AGRICULTURAL
AND FOOD
ENGINEERING
TECHNICAL REPORT

5

ISSN 1814-1137

# Addressing the challenges facing agricultural mechanization input supply and farm product processing

Proceedings of an FAO Workshop held at the CIGR World Congress on Agricultural Engineering
Bonn, Germany, 5–6 September 2006

AGRICULTURAL
AND FOOD
ENGINEERING
TECHNICAL REPORT

5

# Addressing the challenges facing agricultural mechanization input supply and farm product processing

Proceedings of an FAO Workshop held at the CIGR World Congress on Agricultural Engineering
Bonn, Germany, 5–6 September 2006

Edited by
**Brian G Sims**
FAO Consultant

and

**Josef Kienzle, Roberto Cuevas, Gavin Wall**
FAO Agricultural and Food Engineering Technologies Service

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2007

The Agricultural and Food Engineering Technical Reports bring to a broad audience the results of studies and field experience related to agricultural and food engineering within agrifood systems. The reports help us take stock of what we know and clearly identify what we do not know; and in so doing they provide information to both the public and private sectors. The Agricultural and Food Engineering Technical Reports serve to direct further work within agrifood systems.

ISBN 978-92-5-105784-1

# Contents

**Preface** vii

**Acknowledgements** viii

**List of acronyms** ix

**1. The Agro-industries Programme of FAO** 1

What is the programme about? 1

Why is the programme needed? 1

The initiative for the Workshop 2

**2. Challenges for agricultural mechanization in sub-Saharan Africa** 5

**The challenges of mechanizing agriculture in sub-Saharan Africa** 5

*Richard M. Shetto*

Abstract 5

Introduction 6

Mechanization in sub-Saharan Africa 7

Challenges of mechanizing agriculture 9

Towards increased mechanization in SSA 11

The Tanzania Agricultural Mechanization Strategy 13

References 14

**Development strategies for the agricultural machinery industrial sector in Africa** 15

*Chakib Jenane, Matthieu Tockert and Susanne Linghor*

Abstract 15

Introduction 15

Objectives of the study 15

Methodology adopted 16

Results and discussion 16

Conclusion 18

**Linking global markets** 18

*Velu Karuppiah and Herbert Coenen*

Abstract 18

Introduction 18

Indian economy 19

Indian agricultural equipment sector 20

Conclusions 22

**Optimizing land and water use – the role of equipment and input supply** 23

*Brian Sims, Josef Kienzle and Theodor Friedrich*

Abstract 23

Introduction 23

Sustainable land management and rural development 24

Conservation agriculture as a development concept 24

FAO initiatives for strategies that support optimized land and water use with appropriate roles for the private sector and government 24
Conclusions and future action 26
References 26

**Challenges faced by an agricultural machinery manufacturer in new markets like Africa** **27**
*Adel Lünz*
Abstract 27
Introduction 27
Factors affecting the sales of agricultural machinery in Africa 28
Conclusion 29

**3. Using technology to add value and increase quality** **31**

**Innovation, competitiveness and value addition in Mexico's agrifood industry** **31**
*Inocencio Higuera-Ciapara,*
Abstract 31
Introduction 31
The National Innovation System in Mexico 32
Innovation and competitiveness in the agribusiness sector in Mexico 33
Strategic areas of the agribusiness industry supported by the National Innovation System 34
Conclusions 36
References 36

**Local design capacity building applied to small-scale food-processing equipment: a strategic way for adding value for producers** **37**
*François Giroux and Claude Marouzé*
Abstract 37
Introduction: requirements for small-scale food-processing equipment 37
Responding to the demand for well-adapted equipment 37
Main pillars of local design and manufacture of small-scale food-processing equipment 39
Conclusion 40
References 40

**A competency-based qualification programme in automation technology and process control applied to agro-industries in developing countries** **41**
*Chakib Jenane, Theodor Niehaus and Matthieu Tockert*
Abstract 41
Introduction 41
Objective 43
Methodology – industrial survey 43
Findings of the industrial survey 44
Demand-driven solution – competency-based training programme 45
Basic technology needs 45
Partly automated systems 46
Totally automated systems 46
Conclusion 47
References 47

**Product development systems for agrifood innovation in developing and transition countries** 47

*Ray Winger*

Abstract 47
Introduction 47
Product and process development 48
Product development in the food industry 49
Important factors in the product development process 49
Economic impact of food product innovation 50
Conclusions 52
References 53

**Study of resource recycling based sustainable agricultural development in Thailand: Thai–Japanese joint venture agribusiness** 54

*Kasinee Muenthaisong and Takashi Toyoda*

Abstract 54
Introduction 54
Objectives of study 54
Methodology 54
Results and discussion 55
Conclusion 57
References 58

**Poverty reduction and food production in developing nations: a case study of Nigeria** 58

*Ademola Isaac Olorunfemi and Michael Olubusayo Ashaolu*

Abstract 58
Introduction 58
Major challenges 59
Strategies and policy thrust 61
Way forward 62
Conclusion 62
References 63

**4. Key issues, lessons, and outlook** 65

A new paradigm and a persistent problem 65

The challenges of agricultural mechanization in sub-Saharan Africa 65
Policy environment 65
Machinery manufacturing sector 66
Farmer demand for equipment 67
Import of agricultural machinery 67
Farmer adoption and adaptation 67
Environmental protection 68
Gender issues 68

Using technology to add value and increase quality 68
Policy environment and the role of the public sector 68
Technology for value adding requires multidisciplinary actions 69
Participatory technology development 69
Environmental protection 69

The outlook 70
Ensuring an enabling policy environment 70
Coordinating strategic interventions 70
Multidisciplinary actions for technology adoption 70

Advocating agro-industrial development 71
Environmental management is good business 71

# List of figures

2.1 Comparison of area cultivated by different power sources in sub-Saharan Africa, Latin America and Asia 7
2.2 Increases in tractor numbers in SSA and Asia, 1961–2000 8
2.3 Escalating prices of tractors in Tanzania, 1984–2006 10
2.4 Decline in importation of tractors in Tanzania 11
2.5 Age of working tractors in Tanzania 12
2.6 Design-to-cost approach 20
2.7 Total relevant tractor market, and < 60-hp segment (pie chart) 20
2.8 India: tractor population 21
2.9 Farm structure and power deployed in India, and a comparison of tractor-use densities in India, Europe and North America 22
2.10 Farmer field schools 25
2.11 Sales figures for CLAAS products in West and Central Africa 27
3.1 Traditional organization of design 38
3.2 Organization of CESAM method 39
3.3 Some problems and targets of the agro-industrial industries of developing countries 42
3.4 General qualification modules in agro-industries 43
3.5 Technology level and need according to surveyed sectors 44
3.6 Training needs in basic technology 45
3.7 Training structure for partly automated systems 46
3.8 Training structure for fully automated systems 46
3.9 Schematic of the overall product development process 48
3.10 Market equilibrium and price (P) determination of asparagus production (Q) 57
3.11 Cassava-chip processing flow chart 63
3.12 Cassava-flour production flow chart 63

# List of plates


2.1 Common tractor applications for construction 22

2.2, 2.3 Input supply of equipment for new technology, such as CA in SSA, requires the active involvement of risk-averse, local manufacturers. Jab planters (Plate 1) are relatively straightforward, but animal-drawn planters require a higher level of technology 25

3.1, 3.2 Plates 3.1 and 3.2 show greenhouse horticultural production in Sinaloa, Mexico. Pest and disease control are major technological problems. The North America market is readily accessible if grading and packaging are well managed 35


# List of tables


2.1 Levels of mechanization in SSA 7

2.2 Country clusters grouped according to market, income and population criteria 17

2.3 Uniparts Group profile 19

2.4 India: GDP growth rates and forecast 19

3.1 Potential of sectors to stimulate final demand and economic growth in Greece, 1980 52

3.2 Freight-on-board value of New Zealand food exports 52

3.3 Marginal physical products, marginal value products, and marginal factor costs for six asparagus production inputs 56

3.4 Yields, prices, production costs, returns and profitability of asparagus production in 2003 56

3.5 Poverty trends and projections in Nigeria 59

3.6 Human poverty indicators for Nigeria and developing countries from other regions 59

3.7 Sources of power for land preparation 61

3.8 Engine power available for agriculture in different countries and continents 61

# Preface

In October 2004, the President of the International Commission of Agricultural Engineering (CIGR)[1], Prof. Dr.-Ing Axel Munack, and the President of the Max-Eyth Association for Agricultural Engineering within the Association of German Engineers (VDI-MEG), Dr. Ludger Frerichs, invited FAO to consider becoming a co-organizer, together with CIGR, the European Society of Agricultural Engineers (EurAgEng) and VDI-MEG, of the World Congress on "Agricultural Engineering for a Better World" which was scheduled to be held in September 2006 in Bonn, Germany. The Director of the Agricultural Support Systems (AGS) Division of FAO, Dr Geoffrey C. Mrema, readily agreed to this request. The AGS Division (which in January 2007 became the Rural Infrastructure and Agro-industries Division) was then reviewing its mandate and activities in area of agricultural engineering and agro-industries development especially with regard to their impact on food security.

FAO is a global knowledge broker for the agri-food industry, including for technologies for production and processing. With the review of the mandate of the AGS Division emphasis changed from tackling problems directly related to production aspects to increased focus on strengthening input supply systems and value chain development. Improvements in these areas have the potential to facilitate market access for producers and enhance the potential to sustain and improve livelihoods and well being at what ever scale and in whatever region of the world.

FAO agreed to prepare and conduct two Workshops within the CIGR World Congress. The first one was on the subject of 'Challenges for Agricultural Mechanization in sub-Saharan Africa' while the second workshop focused on 'Using Technology to Add Value and Increase Quality'. It was concluded that it was timely for these themes to be presented in preparation for the challenges of the 21st century and to address questions such as: 'what should be the contribution of Agricultural Engineers and Technologists in FAO: first to the global knowledge system and secondly to tackling problems such as food security, environmental sustainability, agri-business and rural industries development.

The process of preparation for these workshops at the CIGR World Congress was in many respects a self reflection exercise for FAO. The results of the CIGR meeting do, to some extent, reflect the new philosophy and approach of the Rural Infrastructure and Agro-industries programme of FAO whose highlights are provided in Chapter 1 of this document. The contribution of the authors, as well as the conclusions and way forward outlined in Chapter 4, encourage the readers and also decision makers to consider the important role of engineering technologies in development and indeed for a better world as proposed by the theme of the Congress.

[1] Commission Internationale de Génie Rurale

# Acknowledgements

The editors are pleased to acknowledge the contributions of the persons who made this Workshop possible. The idea was conceived by Geoffrey C. Mrema, FAO, and Professor Axel Munack, the then President of the International Commission for Agricultural Engineering. The support of the Organizing Committee for the CIGR World Congress in arranging the venue and in organizing the travel and accommodation is gratefully acknowledged.

The Workshop was only possible because of the willingness of the speakers to prepare and present papers – we are indebted to them for their hard work. The role of the Workshop participants in the discussion sessions was also pivotal in distilling the issues that will help focus further work in many parts of the world.

We also wish to make special mention of the behind-the-scenes assistance of Ann Drummond (FAO) for handling all of the communication during the lead-up to the Workshop, and to thank Larissa D'Aquilio (FAO) for helping with the publication process and the desktop publishing, and Julian Plummer (FAO Consultant) for the English editing.

# List of acronyms

| | |
|---|---|
| AGS | Rural Infrastructure and Agro-industries Division |
| AGST | Agricultural and Food Engineering Technologies Service |
| AC | Average cost |
| AEI | Agricultural equipment institute |
| AMIS | Agro-related metalworking industrial system |
| ASC | Average social cost |
| ASDS | Agricultural Sector Development Strategy (the United Republic of Tanzania) |
| ATC | Average total cost |
| AU | African Union |
| CA | Conservation agriculture |
| CBT | Competency-based training |
| CESAM | Conception d'Equipements dans les pays du Sud pour l'Agriculture et l'agroalimentaire, Méthode |
| CIGR | International Commission of Agricultural Engineering |
| DAP | Draught animal power |
| DC | Developing country |
| DW | Durbin–Watson statistic |
| EU | European Union |
| FDI | Foreign direct investment |
| FY | Financial year |
| GDP | Gross domestic product |
| HACCP | Hazard analysis critical control point |
| ICNP | Innovative completely new product |
| IFAD | International Fund for Agricultural Development |
| LE | Line extension |
| MC | Marginal cost |
| MDG | Millennium Development Goal |
| MEC | Marginal environmental cost |
| MFC | Marginal factor cost |
| MSC | Marginal social cost |
| MVP | Marginal value product |
| NAFTA | North American Free Trade Agreement |
| NCST | National Council for Science and Technology (Mexico) |
| NEEDS | National Economic Empowerment Development Strategy (Nigeria) |
| NEPAD | New Economic Partnership for Africa's Development |
| NGO | Non-governmental organization |
| NIS | National Innovation System (Mexico) |
| NPD | New product development |
| NSGRP | National Strategy for Growth and Reduction of Poverty (the United Republic of Tanzania) |
| ODA | Official development aid |
| PA | Production automation |
| PAXIS | Pilot Action of Excellence on Innovation Start-ups (European Union) |
| PC | Process control |
| PD | Product development |
| PLC | Programmable logic controller |

| | |
|---|---|
| PNC | Products new to the company |
| PTO | Power take-off |
| R&D | Research and development |
| SADC | Southern African Development Community |
| SKU | Stock-keeping unit |
| SLM | Sustainable land management |
| SME | Small and medium-sized enterprise |
| SNI | National System of Scientists and Technologists (Mexico) |
| SSA | Sub-Saharan Africa |
| TAMS | Tanzania Agricultural Mechanization Strategy |
| TEC | Total environmental cost |
| UNDP | United Nations Development Programme |
| UNIDO | United Nations Industrial Development Organization |
| USP | Unique selling point |
| VAP | Value added product |

Chapter 1
# The Agro-industries Programme of FAO

## WHAT IS THE PROGRAMME ABOUT?

Until 2005, the Agro-industries Programme of FAO had dealt *inter alia* with subjects such as the development, efficient utilization and management of food and agricultural process engineering technologies. The programme underwent a strategic readjustment towards the end of 2005. As a result of considering past work and anticipated future needs related to agribusiness, agricultural engineering, mechanization, post-harvest handling, agroprocessing, value-adding technologies, bioenergy, marketing, and rural finance, a need to re-orient work became obvious. Greater emphasis is now placed on the development and expansion of competitive enterprises that add value to the outputs of farmers. Emphasis is also being given to the efficient operation of industries that manufacture and deliver inputs to agriculture, most notably machinery and equipment.

The programme works through the following major themes:

- policy and institutional support for agribusiness development, supply chain management and commercial farming;
- policy and institutional support for fostering mechanization and agro-industry innovation;
- policies and strategies for dynamic, client-oriented marketing and financial systems;
- strengthening global and regional knowledge networking and partnerships;
- creating enabling environments for agribusiness and agro-industry development;
- capacity building for small-scale and medium-scale agro-enterprises, business linkages and value chains;
- ensuring product quality and safety in agro-industries.

## WHY IS THE PROGRAMME NEEDED?

The key to poverty reduction is accelerated economic growth and employment generation. The establishment of viable agroprocessing enterprises in rural areas is crucial to creating employment and income opportunities and, thereby, enhancing the demand for farm produce. In rural areas, economic growth will, in most instances, be led by the growth of commercial agrifood systems that are run efficiently and are responsive to evolving market demands. The efficiency of post-harvest handling, processing and marketing operations is a major determinant of the prices paid by urban and rural poor, and it is an important factor in ensuring household food security. Improvements in the performance of the agroprocessing and distribution sectors also contribute to the safety and quality of food for all households. Agro-enterprise development has the potential to provide employment for the rural poor in off-farm activities, such as the handling, packaging, processing, transporting and marketing of food and agricultural produce. Similarly, input suppliers as well as manufacturers of agricultural machinery and equipment have a critical role to play in ensuring that the farm sector has access to inputs (equipment and materials) at competitive prices.

Globalization and market liberalization create opportunities for countries to trade agricultural and food products. However, they also produce challenges and carry risks. In order for agro-industries to be competitive, the enterprises need to:

- understand consumer needs and wants;
- employ skills and technologies to gain efficiencies;
- deliver quality goods in the quantities and timing schedules required;
- forge reliable and mutually supportive relationships up and down the supply chain.

The problem of poverty reduction is further complicated by the diversity of resources and capacities that farmers have. It is extremely difficult, if not impossible, for some small-scale farmers with very limited resources and severe constraints to labour productivity to increase production to the extent that they have a surplus to their household needs that represents a commercially attractive volume for many value chains. It is these farmers who often lack access to any form of mechanization for crop establishment, weed control, irrigation, post-harvest handling or processing.

In some cases, even commercial farmers cannot make the transition to mechanized farming and to the production of goods to meet the expectations of more sophisticated national and international markets. It is clear that some form of kick-start is required to help the farming sector in many low-income countries to contribute to broader economic development.

## THE INITIATIVE FOR THE WORKSHOP

The International Commission for Agricultural Engineering (CIGR) adopted the theme "Agricultural Engineering for a Better World" for their World Congress 2006. FAO and the CIGR share a joint interest in disseminating and sharing knowledge. Therefore, it was determined that an FAO-organized workshop would be appropriate and timely as part of the CIGR World Congress. FAO chose to focus the Workshop on the challenges of creating sustainable and viable machinery supply chains for enhancing mechanization, and of using technology to add value to, and increase the quality of, agricultural products. These two themes captured the critical need to add value so that farmer incomes can grow and jobs can be created. It is widely recognized that small-scale and poor farmers need to mechanize in order to increase production. Our analysis has shown that the key impediments to their doing so are the lack of efficient machinery supply chains and the lack of farm profit to afford to mechanize and/or create a demand for mechanization inputs. Tractors and equipment of all sizes and degrees of sophistication are available in the world market. The challenge is to grow farmer income and create the private-sector supply chains to supply the equipment to farmers at an affordable price.

Innovation through the creation, diffusion and use of knowledge has been acknowledged as a key driver of economic growth. Adding value to the crops and other outputs produced by farmers is an efficient way to climb the competitiveness ladder. FAO believes that technical development and innovation strategies that have led to value-added products (VAPs) and better returns to farmers and processors merit further debate. Evolving market expectations to achieve higher quality and better prices, and the increased vertical integration of food chains are challenging all sectors of agriculture. Experiences and technologies to help meet this ongoing challenge are issues of concern. At production level, innovations are similarly important and possible. Examples are direct-seeding technologies and no-tillage mechanization that require less energy and labour. They also result in reduced costs and lower environmental impacts compared with conventional production systems.

The themes of the Workshop were seen to be consistent with current development paradigms that emphasize that poverty reduction occurs through:

- lowering food costs, reducing food supply uncertainties, and enhancing access to high-quality and safe foods for improving the diets of the rural and urban poor;
- providing widespread employment and entrepreneurial opportunities in both rural and urban areas, thereby increasing and diversifying household incomes;
- creating opportunities for farmers to integrate into local, national and international markets in order to achieve higher financial returns.

The themes also recognize the importance of the customers and their expectations, and that the aggregate representation of these expectations is a market (village, national or global). Whether the customer is a farmer in need of a tractor (the input supply chain) or a buyer of a food product in a nearby town, the supplier that wishes to sell must meet that customer's expectations. Of equal importance is that the themes also capture the need for continuous innovation in order to maintain competitiveness.

Although there is consensus on the need to develop farm input supply chains and value chains for farm produce, it is far less clear what policies and strategic initiatives are needed in order to kick-start and sustain change in low-income countries.

The Workshop was intended as an opportunity to bring together experiences from several countries and to benefit from the presence of agricultural engineers and other engineering professionals from around the world to discuss the two themes. It was anticipated that the papers and discussion would identify issues that might guide the future work of FAO and key partners, and help FAO and Member Countries to think differently about the issues.

The Workshop was organized as two thematic sessions. The first was oriented to agricultural input supply chains with an emphasis on farm machinery and equipment supply. The second focused on adding value to agricultural products. The papers presented in these two sessions appear in Chapters 2 and 3, respectively. Chapter 4 analyses the key issues emerging from the experiences presented and summarizes the lessons learned. It then gives some concluding remarks and indicates possible ways forward.

# Chapter 2
# Challenges for agricultural mechanization in sub-Saharan Africa

The first session of the Workshop looked at the challenges that are still making appropriate farm mechanization difficult in many African countries. The session comprised the following five presentations:

- Lead paper: The challenges of mechanizing agriculture in sub-Saharan Africa.
- Development strategies for the agricultural machinery sector industrial sector in Africa.
- Linking global markets.
- Optimizing land and water use – the role of equipment and input supply.
- Challenges faced by an agricultural machinery manufacturer in new markets like Africa.

## THE CHALLENGES OF MECHANIZING AGRICULTURE IN SUB-SAHARAN AFRICA

*Richard M. Shetto, Assistant Director, Mechanization Section, Ministry of Agriculture, Food Security and Cooperatives, Dar es Salaam, the United Republic of Tanzania*

### Abstract

The economies of most sub-Saharan Africa (SSA) countries are strongly dominated by the agriculture sector, which contributes between 15 and 60 percent of their gross domestic product (GDP) and provides employment for more than two-thirds of the population. However, agriculture in these countries is still dominated by the smallholder and subsistence sector, which is characterized by low capital, limited technical know-how, limited infrastructure and support services, leading to low crop production. In overall terms, humans are the principal source of power, cultivating about 65 percent of the total area under crops, with draught animals cultivating 25 percent and tractors only 10 percent. The number of tractors in SSA countries has increased slowly compared with Asia. In 1961, SSA had 172 000 tractors while Asia had 120 000 tractors. In 2000, it was estimated that the number of tractors had increased to 6 000 000 in Asia but to only 221 000 units in SSA.

After gaining independence, many governments promoted the use of tractors in an effort to increase both food and cash crop production. Government-run tractor hire services were introduced, and soft loans and subsidies were provided to farmers to enable them to purchase tractors. This was not very successful because of poor management and supervision, weak infrastructure and the general poor performance of the economy. Most governments abandoned the approach in the late 1980s following economic structural adjustment programmes.

The outlook for mechanization in most SSA countries is now depressing, and for the past three decades its development has stalled, and actually in some, it has retrogressed. Tractor sales have declined, and in many countries more than 40 percent of the tractors currently working in the field are more than 15 years old as the importation of new tractors has not kept pace. A recent survey of 40 districts in Tanzania showed that only about 15 percent of the tractors are 10 years old or less, meaning that about 85 percent of the tractors in these districts are working beyond their economic life. The major factors that have slowed the development of mechanization in SSA countries include:

- the low purchasing power of most small-scale farmers;
- low producer prices;
- high cost of agricultural machinery;
- lack of agricultural credit;
- lack of well-trained operators and mechanics for agricultural machinery;
- lack of suitable machinery packages for the main agricultural operations;
- importation of tools and machinery of poor quality;
- generally poor technical know-how.

Therefore, a new outlook needs to be taken on mechanization in SSA countries in a move towards enabling these countries to meet their obligations in increasing agricultural production and productivity. Consideration should be given to the constraints on the smallholder sector as it dominates agriculture

in the region. Advantage should be taken of the numerous government policies and strategies that are supportive to agriculture and mechanization. Commercialization of agriculture should be a key element in the development process in SSA countries. Particular attention should also be given to promoting medium-scale and large-scale farmers, given the low profitability of many smallholdings and the high level of investment that would be required for their development. These farmers may play a vital role in the provision of mechanization services to smallholder farmers, who may also be engaged in contract farming, thus increasing the demand for mechanization and making the technology more sustainable.

The enabling environment, described as a development requirement in many policy statements, should be translated into actions to support the private sector in order to allow it to grow and operate effectively so that it can deliver the desired goods. Some areas that should be looked at include: tax reviews on agricultural machinery and spare parts; training and human resource development; and research and development (R&D). To kick-start the process, stop-gap measures, such as the provision of targeted soft loans, may be considered, as they have been instrumental in the uptake of some new technologies in various countries. This brings about the need for putting in place a strategy for a set of concrete actions that would ensure that adequate mechanization inputs in agricultural production are available and are optimally utilized so as to contribute to the development of agriculture in SSA countries and, hence, poverty reduction.

In 2005, the Ministry of Agriculture Food Security and Cooperatives in Tanzania embarked on the formulation of a mechanization strategy, with FAO providing technical and financial support. The process involved wide consultation with various stakeholders through workshops and field surveys. The Tanzania Agricultural Mechanization Strategy (TAMS) is a framework for guiding the development process of the mechanization subsector in contributing to the national development aspirations of poverty reduction and economic growth spelled out in the Agricultural Sector Development Strategy (ASDS) and other national policies and strategies that are encapsulated in the National Strategy for Growth and Reduction of Poverty – NSGRP (2005). It spells out the means of enhancing the contribution of agricultural mechanization towards realization of the national goal.

The strategy identifies eight strategic action areas under which a set of activities that need to be implemented have been developed. These are:

- improving access and availability of mechanization inputs;
- commercialization of agriculture through mechanized farming;
- promoting agriprocessing and rural-based agri-industries;
- improving livelihoods and land management through conservation agriculture;
- improving farmers' access to technologies and services;
- improving financing of agricultural mechanization;
- improving policy, legal and regulatory environment for agricultural mechanization;
- cross-cutting and cross-sectoral issues.

The effort to improve mechanization will be associated with better land management to avoid some negative effects in land degradation, such as soil erosion and compaction. Farming practices such as conservation agriculture will be promoted as they improve the productivity of the soil leading to increased crop yields and environmental conservation. They save farm power and labour requirements owing to the elimination of ploughing and reduction in weeding efforts, so guaranteeing more sustainable crop production.

## Introduction

Agriculture dominates most economies in sub-Saharan Africa (SSA), contributing 30–50 percent of the gross domestic product (GDP) and foreign-exchange earnings. The sector is also the largest source of employment, and the livelihoods of more than two-thirds of the population depend on farming. Therefore, a strong and growing agriculture sector is essential for economic development both in its own right and to stimulate and support the growth of associated industries (FAO, 2005).

In the last two decades, most SSA countries have witnessed fundamental restructuring of their economies, going through a dynamic transformation from centralized to market-oriented economies. Markets, exchange rates and interest rates have been liberalized. Trade restrictions have been removed. State monopolies in the export and import trade have been dismantled. Many state-owned industries have been privatized. Government services have been decentralized and downsized. Private-sector investment has been encouraged.

These policy and economic reforms resulted in many economies growing at annual rates of about 3 percent or more in the 1990s. However, in many countries, this growth has not been matched by rises in per-capita income. Poverty is still widespread and more than two-thirds of the population of SSA countries survive on less than US$1/day.

Agriculture in these countries is still dominated by the smallholder and subsistence sector, which is characterized by low capital, limited technical know-how, and limited infrastructure and support services. The major factors contributing to low yields have been identified as including: low adoption of improved crop production techniques (including mechanization); low and unstable commodity prices; highly variable rainfall; and low level of utilization of available land. Increased food production is also partly constrained by the unreliable supplies of key inputs, such as improved seed, fertilizer, chemicals, agricultural tools and machinery, and the poor technological knowledge of the majority of farmers.

In many farming systems, the hand-hoe is the dominant tool used in cultivation. The low field capacity of hand tools sets obvious limitations on the area of crops that can be grown using family labour. On average, many households only manage 0.2–2.0 ha in a cropping season. This results in low crop production, leading to household food insecurity and low incomes in the rural communities, thereby perpetuating rural poverty.

## Mechanization in sub-Saharan Africa

### *Status of mechanization*

In SSA, in overall terms, humans are the principal source of power, cultivating about 65 percent of the total area under cultivation, with draught animals cultivating 25 percent and tractors 10 percent only. In comparison, in Asia, 30 percent of the land is cultivated by hand, 30 percent by draught animals and 40 percent by tractors. In the Near East and in North Africa, only 20 percent of the land is prepared by hand, another 20 percent by draught animals, while tractors are a significant source of farm power cultivating 60 percent of the total area cultivated (Figure 2.1). The use of tractors is also well established in Latin America and the Caribbean, where they cultivate 50 percent of the total area cultivated, with draught animals cultivating 25 percent and manual power the remaining 25 percent (Clarke and Bishop, 2005).

FIGURE 2.1
**Comparison of area cultivated by different power sources in sub-Saharan Africa, Latin America and Asia**

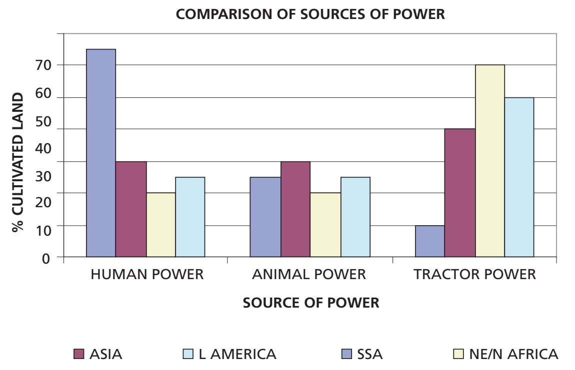



TABLE 2.1
**Levels of mechanization in SSA**

| SSA region | % Land cultivated by: | | |
|---|---|---|---|
| | Hand | Draught animals | Tractor |
| Central | 85 | 11 | 4 |
| Western | 70 | 22 | 8 |
| Eastern | 50 | 32 | 17 |
| Southern | 54 | 21 | 25 |

Source: FAO, 2001.

Within the SSA region, there are some marked differences in the levels of mechanization, with manual power being dominant in the central region, draught animals being used to a greater extent in western and eastern Africa, while in southern Africa there is an increasing use of tractors (Table 2.1).

The use of tractors as a source of power is extremely limited in SSA and is concentrated in a few countries. In 2000, it was estimated that the number of tractors used in agricultural production in SSA was 221 000 units, compared with 6 000 000 in Asia, 1.8 million units in Latin America and the Caribbean and 1.7 million units in North Africa and the Near East. The Southern Africa region (covering Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe) had 110 000 units (about 50 percent of the total number of tractors for SSA). The remaining SSA countries had 107 500 tractors, with about 72 percent (77 400) of them in only six countries – Nigeria having 28 percent of tractors in use, followed by Kenya (11 percent), Angola (10 percent), Tanzania (7 percent), Zambia (6 percent) and Uganda (5 percent).

