4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific

Leading the Way for Climate-smart Agriculture through Machinery and Practices

23-25 November 2016

Hanoi, Vietnam

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

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

The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 Member States and 9 Associate Members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries'sustainable and inclusive development ambitions.

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Room 2060, 20th Floor
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This synthesis report comprises of the proceedings of the 4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific, held on 23-25 November 2016 in Hanoi, Vietnam. It was prepared by a team at the Centre of Sustainable Agricultural Mechanization (CSAM) under the overall guidance of Dr. Li Yutong, Head of CSAM. The presentations and speeches were provided by participants and speakers of the forum.

Special thanks go to Ms. Ianina Kalinich, Ms. Feng Yuee, Ms. Wing Yu Carter Cheng, Ms. Yidan Xu and Ms.Yanni Dong for summarizing, compiling, and proofreading the country reports. CSAM is also grateful for Mr. Sun Yi's effort in layout design for the report.

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Executive Summary

The Fourth Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific was convened on 23-25 November 2016 in Hanoi, Vietnam on the theme of "Leading the Way for Climate-smart Agriculture through Machinery and Practices" to explore approaches to advance Climate-smart mechanization in the Asia-Pacific Region and share proven practices as well as lessons learned.

The three-day Forum brought together over 50 participants working in the field of sustainable agricultural mechanization including representatives of pertinent international and regional organizations, government officials and other stakeholders from 16 countries in Asia and the Pacific region, namely, Bangladesh, Cambodia, China, Fiji Islands, India, Indonesia, Fiji, Lao PDR, Malaysia, Nepal, Pakistan, Philippines, republic of Korea, Sri Lanka, Thailand, and Vietnam.

The Regional Forum on Sustainable Agricultural Mechanization is an annual strategic initiative of the Centre for Sustainable Agricultural Mechanization (CSAM) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), aiming at promoting high-level policy dialogue and regional cooperation in the field of sustainable agricultural mechanization. This year, the event was co-organized by CSAM and the Viet Nam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP) with the support of the Centre of International Cooperation Service of the Ministry of Agriculture and Rural Affairs of China.

The Forum focused on how low-carbon technologies and innovative practices in the Asia-Pacific region are being applied and disseminated. In her remarks during the event, Ms. Li Yutong, Head of CSAM, emphasized that "Agriculture is highly exposed to climate change, and contributes to climate change through the release of greenhouse gases into the atmosphere. Agriculture can contribute to climate change mitigation by reducing greenhouse gas emissions and by sequestering carbon while maintaining food production. Sustainable agricultural mechanization is one of the indispensable methods to facilitate Climate-smart agriculture in the region."

In order to mitigate the impacts of climate change and achieve the Substainable Development Goals (SDGs), these Proceedings synthesize the country papers presented by participating countries as well as propose lessons learned and good practices for regional cooperation among countries on Climate-smart agricultural mechanization. As borne out by the country papers, there are some common constraints and challenges faced by the agricultural sector in countries of the Asia-Pacific region. In response to these challenges, special attention needs to be paid to the areas and measures listed in the table below.

Table 1: Major constraints and challenges and potential measures for Climate-smart mechanization in the Asia-Pacific region

Major constraints and challenges	Potential measures
• Shortage of skilled workforce • Inefficient use of natural resources • Decline in arable land and productivity • Low awareness of technological developments and programmes in Climate-smart mechanization • Underdeveloped manufacturing infrastructure and high price of agricultural machinery • Limited scale of investments by manufacturers • Inadequate policy and legislative frameworks for sustainable agricultural mechanization.	• Provision of necessary training for farmers • Strengthening R&D capabilities for Climate-smart mechanization • Application of new technologies for efficient and effective management of resources • Awareness raising amongst relevant stakeholders to change traditional mindsets • Incentives and support for agricultural machinery including national and private banks • Promotion of more integrated trade and investment in agricultural machinery to meet country needs • Coordinated actions involving governments, farmers, private sector and civil society

Overall, measures for advancing Climate-smart agricultural mechanization and strengthening related regional cooperation can be categorized into three main groups, namely capacity building, technology enhancement, and policy support. From the perspective of capacity building, training programmes can be implemented for different segments of farmers to develop their skills and coping capacity under the scenario of climate change while agricultural machinery enterprises should be supported to strengthen their capacities for machinery development and innovation. In relation to technological enhancement, there is a need to support the efficient and environmental-friendly use of mechanical inputs combined with Geographical Information Systems (GIS) and data management technologies. Engaging a diverse range of institutions in the development of climate resilient mechanization technologies is also requisite. From a policy perspective, measures are required to increase the affordability of machinery, tools and implements for farmers. Enhanced support from governments at both the national and international levels is also required to accelerate the application of Climate-smart mechanization technologies and further cooperation. Implementation of appropriate policy and legislative frameworks should be strengthened taking into account environmental and other regulatory standards.

Moreover, to integrate Climate-smart agricultural mechanization into efforts for sustainably enhancing agricultural productivity and resilience to climate change, governments and non-government stakeholders should consider good regional and global practices and lessons learned for which dialogue and knowledge exchange is vital. This can enable sustainable agriculture mechanization to play a positive role in promoting climate change adaptation and mitigation, reducing poverty and enhancing food security.

List of Abbreviations

ABEI	Agricultural and Biological Engineering Institute
ADB	Asian Development Bank
ADS	Agricultural Development Strategy
AEPC	Alternative Energy Promotion Centre
AFMTs	Agri-fishery mechanization technologies
AMDP	Agricultural Mechanization Development Program
AMIS	Agriculture Management Information System
AMMDA	Agricultural Machinery Manufacturers and Distributors Association
AMTEC	Agricultural Machinery Testing and Evaluation Center
AWD	Alternate Wetting and Drying
BAFE	Bureau of Agricultural and Fisheries Engineering
BAFS	Bureau of Agricultural and Fisheries Standards
BAI	Bureau of Animal Industry
BAR	Bureau of Agricultural Research
BFAR	Bureau of Fisheries and Aquatic Resources
BPI	Bureau of Plant Industry
BSWM	Bureau of Soil and Water Management
CA	Conservation agriculture
CAU	China Agricultural University CHED Commission on Higher Education

CLSU	Central Luzon State University
CORIGAP	Closing Rice Yield Gaps in Asia with Reduced Environmental Footprints
CSA	Climate-smart Agriculture
CTRC	Conservation Tillage Research Centre
FMI	Farm Machinery Institute
GAI	Green Area Index
GAP	Good Agricultural Practices
GCF	Green Climate Fund
GEF	Global Environmental Fund
GHGE	Greenhouse Gas Emission
GLP	Good Livestock Practices
GVP	Good Veterinary Practices
HEI	Higher Education Institutions
HWD	Hot Water Dip
INDC	Intended Nationally Determined Contributions
INM	Integrated Nutrition Management
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IRRI	International Rice Research Institute

KSAE	Korean Societies of Agricultural Engineering
LLDA	Laguna Lake Development Authority
LLL	Laser-Controlled Land Leveling
MARD	Ministry of Agriculture and Rural Development
MARDI	Malaysian Agricultural Research and Development Institute
MOA	Ministry of Agriculture
MoAD	Ministry of Agricultural Development
MRD	Mekong River Delta
NAMEA	Nepal Agricultural Machinery Entrepreneurs Association
NARC	Nepal Agricultural Research Council
NFA	National Food Authority
NIA	National Irrigation Administration
NICRA	National Innovation on Climate Resilient Agriculture
NITC	National Information Technology Center
NITP	Non-Conventional Irrigation Technology Project
PARK	Pakistan Agricultural Research Council
PCA	Philippine Coconut Authority
PCAARRD	Philippine Council for Agriculture
PCAF	Philippine Council for Agriculture and Fisheries

PCC	Philippine Carabao Center
PGPC	Philippine Grains Postproduction Consortium
PPCR	Pilot Program for Climate Resilience
SAMS	Sustainable Agricultural Mechanization Strategies
SIAEP	Sub-Institute of Agricultural Engineering and Postharvest Technology
SLM	Sustainable Land Management
SME	Small-Medium Entrepreneurs
SRA	Sugar Regulatory Administration
SRI	Systems of Rice Intensification
SUC	State Universities and Colleges
TLUD	Top-Lit Up-draft
VIAEP	Vietnam Institute of Agricultural Engineering and Postharvest Technology
VRT	Variable Rate Technology

Welcome Remarks

Mr. Le Quoc Doanh
Vice Minister
Ministry of Agriculture and Rural Development
Vietnam

Ladies and Gentlemen,

On behalf of the Ministry of Agriculture and Rural Development of Vietnam, I am honored to welcome you in Hanoi to participate in the 4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific of CSAM with the theme – "Leading the Way for Climate-smart Agriculture through Machinery and Practices".

In recent years, changes in agricultural structure, land use and climate have been increasingly affecting our socio-economic life. For example, arable land has been reducing gradually because of rapid industrial development and drastic rise in labor cost. Various natural resources, not limited to water and the air, have become increasingly polluted because of the prevailing methods of cultivation and overuse of chemicals in agricultural production, which make food safety a major concern of our daily lives.

In this respect, sustainable agricultural mechanization is crucial to our living standard and socio-economic development in the long run. To further the progress of such an endeavor, the 4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific will bring together stakeholders in the region to share and discuss the best practices of Climate-smart agricultural mechanization for evidence-based decision-making and extensive diffusion in communities across the region.

This conference will provide an incredible platform for government officials, researchers and academics, extension service managers, private sector representatives, agricultural and ecological engineers, and representatives of international and regional organizations to initiate real actions that improve living standards and contributing practically to a greener, cleaner, and more beautiful planet.

To end with, I hope the forum is a great success. I would also like to express my gratitude to CSAM for organizing and to Vietnam for hosting this remarkable event.

Thank you.

Welcome Remarks

Mr. Pham Anh Tuan
Director General
Vietnam Institute of Agricultural Engineering and Post-Harvest Technology

Dear Ms. Katinka Weinberger,

Ladies and gentlemen,

I am pleased to welcome you in Hanoi to participate in the 4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific of CSAM with the theme of “Leading the Way for Climate-smart Agriculture through Machinery and Practices”.

As we know, sustainable agricultural mechanization is getting more and more important across the globe. Effective application of research results can ensure sustainable development in agriculture, which will contribute to improve human lives and protect the earth environment and land resources for the future generations.

In this conference room today, I see capacity and experience that make real contribution to the betterment of our planet earth and our living standards in general.

I hope that all of us will use coming hours effectively to share insightful ideas.

Thank you for your participation in the forum.

Opening Remarks

Ms. Katinka Weinberger
Chief
Environment and Development Policy Section
Environment and Development Division
Officer-in-Charge
Centre for Sustainable Agricultural Mechanization
United Nations Economic and Social Commission for Asia and the Pacific

Distinguished Mr. Le Quoc Doanh, Vice Minister of the Ministry of Agriculture and Rural Development of Vietnam;

Distinguished Mr. Pham Anh Tuan, Director General of the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP);

Representatives of CSAM Member Countries;

Ladies and Gentlemen,

On behalf of the Centre for Sustainable Agricultural Mechanization of the United Nations Economic and Social Commission for Asia and the Pacific, it is my pleasure to welcome you to the 4th 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. Since 2013, three Forums were organized providing a unique opportunity to key stakeholders in our region to share and elaborate on important topics related to the whole spectrum of agricultural mechanization.

The 4th Regional Forum has chosen “Leading the Way for Climate-smart Agriculture through Machinery and Practices” as its guiding theme. This theme is very timely. Earlier this month on the 4th, the Paris Agreement on Climate Change entered into force; an important achievement in our global collective efforts to address climate change.

The preamble of the Paris agreement makes explicit reference to food security and production. It acknowledges “the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change”.

80% of the Intended Nationally Determined Contributions (INDCs) submitted by countries committed to action on agricultural mitigation, and 90% of INDCs that include adaptation selected agriculture as a priority sector for action.

We thus now have a strong framework for climate action in the agricultural sector.

What is needed now is action.

- The effects of climate change, such as increasing frequency and intensity of 'extreme events', increasing average temperatures, changes in rainfall patterns, and changes in water availability, are already undermining global efforts to assure food security and nutrition.
- On the other side, agriculture and land-use change, mainly deforestation of tropical forests, contribute around one quarter of the global anthropogenic greenhouse gas emissions. It is impossible to address climate change without considering change to current production practices in the agricultural sector.
- 76% of the world's poor live in Asia-Pacific's rural areas. More than 2.2 billion people in our region rely on agriculture for their livelihoods. The people in our region are likely to be hit hardest by climate change.

Food systems in the region need to change to allow for sustainable productivity increases and higher incomes of farmers and adapt to and build resilience of communities to climate change and variability. All of these are encapsulated in the Climate-smart agriculture (CSA) approach.

Climate-smart agriculture is an approach that can help to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to sustainably increase agricultural productivity and incomes; adapt and build resilience to climate change; and reduce and/or removing greenhouse gas emissions, where possible.

Agricultural mechanization can play a positive role in achieving Climate-smart agriculture both in adaptation and mitigation.

- Consider for example more efficient use of water and fertilizers;
- Improving land management, for example through laser leveling;
- Enhancing crop residue utilization;
- Reducing post-harvest losses;
- Conservation agriculture and precision agriculture;
- Also, fuel use efficiency of agricultural machinery and equipment in the region has large room to improve. For instance, the fuel consumption of the tractors produced in China is generally 30% higher than the consumption of American and Germany tractors of same horse power.

CSAM, a regional institution of the Economic and Social Commission of Asia and the Pacific (ESCAP), is devoted to sustainable agricultural mechanization in the region. In its nature and mandate, CSAM has the responsibility to facilitate efforts of member states in achieving Climate-smart Agriculture and Sustainable Development Goals.

We are meeting today in Hanoi at the 4th Regional Forum to:

- Improve the awareness of key stakeholders on the role of mechanization in achieving Climate-smart agriculture;
- To share and document experiences with agricultural machinery knowledge, technologies and practices that contribute to the adaptive capacity and income security of farmers in the region while also reducing GHG emissions; and
- To facilitate cooperation between different stakeholders in the field of Climate-smart agricultural machinery technologies and practices in the region.

I look forward to listening to your insightful thinking and sharing of best practices in your respective countries in the coming two days.

Last but not the least, please allow me to express my deep appreciation to our co-host – the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP) for their commitment and dedication. They have shown incredible support in organizing this Forum. My sincere gratitude also goes to the Centre of International Cooperation Service of the Ministry of Agriculture and Rural Affairs of China for supporting the poster exhibition in parallel to the Forum.

Ladies and Gentlemen,

I wish you every success to your deliberations in Hanoi.

Thank you.

Opening Remarks

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

Distinguished Mr. Pham Anh Tuan, Director General of the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP);

Distinguished Mr. Katinka Weinberger, OIC of the Centre for Sustainable Agricultural Mechanization;

Representatives of CSAM Member Countries;

Ladies and Gentlemen,

It is a great pleasure and privilege to attend the 4th Regional Forum on Substaintial Agricultural Mechanization in Asia and the Pacific and deliver opening remarks today. I wish to thank Mr. Katinka Weinberger for the kind invitation before I assume office in CSAM on 28 November 2016. I am happy and honored to be here with all of you.

Everyone here has witnessed the notable efforts CSAM made in the past few years to recraft its strategic direction, revive its vitality, re-delineate its project framework, and re-define its partnership strategies and outreaching endeavor. A series of innovative and need-oriented projects and activities have been developed and implemented.

The Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific is one of the flagship activities of CSAM providing a unique platform to exchange sound policy options, pursue policy advocacy, and mobilize political commitment in implementing regional actions addressing shared interests and concerns as well as the emerging and critical issues of sustainable agricultural mechanization.

Meanwhile, CSAM is striving to ensure the quality and performance of the agricultural machinery produced and traded in the Asia-Pacific region via the Asian and Pacific Network for Testing of Agricultural Machinery (ANTAM), to rally support of private sector of agricultural machinery and promote regional trade and investment through the Regional Council of Agricultural Machinery Associations in Asia and the Pacific (ReCAMA), to build regional database on agricultural mechanization, to provide tailored capacity building activities to member countries, and so forth.

The image and influence of the Centre has been significantly enhanced in the community of the agricultural mechanization within and beyond the region. This can be effectively evinced by the active participation and solid contribution of member countries to the Centre's initiatives, and extensive partnership established of the Centre with various key stakeholders in this community. And, it is barely possible without all your active participation and invaluable contribution.

Built upon the existing achievements, CSAM will continue to work on the causes we hold truth in and give our best effort to design and implement more fit-for-purpose activities. This will facilitate your efforts to achieve sustainable agricultural mechanization which contributes to food security, poverty alleviation, and livelihood improvement in your countries.

CSAM look forward to working with all stakeholders within and beyond the region to inspire innovative thinking and build synergy with governmental agencies, research institutes, the private sector and NGOs as well as international and regional development counterparts.

I look forward to working with all of you in this exciting and promising cause in the future and appreciate your continuous support and contribution in advance.

Ladies and Gentlemen,

Agriculture is highly exposed to climate change and contributes to climate change through the release of greenhouse gases into the atmosphere. However, agriculture can also contribute to climate change mitigation by reducing greenhouse gas emissions and by sequestering carbon while maintaining food production. Sustainable agricultural mechanization is one of the indispensable methods to facilitate Climate-smart agriculture in the region.

I am fortunate to have this chance to meet and learn from you on the feasible way for Climate-smart agricultural mechanization as well as the insights for the Centre's development.

I would like to extend my special thanks to the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP) and the Centre of International Cooperation Service of the Ministry of Agriculture and Rural Affairs of China for their commitment and support to the 4th Regional Forum of CSAM.

I wish you every success to your deliberations in the coming two days.

Thank you.

I. Keynote Speeches

Adapting Agricultural Systems in a Changing Climate: Climate-smart Agriculture and Sustainable Agricultural Mechanization Strategy

Ms. Mayling Flores Rojas
Agricultural Systems Mechanization Officer
Regional Office for Asia and the Pacific
United Nations Food and Agriculture Organization

In Asia and the Pacific region, the adverse impacts of climate change have already affected the livelihoods and food security of rural communities. [1]Climate change has great negative impacts on people's health and safety, with the poorest people in the poorest countries suffering the most. [2]Some 90% of the world's poverty population are found in East Asia, South Asia and Sub-Saharan Africa.[3] Improving food security and eradicating global poverty cannot be achieved without strengthening the resilience of smallholder farmers and rural communities in dealing with climate change impacts. [4]

All countries in Asia and the Pacific islands are vulnerable in face of climate change. [5]Six out of ten countries in the world, for Myanmar, the Philippines, Bangladesh, Vietnam, Pakistan and Thailand in particular, are affected by extreme weather events from 1995 to 2014.[6] These countries were hit by floods, heavy monsoon rains, tropical storms, landslides and typhoons. Often these extreme weather conditions kill thousands of people, displace families, damage agriculture, and threaten food security.[7] In face of increased scarcity of resources, shocks and forced migration induced by Climate Change, rural women are subject to alarming level of vulnerability.[8] Actions to combat climate change are urgently needed in the region.

The Paris Agreement, which has been ratified by 125 parties of the UNFCCC and entered into force on 4th November 2016, sets a new course for global climate efforts, steering all nations towards a common cause to tackle climate change and adapt to

1 FAO. 2016. The State of Food and Agriculture: Climate Change Agriculture and Food Security
2 IFAD and The Global Mechanism. 2009. Climate Change Impacts in the Asia/Pacific Region. Retrieved September 01 2016, from http://www.ifad.org/events/apr09/impact/pacific.pdf
3 FAO. 2016. Leaving no one behind: Addressing Climate Change for a world free of poverty and hunger
4 FAO. 2016. The State of Food and Agriculture: Climate Change Agriculture and Food Security
5 FAO. 2016. Leaving no one behind: Addressing Climate Change for a world free of poverty and hunger
6 Germanwatch. 2016. Global Climate Risk Index 2016: Who Suffers Most From Extreme Weather Events? Weather-Related Loss Events In 2014 and 1995 to 2014
7 ADB.2016. Assessing the Intended Nationally Determined Contributions of ADB developing members
8 Women's Environment & Development Organization (WEDO). 2007. Changing the Climate: Why Women's Perspectives Matter. Women's Environment and Development Organization Information Sheet

its effects, with enhanced support to assist developing countries in the mitigation and adaptation process.[9] The Agreement aims to strengthen the global response to the threat of climate change and bolster the ability of countries to deal with the impacts of climate change.[10] These goals are expected to achieved through "Nationally Determined Contributions" (NDCs) and guide country-level actions on climate change in the upcoming years.[11] Out of 46 countries[12] in Asia and the Pacific, 44 have submitted "Intended Nationally Determined Contributions" (INDCs).[13] In their INDCs, more than 85% of the countries in Asia and 60% of countries in the Pacific have key measures on Agriculture and Natural Resources Management; more than 90% of the countries in Asia have adaptation measures and 70% have mitigation measures. In Pacific countries, mitigation measures cover more than 80% and adaptation measures represent 60% of their INDCs. [14]

Agriculture will play a key role in climate change efforts because of its potential to provide opportunities for adaptation and mitigation, socio-economic and environmental co-benefits.[15] Agriculture is the main source of livelihoods of rural communities in Asia and the Pacific; it is also the human activity affected mostly by climate change.[16] Smallholder farmers, herders, fisher folk and foresters can, to a certain extent, mitigate the effects of climate change by adopting Climate-smart practices and technologies, diversifying agricultural systems and food systems, diversifying on- and off-farm income, and improving sustainable management of natural resources. [17]

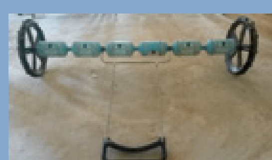
In order to transform the agricultural and food systems and diversify smallholder livelihoods, additional investment in the agricultural sector is required in forms of infrastructure development, provision of effective and up-to-date extension services, climate information, improving market access, provision of credit and social insurance schemes.[18] Opportunities for financial, technological and capacity building support for transforming INDCs into specific actions, policies and measures exist in manifestation of Green Climate Fund (GCF), Global Environmental Fund (GEF) and bi-lateral

Box 1. ***Example of SAM contribution to CSA pillar 1 (food and income) and 2 (Climate Change Adaptation): Drum seeder and Portable Cutter, Technologies that save money and time.***

Under FAO Save and Grow Farmer Field Schools (FFS) in three districts of Sayabouly province Lao PDR, direct seeders were demonstrated in the rice fields for direct seeding. Compared to manual transplanting, which is a common technique for planting rice in the province, direct seeding saves 157,163 LAK (19 USD) and 118 hours per hectare during the first planting season. The direct seeder is paid off during the first planting season. During the second and subsequent planting seasons the money saved is approximately 857,163 LAK (106 USD) mainly coming from the reduction in labour cost.
The labour productivity increases 8 times when using a drum seeder and 4 times fewer seeds are needed per hectare when compared to manual transplanting.

