiring service starts in Kabete to plough and harrow for maize from November to January the following year. The tractor then moves to Nyahururu, one of the granary areas in Kenya for wheat and maize. He needs to transport his tractor and equipment over 700 km by hiring a lorry to Lamu for the maize crop. Then he asks the operators to drive from Lamu to Taveta near Mt. Kilimanjaro for beans and maize. The harrow is pulled by the tractor and the disc plough is mounted on it. The tractor works continuously in Oloitokitok nearby Taveta from June to August. The long season is ended in Kabete in September for maintenance work.

The hire service is provided to farmers if they pay half of the service fee when signing the contract. The remaining 50 percent is collected on completion of the job. He charges 2 000Ksh (25USD)/acre for ploughing and 1000Ksh/acre for harrowing. He estimates that the capacity of the tractor is 10 acres/day for ploughing and 15 acres/day for disc harrowing. He employs two qualified (over 5-years experience) operators and pays them 10 percent of the hire service fee for their work. Additionally he provides them with meals and accommodation during field trips.

He believes that he is able to pay back the credit with interest in 2 years. The critical issue is an incentive for operators to increase the volume of hiring work. There are no problems of spare parts supply and maintenance service, he says. He is willing to purchase a lorry to transport his machines as well as transport hay as a new business.

Estimated gross annual income: 2 000 000Ksh (25 600USD)*

Sales: 20 000Ksh/day x 250 days/year = 5 000 000Ksh

Fuel cost: 80Ksh/litre x 8litre/acre x 10 acres x 250 = 1 600 000Ksh

R&M cost: 500 000Ksh. Operator cost: 750 000Ksh. Other costs: 250 000Ksh

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*1 USD = 78Ksh (May 2010)

The local manufacture of machinery may focus on various models and types of machines suitable for local conditions. This is an activity led by local industry and encompasses not only simple hand tools but also simple implements and equipment for smallholder farmers who have little capital to access and own more expensive engine-powered machines. Individual machine prices should not be excessive when taking into consideration the purchasing power of smallholder farmers, but the number of users can be large enough to make a profit and to generate employment in the small industry sector.

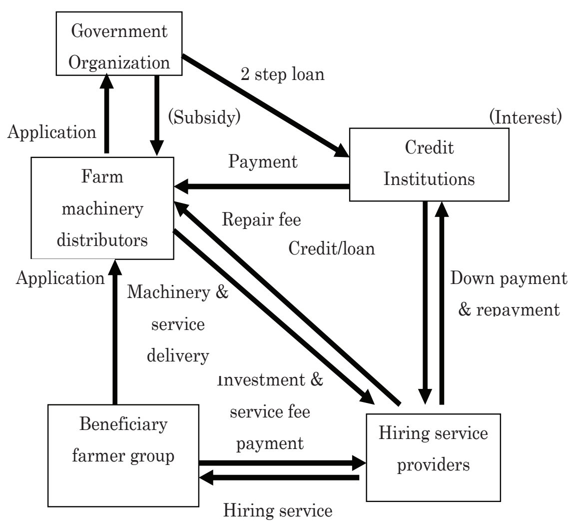
12.5.4 Institutional innovations and investment opportunities

The success of agricultural mechanization in Japan was made possible by an increase of farmers' capital and by government subsidies for farmers purchasing modern machines. New Growth International (2009) conducted a study on technology transfer to smallholder farmers, and concluded that the public roles in agricultural innovation systems should be based on providing incentives for welfare-enhancing private-sector investment.

Traditionally approaches to agricultural technology development depended on the public sector based on one-way information flow. Today the private sector has come to be considered a major source of innovation and communication in the agricultural sector. Interactions of public and private partnerships and collective initiatives are considered crucial to agricultural innovation and diffusion. However, actual outcomes depend on the performance of stakeholders concerning development and diffusion of agricultural innovation under given contexts.

A better business opportunity should be given to hire service providers who, as well as large commercial farmers, are key promoters of agricultural mechanization for smallholder farmers. The difficulty of collecting service fees from farmers can be a bottleneck to the expansion of this kind of business. Soft loans are only available for farmers with collateral, such as larger farms with land title. A mechanism to promote hiring services is proposed in Figure 12.3. This is based on the farmer-owner-operator situation that is believed to be a key for success in mechanization.

FIGURE 12.3
Proposed mechanisms to promote hire service for smallholder



The beneficiary farmer group could make a contract with a hiring service provider by investing a certain amount based on the area of farms to be serviced. A cooperative can select an innovative farmer member as a service provider as well as a machine operator. Although the selected farmer should be able to invest more on shelter for farm machinery and initial running cost of machines. The group can apply for machine purchase to a farm machinery distributor through a facilitating arrangement of the government and a finance institution. The collected investment from beneficiary farmers and the service provider's own capital can be used as a down payment for the acquisition of the selected machinery. After completion of the repayment, ownership of the machine is transferred from the distributor to the hire service provider. It may be much easier to collect the service fees if a trader becomes a hire service provider or a financial institution in some cases. The possible application of such a scenario will be site specific as the confidence of the beneficiary group to make such an investment will depend on the characteristics of each community.

12.6 PUBLIC SECTOR AND DONOR-LED INTERVENTIONS

12.6.1 Basic requirements for the public sector

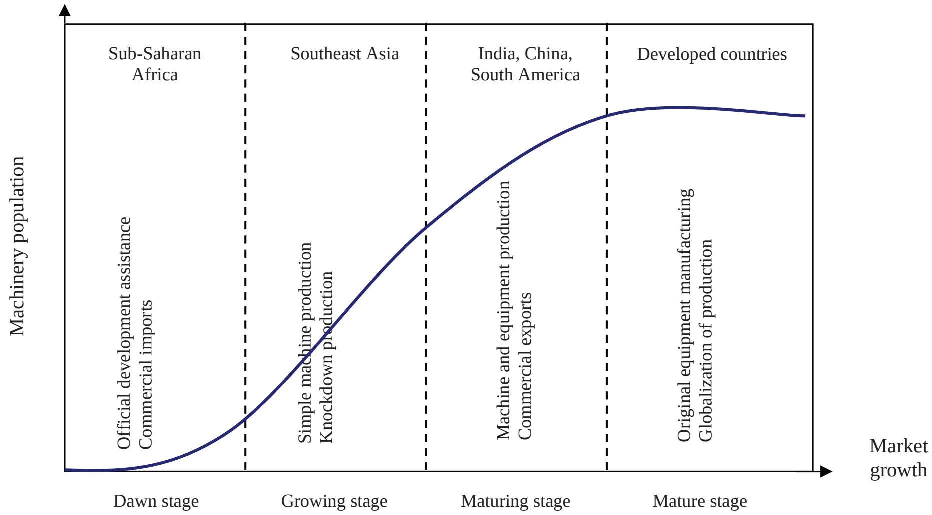
The basic actions required from the government sector are not so different from those listed in Section 5.1, but the approach could be different. Ideally a government should have a clear policy on agricultural mechanization that promotes continuous private investment not only in agricultural machinery but also in agriculture as a sector. It will generally not be possible to have investment in agricultural mechanization without profitable agriculture. Direct intervention in financial support to farmers may distort the market economy and this is especially true with regard to gifts distributed as political gestures. Such retrograde interventions should be eliminated to encourage private sector participation in the sector.

The policy should be based on a long term vision for agricultural development and the strategy should be reviewed periodically to reflect the economic situation to maintain profitability in the sector. The stages of development of agricultural mechanization can be expressed by a curve as shown in Figure 12.4.

As a sector moves from one stage to another, the agricultural mechanization policy should be reviewed. The government is required to select options for promoting agricultural mechanization with clear criteria. All actions should have appropriate budgetary support for timely implementation.

Human resource development is an important role of the government. The traditional education system may not be suited the current world situation. There may be enough engineers to come up with agricultural innovations but the innovations may not be diffused to farmers because the relevant socio-economic aspects have not been taken into consideration. A solution could be to form a multi-disciplinary team to solve the technical, socio-

FIGURE 12.4
Stages in the development of agricultural mechanization



economic and environmental problems. It is, however, necessary to nurture inter-disciplinary compliant people if we seek a real synergy effect from a multi-disciplinary team. There are job categories of engineers, technicians and artisans in some countries, but such rigid classification can cause poor agricultural innovation. The farming community, as potential users, needs to be involved from the outset and its innovative talent harnessed to produce more acceptable technical solutions.

12.6.2 Enabling environment to promote agricultural mechanization

For sustainable agricultural growth, investment in the agricultural sector is a fundamental requirement. Eyo (2008) reported on a Nigerian study that showed how macroeconomic policies that reduce inflation, increase foreign private investment in agriculture, introduce favourable exchange rates and provide agricultural credit, can have a significant effect on agricultural output growth and would be an invaluable government investment in the sector to ensure growth in agricultural output.

Improving agricultural production is only an initial action. It is important for farmers to recover their investment in agriculture by securing output markets. A lack of basic infrastructure such as roads and bridges from farm to markets may prevent access to output markets. In the case of land-locked countries, the international border may be an obstacle to the import of materials and export of agricultural products. The flower export business in Kenya shows that a possible viable solution for high value-products can be export by air.

From the supplier's point of view, it is necessary to investigate the potential demand. This means how many machines can be purchased by farmers, operators, farming business communities and others. It is not worthwhile to export machines to a country with a small market. For long-term profitability, suppliers are obliged to provide services such as operator training, repairs, supply of spare parts, and after sales service. Establishment of a distribution network is a kind of fixed cost and the total number of potential sales is crucial to determine the sales strategy.

A reduction of the risks associated with businesses is an important factor in the promotion of foreign investment. Transaction costs should be kept under review and control: how many days are required to issue a Letter of Credit? How much is the tax on sales? These are aspects where the government plays an important role. If suppliers add these costs on to the sales price (which they must), farmers are obliged to buy more expensive agricultural machinery. Provision of low interest loans or smart subsidies can stimulate agricultural machinery purchase, but a more important aspect is the formulation of a stable policy to promote appropriate agricultural mechanization. Economic change is always a risk for investors, but political and social risk should and can be avoided by maintaining peace and order and rooting out corruption.

Rural development is critical if smallholder farmers are targeted for agricultural mechanization. As mentioned previously, extending direct subsidies for vulnerable farmers is not usually the right solution. A participatory approach to developing the vulnerable smallholder farmer sector is necessary to empower rural people and to capture their innovative talents. There must be a mechanism to include disadvantaged farmers in the target population, perhaps by forming self-help groups to develop their capacity or as a channel to build partnerships for development. It is basic responsibility of the government to improve the human security of rural people.

12.6.3 Support from the donor community

Donor interventions to agricultural mechanization in particular developing countries have often been partial and have not always been well organized. In particular, technical design interventions have not been adequate if the private sector is not fully involved. Donors used to provide grant aid for farmers as a subsidy to avail themselves of new machines. This may distort the market economy and prevent a sound promotion of agricultural mechanization. Donors are required to provide channels for private investors from developed countries to farm machinery industries and agricultural businesses.

Donors always expect positive results from their development cooperation projects. Experience has taught that unexpected negative impacts often appear after the official termination of projects. Negative impacts are difficult to anticipate because detailed previews or assessments are not fully employed as they constitute additional budget lines in cooperation activities. This lesson can be applied to agricultural mechanization projects. One subsidized programme to procure farm machinery may cause difficulties for others trying to operate a competitive machinery supply situation. Donors should be required to pay more attention to a thorough assessment of the effect of agricultural mechanization on rural society as well as on supply chains. On the other hand, beneficiary countries should control and regulate donor programmes as well as governmental programmes. Without initiatives on the part of the beneficiary countries, no programmes can be properly operated. Donor communities need to find partnerships when working with beneficiary countries.

12.7 CONCLUDING REMARKS

Agricultural mechanization is not possible unless it is profitable for all stakeholders, namely farmers, machine owners, machine operators, machine suppliers, and manufacturers. Difficulties exist and they can't be solved by the private sector alone; governments have important roles to play to lead the promotion of agricultural mechanization.

As a conclusion, human resources have to be enhanced to interact with all stakeholders for the promotion of agricultural mechanization. African countries have contributed less to global warming and climate change than other regions but they have been suffering from the most severe consequences. The global financial depression seriously hampers efforts to encourage private enterprises to expand their activities. Africa will face perilous challenges in the years ahead, but it is a region of vast promise and potential prosperity. It is hoped that African people will revitalize agriculture in the continent and one tool that they have is the stimulation of agricultural mechanization that will lead to sustainable food security and will help to reduce poverty.

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CHAPTER 13
Off-farm use of agricultural machinery

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ABSTRACT

Off-farm use of farm machinery can be an important input into the development of rural infrastructure – especially roads. The development of rural infrastructure has been shown to promote economic growth and reduce rural poverty. Mechanization is an essential input for modernizing agricultural production and access to mechanization services – through custom hiring by smallholders of the services of larger farmers – is crucial. To increase the productive work of tractors, a cross-sector approach should be taken which will include rural infrastructure construction and maintenance. The use of tractors in the agricultural, roads and other sectors is presented. Technical challenges, costs and public and donor sector roles are discussed. The conclusion is that off-farm and multi-farm use of agricultural tractors will act as a catalyst to more widespread mechanization and are to be encouraged. FAO is developing initiatives to add impetus to this movement.

13.1 INTRODUCTION

Rural infrastructural development is an essential prerequisite for development of the agricultural sector. The presence of a good road network, well conceived and maintained is necessary for the delivery of inputs to the farm. It is also vital in the case of commercial farming, which is the sector where mechanization is most in demand, for the transport of farm produce to the market and to the processing enterprises in the post-harvest value chain. This chapter starts from the premise that rural road infrastructure is a public good which plays this important role, and that entrepreneurs who own agricultural tractors and farm machinery (especially trailers, graders and mobile water tanks) can expand the number of useful hours worked each year by using the equipment during slack times in the agricultural calendar for rural road construction and maintenance. The chapter then continues with a discussion of other possible ways to expand the number of useful hours that a tractor can work throughout the year. In this way income can be earned to defray the costs of tractor ownership and to accumulate capital for replacement when the time comes.

13.2 RURAL INFRASTRUCTURE AND THE POTENTIAL FOR INCREASING AGRICULTURAL TRACTOR USE

This section considers infrastructure in terms of rural access roads as they represent the last few kilometres in a country's road network linking the agricultural areas with markets and services. These last few kilometres are crucial for the development of rural areas and the construction and maintenance of these roads can be undertaken using local labour and tractor based technology. This in turn will create rural employment and can increase the utilization of agricultural tractors through both on and off farm activities, thereby creating demand for tractors and investment opportunities for supplying mechanization inputs to the rural areas.

The section first considers the links between rural transport infrastructure and agricultural performance based on research that has identified the positive impact that rural roads have had on increasing agricultural production and employment. It then investigates the investment needs and opportunities for increasing mechanization and discusses the provision of off farm tractor based services. Current donor policies and initiatives affecting the rural roads and agricultural sectors are then discussed in relation to opportunities for providing tractor-based services which is followed by the challenge of providing these services in rural road construction and maintenance, together with the sustainability and viability of using tractors on rural roads. Finally, the initiatives required for the development of tractor-based service providers is discussed in terms of the public, private and banking sectors, donors and international organizations.

13.2.1 Rural Transport Infrastructure and Agricultural Production

In the majority of developing countries, road transport is dominant and carries the major share of passenger and freight traffic and in most cases it is the only means of access to the agricultural areas. Most developing countries have pursued a policy of road network expansion over the last 40 years and these networks now represent their largest assets which are larger than their national railways, airlines and shipping. However, most of this expansion has concentrated on the main road networks at the expense of rural roads which play an important role in the development of rural areas. Although these road networks only carry light traffic and usually consist of gravel roads and seasonal earth tracks, they do connect key agricultural areas with local markets and the main road network (Heggie, 1995).

The relationship between poverty reduction and investment in infrastructure has been the subject of much research which shows the strong links between rural infrastructure investment and the resulting increase in agricultural production and reduction in poverty. Most of these studies have drawn on evidence from South East Asian countries as well as sub-Saharan Africa where investment in infrastructure has been followed by periods of economic growth and reduced rural poverty through increased agricultural production and job creation. Research has also highlighted the importance of investing in complementary infrastructure such as for rural freight and passenger transport, markets, clinics and schools, as essential requirements to raise rural incomes and reduce poverty. Rural infrastructure investment will therefore enable agricultural production to be improved and transaction costs to be reduced, allow market linkages to become developed and labour specialization to take place. This in turn will enable farmers to farm more intensively (due to better access to modern inputs) and to increase the profitability of their mechanization based assets (Escobal and Carmen, 2003).

13.2.2 Investment Needs and Opportunities for Mechanization

The need for tractor based mechanization

Agricultural mechanization policy has been the subject of much debate which centred on the economic feasibility and rationale of using tractors to increase agricultural production in developing countries. Unfortunately, research had indicated that mechanization was uneconomic in Asia and sub-Saharan Africa and donors stopped funding mechanization projects, especially in Africa, from the late 1980s onwards, which also coincided with the introduction of structural adjustment programmes. However, contrary to donor reaction, there were also researchers, notably in India and the USA, who supported the view that farm productivity is directly related to the amount of farm power available, thereby advocating that significant increases in agricultural production can only be achieved through mechanization. (Mrema *et al*., 2008).

Consequently, two contrasting scenarios developed between Asia and sub-Saharan Africa. Government policy in many South-East Asian countries acknowleged that farm productivity was related to farm power and subsidized privately owned mechanization inputs. As a result, the number of tractors in the region increased from 139 000 in 1961 to 1.27 million in 1980. Whereas in sub-Saharan Africa, the tractor population rose from 235 000 in 1961 to only 0.44 million in 1980 as a result of largely publicly owned mechanization inputs.

Mechanization in Asia was started by the demand to mechanize land preparation. The resulting private sector mechanization of the larger land holdings, not only led to timely land preparation but also an expansion of the cultivated area and increased cropping intensity. However, Asian farmers also found that even with subsidized tractors, the economic justification for tractor ownership could only be satisfied by using their tractors' surplus capacity to undertake ploughing and transport for neighbouring farmers (Singh, 2011).

In contrast with Asia, mechanization in Africa has stalled over the past three decades. The public sector tractor hire schemes of the 1960s and 70s were the focus of mechanization in many African countries, but proved ineffective and uneconomic at providing tractor based services and were abandoned in the 1980s and 90s under structural adjustment programmes. In the wake of this abandonment and a lack of interest in tractor mechanization, donors turned to supporting intermediate forms of mechanization such as animal traction, hand tools and small tractors. The development of small tractors was soon discontinued and the limited success of animal traction faltered due to disease, drought and deteriorating animal health services, leaving agricultural production largely reliant upon human power and hand tools (Mrema *et al*., 2008).

Considering these trends and taking into account the globalization of markets, population pressure, rural migration and AIDS, there is now growing concern that sub-Saharan Africa cannot achieve the required agricultural sector growth and development that is needed to combat poverty, whilst relying mainly on human power and hand tools. Clearly there is a desperate need in developing countries, especially in Africa, for tractor based mechanization, therefore it is necessary that governments, donors and tractor owners, are made aware that private tractor ownership can be economically viable and is able to meet a country's mechanization needs through more effective utilization of both existing and future tractor populations. However, the challenge is to demonstrate that an effective demand for tractor-based services exists and that economic rates of utilization and profitability are achievable.

The opportunities for increasing tractor utilization

Agricultural Sector: In most developing countries, agriculture is the lead sector, accounting for up to 50 percent of GDP and providing employment for up to 90 percent of the population. Such countries enjoy a comparative advantage in their agro-industries, based on cheap labour and agricultural raw materials. With the dismantling of regional trade barriers, agro-industries will need to restructure their operations in order to compete in the larger global markets. This restructuring will result in a drive towards increased specialization and flexibility in production, to exploit the limited advantages they have in a free trade environment. However, in order to turn their comparative advantage into a competitive advantage, they will also have to increase productivity, improve quality and increase efficiency.

Under competitive pressure, contracting out selected activities will become a viable alternative for many enterprises compared to providing their own in-house capacity, as practised in the traditionally vertically integrated organisations, such as the tea industry. The advantages of contracting out will allow enterprises to adopt new strategies to meet the challenges posed by global competition. Therefore, the drive by agricultural enterprises towards increasing specialization, cost reduction and greater operational efficiency will offer tractor-based service providers increasing opportunities to broaden their participation in contracted out activities.

Roads Sector: Inadequate and poorly maintained rural road networks are preventing a large proportion of the rural population from participating in the modern economy and donors and governments have now accepted that rural road networks need high priority investment to increase rural access and reduce farm transaction costs. Consequently, the development and maintenance of the rural road network has now assumed a greater significance for donors and governments alike, as rural market access has become a major priority in their drive to increase commercial agriculture and the supply of farm production to competitive markets.

Governments are now bringing decision making for road network management closer to the road users through decentralization and managing roads as a business by commercializing their management, operation and financing. They are also introducing policies to increase the amount of local funding available for road maintenance through second generation road funds and increasing the effective use of available funding by introducing performance based contracting. Road networks are now seen as major assets and need to be managed and maintained as a business. The first priority is to assign legal ownership and responsibility for road networks and under decentralization, local governments have been designated that responsibility. They are also under pressure to adopt performance based contracting for the maintenance of their designated networks as governments begin to divest themselves of the responsibility in favour of contracted out maintenance works. This trend will provide tractor-based service providers with increasing cross-sector market opportunities in the roads sector.

Other Opportunities: Because of the multi-tasking capabilities of the agricultural tractor and the large range of associated equipment and implements that are available, there are numerous opportunities that have been created across most industry groups and sectors for tractor-based services in rural and urban areas. Table 13.1 indicates the range of cross-sector applications for agricultural tractors including associated equipment and the potential opportunities available for providing tractor-based services in developing countries.