The use of draught animals in SSA countries is limited too. It is estimated that there are 16 million draught oxen (FAO, 2006) and 2–3 million donkeys and horses used for agricultural purposes in Africa, as compared with more than 80 million oxen in China and 53 million oxen in India (Winrock, 1992; Starkey, 1988). These draught animals (mostly oxen) are concentrated mainly in rainfed areas in the cotton-based farming systems in the northern parts of West Africa, throughout the maize mixed systems of Eastern Africa, and the highland mixed systems of Ethiopia (FAO, 2001). About 77 percent of these draught animals are found in five countries, with Ethiopia having 53 percent, and Zimbabwe, Kenya, Tanzania and Uganda each having 6 percent.

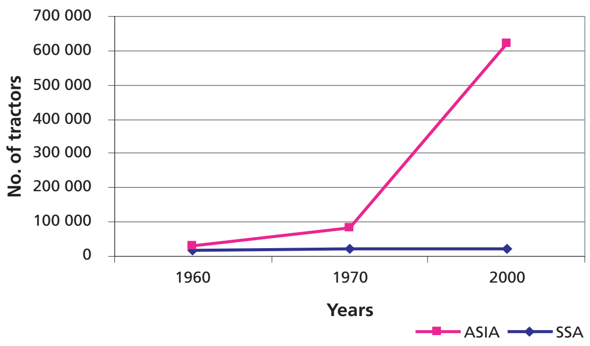
### *Development of mechanization*

The use of draught animals dates back to 2000 BC in Ethiopia. In South Africa, it started in the fifteenth century, while in most parts in SSA it started at the beginning of the twentieth century. In areas where animal traction was introduced, it was mainly associated with European settlers, missionaries and different colonial administrations, which promoted the technology in an attempt to expand cash crop production to serve the industrialized world. Animal traction is one of the major sources of power in smallholder agriculture in the region, contributing up to 40 percent of the total power use in some countries, e.g. Botswana (Panin, Mrema and Mahabile, 1992).

Tractors were introduced from the 1940s onwards, in the periods leading to independence and immediately thereafter. They were first used in commercial, white settlers' farms, but they spread quickly through tractor hire schemes for small farmers, initially promoted by aid agencies, donor countries and tractor manufacturers before the drive was taken up by governments. Policies favouring tractorization were initiated. This led to the establishment of large tractorization schemes in developing countries in the 1960s.

However, the number of tractors in SSA countries has increased slowly compared with Asia and Latin America. The number of tractors in use in SSA in 1961 was greater, at 172 000 units, than in Asia (120 000) and North Africa (126 000). In ten years, that is by 1970, the number of tractors in Asia had increased fivefold to 600 000, and to 6 million units by 2000. In the same

FIGURE 2.2
**Increases in tractor numbers in SSA and Asia, 1961–2000**




period, in SSA countries, the number of tractors increased slowly, peaking at only 275 000 in 1990 and declining to 221 000 units in 2000 (Figure 2.2). The increase in tractors in Asia demonstrates the impact of the green revolution, which fuelled an increase in the demand for farm power.

### *Past efforts and strategies to promote mechanization*

Most African countries have attempted to mechanize agriculture through the use of draught animals and tractors, and many governments have introduced different programmes to promote their use. In earlier days (before independence), the increase in the use of draught animals and tractors was mainly in response to market forces following the increased demand for food and raw materials to meet the requirements of the industrialized world. Draught animals and tractors were introduced to meet the increased power demand needed in expanding the area under cultivation to increase crop production.

After gaining independence, the agricultural mechanization policy in most SSA countries encouraged large-scale, mechanically powered technology. Many governments promoted the use of tractors in an effort to increase both food and cash crop production in a drive to be self-sufficient in food, produce raw materials for local industries, and increase foreign currency reserves. Government-run tractor hire services were introduced, and commercial banks provided soft loans at low interest rates to farmers, cooperatives or farmers groups to purchase tractors. In some cases, subsidies on tractor purchases were also provided. Through these interventions, the number of tractors increased substantially in the region. For example, the number of tractors in Tanzania increased from 9 000 in 1975 to 18 533 in 1985 (Shetto, 2005).

The large introduction of tractors through government hire schemes or cooperatives was not very successful. The poor performance of tractor hire services was attributed to the poor performance of the economy, weak infrastructure and poor management. Under the government tractor hire schemes, the area cultivated per machine was small, fixed costs were high, and the service was usually subsidized. The situation was often compounded by a lack of basic infrastructure to support mechanized technologies. This resulted in poor maintenance, expensive repairs and difficulties in obtaining spares parts.

The disappointing experience with tractorization motivated many African countries to redirect their agricultural policies to draught animal power (DAP). From the 1980s through to the 1990s, government-operated hire schemes in many SSA countries were closed, and support for private sector purchases and hire services was gradually stopped. Governments started to encourage DAP as a more sustainable and affordable option to tractor power for smallholder farmers.

Several development programmes in animal traction were implemented. Financial and technical assistance was provided for research, training, extension, the development of equipment, and the supply of agricultural inputs. DAP training centres were started and extensive demonstrations on animal traction technologies were carried out. Local manufacturing of implements in many countries (e.g. Senegal, Mali, Zambia, Kenya, Uganda and Tanzania) started, and credit systems were set up to enable farmers to purchase implements and other agricultural inputs.

These interventions resulted in increased use of draught animals in the region, and the introduction of large numbers of implements to meet the demand. For example, towards the end of the 1980s, Senegal had some 200 000 horses and 140 000 oxen in use as draught animals, and implements increased from fewer than 10 000 to more than 100 000 carts, 300 000 seeders and 350 000 light toolbars. In Mali, the interventions increased the area under cotton production from 40 000 ha in 1968 to 140 000 ha in 1986, and the average yield increased from 200 kg/ha to 1 200 kg/ha. Farms that adopted animal traction increased to 80 percent, nearing saturation (Wanders, 1992).

However, in the 1980s, the use of DAP in SSA started to decline. This was mainly associated with: (i) the persistent drought that had hit several SSA countries for a number of years, destroying the livestock population; and (ii) cattle diseases, particularly East Coast Fever, which decimated the livestock population. Cattle thefts and rustling were widespread, denying farmers the source of power.

## Challenges of mechanizing agriculture

### *Need for mechanization*

As agriculture is the largest sector in the economy, and bearing in mind that over 70 percent of the population in SSA countries lives and ekes out a living in the rural areas, then its performance has a significant effect on output and the corresponding income and poverty levels of the majority. The improvement of the sector is then paramount in poverty reduction as actions that increase agricultural production will ensure availability and access to food and improve farm incomes and, hence, reduce poverty.

However, over many decades, the performance of agriculture in these countries has not been impressive, being constrained by several factors, among them low utilization levels of mechanization inputs, which considerably limits the area cultivated – hence leading to low crop production. The shortage of farm power has been identified as one of the limiting factors to increased crop production in several countries (FAO, 2001).

Recently, the Southern African Development Community (SADC), meeting in Dar es Salaam in May 2004, recognized that the lack of power was a major constraint to agricultural development in the region and called for urgent efforts to change the situation (SADC, 2004). The SADC emphasized that overdependence on the hand-hoe, the lack of labour at critical times, and the lack of power generally were high among the factors contributing to food insecurity in the region. The meeting resolved to support tillage services through promotion of DAP, small tillage equipment and affordable mechanization as priority areas that will need primary focus in the next two years.

Mechanization generally enhances human capacity, leading to intensification and increased productivity as a result of timely planting, weed control, harvesting, post-harvest handling, and accessibility to markets. It also reduces drudgery, making agriculture a more attractive enterprise.

Timely farm operations are becoming crucial in view of the rainy season becoming shorter in many parts of SSA. This puts much pressure on farmers to accomplish their field operations in the shortest possible time in order to capture the short growing period.

Mechanization is also becoming increasingly important in addressing the shortage of farm power in the rural areas as a result of the declining agricultural labour force, caused by rural–urban migration, increase in non-farm employment opportunities, and the HIV/AIDS and malaria pandemics.

Given the generally abundant land resource in SSA, efforts to increase agricultural production and productivity should include both technologies in order to expand the utilized land area and intensification of the existing cultivated area. This may be achieved through increased mechanization and adoption of other improved technologies, such as improved seed, use of fertilizers, agroprocessing, and accessibility to markets.

***Main constraints in agricultural mechanization***

The development of mechanization in SSA countries has stagnated in the last two decades, being constrained by several factors, including those detailed below.

*Low purchasing power of most small-scale farmers*

A low level of crop production leads to low incomes, which considerably limit the purchasing power of the majority of smallholder farmers, making investment in agricultural machinery and implements difficult.

*Low producer prices*

Farmgate prices offered to farmers, especially at harvest time, are generally low. This further reduces farm incomes, thus limiting investment capabilities. Mwinjilo (1991) observed that the use of draught animals substantially increases the financial burden on farmers, particularly during the early days of adoption. In Malawi, between 1978 and 1982, the overall aggregate price increase in the DAP package and inputs used far exceeded crop price increases, leading to a reduction in gross margins. This made further investment in animal traction unattractive.

*High cost of agricultural machinery*

The price of agricultural machinery has risen sharply in the last 20 years, making it unaffordable for the majority of farmers. Massive devaluation of local currencies and high inflation rates in most SSA countries have sharply increased the prices of agricultural machinery. For example, in Tanzania, in 1984 the price of a 70-hp tractor with a plough, harrow and trailer was TSh460 000. The price rose to TSh5 000 000 in 1990, TSh13 000 000 in 1995, and now stands at more than TSh35 000 000 (Figure 2.3). On the other hand, the price of many crops has not changed much over the years and, in many cases, the prices have declined in real terms. In 1985, a kilogram of maize sold at TSh5.41, which was equivalent to US$0.318, and now (2006) it sells at TSh120.00 (US$0.113). While in 1985 farmers could purchase a 70-hp tractor with implements by selling 870 bags (of 100 kg) of maize, now they have to part with 3 000 bags to acquire the same tractor and implements. In Nigeria, in the same period, there has been a twentyfold increase in the cost of tractors and a tenfold increase in the cost of implements.

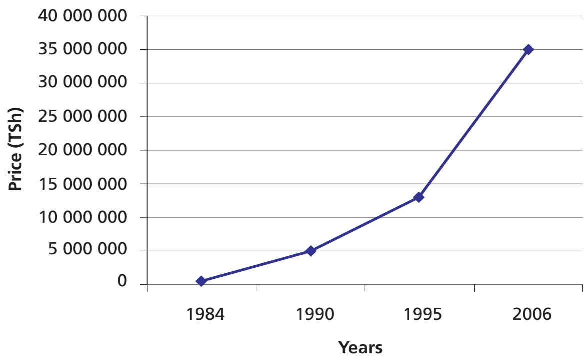
*Lack of agricultural credit*

Many commercial banks in SSA are reluctant to finance agriculture as they claim that the risks involved are too high, especially in smallholder farming. Where such credits are available, stringent conditions have been tied to the loans, making borrowing difficult for farmers as the majority lack the required securities as collateral for the loans.

*Lack of well-trained operators and mechanics for agricultural machinery*

Many of the operators and mechanics who handle agricultural machinery are not well trained,

FIGURE 2.3
**Escalating prices of tractors in Tanzania, 1984–2006**



despite the fact that they handle expensive machines. In most cases, this leads to poor quality of work and expensive breakdowns of machinery, leading to costly repairs and reduced economic lifespan of the machinery.

*Lack of suitable machinery packages for main agricultural operations*
The most mechanized operation is tillage, and transportation to a limited extent. Other operations like planting, weeding and harvesting are rarely mechanized in smallholder farming. This limits the advantages of mechanization as the subsequent secondary operations are done manually using the hand-hoe, which delays the completion of these operations, leading to decreased crop yields.

*Importation of tools, equipment and machinery of poor quality*
Some of the imported equipment is of low quality, resulting in poor performance. There is little control on the quality of imported equipment, sometimes leading to importation of substandard tools, implements or machinery at the expense of the end user.

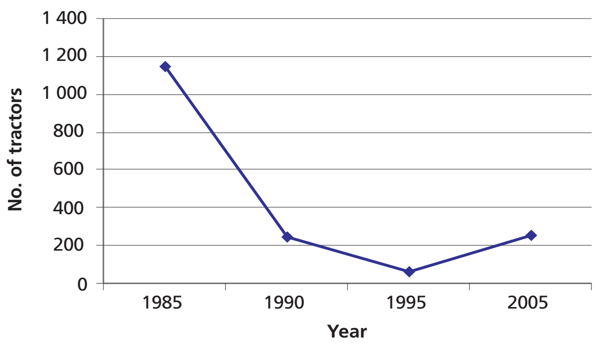
*Generally poor technical know-how*
Inadequate skills and technical know-how on the part of machinery owners lead to high operational costs, making investment in mechanization expensive and less attractive. Many tractor owners do not have agribusiness knowledge and lack business acumen.

On the other hand, service providers, comprising manufacturers, importers, dealers and after-sales services (which include supply of spare parts and provision of repair and maintenance services) are faced with the following constraints:

- inadequate business knowledge and poor technical knowledge in relation to agricultural machinery;
- inadequate capital owing to lack of trade financing;
- low volume of business, resulting in poor cash flow owing to the seasonality of demand of agricultural machinery and implements;
- poor working tools, equipment and underutilized capacity.

Other institutional support services (e.g. research, training and extension) are also weak. They are constrained by: inadequate financing; limited laboratory and testing equipment; lack of transport; and limited human capacity skills. Weak linkages in the research and development (R&D) system between technology development agencies, manufacturers, distributors and farmers exacerbate the situation, leading to poor commercialization of developed technologies.

FIGURE 2.4
**Decline in importation of tractors in Tanzania**




## Towards increased mechanization in SSA

In the last three decades, mechanization in most SSA countries has been taken off the development agenda of international organizations and donor agencies because of its poor performance in the 1970s and 1980s. The outlook for mechanization in these countries is now depressing and its development has stalled. Indeed, in some countries, if anything, it has retrogressed. Mechanization now has a low profile in national agricultural development. The earlier progress that had been made in mechanization in many areas has been lost. Tractor hire services have declined, local manufacturing of implements has ceased as factories have closed down and, in some areas where animal traction had established a foothold, farmers have shifted back to hand-hoeing.

The shortage of farm power in agricultural production is becoming more acute, and many farmers are finding it increasingly difficult to purchase tractors or draught animals. Tractor sales in many countries have declined and more farmers are now shifting towards purchasing second-hand tractors, many of which are more than 10–15 years old. For example, in Tanzania, tractor imports dropped drastically from 1 143 tractors in 1985 to 274 in 2002 (Figure 2.4). In some countries, more than 40 percent of tractors currently working in the field are more than 15 years old as the importation of new tractors has not kept pace.

A recent survey of 40 districts in Tanzania showed that only about 15 percent of the tractors are 10 years old or less. This means that about 85 percent of the tractors in these districts are working beyond their economic life (Figure 2.5). Under these circumstances, the reliability of such tractors is low as they are faced with frequent breakdowns owing to old age, resulting in high down time and worsening the power situation in rural areas. It was observed that only about 5 percent of the tractors are five years old or less, highlighting the increasing difficulty in purchasing new tractors that a lack of capital causes to farmers.

Generally, it was observed that the majority of farmers depend on cash financing to purchase agricultural machinery. Of the sampled farmers, only 3 percent had received loans. The source of funds for the purchase of machinery came mainly from the sale of agricultural produce (69 percent), own savings (19 percent) and from relatives (6 percent). As the prices of crops are low and the productivity is low too, it makes it extremely difficult for farmers to afford to purchase tractors.

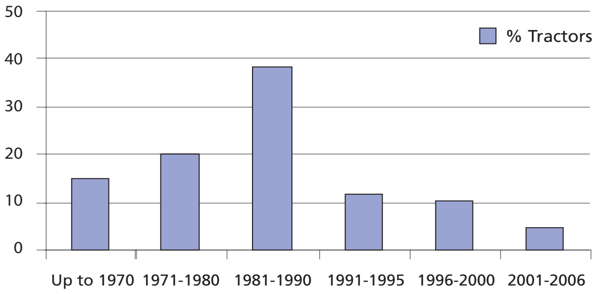
With the declining labour force (because of migration of the youth from rural to urban areas and the effects of the HIV/AIDS pandemic), the farm power situation is made worse, compounding the problem of rural households meeting the farm power requirements, especially during peak labour periods such as land preparation and weeding (FAO, 2005).

Therefore, a new look needs to be taken at mechanization in SSA countries in a move towards enabling them to meet their obligations in increasing agricultural production and productivity. Consideration should be made of the constraints surrounding the smallholder sector as it dominates agriculture in the region.

It is an established fact that the performance of many mechanization programmes has not been satisfactory, but there are also some pockets of successful stories from which some good lessons may be learned. These include the expansion of animal traction in Senegal and Mali, the introduction of single-axle tractors in Mbarali District in Tanzania, and the introduction of 150 tractors in Morogoro Region in Tanzania, to mention but a few. Let us build on these cases to give mechanization its due attention.

Commercialization of agriculture or cash cropping in smallholder farming, as was the case with the introduction of DAP in Senegal and Mali and other countries in West Africa, sustained the technology. Integrated rural development programmes operating in these regions played an essential catalytic and supportive role through marketing and pricing guarantees, infrastructural support and services (including training, extension and the supply of essential production inputs), and a regular supply of implements (including after sales services).

FIGURE 2.5
**Age of working tractors in Tanzania**




Therefore, commercialization of agriculture should be a key element in the development process in SSA countries. The adoption of higher levels of mechanization increases the cost of production in hand-hoe systems. Economic benefits in mechanization are usually obtained when associated with corresponding increases in use of other inputs, such as improved seed, fertilizer, pesticides and water availability. These result in increased production, hence, allowing extra investments to be made in machinery and making mechanization sustainable.

Considering the low profitability of many smallholdings and the level of investment required, particular attention should also be paid to promoting medium-scale and large-scale farmers. These farmers may play a vital role in the development of mechanization through the provision of mechanization services to smallholder farmers. In India and Pakistan, medium-scale farmers hire out their tractors for about 700 tractor hours per year to smallholders, thus playing an important role in creating an effective demand for mechanical technologies. Moreover, medium-scale and large-scale farmers have the capacity to organize more sustainable production systems such as contract farming for smallholders, which will increase the demand for mechanization services, thus making the technology more sustainable.

Draught animal power, tractor power and human power should be seen as complementary power sources for agricultural production, not as mutually exclusive ones. The optimal mix will depend on the requirements of each individual farming operation, and it will change according to the viability of alternative power sources. The relationships between farmers, manufacturers and commercial organizations should be allowed to develop symbiotically without undue interference.

It is proposed that a detailed assessment should be made of each country's capabilities and potentials for agricultural mechanization. Priority should be given to areas where the production potential is high, access to markets is favourable, and the provision of private-sector services from urban centres is feasible. An analysis of the participation of the private sector should be done, and modalities of implementation worked out, based on the current liberalization process and economic transformations that the country is undergoing. Short-term and long-term plans should be drawn up indicating specific responsibilities for both the public and private sectors. The enabling environment mentioned in many policy statements should be translated into actions to support the private sector to allow it to grow and operate effectively in order to enable it to deliver the desired goods.

This brings about the need for putting in place a strategy for a set of concrete actions that can ensure that adequate mechanization inputs in agricultural production are available and are optimally utilized so as to contribute to the development of agriculture in SSA countries and, hence, poverty reduction. It has become clear that the private sector in these countries is still weak and is yet to take up the challenge of meeting the mechanization demands and, hence, there is a need for a kick-start to initiate the process.

## The Tanzania Agricultural Mechanization Strategy

In 2005, the Ministry of Agriculture Food Security and Cooperatives embarked on the formulation of a mechanization strategy, with FAO providing technical and financial support. The process involved wide consultation with various stakeholders through workshops and field surveys in an effort to come up with concrete issues and constraints facing mechanization in the country. Those contacted included: smallholder farmers; large-scale and medium-scale farmers; processors; inputs stockists; traders; marketing agents; transporters; private-sector machinery and equipment supply chain stakeholders (including manufacturers, importers, distributors, wholesalers and retailers); non-governmental organizations (NGOs); government ministries; research and training institutes; extension services; and financial institutions.

The Tanzania Agricultural Mechanization Strategy (TAMS) is a framework for guiding the development process of the mechanization subsector in contributing to national development aspirations of poverty reduction and economic growth as spelled out in the Agricultural Sector Development Strategy (ASDS) and other national policies and strategies, which are encapsulated in the 2005 National Strategy for Growth and Reduction of Poverty (NSGRP). The NSGRP spells out the means of enhancing the contribution of agricultural mechanization towards realization of the national goal.

### *Main features of the TAMS*

The strategy is presented in eight strategic action areas under which a set of activities that need to be implemented have been developed. The strategic action areas attempt to address some of the constraints raised in the ASDS, which aims at achieving a sustained agricultural growth rate of 5 percent/year, primarily through a transformation from subsistence to commercial agriculture. The transformation is to be private-sector-led through an improved enabling environment for enhancing the productivity and profitability of agriculture.

The following eight key strategic action areas have been identified:

- improving access and availability of mechanization inputs;
- commercialization of agriculture through mechanized farming;
- promoting agriprocessing and rural based agri-industries;
- improving livelihoods and land management through conservation agriculture;
- improving farmers' access to technologies and services;
- improving financing of agricultural mechanization;
- improving the policy, legal and regulatory environment for agricultural mechanization;
- cross-cutting and cross-sectoral issues.

Analysis of the participation of the private sector and the modalities of implementation was based on the current market liberalization process and economic transformations. Short-term and long-term plans have been drawn up indicating responsibilities for both the public and private sectors. The use of "technology-incubator" arrangements and cluster systems in support of local manufacture in promoting mechanization technologies have been proposed, as have the provision of soft loans and smart targeted subsidies for machinery acquisition by farmers. Capacity building at all levels on technological innovations, service provision, entrepreneurship and marketing have also been proposed.

The effort to improve mechanization will be associated with better land management in order to avoid some negative effects in land degradation, such as soil erosion and compaction. Farming practices such as conservation agriculture will be promoted as they improve the productivity of the soil, leading to increased crop yields and environmental conservation. They save farm power and labour requirements owing to the elimination of ploughing and reduction of weeding efforts, guaranteeing more sustainable crop production.

Conservation agriculture involves some land management practices that allow for the restoration of soil nutrients, increased infiltration of rainwater and surface water, enhanced retention of soil moisture, the regeneration and maintenance of a good surface vegetative cover and rooting depth. It includes:

- direct sowing/no tillage;
- reduced/minimum tillage;
- retention of crop residues;
- maintenance of complete soil cover, consisting of cover crops or crop residues;
- crop rotations judiciously selected to enhance the crop environment and to avoid buildup of pests and diseases.

It should also be noted that mechanization is not an end in itself, it is just one of the inputs along with several others that, when implemented concurrently, will go a long way to contributing to revamping the agriculture sector. Thus, greater emphasis is a lso needed in improved institutional functioning and service delivery, infrastructure development and greater commercialization among smallholders.

## References

**Clarke, L. & Bishop, C.** 2005. Farm power – present and future availability in developing countries. Paper 2. *Proc. Workshop on Agricultural Mechanization Strategy Formulation*, Sokoine University of Agriculture, Morogoro, Tanzania, July 2005. United Republic of Tanzania, Agricultural Machinery and Structures Section, Irrigation and Technical Services Department, Ministry of Agriculture and Food Security.

**FAO.** 2001. *Farm power and agri-business services support project*, by G. Hendriksen. Final Report (Phase I) MTF/URT/001/MSC. Rome.

**FAO.** 2005. *Contribution of farm power to smallholder livelihoods in sub-Saharan Africa*, by C. Bishop-Sambrook. Agricultural and Food Engineering Technical Report No. 2. Rome. 87 pp.

**FAO.** 2006. *Farm power and mechanization for small farms in sub-Saharan Africa*, by B.G. Sims & J. Kienzle. Agriculture and Food Engineering Technical Report No. 3. Rome. pp. 20–21.

**Mwinjilo, M. L.** 1991. The role of animal draught in smallholder farming systems in Malawi. *In* C.R. Nampoya, ed. *Animal traction and agricultural mechanization research in SADC countries*. Proceedings of workshop held in August 1987, Maputo, Mozambique.

**Panin, A., Mrema, M. & Mahabile, M.** 1992. Government financial assistance programmes to improve the profitability of animal traction in Botswana. *In* P. Starkey, E. Mwenya & J. Stares, eds. *Proceedings of the first Workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA)*, 18–23 January 1992, Lusaka.

**Shetto, R.M.** 2005. Status of agricultural mechanization in Tanzania. *Proc. Workshop on Agricultural Mechanization Strategy Formulation*, Institute of Continuing Education (ICE), Sokoine University of Agriculture (SUA), 6–8 July 2005.

**Southern African Development Community (SADC).** 2004. *Enhancing agriculture and food security for poverty reduction in the SADC Region. Conference Declaration*. Extra-Ordinary Summit on Agriculture and Food Security, Dar es Salaam, Tanzania, May 2004.

**Starkey, P.** 1988. *Animal traction directory: Africa*. Vieweg for German Appropriate Technology Exchange. Eschborn, Germany, GTZ.

**Wanders, A.A.** 1992. Supply and distribution of implements for animal traction: an overview with regional specific scenarios. *In* P. Starkey, E. Mwenya & J. Stares, eds. *Proceedings of the first Workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA)*, 18–23 January 1992, Lusaka.

**Winrock.** 1992. *Assessment of animal agriculture in sub-Saharan Africa*. Little Rock, USA, Winrock International.

## DEVELOPMENT STRATEGIES FOR THE AGRICULTURAL MACHINERY INDUSTRIAL SECTOR IN AFRICA

*Chakib Jenane and Matthieu Tockert, UNIDO, Vienna, Austria*
*Susanne Linghor, School of Oriental and African Studies, University of London, the United Kingdom*

### Abstract
Statistical typology techniques were used for analysing the current situation and the development needs of the agro-related metalworking industrial system (AMIS) in Africa. The analysis also served for formulating the required strategies for the future expansion of the AMIS. Some 48 variables categorized in 6 components were used in the statistical analysis. These were selected according to their relevance to the AMIS – resources, demand, industrial environment, inputs, capacity and gender issues. This resulted in ten groups whose relative strengths and weaknesses were examined in order to identify pointers to strategies for developing the AMIS. The strategies were formulated in a way that would exploit the strengths (opportunities) in order to alleviate the constraints (weaknesses) and, thus, facilitate the formulation of integrated development programmes in this sector.

Industrial development potential is discussed in terms of two major factors: (i) the real demand for farm tools, equipment and machines; and (ii) the existence or otherwise of an industrial environment conducive to the development of metalworking industries for their manufacture. It is suggested that in the presence of these factors, projects providing industrial inputs and production facilities can be justified. In the absence of either demand or an appropriate industrial development environment, there can be little justification for projects aimed at manufacturing on other than an artisanal scale. It is also suggested that, while development of the AMIS in most countries will depend on encouragement of free enterprise in the private sector, the primary need is for information about markets and technology, the development and communication of which is still a public-sector function that needs to be focused through appropriate institutions in each country.

### Introduction
Development studies for Africa have proliferated over the past two decades, but achievement on the ground has been limited and much remains to be done to accelerate the pace of economic and social progress. Agriculture remains the sector responsible for a major proportion of economic activity and the source of formal or informal employment in most African countries – 33 percent of gross domestic product (GDP) and 65 percent of the workforce. Moreover, the agriculture sector in these countries is still at, or below, subsistence levels that marginalize human and social progress. In contrast with other developing regions where agricultural and, particularly, food production have kept pace with population growth, Africa has, on the whole, experienced declining per-capita agricultural production and, in many cases, has suffered reduced self-sufficiency in major food commodities. Nutritional standards are falling, and food now represents on average about 20 percent of total import bills. Therefore, agricultural development is a high priority with many governments. For this development to be achieved, there must be some matching degree of industrial progress.

The low agricultural productivity of many African nations stems partly from a lack of incentives and price support mechanisms to sustain agricultural production in the predominantly small-farm sector. Controlled prices for farm produce, as well as an emphasis on industrial crops, have acted as a disincentive to food production. Another constraint, possibly of greater importance, has been the inadequate attention paid to adapting and extending proven technologies to suit the needs of the African farmer. Furthermore, the symbiosis between the agriculture and industrial sectors, which stimulated the early industrialization of developed economies, has been slow to evolve. Urban wealth has been diverted to importation of food instead of being invested in local food production. Thus, industrialization in support of agriculture has been slow, hesitant and disappointing in terms of income and employment generation.

### Objectives of the study
The objectives of the present study are basically to identify and analyse patterns of development in the agro-related metalworking industrial system (AMIS) in Africa. Taking into consideration the weaknesses and strengths of this subsector and the recent socio-economic trends in Africa, development strategies are formulated with the

aim of contributing to fostering the growth of the AMIS and the productivity of the agriculture sector. A subsidiary objective is to provide a framework for the allocation of priorities for technical assistance and investment support for the AMIS in Africa. Thus, the allocation of planning resources can be made more efficient, allowing adequate attention to be devoted to small countries as well as to large ones.

### Methodology adopted

The systems approach to industrial sector programming was developed at the United Nations Industrial Development Organization (UNIDO) in response to the widely perceived need for increased impact of technical assistance projects on the industrial development of developing countries. Within this approach, technical assistance actions responding to constraints affecting the different components of a system are identified and programmed. The individual project approach is replaced by the programme approach.

The system approach can be applied to the analysis of the AMIS at two different levels. When applied to a large number of countries, it leads to a country-based typology of the system under analysis; it also identifies the main characteristics of patterns of development prevailing in a given sample of countries, and groups countries according to those patterns. At the individual country level, the systems approach leads to a country's integrated development programme for the AMIS under study. An integrated development programme comprises a package of technical assistance and investment projects and policy advice. The programme should gradually eliminate constraints found in the system that at the time of the analysis were found to be delaying investments and growth.

The steps used for the typology study of the AMIS in the present study are as follows:

- Identify and select the components of the AMIS to be analysed, including forward and backward linkages whose interdependent relationships make the system operational in each country under study.
- Select variables and indicators to characterize each component of the system and linkages between them.
- Select dominant variables and indicators by using economic and technical criteria and results obtained from multiple correlation analysis performed on the regional sample.
- Run cluster analysis with dominant variables and indicators and countries fully covered by them. Clustering analysis is run for the whole system. Groups of countries with similar readings in the variables and indicators that characterize components of the AMIS will thus be determined. Two clustering methods were used: average linkage; and Ward's Minimum Variance Cluster Analysis. Both methods had been used in previous typology work. The results produced by Ward's method were found to be more consistent and were used throughout the study.
- For each cluster, identify and describe the pattern of AMIS development to define patterns and stages of development of AMIS in the different country groups.
- Use the results of clustering, correlation analysis and empirical research to identify the strengths and weaknesses of each group in order to establish development strategies that exploit the strengths and address the weaknesses of the AMIS for each group of countries.

