5th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific

Promoting Sustainable Agricultural Mechanization Strategy
12-14 December 2017
Kathmandu, Nepal

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific
CSAM

*The shaded areas of the map indicate ESCAP members and associate members.**

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Executive Summary

The Regional Forum on Sustainable Agricultural Mechanization is an annual strategic initiative of CSAM for high-level policy dialogue and regional cooperation in the field of agricultural mechanization in the region.

On 12-14th December 2017, the 5th Regional Forum with the theme of "Promoting Sustainable Agricultural Mechanization Strategy" brought together over 60 stakeholders of the Centre for Sustainable Agricultural Mechanization (CSAM) to Kathmandu, Nepal to share and discuss their strategies including both sound and proven practices as well as lessons learned. The event was co-organized by CSAM and the Ministry of Agricultural Development of Nepal.

The participants included policy-makers, academics and researchers, extension workers, private sector and industry association representatives, as well as staff from pertinent international and regional organizations from 14 countries in Asia and the Pacific, namely, Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Republic of Korea (ROK), Sri Lanka, Thailand, and Vietnam.

As emphasized by Ms. Li Yutong, Head of CSAM: "Sustainable Agricultural Mechanization covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment. It eases hard labor, relieves labor shortages, improves productivity and timeliness of agricultural operations, improves the efficiency of use of resources, enhances market access and contributes to mitigating climate related hazards. To achieve sustainable agricultural mechanization, implementing a sound and holistic sustainable agricultural mechanization strategy (SAMS) at the national level is crucial."

The Proceedings synthesize the country papers presented by participating countries and propose lessons learned and good practices for regional cooperation among countries on Sustainable Agricultural Mechanization Strategy.

According to the analyses found in the received country papers, below are the most prominent common challenges lying on the path to sustainable, competitive, and inclusive agricultural mechanization in Asia-Pacific:

- Decrease in labor;
- Small farm lands;
- Not skilled workforce;
- Absence of after-sale and repairing services;
- Inadequate legislation framework on water resources management and utilization;
- Machines are not suitable for aged people and women;
- Machines are single purpose;
- High price for agricultural machinery;
- Lack of awareness of existing technologies and programmes in the region;
- Lack of funding.

To cope with the listed obstacles, following good practices shared by member countries could be taken into consideration:

- Subsidies for agricultural machinery provided by national and private banks;
- Establishment of research and development centers, funding pilots;
- Establishment of testing / standardization / quality control / after service / custom hiring centres;

- Training for farmers provided by universities;
- Import of agricultural machinery to be modified and adjusted for certain country needs;
- Boost of private sector.

In order to build a strong SAMS and further successfully implement it, governments should take into consideration all shortcomings and lessons learned identified in the region to be able not only accelerate productivity and efficiency, but proper manage climate change and increasing population. Below are the common suggestions for regional cooperation among countries consolidated into four main groups.

Capacity building	Conduct to farmers training programs on operation, maintenance and repair of farm machinery and equipment; Conduct to training for mechanics and technicians to develop their operational skill; Strengthen to the capacity of agricultural machinery entrepreneurs through (1) the transfer of prototype machines and technologies and (2) training tour to countries which have achieved success in developing and producing farm machinery.
Infrastructure	Improve to farm and water management infrastructure to meet the challenges presented by climate change
Technology	Introduce to appropriate technologies; Enhance to research and development of new agricultural engineering technology which are needed at the present or in the future for different geographical conditions; Introduce to testing and after sales service centers for farm machinery; Expand to insurance and maintenance schemes for agricultural machinery spare parts.
Policy	Sell to farm machinery to farmers on credit and installment payment systems; Support to and encourage local manufacturers to produce farm machinery and equipment with reasonable price in compliance with CSAM's recommended safety and quality standards; Simplify to the process for private sector to import agricultural machinery through low or no tax policy on useful imported machinery; Attract to investment from other countries (FDI).

Potential support from CSAM:

1. Development of a knowledge sharing platform

    - In collaboration with Nanjing Research Institute for Agricultural Mechanization (NRIAM), CSAM supported the development and launch of a platform facilitating communication among academics, researchers, and industrial experts in the field of agricultural machinery across the Asia-Pacific region. Stakeholders are encouraged to join and network with their fellow experts in the region. Intellectual discussions on professional subject matters, exchange of work experiences and insights, and the inquiry into the possibility for cooperation are welcomed on the platform. The platform can be found on the following URL address: www.e-Agriscientist.com.
    - In 2014, the GC proposed to establish a Regional Database project to achieve efficient allocation and comprehensive utilization of technologies, experiences and resources, which will eventually promote the development of regional agriculture mechanization. The project is still ongoing.
2. Organization of workshops, seminars, meetings in response to requests of the member countries.
3. Quarterly report on the developments and updates in the sphere of agricultural mechanization in the Asia-Pacific region. As an initiative, a journal will be proposed, based on the inputs received from the member countries, encompassing challenges, good practices and potential approaches to agricultural mechanization in Asia and the Pacific.
4. Provision of policy advisory services.

Member countries are most welcome to read more detailed information on CSAM's official website and contact CSAM secretariat for future collaboration.


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List of Abbreviations

ABE	Agricultural and Biosystems Engineering
ADS	Agricultural Development Strategy
AED	Agricultural Engineering Division
AERI	Agricultural Engineering Research Institute
AFMT	Agricultural and Fisheries Mechanization Technology
AICRPs	All India Coordinated Research Projects
AMD	Agricultural Mechanization Department
AMI	Agricultural Mechanization Index
AMP	Agricultural Mechanization Policy
AMPOS	Agricultural Mechanization Promotion Operational Strategy
AMPP	Agricultural Mechanization Promotion Policy
ANTAM	Asian and Pacific Network for Testing of Agricultural Machinery
APP	Agriculture Perspective Plan
BARC	Bangladesh Agricultural Research Council
BFI	Bank and Financing Institute
BIS	Bureau of Indian Standards
BOI	Board of Investment
CAGR	Compound Annual Growth Rate
CBS	Central Bureau of Statistics
CEAT	College of Engineering and Agro-industrial Technology

CIAE	Central Institute of Agricultural Engineering
CNC	Computer Numerical Control
CPC	Central Product Classification
CPHSC	Community Post-Harvest Service Center
CSAM	Centre for Sustainable Agricultural Mechanization
CTAM	Center for Testing of Agricultural Machinery
DOA	Department of Agriculture
FDI	Foreign Direct Investment
FMRC	Farm Mechanization Research Centre
FMTC	Farm Mechanization Training Centre
FMTTI	Farm Machinery Training and Testing Institutes
GAI	Green Area Index
GDP	Gross Domestic Product
GoN	Government of Nepal
HEI	Higher Education Institutions
IAARD	Indonesian Agency for Agricultural Research and Development
ICAERD	Indonesian Centre for Agricultural Engineering Research and Development
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technology
IoT	Internet of Things

IRRI	International Rice Research Institute
KSAE	Korean Societies of Agricultural Engineering
LLP	Low Lift Pump
MAMI	Modified Agricultural Mechanization Index
MARDI	Malaysian Agricultural Research & Development Institute
MOAC	Ministry of Agriculture and Cooperatives
MoAD	Ministry of Agricultural Development
MOP	Muriate of Potash
NABARD	National Bank for Agriculture and Rural Development
NAP	National Agricultural Policy
NARC	Nepal Agriculture Research Council
NARS	National Agricultural Research System
NC	National Certificate
NESDP	National Economic and Social Development Plans
OFC	Other Food Crops
PMAMO	Prime Minister Agricultural Modernization Project
RDI	Research &Development Institutions
RTK	Real Time Kinematics
SAMS	Sustainable Agricultural Mechanization Strategy
SAU	State Agricultural Universities

SCI	Science Citation Index
SIFC	Small Industry Finance Corporation
SLCARP	Sri Lanka Council for Agricultural Research Policy
SMAM	Sub-Mission on Agricultural Mechanization
SMI	Small and Medium Industries
STW	Shallow Tube Well
T&E	Testing and Evaluation
TESDA	Technical Education and Skills Development Authority
UPLB	University of the Philippine Los Baños
VIAEP	Vietnam Institute of Agricultural Engineering and Post-Harvest Technology
VRA	Variable Rate Applicator
VRT	Variable Rate Technology
WEF	World Economic Forum

Welcome Remarks

Dr. Suraj Pokharel
Secretary
Ministry of Agricultural Development
Nepal

Dear Mr. Li Hong, Permanent Representative of China to ESCAP;

Ms. Li Yutong, Head of the Centre for Sustainable Agricultural Mechanization of the United Nations Economic and Social Commission for Asia and the Pacific;

International delegates from different organization involved in agricultural mechanization of Asia and the Pacific representing Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Pakistan, Philippines, Republic of Korea, Sri Lanka, Thailand and Vietnam;

Scientists from IRRI, representatives from CIMMYT, CSAM, national participants, media persons, ladies and gentlemen:

I, on behalf of Government of Nepal, Ministry of Agricultural Development, would like to welcome you all at the 5th Regional Forum Meeting on Sustainable Agricultural Mechanization in Asia and the Pacific with the theme Promoting Sustainable Agricultural Mechanization Strategy in Asia and the Pacific region.

Nepal is a predominantly agricultural country with about 66% employees that contribute 29.37% in national GDP. It is dominated by smallholdings having 0.68 hectors in average. Low investment capacity of Nepalese farmers, lack of infrastructure and market availability have long restrained the country to use traditional agricultural technology. The young generation is not willing to work in agriculture, and migration to urban area and aboard for non-agricultural section is an increasing trend. This has resulted in old age and feminization in agriculture. However, in present days, awareness and emerging commercial agriculture has allowed Nepal to go for appropriate agricultural mechanization.

Recent changes in the political situation (transformation to Federal Democratic Republic of Nepal) and adoption of a new Constitution 2015 emphasized the importance of agriculture in increasing production and productivity of agricultural sector through commercialization, industrialization, diversification and modernization along with developing agricultural tools, and accessing market with appropriate price for the production.

On 29 August 2014, Government of Nepal approved Agricultural Mechanization Promotion Policy with the following objectives:

1. Promote agricultural machinery appropriate to socio-economic and geographic conditions of the country;

2. Promote partnership between public and private sectors as well as cooperatives;
3. Promote environment and women friendly agricultural machinery;
4. Provide appropriate institutional arrangements for agricultural mechanization.

In 2015, the government also approved a 20-year strategic plan named Agricultural Development Strategy (ADS) 2015, allocating agricultural mechanization as one of thirteen core priorities. Private sector has been visualized as a major player to boost agricultural mechanization in the country.

Additionally, Agricultural Mechanization Promotion Operational Strategy (AMPOS) endorsing short, middle and long-term targets to increase mechanization level from 40% to 70% by 2027 is currently pending approval.

Ministry of Agricultural Development implemented Prime Minister Agricultural Modernization Project (PMAMP) in 2016, which will last for the next 10 years. It has given high priority to commodity wise agricultural mechanization and programs like establishing community post-harvest service centers and community custom hiring centers, etc.

As I mentioned above, the government has given high priority to commercialized agriculture considering agricultural mechanization as one of the important inputs to boost production and productivity.

I am confident that this forum will give opportunity to stakeholders in the Asia-Pacific region to share insights in national policies, strategies, and to identify innovative solutions for sustainable agricultural mechanization among the participating countries. I hope that the forum will pave to the formulation of valuable guideline strategy for sustainable agricultural mechanization within each of the member countries.

Once again, I welcome you in the Himalayan country and wish you a pleasant and wonderful stay.

Thank you.

Opening Remarks

Ms. Li Yutong
Head
Centre for Sustainable Agricultural Mechanization
United Nations Economic and Social Commission for Asia and the Pacific

Honorable Dr. Suraj Pokharel, Secretary of the Ministry of Agricultural Development of Nepal;

His Excellency Mr. Li Hong, Permanent Representative of the People's Republic of China to ESCAP;

Distinguished delegates from CSAM Member Countries and International Organizations;

Ladies and Gentlemen,

It is my great pleasure to welcome you to the 5th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific.

The Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific is a flagship initiative of CSAM for promoting high-level policy dialogue and regional cooperation. Since 2013, four Forums have been successfully organized, providing a unique opportunity to key stakeholders in our region to share and elaborate on important topics related to the various dimensions of agricultural mechanization.

Countries in the Asia-Pacific region face significant challenges to achieving the 2030 Agenda for Sustainable Development that was adopted by the global community at the United Nations General Assembly in September 2015. Focusing on the theme of "Promoting Sustainable Agricultural Mechanization Strategy", the 5th Regional Forum is timely and targets to address real challenges and constraints in the region.

These challenges include persistent poverty, reduced availability of agricultural labor, demographic changes that result in larger proportion of ageing agricultural workers in agriculture, inadequate capacities and access to resources for women, inefficient agricultural value chains, degradation of natural resources and the environment, and impacts of climate change.

Thus, agricultural mechanization must move from pure technology to a broader context, meeting technological, economic, social, environmental and cultural requirements, offering innovative and economically viable opportunities for growers, consumers, policymakers and other stakeholders in the entire food system. In other words, sustainable agricultural mechanization acquires importance in today's context. Sustainable Agricultural Mechanization covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment. It eases hard labor, relieves labor shortages, improves productivity and timeliness of

agricultural operations, improves the efficiency of use of resources, enhances market access and contributes to mitigating climate related hazards.

To achieve sustainable agricultural mechanization, implementing a sound and holistic sustainable agricultural mechanization strategy (SAMS) at the national level is crucial. It is a prerequisite to creating an enabling policy framework, as well as an institutional and market environment in which farmers and other end-users have a wide choice of farm power and equipment suited to their needs within a sustainable delivery and support system.

A national sustainable agricultural mechanization strategy needs to take into account not just the specific technical, engineering, economic and social aspects, but also the linkages and inter-dependencies with other sectors and their roles in agricultural mechanization along the value chain. A sustainable agricultural mechanization strategy must provide a holistic framework for making decisions on allocating resources, addressing current challenges, and developing achievable actions and programmes through a structured, but flexible, participatory process engaging all pertinent stakeholders in an innovative and coherent manner including policy makers, researchers and academics, private sector equipment and service providers, and farmers.

Actually, quite a number of countries in the region have already formulated and implemented agricultural mechanization strategies or similar long-term development plans.

CSAM is a regional institute of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) with a vision to achieve production gains, improved rural livelihood and poverty alleviation through sustainable agricultural mechanization for a more resilient, inclusive and sustainable Asia and the Pacific. It has a mandate to facilitate discussion and knowledge exchange on the theme of sustainable agricultural mechanization strategy formulation, practices and achievements in the region. And CSAM is pleased to play a role in convening key stakeholders to explore opportunities for synergy and collaboration.

In this context, the 5th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific aims to bring together the key stakeholders from member countries as present today, to share and discuss their strategies including both sound and proven practices as well as lessons learned.

I look forward to listening to your insightful thoughts and sharing of best practices in your respective countries, and more importantly, the potential, and practical opportunities to work together to achieve sustainable agricultural mechanization in order to progress towards the SDGs and realize the commitment to 'leave no one behind' in the coming months and years.

In conclusion, I would like to extend my deep appreciation to our co-host the Directorate of Agricultural Engineering of the Department of Agriculture under the Ministry of Agricultural Development of Nepal for their invaluable commitment and partnership for co-organizing this 5th Regional Forum.

Ladies and Gentlemen, I wish you every success in your deliberations and a very pleasant stay in Kathmandu.

Thank you.

Keynote Remarks

Mr. Li Hong
Permanent Representative of China to
Economic and Social Commission for Asia and the Pacific

Your honorable Mr. Suroj Pokhrel, Secretary of Ministry of Agriculture Development of Nepal, Dr. Li Yutong, Head of CSAM,

Your Excellencies,

Dear Colleagues, Ladies and Gentlemen,

It is a great honor for me to be invited to address the 5th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific as co-organized by CSAM and the Ministry of Agricultural Development of Nepal. I thank the hosts for the hospitality and the thoughtful logistic arrangements.

Dear colleagues,

The 2030 Agenda is a plan of action for people, planet and prosperity. Implementation of the Agenda has been the paramount task for all countries and UN development institutions. Agriculture is crucial to the sustainable development goals of eradicating poverty in all its forms and dimensions and ending hunger everywhere, which are set as Goal 1 and Goal 2 of the SDG. All nations and international communities are striving for the goals relentlessly. This is really a historical combat against poverty by humankind. Our conference this week is clearly part of such efforts. Here I would like to commend the partnership between CSAM and FAO Regional office in Asia and Pacific. I know your two organizations have been working together for quite a few years. The Secretary-General of the UN has been advocating for UN development system reform. One of the directions is to strengthen the coordination and cooperation between different UN development institutions. Your synergy has to go ahead of the reform. This is really a right direction and you set a good model for others. I am looking forward to seeing more substantive joint work between you two and others.

Dear colleagues,

The world today is facing a variety of complex challenges and is undergoing profound changes. Non-traditional threat caused by climate change, environment deterioration, increasing social gaps, infectious diseases and terrorism are approaching us ever unprecedented and affecting our daily life in various form. Regional turbulences intensification and protectionism, and isolationism rise against globalization, which complicated the world economy recovery. Facing such chaos, the international community must unite more closely and respond collectively. In our Chinese view, all such challenges could only be solved by development. Development is the key to all issues. But the doctrine

and approach of development need to be updated with following features:

First, we should adhere to open development. Opening-up keeps dynamism and vigor, while closing is bound to fall behind. We should pursue international and regional development cooperation through equal consultation, broad participation and shared benefits for all.

Second, we should go along the route of innovative and inclusive development. Innovation is a must instead of alternative for modern economy and for sustainable development. We should seize the opportunity of technology advance to increase investment in innovation, change development mode, cultivate new economy and stimulate the vitality of the market. Inclusiveness of economy is essential for prosperity and even for peace and stability. To guarantee the inclusiveness of economy needs efforts from different level. At international level, special attention should be paid to developing countries with special needs. At the national level, development and distribution policy should be preferential to vulnerable groups.

Third, we should follow the path of interconnected development. In the age of economic globalization, countries are closely linked in their development and they all rise and fall together. No country could seek development on its own. We need to realize interconnected development by regional economic cooperation and integration. Policy and infrastructure connectivity will pave the way for that and increase opportunities for landlocked countries and small developing countries.

Fourth, we should pursue common development for all. As a Chinese saying goes, "A single flower does not make spring; One hundred flowers in full blossom bring spring to the garden". As the Arabic proverb says, “If you want to go fast, go alone. If you want to go far, go together with a group”. Only through common development could we sustain growth and leave no one behind.

China, as an emerging economy, is working with the regional countries and international organizations in pursuing above development scenarios. China is firmly committed to the multilateralism, strongly support the key role of UN in solving international disputes and promoting peace and development.

Over the past 40 years, the Chinese government and people have undergone a profound reform and opening-up and embarked on a successful path of development. China has lifted over 700 million Chinese out of poverty, creating a miracle in the world development history. Chinese government has determined to eliminate the rest 40 million people in poverty by 2020, which will be 10 years ahead of the deadline as set by the 2030 Agenda.

While solving our own problem and promoting China’s development, China has also been contributing to the development of the world. Chinese president Xi Jinping has now proposed to build a community of shared future for mankind, where we will strive for a better life not just for the Chinese people but also those around the world, especially in developing countries. The Belt and Road Initiative is just one of the Chinese-provided public products for strengthen regional and world economic cooperation. It sets forth a grand vision of interconnecting Asia with Europe and beyond through policy coordination, infrastructure connectivity, unimpeded trade, financial integration and people to people bond. It is an open platform for all countries. Extensive consultation, joint contribution and shared benefits are the basic principles under the framework of BRI.

For the last four years, the Belt and Road Initiative has drawn worldwide attention and support. Over 100 countries and international organizations expressed their support and many of them are actively participating in it by synergizing their strategies and plans on connectivity, enhancing production capacity cooperation and strengthening people-to-people exchange. Among the multilateral organizations, UNESCAP took the lead. Nowadays, China and UNESCAP has a lot of projects under implementation, which will both benefit BRI and for UNESCAP’s work on economic cooperation and integration, which brings win-win for both sides.

It should be mentioned that agriculture is an integrated part of BRI. In last May also, Chinese government published an official document on the Vision and Action for Agriculture Cooperation for the Belt and Road Initiative. The document sets basic framework and guidance for BRI agricultural cooperation. It also provides fresh impetus and cooperation space for the pursuit of the Sustainable Development Goals by 2030. Today’s forum is gathered with experts and officials with agricultural mechanization background and agriculture related expertise from our region. I would like to encourage you to communicate with our Chinese colleagues here from the Beijing to explore possible cooperation in the field of agriculture under the framework of BRI. I am sure that there are broad common interesting areas we could find. The Chinese side would be ready to provide political and financial support for such cooperation.

Dear colleagues,

Sustainable Agriculture Mechanization is one of the most effective ways to raise the productivity and reduce the labor intensity of farmers. As a traditional agricultural country, China has deep recognition of the important role of mechanization in agriculture. We are privileged to be the hosting country of CSAM and has been showing strong support to the work of CSAM. Since 2016, China has significantly increased the financial support for CSAM from US$400,000 annually to US $ 1.7 million annually. We are happy to see that under the capable leadership of Dr. Li Yutong and the guidance from ESCAP, the work of CSAM has been deepening expanding and upgrading from time to time.

Your frequent activities in the region manifested the active role and enterprising gesture of CSAM in promoting sustainable development goals. Your flagship projects are welcomed by Member States at the annual ESCAP Commission Sessions, which has been witnessed by great audience including myself. As the host country, we have special expectation for CSAM in promoting both the regional sustainable agricultural mechanization and for implementation of 2030 Agenda. China would also be happy to see a facilitating role of CSAM for regional BRI agricultural cooperation. I am confident that the dialogue and discussion this week here would serve this purpose.

Last but not the least, I wish the forum, the workshop and the council meeting this week a great success.

Thank you all for your attention.

Country Presentations


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Bangladesh

Mr. Sultan Ahmmed
Member Director (NRM)
Bangladesh Agricultural Research Council (BARC)

I. Agricultural Mechanization Country Profile

Bangladesh has made remarkable progress in producing cereal grains (rice, wheat, and maize) and to some extent, vegetables like potato, tomato, cauliflower, cabbage, eggplants, beans etc. by introducing farm mechanization. Among many agricultural inputs, agricultural machinery plays an important role in promoting crop production to a targeted level to sustain self-sufficiency in cereal production in the country. In recent years, significant improvements have been made in the production and marketing of locally made agricultural machinery in the country. Eventually, almost all centrifugal pumps being used in shallow tube wells (STW) and low lift pumps (LLP) are manufactured in the country. Similarly, paddy and wheat thresher, maize sheller, hand and foot-pump sprayer, weeder, engine, and machine spare parts are also being manufactured locally. However, this sub-sector is still recognized as a non-formal sector, and very limited effort has been made so far to assess the sub-sector market demand and supply, domestic demand and potential for export of agricultural machines.

The machinery needs for production and post-harvest processing of crops has the increased significantly in recent time. Despite numerous limitations, the sub-sector is growing quite satisfactorily and has potential to grow faster and able to make substantial contribution in employment generation, poverty alleviation and as a whole in the national development.

Since the early nineties, the demand for agricultural machinery in the country is increasing and the market grew rapidly in recent years. In the last five years, the market grew more than three folds. This also encouraged the local production of agri-machinery and spares parts significantly, and decreased dependency on imports.

Besides, most common agri-machinery and spare parts production, a few items like drum seeder, push-pull weeder, potato harvester, potato grader, fish and poultry feed machine, rice grader, rice polisher, auto crusher machine, auto mixture machine, oil mill, chira/puffed rice mill, rice huller, hot mixture machine, cereal dryer machine etc. are being manufactured in the country. This sub-sector remains unexplored and there is a huge potential for growth and employment generation.

II. National Agricultural Machinery Strategy/Long-Term Plan

2.1 Summary of related policies, strategy/long-term plan

The Government has already attributed due importance to

agricultural mechanization and machinery research. During the last few years, the government invested up to 70% in the price of agricultural machines in terms of development assistance as an incentive and distributed 60,172 different types of agricultural machines among the farmers. Programs like modern machinery distribution, capacity building of village mechanics & operators, quality control measures and policy support activities for the agricultural machinery manufacturers & assemblers are working successfully. The Agricultural Mechanization Road Map 2021, 2031 & 2041 is a great milestone for agricultural mechanization in Bangladesh that has recently approved by the Government and it is prepared by Government organizations led by BARC. In order to achieve the vision 2021 & 2041 within the preview of the national development plan, the said Roadmap will render effective and long-term contribution in materializing modern, economic and profitable agricultural.

National Agricultural Policy (NAP)–2013, published by Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka and it's new version as NAP- 2017 is at the final stage.

Agricultural Mechanization Policy (AMP) formulation has started recently and draft of the documents is under process considering of machine design, development and manufacturing, quality protection by standardization of machines, skill development of researchers, farmers, mechanics and machine operators and marketing system improvement under the supervision of Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka.

2.2 Results from implementation

The Agricultural Mechanization Road Map 2021, 2031 & 2041 implementation is already started by the NARS institutes, DAE and other related institutes.

III. Lessons Learned and Good Practices

Research and development on agricultural machinery and equipment in Bangladesh is progressing at a pace slower than expected. Farmers want affordable and appropriate machines and implements to enhance production and productivity. Both ownership and custom hiring of farm machines are increasing in Bangladesh. Small size of farm holdings, high intensity of cultivation and need of soil conservation, reduction of harvesting and post-harvest losses and value addition to the product demand accelerated R&D activities. The above mentioned suggestions are expected to invigorate needed R&D activities to meet the expectation of the agricultural sector development of Bangladesh.

IV. Suggestions for Regional Cooperation amongst Countries

1. Establishment of a 'Central Institute of Agricultural Engineering (CIAE)' for the continuation of innovation through R&D with government organizations, non-government organizations & development partners initiatives, along with a well-equipped fabrication workshop and adequate funds for running a core program;
2. Modernization of local foundries and workshops through collaboration and experience sharing activities among the Asia-pacific region and industrialized countries;
3. Provide on-job training for the mechanics and technicians to develop their skill, efficiency as well as their ability to produce of quality machines;
4. Strengthening capacity of agri-machinery entrepreneurs through the transfer of prototype machines and technologies and visiting and training of proper personnel in countries which have achieved success in developing and producing farm machinery;
5. CSAM may continue to organize regional meeting and seminar for coordination and cooperation among the member countries.

Cambodia

Mr. Saruth Chan
Director
Agricultural Engineering Department
Ministry of Agriculture, Forestry and Fisheries of Cambodia

I. Introduction

Agriculture continues to be one of the main priority areas of the Royal Government of Cambodia. It contributes about 28.6% to the GDP and employs 60% of the total population (MAFF 2015). Agricultural growth had shown steady improvement averaging 5.3% annually during 2004-2012, which was among the highest in the world. However, the growth had slowed down to around 1-2% in 2013-2014 (World Bank 2015).

Cambodian farming systems are largely subsistence oriented and are dependent on rainfed conditions thereby excessively exposing producers to production uncertainties. Most systems are centered on paddy rice production, which is a staple food in the country and 84% of the total area is under wet season rice (MAFF 2014). Although new irrigation facilities have been constructed and old schemes have been rehabilitated to allow multiple cropping per year, they have yet met with the demand. This restricts the majority of producers to a single rain-fed rice crop per year.

The contribution of agriculture in Cambodian GDP has been decreasing in the last few years (Figure 1). The change of the contribution of agriculture sector resulted from the increase or decrease of other 2 sectors (industry and services). In 2014, agriculture contributed 28.7% to GDP, decreasing from about 34% in 2010, while industry and services accounted for 25.5% and 40.5%, increasing from about 22% and 38% respectively.

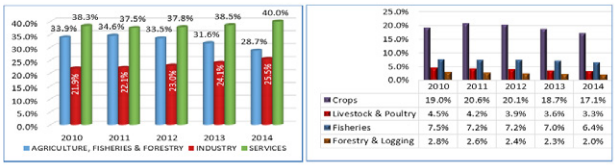

Figure 1: Share of Agricultural Sector and Its Sub-Sectors in GDP from 2010 to 2014 in Cambodia
Source: MOP, 2014

Cambodia grows a range of agricultural crops over a cultivated area of 4,505,267 ha, of which rice accounts for 3,052,420 ha, subsidiary and industrial crops 941,028 ha, permanent crop 183,048 ha and rubber plantation 328,771 ha (MAFF, 2013). The main crops are paddy (wet season, dry season, receding and floating), corn, soybean, mung-bean, cassava, sugarcane, peanut, sesame, sweet potatoes, Chinese cabbage, cauliflower, lettuce, watermelon, and tobacco. Plantation and industrial crops include rubber, cashew nut, pepper, palm sugar, palm oil and fruit trees (mango, pineapple, jackfruit, durian, rambutan, and banana). Teak wood and acacia are two of the main commercial forest timber species and non-timber forest products include bamboo, grass,

fodder, honey, and mushrooms. Firewood is also collected.

Within the agricultural sector, crop production constitutes more than half of total production, being at 59.4% in 2014. The rest are fisheries (22.2%), livestock (11.3%) and forestry (7%) (Figure 2).

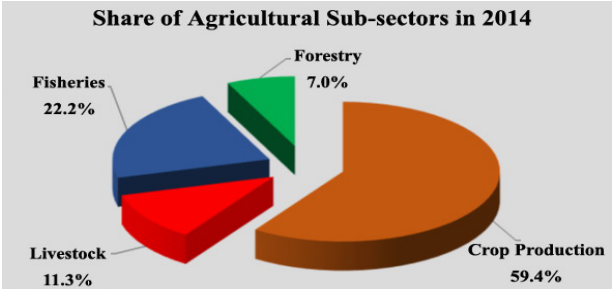

Figure 2: Share of Agricultural Sub-Sectors in 2014 in Cambodia
Source: MOP, 2014

Labor force in Cambodian economy is categorized into three important sectors, namely agriculture, industry, and services (Figure 3). Agriculture saw a significant reduction in labor force in the last five years due to demand resulted from growth in the other two sectors. The share of labor employed in agriculture decreased about 9% from 57.6% in 2009 to 48.7% in 2013, whereas industry and services saw their share increased 4% and 5% respectively during the same period. One reason is increasing migration of rural people to urban centers to work in industry and service sectors.

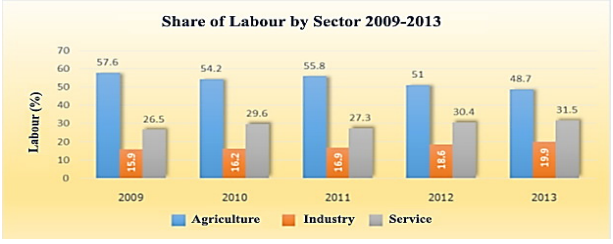

Figure 3: Share of Labor by Sector 2009-2013 in Cambodia
Source: MOP, 2014

Improvement of the agricultural sector is paramount in poverty reduction. Commercializing smallholder agriculture and accelerating its growth rate is essential in increasing agricultural production as a means of pulling the majority of the rural poor out of poverty. Given the generally abundant land resource, efforts to increase agricultural production should include both technologies to expand utilized land area and intensification of the existing cultivated area. This may be achieved through mechanization and adoption of other improved technologies such as improved seed, use of fertilizers, agro-processing and accessibility to markets.

1.1 Agricultural Farms in Cambodia

According to the census of agriculture in Cambodia 2013 (Figure 4), the average agricultural land operated per farm household was around 1.6 hectares (Average area per parcel 0.6 ha). Farm households with total holdings size less than 1 ha and between 1 ha to 3.99 ha account for 47% and 45% respectively.

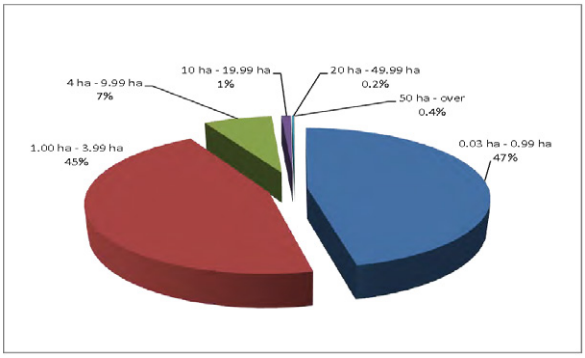

Figure 4: Percentage of Agricultural Holdings with Separate Lands by Size of Holding in Cambodia
Source: CAC 2013

The average land area of agricultural holding by province is presented in Figure 5. The average area of separate agricultural lands used by the household holdings in the Tonle Sap Lake Zone and Mountainous and Plateau Zone was higher than the national average. Sixteen provinces have average household agricultural holdings larger than the national average of 1.64 ha. The average size in those provinces ranged from 5.01 ha in Oddar Meanchey and 3.01 ha in Banteay Meanchey to 1.75 ha in Kampong Thom and Tbong Khmum. In the Plateau and Mountainous Zone, all provinces (Except Kampong Speu) had an average land size of more than 2 ha. Provinces with the average size below the national average included Kampong Speu (0.96 ha), Kep (0.91 ha), Takeo (0.91 ha) and Kandal (0.83 ha).

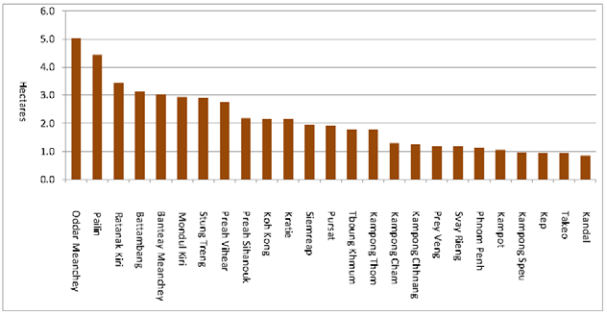

Figure 5: Average Land Area of Agricultural Holding by Province in Cambodia
Source: CAC 2013

Cambodia is characterized by a diversity of farming systems which can be classified in seven major groups: four rice-based farming systems, two "chamcar" crops-based farming systems, and a more limited industrial production system (GRET, IRAM et al. 2000). These systems differ in their potential for intensification, diversification, and commercialization. However, low productivity terraced rain-fed rice farming systems are undertaken by around 70% of the rural population, representing 80% of the rice cropping area and 70% of paddy production; which explains the low performance observed at the aggregated level.

The four major types of rice farming system include (GRET, IRAM et al. 2000):

1. The one found in non-irrigated terrace zones, characterized by poorly productive and rainfall-dependent seasonal rice cropping, is frequently associated with sugar palm. This system is the most common among Cambodian farmer. Recent changes include the introduction of double cropping.
2. Flood recession zones where water control allows intensive rice cropping. With good water and soil fertility control, evolution can be rapid towards either specialization in intensive rice farming–with land concentration and development of a salaried workforce -, or towards the diversification of production.
3. Floating rice, in large flooded fields, where the extensive nature of farming practices allows good labor productivity but in which hydraulic risks are higher. These systems are regressing and evolving either into flood recession rice or into irrigated double cropping.
4. Upland rice-based systems, involving slash-and-burn land preparation, mainly located in less densely populated areas of North-Eastern provinces. These systems are less rice based, with increased population inflows and the development of cash crops by migrants.