In Sayabouly province, some farmers were using portable cutters for harvesting the improved rice variety during the rainy season. The portable cutter can save 58 hours of work per hectare when compared to manual harvesting with a sickle. During the first harvest there is no money saved because of the investment cost of the machine (approx. 60 USD), from the second harvest onwards there is a saving of 333.081 LAK (41 USD). The labour productivity increases by 5 times when using a portable cutter compared to manual harvesting.

While increasing the labour productivity (allowing timely planting and harvesting) and reducing the production cost, both the drum seeder and the portable cutter may represent an additional source of income for farmers as they could provide services for planting and harvesting to other farmers.



Portable cutter with a guider
©Mayling Flores Rojas

Drum seeder (6-row)
©Mayling Flores Rojas

Source: Author (Based on field visit and interviews made to students, graduates and trainers of Save and Grow FFS, Sayabouly province, Lao PDR).

9 UNFCCC. 2016. The Paris Agreement. Retrieved January 23 2017, from http://unfccc.int/paris_agreement/items/9485.php
10 UNFCCC. 2016. The Paris Agreement. Retrieved November 18 2016, from http://unfccc.int/paris_agreement/items/9485.php
11 UNFCCC. 2016. The Paris Agreement. Retrieved November 18 2016, from http://unfccc.int/paris_agreement/items/9485.php
12 46 is the total of Member countries of FAO Regional Office for Asia and the Pacific
13 UNFCCC. 2016. The Paris Agreement. Retrieved January 23 2017, from http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx
14 ADB.2016. Assessing the Intended Nationally Determined Contributions of ADB developing members
15 FAO. 2016. The State of Food and Agriculture: Climate Change Agriculture and Food Security
16 IFAD and The Global Mechanism. 2009. Climate Change Impacts in the Asia/Pacific Region. Retrieved September 01 2016, from http://www.ifad.org/events/apr09/impact/pacific.pdf
17 FAO. 2016. The State of Food and Agriculture: Climate Change Agriculture and Food Security
18 Ibid

and multilateral contributions as well as through government and private sector supporting these areas. [19]

The Contribution of Sustainable Agricultural Mechanization Strategies (SAMS) to Climate-smart Agriculture (CSA)

The strategic objectives of FAO are to make agriculture, forestry and fisheries more productive and sustainable; reduce rural poverty; enable inclusive and efficient agricultural and food systems, increase the resilience of livelihoods to threats and crises through Climate-smart Agriculture (CSA) and Sustainable Agricultural Mechanization Strategies (SAMS) in Asia and the Pacific region.

SAMS is a planning strategy that takes a holistic approach to address the sustainable use of mechanization across the entire agri-food chain, from land preparation and crop husbandry to harvesting and post-harvest handling and processing.[20] SAMS´s goal is to ensure that the use of sustainable agricultural mechanization contributes to food security, economic development and ecological balance in Asia and the Pacific Region. [21]

CSA is an approach that helps to guide the actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate.[22] CSA pillars are based on (1) sustainably increasing agricultural productivity and incomes (food and income) (2) adapting and building resilience against climate change (adaptation) (3) reducing and/or removing Greenhouse Gas (GHGs) Emissions, where possible (mitigation). [23]

SAMS contribute to pillar 1, related to food and income, by increasing land and labour productivity, reducing production cost (see Box 1), reducing post-harvest losses and adding value to food produce.

The contribution of SAMS to pillar 2 on adaptation to climate change includes timely planting and harvesting to cope with erratic rainy pattern and efficient water management and conservation.

Box 2. SAM and Post-Harvest Losses, Contribution to CSA pillar 3 (Climate Change Mitigation):

Post-harvest losses of fruits and vegetables in Asia and the Pacific region can be as high as 50%, for rice they are estimated to be around 12-37%.a Food losses and food waste together are the third largest emitters of GHGs in the world after China and USA.b

Potential exists for increasing the efficiency across the value chains and reducing the post-harvest losses through Sustainable Agricultural Mechanization (SAM) and improved post-harvest management in the region. Further analysis to better understand the specific contribution of agricultural mechanization on the reduction of post-harvest losses is needed.

Source: a FAO. 2013. High-level Multi-Stakeholder Consultation on Food Losses and Food Waste in Asia and the Pacific Region. Bangkok, Thailand
b FAO. 2013. Food wastage footprint Impacts on natural resources

SAMS contribute to pillar 3, related to mitigation of GHGs, by increasing the efficiency in the use of inputs such as fertilizers, reducing the burning of crop residues and post-harvest losses (See Box 2). Minimum soil disturbance is one of the components of Conservation Agriculture (CA) which can be achieved by using direct seeders for minimum-tillage. Both Systems of Rice Intensification (SRI) and Alternate Wetting and Drying (AWD)[24] require a thorough land levelling for efficient water distribution and drainage. CA, SRI and AWD are a set of sustainable agricultural practices that increase the efficiency in the use of water and reduce the emission of GHGs. [25]

There are trade-offs on the contribution of SAMS to pillar 3. As human power mechanization does not emit GHGs, mechanization powered by fossil fuel and animals do emit GHGs. The research on this trade-off is limited: it may be important to carry out further research on the implications of mechanization and its contribution to GHGs. Alternatively, renewable energy such as solar energy to power equipment can be promoted, and solar dryers and solar water pumps are found in the region.

19 ADB.2016. Assessing the Intended Nationally Determined Contributions of ADB developing members
20 FAO.2015. A Regional Strategy for Sustainable Agricultural Mechanization. Sustainable Mechanization across Agri-Food Chains in Asia and the Pacific region
21 Ibid
22 FAO. 2016. Climate-smart Agriculture. Retrieved November 18 from http://www.fao.org/Climate-smart-agriculture/en/
23 Ibid
24 The International Rice Research Institute (IRRI) and various national partners have been involved in the development and testing of AWD. The findings show that AWD when compared to continuous flooding can reduce water use by up to 30% without adverse impacts on rice yield (adaptation contribution) and AWD can decrease the methane emissions by around 50% from rice cultivation (mitigation contribution). Retrieved 10 December 2016 from http://books.irri.org/AWD_brochure.pdf
25 FAO. 2016. Save and Grow in practice: Maize, Rice, Wheat.

A more detailed description of the contribution of SAMS to specific pillars of CSA and examples of agricultural mechanization used are found in the Table 1.

There are synergies between CSA and SAMS, both of which are holistic approaches addressing the socio-economic and environmental dimensions. Both focus on the needs of smallholders' farmers and small-medium entrepreneurs (SMEs), and are based on and adapted to local conditions and to different agricultural and food systems (across the value chain) and promote sustainable practices and technologies. CSA and SAMS complement each other in tackling climate change impacts and improving the livelihoods of people in the rural communities.

Table 1: Contribution of SAMS to CSA Pillars

CSA pillars	SAMS Contribution	Examples of Agricultural Mechanization
Sustainably Increasing Agricultural Productivity and Incomes (Food and Income)	+ Increases land and labour productivity	Power tillers for land preparation; drum seeders for direct seeding; rice and vegetables transplanter; portable cutters; walk-behind reapers and combine harvesters for harvesting and water pumps for irrigation during the dry season
	+ Reduces production cost	Manual and mechanical fertilizer deep placement for increasing the efficiency in the use of fertilizers; jab planters, drum seeders and power seeders for increasing efficiency in the use of fertilizers and seeds; electrical; mechanical and solar water pumps to power drip irrigation systems for increasing efficiency in the use of water
	+ Reduction of post-harvest losses	Threshers; solar dryers for increasing the shelf life of food; efficient transport systems
	+ Value addition to food produce	Threshers; dryers; mill; graders; packing machines; milk separators; oil extractors; fibre processing (these all contribute to off farm jobs creation)
Adapting and Building Resilience Against Climate Change (Adaptation)	+ Timely planting and harvesting to cope with erratic weather	Power tillers for land preparation; drums seeders for direct seeding; manual and mechanical rice and vegetables transplanter; portable cutters; walk-behind reapers and combine harvesters for harvesting and water pumps for irrigation during the dry season
	+Efficient water management and conservation	Land leveler attached to power tiller or animals for improving the distribution of water in the plots; manual; animal and mechanical power tools, equipment and machinery used for minimum tillage and direct seeders for planting on crop residues (Conservation Agriculture CA)
3. Reducing and/or Removing GHGs, where possible (mitigation).	+ Reduce GHGs Reduce post-harvest losses	Threshers; solar dryers for increasing the food shelf life; efficient transport systems
	Reduce crop burning through alternative use of crop residues	Rice straw baler (for animal feeding or mushroom cultivation); manual, animal and mechanical power tools; equipment and machinery used for minimum tillage and direct seeders for planting on crop residues (Conservation Agriculture CA)
	Reduce misuse of chemical fertilizers	Manual and mechanical fertilizer deep placement
	System of Rice Intensification (SRI) [26] and Alternate Wetting and Drying (AWD) [27]	A thorough land levelling is key for performing AWD; land leveler attached to power tiller or animals for improving the distribution and drainage of water in the plots
	- Emit GHGs	All mechanical and animal power equipment and machinery emit GHGs As an alternative, promote the use of renewable energy. solar water pumps and solar dryers are used in the region

Source: author

Note: + means positive contribution, - means negative contribution

26 Ibid

27 For more information visit http://books.irri.org/AWD_brochure.pdf and https://ccafs.cgiar.org/bigfacts/data/theme/evidence-of-success/CGIAR_Evidence_of_Success_crops3.pdf

To tackle climate change, the role of FAO is to:

- Provide technical, strategic and policy support to national governments in the region, including through projects and programmes addressing climate change adaptation and mitigation measures to develop and implement NDCs actions and gain access to International Financing Schemes such as GCF, GEF, EU, etc.
- Document case studies on the socio-economic and environmental benefits and limitations of CSA and SAM interventions for knowledge sharing and awareness raising
- Support the creation and diversification of on- and off-farm jobs through the usage of SAM in the rural communities for increasing climate change resilience and improving the livelihoods of smallholders' farmers and SMEs
- Support the development of green value chains which are environmentally friendly and economically profitable and create market access for smallholders' farmers and SMEs
- Encourage countries in the region to adopt and expand CSA for achieving sustainable agricultural and food systems development
- Continue the work on gender equality and closing the gender gap to give equal opportunities for women and men to access mechanization, technology, information, and other assets to better respond and adapt to the impacts of climate change
- Encourage further analysis on contribution of agricultural mechanization to the reduction of post-harvest losses and trade-off related to the use of agricultural mechanization in the context of climate change and agricultural development
- Host the Global CA-CoP Conservation Agriculture Community of Practice for sustainable production intensification and land management (http://www.fao.org/ag/ca/)
- Generate statistical data, resources and schemes for monitoring progress. Relevant resources can be found on the following link:
- http://www.fao.org/climate-change/resources/publications/en/, the publication on SAMS can be found in http://www.fao.org/publications/card/en/c/78c1b49f-b5c2-43b5-abdf-e63bb6955f4f/

A Road to Sustainable Agricultural Mechanization – the Experiences of Conservation Agriculture in China

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Li Hongwen, Changjiang Scholar, Taishan Scholar, Professor of China Agricultural University, head of conservation tillage research centre, MOA (CTRC). He began his research on conservation tillage in 1992. By now, he had published more than 100 paper in Chinese and English related to the topic, acquired over 60 Chinese patents for conservation tillage machines, and won the National Science and Technology Award three times.

Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture which will ultimately improve farmers' livelihoods through the application of three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. CA bears substantial potentials for all sizes of farms and various agro-ecological systems, while smallholder farmers are the group that is in the most urgent need to adopt this practice. CA is a way to combine profitable agricultural production with environmental concerns and sustainability, whose applicability has been demonstrated in a variety of agro-ecological zones and farming systems. Practitioners also perceived it as a valid tool for Sustainable Land Management (SLM).

In China, the study of conservation tillage, which reflects the mentioned three principles of CA, was started in 1992. Before this, China has got nearly 40-year experience in no till research and mainly focused on agronomy with the absence of machinery.

Conservation Tillage Research Centre (CTRC) was established by the Ministry of Agriculture (MOA) of China in May 1999 and is now located in China Agricultural University (CAU). After a decade of research, the Chinese government began the promotion of conservation tillage in 2002. A national plan for conservation tillage was enacted by the MOA, and then approved by the State Council. Conservation tillage is not only listed as a primary technology in Sustainable Agriculture Plan (2015-2020) enacted by MOA, but also a major agricultural technology to reduce greenhouse gas emission in National Programme on Climate Change (2014-2020). Conservation tillage was also recognized as a type of sustainable agriculture in the article of Chinese Premier Li Keqiang.

With years of effort, conservation tillage has proven to be a technology whose advantages outweigh the disadvantages. And the public concern focuses on how to make the best of conservation tillage, rather than if it should be applied in China.

In 2000, there were less than 10 factories producing no till seeders, while the total conservation tillage area was about 60,000 ha. By the end of 2015, there were more than 240 factories producing no till seeders and the total area of conservation tillage had increased more than 100 times. Conservation tillage has been implemented in all the northern provinces and some parts of the southern provinces.

Studies related to conservation tillage won four National Science and Technology Awards, which is the highest Science and Technology Award in China.

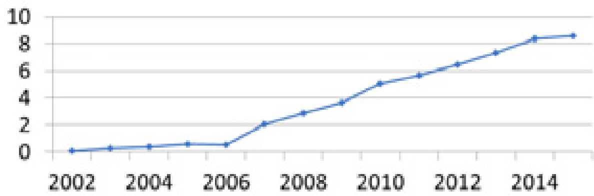

Figure 1: Development of Conservation Tillage in China (Mha)

Experiences of applying conservation tillage in China are listed below:

1. The basis of applying CA is advanced and applicable no till seeders.
2. The basis of Convincing potential users is the data from long-term scientific experiments, not only experiences from others.
3. The basis of ensuring good sowing quality is stubble handling before or while sowing.
4. Scientific data and benefits from demonstration are necessary to change traditional mindsets of farmers and agricultural policy makers and other people in agricultural field.
5. All sustainable agricultural technologies provide long-term benefits, should get government support.
6. Minimal soil disturbance, stubble cover and crop rotation are the three main principles of CA. At the beginning, complete no till, 100% stubble cover and crop rotation are not required at all seasons. Farmers can start from minimum tillage and then no tillage, even though minimum tillage disturbs more soil than no tillage.
7. CA can be used for most crops, but at the beginning, there's no need for us to try CA on difficult crops (no applied experiments, no suitable machines)
8. Farmers and farmer groups are the users of CA, they are encouraged to promote CA to others.
9. Propaganda is necessary to popularize conservation tillage to the public.

Mechanization and Postharvest Management for Sustainable Rice Production

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I. Challenges of Mechanization and Postharvest in Rice Production

To answer the question of what roles mechanization and postharvest management play in sustainable rice production, it is necessary to identify the challenges that farmers face in the adoption of mechanized solutions and in postharvest activities. Constraints facing mechanization and postharvest operations in Asian rice farming often include small, irregular, and widely distributed fields; a lack of or poor condition of infrastructure; inappropriate machinery; low quality and availability of after sales services; and limited training and knowledge of farmers, operators, and service providers. The monsoon climate also brings a number of challenges as the volume of water in fields often impedes access and operations in farmers' fields, particularly at the time of harvest.

The importance of effective land leveling cannot be overstated. Unleveled fields at the time of crop establishment can cause problems throughout the lifespan of the crop and can ultimately result in sub-optimal grain quality at harvest time. Unleveled fields can result in reduced water- and nutrient-use efficiency of the crop; increased weed density; uneven maturity; high risk of lodging; and increased harvesting losses with poor grain quality, and high processing losses.

Crop establishment is a laborious process and, with the increasing scarcity and cost of agricultural labor, is becoming a bottleneck in rice production. The establishment of rice crops has traditionally been a manual operation, with farmers or agricultural labor either broadcasting seeds onto the soil surface or transplanting seedlings into soft, puddled soil. Similarly, the application of fertilizers and pesticides is also largely reliant on manual labor. The work is very laborious, making it less attractive to youth and the next generation of rice farmers.

Physical and economic shortages in labor and the unavailability of machines increase harvesting costs and often lead to delays in the harvesting process. These delays cause an increase in yield losses at the time of harvest. Sun drying and the use of low-quality dryers, as well as ineffective storage, can result in 10-25% postharvest losses. If these losses can be reduced by 5%, this would equate savings of 15 million tons of rice per year in Asia would be saved, which equates to US$ 5-6 billion per year.

Another critical issue in postharvest operations when considering mechanization as a solution to labor shortage is rice straw management. In Asia, around 60% of the 300 million tons of rice straw produced each year is burnt in the field, which results in hazardous air pollution, increased emission of greenhouse gases, and loss of nutrients from farmers' fields.

To overcome these problems, advanced and sustainable technologies should be introduced and adopted by rice farmers. Suitable mechanized practices must be identified in specific locations and regions, and the sustainability of these solutions must be quantified for using various tools and methodologies, which could include lifecycle and sustainability assessments. To support the introduction of new mechanization and postharvest technologies and practices in a sustainable and integrated system, a value-chain approach and public-private partnership models are needed. Multi-stakeholder platforms, such as learning alliances, can facilitate and accelerate the improvement of current situations through partnership with various value-chain stakeholders.

II. Available Technologies Applied and Developed by IRRI

Among developed technologies that are already obtainable for operation, laser-controlled land leveling (LLL) (Figure 1) is widely used in many parts of Asia. Applying LLL for 1 ha of rice field can reduce 282 kg CO2-eq; increase yield by 5-15%; and save water by 20-25% or even up to 60% in some areas.

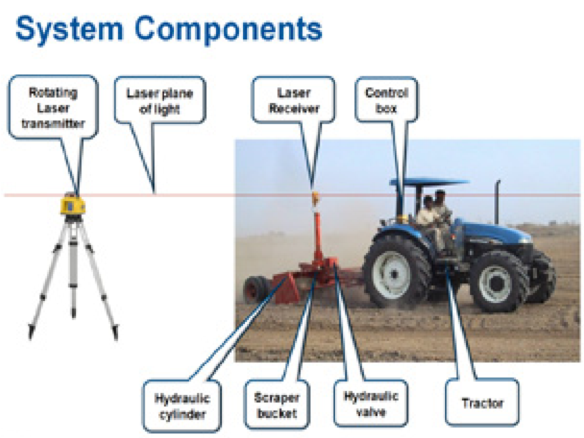

Figure 1: Laser-Controlled Land Leveling
Source: Trimble

Mechanized innovations to overcome labor shortages at crop establishment include simple drum seeders for wet seeding, tractor-mounted drill seeders for dry direct seeding, and mechanical transplanters. Fertilizer spreaders and tractor-mounted boom spray systems are overcoming labor shortages and reducing the drudgery of in-crop care. These innovations save time, reduce environmental impacts through uniform and accurate application rates of agronomic inputs, and improve health and safety outcomes for operators.

Several solutions have been developed in recent years to reduce losses and maintain grain quality, and improving postharvest drying and storage. For village-level drying, the Solar Bubble Dryer (Figure 2) is a suitable drying solution that only use solar energy for operation which can reduce losses and uses only solar energy for operation. For the commercial sector and farmer groups, a flatbed dryer (Figure 3), utilizing a rice husk furnace to produce hot air for drying, can reduce losses by 2 to 5%.

Figure 2: The Solar Bubble Dryer

Figure 3: Flatbed Dryer Using Rice Husk Furnace.

The downdraft rice husk furnace (Figure 4) for paddy drying such as the flatbed dryer, is an environmentally friendly technology for small-scale mechanical dryers. Its benefits include high efficiency that reach almost 80%, use of renewable energy, and low pollution. The downdraft rice husk furnace for paddy drying is carbon neutral and uses an improved air-cooled grate. A patent application for this technology is pending.

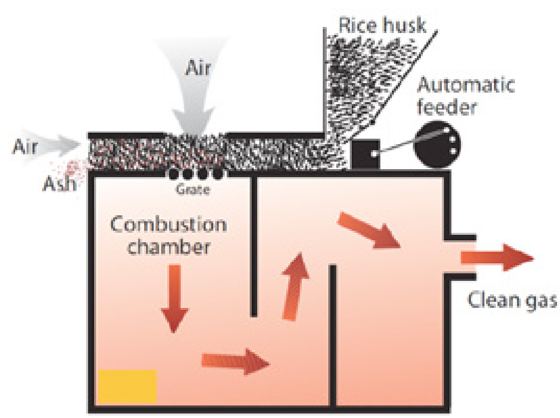

Figure 1: 4a. Principle of a Downdraft Rice Husk Furnace
Source: IRRI

Figure 4b: The Downdraft Rice Husk Furnace Used for Flatbed Dryers in the Philippines.

For safe and effective storage, hermetic storage systems create a naturally-modified, low oxygen and CO2-rich atmosphere, which eliminates the activity of pests and thereby maximizes grain quality. This also lowers the need for pesticides. Hermetic storage systems are now available from small (50 kg), individual farm-scale bags to large systems that can be used in commercial milling and seed production operations.

The availability and capacity of remote sensing technologies provide opportunities to improve the efficiency and decision making of farmers, extension agents, policy makers, and other stakeholders in the rice value chain. Crop modeling and monitoring can be carried out by drone and remote sensing systems. Modeling rice crop productivity uses advanced information technologies to define indicators of crop growth status for better nutrient management and better prediction of crop yields. The timeliness and accuracy of this information is crucial for decision making at many levels within the rice value chain.

Apart from innovation, supporting approaches such as public-private partnership models and learning alliance platforms for engaging with multiple stakeholders from different sectors should be taken into consideration. The reasons to create these platforms are to transfer technology, build capacities for manufactures, operators, and users of mechanization and postarvast technologies, enhance knowledge on rice quality assessment, and crate pathways to scale out new technologies. Complementary interventions focus on developing business models for mechanization and postharvest management and building stakeholder networks for out-scaling.

