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# A regional strategy for sustainable agricultural mechanization

Sustainable mechanization across  
agri-food chains in Asia and the  
Pacific region

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# A regional strategy for sustainable agricultural mechanization

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Sustainable mechanization across agri-food chains in Asia and the Pacific region

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# Foreword

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The Food and Agriculture Organization of the United Nations (FAO) has, since its inception in 1945, been supporting agricultural mechanization programs in different parts of world. This support has been in the form of the provision of technical assistance to member countries as well as in the generation and documentation of new knowledge on the experiences of different countries and regions of the world on the process of agricultural mechanization development. For much of the period before 1990 the focus on agricultural mechanization, by FAO and other development agencies, has been on improving the farm power situation in the developing world. It was assumed then that, it was just a matter of time before agriculture in most of the developing world would be transformed to the extent that the use of higher levels of farm power in field and post-harvest operations would be ubiquitous as it had occurred in the developed world during the middle part of the twentieth century.

FAO and the UNESCAP Centre for Sustainable Agricultural Mechanization (UNESCAP/CSAM) in 2011, established collaboration in order to assist and support countries, in developing *environmentally sustainable agricultural mechanization strategies*. Over the past three years (2011–14), both organizations have jointly convened a number of consultations with member countries. These consultations have focused on obtaining a clearer picture of the status of agricultural mechanization in Asian countries, sharing experiences among countries in Asia and the Pacific region and identifying constraints as well as best options for achieving environmentally sound and sustainable agricultural mechanization in the region. These consultations also underlined the critical importance of moving toward sustainable agricultural practices, by not only increasing access to environmentally sound farm machinery and implements, but also by developing and transferring land preparation and crop husbandry techniques that contribute to the enhancement of sustainable rural livelihoods as well as to the reduction of pressure on natural resources which are the main foundations for sustainable food security.

While mechanization strategies and policies are country specific, national strategies are best formulated when guided by insights and parameters identified within a framework which factors in outlooks with regional and global perspectives. A single mechanization strategy does not capture the diversity that exists across countries in this large and diverse region. However, several aspects related to policy formulation and strategy development can benefit from a common framework.

FAO commissioned a team led by Dr Geoffrey C. Mrema, former Director of the Rural Infrastructure and Agro-industries Division of FAO, to compile a draft document on the key issues identified through these consultations and which are likely to affect the process of developing sustainable agricultural mechanization strategy (SAMS) in the region. The draft document was specifically prepared to serve as backgrounder to discussions at a *High-Level Multi-Stakeholder Consultation on Sustainable Agricultural Mechanization Strategy for Asia and the Pacific Region* convened by FAO in collaboration with the UNESCAP/CSAM in Bangkok, Thailand from 26 to 27 June 2014. This Consultation was attended by 70 individuals, including senior level Government officials – Ministers of Agriculture and Directors responsible for Policy and Planning and for Agricultural Mechanization

– representing twenty one member countries from across the region. Also attending were representatives from tertiary education institutions, manufacturers of agricultural machinery and implements, civil society organizations as well as development partners.

The Consultation sought to reach consensus on issues that would enrich the strategy and policy of member nations for achieving sustainable food security while taking cognizance of lessons from past policies and strategies as well as future socio-economic and technological trends. Specifically the discussions aimed at providing participants an opportunity to reach consensus on the process of: developing/adjusting their mechanization strategies in the light of broader regional/global trends and their national priorities; and selecting among key strategic options while considering implied trade-offs (or consequences) instead of being prescriptive.

This strategy document is a new and revised version of the original draft background report discussed at the High Level Multi-Stakeholder Consultation. It incorporates the comments, and recommendations of stakeholders at this Consultation.

I would like to specifically thank Dr Bing Zhao of UNESCAP/CSAM and all the participants for their contribution during and after the Consultation. I would also like to thank Professor Geoffrey Mrema, Dr Peeyush Soni and Dr Rosa S. Rolle for their contributions in the preparation of this report.

A handwritten signature in black ink, consisting of a long horizontal line that curves upwards and loops back to the right, ending in a stylized 'K' shape.

**Hiroyuki Konuma**

*Assistant Director-General and Regional Representative  
FAO Regional Office for Asia and the Pacific*

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## Abbreviations and Acronyms

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AGCO	Allis-Gleaner Company
ANTAM	Asia Network for Testing Agricultural Machinery
APCAEM	Asia-Pacific Centre for Agricultural Engineering and Machinery
CA	Conservation Agriculture
CGIAR-TAC	Consultative Group for International Agricultural Research – Technical Advisory Committee
CKD	Completely knocked down
CNH	Case New Holland
CSAM	Centre for Sustainable Agricultural Mechanization
DAT	Draught Animal Technology
DPRK	Democratic People’s Republic of Korea
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
IAER	International Association of Electronics Recyclers
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technologies
ILO	International Labour Organization
IRRI	International Rice Research Institute
LAC	Latin America and the Caribbean
LSF	Large-scale farmers
MNC	Multinational Corporations
MSF	Medium-scale farmers
NABARD	National Agricultural and Rural Bank
OECD	Organization for Economic Co-operation and Development
PRC	People’s Republic of China
R&D	Research and Development
ROK	Republic of Korea
SAM	Sustainable Agricultural Mechanization
SES	Soil Erosion Service
SKD	Semi knocked down
SSA	Sub Saharan Africa
UNESCAP	United Nations Economic and Social Commission for Asia Pacific
UNIDO	United Nations Industrial Development Organization
USA	United States of America
WB	World Bank



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## Executive Summary

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The Asia-Pacific region has made significant progress over the past five decades in agricultural mechanization – from the pessimistic situation of the 1960s when the region was basically at the bottom of the global agricultural mechanization league to the situation half a century later when it has the largest annual global sales of agricultural machinery – greater than even North America where mechanically powered mechanization was pioneered at the beginning of the twentieth century. The debate in the 1960s on agricultural mechanization in Asia was essentially about the desirability, feasibility and the social consequences of replacing draft animals, as a source of farm power, with internal combustion engines.

In the second and third decades of the twenty-first century Asian countries will be on the verge of completely replacing draft animals as sources of farm power with tractors (either 4-wheeled or 2-wheeled or a combination of both depending on the country), and diesel and/or electrical motors for powering irrigation pump-sets as well as equipment for harvesting, post-harvest handling and processing. This is indeed a great achievement which could not have been contemplated even at the turn of the twenty-first century. The tractor may well be regarded as the hero of the agricultural revolution occurring in this region in the twenty-first century just as White (2000) belatedly branded it as the 'Unsung Hero' of the agricultural revolution which occurred in the United States of America in the middle part of the twentieth century.

A shift from traditional labour-intensive production and post-harvest operations to mechanized labour-saving technologies is taking place across Asian agriculture in response to rising labour scarcity, greying agricultural populations, increasing labour costs and the increasing feminization of agriculture due to the propensity of more men than women migrating to urban areas as well as to the development of modern value chains which respond to increasing market development and trade opportunities within the region and globally.

Earlier debates on mechanization were confined to on-farm production issues and failed to capture the off-farm uses of mechanization inputs where farmers were realizing economies of utilization of their mechanization investments. In addition, agricultural mechanization is successful when there is an effective demand for the outputs of farming (including for on- and off-farm value addition). For sustainability, the entire agri-food chain including financing of capital investments required to support the acquisition of farm machinery and implements must be considered. Further, mechanization technologies for agri-food chains can contribute significantly to programs for reducing losses along entire food chains as well as to programs for maintaining rural infrastructure and increasing employment opportunities especially for the youth and women in the rural areas. Hence, rather than focusing exclusively on mechanization of on-farm operations, it is now necessary for mechanization strategies to cover the entire agri-food chain – from inputs through to on-farm production and harvesting, to post-harvest handling and processing as well as to include consumer protection issues, i.e. food safety.

Sustainable Agricultural Mechanization Strategy or SAMS, is a planning strategy that contributes to the agricultural goal of sustainability, while meeting food self-sufficiency, generating economic development and inclusive growth as well as social benefits. SAMS is part of the enabling environment for the development of sustainable, inclusive and efficient agri-food value chains including crops, livestock, fishery and agro-forestry value chains. It integrates consideration for the on- and off-farm use of mechanization inputs including paying special attention to the needs of youth and women in rural areas. SAMS also integrates consideration for the dominance of smallholder farmers and their input suppliers and service providers as well as, micro, small and medium agro-food processing enterprises across the region.

As the farm power situation is being transformed, the development debate on on-farm mechanization is now turning to current land preparation and crop husbandry techniques and their contribution to enhancement of the sustainability of the entire agricultural system. Environmental, socio-economic and demographic trends which are likely to occur in the region over the next three to four decades will exert considerable pressure on agricultural systems to implement more sustainable agricultural strategies.

The new paradigm of “sustainable production intensification” as described in a recent FAO publication titled *Save and Grow*, recognizes the need for productive and remunerative agriculture that conserves and enhances the natural resource base and which positively contributes to the delivery of environmental services. Sustainable crop, forestry and livestock production intensification must not only reduce the impact of climate change on agricultural and forestry production, but must also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils.

Inappropriate agricultural machinery, equipment and implements, coupled with their improper utilization can lead to increased pressure on fragile natural resources by accelerating soil erosion and compaction, promoting the over-use of chemical inputs and result in opening up of lands that currently serve as valuable forest reserves and rangelands. There is currently a global movement advocating for minimum and/or zero tillage and planting techniques – more generally known as conservation agriculture – in the quest for environmental sustainability. Zero tillage in cereal systems in South Asia, have for example helped in saving fuel and water, in reducing the cost of production and in improving system productivity and soil health.

At the farm level, SAMS must, therefore, bring in a focus on the adoption of sustainable land preparation and crop husbandry techniques, drawing lessons from, among other areas, the successes achieved in those countries in the region that have transformed their main source of farm power from animate to mechanical. In this respect, to succeed the region will need to prioritize strategies for different countries, agro-ecologies and farming systems.

SAMS must also factor in the dominance of smallholders and other value chain stakeholders across the region and seek to identify strategies that facilitate their access to larger items of agricultural machinery such as tractors, harvesters, threshers and milling equipment. This can be done through providing to small farmers, custom hiring services or through the development of business models for the provision of mechanization services to them. This will also include the development of financial models which enable small farmers themselves, to access agricultural machinery for their

own use, and for rental to other farmers through the operation of hire services. Other strategies include the design of equipment at a scale that is best suited to their needs or through empowering farmer organizations in order to facilitate their access to mechanization inputs through cooperative mechanisms.

Experience gained from mechanization policies and strategies of the 1970s shows that it was the medium- and large-scale farmers who spearheaded mechanization efforts as they were the ones who were able to procure agricultural machinery and implements as well as being able to provide mechanization services to small commercial farmers and peasant subsistence farmers. They were also the ones who were able to set up and sustain the farmer support institutions required for commercial agriculture to thrive. These farmers will likely continue to play an important role in the development of SAMS in the region. By addressing the role of mechanization inputs such as electric and diesel powered mechanical equipment, SAMS will contribute to increasing the efficiency of water use in agriculture – a key sustainability issue for Asian agriculture.

Increased investment in research and development by both the private and the public sectors will be required. Linkages between research and development organizations under the public sector and those under the private sector will need to be strengthened – there is no point in having large public sector research and development institutions and establishments which year in and year out churn out a large number of prototypes that do not move beyond laboratories and/or workshops. As the region seriously begins its efforts to change its land preparation and crop husbandry practices from conventional tillage to more sustainable methods and technologies, research and development inputs will be critical to the determination of what works in production systems under local conditions.

The region currently has a large manufacturing sector for agricultural mechanization inputs and there is an urgent need to determine how that sector can be incentivized to develop and manufacture machinery, implements and equipment that contribute to sustainable mechanization practices across agri-food chains. It will be necessary to develop national and regional standards as well as testing centers for machinery, implements and equipment for use across agri-food value chains. In this regard, the region has already made some progress through establishing the Asia Network for Testing Agricultural Machinery (ANTAM) under the auspices of the Centre for Sustainable Agricultural Mechanization (CSAM). ANTAM should be catalytic in initiating regionally and internationally validated standards and regulations for the emerging agricultural machinery, implements and equipment industry in the region.

Building the capacity of member countries to implement SAMS will be critical to the success of mechanization programs in the region. The human resources instrumental for the success of the transformation of the farm power situation were trained in the 1960s and 1970s – mostly through aid programs of the major donor agencies. Many of these have now retired from the system and a second (and in some countries a third) generation of experts is emerging. Further, many of the training and education programs established in the 1960s and 1970s are in decline in quite a number of universities due to competition with other sectors (such as ICT etc.) and also the decline of funding and employment opportunities in the public sector. Capacity building must include the youth and integrate consideration for gender issues, given the growing feminization of agriculture in the region with the propensity of male out migration from rural areas.

A critical factor for the success of SAMS is coordination across government ministries and with value chain stakeholders. Policies and strategies for the mechanization of agri-food chains require inputs from many ministries in the Government – including ministries of Agriculture, Trade and Industries; Finance and Economic Planning; Research and Development; Environment as well as Education. Coordination of the inputs of these various ministries is critical to the successful formulation and implementation of SAMS at the national and regional levels. This coordination is required within the public sector as well as with the private sector where there are many stakeholders including farmers and their organizations. Also the long-term commitment to SAMS by key policy makers is critical to catalyzing long-term support from its multi-stakeholders – which is essential for its successful implementation. Advocacy for such support by the key stakeholders will therefore be critical to the success of SAMS.

The emerging scenario, during the coming three to four decades, in mechanization is quite different from that of the third quarter of the twentieth century. New guidelines and processes are, therefore, required to assist member countries in policy formulation and in developing SAMS to cover the entire agri-food value chain. These guidelines must take cognizance of the prevailing mechanization scenario and futuristic scenarios as well as experience gained in the region over the past five decades. This requires the development of regional specific guidelines for SAMS, through a regional consultative process.

Finally, preliminary areas for national and/or regional action plans are identified including, among others: assisting those countries which require support for their programs for finalizing the conversion of their farm power from animate to mechanical sources; helping countries in coming up with short, medium and long term plans and technologies for the conversion from conventional tillage to more sustainable land preparation and crop husbandry techniques; widening the scope of mechanization planning to include the entire agri-food chain from the field to the consumer; as well as bringing in a specific focus on small scale farmers while also addressing medium and large scale farmers and the specific needs of women farmers – including the design of mechanization technologies that are best suited to the physical constructs of female farmers. A key issue is to ensure that mechanization positively contributes to the empowerment of women by increasing their labour productivity and reducing the drudgery associated with on-farm operations.

Other priority areas include strengthening the capacity for the manufacture of quality machinery and implements required for SAMS, including developing systems for setting standards and testing protocols; capacity building including for farmers and particularly young farmers and women farmers as well as for technology development and transfer systems and financing modalities for investments in sustainable mechanization systems. Also required will be the need to establish mechanisms for regional cooperation and coordination in order to facilitate the exchange of information and technologies as well as to design and implement collaborative regional programs and projects on SAMS where economies of scale and scope dictate so.

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# I. Introduction

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Sustainable Agricultural Mechanization Strategy or SAMS is a planning strategy that contributes to the goal of sustainability across the agri-food value chain, while meeting food self-sufficiency, generating economic development and inclusive growth as well as social benefit. It is effectively an element of the enabling environment for sustainable, inclusive and efficient agri-food value chain development. SAMS integrates consideration for the on- and off-farm use of mechanization inputs with special consideration and attention to addressing the needs of youth and women in rural areas. SAMS also integrates consideration for the dominance of smallholder farmers and micro-, small and medium agro-food processing enterprises across the region.

FAO and UNESCAP/CSAM, in December 2011, jointly convened a *Round-table on Developing Environmentally Sustainable Agricultural Mechanization Strategies (SAMS) for Countries in the Asia-Pacific Region*.

The objectives of the Consultation were to:

- Obtain a clearer picture of the status of agricultural mechanization in Asian countries;
- Share experiences among Asian-Pacific countries and identifying constraints as well as best options for achieving environmentally sound and sustainable agricultural mechanization in the region;
- Develop a framework for a Sustainable Agricultural Mechanization Strategy (SAMS) in the Asia-Pacific region.

A key output of this Round-table was the development of a strategic framework founded on five key pillars upon which the development of SAMS in Asia and the Pacific Region is anchored:

**Pillar 1** – Assessments and analyses of the current status of agricultural mechanization

**Pillar 2** – Enabling policies and institutions

**Pillar 3** – Human resource capacity development

**Pillar 4** – Investment in SAMS

**Pillar 5** – Advocacy on sustainable agricultural mechanization

A workshop convened at the FAO Regional Office in Bangkok in April 2012, produced an outline for a report to be prepared by countries in the region consolidating data and information of relevance to Pillar 1, under the strategic framework. Country reports prepared in accordance with the outline developed were presented at a Workshop on SAMS convened by CSAM and FAO in Sri Lanka, in November, 2012. Further, a number of country papers, prepared from a policy perspective, were presented to a Regional Forum on Sustainable Agricultural Mechanization in the Asia-Pacific Region, convened by UNESCAP/CSAM in October 2013 in Qingdao, China.

The consultations on SAMS underlined the critical importance of moving toward sustainable agricultural practices, by not only increasing access to environmentally sound farm machinery and implements, but also by developing and transferring land preparation and crop husbandry

techniques that contribute to the enhancement of sustainable rural livelihoods as well as the reduction of pressure on natural resources which are the base for food production.

It is important to realize that although mechanization strategies and policies are country specific, national strategies are best formulated when guided by insights and parameters identified within a framework which factors in outlooks with regional and global perspectives. A single mechanization strategy does not capture the diversity that exists across countries in this large and diverse region. However, several aspects related to policy formulation and strategy development can benefit from a common framework. Beyond these common areas, it is extremely useful to consider policies and strategies in the context of specific situations.

The key issues identified through a comprehensive survey of current literature on agricultural mechanization, as well as through these consultations were compiled into a draft background document to a *High-Level Multi-Stakeholder Consultation on Sustainable Agricultural Mechanization Strategy (SAMS) for Asia and the Pacific Region*, convened by FAO in collaboration with UNESCAP/CSAM in Bangkok, Thailand from 26 to 27 June 2014. This workshop was attended by 70 individuals, including senior level officials – Ministers of Agriculture and Directors responsible for Policy and Planning and for Agricultural Mechanization – representing twenty one member countries across the region. Also attending were representatives from tertiary education institutes, manufacturers of agricultural machinery and implements, civil society organizations as well as development partners such as the World Bank and the CGIAR centers.

This draft background document was developed in order to help participants reach consensus on the process of:

- (1) Developing/adjusting their mechanization strategies in the light of broader regional/global trends and national priorities;
- (2) Selecting among key strategic options while considering implied trade-offs (or consequences) instead of being prescriptive.

The Consultation sought to reach consensus on issues that would enrich the strategy and policy of member nations for achieving sustainable food security while taking cognizance of lessons from past policies and strategies as well as future socio-economic and technological trends. Discussions during the Consultation underlined the need to address mechanization strategy in agricultural systems – crop, fisheries and agro-forestry – and across the entire agri-food chain from inputs through to on-farm production and harvesting, to post-harvest handling and processing as well as to include consumer protection issues i.e. food safety.

This publication is a new and revised version of the original draft background document discussed during the High Level Multi-Stakeholder Consultation. It incorporates the comments and recommendations of stakeholders at the Consultation and the issues on which technical consensus was reached of relevance to key elements of SAMS in Asia and the Pacific region. A report of the proceedings of the High Level Multi-Stakeholder Consultation is being published separately (FAO-RAP, 2014).

Chapter 2 of this document provides an overview of the agricultural sector in Asia and the Pacific region focusing on key trends that are likely to influence developments in the sector especially those

that are relevant to the use of agricultural mechanization inputs. In Chapter 3, a review of agricultural mechanization developments in Asia and the Pacific region is presented focusing on the past fifty years and the increased integration of the agricultural machinery industry across the region. Following on the integration occurring in the region, a discussion on the need for a regional framework for SAMS that takes a broader approach to address mechanization strategy across agri-food value chains, is presented in Chapter 4, highlighting some of the elements emerging from the deliberations in various fora convened during the past three years.

In Chapter 5 key issues and constraints which are likely to influence the development of sustainable agricultural mechanization strategies across agri-food chains in Asia and the Pacific region are discussed. In the final and concluding Chapter 6, the main thematic areas and options for sustainable agricultural mechanization strategies across agri-food chains in Asia and the Pacific region are presented, highlighting the need for regional mechanisms to facilitate advocacy for SAMS, exchange of knowledge and experiences, as well as technologies.