Forty-eight variables were selected in different groups relating to:

- the input situation and productive capacity of the AMIS in each country;
- the local industrial environment;
- the demand for agricultural tools and equipment arising from the agricultural industry system found in each country;
- the resources available to the system in which the AMIS operates;
- the productive capacity of the AMIS;
- gender issues.

### Results and discussion

The clustering process described above resulted in the identification of ten groups of countries (Table 2.2), each of which should respond to a set of strategies aimed at developing the AMIS. Some strategies might be common to several or all groups. Others will be more group-specific but, even so, may apply to more than one group. Once development strategies have been formulated, programmes and projects can be devised to achieve the strategic objectives laid down.

The analysis of recent development trends in Africa shows that opportunities exist in many countries for artisanal or industrial manufacture of farm tools, equipment and machines of

TABLE 2.2
**Country clusters grouped according to market, income and population criteria**

| **Group 1: industrialized, high income, large existing markets** | | | **Group 6: densely populated, low income, latent markets** | | |
|---|---|---|---|---|---|
| Algeria | Morocco | Zimbabwe | | | |
| Egypt | South Africa | Tunisia | Congo DR | Malawi | Tanzania |
| Libya | | | | | |
| **Group 2: high income, small markets** | | | **Group 7: large markets, good potential** | | |
| Botswana | Namibia | Gabon | Ethiopia | Ghana | Nigeria |
| Mauritius | Swaziland | | | | |
| **Group 3: low investment importers, potential markets** | | | **Group 8: semi-industrialized; good markets** | | |
| Angola | Eritrea | Sudan | | | |
| Burkina Faso | Lesotho | Togo | Kenya | Senegal | Zambia |
| Chad | Mauritania | | | | |
| Uganda | Niger | | | | |
| **Group 4: moderate income, self-sufficient in simple products** | | | **Group 9: small, low-income agricultural economies** | | |
| Benin | Côte d'Ivoire | | Burundi | Rwanda | Somalia |
| Cameroon | Mali | | Central African R. | Sierra Leone | Liberia |
| **Group 5: moderate income, densely populated** | | | **Group 10: small populations, small markets** | | |
| Congo Republic | Madagascar | | Cape Verde | Gambia | Sao Tome and Principe |
| Guinea | Mozambique | | Comoros | Guinea Bissau | |
| | | | Djibouti | Equatorial Guinea | Seychelles |

varying degrees of complexity, depending on the level of industrial development reached. In fact, population growth and urbanization have created an urgent need for crop production equipment – stimulate rural employment and reduce rural–urban migration. HIV/AIDS robs farming households of adult muscle power and has implications for the accelerated turnover of skilled staff, not only in labouring grades but also in management. The transition of many countries to more liberal and, in some cases, more democratic forms of government (with concomitant positive effects on free enterprise) should provide support for more sustainable industrial development. Climate patterns and arid conditions stimulate research and development of suitable equipment. Finally, modern industrially-produced equipment is, in most cases, now too expensive and overspecified for the levels of complexity and investment needed in many African countries.

Considering these trends, a number of 11 common strategies can be applied to all the countries under study:

- In each country, a suitable institution should be identified to take on the responsibility for development of the AMIS.
- This institution, possibly an agricultural equipment institute (AEI), should coordinate closely with agricultural research and extension organizations to ensure that the national production programme for AMIS products is aligned with both traditional and newly developing needs for tools and equipment.
- The strategy for the AMIS should, therefore, be to work closely with the food processing industry to develop and market whatever equipment is needed to support the diversification of crop use that might enhance income generation among farming communities and expand opportunities for industrial development.
- Further foster the development of the artisan producers of AMIS products and promote their transition from artisan to SME.
- Evaluate industrial production plans on the basis of real, researched demand to integrate production within an existing metal-manufacturing sector and to exploit potential for diversification in the interests of rational production economics.
- The strategy for distribution and service support should be to evaluate existing arrangements and to assist where necessary to induce improvement.
- In terms of communication strategies, AMIS enterprises should acquire the means to gain access to worldwide sources of information. That is, they should equip themselves with computer systems and accounts with Internet service providers. It is suggested that an African AMIS Intranet be created.
- The AEI should assess the infrastructure in which the AMIS operates in order to identify constraints, which might be addressed within the AMIS itself.
- The strategy suggested for policy issues

is to identify them, to document them in such a way that their constraining influence is clearly understood, and to approach relevant government agencies in such a way that sufficient support is obtained for the necessary changes.
- Each country should assess the potential role of whatever regional bodies exist in its region and to explore with each such body the ways in which it might influence industrial development in the national AMIS.
- A common strategy for addressing gender issues in relation to equipment needs is to examine the role of women in agricultural and agro-industrial operations in order to research the market for equipment specifically suited to women's uses and to plan production of such equipment.

### Conclusion

There are arguments for and against agricultural mechanization in terms of rural employment, social and cultural factors, and implied dependence on imported resources (e.g. fuel and repair parts) needed to support the increased use of machines. However, the fact remains that few operations can be carried out entirely by hand. Tools of some sort are always needed. In addition, under the tropical conditions encountered over much of the African continent, human muscle power employed in manual farm work cannot produce much more food than the amount that is needed to sustain its own energy output. Thus, under low-technology, largely manual farming systems, agricultural output remains at a subsistence level and cannot provide the surpluses needed to feed non-farming sectors of the population. Thus, agricultural development is closely linked to the availability of adequate equipment. The provision of such equipment, even at the simplest level, is a commercial and industrial operation. A demand and supply situation exists – a market for tools that opens up opportunities for local manufacture on a scale appropriate to the size of the market.

As the cornerstone of most developing economies in Africa, agriculture needs to be lifted onto a new stage of economic and technical development in the interests of better nutrition and health, poverty reduction and income creation. To assist this process, there is a need for provision of better tools and equipment from an industrial subsector that, in turn, can be developed in its own right as an engine of economic growth and job creation.

## LINKING GLOBAL MARKETS

*Velu Karuppiah, Sales and Marketing Manager, Uniparts India Limited, New Delhi, India*
*Herbert Coenen, Chief Executive Officer, Uniparts India Limited, New Delhi, India*

### Abstract

The Uniparts Group (in India and the United States of America) is described. The Indian economy is growing rapidly and is soon expected to achieve a world number three ranking. Selling in the Indian market and factors for success include: value for money; regionally relevant customer benefits; and design for cost reduction. Poor infrastructure is a major limitation. The fluctuating agricultural equipment sector in India is driven by the quality of the monsoon, crop prices and financing possibilities. Growth rates of 8–10 percent are predicted for the next few years. World total annual tractor production exceeds one million units, and India produces 51 percent of the under-60-hp category. The tractor population of India is approximately 2.6 million units. Data are given on tractor distribution and farm size distribution in India, although farm size consolidation is difficult to measure. The market for tractors is expected to grow to some 450 000 units/year, but predictions for the implement market are more difficult to make as both the formal and informal sectors are involved. Guidelines for entering and operating in the Indian market are suggested.

### Introduction

The Indian economy grew by 8.1 percent in financial year (FY) 2005–06, and a growth of 7.6 percent has been forecast for 2006–07 (Asian Development Bank). This indicates the importance of the Indian economy compared with a forecast of approximately 2 percent for the economies of the United States of America, the Eurozone and Japan. The growth is driven by strong performance in industry, the services sector and a rebound of the agriculture sector after weaker performances in previous years (with its trough in 2001, when there was a decline in tractor production from 280 000 units to 167 000 units/year).

We provide a set of information for those who are interested in the Indian economy, with specific emphasis on the agricultural equipment situation.

It is important to know from which position and based on what background the statements are made. Therefore, we have to provide a brief

TABLE 2.3
**Uniparts Group profile**

| | |
|---|---|
| Founded: 1984 | |
| 2 100 employees, o/w 1 850 are employed in India | |
| Manufacturing at 7 locations, o/w 5 are in India: | |
| | 3 locations in Noida (suburb of New Delhi) |
| | 2 locations in Ludhiana |
| | 1 location in Augusta (USA) |
| | 1 location in Eldridge (USA) |
| **Core products:** | |
| | 3-point linkage systems |
| | Machined components for tractor as well as non-tractor applications |
| | Machined components for construction, forestry and mining |
| **Core competency:** | |
| | Forging (in-house) |
| | Conventional & CNC machining for various processes, laser cutting, welding |
| | Surface grinding |
| | Various heat treatment processes |
| | Finish – plating, e-coat, wet & powder paint |
| | Market intelligence |
| | Design and product verification capability |

introduction to Uniparts Group and Uniparts India Ltd., so that everybody can understand the whole context.

Uniparts Group is a wholly Indian private-owned venture, servicing the agricultural market since the beginning of 1984. Until 2000, it was a purely export-oriented company, with an unconsolidated revenue of US$59.33 million in FY 2005/6, of which 16.8 percent was from domestic sales. The main export markets are the United States of America, Europe and Japan. Table 2.3 gives an overview of the company's location, competency and products.

## Indian economy

India's economy now ranks as number ten (World Bank) and is expected to grow and move up to rank third behind the United States of America and China within 12–15 years. If we consider purchasing power parity, it already ranks as number four (World Bank) after the United States of America, China and Japan. Table 2.4 shows the growth in growth domestic product (GDP), and the forecast for the current fiscal year.

The growth is driven by the service sector, which contributes about 53 percent to the GDP, a strong manufacturing base (about 27 percent), and it is backed up by good prospects in the agriculture sector (about 20 percent). Comparing growth rates, especially with China, it has to be considered that foreign direct investments in China are significant higher – approximately 10 times – compared with India. In addition, the stock market in India reflects the growth rates and indicates an improvement in industrial efficiency, while the stock market in China declined significantly between 2001 and 2005 despite superb macroeconomics.

Despite these key indicators, many people underestimate the size and complexity of the Indian market owing to the size of the country and population. India's population has grown from approximately 350 million at independence in 1947 to 1 100 million (World Bank), and has an annual growth rate of 1.5 percent. The total land mass of India is very similar to the land mass of the EU15 states. Fifty-two percent of India's workforce is engaged in the agriculture sector and 70 percent of the population is rural (FAO). This clearly indicates that, for consumer goods, the buying power lies in rural India and is highly sensitive to the performance of the agriculture sector. This is one reason why the quality of the monsoon is still, for very many market segments, an indicator, and is closely monitored. The driver for domestic demand is the young, upcoming generation – the average age is 21 years (Federation of Indian Chambers of Commerce) – and the large segment of middle class in the population, which is estimated according to different sources at approximately 250–300 million people. As already indicated, the Indian market provides huge potential in regard to sourcing as well as selling. It has to be understood that the Indian market, especially in regard to selling, has its own rules. It is an extremely price-sensitive market, and we would like to highlight some success factors for selling in the Indian market:

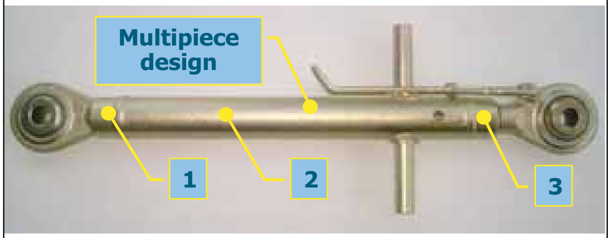
- Value for money – owing to the competitiveness and clear thresholds in terms of affordability by the customer.
- Communication of customer benefits – a strong focus on benefits in an Indian context

TABLE 2.4
**India: GDP growth rates and forecast**

| | 2002/03 | 2003/04 | 2004/05 | 2005/06 | FC 2006/07 |
|---|---|---|---|---|---|
| | | | (%) | | |
| Agriculture | -5.2 | 9.6 | 1.1 | 3.0 | |
| Industry | 6.4 | 6.6 | 7.3 | 8.1 | |
| Service | 7.1 | 9.1 | 8.6 | 8.3 | |
| GDP | 4.0 | 8.5 | 6.9 | 8.1 | 7.6 |

Sources: Asian Development Bank, and Confederation of Indian Industry.

FIGURE 2.6
**Design-to-cost approach**




is vital. A unique selling point (USP) in the United States of America or Europe is not automatically (and in many cases not) a USP in India. For example, in India, Nokia launched a phone with a torch owing to the poor power supply and the power cuts.

- Design to cost – this approach will be reflected in the product design as well in the processing. Owing to the fact that cost drivers are different to other economic zones, the approach can be different.

Figure 2.6 shows an example of a design-to-cost approach where the original top-link design based on a single-piece centre member had been replaced by a multipiece design. This approach allowed the use of a different material grade for the tube (item 2), and the material saving more than compensated for the required welding.

The infrastructure in India must be seen as a major limitation and the challenge for the future. It is a fair assumption that the improvements in infrastructure are not keeping pace with the growth rate of the economy. The problems in infrastructure vary from region to region but, generally speaking, have significant implications owing to power cuts, road transportation, water supply, sewage systems, waste management, etc. Being located in New Delhi, we use Mumbai as a port. The land transit time for containers varies from 7 to 20 days for the 1 500 km from New Delhi to Mumbai.

## Indian agricultural equipment sector

Uniparts India Limited services the global agricultural industry and, within this, predominantly the tractor segment in the domestic markets of Japan, the United States of America, and Europe. The fluctuations in the previous ten years in the tractor market have been pretty significant. The tractor market crashed from a run rate of 280 000 units in FY 1998/99 to fewer than 170 000 units in 2001/02 (Uniparts in-house database). The agricultural equipment sector is driven by a few variables, of which monsoon, crop prices and financing are the most critical factors. In FY 2005/06, the tractor segment saw a growth of 30 percent over the previous year, and approximately 310 000 units were produced, of which 262 000 were sold in India and the balance exported (Uniparts in-house database). The indications of a growth rate of 8–10 percent (Tractor Manufacturers Association) for the next few years are estimated by considering central policy, the low level of buffer stocks for food grain as well as the realistic incentives given to dealers. There are 14 brands produced by 12 tractor manufacturers in India, of which four account for two-thirds of the market.

FIGURE 2.7
**Total relevant tractor market, and < 60-hp segment (pie chart)**

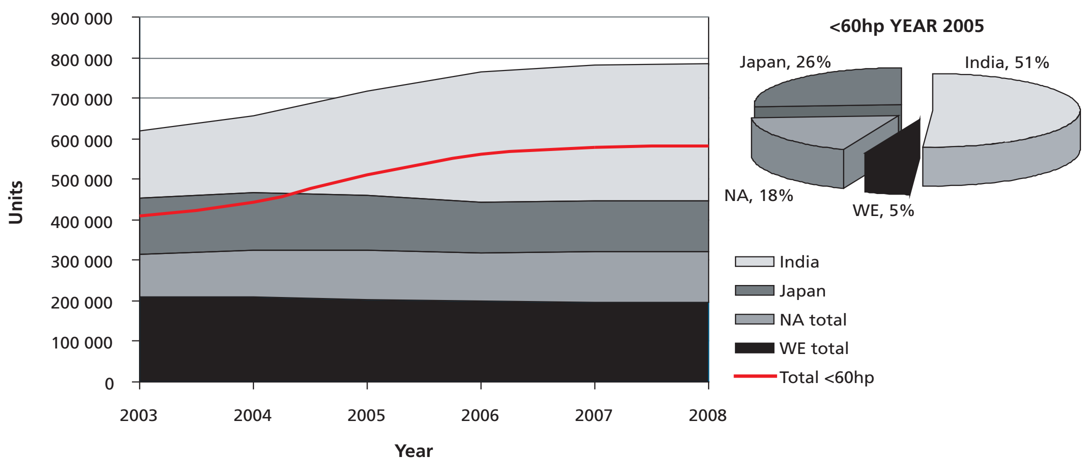
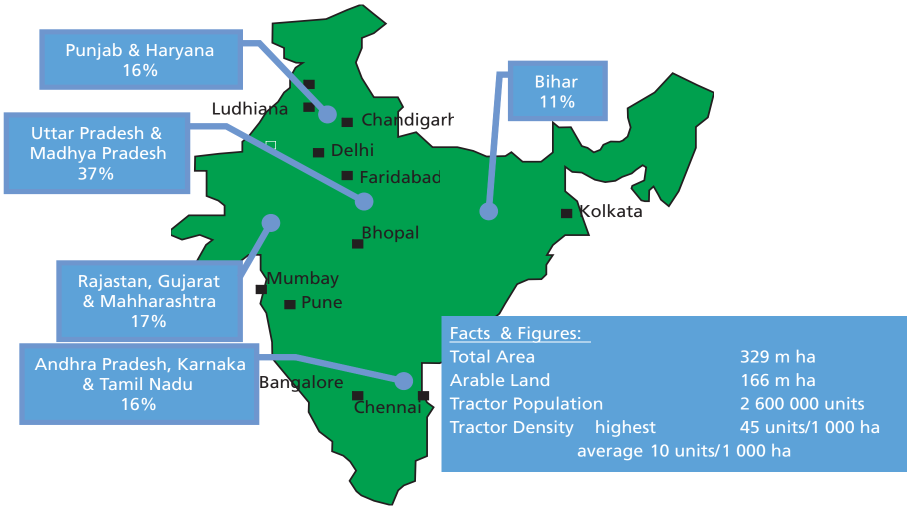


FIGURE 2.8
**India: tractor population**




Source: Uniparts in-house database.

We estimate the worldwide total tractor production to be approximately 1 070 000 units (Uniparts in-house database). Due to our market accessibility, we discount this market to a relevant market for Uniparts India Ltd. of approximately 800 000 units. Figure 2.7 shows the relevant market in all horse power categories, as well as the split for the < 60-hp range. Of the total relevant market, 72 percent is < 60 hp, of which India produces 51 percent (pie chart in Figure 2.7), followed by Japan with 26 percent, North America (NA) with 18 percent and Europe (WE) with 5 percent. To avoid any confusion, the data do not consider power tillers and walk-behind tractors. For India, these have very little relevance, in fact almost none.

The total tractor population in the market is estimated at approximately 2.6 million units (Uniparts in-house database). It also has to be considered that tractors are used extensively for haulage, which is considered to be approximately 60 percent of tractor usage. Figure 2.8 shows the distribution of tractors in the different regions of India.

Considering the tractor market and tractor population, the average power rating is low and does not allow an intensive mechanization and usage of power take-off (PTO) driven implements. Comparisons of tractor distribution in different power categories 1995 (GKN Walterscheid GmbH) versus 2005 (Uniparts in-house database) show that the average power rating of tractors sold has grown by about 10 percent. The increase is taking place at a slower pace than predicted in 1995. This is reflected in tractor sales and the fact that the > 40 hp range is the fastest growing segment.

Having said this, it will lead to a next major area of interest. What will be the medium-term market potential of the Indian tractor market?

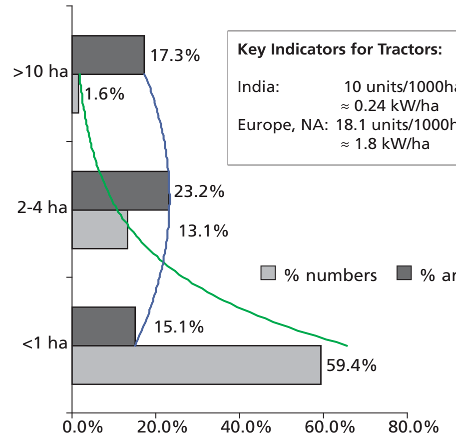
Figure 2.9 shows the structure of landholding in India. It reflects the small-scale farming seen by travellers in India. It does not reflect properly the fact of a virtual land consolidation taking place where land is farmed jointly. Further assessment of this effect and the implications for mechanization is difficult and not possible for us at this time.

Plate 2.1 shows a common non-farming application for tractors, and it provides an appreciation of the difficulty of projecting the market potential for tractors. Despite this difficulty, some assumptions have been made:

- The political climate will remain unchanged in principle.
- The monsoon will behave normally and in accordance with past weather records.
- Average tractor horse power will grow by approximately 35 percent in the medium term.
- The share of tractor usage for haulage and non-farming applications will not change drastically.
- The average age of tractors is to be considered at approximately 15 years.

Based on these assumptions and the fact that

FIGURE 2.9
**Farm structure and power deployed in India, and a comparison of tractor-use densities in India, Europe and North America**




H. COENEN, UNIPARTS INDIA LTD.

**Plate 2.1**
*Common tractor applications for construction.*

a certain share of tractors will be exported, we project that the market will have a potential of 450 000 units/year.

Assessing the market for implements is extremely difficult because there is a formal as well as an informal sector. Tractors and other prime equipment are produced in the formal sector and data can be made available. The bulk of the equipment for tillage, seeding, plantation, etc. is produced in a decentralized manner by local manufacturers in an unorganized fashion.

The total market for combines is approximately 1 800–2 000 units/year (Uniparts in-house database; CLAAS India), of which some 1 000 units are tractor-mounted combines, and the balance are self-propelled machines. The predominant market for combines is Punjab, and 90 percent are sold to contractors (GKN Walterscheid GmbH). Tractor-mounted combines had become popular owing to the availability of higher horse-power tractors and the fact that on some models PTO power is very efficient. Considering the fact that combines are run by professionals following the season and travel long distances, the self-propelled combine will be the technology for the medium-term future. It is expected that the market will double in size within the next 5–6 years.

The market size of power tillers (walk-behind) is estimated to be 16 000 units/year (Media Labs Asi). This market has been flat for the past five years and has not seen any significant growth. Moreover, it has not followed the cycles of the tractor market with its ups and downs.

The market for mowers is estimated at about 1 500 units/year.

As indicated earlier, there are factors (crop prices, monsoon quality, etc.) that can have a significant implication for the development of India's agricultural industry. There is clearly one area of concern, which is the maturity of the market to handle more sophisticated equipment. The degree of mechanization is largely driven by the compliance of the equipment to international standards and certain minimum standards in regard to safety. Being compliant provides the advantage of exchangeability.

## Conclusions

The Indian economy is a robust economy with a substantial growth potential that is driven by the significant domestic demand in various sectors as well as the export market. Having said this, the Indian market has to be seen as an important economy for global players to participate in the agriculture sector. Besides cost, the business ethics, language skills, availability of management skills as well as highly educated workforce and the demographics are soft factors that should not be underestimated in developing a business relationship. We hope that the details provided show that there are companies like Uniparts with a significant market intelligence available, which can be offered to the global market. The domestic as well as the export markets can draw advantages in leveraging these resources. Shown below are the success factors for "Going to India".

- Local content: To tap the Indian potential, a localized solution is mandatory. Obviously, there is a differentiation between a participant in the Indian market (selling in India) and using India as a supply base.
- Patience: India is not a country that is

easy to access, and it has its own market drivers, which are in many cases not easy to understand for foreign companies. A well-defined strategy that addresses the objectives in India, as well as at the home base, is vital. For a successful Indian strategy, India should become an integral part of the overall strategy with well-defined boundaries and an understanding of what India will be able to contribute.
- Local skill set: Build on the local skill set – select partners that provide the skill set or have the ability to develop the skill set of doing business in the export market. In the case of market participants, a local management is mandatory.
- Relationships: Relationships are extremely important. This goes back to the family as a strong institution and where the social community is the insurance to overcoming the day-to-day surprises in a country with a weak infrastructure. Be careful when selecting the partner – equipment is easy to change, people are difficult to change.

The Indian tractor market must be expected to remain at more than 300 000 units/year, with the potential for more than 450 000 units/year. This is driven by fact that, in the medium-term future, a substantial number of tractors will be used in non-agricultural applications (haulage and construction) and supplied into the export market.

Mechanization will proceed and with an increasing need to implement compliance with international standards and especially safety standards. The highly decentralized production of farm equipment, the ignorance of international safety standards by local producers, and the low appreciation of safety hazards by users will be a major challenge for industry and official bodies.

## OPTIMIZING LAND AND WATER USE – THE ROLE OF EQUIPMENT AND INPUT SUPPLY

*Brian Sims, Engineering for Development, Bedford, the United Kingdom*
*Josef Kienzle, FAO, Rome, Italy*
*Theodor Friedrich, FAO, Rome, Italy*

### Abstract

The achieving of the UN Millennium Development Goals, of eradicating extreme poverty and hunger and ensuring environmental sustainability, is increasingly elusive. Plough-based agriculture is a major cause of land degradation throughout the world. More sustainable land management (SLM) practices with less soil disturbance and enhanced agronomy have been developed – conservation agriculture (CA) being a good example. Because of the availability of the technology, FAO has been assisting countries with their CA programmes. Although the projects are promising, there are still constraints to scaling up the technology. CA takes time to become embedded and to start to produce superior yields. The value of mutually supportive farmers' groups is critical. Local machinery manufacturers are important for sustainability.

### Introduction

The increasing world population means that there will be more mouths to feed, and so food production will have to increase. There are other factors at work in the agriculture sectors of many developing regions. In sub-Saharan Africa (SSA), for example, it is estimated that tens of millions of people are infected with HIV, and this will lead to a highly significant mortality rate. The same situation applies to the current malaria pandemic. The number of children, many of them orphans, who will be obliged to do farm work will rise. An additional threat to the agricultural labour force results from the continuing migration from the rural to the urban sector.

The UN Millennium Development Goal (MDG) 1 (the eradication of extreme poverty and hunger) is now wildly off track. The laudable goal of halving the number of people starving by the year 2015 is lamentably modest. Even so, it is unlikely to be met, at least in SSA, until the next century. Inextricably linked to MDG1 is MDG7 with its emphasis on achieving environmental sustainability. Environmental protection and poverty reduction must be achieved together, and sustainable land management (SLM) initiatives are a natural product of developmental efforts to that end. Failure to implement land-use practices that do not embody the SLM philosophy will have the greatest negative impact on the poor who depend on the natural resource base for their livelihoods.

If we add to this already grim picture the impact of world trade liberalization on smallholder livelihoods in developing countries, then we can see that, instead of helping to reduce poverty and increase food production, in many cases the opposite effect is being achieved (Hertel *et al*., 2003). We do, however, recognize that rural families very often have complex livelihoods strategies, of which agriculture may be only one component (Ellis and Biggs, 2001). Input prices cannot be controlled, and, in some cases, imports of inferior quality products displace traditional inputs (e.g. hoes and axes) that were of a reliable quality, were suited to local conditions, and created local employment. Having said this, it remains an indictment on humankind that continued poverty obliges millions of small farmers to rely on their own muscle power and hand-hoes to cultivate their soils and to control weeds. This happens while labour-saving and yield-enhancing technology is readily accessible to the better-off.

## Sustainable land management and rural development

Loosening the topsoil with cultivation implements exposes it to the erosive forces of wind and rain. This will frequently result in a rapid reduction in soil fertility and a consequent decline in crop yield and quality. Many farmers are fully aware that their yields are declining, and that their production costs are relentlessly high. However, smallholder farmers in developing countries are very often desperately short of the financial capital needed to invest in SLM technology. Although there will usually exist possibilities to save for a major investment, or to borrow the necessary capital, the competing demands can result in a low priority being given to crop production technology.

In general, attempts to control erosion and maintain soil fertility have suffered from a lack of appreciation of the underlying problems. Soil has not been regarded as a living entity that needs to be protected and sustained. Tillage destroys soil organic matter, it results in degraded soil structure and is damaging to soil biota. New thinking on the importance of better soil husbandry for increasing the populations of beneficial soil organisms is now forthcoming (Shaxson, 2006). Increasing the activity of organisms that convert carbon substrates to humus will improve soil particle aggregation, water infiltration and holding capacity and, indeed, soil formation. The addition of organic carbon to the soil system is of prime importance.

## Conservation agriculture as a development concept

Sustainable practices involving permanent soil cover, minimal soil disturbance and crop rotations have been developed. When agriculture is practised with the employment of these key components, it has come to be described as conservation agriculture (CA). In response to a dearth of technology, farmers in Brazil started to experiment with more sustainable alternatives, and CA for small-scale farmers was born (FAO, 2000). The development of successful technology and its application to sustainable practices has been made possible by a synergy between three main groups of actors: farmers, researchers and manufacturers. Pretty *et al*. (2006) have shown the positive impact of CA principles in agricultural improvement projects worldwide. For these reasons, CA is viewed as a powerful engine for development, and this is why FAO is assisting many countries with their CA programmes.

## FAO initiatives for strategies that support optimized land and water use with appropriate roles for the private sector and government

FAO has been actively supporting countries in bringing the major stakeholders together to forge strategies for agricultural mechanization. As part of these discussions, FAO emphasizes that mechanization strategies cannot be seen as disconnected from strategies for sustainable land management.

More concretely, FAO supports countries in piloting projects with a CA component within their agricultural development plans, and some lessons have been learned.

### *Farmer groups*

Because CA is an innovation, many farmers have many doubts. It has been important to work with voluntarily formed farmer groups that have access to CA technology and can put it into practice in a way that is a group learning experience. Mistakes will be made early on, but these can be discussed

FIGURE 2.10
**Farmer field schools**

Source: GTZ Sustainet (2006).

and corrected by discussion within the group. The formation of farmer self-help groups (e.g. farmer field schools) can rapidly bring confidence in the understanding, use and adaptation of novel practices such as CA (Figure 2.10). It also adds some discipline to the equipment use, care and maintenance.

### *Extension service*

Conservation agriculture requires a drastic change in thinking, and the peer pressure among farming communities can make it very difficult for farm families to adopt such a radically different practice. The farmer groups can do much to provide a mutually supportive environment for adopting farmers. However, it is also necessary to have competent extension workers on hand to provide the answers to the technical questions that are bound to arise.

### *Financial constraints*

Change is risky, and it is extremely probable that yields will not be maintained in the first three or so years after the adoption of CA. In consequence, there will be a dramatic fall in labour and energy requirements with CA, but also crop income might fall for a few years. In addition, there are the investment costs associated with the acquisition of CA technology. Farmers will often need help to calculate the expected financial impacts of change. They may also need help to soften the blow of acquiring the necessary technology. This could be by means of machinery pools, grace periods on loan repayments, or other means of ameliorating the financial burden.