13.2.3 The provision of "Off Farm" Tractor-based Services

Cross sector Approach

The principal argument for encouraging the development of tractor-based service providers is the crucial role they can play in the development of rural areas as well as increasing agricultural production. Increasing agricultural production is dependant upon motivating farmers and only through incentives will they respond by bringing new areas into cultivation and farming more intensively. However, the majority of farmers rely on family labour for crop production using hand tool technology. Their productive capacity is limited to farming 1.5 to 2.0 hectares efficiently and effectively and even with incentives, they will be unable to increase their cultivated area much beyond two hectares or farm their existing holding more intensively without access to mechanization.

TABLE 13.1
Rural sector activities and potential applications for tractor-based services

No	Sector	Tractor based activities	Tractor based equipment
1	AGRICULTURE	•Land preparation •Crop growing operations •Harvesting •Farm infrastructure: roads, earth dams, fencing •On farm processing	•Plough, harrow, cultivator, sub soiler, land leveller, ridger •Planter, seed drill, fertiliser spreader, boom sprayer, pump •Trailer, thresher, trailed combine, baler, forage harvester, mower •Dam scoop, grader blade, post hole auger, trailer •Hammer mill, rice huller and winnower, blower/suction fan
2	FORESTRY	•Transplanting and thinning •Logging and extraction •Collection of fuel wood •Forest access and extraction roads	•Trailer •Trailer, winch, backhoe or front end loader with log grab •Trailer, mobile saw bench •Towed grader, grader blade, trailer, front end loader, backhoe
3	MINING & QUARRYING	•Sand and gravel extraction and screening •Crushing stone- building, road making cement. •Clay extraction -ceramic & refractory industry •Salt extraction, solar evaporation and crushing	•Trailer, front end loader/bucket •Trailer, front end loader/bucket •Trailer, front end loader/bucket •Trailer, front end loader/bucket
4	MANUFACTURING	•Wood and wood products, mobile saw milling •Brick and block products	•Trailer, mobile saw bench, planer •Trailer, front end loader/bucket and pallet forks
5	CONSTRUCTION	•Landfill/levelling/Land drainage •Earthmoving and excavation •House/commercial/farm building •Highways, roads, bridges, tunnels, railways, ports and airfields •Irrigation, sewage, pipe/ power lines, boreholes •Plant hire renting out machinery with operator	•Trailer, front end loader /bucket, grader blade, vibrating roller •Back hoe, front end loader, dam scoop, towed scraper •Back hoe, trailer, front end loader, compressor, pump •Back hoe, trailer, front end loader, dead weight/vibrating roller, pneumatic roller, compressor, pump, concrete mixer, vib. Pokers •Back hoe, trailer, front end loader, compressor, pump, scraper •Tractors and all associated equipment and attachments
6	TRANSPORT	•Road Transport liquids, goods, people	•Flat Trailer, dump trailer, low loader trailer, fuel/water tanker

These farmers need access to a low cost, flexible source of farm power that offers minimum risk but enables them to respond quickly to production incentives by ensuring timeliness of operations. Such a source of farm power is available by making more efficient use of the private tractor capacity that exists in the majority of developing countries through the mechanism of contract hiring which is still relatively under utilized.

The major issue facing developing countries is how to make tractor-based technology available to farming families in the rural areas. It is clear that, due to capital constraints, every farm household cannot own a tractor; but they should have access to tractor-based services. In the past, governments have introduced public tractor hire schemes to achieve this aim but these have long since been abandoned as uneconomic. This leaves the private sector tractor owners to meet demand and as they are predominantly practising farmers, they are able to use their tractors' surplus capacity to supply a service to neighbouring farmers.

However, the level of annual utilization being achieved by these individual tractor owners is insufficient to be economic, being typically less than 500 tractor hours per year. At these levels of utilization, farmers cannot support tractor ownership and find themselves in a downward spiral of insufficient income to cover the costs of maintenance, repairs and replacement.

The reason for low utilization is a failure to achieve continuity of work throughout the year. This under-utilization is caused by tractors being used mainly in small scale agriculture undertaking primary cultivation and transport, which provides only narrow windows of opportunity for work during each cropping season. After these windows close the tractor is idle until the next peak demand. To address this problem, tractor owners should consider taking a cross-sector approach to providing tractor-based services throughout the year.

The promotion of tractor-based services across non-traditional industry sub-sectors will generate new opportunities to exploit the agricultural tractor's full potential. The limiting factor is the lack of awareness by tractor owners and rural based enterprises of the potential opportunities that exist. Furthermore, tractor owners must have the capacity to provide tractor-based services to meet contractual requirements. For these reasons, governments will need to provide support to identify and exploit cross sector market opportunities and to assist in developing the tractor owners' capacity to meet those opportunities (FAO, 2009).

Business Linkages as a Development Tool

An effective model for the development of tractor-based services is based on the concept of business linkages. These linkages are commercial relationships agreed between businesses of all sizes and must be mutually beneficial to all parties. Such linkages are a normal form of business life in market based economies and can provide a flexible tool to support a variety of development processes in developing countries.

The most common form of linkage arrangement is sub-contracting which is the basis on which tractor-based hire services operate. Business linkages also allow tractor owners to diversify from farming into providing tractor based services, or to specialize in a particular sector such as transport or road maintenance. In both cases, diversification enables economic efficiency to be improved and provides opportunities for increased employment and benefit distribution in the rural areas.

In most developing countries, and especially many in sub-Saharan Africa, structural adjustment programmes have liberalized their economies and opened up their markets to global competition. Consequently, private sector businesses in the lead sectors, such as agriculture, are acutely aware of the need to increase production and expand their export markets, whilst at the same time increasing their efficiency in order to stay competitive. In most cases, expansion is being hampered by the high investment costs required to fund the procurement of capital assets. Therefore companies are already turning to sub-contracting as a way of overcoming capital shortages.

Contract farming is also becoming an increasingly important aspect of agribusiness as a means of organizing commercial agriculture for both large and small scale farmers. Changing consumption habits worldwide, such as fast food, supermarkets and the expansion into fresh and processed food products, are also providing the impetus for growth in contract farming. This in turn will provide increasing opportunities for tractor-based services in providing mechanization inputs to the small contracted farmers.

Similarly, in the traditional vertically integrated agribusinesses such as tea and sugar cane, the restructuring of their businesses to achieve competitive advantage will force management to concentrate on their core business activities to provide added value and look towards contracting out their non-core activities to off set investment capital shortages. Again, these business trends will provide opportunities for the tractor based service providers to undertake contracted out non core activities.

13.2.4 Donor Policies and Initiatives in the Road and Agricultural Sectors

Roads Sector

Donor policies and initiatives have a major impact on the pace and direction of development and are being constantly revised and updated. Current development trends that are influencing donor policies and initiatives include the following:

1. Targeting poverty alleviation and economic growth in rural areas.
2. Using Performance Indicators to measure a country's progress on rural access.
3. Targeting "Rural Transport" as a whole and not just "Rural Roads".
4. Decentralization of road network management and maintenance.
5. Commercialization of roads through a Road Agency and collection of road user charges.
6. Encouraging private sector investment through "Public-Private Partnerships".
7. Promoting "Output Based Aid" through "Performance Based Subsidies".

In the past, rural transport projects focused mainly on physical outputs with projects being selected on the basis of economic rates of return. There was little participation by stakeholders in road works selection and road maintenance was left for governments to fund and organize. Such an approach has led to the inefficient allocation of public funds and non transparent selection of the road works to be undertaken. This approach has left a large population of rural people still without basic access and led donors to begin taking effective demand for transport services into consideration when developing investment options, technical design and network improvements. Therefore, donor initiatives supporting rural roads are specified as "rural transport projects" and support a range of transport infrastructure improvements besides roads. Consequently, the largest share of rural transport lending comes from multi sectoral projects which originate from agriculture and rural development.

The key objectives of most rural transport policies and strategies are aimed at poverty reduction as this is directly linked to improved rural access to economic and social services. However, rural access is determined by the availability of both transport infrastructure (roads) and services (motorized and non motorized transport) at village level. The main distinction between the provision of transport infrastructure and services is that infrastructure is provided by the public sector and services by the private sector. Consequently, such policies and strategies must specify the management and financing arrangements for rural roads as well as providing an enabling environment to encourage the development of motorized and low cost forms of rural transport services. Both sectors nevertheless, provide significant opportunities for tractor-based service providers as seen from the examples of rural transport policies and strategies being implemented by a sample of developing countries (Table 13.2).

TABLE 13.2
Components of a selection of rural transport programmes

COUNTRY	MAIN COMPONENTS OF RURAL TRANSPORT POLICIES AND STRATEGIES
Tanzania	Community participation in rural infrastructure, private sector development.
South Africa	Poverty alleviation through community based public works & economic development
Madagascar	Promoting intermediate forms of transport and rehabilitation of rural road network.
India	Provision of all weather access to unconnected rural settlements.
Bangladesh	Increasing rural incomes through labour based road construction and maintenance.
Cambodia	Community development & maintenance of rural roads using labour based methods.
Peru	Sustainability of rural roads through community based rural road maintenance.

Source: IRF, 2010

A fundamental requirement for the sustainable improvement of rural infrastructure is clear guidelines on who is responsible for financing maintenance and capital improvements. In the past, governments had the responsibility, but given the scarcity of financial and human resources there are too many kilometres of roads and paths for governments to take responsibility for. Therefore, bringing more of the rural network under regular maintenance requires innovative ways of combining financial and technical resources of both the public and private sectors. A sustainable framework for maintaining rural roads must be built around financial arrangements between government, communities and the private sector as practised in many industrialized countries where private ownership of public roads has proved to be both cost effective and efficient at the lowest levels of the network. Given the drive for decentralization and increasing the role of the private sector, the time is right to adopt institutional arrangements that encourage small farmers who are the largest private sector group, to assume more responsibility for the lowest levels of the rural network (Malmberg Calvo, 1998).

Agricultural Sector

Until recently, the agricultural sector in the developing world has been neglected by both governments and donors alike. The donor community has failed to implement a separate strategy for agriculture, especially in sub-Saharan Africa, except as part of a wider rural development approach and even this modest input was subsumed over time into a broader rural focus, further diminishing the importance of agriculture. However, with the introduction of MDGs and the realization that these performance indicators will not be met without first addressing the potential of the agricultural sector, government and donor strategies have finally recognized the agricultural sector as a potential driver of growth and poverty reduction (World Bank, 2007).

Nevertheless, government strategies need to reflect that farmers need incentives to practise intensive agriculture and to take risks. Therefore a number of factors need to come together at the same time such as improved seeds, water, credit, access to markets and adequate returns. In parallel, donors need to focus on agricultural development as a key priority with attention on increasing agricultural productivity through expansion of irrigation and increasing productivity of rain fed agriculture. In addition, they need to implement mechanisms, including public-private partnerships to provide farmers with credit, water, seeds and fertilizer as well as supporting the development of marketing and transport infrastructure (World Bank, 2007).

13.2.5 The Challenge of Providing Tractor-based Services in Rural Roads

Labour and Tractor-based Technology in Rural Road Construction

The reliance, by most developing countries, on the use of heavy construction equipment for undertaking road works not only requires a high capital investment, but the progress of works is dependent upon the supply of spare parts, skilled mechanics, operators and workshop facilities. In contrast, rural road construction and maintenance offers considerable scope for increasing efficiency and cost effectiveness by adopting alternative work methods that rely on locally available resources such as labour and tractor-based technology that can be implemented by small scale local contractors.

In the 1970s, donors and international organizations focused their attention on determining the feasibility of using labour and tractor-based methods for the construction of rural roads. These methods not only generated rural employment, but also created opportunities for using agricultural tractors for water and gravel haulage and material compaction. The emphasis of donor attention was on the quality of the completed labour-based works compared to using heavy construction equipment. This was found to be comparable and it was accepted there was scope for the use of labour-based methods in the roads sector. However, the relative cost of using labour-based methods compared to construction equipment was dependent upon the wage levels for unskilled labour, the availability of heavy equipment and spare parts, and the type and design of the works to be undertaken. In addition, the pilot projects initiated during the late 1970s, created an artificial environment by circumventing labour regulations and normal financial procedures. Although these projects proved that labour-based methods were feasible, the artificial project structures created soon collapsed after the projects ended and governments went back to using heavy equipment based methods of construction for rural roads. This was not surprising, given the centralized road management structure that existed in most countries and their highly bureaucratic financial procedures created delays in payments which favoured equipment-based construction and hindered the expansion of labour-based methods. (Stock and de Veen, undated).

Consequently, the key reforms identified for the expansion of labour-based methods included government commitment, revised labour laws, a reliable flow of funds and decentralized administrative structure. Donors are now encouraging governments to address these short comings through their policies and strategies for decentralization of road network management, second generation road funds, public-private partnerships, community contracting and promoting performance based contracting. This encouragement for using labour-based methods for rural road construction not only increases the opportunities for rural employment but also for the use of tractor-based services in support of labour-based construction methods.

Labour-based road construction and maintenance projects have also provided opportunities for local small scale contractors to become trained in labour-based road construction techniques and to acquire ownership of agricultural tractors and intermediate road construction equipment. However, the barriers of entry for an individual tractor owner to break into labour-based roads contracting are a major challenge, as contractor selection by central government, local government and district councils is usually based on the following criteria:

- Must be a registered company with VAT registration
- Must be a registered contractor with the appropriate Ministry of Roads/ Works
- The company owner must be trained and have experience in labour-based road works
- The company must have its own equipment or have access to hired equipment

Such barriers will exclude farmers and individual tractor owners from becoming prime contractors, without training, but it does not prevent them from undertaking tractor-based sub-contracting work for a prime contractor. Also, in addition to the formal roads sector, there are also opportunities for tractor-based sub contracting on road works in national parks, ago-industrial estates and large commercial farms.

Labour and Tractor based Technology in Rural Road Maintenance
Bituminised and gravel road maintenance is divided into two main categories, routine, and periodic and each of these categories can be broken down into equipment related and labour related activities. Routine maintenance is undertaken annually and the regular activities for the equipment based works consists of tyre dragging (in some countries) during the dry season and towed grading during the rainy season. It is necessary to maintain the original road profile using existing surface material and this is best undertaken using a light weight (2 tonne) towed grader. A 60-75 hp agricultural tractor is best used for this work as well as for towing trailers and water bowsers.

Periodic maintenance is undertaken every 5 – 6 years and involves reshaping the road profile, re-gravelling and reinstating or reconstruction of the drainage system. The equipment related works involves reshaping the road profile using a heavier towed grader (5 tonnes) towed by a 100 hp agricultural tractor. The re-gravelling also includes gravel haulage, gravel spreading, watering and compaction which is best achieved using a 100 hp agricultural tractor and associated towed grader, trailers, roller and water bowser.

The challenge of providing tractor based services in road maintenance is meeting the requirements for two different sizes of tractor and towed graders to perform routine and periodic maintenance. In addition, 3-5 tonne gravel trailers (two per 50 hp tractor) water tanker and towed dead weight roller are standard equipment for rural road construction. Clearly farmers and tractor owners do not own this type of equipment, except for the trailer, therefore it would have to be hired from a contractor or hire company.

13.2.6 The Sustainability and Economic Viability of using Tractors on Rural Roads

Tractors versus Trucks
When donors started to fund labour-based road projects during the 1970s, tractor-based technology was considered the cheapest, and most sustainable technology to use for the haulage of gravel. In 1976, the World Bank guidelines for labour-based construction programmes compared the cost of a truck with a tractor and a two trailer combination and the tractor trailer combination was found to be the cheapest option up to a haulage distance of 10 km. In addition, the tractor trailer combination was seen as appropriate because it was based on simple technology, of robust construction and therefore simple and cheap to maintain. However, in the last twenty years the availability of

low cost small tipper trucks has increased in developing countries whilst at the same time tractors from developed countries increased in sophistication, horse power and cost. This caused the unit cost of haulage capacity to double for tractor and trailers between 1976 and 1997 as shown in Table13. 3, making the small trucks a viable option for gravel haulage from 2-3 km, especially as the sources of gravel were beginning to decline and the average haulage distance was increasing.

TABLE 13.3
Unit cost of haulage capacity for trucks and tractors (USD/m³)

VEHICLE	1976	1997
Truck (5-6 m³)	2 417	8 683
Tractor/2 Trailers (3-4 m³)	3 457	15 649

Source: Illi, 1997

With the emergence of India and China as major players in the export of cheap, small to medium horse power tractors to developing countries, the unit cost of haulage capacity has now swung back in favour of tractors and trailers. In addition, because of the agricultural tractors multi-tasking capability, good off road performance and simplicity in operation, repair and maintenance, they are still cost effective and can be fully utilized in support of labour-based methods of road construction and maintenance. Consequently, they are still the preferred option by labour-based contractors, unless the gravel haulage distance is over 10 km. In this case, small trucks would do the gravel haulage and tractors would undertake water haulage, watering road ways, material compaction and grading.

Tractor/Towed Grader versus Motor-grader

Heavy construction plant, such as motor-graders, are dedicated production machines that are designed for large equipment based construction and rehabilitation road projects where the capacity of each type of machine is programmed into the construction process. On the other hand, where the construction process is not continuous and requires a frequent change in activity, tractor-based technology offers a cheaper and more flexible investment that is more compatible with labour-based methods of construction and maintenance. The motor-grader, like the tipper truck, is a single tasking machine and without a continuous single type of activity, economic rates of utilization cannot be achieved, unlike a tractor which can be utilized to undertake a number of different activities including towed grading. Although the output of a tractor and towed grader is slightly less than a motor-grader, this is more than off set by its multi-tasking capability allowing it to be fully utilized throughout the year.

The economic viability of tractor towed grading can be seen from Table13.4 when compared with the daily cost of owning and operating a motor-grader.

The Table shows that the tractor and towed grader is 54 percent cheaper to own and operate. From work undertaken in Kenya, the output of the motor-grader was found to be 20 percent higher than the tractor and towed grader, therefore the cost per kilometre of road maintenance was lower. However, because the tractor and towed grader was more mechanically sustainable and the tractor more flexible in terms of the type of work undertaken, the availability and therefore overall utilization was higher than for the motor-grader and the owning and operating costs per hour were lower.

TABLE 13.4

Comparison between the operating costs of motor-graders and tractor-drawn graders (USD/day)

Cost Components	COST PER DAY (USD)	
	Motor-grader (120 hp)	Agricultural Tractor (100 hp) + Towed Grader (5 tonnes)
Ownership Costs	366	131
Operating Costs	267	152
Overheads (Profit)	200	100
TOTAL	**833**	**383**

Source: Petts, 1997

13.2.7 Initiatives for the development of Tractor-based Service Providers

Government policy

The Asian experience has shown the importance of encouraging and supporting farm mechanization through appropriate policies that address issues of the profitability of farming, land tenure and ownership. The experience has also shown that the availability of agricultural machinery is essential for stimulating effective tractor demand and promoting the sustainable mechanization of agricultural production. Government policies need to encourage the development of new supply chains with India and China who are already established global players in the export of low cost unsophisticated agricultural machinery which is appropriate for developing countries. However, such policies must also include the establishment of dealership networks to service the machinery being imported.

Structural adjustment provided the impetus for governments to place tractor hire services into the hands of the private sector, but poor agricultural performance over the years has restricted growth and investment in these services. Therefore, governments must use their agricultural mechanization policies (where they have them), as a vehicle to promote the development of private sector tractor-based service providers on a cross sector basis as a sustainable and cost effective method of increasing tractor-based mechanization.

Banking and Financial Sector

In the past, governments have enhanced the supply of term finance through agricultural development banks and credit projects, but because of poor performance, most credit programmes have been phased out and agricultural development banks liquidated. The resulting gap in the funding available for term lending has not been filled and the availability of term finance for farmers remains limited (Hollinger, 2004).

The depressed state of agricultural bank lending and the lack of interest shown by donors and governments has been a major constraint in financing tractor-based mechanization. Investment in tractors and machinery requires large amounts of capital which is beyond the self financing capacity of most farmers; therefore an innovative approach to tractor finance on reasonable terms and conditions is a major requirement. Fortunately, such an approach has been developed (for example in Tanzania and Zambia) through a private sector initiative involving a commercial bank, a development company and a tractor dealership. This joint initiative has been set up to assist farmers to purchase tractors under more favourable banking terms than those being offered by the banking sector.

This innovative tractor financing scheme is a major step forward and has proven to be a viable and sustainable model that can be replicated on a national or regional scale across Africa. The model also lends itself to being developed as a public-private partnership (PPP) to include public and private capital and donor support to enable the financial sector to work with farmers, tractor dealerships and other stakeholders.

Roads Sector (Local government and urban/district councils)

Donors are actively encouraging the use of low cost labour-based technology and the development of small scale private sector labour-based contractors for rural road construction and maintenance. A large number of projects have already been implemented in Africa and Asia using labour for the principal activities, but relying on agricultural tractors for material haulage, road compaction and road grading. These activities offer tractor owners substantial opportunities for providing tractor-based services in this sector. However, despite the success of labour-based technology, the majority of governments are still reluctant to include such technology in their regular rural roads programmes. Therefore, donors must continue to make governments aware of the advantages and cost effectiveness of using labour and tractor-based technology in rural road maintenance and construction.

Agro-Industry Sector

There are two groups in this sector, the first group undertakes all their activities in-house and provides few opportunities for contracting out tractor-based services. However, these private sector businesses are becoming acutely aware of the need to increase efficiency in order to stay competitive in the face of global competition. Restructuring to achieve competitive advantage will oblige them to concentrate on their core business activities and look to contracting out their non-core activities to stay competitive. This will provide opportunities for tractor-based services.

The second group undertakes contract farming which is becoming an increasingly important aspect of agribusiness as a means of organizing commercial agriculture for both large and small scale farmers. Changing consumption habits worldwide and expansion into fresh and processed food products are also providing the impetus for growth in contract farming. This group shows great initiative by actively encouraging the provision of tractor-based services and are also responsive to the needs of tractor owners by providing loans to repair tractors and purchase fuel prior to undertaking contract work.