"Chamcar" cropping refers to widely diversified farming systems in which rice cropping is most often found but where "dry" cropping is prevalent. They can be grouped in (GRET, IRAM et al. 2000):

1. Riverbank farming systems, dominated by diversified cropping systems following the annual flooding cycle, with high development potential. Land prices are high and land concentration induces the emergence of larger farms with mechanization and use of a smaller workforce.
2. Red and black soils upland farming systems, where rubber farming is concentrated, and other cash crops are developing fast. The future of these systems depends on the restructuring of the rubber industry and to the development of annual crops, notably maize, soybeans, and other tree crops such as cashew nuts or bananas.

The last system is the modern, capital intensive one found mostly near cities, whether in riverbank zones (around Phnom Penh) or in combination of riverbanks and terraces (Battambang, Siem Reap), intensive market garden cropping, and industrial chicken farming, orchards, etc. The evolution of this system depends on the expansion of urban markets, labor costs, and development of alternative uses for capital in other economic sectors, as well as the evolution of external markets for the main export commodities (oil palm, soybean, cashew nut, etc.) (GRET, IRAM et al. 2000).

In addition to the seven major types of farming systems, agrarian structure in Cambodia can be classified into agroecological zones and micro-zones as follows.

There are four agro-ecological or ecosystem zones in Cambodia: Northeast, Mekong, Coastal and the Tonle Sap (Figure 6).

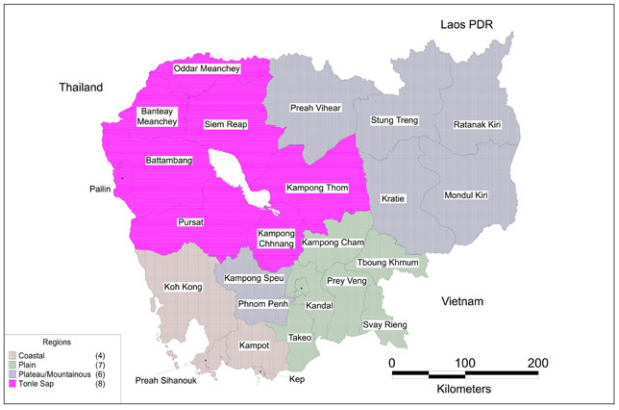

Figure 6: Ecosystem Zones in Cambodia

Eight provinces constitute the Tonle Sap Lake Zone: Banteay Meanchey, Battambang, Pailin, Siem Reap, Oddar Meanchey, Kampong Thom, Kampong Chhnang, and Pursat. Geographically hilly with mountains and plateaus, Pailin and Oddar Meanchey have no villages within the lake area. However, for historical and administrative reasons, these two provinces are still considered within the Tonle Sap Lake Zone, as both were once part of Battambang and Siem Reap. Around 30% of the population in Siem Reap, Battambang, Pursat, and Kampong Chhnang are situated around the lake.

Seven provinces constitute the Plains Zone: Kampong Cham, Kandal, Phnom Penh, Prey Veng, Svay Rieng, Takeo, and Tbong Khmum.

Six provinces constitute the Plateau and Mountainous Zone: Kampong Speu, Preah Vihear, Ratanak Kiri, Mondul Kiri, Kratie, and Stung Treng. Ninety percent of villages in Preah Vihear, Pailin, and Mondul Kiri, and between 60% and 80% of the population in Oddar Meanchey and Stung Treng are situated in hilly, mountainous and plateau areas.

Four provinces constitute the Coastal Zone: Kampot, Koh Kong, Preah Sihanouk, and Kep. Within the four provinces, Kep has the largest percentage of villages (44%) located on coastal waters followed by Koh Kong (39% of villages) and Preah Sihanouk (21% in villages). Kampot has the lowest percentages of villages on coastal waters.

There are four micro zones in Cambodia which are defined as:

1. Zone A: fully irrigated zone in dry season,
2. Zone B: rainfed,
3. Zone C: zone with supplemental irrigation in the wet season, and
4. Zone D: chamcar.

Rice-based farming systems include not only rice, but also other crops (e.g. vegetables, maize, soybeans), animal production (aquaculture and livestock), and potentially a wider range of horticultural products (fruits, spices, mushroom, flower, herbs, and medicinal plants). The key to unlock the values in rice-based farming system is to increase productivity and diversify into higher value activities, both at farm level and particularly in the postproduction stages of the value chain (processing, marketing, postharvest operations). In order to increase income of smallholder households, agriculture will need to intensify and lower the cost of production, diversify towards higher value products, and ensure that farmers and enterprises are competitive and well-integrated with rapidly growing urban and international markets. However, there exist numerous constraints that would pose difficulties to the process of intensification, diversification, and market integration of technology, marketing, water, and capital.

1.2 Agricultural Mechanization in Cambodia

Agricultural Mechanization in Cambodia deals with the design of farm machinery, the location of farm structure, farm drainage, soil management and erosion control, water supply and irrigation, biotechnology and with the efficient planting, harvesting, storage, and processing of farm commodities.

This sector has been growing since the 1990s, especially in land preparation, irrigation, threshing, and harvesting.

The increasing rate of tractors during the last 10 years was about 13% (4,247 units in 2006 and 11,960 units in 2015). The provinces around Tonle Sap Lake and dry season rice areas in the south have a higher growth rate. The number of power tiller significantly increased at the rate of about 27% during the last 10 years (29,706 units in 2006 and 228,659 units in 2015). The most significant increase in number was rice combine harvest which was only introduced in 2006. Its growth rate was about 48% from 325 units in 2006 to 5,519 units in 2015. (Table 1)

Similarly, the increased rate of threshers in the same period was about 11%. Water pumps were also widely used in irrigated areas around Tonle Sap Lake and dry season rice in the south (12% increase). The increasing rate of rice milling machines was the least at only about 4%.

Table 1: Statistic of Agricultural Machineries in Cambodia 2006-2015

No.	Description	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	Combine harvester	325	395	430	836	947	1,548	4,820	4,580	5,503	5,519
2	Rice threshers and pedal threshers	7,795	8,036	8,237	13,798	14,390	15,210	16,146	17,542	17,532	18,210
3	Rice milling	38,618	38,680	39,429	47,620	48,217	48,753	54,328	55,270	54,062	54,052
4	Tractor	4,247	4,475	4,611	5,495	6,200	6,786	8,961	9,467	11,940	11,960
5	Powertillers	29,706	34,639	38,912	53,220	66,548	77,421	128,806	151,701	228,456	228,659
6	Water pumps	127,610	131,702	136,061	164,974	166,633	183,502	231,942	255,954	326,832	327,010

Source: Department of Agricultural Engineering 2015

Currently, farm operations, which were done manually or by draft animal, have been replaced by machines mainly in land preparation, spraying, weeding, harvesting, threshing, and milling. However, in some regions, animals are still used for land preparation and transportation, especially in those regions where farm infrastructures are not well developed, and farm size is small (less than 0.5 ha per household) which is not suitable for the use of machines and difficult to access by road because they are located far from main roads. In the northwestern provinces and the provinces located around Tonle Sap lake such as Battambang, Banteay Meanchey, Pursat, Kampong Chhnang and Kampong Thom where farm size is bigger (1 to 5 ha per household), mechanization is much required to replace animals.

Other farm operations such as transplanting, fertilizing, etc. are still done manually because they are complicated to be mechanized and because of their availability in local market and prices are still issues. Recently, government agencies have introduced direct seeding machines in order to improve the efficiency of sowing. Rice transplanter has also been introduced recently. However, its adoption is still not clear since majority of rice fields are rainfed. They are difficult to manage water and the land is not leveled.

Power tillers are used throughout the country by farmers with small land holding size. Large tractors are preferred by owners of rubber, cassava and sugar cane plantations, and other concessional lands granted by the government.

The northwestern region (Pailin, Battambang, Banteay Meanchey) is characterized by large land size per household. There, large tractors and combine harvesters are used.

In northwestern region as well as upland region, large tractors with power more than 50 HP are preferred, of which the majority are MTZ tractors from Belarus; Kubota and Yanmar assembled in Thailand; Mahindra and John Deere from India; and Foton from China. Power tillers are imported from Thailand, China, or Japanese brand assembled in Thailand. Their powers range from 12 to 15 HP.

In provinces around Tonle Sap Lake, low-lift engine pump is used to irrigate rice fields. Power tiller is used to drive this pump. In southern provinces such as Takeo, Kandal and Prey Veng, where groundwater is sufficient for irrigation in dry season, the centrifugal pump is used.

Due to labor shortage in rural areas and production intensification, harvesting is commonly performed by combine harvesters. Combine harvesters (small and medium) are accessible mostly through service providers, since their prices are comparatively expensive, and the harvesting season is short. To maximize the use of the machine, some service providers move their harvesters around to other areas where harvesting is required for both rainy and wet season rice.

1.3 Challenges of Agricultural Mechanization

In order to promote agricultural mechanization in Cambodia, there are several major obstacles to be considered:

1. Structure of the provincial office of agricultural engineering is still weak;
2. Inadequate skilled workforce at both national and provincial level;
3. Credit scheme for buying farming machines and equipment does not exist;
4. Most of the workshops for repairing and maintenance of farm ing machines and equipment are not available in the rural areas;
5. Annual budget allocated for the implementation of agricultural engineering activities fails the nationwide coverage;
6. Fewer activities on research and development for agricultural engineering and technology and it exists mainly at the national level;
7. Inadequate legislation framework on water resources management and utilization;
8. Institutional capacity building on water resources management and utilization remain limited at both national and provincial level;
9. Some of the irrigation schemes are not well functioning from the main reservoir to the agricultural farms;
10. Water resource management and utilization is not undertaken in an integrated manner;
11. Limited water access from the canal to the agricultural field;
12. External support and cooperation with development partners is still missing; and
13. Gap in cooperation with private sector dealing with agricultural engineering and technology.

II. Agricultural Mechanization Strategy in Cambodia

The strategy targets mechanized production of crops, vegetables, fruits, livestock, forestry, fisheries, and rubber. However, the current focus includes but not limited to mechanized production of rice, maize, cassava, vegetables, and fruits.

It is envisioned that, by 2020, at least mechanization level about 67.78% of rice field operations from land preparation up to milling will be reached in Cambodia.

In order to support the Agricultural Mechanization Strategy in Cambodia to be implemented smoothly and successfully at national wide the four key drivers will serve in promoting agricultural mechanization from 2016 to 2020 as below:

1. Enabling profitability of agricultural engineering - Given the diversity in terrain types of Cambodia, the appropriate choice of mechanized inputs in farm operations have a significant effect on agricultural production and productivity, the profitability of farming, and on the environment. Ultimately, the farmer and other end users should make a decision on usage and the levels of mechanization options.
2. Skill development and capacity strengthening - Increasing the capacity and skill levels of human resources should be a major priority in promoting agricultural mechanization in Cambodia. Skills are needed along the entire supply and value chains – artisans, operators, and farmers, other end-users, service providers (mechanics, engineers), suppliers and extension agents.
3. Improving agricultural productivity and rural livelihoods - Increased productivity leads to commercialized agriculture. The commercialization, in many diverse circumstances, led both to an increase in household income and to changes in the way household resources are organized to earn that income (J. V. Braun & E. Kennedy, 1994). Specialization and the development of markets and trade that characterize commercialization are fundamental to economic growth. One of the most important factors for maximizing the potential benefits from agricultural commercialization and for minimizing damage is to promote technological change in subsistence food crops along with commercial crop production for household food security. However, commercialization of agriculture will be a gradual process. It will require increased levels of public and, in particular, private investment at all levels of agricultural activities, including primary production, marketing, input supply and processing.
4. Improving policy, legal and regulatory environment - It will serve as the four key drivers in promoting agricultural engineering in Cambodia and it is critical for the promotion of agricultural mechanization in the country. All the different policy viz. agricultural, industrial, labor, energy, export/import etc. are needed to be streamlined for promotion of agricultural mechanization. Policy support is also needed for following areas for promotion of agricultural mechanization in Cambodia. At present, Cambodia has no institution to undertake machinery testing, quality control and standardization. The proposed testing institution, Center for Testing of Agricultural Machinery (CTAM), could be established under the Department of Agricultural Engineering. There is also a need for legal measures for standardizations and certification.

The main four pillars of the strategic objectives of agricultural engineering development for Cambodia are as shown in Figure 7.

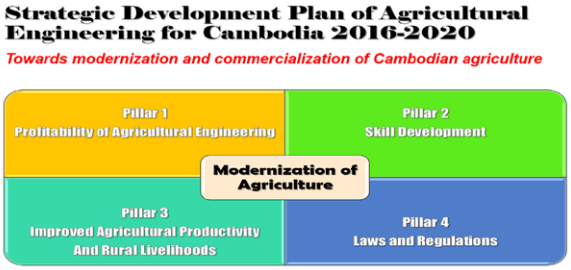

Figure 7: Strategic Objectives of Agricultural Engineering Development for Cambodia

III. Lesson Learnt and Good Practices

Based on actual practices and experiences that have been implemented with relevant stakeholders, especially with farmers, the following are some of the key points to be taken into consideration:

- Raising farmers' incomes allow greater saving and the demand for agricultural mechanization services;
- Climate change and migration of rural young people. This has led to a shortage of manual labor, particularly at peak times, which has caused rural wages to increase;
- Labor shortages have increased the demand for agricultural mechanization custom hire services to complement hired labor, especially at peak times of land preparation and harvesting;
- Introduce of agricultural land consolidation in order to improve the effectiveness of utilization of agricultural machines;
- Close collaboration between the public and private sectors on agricultural mechanization. It is a joint responsibility of public and private organizations in agricultural mechanization activity and provides benefits on managing and disseminating knowledge and experience of agricultural mechanization to the end users;
- Involvements in the CSAM initiatives, as well as ANTAM, are useful and are beneficial for Cambodia to develop and improve its agricultural mechanization for efficient use of agricultural machinery. Promotion of green agricultural technology in

Cambodia. Strengthen good cooperation among CSAM members in Asia and the pacific.

IV. Conclusion and Suggestions

Agricultural mechanization in Cambodia played an important role to ensure food security, poverty reduction, and economic development through promoting agricultural intensification and diversification, ensuring the sustainable natural resources management and conservation, and adapting to climate change. In order to achieve this strategic development plan, the Department of Agricultural Engineering anticipates support and assistance from the government and development partners in terms of funding and technical assistance to improve agricultural mechanization research and development and to strengthen the human resource development.

The strategic development plan for agricultural engineering for Cambodia will be greatly useful in an implementation direction and become more credible and transparent for development partners to contribute the resources in the priority activities for agricultural engineering development as well as Cambodia's economic growth.

In order to strengthen good cooperation on agricultural mechanization and development amongst countries in Asia and Pacific, there are some suggestions should be considered as below:

- Strengthen and support the existing policy and strategy on agricultural mechanization to increase agricultural productivity, ensure food security and improve living condition of farmers;
- Improve on farm and water management infrastructure to meet the climate change.
- Introduce appropriate technologies that can be applied and scaled up;
- Support and encourage local manufacturers to produce farm machinery and equipment with reasonable price, safety, quality and suitable for local geographical conditions;
- Provide capacity building to relevant stakeholders to improve their knowledge and skills in agricultural engineering technology and management;
- Enhance research and development of new agricultural engineering technology which are needed at the present or in the future for different geographical conditions;
- Promote environmentally friendly agricultural engineering practices for agricultural production and water conservation that will result in sustainable economic growth; and
- Improvement of collaboration both inside and outside the region as well as building good relationships between public institutions, private sector, development partners, farmers and other stakeholders to enhance efficient management of agricultural mechanization.

China

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I. Development Status of Agricultural Mechanization in China

Agricultural machinery is an important technical basis for agricultural production. In recent years, the Chinese government has put heavy emphasis on the development for agricultural mechanization through a wide range of legislations, including the Agricultural Mechanization Promotion Law, the Agricultural Machinery Safety Supervision and Management Provisions Law, and the Law to Promote Sound and Rapid Development of Agricultural Mechanization and Agricultural Machinery Industry. In addition, the development of agricultural machinery is regarded as the key areas of the "Made in China 2025" campaign. A series of policies and measures to support the development of agricultural mechanization were introduced, which aroused the enthusiasm of farmers to purchase and use machines and promoted the sustained and rapid development of Agricultural Mechanization in China and became the highlight of the development of China's agricultural modernization.

In recent years, owing to the promotion of various policies and active demand of agricultural machine, the amount of agricultural machinery and equipment has increased rapidly. The level of agricultural mechanization has seen major progress. This plays an important role in the steady improvement of agricultural production capacity, acceleration of the integration of various industries in rural areas, and the continuous growth of farmers' income.

Agricultural mechanization in China has undergone rapid development in recent years. It can be reflected by different aspects of development. Firstly, the total amount of agricultural machinery equipment has reached a new level. By the end of 2016, the total power of agricultural machinery reached 0.97 billion kilowatts, 20% higher than in 2012, and it is predicted to exceed 1 billion kilowatts this year. With positive progress of technological innovation, the number of high-horsepower, high-efficiency, high-performance and multifunctional machines holdings have increased sharply. China has become the biggest agricultural machinery-manufacturing country, whose products sell all over the world. Secondly, the operation level of agricultural machinery has stridden forward. In 2016, the comprehensive mechanization rate of crop cultivation reached 65.2%, 8 percentage points higher than that in 2012, and it is expected to increase by more than 1 percentage points this year. Wheat production has basically achieved whole process mechanization, mechanization rate of rice and corn production is more than 80%, the level of mechanization on sugarcane, cotton, and rape has made a breakthrough, the power resource of agricultural production in China has transformed from

animal to machine. Last but not least, socialized serviceability of agricultural machinery has improved. The emerging agricultural machinery service organizations represented by agricultural machinery cooperatives spring up. In 2016, the total number of agricultural machinery households and service organizations in China reached 42 million. Trans-regional operation, planting by substitutes, complete trusteeship and other agricultural service models constantly innovate, the range of agricultural machinery services continue to expand, promoting the abutment of small farmers and large-scale mechanization production, improving various forms of moderate-scale management of agriculture. In 2016, the income of China's agricultural mechanization service reached 540 billion RMB, an increase of 12.7% compared to 2012. Agricultural mechanization service has become a new type of agricultural production service industry and an important channel to increase farmers' income.

II. Development situation of Agricultural Mechanization in China

At present, China has entered a critical period of accelerating the transition from traditional agriculture to modern agriculture. The internal and external environment for the development of agricultural mechanization is undergoing a profound historical evolution. The market demand for mechanization has become increasingly apparent.

First, the usefulness of mechanization has become more and more noticeable in accelerating agricultural modernization. Modern agricultural equipment is much more than just a production tool that replace artificial labor and reduces labor intensity. The level of mechanization has an increasingly direct influence on the costs of agricultural production, farmers' willingness to plant, the standardization of advanced agricultural technology, the reform in the way of agricultural production and management, reduction of agricultural inputs and waste recycling.

Second, the transfer of rural population to non-agricultural industries and urban areas is obvious. The development of diversified moderate-scale management has been accelerated. What's more, promoting the new-typed industrialization and urbanization, making agricultural production become standardized, large-scale, specialized, organized and socialized, cracking the dilemma that the oppression of high costs and low prices, growing more urgent in demand for agricultural mechanization.

Third, the environment for the development of agricultural mechanization is increasingly favorable. The Outline of the Thirteenth Five-Year Plan for National Economic and Social Development explicitly called for accelerating agricultural mechanization, agricultural equipment technology research and raising the level of agricultural intelligence and precision. Technology and product innovation of agricultural machinery industry become more and more active and the demand for new equipment will be expected to be met to a greater extent since "Made in China 2025" has been launched. Agricultural informatization has become a revolutionary force to promote the transformation in development mode of agricultural mechanization.

Compared with the new demands for the development of modern agriculture, the development of China's agricultural mechanization is still unbalanced and inadequate. The unbalanced development mainly shows as "Three High and Three Low". For crop, the comprehensive mechanization level of the three staples (wheat, rice and maize) is relatively high while the counterpart of economic crops such as cotton, oil and sugar is low. For region, the mechanization level in the northern drylands and plains is high while the southern paddy fields and hilly areas relatively low. For industry, there is the higher level of mechanization in planting and lower level of mechanization in animal husbandry, fishery, preliminary working of agricultural products, fruit-vegetable-tea industry and facilities farming. The inadequate development mainly shows as "Three More and Three Less". Low-powered and backward machines are more than high-powered and high-quality equipment. The machines that apply to only one operation are more than precision multiple machines. Besides, there is a considerable population of small-scale scattered farmers who use their machines only for themselves rather than large-scale specialized and integrated agricultural service organizations.

III. Development Goals and Strategic Priorities of Agricultural Mechanization in China

Last year, China's Ministry of Agriculture issued the 13th Five-year Plan for the Development of Agricultural Mechanization. The plan sets out the following development goals: by 2020, the production of main crop will be fully mechanized; the remarkable progress will be made in the comprehensive mechanization of farming; breeding and processing; the new pattern of the development for the agricultural mechanization in regional coordination will be basically formed; and the provinces with qualifying conditions will take the lead in basically realizing agricultural mechanization. Among them, the comprehensive mechanization rate of tillage,

planting, and harvesting will reach 70%. The main grain crop will basically achieve the full mechanization for the whole process of the production. There will be a clear breakthrough in the full mechanization of the production of economic crops. The social service capacity of agricultural machinery will be significantly enhanced and will build 500 demonstrated counties which are completely mechanized.

In addition, by 2025, we hope that the comprehensive mechanization rate of the tillage, planting, and harvesting will reach 75%, the production of main crop will reach comprehensive mechanization basically in dominant growing areas, and the comprehensive agricultural mechanization will make significant progress.

To adapt to the new situation and grasp the new requirements, we will aim at better meeting the new needs of the majority of farmers in mechanized production, accelerate the transformation and upgrading of agricultural mechanization and provide strong support to push agricultural supply-side structural reform and implement the strategy of rural revitalization. We will focus on the following seven plans.

Driving technological innovation of agricultural mechanization: The government will carry this policy out by providing guidance for technological innovation of agricultural mechanization by publishing science and technology program, bringing out the list of requirements, putting forward project suggestions, establishing research bases, establishing and funding some pilots for the use of emerging agricultural machines, and building technology innovation alliance, etc.

Developing the whlole-process mechanization of main crops: Specifically, the government plans to begin pilot schemes in 500 demonstration counties for whole-process mechanization. In these counties, the government will provide sufficient subsidies for purchasing machines used for key link in whole-process mechanization, enhance investment in demonstrated projects, strengthen the performance review, and encourage the qualified areas to develop whole process mechanization in the whole village, county, and province.

Developing agricultural mechanization in hilly area: The government intends to focus on improving the application conditions of agricultural machinery, strengthen machine supply and activate service mechanism, create supporting policies, and strive for comprehensive support of investment in basic construction of farmland at all levels, scientific and technological projects and financial funds.

Improving ability to the extension of agricultural mechanization technology: The key point is to promote extension agency commonweal, extension subject diversification, extension emphasis in each process, extension domain comprehensive, extension technology integration, extension service diversification, and transform extension methods, strengthen support system, optimize service supply.

Building up the new agricultural machinery operation and the service: The key is to establish a batch of new business entities which integrate agricultural production and service, and to train practical talents in large-scale such as the directors for agricultural machinery cooperative, agricultural machinery drivers and maintenance workers.

Guaranteeing operation conditions of agricultural machinery: The focus is on guiding local governments to actively participate in the implementation of major national construction planning, improving operating conditions of agricultural machinery, and promoting public management and serviceability of agricultural mechanization.

Promoting information integration of agricultural mechanization: The key aims are to promote the digitalization of agricultural mechanization, support and guide the application of information technology, and to build educational platforms to deepen this development.

In conclusion, it should be emphasized that:

- Agricultural mechanization in China continues to maintain a rapid development;
- The imbalance and inadequate in development of agricultural mechanization is still prominent;
- Implementation of the “Seven Plans” is crucial to the realization of Agricultural Mechanization Development Goals 2020.

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I. Agricultural Mechanization Country Profile

Indian agriculture employs about 55% of the total workforce and contributes to only 14% in the GDP of our country, which makes farming in India less remunerative. The average farm size in India is small (1.15 ha) and small and marginal land holdings (less than 2.0 ha) account for 85% of land holdings. Mechanizing small and non-contiguous groups of small farms is against 'economies of scale' for individual ownership of farm machinery. The labor availability in agriculture is expected to go down to 41% of the total workforce in 2020. With no possibility of increase in net cultivated area and diminishing farm labor availability, intensive agriculture with higher input use efficiency is essential for the growth of Indian agriculture in the near future.

Presently, the farming machines in India are being used primarily for production of food crops like cereals, pulses, and oilseeds. The mechanization of Indian agriculture has increased considerably and reached an overall mechanization level of 40-45% during the recent past. A large number of manual, animal drawn, self-propelled, power tiller and tractor operated equipment and machinery have been developed and are commercially available for carrying out different farm operations in major crops. Sugarcane is one crop in which there has been little mechanization in India, all farm operations from planting to harvesting being labour dependent and cost of cultivation is high.

1.1 Farm Power Availability

Farm mechanization in India is still in its early stages during the last two decades. It was only able to achieve a meagre growth rate of less than 5%. Agricultural workers, draught animals, tractors, power tillers, diesel engines, electric motors are used as sources of farm power in Indian agriculture. The total power availability on Indian farms has increased from 0.293 to 2.02 kW/ha during the last 42 years. The combined share of agricultural workers and draught animals in total farm power availability in India reduced from 60.8% in 1971-72 to 10.1% in 2012-13. On the other hand, the share of tractor and electric motor in farm power availability increased from 6.8 to 45.8% and 14.0 to 26.8%, respectively during the last 41 years. The predicted values of farm power availability and productivity in India for the year 2020 are 2.2 kW/ha and 2.3 t/ha respectively.

1. Tractor

Tractors play an important role in the mechanization of Indian agriculture. The domestic tractor sale increased at a Compound

Annual Growth Rate (CAGR) of 9.39% during the last 54 years and reached a level of 493,764 units in 2015-16. The trend of increasing sale of tractors over the years indicates a growing acceptance of tractor operated agricultural machines and equipment with the farmers. The current trend in sale of tractors indicated the highest share of 43% for 31-37 kW category tractors and followed by 36% share for 23-30 kW tractors. The requirement of high power category tractors in India increased for using high capacity farm machines on custom hiring basis. The Haryana state of India has the highest tractor density of 96 tractors per thousand hectares of net sown area and followed by 79 for Punjab. It was observed that rainfall pattern, land holding size and government policies affected the sale of tractors in India.

2. Power Tiller

The current market for power tillers in India is estimated at 50,000 numbers during 2016-17. The market for power tillers in India is mainly concentrated in the eastern and southern parts of the country owing to the small land holdings per farmer in these regions and high cultivation of rice crops. Overall power tiller density is 2.21 per thousand hectares of net sown area. The power tillers market in India is dominated by two players from south India viz. VST Tillers Tractors Ltd., Bengaluru (Karnataka) and Kerala Agro Machinery Corporation Ltd. (KAMCO), Athani (Kerala).

3. Combine Harvesters

The combine harvesters market in India is estimated at 4,000-5,000 units annually by sales which have grown at a CAGR of 28% since 2006. The tractor mounted and self-propelled combines occupy around 60% and 40 % of the total combine harvesters market in India respectively. Tractor on top combines is mainly concentrated in southern states viz. Tamil Nadu, Kerala, Andhra Pradesh and Karnataka of the country on custom hiring. Punjab, Haryana and Tamil Nadu states have a strong presence in the combine harvester market in India.

The overall mechanization level in India is only 40-45% even though 90% of total farm power is contributed by the mechanical and electrical power sources. However, all operations are not uniformly mechanized. Operation-wise mechanization levels are 42% for soil working and seedbed preparation, 29% for seeding and planting, 34% for plant protection and 37% for irrigation. In the case of harvesting and threshing, the level of mechanization is 60-70% for wheat and rice and less than 5% for other crops. The operation-wise mechanization for harvesting, crop care and seeding are the top priority for the farmers in India for cereal and horticultural crops, but mechanization of the above operation is not up to the level of farmer's expectation till date. Farmers need complete mechanization package for major crops.

II. National Agricultural Machinery Strategy/Long-Term Plan

The level of mechanization in India is still lower than United State (95%), Western Europe (95%), Russia (80%), Brazil (75%) and China (57%). The average farm power availability in the country is still at a low level as compared to other developing countries like China, Korea and Japan. Unlike other agricultural sectors, farm mechanization sector in India has a far more complex structural composition. It is facing various challenges related to farm machinery and equipment, technology, markets, operations, legislation, policy framework and other related areas. Land size, cropping pattern, market price of crops including Minimum Support Price (MSP), availability of labour and cost of labour are the major factors deciding the agricultural mechanization.

The approach of the Government of India for research and development of farm equipment and machinery and their testing, quality control and popularisation among the stakeholders is given below.

2.1 Research and Development

Research and development efforts and approaches in agricultural mechanization in India have been directed towards finding cost-effective solutions to location-specific problems of agriculture. Indian Council of Agricultural Research (ICAR), New Delhi is the apex body which primarily looks after the need for research and development activities, need-based region, specific technologies and specific-problem related issues. The engineering division of ICAR comprises of five research institutes, six All India Coordinated Research Projects (AICRPs) and two network projects. Four Coordinating Cells of AICRPs with their centres are operating from the ICAR-Central Institute of Agricultural Engineering, Bhopal, which caters to the engineering needs emphasizing on sustainable agricultural mechanization of the country. These are 1) Farm Implements and Machinery (25 centres), 2) Ergonomics and Safety in Agriculture (11 centres), 3) Renewable Energy Sources (16 centres) and 4) Utilization of Animal Energy (9 centres).

2.2 Public-Private Iinkage

The private sector involvement in Indian agriculture is a recent development. Future breakthrough technologies in agriculture mechanization will come increasingly from the private sector, and India's private sector has the strength to multiply those technologies and to reach millions of farmers (small and big) in the fastest possible way. There is a need to organize these sources in an orderly manner, so that in the process, apart from the private sector profitability, the farming community is also benefited. This will help to bring Indian agriculture to a higher and more sustainable growth and be the most powerful engine for poverty reduction. For areas and realms, the private sector has not shown much interest, such as rainfed areas, tribal areas, natural resource management, pulses, millets, the role of public research would continue to be critical. In addition, much equipment are being developed in public-private partnership mode by involving manufacturer at the research and development stage.

2.3 Extension

Extension activities are mainly carried out by Krishi Vigyan Kendras (KVK) and centres of AICRPs. Today, India has more than 660 KVKs under eight zones. These KVKs locate in different parts of the country, to promote region-specific, farmer-friendly newer technologies for enhancing agricultural production through minimum use of inputs.

2.4 Testing and Quality Control

The adoption of agricultural machinery is greatly influenced by testing/standardization, quality control and after sales services available to the farmers. Since most of the farming machines are manufactured in India in small-scale industries, the quality is affected by the manufacturing technology adopted by them. Testing and evaluation enhance the quality production of machines. In addition to the four major farm machinery training and testing institutes located in Madhya Pradesh, Haryana, Andhra Pradesh and Assam states, recently 30 new centres including State Agricultural Universities and Institutes under Indian Council of Agricultural Research have been approved by the government of India to conduct quality certification evaluation for manufacturers.

Research and development institutions and quality certification agencies conduct the Testing and Evaluation (T&E). Testing and evaluation is conducted on newly developed equipment during its serial production, to facilitate and ensure quality, reliability, durability, functional ease, comfort in operation and reduced cost of operation. Testing is conducted with well-defined standard parameters, defined in the Bureau of Indian Standards (BIS), ISO, or OECD standards, and whereas evaluation is done to measure the performance under simulated or field conditions for the parameters for which the equipment has been designed. Standardization and quality of implement manufacturing in India is ensured mainly by BIS, and over 500 standards on agricultural machinery are prescribed.

2.5 Training (vocational academic, short term focused training on specific topics)

Vocational training, academic training, short-term focused training on specific topics and need-based private-industry oriented training are conducted by ICAR institutes and state agricultural universities. At CIAE, Bhopal, Technology Transfer Division conducts periodical and need-based training. Technology developed is also exhibited in various kissan melas and agricultural machinery exhibitions which help in disseminating the newly developed technologies, leading to sustainable agricultural mechanization.

2.6 Financial institutions

The purchasing power of the farmers in India is low. The government provides subsidy and credit at a reduced rate to the farmers who are economically and socially at a disadvantageous position to adopt modern technologies. The long-term credit is usually availed for the purchase of mechanization inputs and short term for the purchase of seed, fertilizer etc. The agricultural machines and tractors are purchased through credit, available from organized financial institutions. National Bank for Agriculture and Rural Development (NABARD) is the main refinancing institution. The government also provides incentives to farmers for modernization of agriculture. This is linked to crop-specific programmes operated by state governments. A large number of nationalized banks, private banks and commercial and cooperative banks provide credit for the purchase of machinery. All nationalized banks have exclusive agricultural banking divisions.

2.7 Sub-Mission on Agricultural Mechanization

In order to lay special emphasis on farm mechanization in India and to bring more inclusiveness, a dedicated Sub-Mission on Agricultural Mechanization (SMAM) for the XII Plan (2012-17) was launched with an estimated outlay of US$ 350 million for the plan period by Machinery & Technology Division (M&T), Department of Agriculture and Cooperation, Ministry

of Agriculture of Government of India. SMAM has put 'Small & Marginal Farmers' at the core of the interventions with a special emphasis on 'reaching the unreached', i.e. bringing farm mechanization to those villages where the technologies deployed are decades old. Besides, the mission also proposes to cater to 'adverse economies of scale' by promoting 'Custom Hiring Services' through 'the rural entrepreneurship' model. The mission aims at catalyzing an accelerated but inclusive growth of agricultural mechanization in India.

The Sub-Mission on Agricultural Mechanization provides financial assistance for promotion and strengthening of agricultural mechanization through training, testing and demonstration, post-harvest technology and management; procurement of selected agriculture machinery and equipment; establishment of farm machinery banks for custom hiring; establishing hi-tech productive equipment centres to target low productive agricultural regions and assistance for increasing farm mechanization. The strategies under the sub-mission are as follows:

1. Conduct performance testing for various farm machinery and equipment at the four Farm Machinery Training and Testing Institutes (FMTTI) and 30 designated State Agricultural Universities (SAUs) and ICAR institutions.
2. Promote farm mechanization among stakeholders by way of on-field and off-field training and demonstrations.
3. Provide financial assistance to farmers for procurement of farm machinery and implements to promote ownership of various agricultural machinery and equipment.
4. Provide suitable financial assistance to establish Farm Machinery Banks for custom hiring for appropriate locations and crops.
5. Provide financial assistance to set up hi-tech and high productive machinery hubs for high-value crops like sugarcane, cotton etc.
6. Provide financial assistance on per hectare basis to the beneficiaries hiring machinery/equipment from custom hiring centres for promotion of mechanized operations in low mechanized areas.
7. Provide financial assistance to small and marginal farmers for hiring machinery and implements in low mechanized regions.
8. Provide financial assistance to promote appropriate technologies and to set up farm machinery banks in identified villages in low mechanised states.
9. Promotion of farm machinery and equipment in northeastern region by extending financial assistance to beneficiaries in high-potential but low mechanised states of north-east.