### *Local manufacture*

Although it is perfectly acceptable to promote the CA concept in a new region through the use of imported equipment, there will eventually be calls for local manufacture. However, in an initial phase the import of completely knocked-down equipment with local assembly could be a suitable intermediate step between importation and local manufacturing. It would reduce the cost and facilitate the technology transfer for local production. Simple equipment, such as rippers and jab planters, can quite easily be made by local artisans (Plates 2.2 and 2.3). However, the role of artisans is probably best kept to that of repairing equipment and providing replacements for wearing parts. Batch production should be the responsibility of better-equipped, larger-scale manufacturers that are able to control quality and ensure product uniformity. In SSA, this has proved to be something of a problem as potential

B.SIMS

B.SIMS

**Plates 2.2 and 2.3**
*Input supply of equipment for new technology, such as CA in SSA, requires the active involvement of risk-averse, local manufacturers. Jab planters (Plate 2.2) are relatively straightforward, but animal-drawn planters require a higher level of technology.*

manufacturers almost unanimously ask for evidence of demand or require a pre-paid, firm order before producing for an unknown, risky market.

*Contract farming*

Recently, there has been a surge of interest in contract farming as a mechanism to govern linkages between farmers and agribusiness (FAO, 2005). Supply chain management principles have found fertile ground in the agrifood sector for their application. Contracting is seen as a means to facilitate the integration of small farmers into supply chains, and it certainly has great potential with regard to the application of CA equipment.

*Local research and development*

The success of CA for small-scale and medium-scale farmers in Brazil has been due to the synergistic interactions of farmers, researchers and manufacturers. It is vital to have an active and healthy research and development (R&D) capacity to facilitate adaptations to local conditions. The most likely venues for this kind of activity will be universities and agricultural research stations. However, these must be encouraged to apply themselves to R&D relevant to the realities of the local situation by working with farmer and manufacturer groups rather than in isolation, as is too often the case at the moment.

## Conclusions and future action

Initiatives for CA promotion in developing countries have concentrated largely on piloting the concept in order to gauge potential and interest. In all cases, there has been an immediate and positive reaction to CA from local farmers. Their demands will now have to be satisfied.

Local artisans are generally well able to repair and maintain the currently available CA equipment. They are also capable of manufacturing replacement wearing parts, especially soil-acting parts such as chisel points and jab-planter beaks.

Importing equipment from other countries (especially Brazil), while attractive from the point of view of the exporters, is not likely to be a viable long-term solution. Local supply will usually be the preferred option.

Local manufacturers in many developing countries are not willing to risk batch production without firm orders. Moreover, farmers are unlikely to be willing to pay in advance for an unproven product.

National agricultural mechanization strategies aim to chart the development of this sector in a countrywide context. Strategies provide a range of possible options to farmers so that they can make sensible choices in the context of their own situation. Mechanization strategies need to look at the local manufacturing situation and to include measures that will stimulate it to provide such a range of choices. These could include the initial purchase of batches of equipment for subsequent distribution and cost recuperation.

Mechanization strategies should also look at the provision of a testing and evaluation service to ensure the performance and reliability of locally manufactured equipment. Typically, such a facility could be installed in an already established university agricultural engineering department, or in an established agricultural research centre. New facilities will seldom be required.

High-quality CA extension personnel and messages are necessary. This presupposes good training for extension agents with good access to farmer training materials.

## References


**Ellis, F. & Biggs, S.** 2001. Evolving themes in rural development 1950s-2000s. *Dev. Pol. Rev.*, 19(4): 437–448.

**FAO.** 2000. *Soil management and conservation for small farms*, by V.H. de Freitas. Soils Bulletin No. 77. Rome. 66 pp.

**FAO.** 2005. *The growing role of contract farming in agri-food systems development: drivers, theory and practice*, by C.A.B. da Silva. Agricultural Management, Marketing and Finance Services (AGSF), Agricultural Support Systems Division. Rome. 30 pp.

**GTZ Sustainet**. 2006. *Sustainable agriculture: A pathway out of poverty for East Africa's rural poor: Examples from Kenya and Tanzania*. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn.

**Hertel, T.W., Ivanic, M., Preckel, P.V. & Cranfield, A.L.** 2003. *Trade liberalization and the structure of poverty in developing countries*. Seminar prepared for presentation by Thomas Hertel at the FAO, Rome, 12 December.

**Pretty, J.N., Noble, A.D., Bossio, D, Dixon, J., Hine, R.E., Penning de Vries, F.W.T. & Morison, J.I.L.** 2006. Resource-conserving agriculture increases yields in developing countries. *Env. Sci. & Tech*. (accepted for forthcoming publication).

**Shaxson, T.F.** 2006. Re-thinking the conservation of carbon, water and soil: a different perspective. *Agronomie*, 26: 1–9.

## CHALLENGES FACED BY AN AGRICULTURAL MACHINERY MANUFACTURER IN NEW MARKETS LIKE AFRICA

*Adel Lünz, CLAAS KGaA mbH, Harsewinkel, Germany*

### Abstract

Modern agricultural machinery is complex; users and dealers require training to ensure optimal use and maximum returns from the investment. The CLAAS Company has increased tractor sales, in comparison with harvesting machinery, since merging with Renault Agriculture. Modern companies today are more likely to be systems consultants in addition to manufacturers and sellers. Some of the problems encountered are related to the complexity of state-of-the-art equipment and especially the complexity of electronic systems used for machinery operation. Corruption is a virus militating against the best interests of country and company alike. Some solutions are suggested. The special factors affecting agricultural equipment sales in Africa include: climatic conditions and water shortage; prioritization of the agriculture sector; finance arrangements; farm size; and training needs in modern technology. CLAAS is committed to responding positively to this situation and is investing accordingly.

### Introduction

Operating agricultural machinery in Africa today is not always an easy matter. For a western manufacturer such as CLAAS, because of the complexity of the equipment and the need for technical knowledge, it is not simply a question of negotiation and selling a product.

As a premier worldwide high-technology company in the agricultural machinery sector, it is very important for us to establish a strong dealership base. To ensure high levels of competence, training is organized in our in-house academy and also directly in the countries where the new products are introduced. It is very important that the customer learns how to optimize the use of the product in order to maximize the return on the investment.

The start-up activities in Africa were very promising for CLAAS but there was not enough potential to justify developing a long-term strategy for the region. For several years, CLAAS has been doing business in Africa, but only for harvesting machinery. However, since we started with the tractor business, after having taken over the agricultural branch of the French tractor manufacturer Renault Agriculture, CLAAS has increased its activities in the region. A new product range has been designed to provide appropriate machines for farmers with smaller land holdings.

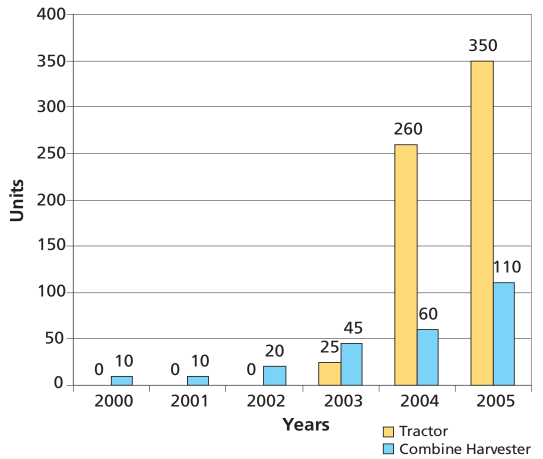
Figure 2.11 gives the sales figures for West and Central Africa between 2000 and 2005, which show the relative importance of tractor sales to the rest of the CLAAS business since 2003.

Today, a manufacturer such as the CLAAS Company is more a system solution provider in agriculture than solely a manufacturer, changing the task in principle from purely selling to agroconsulting.

Agroconsulting means addressing problems and providing solutions, and this has posed the following problems for CLAAS in Africa:

- The farmers and users of machinery need to know exactly what kind of equipment they require in order to reach satisfying results in as short a period of time as possible. The decision about purchasing a machine is often made on a financial basis, the product has to be as low cost as possible. However, what farmers obtain may often not be appropriate for their needs and productivity levels.
- The decision to buy agricultural machinery is centralized in many countries at the Ministry of Agriculture. This kind of centralization can cause us problems in terms of communication and also in terms of presentation. Ministries may have preferences in terms of manufacturers, sometimes this can be very subjective and sometimes hard

FIGURE 2.11
**Sales figures for CLAAS products in West and Central Africa**



for us to understand! I had an experience in a West African country where the ministry wanted a special tractor colour (in this case red). The explanation was that the colour can be identified from far away and it is easier to see where the farmers are working!

- We have visited many countries with huge machinery pools, and often we could see only a few machines running and the others not working. After we checked the machines, we found out that they frequently only had slight defects (total repair costs not more than EUR5) paralyzing so many machines that cost several thousand euro.
- Due to the very rapid development of electronic systems, machines are becoming more and more complex. To handle such machines, the driver has to be well trained in order to operate them effectively. There is no modern agricultural machine today that runs completely mechanically, starting with the injection pump to the electronic engine management system, to the on-board information system, and so on. However, to date, we have not received any request from a local agricultural university on this subject! CLAAS is working hand in hand in many countries in western and eastern Europe with agricultural universities to present recently developed machines fitted for local markets, to exchange experience and to research into new products that would be a benefit for the countries involved.
- Corruption is one of the biggest problems we are faced with in some African countries. Contracts are sometimes signed without any plausible explanations. We should fight against this virus in order to make long-term partnerships possible from which both parties can profit.

Some possible solutions to these problems include:

- Build long-term partnerships between manufacturer and end users in the form of technical assistance, technical training, exchange programmes and incentive programmes.
- Explore the possibility of having a direct link to national agricultural universities and to international development organizations working locally (FAO, World Bank, etc.).
- Organize Web exchange platforms to talk about news, possibilities and problems and to find solutions!
- Work more closely with donor organizations and finance institutions to establish adequate structures and methods for sound investments in agricultural technology.
- Fight corruption more seriously to keep the relationship between manufacturer and recipient countries clean. Rather, try to use the money in effective programmes for demonstration, technical advice and training.

## Factors affecting the sales of agricultural machinery in Africa

*Climatic conditions*

It is a very big challenge for agricultural machinery manufacturers to design machines that perform well under different, severe, local climatic conditions. To be able to do so requires considerable technical knowledge and close cooperation with the research and development (R&D) department, combined with experiences gained directly from the field by the R&D teams working and testing in different areas of the world and through cooperation with state agricultural R&D organizations. The experience of experts and international organizations, such as FAO, that already know the market is needed for the development of machines compatible with local climatic conditions.

*Prioritization of agriculture in Africa*

In recent years, the governments of some African countries have lowered the priority of agriculture in favour of the energy and mining sectors. Due to the huge demand on the world markets for raw materials, we are faced today with the fact that many more states invest in the extractive industries; and history has shown that countries abandoning agriculture for other businesses face huge problems with their populations. As some countries in Africa have concentrated more and more on the lucrative oil and mining industry sectors, investment in the agriculture sector has declined steeply. An important difference between the mining and oil sectors and the agriculture sector is that in agriculture it is individuals who invest, and so the financial burden is felt more acutely. Subsidies for the purchase of agricultural machinery are not the solution, as we have seen in highly subsidized economies. Development efforts should rather be used to channel capital into agriculture for the purposes of environmental protection, food production and even renewable resources production. These could become profitable areas, and countries with financial resources from mining and oil could invest in building them up. Agriculture is a long-term business and is not only an investment for ten years or so.

Because of the existing focus on the oil and mining industries, agriculture and, consequently, the population are neglected (up to 80 percent of the population in some countries are employed in agriculture). The risk of malnutrition increases. The dependence on imported food increases and local knowledge is lost. Today, in many African countries, agriculture is synonymous with poverty.

*Water scarcity and renewable energy*

A significant factor in the evolution and marketing of products is the endemic water shortage in many regions of Africa. Effective water management is required for rainfed agriculture, and so specialized equipment, such as direct seeders, subsoilers and chisel ploughs, is increasingly in demand. It is expensive and arduous to explore for and exploit additional water sources for agriculture. Under these circumstances, investment in machines and equipment is difficult and complicates the purchase, financing or leasing of machines. CLAAS is using and promoting utilization of machines with biodiesel, and it is also working with some institutes to see how modern farming can save water. We have a lot of projects in these areas with partner universities and institutes. These include using renewable energy to run a farm! CLAAS is also working with companies in the sector to provide customers with subsoilers, rippers and direct seeders. The straw residue is collected by baler to be used to generate electricity. Some successful projects have been implemented in other continents, and the experience gained could be of value in Africa.

*Purchase and/or financing of the machines*

The promotion of leasing and other models for financing in Africa currently only exists through a few bank schemes. However, it is indispensable for the agriculture sector. CLAAS is running a leasing and financing bank as a joint venture with BNP Paribas. This company, CLAAS Financial Services, designs specific financial products in some countries. We think that these finance models are also applicable in Africa under different conditions. The financing volume through help / technical assistance cannot cover the requirements completely. This underscores a very difficult issue that needs to be dealt with. The farmers need to organize themselves into cooperatives in order to exert more leverage and make their needs known in their Ministry of Agriculture. Farmers can then develop a business plan for eventual financing.

*Farm size*

An incentive for larger and consolidated farm sizes is necessary in the field. A manufacturer such as CLAAS can influence positively or create incentives to achieve this. Farm sizes of fewer than 10 ha are difficult to manage economically with expensive machinery. Farmers should be encouraged to organize themselves and to amalgamate their fields in order to reduce travel time between plots.

*Machinery training for farmers*

The advent of new production techniques (e.g. precision farming and renewable energy) requires training and education centres. This is one area with the potential to improve sales of equipment. Would CLAAS support such training centres financially? The answer is "yes". Every year CLAAS trains more than 18 000 users, farmers, students, etc. all over the world!

*Cooperation with universities and institutes of agriculture*

One key to success in the development process is working together on new machines and equipment that would be adapted and adopted by local farmer groups according to their specific needs and requirements. In this way, the new prototypes and machines can also be presented and demonstrated in order to find a better solution or technique for a specific task.

## Conclusion

Is a company like CLAAS still interested in business with Africa with all the problems faced there, with all the sales lost because of an unfathomable decision that we never understood?

The answer is a clear yes! CLAAS does not just have a responsibility to improve performance and technology of the machines! CLAAS is also socially responsible and is active on the world development scene.

We want to develop the business in Africa. We have just started, with a very good record so far, and we hope that one day in the near future Africa will be one of the biggest customers of CLAAS, not because of corruption but because of satisfaction with the products and the services that we provide 365 days a year!

# Chapter 3
# Using technology to add value and increase quality

The second workshop session examined the challenges facing the value addition chain for the products of agricultural production. Six papers were presented:

- Lead paper: Innovation, competitiveness and value addition in Mexico's agrifood industry.
- Local design capacity building applied to small-scale food processing equipment: a strategic way for adding value for producers.
- Product development systems for agrifood innovation in developing and transition countries.
- Study of resource recycling based sustainable agricultural development in Thailand: Thai–Japanese joint venture agribusiness.
- A competency-based qualification programme in automation technology and process control.
- Poverty reduction and food production in developing nations: a case study of Nigeria.

## INNOVATION, COMPETITIVENESS AND VALUE ADDITION IN MEXICO'S AGRIFOOD INDUSTRY

*Inocencio Higuera-Ciapara, Centro de Investigación en Alimentación y Desarrollo, Consejo Nacional de Ciencia y Tecnología, Hermosillo, Sonora, Mexico*

### Abstract
In order to become internationally competitive in the agrifood market, Mexico is investing in its research and development (R&D) capabilities. Many countries and regions in the developed world have established programmes to foster innovations; among them is the European Union's Pilot Action of Excellence on Innovation Start-ups (PAXIS). In Mexico, the investment in technology innovation has traditionally been low. To address this situation, Mexico has implemented its National Innovation System (NIS) via the National Council for Science and Technology. The NIS has created trust funds for demand-led R&D in specified priority technical areas. Currently, more than 4 500 projects are being funded. Ministry of Economics funding, for example, is directed towards increasing competitiveness in small and medium-sized enterprises (SMEs) through product process and improvement. Human capital improvement is encouraged through financial incentives to innovative scientists via the NIS. With regard to the agribusiness sector in Mexico (and throughout Latin America), there are problems associated with a large percentage of subsistence-level farmer producers, and this situation needs to be countered by consolidation into SMEs or cooperatives. However, some states are more highly developed and are dealing with the challenge of adding value to agricultural products in order to close the gap between producer and consumer. Strategic areas being addressed are: biocontrol; greenhouse development; by-product utilization; and food safety.

### Introduction
The widespread transformations occurring at the national and international levels have fostered growing competition among countries and given rise to a new kind of world economy that is characterized by three key elements:

- Competitive capacity has become strongly dependent on the level of knowledge generation, dissemination and incorporation into the production processes.
- New ways of production organization have emerged
- Competition has evolved from a price-driven model to one led by technology and functionality.

These three elements underline the role of scientific and technological knowledge creation and utilization to create wealth. The way in which companies develop the capacity to generate and mobilize knowledge for innovation has been analysed from the capability development perspective at the project and at the organizational level by Un (2000).

An innovation system can be characterized as the series of complex interplays between government, private enterprises and knowledge-generation institutions (universities, research centres, and research and development [R&D] groups) leading to highly competitive production and distribution processes and, therefore, to sustained economic growth. Various countries and regions, most notably the United States of America, Japan, Canada, and the European Union (EU), have established outstanding programmes to foster innovation and the creation of innovative enterprises. For example, the EU has identified 22 areas of excellence, selected on the basis of 13 scientific, technical and economic indicators, as well as available infrastructure and policy measures implemented by specific regions to foster innovation. Based on such evidence, the EU has established and implemented specific programmes to encourage the development of innovative enterprises. Its Pilot Action of Excellence on Innovation Start-ups (PAXIS) is a major effort. In addition, the recently established prize for the most innovative region underscores the efforts to establish a regional cooperation network among countries. This effort is quite unique and it involves the highest-ranking authorities in the participating governments (PAXIS, 2006).

However, most developing countries have made only marginal progress towards the articulation of regional innovation systems, and the potential benefits of this new paradigm are yet to be realized, particularly in the realm of the rural sector, where large numbers of people still remain at the subsistence level. Among the most important dimensions of competitiveness lacking in developing countries are: (i) technological change – which is the strongest source of structural change within a given economy – is not distributed evenly among regions; (ii) adequate human resources to utilize the opportunities of the global marketplace in a timely manner are scarce due to a range of factors; and (iii) a wide gap exists between research and innovation capabilities. As a whole, developing countries have relied on importing and improving technologies, but the development of an independent innovation capacity has been neglected. This in turn has made it impossible to construct national innovation systems that will contribute to the development and diffusion of technologies and provide the framework to implement policies fostering the innovation process.

Various studies have shown that Mexico is a country where the role of innovation is yet to be fully realized, in spite of the geographical advantage due to its proximity to the world's largest economy. Most notably, the Knowledge Assessment Methodology developed by the World Bank (World Bank, 2006) – which includes quantitative and qualitative variables to compare the four pillars of a knowledge economy (economic incentive regime, institutional regime, education, and innovation) with its competitors – clearly shows that Mexico lags behind other Latin American countries with a gross domestic product (GDP) of similar size. In the period 1991–2001, there was a very limited effort to increase the total expenditures on science and technology activities in Mexico; the percentage of GDP destined towards science, technology and innovation activities averaged only 0.43 percent and the number of patents granted to Mexican nationals remained stagnant. On the other hand, the fact that Mexican enterprises have developed their competitive strategies based on cost reductions instead of market penetration strategies is clearly contrary to the policies implemented by the Asian competitors through technological innovation and economies of scale (Ruiz-Durán, 2005).

### The National Innovation System in Mexico

In the light of the above conditions, Mexico started the implementation of a new scheme for fostering a National Innovation System (NIS) through science and technology. This scheme started in June 2002 with the approval of the new Law for Science and Technology by Congress. The new law provided the legal framework to implement a new "demand-oriented" model based on new instruments to finance basic science, applied research, and technological development programmes in order to integrate science, technology and innovation. The key arm to implementing such a policy change is the National Council for Science and Technology (NCST), whose legal status within the Federal Administration was changed from being a Ministry of Education Office to a decentralized public body reporting directly to the President of Mexico.

The main instruments created under the new law and implemented between 2002 and 2006 are:

- Sectoral funds: These funds are independent financial trusts that are structured with concurrent economic resources between each of the Federal ministries and the NCST. The funds are used to finance applied research, infrastructure, and human capital formation projects. The major difference with traditional financing schemes is that projects are designed to meet specific demands previously determined according to the priorities of the sector. To date, 15 sectoral funds have been created with the Ministries of Economics, Agriculture, the Interior, Public Health, Environment and Natural Resources, Social Development; the National Commission for Water Resources Management; and the National Commission for Forestry; among others. More than 4 500 projects are currently underway under the sectoral fund programme, and all of these projects were previously determined to be relevant to a particular sector or to contribute knowledge leading to a practical solution. The sectoral fund with the Ministry of Economics is particularly relevant to the efforts to introduce innovation within the private industry. It funds projects destined to increase competitiveness through product or process improvement and focuses primarily on promoting innovation in small and medium-sized enterprises (SMEs).

- Mixed funds: The main objective of mixed funds is to promote regional development through science and technology projects with high relevance to the needs of each of the 32 states that make up the United Mexican States. To date, 32 funds of this type have been created.
- Support for technology and entrepreneurship: Three programmes have been established to support technology transfer and business creation based on innovation. The first one finances prototype development, patenting costs and feasibility studies so that scientific or technological developments may be transformed into investment prospects that will generate new high value-added business. The "Entrepreneurship Programme" offers capital supply to private firms that wish to start or develop businesses based on scientific discoveries or technological developments. In addition, a warranty capital fund has been created to facilitate access to credit lines to those enterprises that wish to diversify their production lines or increase their working capital. This programme works through the commercial banking system.

In order to promote education on innovation and innovation systems, a special programme on business schools focusing on innovation was designed to promote the adoption of best practices regarding management and the use of innovation, technology and intellectual capital protection, as well as the creation of new businesses based on scientific and technological development.

A major policy focus in the period 2001–06 at the NCST has been the support of human capital formation through two major programmes: the National System of Scientists and Technologists (SNI); and the National Scholarship Programme. The SNI comprises a system of individual accreditation according to scientific and technological productivity, which is assessed by committees of peers in seven fields of knowledge: mathematics and earth sciences; biology and chemistry; health sciences; humanities; social sciences; biotechnology and agricultural sciences; and engineering. SNI membership grew by 62 percent from 2001 to 2005. This growth indicates a significant enlargement of the human capital devoted to scientific and technological development activities in Mexico. On the other hand, the number of fellowships awarded to graduate students, nationally and abroad, almost doubled in the five-year period. Interestingly, the number of patents applied for by Mexican citizens in North America, the European Union and Asia has also grown very significantly in the last five years.

### Innovation and competitiveness in the agribusiness sector in Mexico

Agriculture and agribusiness development in Mexico have undergone a substantial transformation since the inception of the North American Free Trade Agreement (NAFTA) in 1994. On one hand, the country has experienced substantial growth in export-oriented activities, mainly from fruit and vegetable projects, and this has led to new developments in applications of greenhouse technology, improved packaging facilities, and significant improvements in the manufacturing of high value-added agricultural products. However, large segments of the rural population, now at 25 percent of the country's total of 103 million, still remain at subsistence or below subsistence levels. The increasing flow of agricultural workers migrating to the United States of America is largely due to the increasing difficulties to make a decent living from traditional agricultural operations, and also to the increasing imports of agricultural products at very low prices. Furthermore, under Article 703 of the NAFTA Treaty, as of January 2008 no tariffs will be applied to imports of basic staples of the

Mexican diet (corn, beans, sugar, and powdered milk), putting even more pressure on the ability of the rural sector to compete.

The official classification of agribusiness within the economic activities of the country places it under the manufacturing industry class and the division of processed foods and beverages. Interestingly, this sector has experienced an average growth rate of 5 percent in the last six years. The division of processed foods and beverages is integrated by 12 branches (beef and dairy products; fruits and legumes; wheat milling; corn milling; coffee processing; sugar; vegetable oils and fats; animal feeds; alcoholic beverages; beer and malt; soft drinks; and other processed foods). About 98 percent of the total enterprises classified as agribusiness are considered SMEs (Ochoa, 2000).

From the agribusiness perspective, the regions with the highest level of development are located in the central, northwest and northeast regions of Mexico. They include the states of México, Coahuila, Morelos, Guanajuato, Aguascalientes, Jalisco, Puebla, Veracruz, Sinaloa, Sonora and Nuevo León. On the other hand, the southern states of Chiapas, Guerrero and Oaxaca are considered to be the least developed in terms of their agribusiness potential. A common problem in these and other underdeveloped states is their small landholdings, as it is estimated that more than 6 million farmers have holdings of 5 ha or less. The same problem exists throughout Latin America, where low levels of production, coupled with a lack of technological advancement, place small agricultural producers at a clear disadvantage (AC-IICA Ecuador, 1999).

An additional problem stems from the fact that, as Mexico becomes more integrated into the global marketplace, it will face greater difficulties in making its own agribusiness industry competitive and economically feasible. Therefore, the need to introduce innovative concepts into the SME agribusiness sector is even greater. Regional production specialization should go hand in hand with the processing of specific high value added products. In addition, the development of various organizational models (integration of small producers; cooperatives) should be further explored in order to attain economies of scale.

## Strategic areas of the agribusiness industry supported by the National Innovation System

### *Biocontrol*

Biocontrol is the application of biological systems and/or natural substances for the control of: insects, pests and micro-organisms that cause disease in plants; microbes that cause rotting in fruits; external parasites in cattle; and enteropathogenic bacteria in foods (Bolivar-Zapata, 2003). Biocontrol may allow the production of safer food thanks to the elimination of pesticides and other chemicals during production or post-harvest operations. Biocontrol has been one of the key support areas in the sectoral fund between the NCST and the Ministry of Agriculture, particularly as it relates to:

- anthracnose control in mango;
- biological control of fungi during coffee production and processing;
- aquatic weed control;
- massive production of entomopathogenic fungi from arid zones;
- application of *Bacillus subtilis* strains to corn seeds and its metabolites for the control of root pathogens;
- bioproducts for the control of black Sigatoka (*Micosphaerella fijensis*) in banana cultivation;
- bioinsecticides from the Mexican plant *Willardia mexicana* against the maize parasite *Spodoptera frugiperda*;
- fruit fly control by endemic parasitoids in Veracruz.

All these projects were previously determined to be of significant economic impact to the farmers, and in each case the mechanism for technology transfer has been incorporated as a key responsibility of the project leader.

### *Greenhouse development*

The greenhouse industry has been growing at an exponential rate in Mexico since the late 1980s. The production area has increased from 50 ha in 1990 to well over 1 500 ha in 2006. This industry currently generates US$400 million in net sales and close to 20 000 jobs. A large majority of the crops produced in greenhouses are destined for the export market and they comprise tomatoes (70 percent), cucumbers (15 percent) and peppers (10 percent), as well as minor quantities of eggplant and other horticultural crops (Plates 3.1 and 3.2). The main technological problems faced by greenhouse producers are also related to:

B.SIMS

B.SIMS

**Plates 3.1 and 3.2**
*Plates 3.1 and 3.2 show greenhouse horticultural production in Sinaloa, Mexico. Pest and disease control are major technological problems. The North America market is readily accessible if grading and packaging are well managed*

pests, food safety during harvesting and packing operations, and the availability of specialists for the operation of sophisticated electronically-controlled monitoring systems. These problems have been addressed by specific projects through the network of research centres coordinated by the NCST, particularly as they relate to: food safety control inside greenhouses; the substitution of imported substrates; the use of biocontrol strategies to avoid pesticide use; and the optimization of water use. We envision a continued growth of the greenhouse industry in Mexico and the development of new technology platforms adapted to local conditions.

***By-product utilization***

The utilization of agricultural by-products is one of the most dynamic areas for the purposes of upgrading the total value of crops. In addition, the boom in the nutraceutical (or functional food) industry has provided a new impetus for the utilization of low-cost raw materials containing bioactive compounds. Once these compounds have been isolated, packaged and marketed, they can contribute very significantly to increasing the total return of agricultural operations. This perspective has provided renewed interest in Mexican agribusiness, and the NCST has supported numerous projects within the mixed funds to characterize current opportunities. Among the most promising initiatives are the development of:

- an industrial process to produce xilitol and inverted sugar through an enzymatic process from sugar-cane waste products and blue agave;
- antioxidant extraction from grape-seed waste;
- extraction of carotenoids and capsaicin derivatives from *Capsicum annum* peppers;
- fructose extraction from cactus pear fruits (*Opuntia* spp.);
- antioxidant production from oregano (*Lippia* spp.).

*Improvements in food safety*

Outbreaks of infectious diseases due to the consumption of contaminated foods, particularly fruits and vegetables, have resulted in more stringent microbiological regulations all over the world. The United States of America has recently implemented a law to reduce the risk of contamination in fruits and vegetables. This initiative is considering subjecting all horticultural food imports to pathogen-free and toxic-residue certification before they enter the country. Many factors can contribute to the presence of pathogenic micro-organisms in food products:

- contamination of water used for irrigation purposes;
- low disinfection efficiency of available systems in packing houses;
- sanitary conditions during handling and packing;
- worker hygiene;
- integrity of packaging materials;
- storage conditions.

In addition, the changes in lifestyle and the new technologies that have been introduced have increased the possibilities that foods carry specific pathogenic micro-organisms. Thus, the control of *Salmonella*, *Klebsiella*, enteropathogenic *Escherichia coli*, *Bacillus cereus*, *Clostridium perfringens* and *Listeria monocytogenes* is crucial if horticultural products are to remain competitive. Various actions have been taken within the NIS to develop: (i) antifungal and antibacterial compounds from natural sources; and (ii) rapid methods to detect and control pathogenic *E. coli* 0157H7 in fresh produce. Moreover, the detection of critical control points in horticultural product packing houses in order to develop proper hazard analysis critical control point (HACCP) plans has been addressed.

## Conclusions

The innovation approach to the agrofood business industry in Mexico is providing key answers to the urgent need for increased competitiveness in world markets. Many problems caused by the small size of agricultural operations are being solved through the consolidation of producers and the design of strategic marketing plans that aim to take advantage of economies of scale. Addition of value in agricultural products is closely linked to the marketing end of the supply chain continuum. Thus, producers should make every possible effort to reach the end consumer utilizing proper post-harvest methods, storage and marketing conditions, as well as modern, cost-effective packaging systems. Process and product certification to guarantee food safety and high quality standards will continue to play a key role in the success of small and medium-scale operations.