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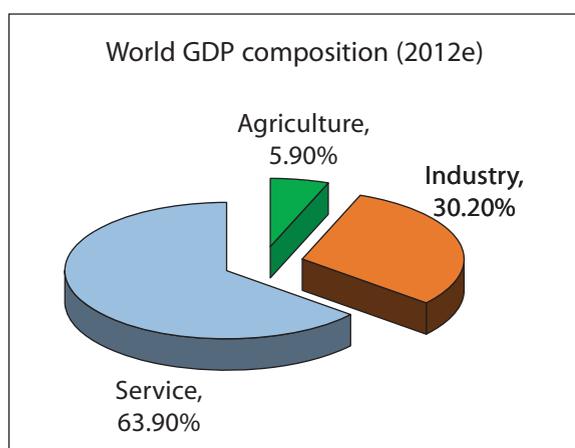
## II. Agricultural development in Asia and the Pacific region: an overview

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### 2.1 The global context and world food security

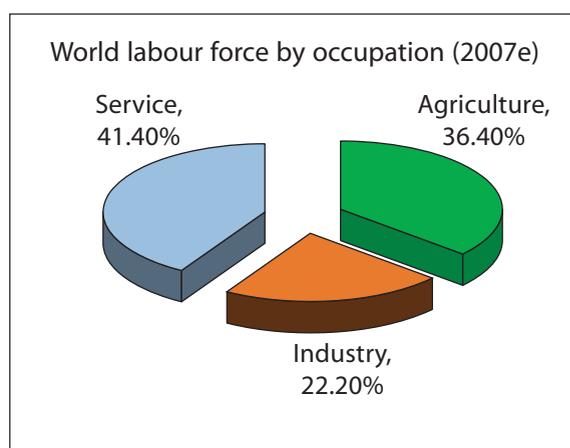
During the first half of the twenty-first century the world is facing multiple challenges of feeding growing populations, alleviating poverty, protecting the environment, and responding to climate change. Left unchecked, these challenges may perpetuate hunger and malnutrition, reduce economic growth – leading to political instability and pose irreversible damage to the environment and to human survival. Globally, approximately 870 million people were reported to be chronically hungry in 2011 (FAO, 2012). During the period 2010 to 2012, 13 percent of the population of Asia and the Pacific region experienced severe forms of hunger and malnutrition. However, while this proportion declined from 22 percent during the period 1990 to 1992, still as of 2012, approximately two-thirds of the world's undernourished population lived in the Asia and Pacific region (FAO, 2013).

Perhaps the greatest challenge which the world is facing at the beginning of the second decade of the twenty-first century is how to feed and adequately nourish an additional two billion people by the end of the subsequent four decades. This, combined with increasing incomes in the developing world and the growing need for energy, is likely to lead to an increased demand for agricultural products at an unprecedented rate. With global demand for food expected to increase by 60 percent by 2050 (OECD-FAO, 2012), farmers in all regions of the world will need to produce as much food over the next 40 years as they have in thousands of years to date. Worldwide, these farmers constitute more than one-third of the labour force and they contribute about 6 percent of global GDP (Figures 2.1 and 2.2).



Source: World Bank, 2012

**Figure 2.1: Sectorial composition of World GDP**



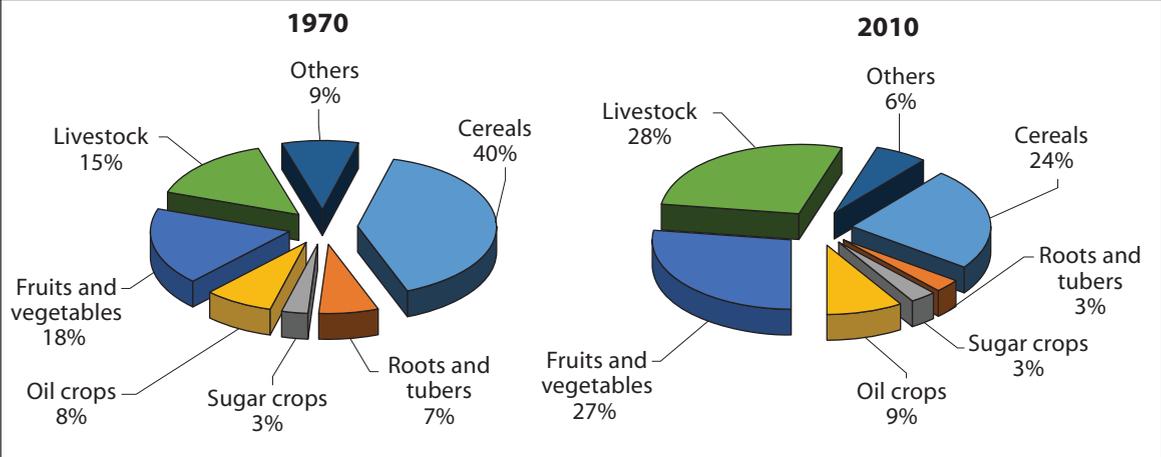
Source: World Bank, 2012

**Figure 2.2: Distribution of world labour force by occupation**

History has, however, shown that agricultural development is one of the most effective ways for remedying food security-related challenges. In particular, global food security is advanced when the world empowers smallholder farmers to maximize their agricultural and overall economic potential. Agriculture is also the most effective route to fighting poverty in many of the poorest regions of the world. Research shows that a 1 percent growth in the agricultural economy fuels a 6 percent increase in spending by the poorest 10 percent of the population. Far less income filters down to the poor from the growth of other parts of the economy (World Bank, 2008).

### 2.2 Agricultural development in the Asia-Pacific region

Stretching across some 45 billion ha, Asia claims the largest land area in the world, comprising about 30 percent of the global land area, where agriculture is far more than a mere factory for producing calories. It is a livelihood and a culture as well as a tool for improving health, maintenance of peace, empowering of women, fuelling economic growth at home and abroad and protecting the environment through processes such as drawing atmospheric carbon into the ground.



Based on data from Briones and Felipe (2013)

**Figure 2.3: Composition of agricultural output (at constant US\$) for developing Asian countries, 1970 and 2010 (%)**

A comparison of the composition of agricultural output for developing Asian countries for 1970 and 2010 is presented in Figure 2.3. It is evident that the focus of agrarian activities has shifted considerably across the region. Further, while there is a shift in the monetary value of the agricultural output of the region, cereal production continues to be the main pre-occupation of the agricultural sector. In this regard, rice remains the staple food crop in Asia as it continues to be the main source of calories for an overwhelming majority of the population in the region. Over 90 percent of the world’s rice supply comes from Asia, and the production, marketing and consumption of rice, constitute a major industry sector in itself which involves millions of resource-poor smallholder farmers.

In 2011, the total paddy output of the top ten rice producing countries in Asia was estimated at about 611.5 million metric tons (FAOSTAT, 2012), increasing by about 5 percent over the output in 2006 at 583.9 million metric tons (FAOSTAT, 2007). It is estimated that for every 50 million people added to the region's human population, an additional five million tons of paddy must be produced with less land, less water and less labour and in more efficient as well as environment-friendly production systems that are more resilient to climate change.

**Table 2.1: Cereal yields in countries of Asia and the Pacific region (2011)**

	kg/ha		kg/ha		kg/ha
Timor-Leste	2 252	Sri Lanka	3 503	Indonesia	4 886
Nepal	2 481	DPR Korea	3 749	Japan	4 911
Pakistan	2 718	Myanmar	3 880	Viet Nam	5 383
India	2 883	Malaysia	3 920	China	5 706
Cambodia	2 925	Lao PDR	4 045	Rep. of Korea	7 038
Thailand	3 065	Bangladesh	4 191	World	3 708
Philippines	3 341	PNG	4 457		

**Source:** World Bank, 2013

The major rice producing countries of the region can be grouped into surplus, self-sufficient and deficit countries depending upon their capacity to produce the rice requirements of their respective populations. Rice surplus countries which are also rice exporters include India, Myanmar, Pakistan, Thailand and Viet Nam, while some self-sufficient countries include Bangladesh, Cambodia, Japan, Lao PDR, China and Republic of Korea. The rice deficit countries which are struggling to attain self-sufficiency status include Indonesia, Malaysia and the Philippines.

From an economic development standpoint, the Asian countries show wide variation in their income classification (Table 2.2) that somehow also dictates their capacity to modernize their respective production and post-production sectors. High income countries such as Japan, the Republic of Korea and China have attained the status of fully modernized production and post-production sectors, while upper middle-income countries like Thailand and Malaysia have achieved significant improvements.

**Table 2.2: Classification by income of selected countries in Asia and the Pacific region**

Low income	Low-middle income	Upper-middle income	High income
Cambodia	Indonesia	Malaysia	Japan
Myanmar	Lao PDR	Thailand	Republic of Korea
Bangladesh	India	China	
	Viet Nam		
	Philippines		

**Source:** World Bank Indicators, 2011

Many lower middle and low income countries continue to grapple with numerous key constraints related to accessing modern tools, equipment and implements, inadequate infrastructure, weak human resource capacity and government policies that adversely impact on their capacity to achieve food security. There is, therefore, the need to reverse current trends of slow yield growth as well as inefficient and often poor management of natural resources and poor management of the post-harvest sector.

## **2.3 Factors that are likely to influence future agricultural development in the region**

Several factors and/or issues could threaten future agricultural production in the region. These include:

### *i. Demographic trends*

Currently, much of the growth in world population is occurring in the Asian region. Projections are that by 2025 the region will need 684 million tons of paddy, or 20 percent more than the quantity of rice produced in 2000, to meet the food needs of its projected population. This equates to requiring an increase in rice production of approximately 5 to 7 million tons of paddy annually, which is equivalent to adding around 2-3 million hectares of new land per year at current average yield levels (Table 2.1). Such land is not available and increased production will therefore have to come mainly from increased yields and reduced post-production losses. On the other hand, as rice consumption increases there will also be a shift toward dietary diversification and an increased demand for higher-quality food items such as livestock products as well as fruits and vegetables owing to rising living standards attributed to strong economic growth in many developing countries in the region.

Improvements in the overall post-production sector will be needed for the production of safer food of good quality as well as in reducing post-production losses both quantitatively and qualitatively. Less labour will be available for farming as more people, especially young males, move to the cities to look for jobs outside of the agricultural sector. Rising rural wages will force farmers in Asian countries to search for labour-saving technologies, thus increasing the demand for farm mechanization. Also with increasing feminization of agriculture due to the propensity of more men migrating to urban areas than women, there will be an increased demand for labour saving technologies as well as for gender specific interventions in mechanization programs.

### *ii. Decline in productivity growth*

According to the International Rice Research Institute (IRRI), growth in rice yields has fallen over the recent years, partially due to a decline in investment in research on rice productivity enhancement since the early 1990s, from 2.2 percent during the period 1970–1990 to less than 0.8 percent in the 1990s and 2000s. Land available for rice production is also declining as land around urban areas (much of it irrigated), is being converted to other uses such as for housing and industry, thus requiring increases in cropping intensity on currently farmed lands.

Rice is the most dominant user of water in most countries in Asia. Approximately 80 percent of water in the region is used for agriculture, 90 percent of which is utilized for rice production. With the

rapidly increasing demand for water by industrial and municipal users, competition for water is becoming increasingly fierce thus warranting increased attention.

*iii. Threat of climate change*

Climate change has potentially grave consequences especially for rice production and, consequently for global food security. Rice-based production systems in most developing Asian countries are highly vulnerable to the risks of climate change and have little capacity to cope with its impact. Water shortages, low water quality, increasing temperatures, rising sea-levels, floods and more intense tropical cyclones are real risks that will lead to the deterioration of farming environments in many areas of the region.

Of much concern are the “delta countries” such as Viet Nam and Bangladesh, which have contributed more than half of the growth in Asian rice production and appear to be most vulnerable to sea-level rise and erratic weather patterns due to climate change. These trends require the development and implementation of sustainable cropping systems that include innovative crop management practices and efficient post-production systems that are resilient to climate change to minimize risks.

*iv. Changing dietary habits*

The economies of most countries in the Asian region are undergoing major transformation (Timmer, 2010). This transformation is driven by rapid economic growth including increased integration of domestic markets to the global marketplace that has led to high growth in individual incomes in most countries in the region. Income growth has, in turn, induced shifts in consumer preferences toward increasingly diversified, safe and high-value food products. Shopping habits are also changing resulting in an increasing demand for high-quality packaged and branded foods brought about by the modernization of food retailing as manifested by the phenomenal growth of supermarkets and hypermarkets in urban centers of the region.

Consumer demand for specialty food products that comply with quality standards is rapidly growing in export markets, and presents great opportunities especially for growth of farm incomes. The confluence of these trends will continue to exert further pressure on existing agricultural on-farm production and post-production systems in the region that demand decisive action toward strategic system improvements if countries are to remain competitive both in domestic and export markets.

*v. Rising food and energy prices and declining farm incomes*

Global commodity prices experienced a decline up to early 2000, and showed a slow but steadily increasing trend between 2003 and 2006, after which they intensified from 2006 to the middle of 2008 before declining in the second half of that year (FAO, 2011). Particularly for rice, factors that contributed to the price increases include, among others, higher production and transport costs as a result of higher fertilizer and petroleum prices, slower productivity growth and weather risks. Also trade policies, such as export bans and aggressive buying by governments, that encouraged producers to withhold supplies, traders to increase stocks and consumers to engage in panic buying, all contributed to the increase in prices. These conditions invariably led to lower farm output, including declining farm incomes in some cases.

High and volatile food prices are predicted to continue in the near and medium term which could worsen food insecurity of not only the rural poor, who are in many cases net buyers of food, but also the urban poor – who are likely to constitute a significant proportion of the urban population and who exert inordinate pressure on food price policies. Increased production including conservation of food that has been already produced through improved post-production systems is likely to contribute, in no small part, toward alleviating food insecurity.

*vi. Need to consider the entire agri-food chain*

At present, agricultural production continues to receive full attention and unwavering support to address the above-mentioned challenges or constraints. The first Green Revolution which occurred in the region in the 1960s and 1970s focused largely on, on-farm production constraints. The post-harvest sector was then not considered a priority until the bumper harvests of the 1970s began to choke the post production infrastructure leading to massive losses. Thus it was only in the early 1980s when there was a concerted effort, initially focused on storage, to tackle post-harvest constraints of the food chain.

High post-harvest losses that occur all along the chain from production to consumption exacerbate food insecurity affecting especially the poor who spend a high percentage of their disposable income on staple foods. Post-production systems will, therefore, have to be strengthened to ensure food security and also to enhance the growing export opportunities for countries of the region to meet growing market demands within the region and globally (Mrema and Rolle, 2002). There is need therefore to analyze the entire value chain from the supply of production inputs through on-farm production and post-harvest systems improvement, to the marketing and distribution of the food to the ultimate consumer, in order to address mechanization needs that can support and improve technical and economic efficiency in these chains.

Traditional value chains dominate across most countries in the region, although modern value chains operate in parallel with these traditional chains. With few exceptions, agricultural value chains in most developing countries of the region are technically and structurally still inefficient, compounded with weak coordination and collaboration among chain stakeholders. SAMS must, therefore take a more holistic and inclusive approach covering the entire value chain as opposed to past practice where the focus was on on-farm production.

*vii. Need for sustainable production intensification*

A confluence of factors such as rising incomes, urban growth, increasing consumer demand for convenience and for agricultural products that are safe and of good quality; technological innovations and the phenomenal growth of modern food retailing and fast food chains across the region have transformed agricultural markets at the local, national, regional and international levels. The response of the Asian countries to this transformation has included policy and regulatory actions on sustainable intensification of on farm agricultural production as well as on quality, safety and reliability of supply.

Further, the new paradigm of “sustainable production intensification” recognizes the need for productive and remunerative agriculture that conserves and enhances the natural resource base and environment, and which positively contributes to the delivery of environmental services.

Sustainable intensification of crop and livestock production must not only reduce the impact of climate change on the production system but must also mitigate the factors that cause climate change, by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in the production systems both above and below the ground in order to improve ecosystem services for better productivity and a healthier environment.

*viii. Sustainability and mechanization of agri-food chains*

The functionality of environmentally friendly agricultural management practices is highly dependent on suitable mechanization technologies. Mechanization removes the drudgery associated with performing agricultural tasks by farmers and supply chain stakeholders, overcomes time and labour bottlenecks thus enabling the performance of tasks within optimum time windows and can influence the environmental footprint of agriculture, leading to sustainable outcomes.

On the other hand, inappropriate mechanization can lead to increased pressure on fragile natural resources by accelerating soil erosion and compaction, promoting the overuse of chemical inputs and encouraging farmers to open lands that currently serve as valuable forest reserves and rangelands. Other environmental costs include the contribution of mechanization to changing climate conditions by adding greenhouse gas emissions.

Actions to mitigate all of these impacts will need to be long term and well planned for the sustainability of the agri-food system as it increasingly intensifies not only in on-farm production but as actions are taken to improve the performance of the entire value chain from the farm to the consumer. This requires increased utilization of mechanization technologies and must be done in a sustainable manner. Long-term sustainability of the entire agri-food system must be a major driving force in the formulation of sustainable mechanization policies and strategies. There is thus an urgent need for the region to develop and implement Sustainable Agricultural Mechanization Strategies (SAMS).

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## III. Agricultural mechanization in Asia and the Pacific region

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Asia and the Pacific region has made significant progress over the past five decades in the field of agricultural mechanization – from the pessimistic situation of the 1960s when the region was basically at the bottom of the global agricultural mechanization league, to the situation half a century later when it has the largest annual global sales of agricultural machinery and implements – greater than even North America where mechanically powered mechanization was pioneered at the beginning of the twentieth century.

Mechanization can make a significant contribution toward achieving sustainable agricultural production. This Section broadly reviews the role of different aspects of mechanization within the context of its contribution to sustainable agri-food systems, starting from farm power and agricultural implements to the socio-economic factors as well as environmental and energy issues involved (see Box 3.1 for basic definitions of common mechanization terminology).

From a sustainability perspective, the debate on agricultural mechanization in developing countries has revolved around two aspects: First: the feasibility and impact of using higher levels of farm power in agricultural production and Second: the impact of some of the practices associated with the continuous use of modern agricultural implements on the environment and natural resources. The first aspect on the use of higher levels of farm power was of concern to development experts especially during the last four decades of the twentieth century while the second aspect on the environmental impact of agricultural machinery and implements has been of greater concern from the beginning of the twenty-first century.

In a discussion on mechanization of agri-food systems in Asia (and indeed in most of the developing world) it is important to recognize the distinction between these two aspects and analyze them separately otherwise the issues get mixed up and the debate becomes unnecessarily complex.

### **3.1 Farm power as a sustainable mechanization input**

In Asia, the early debate about farm power and mechanization was largely about the replacement of draught animals with tractors in land preparation and other crop husbandry tasks, as well as using diesel or electric pumps in irrigation and mechanically powered threshers in post-harvest operations. Asian farmers had a long tradition, spanning several centuries, of using draught animals (bullocks, buffaloes, elephants, camels, horses and mules) as a source of power in agriculture. In the 1960s the advent of mechanization (then equated to increased use of mechanical technologies such as tractors), was taken for granted by most development practitioners. It was then assumed that only within a matter of time agriculture would be transformed and developed to the extent that the use of tractors by farmers – either owned by them or through tractor hire services provided by governments and/or private operators – would become ubiquitous in most of the developing world (Giles, 1966).

The successful introduction of tractors, as the main source of farm power, in the United States of America which occurred between 1920 and 1960, and in Europe which occurred between 1945 and 1970, greatly influenced the debate in Asia on replacing draught animals with mechanical power. As has been noted by White (2000), the USA experience, where during the period from 1925 to 1960, tractors replaced about 24 million draught animals then in use in agricultural production, makes the former the unsung hero of twentieth century innovations. The same transformation of the farm power situation occurred in Western Europe between 1945 and 1975 (Esmay and Faidley, 1972; Kurdle, 1975; Promsberger, 1976; Burch, 1987; Gibb, 1988). It was not then unreasonable to assume that the same transformation would occur in most of the developing world.

### **Box 3.1: Basic definitions of selected mechanization terminology**

As has been noted in FAO (1981), the introduction and application of agricultural mechanization in the development process is decided by people with diverse training, backgrounds and interests. It is therefore important for these individuals to have a common understanding of the different terms used to describe mechanization. The following terms associated with agricultural mechanization are used in this report:

**Agricultural mechanization** embraces the manufacture, distribution and operation of all types of tools, implements, machines and equipment for agricultural land development and farm production as well as for harvesting and primary processing of agricultural produce. It includes three main power sources:

- **Hand-tool Technology:** tools and implements which use human muscle as the main power source.
- **Draught Animal Technology (DAT):** machines, implements and equipment powered by animals e.g. horses, oxen; buffalo; donkeys etc.
- **Mechanical-Power Technology:** highest level of mechanization powered by engines and/or motors such as tractors, motors using petrol or diesel or electricity to power threshers, mills, centrifuges, harvesters, irrigation pumps etc.

**Tractorization** refers to the application of tractors of any type (single axle 2-wheel tractors (2WT); two-axle 4-wheel tractors (4WT) or track-type) and of any horsepower rating to activities associated with agriculture.

**Farm mechanization** is technically equivalent to agricultural mechanization but refers only to those activities occurring inside the boundaries of the farm unit.

**Agricultural motorization** refers to the application of all types of mechanical motors or engines regardless of energy source to activities associated with agriculture.

**Agricultural implements** are devices that perform agricultural tasks which are attached to, pulled behind, pushed or otherwise to a human; animal or mechanical power source.