III. Lessons Learned and Good Practices

Agricultural mechanization should contribute to a sustainable increase in productivity and cropping intensity so that the planned growth rates in agricultural production are achieved. Mechanization is capital intensive and substantial sums have been invested in the country. India adopts a policy of selective mechanization under diverse conditions, which make the agricultural mechanization a challenging task. An appropriate mechanization technology suiting to the needs of the farmers is required to be adopted. This may be achieved by following a few points as mentioned below.

- The widely fragmented and scattered land holdings in many parts of the country need to be consolidated (virtual or real) to give access for their owners to the benefits of agricultural mechanization.
- There is a need to have more interaction among farmers, researchers and development workers, departments of agriculture and industry to make farm machinery research and development base stronger.
- The rice transplanting operation can be mechanized by the introduction of self-propelled walking type rice transplanters on small and medium land holdings. The riding type of rice transplanter may be introduced on large size land holdings on custom hiring basis.
- The benefits of agricultural mechanization should be extended to all categories of farmers with due consideration to small and marginal farmers, to all cropping systems including horticultural crops and all regions of the country especially the rainfed areas.
- There is a need to innovate custom service or a rental model by institutionalization for high-cost farm machinery such as combine harvester, sugarcane harvester, potato combine, paddy transplanter, laser guided land leveller, rotavator etc. and can be adopted by private players or State or Central Organizations in major production hubs.
- The high capacity rice combines may be introduced to paddy growing areas on custom hiring basis. It will help in timely harvesting and better yield of paddy crop.
- Medium and large scale farmers or rural unemployed youth may be provided with government subsidies to encourage them to buy and to apply advanced medium and high size machinery such as cotton picker, rice transplanter, sugarcane harvester and combine harvester on their fields.
- The farm machinery bank may be established for machines being manufactured elsewhere in the country and supply to users/farmers on custom hiring mode.
- Provision may be made for special credit support at lower

interest rates to rural individuals, venturing into entrepreneurial use of farm machinery through custom hiring.

- Manufacturing units that are set-up in areas with lower mechanization needs to be supported by extending tax and duty sops. This would result in easier reach of the equipment to farmers in those areas.
- There is a need for quality manufacturing and after sales support for reliability of farm machinery. This may be achieved by streamlining of the testing procedure, training of engineers and conducting testing of farm equipment for standardisation and quality control in farm equipment manufacturing.
- There is a need for strengthening training programmes at various levels and for different categories of people on operation, repair and maintenance of agricultural machinery, tractors, power tillers, rice transplanters, combines etc. and for transfer of technology.

IV. Suggestions for Regional Cooperation amongst Countries

The suggestions for regional cooperation among countries are:

- There is a need to develop and promote agricultural machinery that is resource and energy efficient.
- There is a need to put more emphasis on the promotion of sustainable agricultural mechanization through public-private partnership in the region.
- The quality, testing and after sales service of farm machinery should be given importance for sustainable agricultural mechanization in the region.
- The comfort, safety and gender issues should be considered in the design of farm machinery.
- The need to optimize the capitalization of agricultural machinery use.

Indonesia

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I. Introduction

The total population of Indonesia is approximately 253 million people in 2016. The population growth rate is by 1.34 % per annum. Rice is the main staple food. Therefore, maintenance of food resilience and national food security is the major concern of the Indonesian government. National rice consumption increases in line with population growth. In 2016 rice consumption accounted 33.84 million tons, while milled rice production was 42.5, 45.3 and 47.5 million tones in 2014, 2015 and 2016 respectively (Indonesia Statistical Bureau, 2017).

According to the data of 1990, about 70% of the total population was farmers. Due to the better job opportunities and higher income in the non-agricultural sphere, which boosted economic development in the country, many farmers shifted to non-agricultural sector. Consequently, the percentage of people involved in agriculture dramatically decreased from 70% to 37 % in 2016, causing farm labour scarcity and more expensiveness.

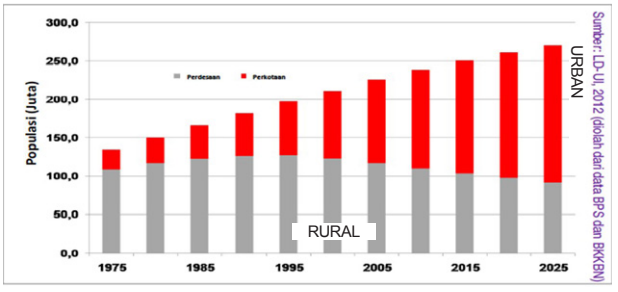


Figure 1: Labor Composition Working in Urban and Rural Areas of Indonesia

The total agricultural area is about 20 million ha, consisted of wetland paddy area, upland agricultural area and garden, while the size of an average land holding is only 0.3 ha per farmer.

Table 1: Area of Agricultural Land in Indonesia

Type Of Agricl Land	Total Areas
1. Wet land rice	8,112,103.00 ha
-Irrigation	4,819,525.00 ha
-Rain-fet	3,292,578.00 ha
2. Upland	11,876,881.00 ha
3. Sub optimal land	11,300,000.00 ha

Source: Indonesia Statistical Bureau, 2015

Although in 1984, Indonesia has achieved self-sufficiency in rice production, operating costs were deemed higher than in other Asian countries because of pricey labour cost and low production efficiency. During the period 2014 - 2019, the Indonesian government has been focusing on increasing rice production while reducing its operating costs to escalate competitiveness. One of the government strategic programs in agriculture is the massive introduction of rice farm machinery to farmers through loans and grants. Since rice is the main indicator of national security and stability, Indonesia's agricultural development has been mainly focused on rice. There are also other programmes aimed at increasing production of maize, soybean, sugarcane, shallot, chilly and cattle beef to achieve sustainment. The targets of national agricultural development 2014-1019 include :

1. Increase in food stock and food diversification;
2. Increase in added value and competitiveness of agricultural products;
3. Reduction in food import while increasing export of agricultural products;
4. Provision of raw materials for bioindustry and bio-energy;
5. Increase in farmer income and welfare.

Maintaining rice surplus and reducing production cost are not easy because of certain issues: 1) high rate of land conversion, 2) massive shift of labor to non-agricultural segment 3) climate change which causes flood and drought that change cropping calendar and boost pest dissemination, 4) demolition of irrigation canal caused by flood and lack of repair and maintenance service, 5) high post-harvest losses, and 6) mismatch between condition of agro-ecosystem, and machines introduced to farmers, which are unfavorable for the development of sustainable agricultural mechanization.

Population growth and industrial development, particularly in most of big cities in Indonesia, require lands. Consequently, the price of land increases dramatically and forces farmers to convert or sell their arable land to other purposes such as housing, infrastructure, industrial land. Agricultural land conversion rate reached 80,000-100,000 ha/annum.

Economic development in industry, business, services and other sectors has created jobs with better wage rate for Indonesian people, including farmers. Consequently, there are shifting job from agriculture to non-agriculture sector. Within the last decade, more than 5% of total agricultural labor has shifted their job to nonagricultural sector (Figure 1).

The impact of climate change increases the occurrence of extreme climate, flood and drought, which usually shift the cropping pattern. Flood has destroyed crops and damaged irrigation and drainage facilities.

Post-harvest losses of rice are considerably high: more than 10% of raw rice is scattered in the field during manual harvesting, and more than 5% is lost due to poor threshing, drying and milling process. These problems threaten sustainable self-sufficiency and the surplus of rice.

II. Strategy to Achieve the Sustainable Rice Production

To achieve the target of agricultural development and maintain the surplus of rice while reducing production costs, the Ministry of Agriculture has set up medium-term strategy as shown in Figure 2.

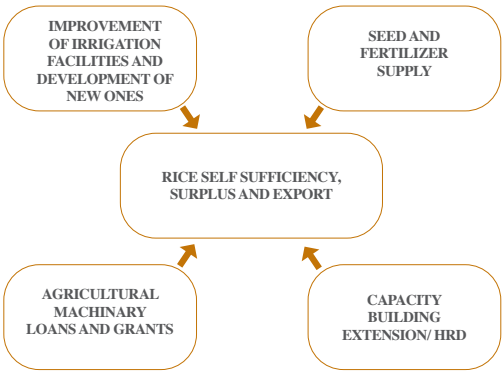


Figure 2: Medium Term Strategy in Indonesia to Achieve Rice Self-Sufficiency and Export

The strategy includes: 1) improvement of the existing irrigation facility and developing new irrigation facilities, 2) guarantee loans of and grants for agricultural machines to the rice farmers groups, 3) intensification of rice production to increase crop index and speed up production process while maintaining rice self-sufficiency and surplus, 4) expansion of new agricultural areas to substitute agricultural land conversion, 5) capacity building for extension workers, managers, operators and technicians of agricultural machines custom hiring units at district and provincial levels, and 6) improvement of existing and creation of new regulation for agricultural mechanization development.

2.1 Development of Sustainable Agricultural Mechanization to Support Rice Production, Self Sufficiency and Export

Partly mechanized intensive rice farming system to increase rice production in Indonesia has been started in 1972 since high

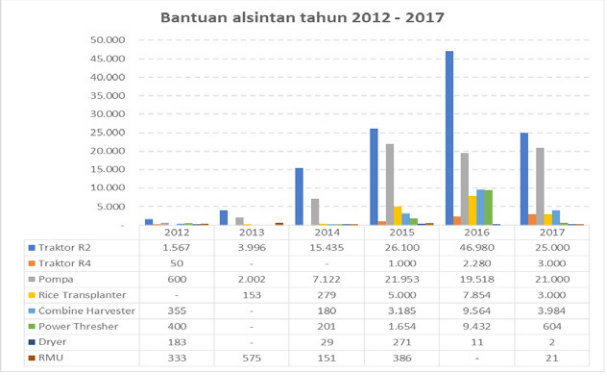
yielding variety was introduced. Agricultural machinery as an input for rice production has helped farmers to increase their capability to cultivate land. In 1984, Indonesia achieved self-sufficiency of rice. During that period, agricultural machinery introduced to farmers was limited to the two-wheel tractor, irrigation pump and power thresher.

The development of agricultural machinery technology and industry for rice in Asian countries gave a good example for Indonesian farmers to modernize rice farming system by using various types of agricultural machinery. Modern fully mechanized rice farming models were launched in 2014. The approaches of modern rice farming system were aimed not only at increasing rice production, but also at improving agribusiness management to escalate farmer income and welfare (Kasryno and Suryana, 1992). This strategy was considered to be a key for the successful development of sustainable agricultural mechanization.

To carry out sustainable agriculture development, problems listed above should be overcame. One of the methods is to apply modern rice farming system by using farm machinery with horizontal, vertical and special approaches for various rice farming business conditions (Simatupang, 2014). This method was considered to have comparative advantage in increasing income of the Indonesian farmer. Several studies on the development of modern rice farming system show that fully mechanized rice farming practices from land preparation up to harvesting has increased rice production by 15-20%, reduced rice operational cost by 20%-30% and reduced land preparation, weeding, harvesting and threshing by more than 60% compared to conventional methods (ICSEP, 2015). This system could help to increase rice production, maintain rice self-sufficiency, reduce operational cost and boost food export (Ministry of Agriculture, 2015).

The massive introduction of agricultural machinery to support modern rice farming system considering environmental, cultural, economic and social aspects has been included into the government program 2014-2019. The government of Indonesia has given loans and grants for agricultural machinery and distributed more than 235,000 units of various types of agricultural machinery for rice production including two-wheel tractors, four-wheel tractors, irrigation pumps, rice transplanters, combine harvesters, dryers and rice milling units (Figure 3).

Ministry of Agriculture has also formulated a strategy and program to increase utilization efficiency of agricultural machinery which has been distributed to farmers. There are some requirements to follow in order to achieve sustainable agricultural mechanization. Agricultural machines must: 1) be able to respond problems faced by farmers in the right manner, 2) have comparative advantage among other technologies, 3) match farming conditions, 4) be environmentally acceptable, 5) give reasonable profit to a stakeholder, 6) have guaranteed post-sale service (training for manager, technician, operator, spare part, repair and maintenance).



	2012	2013	2014	2015	2016	2017
Traktor R2	1.567	3.996	15.435	26.100	46.980	25.000
Traktor R4	50	-	-	1.000	2.280	3.000
Pompa	600	2.002	7.122	21.953	19.518	21.000
Rice Transplanter	-	153	279	5.000	7.854	3.000
Combine Harvester	355	-	180	3.185	9.564	3.984
Power Thresher	400	-	201	1.654	9.432	604
Dryer	183	-	29	271	11	2
RMU	333	575	151	386	-	21

Figure 3: Loans of and Grants for Agricultural Machinery provided Ministry of Agriculture to Famer Group in 2012-2017 in Indonesia
Source: DG PSP, 2017

Modern rice farming system was developed based on a good agricultural practice that includes usage of agricultural machinery for land preparation, planting, fertilizer application, pest control, harvesting and post-harvest activity (Ministry of Agriculture, 2015).

There are some challenges that could be faced while developing sustainable agricultural mechanization, those are: 1) mismatch between agricultural machines introduced to the farmers and agroecosystem, social and economic and cultural conditions of Indonesian farmers in each district; 2) human resources capacity in planning the need of agricultural machines in each district is weak; 3) quality of agricultural machinery marketed in Indonesia varies; 4) inspection and control of agricultural machines at the market are weak.

2.2 Strategy for the Development of Sustainable Agricultural Mechanization in Indonesia

To solve the problem in the development of sustainable mechanization to increase rice production, maintain self-sufficiency, food surplus and export food products, the Ministry of Agriculture has formulated several regulations, strategies, and developed models of modern rice farming system with agricultural mechanization.

More than 7 regulations and 2 guidelines have been formulated and issued since 1971. Those are:

- Government Regulation Number 65, 1971 related to the regulation of industry of rice milling unit, rice husker and polisher. (Purpose: to control the number and specification of RMU to increase recovery, rice quality and efficiency of RMU)
- Indonesia Act Number 12, 1992, concerning Crops Farming System. (Production and distribution of agricultural machinery and tools need to be controlled, monitored and supervised)
- Ministry of Agriculture Regulation Number 65, 2006. (Procedure of controlling on marketing, purchasing and utilization of agricultural machinery in Indonesia).
- Ministry of Agriculture Regulation Number 05/ Permentan/12/2006 (Testing Procedure and Certification of Agricultural Machinery).
- Ministry of agricultural regulation Number 25/ Permentan/ pl.130/5/2008. (Development of Agricultural Machinery Custom Hiring Business).
- Ministry of Manpower Regulation Number No 217, 2016. (Performance Standard for Competency of Indonesian Workers involved in the area of Agricultural Mechanization Development, particular: planner, engineer, manager, operator and technician of agricultural machinery and tools.
- Guideline of DG of Agriculture Infrastructure, 2017. (Guideline for the implementation of procurement, distribution of and grants for Agricultural Machinery)
- Guideline of DG of Agriculture Infrastructure, 2017. (Guideline for Implementation and Management of Agricultural Machinery Brigade).
- Road Map of Agricultural Machinery Technology to Support the development of modern farming by the Indonesian Agency of Agricultural Research and Development, Ministry of Agriculture, 2017.

Strategy for the development of sustainable agricultural mechanization in Indonesia has been formulated based on the strategy of the Ministry of Agriculture focusing on increasing food production and competitiveness, maintaining surplus, stability and export, as shown in Figure 4. This strategy will be implemented gradually to strengthen the capability of the farmer, operator, technician, manager of custom hiring as a user of agricultural machinery, industry of agricultural machinery, researcher and engineer as linker between the user and industry and business including trader, exporter and importer of agricultural machinery.

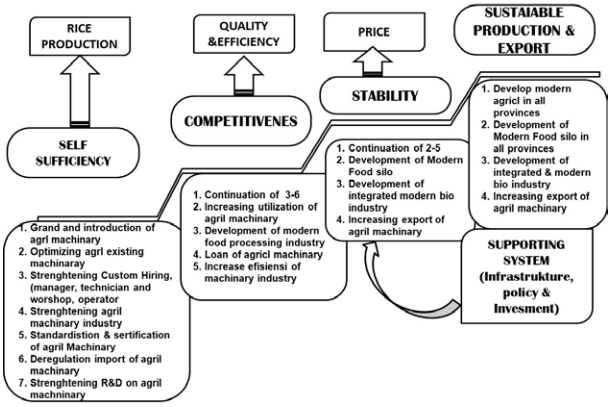


Figure 4: Strategy for Sustainable Agricultural Mechanization Development in Indonesia to Support Self-Sufficiency and Export
Source: Unadi A. and Prabowo, A., 2016

Strategy phase I.

1. Introduction of agricultural machinery, provide grants to farmers and farmer groups;
2. Optimizing existing agricultural machinery through developing various models of sustainable agricultural mechanization;
3. Strengthening the Custom Hiring Business Unit (manager, technician, operator and workshop);
4. Strengthening agricultural machinery industry;
5. Strengthening standard & certification of agricultural machinery;
6. Deregulation imports of agricultural machinery;
7. Strengthening R&D on agricultural machinery.

Strategy phase II

Continuation of 3-6

1. Develop modern farming system with agricultural mechanization in all provinces;
2. Development of modern food processing industry;
3. Loan of agricultural machinery for farmers and farmer groups;
4. Increase efficiency of agricultural machinery industry.

Strategy phase III

Continuation of 2-5

1. Development of modern food silo;
2. Development of integrated modern bioindustry;
3. Increase the export of agricultural machinery.

Strategy phase IV

1. Development of modern food silo in all provinces;
2. Development of integrated and modern bioindustry;
3. Increasing export of agricultural machines.

Model of modern rice farming system using good agricultural practices approach supported by full mechanization has been developed and tested in a several districts to show that agricultural mechanization increases land and labor productivity, reduce post-harvest losses, reduce operational costs. The modern model has been developed in Pontianak, West Kalimantan in 2015, Sukoharjo, Boyollali, Sragen and Klaten district, Central Jawa Province in 2015-2017 and Ngawi district, East Jawa Provinces in 2016 and Indramayu district, West Jawa Provinces in 2017. The area of the modern farming system was 100-200 ha per district. Good agricultural practices include rice planting system - Jajar Legowo method, application of balance fertilizer base on soil fertility map, pest control.

Land preparation was carried out by power tiller and 4-wheel tractor equipped with disk plow, rotary tiller, and leveler. Planting was carried out using walking type of jajar llegowo rice transplanter with dapok (KAPOK?) seedling trays, power weeder for weeding, combine harvester for harvesting and post-harvest machinery including circulated vertical dryer, improved rice milling unit with packaging to produce high recovery and good quality of milled rice and storage has been introduced to farmers and farmer groups. The model of integrated rice business system is a key element for modern rice farming development intended to increase farmer income and welfare. The model has shown that modern rice farming system has increased rice productivity between 1-2 ton/ ha, reduce labor for land preparation, transplanting, weeding and harvesting more than 70 man-days, reduce cost about 30%, reduce scattered losses about 6 %, increase milling recovery by about 4% and increase the quality of milled rice as shown in table 2, 3 and 4.

Table 2: Time-Efficiency from Usage of Machinery Compare to Conventional Method in Jawa and South Sulawesi Provinces in Indonesia

Field Activity	Manual (Man-day)	Fully mechanized (Man-day)	Difference	
			(Man-day)	%
Land preparation	20	3.0	-17.0	-85.0
Seedling and transplanting	19	7.5	-11.5	-60.5
Weeding	15	2.0	-13.0	-86.7
Harvesting	40	7.5	-32.5	-81.3
Total	94	20.0	-74.0	-78.4

Source: ICSEP, 2015

Table 3: Difference between Production Costs while Using Conventional and Fully Mechanized Methods in Several Districts in Jawa and South Sulawesi Provinces in Indonesia

Field Activity	Manual (Rp/ha)	Fully mechanized (Rp/ha)	Difference	
			(Rp/ha)	%
Land preparation	1,600,000	1,200,000	-400,000	-25.0
Seedling and transplanting	1,720,000	1,100,000	-620,000	-36.0
Weeding	1,200,000	510,000	-690,000	-57.5
Harvesting	2,857,125	2,285,700	-571,425	-20.0
Total	737,126	5,095,700	2,281,425	-30.9

Source: Handewi, P.S. et al, 2015

Table 4: Reduction of Losses and Improvement of Recovery and Milling Quality of Milled Rice Using Combine Harvester, Thresher, Combine Harvester and Improved Rice Milling Unit in Indonesia.

Activity	Loses (%)		Quality (%)	
	Existing method	Improved machinery	Existing method	Improved machinery
Rice harvesting	9,4	3		
Threshing	5	2		
Drying: • Milling recovery • Whole grain • Broken grain	-	-	 59 35 65	 62 65 35

III. Conclusion

Policy, regulation, strategy and program of the development sustainable agricultural machinery to rice production and surplus, competitiveness and finally export has been formulated. Various models of modern rice farming system with full mechanization have been developed. The success in implementing the policy, regulation, program will strongly depend on implementation and collaboration between all stakeholders.

Malaysia

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Department of Agriculture Malaysia

I. Agricultural Mechanization Country Profile

Malaysia is in the third phase of the National Agricultural Policy or the NAP3. This policy emphasizes the modernization and commercialization of the agricultural sector to ensure its continued competitiveness. NAP3 would also be mandated to contribute to poverty reduction in line with the United Nations Millennium Development Goals (MDGs). The overriding objectives of NAP3 are the maximization of income through the optimal utilization of resources in the agricultural sector, maximizing agriculture's contribution to national income and export earnings and maximizing income of producers. The mechanization of the agricultural sector is the key factor in achieving these objectives. Therefore, it is important for Malaysia to develop a strategy and plan to make this policy a success.

1.1 Agricultural Engineering Division in Department of Agriculture (DOA)

Agricultural Engineering Division in the Department of Agriculture (DOA) is responsible for providing technical services in the discipline of agricultural engineering to accelerate the transformation of the agricultural sector in the field of mechanization and automation. The function of the Agricultural Engineering Division is to adapt, suggest and promote agricultural engineering technology which includes production activity, structure and infrastructure, agricultural irrigation and drainage, post-harvest technology and processing technology, development of farms mechanization and automation. Agricultural Engineering Division conducts activity in designing irrigation and drainage system for Agriculture. The designing is depending on the irrigation system, which follows the specification according to the requirements. For instance, This Division had design pump, pond size and others. In the scope of structure and infrastructure, This Division also designs and prepares the specification according to the needs in the areas such as farm road, pump house, rain shelter system and others which can be found in The Permanent Food Park (TKPM), Department of Agriculture (DOA). TKPM was designed as one of the strategies under the 3rd National Agriculture Policy (DPN3) to encourage the implementation of a large scale, commercial and high technology agriculture project by the entrepreneurs and the private sector.

This Division also repairs the vehicles and agricultural machinery in DOA, performs maintenance of vehicles and agricultural machinery, fabrication of machinery and agricultural tools, expertise in rice fields, conduct promotion and demonstration of latest agricultural tools and machinery, special program monitoring: Paddy Straw Management Program, logistic management expertise services, training to officers and farmers, measuring soil, "Combined Harvester" and land preparation work. It is located at the Agricultural Complex in Serdang Selangor, Malaysia. Agricultural Engineering Division has three (3) main sections, namely Section of Project Engineering (SKP) who provides agricultural engineering technical support and services

in the form of consultation and advisory and project monitoring services to the Department of Agriculture, Agricultural Agencies, Entrepreneurs and Farmers. Logistic Management Section (SPL) provides logistics support services and Section of Development of Agriculture Technology (SPTKP) is to develop and adjusting the agricultural engineering technology to enhance the productivity and competitiveness of the agricultural sector of the country.

1.2 Engineering Research Center, Malaysian Agricultural Research & Development Institute (MARDI)

Engineering Research Center was established in MARDI is in line with the requirements of the National Agricultural Policy to carry out research, development and commercialization of technology; hardware and software, equipment, systems, mechanization/ automation and information for the agricultural and food industry. It aims to improve the productivity and quality results at competitive production costs, reducing labor and time-saving operation for commercial production, thereby helping to enhance farm business profitability. Engineering Research Center was established in May 2015. Previously this center is known as the Mechanization and Automation Research Center. There are three R&D programmes in the center and known as Postharvest Mechanization & Food Processing, Farm Mechanization and Precision Agriculture.

Engineering Research Center has developed technologies in mechanization and automation that can be used by the national agro-food sector. Research and development which includes food mechanization and post-harvest; mechanization of farm production; and precision agriculture. The main thrust areas of research in food mechanization and post-harvest is to provide the solutions to the mechanization issues of food small and medium industries (SMIs). The core R&D is to produce food processing machines which are suitable for SMIs. In addition, it also provides a solution to the post-harvest handling and storage of agricultural commodities with the development of mechanized systems, which is more efficient and effective. Production of farm mechanization program undertakes research to provide solutions for crop production on the farm. Mechanization needs including activities related to crop production systems involving operations such as land preparation, maintenance, harvesting, handling crop and water management systems. While the role of precision agriculture program is to obtain solutions to the problem of automation in crop production, development of agricultural structure and building environments. Emphasis is also given to increasing productivity and labor savings through automation and the use of sensors in agriculture and food production systems. Some areas of automation that are actively explored are the development of sensor systems, instrumentation, mechatronics, information and communications technology (ICT).

II. National Agricultural Machinery Strategy/Long-Term Plan

2.1 Summary of related policies, strategy/long-term plan

Action Plan of Mechanization and Automation in Agro Food (2013-2020), Malaysia

Strategy

1. Establish the pathway and coordination in Mechanization and Automation
2. Strengthen Research & Development Program/Activity
3. Increase Ownership of Agricultural Mechanization
4. Establish the involvement of Private Partnership/Institutional of Farmer
5. Increase Capacity in Manufacture and Distribution of Affordable Machinery
6. Human Resource Capacity Development and Capabilities in Mechanization and Automation
7. Control Pest & Disease-Control the Transfer of Machinery

Long-Term Plan

1. Policy coordination through the establishment of Mechanization and Automation Division at the Ministry of Agriculture and Agro-based Industry, Malaysia
2. Enforcement:
   - Rules of rice planting simultaneously / control the transfer of machinery
   - Usage of bio-organic fertilizer
3. Construction:
   - Concrete drainage
   - Farm road according to the requirements of mechanization and automation
4. Mechanization and Automation innovation incentives that can be commercialized
5. Increase ownership of agricultural mechanization through matching grant / engagement with private/bankinginstitutions

2.2 Results from implementation

1. Towards modern agriculture as international level

2. Increased profit / productivity / income
3. Increasing number of skilled trainers / skilled workers / machinery entrepreneurs
4. Optimizing the value chain within the agro-food community
5. Reduce the usage of labor source
6. Cost reduction to government
7. Strengthening of the role of private / institutional of farmers / banking institution

III. Lessons Learned and Good Practices

Agricultural Engineering Division in the Department of Agriculture (DOA) has Agricultural Engineering Training Centre (PLKP) in few states in Malaysia. The main goal is to provide formal training and intensive on the state of youths in the field of agricultural engineering. These include training of agricultural machinery operation, such as tractors and "backhoe loader." Participants who were aged 21 years and older will get a driving license class "H" issued by the State Road Transport Department. The centre is also willing to accept participants comprising government / statutory bodies who are interested in pursuing the field of agricultural engineering. At the end of the course, participants will be given certificates according to grades based on their competencies and skills examinations. Agricultural Mechanization course will be conducted two times in a year intake. Each intake will take approximately 20 weeks. The number of participants is about 30 people for each intake. Participants will be trained using the theoretical 30 % and practical training 70% in agricultural engineering. In addition, PLKP also conducts short-term courses such as the operation and management of agricultural machinery and irrigation systems. Apart from that, good practice is also included in the agricultural mechanization course which is related to sustainable agricultural mechanization, machinery testing, and agricultural technology transfer with a view to improve food security and sustainable agriculture development in Malaysia.

MARDI has successfully developed variable rate technology (VRT) for seeding and fertilizer applications. In rice precision farming, management of variabilities in the field is very important. Land preparation before seeding is critical since it is the first step of controlling variabilities. The variability of land leveling of paddy fields would affect seeding operations. One way to manage this and consume less operation time is by using an automated land leveling system. The automated land leveling system uses a Trimble FMX Display with Field Level II Survey and Design Module and built-in farm-works software, Trimble GPS Receiver and an RTK (Real Time Kinematics) Base Station. The Trimble GPS receiver was mounted on a rotary tiller while the Trimble FMX display was mounted on a quad-steel-tracked tractor. The automated land leveling system can produce an accuracy of + 2 cm vertically and + 1 cm horizontally. The automated land leveling system is comparable to manual land leveling measurement using laser, with less time consumed and faster results. The treatment map of field levelness will be generated and uploaded to variable rate applicator , and seed broadcasting is according to specific management zone with precise seed-rate shall be applied.

Variable rate technology (VRT) for fertilizer application is one of the important components in rice precision farming. The developed system consists of field data collection, processing and analyzing unit, treatment map and the variable rate applicator (VRA). Two types of field data collection have been established i.e. ground truth data sampling in grid form of selected location and unmanned aerial vehicle, UAV-based image capturing for large area. Fertilizer calculation software which is based on GAI (Green Area Index) model has been developed to calculate the fertilizer NPK (Nitrogen(N), Phosphorus (P), and Potassium(K)), urea and MOP (Muriate of Potash) and to generate treatment map. Total amount of fertilizer for a specific management zone was determined. The treatment map, which indicates the amount of fertilizer to be applied based on this management zone, will also be generated. The VRA, a tractor driven applicator, has been used for variable rate fertilizer application. The field location was guided through the tractor mounted GPS. Once the tractor reached the position signal, the VRA controller triggered the metering device to control the spreader orifice at a specific level which is equivalent to the required fertilizer amount. The technology is expected to save the fertilizer input by 15%-25%. The developed technologies will increase rice industry efficiency along the value chain so that it becomes more productive and competitive. It is also able to attract young generations to participate in the paddy industry and thus increase the country's rice production.

IV. Suggestions for Regional Cooperation amongst Countries

Malaysia looks forward to collaborating with private organizations to increase knowledge exchange on mechanization and automation in agriculture. This includes fostering partnerships among public and private sector institutions to promote innovation and to build on existing practices and technologies. Malaysia also seeks private organizations to provide technical assistance through projects and programmes, implement sustainable agricultural mechanization practices and technologies tailored to local conditions.

Myanmar

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I. Agricultural Mechanization Country Profile

Myanmar is located between latitude 9° 32' and 28° 31' N, 92° 10' and 101° 1' E with total area about 676, 577 sq. km and borders with Bangladesh, India, China, Laos and Thailand. Climate is tropical, sub-tropical and temperate.The population in Myanmar is about 52.476 million.

Myanmar is an agrarian country with two-thirds of its population (40 million) involved in agriculture. Myanmar is rich in natural resources with diverse agro-ecological conditions with opportunities for doing business in agriculture. Farmland consolidation is essential for pursuing agricultural mechanization, which will reduce losses, increase crop quality and production and improve farmers' income. Agricultural Mechanization Department performs the transformation from conventional agriculture to mechanized agriculture.

II. National Machinery Strategy/Long-Term Plan

Agricultural Mechanization and Input Policy plan to:

1. Increase usage of well-adapted and high-quality farm machinery and equipment in efforts to transform conventional agriculture into a more mechanized agriculture;
2. Improve agricultural commodity value chains by introducing machinery and equipment to postharvest and value-added activities, thereby enhancing the production of high-quality agricultural products;
3. Support capacity building for technological development in agro–based industries by using modern machinery and equipment in primary and value-added processing.

The agricultural mechanization strategies aim to:

1. Encourage farmers to consolidate their fields (including farm roads, drainage, irrigation networks, land leveling) to promote mechanization for land preparation, seeding, transplanting and harvesting. In irrigated areas, this action could be promoted by water user associations;
2. Improve the utilization of farm machinery by the public sector and rural farmers;
3. Ensure a gradual handover or privatization of mechanization stations which are currently under the AMD to private sector or farmers organizations;
4. Provide training programs for farmers and private sector on proper operation and maintenance of farm machinery;
5. Promote the emergence of rural workshop for agricultural machinery repair and maintenance.

6. Collaborate with private sector and ensure timely availability of spare parts;
7. Provide financial analysis to guide investment decisions of farmers under different agro-ecological conditions.

Results for Implementation

Table 1: Status of Machinery Effective Area in Myanmar - Utilization of Power Tiller and Tractor

Power Tiller	Net Sown Area, Hectares	Power Tiller Effective, Hectares	Consolidated Hectares
478,030 units	12,010,000	3,824,272	35,182

Tractor	Net Sown Area, Hectares	Tractor Effective, Hectares	Consolidated Hectares
29,531 units	12,010,000	3,543,840	35,182

Table 2: Farmers-owned Machinery in Myanmar (Last Five Years)

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Tractor	1,119	11,839	14,265	18,524	25,708	29,531
Power Tiller	227,489	257,971	286,097	300,247	467,278	478,030
Combine Harvester	307	668	1,680	1,972	4,759	5,538

Status of Import of Farm Machinery Widely Used in Myanmar

Table 3a: Status of Import of Tractor Widely Used in Myanmar

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
China	792	3,193	7893,	4,599	8,617	1,522
Thailand	141	383	4,583	7,703	7,586	136
India	768	1,635	2,305	2,239	4,688	2,303
Korea	3	4	4,423	1,170	502	42
Japan	55	115	445	282	716	424

Table 3b: Status of Import of Combine Harvester Widely Used in Myanmar

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Thailand	76	0	2,219	4,402	3,122	55
China	86	1,046	1,622	2,295	2,523	438
Japan	41	844	1,032	64	15	18
Korea	0	419	256	234	0	0
India	0	1	18	1	16	4

III. Lessons Learned and Good Practices

Good Practices in Agricultural Mechanization

The utilization of farm machinery and equipment for various activities of agricultural production has been increased in both State and private sectors in attempts to boost the agricultural production. To increase cropping intensity has also expended the use of machinery from land preparation to harvesting and post-harvest activities. Required machinery are produced and assembled locally or imported to be distributed to the farmers.

Table 4: Status of Machinery Utilization in Myanmar

No	Type of Machinery	Utilization (Qty)	Sold by AMD (Qty)
1.	Tractor	29,531	773
2.	Power Tiller	478,034	107,806
3.	Combine Harvester	5,538	82

Efforts are being made to eliminate the traditional way of threshing paddy and to mitigate post-harvest losses through introduction of threshers and combine harvesters.

A two-year installment plan for agricultural machinery distribution to farmers is being offered by the Agricultural Mechanization Department (AMD) in order to provide easy access and affordable machinery for farmers. Farmers need to pay only 35% as a down payment of the machinery value. The remaining sixty-five percent will be paid in installments once a year over the next two years.

To enable local farmers to buy tractors, the Agricultural Mechanization Department is cooperating with farming tools trading companies. The local farmers need to pay 10% of the total price as a down payment and will be allowed to use the farming tool after making the down payment. The remaining 90% must be paid off in six equal installments in three years.

AMD arranges the provision of farm mechanization services on land preparation, transplanting, harvesting, and threshing in paddy cultivation aiming to enhance farmers' income and social livelihood by increasing production quality and mitigating losses. Land development activities for transformation from conventional agriculture to mechanized agriculture and land consolidation process are being undertaken as following:

1. Construction of farm roads;
2. Construction of irrigation canals and drainages;
3. Transformation of small plots into bigger plots;
4. Establishment of modern-mechanized farms throughout the country to enable farmers to increase their productivity by growing double and multiple seasons. It enables farmers to get quick advantages through the increase of crop production as well as per capita income.