## References

**AC-IICA Ecuador.** 1999. *Situación y perspectivas de la agroindustria y microempresa rural en el Ecuador*. Costa Rica. Inter-American Institute for Cooperation on Agriculture (available at http://www.infoagro.net).

**Bolivar-Zapata, F.** 2003. *Recomendaciones para el desarrollo y consolidación de la biotecnología en México*. Consejo Nacional de Ciencia y Tecnología y Academia Mexicana de Ciencias (Editors). Mexico. p. 68

**Ochoa, M.R.** 2000. La Agroindustria en México. *Revista*, Vol. 2. No. 11 (available at http://www.cce.org.mx).

**PAXIS.** 2006. (available at http://cordis.europa.eu).

**Ruiz-Durán, C.** 2005. *Comparative development: the emergence of science and technology models. What has failed in the case of Latin America?* Paper presented at the Workshop on Latin American and Asian Experiences: Coming into the knowledge society. Forum on Mexico and the World: Strategies for the Future. Historic Project of the Mexican Nation. 25 October.

**Un, C.A.** 2000. *Organizational capabilities, knowledge and innovation: strategies for developing the capability to mobilize and create knowledge for innovation*. Boston, USA, Sloan School of Management, Massachusetts Institute of Technology (available at https://dspace.mit.edu). (PhD thesis)

**World Bank.** 2006. *Knowledge Assessment Methodology* (available at http://www.worldbank.org).

## LOCAL DESIGN CAPACITY BUILDING APPLIED TO SMALL-SCALE FOOD-PROCESSING EQUIPMENT: A STRATEGIC WAY FOR ADDING VALUE FOR PRODUCERS

François *Giroux, ENSIA-SIARC, Montpellier, France*
*Claude Marouzé, CIRAD, Information and Technologies for Agri-Processes UMR, Montpellier, France*

### Abstract

The principle of processing raw materials in order to add value is well known. However, it requires professional skills and resources in order to bring benefits to the smaller-scale stakeholders in developing countries. In order to increase productivity, small-scale processing equipment is needed to facilitate the management of the quality of the processed food. Regarding the local supply of small-scale food-processing equipment in developing countries (DCs), there is a clear lack of well-adapted equipment, especially in the secondary processing of solid and liquid foods for preservation (and also in packaging). Given this situation, two solutions can be developed: importation of externally-designed equipment and its adaptation to its new working environment; or building local capacity to design and manufacture new equipment, well adapted to all the requirements of local users.

Because it is difficult to import simultaneously both the equipment and the sociotechnical environment of its application, the second way has been developed through applied research activities, in partnership with manufacturers, users, research centres and universities in DCs. The components of this new design process are presented, underlining the specificities of such an organization of the equipment development process. The first successful results allow positive extrapolation to the near future, where local design is a regular organized activity responding to the demands of producers for adding value to their agricultural products.

### Introduction: requirements for small-scale food-processing equipment

While small-scale agrifood-processing equipment seems technically simple to design and manufacture, it is paradoxical that it often provides only partial or poor solutions to the requirements of the users, who then express their dissatisfaction. Generally speaking, the users wish to improve their incomes and quality of life by increasing their productivity and by decreasing the drudgery of processing, which is mostly still manual. It should also be added that the equipment must be adapted to the socio-economic and sociotechnical environment of the users in terms of purchase price, operating cost, use of available energy sources, and capacity to ensure rapid, low-cost maintenance. When a detailed functional analysis of the users' needs is performed, it becomes clear that small-scale food-processing equipment has to include a range of qualitative and quantitative characteristics. Thus, the process of designing small-scale equipment does not involve any reduction in the necessary rigour in needs analysis. It also should be remembered that equipment for small-scale use must also include the necessary microbiological safeguards.

Whatever the processing chain (fruits and vegetables, dairy products, cereals and pulses, etc.), the equipment employed should allow management of the process and its control to adapt both upstream to the variety of the raw materials, and downstream to the variability of the market. After a rapid survey of the existing equipment, it is clear that most small-scale equipment provides the operators with little objective information to enable them to control the process. At the same time, there is a lack of information on the process variables, and a lack of possibilities for changing the process parameters during the process.

In short, the supply of commercially available equipment is still insufficient or inappropriate to satisfy the needs of small companies. At the same time, this supply is often cited as a key factor of economic development in the developing countries (DCs) with a strong agricultural tradition.

This paper argues that equipment design and use must be user-centred, and not only reflect the designer's perception, allowing value addition to a wide range of tropical raw materials.

### Responding to the demand for well-adapted equipment

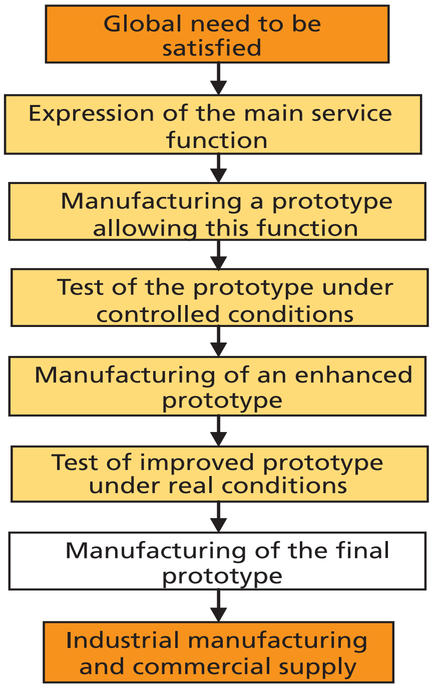
The first possibility is to import the equipment from other parts of the world, in particular from tropical areas of Asia or Latin America. Examples are: Indian oil press; Chinese rice huller; and Colombian cassava starch extractor. Even if this first way seems to be easy, it suffers from the generally low level of trade in these products between tropical zones of the world and, consequently, does not provide satisfactory local after-sales service. User dissatisfaction frequently arises as a result. The fact is that one can quite easily transport a machine from one continent to another, but one cannot transport the technical and economic environment for which equipment was initially designed and manufactured. For example, in the "trades villages" of north Viet Nam, very low cost, small-scale extrusion machines are usually available. They are generally used to process rice noodles. These small extrusion machines have a monoscrew that wears quickly after only a few hours of use because of the low quality of materials. In consequence, this screw must be repaired regularly, once or twice per month. This is very easy insofar as, in these "trades villages", well-equipped and qualified workshops are available to do this work. However, if the same extrusion machine were imported to an African zone where there were less possibility of such repair work, as is generally the case, obviously the machine would not be serviceable and would quickly be abandoned.

A variation on the process of importation, well developed in many tropical DCs, is the "adaptation–copy" process. The idea is to manufacture imported equipment locally, without paying any fee to the original designers. Generally, adaptation consists of changing some materials, some manufacturing processes or some size parameters. This method, often based on a "trial and error" concept, pays little attention to the level of costs or deadline management. However, the practice should not be ignored, especially in cases of regional transfers where the technical and economic environments are similar.

Adaptation can also be applied to the choice of raw material. It may be possible to use a machine initially designed to treat one type of product for another product that seems a priori relatively similar. The result is generally not perfect because the equipment may not have a sufficient range of adjustment or cannot cope with specific aspects of the new product. For example, an Engelberg huller can be adapted for the dehusking of fonio grain (Digitaria exilis), but it is clear that this decorticator was not originally designed for this type of cereals. On the other hand, this type of adaptation of use does not enable the processing of new agricultural raw materials for which no similar machines can be used as a reference.

A second approach is to develop local design

FIGURE 3.1
**Traditional organization of design**




capacity in order to produce responses to the users' requirements quickly and adequately. Cobuilding of equipment between designers and users is possible, and we recommend this way because there is no limitation to the applications addressed according to the users' needs. Analysis of the traditional processes of local design (Figure 3.1) highlights the key factors that have to be changed in order to optimize the production process (Giroux, 2000). First of all, it is plain that the needs analysis is not sufficient, when this important part is the first step of this sequential process. This means that designers quickly replace the users' requirement with their own perception of the need. Generally speaking, it is not possible to capture the problem holistically and then, separately, to design the technical solution. During the first assessment of the need, only the main service function is taken into account. Designers and users have to cobuild the final solution together. In the usual design process, the first prototype is manufactured too early, this precludes any fundamental modifications to the technical principles selected. Step by step, the prototype is tested in different contexts; after each test, modifications are needed. In this framework, the design process can last many years and, in the end, no commercial version is available for the users.

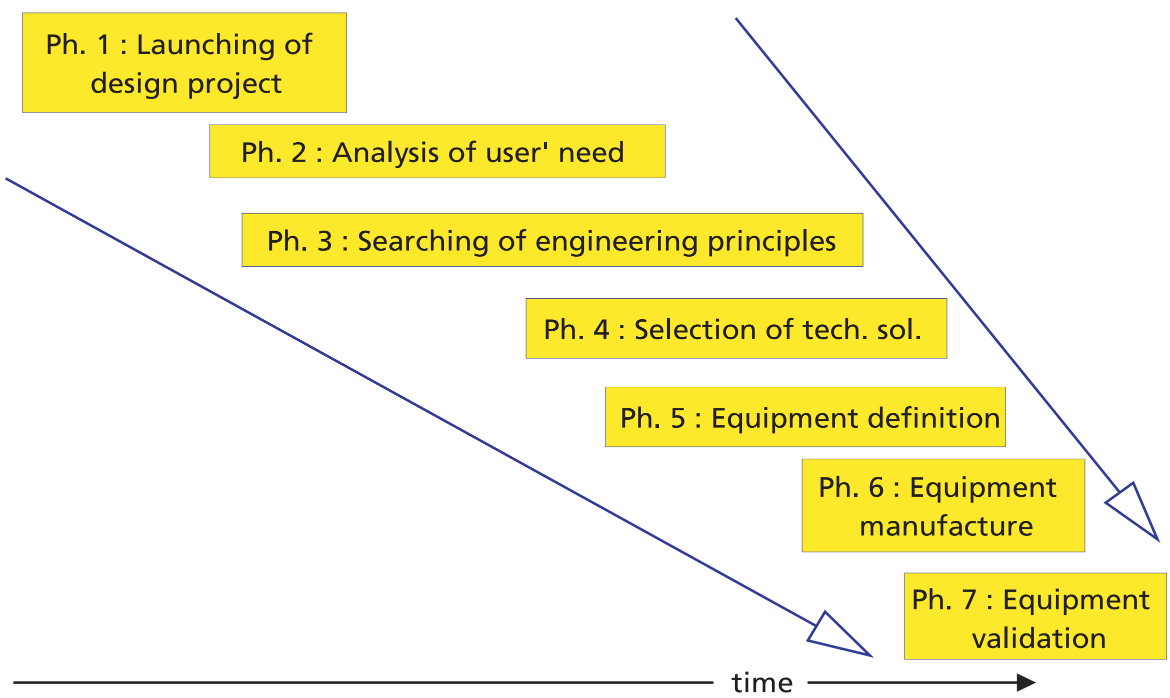
**Main pillars of local design and manufacture of small-scale food-processing equipment**

In recognition of the fact that many prototypes never reach the market, and after an analysis of the parameters of success stories, a new designed method has been developed, named Conception d'Equipements dans les pays du Sud pour l' Agriculture et l'agroalimentaire, Méthode (CESAM), specifically for the DC environment (Marouzé, 1999; Marouzé and Giroux, 2004). As indicated in Figure 3.2, this method uses concurrent engineering, and it is multidisciplinary and user-centred. During the course of developing real design projects in DCs, several aspects of the process have been developed. Some specific points to be highlighted are:

- The design team has to include several complementary skills that cannot be summarized as a mechanical problem. It is necessary to have: (i) a good knowledge of the agricultural raw material (composition, process of degradation, micro-organisms present, etc.); (ii) a good knowledge of the physical and biochemical process of transformation and conservation; (iii) social and technical knowledge of the environment of the users; and (iv) at least a basic knowledge of economics. The design must be focused on users in order to understand well what they want, how they are working, and what their financial capability is.
- Knowledge of the principles and technical solutions developed in related fields is required. Simply repeating an existing solution, slightly modified, does not enable the technological and economic analysis necessary to arrive at an optimal resolution of the problem (Marouzé and Dramé, 2005; Marouzé *et al*., 2006a).
- Maintenance and local manufacturing are taken into account in the first phases of design because they are an important limiting factor in many DCs (Marouzé *et al*., 2006b).

In comparison with the traditional design method, emphasis is given to the CESAM method for the following key reasons. First, the needs analysis is much more detailed and encompasses the whole environment of the future equipment during its life cycle; this needs analysis continues during the entire design process, until the final product. A second important factor relates to the investigation into the principles to be

FIGURE 3.2
**Organization of CESAM method**



incorporated in the final equipment. Indeed, the user is not required to be familiar with these principles or with the technical solution that will be finally implemented, but only with the functions required and, of course, the cost. The majority of users express a requirement to have "less expensive" equipment, but this request must be analysed and it is not rare to note important differences between the vision of the designers and that of the users.

The CESAM method has already been applied by local multidisciplinary design teams in DCs, e.g. Colombia (Arcila *et al*., 2000), Benin (Godjo *et al*., 2003), and Senegal (Ndiaye, Marouzé and Giroux, 2002), but its diffusion is still not widespread owing to the lack of means for its extension.

## Conclusion

After the first success obtained through such local design management in the framework of applied research, it is necessary to proceed by teaching this kind of methodology in the technical universities of the DCs. Methods and tools obtained from research activity are now available and have to be transferred to the economic field through education. Capacity building in the field of small-scale food-processing equipment design is a promising way of achieving added value in agricultural products for a large range of rural stakeholders.

## References

**Arcila, M., Marouzé, C., Oliveros, C. & Giroux, F.** 2000. Lancement de la trajectoire technologique d'un outil d'aide à la récolte manuelle du café en Colombie. *Rev. Sci. Tech. Conc*., 7(2): 1–15.

**Giroux, F.** 2000. *Pour une conception coopérative dans les pays du Sud. Application aux équipements de petite capacité dans les domaines agricole et agroalimentaire*. HDR de l'Institut National Polytechnique de Grenoble, Discipline mécanique (60ème section CNU) soutenue le 19 juin 2000.

**Godjo, T., Marouzé, C., Boujut, J.F. & Giroux, F.** 2003. *Analysis of the use of intermediary objects involved in the design of food processing equipment in developing countries. The case of a peanut processing plant in Benin*. 2003 International CIRP Design Seminar, May 12–14, Grenoble, France.

**Marouzé, C.** 1999. *Proposition d'une méthode pour piloter la trajectoire technologique des équipements dans les pays du Sud. Application au secteur agricole et agroalimentaire*. Paris. (Thèse ENSAM Paris)

**Marouzé, C. & Dramé, D.** 2005. *Search and selection of an operating principle for cleaning fonio, development of a winnowing channel*. International Congress on Technological innovation and enhancement of marginal products, 5–7 April 2005, Faculty of Agricultural Science of University of Foggia, Italy.

**Marouzé, C. & Giroux, F.** 2004. *Design method in the context of developing countries: application to small-scale food processing units*. CIRP Design Seminar 2004. Design in the Global Village, 16–18 May, Cairo.

**Marouzé, C., Ndaw, B., Truchot, P. & Giroux, F.** 2006a. Equipment design processes in developing countries: cereal mill maintenance in Senegal. Article submitted to *J. Qual. Main. Eng*.

**Marouzé, C., Thaunay, P., Fliedel, G. & Cruz, J.-F.** 2006b. Designing a fonio mill; screening an operating principle and its validation. Article submitted to *Agric. Mech. Asia, Afr. & L. Am*.

**Ndiaye, A., Marouzé, C. & Giroux, F.** 2002. Cooperative design in developing countries. Case study of a rice grader to sort small brokens in Senegal. *Int. J. Des. Sci. & Technol*., 9(2): 131–143.

## A COMPETENCY-BASED QUALIFICATION PROGRAMME IN AUTOMATION TECHNOLOGY AND PROCESS CONTROL APPLIED TO AGRO-INDUSTRIES IN DEVELOPING COUNTRIES

*Chakib Jenane and Matthieu Tockert, UNIDO, Vienna, Austria*
*Theodor Niehaus, Festo Didactic Gmbh & Co. KG, Denkendorf, Germany*

### Abstract

The paper presents a competency-based qualification programme in automation technology and process control that aims to contribute to improving the skills and productivity in agro-based industries in developing countries. It defines a qualification or training programme to transfer the necessary know-how in basic technologies of automation and partly integrated or totally integrated automated systems in production automation and process control.

The proposed programme results from an industrial survey of 27 companies involved in the food, wood, textile and leather processing industries for which the technological standards and needs were evaluated. The survey was conducted in three countries, namely, Indonesia, Malaysia and Thailand, and the assessment covered the companies' profile, technology and production process, and the skills of their engineers/technicians.

The findings of the industrial survey showed that most companies assessed were facing problems of: (i) declining competitiveness in terms of quality and productivity; (ii) significant post-harvest losses; (iii) insufficiently qualified engineers/technicians; and (iv) lack of adequate technologies/processes to improve the efficiency of their plants. Based on these findings, a competency-based qualification programme in automation technology and process control applied for agro-industries offering demand-driven solutions was proposed. This programme is not only meant to enhance (or upgrade) the industrial competitiveness of developing countries, but rather involve them in the utilization and further development of available modern technology, such as mechatronics.

### Introduction

In many developing countries, the agro-industrial sector plays an important role in terms of its contribution to gross domestic product (GDP), employment and in improving the living conditions of the population generally. However, with the current challenges of global economic integration, technological advances and trade liberalization, this sector is faced with declining competitiveness with critical points such as:

- lack of product quality in general;
- outdated products that do not consider current market trends;
- poor designs that cannot compete internationally;
- inappropriate methods for goods preservation;
- production too expensive due to losses through waste and rejected goods;
- obsolete production methods and production equipment;
- inadequate production flexibility.

These deficiencies are mainly caused by factors such as:

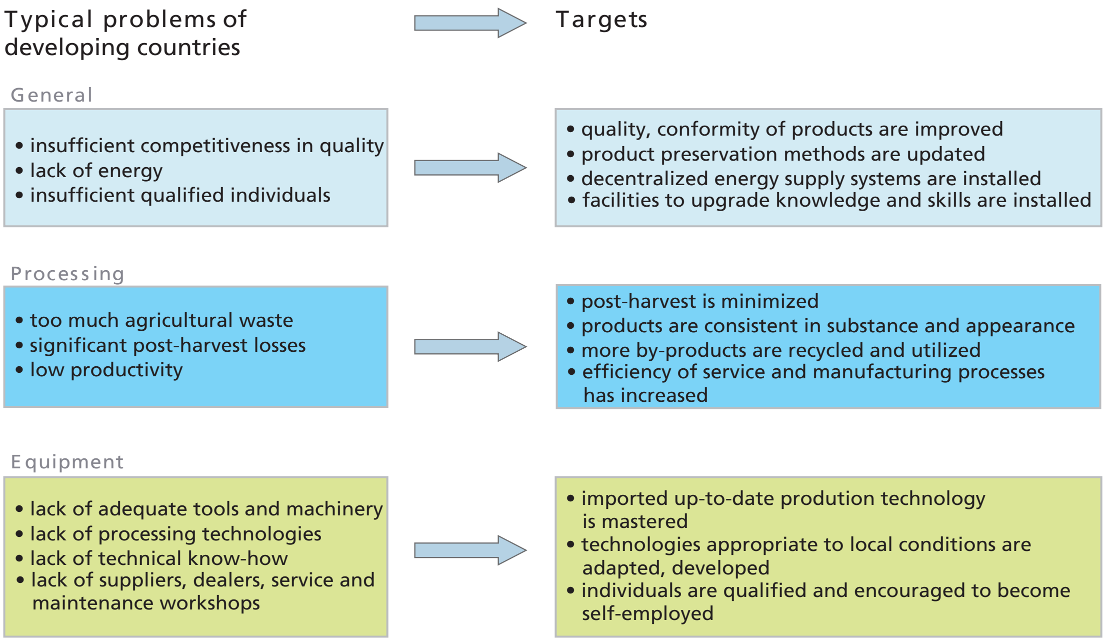
- lack of information and qualification of the acting individuals;
- lack of quality standards for processes and products;
- inability to take up new technologies to adjust to rapid changes of market trends;
- lack of management skills, e.g. modern marketing techniques or ability to act successfully in a free market environment.

In addition to these factors, there are indirect losses caused by negative environmental impacts of the production, by insufficient occupational safety, or by inefficient power consumption. Figure 3.3 presents a summary of typical problems and the targets to be reached by developing countries in order to improve the present situation of their agro-industrial sector.

A core issue of the above-mentioned problems is human resources development for economic and social progress. According to a World Bank report (Salmi, 2000), today's economic growth is as much a process of knowledge accumulation as of capital accumulation. It is estimated that in advanced countries, firms devote one-third of their investment to knowledge-based intangibles, such as training, research and development (R&D), patents, licensing, design and marketing. In knowledge-driven economies, ever-greater numbers of workers and employees need higher-level skills. This is confirmed by recent analyses of rates of return in a few Latin American countries (Argentina, Brazil and Mexico).

Some countries, e.g. Greece, Japan and Singapore, have customized training programmes for their technical and managerial labour /

FIGURE 3.3
**Some problems and targets of the agro-industrial industries of developing countries**




engineers to meet the development needs of their industries and businesses for the twenty-first century (Chamilothoris, 2004; JSPP21, 2005). A focus of these programmes is on the appropriate use of mechatronics technologies leading to cost-effective and high performance systems for the industry – an urgent necessity to respond to the rapidly evolving global challenges. Similarly, in Bangladesh, Hungary, South Africa, Switzerland, Viet Nam and other countries, the study of mechatronics and its implementation in industry is becoming a very important objective of the education sector (Bradley, 2004).

Mechatronics is defined as the synergetic combination of electronics, computer control and mechanical engineering in the design of products and processes. It covers the interfaces between these single technologies and their technical combination. By itself, it is not a technology, but rather a way of thinking and, therefore, the essential element of automation technology and process control (Eckart, 2006). Accordingly, mechatronics curricula have to be seen with the primary objective of developing the capacity of automation graduates to organize and resolve technological problems, preferably requiring inputs from a group of specialists or other technologists, in general (Chamilothoris, 2004).

While the specific training needs for the agro-industrial sector have witnessed significant transformations in advanced countries (technological innovation and application of mechatronics, demand patterns, etc.), this is not the case in most developing countries. This may be related to the fact that this sector covers several fields including a conglomerate of activities, procedures and products. This makes it difficult to define a uniform training approach. However, there are considerable consistencies, in particular in the area of technological fundamentals and cross-sectoral qualifications, that can be designed in a mechatronics course enabling practical integration. Figure 3.4 provides a non-exhaustive list of these, which can be divided into three categories: fundamentals; applied technologies; and product-specific technologies. The latter have to take into consideration the specific requirements of the country or the region.

This paper proposes a competency-based qualification programme in automation technology and process control (mechatronics) applied to agro-industries in developing countries. It is designed to be applied in a centre of excellence with a view to:

- providing knowledge and skills upgrading by imparting training;
- serving as a demonstration centre for basic and advanced technologies;
- mastering adequate tools, machinery and automation technology;

- identifying and transferring appropriate manufacturing techniques;
- providing technical assistance and advisory services;
- generating and disseminating technical and entrepreneurial information;
- having a lasting effect by creating multipliers of know-how;
- contributing to quality assurance by laboratory testing.

## Objective

Taking into consideration the rapid transformations around the world and the challenges facing developing countries, the main objective of this paper is, based on industrial demands, to define a flexible and modular training programme in automation technology and process control, targeting enhanced knowledge and skills to promote the competitiveness of the agro-industrial sector.

## Methodology – industrial survey

In order to be able to define an entire concept of competency-based qualification programme in automation technology and process control in the area of agro-industries, the demands and needs or the technological gaps of the industry have to be evaluated in advance. However, the agro-based industry is a huge sector and there are many developing countries. Thus, for the purposes of this study, the survey was limited to three Southeast Asian countries that are fast growing and embrace many agro-based companies (Indonesia, Malaysia and Thailand).

Field investigations in the form of interviews were carried out in 27 randomly selected companies, with an average of 200–1 000 employees, representing the main subsectors. Within the food subsector, 15 companies were surveyed, while 5 textile, 4 wood and 3 leather companies were visited. The industrial survey covered fundamental data including the company profile, production

FIGURE 3.4
**General qualification modules in agro-industries**

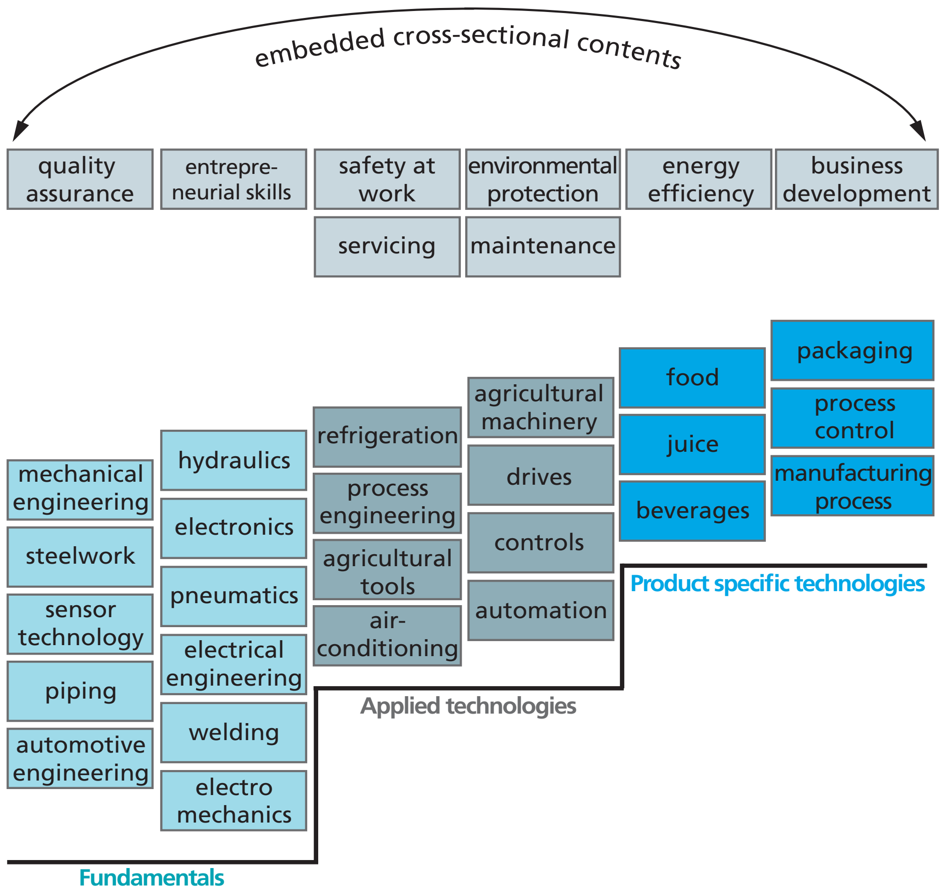
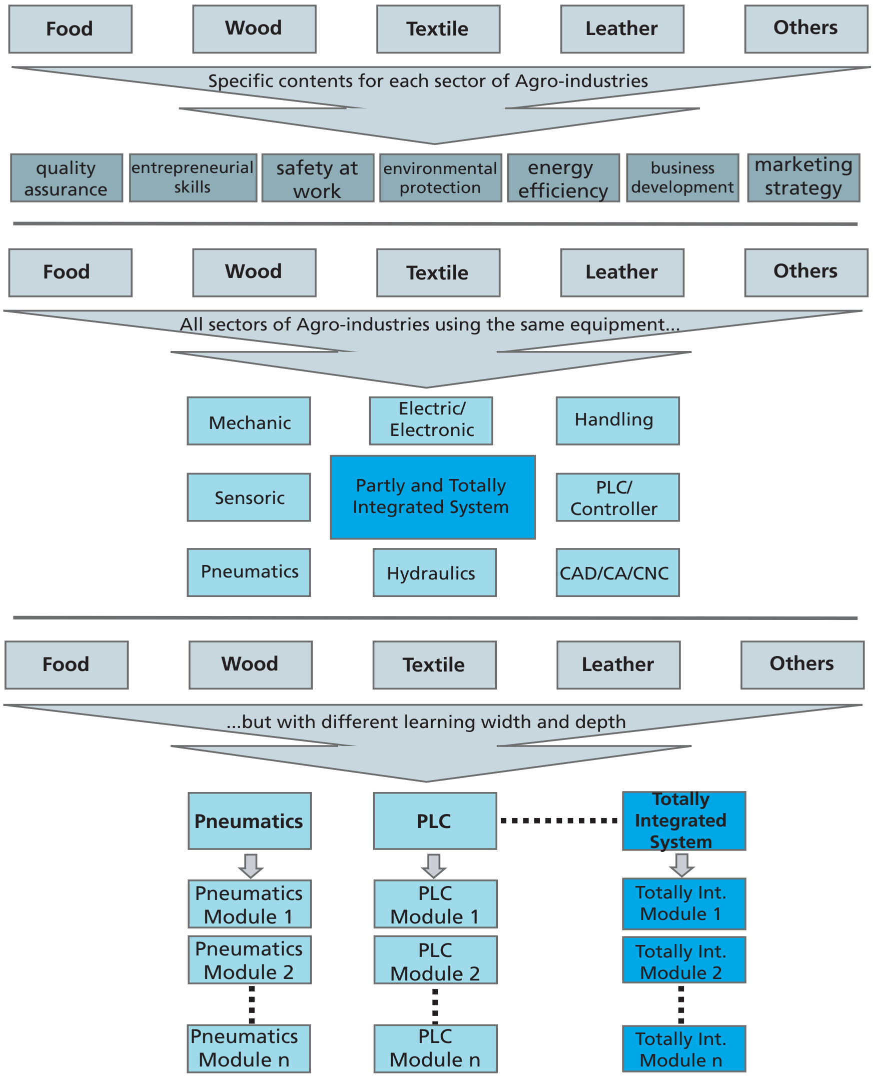


FIGURE 3.5
**Technology level and need according to surveyed sectors**




Note: CAD = computer aided design; CAM = computer aided manufacture; CNC = computer numerical control.

process, technology application, and labour / technician skills.