Donors and International Organisations

Donor initiatives supporting rural roads are referred to as rural transport projects and support a range of transport infrastructure improvements besides roads. The largest share of rural transport lending comes from multi-sector agriculture and rural development projects. Although the beneficial impact of rural roads on the performance of the agricultural and transport sectors is well known, the important role that agricultural tractors can play in the development of these sectors is less well understood and FAO is developing initiatives to promote tractor-based services either through providing development programmes or training seminars using their guidelines and training materials.

Donors are also encouraging an integrated cross-sector approach to planning rural development by taking a sector wide rural transport approach and encouraging the use of planning tools and international performance indicators. Therefore, the formulation of integrated rural development policies and strategies, covering transport, transport facilities, roads and agriculture, is a pre-condition for donor investment. Consequently, FAO is taking the initiative to ensure that a country's mechanization strategy addresses the use of tractor-based technology on a commercial basis in rural development across all sectors and also supports the development of tractor-based service providers.

13.3 OTHER OFF-FARM USES OF AGRICULTURAL TRACTORS[44]

13.3.1. Transport

Rural transport is normally a year-round requirement. Rural dwellers need the service to get goods to and from market and for a host of other needs of the rural family ranging from social visits to seeking emergency medical care. Rural transport can be provided by a range of means from head loading to hand and animal drawn carts, tractors and trailers and more sophisticated engine-powered vehicles. In the context of this chapter the tractor and trailer option is the relevant one; and it assumes that the tractor is already owned by

[44] Contributed by Brian Sims, FAO Consultant. briangsims@aol.com

the farm family looking to widen its application by taking on a wider range of off-farm work for more months of the year.

Adding transport to the portfolio of activities capable of being performed by a tractor can have a number of positive outcomes (FAO, 2009):

- Improved efficiency of the farm business. Transport off the farm by tractor and trailer can reduce costs per trip and increase payloads when compared to more traditional options such as human or animal powered vehicles. It is usually the primary purpose of expanding into rural transport to increase the number of paid hours of work for the tractor and so increase the owner's income and ability to cover the replacement costs of the tractor and trailer.
- Relief of drudgery. This is especially the case for women who may be responsible for transporting water and firewood.
- Promotion of improved access and market linkages. Transport enterprises allow increases in productivity in a local area. It is worth increasing output (by increasing cropping areas or by farming more intensively, for example) if the excess production can easily and cheaply be brought to market.
- Promotion of farmer organizations. The nature of transport enterprises encourages farmers (especially smallholder farmers) to group together in formal or informal associations. Farmer organizations have many advantages in terms of greater lobbying, bargaining and purchasing power, ability to respond to donor-funded projects, and risk sharing.

Tractor and trailer transport is not the cheapest in terms of dollars per ton-kilometre, as can be seen in Table 5. But considering that the farmer, or farmers' group already have invested in the tractor and now wish to increase its annual work output by adding a trailer, the marginal investment implications are fairly modest. As can be seen from Table 13.5, the cost per tonne-km is low for the tractor trailer option.

TABLE 13.5
Some means of transport with indicative characteristics

Transport type	Indicative values					Some important requirements	
	Cost (USD)	Load (kg)	Speed (km/h)	Range (km)	Cost/ton-km	Mechanics	Good roads or tracks
Hand cart	60	150	4	5	0.35	low	medium
Ox cart	500	1 000	5	10	0.20	medium	medium
Trailer (for tractor)	1 000	2 000	25	50	0.20	medium	medium
Pick-up truck	12 000	1 200	80	200	0.70	high	high

Source: Adapted from FAO, 2009
The table shows order of magnitude indicative figures only. The costs per tonne-km are very approximate and highly sensitive to factors of cost, loads and distances.

13.3.2 Other off-farm options

Whilst rural transport is likely to be an almost universal requirement and represents a safe investment option for the tractor owner, other potential options for increasing the earning power of the tractor through off-farm operation are more site-specific. If the opportunities present themselves then the following options (amongst others) can be pursued in a given situation:

- Use of the tractors as a **stationary power unit** driving machines through the power take off shaft. This can be for the following:
  - Grain milling (typically wheat and maize)
  - Rice milling
  - Oil expelling (from a range of oil seed crops)
  - Irrigation water pumping
  - Timber sawing
  - Electricity generation

Experience has shown, however, that the preferred option for these applications is a separate stationary engine. Dependence on a tractor, with other agricultural jobs to do elsewhere adds uncertainty and is seldom seen as a permanent solution.

- Use of the agricultural tractor in building construction projects. This is likely to comprise mostly transport of building materials, but could involve earth moving if the requisite implements can also be offered. These would include scrapers, dozer blades, buckets and rear-mounted rippers.

13.4 OFF-FARM OPTIONS IN RNAM PARTICIPATING COUNTRIES[45]

The Regional Network for Agricultural Machinery (RNAM), which was an Asian inter-country project initially of eight countries in 1977 and finally of 11 countries by its end in 2002, had not included in its programme of activities the use of agricultural power and machinery in off-farm operations. Nevertheless, in the member countries, farmers and agro-industrial entrepreneurs who own tractors, small engines and electric motors have realized the benefits of increased utilization of these resources and of deriving additional income by rendering services outside the farm. In particular this includes transport of goods and people, handling of construction materials as well as processing of food and feed crops. There are also opportunities as agri-business enterprises for providing contract services to urban residents for garden tillage, bottled water delivery, lawn mowing, tree and hedge pruning as well as landscaping in collaboration with entrepreneurs and professionals engaged in related activities such as agriculturists, landscapers, and construction contractors. Increased awareness and improved management of off-farm use of agricultural machinery may therefore strengthen the strategy for the promotion of agricultural machinery in developing countries because of

[45] Contributed by Reynaldo Lantin, FAO Consultant. rmlantin@yahoo.com.

the extra income generated during the off-season or slack period in field operations. Research and development institutions may explore the possibility of developing machinery for such domestic purposes and collaborating with local manufacturers to make them available to farmers to complement their range of agricultural machinery and increase utilization of their resources. The expanded usage could provide enough incentives to motivate farmers to become entrepreneurs during slack periods. They would get ready cash because the non-farming clients will normally pay on delivery unlike farmers who may be constrained to pay in kind after harvest time.

Mechanization of transportation has provided an opportunity for enterprising farmers to meet the need for saving time and human energy in the movement of goods and people in the rural and peri-urban areas. There is usually a lack or scarcity of transportation services in rural areas, which are remote from urban centres because of lack or inadequacy of infrastructures and regular services. Rural as well as farm-to-market transport may as well be considered as part of the agricultural production system and as such has probably been one of the first activities to be mechanized in the history of agriculture. The use of draught and pack animals like the horse, ox and buffalo along with sleds, carts, wagons, carriages and other towed wheeled vehicles has been a traditional mechanized form of military and civil transport. These methods can now be replaced with tractors and trailers.

Use of two-wheel tractors

In the Philippines (and elsewhere) 2-wheeled tractors (2WTs) are commonly used to pull a trailer. The power unit is convertible into a 2WT with attached implement for use in the rice field.

In a survey of power tiller or 2WT utilization in two rice-producing provinces, Juarez and Duff (1981) reported that farmers with farms in the range of 5-10 ha utilized their 2WTs for 7.9 to 48.7 worker-days/season on their own farms and 5.0-30.0 worker-days/season for custom work but did not utilize them for off-farm jobs. Farmers owning less than 5 ha utilized their 2WTs for 4.2-24.0 worker-days/season in their own farms, 2.5-15 worker-days/season for custom work and 0.3-0.9 worker-days/season for off-farm jobs. Two workers take turns in the field operation of the 2WT every two hours during the work-day because of the drudgery of walking behind the tractor. However, only one worker was needed for operation of the trailer and other off-farm uses.

In Nepal, the sales of 2WTs and trailers increased when entrepreneurs discovered that full-time servicing the transport needs of urban and peri-urban dwellers was a lucrative income-generating business (Justice, 2004). Apart from the immediate cash returns from the services, the owners of the agricultural equipment took advantage of the franchise-free transport business. However, such use was eventually banned in Kathmandu because proliferation of the power and machinery purportedly resulted in traffic congestion and air pollution in the city but more perhaps because of the lobbying of the franchised transportation industry.

In Bangladesh and Nepal, the 2WT is utilized as a transport power unit with a trailer to transport people as well as farm goods, implements and materials including fodder, firewood and livestock in rural areas and in some places to haul water and milk in tanks and individual containers. It is also used to transport or handle construction materials.

Similarly, in the other member countries of RNAM, farmers use their 2WT pulling a trailer as a house-to-farm transport vehicle for their farm implements. Farm workers often hitch-hike when they can be accommodated in the trailer. Enterprising farmer-owners of such small trailer tractors which can negotiate through narrow trails have made extra income by charging transport fees from the community to the town or market during weekends and holidays. Sometimes the vehicle is hired for short-distance hauling of earth, stones, sand, gravel and cement materials and other construction materials.

Off-farm use of stationary engines

During the dry season in places where there are no gravity irrigation structures or water services are insufficient, the farmer utilizes the engine by mounting it on a pumpset base to draw water from either a shallow tube well, deep well, canal or river. Engine pumpsets are fast replacing manual methods of transferring water from a lower level to a slightly higher level ground. In Thailand, the engine is commonly used to drive the high-volume and low-head axial-flow pump to draw water from a canal which is lower than the field level by one to two metres.

13.5 CONCLUSIONS

Research has identified the existence of strong linkages between rural infrastructure investment and the resulting increase in agricultural production and reduction in poverty. In addition, it is now widely accepted that farm productivity is directly related to the amount of farm power available. However, from the South-East Asian experience even subsidized tractors are uneconomic unless utilization is maximized by undertaking both on and off farm activities. Therefore, in order to increase the demand for tractors, tractor owners need to be sure that tractor ownership is profitable and there is a market for tractor-based services both on and off the farm.

Most agro-industries are now under competitive pressure due to global competition and are busy restructuring their operations in order to compete in the larger global markets. This restructuring will lead to increased specialization in production and to contracting out selected non-core activities, thereby providing tractor owners with increasing opportunities to participate in these activities.

In order to increase off farm activities, tractor owners have to be prepared to market their tractor-based services across all business sectors in the rural areas. There is already a strong link between tractor-based technology and labour-based rural road construction and maintenance. This link has become well established because of the tractor's multi-tasking and off road capability, mechanical sustainability and cost effectiveness. Therefore a substantial market already exists in the roads sector and this needs to be exploited by tractor owners.

Both donors and governments have recognized the importance of the rural road networks and the agricultural sector as potential drivers of economic growth and poverty reduction in the rural areas. Consequently, in many countries they have in place substantial policies and strategies targeting the rural roads and agricultural sectors and these are reflected in programmes to increase rural access, maintain rural roads through community participation and improved access to credit and other agricultural inputs. Clearly donor and government policies are creating country programmes that will benefit tractor owners by creating opportunities for providing both on and off farm tractor-based services. However, the limiting factor is the lack of awareness by tractor owners and many rural based enterprises of the potential opportunities that exist for contracted out services. In addition, tractor owners must also have the capacity to provide tractor-based services to meet contractual requirements. For these reasons tractor owners will need guidance and support to identify and exploit cross sector market opportunities and develop their capacity to meet such opportunities. FAO is already developing initiatives to promote tractor-based services through development programmes and training seminars using their guidelines and training modules. They are also assisting countries to develop mechanization strategies that will address the development of tractor-based services on a commercial basis across all sectors in the rural areas.

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CHAPTER 14

Agricultural machinery manufacturing and supply

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ABSTRACT

This chapter briefly examines current trends in the multinational tractor manufacturing industry, and their impact on developing economies. The main focus is on developing and reinforcing the agricultural machinery industry manufacturing and service industries in developing countries. The mechanization input chain is examined and the roles of the major stakeholders are discussed. These include those for: credit provision, machinery testing, extension, training, raw material supply, provision of innovative ideas, machinery dealers, hire service providers, maintenance and repair services and, of course, farmers. The roles of the public and private sectors in the support of manufacturers are described. The private sector should concern itself with finance, retail, repair and hire services. Whereas the public sector should be involved with finance (where needed and where private sector provision is inadequate), tax incentives, smart subsidies, innovation incentives, rural infrastructure and extension. Cross cutting issues (involving both sectors) include training in technical and financial aspects, and machinery testing.

14.1 INTRODUCTION

The main focus of this chapter is on local manufacture of equipment for national markets. This means that there is an emphasis on the mechanization needs of smallholder farmers. However national and multinational tractor companies are now seeking to enter the African market as they see it as the next major market to be captured. After an introduction to the recent trends in the multinational tractor industry, information of penetration of the African market is pulled together from other chapters in this book.

14.1.1 Current trends in world markets for agricultural machinery

The 21st Century has seen some remarkable advances made in manufacturing quality and quantity and currently there is a shift of the centre of gravity of world-wide production and marketing. The multinational agricultural tractor and machinery industry is dominated, in 2010, by a few major companies although it should be noted that mergers and sales of companies continue in a fluid environment. As an example, Caterpillar, once well known for its track laying crawler Challenger agricultural tractors, linked with Claas in Germany in 1997 to sell the line as Claas machines in Europe. At the same time Caterpillar marketed Claas combines in the US. A joint venture followed with Claas combines being manufactured in the US. However in 2002 this operation was sold to Claas; also in 2002 the Challenger tractor line was sold to AGCO and so in this year Caterpillar effectively ceased all agricultural machinery related activities.

The multinational companies operating today are:

John Deere with headquarters in Moline, Illinois has an almost bewildering array of operations of its Agriculture and Turf Division around the world. The company has major agricultural machinery manufacturing activities in many countries in North and South America, Europe, Australia, India and China (www.deere.com).

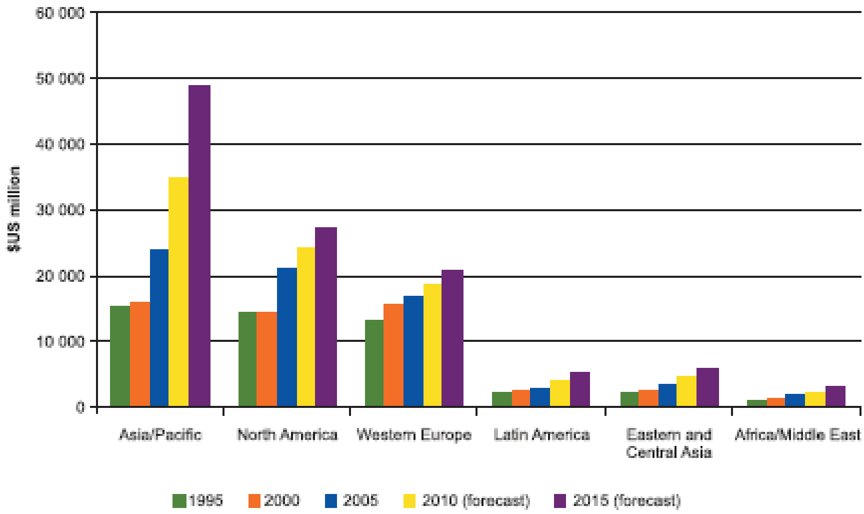
AGCO (from Allis-Gleaner Company) was formed in 1990 and now operates in 140 countries with a network of 700 full-service dealers. The flagship tractor companies owned are Challenger, Massey-Ferguson, Valtra and Fendt and in addition the company manufacturers a wide range of associated equipment including for harvesting, hay making and irrigation.

Case New Holland (CNH) was created in 1999 through the merger of New Holland and Case. It now manufactures three world tractor brands: CaseIH, New Holland Ag and Steyr. Ford bought New Holland in 1986 to form Ford New Holland and the entire CNH Company is now a subsidiary of Fiat S.p.A and operates globally in 170 countries.

Claas is a tractor and harvesting machinery company based in Germany but has manufacturing operations in other European countries (France and Hungary) as well as Russia, India and the USA. Claas took over Renault Agriculture in 2003; since then Claas sells former Renault tractors as 'Claas' and has boosted its turnover with this move.

The world market for agricultural machinery is currently dominated by demand from countries and regions with large, modern agricultural sectors. North America, Western Europe and Japan accounted for 60 percent of sales in 2005 (Figure 14.1). However these are not rapidly developing markets and most sales are for replacement rather than new investment. Manufacturers compete by improving the energy efficiency, sophistication and comfort of their machines and also by providing finance and strong after-sales service. In North America and Western Europe sales are expected to grow by 2.5 percent annually from 2010 to 2015, and by 1 percent in Japan over the same period (World Bank, 2010).

FIGURE 14.1
World sales of agricultural machinery 1995-2015



Source: World Bank, 2010

In developing regions of the world, farm machinery markets offer much greater future potential both in terms of market size and market growth. Rapid mechanization of the agricultural sectors of Latin America and Asia means that markets in these regions are forecast to grow at annual rates of 6-10 percent between 2010 and 2015. By 2015 developing countries are expected to account for more than 50 percent of world market sales and China is likely to surpass the USA as the biggest single market for agricultural machinery.

Agricultural machinery (especially tractor) manufacturers in China, India, Pakistan, Brazil, Turkey, Iran and Belarus have accrued substantial benefits from the increased demand for machinery from developing countries. India's Mahindra & Mahindra Company is now the fourth largest producer of tractors in the world and is expected to challenge Deere and Company as the largest producer by 2010. Many of these manufacturers have prospered by supplying the market for smaller, lower-cost machines suited to small-scale low-income farmers who predominate in their countries. But while there is a need for more farm power in the developing world, exports to other low-income countries are usually limited and most of the low cost machinery produced by the major manufacturers in China, India and Turkey, is sold in their own growing domestic markets.

One result of the growing number of tractor manufacturers in developing countries (especially India and China) is that the cost of farm power (in terms of dollars per horsepower) is declining. This is good news for the world's farmers working to emerge into commercial markets and if the reduced price of power can be coupled with robustness and reliability of the tractors then the stage is set for a transformation in farm power availability.

14.1.2 Tractor assembly and manufacture in developing countries

Other chapters in this publication have given some indication of the activities of multinational companies in developing countries. Gajendra Singh (Chapter 5: Agricultural mechanization in India) describes how the mechanization scene in India started with the importation, by the state of a few models in the early 1940s. Tractor production (by the Eicher Company) started in the 1960s in parallel with 2WT tractor manufacture. In the period of the 1970s to the present, the number of tractor manufacturers has increased and draught animal power declined in importance. By the 2000s three major multinational companies were established in the country (John Deere, New Holland and Same) and as a result of mergers, Mahindra & Mahindra (M&M) and Tractors and Farm Equipment (TAFE) have become huge conglomerates with international operations. Basam Snobar and El Hassane Bourarach (Chapter 7: The Near East) describe the development of the tractor and machinery industries in various countries of the region. So that Algeria and Libya entered into state-owned joint ventures in the 1970s. The Iran Tractor Manufacturing Company (ITMCO) has been manufacturing Massey Ferguson tractors since 1975 and has since entered into agreements with Uganda, Tajikistan, Zimbabwe and Venezuela to set up factories in those countries. Mathias Fonteh (Chapter 3: Agricultural mechanization in West and Central Africa) reports on the plans and achievements of Chinese and Indian (M&M) companies to establish manufacturing presences in Nigeria, Ghana, Cameroon, Chad and Gambia. These are just some of the examples of international companies competing for business in developing countries, and particularly in the African continent.

FIGURE 14.2
Reception of SKD John Deere tractors by AFGRI, Zambia

Source: (Photo: Josef Kienzle)

Tractors can be assembled in newly industrializing countries either from kits that are completely knocked down (CKD); or Semi knocked down (SKD). They can, of course also be imported fully assembled. The first step in manufacture is to assemble machines locally, for example the AFGRI Company in Lusaka receives SKD John Deere tractors and then assembles them on site in Lusaka (Figure 14.2). Similarly the SARO company in Zambia, which supplies Landini, FarmTrac and TAFE tractors receives all of them in SKD kits and assembles them on-site in Lusaka (Figures 14.3 and 14.4).

FIGURES 14.3 & 14.4
SKD TAFE kits arriving at SARO, Zambia

Source: (Photo: Josef Kienzle)

14.2 LOCAL MANUFACTURE OF FARM MACHINERY

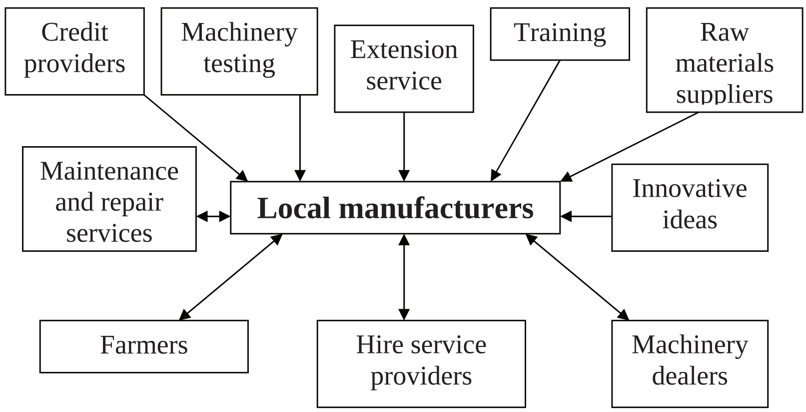
The following sections examine aspects of the local agricultural machinery manufacturing industry. The main thrust is on encouraging local manufacture of equipment for smallholder farmers emerging from subsistence into commercial agriculture and requiring the essential input of farm power and associated implements to achieve greater productivity. Although developing countries can initiate the mechanization of their farms through imports of appropriate equipment, it will generally be in their interests to develop an indigenous industry that can cater for specific local needs using locally available materials and skills. This reduces the dependence on long (and expensive) supply lines subject to the vagaries of currency exchange rates and risky in terms of the supply of replacement parts and services.