Table 5: Consolidated Mechanized Farmland in Myanmar

No	Region/ State	Hectare
1	Kachin State	855
2	Kayar State	442
3	Kayin State	1,375
4	Sagaing Region	1,193
5	Tanintharyi Region	267
6	Bago Region	5,207
7	Magway Region	949
8	Mandalay Region	2246
9	Mon State	902
10	Rakhine State	437
11	Yangon Region	12,437
12	Shan State	477
13	Ayeyarwaddy Region	4,276
14	Nay pyi taw Council Area	4,119
	Total	35,182

Table: 6 Imported Farm Machinery in Myanmar

No.	Type of Machinery	2013-14	2014-15	2015-16	2016-17	2017-18 (30.9.17)	Total
1	Tractor	5,330	19,798	16,218	22,635	4,861	68,842
2	Power Tiller	115,847	164,059	237,506	280,563	66,383	864,358
3	Mono Wheel Tractor	10,686	22,428	9,130	11,885	3,660	57,789
4	Cultivating Roller Boat	6,625	8,425	4,490	5,210	-	24,750
5	Transplanter	25	237	73	77	150	562
6	Paddy Reaper	3,176	7,562	10,406	10,491	821	32,456
7	Combine Harvester	2,319	5,177	7,105	5,678	515	20,794
8	Paddy Dryer	4	10	24	25	9	72
9	Thresher	392	4,430	442	186	250	5,700

Table 7: Country of Origin of Imported Tractors in Myanmar (30.9.2017)

No.	Imported Country	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18 (30.9.17)	Total
1	Japan	55	115	445	282	716	424	2,307
2	Korea (South)	3	4	4,423	1,170	502	42	6,144
3	Thailand	141	383	4,583	7,703	7,586	136	20,532
4	China	792	3,193	7,893	4,599	8,617	1,522	26,616
5	India	768	1,635	2,305	2,239	4,688	2,303	13,938
6	Others (Italy,Brazil, Czech,Mexcico)	31	-	149	225	526	434	1,365
	Total	1,790	5,330	19,798	16,218	22,635	4,861	70,632

Table 8: Country of Origin of Imported Combine Harvesters in Myanmar

No.	Imported Country	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18 (30.9.17)	Total
1	Japan	41	844	1,032	64	15	18	2,014
2	Korea (South)	-	419	256	234	-	-	909
3	Thailand	76	-	2,219	4,402	3,122	55	9,874
4	China	86	1,046	1,622	2,295	2,523	438	8,010
5	India	-	10	18	10	16	4	58
6	Others (Vietnam, Belgium)	-	-	30	100	2	-	132
	Total	203	2,319	5,177	7,105	5,678	515	20,794

Training & Education

From 1980 to 2017, several pieces of training were held for departmental staffs and farmers of farm machinery operation in AMD training centers (Meikhtila,Bago,Naypyitaw-Yezin) and regional AMS. In total, 38,096 trainees participated. 20,327 of them were departmental staffs and 17,769 were farmers.

IV. Suggestion for Regional Cooperation amongst Countries

Myanmar has great potential to become the major "food basket" of the region. Technologies and cooperation are required to enhance sustainable agricultural mechanization in Myanmar for such purpose.

In order to develop sustainable agricultural mechanization, the following suggestions should be taken into consideration:

- Establishment of agricultural machinery manufactories with foreign direct investment (FDI);
- Approval of private sector import of agricultural machinery only when quality is classified by a testing body;
- Selling farm machinery to farmers on credit and installment payment system;
- Availability of spare parts of agricultural machinery manufactured locally with the FDI and imported from other countries;
- Foreign and local private sector investments in custom hiring service of farm machinery are widely needed for small scale farmers who cannot afford to buy expensive farm machinery;
- Conducting training programs for farmers on operation, maintenance and repair of farm machinery and equipment by manufacturers;
- Exchange of views and information on research and development of agricultural machinery carried out by government agencies and private institutions;
- Delivering information on high quality and long service duration of agricultural machinery and equipment on brand, country of origin, model and dealer via local network in the region.

Nepal
Nepalese Agricultural Mechanization Policy and Strategy

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I. Introduction

Nepal is a mountainous and predominantly agrarian land-locked country. It is home to 28.98[1] million people as of 2016 with 10 religious regions having 125 caste/ethnic groups and 123 languages spoken as mother tongue. It is located in the southern slopes of the Himalayas, bordering the Tibet Autonomous Region of the People's Republic of China in the North and the Republic of India in the South. In the north, there is the great Himalayan range, 8 out of the 14 highest peaks in the world above 8,000 meters including the highest peak of the world Mt. Everest of 8848 meters. It has three ecological zones: mountain, hill and terai (plain land), starting from 72 meters above mean sea level. The hilly and the mountainous regions account for 77 percent of the total land area of 147,181 sq. km, while the terai plain accounts for 23 percent of the area[2]. About 22% people are still below poverty line. Average land holding is 0.68 ha.

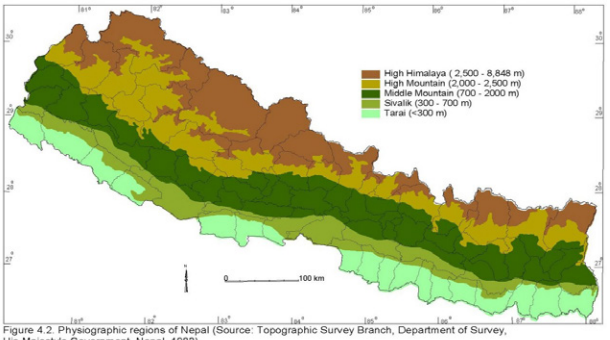

Figure 4.2: Physiographic regions of Nepal (Source: Topographic Survey Branch, Department of Survey, His Majesty's Government, Nepal, 1983)

Figure 1. Physiographic Regions of Nepal

1.1 Overview of the Agriculture Sector

Nepal is an agrarian country, with agriculture contributing 29.37% of total national GDP (2016/17)[3], [4]and more than 66 % of total employment. Agriculture occupies around 21 percent of total land area of the country, out of which 53 percent is been irrigated. It is the backbone of rural livelihood with major crops: paddy, maize, wheat, horticulture etc.; major livestock: cattle, buffaloes, sheep/goat, pigs and poultry. The area of food crops and their production details are given in Table 1.

1 http://countryeconomy.com/demography/population/nepal
2 Agriculture Year Book 2014
3 Economic Survey, Fiscal Year 2016/17, Ministry of Finance, GoN
4 According to Nepali calendar, fiscal year starts from 16 July to 15 July.

Table 1: Area of Food Crops and Their Production Details in Nepal

Crops	2014/15			2015/16			2016/17		
	Area (Ha.)	Production (MT)	Productivity (MT/Ha)	Area (Ha.)	Production (MT)	Productivity (MT/Ha)	Area (Ha.)	Production (MT)	Productivity (MT/Ha)
Paddy	1,425,346	4,788,612	3.36	1,362,908	4,299,078	3.15	1,552,469	5,230,327	3.37
	-4.14	-5.12	-1.02	-4.38	-10.22	-6.11	13.91	21.66	6.81
Maize/Corn	882,395	2,145,291	2.43	891,583	2,231,517	2.50	897,789	2,320,000	2.58
	-4.99	-6.04	-1.10	1.04	4.02	2.95	0.70	3.97	3.25
Wheat	762,373	1,975,625	2.59	745,823	1,736,849	2.33	750,000	1,841,000	2.45
	1.05	4.91	3.82	-2.17	-12.09	-10.14	0.56	6.00	5.41
Millet	268,050	308,488	1.15	266,799	302,397	1.13	263,101	306,215	1.16
	-1.16	1.44	2.63	-0.47	-1.97	-1.51	-1.39	1.26	2.69
Buckwheat	10,819	10,870	1.00	10,842	11,640	1.07	10,890	11,979	1.10
	2.94	5.18	2.17	0.21	7.08	6.86	0.44	2.91	2.46
Barley	28,053	37,354	1.33	28,368	32,806	1.16	26,943	32,144	1.19
	-0.43	7.27	7.72	1.12	-12.18	-13.15	-5.2	-2.0	2.04
Total Food Crops	3,377,036	9,266,240	2.74	3,306,323	8,614,287	2.61	3,501,192	9,741,665	2.78
	-2.96	-3.10	-0.14	-2.09	-7.04	-5.05	5.89	13.09	6.79

Source: Economic Survey, Fiscal Year 2016/17, Ministry of Finance, GoN
Note: Figures in the lower rows in each crop growth in percent as compared to that of previous fiscal year.

However, the average growth rate of this sector in last 10 years remained at 2.9 percent[5]. Agriculture is important for Nepalese economy not only for providing consumable product but also for raw materials to industries and tradable items. In 1995 the government implemented and then completed a 20-year Agriculture Perspective Plan (APP). Recently, the government has approved the Agriculture Development Strategy (ADS) for next 20 years.

1.2 Overview of Agricultural Mechanization

Previously, mechanization was not considered as an input to enhance productivity and was not given emphasis in national plan and program. However, at present since the youth choose to urban area and aboard for better opportunities, the nation begins to consider agricultural mechanization as one of the inputs to retain and attract youth in agriculture. It has become a pathway which is showed by developing the Agricultural Mechanization Promotion Policy 2014 (AMPP) and Agricultural Mechanization Promotion Operational Strategy (AMPOS). Agricultural Mechanization has included as one of the 13 core outputs of Agricultural Development Strategy (ADS).”

It is difficult to find data regarding types, models, numbers, agricultural machine, etc. Since several organizations are responsible for this matter, Nepal conducts National Sample Census of Agriculture every 10 years by Central Bureau of Statistics (CBS), which started from 1961/62. It is considered as one of the largest statistical operations in Nepal. The Sixth National Census was conducted in 2011/12, which included households using agricultural implements and other machines. Table 2 shows the trend of households using agricultural machinery and equipment for the last 20 years.

5 http://mof.gov.np/uploads/document/file/Final%20Economic%20Survey%202071-72%20English%20(Final)_20150716082638.pdf

Table 2: Trend of Households Using Agricultural Machinery and Equipment in Nepal within 20 Years

Types of Equipment	1991/92		2001/02		2011/12*	
	Holdings using equipment ('000)	No. of items ('000)	Holdings using equipment ('000)	No. of items ('000)	Holdings using equipment ('000)	No. of items ('000)
Iron ploughs	315.1	354.5	870.3	890.2	1,073.4	856.3
Power tillers	5.6	1.6	15.6	11.8	75.7	10.4
Shallow tube wells	50.9	48.2	119.7	109.5	367.7	262.0
Deep tube wells	20.1	15.7	58.6	51.5	159.7	82.0
Rower pumps	3.5	3.8	22.7	21.8	79.1	36.2
Tractors	35.2	5.5	272.9	150.6	844.7	37.4
Threshers	85.6	19.9	249.5	129.1	803.1	51.9
Pumping sets	81.1	41.3	210.4	146.1	548.2	150.3
Animal drawn cart	204.6	198.1	226.4	199.1	335.0	159.9
Sprayers	50.2	23.4	203.0	145.9	574.0	282.3
Others	296.5	878.4	449.0	1,072.7	290.1	83.5

Source: National Sample Census of Agriculture, CBS

Another source of data for agricultural machines is number of tractors and power tillers operating in the country. Tractors and power tillers that use road has to be registered. According to Department of Transport Management, the total number of tractors and power tillers was 113,481 in 2015/16. But the actual numbers of tractor and power tiller respectively is not known as both are registered in the same category. The total number may vary as power tiller operating only in agriculture has not been registered. The trend of registration is shown in Figure 2. It is in an ascending trend as demand of rural transport and agricultural mechanization is also increasing.

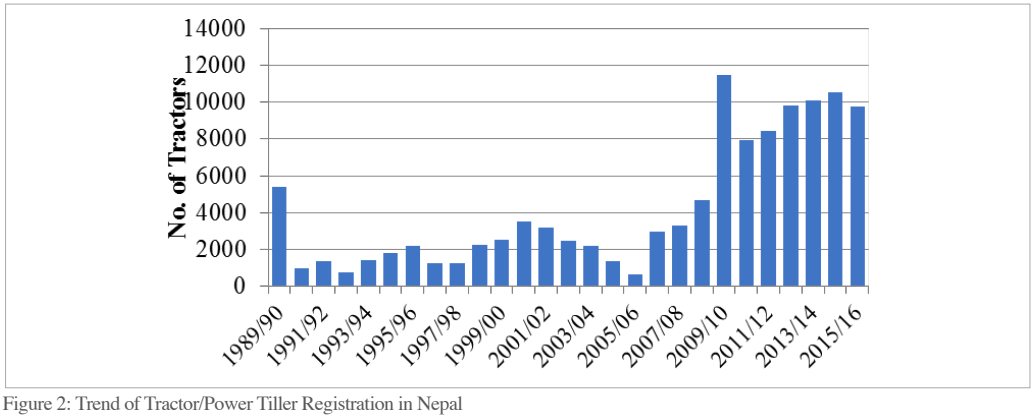

Figure 2: Trend of Tractor/Power Tiller Registration in Nepal
Source: Department of Transport Management

The locally manufactured machinery include small tools, ploughs, different attachments to tractors and power tillers, different threshers, seed grader, coffee roaster and pulper, processing machines etc. However, the exact data of manufactures, types, models are unavailable at present.

There is a high demand in imported agricultural machinery as they are subject to 1% customs duty and zero VAT until 2016/17. The table 3 shows some of the agricultural related machineries imported according to HS codes in the year 2016 -2017.

Table 3: Agricultural Machinery Imported in Nepal in 2016-2017

HS Code	Description	Unit	Quantity	Value in NPR '000	Source Country
87011010/87011090/87019000	Tractor including power tiller	PCS	38,896	11,451,192	India, China
84322900	Harrows (excl disc harrows), scarifiers, cultivators, weeders, hoes including mini tiller	PCS	221,151	1,070,647	India, China, Indonesia
84323000	Seeders, planters and transplanters	PCS	2,763	20,042	India, China
84328000	Soil preparation/cultivation machinery; lawn/sports-ground rollers	PCS	38,068	143,689	India, China
84335100	Combine harvester-threshers	PCS	1,930	353,761	India, China, Japan
84335200	Threshing machinery for agricultural produce	PCS	21,933	654,189	India, China, New Zealand, Turkey
84335300	Root or tuber harvesting machines	PCS	2,711	23,855	India, China
84335900	Harvesting machinery	PCS	17,802	58,737	India, China, Japan

Source: Department of Customs

Nepal has been a member country involved in different activities related to agricultural mechanization organized by the Centre for Sustainable Agricultural Mechanization (CSAM) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). One of the CSAM's activities is to create a database on agricultural mechanization in Asia and the Pacific was initiated in March 2016. Directorate of Agricultural Engineering (DoAEngg) is a focal institute representing Nepal. A resourceful database is expected to be generated by this initiative.

II. Agricultural Mechanization Policy and Strategy

The Constitution of Nepal 2015 is the fundamental law of Federal Democratic Republic of Nepal, to which agriculture and related subject are given special emphasis and clearly spell out its importance. It briefly describes agriculture and related subjects, and responsibility of the government. In Article 51 "State policies", section "e"- "Policies regarding agriculture and land reform of Part 4, Directive Principles, Policies and Responsibilities of the State" has stated:

- Protecting and promoting rights and interests of peasants and utilizing the land use policy for increasing production and productivity of agriculture and for commercialization, industrialization, diversification and modernization of agriculture;
- Making proper utilization of land through proper regulation and management on the basis of productivity of land, its nature, and also by maintaining environmental balance;
- Making arrangements for agricultural tools and an access to market with appropriate price for the produce.

Agriculture Sector Wise Policies

Nepal has sector policies for proper implementation. There are more than 20 different agriculture-related polices such as: National Agriculture Policy 2004, Agriculture Business Promotion Policy 2006, Agriculture Biodiversity Policy 2006, National Tea Policy 2000, National Coffee Policy 2003, Dairy Development Policy 2007, National Seeds Policy 1999, National Fertilizer Policy 2001, Irrigation Policy 2003, Poultry Policy 2011, Pasture Policy 2011, Floral Promotion Policy 2012, National Land Use Policy 2012, National Cooperatives Policy 2012, Commerce Policy 2008, Climate Change Policy 2010, Industrial Policy 2010, Supply Policy 2012, Science and Technology Policy 2012, Biotechnology Policy 2006, Agricultural Mechanization Promotion Policy, 2014, etc.

- **Agricultural Mechanization Promotion Policy 2014**

Apart from ADS, the Government of Nepal (GoN) approved and released the Agricultural Mechanization Promotion Policy (AMPP) on 29 August 2014.

The vision of the AMPP is "to contribute to national development through modernization and commercialization of present agriculture system by using agricultural mechanization".

The mission is "to contribute to sustainable economic development through the agricultural mechanization and agribusiness modernization".

The goal is "to research, develop, adopt adapt?, extend, and promote agricultural machines, implements and equipment to

increase agricultural productivity and make it sustainable and competitive".

It has visualized four main objectives to achieve agricultural mechanization in the country:

1. To increase productivity through appropriate agricultural mechanization as per the economic and geographical needs of the country in order to develop the sustainable, competitive and commercial agriculture sector;
2. To develop the services and business of agriculture machinery through the coordination among the government, private sectors and cooperatives in order to increase the access of the farmers and the business people;
3. To identify and promote women and environment friendly agriculture machinery;
4. To establish and strengthen the organizational structure to develop, quality standardization, regulation, monitoring and promotion of agriculture machinery for agricultural mechanization.

The Agricultural Mechanization Promotion Operational Strategy along with implementation plan and budget estimation is on the final stage of approval at the Ministry of Agricultural Development (MoAD) for effective implementation of AMPP for improvement of transformation of traditional agriculture to commercialization.

- **Agricultural Development Strategy (ADS) 2015**

For the overall development of agriculture in the country, GoN has approved the Agricultural Development Strategy (ADS) on 26 July 2015. It is a 20-year strategic planning from 2015 to 2035. ADS has identified Agricultural Mechanization as one of the thirteen core priorities for achieving the higher productivity target envisaged by it (Agricultural land productivity AGDP value US$ 4,787/ha). Before ADS, the Agricultural Prospective Plan (APP) that ended in 2015 guided the plans and programs in agriculture.

The vision of ADS is "a self-reliant, sustainable, competitive, and inclusive agricultural sector that drives economic growth, and contributes to improved livelihoods and food and nutrition security leading to food sovereignty."

The ADS will have impacts on three groups of farmers (commercial, subsistence and landless). Commercial farmers are directly affected by most of the ADS measures (for example, in the case of irrigation, mechanization, value chain development and exports).

In the Agricultural Development Strategy (ADS), private sector is identified as a major player to boost agricultural mechanization in the country. In the output section 2.10 “Range of Mechanization Options accessible to Farmers through the Private Sector”, it is clearly mentioned that: "A mechanization strategy should focus on creation of awareness, demand stimulation, a concessionary financing arrangement, technical capacity building of the dealer network (particularly for the 2-wheel power tillers and mini-tiller dealers) throughout the country and modifications in taxation".

This strategy needs a lot of coordination with the private sector equipment providers and the banking sector. The approach would be oriented at: 1) power tillers with multifunctional tilling options in the terai; 2) gradual increase in the numbers of mini 2-wheelers (with some optional attachments) in hilly areas; and 3) labor-saving low energy implements and mechanized irrigation in the mountains.

Table 4: Six Components of and Proposed Activities for Agricultural Mechanization in ADS in Nepal

Components	ADS Proposal
Distribute information	1. Conduct social marketing campaigns on a cost-sharing basis with 2-wheel tractor importers and dealers emphasizing the advantages of a 2-wheel tractor for the traditional forms of cultivation, harvesting etc. 2. Conduct three separate campaigns; viz., one for the mountainous, hilly and terrain regions, with the aim of creating farmers’ awareness of the potential options and choices.

Components	ADS Proposal
Improve customer access to finance	Promote commercial banks to finance dealers to on-lend to their customers under two options: 1) Extend credit on commercial terms to dealers 2) Access cheaper credit from the Rastra Bank's "deprived sector" lending program (cooperatives and micro-finance institutions).
Improve capacity building of service and maintenance providers	1. Support dealers to increase the technical capacity of existing smaller workshops that are scattered through the countryside, rather than setting up their own repair workshops. These workshops could also stock spare parts and act as small brokers for around 30-35 dealers operating in major commercial centers. 2. Support dealers in offering technical training for 1,000 farmer/service providers to enable them to become local experts in the impacts of mechanization (additional germination rates, cost saving implications, the advantage of zero leveling, the impact of seed drills etc.)
Enable the business environment for leasing agricultural equipment	1. Provide legal clarification (ruling) that the Banking institutions Act does not restrict nonbanking institutions to engage in leasing; 2. Establish a pledge registry (under the Secured Transactions Act or under by amendment to the Contracts Act) to allow securing the financing for leasing operations by leasing companies.
Revise regulation and taxes to support mechanization	1. Waive the VAT amount and import duty on spare parts to reduce the proliferation of sub-standard spare parts brought illegally across the border and promote business of local dealers and sub dealers; 2. Remove the 5-year restriction on change of ownership of 2-wheel tractors, to encourage mechanization; 3. Impose full VAT on the purchase of 4-wheelers but not on 2-wheelers. Most 4-wheel tractors are use exclusively for commercial transport rather than for agriculture; 4. Reduce the road tax for Power Tillers. Currently, the levy is USD 28 for Tractors and USD 22.3 for Power Tillers, which is clearly a disincentive for a Power Tiller buyer, if it is to be use solely for agriculture. [6]
Involve pilot a voucher scheme	Entail provision of a 30% subsidy on all attachments for 2-wheelers and 4-wheelers, to increase the rate of attachment usage (seed drills, reapers, laser levelers, planters etc.). This would last just 3 years and be accompanied by the above-mentioned social marketing campaign.

- **Agricultural Mechanization Promotion Operational Strategy (AMPOS)**

AMPOS is a guiding document with implementation plan, cost-estimation, institutional and regulatory framework that has been formulated following intensive review of the current practices and status of agricultural mechanization in the country, best practices and lessons learned from Nepal and other countries. It has focused on "Sustainable Agricultural Mechanization for Food Security and Agricultural Commercialization" the overall purpose of AMPOS is to raise the level of mechanization for increased land and labor productivity by adopting appropriate and sustainable agricultural mechanization technologies. The strategic framework for the AMPOS is comprised of the following four interrelated elements:

- Enhancement t of demand and use of appropriate agricultural machinery;
- Improvement of supply situation with priority given to domestic fabrication;
- Consolidation of the innovation system;
- Design and implementation of appropriate policy, institutional and regulatory measures.

AMPOS identified six components comprised of the above four interrelated elements.

Table 5: Six Components of Agricultural Mechanization Promotion Operational Strategy in Nepal

Component 1	Enhance access to and use of agricultural machines and equipment at farm level
Component 2	Domestic production and fabrication of feasible agricultural machines, movable parts and equipment
Component 3	Innovation in agricultural mechanization
Component 4	Improvement in business environment for the traders
Component 5	Repair and maintenance facilities of agricultural machinery
Component 6	Policy, institutional reform and regulatory support

AMPOS has identified 38 activities and 105 sub-activities within 6 components to achieve the set targets for raising the level of agricultural mechanization over short-term (2 years), medium-term (5 years) and long-term (10 years) period as shown in Table 6.

Table 6: Targets Set by the AMPOS, for Raising Level of Agricultural Mechanization in Nepal

Indicators and unit	Status	Short-term (2017-2019)	Medium-term (2019-2022)	Long-term(2022-2027)
% of agricultural mechanization	40%(Terai-61%, Mid-hill 15%, mountains-2%)	50	60	70
Power use in Kw/Ha (Mechanical)	0.67	0.74	0.85	1.19

Source: AMPOS Study Team Report

III. Lessons Learned and Good Practices

The plans and programs of the government are the milestones to achieve effective implementation of policy and strategy of the country. Annually allocated budget plays the key role in archiving the targets covered by the strategy. Availability of human resources and coordination among the interdisciplinary agencies like extension, research and education institutes are also important factors for achieving the goals. Some of the lessons learned and good practices guided by the policy and strategy in the Nepalese context are pointed out as follow:

- Enforcing Law: The existing policy and strategy do not include regulations regarding integrated straw management, which is one of the key issues appeared few years ago. Livestock farmers became to complain about rice and wheat straw burning that destroys feed and causes pollution. As a response, on March 15 in 2015, the government of Nepal has approved a law banning import and custom hiring of combine harvester without baler or straw chopper.
- Establishment of testing and training centers: As mentioned in the policy and strategy, a country should have testing and training centers. Establishment of a testing center under the Agricultural Engineering Division (AED) of Nepal Agriculture Research Council (NARC) and training center under Directorate of Agricultural Engineering of Department of Agriculture (DoA) is under process.
- Establishment of Community Post-Harvest Service Center (CPHSC). Mechanizing post-harvest handling is one of the key aspects of the policy and strategy. To address this issue, the CPHSC model has been established. So far, there are eight CPHSCs in terai and one in mid hill on cost sharing basis between farmers group and cooperatives.
- Establishment of Community Seed Bank. The livelihood of poor farmers is yet another agenda of the policy and strategy. After a devastating earthquake on 25 April 2015 with 7.8 magnitudes, that led to a massive damage of seed and grain kept by individual farmers at home in the affected districts. In response to this matter, the government has decided to construct Community Seed Banks for safe and central storage in this area. CSBs are managed by DoAEngg.
- Program for Rural Livelihood. Attracting youth as a main stakeholder to rural livelihood is the prime concern of the national programme. Several directions of human resource development of rural youth are listed below:

  - Basic Training for Blacksmiths
  - Resource Center for Blacksmiths
  - Special Training for Power Tiller Repair and Maintenance
  - Special Training for Blacksmiths
  - Basic Training for Power Tiller Operator
  - Resource Center for Power Tiller Repair and Maintenance

- Demonstration and Exhibitions. Demonstration and exhibitions in PPP model are in high priority of national program. At the national level, agricultural mechanization exhibitions are jointly organized with professional associations like NAMEA. Below are listed several examples of demonstration and exhibitions that could be held:

  - Minimum Tillage Technology

6 1USD=NPR 103.28 as of December 12, 2017

- Harvesting Technology
- Mini Tiller Technology
- Mobile Demonstration
- Agricultural Mechanization Exhibition

- Subsidy Program.

Interest Subsidy: Agricultural mechanization related loan has been financed by Bank and Financing Institutes (BFI's) to farmer groups, cooperatives, and company for a maximum of 5 years, whereas the capital investment will be paid by the beneficiary.

Agricultural Machinery Subsidies: Subsides in capital investment in agricultural machinery was started 5 years ago driven by farmers demand. Shortlist of agricultural machinery, manufacturers, suppliers, dealers are sent to all 75 District Agriculture Development Offices (DADOs). Farmers, farmers groups and agriculture cooperatives can then choose the machines they need, and DADO will recommend these machines to DoAEngg for final payment.

- Custom Hiring Center

Custom hiring of agricultural machinery is an informal business between farmers. A model of a formal custom hiring center with the name "Agricultural Machinery Community and Implement Service Center for Custom Hiring" has been initiated in four locations of terai districts within the last 4 years. The new concept of custom hiring center with a locking period of 4 years for individual farmers financed 50% by a bank and 50% by the government has been initiated and a guideline named "Custom Hiring Service Centre Guideline 2017" has been developed and submitted to MoAD for final approval.

IV. Suggestions for Regional Cooperation amongst Countries

As discussed earlier, the policy and strategy are a guiding document for sustainable agricultural mechanization in the country. Since some of the member countries do not have clear policy on SAM, some key recommendations for regional cooperation are summarized as follow. Member countries are encouraged to:

- Share national policy, strategy and guidelines;
- Cooperate in national policy and strategy formulation;
- Identify and share innovative solutions for sustainable agricultural mechanization;
- Identify potential areas/countries requiring assistance;
- Develop Sustainable Agricultural Mechanization Strategy (SAMS).

Pakistan

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I. Introduction

The Islamic Republic of Pakistan is an ancient civilization, although its political boundaries were drawn only seventy years ago, when it gained independence on 14 August 1947. Initially comprising East and West Pakistan, separated by 1,770 kilometers of India, its present territory since December 1971 is confined to the former West Wing, which has a total area of 79.61 million hectares[1]. It mainly consists of four provinces i.e. Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh. Pakistan lies between the longitudes of 23º30' and 36º45' North and between the latitudes of 61º and 7 º31' East. This territory is a region of diversified relief, with mountains to the north and west, and arid and semi-arid expanses to the south and east. Down in the centre is a flat fertile plain, fed by the Indus and its tributaries. Beneath the northern part of this plain, hydrologists found a huge freshwater lake, equal in volume to ten times the annual discharge of the rivers flowing above. The Indus plain has the largest canal irrigation system in the world, making cultivation possible despite scanty and erratic rainfall and ranges of extreme temperature[2].

Pakistan is bound by the Himalaya, Karakoram and Hindu Kush mountain ranges in the north which host the world's largest ice reserves. These mountains are the water tanks over the roof, which provide water to the reservoirs. Climatically Pakistan, located in the north of the tropic of cancer, possesses a great range of diversity, from some of the hottest in the world in the Jaccobabad and Sibbi districts to the snowy cold of Laddakh and Balochistan. In the plains, the minimum temperature in January varies from 4ºC to 15ºC and June/July from 25ºC to 30ºC. The maximum temperature in January varies from 17ºC to 24ºC and in June/July from 32ºC to 45ºC. Jacobabad has even recorded an absolute maximum of 53ºC. Pakistan suffers from a general deficiency of rainfall. Under the influence of the troughs of westerly waves as well as frontal systems, the northern half of Pakistan receives substantial rainfall over low elevation plains and snowfall in mountainous regions during the winter season. Summer adds monsoon to Pakistan, which contributes about 60% of the annual total precipitation from July to September[3]. In the plains, rainfall varies from 127 mm in upper Sindh to 1,250 mm in the Himalayan sub-mountain areas.

Pakistan is the 6th most populous country in the world with

1 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25.

2 Khan, Fazle Karim (2003). Pakistan: Geography, Economy and People. Oxford University Press, Karachi, Pakistan.

3 Rasul, G. and D.H. Kazmi (2013). Wheat Yield Prediction and Climate Change in Potohar Region of Pakistan. LAP Lambert Academic Publishers, Germany.

a population count of 199.71 million. Despite movements of people from farms to cities, the country remains predominantly rural. Around 60 percent of the country's population lives in rural areas. The literacy rate in Pakistan, which was estimated at 59 percent (70 percent male and 48 percent female) during 2015-2016, is still behind other countries of the region. Pakistan's economy is characterized by a predominance of agriculture a strong industrial base with a large domestic market and an ample supply of skilled human resources. In general, Pakistan has a well-developed physical infrastructure and good communication facilities.

1.1 Agriculture

Agriculture is the lifeline of the Pakistan economy. In 1947, agriculture was the dominant sector of the country. Its share in the GDP has fallen considerably since then, while the share of manufacturing, construction and services has risen. Although agriculture's share in the GDP has declined considerably between 1949-50 and 2016-2017, from 53 percent to 19.53 percent, yet it remains an important sector of the economy. The employment share of agriculture has declined by far the less (from 66 percent to 42.3 percent) over the same period[4].

In terms of contribution to national income, employment, markets for industry and supply of raw materials or products for export, agriculture remains the foundation of Pakistan's economy[5,6]. Agriculture sector thus plays a pivotal role in national development, food security and poverty reduction. It is the major contributor in the overall export earnings of Pakistan. Agriculture and agro-based products also account for approaching two-thirds of the total foreign exchange earnings from exports. They supply many of the major industries with the raw materials and consume around one third of the industrial finished goods. The share of food group alone in the total export of Pakistan for 2014-2015 stood at 17.5 percent[7].

Agriculture is equally important to industrial development as it provides raw material for several value-added industries. Out of about 5,000 industrial establishments in Pakistan, about 60 percent are agro-based. The rapid growth of Pakistan's urban areas indicates that demand for high-value perishable products such as fruits, vegetables, dairy and meat is on the rise. Government is focusing on increasing the yield for rural growers through major infrastructure investments, including reliable transport networks and other building blocks for modern supply chains. China Pakistan Economic Corridor (CPEC) will contribute immensely to the enhancement of agribusiness benefits by tapping value-added product innovation and supply chain[8].

The total geographical area of Pakistan is 79.61 million hectares, out of which Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh Provinces have 34.72, 10.17, 20.63 and 14.09 million hectares areas, respectively. Table1 gives the land utilization statistics of Pakistan. Pakistan's agriculture mainly depends on the canal irrigation system. Out of the total cultivated area of 22.08 million hectares, 19.28 million hectares (87.3 percent) are irrigated and the balance 2.8 million hectares (12.7 percent) are rainfed[9].

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4 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25.

5 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25.

6 Anon., (2016). Agricultural Statistics of Pakistan 2014-2015. Economic Wing, Ministry of National Food security and Research, Government of Pakistan, Islamabad, May.

7 Anon., (2016). Agricultural Statistics of Pakistan 2014-2015. Economic Wing, Ministry of National Food security and Research, Government of Pakistan, Islamabad, May

8 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25

9 Anon., (2016). Agricultural Statistics of Pakistan 2014-2015. Economic Wing, Ministry of National Food security and Research, Government of Pakistan, Islamabad, May

Table 1: Land Utilization Statistics of Pakistan, 2014-2015 (Million ha) (P)

Province	Geographical Area	Total Area (4+5+6+7)	Forest Area	Not Available for Cultivation	Culturable waste	Cultivated Area (8+9)	Current Fallow	Net Area Sown	Area Sown More Than once	Total Cropped Area (9+10)
1	2	3	4	5	6	7	8	9	10	11
Punjab	20.63	17.50	0.49	2.97	1.52	12.52	1.89	10.63	5.88	16.51
Sindh	14.09	14.10	1.03	6.29	1.60	5.18	2.80	2.38	0.84	3.22
Khyber Pakhtunkhwa	10.17	8.45	1.31	4.01	1.25	1.87	0.61	1.28	0.60	1.88
Balochistan	34.72	17.94	1.72	9.83	3.88	2.51	1.45	1.06	0.01	1.06
Pakistan	79.61	57.99	4.55	23.10	8.25	22.08	6.75	15.35	7.33	22.67

Note: (P) - Provisional

Wheat, rice, cotton and sugarcane are the major crops in Pakistan. Wheat crop is grown in Rabi (winter) along with oilseeds, coarse grains and pulses. The most important Kharif (summer) crops are cotton and rice, depending upon the ecological zone. The busiest periods in farming occur between April and June, and October and November, when harvesting of the major crops overlaps with land preparation for the next crop. The power and labor constraints are felt most severely where water availability permits double cropping on the same land. The area, production and yield of the four major crops are given in Table 2[10]. The share of cropped area has changed over time (Table 3)[11].