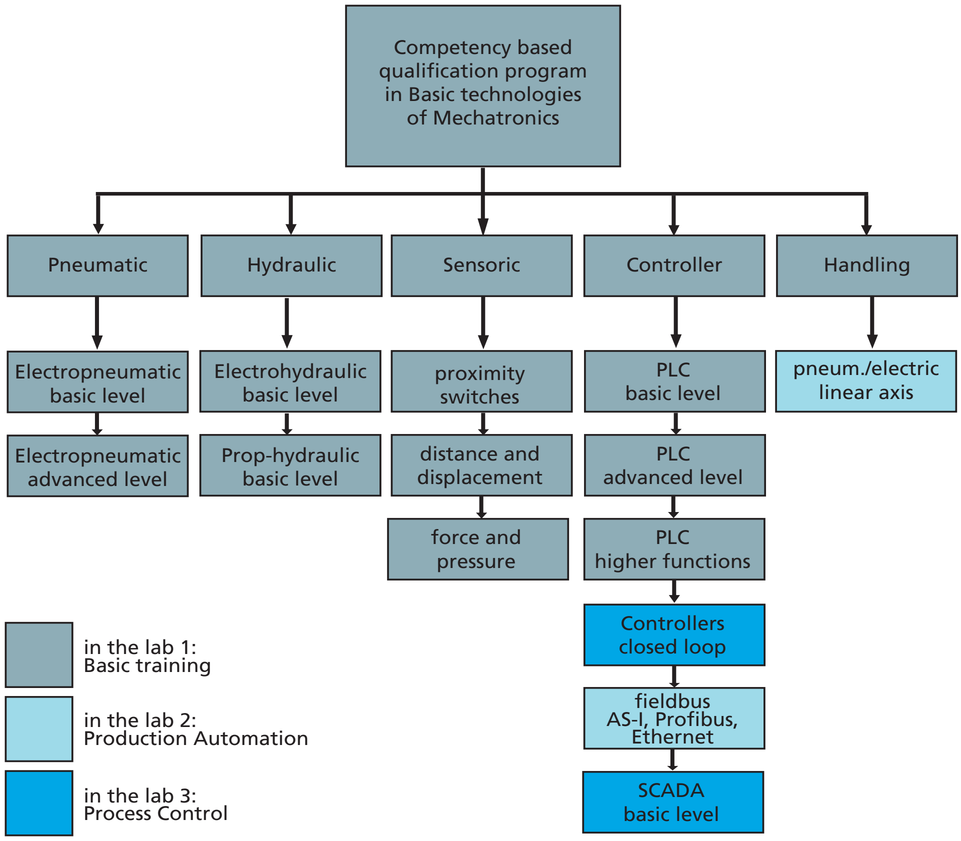
An important element of the survey was the evaluation of the level of automation in each subsector in order to determine any significant difference in the level of automation and process control based on the area or sector itself. Furthermore, in designing the questionnaire for the survey, the focus was not only on searching to develop a training course adopting automation technology and process control, but also to provide a programme of integrated interventions at sectoral level aimed at strengthening, establishing or rebuilding value chains from producer to local, regional and international markets (from pre-production activities to industrial processing and marketing).

## Findings of the industrial survey

Comparing the level of automation within surveyed companies, it can be seen that the level of hand-working, part and full automation is more or less the same within each sector, but varies between the sectors. The food subsector is the most automated. The leather industry (the shoe industry in particular) also has a high level of automation using industrial robots. For the wood and textile industry, the companies are mostly producing end-user products (e.g. furniture and garments), thus their level of automation is rather low. For the processing stage, it can be seen that the more a product is being processed, the more the companies are using fully automated systems.

Analysing the data for technology application, it can be seen that fluidics (pneumatics and

FIGURE 3.6
**Training needs in basic technology**




Note: ASI = actuator–sensor–interface; SCADA = Supervisory Control And Data Acquisition System.

hydraulics) is widely used within all subsectors. This is also the case of servo-fluids systems. However, it was expected that industrial process controls (PCs) would replace programmable logic controller (PLC) technology, but the findings of the survey contradicted this. Figure 3.5 summarizes the different needs and activities according to the product and the technological level / technologies used within the different parts/sectors.

Concerning education/skills data, it appeared that the educational level of the employees is rather low. Forty-five percent are vocational workers and only 9 percent possess a university degree. Furthermore, it seems that the educational training contents of occupational training institutes are not covering the needs of the agro-based industry. Only 55 percent and 27 percent of the companies, respectively, claim that the know-how and the skills of the graduates meet their needs.

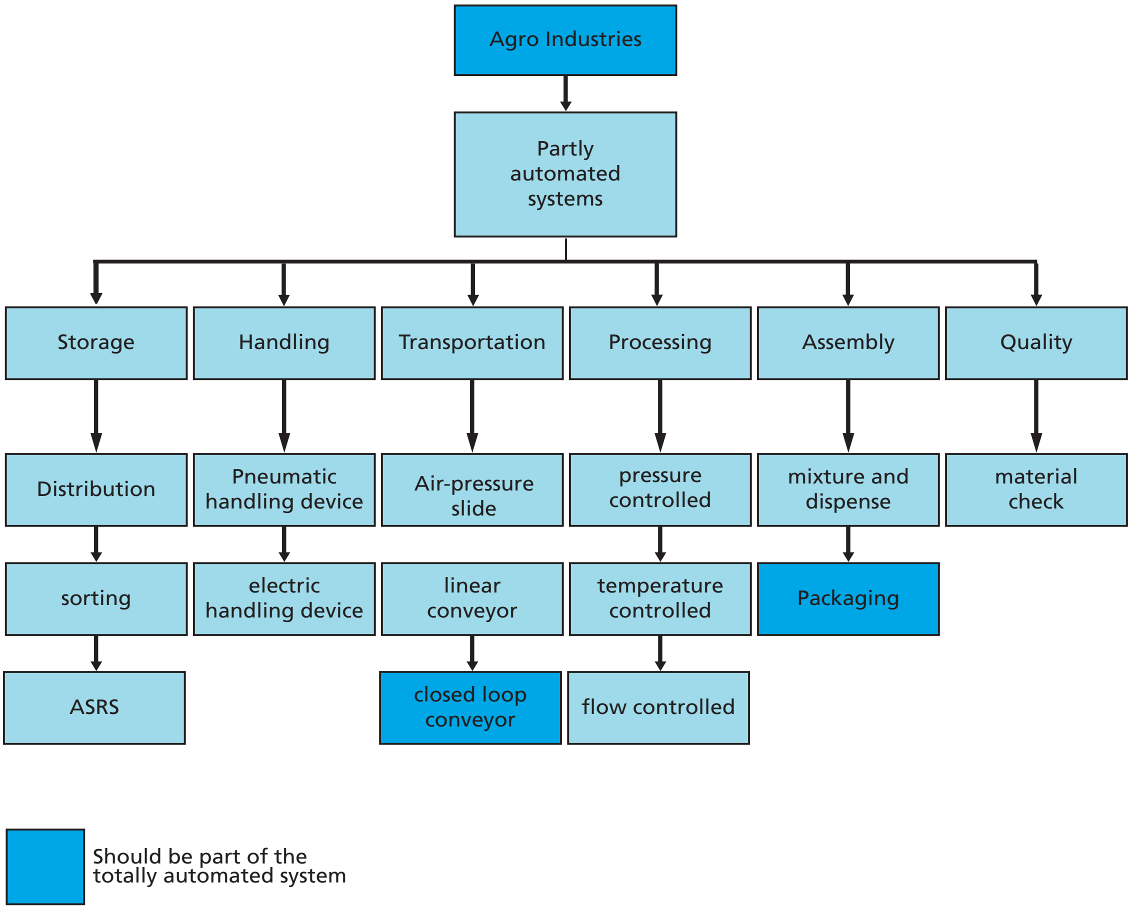
### Demand-driven solution – competency-based training programme

Based on the industrial survey findings, a competency-based training (CBT) programme on automation technology and process control was designed with a specific focus on the needs of the agro-industrial sector – enhancing the productivity. The CBT design has two central elements: (i) skills – a task or group of tasks performed to a specific level of competency or proficiency that often use motor functions and typically require the manipulation of instruments and equipment (some skills, such as counselling, are knowledge- and attitude-based); and (ii) competency – a skill performed to a specific standard under specific conditions.

### Basic technology needs

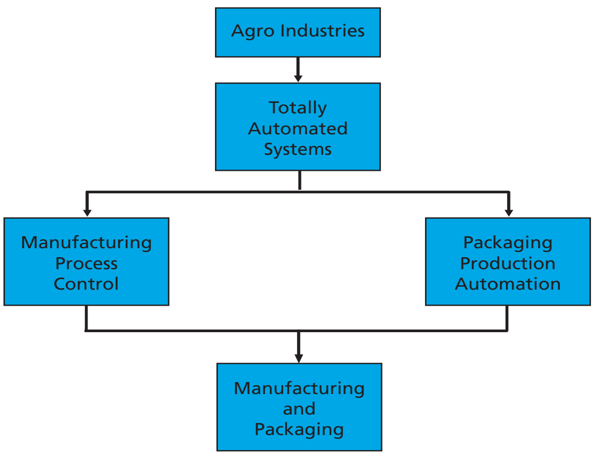
The basic technologies that should be part of the CBT are training modules of mechanics and electrics/electronics (Figure 3.6). These will be part of a partially or totally automated system in production automation or PC, and are integrated within a material-flow or a production-process

FIGURE 3.7
**Training structure for partly automated systems**




Note: ASRS = automated storage/retrieval systems.

FIGURE 3.8
**Training structure for fully automated systems**




step. The emphasis here should be application-oriented, by means of focusing on the needs as an integrated part of a material-flow and signal-flow through an entire system.

## Partly automated systems

Partly automated or integrated systems must represent at least one single process step within the industrial production. They should be a combination of single basic technologies and a mechatronics system. In comparison with basic training, the brainware, or teachware, must cover the different actions within a company to design, set up, programme, maintain and service a system. Figure 3.7 illustrates the needs.

## Totally automated systems

A totally automated system is a combination representing a process step in the industrial production, together with an entire automated system with a real material-flow and signal-flow. The important requirement is that the manufacturing process (based on PC) and the manufacturing / packaging process (based on production automation – PA) could be used as stand-alone or in combination (Figure 3.8).

### Conclusion

The global and regional trends in market and technology development constitute a serious challenge and opportunity for the growth of industries in the developing world. The present deficiencies, both in terms of technology and skills, result in enormous economic potential losses of value added and employment opportunities. Bridging this gap is an essential step towards achieving enhanced competitiveness for these industries. This could be achieved through the promotion of an unconventional approach that involves targeted industries in the utilization and further development of available modern technology, such as mechatronics technologies. In this respect, a competency-based qualification programme based on the actual needs of the industry is considered to be a powerful tool for rapidly meeting the challenge of industrial modernization in developing countries.

### References

**Bradley, D.** 2004. *What is mechatronics and why teach it?* Dundee, UK, University of Abertay.

**Chamilothoris, G.E.** 2004. *A participative approach to the teaching of mechatronics: learnings from the field*. 5th International Workshop on Research & Education in Mechatronics, Kielce.

**Eckart, W.** 2006. *A competency-based qualification program in automation technology and process control for developing countries*. Germany. Festo Didactic GmbH.

**JSPP21.** 2005. *Mechatronics system technology*. Japan-Singapore Partnership Programme for the 21st Century. JICA Office in Singapore.

**Salmi, J.** 2000. *Tertiary education in the twenty-first century: challenges and opportunities*. World Bank.

## PRODUCT DEVELOPMENT SYSTEMS FOR AGRIFOOD INNOVATION IN DEVELOPING AND TRANSITION COUNTRIES

*Ray Winger, Institute of Food, Nutrition and Human Health, Massey University, New Zealand*

### Abstract

The world food industry is worth more that US$2 trillion (US$2 × $10^{12}$) annually. Consumer preferences are largely shaped by income levels; with higher incomes tending to lead to greater consumption of meat and dairy products in developing countries. In developed countries, the trend is more towards labour-saving or ethically-oriented products. Product development (PD) is the lifeblood of the food industry, the PD process is described. Innovation in PD is contextual and depends on location and the range of products currently in a given market. Important (both positive and negative) factors in PD are reviewed. The global market for processed food is discussed and reasons are suggested for the slowdown in trade since the mid-1990s. Overstretched supply chains are one factor forcing more local production. The importance of value-added food products to national economies is discussed with reference to examples from Greece, Chile and New Zealand.

### Introduction

The food industry is present in each and every country, and the food share of total household expenditures amounts to 10–14 percent in high-income countries and 40–50 percent in low-income countries. Therefore, the global food industry is one of the largest, if not the largest, industries in the world. Global retail food sales (for which data exist) exceed US$2 trillion (US$2 × $10^{12}$) per annum.

Market size, as indicated by retail sales value, is much larger for developed countries. The United States of America, the European Union, and Japan together account for more than 60 percent of total retail processed food sales in the world. However, market growth has generally been faster among developing countries, particularly lower-middle-income countries such as China, Morocco, the Philippines, and many Eastern European countries. The transitioning Eastern European countries, such as Bulgaria, Romania and Ukraine, experienced double-digit growth in retail sales of many food and beverage products during the late 1990s. While sales in these markets have stabilized, Asian markets have picked up in the past few years and processed food product sales are expected to continue to increase significantly.

Consumer preferences, shaped primarily by incomes, changing lifestyles, and evolving cultural preferences, largely determine the items available in grocery stores in different markets. In developing-country markets, higher incomes may result in diet upgrades, with increased demand for meats, dairy products, and other higher value food products. These include packaged cereals, pasta, oils, and other items used in meal preparations. In the developed-country market, when consumers already consume sufficient quantities of these items, sales growth is noted for labour-saving products, such as prepared meals. Food sales in developed country markets are also being influenced by consumer preferences for greater product variety and food products possessing specific attributes, for example, products perceived to be safer or more healthy, or products produced in ways that are more beneficial to the environment and take animal welfare and equitable labour concerns into consideration.

In the food industry, just as any other industry, product and process development is considered a vital part – indeed the lifeblood – of smart business strategy. Failure to develop new and improved products relegates firms to competing solely on price, which favours the players with access to the lowest cost inputs (land, labour, etc). Adopting a low-cost strategy can have unexpected consequences for the economy as a whole when another country with a lower cost structure enters the market.

Consumers' demands keep changing over time. These changes range from basic considerations, such as improving food safety, shelf life, and reducing wastage, to demands for increasingly sophisticated foods having special characteristics in terms of nutritional value, palatability, and convenience. The actual product development process is determined by the interaction between consumer expectations and demand, the technical capacity of the food producer, and emerging knowledge from food science research.

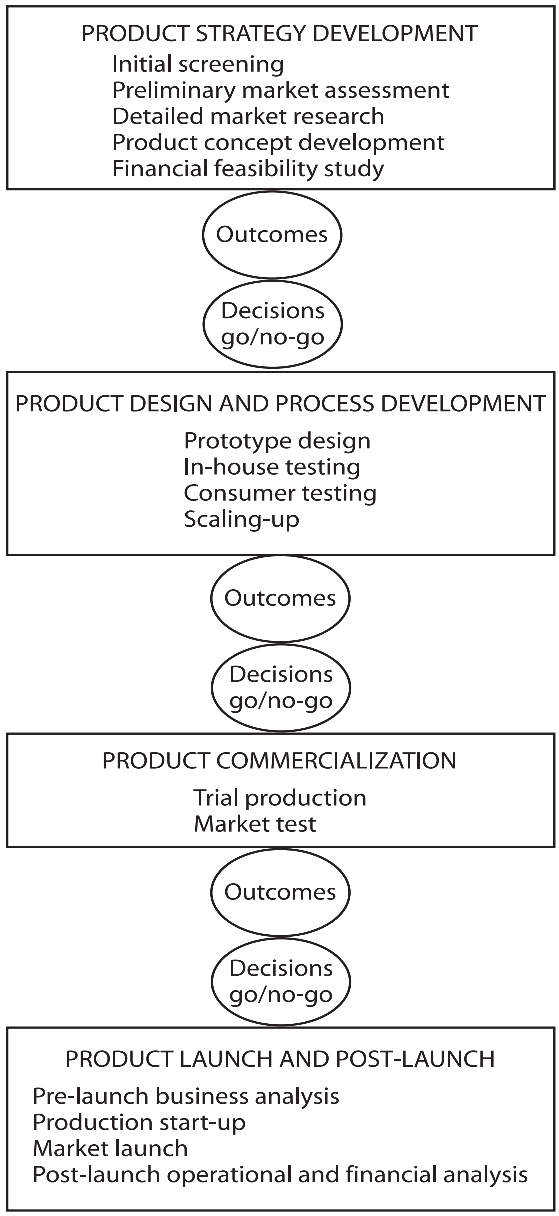
**Product and process development**

Product and process development (commonly referred to as product development or PD) is systematic industrial research to develop products and processes satisfying a known or suspected consumer need. PD is a method of industrial research in its own right. It is a combination and application of natural sciences with the social sciences – of food science and processing with marketing and consumer science – into one type of integrated research whose aim is the development of new products. There are essentially four basic stages in these models for every PD process:

- product strategy development;
- product design and development;
- product commercialization;
- product launch and post-launch.

Each stage has activities that produce outcomes (information) upon which management decisions are made (Figure 3.9).

FIGURE 3.9
**Schematic of the overall product development process**




Sources: Siriwongwilaichat (2001); adapted from Earle and Earle (2000).

There are many ways to classify the degree of newness of a product. One useful example uses seven categories:

- creative products;
- innovative products;
- new packaging of existing products;
- reformulation of existing products;
- new forms of existing products;
- repositioned existing products;
- line extensions.

Siriwongwilaichat and Winger (2004) found that in Thailand between 1996 and 1999 new food products launched could be classified as: innovative completely new products (ICNPs) (9 percent); products new to the company (PNC) (25 percent); value added products (VAPs) (25 percent); and line extensions (LEs) (40 percent).

Crucial to the discussion of PD is to recognize that “innovation” is contextual. The consumers’ perception of product newness depends on the location of the consumer and the types of food products currently or recently on the market. For example, Asian food products were new products in Western supermarkets in the early 1990s, but they were well-established and traditional products in Asia.

The challenge for PD is to develop a product that is acceptable to the target consumer. For example, ice cream flavours found in Asia (e.g. coconut, mango, durian and corn) are not popular in western countries, which normally feature chocolate, vanilla and strawberry flavours. Even countries of seemingly similar culture can have major differences. For example, Australians prefer mango flavours in their foods (such as cereals and muesli bars) whereas New Zealand consumers prefer berry fruits in similar products. A recent launch of coloured ketchup in the United States of America was a tremendous success for Heinz, whereas the same launch in Australia and New Zealand was a major failure.

The key principle in PD, which differentiates this research from all other natural science research, is the mandatory need to ensure the development meets a consumer demand. Without a market, no matter how innovative the change, there will be no sales and the product will be worthless.

A major feature that distinguishes food product development from other forms of PD is the ethical considerations of producing a large volume of safe food for human consumption. This is coupled to the fact that food raw materials are labile, unstable and must be stored for prolonged periods of time prior to processing and consumption.

### Product development in the food industry

Supermarkets in Australia (population 19 million) and New Zealand (population 4 million) have about 12 000–25 000 food and beverage stock-keeping units (SKUs) on their shelves. In the United States of America (population 283 million) and Europe (population 729 million), this number may extend to as high as 40 000. Typically in Australia / New Zealand, 5 000–10 000 “new” products are offered to these supermarkets each year (about 18 000 a year in the United States of America), and about 10 percent are chosen to be displayed on the shelves. New introductions to the shelves are almost always linked to the discontinuation of another product. Of the 500–1 000 new products introduced by the supermarkets each year, less than 1 percent will still be on the shelves in five years’ time.

The food industry is a low-tech industry – meaning it has a low level of research and development (R&D) expenditure. It is also an industry in which it is difficult to distinguish between products. There are few barriers to market entry and it is hard (although not impossible) to use patents or other forms of intellectual property rights in the food sector. So, product characteristics are copied by competitors, who produce “me-too” products. There is a low rate of radical change, and coupled with the high failure rate of food products following market launch, this requires that the methodology for new food product development needs to become focused, quantitative, rapid and knowledge-based (Stewart-Knox and Mitchell, 2003).

### Important factors in the product development process

The food industry appears to be populated with companies that prefer to re-develop existing products (incremental change) rather than create new products (radical change). Because food product development is considered a highly risky venture, the incremental change strategy may be an attempt to increase success rates. Ironically, this apparently “safe” approach perpetuates the problem of high food-product failure as truly innovative products are often more successful for a company (Stewart-Knox *et al*., 2003).

Product success is dependent on several factors during the product development process (De Brentani and Kleinschmidt, 2004; Stewart-Knox and Mitchell, 2003):

- the product being unique and superior;
- good understanding of consumer wants, needs and preferences;
- an open and innovative global new product development (NPD) culture;
- commitment of sufficient resources to the NPD programme;
- cross-functional teams;
- effective communication between PD team personnel;
- careful planning at the concept stage of PD;
- top management support;
- involvement of senior personnel;
- thorough market research;
- effective product marketing and launch.

That food (not only the type of foods eaten, but also how food is produced, prepared and used) is deeply rooted in many cultures implies that there are likely to be cross-cultural differences in terms of factors for success in food product development. Therefore, success factors from one country do not necessarily translate well in another country (Costa, Dekker and Jongen, 2001; De Brentani and Kleinschmidt, 2004; Stewart-Knox and Mitchell, 2003).

On the other hand, factors that are associated with product failure have been reported as:

- lack of market knowledge, e.g. due to poor market research;
- misdirected marketing efforts;
- dynamic and competitive markets;
- inadequate market size;
- resistance by marketing staff;
- technical problems;
- high prices;
- distribution problems;
- internal conflicts.

It seems that product failure is most closely linked to inadequacies within predevelopment activities (Stewart-Knox and Mitchell, 2003; Ilori, Oke and Sanni, 2000).

### Economic impact of food product innovation

Agricultural production has become progressively more mechanized, efficient and cost-effective over the last 80 years (Hennessy, 2004). One of the key economic drivers is the relative impact of cost seasonality of production – regions with strong seasonal cost advantages will tend to produce lower value products. An increase in demand for more processed food products induces a shift towards non-seasonal production.

Whereas agricultural production is captured by the region or country where it is grown, other sectors (such as equipment/machinery, banking and biotechnology) represent portable opportunities and ideas. Agricultural production, with the exception of fresh fruit and vegetables, is generally processed where it is produced and cannot be readily relocated to another country or region.

The expansion into international markets is invariably driven by the food-processing sector, not the traditional agricultural or commodity-based raw materials (Athukorala and Sen, 1998; Martin, 2001; Rae and Josling, 2003). Commodity producers are finding that an increasingly difficult and competitive environment is driving down commodity prices, especially where products are not differentiated (Barone and DeCarlo, 2003).

Between 1975 and 1985, the global processed food trade increased by 5 percent/year. This increased to 9.4 percent/year from 1985 to 1995. In 1985, processed foods accounted for 55 percent of the total value of agricultural exports from developed countries, but only 40 percent of those from developing countries. By 1995, processed foods represented 66 percent of the agricultural exports from developed countries and 56 percent of those from developing countries (Rae and Josling, 2003). The reasons for the growth of processed foods in world trade are complex, but Athukorala and Sen (1998) suggested the "internationalization of food habits", increased importance and consumer demand for processed food, international migration, tourism and others may have provided a strong demand for growth in developing countries. Improvements in food technology, refrigeration facilities, transportation and supply chain management have made processed food items readily tradable across national boundaries.

There are some good examples of innovative and effective PD in developing countries, such as the Royal Project in Thailand (FAO, 1996) or the value-added food products processing in Myanmar (Kyi, 2002).

Countries with processed food growths greater than 15 percent/year include Bangladesh, Bolivia, Chile, Indonesia, Malaysia, Republic of Korea, and Thailand. There is convincing evidence that domestic policy regime is the key determinant of the expansion of manufacturing exports from developing countries. There was a stronger correlation between growth in manufacturing exports and processed food exports than there was between processed food exports and exports of primary products.

Athukorala and Sen (1998) emphasized the "spread effects" of the processed food industries in developing countries. Processed food industries have a large domestic resource content. By contrast, the production of conventionally manufactured non-food exports from developing countries is generally highly import dependent.

In a more recent study, Regmi and Gehlhar (2005) report that, contrary to initial expectations, the phenomenon of a growth in export of processed foods has not led to significant growth in global trade. Only 6 percent of processed food sales are traded compared with 16 percent of major bulk agricultural commodities. Although consumer demand for processed foods continues to grow globally, growth in trade has generally stalled since the mid-1990s. Global trade in processed food grew rapidly during the 1970s and 1980s, as consumers in high-income countries demanded more foreign food products. Through the mid-1990s, these products accounted for a bigger share of growth in agricultural exports of the United States of America, with expanding exports to Japan, Canada and Mexico. However, since the mid-1990s, growth in both global processed food trade and that of the United States of America has slowed, and bulk agricultural commodities have accounted for more of the recent growth in agricultural exports from the United States of America.

The slow growth in trade of processed food products has often been attributed to existing multilateral trade rules that favour trade in raw commodities at the expense of processed products. However, trade policy is not the whole story. Many other factors affect the choice of locations to produce and sell food products. Patterns of food trade are strongly influenced by the changing nature of competition in the global food industry, which is influenced by factors such as shifting consumer preferences and the growth in multinational food retailers, and the ways they manage their global supply chains. Consumer-driven changes are increasingly pushing food suppliers to meet consumer demand and preferences at a local level, even as the food industry becomes more global. The product life cycle for processed foods has become progressively shorter – most products show a cycle of 6–12 months. Therefore, international distribution pathways and supply chains are too long for companies to risk final product preparation unless it is close to market. Local processing allows manufacturers to strategically tailor both manufacturing and packaging to suit local tastes, preferences, and retailer needs. The result of this trend has been an acceleration in foreign direct investment (FDI), often at the expense of trade. As a case in point, food companies based in the United States of America sell five times (US\$150 $\times 10^9$) more through FDI sales than through export sales (US\$30 $\times 10^9$).

It is also worth noting that food companies such as Nestle, Unilever and Kraft are truly global – having manufacturing sites all around the world. However, retail giants, such as Carrefour, are only regional. There are no truly global retailers.

Mattas and Shrestha (1989) described the impact of the food sector in Greece – an economy heavily dependent upon its natural abundance of food. They emphasized the interdependence of economic sectors. As background for this discussion, in Greece in 1980:

- agriculture constituted roughly 21 percent of output;
- the food sector comprised 10 percent of value of exports;
- agriculture employed 33.6 percent of the labour force;
- raw and processed foods constituted 21.4 percent of the national economic demand.

These authors reviewed the potential for the food sector to stimulate economic growth and development. The output multiplier (or total effect) of stimulating output for the national economy (average across all sectors) was 1.30. This means that an expansion of US\$1 $\times 10^6$ in the whole economy's final demand would generate an additional output of US\$1.3 $\times 10^6$.

A comparison across all the key economic sectors for the Greek economy in 1980 is shown in Table 3.1.

The overall output multiplier was high for the processed food sector. The interdependence of many different sectors with the food sector results in a major impact on the overall economy (as displayed by the multiplier). For example, an increase of US\$US1 $\times 10^6$ in income from the processed food sector would generate US\$4.26 $\times 10^6$ of income in the economy and an analogous increase in employment. This was the highest multiplier of any sector.

This paper exemplifies the critical economic impact of the processed food industry on a small economy that is based on agriculture. The leverage for the economy as a whole, from stimulating the expansion of the food sector, was clearly seen.

Using Chile as the example, Athukorala and

TABLE 3.1
**Potential of sectors to stimulate final demand and economic growth in Greece, 1980**

| Sector | Output | Income | | Employment | |
|---|---|---|---|---|---|
| | Multiplier or total effect | Total effect | Multiplier | Total effect | Multiplier |
| Raw food | 1.27 | 0.64 | 1.12 | 2.87 | 1.11 |
| Processed food (including beverages) | 1.79 | 0.34 | 4.26 | 1.53 | 4.65 |
| Tobacco | 1.31 | 0.14 | 2.54 | 0.67 | 2.94 |
| Mining | 1.17 | 0.54 | 1.07 | 0.83 | 1.16 |
| Textiles | 1.45 | 0.30 | 1.62 | 1.33 | 1.79 |
| Furniture | 1.79 | 0.24 | 1.68 | 1.12 | 1.58 |
| Machinery | 1.29 | 0.24 | 1.32 | 0.95 | 1.32 |
| Construction | 1.39 | 0.34 | 1.39 | 1.47 | 1.22 |
| Trade | 1.18 | 0.28 | 1.11 | 2.06 | 1.08 |
| National economy | 1.30 | 0.40 | 1.36 | 1.72 | 1.33 |

Source: Modified from Mattas and Shrestha (1989).

TABLE 3.2
**Freight-on-board value of New Zealand food exports**

| | Value (NZ$ × $10^6$) for years ending June 30 | | | | |
|---|---|---|---|---|---|
| Food type | 2000 | 2001 | 2002 | 2003 | 2004 |
| Value added | 5.28 | 6.71 | 7.41 | 7.60 | 8.11 |
| Commodity | 6.57 | 8.80 | 8.68 | 6.67 | 6.92 |
| Total | 11.85 | 15.51 | 16.09 | 14.27 | 15.03 |

Sen (1998) studied the relative importance of market-oriented policy reforms and industrial restructuring on economic development. One of the key factors of the spectacular Chilean growth in the 1980s was the expansion of exports. While many reports have focused this success on the "primary sector", these authors evaluated the International Industry Classification codes of exports from Chile and concluded that the impetus for export expansion had clearly come from "agro-based manufacturing activities" – not the traditional primary goods. These results were compared with 37 countries where data were available and complete for the years 1970–1994. Results included:

- manufacturing exports increased from 66 to 81 percent of total exports;
- manufacturing share in developing countries increased from 27 to 79 percent;
- developing countries' share of manufacturing exports increased from 6 to 24 percent;
- processed food as a percentage of manufacturing exports increased from 26.2 to 36.7.

The dynamic nature of added-value food exports on an economy that is heavily dependent upon agricultural inputs has been defined by Winger (2005). Using the Harmonized System Classification of exports, food and agricultural products exported from New Zealand were assessed in terms of commodities and added-value products. Given that these products represent 50 percent of New Zealand's manufacturing income, their importance can be compared with developing countries with a strong agricultural base. An annual comparison was made from 2000 to 2004 (the only years with consistent export classification). Table 3.2 summarizes the results.