**Agricultural machinery** is a general term used to describe tractors, combines, implements and devices more sophisticated than hand tools which are animal/mechanically powered used in agricultural production.

**Agricultural equipment** normally refers to stationary mechanical devices such as irrigation pump-sets, hammer mills, centrifuges, milking machines etc.

**Post-harvest operations** refer to those activities carried out after harvesting the crop on the farm or on the way to the consumer – handling, primary processing, storage etc.

Five main reasons were advanced to justify replacement of the power source in primary cultivation from animate (either human or draught animals) to mechanical (i.e. tractors) sources: a) expansion of the area under cultivation, b) facilitation of timelier field operations resulting in an increase in cropping intensity and overall productivity, c) the multi-functional use of mechanization – tractors were not only useful for land preparation but could also be used in transportation as well as to power implements and equipment used in improving and maintaining farm and rural infrastructure in general (e.g. drainage and irrigation canals, fencing, rural roads), d) mechanization could overcome seasonal shortages of labour and/or release labour in critical periods for other productive tasks, and e) mechanization reduced the drudgery associated with farm work, especially for power intensive tasks such as tilling the land with a hand hoe. This is particularly important in tropical areas where high temperatures and humidity render farm work reliant on human muscle power to be ergonomically quite difficult and arduous.

A number of experts in the development community argued for a cautious approach to the ubiquitous introduction of mechanical technologies. These experts argued that mechanically powered agricultural mechanization often leads to the displacement of labour and other socio-economic problems, including unemployment, landlessness, rural-urban migration, inequitable distribution of wealth and increases in absolute poverty. They also pointed to problems of balance of payments because of the need to import machinery, fuel and possible technical assistance. They further argued that land holdings were often small and fragmented, making it difficult to use tractors efficiently; that the adoption of lumpy and indivisible mechanical technologies did not necessarily lead to increased yields, and that increases in productivity could be achieved by the use of divisible and scale-neutral biochemical inputs such as improved seeds and fertilizers (Esmay and Faidley, 1972; ILO, 1973; Binswanger 1978; 1986). The poor performance of government-sponsored and operated tractor hire schemes in many developing countries in the 1960s and 1970s strengthened the arguments against the widespread use of tractors and other mechanical technologies. Also the intermediate technology movement was then quite strong and influential in the international development agencies – the tractor was then considered to be an advanced technology (Dumont 1966; Bunting, 1970, Bartsch, 1977).

These two opposing viewpoints dominated the mechanization debate in the 1970s and 1980s among leading development experts, in particular in the major international development agencies, e.g. FAO, ILO, World Bank, ADB etc. In order to bridge the gap between the two viewpoints among policy-makers and development specialists, FAO and the OECD convened an expert consultation on “Agricultural Mechanization and its Effect on Production and Employment,” in February 1975 in Rome, Italy, to discuss the effects of farm mechanization on production and employment in the developing regions of the world (FAO, 1975). Experts at the consultation agreed that farm mechanization should lead to increased production while reducing the drudgery associated with performing agricultural tasks using hand tool technology. With respect to its unemployment effects, however, the experts noted that there were so many variables that could affect employment in agriculture that it was extremely difficult to isolate the effects of farm mechanization.

The experts concluded that urgent action was required to determine whether or not continued growth in farm mechanization was “socially desirable,” which could only be done by conducting field studies in the countries concerned. The consultation then recommended ‘appropriate mechanization,’ which combines hand tool, animal and mechanically powered agricultural

implements and equipment suited to the physical, cultural, economic and technological environment of the country concerned. Further, the need to train manpower for all aspects of agricultural mechanization programs was highlighted, noting specifically that "...manpower training requirements for extension in the use, or introduction of farm mechanization based on animal power were considerable, particularly if attempts are made to introduce draught animals in areas where there was no tradition of animal husbandry and use of draught animals" (FAO, 1975).

It was also recommended that developing countries should formulate agricultural mechanization policies and develop strategies for their implementation, and for increased expenditure on research in agricultural mechanization within the national agricultural research systems. There were specific recommendations to FAO, particularly of relevance to developing guidelines for determining and evaluating appropriate forms and levels of farm mechanization to suit different ecological, social and economic conditions of the developing countries. It was also suggested that FAO should provide support to governments in setting up advisory services in the field of agricultural mechanization and strengthen its information services to provide multidisciplinary information on agricultural mechanization.

Quite a number of socio-economic studies on agricultural mechanization were undertaken in the 1970s to 1980s all over the developing world highlighting the positive and/or negative impacts of agricultural mechanization. Regardless of the robustness and validity of these socio-economic field studies, they were a critical factor leading to reduced attention to mechanization in the international development agencies from the late 1980s up to the turn of the twenty-first century. However, the momentum for mechanization in Asia, and to a lesser extent, in Latin America, had reached a level where it was unstoppable by this change of priority by the major international development banks and donor agencies. The farming community as well as the agricultural machinery industry and agricultural support services and institutions in many Asian countries were strong enough to resist this change in policy by the major development organizations and hence the pace of mechanization was largely unaffected (Ahmed, 1972; Binswanger 1978; 1984; 1986; Balis, 1978; Farrington *et al.* 1982; Singh 2001; 2013; Mrema *et al.* 2008).

Thus by the turn of the twenty-first century the farm power situation in most Asian countries had been significantly transformed and the issue was not about the desirability of the introduction of mechanical technologies but on when they would replace the animate power which had been the main source of farm power in the twentieth century especially in land preparation and crop husbandry (Box 3.2). Also the experience of the region does show that mechanization of processing and pumping has tended to precede the mechanization of crop husbandry and harvesting operations. Further mechanization of power-intensive processing and pumping operations can be profitable at low wage rates (Singh, 2013; Renpu, 2014).

Today, countries across the region differ widely with respect to how they make use of farm power as an input of their agricultural mechanization strategies. Three types of farm power sources are being widely promoted in many countries and are rapidly being adopted across the region:

- *Tractors:*
  - Small 2-wheel single axle tractors (2WT).
  - Medium horsepower 4-wheel and two axle tractors (4WT). Some countries like India and China are increasingly moving toward higher horsepower tractors.

- *Electric or diesel pump-sets* for irrigation.
- *Motorized/powered equipment* for harvesting, threshing and other post-harvest handling and processing operations including transportation and logistics beyond the farm-gate.

It is apparent that all countries in the region are in the process of transforming their sources of farm power into these three categories. Some countries are at quite an advanced stage having reached or about to reach up to 70 percent use of mechanical power in their land preparation operations, while others have still got some way to go in this respect and/or have suffered from inappropriate and fragmented approaches to mechanization. In general, agricultural production and food security in the latter group of countries is, therefore, adversely affected owing to the insufficient use of farm power and the inappropriate use of farm machinery and implements thereby negatively impacting on environmental sustainability, labour productivity and/or labour scarcity.

### **Box 3.2: Draught animal power and sustainability in Asian agriculture**

Draught animals have played a key role, over many centuries, in providing farm power in Asia and the Pacific region. In the 1960s both China and India had over 100 million draught animals in use in their agricultural systems, providing power for tillage, transport and even some processing operations. A manufacturing industry for implements and equipment for use by draught animals was created at both the artisanal village level and also at the large scale industrial level. However, since the 1990s the use of draught animals as a power source in Asian agriculture has declined appreciably (e.g. in India the number of draught animals in use declined from over 85 million in 1975 to about 53 million in 2005 and is projected to decline to 18 million by 2030, Singh, 2013). In Bangladesh, the cyclones of the 1980s killed most of the 11 million draught animals in use in 1983/84 and these were replaced by 2-wheel tractors (400 000 units) and 4-wheel tractors (15 000 units; see Box 5.1). Similarly in China it is projected that draught animals will be completely replaced by a combination of 2WT and 4WT by 2025 (Srivastava and Ojha, 1987; den Hertog and van Huis 1992; Renpu, 2014).

The changeover from draught animals to mechanical power has enabled farmers in these countries to use the fodder/land they had to maintain for feeding these animals, for other purposes (e.g. keep dairy animals etc.). Notwithstanding the dramatic changes which have occurred over the past three decades and which are likely to occur in the next two decades on the use of draught animals in agriculture, there are still quite a number of social scientists who advocate for their continued promotion in agriculture ostensibly due to their being renewable sources of power/energy and more environmentally sustainable (Dikshit and Birthal, 2010). The veracity of such claims needs to be scientifically and objectively analyzed and the issue resolved. As Adams, 1988 noted, claims that draught animal technology (DAT) could be more efficient, energy-wise, than mechanical technologies defy the basic laws of physics.

## **3.2 Agricultural implements and sustainability**

A notable feature of the debate on agricultural mechanization in Asia during the second half of the twentieth century was the inordinate concern on the source of farm power. The impact of the implements being hitched to these power sources especially for land preparation and crop husbandry was of less concern to most scientists and development practitioners. Land preparation by draught animals had been practiced in the region for several centuries and employed the same design of tillage implements as that used on tractors – the only difference being that the number of tines/ploughs on the implement being more in the latter case.

Studies on mechanization in Asia in the 1960s and 1970s were not, therefore, that much concerned about the impacts of tillage implements being hitched to draft animals and/or tractors until much later. Research on tillage then was more concerned about the need to reduce the draft power requirements and the versatility of the implements for multi-purpose use – ploughing, harrowing, planting and weeding (Lal, 1998; Starkey 1986). Sustainability was analyzed from the perspective of the consequences and impact of biochemical inputs rather than on the basis of the types of implements used for land preparation and crop husbandry (Randhawa and Abrol, 1999).

On the other hand, mechanized tillage was considered one of the major contributors to the dust bowls in the United States of America in the mid-1930s and which led to the establishment of the Soil Erosion Service (SES) and a large long-term research program focused on tillage implements and practices. It is in this context, therefore, that minimum tillage practices and conservation agriculture gained much traction in North and South America (Troeh *et al.* 1980; Lal, 1998; Friedrich, 2013). The environmental impact of mechanization – especially that of tillage implements and practices – became an issue of major concern in Asia only in the late 1990s and at the beginning of the twenty-first century and will continue to feature highly in the process of planning for sustainable agricultural mechanization strategies in the region.

### **3.3 Socio-economic issues**

From a user perspective, agricultural mechanization removes the drudgery associated with agricultural labour and overcomes time and labour bottlenecks to perform tasks within optimum time windows, thereby increasing efficiency in production systems. Socio-economic concerns on the sustainability and the impact of the introduction of higher levels of mechanization, have historically revolved around the following issues:

- The negative perception that mechanization would result in increased unemployment of farm laborers and thus contribute to increased rural poverty.
- That it would lead to increased inequities due to the perception that large scale farmers would benefit more from mechanization while small scale farmers would be marginalized. It was then argued that many small scale farmers were likely to be bankrupted and become unemployed laborers (ILO, 1973).
- The economics of tractors, as a source of farm power, was questioned – it was argued then that use of the tractor as a source of farm power, was not profitable as compared to alternatives such as draught animals (Binswanger, 1978).
- Ergonomic factors such as the drudgery of performing power intensive farm operations with draught animals and/or hand-tools as well as the resulting social impact leading to the young and educated migrating from rural areas for better and ergonomically more comfortable jobs in the urban areas in industry and services (FAO, 1975).
- The level of assistance by the public sector and/or governments in incentivizing the adoption of mechanization technologies through low interest credit and/or subsidies to farmers for procurement of agricultural machinery, implements and equipment as well as provision of other support services.
- Timeliness in performing key field tasks such as land preparation, planting, weeding and harvesting in both irrigated and rain-fed agriculture and the role of different mechanization systems to facilitate this.

These issues are likely to continue to feature in future discussions on sustainable agricultural mechanization strategies.

### **3.4 Environmental issues**

The Green Revolution which occurred in the 1960s and 1970s in Asian countries revolutionized agricultural and economic development. However, the Green Revolution worked best in areas with good soil and water resources and where returns on investments in infrastructure development, technology application and on inputs were high as well. Gains in agricultural production achieved by the Green Revolution were, however, made at the expense of the environment resulting in some areas in, among other things, land degradation, salinization of irrigated areas, over extraction of groundwater as well as the build-up of pest resistance and loss of biodiversity.

Another challenge for agriculture is its environmental footprint and the impact of climate change. Agriculture is responsible for about 30 percent of the total greenhouse gas emissions of carbon dioxide, nitrous oxide and methane, while being directly affected by the consequences of a changing climate. These environmental impacts have necessitated a focus on the development of sustainable agricultural production systems, i.e. systems that maintain optimal production without jeopardizing production factors. The new paradigm of “sustainable production intensification” recognizes the need for productive and remunerative agriculture that conserves and enhances the natural resource base and the environment, and which positively contributes to the delivery of environmental services.

Sustainable agricultural production intensification must not only reduce the impact of climate change on crop and livestock production but must also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in agricultural production systems both above and below the ground in order to improve ecosystem services for better productivity and a healthier environment.

This concept is very well described in the recent FAO publication titled *Save and Grow* which explains how agricultural practices in the future could still result in increased production while conserving the natural resource base. The use of inappropriate mechanization inputs can lead to increased pressure on fragile natural resources by accelerating soil erosion and compaction, promoting the over-use of chemical inputs and encouraging farmers to open lands that currently serve as valuable forests and rangelands.

In the quest for environmental sustainability, there is currently a global movement advocating for more environmentally friendly land preparation and crop husbandry practices including among others, minimum and/or zero tillage and planting techniques – more generally known as conservation agriculture. Zero tillage techniques used in some cereal systems in South Asia, have for example helped in saving fuel and water, in reducing the cost of production and in improving system productivity and soil health (Singh, 2013). Due to a multiplicity of reasons, the use of these techniques is still, however, very limited in Asia as compared to other regions such as North and South America as well as Australia (Friedrich, 2013).

At the same time, with increasing urbanization trends, the ranks of the urban poor will continue to swell in numbers and they will demand food products in convenient formats and at reduced prices.

Entrepreneurs are likely to respond to this increased demand by engaging in the commercialization of new food products in convenient formats and will require increased use of mechanization inputs. However, these mechanization inputs must be sustainable and must not negatively impact the environment.

### 3.5 Water use in agriculture and sustainability

In 2011, total renewable water resources in the Asia-Pacific region equaled 20 521 billion cubic meters (World Bank, 2013), which represents approximately 38 percent of total available water in the world. Agriculture is considered to be the largest user of fresh water, as it draws about 70 percent of the available fresh water on earth. Annual fresh water withdrawal for agriculture, expressed as a percentage of total fresh water withdrawal in 2011, for selected countries of Asia and the Pacific region is summarized in Table 3.1.

**Table 3.1: Annual fresh water withdrawals for agriculture in selected Asian countries in 2011**

% of total fresh water withdrawal		% of total fresh water withdrawal	
Bangladesh	87.8	Malaysia	34.2
Bhutan	94.1	Myanmar	89.0
Cambodia	94.0	Nepal	98.2
China	64.6	Pakistan	94.0
India	90.4	Papua New Guinea	0.3
Indonesia	81.9	Philippines	82.2
Japan	63.1	Sri Lanka	87.3
Korea, Democratic Republic	76.4	Thailand	90.4
Korea, Rep. of	62.0	Timor-Leste	91.4
Lao PDR	93.0	Viet Nam	94.8

**Source:** World Bank, 2013

Asian countries can be grouped according to the percentage rate of withdrawal of total fresh water, as: a) Very low withdrawal (<35 percent), Malaysia; b) Low withdrawal (60–65 percent) including China, Japan, Republic of Korea; c) Moderate withdrawal (75–90 percent) comprising Bangladesh, DPR Korea, India, Indonesia, Myanmar, Philippines, Sri Lanka, Thailand; d) High withdrawal (90–95 percent) including Bhutan, Cambodia, Lao PDR, Pakistan, Timor-Leste, Viet Nam; and e) Very high withdrawal (95–100 percent), Nepal.

Despite the fact that modern agriculture relies on irrigation facilities, the use of irrigation pumps is visibly diverse among countries of Asia and the Pacific region. Table 3.2 summarizes the number of irrigation pumps that include both diesel as well as electric pumps. The use of such pumps has increased exponentially in this region: in India the use of pumps grew from 0.4 million in 1960 to 6.2 million in 1980, to 19.5 million by 2000, and to 28 million in 2010. In Bangladesh, the use of pumps grew from 0.0356 million in 1977 to 0.303 million in 1996 to 1.329 million in 2006 and to 1.3 million in 2010; while in Cambodia, it increased from 0.064 million in 2001 to 0.167 million in 2010. However, the excessive use of pumps also led to the overdraw of groundwater, and as a result, countries of Asia and the Pacific region have recently been facing depleted water

**Table 3.2: Use of irrigation pumps (diesel and electric pumps) in selected Asian countries**

Year		Irrigation Pumps (millions)
2010	India	28.000
2010	Indonesia	0.090
2010	Bangladesh	1.300
2010	Nepal	0.130
2010	Cambodia	0.167
2011	Malaysia	0.097
2011	Myanmar	0.177
2011	Thailand	2.022

**Sources:** Singh (2013); CSAM-FAO Country Reports

tables during the summer months. Even to fetch drinking water, farmers and particularly women and children have to travel farther than before.

Agricultural irrigation is actually one of the largest consumers of water worldwide and with population growth and industrialization, there is an increasing demand for water by other consumers. The availability of water for agriculture is likely to be reduced and so water saving technology is paramount to the sustainability of irrigated farming which, due to its higher production levels, is contributing a much higher proportion of overall food production in the region than its actual share of cropped land. It will, therefore, be necessary to economize on water use in irrigated farming. Specifically for paddy, the highest consumer of irrigation water, new cropping methods, under the System of Rice Intensification (SRI), allow significant water savings by avoiding permanent flooding and creating an aerobic soil environment.

In addition to agronomic practices, direct water management methods have a major influence on water use in agriculture. In Asian countries surface irrigation schemes are the most widespread form of irrigation. These include basin type flood irrigation which can be considered as the most wasteful due to the large evaporation surface. Bed and furrow systems, which can be used even for crops like rice and wheat, allow a significant reduction of the open water surfaces and consequent evaporation losses. Other irrigation methods, using pressurized pumping systems to irrigate crops from the top such as sprinklers are more efficient in water use. Other technologies such as, micro sprinklers or drip irrigation are the options which are most water efficient and also consume the least power and hence should be more sustainable (FAO, 2011b; Friedrich, 2013; World Bank, 2013).

### **3.6 Energy issues**

The global energy crises of the 1970s and 1980s resulted in sharp increases in energy prices and drew the attention of development experts to the sustainability of agricultural mechanization systems based on farm power that are dependent on fossil fuels. These energy crises also led to increased attention by research organizations on alternatives to motorized mechanization systems under the so called 'intermediate' and/or 'appropriate' technologies as these were viewed as being more sustainable and socially desirable in the developing regions of the world.

### **Box 3.3: Lessons from the Asian Mechanization Experience of the 1960–1990s**

The following are the major lessons from the agricultural mechanization experiences between 1960 and the 1990s in the Asia and the Pacific region, especially in the early stages where farm power, as a mechanization input, played an inordinate role in influencing policy and strategy formulation:

- i. Mechanization of processing and pumping tended to precede the mechanization of crop husbandry and harvesting operations. Further, mechanization of power-intensive processing and pumping operations was profitable at low wage rates in many cases.
- ii. Mechanization of difficult and arduous tasks, such as land preparation, did not necessarily lead to unemployment. Increments in field productivity stemmed from combinations of technologies used as a package, including farm power and biological technologies.
- iii. To pay for investments in mechanical technologies, farmers have to be able to generate income and profit from their production; sustainable mechanization has often been associated with programs that facilitated or supported access to organized markets for cash and food crops such as cotton, rice, wheat, etc.
- iv. Tractorization has often led to increases in farm size through land consolidation and procurement of adjacent farms. Because of the high capital costs associated with tractors, only medium and larger farms were in the position to exclusively utilize them efficiently (see boxes on experiences from India and Bangladesh in Chapter 5).
- v. Farmers who purchased tractors were able to use them profitably only if the tractors were also used for other off-farm activities such as transportation in addition to on-farm activities. Where rental markets existed or could be established, farm size has had less influence on the pattern of mechanization (e.g. in India see Box in Chapter 5).
- vi. Substitution of labour by tractors tended to occur as a result of the high supervision costs associated with hired labour, particularly on larger farms. Government subsidies, tax concessions and over-valued exchange rates may have accelerated the pace of tractorization especially in the 1960s and 1970s when exchange rates were fixed by Governments rather than by the market.
- vii. Efforts to design and promote implements and machinery specifically for particular farming systems or specific groups of farmers have not fared well (Starkey, 1988; Holtkamp, 1992).
- viii. The early focus was on power sources for land preparation and environmental concerns did not feature highly until the 1990s when soil compaction by machinery became an issue of concern. From the beginning of the twenty-first century the environmental impact of conventional tillage practices has increasingly become an issue of concern.

The above is drawn from a review of literature in this area – more specifically by ILO, (1973); FAO, (1975); Mc Inerney and Donaldson, 1975; Binswanger, (1978 & 1986); Farrington *et al.* (1982); Rijk, (1983); IRRI and ADC, (1983); Burch, (1987); Starkey, (1988); Singh (1998; 2001; 2011); Mrema *et al.* (2008); Kienzle *et al.* (2013); Renpu (2014).