Table 2: Area, Production and Yield of Major Crops in Pakistan, 2016-2017(P)

Crop	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)
Wheat	9,052	25,750	2,845
Cotton	2,489	10,671*	730**
Rice	2,724	6,849	2,514
Sugarcane	1,217	73,607	60,428

Note: (P)- Provisional

* '000 bales ** Lint

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Table 3: Distribution of Cropped Area in Pakistan (Percent of cropped area)

Crops	1959-60	1969-70	1979-80	1989-90	1999-2000	2009-2010	2014-2015
Food Crops	54.8	58.3	56.0	54	56	58	62
Cash Crops	12.1	14.5	14.9	16	18	18	19
Pulses	11.6	8.0	8.1	7	6	6	5
Oilseeds	4.1	3.2	2.8	2	3	3	3
Vegetables	0.7	0.7	0.8	1	1	2	1

10 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25

11 Anon., (2016). Agricultural Statistics of Pakistan 2014-2015. Economic Wing, Ministry of National Food security and Research, Government of Pakistan, Islamabad, May

Crops	1959-60	1969-70	1979-80	1989-90	1999-2000	2009-2010	2014-2015
Condiments	0.3	0.3	0.6	1	1	1	1
Fruits	0.6	1.2	1.5	2	3	4	3
Others	15.8	13.7	15.1	17	11	9	6

Note: N.B. vegetables include potatoes

Food grains : wheat, rice, jowar, maize, bajra and barley.

Cash crops: sugarcane, cotton, tobacco, sugar beet, jute and guarseed.

Pulses: gram, mung, mash, masoor, mattar, other kharif and rabi pulses.

Oilseeds: rapeseed & mustard, sesame, groundnut, linseed, castor seed& other oilseeds.

Condiments: chilies, onion, garlic, coriander, turmeric and ginger.

1.2 Agricultural Mechanization

Agricultural mechanization is an important input in modern agriculture. It improves productivity of land and labor besides increasing cropping intensity and helping in ensuring timely crop stand establishment, cultural practices, harvest and reduction in post-harvest losses. A transition from subsistence to commercial farming can be achieved through the diffusion of modern, efficient, cost-effective mechanization technologies to the food production systems. The efficient use of scarce agricultural resources coupled with sustainable agricultural mechanization is, therefore, of extreme importance[12].

Agricultural mechanization has been selective in Pakistan. Only those operations, which subject to labor or power constraints are mechanized. The effects of mechanization have, overall, been positive. It has not only increased on-farm income and labor productivity but also generated off-farm employment in manufacturing, supply, servicing of agricultural machinery, supply of other inputs and post-harvest handling of increased agricultural production[13].

The most popular forms of agricultural machinery in Pakistan include bulldozers, power rigs, tube wells and tractors with cultivators, wheat threshers, sprayers and trailers. Mouldboard plough and disc plough for deep tillage are gaining popularity. Bulldozers and power rigs are operated and maintained by the public sector on subsidized rates to the farmers whereas tractors and other machines are owned generally by large and medium sized farmers themselves. The medium-sized farmers provide in general, their tractors and other farm machines on rental basis to their neighboring small farmers in addition to their own use[14].

Table 3 shows population of tractors and important tractor operated machinery available in the country according to census of 2004[15] compared with those of 1975, 1984 and 1994. It reflects increasing trends of their use.

Table 4: Ownership of Selected Tractor Drawn Machinery in Pakistan (Numbers)

Machinery	Census Year			
	1975	1984	1994	2004
Tractor	35,714	157,310	252,861	401,663
Cultivator	31,619	146,863	236,272	369,866
Mold Board Plough	2,734	7,319	28,413	40,050
Bar / Disc Harrow	2,373	8,140	13,233	23,764
Disc Plough	2,938	6,355	20,372	29,218
Drill /Planter	1,174	11,251	64,126	70,810
Ridger	1,174	4,711	10,987	71,338
Trailer	18,074	98,787	176,412	242,655
Thresher	5,635	78,377	112,707	137,270

At present, most of the crop production operations including tillage and seedbed preparation are partial to fully mechanized in Pakistan except for sowing operation of sugarcane, rice and maize on furrows which are performed mostly by manual labor. The harvesting operation of cotton and sugarcane is also not yet mechanized (Table 4).

12 Anon., (2005). Medium Term Development Framework 2005-2010. Planning Commission, Government of Pakistan, Islamabad, May

13 Anon., (1988). Report of the National Commission on Agriculture. Ministry of Food, Agriculture and Cooperatives, Government of Pakistan, Islamabad

14 Amjad, N.; Shahid, L.A.; Ahmad, T. and S.A. Kalwar (2011). Agricultural Mechanization in Pakistan: ABEI Contributions. Proceedings of the International Seminar on Role of Agricultural Machinery on Poverty Alleviation and Food Security in Pakistan, held at University of Agriculture, Faisalabad, pp. 71-78, 21-26 March

15 Anon., (2005). Agricultural Machinery Census 2004. Statistics Division, Ministry of Finance Economic Affairs, Agricultural Census Organization, Lahore

Table 5: Mechanization Status of Crop Production Operations in Pakistan

Crop	Land Preparation	Sowing	Irrigation	Spraying	Inter-culture	Harvesting	Threshing
Wheat	Highly	Low	Semi	Low	Nil	Semi	Highly
Cotton	Highly	Semi	Semi	Highly	Highly	Nil	-
Rice	Highly	Nil	Semi	Low	-	Semi	Semi
Sugarcane	Highly	Semi	Semi	Semi	Semi	Nil	-
Maize	Highly	Semi	Semi	Low	Semi	Low	Highly
Potato	Highly	Semi	Semi	Highly	Highly	Semi-	-
Pulses	Semi	Semi	Low	Low	Low	Low	Highly

Free market and globalization challenges have called for modernization of the agricultural sector. The role of mechanization is critical for efficient and profitable agriculture. It also serves a crucial role in the promotion of climate-smart agriculture by enhancing water productivity, precision agriculture, efficient harvest and post-harvest operations, value addition and product development. Mechanization level achieved so far in Pakistan has benefitted agriculture in terms of increasing cropping intensity, timeliness of farm operations, reducing harvest and post-harvest losses and addressing labor scarcity and food security issues. However, in order to become competitive, there is a strong need to gradually shift to advanced level of mechanization.

In private sector, tractor manufacturers have made significant contribution in the indigenization of tractors by deleting substantial quantities of imported components under joint venture. Local manufacturing of tractors has not only saved foreign exchange but also provided employment opportunities by establishing assembly lines at tractor manufacturers' premises and through vending industries. There were five firms that were licensed initially for assembly/local manufacturing of tractors in collaboration with the foreign firms of different makes, namely; Massey Ferguson, Fiat, Belarus, Ford and IMT. At present, there are eight tractor manufacturers (Table 5) with total installed capacity of 91,000 per year[16]. There are, however, mainly two firms (M/s Millat Tractors and M/s Al-Ghazi Tractors) which are engaged in manufacturing of tractors in Pakistan with their combined annual installed manufacturing capacity of 65,000 units. These manufacturers have achieved around 90% deletion of their popular models. The total tractors sales in calendar in Pakistan for the years 2016 and 2017 are reported around 42,500 and 61,000(as of 4 December 2017), respectively.

Table 6: Status of Tractor Industry in Pakistan

No.	Tractors	Capacity	2009-10	2010-11	2-11-12	2-12-13	2013-14	2014-15
1	Millat Tractors (Massey Ferguson)	40,000	40,177	42,188	32,003	32,003	21,600	28,105
2	Al-Ghazi (Fiat/CNH)	25,000	31,430	28,582	16,117	18,856	11,920	16,647
3	Universal	3,000	121	85	31	12	3	0
4	Hero Motors	3,000	772	1,017	538	792	409	0
5	Farm-All	3,000	14	0	166	140	74	-
6	Arzoo Tractors	3,000		0	0	0	40	0
7	PM Auto Industry	5,000	475	389	43	163	206	0
8	Orient Tractor	9,000				11	1,001	1,110
	Total	91,000	72,989	72,261	48,898	51,977	35,253	45,862

The domestic tractor industry has played a significant role in fulfilling the requirement of low-cost tractors to farmers. The growth of tractor industry up to 2010-11 can be attributed to a trend toward greater mechanization in agriculture in Pakistan, high indigenization level and

16 Anon. (2016). Automotive Development Policy 2016-2021.Engineering Development Board, Ministry of Industries and Production, Government of Pakistan, Islamabad, 21 March

occasional government subsidy schemes to support agriculture sector. However, from 2011-12 to 2013-14, production volumes dropped significantly, mainly due to uncertainty in the market because of frequent changes/imposition of Sales Tax (Table 6)[17].

Table 7: Year-Wise Detail of GST on Tractor Industry in Pakistan

Time Period	GST (%)	No. of Months
March – June 2011	17	4
July 11-Jan 2012	16	7
Feb 12-Dec 2012	5	11
Jan 13-Nov 2013	10	11
Jan 14-June 2014	16	6
June 2014-onwards	10	14

At present, there are around 570,400 operational tractors available in Pakistan; 92% have cultivator, 30% have MB plough, 15% have disc plough, 5% have chisel plough, 15% have rotavator, 25% have disc harrow, 5% have ridger and 20% have seed drill. Total farm power available in Pakistan is 1.11 kW/ha excluding tube wells and 1.53kW/ha including tube wells, which is low compared to other comparable economies of the region.

There were 15 farm machinery manufacturers in 1959. As a result of liberal government policies such as the rebate on import duty for raw material, exemption/reduction of sales and income tax, their number increased to around 600. Local farm machinery industry is producing farm implements/machines for land development, seedbed preparation, crop stand establishment, inter-culture, harvesting and threshing, crop protection and farm produce haulage.

The organizations dealing with the issues related to agricultural mechanization in Pakistan include: Ministries of National Food Security & Research, Industries and Production; Science and Technology; Commerce and Textile; Planning, Development and Reforms; Research and Development institutions, mainly Agricultural & Biological Engineering Institute (ABEI), NARC, Islamabad under Pakistan Agricultural Research Council (PARC) at Federal level, Agricultural Mechanization Research Institute (AMRI), Multan under Government of Punjab, Agricultural Mechanization Research Cell (AMRC), Tandojam under Government of Sindh, Centre for Agricultural Machinery Industries, Mian Channun under Government of Punjab and Agricultural Light Engineering Program (ALEP), Mardan under Government of Khyber Pakhtunkhwa; agricultural machinery manufacturers; financial institutions; federal and provincial autonomous bodies; provincial directorates of agricultural engineering; and, agro-services providers.

Both ABEI and AMRI are involved in testing and evaluation of local and imported farm machines, development of new machines/adaptation of imported machines to local conditions, improvements in locally manufactured machines and provision of technical assistance to local farm machinery manufacturing industry. Salient achievements of the ABEI and AMRI are summarized in Table7.

17 Anon. (2016). Automotive Development Policy 2016-2021.Engineering Development Board, Ministry of Industries and Production, Government of Pakistan, Islamabad, 21 March

Table 8: Mechanization Technologies Developed and Commercialized by the R&D Institutions in Pakistan

Description	Agricultural & Biological Engineering Institute (ABEI), NARC, Islamabad	Agricultural Mechanization Research Institute (AMRI), Multan
Mechanization technologies developed and commercialized	Tractor front mounted reaper-windrower, groundnut digger,groundnut thresher, sunflower thresher, soybean thresher, paddy thresher, pneumatic row crop planter, zero-till drill, fertilizer band placement drill, canola thresher, wheat straw chopper-cum-blower, milking machine, mobile seed processing unit and olive oil extractor.	Seed drills, planters, ridger, bed shaper, weeders, wheat thresher, rotaryslasher, potato planter, groundnut digger, maize sheller, rotary tiller, boom sprayer, fertilizer spreader, axial flow pump, seed cleaner grader, hand dibbler, furrow bed shaper planter, soil hard pan tester, bullock drawn implements, and mobile bhoosa chopper and baler.
Mechanization technologies being developed	Pak seeder, PTO disk plough, vegetable planter, turmeric dryer, solar-cum-gas fired dryer, solar tunnel date dryer, mini seed cleaner-cum grader, flat bed dryer for canola, sunflower, maize& groundnut, mango picking & pre-cooling machine, nursery raising plant, hot-water treatment plant for eradicating mangoes fruit fly infestation, wood shredder, maize fodder cutter and shredder, mobile high capacity sugarcane crusher and psyllium processing machinery.	Trencher, fodder cutter bar, sugarcane base cutter, pneumatic drill, rotary ditcher, briquetter, ejector pump, biogas plant, groundnut sheller, seedbed finisher, stubble shaver, and orchard sprayer.

1.3 Challenges and Opportunities for Agricultural Mechanization

Agricultural mechanization is primarily limited to crop production in Pakistan. The available farm power in Pakistan is around 1.11 kW/ha excluding tube wells. At the same time, tractor power is underutilized due to non-availability of a complete set of machines with individual tractor owners at an affordable cost. The existing custom hiring services for farm machinery are inadequate. Wheat production in the country stands substantially mechanized; however, production of rice, maize, cotton, sugarcane, vegetables and fruit remains partially mechanized. Wheat and rice harvesting are achieved using imported old combine harvesters. Farmers have no access to modern machinery such as rice transplanters, vegetable planters, fruit pickers, cotton pickers, sugarcane harvesters, potatoes diggers-cum-shakers, orchard pruning equipment etc. There is a partial adoption of greenhouses and other advanced techniques for vegetable production. The use of solar energy for high-efficiency irrigation system under water stressed environment has a great potential for adoption. The equipment used for farm level value addition is almost non-existent, thereby resulting in high post-harvest losses and low level of value addition at community level.

The key constraints in the farm level mechanization include: inefficient utilization of available tractor power; slow rate of adoption of high efficiency irrigation systems; low manufacturing focus on small-scale value-addition machinery to reduce post-harvest losses; use of inefficient second-hand combine harvesters; dearth of machinery for small-scale dairy farming; lack of standardization for quality enhancement of farm machinery; and, non-availability of complete package of agricultural machinery at community level.

Small and large landholdings are posing a challenge to mechanization. Small farmers have low purchasing power, while most large landholders generally do not invest that much in mechanization technologies. There is a dearth of repair workshops in rural areas consequently farmers travel long distances to get their machinery repaired. Sugarcane harvesters and cotton pickers are complex and expensive machines to be owned by individual farmers. Moreover, farmers are reluctant to bear losses, which may result the inefficient usage of these machines. Poor quality of locally produced machinery is another constraint for mechanization.

At present, farm mechanization is limited to crop production. Its scope needs to be expanded to introduce technologies for proper drying and storage of grains, and processing units for value addition to agricultural produce at the farm/village level. There is great potential to export fruit and vegetables if efforts are made in their proper curing/pre-cooling, sorting/grading and packaging at farm/community level.

The private sector should also focus on having their own R&D facilities to meet the obligation of product quality at competitive prices. They should be encouraged to have qualified and experienced human resource at their strength and allocate adequate percentage of their turnover for R&D work. The public-sector R&D institutes should also be upgraded and focus on market-driven issues, and such institutes need to be established in each province.

There is a good business opportunity in establishing central facilities for the manufacturing of specialized/critical components like gears, sprockets, wearing parts of soil-engaging parts to promote quality in agricultural machinery manufacturing besides creating job opportunities for skilled workforce.

Joint venture avenues for local production of specialized machinery like rotavator, disc plough, vegetable and paddy transplanters, combine harvester, sugarcane harvester and cotton picker need to be explored with attractive government incentives such as soft term loan, import duty relaxation and tax holidays. This will help in upgrading mechanization level, attracting foreign direct investment, and creating employment opportunities in this sector.

Farm machinery being an expensive input, encourages setting up of rental service centers for their easy access. This will promote the widespread use of agricultural machinery for land preparation, seeding, planting, transplanting and harvesting of sugarcane, maize, wheat, rice and cotton crops etc.

The Long-Term Plan (2017-2030) set under the China-Pakistan Economic Corridor (CPEC) gives a comprehensive framework for bilateral cooperation between China and Pakistan, particularly towards industrialization, value-addition, and job creation. Investments would resultantly flow to the special economic zones envisaged across Pakistan. These zones aim at increasing yields and benefiting farmers. Establishment of the state-of-the-art agricultural and food processing facilities in these zones will not only help in increasing output and efficiency but also enable Pakistan to export agricultural products to China and other lucrative destinations including the Middle East[18].

II. Agricultural Mechanization Strategy

Policies are developed by the government to achieve specified objectives. Strategies define the way in which policies are to be implemented. With the emphasis towards market liberalization and the recognition that the private sector is among the most important actors to play its part in the development of an economy, Agricultural Mechanization Strategy (AMS) formulation emphasizes the creation of enabling environment for the adoption of appropriate farm tools, implements and machinery in most effective and efficient way. The output of an AMS consists largely of policy and institutional recommendations and reforms but may also include specific programs and projects. In a dynamic situation, enabling environment change over time and therefore, an AMS will need to be regularly refined, revised and adjusted; an AMS should therefore, be dynamic[19].

2.1 Historical Perspective

The Food and Agriculture Commission of 1960 considered the scope of introducing mechanization in Pakistan but cautioned against the possibility of displacement of human labour by machinery. Farm Mechanization Committee appointed by the government of Pakistan in 1968, which was set up for investigating various problems associated with farm mechanization, analyzed the agricultural system and recommended programs for 5, 10 and 15 years.

The role of farm mechanization in boosting agricultural production was also recognized in the Sixth Five Year Plan (1983–1988). The National Commission on Agriculture set up in April 1986 also stressed the need for farm mechanization while formulating its recommendations[20].

RNAM also issued guidelines in formulating policies and strategies, catalyzed the conduct of national workshops and disseminated information on agricultural mechanization policies and strategies to the participating countries including Pakistan. RNAM conducted a workshop on planning, policies, and strategies on agricultural mechanization in 1983, which was followed by a

18 Anon. (2017). Top Cooperation body okays CPEC Long-Term Plan. Daily 'Dawn', Islamabad, 22 November

19 http://www.un-csam.org/publication/CIGR_APCAEM_Website.pdf

20 Anon., (1988). Report of the National Commission on Agriculture. Ministry of Food, Agriculture and Cooperatives, Government of Pakistan, Islamabad

training workshop on the same subject in 1986. It recommended systematic planning and implementation of mechanization programmes and projects, through various technical advisory meetings, regional workshops, and advice from mechanization experts.

In the early 1990s, the National Agricultural Policy of Pakistan placed due emphasis on farm mechanization. The following six main issues related to farm mechanization were highlighted in the policy document:

1)Appropriate mechanization; 2)dependence of tractor sales on institutional credit; 3)limited use of farm implements; 4)quality of locally produced farm equipment; 5)optimum irrigation water use; 6)post-harvest practices.

The above issues were raised very timely, and the following five steps were proposed in the action plan to address the issues: A minimum package of implements specified according to agro-ecological zones would be made mandatory with the purchase of tractors through credit. Incentives should be provided to the farmers willing to adopt newly developed equipment/technologies like sprinkler/drip equipment, hydra ramp pumps, mechanical rice transplanters, combine harvesters, post-harvest equipment etc. Incentives should be provided for the establishment of agro-services rental centres in the public and private sectors. Farm machinery training centres in public/private sectors should be strengthened. Steps should be taken to encourage the setting up of agricultural machinery repair workshops by local artisans at the village level.

Moreover, FAO also developed Sustainable Agricultural Mechanization Strategies for Asia-Pacific Region during 2014.[21] However, Pakistan was not considered in the strategy formulation process.

2.2 Results from Implementation

1. Government of Pakistan reduced tariff (custom and excise duties) on the import of agricultural machinery from 30% to 9% in the financial year budget 2015-16.
2. On the recommendation of MNFS&R, the Government of Pakistan allowed the import of specified agricultural machinery and equipment with reduced custom duties ranging from 0% to 5% to create healthy competition among the local agricultural machinery manufacturing industry[22].
3. The list of specified agricultural machinery included: tractors, combine harvesters, horticulture and floriculture machinery, irrigation draining equipment, greenhouse farming equipment, land leveling, bulldozers, angledozers, laser land levelers, land planners, seeding and planting machinery, pneumatic planters, transplanters, vegetable seedling transplanters, high efficiency irrigation and drainage equipment, dairy, livestock and poultry machinery etc[23].

III. Lessons Learned and Good Practices

- There were 15 farm machinery manufacturers in 1959. As a result of liberal government policies such as the rebate on import duty for raw material, and the exemption/reduction of sales and income tax, the number of farm machinery manufacturer increased to around 600.
- The import of agricultural machinery has witnessed a significant growth of 25.6% during FY 2016-17 (July-March) compared to the corresponding period of previous year as customs duty on import of harvesters and planters was reduced to zero to promote mechanized harvesting and planting operations in the country[24].
- The growth of the tractor industry can be attributed to a trend towards greater mechanization of agriculture in Pakistan due to holiday in different government taxes on tractors and other agricultural machinery, high localization level and occasional government subsidy schemes to support agriculture. However, production volumes dropped significantly mainly due to uncertainty in the market because of frequent changes/ imposition of Sales Tax (Table 6).
- During 2016-17 (July-March), a total number of 37,634 tractors were locally manufactured compared to the production of 21,229 during the same period last year, witnessing a significant increase of 77.3 percent as the GST on locally manufactured/ imported tractors have been reduced from 10 percent to 5 percent that has increased the demand of tractors[25].

21 Anon. (1987). Policies and Strategies for Agricultural Mechanization in RNAM Participating Countries. Regional Network for Agricultural Machinery, University of the Philippines at Los Banos, the Philippines, April

22 The Fifth Schedule (Part-I). Imports of Plant, Machinery, Equipment and Apparatus, including Capital Goods for various industries/sectors, Federal Board of Revenue, Government of Pakistan, Islamabad

23 The Fifth Schedule (Part-I). Imports of Plant, Machinery, Equipment and Apparatus, including Capital Goods for various industries/sectors, Federal Board of Revenue, Government of Pakistan, Islamabad

24 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25

25 Wasti, Ejaz S., et al (2017). Pakistan Economic Survey 2016-2017. Economic Adviser's Wing, Finance Division, Government of Pakistan, Islamabad, May 25

- Renting of tractors with tillage implements, sprayers, and wheat threshers by individual farmers to their neighbors increased.
- Renting of combine harvesters by custom hiring companies was also enhanced.
- The Government of Khyber Pakhtunkhwa has set up Model Farm Service Centers at the district level which besides the facilitation of provision of other agricultural inputs, provide agricultural machinery services to the small farmers.
- Sindh and Punjab Governments have provided subsidies occasionally on farm machinery to selected farmers.
- The details of subsidies provided, for instance by the Government of Punjab, for the provision of improved farm implements to the tractor owner farmers are given in Table 8.

Table 9: Provision of Farm Machinery to Farmers on 50% Subsidy by Government of Punjab, Pakistan

No.	Year	Machinery	Amount (PKR*Million)
1.	2015-17	Rotavator, Disc Harrow, Chisel Plough, Seed Drill and Sugarcane Ridger	1145
2.	2010-11	Wheat Straw Chopper-cum-blower	31.5
3.	2008-10	Rotavator, Disc Harrow, Chisel Plough, M.B. Plough, Coulter Drill, Rota Drill, Groundnut Digger, Reaper-windrower, Potato Planter, Potato Digger, Sugarcane Planter, Sugarcane Ridger, Vegetable Ridger, Maize Sheller, Citrus Sprayer and Dogger Cutter	459

Note: * 1 USD = 106 PKR

- The Government of Punjab has developed a project titled as 'Establishment of Hi-Tech Mechanization Service Centers (HMSCs)' for the implementation on cost sharing basis with the private sector. The overall objective of the project is to provide modern farm machinery and equipment on a rental basis to the farmers in all the districts of Punjab in two phases through these centers. The total cost of the project is PKR 3,830.205 million. These centers will be operated by the private sector.
- For providing more access to small and medium farmers to mechanization technologies, Zarae Taraqiyati (Agricultural Development) Bank of Pakistan and most of the commercial banks are providing credits for the purpose. Five major banks as a group have disbursed Rs 236.6 billion or 69.6 percent of its annual target, ZTBL disbursed Rs.57.5 billion or 56.1 percent of its target of Rs.102.5 billion while Punjab Provincial Cooperative Bank Limited disbursed Rs.6.9 billion i.e. 55.1 percent against its target of Rs.12.5 billion during the period under review.
- The National Food Security Policy has been drafted during 2017 with a view to reduce poverty, promote sustainable food production systems (crop, livestock, and fisheries) by achieving an average annual growth rate of 4% and making agriculture more productive, profitable, climate-resilient and competitive. It was considered necessary to enhance productivity of crops by extending the supply of essential agricultural inputs such as seed, fertilizers, pesticides and credit. Moreover, the means to enhance irrigation water availability and its efficient use besides enhancing the pace of agricultural mechanization in the country are also emphasized. The policy measures suggested related to mechanization include[26]:

  - Reduction in duties and taxes on the import of farm machinery in short to medium term.
  - Reduction in GST on sale of farm machinery to enhance the pace of farm mechanization.
  - Develop efficient farm mechanization and processing technologies to reduce the cost of production, enhance the timeliness of operations, add value to crops and reduce post-harvest losses at farm level.
  - Promotion of precise agriculture for profitable production.
  - Incentives for import of machinery for hay/silage making, milking, dairy, and meat products.
  - Aquaculture mechanization for intensive production, processing, and maintaining cold chain.
  - Persuasion for the establishment of a 'National Center for Testing of Agricultural Machinery (NCTAM)' with regional/provincial satellite institutions in the country.

26 Khan, Abdul Shakoor and M. Farooq (1993). Strategies for implementation of agricultural mechanization policies in Pakistan, Journal of Science Technology and Development, Vol. 12 No. 2, April-June, Pages: 10-18

- Development of the National Network of Agricultural Mechanization to coordinate agricultural mechanization R&D in the country.
- Promotion of the use of alternative and renewable energy sources at farm level.
- Establishment of machinery pools as farm-services centers by provinces in private sector.
- Promotion of innovative practices that increase yields and soil fertility (e.g. Hydroponic Agriculture) for profitable production.
- Incentivizing industry for manufacturing quality farm machines.
- Indigenization of economically viable farm mechanization technologies.
- Mechanization/processing/value addition through cluster approach.

IV. Suggestions for Regional Cooperation among Countries

- A sub-network of CSAM member countries in need of developing their agricultural mechanization strategies should be developed.
- The policy advisory services needed by these member countries for the formulation of their Agricultural Mechanization Strategies (AMSs) should be provided by CSAM.

Philippines

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I. Introduction

The Philippines is still an agricultural-based economy with an estimated total population of 103.5 million Filipinos living and deriving food from an estimated 10,188 square kilometers of agricultural land and 1,830 square kilometers of water. About 11.29 million Filipinos or 29% of the total share of employment in the country are in the agricultural sector, of which 8.39 million are men and 2.90 million are women. They are providing agricultural products for food, feed, fiber and alternative fuel that contribute to about 9% of the total gross domestic product of the country. The major staple foods of Filipinos are rice and corn while other major products are sugarcane and coconut. The Philippines ranked 8th in terms of the total rice production area of 4.5 million hectares. However, it also ranked 11th among the top 15 countries depending on rice importation to feed its population. Figure1 shows the country's land distribution of agricultural area and type of utilization while Table 1 presents the agricultural background of the Philippines (Country Stats Philippines, 2017).

Figure 1: The Philippine Map
Source: Country Stats, Philippines accessed November 2017

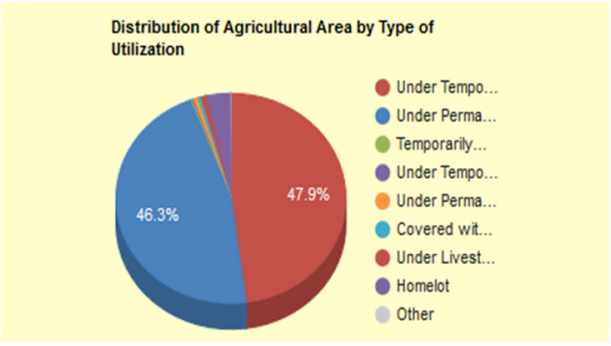

Figure 2: Land Distribution of Agricultural Area and Type of Utilization, Philippines
Source: Country Stats, Philippines accessed November 2017

Table 1: Agricultural Background of the Philippines

Location:	Southeastern Asia, archipelago between the Philippine Sea and the West Philippine Sea, east of Vietnam
Area:	total: 300,000 square kilometers
	land: 298,170 square kilometers
	water: 1,830 square kilometers
All Farms/Holdings:	7.190 million hectares
Under Temporary Crops:	3.444 million hectares
Under Permanent Crops:	3.329 million hectares
Temporarily Fallow:	0.014 million hectares
Under Temporary Meadows and Pastures:	0.014 million hectares
Under Permanent Meadows and Pastures:	0.044 million hectares
Covered with Wood and Forest:	0.033 million hectares
Under Livestock and Poultry Raising:	0.057 million hectares
Under Aquaculture:	0.002 million hectares
Other Main Use of Farm/Holding Parcels:	0.005 million hectares
Homelot:	0.240 million hectares

Source: Country Stats, Philippines accessed November 2017

The introduction of suitable, appropriate, innovative, gender sensitive, and resilient agricultural and fisheries mechanization technologies (AFMTs) will, among others, enable the agri-fishery sector to open up other areas for agricultural productivity. These AFMTs could: 1)contribute in full utilization of products and by-products; 2)cultivate on a sustained production of uplands, hilly lands, swamplands and other non-arable lands; 3)intensify and diversify farming systems which will, in turn, generate employment; 4)reduce or minimize postharvest losses; 5)increase the value added to farm and fishery products through secondary and tertiary processing; 6)help bring equity among Filipinos in the access to basic production resources.

Based on RA 10601 otherwise known as the Agricultural and Fisheries Mechanization Act of 2013, agricultural and fisheries mechanization are refered as the development, adoption, assembly, manufacture and application of appropriate, location specific and cost-effective agricultural and fisheries machinery using human, animal, mechanical, electrical, renewable and other nonconventional sources of energy for agricultural production and postharvest/ postproduction operations consistent with agronomic conditions and for efficient and economic farm and fishery management towards modernization of agriculture and fisheries.

Table 2: The Philippines, Country Background

Item	Description	Data
Geographical location	Latitude :	NL: 4.7 o N SL: 21.5 o N
	Longitude:	EL : 117 o E WL:127 o E
Meteorological conditions	Temperature	Min. 26.1 o C Max. 28.4 o C
	Annual precipitation	2000 mm/year
Agricultural Conditions	Total area	300,000,000 km2
	Total land area	298,170,000 km2
	Total water area	1,830,000 km2
	Agricultural land (2015)	10,187,678km2
	Temporary crops	3,444,000 km2
	Permanent cropland	3,329,000 km2
	Agricultural farms (2002) All farm holdings (2015)	4,820,000 farms 7,190,000 km2

Item	Description	Data
Agricultural Conditions	Staple foods	RICE: (2015) Area harvested: 4.660 million ha Production: 18.150 MMT farm gate price: P18.04kg
		CORN: (2015) Area Harvested:2.560 million ha Production: 7.520 MMT farm gate price: P12.01/kg
	Other staples	Root crops and plantain
	Other major crops	Sugarcane, coconut
	Top export crops	Coconut Oil (23%), banana (13%), tuna (7%) pineapple & products (11%)
Population and Employment	Total population	103.500 million
	Total employment	38.74 million
	Employment in agriculture (2017)	11.29million (29 % employment share) Male:8.39 million Female:2.90 million
	Ave wage rates (2017) Agricultural sector	P267.47
Economy (2015)	GNI at current prices	P 16,115 billion
	GDP at current prices	P 13,322 billion (9% share from agriculture)
	GVA at current prices (agriculture and fishing)	P1,364 billion

Source: Countrystat. psa.gov.ph,(accessed November 2017).

With the new challenges described in the UN Sustainable Development Goals in 2015, the Philippines recognizes the important role of agricultural mechanization to address the interconnected goals on sustainable agriculture and empowering the small farmers to increase productivity. Hence, the acceleration of the use of AFMTs is being purposively implemented in the country. AFMTs should not only be technically-sound but should be well accepted and utilized by the different stakeholders in the food chain to achieved sustainable production. If we want to outrace the demand of the ever-growing population, the use of AFMTs should be given focus and a sound and sustainable agricultural mechanization strategy (SAMS) should be in place.

This paper aims to present the current level of agricultural mechanization in the Philippines and the different policies formulated for the acceleration of the diffusion and utilization of AFMTs in the country. It also includes some lessons learned and good practices applied during the implementation of such policies and suggestions for possible regional cooperation amongst Asia and Pacific countries.

Level of Agricultural Mechanization in the Philippines

One of the bases for the acceleration of the diffusion and utilization of AFMTs is the level of agricultural mechanization which is being represented by the Agricultural Mechanization Index (AMI). AMI is an indicative measure of the level of mechanization and has been the basis for agricultural mechanization interventions for the development of the agricultural sector. There are various methodologies in achieving AMI. In the Philippines, institutions involved in the promotion of AFMTs have different methodologies in expressing the AMI of the country. Moreover, Asia and the Pacific countries have also different methodologies in expressing their level of mechanization indicated by AMI.

In 2017, the Philippines initiated a policy study to harmonize the different methodologies being implemented worldwide. It was found out that at least six methodologies are being used to express AMI as presented in Table 3.

Table 3: Methodologies in Measuring the Level of Mechanization in Philippines

Methodology	Description	Equation
Horsepower per hectare	Sum of the contribution of each of the major sources of power multiplied by its assumed hp contribution divided by the total available area	$\frac{Horsepower}{Hectare}$
Percent Technology Utilization (Amongo et al. 2013)	Level of mechanization by type of technology (manual, man-animal power, man-machine power, combination of types of technology), by type of farm operation	$= \frac{Number\ of\ farmers\ using\ (type\ of)technology}{Total\ no.\ of\ farms\ responding} \times 100$
Percent Area Covered by Technology (Amongo et al. 2013)	Level of mechanization by type of technology (manual, man-animal power, man-machine power, combination of types of technology), by type of farm operation	$= \frac{'ea\ serviced\ by\ (type\ of)technology}{Total\ area\ of\ farms\ surveyed} \times 100$
Qualitative AMI Three major levels (UPLB-BAR, 2001)	Low mechanization means that an operation is done with the use of non-mechanical power source such as man and animal. Intermediate mechanization refers to operations done with the use of non-mechanical power source in combination with the use of a mechanical power source operated by man. High mechanization involves operations done solely with the use of mechanical power source operated by man.	
Number of tractors per hectare	Number of tractors utilized in a given unit area	$\frac{No.\ of\ Tractors}{100\ Hectares}$
Energetics (Chamsing, 2007)	Energy inputs: human labor, machinery, animal, seeds, irrigation, fuel, fertilizers and pesticides Direct input (energy from human labor, animal power, fuel and electricity for priming agricultural machinery) Indirect input (seeds, fertilizers and pesticides) Energy outputs: rice yield and husk	$\frac{Energy\ Output}{Energy\ Input}$

Sources: as cited in Amongo, et al. 2017

With these different methodologies, a Modified Agricultural Mechanization Index (MAMI) was formulated based on horsepower per hectare, which is the most common index used to express the level of mechanization. MAMI is now being considered by the Department of Agriculture to be used in the calculation of the level of mechanization in the country. MAMI will serve as a basis for the acquisition, distribution and utilization/adaption of AFMTs with the end goal of increasing the level of mechanization in the countryside for sustainable development. Table 4 shows the development of the level of mechanization in the Philippines with the new calculated index using MAMI.