Clearly, the importance of innovation and adding value to food products at a country level is important in export marketing. While there were fluctuations in export earnings from commodities (e.g. from 2002 to 2003), the income returns from added-value products kept increasing every year. The proportion of added-value products increased from 44.5 percent of exports in 2000 to 54 percent of exports in 2004.

## Conclusions

The features of the food industry are:

- There are a large number of new products offered to retailers each year, and inclusion of a new product almost always leads to discontinuation of another product.
- Only a very small proportion of new products are radical changes, the majority are incremental changes.
- Of the order of 75 percent of new products are considered to be failures.
- In comparison with other industries (e.g.

electronics and biotechnology), there is a very low level of R&D undertaken.

When the economic impact of the food industry was examined, it was determined that:

- Economies that are heavily reliant on agriculture showed that expansion of the food sector greatly expanded all sectors of the economy. The analysis also showed that there was a much greater influence on the non-food sector from stimulating the processed food sector, rather than the raw material (agriculture) sector.
- Exports of processed foods as a proportion of total agricultural exports grew markedly in a wide range of countries up to the mid-1990s.
- There was a stronger correlation between growth in manufacturing exports and processed food exports than there was between processed food exports and exports of primary products.

It is clear that the food industry is an important economic actor in every country, and that PD is a key feature of companies' strategies to remain competitive and to grow.

## References

**Athukorala, P. & Sen, K.** 1998. Processed food exports from developing countries: patterns and determinants. *Food Pol.*, 23: 41–54.

**Barone, M.J. & DeCarlo, T.E.** 2003. *Emerging forms of competitive advantage: implications for agricultural producers*. MATRIC Research Paper 03-MRP 5. Midwest Agribusiness Trade Research and Information Center, Iowa State University (available at www.matric.iastate.edu).

**Costa, A.I.A., Dekker, M. & Jongen, W.M.F.** 2001. Quality function deployment in the food industry: a review. *Trends in Food Sci. Technol.*, 1: 306–314.

**De Brentani, U. & Kleinschmidt, E.J.** 2004. Corporate culture and commitment: impact of performance of international new product development programs. *J. Prod. Inn. Man.*, 21: 309–333.

**Earle, M.D. & Earle, R.L.** 2000. *Building the future on new products*. UK, Leatherhead Publishing. 112 pp.

**FAO.** 1996. *Agro-industry for the development of small farmers: a case study of the Royal Project Food Processing Section*. Prepared by the Industrial Management Co., Ltd and King Mongkut's Institute of Technology Thonburi, Thailand. Rome.

**Hennessy, D.A.** 2004. *Product development, cost seasonality, region marginalization, and a more demanding consumer*. Center for Agricultural and Rural Development, Iowa State University (available at www.card.iastate.edu).

**Ilori, M.O., Oke, J.S. & Sanni, S.A.** 2000. Management of new product development in selected food companies in Nigeria. *Technovation*, 20: 333–342.

**Kyi, D.W.W.** 2002. *Value-added food products processing for micro-income generation of rural communities in Myanmar*. Project MYA/99/007. Myanmar, FAO/UNDP.

**Martin, M.A.** 2001. The future of the world food system. *Outl. Agric.*, 30(1): 11–19.

**Mattas, K.A. & Shrestha, C.M.** 1989. The food sector and economic growth. *Food Pol.*, 14: 67–72.

**Rae, A. & Josling, T.** 2003. Processed food trade and developing countries: protection and trade liberalization. *Food Pol.*, 28: 147–166.

**Regmi, A. & Gehlhar.** 2005. Processed food trade pressured by evolving global supply chains. *Amb. Wav.*, 3(1): 12–19 (also available at www.ers.usda.gov).

**Siriwongwilaichat, P.** 2001. *Technical information capture for food product innovation in Thailand*. New Zealand, Massey University. (PhD thesis)

**Siriwongwilaichat P. & Winger, R.J.** 2004. Technical knowledge for food product innovation in Thailand. *Agribusiness*, 20(3): 233–252.

**Stewart-Knox, B. & Mitchell, P.** 2003. What separates the winners from the losers in new food product development? *Trends in Food Sci. Technol.*, 14: 58–64.

**Stewart-Knox, B., Parr, H., Bunting, B. & Mitchell, P.** 2003. A model for reduced fat food product development success. *Food Qual. Pref.*, 14: 583–593.

**Winger, R.J.** 2005. *A study into the level of added-value products in New Zealand food and beverage exports*. Report for New Zealand Trade & Enterprise, New Zealand.

## STUDY OF RESOURCE RECYCLING BASED SUSTAINABLE AGRICULTURAL DEVELOPMENT IN THAILAND: THAI–JAPANESE JOINT VENTURE AGRIBUSINESS

*Kasinee Muenthaisong and Takashi Toyoda, Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology, Japan*

### Abstract

Agricultural sustainability embraces the production, economic and marketing systems, and environmental and development policies. A theoretical conceptual framework is proposed for joint venture agribusiness when making decisions about sustainability on the basis of technical and economic efficiency. The economics model incorporates the Cobb–Douglas production function. Sustainability is measured for a sample of asparagus producers contract farming with a joint venture company. The costs of the environmental impact on soil and water are considered together with development policy implications in the context of sustainability. Results indicate that the labour, inorganic and organic fertilizer, seed, fuel and agrochemical input factors have a significant effect on asparagus production. The elasticity value is > 1, indicating an increasing return to scale. The technical and economic efficiencies of each factor show that farmers should increase or decrease their use in each case in order to reach the optimal utilization of each factor and obtain maximum profit. The environmental costs of asparagus production are calculated and analysed.

### Introduction

Japan is an important partner of Thailand's agriculture sector, being both importer and large-scale investor. Thai–Japanese joint venture agribusiness is successful on many fronts. The contribution of Japanese agribusiness has been not only to standardize the supply chain of Thai agricultural products for easy access to the Japanese market, but also to improve the living standards of local farmers and to reduce the environmental impact resulting from the contract farming system.

The important issues of the use and conservation of natural resources and environment have not been clearly studied to date. Further study is needed to clarify the impact of a Thai–Japanese joint venture asparagus production agribusiness on natural resources and the environment.

Assessment of the impact on natural resources and the environment arising from growing asparagus under this arrangement will give the necessary information to enable systematic and effective management and conservation of natural resources.

### Objectives of study

The objectives of the study were:

- to investigate the impacts on natural resources and the environment of the marketing and production systems for asparagus export;
- to assess the direct and indirect costs of asparagus growing on the environment and natural resources;
- to indicate the way forward in terms of policies and mitigation of the negative impacts on natural resources and the environment resulting from asparagus production.

### Methodology

An economics model for assessing environmental cost was applied. The model used in the study has four aspects:

- Consideration of the production system of asparagus growing to show the relationship between the various production factors.
- Consideration of the cost structure system and private profitability through analysis of the costs to farmers and the rate of return received.
- Consideration of the environmental impact arising from asparagus farming through an analysis of the impact on soil and water resources from an economic perspective. This is done by calculating the social cost through non-market values and environmental cost methods.
- Consideration of policy implications arising from the cost data. The environmental impact assessment includes the net social profitability and social price from growing asparagus as well as suggestions for environmental management through fiscal measures.

The study focus is in the locality of Nakhon Pathom Province, Thailand. All data and information used in the analysis were gathered from detailed interviews with 60 farmers who cultivated asparagus for export in the 2003 season.

## Results and discussion

The first objective of this study was to estimate the input–output relationship of asparagus production in Thailand. This was achieved by using a Cobb–Douglas production function for estimating the technical efficiency of asparagus production for export (Cobb and Douglas, 1928).

The estimated production function of asparagus exporting farms can be written in Cobb–Douglas form as:

$$Y = 0.325\, X_1^{0.155*} X_2^{0.204*} X_3^{0.414*} X_4^{0.175*} X_5^{0.820**} X_6^{0.031**} \quad (1)$$

(3.797)** (8.257)** (2.007)**

$$\ell nY = A\,(=-1.123) + 0.155\ \ell nX_1 + 0.204\ \ell nX_2 + 0.414\ \ell nX_3 + 0.175\ \ell nX_4 + 0.820\ \ell nX_5 + 0.031\ \ell nX_6 \quad (2)$$

$R2$ -adjusted = 0.85, F-test = 59.36 *

where:

- $Y$ = asparagus yield (kg/ha);
- $X_1$ = human labour (person-days/ha);
- $X_2$ = chemical fertilizer used (kg/ha);
- $X_3$ = organic fertilizer (kg/ha);
- $X_4$ = pesticide (US$/ha);
- $X_5$ = seed (US$/ha);
- $X_6$ = fuel (US$/ha);
- $A$ = constant coefficient = -1.123;
- *ln* = natural logarithm;
- * = significant at p = 0.05;
- ** = significant at p = 0.10.

All variables were expressed in natural logarithms, the F-tests indicated the joint significance of all independent variables; and the value of the adjusted $R^2$ was relatively high at 0.85. All the input variables had the expected signs and their coefficients were statistically significant at the 5-percent level or 10-percent level. From the Cobb–Douglas production function (Equation 2), $A = -1.123$. This constant, as it is negative, indicates that without the use of the six inputs (labour, chemical fertilizer, organic fertilizer, pesticide, seed, and fuel) in the production process, we would expect an asparagus yield of 0 kg/ha.

Heady and Dillon (1961) state that the Cobb–Douglas production function can be used to measure the returns to scale. The returns to scale show the change in output relative to a proportional change in all inputs. The regression coefficient for each factor can be interpreted directly as elasticity. The sum of regression coefficients of production is a measure of return to scale. This is a functional form of the Cobb–Douglas production function:

$f(K,L) = bK^aL^c$

where:

- $K$ = capital;
- $L$ = labour;
- if $a + c = 1$, production function has constant return to scale;
- if $a + c < 1$, returns to scale are decreasing;
- if $a + c > 1$, returns to scale are increasing.

Assuming perfect competition, $a$ and $c$ can be shown to be the share of labour and capital in output. The result reveals that the production function shows increasing returns to scale. That is, an increase of 1 percent in each of the six inputs would result in a greater than 1-percent increase in asparagus output. Equation 2 shows a positive relationship between all variables and asparagus produced. This is due to an increasing effect on asparagus yield as a result of applying the variables.

The Cobb–Douglas production function can be applied to utility. Economic efficiency occurs when the ratio of the marginal value product (MVP) of each input to its marginal factor cost (MFC) is equal to one (MVP/MFC = 1). If the magnitude of the ratio deviates from one, it indicates inefficient allocation of resources (Heady and Dillon, 1961). A situation in which the MVP of an input is less than its price means that the factor of production is overutilized. On the other hand, if the MVP of an input is greater than its price, then the factor of production is being underutilized. The relationship can be expressed mathematically as:

| | | | |
|---|---|---|---|
| | MVPxi | = | Pxi |
| | MVPxi | = | (MPPxi) (Py) |
| then | (MPPxi) (Py) | = | Pxi |
| or | MVPxi / Pxi | = | 1 |

where:

- MVPxi = marginal value product of input i;
- MPPxi = marginal physical product of input i;
- Py = output price;
- Pxi = price of input i;
- i = 1, …………….n.

If:

- MVPxi / Pxi < 1 = the input i of production is overutilized;
- MVPxi / Pxi = 1 = absolute efficiency has been achieved in the economics of the particular input of production;

TABLE 3.3
**Marginal physical products, marginal value products, and marginal factor costs for six asparagus production inputs**

| Variable | Elasticity | MPP | MVP | MFC or Price | MVPxi / Pxi |
|---|---|---|---|---|---|
| | | | | (US$) | |
| Labour | 0.155 | 4.9592 | 5.90 | 3.00 | 1.97 |
| Chemical fertilizer | 0.204 | 2.3420 | 2.79 | 3.34 | 0.84 |
| Organic fertilizer | 0.414 | 0.5161 | 0.61 | 0.08 | 7.63 |
| Pesticide | 0.175 | 16.3997 | 19.52 | 1.00 | 19.52 |
| Seed | 2.909 | 143.0306 | 170.21 | 1.00 | 170.21 |
| Fuel | 0.031 | 5.4073 | 6.44 | 1.00 | 6.44 |

Source: Authors' calculations, 2003 field survey.

TABLE 3.4
**Yields, prices, production costs, returns and profitability of asparagus production in 2003**

| Item | Value |
|---|---|
| Yield per ha (kg) | 25 227.35 |
| Farm-gate price (US$ per kg.) | 0.95 |
| Gross return per ha (US$) | 30 020.55 |
| Total cost (US$ per ha) | 8 307.01 |
| Net profit (US$ per ha) | 21 713.54 |
| Net return per ha (US$) | 22 017.75 |

Source: Authors' calculations, 2003 field survey.

- MVPxi / Pxi > 1 = the input i of production is underutilized.

The profit-maximizing conditions require the MVP to equal the respective unit factor prices (Debertin, 1986). In other words, the maximum efficiency of resource use occurs when revenue gained from using one additional unit of input is equal to the cost of that additional unit. In the case of the labour, organic fertilizer, pesticide, seed and fuel inputs, these are used inefficiently as their allocative efficiency coefficients equal 1.97, 7.63, 19.52, 170.21 and 6.44, respectively (Table 3.3), which are all greater than one. This denotes that labour, organic fertilizer, pesticide seed and fuel are underutilized in production. It suggests that the profits of asparagus production could be increased by increasing these inputs. Chemical fertilizer is also used inefficiently, the MVP is less than the input price, or the allocative efficiency coefficient equals 0.84. This implies that chemical fertilizer is overutilized, and that profits of the asparagus enterprise could be increased by reducing the quantity of the input in production (Table 3.3).

The marketing system of asparagus has two elements: an open market; and a contract system. The Thai–Japanese joint venture companies made contracts with farmers' groups (not with individual farmers) under witness of the district agricultural extension officers. The officers acted as coordinators and witnesses to arrange meetings between companies and committees from the farmers' groups, to supervise the formulation of contracts and to ensure that both parties agree to the contract. Some joint venture companies provided financial support, new knowledge and new technical information for farmers. The meetings were organized by extension officers for the benefit of farmers.

With regard to the costs, returns and profitability for the farmers, the profitability analysis in Table 3.4 reveals that asparagus farming is profitable (both per hectare and per kilogram).

Contract farming gives advantages to both farmers and the joint venture company. Farmers have an assured market, stable income, access to the company's services, including credit and technical expertise. The joint venture companies have an assured supply of high quality asparagus with less fixed investment and at lower cost.

The analysis of total environmental cost (TEC) arising from growing asparagus will consider two elements: the cost of soil improvement ($TEC_1$); and the cost of impact on water ($TEC_2$). $TEC_1$ can be calculated by:

$$TEC_1 = Ld + Kr + Kd + La \qquad (3)$$

where:

- $Ld$ = cost of improvement in soil nutrient status (US$/ha/year) (based on the organic fertilizer used),
- $Kr$ = opportunity cost of agricultural equipment used for the improvement of soil (US$/ha/year);
- $Kd$ = depreciation cost of agricultural equipment used for improvement of soil (US$/ha/year);
- $La$ = labour cost of rehabilitating the soil to its original condition (US$/ha/year).

$TEC_2$ can be calculated by using the concept of the reduction in productivity of the neighbouring area as a result of asparagus irrigation water becoming contaminated with agrochemicals and fertilizer (although, of course, fertilizer in runoff water may have a positive effect on yield). When the water from asparagus fields is released and flows through the adjacent industrial sugar-cane field, it induces changes in the natural fertility of the soil. Sugar-cane output is affected negatively, leading to a reduction in the value of sugar-cane output.

$TEC_2 = (Y_1 - Y_2)(P_1 + P_2) / 2$ (4)

where:

- $Y_1$ = sugar-cane yield (at price $P_1$) before the impact;
- $Y_2$ = sugar-cane yield (at price $P_2$) after the impact;
- $(P_1 + P_2) / 2$ = average price of industrial sugar-cane product.

The field survey revealed that the TEC from growing asparagus for export can be expressed as the following simple linear regression:

$TEC = TEC_1 + TEC_2$; $TEC = a + bY$.

From the analysis, it becomes:

$TEC = 1.459 + 0.065Y$ (5)

$R^2 = 0.80$; F-test = 4.637*; DW = 1.923.

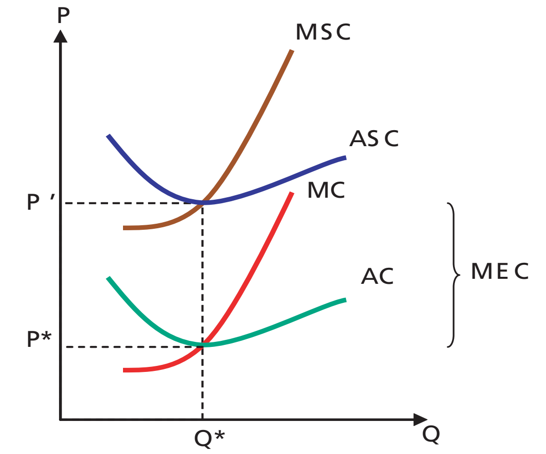
The estimated model can be interpreted as follows.

The F-test of the joint significance of all independent variables is significant at $p = 0.05$. The high adjusted $R^2$ value in the model indicated that the variable Y (asparagus yield, kg/ha) accounted for 80 percent of the variation in total value of the environmental cost. Durbin–Watson (DW) is used for testing first-order autocorrelation in equations. The DW value was below the critical value at the 5-percent level. The environmental cost function in Equation 5 shows that a 1-kg increase in asparagus yield will increase the environmental cost by US$0.065. Equation 5 allows calculation of the marginal environmental cost (MEC) that is equal to US$0.065 from the production of 1 kg of asparagus.

The price established for asparagus for export should reflect the marginal social cost (MSC) by adding the farmer production cost and environmental cost. The MSC is used for making decisions on production planning at farmer level and at government level for determining agriculture policy. The relationship of price level of asparagus arising from the marginal cost (MC), MEC and MSC is shown in Figure 3.10.

In the open market, the average cost (AC) (sometimes also called average total cost - ATC) is used to explain the average cost to the private-sector farmer and does not include any environmental cost. The market price of asparagus derived from the private cost (MC) for the

FIGURE 3.10
**Market equilibrium and price (P) determination of asparagus production (Q)**




Note: MSC = marginal social cost; ASC = average social cost; MC = marginal cost; AC = average cost; MEC = marginal environmental cost.

farmer is P* = MC = US$0.95/kg when the AC is minimum, that is the appropriate minimum price level which does not include an environmental cost (MEC). When the environmental cost is added, the asparagus price will increase from P* to P' where the ASC is at a minimum. The optimal price of asparagus produced for export under contract, taking the environmental and social costs into account, should be equal to P' = MSC = MC (US$0.95) + MEC (US$0.065) = US$1.015/kg.

The appropriate environmental tax level of growing asparagus for export should take this environmental cost to society into account.

## Conclusion

This study provides an overview of the development of a joint venture agribusiness involving asparagus production in Thailand for export to Japan. The sustainability of asparagus production under contract farming conditions depends on the collaboration of farmers to produce a high-quality product by using local natural resources. Farmers' groups can centralize production from individual farmers and exercise bargaining power in marketing. The joint venture company and government officials should be encouraged to give training to farmers in the new technique and knowledge for producing high-quality products. It is hoped that the results of this study will provide guidance to the policy-makers concerned regarding the sustainable development of agriculture.

## References

**Cobb, C.W. & Douglas, P.H.** 1928. A theory of production. *Am. Econ. Rev*., 18(Supplement): 139–165.

**Debertin, D.L.** 1986. *Agricultural production economics*, pp. 261-264. Macmillan Publishing Company.

**Heady, E.O. & Dillon, J.L.** 1961. *Agricultural production functions*. Ames, USA, Iowa State University Press.


## POVERTY REDUCTION AND FOOD PRODUCTION IN DEVELOPING NATIONS: A CASE STUDY OF NIGERIA

*Ademola Isaac Olorunfemi and Michael Olubusayo Ashaolu, Department of Agricultural Engineering, Lagos State Polytechnic, Lagos, Nigeria*


### Abstract

The most difficult challenge facing Nigeria and its people today is the reduction of poverty resulting from low agricultural productivity. It is the major obstacle in the pursuit of socio-economic growth. The poverty rate in Nigeria increased from 27 percent in 1980 to 66 percent in 1996, and by 1999 it was estimated that more than 70 percent of Nigerians lived on less than US$1/day. A life expectancy of merely 54 years, infant mortality of 77 per 1 000, and maternal mortality of 704 per 100 000 live births are among the worst in the world. This paper identifies some of the factors contributing to poverty in Nigeria: problems in the productive sector; widening income inequality; weak governance; and environmental issues. The conclusion is that a strategy is needed that promotes the diversification of the productive base of the economy from oil to fostering market-oriented, private-sector-driven economic development with strong local participation. The paper holds that the development of an indigenous competitive entrepreneurial class in a global market in which technology and skills play the major role in the development of agriculture is a prerequisite for the sustainable development needed to move towards meeting the Millennium Development Goals.


### Introduction

One of the most challenging issues confronting policy-makers in developing nations is the lack of sustainable agricultural food production programmes to meet the needs of the growing populations. The population growth rate in most developing countries (including Nigeria) is too high when compared with the low food production rate. There is an endemic food shortage for humans and animals resulting from recurring drought as experienced, for example, in Niger and Chad in 2004 and 2005, respectively. This has resulted in the large-scale migration of people with reports of disease outbreaks and malnutrition. Table 3.5 gives details of poverty levels in different sectors of the Nigerian

TABLE 3.5
**Poverty trends and projections in Nigeria**

| Year | Poverty level | | | | | Estimated total population | Population in poverty |
|---|---|---|---|---|---|---|---|
| | (%) | | | | | (million) | |
| | National | Urban | Rural | Male-headed households | Female-headed households | | |
| 1980 | 28.1 | 17.2 | 28.3 | 29.2 | 27.0 | 65.0 | 17.7 |
| 1985 | 46.3 | 37.8 | 51.4 | 47.3 | 38.1 | 75.0 | 34.7 |
| 1992 | 42.7 | 37.5 | 46.0 | 43.1 | 39.9 | 91.0 | 39.2 |
| 1996 | 65.6 | 58.2 | 69.8 | 66.5 | 68.5 | 102.3 | 67.1 |
| **Estimated projections for 2015 under different population growth rate scenarios** | | | | | | | |
| Low | 21.4 | 14.6 | 17.2 | 18.5 | 20.3 | 140.9 | 30.1 |
| Medium | 21.4 | 14.6 | 17.2 | 18.5 | 20.3 | 178.5 | 38.1 |
| High | 21.4 | 14.6 | 17.2 | 18.5 | 20.3 | 189.2 | 40.4 |

Source: Sattaur, 2004.

TABLE 3.6
**Human poverty indicators for Nigeria and developing countries from other regions**

| | People not expected to survive beyond 40 years | Population without access to: | | | Distribution of income | |
|---|---|---|---|---|---|---|
| | | Safe water | Health services | Sanitation | Poorest 20% | Richest 20% |
| | (% population) | (%) | | | | |
| Nigeria | 33.3 | 51 | 33 | 59 | 4.4 | 57.3 |
| Kenya | 41.0 | 21 | 29 | 4.0 | 4.0 | 62.3 |
| Indonesia | 12.3 | 26 | 57 | 47 | 8.0 | 44.9 |
| Egypt | 9.9 | 13 | 1 | 12 | 9.8 | 39.0 |

Source: UNDP, 2001.

population with projections for 2015.

A report by the United Nations Development Programme (UNDP, 2005) identified the poverty indicators for most developing nations. They include inadequate: basic infrastructure; human capital; and public administration. These are considered to be the foundations for economic development and private-sector-led growth. Developing nations lack:

- good roads;
- fertile soils;
- electricity;
- safe cooking;
- fuels;
- clinics;
- schools;
- adequate and affordable shelter.

People are chronically hungry and burdened by disease. There are inadequate public-sector salaries and information technologies, which make public management chronically weak. Such countries find it difficult to attract inward investment or to retain their skilled workers, so encouraging a brain-drain. The poverty situation in Nigeria is also exacerbated by worsening income inequality in the country. In 1992 and 1993, the income share of the poorest 20 percent of the population was 4 percent compared with 49 percent for the richest 20 percent. By 1996 and 1997 the share of the poorest 20 percent of the population was only 4.4 percent while that of the richest 20 percent had climbed to over 56 percent, indicating increasing inequality in the country (Table 3.6). The majority of the poor in Nigeria are rural dwellers and engaged largely in farming. Income generation is low and food consumption requirements at household level cannot be satisfied (Federal Office of Statistics, 2004). The potential of the agribusiness sector as a major employer of the growing labour force and an earner of foreign exchange has been undermined. The rate of growth in agricultural production has stagnated and failed to keep pace with the needs of a rapidly growing population, resulting in a progressive increase in import bills for food items, grains, fruits and vegetables, fish, meat and other processed food products.

## Major challenges

The pursuit of poverty reduction in Nigeria will require a wide-ranging communal effort and will include social, economic, political, cultural and environmental factors. Table 3.6 presents some human poverty indicators in Nigeria compared with some other developing countries.

The major causes of poverty in Nigeria (Federal Office of Statistics, 2004) are:

- poor access to employment opportunities;

- inadequate physical assets, such as land and capital, and minimal access by the poor to credit even on a small scale;
- poor access to the means of supporting rural development;
- poor access to markets where the poor can sell goods and services;
- low endowment of human capital;
- destruction of natural resources leading to environmental degradation and reduced productivity;
- poor access to assistance for those living at the margin and those victimized by disasters;
- lack of participation in the design, implementation and monitoring of development programmes.

Most developing nations in sub-Saharan Africa (SSA) are vulnerable to the widespread incidence and severity of poverty. The economies of the countries in the region are characterized by social and income inequality, manifested in wide disparities in:

- wealth;
- material possessions;
- power;
- prestige;
- access to employment;
- financial resources
- social services;
- life essentials, including food, shelter and drinking-water.

The performance of the agriculture sector in Nigeria has been erratic and on a downward trend in the past decades. Food production in Nigeria has failed to keep up with rapid population growth as a result of inappropriate agricultural technology. The green revolution programme, which succeeded in boosting food production in Asia in the 1960s, failed to accomplish similar success in SSA, especially in Nigeria, with grave consequences for farmers' incomes and rural poverty (Imoudu and Igbotayo, 2004).

The following constraints contribute to the food production deficit in many developing nations:

- Most farmers rely on rainfed agriculture, which is accompanied by the persistent risk of drought.
- An absence of appropriate irrigation technology, which has curtailed production in various countries.
- The lack of adoption of improved seeds and fertilizers owing to the low income of farmers and the withdrawal of state subsidies.
- Natural disasters, e.g. Mauritania, Senegal and Niger have been affected by severe floods with damaging implications for food production. Floods have also wreaked havoc in such countries as Benin, Ghana, Togo and Nigeria. Some similar disasters in Nigeria include: erosion hazards in Abakaliki; flooding in Jalingo, Oke-Ogun; and desertification in Maiduguri.
- Prevalent civil strife, which has become a factor hindering agricultural performance in Liberia, Sierra Leone, Congo, Sudan and Côte d'Ivoire among others.

Olorunfemi, Ashaolu and Dahunsi (2004) observed that the majority of Nigerian farmers still depend on peasant tools. Seventy-five percent of producers are small-scale, peasant farmers, far outnumbering the medium-scale and large-scale farmers (20 percent and 5 percent, respectively). They suggest that an element of an agricultural development strategy should be to develop appropriate tools for smallholder farmers. Development of the large-scale farm sector can be left to the private sector.

Agricultural performance in West Africa had a mixed performance in 2002 and 2003 with moderate growth in food production stemming from increased rainfall in most countries of the subregion. According to FAO (2002), several countries, in particular Benin, Gambia, and Liberia, saw agricultural production expand strongly. However, Burkina Faso, Niger, Mali, Sierra Leone and Togo all experienced a decline in overall net output.

More specifically for the Nigerian situation, Olusanya (2004) identified the factors threatening food production as follows:

- Environmental degradation, which is characterized by land management, water resources degradation, deforestation and loss of biodiversity.
- Underdevelopment of rural areas.
- Inadequacies of agricultural inputs, extension services, infrastructure and machinery.
- Low level funding of research institutes – Nigeria allocates only 0.1 percent of the annual budget to agricultural research and development.
- Low human-capacity building.
- Underutilization of potential food resources.
- Low investment in food resource programmes.
- Nigeria's national grain reserve programme is

poorly planned and funded.
- Lack of comprehensive technology application in agricultural food production. The majority of Nigeria's farmers still rely on peasant tools.
- Non-viable food procurement programme.
- Source of power for soil preparation is mostly based on human energy (85 percent) compared with what is available in China and India (Table 3.7). Table 3.8 indicates the available power for agricultural production in contrasting countries.

## Strategies and policy thrust

Nigeria's strategy for confronting the challenges of poverty has been established in the National Economic Empowerment and Development Strategy (NEEDS) (Sattaur, 2004).

NEEDS fundamental strategy is based on the following goals:
- wealth creation;
- employment generation;
- poverty reduction;
- value orientation.

These goals are built on the following macroeconomic premises:
- Improving human capital by means of: provision of good health; education; integrated rural development; housing development, gender and geopolitical balance; and pension reforms.
- Promoting private enterprise through: privatization and liberalization; trade; regional integration; and globalization.
- Governance reforms that involve: transparency; service delivery; budget and expenditure reforms.

TABLE 3.7
**Sources of power for land preparation**

| Country | Comparative importance of human and mechanical power sources | |
|---|---|---|
| | Human energy | Mechanical power |
| | (%) | |
| Nigeria | 85 | 10 |
| Botswana | 20 | 40 |
| Zimbabwe | 15 | 55 |
| China | 22 | 52 |
| India | 18 | 61 |
| Swaziland | 15 | 50 |

Source: Udigboh, 2002.

TABLE 3.8
**Engine power available for agriculture in different countries and continents**

| Country | Watts/ha |
|---|---|
| Nigeria | 18 |
| United States of America | 783 |
| Europe | 694 |
| China | 142 |

Source: Anazodo, Abimbola and Dairo, 1987.

The key policy thrusts of NEEDS include the following:
- Create a predictable macroeconomic environment in which resources are used efficiently, predicated on a medium-term expenditure framework that ensures predictable and sustainable public finance at all levels of government.
- Adopt policies that are consistent with raising domestic savings and increasing private investments.
- Maintain a sustainable level of public debt.
- Promote exports and diversify exports away from oil.