The principal stakeholders and services impacting on the manufacturing business are identified and include: credit provision, machinery testing, extension, training, raw material supply, innovative ideas, machinery dealers, hire service providers, maintenance and repair services. The roles of these actors and the interactions between them are described and discussed. Subsequently the relevance to the private and public sectors are discussed with reference to service provision for the manufacturing industry. The private sector will be principally involved in: finance provision, retailing, repair and maintenance and machinery hire service contracting. The public sector will also be active in finance provision but will dominate in the fields of: tax incentives, subsidies, incentives for innovations, rural infrastructure and extension. There are some crosscutting issues that involve both sectors and these include training in business and technical skills and machinery testing.

14.2.1 The mechanization input supply chain

Agricultural mechanization is a means to increase labour and land productivity and is but one element in the array of inputs needed for a successful farming enterprise. As with any other input, agricultural mechanization has a supply chain comprising a number of stakeholders. Each of the stakeholders, with the possible exception of some of the services provided by the public sector, is active in the supply chain in order to make a living. This means that their activities must generate a surplus which will recompense them for their time and effort. Figure 14.5 illustrates some of the possible interactions in the chain.

FIGURE 14.5
Mechanization supply chain stakeholder interactions from the perspective of local manufacture



Roles played by supply chain stakeholders

Taking each of the stakeholders indicated in Figure 14.5 in turn, their roles will now be briefly summarized:

- *Credit providers*

At the level of the smaller scale manufacturing industry, the existence of a formal credit supply may not be a major preoccupation. However there may be times, for example when it makes financial sense to order raw materials in bulk, that credit facilities will be required. Credit provision to promote the development of local industry could be government policy, in which case there may be provision through a development bank. Otherwise the manufacturer would need to be on good terms with their local bank and have lines of credit agreed.

Credit is often available on a short term basis (a few months) from suppliers who are keen to retain and expand the business. And of course the manufacturers themselves will extend some credit to their clients (farmers, dealers and hire service providers) for short periods.

- ***Machinery testing***

Machinery testing is a contentious issue. Typically the attitude of many smaller scale manufacturers is that what they produce is the best that there is and so there is no need for testing. This is probably a short-sighted view and may go some way to explaining the frequently heard lament of potential farm machinery manufacturers that the small and medium scale farmer is an unreliable and risky market. At the same time farmers observe that equipment is too expensive, or not available, or has no service backup, or all three. What is clear is that better contact between manufacturer and farmer clients would be a good first step in improving the relationship and helping to ensure that the equipment manufactured satisfies the technical demands of farmers and at prices that they can afford. Development of a regime of on-farm testing of prototypes could create the necessary information flow between manufacturer and end-user that would go a long way towards creating a more profitable working relationship between the two stakeholders.

- ***Extension service***

It is a sad fact that public sector extension services in many developing countries are often viewed as unworthy of adequate investment. The result is that extension field staff are not sufficiently highly motivated and have little to offer their farmer clients. In fact farmers may often have better knowledge of innovations than the extension service itself. This can be a result of exposure to new ideas from NGOs and other development agencies and will be in contrast to the out of date information sources available to public sector extension staff. In contrast to this situation, where extension staff are well trained, well equipped and kept abreast of innovations, they will be well motivated and will offer a vital service to farming communities. This puts them in a strong position to interact with manufacturers and so ensure that farmer needs are being fully met. Box 14.1 gives an example of how well-trained extension staff can offer an invaluable service to a local manufacturer.

- ***Training***

Manufacturers, especially small-scale manufacturers, are notoriously deficient in business skills. Record keeping is often inadequate (sometimes non-existent) and so details of the costs of production are lacking. If production costs are not known with precision, then calculating a sustainable product price is very difficult. The best guide is often what the competition may be charging and this could also be based on guess work. Manufacturers frequently cite business skills training when surveyed on their needs for business improvement and it is probably the most important aspect that needs attention to strengthen the manufacturing sector.

In parallel with business skills training, there is also a strong demand for technical training. This is especially important in aspects of design of agricultural machinery which may not be fully understood. Whereas historically artisans arrived at the right answer by trial and error, this is no

BOX 14.1

How Extension and Training can Improve Local Manufacture: The Case of Nandra Engineering, Tanzania

Nandra Engineering in Moshi, Northern Tanzania manufactures a range of agricultural equipment including animal draught and tractor-mounted ploughs and cultivators together with crop processing machinery and no-till planters. Following a trade mission to Brazil in 2008 (organized by FAO and part of a regional development project) Managing Director Frank Lesiriam became motivated to enter the conservation agriculture market. The factory now makes hand-held and draught animal no-till planters as well as Zambian-designed subsoilers and reduced tillage rippers. However neither Frank nor any of his manufacturing staff have much contact with the agricultural community which Nandra serves.

This changed following an FAO training course in conservation agricultural machinery for lead farmers and front line extension staff from the Tanzanian Ministry of Agriculture, Food Security and Cooperatives. As part of the training, participants learn how to calibrate and operate no-till planters and one of the machines that they tested was a prototype from Nandra. The results of the calibration and field operation sections of the course were relayed to Frank Lesiriam who was able to incorporate major changes in the design to make it conform to the requirements of local farmers. The machine is now on sale and demand far outstrips supply at the moment.

The moral of this tale is that interaction between manufacturer, user and extension staff can result in a better machine more suited to the needs of the farming community and so be more likely to enjoy healthy volumes of sales.

Nandra no-till planter being tested on farm during farmer and lead extension worker training longer an efficient means of product development. Design parameters in such areas as soil engaging units (shares, chisel points, subsoilers, etc,) seed metering mechanisms, ergonomics to ensure machinery can be operated by women as well as men, are all aspects that are well understood and can be imparted to local manufacturers through technical training programmes.

- ***Raw material supply***

Key to the success of a local manufacturing enterprise is timely access to the raw materials required to manufacture the product line. This is especially true with the artisanal manufacturer and repairer (the blacksmith, or *jua kali* in East Africa). This group requires constant access to carbon steel to repair plough shares and ripper points. They increasingly complain that supplies (of, for example, vehicle leaf springs) are becoming more scarce as scrap steel is being collected for recycling. To secure supplies artisans may have to devote time to searching scrap metal merchants' sites in capital cities.

Other steel supplies may be imported and are often best bought in bulk to reduce the unit cost. For an individual manufacturer this could mean a heavy investment in stock (which may require credit) the value of which cannot be realized until the final product is sold to the customer. This would typically be a matter of months and brings in the issue of the opportunity cost of the capital invested in the raw material. Collaboration of the sort demonstrated by the Morogoro Engineering Cluster Initiative in Tanzania (Box 14.2) could provide a worthwhile solution.

- ***Innovative ideas***

Smaller-scale manufacturers get their innovative ideas from a number of sources. But at the same time their access to new sources of inspiration may be somewhat limited. We have seen that, far too frequently, this class of manufacturers may have limited access to the farming and extension communities where demands for new equipment could be expected to emanate. Although the internet is poised to have a major impact on the current situation, at the moment the usual route for obtaining new ideas is from external sources. Box 14.3 gives an example of how an international research centre engaged constructively with a local manufacturer in Bolivia to open new avenues of possibilities for a business that had become a little stagnant in terms of new, profitable product lines.

Another way that external sources can positively influence the output of a small-scale manufacturing business is through association with international development organizations. In 2008, FAO organized a trade mission for East African manufacturers to Brazil to interact with their homologues in the fertile conservation agriculture (CA) machinery development environment in that country[46]. Through a programme of visits to local manufacturers in southern Brazil, followed by a three-day workshop which promoted the development

[46] http://www.act-africa.org/publication/LAB/index.html

BOX 14.2

Morogoro Engineering Cluster Initiative (MECI), Tanzania

The MECI has been formed to benefit from the synergies of association with member engineering companies. It comprises 12 core workshops which include the manufacture of agricultural engineering related products in their production lines. The owners have regular monthly progress meetings and there is an annual expanded meeting when other relevant bodies are invited to attend. These include academic and research institutions, government ministries and artisan (*jua kali*) groups.

One demonstration of the benefits of participating in the MECI is the sharing of work between members when such action is convenient in order to capture large orders and to meet deadlines. For example one member recently gained an order for 70 trailers to be used with imported power tillers. To keep to the goal of producing 6 trailers per day (necessary to comply with the contract) the company is concentrating on the manufacture of axles, hubs and braking systems whilst other MECI members have been sub-contracted to supply the bodies and connecting linkages.

In a similar way MECI members can combine forces to procure raw materials in bulk and so reduce the need to have working capital tied up in excessive stocks, and at the same time reduce the unit cost of essential inputs.

Production of power tiller trailer axle sub-assemblies in the workshop of a MECI partner, Morogoro, Tanzania

of individual contacts and interactions, several businesses have been inspired to develop their own lines of CA equipment adapted to the East African situation and market. Figures 14.6 and 14.7 show aspects of this technology transfer through exposure to innovative ideas.

- ***Machinery dealers***

Unless the market for a local manufacturer is very limited (a single region for example); or unless the manufacturing enterprise is deliberately small-scale with no potential for expansion, then promotional efforts will be needed and these include a network of machinery dealers. Hardware stores will typically often buy small batches of equipment aimed at the smallholder farming

BOX 14.3

Innovative ideas from external sources: the case of CIFEMA-SAM in Bolivia

CIFEMA-SAM is a small-scale agricultural machinery manufacturing business in Cochabamba, Bolivia. Established in the 1970s with technical assistance from the Swiss government, it has built up a product range of draught animal powered conventional tillage equipment that includes ploughs, harrows and cultivators.

A technical cooperation programme with the UK's Department for International Development (DFID) led to the creation of an associated draught animal R&D unit which worked in close participation with the farming community and supplied innovative ideas to the factory. Because the ideas had been developed with farmers, the demand for them to be available on the market was practically immediate; positive results were draught animal carts and lightweight implements with high-lift harnesses for equids. A further development was a collaborative research project with the International Maize and Wheat Improvement Center (CIMMYT) which led to the tripartite group developing a no-till small grain seeder for animal traction[1]. Although thoroughly tested on-farm in Bolivia, it was also possible, through the CIMMYT link, to repeat the process in India and Pakistan and so receive invaluable practical feedback to improve the design. The final result now enjoys commercial success as batches are built for sale by the CIFEMA-SAM factory.

Field trials of a draught animal powered no till small grain seeder. And partially built machines in the CIFEMA-SAM factory.

[1] http://www.fao.org/docs/eims/upload/agrotech/1927/R6970_19.pdf

FIGURE 14.6

East African entrepreneurs visit the Knapik factory in Brazil during their trade mission in 2008

FIGURE 14.7

Mohammed Elmi – a Tanzanian participant in the Brazil mission – has been inspired to design and build a no-till planter and power tiller

community, so that when farmers travel to town to make essential farming input and household supply purchases, they can also be sold equipment such as machetes, shares or replacement discs. This is usually a simple arrangement whereby the storeowner will visit the factory, buy a batch and then resell the equipment with an appropriate mark up.

FIGURE 14.8
A participating dealer in the network set up by CIFEMA-SAM in Bolivia (See Box 3)

However as equipment becomes more complicated, then a network of knowledgeable dealers becomes a desirable way of ensuring an ever widening circle of satisfied users. Dealers can be brought to the factory (in small groups) for technical training which will include correct field adjustments, maintenance and repair. They can also be kept up to date on technical improvements and new products. The fruits of this training can then be passed on to actual and potential users. Dealers can present equipment at local field days and machinery exhibitions to increase awareness and are likely to be well known and trusted members of their local community (Figure 14.8).

A carefully nurtured dealer network will almost certainly lead to increased demand and the dealers can be trusted to order batches of equipment without pre-payment – only paying the factory after the sale has been made. Dealers can also be a valuable source of feedback from the farming community. This can be passed to the factory for appropriate action to be taken and so result in improved product quality and better adaptation to local conditions.

- ***Hire service providers***

Investment in agricultural machinery is usually the result of a major decision-making process for farmers and the alternative of hiring in the services of expensive, but infrequently used, machines is increasingly attractive. Hire service providers can be experts in the operation of complicated machinery and can offer a service which is possibly technically better than that which a farmer-owner could provide for himself. Perhaps more importantly it means that the farmer is not incurring any of the costs of owning the equipment (depreciation, interest and operating costs). On the negative side, the timeliness of the operations carried out may not always be absolutely optimal as frequently all or most of the clients will demand the service at the same time. The optimal window for planting, for example, may only be a few days in a particular region. Delaying after the best planting date will result in lower yields.

Hire service providers are, therefore, important customers for a manufacturer and should be nurtured in the same sort of ways as the dealers. They can be given specialist training to ensure maximum machinery performance in the field; and they can receive specialist training on operation, repair and maintenance as well as regular updates on innovations. It could be the case that, at the smaller end of the scale, the hirer is also the manufacturer as in the case from Kenya described in Box 14.4.

BOX 14.4

Benson Kamau: jab-planting contract hire service provider

Benson Kamau is a resourceful 45 year-old entrepreneur from Njoro, Rift Valley Province, Kenya. A carpenter by trade he has received artisan training at the Nakuru Agricultural Technology Development Centre and, as a keen conservation agriculture (CA) practitioner, has been active as a lead farmer in several farmer, extension officer and entrepreneur training courses run by FAO CA projects.

As well as practising his carpentry for making furniture and doors, Benson also makes and sells jab planters. He only manufactures to order, keeping no stock and receiving a 75 percent deposit of the Ks 4000 (USD54) price before starting work. This selling price gives him a reasonable 30 percent profit margin over the cost of materials to compensate him for his time. He takes three days to make and deliver each unit.

A third enterprise is his custom jab-planting service. For this he employs three casual workers equipped with his own brand planters and plants around 30 acres a year. His clients' main crops are maize and beans. He charges Ks1200 (USD16) per acre.

And then Benson is a farmer. He has 2 acres of CA maize and beans which he naturally plants and tends himself. He owns two donkeys which he uses for draught work – principally ripping, when needed, before jab planting.

Always ready to put his efforts to profitable use, Benson also does occasional construction work (where his carpentry skills are again in high demand) and now has assignments as a lead CA farmer and flourishing entrepreneur which makes him ideally qualified to help as an instructor in practical farmer training courses.

In the future Benson would like to expand his fabrication enterprise; at the moment he rents his workshop equipment (welder, drill and grinder) when required and would like to establish himself as a bona fide manufacturer of a range of CA equipment for the local market. His resourcefulness and ability to multi-task should put him in good stead.

Benson Kamau demonstrates the adjustment of an ox-drawn ripper during a farmer-training workshop

Hire service providers are, therefore, important stakeholders in the farm equipment supply chain, demanding equipment from manufacturers and services from repairers whilst being very aware of farmer requirements and demands.

- *Maintenance and repair services*

In a similar way to dealers and hire service providers, maintenance and repair of agricultural equipment is a key activity in the supply chain. *Jua kali* artisanal manufacturers will usually also offer repair services and very commonly provide an invaluable service to local farming communities. At the top end of the scale, repair and maintenance workshops will require specialist staff training (from the manufacturer) and specialist tools and jigs in order to provide an adequate service for modern complex machines.

A dearth of repair and maintenance facilities is frequently cited as a main reason for the slow diffusion of agricultural machinery technology and it is certainly in a manufacturer's best interests to encourage an active technology sharing relationship with the mainstream repair stakeholders. Even a simple machine like an ox-drawn cart with pneumatic tyres will need a specialist tyre repair service near to the place of use. Remote villages are unlikely to see this type of service develop until there is a critical mass of carts (in this case) to justify the necessary investment. The same is true of most equipment, no-till planters or combine harvesters, for example, which cannot work if their repair is not speedily effected at the right time (Figure 14.9).

FIGURE 14.9
Timely repair is essential to reduce downtime at critical periods of the farming year. A broken combine at harvest can mean the loss or deterioration of a crop

- *Farmers*

The final, but most important, stakeholder in the farm machinery supply chain is the end user or farmer. It is a truism to say that if the farmer does not value the work produced by a machine then he is unlikely to invest in it, or seek the services of a hire service contractor. Consequently it is important that a good relationship is built between manufacturer and farmer so that the right type of machinery can be put on the market at the right price.

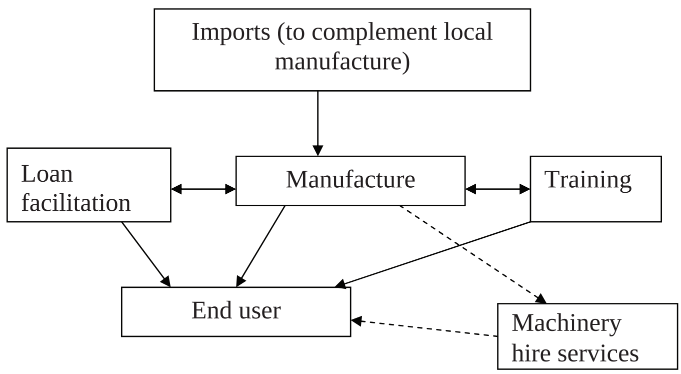
As has been noted, at the artisanal end of the scale there is often a direct relationship between manufacturer (and repairer) and farmer. This direct relationship becomes increasingly difficult as the size of the manufacturing enterprise grows. For this reason the importance of other stakeholders (dealers, extension workers and hirers) has been seen and discussed.

For a medium scale manufacturer the value of close contact with the farming community cannot be over-emphasized, but at the same time it is often this key link that is missing. It is frequently lamented by manufacturers that the smallholder farming community is too unreliable, has no access to capital and is not a market worth working for. Other manufacturers take a different view and are prepared to bring together all the elements that would-be machinery owners may need.

The Demaco factory is one of the MECI group in Tanzania (see Box 14.2) and brings together its own manufacturing capabilities (complemented by imports) with loan facilitation and training (Figure 14.10). Demaco's currently

FIGURE 14.10

An example of how manufacturers can take control over service provision to end users by marshalling the services of other supply chain stakeholders. The example of Demaco in Tanzania. (The dashed line indicates a pipeline project)

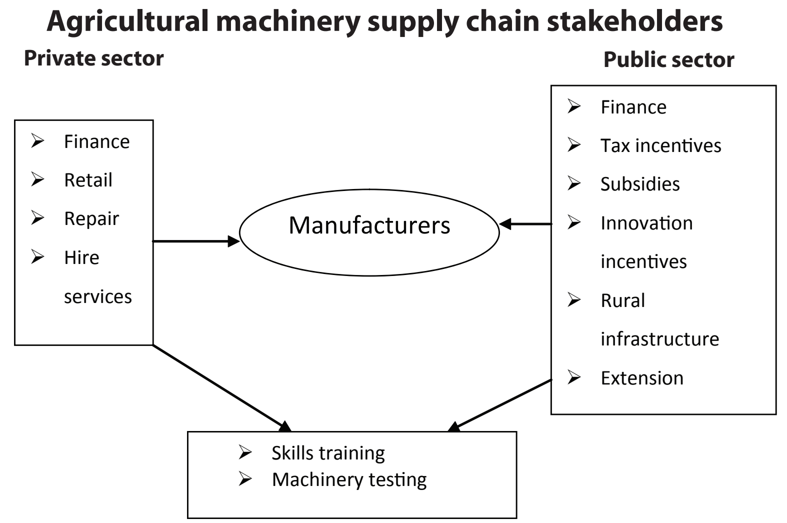


most important enterprise is manufacturing agricultural machinery (which emphasizes post-harvest machinery but also includes power tiller trailers – see Box 14.2). Their import enterprise (in collaboration with other specialist importers) provides tractors and associated machinery and spare parts. They have found it of great benefit to act as an intermediary between end users (individuals but mainly farmer groups) and finance institutions (generally commercial banks). This benefits the end user and, of course, Demaco's business as well. Demaco guarantees to be able to offer technical services for repair and maintenance throughout the loan period. The next link in the chain is technical training and Demaco offers technical training courses both to machinery operators and also to the machinery owners. A project which is due to come on stream in 2010 is the operation of machinery hire centres where expensive items will be well maintained and operated by skilled staff. A demand for this type of service has been identified for operations such as planters and combine harvesters and Demaco expects that the centres will become their most important line of work in the future. This is but one example of how problems can be overcome by innovative thinking which brings the skills and services of supply chain stakeholders to bear on the situation to the benefit of all concerned, but principally to get farm machinery built and into the hands of users and producing agricultural produce.

14.2.2 The roles of the public and private sectors

The diversity of stakeholders in the farm machinery supply chain will be clear from the previous discussion. Some contributions are best made from the public sector whilst others are best left to the private sector, this aspect will now be explored in greater detail. Figure 14.11 provides a possible scenario for the most likely sector for each of the services provided.

FIGURE 14.11
The services provided by the public and private sectors in the farm machinery manufacturing supply chain



Private sector

Finance, for initiating, operating and expanding a manufacturing business is best left to the private sector which will normally have commercially available finance instruments suitable for entrepreneurs seeking additional capital.

This sector is normally the most appropriate for retailing agricultural machinery to farmers and contractors. Hardware stores have a vested interest in providing good quality equipment at an accessible price and as such form a vital link in the supply chain between manufacturers and end users.

Farmers' associations will commonly exploit their enhanced purchasing power by buying equipment at bulk or wholesale rates and then selling equipment on to individual farmer members with only a modest mark up.

These arrangements are convenient for manufacturers, who sell in batches to a trusted client rather than having to sell to individuals with the added overheads that would be accrued.

Repair and maintenance services are almost always in the private sector. Whereas the sector can often be made more effective and efficient through public sector training programmes, the sustainability of a maintenance and repair service will depend on a close relationship with the client which will always include end users and will frequently also involve manufacturers in the supply of replacement parts and technical expertise.