Table 4: Agricultural Mechanization Index in the Philippines, 1968-2017.

Year	Ami (Hp/Ha)	Considerations	Source
1968	0.198	Rice-based farming system	RNAM (1994) as cited by PCAARRD, 2007. Mechanization Status. Agricultural Machinery Information Network.
1980s	0.360	Rice-based farming system	as cited by S.C. Capareda.1994. Issues and Trends in Farm Power and Machinery. Philippine Agricultural Mecha-nization Bulletin. Vol. II No.3. AMDP, CEAT, UP Los Baños.
1990	0.520	Rice-based farming system	RNAM, 1990. Technical Report. Economic and Social Commission for the Asia and the Pacific. Regional Network for Agricultural Machinery (ESCAP-RNAM).
1998	1.680	Rice and Corn based farming system utilizing human, animal and mechanical	Rodulfo, V.A. Jr., R.M.C. Amongo and M.V.L. Larona. 1998. Status of Philippine Agricultural Mechanization and Its Implications to Global Competitiveness. Philippine Agricultural Mechanization Bulletin. Vol. V No.1. AMDP, CEAT, UP Los Baños.
2010	1.500	Rice-based farming system utilizing single cylinder engines	Panagsagan, J.R. 2011. 2006-2010 Engine Sales Statistics Relevant to Determining the Level ofMechanization. Paper presented during the Harmonization Workshop on the Level of the Philippine Agricultural Mechanization. (presented by AMMDA)

Year	Ami (Hp/Ha)	Considerations	Source
2013	2.310 1.230	Rice-based farming system for all crops	R.SM. Dela Cruz, S.B. Bobier. 2013. Farm Power Available for Utilization in Philippine Agriculture. Unpublished Report. PHilMech (paper submitted for publication)
2017 (MAMIrice) Mindoro Oriental	3.915	Rice- based farming system Man-Machine system	Amongo RMC, M.V.L. Larona, M.K.S. Onal, CIL Ilao, GNL Lalap, LE Oguis & PB Melendez. 2017. Operational Procedure & Policy for the Standardized Agricultural Mechanization Index in the Philippines. Terminal Report. UPLB-BIOMECH-PCAF-DA project.

Source: Amongo, et al., 2017

II. National Agricultural Mechanization Policies and Initiatives

- **RA 8435. Agricultural and Fisheries Modernization Act (AFMA) of 1997**

RA 8435: An act prescribing urgent related measures to modernize the agriculture and fisheries sectors of the country in order to enhance their profitability and prepare said sectors for the challenges of globalization through an adequate, focused and rational delivery of necessary support services, appropriating funds therefore and for other purposes.

AFMA advocates the development and sustainability of the agri-fisheries sectors in accordance with the principles of: a) poverty alleviation and social equity; b) food security; c) rational use of resources; d) global competitiveness; e) sustainable development; f) people empowerment; and g) protection from unfair competition.

The law advocates an equitable distribution of the country's income and wealth, sustainable supply of its goods and services for the people; and an increased production performance as a significant factor to improve citizens' quality of life, especially living standards of the underprivileged. It generally aims to accelerate industrialization through agricultural development that make efficient use of human and natural resources.

Providing opportunities to all sectors of the economy (including private enterprises, corporations, cooperatives and other collective organizations) for improvement and enjoying the benefits of development shall be one of the major goals of the law.

The law prescribed measures for the major support services to modernize the agri-fisheries sectors, particularly on: 1) production and marketing support services; 2) credit; 3) irrigation; 4) information and marketing support services; 5) other infrastructures including public and private such as fish ports, seaports and airports, farm to market roads, common infrastructures, water supply system, research and technology infrastructures, research and technology facilities, public markets, abattoirs, and agricultural machinery.

Market approach strategies are to be utilized to support the agri-fisheries sectors, which are major contributors to the attainment of food security, environmental protection, and balanced urban and rural development. The welfare of the consumers, especially the lower income groups, shall be ensured. Further, farmers shall be encouraged to shift to more profitable crops.

- **RA 10601. The Agricultural and Fisheries Mechanization (AFMech) Law of 2013**

RA 10601: An act promoting agricultural and fisheries mechanization development in the country.

The AFMech Law is the most recent law implemented on agricultural and fisheries mechanization. It recognizes the significant role and contribution of agricultural mechanization to agricultural development. It provides the comprehensive legal framework for the distribution, supply, assembling, manufacturing, research, development and extension, promotion, regulation, use, operation, maintenance and project implementation of agricultural and fisheries machinery and equipment in the country (NAFMP-DA, 2017).

The law advocates the following: 1) the promotion of appropriate agricultural and fisheries mechanization technologies to increase agricultural productivity for food security and safety and increase farmers income; 2) improvement and the local assembling and manufacturing industry; 3) development and enforcement of standards, testing and evaluation, and registration of agricultural and fisheries machinery to ensure their quality and safety; and accreditation of suppliers, assemblers and manufacturers for their compliance to quality standards; 4) improvement of support services including marketing and credit facilities, research, training and extension programs, infrastructures, and postharvest facilities; 5) consolidation of agricultural and fisheries mechanization programs; and 6) provision of integrated support services to farmers and stakeholders for the successful operation and management of agricultural and fisheries mechanization projects.

The law directs the support and participation of the various stakeholders which include farmers/ fisherfolks and their associations or cooperatives, government line agencies, local government units, academic institutions, private agencies (local assemblers, manufacturers, suppliers, importers, cooperatives), and all other concerned agencies/ stakeholders (R.A. 10601 of 2013).

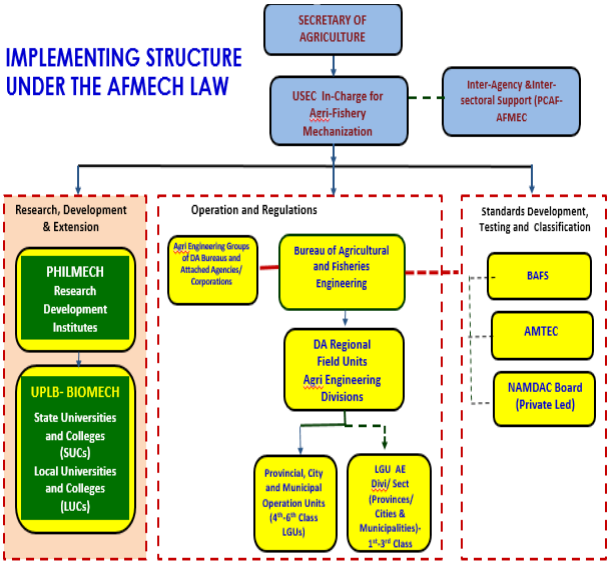

Figure 3: The National Agriculture and Fisheries Mechanization RDE Conceptual Framework 1 in Philippines
Source: NAFMP, 2016

Figure 2 presents the implementing structure of AFMech Law of 2013, while Figure 3 highlights the RDE agenda.

- **RA 10915. The Philippine Agricultural and Biosystems** Engineering (ABE) Act of 2016

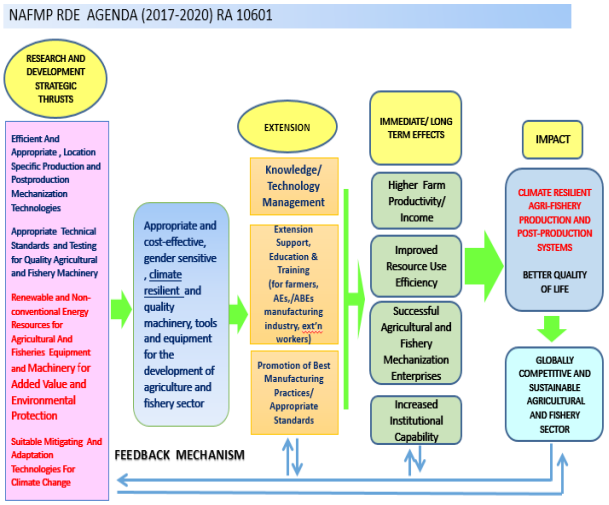

Figure 4: The National Agriculture and Fisheries Mechanization RDE Conceptual Framework 2 in Philippines
Source: Pasalo, 2016

RA 10915: An act strengthening, modernizing and aligning the practice of agricultural engineering in the country into the internationally recognized practice of agricultural and biosystems engineering, and for other purposes.

The law aims to strengthen the different areas of practice of the agricultural engineering profession through Career Progression and Specialization. It also encourages considerations for agro-industrial development, food security, bio-energy, and environmental protection program through proper recognition of the profession, appropriate work positions, and greater professional responsibilities. The law exerts efforts to strengthen the professionalization of the Philippine agricultural and environmental bureaucracy and increase productivity and efficiency in the agricultural farm operations. Other provisions of the law focus on: 1) updating of the education curriculum of the agricultural and biosystems engineering; 2) examination, registration of licensure of the practitioners; 3) development of the professional competence of the practitioners through continuing professional education; 4) accreditation of an integrated national professional organization; and 5) prohibition of foreign agriculture and biosystems engineer to be issued a temporary license to practice the agricultural and biosystems engineering profession unless his/her country of origin allows Filipino agricultural and biosystems engineers to practice in his/her country.

Consequently, with the enactment of the law, the BSABE program has been revised from a five-year to a four-year curriculum to conform and align with the rest of the universities in the world

offering the BSABE program and in line with the implementation of the K-12 program of the country. With its revision, the current Higher Education Institutions (HEIs) offering the traditional AE for five years will slowly be shifting to offer the revised 4-year BSABE program. Table 5 shows the distribution of HEIs offering the BSABE program.

Table 5: Distribution of HEIs Offering the BSAE Program in Philippines

Island Group	Region	Location of Heis		Heis (No.)
Luzon	NCR			1
	CAR	Benguet, Kalinga		2
	1 - Ilocos	Ilocos Norte, Ilocos Sur, La Union		3
	2 - Cagayan Valley	Cagayan, Isabela, Nueva Vizcaya,		3
	3 - Central Luzon	Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, Zambales		6
	4 -A- CALABARZON	Cavite, Laguna (2), Rizal		4
	4 -B- MIMAROPA	Oriental Mindoro, Palawan, Romblon		3
	5 - Bicol	Albay, Camarines Norte, Camarines Sur, Masbate		4
			Subtotal	**26**
Visayas	6 - Western Visayas	Capiz, Iloilo, Negros Occidental		3
	7 - Central Visayas	Bohol		1
	8 - Eastern Visayas	Eastern Samar, Leyte, Northern Samar, Western Samar		4
		Subtotal		8
Mindanao	9 - Zamboanga Peninsula	Zamboanga del Norte (2), Zamboanga del Sur		3
	10 - Northern Mindanao	Bukidnon, Misamis Occidental, Misamis Oriental		3
	11 - Davao Region	Compostela Valley, Davao del Norte, Davao del Sur		3
	12 – SOCCSKSARGEN	North Cotabato, South Cotabato,		2
	13 – Caraga	Agusan del Norte, Agusan del Sur, Surigao del Sur		3
	14 -ARMM -			0
			Subtotal	**14**
			Total	**48**

Source: Amongo et al., 2013

Operational Procedure & Policy for the Standardized Agricultural Mechanization Index in the Philippines

The project was implemented by BIOMECH, CEAT, UPLB and funded by the Department of Agriculture-Philippine Council for Agriculture and Fisheries in 2016. The general objective of the project was to formulate a national policy to indicate the agricultural mechanization index for rice crop production and postproduction systems in the Philippines. The project was implemented to address the need to have a standard agricultural mechanization index. Despite the recognition of the mechanization index as an indicator or measure of the country's level of mechanization, there has been no standard procedure or methodology for the computation or measurement of such. This deficiency creates difficulties in monitoring the level of mechanization from one period to another since the procedure of computation may vary from period to period. The level of mechanization in the Philippines had been measured more commonly in terms of hp/ha. Other common measures on the level of mechanization were in terms of percent utilization and percent area coverage as reported by survey respondents in terms of the different sources of power, namely, manual system, man-animal systems, and man-machine systems for each farm operation per type of crop. Another procedure which is gaining credence in expressing the level of mechanization is through the expression of the mechanization index in terms of energetics (Mega Joules/hectare) (Amongo et al, 2017). In spite of the existence of AMI values to express the level of mechanization in the Philippines from 0.198 hp/ha in 1968 (RNAM, 1994 as cited by Amongo et al., 2017) to 2.31 for rice –based farming system in 2013 (de la cruz, 2013 as cited by Amongo et al., 2017), as indicated in Table 2, it may be difficult to compare the values or measure the rate of

increase, since the procedure used in 1968 is not the same as the procedure in 2013.

The output of the project is a policy that will implement an operational procedure to measure agricultural mechanization index, particularly for the rice crop production and postproduction system of the country's regional administrative divisions. The procedure is a policy support for the government's mechanization program. It expected that the modified agricultural mechanization index (MAMI) should provide a basis for policy and decision makers to come up with well-informed decisions for the acquisition, distribution and utilization/adoption of agricultural mechanization technologies for various crops or commodity. The procedure will provide for the regular updating of mechanization index for research, development, extension activities, and policy decisions related to agricultural mechanization (Amongo et al., 2017).

Results from the implementation of the various laws related to agricultural mechanization

- **RA 8435. Agricultural and Fisheries Modernization Act (AFMA) of 1997**

A study conducted to assess the implementation of AFMA was published in a book entitled "Modernizing Philippine Agriculture and Fisheries: The AFMA Implementation Experience". The book, which was authored by economists and experts, noted that AFMA is a well-designed legal framework, but it had too ambitious goals that tried to do many things involving many agencies with a lack of resources for implementation. The study also noted that AFMA suffered many flaws as described below: (Catipay, A. BusinessWorld, June 20, 2008 http://www.gmanetwork.com/news/news/nation/102244/ agriculture-fisheries-law-does-too-much-for-too-little-study/story/:)

1. The budget allocation by components, in percentage terms, was not followed.
2. There was bias for production-support, to the detriment of marketing, research and development, human resources development, and interagency linkages.
3. There was little concern for regional priorities.
4. The need for sound criteria for project selection was not explicit.
5. The role of private investments in growth and job creation was not clear.
6. Program benefit monitoring and evaluation were severely inadequate, which in part hindered the ability of the review team to conduct more in-depth analyses.

- **RA 10601. The Agricultural and Fisheries Mechanization (AFMech) Law of 2013**

The implementation of AFMech induced the government's increased investment in the distribution of agricultural mechanization technologies throughout the country in support of the food security and sufficiency programs. Budget allocations for farm mechanization had increased from PhP1 Billion in 2011 to PhP2.4 billion in 2013. Further, the government's mechanization program targeted acquisition and distribution of significant numbers (in tens of thousands) of postharvest machines and on-farm machines. The program aimed at subsidizing 85% of the machine's acquisition cost, with 15% as the beneficiaries' equity (The Philippine Star, 2012 as cited by Amongo et al., 2017). The DA budget for mechanization further increased to PhP 2.69 billion in 2016 for the construction, procurement, and distribution of agricultural equipment, machines and facilities, while allocating PhP 1.29 billion for the construction, restoration and rehabilitation of small-scale irrigation facilities (Business Mirror, 2016 as cited by Amongo et al., 2017). The increasing trend in budget allocation for agricultural machinery acquisition and distribution indicated the strong government's stance to boost agricultural mechanization for agricultural productivity and food sufficiency.

The law requires the formulation of a five-year National Agricultural and Fisheries Mechanization Program (NAFMP) (2017-2022) in consultation and collaboration with concerned government agencies, private sector and stakeholders for the coordination and implementation of the law. The NAFMP provides general approaches, strategies, and interventions that address the issues and problems facing agricultural and fishery mechanization and takes into account the gender, climate change, and environmental considerations. Specifically, these are the issues and recommendations generated during the National Agri-Fisheries Mechanization summit and area-wide/regional public consultations conducted by the government from 2014-2015.

The NAFMP integrates the various agri-fisheries programs and projects of concerned national government agencies, local government units, and state colleges and universities, and advocates the participation and involvement of the private sector. Its five components include: a) Local Assembly and Manufacture of Agri-Fishery Machinery; b) Research, Development and Extension; c) Standards and Regulations; d) Support Services and Institutional

Development; and e) Human Resource Development. Overall, the NAFMP provides direction shall serve as the overall agriculture and fishery sector mechanization program to guide in the planning, programming, budgeting and monitoring of DA.

Some of the key developments of the AFMech Law

1. Completion of Policy Study in Support to the Local Assembly and Manufacturing of Single Cylinder Engine for the Philippine Agri-Fisheries Sector - The general objective of the project is to create the enabling technical, operational and investment environments that will attract local investor and foreign partner to a joint venture agreement for the local assembly of small agricultural engine (June 2016-June 2017).
2. Completion of the Policy Study on Operational Procedure & Policy for the Standardized Agricultural Mechanization Index in the Philippines - The general objective of the project was to formulate a national policy to indicate the agricultural mechanization index for rice crop production and postproduction systems in the Philippines (March 2016 – May 2017).
3. Conduct of an evaluative study on Intensive Use of Mechanized Technology in the Agriculture Sector: An Evaluation of the Effects and Implications in Selected Commodity Value Chains (rice, corn, coffee, and cassava) - The study seeks to generate critical policy recommendations in support to the DA's priority agenda on farm mechanization, as well as strategic and effective postharvest, storage and processing facilities that can lead to increased productivity and competitiveness, in the light of the current ASEAN integration (September 2017-October 2018).
4. Organization of the National Agriculture and Fisheries Mechanization Research, Development and Extension Network (AFMechRDEN) of the R&D Institutions (RDIs) and Higher Education Institutions (HEIs). The membership of the network includes concerned stakeholders, including RDIs, HEIs, LGUs, Regional Field Units.
5. The AFMechRDEN has established and operationalized the AFMechRDE database information system for the RDIs and HEIs.
6. Development and operationalization of the Agricultural and Fisheries Engineering Resource Network (AFMechERN) -The network shall be used for the online registration of agricultural and fisheries machinery and equipment for monitoring agri-fisheries mechanization and infrastructure projects.
7. Strengthening of the Philippine National Standards for Agriculture Mechanization Technologies through the creation of the Bureau of Agriculture and Fishery Standards (BAFS). – Since the implementation of the AFMech Law, several national standards on agricultural machines had been approved.
8. Development of Training Regulations for the operation of agricultural machinery by the Technical Education and Skills Development Authority (TESDA) – As part of the Human Resource Development of the law, the TRs are significant for the conduct of training of critical mass of manpower required for the operation of various agricultural machines. Out of 7 new TRs, 3 had been promulgated for implementation. These are: (1) Agricultural Machinery Operation (Non-rice) –National Certificate (NC) 3; (2) Drying and Milling Plant Servicing – NC2; (3) Milking Operation – NC2. The other TRs which are being developed for promulgation implementation are: (1) Hatchery operation-NC2; Biogas System Installation and Maintenance – NC2; (3) Irrigation System - Installation and Maintenance – NC2; (4) Farm Machinery Servicing (Tractor) -NC 3. The existing TRs are Rice Machinery Operation-NC2 and Rubber Processing – NC2
9. In connection to the approval of TRs, the Agricultural Training Institute, extension and training arm of DA, has allotted a budget for the conduct training nationwide.
10. The TESDA has already accredited HEIs offering BS ABE program which can serve as Rice Machinery Operation Assessment Center and RMO Training Center. It has also sponsored scholarships for the Training Methodology 1 for Rice Machinery Operation.
11. Initial efforts are being done for the implementation of contiguous farming as part of the component on Support Services and Institutional Development. This includes allocating budget for the conduct of a policy study on the formulation of guidelines for the contiguous implementation farming in the Philippines. Another key activity is the sourcing of funds and/or allocating of funds for the pilot implementation of contiguous farming.

- **RA 10915 Philippine Agricultural and Biosystems Engineering (ABE) Act of 2016**

With the enactment of the law, the revision of the BSABE program from a five-year to a four-year curriculum will be implemented in 2018 through a CMO –CHED which is already finalized and endorsed by the Commission on Higher Education En Banc. The curriculum is aligned with the ASEAN qualifications framework and to be piloted to conform and align with the rest of the Universities in the world.

Two national forums were conducted as a result of the ABE Law. These are:

1. National Consultation Workshop on the Agricultural and Biosystems Engineering and the Implementation of the Agricultural and Fisheries Mechanization Law (R.A. 10601) for Higher Education Institutions (HEIs), March 15-17, 2017, Electrical Engineering Auditorium, College of Engineering and Agro-industrial Technology (CEAT), University of the Philippine Los Baños (UPLB), College, Laguna, Philippines.
2. National Forum on the Implementation of Agricultural and Biosystems Engineering and Mechanization Regulations, November 8-9, 2017, Century Park Hotel, Manila, Philippines.

- **Operational Procedure & Policy for the Standardized Agricultural Mechanization Index in the Philippines**

The government will adopt the procedure/methodology for the computation and updating of the agricultural mechanization index through the regional field units. A manual will be published as a guide for measuring the level of mechanization.

III. Lessons Learned and Good Practices

- Implementing/Operational structure is an important factor in the implementation of the law. The structure will guide as to the agencies or stakeholders involved and their respective roles and functions. As lessons learned from AFMA, there is a need to streamline and identify key agencies that are responsible for respective outputs.
- The successful implementation of a law depends on various factors such as availability of resources, capable manpower to execute the plans and programs and cooperation of various stakeholders. It is necessary that the main goals to be achieved are well articulated and key agencies are adept as well as capable of handling their respective responsibilities.
- There should be a strong monitoring and evaluation system for the agricultural and fisheries mechanization plan to mitigate problems and strengthen positive outcomes of implementation. The monitoring system should be able to follow through the timeline and present current updates and developments on agricultural mechanization in general.
- There is a need for the implementation of firmer rules, close monitoring of funds, and conduct of impact assessment studies to avoid wastage of government funds in the acquisition of agricultural mechanization technologies. The distribution of mechanization technologies should be matched to the farm requirements and farmers' collective needs. Thus, needs assessment is a must prior to the mass distribution of mechanization technologies.
- Participatory approaches should be adopted in planning and implementing the whole cycle of agricultural mechanization projects. Feedback mechanisms should be in placed to address project faults and weaknesses.

IV. Suggestions for Regional Cooperation amongst Countries

- Although the implementation of Sustainable Agricultural Mechanization Strategies may vary from country to country, sharing of experiences and lessons learned on promoting SAMS is a good way to avoid past errors and learn from the good examples. The Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific is an appropriate venue for knowledge sharing and learning among member countries.
- An internet-based site may be established where CSAM member countries may share scientific-based resources and information materials on the implementation of SAMs for increased connectivity and interactions. Although the Regional database is already initiated by CSAM, the results and effect are still to be felt in the Regional Cooperation.
- The regional cooperation could be strengthened through setting up of regional cooperation plans for SAMs.
- On human resource development, there should be a mechanism for the exchange of Information/Harmonization of Agricultural Mechanization/ABE Education in Asia and the Pacific. Although there is an ASEAN Qualifications Framework for the harmonization of the bacaalaureate program, its harmonization with the other Asia and the Pacific countries are still to be in place. These should be done for greater mobility of Agricultural & Biosystems Engineers by establishing a Credit Transfer Scheme among National Qualification Frameworks. It should also include Manpower Supply and Demand Study for agricultural mechanization services in the region for efficient utilization of the human resources of each country in the regional cooperation network.
- Development and implementation of collaborative RDE platform amongst nations in the implementation of SAMS.
- CSAM may lead in the advocacy to amend the UN Central Product Classification (CPC) Version 2.1. to include agricultural and biosystems engineering and agricultural mechanization services as one of the major focuses of CPC.

Republic of Korea

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I. Agricultural Mechanization country profile

Farmer population and employment prospects:

Over the past 20 years, the population of Korean farmers has decreased steadily from 2.48 million to 2.75 million in 2014. In 2016, it decreased by 5.3% to 2.59 million compared with the previous year. It seems clear that the overall decline in farm population will continue. The reason for this is deterioration of conditions of the farm trade and decrease in income.

In 2025, it is estimated that 201 million people will be reduced to less than 2 million people. Of course, the proportion of the population of the farmer will continue to shrink and fall to below 4% by 2025. Farmland lakes will be reduced to less than one million.

Along with the declining population of farm households, their aging is also continuing and will continue in the future. This is because the population of farm households under 54 years is decreasing and the population aged 65 years, and older is expected to increase. The proportion of people aged 65 and over will increase from 39.9% in 2016 to 47.7% in 2025. The development of technology will be supported, but the problem of the rural labor force can be serious. Income reduction and relative lack of indirect living capital in rural life and educational difficulties make it difficult for agriculture inflow population to increase to be.

Table 1: Farm Households of Republic of Korea

	unit	'13	'14	'15	'16
total households	thousands	18,206	18,457	19,561	19,285
farm	thousands	1,142	1,121	1,089	1,068
(compare to total households)	%	(6.3)	(6.1)	(5.7)	(5.5)
°farmer age					
-under 49 years	%	9.3	8.2	9.0	7.5
-50~59 years old	%	23.4	22.5	22.7	21.4
-over 60 years	%	67.3	69.2	68.3	71.1
-over 65 years	%	53.5	55.7	53.5	55.5
* years of average	years	65.4	66.5	65.6	-

Table 2: Farm Population of Republic of Korea

	unit	'13	'14	'15	'16
□ country population	thousands	50,220	50,424	51,069	51,246
- over 60 years	%	17.1	17.7	18.5	22.9
- over 65 years	%	12.3	12.7	13.0	17.1
* average years	years	39.3	39.8	40.4	-
□ farm population	thousands	2,847	2,752	2,569	2,496
(compare to total households)	(%)	(5.7)	(5.5)	(5.0)	(4.9)
-over 60 years	"	47.8	49.7	50.3	53.1
-over 65 years	"	37.3	39.1	38.4	40.3
*farm population per household	person	2.5	2.5	2.4	2.3
°woman farm population	thousands	1,461	1,412	1,305	1,275
(compare to farm population)	(%)	(51.3)	(51.3)	(50.8)	(51.1)

II. National Agricultural Machinery Strategy/Long Term Plan

2.1 Agricultural mechanization policy objective

The goal of the agricultural mechanization project in 2015 is to strengthen the competitiveness of the agricultural machinery industry by promoting agricultural mechanization and export. In order to reduce agricultural productivity due to the decrease of rural population and lack of labor force due to aging and feminization, and low-income agricultural products due to expansion of market opening such as Korea-China FTA, there is concern about the domestic market. As a policy measure, the goal is to achieve a mechanization rate of 65% by 2018 years.

The main policy tasks are to promote the use and use of agricultural machinery that is easy for women and aged farmers to use, and to develop R & D and infrastructure for field agricultural machinery, where women are mainly engaged in agriculture.

Farming area of farmland is less than 0.3 ha, and more than 90% of the farms are small, so it is difficult for individual farmers to buy and use agricultural machinery. We focus on machine mechanization by promoting consistent mechanization from sowing to harvesting of nine major crops, such as potatoes and beans.

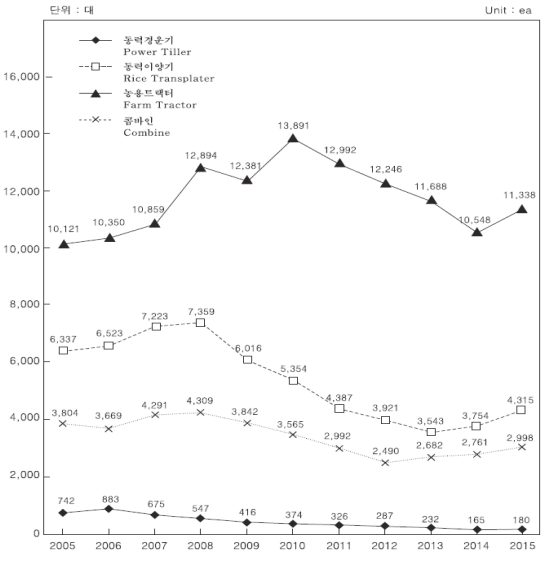

Figure 1: Annual Supply of Selected Agricultural Machinery of Republic of Korea.

To supply high-quality agricultural machinery to farmers, they strengthened their agricultural machinery. It is imperative to swiftly respond to the needs of agricultural machinery, including enhancing the safety and quality competitiveness of agricultural machinery, increasing agricultural machinery crops, expanding agricultural machinery, and strengthening international testing. In particular, the growing popularity of advanced technologies such as IT, BT, and NT is driving the proliferation of diverse types of high-performance automation. Agricultural machinery testing can not only prevent farmers from damaging farmers, but also assume significant weight gains in production and export of high-quality agricultural

machinery. Therefore, the Commission plans to promote the best effort to produce high-quality agricultural machinery by diversifying the number of agricultural machines and expanding the number of licensed agencies.

Table 3: Status of Agricultural Machinery Utilization of Republic of Korea

가. 수도작 작업별 기계화율 Ratio of Mechanization for Rice Farming

단위 : % Unit : %

연도 및 시도 Year and Province \ 항목 Item	평 균 Average	경운, 정지 Tillage	이 앙 Transplant	수 확 Harvesting	방 제 Spray	건 조 Drying
2002	88.9	98.8	98.4	99.1	99.6	48.6
2004	89.9	99.1	98.4	99.4	99.5	53.2
2006	89.9	99.1	98.4	99.4	99.5	53.2
2008	90.7	99.0	99.2	99.5	99.4	55.6
2010	91.5	99.9	99.8	100.0	99.3	58.5
2012	94.1	99.9	99.8	99.9	99.7	71.6
2014	97.8	99.9	100.0	99.9	99.0	90.1

벼 영농규모별 승용기계화율 Ratio of Riding Mechanization for Cultivating Area

0.3 ha 미만	~0.3 ha	55.1	81.3	61.8	94.6	11.3	26.4
0.3~0.5 ha	0.3~0.5 ha	65.4	87.5	81.6	99.5	14.3	43.9
0.5~1.0 ha	0.5~1.0 ha	64.5	88.1	70.1	98.4	10.9	55.2
1.0~2.0 ha	1.0~2.0 ha	69.0	91.5	67.3	99.5	10.1	76.5
2.0~5.0 ha	2.0~5.0 ha	75.5	98.8	83.2	97.8	9.3	88.6
5.0 ha 이상	5.0 ha~	84.0	100.0	99.3	99.4	23.3	97.9

주 : ① 규모별 승용기계화율은 '06년 국립농산물품질관리원의 조사 실적임.
② '02년부터 격년제로 조사하였으며, '08년부터 국립농산물품질관리원에서 농진청 농업공학부로 이관되어 조사함.

2.2 Research of Korean Agricultural Engineering

Basic Research

Basic research in the field of agricultural machinery is mainly carried out by the University, the Department of Agricultural Engineering, the National Institute of Agricultural Science, and the Rural Development Administration.

The results of these basic studies are published in the Journal of Biosystems Engineering (Journal of Biosystems Engineering) and Winter and Summer Scientific Committees of the Korean Society of Agricultural Engineers.

As a part of efforts to promote internationalization through entry into the SCI (Science Citation Index) list of the Journal of Korean Society of Agricultural Engineering, 2012, the title of the journal was changed from "Journal of Agricultural and Biosystems Engineering" And started publishing articles in English as English manuscripts.

In addition, efforts to improve the quoted index of the articles and to increase the contribution rate of foreign authors' articles are expected to be achieved soon.

Like many other Asian countries, there are Korean Societies of Agricultural Engineering (KSAE) and Agricultural Machinery (KSME) in Korea separately, and they have made significant contribution on development of rural area as well as agriculture for last more than 50 years. In this subchapter, publications on those two journals will be introduced to show current status of researches actively conducted in Korea. KSAM has a total of 5 working groups, which include field system engineering, environmental engineering and energy, post-harvest engineering, bio-engineering, and information processing. In 2016, about 33.2% of KSAM published papers were on the field system engineering while 25.3% and 18.1%, are about environmental engineering/energy and information processing respectively. In particular, studies on agricultural buildings such as greenhouse and livestock houses have been greatly supported by the Korean government recently because more than 64% of the land is mountain area with very distinguishable 4 seasons. There are many important limitations to increase productivity of agricultural products in these areas. Only protected cultivation can guarantee annually stable production of high-quality agricultural products.

2.3 Long-term plan (The 4th Industrial Revolution and Precision Agriculture)

2.3.1 Introduction

The key phrase used at the World Economic Forum (WEF)[1] was the Fourth Industrial Revolution. Klaus Schwab, the founder of the WEF, argued that the Fourth Industrial Revolution has already arrived. He argued that the pace, scope, and influence of social changes that follow the Fourth Industrial Revolution will be entirely different from previous revolutions.

The Fourth Industrial Revolution (4IR) refers to the oncoming revolutionary era in which Information and Communication Technology will converge (ICT). The revolution will spark new technological innovations in six areas: artificial intelligence, robotics, Internet of Things (IoT), unmanned vehicles, three-dimensional printing, and Nano-technology. The 4IR will include a variety of new technologies that use big data to incorporate the physical, biological, and digital worlds in a way that will affect all sectors of life.

1 The world Economic Forum, better known as the Davos Forum, is a Swiss nonprofit foundation, based in Cologny, Geneva. Recognized by the Swiss authorities as an international body, its mission is cited as “committed to improving the state of the world by engaging business, political, academic, and other leaders of society to shape global, regional, and industry agendas”. The Forum is best known for its annual meeting at the end of January in Davos, a mountain resort in Graubünden, in the eastern Alps region of Switzerland (From Wikipedia, accessed July.30th, 2017).

2.3.2 Preparing for the Fourth Industrial Revolution

In the era of the Fourth Industrial Revolution, new technologies and new businesses that cannot be defined by existing laws and systems will be developed. The positive regulation method of controlling gene expressions in gene therapy is currently illegal. In order to use positive regulation, businesses waiting to use new technologies and services will have to wait for laws to be enacted.

In order for the 4IR to be rooted in agriculture, it is necessary to promote the safety of agricultural work and rural life, and to create a favorable environment for cyber technology and cloud infrastructures. This will prevent medical and cultural inconveniences in rural areas.

Wearable IoT and mobile devices are concrete methods in which we can implement agricultural work safety, cyber physics systems (CPS), remote medical, cybercultural life, and aged farmers' life safety and health information Big Dataization.

- **Agricultural Robots**

A robot is a machine that moves independently, imitates humans, recognizes the external environment, and makes independent judgements about how to handle different situations. Agricultural robots will operate in every area of the agricultural process, including production, processing, distribution, and consumption. They will recognize the service environment and autonomously provide intelligent work or services. Agricultural robots can be defined as "intelligent agricultural production systems that can minimize human intervention, control themselves, and maximize efficiency". Traditional farming machines and unmanned aerial vehicles can be utilized by robots in the fields of agricultural product selection, automated distribution systems, facility horticulture, and automated livestock care.

Robot usage can be divided into three fields, depending on where they are used. These fields include open-field agriculture robots, facility agriculture robots, and livestock robots. These fields will aim to improve productivity through automation, unmanned farming, and the promotion of eco-friendly farming.