The projected strategy for sustainable food production includes:
- Reactivation of the River Basin Development Authority and other urban water development schemes.
- Rationalization of water resource use to allow the present generation to survive without compromising supplies for future generations.
- Protection of watersheds to enhance underground water supply for sustainable aquifer recharge.
- Increasing the productivity of small farmers.
- Increasing employment in commercial agriculture.
- Encouraging private-sector participation in the transformation of agricultural production.

To restore agriculture to its former status as a leading sector in the economy, NEEDS sets the following targets:
- Achieve a minimum annual growth rate of 6 percent in agriculture.
- Raise agricultural exports to US$3 billion by 2007, with cassava as the major component.
- Reduce food imports drastically, from 14.5 percent of total imports to 5 percent by 2007.
- Develop and implement a scheme of land preparation services to increase cultivable arable land by 10 percent/year and foster private-sector participation through incentive schemes.
- Promote the adoption of environment-friendly farming practices.
- Protect all prime agricultural lands for continued agricultural production.

The formulation of the protocols of the New Economic Partnership for Africa's Development

(NEPAD) by the African Union (AU) have informed NEEDS. The NEPAD programme of action is holistic, comprehensive and an integrated sustainable development initiative for the revival of Africa. NEPAD priorities include:

- Establishing the conditions for sustainable development by ensuring:
  - peace and security;
  - democracy and good political, economic and corporate governance;
  - regional cooperation and integration;
  - capacity building.
- Policy reforms and increased investment in the following priority sectors:
  - agriculture;
  - human development with a focus on health, education, science and technology and skills development;
  - building and improving infrastructure, including information and communication technology, energy, transport, water and sanitation;
  - promoting diversification of production and exports, particularly with respect to agro-industries, manufacturing, mining, mineral beneficiation, and tourism.
  - accelerating intra-Africa trade and improving access to markets of developed countries;
  - the environment.
- Mobilizing resources by:
  - increasing domestic savings and investment;
  - improving management of public revenue and expenditure;
  - improving Africa's share in global trade;
  - attracting foreign direct investment;
  - increasing capital flows through further debt reduction and increased official development aid (ODA) flows.

## Way forward

To promote harmonized and integrated science and technology driven agricultural development, Nigeria should establish a national research and development council. To promote the transformation of agricultural production in Nigeria, the following steps are recommended:

- Curtail rural–urban migration.
- Ensure the provision of adequate processing and storage facilities with sufficient input supply and distribution networks.
- Discourage continued dependence on rainfed agriculture.
- Ensure the provision of an adequate incentives framework while preventing pervasive distortion in the macroeconomy.
- Encourage a land tenure system that promotes the acquisition of land for mechanized farming.
- Expand and strengthen agricultural extension services, and promote indigenous capacity and technologies in response to local conditions.

A priority for Nigeria is the development of appropriate local and affordable technology for food processing and storage crop planting and harvesting equipment. Some of these technologies are:

- Crop storage structures with predominantly locally based materials, such as:
- Improved mud-brick storage structure (cone-shaped and cylindrical type of 0.5–1.0 tonne capacity).
- Pot-in-pot made from burnt brick wall and sand for water circulation (1.0 m × 1.0 m × 0.8 m with a capacity of 600 kg).
- Fertigation equipment using bamboo wood for water distribution and application.
- Food-processing machines for cassava chips and flour. The flow process is presented in Figures 3.11 and 3.12. The processing techniques improve the quality of processed food and generate more earnings for the farmers. The lack of appropriate processing techniques has been responsible for most post-harvest losses recorded in Nigeria.

Research and development activities need to be integrated to improve techniques in collaboration with local farmers. The farmers, grouped into cooperatives, are integrated with research centres to participate in the development of planting, harvesting, and processing equipment for the benefit of the farmers who are the direct beneficiaries.

## Conclusion

The monolithic nature of Nigeria's economy, with its major emphasis on oil, has weakened modernizing activities in the agriculture sector. The major emphasis should now be to encourage private-sector participation in food production with the active promotion of increased local content. Nigeria needs a policy for the manufacturers of strategic basic equipment under a national steering committee to encourage collaboration between institutions in the manufacturing, agriculture and research sectors. The 75 percent of farmers who are resource poor and still use peasant tools should be empowered with affordable tools as a means of stimulating the technology input in land clearing, cultivation, storage and processing equipment. Resource-poor farmers should participate in farmer-led technology research and development. With the farmers involved, it will be easier to judge the appropriate cost of technology on offer, and necessary modifications can be made while making sure that the technology develops to fit with the farmers' needs. A faster, more effective linkage with industry is also necessary in order to achieve maximum value-addition and processing for export. A new agricultural and rural development policy aimed at reversing the trend in the import of food through a progressive programme for agricultural expansion is urgently needed. The Millennium Development Goals would also be realized sooner if adequate attention were placed on the NEEDS strategy and policy thrust for the agriculture sector.

FIGURE 3.11
**Cassava-chip processing flow chart**

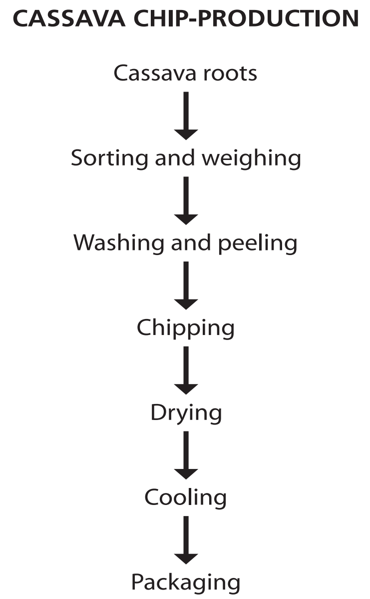
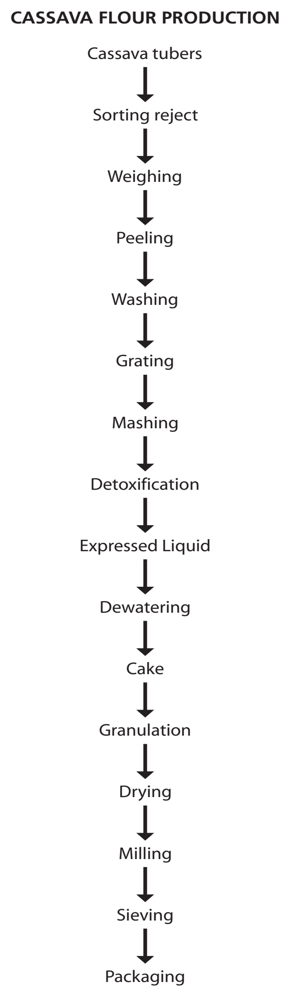



FIGURE 3.12
**Cassava-flour production flow chart**




## References

**Anazodo, U.G.N., Abimbola, T.O. & Dairo, J.A.** 1987. Agricultural machinery use in Nigeria. The experience of a decade (1975–1985). *Proc. 11th Annual Conference of the Nigerian Society of Agricultural Engineers*, pp. 406–429. Zaira, Nigeria.

**FAO.** 2002. *The state of food insecurity in the world*. Rome.

**Federal Office of Statistics.** 2004. *Millennium Development Goals report*, pp. 8–11. Abuja.

**Imoudu, P.B. & Igbotayo, S.A.** 2004. The challenges of food security and implications for regional development in West Africa. *Proc. 2nd West Africa Society of Agricultural Engineering International Conference on Agricultural Engineering*, pp. 395–405. Kumasi, Ghana, Kwame Nkrumah University of Science and Technology.

**Olorunfemi, A.I., Ashaolu, M.O. & Dahunsi, B.I.O.** 2004. Engineering food security in a developing nation, a case study of Nigeria. *Proc. 2nd West Africa Society of Agricultural Engineering International Conference on Agricultural Engineering*, pp. 422–438. Kumasi, Ghana, Kwame Nkrumah University of Science and Technology.

**Olusanya, A.M.** 2004. Engineering sustainable food security in the alleviation of poverty. *Proc. National Engineering Conference and Annual General Meeting*, pp. 60–69. Abuja.

**Sattaur, O.** 2004. *NEEDS Nigeria*, pp. 20–22. Abuja, National Planning Commission.

**Udigboh, E.U.** 2002. Level of agricultural mechanization in Nigeria. Paper presented to Commemorate Agricultural Engineering in Nigeria: *30 years of University of Ibadan Experience*, pp. 42–56, Ibadan, Nigeria.

**United Nations Development Programme (UNDP).** 2001. *Human Development Report*. Lagos, UNHDR Millennium Edition.

**United Nations Development Programme (UNDP).** 2005. *UN Millennium project 2005. Investing in development: a practical plan to achieve the Millennium Development Goals Overview*, pp. 28–35. New York.

# Chapter 4
# Key issues, lessons, and outlook

## A NEW PARADIGM AND A PERSISTENT PROBLEM

It became readily apparent during the Workshop that, while the two themes raised some common issues, the problems they addressed had a very different genesis. On the one hand, agricultural mechanization in SSA is a long-standing problem that seems to be caught between concerns of agricultural productivity, policy, socio-economics and environmental impact. Many of the ideas developed in the papers and during the discussion highlighted one or several of these aspects that may have been all too familiar to the experienced experts and long-term development practitioners. Nonetheless, agricultural mechanization development, especially for SSA, remains a topical and pressing issue that requires a new way of thinking and a comprehensive approach in order to facilitate change for the better. Conversely, the topic of value addition is not part of a long-standing problem; rather, it is an issue that arises from a paradigm shift in the way we look at agriculture and the modern agrifood system. We are moving away from a view of agriculture and food as a supply-driven, quantity-driven, and in fact mainly cereal-driven system, towards a paradigm of a demand-driven structure that encompasses the entire food chain. In a demand-driven food chain, where consumers are the key actors, every effort must be made to determine what they will pay for and then to add value to farm produce in such a way that consumers' expectations are met.

There is a risk that the new paradigm for agriculture is seen as only being relevant to export markets; this is not the case. It is applicable to all markets from village to capital city to export. However, the application of a market-led viewpoint requires acknowledgement that this is only relevant to farmers that produce a surplus. For farm households not able to produce a surplus of any of their farm products, their immediate needs are more likely to relate to food security and farm productivity. The challenge is to facilitate appropriate assistance for such farm households to move to being food secure and able to link to markets. Achievement of this transition will require *inter alia* agricultural mechanization and value addition. Therefore, agricultural mechanization and value addition should be seen as interdependent.

In this chapter, key issues and lessons are distilled from the papers and the discussions for each of the two themes; these are then crystallized into a series of points that may guide future thinking and action.

## THE CHALLENGES OF AGRICULTURAL MECHANIZATION IN SUB-SAHARAN AFRICA

The productivity limitations caused by farm power (energy) shortages seem to be well understood. However, donors and decision-makers in development run the risk of neglecting the fact that in order for small farmers to produce sufficient food or raw materials for value addition, some form of energy is required (e.g. food or fuel, whether fossil or renewable). Moreover, there is a real gap between the financial resources available to smallholder farm families and the cost of the technological solutions in the market. It is also of concern that this obvious gap does not seem to have been filled by equipment contractors or commercial larger-scale farmers providing input supply and mechanization services to these smallholder farm families. This gap is also a major constraint on the development of local manufacturing industries. The following are some of the recurrent themes emerging from the idea-sharing sessions.

### Policy environment

A key issue in the establishment of an enabling environment for public-sector investment in the agricultural mechanization and supply chain industries is good governance, free from corruption and transparent. A government that is held to account for its actions is one of the most important determinants of the fate of a country and of the productivity of its public investment.

It is logical to conclude that without a policy environment conducive to supporting change, then the likelihood of sustainable progress in agricultural development generally, and agricultural mechanization in particular, is extremely remote. Farmers need to mechanize (i.e. use human, animal and motorized power to apply tools, implements and machinery in order to improve labour and land productivity) if they are to produce a surplus for markets. The need is even more crucial for smallholder farmers who will usually need to mechanize in order to extract themselves from subsistence production, with little hope otherwise of breaking out of the cycle of drudgery and poverty.

Prerequisites for the creation of a supportive policy environment are the political will to encourage positive change and the formulation of strategies to facilitate development in that direction. An example discussed in the Workshop was the TAMS, which has the following action areas:

- improving access to, and the availability of, mechanization inputs;
- enabling commercialization of agriculture through mechanized farming;
- promoting agroprocessing and rural-based agro-industries;
- improving livelihoods and land management through CA;
- improving farmers' access to technologies and services;
- improving the financing of agricultural mechanization;
- improving policy, legal and regulatory environments for agricultural mechanization;
- taking into account cross-cutting and cross-sector issues.

It was argued that such a strategy is rather general to be of much practical use when developing the agriculture sector. Moreover, policy analysts need more than a set of general recommendations; they need a prioritized list of actions that, if implemented, will guide the commercialization of agriculture with the associated commercialized inputs and mechanization services supply. It was contended that the major uncertainty appears to be how to start the process, i.e. what the catalyst for change is. However, the counterargument was given that, without such a strategy umbrella, it is difficult to address the location-specific problems as they arise. In many rural locations in SSA countries, specific measures will be needed in order to kick-start the mechanization process for agricultural development. Once the need is recognized by local actors, national policy-makers and international donors, then the strategy can be brought into play through, for example, the provision of loans for equipment purchase, and through training and capacity building for users and owners of equipment and machinery, and indeed for the support services needed for repair and maintenance. This point was accepted, but the matter of what to subsidize or where to provide tax or import tariff relief was not answered. Furthermore, there did not appear to be consensus on the argument in favour of subsidies, tax or import tariff relief for mechanization (although a strong case can be made for applying subsidies to resource-poor farmers in developing countries in the same way that developed-country agricultural subsidies are justified).

There was a call for a further workshop to take the discussion of strategy forward and for the UNIDO and FAO to undertake an analysis of the implications of subsidies and tax relief in support of agricultural mechanization.

### Machinery manufacturing sector

Generally speaking, and with few exceptions, agricultural mechanization and its supporting industry do not appear to be thriving in most African countries. Currently, there is a very small number of private-sector companies (perhaps as few as 100) active in the agricultural machinery sector and the sector employs less than 1 percent of the industrial labour force.

Lessons can be learned from other countries and continents, but successful solutions will probably always be location-specific. The artisan sector is moderately well developed in many SSA countries and is able to satisfy the demand for simple hand and DAP equipment (e.g. rippers). It was postulated that a strategic option could be to empower, encourage and equip this sector so that it can make the transition to the level of small and medium-sized enterprises (SMEs). This would facilitate the supply of the equipment and services that the growing commercial agriculture sector will need in order to service its mechanization requirements.

Existing SMEs already capable of making a contribution to the agricultural mechanization requirements also need support in order to be able to supply novel equipment at a price that is affordable to smallholder farmers. Equipment supply remains a major obstacle to development, and it can be encouraged by making the market less risky. At the moment, SMEs are reluctant to invest in batch production for end users who are notoriously short of financial capital; the risk is often too great. It should be emphasized that investment in agricultural-production-related businesses has always faced greater risks than other enterprises, as the business is of a seasonal nature and vulnerable to weather, climate and economic threats. Moreover, mechanization inputs for land preparation, tillage, seeding and weeding are several months away from harvesting and, hence, from the possible pay-back period. This time gap of several months is an additional obstacle faced by both subsistence and commercial farmers. The same problem does not occur to the same degree for investments in the post-harvest, processing and value-addition industries. However, the highest labour peaks (and, hence, mechanization needs) are for land preparation and weeding as well as harvesting. A national strategy aimed at providing more options to farmers can encourage batch production of suitable, farmer-demanded equipment by SMEs through batch-purchasing arrangements.

Attention was drawn to the impact on local manufacturing enterprises of removing import tariffs and subsidies. The case of a North African country was cited where opening the economy had debilitated the local agricultural equipment manufacturing sector.

**Farmer demand for equipment**

Individual smallholder farmers are extremely vulnerable and, not surprisingly, reluctant when it comes to experimenting with, or investing in, novel technology. Experience has shown that farmer groups with a common interest, e.g. in direct planting, are often mutually supportive and less risk averse. Well-motivated farmer groups can create local demand for new technology (e.g. through the formation of group savings schemes), and this can in turn encourage local manufacturers to supply the market with greater confidence.

The creation of soft loan schemes to supply credit to smallholder farmers for equipment purchase might seem to be a viable option. However, the loans (as opposed to grants) will have to be paid back eventually, and this could become a burden for the smallholder farm family. Group savings schemes would seem to be a less risky option for vulnerable individual farm families.

The experience of South Asia was highlighted; in this case, there were significant off-farm income earning opportunities for tractor owners in providing transport services and in road construction and maintenance. This allows expensive equipment to be in productive employment for a greater part of the year and so unit costs can be reduced for custom work.

**Import of agricultural machinery**

While the local supply chain is becoming established, a short-term and medium-term solution would be to import equipment from countries with an established manufacturing sector. A successful example of such an arrangement is the importation of CA equipment into SSA (especially East Africa). The supply of such equipment to the Brazilian market has built up in the past decades to become a private-sector activity supplying the needs of a wide range of farm sizes, from smallholders to larger commercial farmers. Farmers in SSA (and elsewhere in the world) can benefit from the results of this evolutionary process through the import of appropriate equipment, such as no-till planters and pedestrian-pulled sprayers. However, there may be difficulties associated with this approach that will need to be overcome. High import tariffs and transport costs may make the imported equipment too expensive for the intended customers in SSA. There may be corruption in the supply chain, which will, eventually, have the same effect. Dealership networks will need to be set up and the necessary training given in order to ensure quality after-sales service. In addition, there is always the fear among the exporting companies that their equipment will be copied. This real danger could perhaps best be overcome by entering into joint-venture arrangements with SSA manufacturers from the outset.

**Farmer adoption and adaptation**

While equipment importation such as the Brazil – East Africa example may prove to be a workable and sustainable solution, the second challenge remains that ideally it is farmer demand that will need to drive the market for the products. Likewise, with group finance schemes, it would appear to be useful in the context of small farmers that local adaptation and adoption of equipment be best facilitated through a participatory technology development process. The outcome of this process is locally adapted and manufactured parts compatible with the imported equipment but made with locally available raw materials and knowledge.

The points made by Jenane *et al.* regarding the influence of the industrial capacity of a country on the likely make-up of the agricultural machinery sector were highlighted in discussion. There was general support for the notion that a small country lacking a significant industrial base would be unlikely to be able to support agricultural machinery manufacture and would most likely import and, at best, assemble the machinery required for agricultural mechanization. The policy framework of the country would need to recognize this. Conversely, countries with an industrial base could aspire to a greater level of local manufacture if the agro-industrial sector could compete with imported equipment.

### Environmental protection

Declining crop yields and increased soil degradation are of great concern to farmers in SSA. To society as a whole, the destructive impact of soil erosion and deforestation on infrastructure, such as roads and dams, is a cost that has to be borne. Rural–urban migration resulting from the increasing difficulties of deriving a livelihood in a scenario of depleting assets is a social problem that has a profound impact on urban infrastructure, human welfare and security. Agricultural development strategies resulting from sound sector policies can recognize the complementary nature of addressing smallholder needs for increased output with less energy input on the one hand, and environmental protection on the other. Sustainable land management (SLM) practices that have the long-term welfare of the natural and human capital assets of the nation at heart will require novel agricultural mechanization options capable of remedying the damage caused by inappropriate options (e.g. topsoil loss, plough pans, and soil compaction). These new options must be supplied from manufacturer to end user via a distribution supply chain comprising stakeholders, all needing to make a livelihood. Linking environmental protection to SLM and improved rural-sector livelihoods is one way of encouraging adoption and consensus.

### Gender issues

Agricultural equipment for smallholder farmers has frequently been designed in relative isolation from the end users. This has often created problems for women users, who can sometimes find heavy equipment difficult to control and manoeuvre, even if they are permitted to use it. The devastating impact of the HIV/AIDS pandemic in many SSA countries has led to the spread of female-headed households, and even orphan-headed households, as adult men succumb to the disease in disproportionate numbers. The need for lighter, easier-to-control equipment should be catered for in the equipment supply chain. Manufacturers should consider the ergonomic requirements of their end users to a greater extent than is currently the case.

## USING TECHNOLOGY TO ADD VALUE AND INCREASE QUALITY

Fresh agricultural produce is often seasonal and generally commands indifferent prices in local markets. Adding value to basic products through processing generally has the aim of increasing value, either through a change in the nature of the product to satisfy consumer demand, or to enable it to be stored well in order to preserve it from spoilage and to await more favourable prices or to make it available for export. In addition to the specific themes developed by each of the presenters in this session, several general points emerged during the workshop discussions.

### Policy environment and the role of the public sector

As in the case of the machinery supply chain, the emergence, growth and viability of enterprises that add value to farm outputs is dependent on a supportive policy environment; providing such an environment is one of the major roles of the public sector. There was widespread support for the view that in liberalized markets it is probably best to leave the private sector to orient its production towards its consumers. However, there was a rich discussion of the question "how can the public sector usefully intervene?" Three themes emerged:

- Understanding the consumer: It was suggested that many small-scale enterprises struggle to understand consumer expectations. Examples were given of programmes to fund market studies for SMEs launching products. It was also contended that a better understanding of the fundamentals of consumer decision-making in markets is a public-good research output that should be undertaken by the public sector. This was supported by a call for a better

understanding of informal markets, which dominate in many developing countries; it was postulated that market research tools developed for higher-income economies may not be optimal for informal food sectors.
- Value chain innovation: The importance of the capacity of an enterprise to innovate in terms of adopting new technology to increase productivity, to produce products for new markets, and to develop new and improved products for existing markets was emphasized. The high economic leverage that growth of the food sector can apply to rural development was noted, and it was argued that the positive externalities from growth in the value-added food sector provided justification for public-sector support. However, the high cost of innovation and the risks associated with it were a particular concern. Participants emphasized that investments by the public sector should be in partnership with the private sector and had to be targeted to specific product groups with a clear understanding of consumer needs. Public-sector programmes to link research institutions more closely with the private sector were praised.
- Niche markets: It was suggested that enterprises need to be aware of the economies of scale that can be achieved in larger processing plants. However, this was countered by a number of interventions that argued that small enterprises can prosper by focusing on niche markets for which they have an intimate understanding of the needs and for which they can deliver superior products and services. Examples include organic and fair-trade products aimed at niche markets in industrially developed economies. In this way, economies of scale are less important. It was suggested that the public sector consider programmes to support the development of clusters and to assist small enterprises in identifying pathways to migrate to higher-value products as an alternative to the search for economies of scale.

### Technology for value adding requires multidisciplinary actions

Agribusiness enterprises engaged in food production need to bear in mind the whole value chain from farmer to consumer. A number of speakers endorsed a holistic approach, from farm to fork, to ensure that constraints can be alleviated before bottlenecks build up. Using technology to add value and increase food quality requires multidisciplinary actions, including the social sciences, economics and ergonomics in addition to the engineering skills. This combination of disciplines should be employed to ensure that the resulting technologies are practical and cost-effective and, in this way, that they will be of long-term benefit to the agro-industrial development initiative. Although no clear recommendation emerged on how this should be achieved, it was clear that the public and private sectors need to partner in appropriate initiatives.

### Participatory technology development

There was very useful discussion on the matter of technology development. In general terms, the speakers agreed that once a market need has been identified and the processing requirement defined, the equipment can either be imported or developed locally. Importation, while offering a rapid response, does not always provide a complete answer. It is relatively easy to import equipment but impossible to import the socio-economic and technical support environments for which it was designed. For this reason, the fairly common model of importation followed by local adaptation is also not very satisfactory. It was accepted that partnerships between manufacturers, R&D institutions and, crucially, potential user groups are far more likely to produce a technology and a product with good market potential. Products of participatory technology development will be user-oriented rather than the traditional designer-centred. This approach has the added advantage of building local capacity for the design and manufacture of food-processing technology. The role of the public sector in this process has been highlighted under value chain innovation (above).

### Environmental protection

The discussion drew attention to the environmental costs of agricultural production that historically have seldom been taken into account in the developing-country context. The agrifood industry runs the risk of being a potential environmental polluter and, while helping this industry to become established in a competitive economic environment, more care must be taken to ensure that the environmental costs to natural resources are not ignored.

The invaluable agricultural inputs of soil and water must be conserved by more sustainable environmentally-friendly production practices. Waste products need to be recycled, and this requires that they not be considered as "waste products" but rather as valuable inputs into other enterprises. An example is the disposal of processed agave in the tequila production industry in Mexico. The traditional practice of simply dumping the product and consequently contaminating waterways is being replaced by more sustainable options in which the waste is processed into organic compost. A useful observation emerged in the context of product branding for high-income markets; the point was made that how a product is made can be an important product attribute for some consumers. An example is wood products produced from managed forests.

## THE OUTLOOK

The Workshop served to bring together engineering expertise and authoritative voices to consider and comment on the issues of agricultural mechanization in SSA and on how to use technology to add value and increase quality. An analysis of the papers and discussions identified the following five major points to be borne in mind when planning development interventions on these two interrelated issues.

### Ensuring an enabling policy environment

Government policy relating to farm mechanization and the agrifood industry will have a major impact on the development of the supply and value chains associated with them. Assistance will often be required in order to orient industrial and agricultural development strategies to enhance the environment for the private sector. There are examples of public-sector programmes that have been successful in enhancing the growth and development of SMEs in the food sector. The Workshop also identified specific aspects of public-good research, such as understanding the fundamentals of consumer decision-making in informal markets.

### Coordinating strategic interventions

Strategic interventions aimed at encouraging and supporting innovation and R&D in supply and value chain industries will have more impact if they are the result of synergistic cooperation and coordination between the public sector and private enterprises. A corollary also exists in terms of international development agencies; agencies with specific technical capacities such as FAO and the UNIDO share a common interest in the manufacturing and processing agro-industries.

Mechanization efforts have not been notably successful to date in SSA; adopting a more strategic and integrated, but most importantly, a fresh and innovative view may reverse that trend. Such a view must consider a wide range of issues, starting from the necessary enabling environment that would support agribusiness and agro-industries to develop, but also encompassing the following points that are interrelated and which, therefore, should be tackled in a coordinated and strategic manner:

- finance schemes that take into account the special risks that small farmers and manufacturers face owing to the seasonality of crop production and exposure to the vagaries of the climate;
- socio-economic issues and the need to make farming attractive to the younger generation in order for them to remain in the agrifood sector;
- the availability of modern, labour-saving technologies;
- a proactive attitude towards avoiding potential threats to the environment and subsequently emphasizing a way of mechanization that is in line with SLM principles and waste-product management;
- recognizing that: (i) in SSA, it is mostly rural women who carry the major burden of providing human energy / farm power for working the land to earn a subsistence living; and (ii) these women have an equal right to access inputs and equipment that enable them to produce for markets in order to improve their standard of living.

### Multidisciplinary actions for technology adoption

Using technology to add value and increase food quality requires multidisciplinary actions, as does overcoming the hurdles to agricultural mechanization. Including the social sciences, economics and ergonomics alongside engineering skills is the pathway most likely to result in building the capacity of farmers and enterprises to adopt technologies in order to improve productivity and to produce new products.

Such participatory technology development approaches enable a holistic approach to the problems and build recognition of the advantages that each player can bring to the process of ensuring that the final product is what the consumers want.

**Advocating agro-industrial development**
Sub-Saharan Africa needs agricultural mechanization and agro-industries. Technical and financial support to stakeholders in the mechanization input and value-added supply chains will produce long-lasting results. This message needs to be made clear, especially to major decision-makers in donor agencies and financial institutions as well as to the key actors in the governments of developing countries.

**Environmental management is good business**
Agro-industries and farm mechanization have too often been associated with environmental degradation. This can no longer be the case today as the technology for SLM is now available and agro-processing technologies can both reduce processing residues and recycle them in a way that enhances the environment rather than degrading it. It is possible to build good environmental management into product attributes and to use certification systems such that product value is enhanced in certain markets.

## FAO AGRICULTURAL AND FOOD ENGINEERING TECHNICAL REPORTS

1 Production and processing of small seeds for birds, 2005 (E)
2 Contribution of farm power to smallholder livelihoods in sub-Saharan Africa, 2005 (E)
3 Farm power and mechanization for small farms in sub-Saharan Africa, 2006 (E)
4 Honey bee diseases and pests: a practical guide, 2006 (E)
5. Addressing the challenges facing agricultural mechanization input supply and farm product processing, 2007 (E)

Availability: September 2007

| | | | | |
|---|---|---|---|---|
| Ar | + | Arabic | Multil – | Multilingual |
| C | + | Chinese | * | Out of print |
| E | + | English | ** | In preparation |
| F | + | French | | |
| S | + | Spanish | | |

Copies of FAO publications can be ordered from the online catalogue at:
http://www.fao.org/publishing/

or from the

Sales and Marketing Group
Electronic Publishing Policy and Support Branch
FAO Communication Division
Viale delle Terme di Caracalla
00153 Rome, Italy

E-mail: publications-sales@fao.org
Fax: (+39) 06 57053360
Web site: http://www.fao.org/icatalog/inter-e.htm

# Addressing the challenges facing agricultural mechanization input supply and farm product processing

Proceedings of an FAO Workshop held at the CIGR World Congress on Agricultural Engineering Bonn, Germany, 5–6 September 2006

The World Congress on "Agricultural Engineering for a Better World" was held in September 2006 in Bonn (Germany) and was co-organized by FAO Rural Infrastructure and Agro-Industries Division, the International Commission of Agricultural Engineering (CIGR), the European Society of Agricultural Engineers (EurAgEng), and the Max-Eyth Association for Agricultural Engineering within the Association of German Engineers (VDI-MEG).

As a preparation for the challenges of the twenty-first century, FAO conducted two workshops within the Congress. The first targeted the subject of "challenges for agricultural mechanization in sub-Saharan Africa", and the second focused on "using technology to add value and increase quality".

FAO is a global knowledge broker for the agri-food industry, including technologies for production and processing. In particular, the Agro-Industries Programme of FAO is increasingly tending to focus on appropriate input supply, innovation and value chain development. Improvements in these areas have the potential to facilitate market access for producers and enhance the potential to sustain and improve livelihoods and well-being at whatever scale and in whatever region of the world.

This Technical Report contains the results of the Congress, and encourages both readers and decision-makers to consider the important role of engineering technologies for development and, indeed, for a better world.

ISBN 978-92-5-105784-1 ISSN 1814-1137

9 789251 057841

TC/D/A1249E/1/09.07/1000

5 Addressing the challenges facing agricultural mechanization input supply and farm product processing FAO