The use of draught animals in agricultural systems is declining across the region, and projections are that the contribution of animate power to the farm power situation in most countries will become insignificant by 2020 ( Box 3.2). Tractors (either 2-wheel or 4-wheel) are becoming the standard source of farm power across the region and attention is increasingly being paid to developing improved implements to be used in land preparation with reduced environmental damage. 2-wheel tractors are, in general, single axle low horsepower tractors also known as power tillers, while 4-wheel tractors, have two axles and engines ranging from 15 hp to over 100 hp. 2-wheel tractors are used for land preparation mostly in wetland areas – either in flooded plains or in irrigated lands, while 4-wheel tractors can be used anywhere. They are, however, more widely used in rain-fed areas where the power requirements for tillage are higher.

Of late, the trend in some countries is to move to higher horsepower 4-wheeled tractors, which would seem to go counter to the recommendations by conservation agriculture experts, of encouraging the use of low horsepower tractors in the region. As an example in India, the sales of tractors of over 50 hp increased from 7.3 percent of the total number of tractors sold in 2000 to 15.9 percent by 2011, while the corresponding figures for 40–50 hp tractors was 14.1 percent in 2000 and 28.4 percent in 2011 respectively. On the other hand, there was a decline in the percentage of smaller tractors sold e.g. sales of those in the range 31–40 hp declined from 55 percent in 2000 to 42 percent in 2011 and those in the range 21–30 hp showed a similar trend declining from 23–12.7 percent of total tractor sales (Mehta, 2013). The figures for China show even higher growth rates for sales of high horsepower tractors over the past decade (Tam, 1985; Singh, 2010; Singh, 2013; Mehta, 2013; Friedrich, 2013; and Renpu, 2014).

**Table 3.3: Accounting for growth in agricultural output in China: 1965–1989 (Fan & Pardey, 1992)**

Factor	% Contribution to growth
Land	-0.9
Irrigation	3.3
Labour	3.4
Farm Power	11.8
Institutional change	13.8
Research	19.8
Fertilizer	21.3
Other factors	27.6
<b>Total</b>	<b>100%</b>

### 3.7 Conclusions

The main issue of concern in so far as agricultural mechanization in Asia was concerned in the second half of the twentieth century was the consequence/impact of the ubiquitous introduction of mechanical technologies in place of draught animals as a major source of farm power from ergonomic, technological, economic, social and equity perspectives. The implements that were powered by these mechanical technologies were, by and large, similar in design to those drawn by

draught animals which had been used in the region for several centuries. Further, the debate on mechanization was focused on land preparation and crop husbandry with little attention being paid to the post-harvest sector.

The main agricultural development issue then was to increase agricultural productivity and overall production to attain food security for a largely agrarian population and farm power was regarded as a major input. While earlier studies by among others, Giles, 1966, did show correlation between farm power and increased yields and productivity in the then Third World agriculture, this was however not universally accepted (Binswanger, 1978). Thus the contribution of mechanical technologies including farm power in the Green Revolution has been greatly underrated in the literature by development experts when compared to the role of bio-chemical technologies (fertilizers, high yielding varieties, crop protection technologies) as well as that of the socio-economic inputs (marketing, farm management and farming systems). Data from India shows that farm power utilization increased from an average of less than 0.1 kW/ha in the 1960s to about 1.45 kW/ha in 2005. Further grain yields are significantly higher in states where the utilization of farm power is higher as compared to those with low rates (e.g. Punjab with 3.5 kW/ha with an average grain yield of 4.03 MT/ha compared to corresponding figures for Tamil Nadu at 0.9 kW/ha and 2.26 MT/ha respectively, Singh 2011, 2013).

Likewise, data from other countries in Asia (and in Latin America) show significant increases in the use of powered mechanization inputs over the past six decades. The growth in agricultural output which has occurred in these countries has been attributed to, among other inputs, increased use of mechanical technologies, e.g. in China the growth in agricultural output which occurred between 1965 to 1989 has been attributed, on a percentage basis, to fertilizers, research, institutional change, farm power and irrigation at 21.3, 19.8, 13.8, 11.8 and 3.3 percent respectively (Table 3.3, Fan and Pardey, 1992). The main lessons from the Asian experience of the second half of the twentieth century in agricultural mechanization are summarized in Box 3.3.

At the turn of the 21<sup>st</sup> century considerable progress had been made by quite a number of countries in Asia and the Pacific region in changing their main sources of farm power from animate to mechanical. The rapid economic development of the last decade of the twentieth century coupled with other socio-economic and demographic trends occurring since then have increasingly drawn the attention of development experts to the sustainability of the mechanization systems being introduced especially as related to their environmental, technological and socio-economic impacts. It is in this context, therefore, that FAO and UNESCAP-CSAM have initiated jointly with member countries of Asia and the Pacific region an earnest discussion on the key issues involved in the process of developing and implementing at the local, national and regional levels, sustainable mechanization strategies. These are covered in the subsequent sections of this report.

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## IV. Regional framework for SAMS

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### 4.1 Strategic priorities

SAMS was conceived at the outset as a planning strategy that contributes to the agricultural goal of sustainably meeting food self-sufficiency objectives.

Thus, the overall goal of SAMS as defined by participants to the December 2011 Roundtable on Developing Environmentally Sustainable Agricultural Mechanization Strategies (SAMS) for countries in the Asia-Pacific region is:

***“...To address the UN Millennium Goals Nos. 1 and 7 (food security, poverty alleviation and environmental sustainability) through sustainable intensification of agriculture by creating an enabling environment through a SAMS for the Region...”***

The Roundtable recommended that this goal would be achieved through activities developed under five strategic pillars:

- Pillar 1: Surveys, assessments and analyses of the current status of agricultural mechanization
- Pillar 2: Enabling policies and institutions for SAMS development
- Pillar 3: Human capacity development
- Pillar 4: Financial support to enhance investment in SAMS
- Pillar 5: Advocacy on sustainable agricultural mechanization

The main elements of these five strategic pillars include:

#### **Strategic Pillar 1 – Surveys, assessments and analyses of the current status of agricultural mechanization**

The success of a SAMS necessitates a thorough understanding of the current situation in a country. This constitutes a condition for identifying possible interventions to alleviate problems while capitalizing on the use of existing potential.

Activities would include:

- Assessment of existing agricultural practices and analysis of supply chains;
- Analysis of existing policies;
- Assessment of existing intra- and inter-institutions involved in agricultural mechanization;
- Assessment and identification of technologies suited to specific ecological zones;
- Assessment of the use of targeted subsidies for innovative implements for sustainable agriculture.

## **Strategic Pillar 2 – Enabling policies and institutions for SAMS development**

The principal role of governments is to provide the conditions for the largely self-sustaining development of SAMS with minimum direct intervention. The purpose of any interventions should be clearly identified and fall within the framework of the SAMS with explicit attention to the impacts of other policies on the level and use of equipment and implements in agriculture. With SAMS a new challenge is to formulate and implement policies and strategies that lead to government interventions in a consistent and efficient manner.

Activities would include:

- Review and harmonization of policies, and regulations designed to attract investments in SAMS;
- Development of public-private partnerships (PPP);
- Development and operationalization of a testing and standards formulating mechanism for agricultural mechanization;
- Institutionalization of quality assurance of machinery, equipment and mechanization services; occupational health and safety;
- Development of research and development institutions to enhance innovation in SAMS.

## **Strategic Pillar 3 – Human capacity development**

The idea is to ensure the development of a knowledgeable, well-trained and disciplined labour force with the capacity to drive and sustain private sector-led growth.

Specific activities would include:

- Building the capacity of farmers – especially young farmers, extension staff and local government officials on SAM technologies;
- Building the capacity of manufacturers and distributors to supply inputs (seeds, tools, implements, machines);
- Enhancing information dissemination on mechanical power technologies (including profitability, environmental, social, economic aspects, as well as innovations made to agricultural machinery).

## **Strategic Pillar 4 – Financial support to enhance investment in SAMS**

Agricultural mechanization is capital intensive making it difficult for a majority of farmers to afford, given their dependence on cash financing. In an ideal situation machinery would be financed by borrowing or leasing with repayments taken retrospectively over the life of the machine.

Specific activities would include:

- Review and harmonization of policies, and regulations designed to attract investments in agricultural mechanization;
- Increasing financing for agricultural mechanization from the private sector;
- Improving access to loans for the purchase of mechanization inputs;
- Improving financing for mechanization activities through the establishment of an agricultural mechanization promotion fund.

## **Strategic Pillar 5 – Advocacy on sustainable agricultural mechanization**

It is important to influence public-policy and resource allocation decisions within political, economic, and social systems and institutions. Advocacy encompasses many activities including media campaigns, public speaking, commissioning and publishing of research findings at both the regional and country level.

Specific activities include:

- Promoting a strategic vision for SAMS based on national development objectives (economic growth, sustainable development and poverty reduction as well as increased investment in environmental services; impact of SAMS on employment of youth and women in agriculture);
- Facilitating information sharing and lessons learned about good practices on SAMS;
- Ensuring effective participation by all stakeholders (including non-state actors and private sector) in SAMS processes;
- Developing and maintaining partnerships with the scientific community, non-state actors and the private sector;
- Ensuring wide dissemination of knowledge generated by SAMS and contributing to policy and decision making processes.

Discussions during the High-Level Consultation convened in June 2014, underlined the need to broaden the scope of SAMS to address mechanization strategy in all agricultural systems – crop, livestock, fisheries and agro-forestry – and across the entire agri-food chain from inputs through to on-farm production and harvesting, to post-harvest handling and processing as well as to include consumer protection issues, i.e. food safety.

Chapters 5 and 6, build on key inputs of previous stakeholder consultations, and particularly that of the High-Level Consultation convened in June 2014, in identifying the key issues and constraints for sustainable mechanization in agri-food chains in the Asia-Pacific region (Chapter 5) and addressing strategic themes and options for SAMS (Chapter 6).

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## V. Issues and constraints for sustainable mechanization in agri-food chains in Asia and the Pacific region

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This Chapter is largely based on a review of country reports and presentations delivered during two SAMS forums as well as additional information obtained from reports and policy briefs which have been recently published including the 2013 FAO publication titled: *Mechanization for Rural Development: A review of patterns and progress from around the world* (Integrated Crop Management: Vol. 20, 2013).

A thorough review of available literature suggests that there is a paucity of data, in particular, cross-country analyzed data and information on the status of sustainable mechanization in agri-food chains in the region. Even where information and data exist at the national level, these are difficult to compare across the region as there is no regionally agreed standardized format for collecting and processing such information. Also, in most countries, various agencies/departments of the government are involved in a rather poorly-coordinated way, in addressing mechanization issues – from the ministries of agriculture to those responsible for trade and industries as well as ministries of finance and environment.

The liberalized global economy and the removal of trade restrictions which has occurred from the 1990s has opened up the region to new mechanization technologies – unlike the situation in the 1970s and 1980s when governments exercised an inordinate influence not only on agricultural mechanization policies and strategies but also on the type of technologies that could be imported or even manufactured locally and availed to farmers.

Further, as was noted in Chapter 2 and 3, Asian countries are at different stages in the development and implementation of agricultural mechanization policies and strategies. Some Asian countries are currently experiencing a rapid rate of mechanization in their agri-food value chains while progress in others has been limited due to, among other reasons, implementation of inappropriate and fragmented approaches to mechanization. Agricultural production and food security in the latter group of countries has, therefore, been adversely affected owing to the inadequate utilization of farm power and inappropriate use of farm machinery and implements across agri-food chains, thereby negatively impacting on environmental sustainability and labour productivity.

It is also important to appreciate the fact that the major factors, which influenced decisions on agricultural mechanization in the second half of the twentieth century, are different from those which are likely to influence the same during the first half of the twenty-first century. This applies to decisions at all levels from those made at the farmer level to those of the district agricultural development authorities through to decisions made at the national and regional levels.

The key issues that impact on agricultural mechanization in the region can broadly be grouped into four categories; i.e. a) technical issues, b) institutional and socio-economic issues, c) environmental

issues and d) cross-cutting issues. Although there exists overlaps when classifying issues to a particular category, this categorization helps in portraying a rather true representative image of the regional issues and constraints. These issues will need to be factored in especially when planning and implementing technological issues for SAMS. While some of the issues can be handled entirely at the national level, others will require regional and/or global collaboration.

## 5.1 Technical issues

The High Level Multi-stakeholder Consultation on Sustainable Agricultural Mechanization Strategy convened in June 2014, identified eight key technological issues in so far as strategies for SAM are concerned over the next two decades in the Asia-Pacific region.

### *i. Sources of farm power*

The source of farm power, in most countries of the region, is changing very rapidly from animate (draught animals and human) to mechanical, with an increasing use of 2-wheel and 4-wheel tractors, diesel and/or electric irrigation pumps and motorized post-harvest handling and processing equipment (e.g. India in Table 5.1). A key issue, therefore, is to plan for and facilitate the transition whilst addressing the relevant socio-economic, technical and environmental concerns.

Another key issue is to ensure that these new power sources can be optimally utilized by the farmer on his/her own and/or through rental systems on and off farm. An emerging issue is that some countries (e.g. China and India) are transitioning very rapidly from low horsepower tractors to high horsepower ones – this is likely to occur over the next one to two decades. It will, therefore, be necessary to research and document the technical and socio-economic consequences of these changes as a basis for drawing appropriate lessons to inform the policy and strategy development process for SAMS (Mehta, 2013; Renpu, 2014).

**Table 5.1: Projections for mechanization in India (Singh, 2013)**

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

**Table 5.2: Horsepower availability in agriculture by size of engine for Nepal and Bangladesh (Estimates for 2010)**

Energy Source	Nepal			Bangladesh		
	No. units ('000s)	Total hp ('000)	% of total hp	No. units ('000s)	Total hp ('000)	% of total hp
2WTs*	12	168	10	400	5 600	46
4WTs**	30	900	53	15	460	4
Irrigation shallow tube well pump Diesel***	120	600	36	1 200	6 000	49
Irrigation pump-sets Electric****	10	20	1	100	200	1
Total Available Horsepower		1 688			1 260	

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

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

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

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

\*\*\*\* Electric irrigation pump-sets average 2 hp [From Justice & Biggs, 2013]

**Table 5.3: Farm power, agricultural machinery and electricity in rural areas of China from 2004 to 2008**

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

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

## ii. Land preparation and planting techniques

In the near future, land preparation and planting techniques are likely to remain largely the same as has been practised over the centuries on a significant part of the region's cultivated land. While rapid changes are taking place in sources of farm power, the use of conventional tillage and planting techniques is likely to continue to dominate the region for quite some time to come. The steep learning curve for the application of conservation agriculture techniques as well as the costs associated with changing the implements from those used for conventional tillage to implements for conservation agriculture (including incentivising manufacturers to switch to the new system of implements) are likely to constrain the ubiquitous adoption of conservation agriculture across the

region. As tillage techniques have an inordinate influence on the environmental impact of agricultural production, this is likely to be a major issue of concern for policy makers and environmental activists as well as farmers and the entire agricultural industry including the research and development systems.

*iii. Harvesting and on-farm post-harvest operations*

Harvesting and on-farm post-harvest activities are increasingly being mechanized across the region, with the increasing use of combine harvesters and mechanical threshers across the region. Entrepreneurs are increasingly investing in this sub-sector offering equipment rental services within and across countries in the region through contract farming arrangements and direct hire services. Given current demographic trends in the region, SAMS will have to address issues across the entire value chain, from farm inputs to the output reaching the table of the consumer. It is also by considering the entire system that one can properly factor in the investments required and who should pay for these investments to ensure sustainability of the agricultural sector. With increased regional trade in goods and services, entrepreneurs who offer such mechanization services across the region are emerging and this needs to be factored in the policy and strategy formulation process.

*iv. Food safety and quality issues*

The competitiveness of the agricultural sector is greatly influenced by the status of its technological development including food safety concerns. Improvements in competitiveness will, in a number of cases necessitate the use of new and improved technologies such as precision farming, traceability, mechanized harvesting and post-harvest handling, bulk packaging and processing equipment etc., to support improvements in safety, quality and efficiency of operations. Also the need to ensure the safety and health of agricultural workers including improved hygiene in the work place will increasingly feature in agricultural production and trade protocols such as Good Agricultural Practice (GAP). All of this will require modern equipment and will be an important component of SAMS for countries in the region.

*v. Environmental impacts of mechanization*

It will be increasingly necessary to factor in the environmental impacts of mechanization technologies both on farm as well as off farm and in processing operations. Emerging global issues such as climate change, carbon dioxide emissions and how they are related to mechanization technologies such as techniques for the application of agricultural inputs must also be factored in as key considerations. New and innovative solutions which are environmental friendly, must be explored in order to tackle these challenges that food systems in the region will have to confront.

*vi. Manufacturing of agricultural machinery, implements and equipment*

Technologies for mechanization have largely been developed and disseminated/marketed by the private sector – unlike the case of other agricultural technologies such as plant breeding for high yielding plant varieties, where the public sector has played an inordinate role in their development and dissemination especially in developing countries of the region. The private sector will continue to dominate technology development for the mechanization sector with the public sector assuming a more regulatory role in setting standards, as well as in the testing and certification of technologies.

SAMS will have to factor in future technology development scenarios, and how the private and public sectors can better work together especially in developing technologies for small scale farmers and women, that ensure user safety and which are environmentally friendly.

*vii. Standards and testing of agricultural machinery, implements and equipment*

The creation of regionally harmonized protocols for standards for the testing of agricultural machinery, implements and equipment that are recognized across the region, will go a long way toward increasing regional trade in agricultural machinery and implements. It is expected that this would lead to a reduction of the prices of these items of equipment, which should benefit both farmers and users of mechanization technologies in the region and globally. The establishment of the Asia Network for Testing Agricultural Machinery (ANTAM) with the support of the European Network for Testing of Agricultural Machines (ENAMA) will go a long way toward facilitating coordination and collaboration in the region in this area. This will in turn facilitate trade and the increased use of agricultural machinery and implements, fulfilling common requirements of performance as well as safety for the operator, environment and food consumer. ANTAM will certainly help countries in identifying equipment of good quality and in the regional validation of the machinery they manufacture.

*viii. Technology transfer, technical support services and training*

Much of the trade in traditional agricultural machinery and implements is handled by the private sector. The same will apply for the trade in SAM technologies. The private sector may be reluctant to get too involved in promoting SAM technologies such as those required for use in CA especially as it has already been reported from the experience in North and South America that the learning curve is quite a steep one and it may take quite some time for such technologies to be adopted by farmers in the region. This is where the public sector could come in and through public-private partnership (PPP) initiate and finance joint programs for developing and transferring such technologies.

SAM technologies and practices that are appropriate in use across agri-food chains are relatively new in many parts of the developing world and where the curricula of higher education and training institutions tend to be quite static. Such higher education and training institutions need assistance to revise their curricula as well as to mount refresher courses for their lecturers and instructors on these sustainable technologies for agri-food value chains. Machinery manufacturers could also be encouraged to assist these institutions with their new equipment to be used in training. Likewise the same could be done to the public extension services as well as to research and development organizations. These higher education and training institutions could also be drafted in to offer vocational training, short courses and/or evening courses to staff involved in mechanization supply chains (sales, repair and maintenance, etc.) on sustainable technologies for agri-food value chains (Bell *et al.* 1998; CSAM, 2010).

## 5.2 Institutional and socio-economic issues

Socio-economic issues and institutional capacities are important in the promotion as well as in the adoption of sustainable agricultural mechanization in the region. The major social and economic trends that are likely to have the greatest impact on the agricultural sector and specifically agricultural mechanization strategies in the coming two to three decades are discussed below:

### *i. Urbanization*

In 2010 the urban population of the world crossed the 50 percent total population mark. By 2010, a number of countries in the Asia-Pacific region had more than 50 percent of their populations living in urban areas (Table 5.4). Indeed, it is projected that by 2030 all the countries with large populations will have crossed the 50 percent urban population mark. This presents both an opportunity and a threat to the agricultural sector and specifically to the agricultural mechanization systems in the region.

**Table 5.4: Status of urban population and estimated rate of urbanization in selected countries of Asia and the Pacific region**

Region	Urban population	Urbanization rate, p.a.	Region	Urban population	Urbanization rate, p.a.
World	50.50%	1.85%	Nepal	19%	4.70%
Bangladesh	28%	3.10%	Pakistan	36%	3.10%
China	47%	2.30%	Papua New Guinea	13%	2.90%
India	30%	2.40%	Philippines	49%	2.30%
Indonesia	44%	1.70%	Sri-Lanka	14%	1.10%
Korea, DPR	60%	0.60%	Thailand	34%	1.80%
Korea, Rep.	83%	0.60%	Timor-Leste	28%	5%
Malaysia	72%	2.40%	Viet Nam	30%	3%

**Sources:** World Development Indicators, 2012; World Fact Book, 2012

Urbanization opens up huge market opportunities for food and other agricultural products. The agricultural sector must, however, be equipped to competitively supply this market – otherwise these food and agricultural products will be supplied through imports. In order to be globally competitive the agricultural sector will have to be competitive not only in on-farm production but also in the entire food chain from the farm to the consumer. This will necessitate huge investments in mechanization technologies for on farm production as well as for post-production systems – transportation, warehousing, processing, logistics etc.