A similar situation pertains with hire service contractors (Figure 14.12). There are extremely few examples of successfully run public sector machinery hire services. The industry is best left to the private sector where costs can be controlled and realistic (but profitable) service charges made. Hire service contractors need to develop a close and trusting relationship with their customers to ensure that work is done to the required quality and that payments are made on time. Contractors also need to work closely with other supply chain actors, especially the extension service, to ensure that the services that they are offering are in tune with current extension advice. For example, when CA is being promoted they should have the correct CA equipment and not insist that the only service on offer is for conventional, plough-based, agriculture. In this respect, close coordination with manufacturers is necessary so that innovations are available to the farming community. Of course, in the same way as for repair and maintenance services, and indeed manufacturers themselves, specific training needs may have to be met from outside the sector.

FIGURE 14.12
Successful hire service contractors are almost exclusively to be found in the private sector. They need a close working relationship with their customers, good business management and good coordination with other supply chain participants

Public sector

The public sector will also often be involved in financing the development of the industrial sector, especially if the ultimate beneficiaries are farmers. Supporting innovation, diversification and a strengthened manufacturing sector are often key features of development plans and election manifestos. In addition to offering financial instruments designed to encourage investment in productive capacity (and job creation), the public sector can also provide welcome financial assistance by making batch purchases of novel equipment for subsequent resale to farmers via the extension service. The current consensus is, however, that for sustainable development of the manufacturing sector, its long term interests are best served by the private sector.

The public sector can also be instrumental in promoting technology adoption, at least in the early stages, by extending credit and subsidies to farmers for machinery purchases. However a reflection on the appropriateness of subsidies in today's economic climate may be apposite here (Sims *et al.*, 2009). Subsidies are part and parcel of agriculture in many countries of the world. Developed and developing countries use them to help make farming profitable in an environment where governments also want cheap food and/or want to be competitive on pricing of agricultural products for world trade. There have also been discussions about providing subsidies for CA equipment which would be beneficial to farmers if they resulted in cheaper equipment needed for no-tillage and planting into loose residues. Others argue that no-tillage already results in savings to farmers and improved profits so why use valuable taxes to provide an incentive? In many cases the subsidies don't end up in the hands of the farmer, but are usurped by businesses and other intermediaries. A subsidy made to a manufacturer of equipment for CA may not result in a cheaper price of equipment for the farmer, if the manufacturer decides not to lower the price of his machine. However, the cost of some new agricultural technologies like land levelling are extremely high and it may be better to subsidize this practice for the environmental benefits obtained in water savings, reduced greenhouse gas emissions and improved productivity. The policy should also insist that the benefits reach the farmer through lower equipment and rental costs.

One way that the public sector can ease the burden on private sector manufacturers is by easing the tax burden on their raw materials. Tractors and agricultural machinery are frequently given privileged status by governments actively promoting the development of their national agricultural sectors. Such equipment can usually be imported free of duty. However sometimes (as in the case of Kenya) machinery parts and raw materials (principally steel) are excluded from this arrangement and this puts the national manufacture of agricultural machinery at a disadvantage. Few developing country governments would want to jeopardize the development of their national industrial sector in this way. One simple way of providing tax relief to national agricultural equipment manufacturers would be to give them a rebate on the duty paid for materials that can verifiably be shown to have been used in agricultural machinery construction.

The public sector, especially in developing countries, has historically been notoriously less than successful in developing prototypes and moving them into commercial production. R&D by researchers in isolation from other key stakeholders is a discredited paradigm. New models of collaborative participation are more likely to produce results, especially those that are capable of local manufacture at an affordable cost and which respond to technologies actively being sought by farming communities. When considering a novel technology like CA, a tripartite R&D arrangement, whereby the voices of farmers, manufacturers and researchers have equal value, is an activity that should be funded by the public sector and its longevity should be dependent on the production of outputs valuable to all parties.

Another way that the public sector should be involved in the development of the CA machinery input supply chain is by facilitating the introduction of valuable, farmer-proven, technologies from other regions. One example of this approach is CA in East Africa. The experience of IAPAR[47] in Brazil in creating awareness and interest in draught animal powered NT planters is a useful example. Working with manufacturers and farmers, IAPAR was able to produce a planter which has served as the prototype for many lines of commercial production in ensuing years (Figure 14.13).

FIGURE 14.13
The Gralha Azul animal traction no-till planter and fertilizer applicator developed at IAPAR in the mid-1980s

Rural infrastructure, particularly roads, is a major impediment to the free operation of markets. Poor infrastructure is a disincentive to market access and will always add to input prices. Infrastructure improvement is likely to form part of a wider national strategy for economic improvement (as was, and still is, the case in Brazil), however its importance to mechanization input supply is emphasized. One of the principal causes of failure of public sector machinery hire schemes has been the extraordinarily high cost of transport both in terms of distances and time involved, access to fuel and services in remote areas, and the damage done to farm machinery during transportation. For manufacturers, poor infrastructure (Figure 14.14) will increase distribution costs and make service provision (to users and repairers) less likely, or at least more expensive.

FIGURE 14.14
Poor rural infrastructure raises costs for all agricultural machinery supply chain stakeholders. It is a public sector duty to improve infrastructure to reduce operating costs and stimulate local economies

[47] Paraná State Agricultural Research Institute (Instituto Agronômico do Paraná)

An active, motivated and well trained extension service is a prerequisite for a progressive, developing agricultural sector and this includes the agricultural machinery manufacturing, hire and repair industries. Agricultural extension does not belong wholly in the public sector, but elements of it do. For example, machinery demonstrators from larger scale manufacturers, importers and dealers are part of the extension effort and the public sector service should liaise closely with their colleagues in the private sector. Experience has taught that, unfortunately, extension services have too frequently tended to be neglected, attracting poorly trained recruits who then are poorly rewarded and have nothing of great value to transfer to the farming community. The growing numbers of organized farmer groups (such as FFSs, earthworm clubs[48], friends of the soil and NT clubs) which are proactive in the technical assistance that they demand are a healthy sign that extension services will need to respond to a greater extent to farmers' requirements. The public sector has a key role to play here in ensuring that the extension service delivers high value information and training and in return is highly regarded by the farming community that it serves.

Cross cutting issues

There are (at least) two areas where contribution to improving the status of local machinery manufacturing can be made, these are in terms of business and skills training and machinery testing.

Technical and business management training schemes

There appears to be a great need, as well as a hunger in the developing world, for training programmes aimed at improving business skills and technical competence, particularly for tractor-based enterprises and farm businesses. Large-scale manufacturers, importers and dealers are, of course, fully conversant with the need for financial controls and with the tools needed for calculating costs and profits. Other actors in the supply chain are sometimes less familiar with the methods required and are in need of orientation. These include small-scale manufacturers, hire service providers, machinery repair services and small to medium-scale farmers.

Technical training is an important contribution to development at many levels from manufacturing skills needed by small-scale entrepreneurs, to servicing and repair requirements for new technology (for example, combine harvesters and power tillers) to training in new practices for farmers (for example, CA). Technical and managerial training courses and programmes are expensive for individuals and constitute an ideal and acceptable way for governments to demonstrate their commitment to development by collaborating with the private sector to provide this essential service.

- **Provision of impartial machinery and materials testing services**

[48] For example: *clubes da minhoca; clubes amigos da terra*; FEBRAPDP in Brazil

A mutually respectful collaboration between the public sector and the private sector would make it possible for the public sector to fund impartial machinery and materials testing centres in direct response to the needs of the manufacturing industry. Previous efforts (e.g. in East Africa and Pakistan) have shown that extremely few manufacturers seek advice and guidance from public sector institutions set up to provide those services. A new approach must consider the needs of the industry from the outset. A strategy for sustainability of the service would be to phase out public sector support over a number of years so that the service is maintained by and for the private sector. It is by no means certain that manufacturers would consider such a service to be a worthwhile investment. Local manufacturers in Tanzania, for example, make no or little use of the testing institution (CAMARTEC[49]) that is available to them. In Brazil, manufacturers tend to do their own testing and may only outsource particular aspects that they believe can be done better by others. On the other hand, and also in Brazil, the role of public sector institutions in organizing side-by-side comparative evaluations of NT planters has been a notable success in improving the quality of production machines (Casão Junior, *et al.*, 2012). The trials were made with crops sown 30 days before the public exhibition of the machines at work. This allowed farmers to compare the field performance of different machines and to judge the quality of seed placement and crop emergence (Figure 14.15).

The trials resulted in a marked improvement in planter performance and quality as positive elements were adopted more widely and less effective components eliminated.

FIGURE 14.15
No-till planter at a dynamic evaluation event in 2003 in Brazil

Source: (Photo Ruy Casão Junior)

[49] Centre for Agricultural Mechanization and Rural Technology, Arusha, Tanzania

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CHAPTER 15
Investing in Information dissemination and exchange

Information Dissemination and Exchange

Note: The theme of information dissemination and exchange is discussed in two related chapters. The first, by Trevor Cree with a global perspective and the second, by Reynaldo Lantin which gives an account of experiences from RNAM in Asia.

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ABSTRACT

The dissemination of information on agricultural machinery is an important tool for establishing rational mechanization strategies. The chapter reviews sources of information (from informal discussion groups through field demonstrations to print and film options) and then analyzes the internet options in detail. Emphasis is on the concept of a global agricultural mechanization internet portal and a case study of the Worldwide Agricultural Machinery Directory (WAMED) is exhaustively examined. Information is the key to knowledge and the best way to ensure good information dissemination on agricultural machinery would be by building on the experience already gained by websites such as WAMED.

15.1 INTRODUCTION

The dissemination and exchange of agricultural mechanization information is as old as the first hand tool used for cultivation. The craftsperson who designed and built the first hoe would have been visually observed during its fabrication by his family and possibly by others within his local community. The first field use would have been witnessed by others who may have commented that the quality of work of the hand tool was certainly inferior to the more precise hand weeding undertaken by their womenfolk and that the new development would never be successful. Over time the actual benefits of a more upright working stance and the higher work rates would have been appreciated despite the slightly reduced quality of precise weed control. Passing strangers may also have also stopped to observe the use of hand tools for weeding and over time the message would have been verbally[50] disseminated far and wide.

The earliest transfer of information would therefore have been by verbal communication and through visual practical field observation and demonstration. The development of clay tablets, papyrus, paper and the printing press would have allowed later generations to utilize written language and pictorial drawings to transmit information over far greater distances in a format which was durable and which was not distorted by the imperfect person to person verbal information transfer process. These primary methods of information exchange remain fundamentally important to this day. In recent years additional methods of information dissemination and exchange have been developed including the fixed line telephone, radio, television, mobile telephone, email, film and the internet. Many of the newer methods mean that information can be sent and received locally, nationally and globally almost instantaneously.

This review discusses the alternative methods of agricultural mechanization knowledge transfer with particular reference to countries in the developing world where communication infrastructure may not yet be well developed. There is no doubt that agricultural mechanization information is currently more accessible than at any time in history. The challenge is to make that information available in a format that can be readily accessed and absorbed by the primary agricultural producers in the developing world.

15.2 VERBAL AND VISUAL SOURCES

15.2.1 Verbal Discussion

As previously discussed one of the most effective means of disseminating and exchanging information is the informal discussion between individual farmers in the field and within the local community. There is no more valuable knowledge than that based on first hand practical experience. The farmer or small-scale hire contractor who owns, for example, a particular model of power tiller will have a wealth of useful knowledge about the performance and operation of the machine, its strengths and its weaknesses, costs of operation and profitability for ownership or hire. To transmit such detailed information in writing would be an onerous task and the situation is further complicated by the fact that one particular owner's experience may contrast directly with the experiences of another. Farmer groups, cooperatives and social gatherings are therefore crucial vehicles for verbal information dissemination and exchange.

15.2.2 Radio

Radio is a very useful extension tool in agricultural development since radio reception in most countries is widespread. It is particularly useful for discussions about individual topics, for highlighting certain pests and diseases,

[50] In the context of this chapter 'verbal' is taken to mean 'oral'.

weather forecasts, announcing field demonstration dates and their location, and so forth. With respect to agricultural mechanization its usage is more limited since it is difficult to describe effectively the design and operation of tools and equipment.

15.2.3 Television

The reception of television has expanded significantly in recent years and this medium is particularly useful for agricultural extension work. In many countries, such as China, allocated broadcasting slots have been made in the day for agricultural programmes. The combined visual and sound aspect of television allows a wide range of programmes to be made about hand tool, animal draught and engine-powered field equipment usage. However, in countries where the television networks are primarily controlled by the private sector and financed by advertising there are reduced opportunities for specialized non-commercial agricultural mechanization programmes.

15.2.4 Field Demonstration

The field demonstration is one of the most effective ways of extending new technology to farmers, hire contractors and agricultural extension officers. The demonstrations of specific items of equipment are often arranged by the manufacturers, or their agents, who pay for the costs involved in the hope that sufficient interest is generated to achieve immediate or subsequent sales of their products. Entry to this type of single manufacturer event is usually free of charge. On other occasions individual machinery demonstrations may be organized by the Ministry of Agriculture extension service.

Larger scale field demonstrations may be organized by agricultural magazines or newspapers who invite a number of manufacturers to demonstrate their equipment at specific locations in return for a participation fee. Visitor entry to such events may also incur an entry charge because the potential purchaser has the opportunity to observe large numbers of machinery in a single location. The theme often depends on the time of year with separate demonstration events being held for field cultivation, chemical spraying, animal effluent disposal, harvesting, crop storage and crop processing.

Practical field demonstrations in local conditions are particularly useful to farmers and contractors since they can witness at first hand the positive and negative aspects of individual machines prior to any purchase being made. They can also talk with the manufacturer's representative about technical issues and finance institutions are often present to assist with funding and insurance needs.

15.2.5 Exhibitions and Shows

Fixed location annual farm equipment exhibitions and shows are a major source of information dissemination and exchange. Major international exhibitions include Agritechnica, Germany, EIMA, Italy, and national shows include

BOX 15.1

Case Study: Agritechnica, Germany

The Agritechnica show is held every two years at the Exhibition Grounds in Hanover, Germany, in rotation with a major livestock equipment show, EuroTier. The exhibition covers 320 000 m^2 of floor space and is contained in eighteen exhibition halls. In 2009 there were more than 2300 exhibitors from 46 countries making it the largest show of its type in the world. Attendance during the seven day show totaled 350 000 in 2009 of whom 273 000 visitors were from Germany and the remaining 77 000 were international visitors. The overall attendance included 30 000 farm equipment dealers and distributors, 26 000 staff members from the machinery manufacturing industry and 23 000 farm contractors. To cater for an international audience the Agritechnica website offers translations in four of the major international languages, namely German, English, Italian and French, whilst coverage is also given in a further 12 languages, including Spanish and Chinese.

The Agritechnica event is therefore truly global in scope. Nevertheless it is interesting to note that even though Agritechnica may be considered as an international show a large proportion of the 2 300 exhibitors are of native German origin (1139). The other major exhibiting countries are Italy (275), the Netherlands (90), France (72), Turkey (68), Spain (34) and Denmark (34). This precise breakdown in manufacturer attendance figures indicates that a large number of companies from external countries are not actually represented at foreign exhibitions and therefore the mechanization information picture for the visitor is incomplete if visits are only made to one international event.With respect to the ease of information retrieval the Agritechnica website includes a very useful online directory of exhibitors which allows searches to be undertaken by product, company name and country. The product index (A-Z) has 31 main categories of machinery ranging from agricultural electronics to wind energy installations. Each main category is subsequently divided into a number of product sub-categories to facilitate a more precise search process. For example, the main harvesting category is sub-divided into sections for baling, chopping, combining, conditioning, crop lifting, mowing and miscellaneous machinery. A tertiary level of search refinement is also provided such that the mowing sub-category is further divided into disc, flail, knife, rotary, self-propelled and miscellaneous types of mower. Selection of the disc mower option finally provides a list of 29 manufacturers and each company can subsequently be investigated in turn. For illustrative purposes the first company in the list is Alois Pottinger of Austria and clicking on the active link takes the visitor to the Pottinger Agritechnica company page which provides full contact details, including live email and website links, a full list of company products, exhibition stand location(s) and product photographs. By further following the link to the Pottinger company website the visitor can explore the company and each of its products in detail.

NAMPO, South Africa, and Fieldays, New Zealand. The major benefits of such events are that visitors can see very large quantities of machinery and equipment at close hand, can discuss with manufacturer representatives technical features and prices, can attend lectures on new developments, whilst manufacturers and their dealers have the opportunity to display their products to a very large number of potential buyers in a single location.

It is evident from the above description that the Agritechnica website provides an extremely comprehensive coverage of exhibiting manufacturers not just during the limited exhibition period but throughout the year. The actual manufacturer representation within the online exhibition directories is understandably limited to those companies who pay to exhibit at the individual shows. There are at least 22 major farm equipment exhibitions worldwide each with a natural bias towards their own country's manufacturers and therefore those seeking full information on global product options must visit a number of the shows in person, or consult a number of individual websites to access that information. Very often the formats of the individual exhibition directories and the depth of coverage are different and therefore online product research consulting at least 22 different directory sources can be a time consuming activity.

With respect to investment opportunities it is clear that there are already a large number of successful farm equipment exhibitions in a number of countries. Their income is primarily generated from manufacturer exhibition fees, printed and online directory listings, and from visitor entry fees. It is concluded that the private sector is therefore already well placed to establish such events based on the actual demand for agricultural machinery within individual countries and this is achieved primarily without public sector support. In certain circumstances national shows, such as NAMPO in South Africa, may also act as a regional exhibition resource for neighbouring countries, such as Namibia, Lesotho, Botswana, Zambia, Mozambique and Zimbabwe.

15.3 PRINT SOURCES

15.3.1 Books

Books are a fundamentally important source of technical information and knowledge. Historically books have been accessible through libraries, further education institutions and from commercial bookstores. The Neilsen Book website offers services to booksellers, publishers and libraries with access to over three million titles with the latest prices and availability. It is therefore an extremely useful source for locating textbooks on specific subject areas, including agricultural mechanization. However, the Neilsen website is a subscription based service and so it is not easily accessed by the general public.

Increasingly book purchases are being made online via websites such as Amazon, Barnes & Noble and Waterstones. As well as the general book section Amazon has a "New and Used Textbook" search option. A search for "farm equipment" books yielded 2 182 results whilst a search for "irrigation" books yielded 20 062 results, commencing with the relevant "The Complete Irrigation Workbook: Design, Installation, Maintenance and Water Management" published in 1995. Slightly further down this list

BOX 15.2

Case Study: Napier City Library

New Zealand. Napier library is a very well stocked resource which houses the normal fiction and non-fiction collections. As with most libraries the subject matter is very wide ranging and even though the Napier region is a major horticultural, viniculture and livestock production region the agriculture section within the library is very limited. In fact within the small agricultural section a total of only seven books were located which could be considered directly relevant to agricultural mechanization. A search of the library's computer index similarly revealed a limited list of relevant publications. The preliminary conclusion from this very limited research indicates that public libraries are unlikely to be able to offer immediate access to information in specialist subject fields, such as agricultural mechanization. They do however have the capacity to request books from central locations for subsequent lending.

another relevant book was found entitled "Irrigation of Agricultural Crops", published in 2007. This particular book listing offered the Amazon "Look Inside" option whereby a number of pages could be viewed online prior to purchase. This facility allowed the table of contents and the detailed index to be viewed thereby providing the potential purchaser with a clear introduction to the range and depth of the book coverage, thereby assisting in the purchase decision.

Google Books is a relatively new source of access to online books. In certain cases whole books can be read online but at present they tend to be out of copyright titles or books where the author has given express permission that they may be read in full. A Google Books search for "irrigation systems" yielded a total of 32 000 results of which the majority provided only a limited preview or no preview at all. When the full view option was implemented a total of 1 293 books on irrigation systems were recorded. The FAO book "Fisheries in Irrigation Systems in Arid Asia" is just one example of the usefulness of online book technology and this form of information access is likely to expand considerably in the future. A number of tablet size book readers are already available for purchase, such as the Amazon Kindle, Sony Reader, Barnes & Noble Nook whilst Apple is believed to be entering this particular market in 2010.

15.3.2 Newspapers

The Farmers Guardian is a weekly newspaper published in the United Kingdom with an average net circulation of 51 668 per issue. Although covering the breadth of agricultural topics the paper has a dedicated farm machinery section encompassing news, a directory of manufacturers and classified advertisements for farm equipment sales. Income is generated via newspaper buyer subscriptions, classified advertisement fees and manufacturer product advertisements. The newspaper is also offered in a standard website format and as a prototype digital newspaper, Machinery in Motion. It is anticipated that the digital publication format will largely replace the present day hard copy print format in the future because printing and distribution costs can be substantially reduced and the environmental impact minimized. Suitable digital software is available from a number of companies, for example, PageSuite. The Farmers Weekly is further example of a farmer targeted agricultural newspaper with a dedicated section on farm machinery encompassing news, videos and a classified machinery section. Farmers Weekly has an average weekly circulation of 68 897 and the two identified publications, Farmers Guardian and Farmers Weekly, are direct competitors in the United Kingdom.

Weekly agricultural newspapers in the United Kingdom with distinct farm machinery sections clearly have a substantial readership and therefore their publication can be justified based on their commercial viability. This situation is also valid for certain other European countries and in North America. However, in many developing countries weekly agricultural publications in the print format may not be commercially viable at the present time. Initially a monthly newsletter format may be more appropriate and if successful, consideration can be given to the print newspaper and later online options.

15.3.3 Magazines

Specialist farm equipment magazines, usually monthly publications, play an important role in information dissemination particularly in the developed world. A relatively high level of farmer machinery usage and farmer population is necessary within a specific geographical area to cover the costs of publication and distribution of the print formats. Financial viability is achieved via annual subscriptions, casual purchases from newsagent outlets, manufacturer advertising, dealership advertising and used machinery advertising. If a critical mass of magazine sales is not achieved then advertisers will not advertise their products within a particular magazine and its continued viability therefore becomes uncertain. Increasingly magazines offer a parallel internet version of their publication which helps expand the potential readership beyond national boundaries and subsequently increases advertising opportunities. Competition between magazines can be significant and individual markets can only support a certain number of publications. Usually such magazines are only one part of a global publishers' portfolio of publications covering diverse fields of interest.