III. Ongoing Projects

IRRI, in collaboration with its partners, national systems, and other stakeholders, is currently undertaking a number of projects that incorporate and focus on various mechanization and postharvest technologies. These include the IRRI-CORIGAP project, 2014-2020; the ACIAR-IRRI project in Myanmar, 2012-2017; the BMZ-IRRI rice straw management project, 2016-2019; and the GRISP (until 2016) and RICE (2017-2021) CRPs. Capacity building activities are part of all the projects and include curriculum development, training on technologies, vocational training for support service providers, and customized courses based on specific needs and technologies. Training courses at IRRI can be provided with certification.

IV. Recommendations

Innovation in mechanization and postharvest management of rice production must focus primarily on sustainability and food security. Efforts in developing mechanized solutions in rice farming and suitable postharvest technologies must aim to maximize grain quality and cost-benefit ratio; minimize losses annd environmental impacts; optimize energy-use efficiency; address labor shortage; and consider the social aspects, particularly, but not limited to, gender. It is necessary to leave the idea of “one solution fits all” behind. Instead, suitable practices corresponding to specific problems must be found. It is also important to look at the whole value chain rather than single-component technologies for a specific stakeholder within the system. Public-private partnership models and learning alliances, joint-research platforms, capacity building activities, and advocacy and policy dialogues are all required to achieve sustainable rice production.

Collection and Uses of Rice Straw in the Mekong River Delta – Vietnam

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Mr. Pham Van Tan is the Deputy Director of the Sub-Institute of Agricultural Engineering and Postharvest Technology (SIAEP) under Vietnam Institute of Agricultural Engineering and Postharvest Technology (VIAEP) and Vietnam Ministry of Agriculture and Rural Development (MARD). He obtained his B.A degree in Agricultural Mechanization from the Ho Chi Minh City University of Agriculture and Forestry in 1985. Then, he started to work for VIAEP until now. He acquired his M.A Degree in Food Processing Engineering from Asian Institute of Technology (AIT), Bangkok, Thailand in 1998. After that he continued to study Post-Harvest Technology and received his PhD in Agriculture from the University of Sydney, Australia in 2008. Mr. Tan is a principal member of several scientific and technological committees of VIAEP, SIAEP, Ho Chi Minh City and other Vietnam Southern provinces. He carried out and completed successfully many researches and projects in the fields of agricultural mechanization and post-harvest technology in Vietnam. He also worked as a national consultant and an international consultant for agricultural projects funded by various organizations such as DANIDA, IRRI, World Bank, FAO, GIZ, etc. in Vietnam and several Africa countries. He has been awarded many prestigious prizes by the Vietnam government and Ho Chi Minh City.

I. Background of Rice Production in Vietnam and the Mekong River Delta (MRD)

Vietnam is an agricultural country situated in South-East Asia. It has a total natural land area of 33 million hectares, of which 3.9 million hectares are for rice production with a total rice-growing area of 7.44 million hectares/year. The Mekong River Delta (MRD) has 3.9 million hectares of natural land including 3.8 million hectares of agricultural land. It has 1.9 million hectares for rice production at a rotation of 2 to 3 rice crops per year, approximately 3.8 million hectares of rice growing area per year. With an average yield of 6-7 tons of paddy per hectare, the MRD has an annual paddy output of 24 million tons, which occupies more than 50 per cent of the country output. Milled rice export is mainly from this region. It ranges from 6.5 to 7.5 million tons per year, occupying about 95 percent of the total milled rice export of the country.

II. Chemical Composition and Nutritive Values of Rice Straw

Rice straw is one of the main by-products of rice production. It is rich in polysaccharides. Rice straw consists predominantly of cell walls comprised of cellulose, hemi-cellulose and lignin. Chemical composition of rice straw is shown in Tab. 2.1.

Table 2.1: Ultimate Analysis for Chemical Composition of Rice Straw, Rice Husk and Corncob (% Dry-Ash-Free Basis)

Elements	Rice straw	Rice husk	Corncob
Carbon	45.2	48.9	45.5
Hydrogen	6.5	6.2	6.2
Nitrogen	0.8	0.8	1.3
Oxygen	47.5	44.1	47.0

Source: Wannapeera et al., 2008

Because of relatively high nutritive values and minerals compared with the other by-products of rice or other agricultural by-products (Tab. 2.2), rice straw has been known popularly as a plentiful source of feed for ruminant livestock. Besides, rice straw in the MRD could also be used as organic fertilizer for mushroom growing, mulching, etc.

Table 2.2: Content of Ash and Other Metal Ion Elements in Untreated Rice Straw, Rice Husk and Corncob

Elements	Rice straw	Rice husk	Corncob
Ash content	10.1	17.9	0.9
Metal ion content (mgion/gsample)			
Na	1.01	0.21	0.76
Mg	1.84	0.58	0.05
K	16.79	5.37	7.26
Ca	4.48	1.67	1.04

Source: Wannapeera et al., 2008

III. Current Status the Collection and Handling of Rice Straw in the MRD

Annually, the MRD produces about 25 million tons of rice straw. However, many years ago, serious problems for the natural environment occured after harvest most of the rice straw was burnt off in the fields during harvest.

a. Rice Straw Collection in the MRD

Since 2007, Japanese small balers (Figure 3.1) were imported into Vietnam and the MRD. The 2-wheel small balers are produced by the IHI Star Machinery Corporation. After cutting, threshing, separating, cleaning and packaging fresh paddy, combine harvesters leave rice straw in the fields. The two-wheel balers mounted behind 4-wheel tractors of 20-30 HP are used to collect rice straw from the fields and roll them into small rolls, but still leave them back in the fields. Weight of the small baler is 330 kg. Its working capacity is about 80-120 rolls/hour or appoximate 5-7 hectares/day. Diameter and height of the straw rolls are 50cm and 70cm respectively. Average weight of each straw roll is about 13.5 kg for dried straw and 15-16 kg for moist straw. The small baler requires only one person to operate the tractor. Although the baler can work very well in dried fields of winter-spring rice crops, its capacity decreases in wet or muddy fields of autumn-spring or summer-Autumn rice crops due to the two small rubber wheels.

In recent years, mechanical manufacturers in the MRD such as Phan Tan or Tu Sang mechanical enterprises also studied and made self-propelled balers which could overcome disadvantages of the small star balers. The self-propelled balers can collect rice straw from the fields, form the straw into small rolls and put the rolls into a tank behind the combine baler (Figure 3.2). The tank could contain temporarily up to 30 straw rolls. Power required for the combine baler is about 45 HP. It needs at least 2 persons for operation. One person is the driver and the other stacks the rolls into the tank. Owing to the 2 rubber tracks, the combine baler can work efficiently not only in the dried fields but also in the wet or muddy fields.

Figure 3.1: Japanese Star baler

Figure 3.2: Phan Tan Self-Propelled Baler

At present, after being harvested by rice combine harvesters, rice straw left in the fields of the MRD is sold by rice farmers at a price of USD 50-100/hectare. After being rolled and transported to transporting roads, each straw roll is sold at an average price of USD 1.0-1.1. Service cost of the combine balers is USD 0.30-0.35/straw roll or USD 60-65/hectare. Rice straw in the MRD is also transported to Eastern provinces such as Ho Chi Minh City or Binh Duong province for feeding cattle. Selling price of rice straw in eastern province is about USD 1.4-1.5/roll. Investment costs of the Japanese Star baler and Phan Tan self-propelled baler are about USD 6,700 and USD 14,000 respectively; and the balers could operate approximately 2 to 3 rice crops per year or 200 days per year. Average profit of each straw baler is about USD 100/working shift (8 hours), and the investment cost could be paid back within only one year.

There are also simpler balers manufactured and applied in the MRD like Hai Tinh balers (Figure 3.3). There are no rolling components in the balers. The balers could only pick up rice straw from the fields and put it back into the tanks behind them. This type of balers is cheaper than the self-propelled baler. Its investment cost is about USD 9,000/unit. However, it needs up to 3 people for operation; including 1 driver and the other 2 people working in the tank behind. To support collection activities in the fields and to save labor costs, there are also simple vehicles for transportation of the rice straw rolls from the fields to transportation roads (Figure 3.4). According to a recent survey, total number of straw balers operating in the MRD is about 1,000 units.

Figure 3.3: Hai Tinh Baler

Figure 3.4: Vehicles for Handling Rice Straw Within Fields.

b. Rice Straw Handling in the MRD

There are various means of rice straw transportation in the MRD. However, because there are so many rivers and canals in the region, boats are the most popular transporting means (Figs. 3.5 &

Figure 3.5: Boats for Transportation of Rice Straw Rolls

Figure 3.6: Boats for Transportation of Bulk Rice Straw

IV.

Figure 3.7: Trucks for Transportation of Rice Straw Rolls

Figure 3.8: Trucks for Transportation of Bulk Rice Straw

V. Uses of Rice Straw in the MRD

a. Rice Straw Used for Mushroom Growing

Vietnam is one of the biggest mushroom-producing countries in the world due to a plentiful amount of rice straw, which is about 50 million tons of rice straw per year. Each year Vietnam produces approximately 250,000 tons of mushrooms with an export value of USD 25-30 million. It is mainly from Eastern provinces and the MRD. Export price of salted mushroom is USD 1,790/ton.

Main mushroom growing provinces in the MRD are Dong Thap, Soc Trang, and Can Tho City. Mushrooms are grown mostly in Spring season in order to be sold right before Lunar New Years.

Most mushroom growers are small-scale producers who have about 1,000 – 5,000 m^2 per household on average. The farmers usually apply the traditional methods to mushroom growing. Most of mushrooms in the MRD are grown in open fields (Figure 4.1) or semi-open fields (Figure 4.2). Therefore, it is quite difficult to control temperature, relative humidity of the air, and diseases during the growing seasons, while this situation has been affecting yield and quality of the mushroom seriously.

Figure 4.1: An Open Field Mushroom Growing in Lai Vung District of Dong Thap Province

Figure 4.2: A Semi-Open Field Mushroom Growing in Thoi Lai District of Can Tho City

Recent years, methods of indoor mushroom growing have been developed and scaled up in the MRD. Some farmers and enterprises have built up simple houses with semi-controlled rooms (Figure 4.3) or modern houses with automatic controlling systems (Figure 4.4) to adjust growing conditions such as temperature, relative humidity of the air and the light intensity for the mushroom.

Figure 4.3: A Simple House with Semi-Controls for Mushroom Growing in Thot Not District of Can Tho City

Figure 4.4: A Modern House with Automatic Controlling Systems for Mushroom Growing in Can Tho City

Average selling price of freshly harvested mushroom in the MRD is USD 1.7/kg. However, it could increase up to USD 3.0 – 3.2/kg during vegetarian days of Buddhist. Residues of rice straw after mushroom growing could be used efficiently as fertilizer for rice, fruit trees or vegetables, which helps reduced application of chemical fertilizer which has an impacts on the environment.

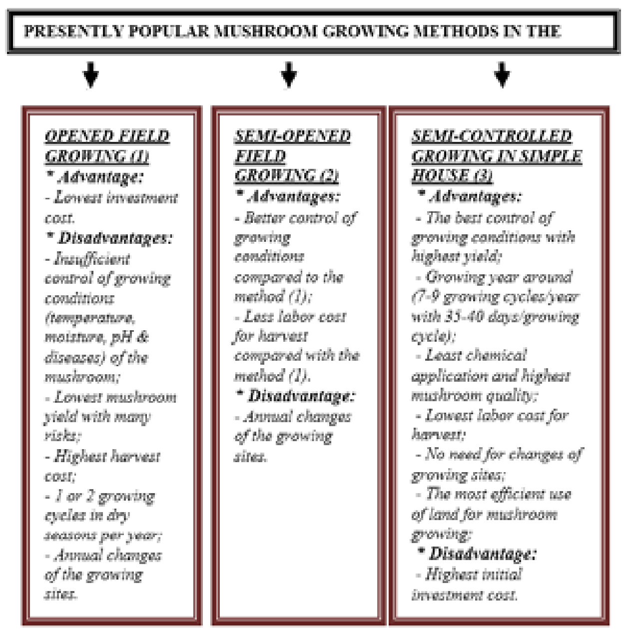

Figure 4.5: Comparison Between 3 Mushroom Growing Methods in the MRD

Comparison of advantages and disadvantages between different mushroom growing methods in the MRD is shown in Figure 4.5. Moreover, initial investment, financial efficiency, profit, and for farmers resulted from the two mushroom growing methods are also compared and shown in Table 4.1.

Table 4.1: Comparison of Financial Criteria Between the Two Mushroom Growing Methods (for 500m^2 of Mushroom Growing)

Criteria for Comparison	Opened field mushroom growing (Traditional method - Method 1)	Semi-controlled mushroom growing in simple house (Improved method - Method 3)
- Initial investment cost (US$)	~ 0	7,500
- Intensive growing ability (number of growing cycles/year)	1 - 2	7 - 9
- Mushroom yield (kg of mushroom/meter of growing band)	0.7 – 0.9	1.67
- Production cost (US$/kg of mushroom)	0.8 – 1.0	1.4
- Average selling price (US$/kg of mushroom)	1.2 – 1.45	2.0
- Unit profit (US$/kg of mushroom)	0.35 – 0.50	0.75
- Annual profit (US$/1,000 meter of growing band. year)	900	9,850

Table 4.1 shows that financial efficiencies of the improved method are always higher than those of the traditional method. Profit and income of the mushroom growers who use of the third growing method are also much higher than those who use the other methods. Besides, Vietnam government also has good policies encouraging mushroom growers. In spite of those, an initial big investment for the third growing method is still a constraint for many small farmers in the region.

b. Rice Straw Used for Mulching and Ruminant Feed

Rice straw is a common mulching material for fruit trees, especially for dragon fruit trees and other vegetables in the MRD. It is used to retain moisture and warmth for soil, and to suppress the weeds.

Long time ago in Asia, rice straw was a major feed for ruminants, especially for cows, bulls and buffaloes. According to the Decision no. 984/QĐ-BNN-CN on “Approval of ‘reformation project of animal production towards an adding value increase and sustainable development’ to the year 2020”, issued on 09/05/2014 by Minister of Agriculture and Rural Development, the animal production of Vietnam will reach 300,000 dairy cows, 12,000,000 beef cattle, and other 3,000,000 buffaloes in the year 2020. The MRD is expanding animal production, particularly cattle in order to meet demands for meat and milk for the country. Although raw rice straw is one of the most important sources of animal feed, its nutrition value could be enriched if it is treated with chemicals, enzymes, fungi or combinations of those. The treated feed could help increase feed intake as well as yields of meat or milk of the animals.

VI. Government Policies Supporting for Agricultural Mechanization and Uses of Rice Straw

Vietnamese government implemented a number of effective policies to support the development of agricultural mechanization:

+ Resolution no. 48/NQ-CP on “Mechanisms and policies supporting for reductions in post-harvest losses of agricultural and aquacultural products” issued on 23/9/2009 by the government. The resolution affirms that organizations, households, and individual farmers can get loans from credit agencies for up to 100% of the total investment cost of machinery. The government will provide the machinery buyers with financial supports up to 100% of the bank interest rate within the first two years, and another 50% of the bank interest rate from the third year onward.

+ Decision no. 497/QĐ-TTg on “Governmental financial supports of bank interest rates for loans to buy machines, equipment or materials for agricultural production and building of houses in rural areas” issued on 17/4/2009 by the prime minister.

+ Decision no. 63/2010/QĐ-TTg on “Policies supporting for reductions in post-harvest losses of agricultural and aquacultural products” issued on 15/10/2010 by the prime minister.

+ Decision no. 68/2013/QĐ-TTg on “Policies supporting for reductions in post-harvest losses in agricultural production” dated on 14/11/2013 by the prime minister.

Both Decision no. 63/2010/QĐ-TTg and Decision no. 68/2013/QĐ-TTg were issued together with short lists of agricultural machines including balers and other equipment for collection and handling of rice straw.

+ Decision no. 665/QĐ-BNN-CB on “Action plans for development in agricultural mechanization and reductions in post-harvest losses of rice in the Mekong river delta” issued on 09/3/2006 by the Minister of Agriculture and Rural Development.

However, even though the above policies are provided, applying for financial supports from the government is still not easy for many buyers of the agricultural machnes because of the complicated procedures.

VII. Social and Economic Benefits from Rice Straw

The uses of rice straw can help developing mushroom production and animal husbandry, particularly cattle production in the MRD, which not only creat more jobs for the rural population but also increase the income of the farmers significantly. These usages can also facilitate the development of the agro-processing industry in rural areas. Moreover, using more rice straw for multi-economic purposes and reducing field burning is also the best way to minimize greenhouse gas emission and protect natural environment from pollutions. All results mentioned above contribute significantly to the sustainability of rice production in the region.

VIII. Challenges and Constraints on Uses of Rice Straw

Despite social and economic benefits mentioned above, there are still many challenges and constraints regarding the uses of rice straw in the MRD.

The size of rice fields in the region is still small as there are so many rivers and canals in the region, that cause difficulties in transporting and operating machines. These geographic constraints also reduce the capacity and efficiency in collecting and handling machines, which lead to an increase in production cost of the rice straw.

Moreover, although there are up to 3 rice crops cultivated per year in the MRD, there is only one rice crop that is harvested in dry season. The other two rice crops are harvested in rainy seasons or in wet conditions, which cause difficulties in collecting, handling, drying, and storing. For this reason, only about 10% of the total rice straw is collected and used in the MRD. The rest of rice straw is still burnt off or left in the fields.

In addition, there is a shortage of appropriate machines/vehicles for collecting, handling, drying, storing and processing the rice straw. Because of the small-scale rice production, small rice farmers cannot afford to buy balers. Furthermore, although the government has good policies for mechanization development, the financial support from the government is limited and not easy to obtain.

IX. Conclusion and Recommendations

Despite the challenges and constraints, there were important achievements in the use of rice straw in the MRD. It will continue to develop and contribute to improvements in rural income and the living standard, as well as a development in agro-processing industry of the region in the coming years. Moreover, an increase in the use of rice straw in recent years reduced environmental pollution and ensured a sustainable development of rice production in the MRD. Moreover, in recent years, if there is an increase in the use of rice straw is an important factor to evaluate whether environmental pollution is reduced and a sustainable development of rice production is ensured.

In order to increase value of the rice straw of the MRD in the coming years, research work on machines and equipment for collection, handling, drying, storage and processing of the rice straw should be continued with stronger supports from the government so that new machines could be manufactured and applied successfully into the practical production. Besides, the processing technology of mushroom should also be developed and applied to improve quality and value of products diversified from mushroom. In addition, rice straw should be also studied for use in animal feed processing industry; for example, total mixed ration (TMR) processing. To maximize value of the rice straw, its usage should be further studied.

II.Country Presentations

Bangladesh
Conservation Agriculture: A Climate-smart Agricultural Technology for Sustainable Crop Production in Bangladesh

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The government should provide financial conservation agriculture (CA) aiming to conserve, improve, and use natural resources more efficiently through integrated management of available soil, water, and biological resources combined with external inputs. It contributes to environmental conservation as well as the enhanced and sustained agricultural production. Conservation agriculture permits direct seeding and it is the combination of three major farming principles for successful crop production.

(i) less soil disturbance, (ii) allow crop residue management and (iii) keep beneficial crop rotation.

Conservation agriculture is a win-win solution to reduce operational and inputs costs including labor, while increasing yields, and to achieve better utilization of natural resources. CA makes efficient and effective utilization of resources possible. Generally, farmers grow rice in puddle land by manual transplanting and process wheat by ploughing and hand broadcasting 3-4 times. This system is slow, time consuming, and costly. There is about 70% of wheat that was planted late due to the lack of advanced technologies (Hossain et al., 2012).

There are many advantages of conservation agriculture practices in respect of crop, soil and nature - (i) overcome delay planting (ii) use residual soil moisture for crop establishment (iii) less irrigation water requirement (iv) reduce amount of fuel (v) more soil water holding capacity (vi) less production cost (vii) less soil erosion (viii) comparatively higher yield.

Followings are the common conservation agriculture-based tillage equipment which are now being used in the fields in Bangladesh.

I. Minimum Tillage Seed Drill

Figure 1: Two-Wheel Tractor Operated Seeder

The minimum tillage seed drill is operated by two wheel tractors (9kW) and it is commonly known as power tiller operated seeder (PTOS) in the farming community. The seeding part of this drill needs to hitch with power tiller drawbar point through nuts and bolts replacing the tilling part. Before starting seeding operation, mixed basal doses fertilizers are broadcasted over the soil surface. The minimum tillage seed drill comprises four operations – shallow tilling with high revolution of tilling blades, seeding in line, seed covering with minimal press, and land leveling (Figure1). Most of the seeds (wheat, lentil, mungbean, maize, rice, chickpea, groundnut, jute) can be sown by the same seed drill with small changes. The effective field capacity of the drill is 0.15 ha/hr. The break-even use of the minimum tillage seed drill is 4.1 ha / year. The break-even use of the minimum tillage seed drill is 4.1 ha / year (Hossain et al., 2009).

II. Strip Tillage Seed Drill

Figure 2: Two-Wheel Tractor Operated Strip Till Seeder

Strip tillage seed drill is one step ahead of minimum tillage seed drill. It is also operated by two wheel tractors and hitches same position as minimum tillage drill. Strip tillage seed drill makes strip with high speed rotating blades, places seed and fertilizer side by side, and covers seed with press wheel. The space between the seeding lines remains untilled. Figure 2 shows the rotary strip till drill. The blades are arranged on the opposite side facing each other. The average speed of rotating blades is 400-450 rpm.

The high speed rotations of the blade cut the previous crop residue and create strips for seed and fertilizer placement. The average width of the furrow strip is 4-6 cm which is sufficient for placement of seed and fertilizers. The width of strip also depends on the specific requirement of the crops. The drill increased effective field capacity by 19% and reduced fuel consumption by 21% comparing to conventional seeding system. (Hossain et al., 2012).

III. Zero Till Drill

This is a pull type seeding machine that seeds and fertilizes at the same time. This no till drill is capable to operate seeding through moderately dense (0.2-0.4 t/ha) crop residue field (Figure 3). A set of press wheel is attached with toolbar frame for closing the seeding furrow. The planter is capable to apply seed and fertilizer in a narrow (3-3.5 cm) opening slit at one operation. The planting depth and seed rate can be adjusted depending on crop standard. Fertilizer management and weed control are the key issues when adopting this new technology. Wheat, mungbean, and maize are planted by the zero till drill in Rice-Wheat cropping system. Zero till wheat is less lodge comparing to conventional planted wheat. The seeder can pull 4 times in soft and medium soil but 3 times in hard soil. Roundup herbicide is applied to kill the weeds before seeding operation. No-till farmers saved 40-65% plant establishment cost by minimizing the average turnaround time to 10-15 days between two crops. The effective field capacity and planting cost of the no till seeder are 0.15 ha/hr and Tk. 1951/ha respectively (Hossain, et al., 2009). This drill enables farmers to seed seeds when moistening soil and planting time are critical. This drill enables farmers to seed seeds when the soil is moisturized and planting time is critical.