On the other hand, urbanization could pose a threat in the sense that with better organization in urban centres, urban populations may demand food that is less costly and of better quality, regardless of the source, and could exert pressure on governments to implement policies which may adversely affect the agricultural sector and investments in it. Any reduction in the effective demand for food and agricultural products from local sources is likely to affect the capacity of farmers and their service providers to invest in agricultural mechanization technologies and infrastructure which are critical for efficient and competitive agri-food value chains.

## *ii. Ageing rural population*

The second key demographic trend is the migration of the young and educated into urban areas, in search of better opportunities. Several country reports point to aging rural and farming populations. If the agricultural sector is to remain competitive it must be able to tackle all of the technological issues of modern food systems like traceability, food quality and safety in addition to managing productivity issues all of which will require considerable investments in mechanization inputs and better water management as well as in rural infrastructure. Agricultural systems will, therefore, need not only young educated individuals, but technically savvy farmers who can network and capture the increasingly competitive local and export markets for agricultural outputs.

## *iii. Feminization of agriculture*

A shift from traditional labour-intensive production and post-harvest operations to labour-saving technologies and mechanization is taking place in Asian agriculture mainly in response to rising labour scarcity and increasing labour costs. Further, rural–urban migration has led to feminization of the agricultural labour force as more men than women are migrating to urban areas often leaving women to manage the rural households. The number of female farmers is increasing across the region.

Formulating a SAMS therefore will require factoring in these demographic trends. It is important to recognize that investments in mechanization inputs are long term unlike in the case of biochemical inputs (seeds, fertilizer etc.) which are short term. Decision makers be they government officials or bank managers will have to consider the age and gender of the farmer (e.g. a bank manager will consider a loan to a 60 year-old farmer to be quite risky compared to that to a 30 year-old, educated and technically savvy farmer – and the situation becomes even more complex if the farmer is a woman).

## *iv. Farm size, farmers and farmer capacity*

Agricultural mechanization especially when it involves the introduction of mechanically powered machinery has been viewed negatively in the context and interest of small-scale farmers. Indeed, the earlier opposition to mechanical technologies was attributed to the need to protect the interests of small-scale farmers. Notwithstanding this opposition to mechanically powered mechanization, the Asia-Pacific region has witnessed a massive transformation of its agriculture with millions of tractors, irrigation pumps, harvesters, threshers and grain milling equipment being introduced each year especially from the 1990s.

As a matter of fact the Asia-Pacific region has emerged over the past two decades (see Figure 5.1) as the largest market in the world, in terms of sales of agricultural machinery, implements and equipment – projected to have sales of US\$49 billion in 2015 (as compared to \$27 billion in North America and \$20.5 billion in Western Europe, World Bank 2010). This is despite the fact that about 87 percent of the world's 500 million small farms (with less than 2 ha) are located in this region (Thapa, 2009; Hazell *et al.*, 2007; APCAS, 2010). Five countries in the region account for approximately 70 percent of the small farms globally – China and India alone account for 190 million and 98 million small farms respectively; while Bangladesh, Indonesia and Viet Nam have 24, 22 and 10 million small farms respectively.

All of these five countries have significantly increased the use of farm power in their small holder agriculture sectors over the past 15 years using different policy and technological options (e.g. India largely through medium horsepower 4-wheel tractors and irrigation pump sets; China through a combination of 4-wheel and 2-wheel tractors while Bangladesh and Indonesia primarily through 2-wheel tractors). The replacement of draft animals by 4-wheel tractors in India is occurring at a rapid rate, wherein the number of bullocks in use declined from over 100 million in 1985 to 53 million in 2005 and is projected to decline to 37 million by 2015 and 18 and 8 million by 2030 and 2050 respectively (Table 5.1 and Box 3.2). The situation in Bangladesh is even more dramatic with almost all the 10 million draft oxen/cattle in use in 1985 having been replaced by 2-wheel tractors by 2010 as explained in Box 5.1. The socio-economic and environmental impacts of such transformational shifts in the source farm power needs to be studied and documented.

### **Box 5.1: Motorization of agriculture in Bangladesh**

Bangladesh has a remarkable history of mechanization, in which the Government of Bangladesh and the private sector have both played important roles. According to Justice and Biggs, 2013, the private sector in Bangladesh focused on the import of inexpensive, low horsepower engines and other machinery from China. While there had been various experiments with Japanese and other 2-wheel tractors and pump-sets during the 1970s and early 1980s, perhaps the main reason for the rapid spread of 2-wheel tractors in the 1990s was a major change in policy in the late 1980s as a result of a national food crisis. After a cyclone hit Bangladesh in 1988 within two and half years of a previous one, taking not only a major toll on human life, but also on the draught oxen population, President Ershad asked what machinery would be most appropriate for their quick replacement. He was told that the Chinese 2-wheel tractors could serve as a quick replacement, but due to the requirements set by the Standards Committee for Agricultural Machinery, they could not be imported.

To overcome this problem President Ershad disbanded the Committee. This action combined with market liberalization policy and the lowering of tariffs resulted in the massive importation of small pump-set engines for irrigation and later 2-wheel tractors and other equipment. These developments coupled with the more recent spread of tens of thousands of small-scale mechanized rice, wheat, and maize threshers-mainly powered by the Chinese diesel pump-set engines makes the Bangladesh agricultural sector, possibly the most mechanized and labour intensive agricultural sector in South Asia, with substantial employment and other growth linkages to other rural and urban sectors (Justice and Biggs, 2013).

In the early 1970s, when Bangladesh was characterized as a “basket case,” no one could have foreseen that the country would, in 2010, have one of the most mechanized agricultural economies in South Asia (Mandal, 2002; Islam, 2009). Approximately 80 percent of all land preparation and other primary tillage operations in the country are mechanized. Mechanization is performed mainly by 300 000 small 2-wheel tractors and the rest by a few (15 000) 4-wheel tractors. Additionally, 60 percent of land is irrigated by over 1 million small diesel powered pump-sets and most of the wheat and much of the rice crop is threshed by small machines (Justice & Biggs, 2013).

Small-scale farmers need not be an obstacle to mechanization provided the right policies (including those for credit, land tenure, and technology) are in place. It is also important to look at other welfare and industrial policies which facilitate the mechanization process. In China for example as Professors Wang and Renpu report, the introduction of large tractors did have positive impact on the

### Box 5.2: Farm size and mechanization in India

The average size of land holdings in India in 2001 was 1.33 ha with only 1 percent (1.2 million ha) consisting of farms of more than 10 ha but constituting over 13 percent of the cultivated land, while farms of less than 1 ha (over 62 percent) constituted about 18.7 percent of the cultivated land – the remaining farms were in the intermediate range with the largest number being medium sized farms (4 to 10 ha) and semi-medium sized farms (2 to 4 ha) which cultivated 24 percent each of the total cultivated land. Thus the three categories comprising large, medium and semi-medium farms (22 million farm holdings) accounted for 61 percent of the cultivated land. It is apparent that farmers of these three categories of farms were instrumental not only to the success of agricultural mechanization in India, but for the overall success of the Green Revolution and the remarkable transformation of the food security situation over the past 50 years (Sarma, 1982; Gol STAT, 2001; 2010).

#### Land Holdings in India

Category	Percentage number of holdings in each category			Percentage cultivated area under CulclCeach category	
	1971	1991	2001	1991	2001
Marginal (<1 ha)	50.6	59.4	62.3	15.0	18.7
Small-scale (1-2 ha)	19.0	18.8	19.0	17.4	20.2
Semi-medium scale (2-4 ha)	15.2	13.7	11.8	23.2	24.0
Medium-scale (4-10 ha)	11.3	7.1	5.5	27.1	24.0
Large-scale (>10 ha)	3.9	1.6	1.0	17.3	13.2
Average holding size (ha)	2.28	1.57	1.33		
<b>Total holding area (million ha)</b>	<b>70.5</b>	<b>106.6</b>	<b>119.9</b>		

Due to the laws of inheritance, the number of holdings is increasing in many states. The situation in Punjab, the state with the highest level of mechanization and with the highest crop productivity, however, shows a reverse trend with the marginal holdings declining from 38 percent in 1971, to 27 percent in 1991 and only 12 percent in 2001, cultivating less than 2 percent of the area. The area under holdings in the semi-medium, medium and large categories in Punjab in 2001, were 22, 43, and 27 percent, respectively thus cultivating 92 percent of the total cultivated area while the marginal and small-scale farmers cultivated only 8 percent. Similar trends are occurring in Haryana and in other parts of the country, (Singh, 2013).

employment situation as labour moved from working on the farm to working in the agricultural machinery and mechanization services industry and this has had considerable impact on rural industrialization (Wang, 2013; Renpu, 2014) while in India farm labourers have been deployed in massive rural infrastructure programs with significant impact on poverty reduction (Singh, 2013).

The key strategic and policy issue here in so far as SAMS is concerned is to accept the reality that given the changes occurring in the wider economy, the farm power situation will change quite significantly over the next two to three decades. The transformation of the mechanization situation which has occurred over the past three decades will continue and in quite a number of countries at a faster rate. It is important in SAMS formulation that countries are assisted in the planning

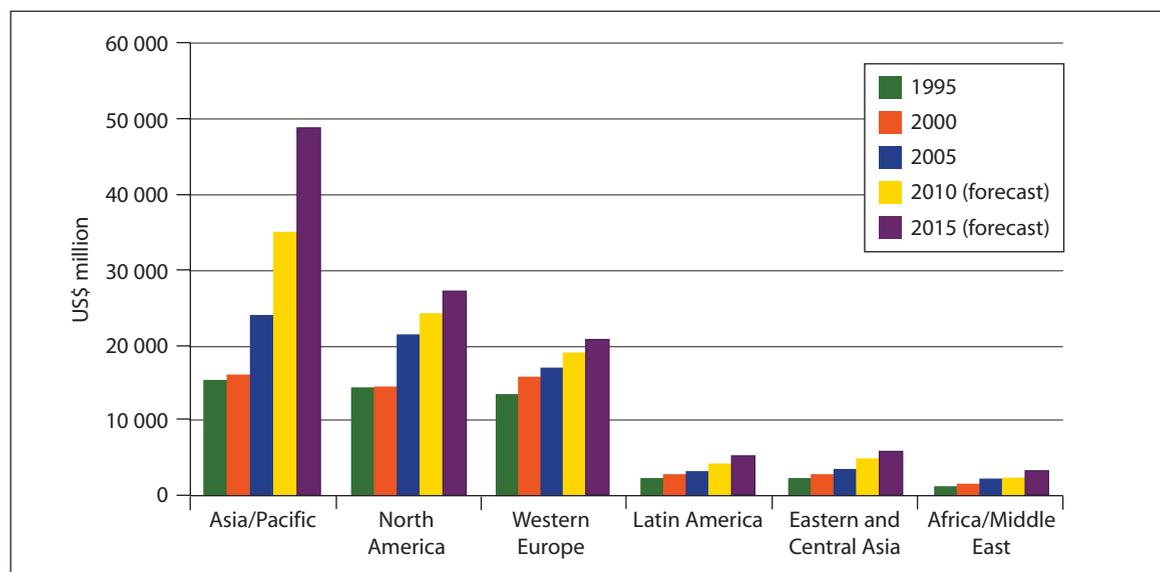
process with lessons and/or case studies of what has occurred in different countries across the region during the past three decades and how these can be emulated and/or scaled-up. Lessons are particularly required on the interactions and business linkages between the medium scale farmers who are able to own the machinery and provide mechanization services to their small-scale compatriots, as well as business models for small entrepreneurs who can establish enterprises to provide mechanization services to other small-scale farmers etc.

v. *Land tenure and its role in facilitating credit for mechanization inputs*

Two socio-economic issues are critical to the success of programs in the mechanization of operations in agri-food chains – these are: i) land tenure issues and ii) credit and finance for the purchase of machinery and equipment. Secure land tenure is essential for successful programs in mechanization. A title deed enables the farmer to get credit for procurement of bulky and expensive investments like agricultural machinery and implements (APCAS, 2010). Also a secure title deed facilitates investments in irrigation infrastructure and for post-harvest handling and processing equipment. It is therefore essential for countries to promulgate laws and regulations through which farmers are enabled to get secure title deeds for their land. Such secure title deeds will not only incentivise the farmer to invest in land improvement infrastructure but will also assure the financial institutions to provide loans for such investments as well as for machinery and equipment.

vi. *Manufacturing of agricultural machinery and equipment*

As shown in Figure 5.1 the Asia-Pacific region has emerged over the past decade as the largest consumer of agricultural machinery and implements in the world. India and China dominate the region in this respect, with nearly all the major agricultural machinery manufacturers having several assembling and/or manufacturing plants in these countries. A few Asian companies are emerging as global champions in the manufacture of machinery and equipment. The Indian tractor



Source: World Bank, 2010

Figure 5.1: World sales of agricultural machinery 1995–2015

manufacturer Mahindra and Mahindra is, for example, emerging as the largest tractor manufacturing company in the world and India lists over ten other large scale tractor manufacturers (Singh, 2013; Sims, 2013). A majority of these companies started off as assembly lines of semi knocked down (SKD) kits before moving to completely knocked down (CKD) kits and subsequently gradually started sourcing the kits from local manufacturers.

**Table 5.5: Production capacity of China's agricultural machinery industry in 1977–2008**

Year	Tractors			Combine harvesters (10 <sup>3</sup> unit)	Internal combustion engines (million kW)
	Large- and medium-sized (10 <sup>3</sup> )	Small-sized (10 <sup>3</sup> unit)	Total (10 <sup>3</sup> unit)		
1977	99.3	230.5	329.8	2.5	20.1544
1978	113.5	324.4	437.8	4.9	20.7206
1986	32.6	747.4	780.0	2.0	51.33
1996	64.7	1 941.4	2 025.1	24.3	180.47
2000	51.0	1 526.7	1 578.6	31.5	173.164
2002	39.3	789.0	852.9	45.3	132.39
2004	98.3	1 794.2	1 970.4	50.0	434.01
2006	197.8	1 916.8	2 114.6	108.0	452.17
2008	217.1	1 879.9	2097.0	70.0	549.77

**Source:** Anon, 2009(a)

Large established companies strive to maintain high standards commensurate with their brands while the new ones strive to establish an identity and brand name. The main problems encountered include the lack of standards and testing facilities across the region thus restricting each manufacturer to the national market according to its licensing agreement (see for example the case of 2-wheel tractors in Bangladesh and how the testing organizations blocked access by farmers to Chinese made power tillers – Box 5.1). Mechanisms to harmonize testing protocols across the region and the establishment of regional centres that are recognized by all countries will go a long way toward facilitating trade in agricultural machinery and implements. As the region has a market value of over \$50 billion for agricultural machinery (Figure 5.1) and is regarded as a low cost manufacturer globally, removal of these non-tariff barriers to trade will contribute significantly to lowering the cost of machinery and equipment and this will be to the benefit of farmers not only in Asia but throughout the developing world. ANTAM should significantly facilitate this.

*vii. The role of the public sector in mechanization supply chains*

Experience of the twentieth century of implementing and offering agricultural mechanization services shows that the operation and management of mechanization supply chains and franchises is best handled by the private sector. The same would be applicable to supply chains for technologies for agri-food value chains. However tempting, the public sector should not be involved in the operation and management of the supply chains and franchises for sustainable agri-food mechanization technologies. The role of the public sector should remain at the broad policy level and to facilitate the creation of regulatory frameworks for the operation of these chains through the coordination of chambers of commerce and business associations.

### *viii. Financing of agricultural mechanization inputs and services*

Credit and finance are critical for agricultural mechanization investments be it in the developed or the developing countries of the region. The same will apply to investments in sustainable agri-food mechanization technologies. State agricultural banks in many countries are responsible for providing loans to farmers and have been used to channel subsidized loans to farmers for the purchase of machinery and other capital investments. Perhaps the best way to finance investments in sustainable agri-food mechanization is for the main line banks to provide such loans – in this way the financing mechanism can be regarded as sustainable as it will be embedded in the systems of regular financial institutions like any other loan.

The public sector should remain responsible for financing those services which are of a public goods nature – like training, licensing of machine operators, research and development, and rural infrastructure including the last mile rural road and/or electricity supply systems. The public sector should also facilitate the creation of an enabling environment for the private sector to finance mechanization investments by enacting appropriate laws for banking and contracts as well as leasing regulations. Where absolutely necessary the public sector could consider providing subsidies for the adoption of particular technologies (e.g. CA technologies) but with a clear exit strategy.

## **5.3 Environmental issues**

Agricultural practices that utilize large quantities of external-inputs such as inorganic fertilizers, and pesticides can overcome specific constraints to crop production. These practices have led to considerable increases in overall food production in the region. However, especially in the most intensively managed systems, these practices have resulted in continuous environmental degradation, particularly of soil, vegetation and water resources. Soil organic matter levels are declining and the use of chemical inputs is intensifying (FAO, 2011a; Montpellier, 2013).

Such misuse of high external inputs for crop production has far reaching effects, according to FAO (2011a) which include:

- i. Deterioration of soil quality and reduction in agricultural productivity due to nutrient depletion, organic matter losses, erosion and compaction;
- ii. Pollution of soil and water through the overuse of fertilizers and the improper use and disposal of animal wastes;
- iii. Increased incidence of human and ecosystem health problems due to the indiscriminate use of pesticides and chemical fertilizers;
- iv. Loss of biodiversity due to the cultivation of a reduced number of species for commercial purposes;
- v. Loss of adaptability traits when species that grow under specific local environmental conditions become extinct;
- vi. Loss of beneficial crop-associated biodiversity that provides ecosystem services such as pollination, nutrient cycling and regulation of pest and disease outbreaks;
- vii. Soil salinization, depletion of freshwater resources and reduction of water quality due to unsustainable irrigation practices throughout the world;
- viii. Disturbance of soil physicochemical and biological processes as a result of intensive tillage and slash and burn methods.

Pollution of groundwater by agricultural chemicals and waste is an increasingly worrying issue in many countries of the region. Pollution from fertilizers occurs when these are applied more heavily than crops can absorb or when they are washed or blown off the soil surface before they can be incorporated. Excess nitrogen and phosphates can leach into groundwater or run off into waterways. This nutrient overload causes eutrophication of lakes, reservoirs and ponds, leading to an explosion of algae which suppress other aquatic plants and animals.

Unfortunately, fertilizer used in many countries in the region is lost and its uptake by plants could be significantly improved. In China, the world's largest consumer of nitrogen fertilizer, up to half of the nitrogen applied is lost by volatilization and another 5 to 10 percent by leaching (UNESCAP, 2013). In the state of Haryana, India, such indiscriminate use of agro-chemicals has resulted in continuous environmental degradation, particularly of soil, vegetation and water resources (Singh, 2000). Insecticides, herbicides and fungicides are also heavily applied in many developed and developing countries, polluting fresh water with carcinogens and other poisons that affect humans and the ecosystem. The unsafe use of pesticides can also reduce biodiversity by destroying weeds and insects and hence the food species of birds and other animals.

Agriculture is not only affected by climate change but also contributes to it, through the emission of greenhouse gases (GHGs). Agriculture accounted for 10–12 percent of total global anthropogenic GHG emissions in 2005 (UNESCAP, 2013). The main sources of emissions are crop and livestock production and management, and forestry and associated land use changes. Among many agricultural activities and inputs contributing to the GHG emissions are fertilizer (manufacturing and application), irrigation, fossil fuel (farm machinery), anaerobic fermentation, and livestock production and these require specific research attention.

Asia and the Pacific region in 2010, was responsible for more than half of the total GHG emissions globally. GHG emissions in Asia and Pacific region in 2010, increased by 1.5 percent from the previous year, which is similar to the global increase. China became the single country with the largest share of global GHG emissions, accounting for about 23 percent of the global total, which is approximately the same share as Latin America and the Caribbean and North America combined (UNESCAP, 2013).

One way to reduce the environmental impacts of modern agricultural production described above, is to adopt CA practices (Box 5.3). It is conceivable that conservation agriculture will feature increasingly in agricultural systems in the region although even its strongest proponents accept that it requires cultural change in cultivation practices and hence has a steep learning curve. Also the profitability of CA may not be that apparent and requires incentives and subsidies for farmers to adopt the recommended equipment (Friedrich, 2013). The negative perceptions on some of the aspects of CA technologies need to be corrected through objective testing of the technologies involved in the region (Box 5.3. on Conservation Agriculture and Box 5.4 on Perceptions on SAMS).