BOX 15.3

Case Study: Farm Trader, New Zealand

A typical farm equipment magazine is Farm Trader which is available for purchase in New Zealand. New Zealand is a major exporter of agricultural products covering arable, livestock, viticulture and horticultural types of production. It is therefore well placed to support a specialist farm equipment magazine. The Farm Trader magazine is owned by ACP Media Ltd. and this fact illustrates the multi-title publishing approach. ACP Media is reportedly the largest magazine publisher in New Zealand publishing a total of 20 different magazines across a wide range of subject matter. Furthermore, ACP Media in New Zealand is itself a subsidiary of ACP Magazines Ltd. in Australia, which again is a division of PBL Media Ltd. This regional and global ownership pattern is common in the media world and illustrates that economies of scale exist and that small independent publishers often have difficulty competing with the major media companies.

BOX 15.4

Farm Trader

The December 2009 edition of Farm Trader consisted of a total of 186 pages of which over 80 pages were devoted to 4624 machinery items for sale, primarily dealership and individual farmer listings. The magazine also included advertisements for new machinery, often in double page, single page and half page formats, providing further important advertising income. The Farm Trader table of contents included a ten page cover story on farm buildings, approximately forty pages covering the field testing of both new and used machinery, six pages on farm fencing and an article reviewing the major Agritechnica exhibition. A feature of such magazines is that they regularly include a useful Buyer's Guide which lists and compares a range of manufacturer products and in this particular month the subject was All Terrain Vehicles (ATVs).

Significant costs are incurred by magazines in the preparation of print advertisements from material received by post from individuals wishing to advertise. The standard Farm Trader advertisement submission system involved a coupon where advertisers provided the magazine with written specifications of the individual machine that they had for sale and its price. Payment for the advertisement was made by cheque, money order or credit card, with advertising prices ranging from NZ$50 (US$35) for a 1/24 page spread, NZ$70 (US$49) for 1/12 page, and reductions for multiple advertisements. The advertising package provided for inclusion in both the print and online versions of the magazine. In recent years processing costs to the advertiser and the publisher have been significantly cut by the use of online advertisement submission whereby the advertiser uploads photographs and machine data themselves in prescribed online formats for a set price. Farm Trader has its own online advertisement submission system allowing the advertiser to select the advertising package, enter the data, build the advertisement and pay directly online.

Two additional examples of farm equipment magazines are Profi: Tractors and Farm Machinery and Farm Equipment. Profi is owned by Landwirtschaftverlag GmbH in Germany which is a specialist agricultural publisher with 32 publishing titles. The Profi magazine is published in the English, German and Russian languages and in 2009 it had an audited readership of 12 890. The annual magazine subscription cost was £51.50 (US$82.40) for the United Kingdom and US$97.00 for overseas mailing. The complete Profi magazine was also available online as a Profi e-Magazine for £19 (US$30.40) per annum. Advertising prices within the magazine ranged from £54 (US$86.40) for black and white 1/32 page up to £2 396 (US$3 833) for four colour 1/1 page. Further Profi website revenue was generated from Google AdSense banner advertisements. It is clear that the dual combination of print and website formats generated significant income to cover the costs of magazine production and distribution. The online version of Profi also included a discussion forum, videos, photographs, machinery buyer's guides, news and feature articles.

The Farm Equipment magazine is based in the USA and is owned by Lessiter Publications which has seven magazine titles ranging from farming to sports. The Farm Equipment magazine covers news, features and video. The subscription for the magazine was US$40 in the USA and US$99 for overseas mailing. The reported circulation totaled 10 975 of which 9 644 were stated to be equipment dealerships, 882 machinery distributors and 449 manufacturer representatives. In addition an Ag Equipment Intelligence newsletter was published monthly which provided agricultural equipment marketing personnel, dealers and analysts with news, analysis and viewpoints of the farm machinery marketplace. The price of the email newsletter was an additional US$299 per annum in the USA and US$499 overseas. The Farm Equipment magazine offered a range of standard advertising options, covering black and white, two colour, four colour and online.

15.3.4 Brochures

Sales brochures are manufacturer publications of individual items of machinery which usually contain descriptive passages of the function and operation of the machines combined with photographs and detailed specifications. Brochures are usually supplied free of charge on request and they can be very useful for comparing one manufacturer's machinery against another. Brochures are relatively expensive to produce and have to be changed as and when machinery designs and specifications are updated. They are however considered to be a useful marketing tool for the manufacturers and their dealership networks. In the early 1980s the FAO agricultural engineering branch maintained a large storeroom filled with manufacturer brochures which had been collected over time. The system provided a useful reference source for in-house FAO engineers and visiting consultants. However, such a facility requires constant management to update and expand the coverage and the necessary staff resources are not always available within public sector institutions. The installed FAO brochure reference system could not therefore keep up with a rapidly expanding list of manufacturers and their changing products. The expansion of internet technology in recent years has allowed manufacturer websites to include brochures for individual items of machinery and these can be downloaded in the PDF format and printed in full colour on demand. This is a very efficient form of marketing which leads to a reduction in brochure printing costs and environmental wastage.

15.3.5 Machinery Test Reports

Independent and unbiased machinery testing reports can be a very useful information resource for those considering the purchase of new machinery. The University of Nebraska Tractor Test Laboratory is the officially designated tractor testing station for the United States and tests tractors according to the codes of the Organization for Economic Co-Operation and Development (OECD). Twenty nine countries adhere to the OECD tractor test codes (including non-OECD members China, India, the Russian Federation and Serbia). To access the test reports on the Nebraska website the Test Reports link can be clicked to take the visitor directly to a page covering 13 major tractor manufacturers. Following the John Deere link, for example, reveals a page with over 130 John Deere tractor models and clicking on the 8330 model results in a PDF format report being shown online. This type of information is clearly invaluable since it can be accessed globally at no cost.

The European Network for Testing of Agricultural Machines (ENTAM) currently comprises 13 member institutions in 10 European countries, namely Austria (BLT), Denmark (AU/DAE), France (Cemagref), Germany (JKI, DLG, KWF), Greece (N.AG.RE.F), Hungary (HIAE), Italy (ENAMA), Poland (PIMR), Spain (CMA, EMA/CENTER) and Switzerland (ART). Following the Tests link on the ENTAM website takes the visitor to a "Category" drop down menu which lists a wide range of machinery and equipment types. There is also a "Manufacturer" drop down menu option and clicking on Celli SpA. of Italy, for example, reveals test results for two company products. Selecting the 2005 report for a soil disinfestation machine takes the visitor to a page dedicated to the Celli Ecostar SC 600. This test documentation can subsequently be accessed via a PDF link where the report is available in both the Italian and English languages.

The ENTAM website includes test reports for a total of 193 items of equipment. Whilst this is clearly very useful data it only represents a fraction of the total number of agricultural machines which have been manufactured in Europe during the last 10 - 15 years. The compulsory testing of all agricultural machinery is regularly proposed by various interested parties in many countries, often by the testing institutions themselves, but the major constraint with this concept is that compulsory testing adds a significant financial burden on manufacturers, particularly the smaller companies. It is generally thought to be more practical to let the market decide which machinery should be successful via farmer usage, practical field demonstration, word of mouth and magazine review articles. Manufacturers who wish to have their machinery tested for technical and marketing reasons are clearly free to do so and their testing fees can subsequently be used to partially cover the costs of the existing testing facilities.

15.3.6 Research Papers

Research papers are an important source of academic agricultural engineering information and are primarily produced by the universities and specialized agricultural research stations. Papers may also be required in order to achieve postgraduate qualifications (MSc & PhD) and to achieve promotion within certain research and university institutions.

Case Study: The CIGR Journal entitled Agricultural Engineering International provides a vehicle for authors in a number of agricultural engineering fields to publish their research papers. The primary CIGR areas of interest encompass Land and Water Engineering; Farm Buildings and Construction; Equipment Engineering for Plant Production; Energy in Agriculture; Management, Ergonomics and Systems Engineering; Post-Harvest Technology and Process Engineering; and Information Systems. To illustrate the publication coverage Volume IX (September 2009) included a paper submitted by researchers from the Department of Agricultural Machinery Engineering, University of Tehran, Iran, entitled "Investigating the cost of wheat production in Iran and the effect of combine availability on harvesting cost." The print and online publication of such papers therefore allows an insight to be gained into the research efforts being undertaken in a large number of countries thereby stimulating international discussion and cooperation.

15.4 OTHER SOURCES

15.4.1 Film

The phrase "seeing is believing" is a particularly relevant statement with respect to information dissemination. First hand visual observation of agricultural engineering activities is both educational and instructive but in most circumstances direct observation is restricted to those living in close proximity to the actual event. Film allows that visual experience to be transported or transmitted over great distances and subsequently to be witnessed by a far larger audience. The first black and white films made a significant impact even without sound since sub-titles could be used to describe the activities on screen. Film projectors could also be set up in remote locations if some form of permanent or temporary electricity supply could be provided. The historical disadvantage of film has been the relative cost of the recording equipment and the necessity for professional editing facilities. In recent years film has been replaced by DVD and CD-ROM options which are more durable, and subsequently by online video.

15.4.2 United Nations

The key UN institutions involved in the agricultural mechanization sub-sector are the UN Food and Agriculture Organization (FAO), the UN Industrial Development Organization (UNIDO) and the UN Asian and Pacific Center for Agricultural Engineering and Machinery (UNAPCAEM).

The appropriate division within the FAO is the Rural Infrastructure and Agro-Industries Division (AGS), whilst the relevant departments within that Division are Agricultural Mechanization, Food and Agricultural Industries, Post-Harvest Management and Rural Infrastructure (Storage). The FAO has established a number of useful information databases in recent years, namely, the International Directory of Agricultural Engineering Institutions (INTDIR); the Conservation Agriculture Technology Database (CAT); University Curricula; the Information Network on Post-Harvest Operations (InPhO) and has directly cooperated with the private sector Worldwide Agricultural Machinery and Equipment Directory (WAMED).

The International Directory of Agricultural Engineering Institutions (INTDIR) potentially provides a very useful global reference source but currently requires significant updating. The individual institutions were requested to update their own details but in practice this did not occur to a satisfactory level. This example highlights the fact that ongoing database maintenance is essential if the overall quality of the product is to be maintained. Budgetary constraints within the UN system have meant that this has not always been possible in the past. The same situation appears to be true for the Conservation Agriculture Technology Database (CAT), which according to the website has not been updated since 2007. The Rural Infrastructure and Agro-Industries Division (AGS) also produces print publications, such as the Agricultural Mechanization Publications (AGS Bulletins). The quality of the publications through the years has been very high but a significant number of the bulletins are only available in print format and this can be expensive both to produce and to purchase. There is therefore a requirement for all relevant AGS Bulletins to be made available online in PDF format, ideally free of any charge since this would increase accessibility in the developing world.

The relevant branch within UNIDO is the Agro-Industry Support Unit which is responsible for promoting rural industries as a means of generating economic and social development. A 2008 UNIDO publication directly related to agricultural mechanization is entitled Services to Agro-Industries: Productive Capacities for Sustainable Livelihoods and further relevant reports can be found on the UNIDO Agri-Business page. UNAPCAEM is a subsidiary body of the UN Economic and Social Commission for Asia (ESCAP) and is located in Beijing, China. Its current membership consists of the following countries, Bangladesh, P.R. China, D.P.R. Korea, Fiji, India, Indonesia, Iran, Malaysia, Mongolia, Nepal, Pakistan, Philippines, R.O. Korea, Sri Lanka, Thailand and Viet Nam. UNAPCAEM, in direct collaboration with WAMED, created a regional Directory of agricultural machinery manufacturers located within its member countries. The Bangladesh directory illustrates the potential to include a very large number of small-scale manufacturers, as illustrated by the Alim Industries listing. The increasing global use of the internet and 3G mobile phones in the developing world means that there is no longer any reason not to include small workshop based manufacturers within the global agricultural mechanization information system. Each company could be allocated its own website page including full contact details and product photographs.

15.5 THE INTERNET

15.5.1 Introduction

Prior to 1990 information dissemination and exchange was limited to methods which had been in existence for many years. The invention of hypertext and the rapid development of the internet have transformed every aspect of communication technology. In the previous discussion it was not possible to omit mention of internet sources because the old and new technologies are now so intertwined. However, a significant number of agricultural mechanization information resources are predominantly internet based and these will now be discussed in turn. Newly manufactured farm equipment is usually purchased through dealerships and agents located in the vicinity of the buyer. The purchaser is therefore aware of the reputation of the seller, can discuss the technical performance details, and can obtain repairs, maintenance and replacement parts, as required. However, there is a growing market for direct internet based sales of new machinery and equipment and it is felt that this practice is likely to expand in the future.

15.5.2 Search engines

There are a number of internet search engines but the leading ones in terms of visitor traffic are Google, Bing, and Yahoo! The search company Google was established in 1998 and in the following twelve years it has grown to be the dominant search engine on the internet. The Google search process is based on a complicated algorithm and a massive databank processing capacity which trawls the world's websites for information and ranks those websites according to their link popularity (PageRank) and their relevance to the keywords used by the searcher. Results are presented almost instantaneously in descending order of relevance. For example, a search for a general term such as 'farm equipment' yielded 3.55 million results in 0.33 seconds. The advantage of the search engine system is that the results are presented almost immediately. The main disadvantage is that the results are not as precise as the searcher might require even when using the advanced search facility. It would be quite reasonable, for example, for a farmer to search for the manufacturers of a specific item of equipment, such as a precision planter, using the search keywords "precision planter manufacturer". However the Google search only provided a total of five results when it is known that there are many hundred manufacturers of precision planters in the world. It is fully anticipated that search engines will become more powerful and refined in the future but the above example demonstrates that search engines currently have serious limitations with respect to the retrieval of precise agricultural mechanization information.

15.5.3 New Machinery Buyer and Seller Markets

Typical online buyer and seller markets encompass such websites as Amazon, eBay and Alibaba. The former are particularly useful for buying and selling relatively low cost items such as books and electrical goods but some websites such as Alibaba specialize in higher value items such as farm equipment. The homepage of the Alibaba website includes a list of 35 main product categories (Agriculture, Apparel, Automobiles etc.) and that is where the search for specific items begin. The website aim is to provide the buyers and sellers of products with a single transaction point and therefore product coverage is extremely wide and agricultural mechanization coverage is only a very small part of the whole. Each main category (e.g. Agriculture) is further divided into sub-categories to facilitate a more precise search, and the sub-category of particular interest to the agricultural engineer under the Agriculture category is Farm Machinery & Equipment. However, for complete agricultural mechanization coverage a search is also required within other main categories since they also contain relevant items, namely, Automobiles and Motorcycles for all terrain vehicles (ATVs), and Manufacturing & Processing Machinery for food and beverage processing machinery. It is therefore concluded that a search for all products related to agricultural mechanization is not a straightforward process since potential items of interest are located in different categories within the Alibaba website.

The Farm Machinery & Equipment sub-category is further divided into nine sub-categories, namely Agricultural & Gardening Tools; Agricultural Greenhouses; Animal Husbandry Equipment; Aquaculture Equipment; Farm Machinery; Farm Machinery Parts; Garden Supplies and Silos. The strength of the buyer/seller type of website is that they have a very wide product coverage and items can be purchased directly online. The main weaknesses, from an agricultural mechanization perspective, are: (i) There is no comprehensive and user friendly directory specifically for the agricultural mechanization sector; and (b) There is a strong bias towards Chinese sources of supply reflecting the original objectives of the Alibaba website which was to provide Chinese companies with access to the global export market.

15.5.4 Used Agricultural Machinery

There has been a local, national and global market for previously owned farm machinery for many years, particularly for high value items such as tractors, combine harvesters and self-propelled forage harvesters. In order for farmers and traders to be able to locate and procure such items there had to be some form of information system. This normally took the form of agricultural newspapers, magazines and auctions but increasingly the focus is through specialized internet websites. Globally there are at least 40 internet websites which specialize in the buying and selling of used agricultural machinery.

Case Study: A typical example is Traktorpool which has sites for 23 European countries thereby taking account of individual language requirements. Taking the Traktorpool United Kingdom website as an example the user is presented with a page which offers the option to Search for equipment to purchase or to Place an Advert to sell equipment. The Search option provides 25 main categories (Tractors, Harvesters, Tillage, Drills/Planters, Livestock Equipment, Forestry Equipment etc.) and once the main category has been selected the search can be refined by equipment category, manufacturer, model, year of manufacture, and gross price. This allows a very precise search to be undertaken if the potential buyer knows what type of machine they are looking for, thereby saving considerable time and effort.

If the visitor wishes to sell an item of equipment they simply click Sell and a secure page is presented which again offers 25 main categories of machinery. Taking the sale of a 'precision drill' under Drills/Planters as an example we are presented with a custom designed page where the item description can be precisely specified, namely, manufacturer, model, year of manufacture, registration date, working width, number of rows, row spacing, types of seed, net price, optional equipment, machine description, photos and location of seller. Sellers therefore have significant flexibility when selling their machinery online whilst the Traktorpool site management inputs are kept to a minimum because all of the data is input by the seller. At the time of review a total of 61 177 machines were available for sale on the Traktorpool website and reportedly over 20 000 visitors visit the site daily thereby illustrating the popularity of this type of used farm machinery resource.

The Traktorpool website income is generated from two main sources, seller listing fees and banner advertising. The basic cost to an individual for placing a single advertisement on the United Kingdom website for 28 days is £6 (US$9.60) and it is therefore a very cost-effective method of reaching potential buyers at minimum cost. Manufacturers and dealerships are also offered the choice of AgriVIP membership which provides a wider range of facilities. Vertical skyscraper banner advertisements (120 x 600 pixels) are priced at 1500 Euros/month (US$2 160) whilst smaller banners are priced at 0.30 - 0.50 Euro (US$0.43 - US$0.72) per thousand views. It would appear, based on the number of items listed and the listing fees, that the Traktorpool websites are able to generate a significant income per month. Such a used machinery enterprise would therefore appear to be commercially self-sustaining and profitable and subsequently there is unlikely to be a requirement for public sector involvement or finance in this field.

As a second example of used farm machinery websites in smaller national markets we can review the New Zealand based Farmpoint resource. This site lists a total of 3728 machinery items of which the majority (3654) are dealer listed with the remainder (74) individually listed. The search for equipment is undertaken via a drop down menu listing 63 categories, from 4x4 vehicles to welding equipment. Some categories are further sub-divided, such as the harvesting category, into forage harvesters, combine harvesters, windrowers, horticultural harvesters and harvester parts. A search for combine harvesters yielded a number of useful results with indicative machine and seller contact details. Sellers of machinery paid from NZ$50 (US$35) to NZ$128 (US$90) per advertisement per month, depending on the size of the advertisement in the print publication, from 1/24 to 1/12 of a page photo, and on single or double issue advertising. All advertisements were uploaded online by the seller thereby minimizing Farmpoint website management costs.

The foundation of any used farm machinery website is the powerful database software utilized to display the equipment for sale. It has to be reliable and incorporate a secure payment system. It is clear from the large number of used machinery websites in existence globally that reliable software is already available and that establishing such a resource in individual countries in the developing world will become viable as global internet and mobile phone usage increases.

15.5.5 Discussion groups and Forums

The former FAO Agricultural Machinery Branch was one of the first institutions to establish an email based discussion forum on agricultural mechanization. Unfortunately overall participation was limited and staff resource commitments meant that the forum had to be closed down after a few years. However, in recent years internet resources for the establishment of networks, online discussion groups and forums have grown considerably and have provided the opportunity for information exchange to occur within and beyond national boundaries. Typical examples are the Profi Forum, the UNAPCAEM Discussion Group, the Global Farm Machinery Network and country specific networks such as the Malaysian Network on Agricultural and Food Mechanization.

The advantage of internet based forums is that they allow people with niche interests to discuss issues with others with a similar interest no matter where they are located in the world. For example, a topic submitted to the Profi Forum on the 24 August 2009 (Case IH Puma CVX tractor) yielded 27 replies concerning opinions both for and against that particular item of machinery. This type of exchange of user experience can be extremely useful, not only to those who contribute to the forum, but to the majority of forum visitors who simply read the discussions of others. A further development on the standard discussion forum format is that provided by internet companies, such as Ning, who encourage users to have a greater role in networking activities by allowing them to establish their own networks and network members to create their own forums and groups, and upload their own videos and photographs. The Ning resource is free of any charge to the end-user since it is funded by the use of discreet advertisements and by optional premium services. Ning is not the only company to offer this type of service but to date there are 1.8 million individual Ning networks encompassing 39 million registered users worldwide. It is therefore likely that an individual with an interest in agricultural mechanization will find a network of interest among that number.

Case Study: The Global Farm Machinery Network was established in 2008 and by the end of 2009 a total of 271 members had enrolled on the site. Network founders have the option to limit site access to invited individuals but an open membership, such as the Global Farm Machinery Network, facilitates a more dynamic growth in membership and a fuller interaction between contributors from different countries. Inappropriate contributions do occur from time to time but these can be monitored and controlled by the network founder and, if necessary, members can be banned. This facility helps to overcome problems with 'spam' contributions which afflict much of the internet. To date the Global Farm Machinery Network membership has created 40 discussion forums, 12 groups, 58 member submitted videos and 374 photographs. The Network currently has a number of shortcomings but over time it is anticipated that membership numbers will grow significantly and the inputs will become more useful.

Global internet users have many demands on their time and there are millions of websites each competing for an individual's attention. Nevertheless the actual existence of the free of charge community network type resource does provide the opportunity for interested parties to create an agricultural mechanization focal point, or focal points, which can be built upon over time without any requirement for private or public sector investment.