Table 4: The Global Robot Market Scale in Agriculture and Fisheries in Republic of Korea (unit: million $)

Division	2013	2014	2015	2016	2017	2018	2019	2020
Agricultural Robot Market	956	1,386	2,329	4,634	8,110	11,760	15,288	19,109
Growth Rate	34%	45%	68%	99%	75%	45%	30%	25%
Milking and Livestock Facilities	879	1,203	1,615	1,918	2,004	1,735	1,798	1,611
High Value-Added Crop	29	55	116	275	568	941	1,376	1,911
Cereal Crops such as Wheat, Rice, Corn, etc.	11	28	186	695	2,109	2,940	3,669	4,395
Grape Pruning and Harvesting	6	6	137	941	1,272	1,570	1,413	969
Seedling Management	14	42	116	292	616	1,047	1,682	2,389
Grass Management (lawn care)	14	43	140	371	811	1,411	2,410	3,058
Unmanned Aerial Management	3	7	19	139	730	2,117	3,210	4,777

Source: World Robotics 2012. IFR

The global robot market[2] is expected to grow at a CAGR[3] of 17% from $ 71 billion in 2015, to $ 135.4 billion in 2019. The robotics market for agriculture and fisheries[4] is estimated to be $ 900 million in 2013 and is expected to increase rapidly to $ 19.1 billion by 2020. The target is expected to be a weed control and harvesting robot.

2 IDC (The International Data Corporation) selected six technologies that were highly likely to grow: IoT (Internet of Things), cognitive(Recognition) systems, next-generation security, AR - VR, robot and 3D printing, and the market for each technology. (2015.10.)

3 Compound Annual Growth Rate

4 IFR (International Federation of Robotics) 2014 Wintergreen Research report

- **Precision Agriculture**

Environmental problems continue to plague the Earth. Yet, the production of safe agricultural products is emerging. Interest in precision agriculture is increasing in order to minimize environmental pollution and maximize the production of agricultural products. Scientists, as well as those involved in agriculture are showing growing interest in this research. In fact, many are interested in precision agriculture because it does not belong to any one field; all fields contribute to the joint effort to solve the problems facing precision agriculture. Breakthroughs in agricultural machinery are of utmost importance; thus emphasis has been placed on engineering in the field. As the world's population continues to increase, there is an urgent need for an increase in food production. This need is hindered by industrial pollution and difficulty producing safe agricultural products due to harmful pesticides and fertilizers. Precision agriculture has emerged as a solution to this need, as it can increase the production of agricultural products while reducing the amount of harmful chemicals applied to the environment. Every crop field has different characteristics that can be measured in quality and quantity. Some examples of these characteristics include soil, nutrients, flow of irrigation water, and pest resistance. These differentiations of characteristics can all exist within a single crop field, so we have found that if we understand the different characteristics of each part of a field, and if site-specific processing is done for each location, the most profit from the least investment can be achieved. Therefore, precision agriculture follows the concept of variable rate agriculture. It is prescription agriculture as well, as optimal profit is obtained based on past information. It has the capability to regulate future field conditions and yield through site-specific management. Precision agriculture is a concept that meets the needs of an advanced society that requires environmental preservation.

As shown in Figure 3, the concept of precision agriculture not only makes agricultural practices more precise, but also makes it viable and efficient by moving it from a statistical approach to a quantitative approach. Therefore, it is not an exaggeration to say that the scope of precision agriculture is the entire agricultural system. As a system of agriculture, three divisions of technology must be utilized in order to fully develop precision agriculture.

The first division is the acquisition of information related to the environment where crops will be grown, such as crop growth status, soil fertility, and climate by location. The method to obtain such information is via sensors placed at each location which can monitor different conditions including the yield of crops, moisture content of the soil, soil nutrients, moisture stress, and the occurrence of pests or weeds. These sensors do not collect information to be later analyzed in a laboratory; they are capable of instantly processing and storing information in real-time.

The second division is the distribution of necessary, measured agricultural material into the crops. Based upon outcomes determined in decision making and crop management, the machine will release seeds, nutrients, and chemicals to the crops.

The third division is the processing of computerized geographical information and databases, along with the farmers' prescribed inputs in order to drive the control systems of various farm machinery. Even if the first two divisions are well developed, it is difficult to carry out precision agriculture if the third decision-making process is lacking (see Figure 4.).

As one sector of agriculture changes and one farmer's agriculture becomes technologically advanced in this way, it does not mean that precision agriculture has been established. That is, precision agriculture does not change farm by farm. Precision agriculture is not a word referring to a single technology, but an overall concept of new changes in agriculture.

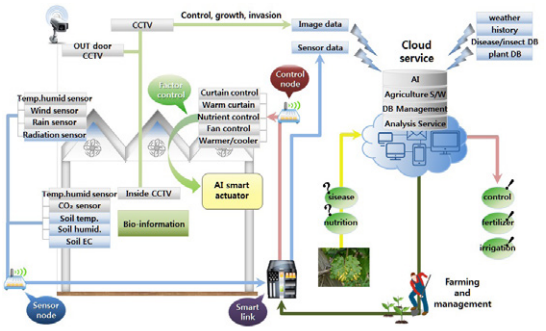

Figure 2: Crop Production Environment Through Biometrics and Artificial Intelligence, Republic of Korea
Source: Convergence of Agriculture R&D and 4th Industrial Revolution, 28p

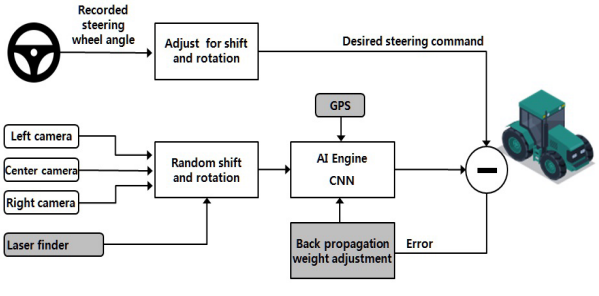

Figure 3: Artificial Intelligence Autonomous Driving and Unmanned Agricultural Farm Machinery, Republic of Korea
Source: Convergence of Agriculture R&D and 4th Industrial Revolution, 37p

Sri Lanka

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I. Agricultural Mechanization Country Profile

The use of tools, implements and powered machinery in agricultural land development, crop production, harvesting, preparation for storage, storage, and on-farm processing is termed as "Agricultural Mechanization". It includes three main power sources: human, animal, and mechanical. Manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements and machines are covered under this discipline with regard to how to supply mechanization inputs to the farmer in an efficient and effective manner.

Contributing to about 8% of the GDP, the agriculture sector plays a pivotal role in the economy of Sri Lanka. Nevertheless, the shortage of workers in agriculture is often blamed for being a cause of low land productivity and quality of produce. Consistent with the economic transformation, the structure of employment in Sri Lanka also changed. The expected migration of agricultural labor towards the industrial and service sectors continues. An analysis of employment trends in Sri Lanka shows that employment outside agriculture - in industry, services, and other categories - grew at an average rate of 4.2% per year from 1990 to.2000. By contrast, employment in the agricultural sector grew negligibly, at an average rate of 0.3 % per year during the same period.

As the decreasing rural population of Sri Lanka is becoming increasingly responsible for feeding the growing urban population, the increase in productivity of agriculture has become an essential feature in stepping towards sustainability. As labor migrates away from agriculture, the productivity of those who remain on the land needs to increase significantly. In actuality, the percentage share of labor employed in agriculture decreased from 47% of total employment in 1990 to 36% in 1999. Therefore, the mechanization of labor-intensive practices in agriculture as a solution to the scarcity of labor has been one of the most frequently discussed subjects among stakeholders.

Objectives of mechanization:

- Increase worker productivity;
- Attract younger generation to agriculture;
- Improve product quality;
- Reduce cost of production;
- Ease of manual operations;
- Precise and timely cultivation;
- Time conservation;
- Changing the attitude towards farming.

Although some field practices have been successfully mechanized,

there is still a great potential for mechanizing the agriculture sector in Sri Lanka. Fragmentation of farmlands, irregular land shapes, and reducing the size of a holding have also become a challenge in mechanizing field operations. Presently, most of the machinery used in the agriculture sector are imported from other countries, spending a colossal amount of foreign exchange every year. Lack of resources for research and development and manufacturing machinery, high cost of production compared with that of the importing countries, lack of incentives for local producers and a small local market etc., have been some of the reasons for limiting local production of agricultural machinery and equipment.

Table 1: Country Statistics, Sri Lanka

Area	**65,610 km²**
Population	21.2 mil (2016)
Life expectancy	72.4 years
Literacy rate	91 %Average
Temperature: • Lowlands • Central Highlands	between 22°C - 33°C between 7°C - 21°C
Average Annual Rainfall	1900 millimeters

The agricultural sector in Sri Lanka mainly comprises of paddy, Other Food Crops (OFC), plantation crops, minor export crops, horticulture and fruit crops, floriculture, livestock, firewood, and forestry. Additionally, fishing and aquaculture are also contributing to the agriculture sector of Sri Lanka.

The agricultural composition shows that the variety of machinery required for the agriculture sector varies from small hand-held tools or equipment to large scale engine-driven machines. Further, every field or processing practice in agriculture cannot be successfully mechanized to replace manual operations due to various reasons. Presently, protected agriculture, especially for producing vegetables, fruits, and flowers has received greater attention of enthusiastic entrepreneurs in the country. It is a well-known fact that mechanization is an important component in precision agriculture. Therefore, the mechanization needs of this sector should also be addressed with greater attention. Finding solutions through mechanization to facilitate compost preparation, reduce chemical usage in agriculture, and minimize wild animal damage to cultivated crops and finished products has also become necessary.

With lesser restrictions on imports, substantial quantities of agricultural machinery are imported to Sri Lanka. Hence, it is paramount that a proper quality assurance and certification system is developed and imposed to safeguard the local farmers and other users of agricultural machinery. The local designers and manufacturers claim that it has been extremely difficult to continue their industries due to financial constraints. Hence, government interventions are required for providing financial support and other required facilities.

Further, a number of machines and equipment designed and developed locally to suit local conditions have not reached the end users due to problems of commercialization. Therefore, appropriate steps should be taken after a careful appraisal to rectify this situation. It will also be of advantage, if both local designers and manufacturers are exposed to advanced technologies available in foreign countries. This situtation emphasizes the need for private and public-sector partnerships in the development and manufacture of agricultural machinery.

Moreover, machinery and equipment suitable for small-scale and village-scale agriculture should be produced with a view to increase job opportunities for rural population, which is often considered as the back-born of the agriculture sector of Sri Lanka. In order to harness the full benefits of agricultural mechanization, new varieties and farming systems also need to be developed to suit mechanization. Nevertheless, it can contribute to environmental pollution and soil erosion, and displaces farm labor. Hence, energy use efficiency, contribution to environmental pollution and worker safety aspects should be given attention to the research and development stage of agricultural machinery.

Table 2: Level of Mechanization in Sri Lanka

Paddy Cultivation	Highly mechanized
Vegetable cultivation	Low level
Other field crops	Moderately mechanized
Fruit sector	Low level
Plantation crops	Low level
Spices	Very low

Much water is needed for land preparation as lands are not properly levelled. Laser levelling can be introduced for land levelling. Two levelers are bought and another two will be purchased for trails and extension. Due to the labor shortage and huge labor cost, bund forming is neglected or poorly done. Bund forming machines have to be introduced. The machine will be purchased under the National Food Production Program this year for trails and testing.

Zero Tillage reduces soil erosion. FMRC has introduced Injector

Planter for Maize, Dry Sowing seeder for paddy. The injector planter is designed to couple for both two and four-wheel tractors. Through extension programs, these machines are becoming popular, and now several hundred is in the field, especially in Uva province. These machines are locally fabricated by small-scale manufacturers registered at FMRC.

The use of organic fertilizer enhances soil quality, water retention and soil functions, increasing the system's potential to overcome climate shocks. FMRC introduced multi chopper for compost making in 1990s. Machine gained much popularity; hence, several local manufacturers fabricate machines locally. But now there are cheaper imported machines in the market.

Table 3: Annual Agricultural Machinery Production/Import by 2015 in Sri Lanka

	Machine/Equipment	Units produced Locally (annual average)	Units imported (annual average)	Approximate Average Value of a machine (USD)	Remarks
1	Single Axle Tractors (SAT)		8,200	2,600	7 & 12 hp tractors with rotovators
2	Twin Axle Tractors (TAT)		4,200	12,500	Up to 60 hp
3	SAT trailers	5,000		650	
4	TAT trailers	2,000		2,600	
5	Sprayers	13,500	12,000	75	
6	Irrigation pumps	5,500	3,500	325	
7	Ploughs for TAT		1,000	500	For TAT
8	Animal drawn ploughs	500		100	
9	Threshers	500		1,200	
10	Winnowing fans	200		60	
11	Mamoties	350,000	300,000	10	
12	Combine harvesters		1,000	26,000	
13	Maize shellers	500		950	SAT driven
14	Paddy transplanters	750		3,000	Manually operated
15	Lowland seeders	500		150	Manually operated
16	Multi choppers	1,000		660	For compost production
17	Paddy cleaners	200		860	For farmer level seed production
18	Power Weeders	1,500		650	For rice cultivation
19	Inter-cultivators	2,500		220	For OFC
20	Paddy reapers	250		1,700	
21	Groundnut shellers	100		1,315	
22	Highland seeders-manual	250		165	
23	Highland seeders-SAT coupled	200		300	
24	Highland seeders-TAT coupled	100		1,315	

II. National Agricultural Machinery Strategy/Long-Term Plan

2.1 Summary of related policies, strategy/long-term plan

Government support for farmers takes several forms, including the provision of credit for producers, the setting of minimum prices for agricultural produce, the building of irrigation works, and the encouragement of internal migration to newly irrigated areas. Since the late colonial period, the government has played a growing role in the provision of credit to smallholders on favorable terms. Until 1986, the main instrument of this policy

was the subvention of cooperative societies.

Agricultural credit took three forms: short-term loans to farmers for the purchase of seeds and fertilizers; medium-term loans, intended for the purchase of machinery; and long-term loans for capital expenditure on storage, transport, and rice-milling apparatus. The long-term loans were not available for individual farmers but were used by the cooperative societies to acquire infrastructural facilities.

Another important policy was the Guaranteed Price Scheme, which came into effect in 1942. Under this program the government agreed to purchase rice and some other produce at set prices. The intention was to support the farmer's standard of living. Since the 1930s, governments have promoted irrigation works and colonization projects in the dry zone in an attempt to increase rice production and reduce land pressure and unemployment in the more densely settled wet zone.

Other long-standing government policies designed to help farmers included subsidies for fertilizer, seed paddy, and other inputs. Government efforts also partly contributed to the adoption of improved cultivation practices and high-yielding seed varieties in paddy farming in the 1960s.

The Sri Lanka Council for Agricultural Research Policy (SLCARP) was established on the 22nd of December 1987 with the enactment of the CARP Act No. 47 of 1987 by having the vision of developing a vibrant, effective and sustainable system of agricultural research promoting socio-economic development in Sri Lanka and mission of strengthening and mobilizing research capabilities of the National Agricultural Research System (NARS), universities, private sector and other stakeholders in partnership in the generation and dissemination of appropriate technologies and information for the development of agricultural sector"

Its mandated functions are:

- Formulation of a national agricultural research policy;
- Organization, coordination, planning, and execution of agricultural research;
- Allocate/generate funds for contract research, monitoring and evaluation, and technology dissemination;
- Develop human resources (scientific & technical) in the agricultural sector;
- Foster regional/international linkages to access modern technology, information, exchange of scientific staff, germplasm, etc.;
- Disseminate technology and scientific information for agricultural scientists, farmers, private sector and other stakeholders;
- Periodic review performance on agricultural research projects, institutions, and divisions;
- Repository of scientific information on agriculture and related fields;
- Provide excellence in agricultural research.

The following institutions and establishments are available for the manufacturers to obtain their required designs, prototypes, technical know-how and testing and certification of the machinery:

- Farm Mechanization research Centre (FMRC), Maha Illuppallama;
- Institute of Post-Harvest Technology (IPHT), Anuradhapura;
- National Engineering Research & Development Centre (NERDC), Ekala;
- Farm Mechanization Training Centre (FMTC), Anuradhapura.

Out of the above four institutions FMRC, IPHT and NERDC are involved in research and development of agricultural machinery. The necessities of different kinds of machines are notified to these institutions in accordance with the respective specialties of them. The requirements are originated from farmers at the grassroots level, officers involved, NGOs who are assisting farmers, and the provincial technical working groups.

In general, a requirement of machinery for a particular operation is indicated to one of the above three institutions. The procedure is to look for the availability of such machines elsewhere in the world. In this regard, the most frequent case is that even promising machines are available, the applicability of them to local conditions had always been questionable. The infrastructure, soil conditions, climatic conditions, inherent practices, and the purchasing power of the farmers had all been obstructive factors to introduce the machines brought from abroad. The aforementioned factors are the main reasons that, except the fuel operated prime-movers including tractors, all other agricultural machinery is produced locally.

The research procedures involved design, prototype production, testing, modifications as needed, final testing, adaptive research, and introduction to the farmers. The mass production of the machinery is totally done by the private sector.

There are also instances that individual companies have obtained the designs from their principals abroad and do modifications to suit local requirements as they are the sole agents in Sri Lanka for these machines and equipment. In such cases, assembly or

semi manufacture is mostly the arrangement. It must, however, be noted that in Sri Lanka there is only a limited capacity for local consumption, and therefore large investment on assembly line type continuous production systems may not be economically viable unless otherwise international market is approached. The local consumption's limited capacity is the main reason for many manufacturers importing their prime movers. Few large-scale manufacturers are capable of investing in R & D work on agricultural machinery. The major cause for this situation is the marginal profit made by the manufacturing industry and seasonal sales of equipment requiring a large investment in stocking manufactured goods.

2.2 Results from implementation

Thanks to tractors, nearly 95% of land preparation is now mechanized. The initial land preparation can be practiced just after land preparation. However, the usage of machinery for plant establishment is still not satisfactory. After launching several projects, over 500 transplanters are now in the field. One transplanter can cover up to 50 acres per season. Farmers of southern part of the island prefer to use FMRC box seeder. Dry sowing is practiced in the northern part of the island, and farmers request dry sowing seeders. Seeders imported from India have been tested and successful. Yet, to be introduced through the extension mechanisms. Dry sowing needs less energy for land preparation. As transplanting needs much water, use of seeders will reduce the use of scarce water resources.

III. Lessons Learned and Good Practices

Even though the farmers are aware of the advantages associated with farm machinery, they are unable to approach them due to various reasons. The main advantages include increase quality and quantity, timeliness, reduce drudgery, reduce production cost and low labour requirement. Above all, the attraction of the present generation to agriculture the machinery has to play a major role. There are two ways in which the farmers could receive the help of machinery for different farming operations. They are:

- by owning them;
- by hiring.

3.1 Owning machines by individuals

At present, there are a number of restrictive factors, as mentioned below, for owning the machines by individuals:

- Poor purchasing power;
- Seasonal usage of machinery;
- Lack of infrastructural facilities;
- Difficulty in obtaining financial facilities;
- Many machines are single purpose;
- Lack of after-sales services.

3.2 Machines hiring facilities

The hiring of machinery by farmers is rare due to the following reasons:

- Non-availability of machines at proximity to the farms;
- Lack of awareness on available technology;
- High and varying hiring charges;
- Some machine owners are reluctant to hire their machinery;
- Insufficient machinery to cater for the demand;
- Financial hardships during peak periods;
- Expected quality of work cannot be achieved.

3.3 Strategies:

Strategies should be created to facilitates for ownership of suitable machinery of individuals at reasonable prices, possibly with installment paid basis, or providing machines hiring facilities at close proximities to the farms.

1. Facilities for owning the machinery

At present, the machine supply and distribution system is completely handled by the private sector. Since there is no control over pricing, except for the competitiveness among the suppliers, farmers have to pay unreasonable charges. Apart from that, there are no sufficiently organized after-sales services and the farmers have no easy access for spare parts etc. Further, there are instances where substandard quality machines have gone to the farmers.

In order to overcome the aforementioned shortcomings, it is proposed to establish machinery sales centers island-wide with the involvement of the Government (possibility should be discussed). These centers are responsible for the followings:

- Provide quality assured machinery to the farmers;
- Provide easy payment facilities;
- Provide better after sales facilities;
- Function as the coordinator between the farmer and the supplier;
- Conduct awareness programs on the available technology with

the help of respective agencies;
- Ensure the availability of repair facilities within the area ;
- Direct the feedback of machinery conditions to decision makers;
- Keep strong linkages with Farm Mechanization Research Centre (FMRC) and Farm Mechanization Training Centre (FMTC).

2. Facilities for hiring farm machinery

Currently, the hiring of farm machinery is done by the individuals and this service is not so effective due to the reasons mentioned above. Therefore, government intervention is essential to provide sustainable, efficient and reasonable hiring facilities. A few years ago, the government-controlled tractor-hiring units failed and compelled to be close down due to inefficient management and especially due to the poor maintenance of the machinery. Accordingly, it is suggested to establish Government-controlled machinery hiring units island-wide to hire the machines through farmer organizations to the individual farmers. The machines made available in these units for hiring may be subject to fewer types. The machines kept at different hiring centers would have to be decided upon the requirement of respective areas. The hiring centers shall hire the machines that can be operate by the farmers themselves.

IV. Suggestions for Regional Cooperation amongst Countries

Despite its high cost and high profile, mechanization is still only an input like any other such as fertilizer, seed and crop protection chemicals, and is one of a mix of management tools that are available to farmer to maximize production and profit. Therefore, in a free market situation, it is inappropriate for governments to have an individual policy on mechanization except as a part contributing towards the realization of broader agricultural policy. To have a policy to 'mechanize' would imply that the introduction and expansion of mechanized inputs is an end in itself, whereas it is only one of a mix of management tools that a farmer uses for agricultural production.

Government policies on privatization and the market, as well as other policies, will affect the way in which mechanization inputs are made available and will determine the effectiveness of the sub-sector. In a free market economy, the amount and choice of mechanization inputs is demand driven, whereas in a planned economy are supply driven. Mechanization should not be an end in itself; therefore, in a truly free choice situation, governments should refrain from making policies which will stipulate by which means or by how much, agriculture will be mechanized. The type and degree of mechanization should be decided by the producers to best suit their business and his own particular circumstances, and the choice of suitable methods will, therefore, be just one of a number of choices that the farmer has to make. The decision whether and how to mechanize is often a complicated mix of reasons with economic reasons paramount.

The purpose of any interventions should be clearly identified and should serve the objectives of the strategy. However, that does not mean that agricultural mechanization can be neglected in the formulation of national policy. On the contrary, exceptional attention should be paid to the effects that other policies have on the level and use of engineering inputs in agriculture.

Table 4: Measures to Be Taken to Reduce Cost of Production and Increase Profit Margin in Paddy Cultivation in Sri Lanka

Operation	Main problem	Affects owing to the problem	Reasons for the problem	Probable solutions
Land preparation	Inability to keep timeliness	Late harvest in Maha resulting in:		Support more farmers to have their own tractors
		Less cropping intensity in Yala due to lack of water in tanks (50%)	Insufficient energy (Should increase to 2.40 hp/ha from present 1.41 hp/ha to advance land preparatory time by one week)	Tractor lending stations Gov/NGO/Private
		Crop damage and losses due to adverse weather conditions	High cost of tractors, unsuitable tractors	Ensure that the benefit of no import- tax policy on tractors goes to the farmers
		High rate of insect and fungal attacks	Lack of labour	Farmers and bankers should be made aware of the importance of FMRC certificate
				Introduce machinery for labour intensive activities (e.g. for repairing and reforming of bunds need 5–6 man days/ac)

Operation	Main problem	Affects owing to the problem	Reasons for the problem	Probable solutions
Weeding and plant protection	Inability to total control of weeds, insects and diseases	Reduced yield and/or total crop losses	Lack of sprayers (one sprayer/5 ha)	Support more farmers to have their own sprayers
			Improper use of sprayers	Sprayer lending stations Gov/NGO/Private
			Incorrect selection of nozzles	Encourage sprayer venders to train their customers
			Low quality sprayers	Farmers and bankers should be made aware of the importance of FMRC certificate
			No labour for transplanting	Encourage use of Mechanical transplanters
			Mechanical weeding still not popular	Popularize mechanical weeding that also has advantage of increasing fertilizer efficiency
Reaping	Excessive delay	Heavy grain losses	Needs heavy labour input	Ensure benefits of no tax policy on combine harvesters goes to farmers
			Reaping takes place at the labour peaks island wide	Encourage local production of two-wheel tractor coupled combine harvesters
				Farmers and bankers should be made aware of the importance of FMRC certificate
				Strengthen the reaper lending system at Agrarian Services Centers
Threshing	Delay in threshing	Discoloured rice	Needs heavy labour input	Support more farmers to have their own threshers
	Expensive	Low quality paddy	Threshing takes place at the labour peaks island wide	Thresher lending stations Gov/NGO/ Private
	High losses	Less rice recovery at milling	Performance of some threshers in the market are not satisfactory	Make farmers aware of advantages of mechanical threshing over the other methods
				Make threshers available at affordable prices
				Farmers and bankers should be made aware of the importance of FMRC certificate
Cleaning	Accidents	Injuries and life threat to the farmers	Substandard quality of artisan produced winnowers	Standardize the design
				Impose strict rules to use standardized winnowers
				Encourage use of cleaning machines

- Introduction of mechanization technologies, which make optimum use of labor and / or productivity rather than displacing labor.
- Adopt low or no tax policy on useful imported machinery while controlling undesirable machinery flowing into the country.
- Promote local manufacture of agricultural machinery and support agro-based industries entrepreneur development schemes.
- Enhance the level of income of farmers facilitating for value adding techniques.

Thailand

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I. Agricultural Mechanization Country Profile

Over the past five decades, the agricultural sector in Thailand has experienced one of the most rapid and extensive processes of mechanization in Southeast Asia, in which the distinguishing feature has been the development of locally-adapted small-scale machinery to meet the needs of agricultural smallholders. This began in the 1960s and 1970s with the local manufacture of two-wheeled tractors used for land preparation in rice cultivation, particularly in the central plain. Mechanization was extended progressively to the use of pumps, planters, weeders, sprayers, threshers, and combine harvesters, not only in the central plain but in the lowland rice-growing and upland field-crop zones of the Northern, Northeastern, and Southern Regions (Figure 1). The rapid increase in the use of two-wheeled tractors from around 90,000 in 1975 to 2.7 million by 2008 is shown in Figure 2, representing a growth rate of 11% and a density in 2008 of 0.14 per ha of agricultural land (or just over 7 ha per two-wheeled tractor). The corresponding decline in the number of buffaloes, the main source of draught power in rice farming before the advent of the two-wheeled tractor, can be seen in Figure 3, from a peak of 6.4 million in 1982 to 1.5 million in 2001 and just over 1.0 million in 2014.

Figure 1: Thailand, Topography and Regions
Source: CartoGIS, Australian National University

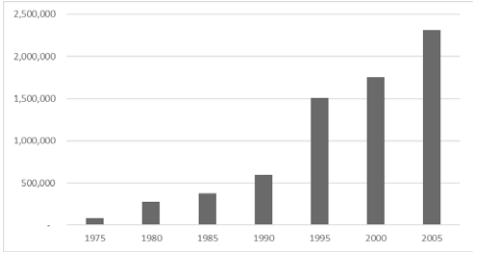

Figure 2: Number of Two-Wheeled Tractors in Thailand, 1975-2000
Source: Chancellor, 1983; Coxhead and Plangpraphan, 1998; Thepent, 2000, 2015

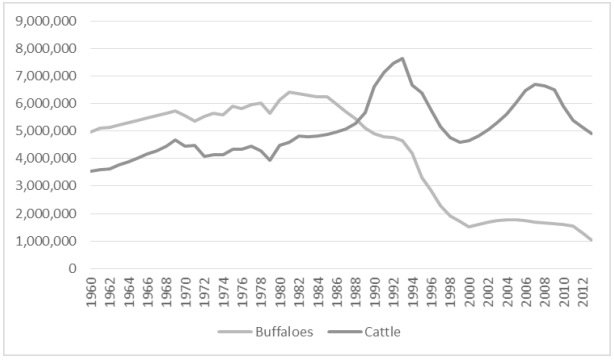

Figure 3: Numbers of Buffaloes and Cattle in Thailand, 1961-2014
Source: FAOSTAT

The current usage of machinery and equipment on farms in Thailand is recorded in Table 1, showing that 41% of holdings use two-wheeled tractors, 41% use four-wheeled tractors, 20% use planters, 30% use small water pumps, 44% use sprayers, 37% use weeders, and 28% use combine harvesters. Apart from four-wheeled tractors, threshers, and combine harvesters, which are predominantly sourced from private service providers, most of this machinery and equipment is owned by the landholder, notably, in 75% of cases for two-wheeled tractors and 76% of cases for engine-powered pumps. Moreover, most of them are manufactured in Thailand by a large number of small-medium private engineering firms, some of which now export machines to neighboring countries. In 2009 there were reported to be 275 firms manufacturing two-wheeled tractors, 386 firms manufacturing combine harvesters, and 1,192 firms providing repairs and maintenance for agricultural machines (Thepent 2015).

The explanation for this rapid mechanization of Thai agriculture lies in the conjuncture of several key elements – the nature of farming in Thailand, dominated by smallholders, with farms averaging around 3 ha, cultivating rice and field crops for both domestic and export markets; dramatic demographic changes, especially a rapid drop in birth rates, contributing to a growing scarcity of agricultural labor; a boom in manufacturing and construction in the 1980s and 1990s, drawing labor out of farming, particularly in younger age groups, a process which has continued at a slower rate in subsequent decades; the development of transport and communication infrastructure facilitating agricultural commercialization and labor mobility; a technological and business environment encouraging competition among small and medium firms to develop suitable and affordable machines for farmers; and a policy environment generally supportive of smallholder agriculture, agribusiness, industrial development, and trade.

The Supply of Agricultural Machinery

The demand for agricultural mechanization came from millions of smallholder farmers engaged in production of rice and field crops for expanding global markets who were faced with increasing labor costs due to increased requirements for labor (arising from intensification of rice production and expansion of field crop production) and a declining agricultural labor force (due to slowing of population growth and rapid rural-urban migration resulting from industrialization). That the supply of mechanization was able to meet this demand, particularly in rice production, was due to the emergence and growth of local manufacturing capacity characterized by large numbers of small- to medium-scale enterprises and a few large firms in close communication with farmers and public-sector researchers. Small machinery firms typically employed 4-5 workers occupying a workshop of 50 square meters. They were located in close proximity to rice farms in the central plain. Large firms with 100 or more workers occupying 3,000 square meters also sprang up in the industrializing provinces to the north of Bangkok. The remarkable development of this agricultural machinery industry in Thailand has been outlined by Anchan (1983), Chancellor (1983), Rijk (1989), Thepent and Chamsing (2009), Thepent (2015), and Soni (2016).

Imports of small-scale machinery from East Asia were also an important part of the mechanization story – as a direct source of supply, as models for local adaptation, and providing components for incorporation in locally-made machines. In particular, small, single-cylinder engines (<16 hp) imported from Japan played a critical role in the early stages of the industry from the 1950s to the 1970s[1]. These engines could be flexibly incorporated in locally-designed pumps and tractors and thus used to power irrigation, cultivation, threshing, and transportation. By the early 1980s about 80% of the single-cylinder diesel engines sold in the country were supplied by two local manufacturers under license from Japanese parent companies[2]. These engines were more expensive but also more durable; they could be used for tractors, water pumping, boat propulsion, and for powering a locally-made transport vehicle (Chancellor 1983).

1 Single-cylinder engines in Thailand are of three capacities: 5-9, 10-12, and 14-16 hp.

2 Siam Kubota Diesel Co. Ltd. and Yanmar Thailand Co. Ltd., both established in 1978 in Pathumthani Province just north of Bangkok.

Table 1: Usage of Machinery and Equipment on Farms in Thailand

	No. of holdings	% of holdings	Source of machinery or equipment				
			Owned by landholder	Coop. or farmer group	Service provider	Government agency	Other
Tractor							
4-wheel tractor	2,427,001	41.1	336,735	4,869	2,056,174	2,966	6,361
2-wheel tractor	2,438,848	41.3	1,827,555	5,631	643,863	1,884	14,359
Water pump							
Engine	1,376,690	23.3	1,049,403	11,340	316,503	9,892	13,871
Electrical motor	330,474	5.6	283,443	2,767	48,364	11,309	1,789
Natural energy	32,758	0.6	17,989	1,125	14,589	2,442	1,690
Sprayer							
Manually-operated	1,273,177	21.5	856,546	2,264	418,894	1,049	8,082
Machine-powered	1,323,153	22.4	845,773	2,476	489,336	1,266	6,104
Weeder							
Manually-operated	1,053,087	17.8	673,112	1,778	373,144	803	8,699
Machine-powered	1,155,443	19.5	748,969	1,542	379,050	1,155	5,880
Planter/seeder							
Manually-operated	720,999	12.2	268,000	2,140	497,155	827	17,764
Machine-powered	167,413	2.8	62,600	438	110,424	163	682
Att. to 2W- tractor	131,381	2.2	73,237	357	60,179	161	858
Att. to 4W-tractor	192,569	3.3	37,120	427	156,223	258	639
Harvester							
Reaper (sugar)	82,044	1.4	3,047	686	78,953	238	258
Combine harvester	1,639,016	27.7	33,095	3,123	1,588,239	2,456	2,646
Thresher							
Rice/cereal thresher	542,887	9.2	14,512	2,652	526,713	1,449	2,544
Corn sheller	173,568	2.9	4,027	1,328	168,737	256	1,077
Rice/cereal winnower	207,718	3.5	4,777	3,302	201,873	714	1,969
Rice mill	1,808,871	30.6	40,515	59,847	1,752,898	9,130	25,564
Milking machine	11,707	0.2	7,622	102	4,091	28	96
Transportation							
4W-truck	1,744,370	29.5	799,979	3,177	931,162	1,772	15,695
6W-truck (and over)	1,037,262	17.5	84,563	2,483	951,690	1,379	3,112
Boat	29,256	0.5	26,362	44	2,733	42	161
Farm truck	943,220	16.0	499,030	3,001	459,441	1,427	9,521

Source: Agricultural Census 2013

II. National Agricultural Machinery Strategy/Long-Term Plan

Throughout successive National Economic and Social Development Plans (NESDP), beginning with the First Plan (1962-1966), there was no explicit policy regarding agricultural mechanization. Indeed, mechanization was not mentioned until the Sixth Plan (1987-1991). However, in 1979, the National Committee for Agricultural Mechanization was established to formulate a policy and strategy, which was approved by Cabinet in 1985. This essentially affirmed the process that was already well underway, encouraging mechanization that increased productivity, with affordable machines of good quality that were suitable to the conditions of Thai farmers[3]. The strategies involved collaboration between public and private sectors in research and development, standardization of machinery to enable certification, training of farmers and manufacturing workers, and facilitating long-term credit for farmers and machinery businesses[4]. The Seventh Plan (1992-1996) reiterated this general support for mechanization and promotion of local manufacturing and extension to farmers, but there was no explicit policy in this or subsequent plans. The Tenth and Eleventh Plans (spanning 2007-2016) made a significant shift to the notion of a "sufficiency economy", emphasizing sustainable agriculture, food security, bio-energy production, energy efficiency, and environmentally appropriate technologies, but none of these emphases has been interpreted or applied in a way to affect ongoing developments in mechanization.