Figure 3: Two-Wheel Tractor Operated Zero Till Drill

IV. Raised Bed Planter

Figure 4: Two-Wheel Tractor Operated Bed Planter

Bed planter is a seeding machine that forms the bed and seed on top of the bed simutaneously (Figure 4). It is a pull type unit which attaches a power tiller that replaces the rotary part of the tiller. The functional parts of the bed planter are (i) toolbar frame (ii) furrow opener (iii) seed box with metering unit (iv) bed shaper (v) chain and sprocket for power transmission. The bed planter tills the soil, applies seed and fertilizer, forms bed, and covers seeds simultaneously. For hard soil, pre-tilled soil is required for bed formation. Wheat, maize, munge ban, lentil, and rice can be grown successfully on bed. Once the formation of new beds is done, these beds can be used successively as strip tilling keeping it permanent. During strip tilling, middle of the blades is released from the rotary shaft and only blades remain in the seeding line. Fertilizers can be applied during seeding operation or basal dozes fertilizers broadcast just before operation. Followings are the major advantages of bed planting (Hossain et al., 2014).

The Main Advantages of Bed Planting System are :

i. Easy irrigation water application and less amount of water required
ii. Keeping bed permanent, crop grown without breaking the beds
iii. Overcoming water logging problem for crop establishment
iv. Higher yield compared to conventional system
v. Minimum rat damage of crop
vi. Easy intercultural operation
vii. Less amount of fertilizer requirement
viii. Rice yield higher in arsenic problem soil compared to conventional method of planting

Inclined plat metering mechanism is introduced for planting maize and other seeds maintaining the standard agronomic requirement. There are 24 rotary blades that can form bed in untilled soil. It is also further improved by introducing fertilizer attachment and replacing the regular fly wheel pulley with 8.5 inches (216 mm dia) pulley so that the rotary speed for proper bed formation is increased. This improvement facilitates gear box error which frequently breaks the pinion of gear. Recently, operator's seat (Figure 4) is also introduced for long distance travel and easy operation. Since farmers accept this technology, service providers started commercial business with it. Crop establishment difference between conservation agriculture system and conventional system are shown in Table 1.

Table 1: Crop Establishment Differences Between Conservation Agriculture System and Conventional Method

Sl No.	Performance parameter	Conservation agriculture system	Conventional system
1	Crop establishment	One pass direct seeding	Land prepared by 3-4 passes; Manual broadcasting
2	Seed rate	Optimum	More than recommended
3	Depth of planting	Uniform	Uneven
4	Irrigation water	Less water	Comparatively more
5	Weeding	Comparatively easy	Difficult to control
6	Fertilizer application	During seeding operation	During land preparation and top dress application (2/3 split)
7	Turnaround time	Minimum	7-9 days required from first ploughing to seeding

There are many advantages of conservation agriculture practices in respect of crop, soil and nature.

Adoption of Minimum Tillage Technology

Considering the advantages and benefits of the minimum tillage seed drill, farmers are purchasing PTOS for their own works as well as custom hiring business. Owners of PTOS in Dinajpur, Rajshahi, Faridpur, Southern part of Bangladesh are using seed drill commercially. It was observed that there is an increase of 60-80 units of PTOS on average every year (Figure 5). At present, there are 1060 PTOSs operating. The adoption rate of minimum tillage in Faridpur area is much higher than other parts of Bangladesh. The seeders are also engaged in preparing onion field in those areas. Three local manufacturers started fabrication of seed drill. The number of bed planters also increased in the Rajshahi area. Last year (2014-15), about 6350 ha was covered by bed planting technology for wheat, maize, mungbean, rice and minimum tillage coverage was 32205 ha. Areas under different tillage techniques are shown in Table 2. Minimum tillage and raised bed systems are becoming increasingly popular among farmers and yearly area coverage is increasing. There are about 43,400 farmers involved in conservation agriculture system.

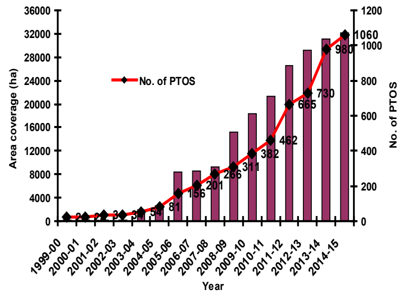

Figure 4: Number of Active PTOS

Table 2: Area under Conservation Agriculture Tillage System in Bangladesh

Name of conservation agriculture tillage techniques	2010-11 (ha)	2011-12 (ha)	2012-13 (ha)	2013-14 (ha)	2014-15 (ha)
Minimum tillage	9,864	17,527	29,225	31,155	32,205
Strip tillage	72	106	108	225	300
Zero tillage	79	59	97	105	110
Raised bed system	4,337	4,636	5,745	5,950	6,350
Total	14,352	22,328	35,175	37,435	38,965

Three years yield comparison was shown in Table 3. It is observed that the tendency of the yield remains the same with conservation agriculture tillage system, which is higher than conventional methods. Farmers are gaining experiences in these new tillage systems for sustaining the crops yield. There was considerable costs saving in CA based technologies (Table 4) over conventional methods. The cost saving of minimum tillage, strip tillage, zero tillage, and bed planting system was 65%, 67.5%, 69%, and 40%, respectively than that of conventional methods of planting.

Table 3: Yield Comparison of Major Crops Under CA Tillage Systems

Conservation agriculture tillage system	2012-13 (t/ha)			2013-14 (t/ha)			2014-15 (t/ha)		
	Wheat	Maize	Mung bean	Wheat	Maize	Mung bean	Wheat	Maize	Mung bean
Minimum tillage	4.7	9.5	1.3	4.5	9.3	1.1	4.2	9.2	1.1
Strip tillage	5.2	9.3	1.2	4.6	8.4	1.2	4.3	9.0	1.1
Zero till	4.4	8.8	1.2	4.1	8.2	1.1	3.9	8.8	1.2
Bed planting	5.2	9.7	1.0	4.8	8.2	1.1	4.5	8.1	1.1
Conventional system	3.5	9.0	0.7	3.6	8.3	0.75	3.5	8.8	0.8

Table 4: Cost of Planting in Different CA Tillage System Over Conventional Methods

Sl. No.	Seeding methods	Cost of seeding (Tk./ha)
1	Minimum tillage	1,950.0
2	Strip tillage	1,850.0
3	Zero tillage	1,740.0
4	Raised bed system	3,394.0
5	Conventional method	5,695.0

Environment Aspect

CA based machines perform seeding operation with minimum disturbance of soil. Soil erosion was comparatively less than conventional method. Fuel used in both conventional and CA systems was shown in Table 5. Conservation tillage system saved 94lit/ha/yr of costly diesel fuel and lessened 44% CO_2 emission into the atmosphere.

Table 5: Comparative Use of Diesel Fuel on Conventional and Reduced Tillage Method

Tillage option	Diesel used (lit./ha/yr)	CO_2 emission (kg/ha/yr)*	Fuel saving (lit./ha/yr)
Conservation agriculture system	119	309.4	94
Traditional method	213	553.8	

Hossain et al., 2009; *1 kg diesel produced 2.6 kg CO_2

Conservation agriculture is a new dimension in cropping system. Thus, research and extension linkage need to be strengthened with multidisciplinary approaches and weed control measurements need to be refined in a much greater scale when adopting CA system.

- Problems of CA technology adoption
- Policy planners are not much convinced about these technology
- Limited investments of local manufacturers to scale-up production linked with uncertain machinery demand
- The great number of resource poor smallholder farmers is not an attractive potential client group of machinery manufacturers
- Manufacturing infrastructure and distribution channels of products are little developed
- High price of machinery and low prices of agricultural produce discourage investments in agriculture, including machines and tools
- Financial organizations are not much friendly to farmers in terms of reducing rate of interest and installments
- Absentee farmer and small landholder have limited access to new technology
- Additional learning is required comparing to conventional system
- Research and extension-farmers' linkages are not well established for transfering about these technologies
- Limited programms are available to promote activities and awareness build up programme

Challenges of Promoting CA Technology

- How to encourage private sectors' investment to scale up these technology
- How to make available appropriate CA implements and tools at an affordable price to farmers
- Trainings to be conducted in different level of workers, considering the advantages of conservation agriculture.
- Policy support is necessary for further acceleration of this technology among the users

Cambodia
Biochar Production Technology in Cambodia and its Application on Agricultural Crops

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I. What is Biochar?

Biochar is a 2,000-year-old practice of converting agricultural waste into a soil enhancer that can hold carbon, boost food security, increase soil biodiversity, and discourage deforestation. The process creates a fine-grained, highly porous charcoal that helps soils retain nutrients and water.

Biochar is an important method to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. It also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution (http://www.biochar-international.org/biochar/carbon).

Biochar can contribute as following:

- Enhance productivity of farmland;
- Achieve environmentally friendly agriculture;
- Organic agriculture;
- Sustainable carbon sequestration;
- Rural promotion (Carbon minus project); and
- Environmental-friendly education.

Biochar can be used for agricultural and industrial purposes as shown in the chart below:

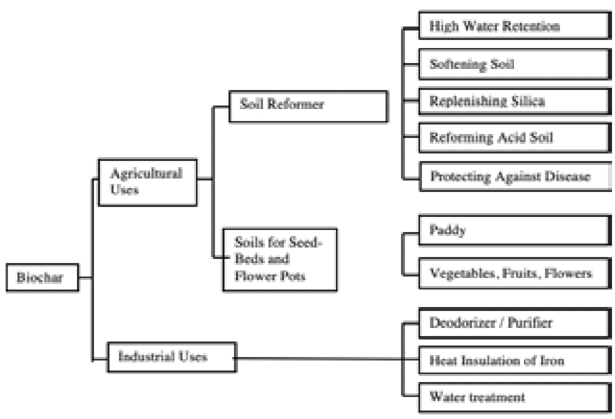

Figure 1: Usage of Biochar

II. How Can We Convert Agricultural Waste Products into Energy in Cambodia?

Many farmers in Cambodia do not use agricultural waste products such as rice stubbles, corn cobs, wood chips, coconut shells, sugar cane residues, peanut shells, etc. to make compost or biochar. They often burn agricultural waste products, which harm the environment because of CO_2, sooth and other emissions into the atmosphere. After harvesting their paddy, stubble and straw remain on land, which are then usually burned by the farmers. Often the uncontrolled burning cause fire on nearby paddy fields that are not yet harvested and even houses are sometimes destroyed. The sooth and CO_2 emissions are released into the atmosphere, causing often respiratory and other health problems to people nearby.

Some initiatives were introduced by converting agricultural waste products into energy for cooking through development of household cook stoves. Further appropriate kiln got introduced to process biochar that are now available in the country.

III. Biochar Production Equipment

Biochar is produced in a range of kilns which vary greatly in performance, size, cost, durability and production scales from small household-level kilns to village-wide and industrial-size systems. The most common biochar kilns are classified at three scales:

- Small-scale: Improved Cookstoves (ICS) produce biochar as a by-product of cooking, either with a twin or single chamber design and an inner chimney. These typically produce up to 1kg per run;
- Medium-scale: Oil-drum kilns, of various designs (100-200-liter capacity), typically produce 7-15 kg of biochar per run; and
- Large-scale: Retorts are high-capacity static brick and metal units producing up to 400kg biochar per run (over 48hrs).

Biochar production technologies can cause environmental pollution if not designed and operated correctly. The better design features can adjust to air inlets, allowing the reaction to start with plenty of air, which can then be shut-off to produce pyrolysis. They also include adjustable secondary air inputs at the kiln or fire boxes where hot temperature combustion is underway to burn-off fugitive emissions of polluting greenhouse gases and black carbon particles.

Many variables influence the properties of biochar, yet the knowledge of the precise relationship between feedstocks and conditions during production and biochar properties remains limited. Biochar producers must develop their own expertise based mostly on local experiences, feedstocks, and knowledge networks.

IV. Design of Biochar Kilns by Department of Agricultural Engineering

Based on lessons learned and shared experiences among biochar kiln designers, among various prototypes of simple biochar kilns, the Department of Agricultural Engineering (DAEng) had developed and designed two types of biochar kiln:

1) Chiveak Tyung Biochar kiln;
2) Mobile Biochar kiln.

- Chiveak Tyung Biochar kiln

  It is a simple Top-Lit Up-draft (TLUD) kiln that has a capacity to hold 20 kg of rice husk or other agricultural wasted materials and its production of biochar can reach up to 50%. The purpose to develop this kiln is to use local material and help farmers and other local users can afford buying and using it for their farm lands.

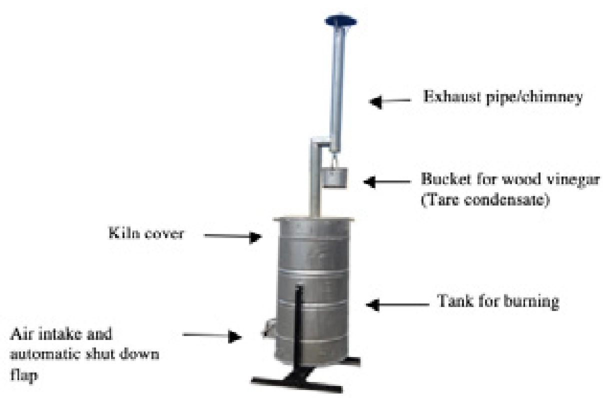

Figure 2: The Picture Shows the Top- Lit Up-Draft (TLUD) Kiln with Some Design Features.

- Mobile Biochar kiln

  The kiln is equipped with 3 separates and enlarged TLUD burning chambers and is fixed on a trailer. Since a power tiller is attached to the railer, the unit can move from one place to another upon farmers' or customers' requests. It can provide service in remote villages and farms. The main purpose of this new design is to convert rice stubble and straw into biochar near the rice fields or farmers' places. The bigger size of the 3 burning chambers should also increase the production capacity and stimulates the economy. The trailer is additionally equipped with a water tank and a hand pump to quench the biochar after pyrolysis has stopped.

  Biochar production should give the rice straw and stubble a higher value as fertilizer and soil improver, and should also prevent the farmers from burning the straw which is rather a common practice after harvest.

Figure 3: The Picture Shows the Mobile 3 Chambers TULD Kiln Fixed on Trailer and Towed by Power Tiller.

V. Conclusions

- Agricultural residues in Cambodia, such as rice husk, rice straw, corn cob, sugarcane bagasse, etc. has limited usage for power generation and soil amendment;
- Biochar can be produced from agricultural residues and considered as a positive solution to increase food security, ease scarce organic resources, and reduce inadequate water and chemical fertilizer supplies;
- Biochar can contribute to the reduction of CO_2 emission in the atmosphere and support environmentally friendly agriculture;
- Biochar kiln can be produced by different methods and materials; and
- The research and development of biochar kiln should consider local conditions to make sure the design is suitable to local users who can afford it.

VI. Future Plan on Biochar Production & Application

- Awareness is raising among relevant stakeholders, including Agricultural Educational Institutions;
- Better information on sharing and extension of the technology through national and regional workshops about the benefits and value of biochar;
- Close cooperation with development partners and private sector to design, improve, and apply biochar converters (kiln); and
- Introduction of biochar application on various crops through biochar training workshops and field demonstrations to farmers and relevant stakeholders.

China
The Path and Cases on China's Sustainable Agricultural Mechanization

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Introduction

Theodore W. Schultz, an American agricultural economist, thought that agriculture would become the drive force of economic growth if the traditional agriculture could be transformed into modern agriculture in developing countries. China is a large agricultural country with massive population. The development of modern agriculture is a significant contributor to the wellbeing of the Chinese people. Agricultural machinery and equipment provide the base of material technology for modern agriculture while agricultural mechanization is a major content and one of the main indicators of agricultural modernization. The Chinese government always attaches great importance to agricultural mechanization development, and agricultural mechanization becomes an important support to promote the transformation of agricultural development methods, to improve agricultural labor productivity and agricultural comprehensive production capacity in China.

At the moment, Chinese agriculture faces several major issues. First, the task to ensure food safety and effective livestock products supply is still arduous: there is an urgent need to change agriculture production methods. Second, resource constraints and ecological environment pressure on the agricultural development continue to grow: there is an urgent need to promote a resource-saving, environmentally friendly, and sustainable development. Third, more and more environmental disasters are happening: the country is in dire need to promote agricultural energy conservation and emissions reduction technology. Accordingly, it would be essential to further promote sustainable agricultural mechanization in China.

I. Agriculture Situation

In 2014, China's agricultural population is 619 million, which is about 45.2% of the total population. The percentages of employees in primary, secondary and tertiary industry are 30%, 30% and 40% respectively, while the composition of gross domestic product of primary, secondary and tertiary industry are 9%, 43% and 48% respectively. China's per capita agricultural labor productivity is RMB25,600(US$3,900) (Table 1), while the annual net income per farmer is RMB9,900 (US$1,500), with an income gap between urban and rural areas of 2.97:1.

China has a total arable area of 120 million ha with more than 60% of hilly mountain area. Total sown areas of farm crops are 166 million ha, of which 113 million ha are for grain crops, i.e. 57% of the total sown area. The sown areas for corn, rice, and wheat are 39%, 30%, and 25% of the total sum for all three crops, which is 78% of the sown areas for grain crops. (Figure1).

China's per capita arable land and fresh water resources are rather low, which are only 25% and 40% of the world's average. China's per capita arable land availability is 0.08 ha, far below the world average of 0.24 ha. But China's total output of grain, vegetables, fruits, meat and aquatic products ranks first in the world. In particular, China's grain output increased in twelve consecutive years from 2004 to 2015 (Figure 2), and it reached 621.44 million tons in 2015. As a matter of fact, it would not have been possible to achieve these gains without fast agricultural mechanization development.

But there is a huge drawback for the continuous increase in grain output for 12 consecutive years in China. Too many resources and environment elements were made fragile because of the rapid development. The effective utilization coefficient of irrigation water in China is only 0.52; it is 0.2 percentage points lower than the world advanced level and the actual water consumption of major grain-producing areas is generally exceeding the sustainable use of water resources. To produce 16% of the world's agricultural product, China's fertilizer consumption accounts for 31% of the world and use intensity is 2.7 times more than the world's average. The pollution cost resulted by excessive use of chemical fertilizers exceeds the benefits of the increased production. Annual pesticide consumption is about 1.8 million tons, but utilization rate is less than 30%. Pesticide usage per unit area is 2.5 times more than the world's average. Plastic film usage on crop fields is about 2.4 million tons per year yet among which only 1.4 million tons can be recycled.

Table 1: China Gross Labor Productivity and Agricultural Labor Productivity from 2000 to 2014

Year	Gross labor productivity (Yuan)	Agricultural labor productivity (Yuan)
2000	7900	4100
2001	8600	4300
2002	9400	4500
2003	10500	4800
2004	12300	6100
2005	14200	6700
2006	16500	7500
2007	20200	9300
2008	23700	11300
2009	25600	12200
2010	3000	14500
2011	35200	17900
2012	38400	20300
2013	43200	23600
2014	46500	25600

Source: China Statistics Yearbook

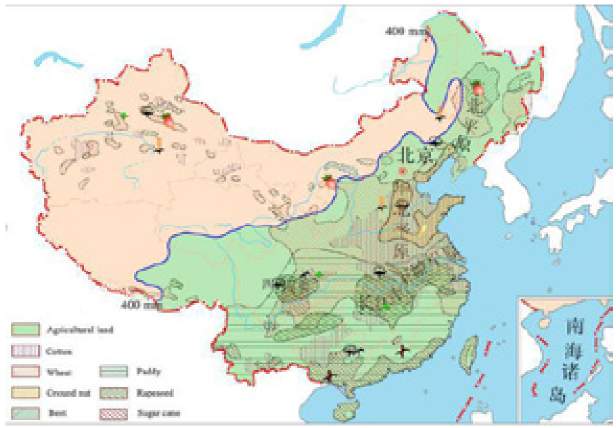

Figure1: Major Agricultural Land and Main Crop Regions of China

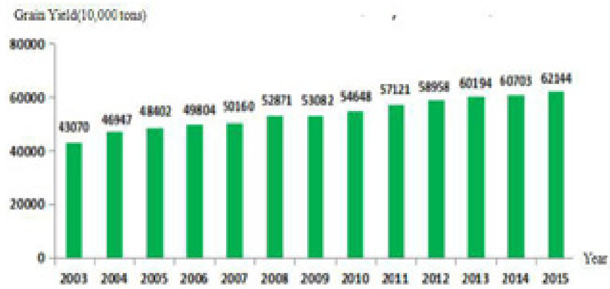

Figure 2: Grain Yield in China from 2003 to 2015

Agricultural production costs rose up but comparative efficiency decreased. Factors of production, such as the price of agricultural production, land rent and labor cost, are rising. Planting benefit showed a downward trend. The pure income of planting a hectare of food is only US$300 (Figure 3).

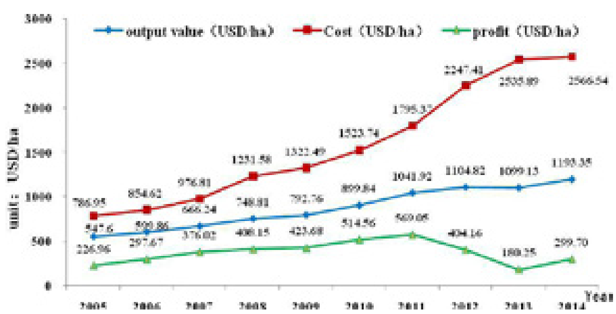

Figure 3: Agricultural Production Costs and Benefit

The comparison of production costs of six major crops between China and the United States in 2014 shows that China's production costs per hectare of wheat and cotton were more than three times of which in the United States (Figure 4). The comparison of production costs of six major crops per 50kg between China and the United States in 2014 reflects that China's production costs of corn and soybean were more than two times of which in the United States (Figure 5).