Countries in Asia and the Pacific region differ widely with respect to their adoption of sustainable agri-food mechanization technologies. With the exception of China and India many countries in the region are focusing on harnessing mechanical farm power and have yet to turn their attention to transforming their conventional tillage practices. The Chinese Ministry of Agriculture currently subsidizes no-till seeding technology to replace conventional tillage technologies with direct seeding technologies compatible with conservation agriculture. Similarly the Government of India

also provides subsidies for no-till seeders and no-till or strip-till equipment for both animal traction and tractors as well as more recently also for single axle tractors. These are, however, just the initial steps in the process of transforming the conventional tillage practices in China and India and there is still a long way to go before more sustainable tillage and crop husbandry practices are used on a significant area of the cultivated land.

### **Box 5.3: Conservation Agriculture (CA)**

Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (Friedrich, 2013). CA is characterized by three linked principles, namely: a) continuous zero or minimal mechanical soil disturbance (i.e. no-tillage and direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil; minimum soil disturbance from cultivation, harvest operations or farm traffic; in extreme cases limited strip tillage), b) permanent organic matter cover of the soil, especially by crop residues, crops and cover crops and c) diversification of crop species grown in sequence or association through rotation or, in the case of perennial crops, associations of plants, including a balanced mix of legume and non-legume crops.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical tillage are reduced to an absolute minimum or avoided, and external inputs such as agro-chemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes (Baker and Saxton 2006; Tandon 2007).

According to Friedrich 2013, in 2010 CA was being applied on about 117 million ha around the world with some farms practicing it for over 30 years. Over the past 20 years, the rate of transformation from tillage-based farming to CA has been some 5.3 million hectares per annum increasing in the last decade to 6 million ha. CA adoption levels in Argentina, Brazil, and Paraguay have reached 70–75 percent of cultivated land while in Western Australia it has reached 90 percent. Adoption in the United States of America which was the first country to have significant no-tillage farming remains low at 25 percent reportedly due to non-supportive policies (Friedrich 2013). The same applies to Europe where significant adoption is limited to a few countries. In Asia significant increase in the adoption of CA has occurred in Kazakhstan (over 4 million hectares in 2008–12) and in China (1.3 million hectares).

According to Tandon (2007) the adoption of CA practices involves changing from conventional tillage practices and requires investments in new implements and equipment as well as having a steep learning curve in the use of new inputs like herbicides. The new implements and equipment are not yet manufactured by the local agricultural machinery companies even though some are beginning to enter into this market. Further CA faces the challenge that it has so far been developed and perfected in North and South America, and Australia by large-scale farmers who invariably make use of large tractors. Also, as indicated above, the third principle of CA – crop rotation and/or fallowing of land – makes it difficult to implement CA techniques given the dominance of paddy cultivation coupled with land scarcity in many parts of Asia and the Pacific region.

Other environmental issues which relate to sustainability include climate change and its impact on agriculture, water use especially as is relevant to irrigation – here there is a need to convert to more efficient water conveyance and application systems as opposed to largely open channel and flooding systems and this will require considerable investments in mechanical systems (pumps; nozzles etc.).

#### **Box 5.4: Perceptions on SAMS – the positive and negative aspects of SAMS for Asian countries**

During working group deliberations of the December 2011 *Roundtable on Developing SAMS for Countries of the Asia-Pacific Region* participants were requested to provide feedback on their perceptions of the pros and cons of SAMS. The following is a summary of their feedback:

##### ***Positive Aspects/Perceptions on SAMS:***

SAMS could help in increasing yields and incomes of farmers and could address labour shortages in countries with high levels of rural-to-urban migration. It was emphasized that farming should be need-based and market oriented. Other positive aspects include the fact that SAMS is useful for the production and utilization of agricultural machinery. It was also noted as a positive attribute that *precision farming* could be included in SAMS and would help to make more efficient use of inputs.

##### ***Negative Aspects/Perceptions on SAMS***

- **For farmers**

- Mechanization will displace rural labour and might not be economically viable for farmers in specific countries; there are financial disincentives to develop a SAMS while it may reduce the need for increasing food production. Larger sized equipment puts more pressure on the environment and may be under-utilized due to the seasonal use of specialized equipment required for SAMS.

- **Of relevance to inputs**

- Farmers will become dependent on internationally sourced inputs and will lose traditional crop varieties and agricultural biodiversity; concerns on food safety and public health; SAM will have a negative impact on traditional manufacturing lines of equipment and can pose a risk to manufacturers; there is need to carefully examine the role of traditional power/equipment combinations (tractor/disc power-tiller/rotovator); farmers engaged in traditional practices would not benefit from SAM since it would disrupt traditional agricultural practices and local service providers could wind up losing business. Local artisans may lose their jobs; smallholder manufacturers will face risks if SAMS is adopted. Incentives for SAMS can be expensive; additional extension services would be required for SAMS.

- **For the environment**

- More land would be required to produce more food. The entire production system would be affected by SAMS. More energy would be required to implement SAMS.

**Conclusion:** It is obvious that the list of negative perceptions on SAMS is much longer than that of the positive ones. This situation has to be changed if SAMS is to take root in the region.

## 5.4 Cross-cutting issues

Policy and research and development issues cut across environmental, institutional and socio-economic issue and technical issues.

### *i. Policy issues*

Policy support is critical to mechanization of agri-food chains especially when 'sustainability' issues are considered. SAMS may require a complete change of current practices in tillage and this will require additional investments in agricultural machinery and equipment. SAMS will also involve policy interventions in, among other areas, industrial licensing and trade policies for agricultural machinery and implements, manufacturing of implements locally and regionally and fiscal policies e.g. subsidies and credit lines; whether to impose and/or waive duty on imported equipment etc. Formulation of these policies will require close coordination within Governments to include not only Ministries of Agriculture but also those of Trade and Industry; Finance and Planning as well as those of Environment, Energy (see Tables 5.1 to 5.5 and Box 5.1 and 5.2).

At the regional level close coordination and collaboration will be required among countries especially as entrepreneurs who offer cross-border mechanization services emerge, given the liberalized trade policies for goods and services. A notable example in this respect is contractors who offer mechanization services (e.g. land preparation and crop husbandry services, paddy harvesting services etc.) across countries according to peak demand seasons for such services.

International development agencies must take a leading role in promoting the sharing of experiences across member countries on successful in-country policies and strategies as well as the enabling policies and regulations that need to be enacted by member countries to facilitate cross border trade in mechanization services and support systems.

### *ii. Research and development*

Public sector research and development activities on agricultural machinery and implements including for sustainable mechanization of agri-food chains, are handled by several Government departments, with poor coordination across departments. These include, among others, Agriculture (mechanization research, soils, post-harvest, irrigation etc.); Trade and Industries (industrial research; manufacturing; patenting; standards; trade licensing etc.); Energy (energy generation and distribution, alternative fuels etc.) and Higher Education (research and education on all aspects of mechanization in schools of agriculture and engineering). In larger countries a single institution may be involved in agricultural engineering research (e.g. IAER under ICAR in India) but this does not mean that all of the work is coordinated by that institution.

At the regional and international levels, the International Agricultural Research Centres (IARCs) under the Consultative Group for International Agricultural Research (CGIAR) were actively engaged in the 1960s and up to the early 1980s in agricultural mechanization research. Much of the work undertaken by the IARCs, addressed the hardware – design and development of implements and equipment such as paddy threshers, animal drawn implements etc., as well as the software – economics of the introduction and utilization of different types of agricultural machinery and implements (Khan 1972; Binswanger 1978 & 1994; Farrington *et al* 1982; IRRI, 1983; Starkey 1988; Byerlee and Hussain, 1993).

At times the two groups – those who worked on the hardware and those who worked on software issues – tended to have diametrically opposite views, and as Gemmill and Eicher (1973) noted, economists and engineers were “talking past each other” on the mechanization issue. This was counter-productive and contributed to the decline of the agricultural engineering and mechanization research units in most CGIAR centres from the 1980s. By the 1990s most work in this area by the CGIAR and its IARCs had been abolished. The CGIAR system therefore has very little capacity in this area at the moment despite the fact that there is currently some advocacy for a new initiative by IARCs in this area (IRRI, 2014).

Much of the serious research and development work as well as technology transfer for agricultural machinery and implements in the region has been undertaken by the private sector. The private sector is also responsible for the manufacture as well as for the distribution of agricultural machinery, implements and equipment to farmers. Some of these private sector entities are branches of Multinational Corporations (MNCs) whilst others are local companies that have established themselves over the past 40 years, e.g. Mahindra in India. Coordinating and regulating the activities of all these entities as well as those of the public sector research and development centres is an issue of concern for countries in the region. This applies both to activities at the national and regional levels. This is one area where for SAMS, the region has to explore the possibility of establishing some regional capacity for coordination to reduce duplication of efforts and increase efficiencies (Soni and Ou, 2010; FAO-RAP, 2014).

### *iii. Advocacy*

SAMS represents a new way of looking at agricultural mechanization and overall agricultural development in the region. There is need, therefore, to sensitize key stakeholders in the public and private sectors on the need for SAMS and its critical role in agricultural development in the region given the socio-economic, demographic, technological and environmental trends and projections for the next two to three decades. It is also important to apprise the public-policy and resource allocation decision makers on the importance of SAMS. Thus the political, economic, and social systems and institutions have to be sensitized of its need and importance.

Advocacy for SAMS will, therefore, be critical. This will necessitate many activities including media campaigns, public speaking, commissioning and publishing of research findings at both the regional and country levels. Specific activities might include: promoting a strategic vision for sustainable mechanization of agri-food chains/systems, that links SAMS directly to national development objectives on economic growth, sustainable development and poverty reduction as well as increased investment in environmental services and the employment of youth and women in agriculture. Other advocacy activities for SAMS include facilitating information sharing and lessons learned about good practices and ensuring the effective participation by all stakeholders (including non-state actors and private sector) in its processes.

### *iv. Capacity Building*

Building the capacity of countries in the region will be critical to the success of SAMS. In this regard there is need to strengthen and rejuvenate the capacity of many of the institutions created in the 1960s and 1970s to train the human resources who were responsible for the Green Revolution. Due to changing economic priorities of the 1990s some have atrophied and will be hard pressed to

handle the concepts involved in SAMS without additional investments in human resources and physical facilities. These institutions will be required to contribute to building the capacities of: (a) farmers (especially young farmers and women), extension and research staff and local government officials on SAM technologies; (b) manufacturers and distributors of inputs (new tools, equipment implements, machines) as well as the franchise holders of agricultural mechanization supply chains and to enhancing information dissemination on sustainable agri-food mechanization technologies including profitability, environmental and socio-economic aspects, as well as innovations made to agricultural machinery and implements. The idea is to ensure the development of a knowledgeable, well-trained and disciplined labour force serving sustainable agri-food value chains with the capacity to drive and sustain private sector-led growth.

v. *Knowledge sharing*

Knowledge sharing through formal and informal regional mechanisms will undoubtedly play a critical role in the implementation of SAMS in the region. The experience of the 1970s and 1980s is invaluable when countries in the region collaborated through the Regional Network for Agricultural Mechanization (RNAM). This Network played a major role in the exchange of information and experiences at a critical stage of agricultural mechanization when countries in the region were embarking on the process of transforming the sources of farm power from animate to mechanical sources. According to Lantin (2013), through its five phases implemented from 1977 to 2002, RNAM was supported by several international FAO, UNDP, UNESCAP, UNIDO – and bilateral – Netherlands and Germany donor countries.

The focus of RNAM was on agricultural mechanization policies and strategies as well as on the exchange of technologies and information on best practices. SAMS will require an even more ambitious and concerted initiative on information exchange and knowledge sharing (FAO-RAP, 2014). This should be more easily organized now as compared to the 1980s given the developments in information and communication technologies (ICT) which have occurred since then, as well as the more developed institutional framework for regional cooperation and coordination in agricultural research, trade and information exchange.

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## VI. Strategic themes and options for sustainable mechanization of agri-food systems in Asia and the Pacific region

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There is no question that significant progress has been achieved in mechanization of agriculture in Asia and the Pacific region over the past five decades. There is however still a lot which needs to be done, particularly in regard to enhancing the sustainability of agricultural mechanization systems.

The strategic themes and options for SAMS in the Asia-Pacific region identified and discussed in this Chapter are drawn largely from an analysis of the overview of the agricultural sector presented in Chapter 2; the lessons from the experience of the region in developing agricultural mechanization during the second half of the twentieth century as presented in Chapter 3 and the issues and constraints for a mechanization of agri-food chains presented in Chapter 5. The foci of the analysis is more on the future, specifically the first half of the 21<sup>st</sup> century. To the extent possible, the themes and options are discussed following the main pillars of the framework for SAMS agreed to, at the November 2011 Roundtable and as discussed at the High-level Multi-Stakeholder Consultation convened by FAO in collaboration with UNESCAP/CSAM, in Bangkok on 26–27 June 2014.

### 6.1 Technical issues

#### *i. Changing the sources of farm power*

Countries within Asia and the Pacific region differ widely with respect to their use of farm power as part of sustainable mechanization of their agri-food systems. It is apparent from the evolution of the agricultural, industrial and overall economic sectors over the past five decades, that the region is settling for four types of farm power sources:

1. Small 2-wheel single axle tractors (2WT);
2. Medium horsepower 4-wheel two axle tractors (4WT) – some countries like India and China are increasingly moving towards higher horsepower tractors;
3. Electric pumps or diesel pump-sets for irrigation;
4. Motorized/powered equipment for harvesting, threshing and other post-harvest processing operations.

It would also appear that all countries in the region are in the process of transforming their farm power into these four categories. Some are at quite an advanced stage having reached or about to reach up to 70 percent use of mechanical power in their land preparation and crop husbandry operations.

The key strategic and policy issue here in so far as SAMS is concerned, therefore, is to accept the reality that given the changes occurring in the wider economy, the farm power situation will change quite significantly in the region over the next two to three decades. This transformation which

commenced over the past two decades will continue and in quite a number of countries at a much faster rate. It seems plausible, therefore, to aim at almost complete replacement of draught animals as a primary source of farm power in the region by 2030.

Key options to be considered, therefore, include:

- Transformation of farm power sources across the region through the complete replacement of draught animals with mechanical power sources. Several countries in the region have a rich experience in this area. It will, therefore, be necessary to support South-South cooperation among countries as a measure to enhance the exchange of technologies and/or experiences to the countries which have still some way to go to achieve the complete replacement of draught animals as a source of farm power.
- Assessment of the economic and environmental impacts of replacing millions of draught animals with mechanical power, through studies designed to capture lessons of the different models/approaches used in the region. Issues such as what has happened (and/or what will happen) to the millions of draught animals and implications of their replacement on the livestock sector, availability of feed resources and grazing land.
- Documentation of lessons from successes achieved in some countries of the region in changing the farm power situation from animate sources to mechanical ones over a fifty year period. Initial position papers are required to address these issues based on a country by country analysis, as information currently available in country reports is inadequate and fragmented and would not lead to firm lessons on the issue. There is no question that the experience of the region, in this regard, is quite rich and varied and important lessons could be drawn from institutional, business, technical, environmental and socio-economic perspectives.
- Country assessments of current and future medium to long term farm power requirements that integrate consideration for the ageing agricultural population, gender and youth issues and the necessary transformation/improvements required as well as areas requiring technical support.
- The manufacturing capacity and trade of farm power equipment (tractors, power tillers; pumps; motors etc.) – regional trade, import tariffs etc.

Implementing the above will require concerted actions at both the national and regional levels by different stakeholders including, among others, government departments involved in agriculture, finance, industry and trade; manufacturers and distributors of agricultural machinery, implements and equipment and research, development and technology transfer agencies in both the public and private sectors as well as regional organizations.

#### *ii. Transforming land preparation and crop husbandry practices*

Land preparation across the region, has been done using draught animals for many centuries. The key focus of mechanization in the region today is, however, on the implements being used for tillage, with a number of experts advocating for the ubiquitous adoption of sustainable land preparation and crop husbandry techniques such as minimum/zero tillage techniques and/or CA in the quest for environmental sustainability. Thus the conventional tillage (CT) implements and practices which have been used for centuries are seen as being environmentally unsustainable.

With the exception of China and India where there are some initial steps on the use of some form of CA and/or sustainable mechanization practices, much of the attention of other countries in the region has been focused on harnessing mechanical farm power. The Chinese Ministry of Agriculture currently subsidizes no-till seeding technology to replace CT implements with direct seeding technologies that are compatible with CA practices. Similarly the Government of India also provides subsidies for no-till seeders and no-till or strip-till equipment which are now available for animal traction, tractors and, more recently, also for single axle tractors (CSAM country reports, 2013).

At the same time, it is noteworthy that the United States of America even after over 70 years of concerted action and massive investments by the public and private sectors has been able to convert only 25 percent of cultivated land to CA techniques as of 2010 (Friedrich, 2013). The adoption of CA practices in North and South America as well as in Australia and New Zealand has been on large farms using large tractors and has involved in addition to no tillage techniques, crop rotations and fallowing of land, which are techniques and practices that may be difficult to adopt in Asian agriculture due to land scarcity and the dominance of small holder farms with rice being the dominant crop.

Key options to be considered:

- Assessment and analysis of current land preparation and crop husbandry practices in the region especially on the types of implements being used and their long term environmental impact and sustainability, including the required transformation.
- Short, medium, and long term planning is required if the region is to succeed in converting the CT techniques to more sustainable land preparation and crop husbandry practices on a significant part of its cultivated land. The switch to such sustainable land preparation and crop husbandry technologies requires concerted effort including first and foremost a national and regional commitment to change from the CT methods; understanding the implications of this including the costs involved in the short, medium and long term as well as the impact on food production and productivity; additional manufacturing capacity and investments for agricultural machinery and implements; and massive research, development and extension effort required at all levels, among other things. As tillage techniques have an inordinate influence on the environmental impact of agricultural production, this is likely to be a major issue of concern by policy makers and environmental activists as well as farmers and the entire agricultural industry.
- Transformation of land preparation techniques: the transformation of tillage practices from CT practices to the minimum tillage techniques being advocated under the conservation agriculture (CA) model which are regarded as being more sustainable, will require a revolution in this regard. This transformation will be more challenging compared to the conversion from animate to mechanical power sources. It involves changing the mindset of nearly everybody who matters in the agricultural sector that the CT practices and implements that have been used for centuries are no longer sustainable and of the need to invest in new and often complicated and expensive minimum and/or no-till implements as well as in developing and learning new land preparation and crop husbandry practices. In essence this requires a revolution in land preparation practices.

The experience of the region, in similar technological transformations is quite rich and varied and important lessons could be drawn from institutional, business, technical, environmental and socio-economic perspectives. Such lessons will be quite useful as the region moves ahead to plan for ‘sustainable agricultural intensification’ which is emerging as the guiding development model for the agricultural sector over the next half a century. Conversion of tillage and crop husbandry techniques and practices is one of the main pillars of sustainable agricultural intensification.

### *iii. Mechanization across the agri-food value chain*

Past analysis of agricultural mechanization tended to be confined to on-farm production issues and failed to capture the off-farm uses of machinery and implements where farmers were realizing economies of utilization of their mechanization investments. It is, therefore of critical importance to widen the debate on mechanization to cover the entire agri-food chain from inputs through to on-farm production to post-harvest and processing issues as well as consumer protection, i.e. food safety.

World wide experience shows that agricultural mechanization has been successful when there is an effective demand for the outputs of farming (including for on and off-farm value addition) and sustainability of mechanization systems has to factor in the entire agri-food chain. Also sustainable agricultural mechanization technologies can contribute significantly in programs for reducing losses along the entire agri-food chain (Box 6.1). Given current demographic trends, SAMS will have to go beyond on-farm productivity issues to include post-harvest systems and the entire food chain.

Key options to be considered in this respect include:

- Addressing the entire food value chain from farm inputs to the outputs of farming reaching the table of the consumer. It is by considering the entire value chain that one can properly factor in the investments required and who should pay for the same to ensure sustainability of the agricultural sector.
- Factoring in the environmental impacts of mechanization technologies both on farm as well as off farm and in processing operations. This will necessitate consideration of emerging global issues such as climate change, carbon dioxide emissions and how they are related to overall farm production and specifically mechanization technologies such as techniques for the application of herbicides and pesticides, precision farming etc.

### *iv. Role of manufacturers of agricultural mechanization inputs*

A key issue to be addressed is the role of manufacturers of agricultural mechanization inputs and how they can be incentivized to develop and manufacture agricultural machinery, implements and equipment that contribute to the sustainable mechanization strategy. While this issue can be handled entirely at the national level in most cases, in others, regional and/or global collaboration will be required. The region, as already discussed in Chapters 3 and 5, has a large agricultural machinery and implements manufacturing sector dominated by the private sector and backed up by thousands of dealers who manage efficient mechanization supply chains and distribution franchises. However tempting, the public sector should not be involved in the direct operation and management of mechanization supply chains and franchises and its role should remain at the broad policy level.

### **Box 6.1: Mechanization across the rice value chain in the Asia and the Pacific region**

There has been an appreciable level of growth in the adoption of mechanization in post-production operations both on and off-farm, driven by farm labour shortages as a result of urban migration, the need to improve farm productivity and to a certain extent reduce operational costs. Technology shifts from manual to mechanized operations are visible in rice harvesting, threshing, drying, handling and milling operations.