Nevertheless, government institutions have played an important role in the development of the agricultural machinery industry since the 1950s, particularly in research and development. The Agricultural Engineering Division (AED), now the Agricultural Engineering Research Institute (AERI), under the Ministry of Agriculture and Cooperatives (MOAC), developed blueprints and prototypes, linked with international research programs (e.g., through a joint farm machinery development project with the International Rice Research Institute (IRRI) from 1975 to 1985), and interacted closely with innovative private-sector manufacturers[5]. The Small Industry Finance Corporation (SIFC) was established in 1964 and was a potential source of support to the emerging farm machinery industry, though it was "hampered by limited funds, which were dependent on state budget allocations, and cumbersome and inflexible government procedures and regulations" (SME Bank 2017). Its successor since 2002, the Small and Medium Enterprise Development Bank of Thailand (SME Bank), is much better resourced. The Thailand Board of Investment (BOI) also plays a role by offering tax breaks and other incentives to attract new projects from domestic and foreign manufacturers (Thepent 2015).

Though government institutions have been broadly supportive of mechanization, policy settings were not always favorable to the local industry. Reflecting on the first two decades of mechanization, Sukharomana (1983: 31) remarked: The farm power strategy of Thailand is remarkable in the sense that it has worked despite formidable handicaps. The government's most important contribution to the development of farm machinery industry appears to be the initial importation of small tractors from which local manufacturers borrowed its present technology. Having successfully borrowed, their industry has flourished with little government support – despite prevailing hostile fiscal policies and the government's indifference to industry needs.

According to Sukharomana (1983: 6), cheap credit through the Small Industry Finance Corporation had been "made available in a trickle", with only three agricultural machinery firms acquiring loans. Sukharomana (1983) was particularly critical of the impacts of trade policy on local manufacturing, with low tariffs on imported machinery (including second-hand tractors) and excessive duties on components, particularly the imported diesel engines that were essential to the local industry. Donovan et al. (1986) also point out that, in the 1970s, local tractor production increased at 14% while the import share dropped below 7% – "despite negative protection." However, in 1981 imports of second-hand two-wheeled tractors from Japan surged, seriously undermining the domestic industry[6]. In response to pressure from local manufacturers, in 1982 the

3 This affirmation was important in that there was some debate at the time about the appropriateness of mechanisation based on its capacity to displace agricultural labour and cause excessive rural-urban migration (Anchan 1983) and to reduce agriculture's capacity to re-absorb labour during economic downturns such as occurred in 1997-8 (Coxhead and Plangpraphan 1998).

4 The second strategy regarding standardisation and certification has had limited impact. Testing is not feasible for small- and medium-scale manufacturers without assembly lines and in any case the local market disciplines these manufacturers without needing formal certification. Testing is, however, enforced for the small one-cylinder engines that form an essential component of other machines, whether locally manufactured or imported. Certification for other machinery imports and exports is voluntary.

5 Professional and industry organisations have provided important links between the private sector, researchers, and government, including the Thai Society of Agricultural Engineers, established in 1976, the Agricultural Machinery Manufactures Industry Club, established in 1980, and the Thai Machinery Association, established in 2001 (Thepent 2015).

6 These 18 hp two-wheeled tractors were recycled after perhaps only 2,000 hours of use, enabling importers to undercut the local product.

Government increased tariffs on imported machines and engines and established import quotas. In Anchan's (1983: 12) words, "clearly, the local manufacturing firms are now well protected." This was consistent with policy[7] towards the automotive industry (and industrial policy in general) which was protectionist from the 1960s to the 1980s, before the general liberalization of trade from 1991 (Natsuda and Thoburn 2011), by which time the agricultural machinery industry was well established and starting to export locally-made two-wheeled tractors and equipment to neighboring countries.

A broader aspect of the policy context relates to energy costs. As in many Asian countries, Thailand has long subsidized energy consumption via a complex set of measures (ADB 2015). Retail prices for diesel, liquefied petroleum gas (LPG), and natural gas for vehicles (NGV) are capped – in the case of automotive diesel at THB 30 (USD 0.85) per liter which is of considerable advantage to farmers using diesel pumps, tractors, and pick-ups. Price subsidies for diesel and NGV apply to all consumers while LPG prices vary with the consuming sector. Electricity prices are subsidized for low-consuming households, as is the cost of providing electricity to rural and remote areas (where coverage is now close to 100%). Modeling suggests that removal of these subsidies without compensation or increased government spending on services would reduce the consumption levels of agricultural households and increase rural poverty, particularly in the North and Northeast, but only marginally, indicating that farmers are benefiting somewhat from the current regime (ADB 2015: 14-16). However, subsidy removal would benefit the agricultural machinery sector most, while harming the motor vehicle and vehicle repair sectors (ADB 2015: 17). This implies that the current regime has been on balance unfavorable to the agricultural machinery industry, though not greatly.

In Thailand, his Majesty the King initiated the philosophy of self-sufficiency for the agricultural sector. It was laid out in the way that small-scale farming households should emphasize farming household consumption first. Thereafter, these small farmers within the country should be gathered into groups or cooperatives for enhancing production and marketing efficiency by exchanging goods and services. (Jitsanguan T, 2000)

Likewise, the concept of "Economy of scope" which is performing different farm activities complementing each other can minimize unit cost. A typical example of it can be seen in the form of integrated farming which is producing multiple complementary products, gaining higher benefits than other monoculture farms. (Jitsanguan T, 2000)

In 2014, the Ministry of Agriculture and Agricultural Cooperatives (MOAC) is pushing large-scale rice farming, insisting that the model will help cut production costs, improving rice quality and ensuring higher earnings for farmers. The large-scale rice farming involves three players, the government represented by the MOAC, the farmers and the private sector, with all the parties taking part, starting from production planning, joint management, setting the quality of rice and marketing. These will lead to cost cuts, increased productivity, increased efficiency in management and marketing of rice crops at better prices. Under this model of rice farming, farmers would be trained in production management, including production technology which is appropriate and modern, leading to higher quality of rice crops and cost cuts, making their product more competitive in the market. The model would help reduce costs by 26.4 percent from 4,500 baht per rai to 3,310 baht per rai (938 to 690 USD/ha) while rice yield increases 12.5 percent from 800 kgs to 900 kgs per rai (167 to 188 USD/ha). In addition, machinery rings plan to set up a grouping of farmers and others involved in agriculture who have come together to pool their resources as a means of controlling costs and making the best use of specialized equipment and expertise. The idea is a member contacts the central office to request a service, e.g. machinery, labor or both. He is put in touch with the nearest member who can satisfy that request. Machinery rings will support this policy that with common investments and mutual aid the managing process of the individual farm should become more efficient and reduce production cost.

III. Lessons Learned and Good Practices

After the establishment of the Rice Department in 1953, the Agricultural Engineering Division (AED) began work on improving imported machines and inventing machines suited to local conditions (Jongsuwat 1980). In the mid-1950s the AED developed a submersible, axial-flow, low-lift pump (tho phayanak) powered by a small diesel engine of 4.5 hp, and in 1957 the design was released for local manufacture (Jongsuwat 1980). This "Debaridhi pump" (named after its inventor, M.R. Debaridhi Thevakul) was commercially produced and widely purchased or hired by farmers to lift water from rivers, canals, and ponds and to drain rice fields. It very quickly replaced the traditional water

7 The tariff on imported machines and engines was raised from 5% to 33% of CIF value and the quota for 2-wheeled tractors was set at 5,337, about a third of the quantity imported in 1981 (Anchan 1983:12).

wheels and scoops and complemented the large government-operated pumps in irrigation projects in the Chao Phraya delta (Molle et al. 2003). It was more efficient and cheaper to run than centrifugal pumps and could be easily transported. By enhancing farmers' ability to irrigate, the pump helped to make dry-season cropping of rice and field crops economically attractive to lowland farmers.

Versions of the Debaridhi pump are still widely used, often powered by two-wheeled tractor engines. In 2001, 80% of irrigation pumps were in the Chao Phraya basin (55% in the Central Region and 25% in the North), 15% in the Northeast, and 5% in the South. By 2008 there were reported to be 1.43 million irrigation pumps in use averaging THB 4,500 (USD 126) per unit, hence a total value of THB 6,439 million (USD 180 million) (Thepent 2015). The 2013 Agricultural Census found that 1.7 million holdings (29%) used an irrigation pump, 81% powered by a diesel engine and 19% by an electric motor (Table 1). Of these holdings, 78% owned a pump and 21% accessed a pump through a "service provider", often a neighboring farmer (Table 1)

As in many countries, there was initially a bias in official circles in favor of large tractors as the symbol of modernized agriculture (Chakkaphak and Cochran 1986). In 1891, the government imported some steam-powered tractors and rotary hoes, but these were expensive and unsuitable for use in paddy fields. In the early 1920s, further agricultural machines were imported for research and development, but there was little progress before the onset of World War II. In the early 1950s, four-wheeled tractors were imported for use on the Rice Research Station and promoted through contract services to nearby farmers, but the project was unsuccessful. In 1958 the AED released the design of a small 25 hp four-wheeled tractor (the "Iron Buffalo") to two firms for commercial production, but it could not compete with imported tractors.[8] In 1960 Ford established an assembly line for four-wheeled tractors, followed in 1964 by Massey Ferguson, but these were for use in dryland farming, not in rice production.

Two-wheeled tractors were also imported in the decade after the war. In 1947, a single-axle tractor with rotary hoes powered by a 5.9 hp petrol engine was imported from Japan, but its low chassis made it unsuitable for paddy fields. Later in the 1950s a Japanese two-wheeled tractor was imported and appeared more suitable. However, the major surge in the supply of tractors for rice farming began in the mid-1960s when workshops around Bangkok began to modify the design of the imported two-wheeled tractors to meet farmers' demands for a cheaper and better-adapted version. One workshop succeeded in simplifying the gearbox and adapting other parts of the tractor, notably by lengthening the handles to enable easier turning in the muddy paddy fields. [9]In 1966 several firms began producing these modified two-wheeled tractors, using imported, air-cooled, single-cylinder petrol engines. Their lower price relative to the imported tractors and their suitability to local conditions (e.g., their greater manoeuvrability) made them popular with farmers and they soon spread to all parts of the central plain. In a 1981-2 survey of 222 farmers in an irrigated area of Suphanburi Province in the central plain, reasons given for using the two-wheeled tractors were – "save time in farm work" (22.8%), "can plant on time" (20.3%), "easy and reduces drudgery" (18.6%), "better ploughing" (12.3%), "increases output" (5.6%), "no animal and human labor available" (4.2%), and "reduces weeding" (3.7%) (Sukharomana 1983).

The high demand led to the establishment of many farm machinery firms in this region. By the mid-1970s, there were about 90,000 two-wheeled tractors in use in Thailand, mostly (76%) in the Central Region. By 1981, there were over 284,000 (Chancellor 1983; Sukharomana 1983). Almost all of these (95%) were locally manufactured by small firms, of which there were about 100 in 1979 (Sukharomana 1983). Small engineering workshops located in rural areas needed only a basic toolkit of an oxy-acetylene torch for cutting and welding and an angle grinder to smooth cuts and joins. Mechanics learned their trade on the job and often subsequently set up their own small business. As the workshops were nearby the paddy fields, there were close interactions between farmers and mechanics in developing the tractors. Workshops would freely copy and adapt designs from existing machines and combine parts from different sources, and farmers would compare the performance of the machines and seek out better models. The tractors of the 1960s and 1970s incorporated the imported single-cylinder engines referred to above. By the 1980s, they were mostly equipped with locally manufactured, liquid-cooled 8 hp diesel engines. These engines were more expensive but also more durable; they could be used also for water pumping, boat propulsion, and for powering a locally-made transport vehicle when not used on the tractor (Chancellor 1983).

The two-wheeled tractor was "so common and so simple in

8 The Iron Buffalo was also designed by M.R. Debaridhi Thevakul.

9 The producer of this first successful model was a village headman, Kamnan Prung Farkaew of the Singkru Dsahagrum factory in Phra Pradaeng, now part of Greater Bangkok (Jongsuwat 1980).

construction that any well-equipped workshop could affect repairs" (Chancellor 1983: 6). During the peak seasons, mechanical workshops worked long hours to repair farmers' machines. Mechanics' services were charged at THB 12.5/hr (USD 0.36) in 1980-81 (about twice the minimum wage for non-metropolitan areas at that time). An excellent road network made for the rapid distribution of spare parts. Owners of the small, locally-made tractors did about 30% of their own repairs and called on workshops for 60% (Chancellor 1983). Chancellor concluded that agricultural machinery systems in Thailand were marked by "an extensive general knowledge of machine repair techniques, a wide availability of low-cost machine repair services and a well-developed network of spare-parts supplies from import and domestic sources, so that repairs could be quickly effected" (1983: 6).

As reported in Table 1, by the 2013 Agricultural Census, 2.4 million holdings (41%) used two-wheeled tractors, and in 75% of these holdings the tractor was owned by the landholder. Most of these holdings were rice farms. By this time a similar number of holdings used four-wheeled tractors, also mainly now manufactured or assembled in Thailand.[10]These holdings were typically dryland farms growing field crops such as sugarcane, cassava, or maize. However, in the case of the larger tractors, 85% of holdings relied on service providers, typically larger landholders in the same district who gained extra income by renting out their tractors for land preparation. Larger tractors were more effective in cultivating the harder dryland soils but too expensive for most smallholders to own. However, the distinct uses of two- and four-wheeled tractors are becoming blurred. Thepent (2015: 4) reports that "there is a growing market for a four-wheel tractor of less than 40 hp with rotary implements which will replace two-wheel tractors for rice cultivation in the central plain region and the lower part of the northern region."

Transplanting rice was a major bottleneck. As discussed above, farmers' main response has been to move to direct seeding by hand broadcasting, both in irrigated and rainfed areas. In 1978, a rice transplanter was imported from China by a local firm which also began manufacturing it (Chamsing and Singh 2000: 3). The transplanter was power operated and capable of handling 12 rows. However, it could not be sold in large numbers as farmers preferred the simpler and cheaper broadcasting method. In recent years there has been renewed interest in the use of transplanters in parts of the central plain due to problems with contamination of rice varieties and weed control under direct seeding. Rice transplanters below 10 hp include 4-row and 6-row walking types and those above 10 hp include 6-row and 8-row ride-on types. Sales of these transplanters have been increasing since 2010, though they still account for a small proportion of planted area (Ken Research 2016). All transplanters are imported from Korea, Japan, and China and are accessed through service providers.

The harvesting of rice, including the operations of reaping and threshing, constituted a second period of peak labor demand; hence, there was strong farmer interest in mechanizing these tasks. In 1975, the AED constructed a prototype axial flow rice thresher using a blueprint from the International Rice Research Institute (IRRI) (Mongkoltanatas 1986). It was released to selected firms in Chachoengsao Province, east of Bangkok, for commercial production and 10 units were immediately sold. However, the design proved unsuccessful. Later in 1975, a new blueprint was released to three firms for commercial production and this version was rapidly and widely taken up by farmers. In 1977 IRRI sent a blueprint for a portable rice thresher. It was produced by one firm but not widely used due to its low capacity. Subsequent experimentation came up with a Thai thresher that doubled the capacity (from 1 to 2 t/hr) and was self-propelled so could be driven to the site (Sukharomana 1983; Mongkoltanatas 1986). This made it ideal for the provision by contractors.

During 1981-2 about 1,000 Chinese reapers were imported and sold for rice harvesting. However, the long-stemmed Thai rice varieties were not suitable for reaping and, in any case, farm-workers had to collect and bind the harvested rice as for manual harvesting, requiring more labor. In addition, the weight of the machines made field operations difficult. Hence the reapers were finally abandoned.

In 1985-7, however, local machinery firms near Bangkok began to fabricate small track-type rice combine harvesters that can go into muddy and even flooded fields (Chiaranaikul n.d.). By the early 1990s, these firms successfully launched a range of these track-type combine harvesters which were acceptable to farmers. They had a capacity of 0.4 to 0.9 ha/hr, providing a substantial saving, and were quickly taken up in the central plain through service providers. In 1997 there were about 2,000 harvesters, mainly in the central plain. As more contractors entered the industry, hiring rates have come down. A survey by AERI for 1999-2000 found that 57% of rice farmers harvested with sickles, 35% used a combine, and 8% used a reaper; most farmers (88%) used a power thresher (Thepent

10 However, the import of second-hand four-wheeled tractors remains a concern to the local industry.

2000). Combine harvesters have since spread to the major rice-growing area of the Northeast, at first through itinerant contractors from the Central Region who trucked their combines to the region and used local brokers to line up groups of adjacent farmers, then through local contractors in the Northeast who were capable of directly negotiating with neighboring farmers (Poungchompu and Chantanop 2016). According to the 2013 Agricultural Census, 1.6 million holdings (28%) used a combine harvester, in 97% of cases accessed through a contractor.

As the use of combines has spread, the domestic demand for reapers and threshers has understandably diminished (Table 1), though threshers are still produced for export to neighboring countries, using the same parts as are incorporated in the combine. At the same time, the high moisture content of grain harvested by combines has stimulated the development of a range of mechanical driers. The higher moisture content was because farmers could not dictate the date of harvesting, having to fit in with the contractor's schedule, and because the grain was no longer dried in the field as it was when threshing was conducted separately. The Agricultural Engineering Research Institute (AERI) has made a significant contribution to the design of these driers. In the late 1990s, the government subsidized the installation of small driers (30 t/day) for farmer groups and large driers (60 to over 100 t/day) for cooperative millers. However, only 10% of the farmer-operated driers were used and mechanical drying is now largely undertaken by the rice mills (Thepent and Chamsing 2009).

Sugarcane harvesters have begun to be imported but were used by only 82,000 holdings (1%) in 2013, almost all (96%) operated by contractors. Harvesting of cassava is still done largely by hand, using locally-developed digging tools. According to Thepent (2014), a maize combine harvester has been available since 1995. From 2005 to 2007, the AERI modified the locally-produced rice combine harvester to be suitable for maize (Chiaranaikul n.d.). Two models were developed, one with minor modifications capable of harvesting 0.3-0.6 ha/hr and one with a four-row cob-snapping unit and modified threshing system capable of harvesting 0.8-1.0 ha/hr. Both models are now in commercial production and are being increasingly used by maize farmers on a contract basis.

Though part of a broader trend, the harnessing of mechanical power for transportation, coupled with public investment in roads and infrastructure, has also had a profound effect on agricultural development. As mentioned above, one of the attractions of two-wheeled tractors in the 1960s and 1970s was the capacity to hitch them to a cart to make a multi-purpose transport vehicle. The so-called "pedestrian tractor" thus became a means to haul people and produce much more easily than with a buffalo- or ox-drawn cart. Imported four-wheeled tractors also became a means of transportation for those who could afford them.

Meanwhile, the highly successful Thai automotive industry, a key component of the growth of the manufacturing sector, focused on the production of commercial vehicles, particularly pick-up trucks, which were highly suitable for conditions in rural areas (Natsuda and Thoburn 2011). Business or excise taxes were set at lower rates than on passenger vehicles since the 1960s, adding to their attraction. The industry produced over a million commercial vehicles in 2010. Many of these have been purchased by better-off farmers and rural dwellers who use them to transport inputs, machinery, and produce for themselves and as a hired service to other farmers.

The agricultural machinery industry has been part of the growth and diversification of the manufacturing sector in Thailand. The Department of Industrial Works reported 2,809 businesses producing and repairing agricultural machinery in 2009 (Table 2). A survey in 2001 by the Agricultural Engineering Research Institute found that 46% of agricultural machinery firms were small (<10 employees), 34% were medium (10-30 employees), and 20% were large (>30 employees). Small firms typically have minimal equipment such as a simple lathe, follow flexible designs such that their products cannot be checked against a template, and employ workers on a daily wage without any fixed job descriptions or assignments. Medium firms have jigs and fixtures in addition to a simple lathe but still follow flexible designs and employ daily-paid labor. Large firms use computer numerical control (CNC) machining and possibly an automated machining centre, follow a systematic manufacturing process that can be checked, and employ monthly-paid staff with specified job descriptions and assignments as well as daily-paid staff and contractors.

The businesses enumerated in Table 2 produced mainly two-wheeled tractors and tillage equipment, sprayers, and combine harvesters. Over 40% provided repairs and maintenance in small workshops scattered through the countryside. A survey of the top 70 agricultural machinery factories in Thailand in 2001 gave an indication of the production capacity, emphasizing the importance of two-wheeled tractors, small tillage implements, sprayers, and pumps (Table 5). Two-wheeled tractors and threshers last about 10 years, diesel engines about 7 years, and irrigation pumps and power sprayers about 6 years (Thepent 2000). Hence the output of 80,000 two-wheeled tractors implies the capacity to maintain a stock of

800,000 on farms. This is just under half the recorded stock on rice farms in 2000, underlining the fact that imports of tractors and a range of other agricultural machinery remain important (Table 5).

Indeed, the Thai agricultural machinery industry has become increasingly integrated into the regional economy, with both imports and exports rising rapidly. According to BOI (2016), the value of agricultural machinery imports tripled between 2009 and 2014 to a total value of USD 1.11 billion (Figure 17). The main sources of imports were Japan, China, and Malaysia. The largest imports by value were water pumps, tractor vehicles and parts, and mechanical sprayers. In the same period the value of agricultural machinery exports increased more than five times to USD 0.79 billion, led by two-wheeled tractors and equipment for cleaning, sorting, and grading seed and grains (Thepent 2015; BOI 2016). The major export destinations were Cambodia, Myanmar, Indonesia, and Saudi Arabia. Agricultural machinery and parts accounted for 7% of imports and 10% of exports of all machinery and parts in 2014 (BOI 2016). [11]

Table 2: Number of Agricultural Machinery Businesses in Thailand, 2009

Type of machinery	No. of businesses
Two-wheel tractors	275
Tillage equipment	329
Planters	16
Sprayers	447
Harvesters	386
Other machinery	164
Repairs and maintenance	1,192

Source: Department of Industrial Works

IV. Suggestions for Regional Cooperation amongst Countries

Countries will collaborate in the areas of agricultural research, particularly for developing cutting-edge technologies to promote sustainable food security and safety. The areas of agricultural research, education and extension will be implemented by mean of the following:

- To exchange faculty staff of agriculture and allied scientists for mutual learning and exchange of ideas in the areas of agricultural research, education and extension;
- To exchange technical information on agriculture;
- To exchange of joint research, workshop, seminar, and training program on subjects agreed upon by the parties.

11 Parts and accessories of tractors were the most important single category of all machinery and parts imports and exports in 2014 (BOI 2016).

Vietnam

Ms. Tam Thi Dinh
Deputy Director
Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP)

I. Overview

In recent years, with the growth of agricultural production, application of production mechanization has rapidly developed. However, agriculture development is still unsustainable. The growth rate tends to fluctuate. Competitiveness is low. Good resources for product development are not consolidated. Research and transfer of scienctific technologies are limited. The economic restructuring and innovation in ways for agricultural production are still slow. Production is still at small scale and fragmented; productivity, quality and value-added of lots of goods are low. Post-harvest losses in both quantity and quality are very high (paddy and rice from 11-13%, maize 16-20%, vegetables and fruit 20-30%). Therefore, application of technological advances and synchronously implementing measures, particularly those related to mechanization to improve productivity, product quality and minimize post-harvest losses, which improve the efficiency of production, stable life and income of the farmers, are crucial.

1.1 Current situation

In recent years, the number of engines and agricultural machines increased rapidly. For example, the number of tractors increased by 2.3 times compared with 2001; harvesters increased 26 times compared with 2006 (focusing primarily in Mekong Delta (the South), accounting for 75% of all harvesters in the country); pesticide spreaders increased 6 times compared with 2006; water pumps for agricultural production increased by 1.2 times compared to 2006. Some kinds of machines reduced in their number, such as threshing machines fell 50% due to the increasing use of combine harvesters, dryers decreased 8% in number but drying capacity increased by 20% (small capacity - 1-4 tons/batch dryers were gradually replaced by large 10-30 tons/batch ones).

Some types of machines tend to shift as 2-wheel tractors to 4-wheel tractors (with a capacity of 12-35 HP) increased by 2.1 times compared to 2006. The level of mechanization of some annual crops (rice, sugarcane, corn) at some stages is high such as land preparation is at an average rate of 90%; rice cultivation 30%; care and plant protection spraying 60%, rice harvesting 35%, drying in Mekong delta 45%.

However, the degree of mechanization in agriculture is still low, inconsistent and not comprehensively developed. Compared to other countries in the region, the usage level of agricultural machinery in Vietnam remains low, averaging only 1.6 HP/ha of cultivated land (some regional countries such as Thailand reached 4 HP/ha, South Korea 10 HP/ha, China 8 HP/ha).

Agricultural mechanization in Vietnam focuses mainly on soil preparation for annual crops, upland crops, threshing, and rice transportation and milling. For stages as sowing, caring, and harvesting, the mechanization level is low.

About manufacturing: domestic mechanical products only meet approximately 33% (by value) of domestic demand. In general, tractors with a capacity of 30 HP, transplanters, sugarcane harvesters, maize harvesters, etc. have not been produced to meet quantity and quality requirements in the country. Foreign investment in the field of agricultural machinery, engine manufacturing, and machine assembling is quite small. Since 2009, KUBOTA Vietnam Company Limited built a plant to manufacture tractors and some other agricultural machines which has a design capacity of 15,000 tractors/year and 2,000 agricultural machines (milling machines, rice and maize harvesters, and transplanters), in Binh Duong Province.

1.2 Problems and challenges

Awareness of the importance of mechanization is limited and inadequate. There is no comprehensive proposal for orientation and strategic policy for agricultural mechanization and post-harvest loss reduction in Vietnam. The implementation of any resolutions or measures is still on individual actual situation, patchwork, and not systematic.

Agricultural production is still small and the yield depends heavily on weather. Since farmers receive a low income, they have limited capacity to use investments in agricultural machinery – not to mention to push forward technological innovation in this realm.

Generally speaking, the technological level of manufacturing agricultural machinery (especially medium and large 4-wheel tractors, transplanters, harvesters, etc) in Vietnam is low. In recent years, there are even declines in the size and number of manufacturers as some of the agricultural machine factories had switched to produce other kinds of machinery. What's more, technological researches in agricultural mechanization is very limited because of a lack of funding. Governmental policies also play an ineffective role in driving it forward.

II. Interests in International Cooperation

To accelerate the rate of agricultural mechanization in the country, the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP) welcome international cooperation very much. The following matters are particularly of the Institute's interests:

- Machinery and equipment for comprehensive mechanization of some major crops: tractors 25-40HP; systems for carpet and tray seedling at concentrated scales; transplanters; corn seeder with fertilizer spreader combinations; corn harvesters
- Machine and equipment systems for growing high-tech agriculture, concentrated production areas of vegetables and fruit including mini soil preparation machines, water saving irrigation system combined nutrient supplier, climate control system, and management system for production of vegetables, flowers and fruit in green and glass houses
- Technology and pre-processing and storage equipment systems to improve grain quality and reduce the loss of Vietnam rice, in which focus on completing 2 - phase drying technology, and design and produce tower dryers with capacity up to 15 tons / h. Research on technology, design, manufacture rice storage silo systems at centralized and industrial scales to suit climate conditions of Vietnam
- Technology and processing equipment to diversify agricultural products
- Machines and equipment for mechanization of industrial husbandry. Technology and equipment for processing of fresh food, silage food and other forms of synthetic fodder for livestock
- Technology and equipment for agricultural waste handling (rice husk, rice straw, corn cobs, sugarcane leaves, etc ...) to create heat energy for semi-processing of agricultural products; Producing pellet for livestock and cattle feed and fuel in rural areas and for industries and producing microbial organic fertilizer and construction materials

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ANNEX 1:
Programme of the 5th Regional Forum

5th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific
ANNEX 1: 12-14 December, 2017
Kathmandu, Nepal

11 Dec.	**Arrival in Kathmandu**
12 Dec.	**5th Regional Forum for Sustainable Agricultural Mechanization in Asia and the Pacific**
09:00-09:30	**Opening Ceremony** Moderator: *Mr. Madhusudan Singh Basnyat, Program Director, Directorate of Agricultural Engineering, Ministry of Agriculture and Development* - Welcome Address: *Mr. Suraj Pokharel, Secretary, Ministry of Agricultural Development of Nepal* - Opening Address: *Ms. Li Yutong, Head of the Centre for Sustainable Agricultural Mechanization, ESCAP* - Keynote Address: *Mr. Li Hong, Permanent Representative of China to ESCAP*
09:30-09:50	**Tea Break and Group Photo**
09:50-11:20	**Country Presentations -** Representatives of member countries briefing the efforts of respective countries on strategy and long-term policies of sustainable agricultural mechanization Moderator: *Mr. Nadeem Amjad, Director General, Agricultural Engineering Division, Pakistan Agricultural Research Council* - Bangladesh - *Mr. Sultan Ahmmed, Director Member (NRM), Bangladesh Agricultural Research Council (BARC)* - Cambodia - *Mr. Saruth Chan, Director, Agricultural Engineering Department, Ministry of Agriculture, Forestry and Fisheries of Cambodia* - China - *Mr. Li Qingdong, Division Director, Department of Agricultural Mechanization, Ministry of Agriculture of China* - India - *Mr. Kanchan Kumar Singh, Assistant Director General, Indian Council of Agricultural Research* - Indonesia - *Mr. Astu Unadi, Senior Researcher, Indonesian Centre for Agricultural Engineering Research and Development (ICAERD), Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture of Indonesia*
11:20-12:00	**Panel Discussion -** To discuss and identify the key elements/components and essential processes for Sustainable Agricultural Mechanization Strategy (SAMS) formulation. **Panel List:** Mr. Sultan Ahmmed, Mr. Saruth Chan, Mr. Li Qingdong, Mr. Kanchan Kumar Singh, Mr. Astu Unadi
12:00-13:30	**Lunch Break**

13:30-15:00	**Country Presentations -** Representatives of member countries briefing the efforts of respective countries on strategy and long-term policies of sustainable agricultural mechanization Moderator: *Mr. K. Alagusundaram, Deputy Director General (Engineering), Indian Council of Agricultural Research (ICAR)* - Malaysia - *Mr. Mohd Syaifudin Abd Rahman, Deputy Director of Engineering Research Centre, Malaysian Agricultural Research & Development Institute (MARDI)* - Myanmar - *Mr. Zaw Khin, Director, Agricultural Mechanization Department, Ministry of Agriculture, Livestock and Irrigation* - Nepal – *Mr. Madhusudan Singh Basnyat, Program Director, Directorate of Agricultural Engineering, Ministry of Agriculture and Development* - Pakistan - *Mr. Nadeem Amjad, Director General, Agricultural Engineering Division, Pakistan Agricultural Research Council* - Philippines - *Ms. Rossana Marie C. Amongo, Director, Institute of Agricultural Engineering (IAE), College of Engineering and Agro-industrial Technology (CEAT), University of the Philippines Los Baños (UPLB)*
15:00-15:20	**Tea Break**
15:20-16:00	**Panel Discussion -** To discuss and understand the main challenges faced by member countries, and lessons learned in implementing SAMS. **Panel List:** Mr. Mohd Syaifudin Abd Rahman, Mr. Zaw Khin, Mr. Madhusudan Singh Basnyat, Mr. Nadeem Amjad. Dr. Rossana Marie C. Amongo
16:00-17:00	**Country Presentations -** Representatives of member countries briefing the efforts of respective countries on strategy and long-term policies of sustainable agricultural mechanization Moderator: *Ms. Rossana Marie C. Amongo, Director, Institute of Agricultural Engineering (IAE), College of Engineering and Agro-industrial Technology (CEAT), University of the Philippines Los Baños (UPLB)* - ROK - Mr. *Sung Jehoon, Senior Researcher, Ph.D., Department of Agricultural Engineering, National Academy of Agricultural Science* - Sri Lanka - *Mr. B.M.C.P Balasooriya, Deputy Director, Farm Mechanization Research Centre, Department of Agriculture of Sir Lanka* - Thailand - *Mr. Viboon Thepent, Director of Postharvest Engineering Research Group, Senior Agricultural Engineering Specialist, Agricultural Engineering Research Institute, Department of Agriculture* - Vietnam - *Ms. Tam Thi Dinh, Deputy Director, Vietnam Institute of Agricultural Engineering and Post-harvest Technology (VIAEP)*
17:00-17:30	**Panel Discussion** – To discuss and identify potential areas for regional cooperation **Panel List:** Ms. Li Yutong, Mr. Sung Jehoon, Mr. B.M.C.P Balasooriya, Mr. Viboon Thepent, Ms. Tam Thi Dinh
17:30-18:00	**Group Discussion on Follow Up Actions** Moderator: *Mr. Anshuman Varma, Programme Officer, Centre for Sustainable Agricultural Mechanization, ESCAP*
18:00-18:15	**Wrap up and Closure** *Ms. Li Yutong, Head of the Centre for Sustainable Agricultural Mechanization, ESCAP*

13 Dec.	**Regional Workshop on Integrated Straw Management in Asia and the Pacific**
09:00-09:20	**Opening of the Regional Workshop on Integrated Straw Management** Moderator: *Mr. Anshuman Varma, Programme Officer, Centre for Sustainable Agricultural Mechanization, ESCAP* - Welcome Address: *Mr. Madhusudan Singh Basnyat, Program Director, Directorate of Agricultural Engineering, Ministry of Agriculture and Development* - Opening Address: *Ms. Li Yutong, Head of the Centre for Sustainable Agricultural Mechanization, ESCAP*
09:20-10:00	**Keynote Presentation** - IRRI Efforts on Integrated Straw Management - *Mr. Hung Van Nguyen, Research Scientist, International Rice Research Institute (IRRI)* - CIMMYT Efforts on Integrated Straw Management – *Mr. Gokul Paudel, Agricultural Economist, International Maize and Wheat Improvement Center (CIMMYT) South Asia* - Outcomes and Findings of CSAM Integrated Straw Management Research - *Mr. Li Hongwen, Professor, China Agricultural University; Team Leader, CSAM Integrated Straw Management Research Team*
10:00-10:20	**Tea Break**
10:20-11:20	- Detailed findings of the East Asia Component of the CSAM Research and workplan of the pilot in China - *Mr. He Jin, Professor, China Agricultural University* - Detailed findings of the South Asia Component of the CSAM Research and workplan of the pilot in India - *Mr. Kanchan Kumar Singh, Assistant Director General, Indian Council of Agricultural Research* - Detailed findings of the Southeast Asia Component of the CSAM Research and workplan of the pilot in Vietnam - *Mr. Pham Van Tan* *Deputy Director, Sub-Institute of Agricultural Engineering and Post-harvest Technology (SIAEP) of Vietnam*
11:20-11:50	**Q&A, Discussion and Follow-ups**
11:50-12:00	**Wrap up and Closure**
12:00-13:30	**Lunch Break**
13:00-18:00	**Pilots Work Group Meeting of Integrated Straw Management** **& (In parallel)** **13th Session of the Governing Council (GC) of CSAM**
14 Dec	**Field Visit (TBC)**
	Visit ICIMOD Knowledge Park; Fisheries Research Division, Nepal Agricultural Research Council (NARC); Floriculture Development Farm of the Department of Agriculture; Tayemaya Farmers Group; and Barsha Pump Site.
15 Dec	**Departure from Kathmandu**

ANNEX 2: Participants List

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