The comparison of labor cost of six major crops per hectare between China and the United States in 2014 indicates that China's labor costs of rice and peanuts were seven times of which in the United States; China's labor cost of soybean was 10 times of which in the United States; and China's labor costs of corn and wheat were 17 and 18 times of which in the United States respectively (Figure 6). The comparison of occupation ratio of labor cost of six major crops per hectare between China and the United States in 2014 shows that American labor costs accounting for total cost of six major crops were all below 10%, but China's labor costs accounting for total cost of six major crops were all above 40% except for wheat and soybean (Figure 7).

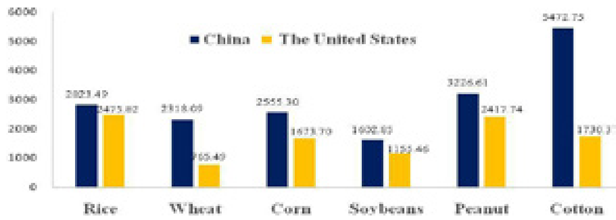

Figure 4: The Comparison of Production Costs of Six Major Crops between China and the United States in 2014 (USD/ha)

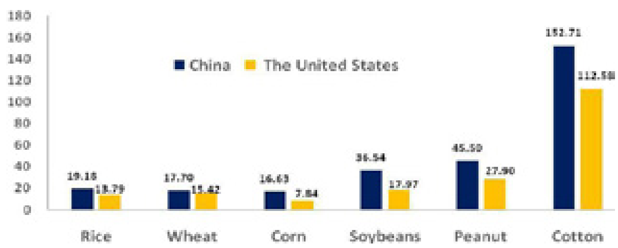

Figure 5: The Comparison of Production Costs of Six Major Crops Per 50kg between China and the United States in 2014 (USD/50kg)

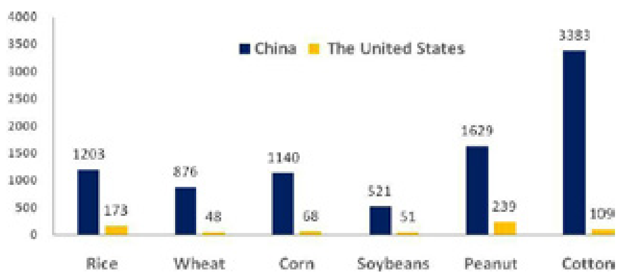

Figure 6: The Comparison of Labor Cost of Six Major Crops per Hectare between China and the United States in 2014 (USD/ha)

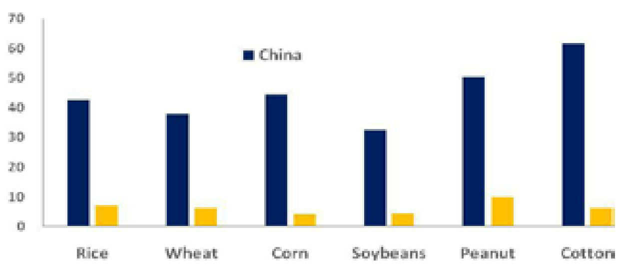

Figure 7: The Comparison of Occupation Ratio of Labor Cost of Six Major Crops per Hectare between China and the United States in 2014 (%)

Meanwhile, increasing proportion of labor force is migrating from rural areas to urban areas. It implies the aging trend of agricultural labor force. There are more than 263 million rural labor migrating into business, among whom 60% are under 40 years. Nearly one-third of agricultural labor force is more than 50 years old. It would be crucial to speed up agricultural mechanization to compensate the foreseeable decline in agricultural labor input.

II. The Situation of Agricultural Mechanization

Since 1949, China has undergone a remarkable development in agricultural mechanization, which has been playing a very important role in promoting the progress of modern agriculture, ensuring agro-product supply, guaranteeing food safety, increasing competitive ability of agro-product, raising farmers' income, and supporting the rapid growth of national economy. It will be presented in five aspects as follows:

a. The Ownership of Agricultural Machinery Has Increased Rapidly

By the end of 2014, the original value of farm machinery reached RMB 878.8 billion, with RMB 3,400 per peasant household on average, making up 65.4% of the fixed assets of agricultural production for them. The total power of farm machinery had reached 1,080 million kW, which increased 9.2 times comparing to 118 million kW in 1978.. The average power availability per hectare now stands at 5.4 kW. Some agricultural machineries including large-mid-sized farm tractors and implements, combine harvesters, and farm load-carrying vehicles, increased quickly and reached 5.68 million, 8.89 million, 1.58 million and 13.77 million units respectively. The matching implement ratios for large-mid-size farm tractors and small-size farm tractors are 1:1.56 and 1:1.77, respectively.

b. The Mechanized Operation Level Is Heightened Steadily and the Service Field of Agricultural Machinery Is spreading Gradually

By the end of 2014, China's crop production comprehensive mechanization level reached 61.6% (Figure 8). The mechanization percentages of plowing, sowing and harvesting reached 77.5%, 50.8% and 51.3% respectively (Table 2). In the case of wheat, 87.0% of sowing and 93.3% of harvesting had been mechanized. For paddy rice, mechanization rates of planting and harvesting reached 39.6% and 83.1%, and mechanization percentage of corn sowing and harvesting reached 83.9% and 56.7%. Mechanization levels for paddy rice and corn are comparatively lower, especially for rice planting and corn harvesting. The mechanization level of potato sowing and harvesting, rape sowing and harvesting, peanut sowing and harvesting, cotton harvesting and sugarcane harvesting are also relatively low (Table 2). There are 20 provinces, municipalities or autonomous regions with integrated mechanized levels of over 50%, and 11 of them are over 70%. The total area of greenhouse is 20.8 billion m² all over China. At present, the field of agricultural mechanization has expanded from grain crops to cash crops, from field agriculture to facility agriculture, from crop farming to breeding industry and agro-product processing, from field production to before-production and post-harvest.

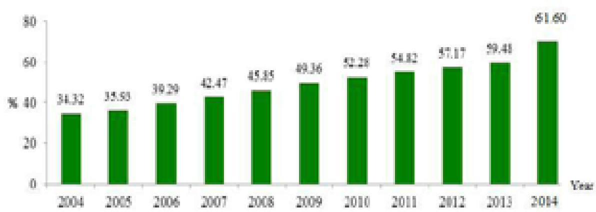

Figure 8: China's Crop Production Comprehensive Mechanization Level from 2004 to 2014

Table 2: Crop Production Mechanization Level in 2014(%)

	Tillage Mechanization level	Planting Mechanization level	Harvesting Mechanization level	The comprehensive level of tilling, planting and harvesting
Crop	77.5	50.8	51.3	61.6
Wheat	100	87.0	93.3	94.1
Rice	98.1	39.6	83.1	76.0
Corn	97.4	83.9	56.7	81.1
Potato	55.9	24.3	23.0	36.5
Cotton	100	86.5	15.2	70.7
Rape	68.0	19.5	24.9	40.5
Peanut	65.9	40.7	29.4	47.4

c. Remarkable Science and Technology Innovations in Agricultural Mechanization

In recent years, there has been a marked progress in technological innovation, which provides a great technical support to increase mechanization levels. For example, in view of key links for main crops' production, the technology and equipment for mechanized paddy production such as transplanting and harvesting and the harvesting machinery for corn have become more mature and brought in major developments. In addition, there have been rewarding progress in conservation tillage, straw crushing and re-utilization, pasture production and processing, safe chemical application, planting and harvesting for main industrial crops such as cotton, rape, peanut, and potato. Along with the agricultural structure adjustment and implementation of The Plan of Area Distribution for Superior Argo-Product, local governments are incentivized to develop agricultural mechanization based on regional contexts, research and disseminate mechanization technologies for special local agro-products, to meet the demand of agriculture production and promote the development of agriculture and rural economy.

d. The Level of 'Socialized Service' of Agricultural Machinery Increased Significantly

Agricultural machinery has become the major technique farmers need to deal with in agricultural production and increasing income. Innovative agricultural machinery service organizations, such as agricultural machinery cooperatives, associations and farm machinery leading households, are emerging. By the end of 2014, there were 175,124 service organizations and 42.9 million households providing mechanized farming service with 55.2 million practitioners. Its gross income reached RMB 536 billion with a total revenue of about RMB 210 billion. Since 1996, relevant ministries and agencies in China have jointly launched the so-called 'Cross-regional Wheat Harvesting Programme' using combine harvesters, which has accelerated the process of market-orientation, specialization, and socialization. Cross-regional harvesting service is now covering not only wheat, but also rice, corn, soybean and potato, with much wider scope and larger areas all over the country.

Figure 9: Agricultural Machinery Socialized Service

e. The Laws and Regulations System for Agricultural Mechanization are Adequate

The 10th meeting of the Standing Committee of the 10th National People's Congress examined and approved The Law on Promoting Agricultural Mechanization of the People's Republic of China, which was drawn into attention / taken into action on November 01, 2004. It is the first law on promoting agricultural mechanization in China, which further defined the promotion function of governments at all levels in agricultural mechanization. It also provided the foundation for policy researches and agricultural machinery development in terms of quality assurance, service of agricultural machinery, application of advanced technology, and equipment for farmers and organizations. It launched measurements to subsidize and provide financial service for farmers and service providers to purchase machines and equipment, to design and apply policies on preferential tax, fuel subsidies and so on. This law further created a constantly developing environment for agricultural mechanization with the combination of government instruction and market-oriented system under the legal frame. It exerts an active and great influence on the cause of agricultural mechanization while encouraging farmers to purchase and use farm machinery and raise productivity.

f. International Exchange and Cooperation Have Been Strengthened

In recent years, China's large market volume has aroused the attention of large international manufacturers of agricultural machinery. They have cooperated with the Chinese relevant departments and enterprises to exploit the market and have also won the market share. In order to encourage the imports of large-size agricultural machinery, Chinese government has promulgated preferential import tax policies. China's agricultural machinery research institutes, colleges and universities, and enterprises are actively strengthening technical innovation and cooperation to improve product quality by introducing advanced experiences and technologies from other countries.

III. Trends of Agriculture and Agricultural Mechanization

The fundamental goals of agricultural development are to ensure national food security, promote the continuous increase of farmers' income, and protect agricultural ecological environment. High efficiency of agricultural production based on scale, standardization, specialization and agricultural mechanization is the important base to achieve the goals. The ultimate goal of agriculture is to achieve agricultural modernization and sustainable development (Figure10).

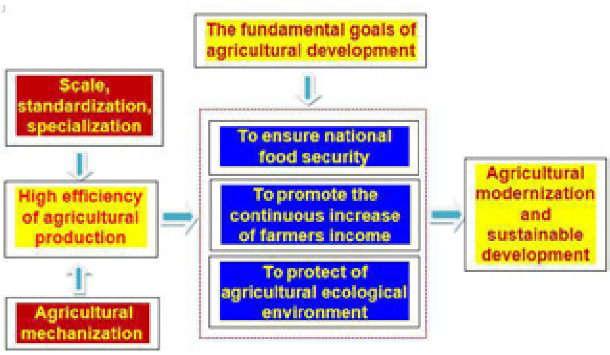

Figure10: The Relationship between Agriculture and Agricultural Mechanization

There are two important viewpoints about America's productivity growth in grain production. W.N. Parker & J.L.V. Colin thought that the role of agricultural mechanization was about 60% of labor productivity growth in wheat production in 1840-1860 and 1900-1910. And Vernon Ruttan & Hayami Yujiro thought the role of agricultural mechanization was about 70% of agricultural productivity growth in the United States in 1880-1960.

American engineering and technology field evaluated that agricultural mechanization was ranked as the 7th out of 20 engineering technologies that plays a huge role in the process of human society progression. This evaluation was based on the fact that agricultural machinery was widely used in agricultural production in 100 years and had triggered fundamental changes to the agricultural production mode. Agricultural mechanization had greatly improved the agricultural labor productivity to ensure the world's agricultural development and food security.

We think agricultural mechanization is a key factor whose level is crucial to form international competitiveness in agriculture and determine the strengths or weaknesses of it during the transition period from traditional agriculture to modern agriculture.

The government leads agricultural mechanization to a fully mechanized agricultural production. It also takes the lead to explore fully mechanized agricultural production patterns (Figure11) to achieve a high-quality, high-efficiency, and sustainable development.

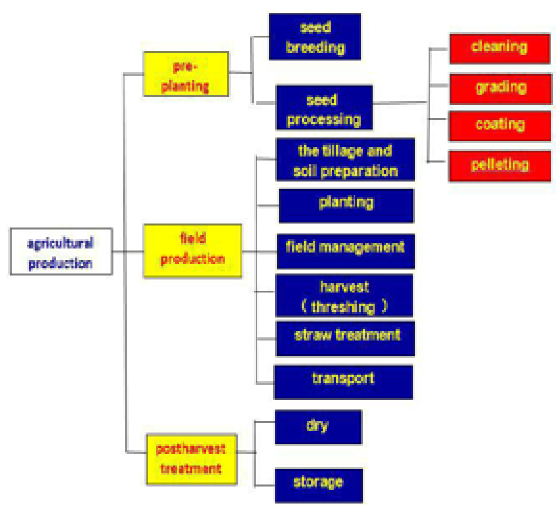

Figure11: Agricultural Production

Sustainable agricultural mechanization technologies will be the priority. China will carry out the strategy of sustainable development to 1) enhance rational utilization and efficient protection of resources of farmland, water and fertilizer; 2) improve agricultural ecological environments; 3) protect agricultural environment from pollution; and 4) promote agricultural resource transformation from intensiveness to sustainability. The key points will be put into the development of advanced and applicable mechanized technologies for the protection of ecological environments and sustainable development.

IV. Path Selection of Sustainable Agricultural Mechanization

Elements and environment of sustainable agricultural mechanization were put forward by Donor Committee on Enterprise Development, (FAO, 2012). They included the government, policies, people and society, values and norms, natural resources, market demands (Figure12).

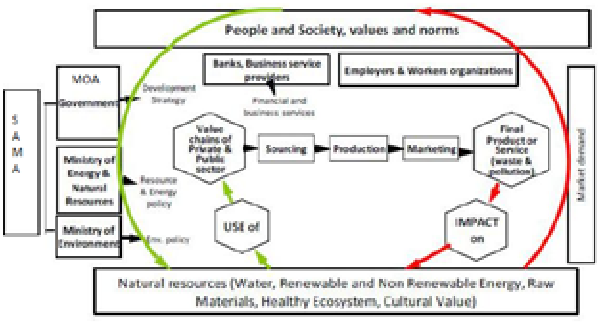

Figure12: Sustainable Agricultural Mechanization Elements and Environment

Sustainable mechanization production technologies and equipment include conservation tillage technology and machinery, agricultural machinery subsoiling technology and implements, water-saving irrigation, efficient plant protection technology and equipment, mechanized technology and equipment of straw returning to field, postharvest treatment and processing mechanized technology and equipment, GIS, GPS used in agricultural machinery and agricultural production which improve the precision and efficiency of production and management, agricultural aviation and so on.

Sustainable agricultural mechanization in China will focus on controlling the total amount of agricultural water, reducing the total amount of chemical fertilizer and pesticide, and treatment of livestock and poultry pollution, plastic film recycling, and straw. The utilization coefficient of agricultural water usage should be improved from 0.52 to 0.55 by engineering measures and water saving mechanized technical measures. The utilizable ratio of chemical fertilizer and pesticide is improved by mechanized precision fertilization and applying pesticide. Resource utilization of agricultural wastes should be achieved by mechanized technologies and engineering measures.

The organization scale and operation scale of agricultural machinery socialized service will continue to expand. In China, there are close to 900 thousand family farms and the arable land per family farm has is 13 hectares on average. There are 57 thousand agricultural machinery cooperatives and a large-scale cooperative usually has 300-400 hectares of arable land who also provides social services. Some agricultural enterprises provide postharvest treatment and processing to guarantee the quality and increase the added value of agricultural products.

Sustainability of policies and measures is very important. Chinese government is paying greatest attention to agriculture, rural areas and farmers, and it promulgated a series of policies to support agriculture production and increase farmers' income sustainably. For example, Chinese central government issued The Law on Promoting Agricultural Mechanization of the People's Republic of China in June 2004, which has brought the development of agricultural mechanization into a legally enabled course. In recent years, both national and local governments in China have adopted a series of measures, such as regional laws and regulations issued by 30 provinces, municipalities, and autonomous regions, to support and promote the development of agricultural mechanization. Since 1998, the country has put in place the policy of agricultural machinery purchase subsidy and the central government alone has allocated RMB 23.7 billion to fund these subsidies in 2014 and 2015. This is sometimes supplemented by additional subsidy regimes and incentives at local levels. The measure of subsidy has greatly aroused farmers' and agricultural production organizations' enthusiasm for the purchase and use of farm machinery, hence accelerated the popularization and use of new equipment and technology. In addition, other policies are also being implemented such as subsidy for scrap update of agricultural machinery, subsidy for agricultural machinery subsoiling, and the promotion and demonstration of the technology and equipment of sustainable mechanization, etc.

V. Case Studies

a. Case Study of Farm Land Scale

The farmland scale is the foundation of agricultural mechanization. Chinese government is implementing The High Standard Farmland Construction Planning now. The speed and the amount of land transfer in China are increased. Large-scale management can improve use efficiency of agricultural machinery power. For example, the agricultural machinery power is 0.75-1.05kW/ha in USA and UK (Figure13)and about 4.95kW/ha in South Korea, but about 5.7kW/ha with 64% of crop production mechanization level in China.

Figure13: Farm Land Scale of Operation in UK and USA

b. Case Study of Cooperatives

Haibin agricultural machinery cooperative in Jiangsu Province has 300ha of arable area and provides 600ha of agricultural machinery operation service (Figure14).

First, the cooperative achieved fully mechanized production and used unmanned aircraft for field plant protection operation to improve the production efficiency. It needed 20 people to work a day to complete 65ha of paddy field plant protection operation in the past but only needs 2 people to accomplish the same amount of work now. In addition, it could reduce pesticide application rate by 10% and save cost by more than 20%.

Second, the cooperative accomplished the paddy field harvest including drying, rice processing, and bagging, which reduced the loss in production process and increased additional value of the finished products by more than 45%.

Third, the cooperative installed the GPS in the tractor and harvester to collect real time information and data statistics for field operation, which increased work efficiency by more than 5% and saved 40% of cooperative management costs.

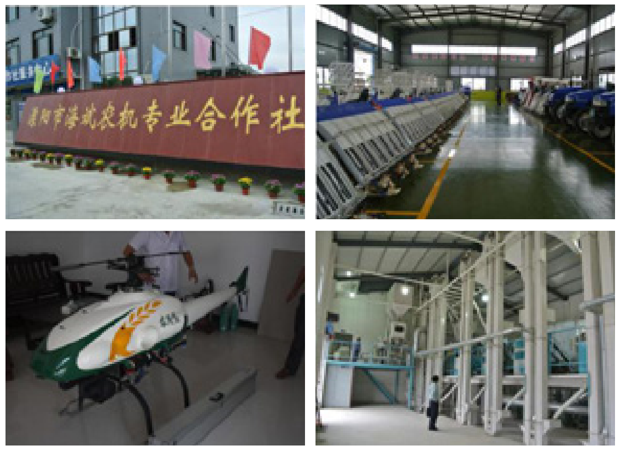

Figure14: Haibin Agricultural Machinery Cooperative in Jiangsu Province

c. Case for Fertilizer Transplanter

The fertilizer transplanter reduces the amount of labor and fertilizer and improves the efficiency of fertilizer (Figure15). Its basic principle is to apply granular compound fertilizer in deep soil at the same time of planting. The field trial result in Jiangsu province proved that fertilizer transplanter could reduce 30% of fertilizer usage and increase rice production by about 6% which brings extra RMB1600/ha. It could also reduce pollution from fertilizer used for field water and soil.

Figure15: The Field Trial of the Fertilizer Transplanter

d. Case for Monitoring Management

The whole monitoring management for agricultural mechanization based on the Internet of Things started in China (Figure 16). The system has many functions including monitoring agricultural machinery position and operation, analyzing distribution and failure, tracking replays and operation time, and processing maintenance.

It can improve agricultural mechanization management efficiency, decrease cost, and increase benefit.

Figure15: The Whole Monitoring Management for Agricultural Mechanization based on the Internet of Things

Conclusions

Agricultural mechanization can improve agricultural labor productivity and farmland ecological environment. Governments should increase the support for agricultural mechanization in China and other developing countries. It must choose the suitable development model in different regions and countries. Governments should enlarge the scale of land management, promote the application and popularization of agricultural mechanization technology of energy saving and environmental protection, and support the development of agricultural cooperatives and family farms. It must examine the costs and benefits of mechanized system to decide the appropriate farm mechanized technology.

Indonesia
Leading the Way for Climate-smart Agriculture through Machinery and Practices in Indonesia

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I. Introduction

Indonesia is an archipelago country, consisted of 1.9 million km2 of land and 3. 3 million km^2 of sea. The number of the population was 253 million in 2015. The total number of agriculture land is 70.2 million ha, among which 8.1 million ha is wetland paddy field; 11.9 million is dry land; and 5.3 million ha is shifting cultivation field.Rice, maize and soy bean are the main food crops of Indonesian farmer. The production of milled rice, maize and soy bean was 40.64 million ton, 18. 6 million ton and 893 thousand ton respectively in 2014.

The targets of agricultural development of Indonesia are 1) to achieve sustainable food sufficiency & security, 2) to increase food diversification, 3) to increase added value, 4) to increase competitiveness and export, and 5) to increase farmer welfare. Although Indonesian rice and maize production was higher than national demand, the sustainability of crops production are threatened by 1) land conversion and degradation, 2) poor irrigation and drainage capacity, 3) high agriculture cost, and 4) climate change.

The average land held by Indonesian farmers is less than 0.5 ha/ farmer. This condition was further reduced by the high land conversion rate in the country, at which about 60,000 ha of fertile agricultural land was converted into non-agricultural purpose every year. In addition, because of the low preference of young people to work in agricultural sector, agricultural workers are shifting to non-agricultural industries such as business and transportation, which decreased rural population and increased urban population.

II. The Role of Agricultural Mechanization in Agricultural Development in Indonesia

Agricultural mechanization is one of the important factors that plays a strategic role in Indonesia's agricultural development, particularly in supporting sustainable food security and coping with the impact of climate change. The important roles of agricultural mechanization are: (a) complementing agricultural labor shortage, (b) speeding up farming operation and increasing land productivity, (c)decreasing yield loses and improving agricultural product quality, and (d) increasing added value of agricultural products and decreasing cost of prodction. Two-wheel tactor, irrigation pump, and power thresher have been used widely by Indonesian rice farmers for land preparation, but rice transplanter and combine harvester are still being introduced to the market (Table 1). To increse rice production and reduce cost of production, since 2014 to 2016 the goverment has given loans and grands to more than 80,000 machinery farms and farmers. This caused a surplus in rice production by more than 10% in 2016.