At different degrees of adoption across the region, harvesting machines are used in cutting the rice crop, in many countries. Use of the combine harvester is increasing in many countries in Southeast Asia with its successful introduction in Thailand, Malaysia, Viet Nam, Myanmar, and more recently in Cambodia and Lao PDR. The popularity of the axial flow thresher has led to the development of a threshing service provision sector in some countries.

Farm level mechanical drying technologies have been promoted by government programs in most countries of the region with mixed results. The rate of adoption of plant level mechanical dryers has been high for reasons of attaining economies of scale and for better control of the drying process resulting in higher quality paddy and milled rice.

In the milling sector, where mechanization has greatly preceded other post-production operations, the technology shift has been from traditional inefficient mills to modern milling systems to improve milling yields and efficiency as well as to reduce milling losses. In terms of in-plant grain handling, there has been an increasing trend in the use of mechanical grain conveyors for more efficient operations within rice milling plants and to reduce handling costs.

Looking at the whole rice supply chain, the adoption of mechanization technologies is quite high in the modern value chains that supply domestic retail outlets and the export markets. To a lesser extent, rice supply chains that link rural and urban markets have adopted partial mechanization in their threshing/cleaning, drying and milling operations.

**Source:** Rapusas, R.S. (2013), FAO-RAP Background paper

Options to be considered include:

- The establishment of mechanization supply chains and dealer franchise networks across the region: A key issue will be how to assist manufacturers with the establishment of supply chains and dealer franchise networks and how to help them to cater for areas where profit margins may be initially small or non-existent. This is particularly the case for new land preparation and crop husbandry implements and equipment.
- Creation of regulatory frameworks by governments, to facilitate the operation and management of mechanization supply chains and franchises through the coordination of chambers of commerce and business associations. In some cases such franchises will operate across national boundaries and offer services at the regional level.

v. *Research, extension and development*

The whole question of research and development within the context of the roles of the private and public sectors must be considered. Mechanization inputs and services will continue to be offered by the private sector. Linkages between the public and private sectors in research and development activities must be strengthened. There is no point in having large public sector research and development establishments which year in and year out churn out a large number of prototypes that do not move beyond laboratories and/or workshops. These prototypes must be transferred under licensing arrangements to private sector manufacturing entities that have a comparative advantage in producing and transferring technologies to farmers through their distribution, marketing and financing franchises for agricultural machinery and implements.

Also the extension of agricultural mechanization technologies has been done through a combination of public and private sector organizations, e.g. private sector enterprises have dominated the distribution and servicing of agricultural mechanization hardware while the public sector has been more involved with the extension of software aspects of public goods such as good cultivation and planting practices, soil and water conservation methods etc. This division of labour on extension is likely to continue. There is however, a need to strengthen the capacity of the public extension services dealing with the hardware as this appears to have weakened considerably over the past few decades (Singh, 2013; Scott & Justice, 2013; Lantin, 2013).

Options to be considered include:

- Research and development at the national and regional levels, geared toward determination of what works best under prevailing conditions in the region.
- Future technology development scenarios that integrate consideration for how the private and public sectors can better work together in developing technologies for stakeholders and particularly small-scale farmers in agri-food chains.
- Technology development, testing, transfer and extension systems: these will play an invaluable role given the need for new technologies for SAMS especially in regard to sustainable land preparation and crop husbandry techniques, as well as for harvesting, post-harvest handling and processing.
- Regional and South-South collaboration for the development and transfer of technologies in order to avoid duplication of effort and where necessary to achieve economies of scale and scope.
- Support for public and private sector collaboration, including developing and enforcing systems for regional patenting and licensing of technologies and innovations. A starting point here, could be the establishment of an inventory of “*who, where and what*” technologies and expertise that are available in the region.
- Linking national and regional research efforts with what is being done elsewhere in the world to determine technologies which have worked well and which could be adapted for use in agri-food chains in Asia and the Pacific region.

vi. *Standards and testing of agricultural machinery and implements*

The Asia-Pacific region is emerging as the largest global market as well as the largest manufacturer of agricultural machinery, implements, and equipment. The establishment of ANTAM – Asian Network

for Testing of Agricultural Machinery – provides a good starting point for regional collaboration in the whole area of manufacturing and testing of agricultural mechanization technologies.

Options to be considered include:

- Establishment of and sustainable financing of testing centers on a regional basis with every country having confidence in such centers. Given increased trade and other trends such as urbanization and emerging food trade as well as quality and safety concerns there will be quite a significant need of interventions by governments in this area at the individual country level and/or regionally. ANTAM will certainly help countries in identifying equipment of good quality and in having the quality of their manufactured machinery validated regionally.
- Develop and implement mechanisms to harmonize testing protocols across the region and create centers that are recognized by all countries. This will go a long way toward facilitating trade in agricultural machinery and implements regionally and globally.

*vii. Promotion of knowledge sharing and ICT*

The benefits of sustainable mechanization will not be fully harnessed by smallholders, unless effective linkages are created with extension systems, including the promotion of ICT and e-Agriculture as well as South-South collaboration. Weak extension systems in many countries of the region, severely constrain the spread of agricultural innovations.

Options to be considered include:

- The promotion of diverse learning and dissemination approaches that involve researchers, extension agents, civil society organizations (e.g. NGOs and farmer organizations) and the private sector to help in promoting the benefits of sustainable mechanization across agri-food chains.
- The use of ICT for the dissemination of information on mechanization options within countries and across the region.
- Establishment of a network among countries to share experiences and approaches on sustainable mechanization across agri-food chains as a high priority.
- Promotion of South-South collaboration across countries in order to facilitate the sharing of knowledge and experience with different SAM technologies.

*viii. Water-use efficiency*

The role of agricultural mechanization inputs in increasing efficiency of water use in agriculture is critical. The region has 15 percent of the global land mass with half of the world's population and thus irrigated agriculture plays a critical role in food security for the region. However, water use efficiency could be significantly increased – especially for irrigated paddy rice which is the largest consumer of water. Although the use of pumps as well as other controlled irrigation systems has increased – a lot more could be done with increased use of mechanization inputs including for reducing the pollution effects of irrigated agriculture.

Water use efficiency has been identified by member countries as one area where agricultural mechanization technologies could have considerable impact.

Options to be considered include:

Technical support programs for the development of irrigation infrastructure (particularly controlled irrigation systems). This will include support for sustainable mechanization inputs in irrigated agriculture – alternative energy sources for powering pump-sets; more efficient use of energy in irrigated agriculture; design and installation of more efficient pumping as well as water conveyance systems and the use of agricultural machinery in the maintenance of irrigation and drainage infrastructure.

## **6.2 Socio-economic and institutional issues**

### *i. Smallholders and farmer organizations*

Smallholder farmers dominate in Asia and the Pacific region, with the average farm size (measured in terms of operational holdings), being less than 2 hectares. A majority of rice farmers in densely populated countries such as Bangladesh, China, India, Indonesia, the Philippines and Viet Nam operate on farms of less than 1 hectare. Farm size is not only small, but is also decreasing over time, owing to increasing population pressure and the limited opportunities for labour to exit from rural areas in some of these countries. In other cases, increasing scarcity of labour induces mechanization which in turn induces an expansion of farm size. Whether or not farm size actually increases is, however, dependent on the nature of land markets, land tenure policy, regulations governing farm size, rural employment opportunities and the availability of custom-hiring services for farm machinery.

With an appropriate enabling environment, that addresses policies including those for credit, land tenure, and technology development and transfer, smallholder farmers will benefit from mechanization. Furthermore, smallholder farmers can reap the benefits of scale in production and marketing by being organized in institutions that reduce transaction costs and increase overall efficiency. Such institutions include group farming, contract farming, clustering, community organizations and farmer cooperatives. Considerable experience exists in the operation and management of such farmer organizations in Asian countries and South-South cooperation could be an important way of sharing of such experiences.

In many cases in the region, it is the more enterprising and comparatively medium and larger scale farmers who have pioneered the mechanization process as they are the ones with the resources for capital investment. They are also the ones who have been able to establish enterprises which have provided mechanization and other services to their compatriots who are peasant and small scale farmers. Further, they are the ones who are likely to provide the necessary volumes required to create viable post-harvest produce handling, marketing and processing enterprises. They are thus critical to the establishment of viable commercial farmer's organizations and cooperatives which not only serve them but provide services to their compatriots who are peasants and small holder farmers. In planning for SAMS it is important to factor in the role and contribution of all farmers from the peasant to small scale marginal, as well as small-scale commercial (SSC), medium-scale farmers (MSF) and large-scale farmers (LSF).

Options to be considered:

- Promoting the custom-hiring of services for sustainable mechanization of operations in agri-food chains: custom hiring is an important mechanism through which most smallholders can access agricultural machinery services. Other than small agricultural tools, large items of machinery such as tractors, harvesters and threshers are used by smallholders on a custom-hiring basis. Such services are efficiently provided by the private sector – hence a suitable regulatory framework and support policies to attract private sector investment for providing such custom services is needed.
- Learning from business models involving the interactions and business linkages between medium scale agri-food chain stakeholders and particularly farmers who are able to own farm machinery and provide mechanization services to their small-scale compatriots, as well as those for other entrepreneurs who can be incentivized to establish enterprises to provide mechanization services to, among others, small-scale farmers.
- Development of policies (including those for credit, land tenure and technology) to support agri-food chain stakeholders and particularly small farmers to access mechanization inputs and/or services.
- Promotion of farmer organizations/cooperatives/clusters: farmer groups and cooperatives could be empowered to access mechanization through local development and community-driven approaches and through capacity building support, as well as through preferential access to institutional credit to procure mechanization inputs.
- Development and promotion of technologies that are less risky and within the investment capacity of agri-food chain stakeholders and particularly small holder farmers.
- Welfare and industrial policies which facilitate the mechanization process should also be considered. In China, for example and as reported by Wang and Renpu, the introduction of large tractors had a positive impact on the employment situation as the labour moved from working on the farm to working in the agricultural machinery and mechanization services industry and this has had considerable impact on rural industrialization (Wang, 2013; Renpu, 2014) while in India farm labourers have been employed in massive government funded rural infrastructure programs with significant impact on poverty reduction (Singh, 2013).

*ii. Financing of investments in sustainable agricultural mechanization*

Investments in mechanization inputs are long term unlike for biochemical inputs (seeds, fertilizer etc.) which are short term. Nearly all the countries in the region have provided some subsidies either through credit or direct grants to farmers to procure machinery and equipment. Much of the investment for mechanization inputs has to be made by the private sector including small-scale farmers who constitute the largest group in the private sector. These farmers are supported by the financial sector (commercial banks etc.). The key issue in this regard is to get the normal financial sector to provide funding through loans and other instruments to support agri-food chain stakeholders to invest in mechanization inputs. The role of Governments is to create an enabling environment whereby these financial organizations are able to commercially lend to farmers and where farmers are able to borrow and profitably invest in mechanization inputs and pay back their loans. Such a financial system is critical for sustainable mechanization of agri-food chains.

Options to be considered:

- Financial mechanisms to facilitate the procurement of machinery and equipment by smallholders, within the context of sustainability of these interventions should be considered. The issue of credit subsidies should be considered especially where they can catalyze the initial procurement of mechanization inputs with the proviso that viable and sustainable farming enterprises ultimately emerge.
- Collaterals for credit for financing the procurement of agricultural mechanization inputs must also be considered – land tenure, for example, plays an inordinate role in this regard. Objective studies on the financing modalities and credit mechanisms (including subsidies) which have been used by different countries for financing mechanization through both the private and public sectors are required as well as an inventory of best practices and failed cases. Lessons from past successful and failed mechanization projects will be quite useful to member countries when developing sustainable mechanization strategies for their agri-food systems.

### *iii. Gender roles and empowerment of women*

A shift from traditional labour-intensive production and post-harvest operations to labour-saving technologies and mechanization is taking place across Asian agriculture in response to rising labour scarcity, increasing labour costs and the increasing feminization of agriculture due to the propensity of more men migrating to urban areas than women. When compared to men, women have less access, control and ownership of land and other productive resources. Their access to public services, such as training, extension and credit is also very limited when compared to that of men. Further, mechanization technologies are often designed to suit the physical constructs of male workers and thus female workers lack appropriate technologies conducive to their physical constructs. The mainstreaming of gender dimensions in the process of developing SAMS is thus quite important.

Key options to be considered include:

- The collection, compilation and analysis of gender-disaggregated data (labour, income, decision making, access to assets and control of resources) to increase awareness among research managers, extension agents and policy makers to help reduce gender inequalities in access to resources and economic opportunities.
- Promotion of the participation of women farmers in meetings and demonstration trials, and in participatory experiments/evaluations related to mechanization in production, post-harvest and processing activities.
- Legislative changes to assure property rights of women to farm and other related assets. Legal entitlement to land will also facilitate women's access to institutional credit.
- Ensuring that mechanization positively contributes to the empowerment of women by increasing their labour productivity and reducing the drudgery associated with on-farm and post-harvest operations. Within this context, specific attention must be paid to ensuring that women in more traditional systems are not displaced and/or lose their sources of income and employment with the introduction of labour saving operations.
- The design and development of gender friendly mechanization technologies as well as support systems for offering mechanization services.

#### *iv. Empowerment of youth*

Rural youth of today are the farmers of tomorrow. They represent a huge potential resource for rural development, but are migrating to urban areas due to a lack of profitable economic opportunities in rural areas. They also migrate to escape from poverty associated with peasant farming which is characterized by the utilization of low levels of mechanization inputs associated with back-breaking and arduous hand-tool technologies. Such migration of young people will not only result in “greying” of the agricultural workforce, but could also contribute to growing urban unemployment.

Young people have enormous potential for innovation and risk-taking that are often the core of smallholder commercial agriculture. They, however, face particular constraints in gaining access to land, credit and new technologies relative to their older peers. Further, decision makers be they government officials or bank managers will have to consider the age and gender of the farmer, among other things (e.g. a bank manager will consider a loan to a 60-year old farmer to be quite risky compared to that to a 30-year old educated and technologically savvy farmer) – it is important therefore that the youth are empowered to remain in farming and mechanization of agriculture is one way to do so. SAMS will have to factor these issues related to empowerment of the rural youth.

Key options to be considered include:

- The provision of targeted training programs that are designed to build the capacity of young people to access as well as effectively and profitably operate and maintain mechanization equipment to support more efficient agri-food chains.
- Given the shift to more knowledge intensive farming and post-harvest handling operations in the region, vocational training will be particularly important in training the youth to take on critical roles in the emerging commercially competitive agriculture and value adding activities.

#### *v. Manufacturing of agricultural mechanization inputs*

The Asia-Pacific region is regarded as a low cost manufacturer of agricultural machinery and implements. Most of what is manufactured in the region is used and/or sold within the region with less than 10 percent of total production sold in global markets. However, the rate of growth in the volume of manufactured output is high such that the region in the near future may emerge as a leading exporter of agricultural machinery and implements to global markets. This will undoubtedly influence prices of agricultural machinery and implements being produced within the region and also their quality. Industrial and trade policies as well as tariffs on imports of agricultural machinery and implements may in turn influence their prices and flow of new technologies from other parts of the world.

Options to be considered include:

- Industrial and trade policies within the region as well as trade with other leading machinery producing countries will influence the competitiveness of the sector especially in producing implements and machinery for sustainable mechanization of operations in agri-food chains.
- National and regional support services to manufacturers such as facilities for standards and testing of machinery.

- Research and development to support innovation in the manufacturing industries especially the small-scale ones including licensing and patenting.
- Incentives and subsidies to support initial manufacturing of equipment and implements which have been adapted to the regional requirements for sustainable tillage and crop husbandry practices.

### 6.3 Environmental issues

#### *i. Land degradation*

As already indicated, the major environmental issue in relation to agricultural mechanization technologies in Asia and the Pacific region is land degradation. This degradation may be caused directly by the technology itself (soil compaction) or may result from the inappropriate use of the technology (soil erosion). SAMS will need to factor in measures which reduce to the minimum, the effect of agricultural mechanization technologies in these two aspects through designing and disseminating appropriate agricultural machinery and implements.

#### *ii. Environmental pollution due to the use of inputs*

As already stated in Chapter 5 agricultural practices that make use of large quantities of external inputs, often result in continuous environmental degradation, particularly of soil, vegetation and water resources. Such misuse of high external inputs for crop and livestock production have far reaching environmental effects including, among others, soil erosion, loss of biodiversity, soil salinization including the depletion of freshwater resources and reduction of water quality; disturbance of soil physicochemical and biological processes as a result of intensive tillage and slash and burn methodologies for land preparation. Coupled with the direct environmental effects of intensive high input agriculture are the threats due to climate change where the sector is not only affected by it, but also contributes to it, through the emission of greenhouse gases (GHGs). The region is a major contributor to GHG emissions and efforts must be made to reduce this.

SAMS should therefore bring in a focus on the reduction of the negative environmental effects of intensification of agriculture as well as to the efforts being taken to meet the challenges of climate change.

Options to be considered include:

- Concerted efforts must be made to eliminate and/or reduce to the minimum, the negative environmental effects of mechanization across agri-food chains, by developing and disseminating technologies as well as formulating and implementing policies which contribute to reducing negative environmental impacts. These efforts should include practices which reduce soil erosion to the minimum and which increase the resilience of the environment.
- SAMS should contribute to the adoption of better methods and technologies which eliminate the inappropriate use of, and increase the efficiency of the handling and use of chemical inputs, like precision agriculture etc.
- SAMS should also contribute to efforts to combat the threat of climate change such as in the reduction of GHG emissions, combating desertification.

## 6.4 Cross-cutting issues

### *i. Agricultural mechanization policy and strategy formulation and coordination*

Agricultural mechanization policy and strategy formulation requires inputs from many ministries in the Government – from the Ministry of Agriculture; Trade and Industries; Finance and Economic Planning; Research and Development, Environment as well as Education. Each of these Ministries has a role to play in the formulation of SAMS and in its implementation. Decision makers at the policy level need to fully appreciate the complexities of the political environment and the trade-offs between competing short-run goals and longer-term development objectives as well as the environmental sustainability dimension – this will be of critical importance in the process of formulating and developing an implementation plan for SAMS.

SAMS requires long-term commitment by a range of stakeholders – this is particularly the case for policy makers who have to take a long term perspective and remain steadfast. If policy makers are not so committed then it is difficult to mobilize the support of the other array of stakeholders for SAMS to invest their time and resources to the effort. The long-term commitment of policy makers is the necessary catalyst for getting the support of other multi-stakeholders to commit themselves and their resources to SAMS. This applies for programs at the local, national and regional levels.

Options to be considered include:

- Coordination of the inputs of various stakeholders toward the successful formulation and implementation of SAMS at national and regional levels. This coordination is required within the public as well as with the private sectors where there are many stakeholders including farmers, agro-food supply chain stakeholders and their organizations.
- Defining the priorities of SAMS, within countries and for different farming systems: Efforts should be directed to ensuring that SAMS is focused and is consistent with the purpose of agricultural mechanization that countries have identified in their long term agricultural and economic development plans. Priority areas for different agro-ecologies and farming systems must be identified in order to ensure focused intervention by SAMS at the country level.
- Development of industrial and trade policies for agricultural machinery and implements, manufacturing of implements locally and regionally, whether to impose duty on imported equipment etc: These policies will require close coordination within Governments to include not only Ministries of Agriculture but also those of Trade and Industry; Finance and Planning as well as those of Environment and of Energy.
- Documentation of lessons from the past as well as case studies to assist countries in the planning process and in scaling up their activities on SAMS (See Box 6.1 for Policy lessons from the experience of the 1960–1990s).

### **Box 6.2: Policy lessons from the experience of agricultural mechanization: 1960–1990s**

Four main policy lessons for agricultural mechanization policy can be gleaned from the largely Asian experiences of the last four decades of the twentieth century (FAO, 2008):

**First:** Attention should be placed on increasing the profitability of investments in mechanization by encouraging commercial agriculture and focusing investments and support necessary to increase the profitability of farm and non-farm enterprises. A critical question in this respect is whether there are entrepreneurs/farmers ready to invest in machinery and implements for use on their farms as well as for providing mechanization services to the small-scale farmers who are unable to marshal such levels of capital investments.

**Second:** Mechanization should be viewed strategically within a longer-term time frame. Despite the array of studies demonstrating that the use of tractors was often not profitable, medium and larger-scale farmers in Asia pushed ahead with their change of farm power source to tractors. Also, policy-makers in general regarded the short-term impact of tractorization as less relevant and important, and took a more strategic longer-term perspective viewing tractorization as part of a broad-based economic development strategy aimed at economic growth and agro-industrialization. Short-term social costs were at times ignored in favour of probable increases in labour demands following intensification. The result was a transformation of the agricultural mechanization scenario over a 40-year period.

**Third:** Mechanization is a complex and dynamic process that cannot be appraised only from the standpoint of factor substitution or net contribution to production. Where mechanization has taken place worldwide, there have been fundamental and interlinked changes in the structure of agricultural sectors, in the nature and performance of agricultural support services, and in the livelihood strategies of farmers and agro-processors. These changes do not necessarily take place simultaneously nor impact on all people in the same way (Smith, 2000; Singh 2008; Mrema *et al*, 2008).