15.5.6 Online Video

The cost of film production has been dramatically reduced in recent years due to the mass production of digital cameras, computer-based video editing software, and the creation of video hosting websites such as YouTube. Previously internet hosting of user created videos was prohibitively expensive due to the high digital storage costs but that situation changed radically when YouTube offered free video hosting up to a certain defined video file size. Subsequently users could create their own videos, edit them on their computer, and upload the finished video product to the internet where their creations could be seen by all those with a web browser and a broadband internet connection. In 2007 it became apparent that individuals, often farmers, were uploading videos of agricultural machinery to YouTube. The videos were spread randomly throughout the YouTube website and so WAMED gathered selected examples into a single location so that finding them would be easier for those with an interest in agricultural mechanization.

At about the same time manufacturers commenced creating videos of their own machinery in operation and included them on their company websites as a marketing and demonstration tool. The manufacturer videos were often of high quality and therefore WAMED decided to create an Agmachine YouTube channel where manufacturer created videos could also be seen globally. It was felt that video would be a very useful way of disseminating information about a wide range of agricultural machines to the developing world. It also meant that individuals did not have to undertake their own search through every manufacturer website in order to try to locate videos of interest. By the end of 2009 the Agmachine Video channel hosted a total of 282 manufacturer videos and these had been viewed a total of 3.5 million times, whilst 354 individuals had subscribed to receive new videos as and when they were uploaded. The viewing figures indicate that quality videos of agricultural machinery in operation are very popular and it is concluded that video offers a very important medium for education and extension.

15.5.7 Business Directories

Well known examples of internet based business directories are Kompass, ThomasNet, Business.com and Kelly's Directory.

Case Study: The Kompass business directory lists 2.3 million companies in 66 countries and caters for 57 000 product categories. The homepage lists 14 main categories including "Agriculture and Food" and this category is further sub-divided into 8 sub-categories, such as "Agricultural, forestry and aquaculture machinery and equipment". This sub-category is further sub-divided into 10 more product divisions, for example, there were 11 438 companies listed under "Agricultural, horticultural and forestry machinery and equipment (trade)". This area of interest is again sub-divided into 32 product categories with, for example, 2204 companies listed under "Sowing and planting equipment (trade)". The above discussion demonstrates that business directory navigation is often far from clear with certain product category descriptions at different search levels being very similar.

At the "Sowing and planting equipment (trade)" level the list of companies is headed by what are termed "Premium Suppliers" and the first of these is Hispaes S.A. of Spain. The full contact details of this company are given including a link to the company website where four language options are found, namely Spanish, English, French and Italian. However when the casual visitor to Kompass wishes to investigate other listed companies they are obliged to officially register on the Kompass site before they can obtain further information. Compulsory registration is a common occurrence with many websites because this provides evidence to potential advertisers of a certain number of registered users, even if those users may only ever visit the site on a single occasion. The registration process generally has a negative impact on the visitor because it is time consuming and personal contact details are required.

Once the Kompass registration process had been completed it became clear that only 40 of the 2204 listed companies had actually paid for the Premium Supplier listing. The remaining companies received a standard listing which covered basic contact details including telephone and fax numbers but not email or website details or active links. One of these companies, C. B. Norwood Distributors Ltd. in New Zealand, can be quickly located simply by using the Google search engine and within no time the company's comprehensive website can be located and the details of its product line can be consulted. This particular example demonstrates that the major business directories are potentially very useful but that they can also be particularly frustrating places to visit because essential company information is deliberately omitted from the majority of the listings due to the particular business model in use, namely premium and standard listings. The fact that the scale of product coverage of most business directories is extremely broad means that they are not therefore specifically focused towards agricultural mechanization.

15.6 THE GLOBAL AGRICULTURAL MECHANIZATION PORTAL CONCEPT

The concept of a Global Agricultural Mechanization Portal is very simple, namely, to provide a single starting point for every global information search related to agricultural mechanization. (A "Portal" is a framework to provide a single point of access to a variety of information and tools). In order to be comprehensive the agricultural mechanization coverage should include active links to large, medium and small manufacturers, news, used machinery, replacement parts, newspapers, magazines, research abstracts, market reports, books, repair manuals, videos, photographs, employment, finance, insurance, manufacturer associations, dealerships, exhibitions, field demonstrations, machinery hire, research institutions, machinery testing, higher education and vocational training.

The previous discussion has illustrated that there are a very large number of high quality and diverse agricultural mechanization information sources already available on the internet as individual entities. The majority of these sites are private sector funded enterprises and their strength is the fact that they predominantly cater for distinct markets based on specific countries and languages and for those requirements they provide high quality resources. Their main weakness, from a global development perspective, is that commercial websites are primarily targeted at developed countries and, in general, do not cater for the needs of the developing world. For example, there are estimated to be over 8000 manufacturers of agricultural machinery in the world, from the largest multi-nationals to very smallest workshops producing one or two important items such as a simple hand tractor and trailer. Historically the majority of these manufacturers have not been represented or their products catalogued. The challenge is how to assist the global internet user to rapidly and easily locate the specific items of equipment or information resources that they require no matter where those resources are located in the world. At the present time many first class resources cannot be found on the largely unstructured internet.

The difficulty with the global concept for a niche subject area such as agricultural mechanization is that the portal needs to be commercially viable if it is to be sustainable in the longer term. A July 2008 market research publication entitled "World Agricultural Equipment to 2012" concluded that the global demand for agricultural equipment would rise 3.8 percent per year from 2008 to reach a figure of US$112 billion by 2012, and that most of that growth would occur in the developing world. It is therefore concluded that the size of the projected market is of more than sufficient value to support a global agricultural mechanization portal which encompasses both developed and developing world requirements.

Case Study: In 1997 an attempt was made to establish a global portal entitled the Worldwide Agricultural Machinery and Equipment Directory (WAMED). A fundamental founding principle of WAMED was that the directory should be provided totally free of charge to the user with no membership subscription or registration barriers to entry. A further underlying philosophy was that the website should be private sector and be financially self-supporting since it was concluded that that was the only way that long-term sustainability could be achieved. It was felt that a major website funded annually by a public sector body, such as the UN Food and Agriculture Organization (FAO) or UN Industrial and Development Organization (UNIDO), would not be able to guarantee the required recurrent funding indefinitely since UN priorities and budgetary resources change over time. If public sector funding was withdrawn at any time then the website would fail.

The initial core information resource of WAMED was to be a global directory of agricultural machinery manufacturers covering items of equipment from the land development stage through to the post-harvest stage, that is up until primary crop processing. WAMED did not aim to cover secondary food processing technology since it was felt that this was an area deserving of its own major website resource. The overall directory objective was to achieve universal manufacturer coverage encompassing multi-national manufacturers, large, medium and small manufacturers no matter what their geographical location since only that approach would achieve the single point of reference goal. Prior to 1997 access to farm equipment information had been primarily restricted to the major manufacturers with significant marketing budgets whilst many smaller companies, who also produced first class products, did not have the financial resources or knowledge to successfully market their products beyond the borders of their own countries, or even their own districts. It was anticipated that such a global directory would ultimately consist of over 8 000 manufacturers but the actual number would be gradually built up over time as resources allowed. To facilitate ease of navigation the Machinery Index was divided into 45 main categories and 263 sub-categories of farm equipment within a carefully structured directory framework. In addition a Company Index (A-Z) was included to facilitate searching when only the name of the company was known, and a Country Index (A-Z) when searchers wished only to consult manufacturer results from specific countries. The indexes were also translated from the English language into German, French, Spanish and Chinese since it was felt that this would significantly increase the global accessibility of WAMED.

Sustainable revenue generation for any enterprise is clearly a critical issue. Consideration was initially given to creating a subscription-based WAMED directory whereby only subscribers could access the information. This business model is used by a number of successful websites in order to achieve commercial viability but it was felt that such a solution would create a significant barrier to entry, particularly to the developing world. An alternative financing concept that was considered was to charge every manufacturer a small annual fee for listing their company within the directory. The major constraint with the company listing fee concept, particularly for a new start-up website enterprise in 1997, was that a fully inclusive global directory of over 8 000 manufacturers could not be established if only a small proportion of manufacturers actually signed up for inclusion. It would no longer be a truly global directory and therefore a primary objective of the project would not have been achieved. An additional factor was that at the time of the WAMED launch in 1997 very few farm equipment manufacturers were aware of the potential value of the internet for sales and marketing whilst even fewer had established their own company websites. A fundamental decision was therefore taken by WAMED to include as many manufacturers as possible completely free of charge in the hope that, over time, the popularity of the website directory would generate demand from manufacturers and other interested parties to advertise within the directory.

The listing process commenced in 1997 and every manufacturer entry was provided with a unique company page, as illustrated by Chafer Machinery Ltd. Each page included company name, postal address, telephone number, fax number, email and website address with an active website link, as available. As previously stated, a number of the major online business directories and buy/sell websites do not provide detailed company contact details or active website links since their own particular business models are built on them acting as an intermediary contact to the listed companies who pay an annual fee, or a per contact fee, in return for receiving business leads. The WAMED viewpoint was that a system that did not include direct website links would be extremely frustrating to the user since essential contact information would always be just beyond reach. Furthermore WAMED felt that such a system would not be sustainable in the longer term once competitor websites provided detailed contact information and website links free of any charge. In 1997 the concept of providing free of charge internet content was considered eccentric but in recent years a growing body of opinion considers that, in general, "digital information wants to be free", as ably outlined in the book, "Free: The Future of a Radical Price", where the author offered the online book for free but provided the opportunity for the print version to be bought for those who preferred the book format. Global publishers, whose newspapers had been founded on relatively high cost advertising revenue to cover high cost print production, are currently having to rethink both their offline and online business models due to significant competition from free publishing sources.

An additional way that WAMED-listed manufacturers could differentiate themselves one from the other would be by paying for enhanced company listings. The first option offered to manufacturers was the enhanced company page whereby the free of charge standard company page was upgraded to include a company profile, a list of company products, and photographs of a selection of those products. It was felt that the fuller information provided by the enhanced company page would encourage WAMED directory visitors to link through to companies who had already established their own websites whilst the enhanced listing would also act as a mini-website for the large numbers of manufacturers who at that time had yet to establish their own website presence. A typical example of the enhanced company page was for the Irish company Hi-Spec Engineering Ltd. which, in addition to the described features, also included multiple active links to individual sections of the Hi-Spec Engineering Ltd. website.

A further WAMED revenue generating possibility was that a large number of manufacturers throughout the world, and even within individual countries, produce virtually identical items of machinery, for example, ploughs, disc harrows, farm trailers and grain storage bins. It was therefore felt that individual companies might wish to emphasize their own particular company products over and above their competitors in the 45 main WAMED categories and in the 263 sub-category indexes for individual products. An example of this type of sub-category index advertisement can be seen under the United Kingdom listings of Potato and Rootcrop Harvesters. The advertisement is for Richard Pearson Ltd. and the advertising package included both the potato and rootcrop harvester sub-category advertisement and an enhanced company page. A further observation is that visitor traffic to extensive websites, such as WAMED, is usually at its maximum at the website entry point and decreases the deeper visitors delve into different compartments of the website structure. Manufacturer advertisements located closer to the WAMED directory homepage receive the greatest visitor traffic and therefore advertising locations were subsequently priced higher at those key website entry points.

During the period 1999 to 2005 WAMED implemented separate authorship contracts on behalf of the UN Food and Agriculture Organization (FAO) and the UN Asian and Pacific Center for Agricultural Engineering and Machinery (UNAPCAEM) to list a substantial number of manufacturers from the developing world within the WAMED Directory. The FAO had been contemplating establishing a similar in-house manufacturer directory for some time but realized that it could not guarantee the long-term funding to support such a resource. The UN/WAMED contracts were therefore examples of public-private sector partnerships whereby the UN achieved its objectives without having to make a long-term commitment to employ in-house staff or resources.

The launch of the Google AdWords programme in 2005 proved to be a major advance for small businesses around the world who wished to advertise their products globally on the popular Google search engine. The strength of the AdWords business model was that companies could set their own monthly advertising spend and also accurately measure the cost of every click through to their company website. Previously businesses would pay a set fee to place banner advertisements on websites for a set period without any accurate record of how many times their advertisement had been viewed or how many times a particular advertisement link to a company website had been activated. Shortly after the launch of the AdWords programme Google launched Google AdSense which provided small website publishers, such as WAMED, with the opportunity to place AdSense banner advertisements throughout their own websites and be paid a fee for every click-through made to an AdWords advertisement. Although the individual payment per click-through was very small, website publishers with high visitor traffic volumes had the potential to generate income without having to employ advertising sales staff or agencies to sell their advertising space. Both Google AdWords and Google AdSense have proved remarkably popular with both advertisers and publishers.

The original WAMED concept of generating revenue through the sale of advertising space to individual manufacturers was basically sound and was based on the valuation of the global agricultural mechanization industry. There is little doubt that an established national or global publisher with a number of existing titles and in-house advertising sales staff could have made WAMED a financial success within a relatively short time, particularly if the website were combined with a monthly magazine publication in digital or print format. However, without the financial resources to employ staff WAMED continued to rely on its ability to generate an increased level of visitor traffic in the expectation that at a future date advertising enquiries would be received directly from the manufacturers or their marketing agents.

Although by 2005 visitor traffic had reached a healthy level for a specialist agricultural mechanization directory it proved insufficient to attract extensive advertiser enquiries. A decision was therefore made by WAMED to place AdSense advertisements throughout the whole website and rely on that medium to generate advertising revenue, whilst the option still remained for WAMED to add manufacturer or other advertising in any location on request.

In parallel significant efforts were also made to expand WAMED visitor traffic by transforming the website from a basic manufacturer directory into a fully fledged global agricultural mechanization portal by expanding the coverage to include links to news, used machinery, replacement parts, magazines, research abstracts, market reports, books, repair manuals, videos, photographs, employment, finance and insurance, manufacturer associations, dealerships, exhibitions and shows, machinery hire, research, machinery testing, and higher and vocational education. The subsequent development of YouTube also allowed WAMED to create the Agmachine Video Channel which by December 2009 had been viewed a total of 3.5 million times. In addition, the advancement of community website software also allowed WAMED to create the Global Farm Machinery Network which by December 2009 received 2 200 visits per month. It can therefore be said that WAMED has already laid firm foundations for a genuine global agricultural mechanization portal which can be built upon and expanded in the future.

15.7 LANGUAGE TRANSLATION

To be truly global information dissemination and exchange needs to be possible utilizing a large proportion of the world languages. At the present time English is the primary language of international commerce and having a single global language does have distinct advantages. However this is clearly impractical and therefore emphasis needs to be placed on those languages which have the largest population base, such as English, Chinese, Hindi, French, Spanish, Portuguese and Arabic. Unfortunately the manual translation of all the global agricultural mechanization literature and database resources into seven languages is not feasible because of the costs involved. Historically the manual translation of key UN documents has been largely restricted to four main languages, namely English, French, Spanish, and Chinese.

The rapid development of software technology in recent years has brought about a significant advance in automatic language translation, such as the Google Translate resource. The Google service offers online translation to and from 51 languages, including languages such as Indonesian, Swahili, Japanese and Persian. At present the accuracy of the automatic translation service is limited but Google is using its vast computer processing power to improve the quality of the product year on year. Notwithstanding its current limitations Google Translate does have the ability, for example, to make a news article in the English language broadly understandable to the Hindi reader, and vice-versa, thereby potentially opening up all information resources to the world.

Case Study: WAMED News - The value of the Google automatic translation service can be demonstrated by visiting the News section of the WAMED website. The news headline links are written in the English language but these headlines and, most importantly, the subsequent English language news articles can be translated into any one of the listed 51 languages.

To achieve this the WAMED News internet address is firstly copied into the Google Translate page. It is then simply a matter of selecting the "Translate from" language (English) and the "Translate to" language, in this case, Hindi. The Translate button is then clicked and all of the original news headlines are automatically translated into Hindi. It is clearly not possible to judge how accurate the translation is but it is anticipated that, though not perfect, the general meaning of the news article headline can be understood by anyone in India with internet access. To further demonstrate the capacity of the translation resource it is simply a matter of choosing a particular news headline and clicking the link to the full website article, where the original article is automatically translated from English into Hindi. Automatic translation is clearly a fundamentally important resource for information dissemination and exchange and it is therefore anticipated that a significant proportion of global websites will have this facility already built-in in the near future thereby opening up the content to a greatly increased global readership. It is anticipated that this translation system will soon be fully incorporated into WAMED.

15.8 THE FUTURE CHALLENGE

Information is the key to knowledge and within the world there are currently millions of potential information sources which can be consulted. It could be argued that recent developments in telecommunications, computers and the internet have actually led to an information overload in the developed world. This is evidenced by the fact that in many countries it is possible for the individual to access hundreds of digital radio stations and television channels, and millions of individual internet websites. Unfortunately the individual only has the capacity to locate and absorb one information source at a time.

A fundamental objective of Google Inc. is stated to be "to organize the world's information and make it universally accessible and useful". Exactly the same objective should apply to the organization of world's agricultural mechanization information and this task is much easier because it is a niche subject encompassing no more that 10 000 separate information sources rather than millions, and the majority of these are individual farm equipment manufacturer sources. The keyword based approach of Google, Bing and other search engines goes some way in identifying useful agricultural mechanization resources but the results are often disappointing and unstructured. For example, a simple keyword search for an "offset disc harrow manufacturer" should be able to identify every manufacturer of that specific item of equipment in the world, ideally grouping them in a structured directory format by country of origin and company of manufacture. A Google search produced 44 100 results spread over 4 410 pages but very few users would look beyond the first ten pages because the results were predominantly a mix of miscellaneous sites not directly related to the precise search objectives. In contrast the human brain has no difficulty in creating an easily understood and easily navigated structured directory for global offset disc harrow manufacturers. This example illustrates the current limitations of the search engine approach.

Private sector entrepreneurs have no obligation or responsibility to provide a comprehensive coverage of the global agricultural mechanization sub-sector, nor should they be expected to do so. Their primary responsibility is to their shareholders and investors who wish to see a profitable return on their investment. The private sector has already shown the ability to create high quality exhibitions, field demonstrations, used farm equipment websites, new machinery buyer/seller websites, online and print magazines and other relevant resources. However the specific needs of the developing world have not been fully addressed to date because they have not been considered commercially viable or sufficiently profitable.

Opportunities do exist in the developing world for private sector investment in general communication technology and the internet. The rapid growth of mobile communications in India, Brazil, Iran, China and elsewhere has demonstrated that entrepreneurs will establish communication networks where real demand exists and this can often be achieved at an affordable cost to the end-user, whether it be a user-group or an individual. Whilst the individual farmer in Bangladesh or Zambia may not own a mobile phone or computer his farmer group, cooperative, village or agricultural extension service may well be able to provide him with access to that resource in the near future. It is therefore concluded that the internet provides the best vehicle to provide the required agricultural mechanization information to the developing world and this can best be achieved through the creation of a global portal in a structured format which is user-friendly and easily accessible in any language.

The options open to the international community are:

- Do nothing and accept the currently imperfect global agricultural mechanization information dissemination and exchange system which is primarily focused on the developed world. This option does not take account of the need to take positive action in line with the UN 2050 targets.
- Create a new in-house UN agricultural mechanization information portal. This option is certainly feasible but it would require significant website establishment and ongoing staffing costs.
- Wait for commercial publishers to establish the required global portal. This may well occur in the future but the private sector has already invested in the most profitable sectors. There is therefore no certainty that that they will act in the near future.
- Build on the existing resources, such as WAMED. The WAMED website has been a pioneer in this field since 1997 but it remains a work in progress. The costs of hosting, upgrading and maintaining such a global information resource are, in international terms, comparatively small but to date visitor traffic for this niche subject area has been insufficient to attract sufficient sponsorship and advertising revenue to fully cover operational costs.

Consideration could be given to further public/private sector cooperation in the form of donor foundation grants or authorship contracts over a set period, primarily to expand the existing information resources and the developing world manufacturer listings, but also to make the site fully accessible in an increased number of languages. Ultimately it is envisaged that this would result in an increase in visitor traffic and advertising revenue to the extent that the site would ultimately become self-financing.

CHAPTER 16

Information Exchange and Networking: the RNAM Experience

Information Dissemination and Exchange

Note: The theme of information dissemination and exchange is discussed in two related chapters. The first, by Trevor Cree with a global perspective and the second, by Reynaldo Lantin which gives an account of experiences from RNAM in Asia.

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ABSTRACT

This chapter is an account of the development of the Regional Network for Agricultural Machinery from 1977 to 2002. It highlights the growth in number of member countries and the successful exchange of information on agricultural mechanization technologies between the members. The structure and functions of the network are described. RNAM was perceived to have a ripple effect, for instance when an effort was made to create a Latin American Small Farm Mechanization Network. Modern communication methods, especially the internet, would make the resuscitation of such ideas a worthwhile consideration.

16.1 THE NETWORK CONCEPT

The Regional Network for Agricultural Machinery (RNAM) was established in 1977 as a project based on the concept of exchanging information, data, agricultural machinery hardware and experiences in the implementation of activities among the initial eight member countries in Asia, namely, India, Indonesia, Islamic Republic of Iran, Pakistan, Philippines, the Republic of Korea, Sri Lanka and Thailand. Bangladesh and Nepal joined RNAM in 1987 and China in 1990. The network of information exchange was preferred over a centre because it would distribute the benefits from the project to the member countries through sharing of experiences and technical developments. Besides, it would strengthen the national institutions already established in the countries through the development of human resources and the catalytic assistance provided by the project.