Even though there were various constraints such as labor shortage and high land conversion rate, food crop production and farmer's income have been increasing during the last five years (Table 1). Key reasons that caused this increase in rice production in Indonesia were the increase in farm machinery utilization and the introduction of a new rice production method called "Jajar Legowo" (Figure 2). Jajar Legowo Rice Transplater was also designed, fabricated and introduced to the farmers to increase rice production (Figure 3). More than 5,000 Jajar Legowo Transplanters have been fabricated and marketed in Indonesia during 2014-2016.

No	Commodity	2010	2011	2012	2013	2014
I. Milled Rrice						
1	Production (000 Ton)	38,659	38,244	40,163	41,456	40,637
2	Consumtion (000 Ton)	34,343	34,822	35,386	35,936	36,442
3	Surplus/Defisit (000 Ton)	4,315	3,422	4,777	5,520	4,195
II. Maize						
1	Prodution (000 Ton)	18,328	17,643	19,387	18,512	18,549
2	Consumption (000 Ton)	13,905	14,645	15,696	15,692	16,569
3	Surplus/Defisit (000 Ton)	4,422	2,999	3,691	2,820	1,979
III. Soy bean						
1	Production (000 Ton)	907	851	843	780	893
2	Consumption (000 Ton)	1,867	2,051	1,971	2,115	2,231
3	Surplus/Defisit (000 Ton)	(960)	(1,200)	(1,128)	(1,335)	(1,338)

Figure 2: Jajar Legowo Rice Production Method.

Figure 3. Jajar Legowo Rice Production Method.

III. Introduction of Agriculture Machinery to Cope with the Impact of Climate Change

Climate change has decreased water availability, disordered flowering system, and increased probability of pest infestation. The availability of water in some reservoirs in Java island has decreased by more than 5%. The water availability of Citarum river decreases by 4.9 million m^3/year and water at Gadjah Mungkur reservoir decreases by 5.7 million m^3/year caused by the impact of climate change and sedimentation. Delay of planting season has decreased rice production by 6.5% in West Java and Central Java and 11% in Bali island. In 2015, rainy season delayed for more than 1 month and started 2 months earlier in 2016. These conditions have caused reduction of crops production in that areas.

By-product is one of the agricultural resources which can be potentially utilized while reducing green house gases. More than 126 million ton/year of agriculture by product such as rice and maize straw, husk and maize cobs, and about 66 million ton/year of animal waste have been produced from the farms in Indonesia. Some of these by products have been used for organic fertilizer and animal feed. However, some farmers burn them to clean agricultural land. This practice produces green house gases that cause climate change. The goverment has conducted some trainings and extensions for farmers and farmers' groups to use agricultural machinery to reduce burning practices of agricultural waste such as the utilization of rice and maize straw chopper (Figure 3) and hammer mill to produce organic fertilizer (Figure 4).

Some agricultural areas, such as in West and East Nusa Tenggara, are characterized by dry land and dry climmate. The amount of average rainfal is usually less than 600 mm/year. These areas mainly produce maize and cattle. Soil and water conservation as well as machinery for conservation agricultural are the main concern of agriculture development in this area. To preserve water in soil, ICAERD introduced crimper for minimum tillage (Figure 5) and roller injector planter for planting maize (Figure 6) that operates by using two wheel tractor in 2015. The capacity of the crimper and 2 rows rolling injector planter are 3 hour/ha and 8 hour/ha respectively. Some farmers were interested to use these machines because it could speed up land preparation and planting. These machines are simple and easy to be fabricated by local artisan. An artisan in West Nusa Tenggara expressed his will to produce these machines.

Figure 3: Straw Chopper of 400 kg/h Capacity Has Been Widely Use by Farmer to Provide Cattle and Goat Feed.

Figure 4: Hammer Mill of 500 kg/h Capacity for Gridding Organic Fertilizer Has Been Introduced and Widely Used by Farmer.

Figure 5: Crimper Was Demonstrated to Support Conservation Agriculture Program in West Nusatenggara Province

Figure 6: Rolling Injector Seeder for Maize Introduce in West Nusatenggara Provice

IV. Conclusion

Agricultural machinery has proven that it can enhance crops production, ease farm labor shortage and reduce cost of crops production in Indonesia. It speeds up land preparation and crops production, which therefore saves water. Minimum tillage using appropriate agricultural machinery such as crimper and rolling injector planter was very helpful for maize farmers particularly those who are in the up land and dry climate area. Overall, agricultural machinery is a crucial mean for farmers to cope with the impact of climate change.

India
Climate-smart Agriculture and Mechanization in India

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The concentration of greenhouse gases (GHG) in the atmosphere has been rising to historical levels, primarily due to fossil-fuel burning and land-use changes. Agriculture is responsible for about 30% of the total greenhouse gas emissions which are mainly CO_2, NO_2 and CH_4 while being directly affected by the consequences of a changing climate. These gases have the potential to trap energy from the sun, which may result in global warming, and this has sparked a world-wide concern that emissions of these gases should be reduced below the 1990 levels by the year 2012 (Kyoto Protocol). The international community realized the need to stabilize and reduce CO_2 and other greenhouse gases emission in agriculture to mitigate extreme conditions brought by climate change. The choices of farming practices, farm equipment and machinery have significant influences on intensification and optimization outcomes as well as on profit and environment. However, until now, agricultural intensification generally has negative effects on the natural resources, such as soil, water, land, biodiversity, and ecosystem. Another challenge for agriculture is its environmental footprint and climate change. It is estimated that global conversion of all croplands to conservation tillage (CT) could sequester 5 billion tons of carbon annually. Extensive field trials in the country have shown that planting of wheat, pulses, and vegetables on beds increased yield and fertilizer use efficiency, reduced herbicide dependence and mobility in the field, and saved seed, fertilizer, irrigation water and soil compaction under heavy rains and draught conditions. An improvement can be achieved by zero tillage if crops are grown on the ridges of a ridge-and-furrow planting configuration. This is, however, profitable and sustainable only if farmers shift to a permanent bed system, i.e., zero/minimum-tilled crops on beds.

In India, significant efforts are underway to develop and popularize the resource conservation agricultural machinery and practices through the combined efforts of several state and national institutions, particularly National Innovation on Climate Resilient Agriculture (NICRA) – ICAR, Rice-Wheat Consortium for Indo Gangetic Plains, and CIMMYT India. The new technologies, on the one hand, are encouraging farmers to take up new ways of managing their resources efficiently and effectively and, on the other hand providing a way to the scientific community to solve emerging problems of climate change due to the reduction in emissions of GHG associated with new technologies. The new developed energy efficient farm machinery and equipment can reduce the emissions of fossil fuels comparing to conventional methods by up to 60 per cent. However, the largest contribution to mitigate climate change with conservation agriculture technology can be obtained from carbon sequestration and the storage of atmospheric carbon in the soil. The levels of carbon to be captured in the soil vary depending on climate and production system. On average, 0.1-0.5 t ha-l y-l of organic carbon can be captured under humid temperate conditions. For farm equipment like straw shavers and rotovators, happy seeder, rotary disc no till drill are required to incorporate crop residues into the soil. It will help mitigate climate change by reducing the emissions of greenhouse gases into the atmosphere. Controlled traffic minimum tillage practice might be seen as a second phase of resource conservation agriculture to overcome the heavy rainfall and water stress due to draught, subsurface degradation and system impacts of wheel ruts from random wheel traffic. Research during the past few decades in India has demonstrated the significant contribution of energy efficient farm machinery and practices in reduction of GHGs as well as in enhancement of carbon sequestration.

I. Climate Resilient Machinery and Practices

No Tillage Seeding/Planting Machinery

No Till Drill

Strip Till Drill

Rotary Slit Till Drill

In India sowing of wheat with traditional method requires 7-8 days in field preparation which delays the sowing process, decreased yields, and increases GHG emission. Hence, for timely sowing of wheat, no till drill, slit till drill, rotary slit till drill and happy seeder were developed. No-tilled drills, strip till drills, and rotary slit till drill were used for direct drilling of wheat on paddy. In these drills, inverted "T-type" furrow openers replaced the conventional furrow openers of the drills. In no-till plots, fuel consumption is 11.30 l/ha comparing to 34.62 l/ha by conventional method resulting in fuel saving of 24 l/ha. There was 67 % saving in fuel due to no-tillage comparing to conventional method (Table 1). Direct drilling (no tillage) can increase trafficability and availability of water in the soil, decrease soil compaction, water evaporation, and lodge condition. It can also reduce soil erosion caused by wind and water and investment in machinery because of the reduced energy requirement and improved timely planting and harvesting. However, to realize the full advantage of zero-tillage and sequester carbon, retention of crop residue especially with controlled traffic measures may further be studied. Potential benefits might include reduced soil compaction and evaporation and increased water infiltration because of the mulch residue. Crop residues may be effective in suppressing weed growth which results in the reduction of herbicides usage.

Table 1: Comparison of Different Types of No Tillage Seeding Machines for Sowing of Wheat after Paddy

Particulars	No till drill	Strip till drill	Rotary slit till drill	Bed former cum seeder/ planter	Conventional seeding (3-ploughing + seed drill)
Operational energy (MJ/ha)	648.96 (67.2)	1,001.8 (49.3)	565.0(71.4)	765.5(61.3)	1,976.62
Cost of operation (Rs/ha)	639.54 (66.4)	979.95 (48.5)	1,000.0(70.6)	754.4(60.36)	1,903.04
CO_2 emission, kg/ha	29.38 (67.36)	46.28 (48.58)	26.0(71.0)	34.66(61.5)	90.0

Figures in brackets show % saving over conventional practice.

Control Traffic/Bed Cultivation System

Research and field experiences in India showed that controlled traffic (CTF) could significantly reduce the effects of soil compaction in crop growth zones. In fact, a major benefit of controlled traffic comes from concentrating the compaction in a defined track. Doing this avoids the need to deep rip to remove compaction and reduces the fuel used in tillage by up to 50%. CTF can be used as a platform for many improvements in cropping systems. It requires modifying equipment so that wheel widths match, allowing tires to run on the same permanent wheel tracks. The most effective way is to move to satellite guided systems or auto steer systems that ensure very little error, which causes overlap and increases the amount of soil compaction. In addition to reducing fuel energy requirements of all operations, CTF allows access to crops during the early growth stages and provides a more precise relationship between the crop (or its standing residue) for planting, fertilizing, and controlling. This enables valuable cropping system options such as inter-row planting of the next crop, physical weed control and split fertilizer application. These methods are significant indirect pathways to reduce agricultural GHG emissions, in addition to other environmental and productivity benefits.

Permanent Bed Former Cum Seeder/Planter

The implement is used to form raised/broad beds separated by furrows and simultaneously undertakes sowing in rows on the bed formed. The machine forms broad beds of size: top width 1,200 mm, bottom width 1,500 mm and bed height 100 mm separated by furrows at an interval of 1,500 mm. It is suitable for sowing wheat, Bengal gram, maize, sorghum, oil seeds and pulses in permanent beds. The CO_2 emission to the atmosphere is 61.5% lower under permanent bed cultivation comparing to conventional flat cultivation system because of the fuel savings (high speed diesel) in field operation. It saves irrigation water in permanent bed system for wheat crop by 36% comparing to flat cultivation practice.

Bed Former Cum Seeder/Planter

In India, equipment to form and shape bed, apply chemicals, and harvest were developed and adopted to match the tractor track width (1,500 mm for tractor of 35 hp) and bed size (bottom width 1,500 mm; top width 1,200mm; bed height 100 mm). Equipment were evaluated for cultivating soybean, wheat, maize, and gram crops on raised bed during kharif and rabi seasons. The specifications and field capacities of equipment are given in Table 2.

Table 2: Package of Equipment for Cultivation of Soybean-Wheat and Maize-Gram Crops on Bed

Operation	Name of the equipment	Specifications	Field capacity ha/h
Raised bed forming cum seeding/planting	Tractor mounted bed former cum seeder/planter	Bed size: top width 1,200 mm, bottom width 1,500 mm, bed height 150 mm, row spacing adjustment from 100 – 500 mm.	0.35
Intercultural operation	Tractor mounted sweep cultivator	Sweep size 5 ×150 mm, for soybean crop and 4 × 150 mm for maize crop.	0.15
Chemical application	Tractor mounted hydraulic sprayer	Tank capacity: 1,50l, no. of nozzles:14, type of the nozzle: hallow cone, adjustable distance between nozzle: 300 –600, Swath: 40 - 60 m.	0.6
Harvesting	Self-propelled vertical conveyor reaper windrower	Reciprocating cutter bar size: 1,000 mm, length of stroke: 75 mm, stroke / min: 740, power: 6 hp diesel engine.	0.21
Bed shaping cum seeding planting	Tractor mounted bed shaper cum no till seeder/ planter	Bed shaper for bed size: top width 1,200 mm, bottom width 1,500 mm, bed height 100 mm and no till seed cum fertilizer drill for planting of soybean-wheat and maize-gram on beds.	0.4

II. Resource Conservation Machinery

Roto Till Drill

In a single operation, there are rotovator equipped tractors for tillage and seed cum fertilizer drill for sowing seeds. The machine performs the tillage operation and directly places seed and fertilizer in the soil under stubble fields of paddy, maize and sugarcane. Cost reduction by time and energy saving and optimization of environmental health by reducing soil compaction are the main highlighted features of this machine.

Roto Till Drill

Till Plant Machine

This machine is a combination of sweep cultivator and seed cum fertilizer drill for tillage which performs sowing operation in one pass. It has nine number shoe type furrow openers for sowing of seed after shallow tillage operation is performed by duck foot cultivator. The working width of machine is 1600-1800 mm and field capacity is 0.35 to 0.4 ha/h. CIAE, Bhopal developed the equipment for minimum tillage sowing of soybean, wheat, gram pulses and oilseeds under vertosol, which can be operated by 35-45 hp tractor.

Till Plant Machine

Rotovator

It consists of a steel frame, a rotary shaft on which blades are mounted, power transmission system, and gearbox. The blades are of L-type, made from medium carbon steel or alloy steel, hardened and tempered to suitable hardness. Rotary motion of tractor PTO is transmitted to rotate the blades mounted on rotary shaft through gearbox and transmission system. Good seedbed and pulverization of the soil are achieved in a single pass of the rotovator, and sowing can be performed by using a 9-row seed cum fertilizer drill. Size of equipment ranges from 1,000-2,000 mm and field capacity from 0.25 to 0.4 ha/h at an average speed of 2.5 km/h. The fuel (HSD) consumption in rotovator seed fertilizer drill, roto-till drill and till plant machines are 20.0, 13.80 and 5.60 l/ha, respectively comparing to 34.62 l/ha by conventional seeding method resulting in fuel saving of 14.62, 20.8 and 29.0 l/ha (Table 3).

Rotovator

Table 3: Energy and Carbon Footprint of Resource Conservation Tillage and Planting Machineries

Particulars	Rotovator + seed cum fertilizer drill	Roto till drill	Till plant machine	Conventional seeding (3-ploughing + seed drill)
Time required (h/ha)	4.5 (58.4)	3.4 (68.1)	1.60 (85.2)	10.82
Fuel used (l/ha)	20.0 (42.2)	13.80 (60.1)	5.60 (81.52)	34.62
Operational energy (MJ/ha)	1,135.65 (42.55)	783.60 (60.3)	322.00 (83.74)	1,976.62
Cost of operation (Rs/ha)	1,093.0 (42.56)	1,000 (47.1)	566.44 (83.34)	1,903.04
CO_2 emission, kg/ha	52.0 (42.22)	35.88 (60.13)	14.56 (83.82)	90.0

Laser Guided Land Leveler

Precision land leveling facilitates surface drainage and uniform distribution of irrigation water throughout the field. Thus, the good quality of work could be achieved by using the laser-guided land leveler with minimum emission of GHGs (Sidhu, et. al. 2001). The precision land leveling has increased yield of paddy (11.24%) and pigeon pea (16.4%) significantly comparing to conventional leveled and graded field. However, increase in yield of wheat and soybean crops is 7.3% and 2.1% which is not significant comparing to conventional leveling. In laser land leveling due to improved water application and distribution efficiency there is a drastic reduction in water use in wheat from 5,270 m^3 ha-1 in traditional land leveling to 3,525 m^3 ha-1 in laser land leveling and an increase in water productivity from 0.82 g wheat grain per liter in traditional leveling to 1.31 g per liter water in precision leveling (Rajput and Patel, 2003).

Laser Guided Landed Leveler

The fossil fuel energy requirement for laser guided and conventional (drag scraper) land levelers is 1,858 MJ/ha and 1,756 MJ/ha respectively. The operational energy for the tractor with guided laser and conventional leveler is 2,105.77 MJ/ha and 1,996.24 MJ/ha respectively. After precision land leveling, fuel consumption reduces by 24% in cultivation and harrowing operation (Jat and Chandra, 2004). Thus, the total fossil fuel and energy consumptions for leveling and tillage operations is 44.16 l/ha and 2,486.65 MJ/ha respectively for the field leveled by guided laser land leveler. It results in CO_2 emission of 114.82 kg/ha in the atmosphere. Similarly, for the field leveled by the conventional drag scraper, fuel and energy consumption is 45.67 l/ha and 2,561.68 MJ/ha for both the operations (i.e. leveling and tillage). Use of laser land leveler saves 1.5l diesel and 3.93 kg CO_2 emission/ha to conventional drag scraper.

Urea Application System Integrated with Spectral Reflectance Based Sensor (Green Seeker)

Variable Rate Urea Applicator

For mid-season, top dressing urea on rice and wheat crops, an on-the-go variable rate urea application system, integrated with spectral reflectance-based sensor (Green seeker) has been developed at CIAE, Bhopal (Anonymous, 2015-16). The applicator can be mounted on back of operator and covers swath width of 4m. The applicator consists of two green seeker sensors which sense the crop health. A "Variable Rate Controller" app has been developed to control the applicator. The applicator is capable of metering 8.5-30 kg/ha N (18.5-65 kg of urea/ha) at 2 km/h forward speed with 25 mm wide fluted roller. Potential carbon emission savings due to precise use of nitrogen are 3.49 kg CE/1,000 kg grain for paddy and 3kg CE/1000 kg grain for wheat.

Renewable Energy-Operated Machine for Lighter Farming Operations

Major conventional power sources for agricultural machinery are fossil fuel-operated engines, electric motor or manual power. All these methods entail considerably expensive running costs, involving drudgery to operator and cause environmental pollution. The commercial, agricultural machinery requires high capital investment and power consumption, which makes it harder for small rural farmers to get access to and purchase. Therefore, manpower remains as a major source of power in most agricultural operations in developing countries. This represents a dire need for further research on the use of the renewable energy in agricultural farming operations. The choice of solar photovoltaic (PV) over conventional means of energy is gaining more and more popularity because of rapidly increasing fossil fuels prices and strict government regulations in order to control environmental pollution. Renewable energy sources such as solar PV possesses considerable potential of being utilized to power small agricultural machinery for carrying out lighter operations, such as manually operated sprayer, seeders, wetland weeders, small tools for intercultural operations in dry land. These operations can be efficiently carried out with the aid of solar PV technologies. Solar PV-operated machinery can be used where electricity is neither available nor reliable. Machinery will be lighter in weight and can be easily transported from one location to another. Photovoltaic panel can also be used for charging the battery to be used for powering the working elements. The PV based machines would provide clean and green energy for agriculture without polluting the atmosphere.

III. Irrigation Equipment and Practices

Water Management

India has had successive droughts in the past two years. Strategies are needed in both short and long terms to mitigate the adverse effects of droughts. It is clear that better and more efficient management of water resources is necessary for India to achieve the motto of 'more crops per drop'. We need a different approach for rain-fed areas. India uses 2–3 times more of water to produce one ton of grain than countries like China, Brazil, and the United States. This implies that if India uses water as efficiently as those countries, irrigation coverage could be doubled or 50% of the water could be saved to irrigate the current amount of land (NITI Aayog 2015). The main strategy should be to increase water productivity, which irrigates more crops per drop.

Energy efficient irrigation systems are moisture stress-based sprinkler and drip irrigation, which are used to apply the proper amount of water as per the soil moisture – plant stress. Water use efficiency of both systems is very high and saves 30-70% water comparing to conventional flood irrigation method. Adoption of these two systems would reduce 30-70% GHG emissions during the irrigation of crops in India. The irrigation efficiency of sprinkler and drip irrigation system are shown in Table 4.

Table 4: Irrigation Efficiencies Under Different Methods of Irrigation (Percent)

Method	Irrigation efficiency, %		
	Surface	Sprinkler	Drip
Conveyance efficiency	40-50 (Canal) & 60-70 (Well)	100	100
Application Efficiency	40-60	70-80	90
Surface water moisture evaporation	30-40	30-40	20-25
Overall efficiency	30-35	50-60	80-90

Source: Sivanappan (1998).

Irrigation Pumps

Diesel engines are the main reasons causing GHG emissions but electric motor indirectly contributes to the electricity produced by the coal-based plants. Zero-tillage farming on 0.25 million ha in IGP saved 75 million m^3 of water in 2002-2003 (Malik et al 2004). Hence, 3.43 million ha of wheat under no-tillage would save an estimated 1029 million m^3 of water every year. It would also reduce operating hours of the pumps, thus reduce emission of CO^2 from engines used for operating the pumps. Hence, we need to develop methods to determine the reduction in CO^2 emissions by the pumps and make improvements in the engines used for running these pumps. As many farmers are going for zero tillage for both kharif and rabi crops, there will be substantial reduction in CO^2 emission, which would help India to claim more compensation and increased carbon credits. CO^2 emission from fuel used for irrigation is given in Table 5.