**Fourth:** While mechanization has been actively promoted by political leaders and governments in the developing world, its successful development has not been dependent on governments being directly involved in offering mechanization services. Instead, where mechanization has been successfully implemented, essential mechanization supply systems and support services have developed largely through private sector initiatives, in response to economic demand – in most cases, starting with support services targeting medium and larger-scale farmers.

#### *ii. Capacity building at the national and regional levels*

It is important to recognize that the human resources who were instrumental to the success of the mechanization programs of the 1980s were trained in the 1960s and 1970s mostly through aid programs of major donor agencies. Many of these have or are about to retire from the system and a second (and in some countries a third) generation of experts is emerging. Further, many of the training and education programs established in the 1960s and 1970s are in decline in quite a number of universities due to competition with other sectors (ICT etc.) and also reduction of public funding and employment opportunities in the public sector. Also, sustainable agri-food technologies and practices are relatively new in many parts of the region while the curricula of higher education and training institutions tend to be quite static.

Options to be considered include:

- Capacity development both in terms of human resources and institutional set-up for SAMS throughout the region. Within this context, a key challenge will be that of rebuilding the capacity of public sector technology development and transfer organizations as they will play a key role in the process of developing and transferring SAM technologies. This capacity building must involve Ministries of Agriculture, Trade and Industries as well as farmer organizations, agri-food supply chain stakeholders and those working in the agricultural machinery and implement supply chains.
- Setting up of regional training programs where economies of scale and scope dictate so. This will necessitate planning and offering of training programs especially at the regional level.
- Revision of curricula by higher education and training institutions and the mounting of refresher courses for their lecturers and instructors on SAM technologies that are applicable across agri-food chains. Also machinery manufacturers could be encouraged to assist these institutions with their new equipment to be used in training.
- Targeted training programs, including vocational training, short courses and/or evening courses designed to build the capacity of stakeholders involved in mechanization supply chains (sales, repair and maintenance, etc.).

*iii. Advocacy and knowledge sharing on sustainable agricultural mechanization*

As SAMS in a way represents a paradigm shift in so far as agricultural mechanization policies and strategies are concerned, it will require considerable advocacy and knowledge sharing amongst all key stakeholders involved. This should be at the local, national, regional and global levels.

Options to be considered include:

- Advocacy, knowledge sharing and sensitization of key stakeholders on the role of SAM in development and the need to plan for SAMS.
- Sensitization of policy makers and other key stakeholders on the need to take a long term perspective on SAMS given demographic and other socio-economic changes such as the need for increasing employment opportunities for youth in agriculture which are likely to occur over the next three to four decades.
- Sensitization of key stakeholders of the need to transform antiquated technologies and practices such as in land preparation, crop husbandry and irrigation in the quest for long term environmental sustainability.
- Establishment of a regional (and country level) network on SAMS with an aim to promote sharing of knowledge, lessons learnt and to enhance regional/sub-regional cooperation and collaboration.

## 6.5 The formulation process for SAMS

During the debates on mechanization of the 1960s and 1970s, FAO and OECD convened a global expert consultation on agricultural mechanization and employment in Rome in 1975 (FAO, 1975). This workshop recommended that each country should formulate its agricultural mechanization strategy (AMS) and FAO was requested to develop guidelines to help member countries in this process. FAO developed these guidelines which were first considered by its Committee on Agriculture (COAG) in 1979. The Asian Development Bank (ADB) and the Asian Productivity Organization (APO) had also developed similar guidelines for use by their member countries (Rijk, 1983; 1989; APO, 1996).

These guidelines, which provide details of the process to be followed at the country level, have been used by FAO in helping member countries in Asia and Africa in particular in developing their agricultural mechanization strategies. They were also adopted by the Regional Network for Agricultural Machinery (RNAM) for Asia. It is difficult to state how useful and applicable the AMS so developed were, as no formal specific evaluation of the program was undertaken. It is notable however that while AMS was a core top priority activity of RNAM during its first phase (1977–1981) it was not a priority activity in subsequent phases (Lantin, 2013).

There is a need to review the guidelines for AMS developed by FAO in 1981 for their relevance today especially given the fact that the emerging scenario during the coming three to four decades in agricultural mechanization is quite different from what pertained during the third quarter of the twentieth century. New guidelines and processes are required to assist member countries in policy formulation and in developing SAMS. These guidelines must take cognizance of the prevailing and futuristic mechanization scenarios as well as the experience gained in the region over the last six decades. To the extent possible, the guidelines and processes should avoid blanket prescriptions.

## 6.6 Conclusion

Asia and the Pacific region has made significant progress over the past five decades in agricultural mechanization. The debate in the 1960s on agricultural mechanization in Asia was essentially about the desirability, feasibility and the social consequences of replacing draught animals, as a source of farm power, with internal combustion engines. In the second and third decades of the 21<sup>st</sup> century Asian countries will be on the verge of completely replacing draught animals as sources of farm power with tractors (either 4-wheeled or 2-wheeled or a combination of both depending on the country), and diesel and/or electrical motors for powering irrigation pump-sets as well as equipment for harvesting, post-harvest handling and processing. This is indeed a great achievement which could not have been contemplated even at the turn of the 21<sup>st</sup> century.

However, as the farm power situation is being transformed, the development debate is now greatly influenced by issues related to the sustainability of the agricultural production system. The environmental, socio-economic and demographic trends which are likely to occur in the region over the next three to four decades will exert considerable pressure on the agricultural system to implement more sustainable agricultural mechanization strategies. The new paradigm of “sustainable production intensification” as described in a recent FAO publication titled *Save and Grow* recognizes

the need for productive and remunerative agriculture that conserves and enhances the natural resource base and the environment, and which positively contributes to the delivery of environmental services. Sustainable crop and livestock production intensification must not only reduce the impact of climate change on crop production, but must also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils.

The SAMS in the region will therefore adopt a holistic and inclusive approach, involving the adoption of sustainable land preparation and crop husbandry techniques as well as increased efficiencies in water use in agriculture; include the entire agri-food chain from the farm to the consumer; and research and development as well as transferring and manufacturing of new mechanical technologies – including both the hardware and software. It will also require the setting up of institutions which facilitate linkages between farmers and financial institutions as well as with manufacturers and distributors of machinery, implements and equipment for the mechanization of operations in agri-food systems and across agri-food value chains.

Finally, countries in the region will need to coordinate their programs for SAMS and in this regard may need to establish regional and innovative mechanisms to foster their cooperation. SAMS is a long term initiative and there are significant benefits to member countries if they cooperate and initiate joint regional programs and projects where economies of scale and scope dictate so. In order to facilitate such regional cooperation there will be a need to consider establishing some regional coordinating mechanisms/networks initially perhaps focused on sharing information and experiences between the countries in the region. Such sharing of information and experiences will enable countries to learn from each other, emulate and scale-up success cases and avoid repeating mistakes made in failed projects. The entire issue of sustainable mechanization of operations in the agri-food value chains in Asia and the Pacific region is too important and too complex to be left to uncoordinated initiatives.

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## VIII. Annexes

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### Annex 1: Summary of status of agricultural mechanization in selected countries of Asia and the Pacific region

Starting from 2011, the FAO Regional Office for Asia and the Pacific (FAO-RAP) in collaboration with the UNESCAP/CSAM, then UNESCAP/UNAPCAEM, organized a number of workshops through which representatives of member countries in the region were requested to prepare summary reports on the status of agricultural mechanization in their respective countries. The following five tables provide a thumb-nail sketch of the status of different aspects of agricultural mechanization in the Asia-Pacific region, as documented in the reports.

The five areas covered include:

- Status of standards and testing of agricultural machinery and equipment,
- Status of government policy on agricultural mechanization,
- Status of agricultural farm holdings,
- Level of mechanization of key farm activities and farm power input,
- Infrastructure and related developments.

The information provided in the following five tables A1 to A5 is drawn entirely from the different country reports which were presented at the workshops/seminars convened by FAO-RAP and UNESCAP/CSAM. As is evident, not all countries reported on all aspects and hence there quite serious gaps in available information.

## Annex 2: Status of standards and testing of agricultural machinery and equipment

	<b>Standards and testing of agricultural machinery and equipment</b>
China	Agricultural machines are tested by government institutions namely: China Agricultural Machinery Testing Centre and the Agricultural Machinery Testing Centers located in each province. While ensuring compulsory compliance with standard codes and performance indicators, greater attention has been given to the noise and emission level and the operational safety of machinery in an effort to minimize adverse impacts on the environment and hazards to human health.
India	The Bureau of Indian Standards (BIS) has established Regional Testing Laboratories to facilitate testing and evaluation, including that of agricultural machinery. Testing is conducted with well-defined standard parameters, defined in BIS, ISO, or OECD standards. As of now, over 500 standards on agricultural machinery are prescribed by BIS. The BIS has also authorized other Government and Semi-Government testing laboratories to conduct testing on their behalf as per BIS Test Codes or ISO Test Codes.
Indonesia	The Indonesian National Standard (SNI) of agricultural machinery is set by the National Standardization Agency of Indonesia (BSN) and is applicable nationwide. Testing and certification of agricultural machinery is offered under the norms of the SNI. Only applicants who have ISO 9001/2008 certification in the production of agricultural machinery and who fulfill the relevant SNI for agricultural machinery can obtain agricultural machinery certification with the SPPT SNI-Certificate – which guarantees product quality. If the applicant has not applied the ISO 9001/2008 in the manufacturing process but has fulfilled SNI or Minimum Technical Requirements (PTM) then the product receives a Letter of Conformity SNI (SKK SNI) or SKK PTM. If the applicant has not applied the ISO 9001/2008 and not fulfilled the SNI or PTM, the product will receive the test report results only. Until 2011, 48 items of agricultural machinery were awarded the Certificate of SPPT SNI (SPPT-SNI) and SPPT SNI and 110 items of agricultural machinery have gained Letter of Conformity SNI (SKK- SNI).
Philippines	The Agricultural Machinery Testing and Evaluation Centre (AMTEC) of the College of Engineering and Agro-industrial Technology (CEAT), University of the Philippines Los Baños (UPLB) is the authorized institution for undertaking the testing and evaluation of agricultural machinery. The mandate of this institution includes establishing technical standards and testing the machines to meet these standards. Machinery testing is, however, voluntary and only manufacturers participating in government bidding for agricultural machinery are required to submit their machines for testing. Further, AMTEC is not mandated to issue certificates of performance on machines tested. To date, more than 200 standards have been developed and adopted through the leadership of AMTEC. Moreover, 263 machines were tested from 2006 to 2009 comprising of prime movers, irrigation machinery, production machinery and post-harvest equipment.

Thailand	<p>The Thai Industrial Standard Institute (TISI), Ministry of Industry is responsible for the standardization of agricultural machinery. Agricultural machinery standards from various countries have been studied and then adapted for Thai agricultural machinery and their corresponding working conditions. More research is, however, required to obtain adequate data for developing standards. Safety standards are an element of each agricultural machinery standard. The National Agricultural Machinery Center (NAMC), established in 1979 under the Research and Development Institute at Kamphaengsaen, Kasetsart University is responsible for the testing of agricultural machinery. The main role of the Center is standardization and testing of locally fabricated or imported agricultural machines and collaborating with the Thai Industrial Standards Institute in standardizing the testing of agricultural machinery.</p>
Viet Nam	<p>Viet Nam has its own standards system consisting of over 6 000 national standards. The Directorate for Standards, Metrology and Quality (STAMEQ) of the Ministry of Science and Technology is Viet Nam's national standards body. Thirty-eight percent of Viet Nam's standards are harmonized with international and regional standards.</p>

### Annex 3: Status of government policy on agricultural mechanization

	<b>Government initiatives/policies favouring agricultural mechanization</b>
Bangladesh	At present, there is no explicit agricultural mechanization policy in Bangladesh. Mechanization is partly included in national agricultural policy. The policy undertakes measures to collect and publicize information through mass media in order to attract private investment in the mechanization sector.
China	The PRC government has well-defined agricultural machinery subsidy policy. This policy has been largely responsible for the rapid development of China's agricultural machinery industry.
India	The Indian government has launched a National Mission on Agricultural Mechanization (NMAM) during the 12 <sup>th</sup> Five-year Plan to bring farm mechanization to those villages where the technologies deployed are decades old.
Indonesia	Indonesia is developing appropriate strategies for selective agricultural mechanization. This location-specific perspective is believed to be the appropriate strategy for potential adoption to enhance the agricultural mechanization level of the country.
Malaysia	The National Field Mechanization and Automation Plan (NFMAP) was drawn up to increase the level of mechanization in all sub-sectors of agriculture. NFMAP was established to set the direction and targets in the adoption of mechanization and automation in agricultural production. A Special Committee on Mechanization and Automation (SCOMA) was formed to coordinate the implementation of all activities related to farm mechanization and automation. All agencies under the MOA are expected to work together in line with the mandate given to ensure this directive is fully implemented by 2020.
Nepal	No specific agricultural mechanization policy has been developed. Nepal has agricultural policies in general, that place strong emphasis on competitive and commercial agriculture but which do not specifically address agricultural mechanization.
Papua New Guinea	The National Agriculture Development Policy (2001–2012) and Papua New Guinea's Vision 2050 are mainly focused towards National Food Security without a specific policy on mechanization.
Philippines	To date the bill for legislation on agricultural mechanization, which would rationalize the implementation of agricultural mechanization, is pending.
Thailand	The Thai government has enhanced its mechanization development plan which is included from the 7 <sup>th</sup> National Economic Development Plan (1992–1996).
Viet Nam	The Resolution No. 26-NQ/TW proposed the industrialization, modernization of agriculture and rural areas while, the Resolution 48/NQ-CP has focused on the stages which have major losses, increase the rate of mechanization, combined with advanced techniques for preservation.

#### Annex 4: Agricultural land holdings

	<b>Average land holdings</b>
Bangladesh	Per capita land holding is around 0.6 ha.
China	There are approximately 200 million households, with an average land allocation of just 0.65 ha.
India	With 129.22 million households, the number of land holdings has been increasing and holding size has declined from 2.30 ha in 1970-1971 to 1.27 ha in 2010-2011.
Malaysia	About 65 percent of paddy farmers have farms of less than 1 ha while, only 4 percent have more than 3 ha of land.
Nepal	The average land holding per household in Nepal is about 0.8 ha.
Philippines	The average land holding of farmers in the country is around 2 ha with plot sizes ranging from 500 to 10 000 m <sup>2</sup> .
Viet Nam	Small and fragmented farm land per household is about 0.7 ha.

## Annex 5: Level of mechanization of key farm activities and farm power input

	<b>Level of mechanization in farm activities</b>
Bangladesh	The available power in agriculture increased from 0.25 in 1960 to 0.32 kW/ha in 1984 and then it increased very sharply to 1.17 kW/ha in 2007.
China	<p>In 2009, the general agricultural mechanization level reached 48.8 percent, and the mechanization of ploughing, sowing and harvesting respectively reached 64 percent, 40 percent and 37 percent. In 2009, the general agricultural mechanization level of wheat, rice and corn was 89 percent, 54.9 percent and 54.8 percent, respectively.</p> <p>Agricultural machinery power per hectare had increased gradually to 7.2 kW/ha in 2009, up 22.0 percent compared to 5.9 kW/ha in 2007.</p>
India	At present in India, tractors are being used for tillage on 22.78 percent of total area and sowing on 21.30 percent of total area. The highest level of mechanization adoption is 60–70 percent observed in harvesting and threshing operations, followed by 40 percent in soil tillage and seed bed preparation, 37 percent in irrigation, 34 percent in plant protection, and about 29 percent in seeding and planting. Wheat and potato cultivation is highly mechanized with 100 percent in seed bed preparation, 90 percent in sowing, about 80 percent in inter-cultural operations and 80–100 percent in harvesting. In case of paddy transplantation, less than 10 percent of mechanization is utilized so far and there is huge scope for mechanization. Similarly in legume and oilseed crops, about 20 percent of harvesting and threshing operations are mechanized. Power availability was 0.48 kW/ha during 1975–1976 and increased to 1.71 kW/ha by 2009–2010. The power availability per unit of production increased from 0.51 kW/ton to about 1.03 kW/ton during this period. The average farm power availability needs to be increased to minimum 3 kW/ha to assure timeliness and quality in field operations.
Indonesia	The current mechanization level in different agricultural activities varies from 100 percent in the case of milling operations and agro-chemical applications followed by about 85 percent in drying, 30 percent in irrigation, 38 percent in tillage and 21 percent in threshing activities. The country's mechanization level is increasing gradually with 6 percent of annual growth rate of hand tractors, 2.54 percent of power threshers, 17.5 percent of water pumps, 4.7 percent of dryers and 2.2 percent in rice milling equipment.
Malaysia	Amongst all the crops cultivated in Malaysia, paddy cultivation and rice processing have reached the highest level of mechanization. In Malaysia, with the exception of highland areas, rice cultivation from land preparation, transplantation to harvesting makes full use of mechanization. For other food crops, mechanized land preparation is available but harvesting is still done manually with some basic aiding tools.
Nepal	In hilly areas only 2.7 percent of holdings own animal drawn iron ploughs for tillage. In the valleys near the road heads farmers have begun making use of power tillers for tillage operations. Due to increasing cultivation of vegetables near urban and peri-urban areas approximately 3 percent of farm holdings in the hills own hand sprayers.

Papua New Guinea	At present, the power input per hectare (mechanization level) in the country is less than 0.68 hp/ha/year.
Thailand	At present, the use of mechanization for land preparation and harvesting have reached 90 percent and 40 percent respectively.
Viet Nam	<p>Rice production in the country is extensively mechanized but adoption of post-harvest technology is still at a low level and requires more attention. So far, in the rice production the highest level of mechanization is in threshing (100 percent) followed by irrigation (86 percent), soil-preparation (72 percent) and sowing (20 percent).</p> <p>The national average of equipped power (mechanization level) is 1.2 hp per ha of cultivated land.</p>

## Annex 6: Infrastructure and related developments

	<b>Infrastructure Development</b>
Bangladesh	Bangladesh has about 2 835 km of railway, 21 269 km of paved road and about 6 000 km of perennial and seasonal waterways. In addition to the roads and railway network, rivers are used for transportation.
India	At present the Indian road network is approximately 4.1 million km and is second largest in the world. It carries about 65 percent freight and 80 percent of passenger traffic. The length of the National highway; Expressways; State highways and other roads are 70 934; 154 522 and 3 884 136 respectively. The railway network also comprises 0.115 million km. Shipping plays an important role in the transportation sector; approximately 95 percent of the country's trade volume (68 percent in terms of value) is moved by sea. India has the largest merchant shipping fleet among the developing countries.
Malaysia	Malaysia's road network covers about 98 721 km and includes 1 821 km of expressways. The road systems in East Malaysia are less developed and of lower quality in comparison to that of Peninsular Malaysia. Malaysia has 118 airports, of which 38 are paved. The railway covers a total of 1 849 km.
Philippines	Of the 199 950 km of roads approximately 39 590 km are paved. Railway systems are in operation only for few remote areas.
Viet Nam	The country has 151 632 km of road network, 2 362 km of railway and about 9 800 km of waterways. In the past decades Viet Nam has invested heavily in building airports and opening many in-country and overseas airlines. The country now has 20 airports, including three international airports, located in three main zones.

## Annex 7: Irrigation facilities

	<b>Availability of Irrigation Facilities</b>
Bangladesh	Irrigation is mostly dependent on ground water. The contribution of ground water in agriculture has increased from 3 percent in 1971 to about 70 percent recently.
China	Of the approximately 1.4 million sq. km of arable land, only about 1.2 percent (116 580 sq. km) permanently supports crops and 525 800 sq. km are irrigated.
India	India has achieved 37 percent of mechanization in irrigation activities.
Indonesia	About 76 percent of the rice acreage is irrigated in Indonesia.
Malaysia	About 322 000 ha (48 percent) of the total paddy areas in the country are provided with extensive irrigation and drainage facilities while the remaining are rain-fed areas. Of the irrigated areas, 290 000 ha are located in Peninsular Malaysia while 17 000 ha are located in Sabah and 15 000 ha in Sarawak. Approximately 217 000 ha of the irrigated paddy areas in Peninsular Malaysia have been designated as main granary areas, while another 28 000 ha distributed all over the country are classified as mini-granary areas.
Nepal	Low cost drip system and plastic tunnels are becoming popular for off-season vegetable cultivation.
Papua New Guinea	Irrigation is not a common practice at subsistence small-scale farm level.
Thailand	Irrigated area is limited and not uniformly spread throughout the country. Irrigation systems are still in a developmental phase that restricts growing more crops per season. Approximately, 75 percent of rice is grown in rain fed areas and about 25 percent in the irrigated areas. About 11.7 percent of irrigated rice area is in the central plain, while 6.4 percent, 5 percent and 1.4 percent in the northern, northeast and southern regions, respectively.
Viet Nam	Agriculture makes use of over 90 percent of the total available water resources with 50 percent being mechanized irrigation while the remaining 50 percent is irrigated using gravity flow and by-hand pumps.



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