RNAM with its Regional Office (RO) based in Los Baños, Philippines, underwent five phases, the first four of which were supported with funding from the UNDP, the donor countries and the member countries. Donors Australia and Japan also gave technical assistance through the provision of experts during the annual meetings of the Technical Advisory Committee (TAC) and the Governing Body (GB). They also provided experts and resource persons during their hosting of training workshops and study visits of groups comprising technical people and manufacturers from the member countries. The Fifth Phase (1992-2002) was supported by the Economic and Social Commission for Asia and the Pacific (ESCAP), the member countries and the donors Germany and the Netherlands; ESCAP was the executing agency in association with FAO and UNIDO. The International Rice Research Institute (IRRI) and the Asian Institute of Technology (AIT) also provided technical assistance to the project.

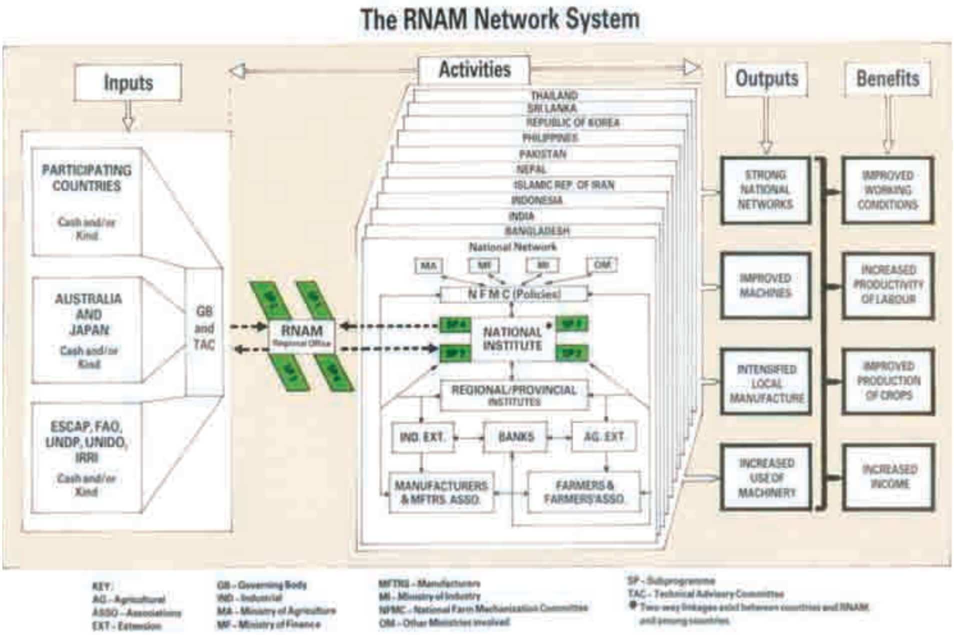
In the implementation of the regional activities, the RO played the crucial role of organizing, coordinating and undertaking follow-up actions as well as serving as catalyst in the implementation of activities and information exchanges among the countries through a designated focal National Institute (NI) in each member country. Each NI implemented the national activities through a National Network (NN) of government, academic, research, development, extension institutions and agencies as well as banks, and farmers' and manufacturers' associations. Central to such implementation was the establishment of the National Farm Mechanization Committee (NFMC) which crafted proposals for policies and strategies for agricultural mechanization for approval by the national economic planning body. The nationally approved strategies served as guidelines, among other provisions, for the importation of agricultural machinery and the enhancement of local manufacture through adaptive design, testing and development of agricultural machinery by the institutions concerned through mutual exchanges of technical information, machinery design drawings and hardware with other member countries. The strategic plan also guided the agricultural and industrial extension institutions in popularizing the machines through facilitating access to credit and dealing with farmers' associations. It also encouraged local manufacture and commercialization of agricultural machinery through the formation of manufacturers' associations.

RNAM also provided assistance in the form of audio-visual equipment to strengthen the information dissemination capabilities. For example, through the Japan-ESCAP Co-operation Fund (JECF), RNAM provided the Nepal NI a mobile demonstration and training unit consisting of a truck containing basic workshop equipment, audio-visual facilities and agricultural machines to be popularized among farmers (ESCAP/RNAM, 1989). It was considered a useful, effective and efficient means for agricultural machinery extension.

The RNAM network system, which comprised the institutional infrastructure supported by fund inputs as well as technical and administrative

FIGURE 16.1

The RNAM network system as of 1987. China joined RNAM in 1990. The SPs had been modified progressively since the First Phase (1987-1991) and into the Fifth Phase (1992-2002). With strengthening of the NIs, the network has been transformed into a centre (UNAPCAEM) and has expanded membership since 2003. The new members include Cambodia, Fiji, Malaysia and Myanmar. It has also included organizations as associate members



advice for the activities under four planned sub-programmes (SPs) to achieve the expected outputs and benefits, is depicted in Figure 16.1 (ESCAP/RNAM, 1987).

The SPs for the Fourth Phase (1987-1991) consisted of the following:

SP 1. Formulation and implementation of appropriate agricultural mechanization policies and strategies;

SP 2. Design and development of selected agricultural machinery;

SP 3. Local manufacture of selected agricultural machinery; and

SP 4. Extension of appropriate agricultural mechanization technology.

During the First Phase (1977-1981), there were subsets of member countries engaged in any of three sub-network activities which comprised testing, evaluation and adaptation of any of rice transplanters, weeders and cereal harvesters, which they had selected. A fourth sub-network activity dealt with improvement of manufacturing technology of seed-fertilizer drills, grain threshers and other agricultural equipment already accepted in the country of origin. The sub-set of member countries working on a particular machine of common interest gave sharper focus and put greater emphasis on development compared with when the country concerned was working on it in isolation. In so doing, the countries that participated in sub-network activities benefited from sharing experiences and results. A sub-network activity coordinator for a machine type travelled to the participating countries and after some period a workshop was conducted in one of the countries. Performance deficiencies of the machines tested and evaluated were identified using test codes developed by RNAM.

Towards the end of the project support from UNDP in 1991, the GB endorsed the continued provision of catalytic assistance to participating countries regarding regional activities, which were identified into five SPs, namely:

- SP1. Extension of agricultural machines (market expansion) through extensive demonstrations in farmers' fields;
- SP2. Manufacture of agricultural machines through sharing of technologies and joint manufacturing arrangements;
- SP3 Design and development of agricultural machines through exchange of information and hardware;
- SP4. Integration of women in agricultural mechanization activities; and
- SP5. Strategies for appropriate agricultural mechanization.

The network system was characterized by personal contacts between the players in the network through meetings, group training courses and workshops, study tours and visits by the NI directors and technical staff, senior government officials and decision-makers and representatives of manufacturers' associations. Unfortunately farmers, the ultimate beneficiaries of the project, were not represented in any such regional interpersonal or face-to-face and farm-to-farm learning activities. Special sub-programmes involving farmers through their farmers' associations would probably have had a positive impact on the speed of transfer of technology directly to the users and feedback from the beneficiaries. Farmers were however involved in the national programmes of the NNs.

The incidental socialization and acquaintance meetings among the representatives as well as their first-hand observations of the farming conditions in the host countries had a positive bearing on the vitality and viability of the network. Such personal contacts, even though brief and perhaps only one-off encounters for some delegates, are significant in increasing the effectiveness of the cross-learning activities and more importantly in sustaining them. Today fast and economic electronic telecommunication facilities, especially the internet strongly complement the contacts initiated during the group activities. In fact, such sustained communications facilitate the inter-country transfer of technologies and ideas. They also foster friendship and informal technical cooperation among the players in the member countries.

16.2 INFORMATION EXCHANGE

Among the benefits derived from RNAM by the participating countries were those pertaining to the exchanges of machinery design drawings and technical information that would otherwise be difficult or slow without the networking project. The give-and-take activity fostered technical cooperation among the developing countries. An example of an exchange activity by the NIs is shown in Table 16.1.

The RO, through its international linkages, also provided information to the NIs on the availability of machinery designs from outside of the network. For example, through the Instituto de Investigación Tecnológica Industrial y de Normas Técnicas (ITINTEC) based in Lima, Peru. Through RNAM, Thailand and Iran requested designs of grain thresher, solar rice drier, husk-winnowing machine and water pump windmill from the ITINTEC. Apart from sourcing from IRRI, RNAM requested designs from AIT, ICRISAT, IITA and other international research institutions.

TABLE 16.1
Designs and drawings of agricultural machinery exchanged among the participating countries of RNAM

Source Country	Agricultural Machinery Design	Requesting Country
India	1. Multi-crop thresher	Pakistan and Iran
	2. Sugarcane sette planter	Pakistan
	3. Rice thresher	Pakistan
	4. Desiccated coconut drier	Philippines
	5. Cassava chipper	Indonesia
	6. Agricultural waste-fuelled drier	Philippines
	7. Paddy winnower	Philippines
	8. Wet and dry grinding machines	Philippines
	9. Four-roller sugarcane crusher	Philippines
Pakistan	1.Vertical conveyor reaper	India
	2. Cotton inverted T-seeder	Nepal
Philippines	1. Forage cutter	Iran and Indonesia
	2. IRRI axial-flow pump	Nepal
	3. IRRI conical weeder	Nepal
	4. IRRI paddy huller	Nepal
	5. Peanut sheller	Nepal and Indonesia
	6. Corn sheller	Nepal and Indonesia
	7. Village rice mill	Nepal
Republic of Korea	Manual soybean planter	Pakistan
Sri Lanka	1. Mark II 6-row rice transplanter	Nepal
	2. IRRI rice transplanter (Sri Lankan model)	Nepal
	3. Upland seeder	Nepal
Thailand	1. Rolling injection planter	Pakistan
	2. Power tiller-attached reaper (commercial unit)	India

Source: ESCAP/RNAM. 1988

16.3 NETWORK PLANNING INITIATIVES IN LATIN AMERICA AND EAST AFRICA

Perceived as RNAM's ripple effect, there had been initiatives of some international development agencies in establishing regional networks in Latin America and East Africa (ESCAP/RNAM, 1986). The United Kingdom's Overseas Development Administration and the British Council convened a conference in Veracruz, Mexico in 1986 to promote the formation of the Latin American Regional Network for Small Farm Mechanization aimed at increasing technical cooperation among Latin American countries and other regions in the aspects of agricultural engineering for the small farmer. Representatives from Brazil, Bolivia, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru and the Dominican Republic as well as from France, UK, and Switzerland participated in the conference (SARH, 1986).

Generally, in most of the countries in Central and North Latin America, produce from the large farm plantation sector is destined for the main urban centres and for export while the produce from the small farm sector is more for the local needs. Imported farm mechanization technologies from North America or Europe were considered appropriate for large farms but were rarely applicable for small farms and needed extensive trials, adaptation and extension. With looming food shortages exacerbated by high population growth, there was also a need to increase production levels on small farms by introducing new technologies that would lead to more efficient use of all available resources including land, water, fertilizer, energy and labour. It was also necessary to increase the profitability of small farms and raise the standard of living of workers to levels comparable to that of urban dwellers.

The main topics discussed during the conference included:

- National profiles of mechanization for the small farmers;
- Power sources;
- Post-harvest systems and processes;
- Non-conventional energy sources;
- Soil and water management;
- Manufacture and adoption;
- Research and development projects; and
- Regional networks for cooperation.

A project proposal was to be prepared with details of the small farm mechanization requirements of each participating country and the establishment of the aims, location, financing and the institutional infrastructure of a regional network. Upon approval by at least five countries, the proposal would be presented to prospective donors.

The Veracruz meeting created interest in the formation of a network similar to RNAM and learning from its experiences in exchange of agricultural machinery technologies on a regional basis that would embrace most countries in South and Central America. That interest however, was probably not sustained but perhaps a revival may be in order after some 25 years, considering the success of RNAM in Asia which has evolved with significant expansion into the Asia Pacific Centre for Agricultural Engineering and Technology (UNAPCAEM) since 2002. There has always been a continuing concern for food security among developing countries and a commitment to achieve the Millennium Development Goals (MDGs) of the UN. Inter-country networking projects as demonstrated by the RNAM project along with adaptive improvements might provide solutions or be part of the strategy for achieving the MDGs in developing countries.

Another indication of the ripple effect of RNAM was the initiative of FAO and ILO in East Africa. They conducted a joint inter-agency mission in Botswana, Ethiopia, Kenya, Sudan, Tanzania and Zambia from 26 January to 9 March 1985 as preparatory work for the establishment of the African Network for Agricultural Tools and Equipment. The proposed inter-agency TCDC (Technical Cooperation between Developing Countries) type network aimed to create/strengthen the national/regional capabilities for identification, development, manufacture, distribution and application of appropriate farm equipment technologies for agricultural growth, food self-sufficiency, poverty alleviation and rural employment generation. The network was also conceived as a link between the national institutions of participating countries in addition to improving coordination among institutions within each country.

The mission noted that small-scale and subsistence farming, which constituted the bulk of the region's agriculture, relied almost exclusively on multi-purpose traditional hand tools. The use of such tools for nearly all agricultural operations, limited the area cultivated and the productivity of the farmer. For example, a simple improvement of the plough to make it lighter, cheaper and with improved performance would already be significant in improving the livelihoods of poor farmers and would cascade into further improvements of other animal-drawn/hand operated implements for tillage, planting/seeding, weeding, harvesting and postharvest operations. Most of such technologies have already been developed and proven in the Asian countries from which the transfer of technologies would be relevant to the needs of most African farmers because of the similarities of farming conditions.

The mission noted and recommended the following:

- Mechanical power technology would complement rather than compete with ox-cultivation; private tractor service providers should be encouraged for greater effectiveness and efficiency compared with government tractor hire services.
- Capacities of existing institutions in disseminating farm equipment technologies should be strengthened through training and technical support.
- There was a lack of well-defined agricultural mechanization policies and strategies although the trend was towards the use of animal draught for the small farmer.

- Although some successes had been achieved in the development and testing of farm equipment innovations, none had been brought to widespread use.
- There was no development and commercialization of prototypes.
- Local manufacturing should be oriented towards small scale rural industries and repair facilities to finish, assemble and retail semi-finished products available from the factory-scale manufacturers.
- There was a need to train rural blacksmiths and upgrade their capacities and facilities.
- There was duplication of research and development efforts as well as an absence of regional trade and an emergence of excess capacity in farm equipment manufacturing in some of the countries; hence, regional cooperation was needed.

RNAM had an opportunity to share its experiences with African countries including Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Ghana, Kenya, Madagascar, Malawi, Morocco, Nigeria, Senegal, Sudan, Tanzania, Togo, Tunisia, Zaire, Zambia and Zimbabwe through delegates to the UGEXPO, an international exposition organized by the Belgian Federation of Agricultural Machinery and Horticultural Equipment and held in Brussels, Belgium from 13 to 17 February 1990. Representatives from the African Regional Centre for Engineering, Design and Manufacture (ARCEDEM) based in Ibadan, Nigeria and the FAO, UNIDO and RNAM also participated in the congress (ESCAP/ RNAM, 1990).

In the congress, the significant accomplishments and impact of the RNAM project on the participating countries were highlighted. Because of RNAM's success as an inter-country project, the idea of initiating the study and creating a Euro-African Network for Agricultural Machinery based on a similar concept of RNAM was discussed. The factors and features that contributed to the success of RNAM consisted of the following:

- Desire of the participating countries in the Asian region to form an inter-country network with support from UNDP and the donor countries as well as their own governments;
- Institutional infrastructure, which emphasized the reasons and requirements for a viable network;
- The advantages of a network over a permanent institution or centre;
- The importance of a regional office and defined goals, objectives, outputs and activities of the project;
- Existence of focal national institutes;
- Importance of defined mechanization policies and strategies;
- Existence of a viable local agricultural machinery manufacturing industry;
- Private sector involvement;
- Institutional and infrastructural support systems;
- Continued human resources development;

- Improvement of facilities;
- Continuous and sustained exchanges of information among the NIs; and
- Periodic project evaluation.

16.4 MODERN COMMUNICATION FACILITIES

The modern communication facilities worldwide greatly facilitate the interactions and exchanges of technical information and are much faster and more efficient than what were available to the RNAM project during its implementation from 1977 to 2002. Personal contacts however, are superior and more desirable although making arrangements and travel are more expensive and take more time than other forms of communication.

Thus, the regional networking activities were reflected in the national network activities through face-to-face information exchanges and interactions among the RO, NIs and the experts from the international development agencies and institutions during Technical Advisory Committee meetings. The RO followed up the activities with the NIs through personal visits to the NIs and through communication facilities that were commonly used during the period, such as telex, cablegram and mail. The wide use of fax and e-mail facilities started during the 1990s. The conduct of regional group training courses, workshops and study tours gave opportunities for personal interactions between the delegates from the different countries.

The RNAM Newsletter, which was published by ESCAP/RNAM with issues coming out in April, August and December of each year, was a useful instrument in disseminating information not only from the member countries but also from other countries which have relevant developed technologies. Most of the materials for the newsletter were submitted by the NIs and included updates of national activities and developments in agricultural machinery design and development, manufacture and promotion among farmers. It also included summary information about agricultural mechanization and machinery gathered from other sources. Thus the newsletter, like a journal, is a useful reference for institutions in developing countries. Issues may be accessed in the libraries of the different NIs of the member countries and of ESCAP, FAO, UNIDO, IRRI and AIT.

The newsletter also chronicled events such as the TAC and GB meetings and provided highlights of the meetings and the summaries of decisions made to supplement the reports arising from the events. Through supplementary issues, the RNAM Newsletter also provided highlights of Agrimach ’89, Agrimach ’91 and Agrimach ’93, which were agricultural machinery exhibitions and symposia organized by RNAM.

The newsletter was a hard copy of information highlighting various regional, national and sub-network activities. It kept the staff of the NIs and the institutions and organizations of the NNs as well as the national government economic planners and the ministries of agriculture informed of the progress, achievements and benefits derived from participating in RNAM.

Thus, it created awareness among decision makers concerning mechanization in agricultural development. The heightened awareness was instrumental in providing support to the NIs particularly in activities concerning the NFMCs as strategies for agricultural mechanization were deemed crucial for agricultural development.

The RNAM Newsletter also provided highlights of activities and lessons learned from regional workshops, training courses, study tours and personal exchanges of engineers and technical persons involved in such activities.

The NIs made arrangements with radio and TV networks to disseminate information about agricultural machinery to rural areas through videos and interviews with experts and successful farmers. The NI in Thailand was particularly active in this activity, which probably contributed to the wide distribution of agricultural machinery developed at the NI in collaboration with local manufacturers.

RNAM provided catalytic assistance to the NIs to upgrade their capacities in the popularization of agricultural machinery and mechanization among farmers and decision makers. Based on FAO's experience in audio-visual training methods, the NIs received slide projection and audio taping sets to make slide film strips as well as video cameras with recorders. However, as emphasized by FAO, training would be needed in production of effective slide sets or film strips especially for illiterate audiences (Fraser, 1985).

In hindsight, the critical issue for the success of the network project rests in the support of the top echelon decision makers including the national social and economic development as well as those by the leaderships of the field implementers including the NIs and the institutions and organizations in the NNs. The communication system extends from the policy makers and NIs to as far down as the field implementers, manufacturers and farmers.

According to Starkey (1988) one lesson that should be learned by institutions is for the existing national and international research, development and extension programmes to be open-minded to make their work more farmer-centred and not to ignore the valuable negative lessons in the course of the conduct of such programmes. Starkey cited the example of the wheeled tool-carrier which as of 1988 had been the subject of research, development and promotion efforts and huge sums of money for three decades yet had never been accepted by farmers in spite of it having been hailed as universally "successful", when in fact it should be considered an expensive failure.

Similarly, a review of the machinery research and development outputs over about 15 years of an international research institution pointed out that out of some 102 pieces of promising and successful technologies in as far as functionality and engineering design was concerned, only two were adopted by farmers and custom service providers and made tremendous impact worldwide. The review posed the question of what made the two items "click" with farmers and why the same success story did not happen to the other 100 technologies. These were of different types from the other two adopted ones and in fact, appeared to be more simple in design, relatively more affordable in cost and some manually operated so were appropriate in terms of power source and many other characteristics. They were all in fact deemed favourable to farmers as revealed in brainstorming sessions and numerous consultations.

This failure of adoption by farmers happened in spite of following the suggested methods found in the literature on development and extension principles, including the need for consulting and collaborating with farmers and manufacturers to put the machinery products in the mainstream of commercialization. For example, Jain (1987) elaborated the techniques of marketing agricultural machinery through the dealership system, market research, product development and communication, which included the use of audio-visual media, including demonstration, TV and radio programmes, films and slides.

The rule of thumb is that some ten years gestation period must elapse before new technologies are adopted. This is assuming that due diligence and sustained efforts in applying the techniques of agricultural extension like demonstrating with the assistance of champions or early adopters are made to promote the technology during that period. The farmers' to-see-is-to-believe attitude and risk aversion because of limited resources may explain the rejection at the start. Premature withdrawal from the promotion field will result in wasted earlier efforts. Farmers have known about tractors and threshers for a long time and they readily adopt improved versions of them subject to their affordability either through direct ownership or through custom hire services.

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Mechanization for Rural Development: *A review of patterns and progress from around the world*

Farm mechanization is a crucial input for agricultural production. Without farm power and the appropriate complementary tools, implements and machines, farmers would struggle to emerge from subsistence production. With demands being exerted on the planet's natural capital by ever intensifying population pressure, the need for sustainable mechanization becomes increasingly urgent.

This book gives a wide-ranging perspective on the present state of mechanization in the developing world and, as such, constitutes a solid platform on which to build strategies for a sustainable future. Farm mechanization forms an integral plank in the implementation of sustainable crop production intensification methodologies and sustainable intensification necessarily means that the protection of natural resources and the production of ecosystem services go hand-in-hand with intensified production practices. This requires specific mechanization measures to allow crops to be established with minimum soil disturbance, to allow the soil to be protected under organic cover for as long as possible, and to establish crop rotations and associations to feed the soil and to exploit crop nutrients from various soil horizons.

The book is the starting point to help the reader understand the complexities and requirements of the task ahead.

ISBN 978-92-5-107605-7 ISSN 1020-4555

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I3259E/1/04.13