Table 5: Emission from Irrigation Pump Sets in India

Parameter	Diesel pump set	Electric pump
Number, million, 2015-16	8.121	26.578
Fuel consumption l/h (Avg. size 5 hp)	1.0	3.7 (kWh)
Command area/pump, ha	4 ha	5 ha
Average area irrigated, million-ha/year	30.0	59.0
Average operating hour/year/pump	400	500
Average diesel/electricity consumption million-l/year and kWh/year	3,248.2	49,169.3
CO^2 emitted, million tons/year	8.45	65.54

1 kWh power emits 1.333 kg of CO^2 in generation. Source: Agricultural Research Data Book (2011)

IV. Residue Management

Burning agricultural residue is now recognized as an important reason causing pollutant emissions. It leads to emission of trace gases such as CH_4, CO, N_2O, NO_x, SO_2, and hydrocarbons. Since CO_2 is C natural, is it not account for agricultural residue. The burning of crop residue in India has resulted 6,606,000 tones equivalent CO_2 emission into atmosphere (INCCA-2010). Also, it has led to adverse impacts on people's health in the region. Burning one ton of straw releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash, and 2 kg SO_2. These gases and aerosols consisting of carbonaceous matter play important roles in the atmospheric chemistry and can affect regional environment, which also has linkages with global climate change. Using different types of farm machinery wheat/paddy straw can be incorporated or mulched in the field (Table 6). Direct rotovation under chopped straw condition followed by drilling was 23.6% cost-effective comparing to the mould board plough + rotovator + drill operations. The mould board plough and rotovator operations gave almost straw free surface (Straw incorporation = 89.7% at 50-125 mm depths).

Table 6: Cost of Residue Incorporation/Mulching for Subsequent Sowings and CO_2 Emission under Different Machinery Used for Wheat Straw

Implement used	Operational cost, Rs/ha	Total operational Cost, Rs/ha	% straw incorporated	CO_2 emission, Kg/ha
Stubble shaver (1) MB plough (1) Rotavator (1) Seed-fert. drill (1)	515 1,750 1,500 1,100	4,865	- 76.70 13.00 -	145.12
Stubble shaver (1) Rotavator (1) Seed-fert. drill (1)	515 1,600 1,190	3,305	- 60.5 -	98.28
Rotavator (1) Seed-fert. drill (1)	2,250 1,427	3,677	10.0 -	99.84
Happy seeder	1,500	1,500	100	31.2

Figures in parentheses show number of passes


MB plough


Stable saver


Rotovator


Happy seeder

V. Using Biodiesel to Reduce Emission

The use of biodiesel can potentially reduce the GHG emissions from engines. The draft National Biodiesel Mission of 2003 suggested aiming to substitute 20% of transport diesel by 2011-2012, requiring 1328 million ton of biodiesel. Thereby India would save at least Rs. 1.17 billion of foreign exchange and improve the trade balance by at least 15%. Biodiesel has very good potential to reduce CO_2 emissions. As the Government of India is committed to promote renewable energies and shift to a low carbon growth trajectory, promotion of biodiesel is one way to reach this goal. Furthermore, biodiesel activities can be an opportunity to receive additional funds through the Clean Development Mechanism established by the Kyoto Protocol. Biodiesel is the only alternative fuel that has a complete evaluation of emission results and potential health effects submitted to the Clean Air Act Section 211(b). Emission results for pure petro-diesel and mixed biodiesel (B20-20%) are given below in Figure 1. The use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide comparing to conventional fuels. From the figure, it is clearly shown that biodiesel gives a distinct emission (particulate matters and total hydrocarbon) benefit almost for all regulated and non-regulated pollutants comparing to conventional diesel fuel except for the emission of nitrous oxide (Nox) which seems to be higher. Nox increases with more concentrated biodiesel in the mixture of biodiesel and petro-diesel. This increase in Nox may be due to the high temperature generated in the fairly complete combustion process on account of adequate presence of oxygen in the fuel. This increase in Nox emissions may be neutralized by the efficient use of Nox control technologies, which fits better with almost nil sulphur biodiesel than conventional fuels which contains sulphur.

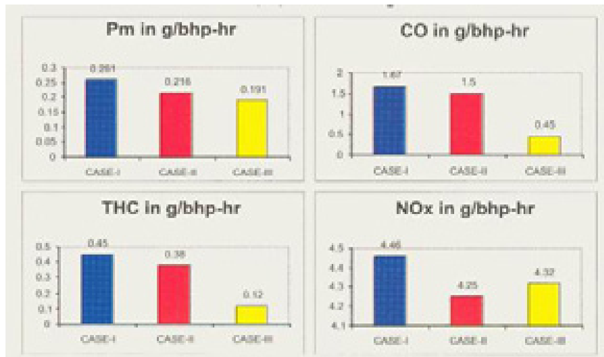

Figure 1: CASE-I: Petrodiesel with 0.05% Sulphur. CASE-II: 20% Biodiesel with 3-degree Injection Timing Adjustment. CASE-III: CASE-II + Catalytic Converter (Source: Twin Rivers Technologies, USA)

India, not well endowed with liquid fuels, is trying to harness crop residues and energy stock through biological and thermo-chemical pathways. Producer gas-run irrigation and agro-processing units are coming up. Dual-fuel engines run on biogas and producer gas give about 60% diesel replacements. Photovoltaic irrigation and illumination systems are in the market and new uses of renewable energy sources are being established and steadily refined.

Conclusion

Crop production in next decade will have to produce more food from limited land under fluctuating weather conditions and natural disasters such as draughts and floods by making more efficient use of technology and natural resources with minimal impact on the environment.

Climate-smart farm machinery as well as soil and water management systems can help improve soil and plant health parameters and reduce production cost and its impact on environment, which are essential to sustained production and productivity.

Improved machinery and practices have been found very effective in reducing GHG emissions for precise land leveling, no tillage seeding planting, irrigation, and crop residue management. Also, they are very effective and efficient in enhancing organic carbon in soil by using mulch or spreading and incorporating crop residues into the field.

Overcoming traditional mind-sets about the conventional tillage and crop residues burning or removal from the field by promoting farmers experimentations with new developed technologies and machineries in a participatory way will help accelerate the adoption of technology for climate-resilient agriculture.

Laos
Lao Farmer's Experience on Resilience Agriculture by Introducing Rice Direct Seeding and Mechanization

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I. Overview of Agriculture Sector

Lao People's Democratic (Republic Lao PDR) is a landlocked country that has 236,800 km^2. The country is divided into 18 provinces, consists of 149 districts, with around 11,390 villages. The population of Lao PDR is estimated to be 6.5 million (2012). The country is home to 49 difference ethnic groups with a high diversity of languages, cultures and traditions.

Lao PDR's agro-climatic profile is divisible into three main zones: the northern mountainous region; the hilly and mountainous region of the center and south, and the Plain of Mekong River. The country has two seasons: dry and wet seasons.

Laos has an agriculture-based economy. Agriculture plays a major role in Lao PDR's economy. According to recent research, agriculture accounted for about 24.1% of gross domestic product (GDP) of the country in 2015. As of the same year, the growth rate of agriculture is about 3.4%; and paddy production reached 4.2 million tons. Of about 80% of the total population in Lao PDR work in agriculture sector. Therefore, climate change has significant effect on the country's agricultural practices.

Lao PDR is vulnerable to natural disasters, including extreme weather events which have been increasing in frequency and intensity. Almost all the country's farming systems are subject to the impact of flooding, drought, and late onset of the rainy seasons. With a high dependency on traditional agricultural systems and a predominance of smallholder farms, the impacts of the mentioned natural disasters can be devastating. The country is highly susceptible to climate change and natural hazards, particularly to flood and drought conditions which seriously affect the country's agricultural production. Although agriculture is gradually declining in terms of its contribution to GDP in recent years, it continues to play a major role in Lao PDR's economy.

II. Current Situation of Rice Production in Lao PDR

The two main rice farming systems make up about two-third of Lao PDR's total cultivated area, namely the (i) lowland irrigated or rain-fed agriculture system prevailing in the Mekong flood plains and the (ii) shifting cultivation farming system dominating the upland areas. Horticulture and coffee are cultivated in smaller systems on the Bolaven plateau. Majority of agriculture production is characterized by near-subsistence farming system. However, over the last two decades, agricultural production has become increasingly mechanized. Improved seed varieties, organic farming, and general reduction in the use of chemical fertilizers, pesticides, and herbicides have been promoted during the past few years as part of the Government's effort to introduce green and clean agricultural development.

In 2016, Lao PDR produced up to 4.2 million tons of rice with the cultivated area of about 794,000 hectares; it increased by 2% in comparison with the production in 2015. 4,200,000 tons of polished rice was exported to China in 2016. Overall speaking, rice production in Lao PDR is constrained by the following issues:

- Excessive use of natural resources leads to negative impact on environment and social-economic development;
- Land and forest degradation;
- Flooding in rainy season and water shortage for dry season;
- Weak of agriculture infrastructure (irrigation system, lack of training center service, limitation of marketing house to include storage, packaging house, cool storage, etc.).

III. General Condition of Agriculture and Food Security

In five-year plan 2016-2020, Lao PDR plans to increase rice production to around 4.7 to 5 million tons, of which 2.1 million ton of the production will be used for domestic consumption and 1 to 1.5 million tons are planned for trading. The Ministry of Agriculture and Forestry has formulated its strategy to ensure food security of paddy rice for 2.5 million tons domestic consumption, of which 2.1 million tons will be intended for direct consumption and 400,000 tons will be intended for reserve.

- The population of Lao PDR by year 2020 is projected to increase to 8.7 million;
- Demand for paddy rice is projected to be 2.5 million tons for domestic consumption, 2.1 million tons for direct consumption, and 400,000 tons for reserve;
- Therefore, Lao farmers have to produce rice in both two seasons and to improve rice productivity for 4.5 to 5.5 tons per hectare.

Overall strategy for rice production

- Achieve 4.2 million tons of paddy by 2015;
- Achieve 4.7 to 5 million tons of paddy by 2020;
- Achieve 5.5 million tons of paddy by 2025;
- Average paddy rice for export expected at 500,000 to 600,000 tons per annual.

IV. Technical Practice for Rice Production Adapting to Climate Change

Agricultural land occupies approximately 2 million hectares in Lao PDR; rice cultivated area takes up about 772,500 hectares; and irrigated land area takes up about 125,000 hectares. Rice cultivation is concentrated in 10 Provinces, namely Champasak, Saravan, Savannakhet, Khamoun, Bolikhamxay, Vientiane Province, etc. Paddy and corn are the two major crops produced in Lao PDR.

Climate change poses a legitimate threat to the country's agriculture, especially for rice production. Lao farmers accumulated lessons from year to year and learn from their own experiences to choose the most appropriate technique to grow rice. The most prominent techniques in Lao PDR are transplanting, broadcasting, direct seeding, and SRI. Recently, direct seeding is a prevalent method that more and more Lao farmers have used in replacement of their traditional rice farming. Such a method is particularly adaptable to the following conditions:

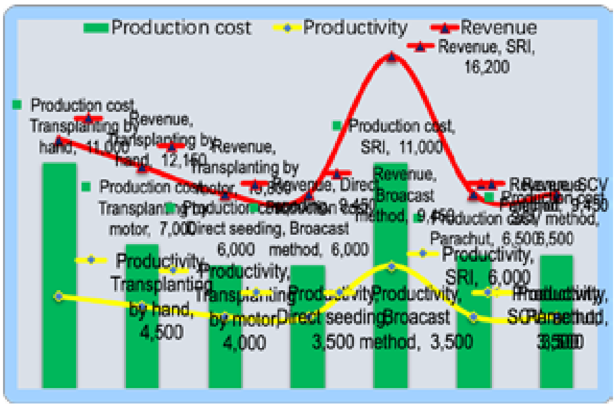
- Water shortage, raining out of season;
- No irrigation scheme available in the rain-fed area in some areas, irrigated rice field is accounting at around 15% of the total cultivated areas;
- Rice direct seeding is one of most common rice cultivated methods in Lao PDR, which has an advantage on resilience agriculture, climate change, less rain, and is suitable for the flooded area;
- By applying direct seeding influence the rice plant growing continuously, resistance to a drought and flooding condition;
- Direct seeding is suitable, and can be applied for wet season and in non-irrigated areas.

Practice Experiences on Rice Direct Seeding

Farmers start to plough the land after 2–4 rains with a depth of about 15-20 cm by two-wheel tractors or 4-wheel tractors, and then leave the land dry under sunshine for 10 to 15 days during the first plough; the second plough takes place before applying seed. The overall process of direct seeding is explained below:

- Rice see germination must be over 90%;
- Seed rate 60-80 kg/ ha;
- Seed deep at 4-5 cm;
- Seeding in a direction of sunset and sunrise;

- After 20-25 days check field to find a death plant and replace it with new seedlings;
- First application after 15 -18 days using NKP 16-20-00 with 100 kg/ha;
- Second application at tillering stage, NKP 46-00-00 with 60 kg/ha;
- Third application at flowering stage fertilizer NKP 15-15-15 with 60 kg/ha;
- After rice flower at about 50% during flowering stage, from this point forward around 30 days farmers can decide to harvest.



The above figure shows the cost-benefit ratios of different rice growing techniques.

Demonstration of how to use mini-combine harvester to farmers is shown above.

V. Lessons Learnt

- Direct rice seeding is one of the most important rice-growing methods in the adaptation to climate change. It is easy for farmers to apply and simple in work process;
- Less cost for poor farmers as a whole rice growing process, suitable for a family in lack of manpower;
- Save time for other family activities;
- It can prevent snail attack, especially rice plant is already grown under heavy rain conditions.

VI. Challenges and Constraints

- Machinery and equipment for rice direct seeding are relatively expensive, so that individual farmer cannot purchase them;
- There are still problems with weed control: some farmers use herbicide to control it during first stage;
- The direct rice seeding method can be applied in rainy season, but rarely for irrigated system in dry season.

Malaysia
Current State Research & Development on Rice Mechanization in Achieving Climate-smart Agriculture

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Abstract

Malaysian Agricultural Research and Development Institute (MARDI) is a government agency under the Ministry of Agriculture and Agro-Based Industry which actively promotes Climate-smart Agriculture (CSA). MARDI has been exploring potential research, technology and practices related to CSA. This report will highlight some of the R&D on mechanization and automation related to CSA. Rice precision farming is one of the examples of the on-going researches and development projects which contribute to the development of CSA in Malaysia. MARDI has developed technology in water management, land levelling and crop maintenance. Technology of tail water reuse system was developed for efficient water management system to collect, store and transport irrigation or rain water runoff on the farm for reuse. The technology will conserve irrigation water supplies through capture and re-use of the water that runs off the field and to improve off-site water quality. Technology for effective land leveling system and variable rate seeding were developed for precision seed broadcasting in rice farming. MARDI also successfully developed variable rate technology (VRT) for fertilizer application. The technology is expected to reduce the amount of nitrogen used by 15%-25% per ha. This reduces emission of greenhouse gases (nitrous oxide) in rice fields. To sustain the rice production and conserve water due to decreasing water resources, climatic changes and competition from urban and industrial users, aerobic rice production was introduced by MARDI which requires much less water input. The mechanization technology has been developed for aerobic rice production which includes machinery for land preparations, row seeder and irrigation system. MARDI has also implemented better rice straw management practice by introducing straw cutter on combine harvester with the aim to reduce the release of methane during straw decomposition in flooded rice fields. All developed technologies will help 1) achieve the CSA to a sustainable increase in agricultural productivity and incomes; 2) adapt and building resilience to climate change and; 3) reduce/remove the greenhouse gas emission.

Introduction

Malaysia is a tropical country with a population of about 30.4 million. It has an average temperature of 27-32 °C, uniform all year round with humidity of about 80- 85%. Annual minimum and maximum rainfall are 1,651 mm and 4,216 mm respectively. There are two periods of heavy rains which occur in April and May and from October to December. Agriculture in Malaysia contributes about 3.6% to GNP and at least a third of the country's population depends on agriculture sector for their livelihood. Thus, significant climate change definitely affects the agriculture sector in terms of production as well as brings socio economics problem to the people who are involved in the sector and the nation as a whole. In Malaysia, the Intergovernmental Panel on Climate Change (IPCC) projections estimate that the region could experience temperature changes from 0.7 to 2.6 degree Celsius and precipitation changes ranging from -30% to 30%. The global aggregated effect of climate change on agricultural production is likely to be small or moderate. Environmental stresses such as drought, high temperature and air pollution are major limiting factors to crop productivity in the tropics. Since 1950, there were 12 major El Nino events recorded by the Malaysia Meteorology Department; the worst occurred in the year 1997/98. An immediate effect caused by the El Nino was a delay in monsoon rain, prolonged drought, forest fire and pollution. It was reported that the losses in the agriculture sector in Peninsular Malaysia caused by the El-Nino were at least RM3.4 billion. Climate-smart agriculture is very important for sustainable agriculture production to ensure food security to the nation. This paper will discuss and highlight the current research and development on rice mechanization in achieving Climate-smart agriculture.

I. Sustainably Increasing Agricultural Productivity and Incomes

Land Leveling System and Variable Rate Seeding

In 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 leads to irrigation problems which affect crop establishment and ultimately yield. One way to manage this and to reduce rice seeding operation time is by using automated land leveling system. The automated land leveling system uses a Trimble FMX Integrated Display with Field Level II Survey and Design Module with built-in farm work software, a Trimble GPS Receiver and an RTK (Real Time Kinematics) base station. In the presented work, the Trimble GPS receiver was mounted on a rotary tiller while the Trimble FMX Integrated display was situated on a quad-steel-tracked tractor. The determination of land leveling index was measured during the final rotor stage where the GPS antenna was mounted on the smoother flap. This minimizes time and labor cost since the leveling index measurement could be done simultaneously while the land is being prepared. The automated land leveling system can produce an accuracy of cm vertically and cm horizontally. The GPS-based automated land levelling system's performance was comparable to a laser-based land leveling system, but with less time consumed and faster results. The leveling index 5 (LI5) was used as a reference to generate a variable rate seeding treatment map for rice. The map was split into three categories (high, low, and even) to facilitate practical use of the variable rate map. The map was uploaded to a variable rate applicator. Seed broadcasting was done using a variable rate and spinning disc spreader with precise seed-rate based off of the treatment map generated. The variable rate seeding was able to ensure a more consistent crop establishment across the paddy field.

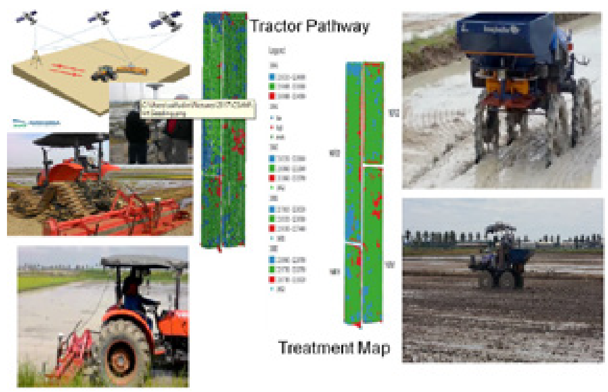


Figure 1: Land leveling System and Variable Rate Seeding

Variable Rate Application of Fertilizer in Rice Precision Farming

MARDI has successfully developed the variable rate technology (VRT) for fertilizer application 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 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%.

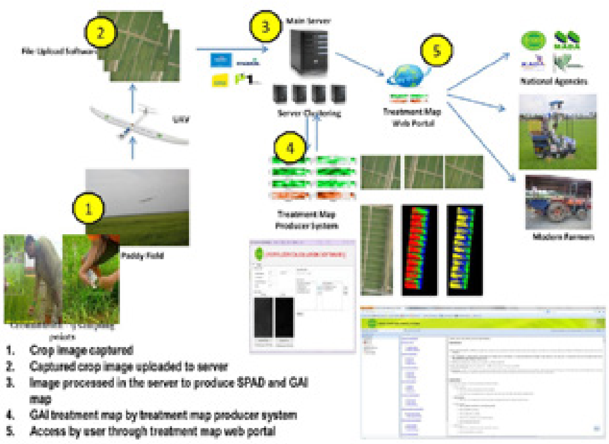


Figure 2: Variable Rate Technology for Fertilizer Application

II. Adapting and Building Resilience to Climate Change

Mechanization Technologies Applied to Aerobic Rice Production

Wetland rice cultivation adopts a high level of mechanization, which requires continuous flooding of paddy fields and needs a very high level of water input. To secure and sustain the rice production and conserve water, aerobic rice production requiring much less water input was introduced. However, the mechanization technology for aerobic rice production is very different comparing to wetland rice. All farming activities for aerobic rice production are performed on aerobic soil conditions. Land preparations for aerobic rice production require disc plough, disc harrow and rotary tillers. At times, rear bucket may be needed depending on land topography and choice of irrigation used. MARDI has developed a new row seeder (called Aerob Row Seeder) to establish row seedling that could ease weed control and field maintenance works that are suitable for small-scale cultivation. Apart from that, MARDI has also imported an Accord Seeder which was modified to suit aerobic rice cultural practices for commercial scale cultivation. Two irrigation methods for aerobic rice cultivation are recommended to achieve high water productivity and also meet water requirement. These two methods are overhead sprinklers and alternate drying and wetting (AWD) surface irrigation. The most suitable choice depends on field topography, water source, pest and disease control, and cultural practices. Research results showed that the overhead irrigation method uses less water comparing to alternate wetting and drying, but the crops under overhead irrigation are more susceptible to disease infestation due to the moist crop environment. However, these two methods produced comparable yield results.

Figure 3: Mechanization Package for Aerobic Rice Production

Technology of Tail Water Reuse System for Rice Production

A tail water reuse system is a planned system to collect, store, and transport irrigation or rain water runoff on the farm for reuse. The purposes are to conserve irrigation water supplies through capture and re-use of the water that runs off the field and to improve off-site water quality. This system normally includes a combination of practices and facilities that collect, convey, store and recycle irrigation runoff water for re-use. The facilities that are required in place and utilized for the system are collection, storage and re-entry. Studies were conducted in MARDI Seberang Perai and showed that the total amount of water saved from rice cultivation ranged from 20 to 30% depending on season and rainfall distribution. The energy cost per ha per season ranged from MYR 60 to 80 based on diesel price of MYR 2.00 a liter and average irrigation events range from 18 to 23 times per season. For chemical residue studies, the residues detected were compared to the LC50 values of fishes. It can be concluded that concentration of alpha-cypermethrin and azoxystrobin found in the rice field water exceeded the LC50 values of fishes. The results also showed that residues detected were localized at the application area rather than being distributed to non-target areas. Also, the qualities of tail water discharge to drain were recorded. The measured parameters included TDS, pH, BOD, COD, copper, conductivity, dissolved oxygen, ammoniacal nitrogen, total nitrogen and total phosphate which were within limit values permitted in Interim National Water Quality Standards for Malaysia (INWQS) Class lll water. Furthermore, the results also showed no adverse effects on paddy crop performance by utilizing tail water for irrigation.

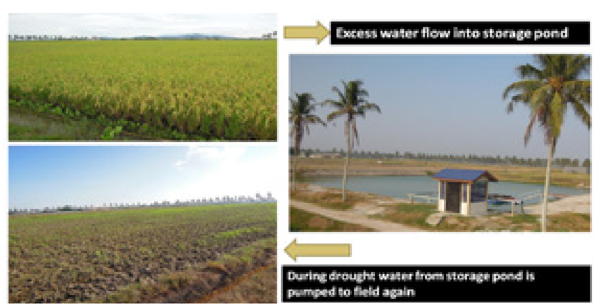


Figure 4: Tail Water Reuse System for Rice Production

III. Reducing and/or Removing Greenhouse Gases Emissions

Precision Farming to Reduce GHG Emissions

In Malaysia, agriculture contributes to 3% of the total greenhouse gas emissions. The emissions come from flooded rice farming (32%), agriculture soils (through use of fertilizer, 30%), manure from livestock (22%) and enteric fermentation (digestion process in ruminants, 16%). Greenhouse gases released from rice farming are traced to emissions of nitrous oxide (from fertilizer) and methane (from straw decomposition in flooded rice fields). Therefore, it is very important to apply good agriculture practices as well as better management to manage rice straw, fertilizer and chemical usage. Farmers need to practice precision farming in order to minimize use of fertilizer, and switch to bio-fertilizer. On-going study has been conducted to monitor how effectively the variable rate fertilizer application can reduce the emission of GHG gases. A few closed chambers have been deployed on the research plot and data were collected and analysed to study how much the emission of GHG gases can be reduced after applying the technology.

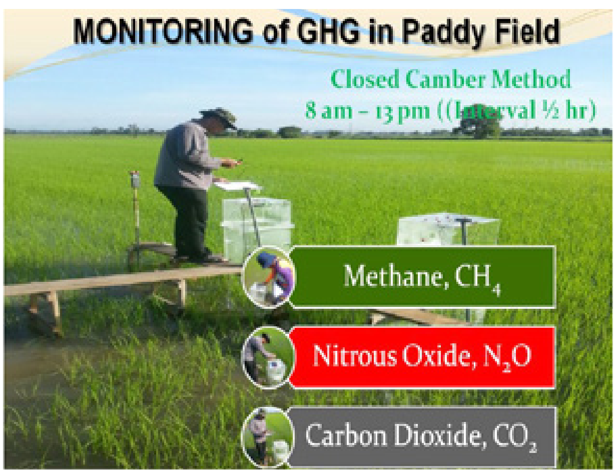


Figure 5: GHG Monitoring in Paddy Field

Rice Straw Cutter on Combine Harvester

Cutting of the paddy straw after harvesting is being practiced by farmers for land preparation for the next season. Rice straw is a good source of nutrients, yield increases due to straw incorporation over straw burning or removal is about 0.4 t/ha per season, and it increases with time as soil fertility builds up. Combustion of one ton of rice straw will produce 3 kg of particulate material, 60 kg of carbon monoxide, 1460 kg of carbon dioxide, 199 kg of dust, and 2 kg of sulfur dioxide. Thus, the amount of rice straw burnt needs to be reduced. Therefore, MARDI has developed a straw cutter attachment for the combine harvester to be used on a new or existing combine harvester. The factors being taken into account were the design of cutter, location of the cutter attachment, power system use and source of power to operate the cutter. The result of using this implement shows that paddy straw cutting length can be decreased from 14 inches to 3 inches while harvesting.

Figure 6: Straw Cuter Mounted on Combine Harvester

Conclusion

MARDI needs to actively pursue the CSA agenda by considering a few important aspects:

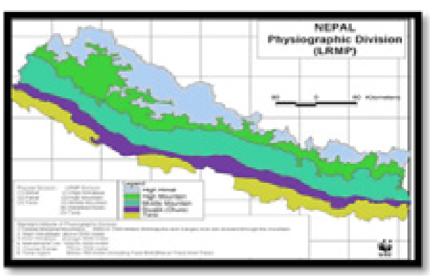
- Strengthening R&D capabilities towards CSA through field mechanization and rice precision farming;
- International linkages on CSA with CSAM, IEEE, CGIAR, ISPA;
- CSA agenda to be pursued by the government.

Policy intervention by the Malaysian government is indeed necessary to induce positive changes within the agricultural system with the aim to reduce the negative externalities affecting the environment (i.e., pollution and waste).

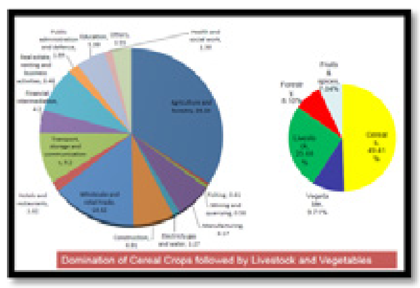
Nepal
Climate-smart Agriculture and Mechanization in Nepal

Mr. Madhusudan Singh Basnyat
Officiating Program Director
Directorate of Agricultural Engineering
Department of Agriculture
Ministry of Agriculture Development of Nepal

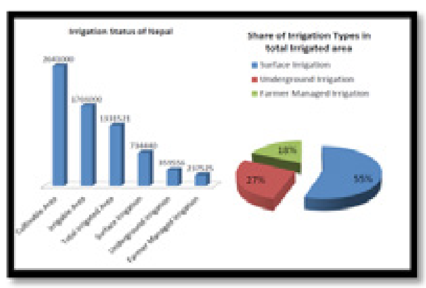
Background



Nepal is a land-locked country surrounded by India on three sides and China on the North of total land area of 147,181 square kilometers. The total population is 28 million, with about 22% of the population below poverty line. Predominantly as an agrarian country, agricultural production contributes one-third (34.33%) of the country's GDP. Average land holding is 0.68 ha, with paddy, maize, wheat, horticulture as its major crops.



Source: Ministry of Agricultural Development (MoAD), 2014/15



Source: Department of Irrigation, 2014/15

Nepal's climatic is influenced by the monsoon circulation. The country receives mean annual rainfall of 1550 mm. 21% of the total land area is cultivable, of which 57% is rain-fed.

I. Climate Change Affecting Agriculture Production

Climate change is one of the global challenges in the 21st century. The most vulnerable countries to the impacts of climate change are the Least Developed Countries, including Nepal. It is the 12th most climate-vulnerable country in the world. Due to climate change, Nepal has been facing tremendous problems in different sectors including agriculture. The effect of climate change on agriculture has been observed in different parts of the country. The vulnerability analysis conducted in different parts of the rural areas indicates the local experience of rising temperature (warmer summers and shorter winters). Meanwhile, the monsoon season is changing (starting late) and intensity of precipitation is unpredictable along with prolonged drought affecting agriculture productivity severely. Moreover, hailstorms, floods and landslides which may have disastrous effects on crops, settlements, livestock and human lives are becoming more and more prevalent. A major challenge for agriculture production is vagaries of weather condition, rainfall, temperature, humidity, wind and hailstorm. The consequence of adverse weather causes flood, landslides, blockage of rivers, and drought, which also affects production. Pest and diseases, fire, quality of inputs, market price of produce are also other factors that affect production. As per table 1, the climate induced natural disasters which caused loss of agricultural land and crop during 1971-2007.

Table 1: Climate Induces Natural Disaster Causing Losses

Events	Loss of agricultural land & crop(ha)
Drought	329332
Flood	196977
Hail storm	117518
Rains	54895
Strong wind	23239
Cold waves	21974
Others (forest epidemic, snow storm, firestorm, thunderstorm, avalanche, plague etc)	83336
Total	**847, 648**

Source: Global assessment of risk ,Nepal Country Report, ISDR, Global assessment report on poverty and disaster risk,2009

Climate change increases drought in arable land and desiccation of natural water resources. Crop production also reduces dramatically due to water scarcity causing the shifting of cereal system to vegetable production in Nepal (National Sample Census Agriculture 2012). Vegetables grown in small area and other land remain fallow after rice harvesting in most of part in Nepal. Rice is top crop in terms of area and production followed by maize and wheat in Nepal. Farmers who grow wheat after rice often face terminal (drought/heat) stress because of late sowing due to delay in land preparation. Wheat farming is difficult due to flooding. In short, unfavorable climatic condition limits agricultural production in Nepal significantly.

II. Status of Mechanization

Most of the agricultural operations in the country are labor-intensive. As the productivity of both crop and livestock is low, the return to labor is less lucrative. The application of mechanization is limited for selected operations only. Agricultural mechanization in Nepal is drawing attention in recent years due to gradual commercialization of agriculture and shortage of labor. Table 2 shows the household using various Machinery/Equipment as per the National Sample Census of Agriculture, CBS, 2012.

Table 2: Households Using Various Machinery/Equipment for the Agricultural Operations

Machinery/Equipments used	No of Households	% Households
Iron ploughs	1,073,441	28.02
Power tillers	75,671	2.49
Tractor	844,700	27.86
Thresher	803,154	20.96.
Pumping sets	548,203	14.31
Sprayers	574,014	14.98
Shallow tube wells	367,744	9.56
Deep tube wells	159,725	4.17
Rower pump (Dhiki)	79,145	2.06
Animal drawn cart	334.978	8.74
Other Equipments	290,084	7.57

Source: National Sample Census of Agriculture, CBS, 2012

The Government of Nepal (GoN) has approved Agricultural Mechanization Promotion Policy on 13 August 2014 and showed the direction for its development in the country. The drafting of Agricultural Mechanization Promotion Operation Strategy is a crucial step to develop a guide map to implement policy effectively. Agricultural Development Strategy (ADS), approved by the Government of Nepal (GoN) on 26 July 2015 has a special section mentioning Private Sector involvement in boosting agricultural mechanization. Promotion of agricultural production was emphasized by the new Constitution of Nepal in 2015. Nepal Agricultural Machinery Entrepreneurs Association (NAMEA) has been officially registered to work for the welfare of agricultural machinery importer, distributor, dealers, and manufactures in the country.

Agricultural Engineering Division under Nepal Agricultural Research Council (NARC) focuses on research and development of agricultural machineries while the Directorate of Agricultural Engineering under Department of Agriculture is responsible for the dissemination of technologies to farmers and entrepreneurs, and facilitating the establishment of workshops and custom hiring centers in the country. The use of machinery is high in the terai region and low in hills and mountains due to the geographical difficulties. Most of the machines are imported from China and India, while some local manufactures have started manufacturing in the country. Table 3 shows the agricultural machinery imported to Nepal in the year 2014/15.

Table 3: Agricultural Machinery Imported in the year 2014/15

Item	Unit	Quantity	Values (NRs 000)	Source
Ploughs	Pcs.	41,600	8,884	China, India
Disc harrows	,,	3,952	36,773	India
Cultivators/harrows	,,	1,89,974	6,90,670	–
Seeder/planter/transplanters	,,	6,408	14,872	India, China
Threshers	,,	21,358	4,80,053	India, China, USA, Japan
Tractors	,,	16,693	58,38,984	China, India
Reaper/harvesters	,,	3,557	44,327	–
Fertilizer distributers	,,	25,827	2,281	–
Combine harvesters	,,	78	66,521	–
Cultivation machineries	,,	8,063	2,212	–
Mowers	,,	51	609	China, India, Taiwan
Hay making machines	,,	57	750	India
Fodder balers	,,	27	1,415	India, China, Japan, Korea
Cleaning, sorting and grading	,,	511	4,520	China, India
Animal feed making	,,	1,76,232	3,23,756	Germany, Netherlands
Grain cleaner/grader	,,	24,903	3,78,556	--
Milking machines	,,	207	6,629	China, India
Milling machineries	,,	4,541	5,29,125	Germ, Indonesia, Turkey

Source: Department of Commerce, 2014/15

III. Policies, Strategies for Climate-smart

In State Policy Article 51 Section (h), policies regarding the basic needs of citizens: Point (12) stipulates, "increasing investment in the agricultural sector by making necessary provisions for sustainable productivity, supply, storage and security, while making it easily available with effective distribution of food grains by encouraging food productivity that suits the soil and climate conditions of the country in accordance with the norms of food sovereignty". According to this policy, climate action has been given high priority.

The Government of Nepal approved the Agricultural Mechanization Promotion Policy on 29 August 2014 and the vision of the policy was to benefit national development through applying agriculture mechanization in present agriculture system to transform to modernization and commercialization. Below are some examples of actions guided by the policy:

- Promotion of fuel efficient and environment friendly machines will be encouraged
- Promotion of technology and machines appropriate for sustainable agriculture and resource conservation will be encouraged
- Use and promotion of the machines reducing the tedious and hard work load of women will be emphasised
- Agricultural machines and equipment utilized for production of organic fertilizer, organic and bio-pesticides and Integrated Pest Management (IPM), Integrated Nutrition Management (INM), Good Veterinary Practices (GVP), Good Livestock Practices (GLP), Good Agricultural Practices (GAP) and Good Fishery Practices will be promoted and extended
- Use of renowned materials and communications technology for the promotion of appropriate agricultural machines and equipment will be highlighted

The government also banned import or seasonal custom hiring of non-environmentally-friendly combine harvester. This action was taken to manage the straw usage for animal feed including stop direct burning that pollutes the environment.

IV. Organization Working for Climate-smart

a) Government Organization

Climate change is a multi-disciplinary issue. Different government organization would be responsible for tackling different aspects of the subject. Government organizations working towards Climate -Smart Agriculture and Mechanization can be summarized as below:

- Ministry of Population and Environment (Focal Point)
  - Alternative Energy Promotion Centre (AEPC)
- Ministry of Science and Technology
  - National Information Technology Center (NITC)
  - Nepal Academy of Science and Technology
  - Pilot Program for Climate Resilience (PPCR)
- Ministry of Agricultural Development
  - PPCR: Building Resilience to Climate Related Hazards Project- Agriculture Management Information System (AMIS)
  - Directorate of Agricultural Engineering, Department of Agriculture
  - Agricultural Engineering Division, Nepal Agricultural Research Council
- Ministry of Irrigation
  - Non-Conventional Irrigation Technology Project (NITP), Department of Irrigation

b) Donors and Development Organization

Donor Agencies

- World Bank
- ADB
- FAO
- USAID
- UKAID
- European Union

NGO/INGO/Development organizations

- International Center for Integrated Mountain Development (ICIMOD)
- CIMMYT Cereal System Initiative for South Asia in Nepal (CSISA-NP)
- iDE-Nepal
- Renewable World
- SAMARTH
- IRRI
- Winrock
- Practical Action
- SNV Nepal
- CEAPRED
- LI-BIRD
- Private Sector

Figure 1: Small Scale Drip Irrigation, Solar Lift Irrigation and Thai Jar for MUS (from left to right)

V. Climate-smart Agriculture (CSA) and Mechanization Technology

Climate-smart Agriculture and Mechanization technology practiced and adopted in Nepal can be categorized as below:

a) Water-Smart:

- Drip & sprinkler
- Rain water harvesting
- Low cost water storage (Thai jars, Soil-cement tanks)
- Solar lift irrigation
- Papa & barsha pump lift
- Mulching
- Precision Land Leveling
- Raised bed
- Direct seeding
- Alternate wetting and drying
- Linking tap to irrigation /conservation ponds
- Zero waste of water by behavior change

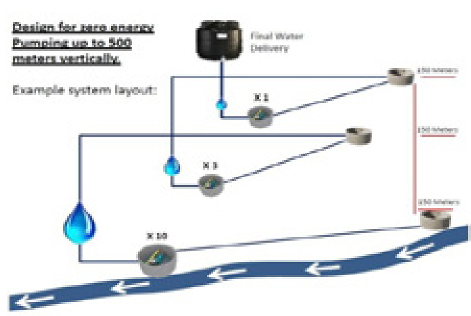


Figure 2: Papa Pump (Hydraulic Ram)

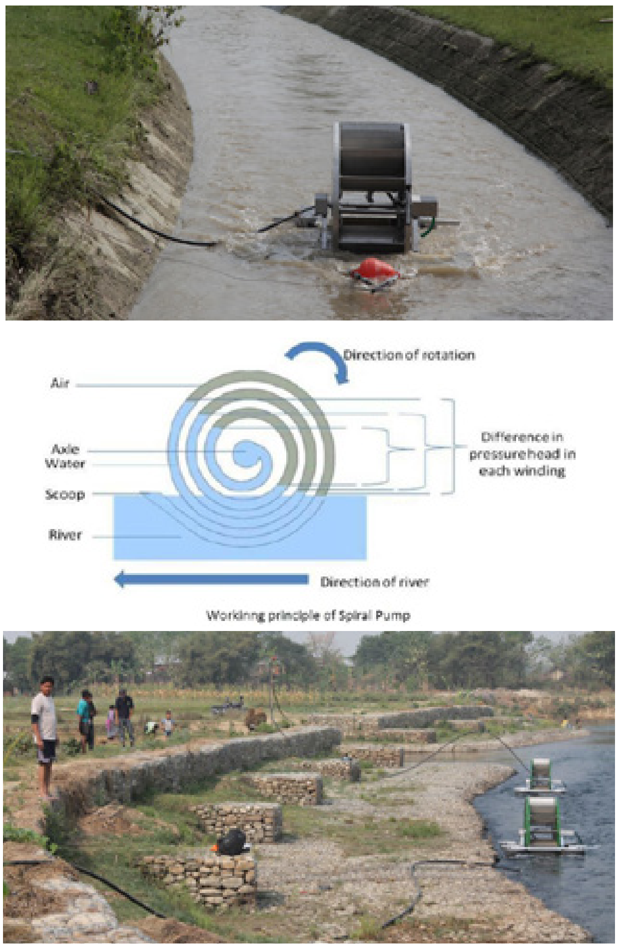


Figure 3: Barsha Pump (Spiral)

b) Weather-Smart:

- Weather forecast
- Insurance
- Weather-index based insurance
- Weather based agro-advisory
- Plastic tunnel for hailstorms and rains
- Crop Diversification
- Agro forestry

Figure 4: Climate and Weather Information

c) Nutrient Smart:

- Green manuring
- Legume integration
- Bio- fertilizer
- Bio-pesticide
- Cattle-shed management

d) Carbon Smart:

- No-tillage
- Minimum tillage
- Residue management
- Planting perennials,
- Agro-forestry
- Fruit orchard

e) Energy Smart

- No-tillage
- Minimum tillage
- Residue management
- Direct seeded Rice
- Biogas (CDM), bio briquette and renewable energy
- Solar pumping
- Papa & barsha pump

Figure 5: Minimum Tillage

Figure 6: Residue Management

f) Knowledge Smart:

- ICTs
- Mobile apps & SMS
- Call center
- Toll free number
- Gender empowerment
- Capacity development
- Behavior change
- Exposure visit

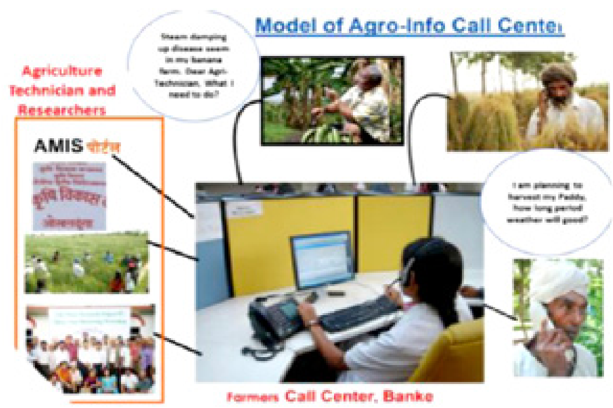


Figure 7: Farmer Call Center

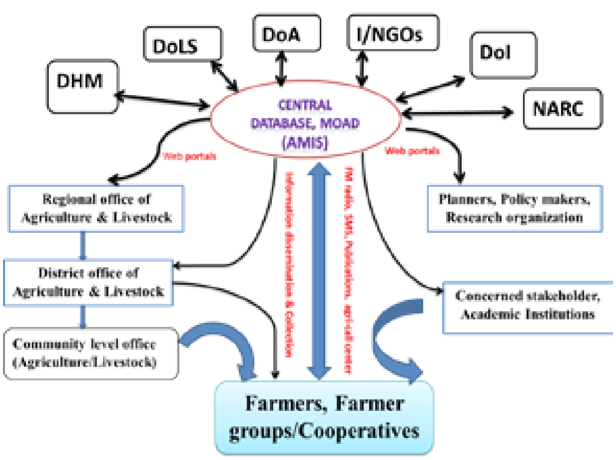
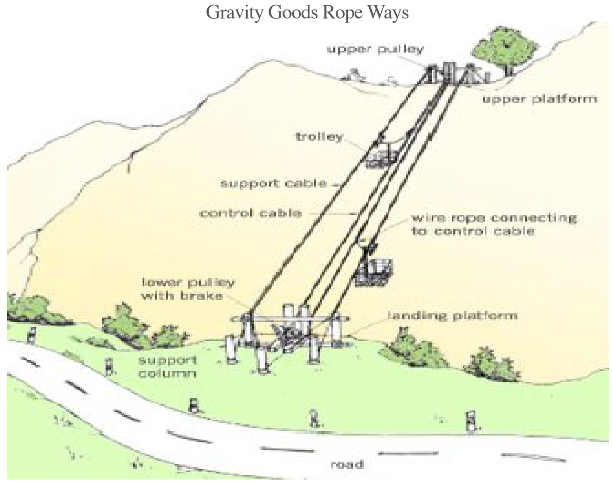


Figure 8: Information Flow Management

g) Haulage-Smart:

- Gravity goods rope ways
- Cable ways (tow-in)

Gravity Goods Rope Ways



Gravity Goods Rope Ways Technology

Cable Ways (Tow-in)

VI. Example of CSA and Mechanization Technology

As mentioned above, there are many technologies for Climate-smart. In particular, the pilot scheme entitled Climate-smart villages (CSV) has already been implemented at 4 sites, including Mahadevsthan, Nayagaun, Patalekhet, and Kavre District, for three years since May 2014 by the Center for Environmental and Agricultural Policy Research. The key adopted strategies include:

a) Water Management: Introduced simple technology on water use and management in irrigation water scare area; i) mulching to maintain humidity; ii) linking drinking water tap to conservation/irrigation ponds; iii) water retention techniques on terraces/farm land; iv) sprinkler or drip irrigation where feasible; v) concept of zero waste on water through behavior change. Besides these methods, farmers are also aware of the importance of soil moisturization in their fields.

b) Crop and Cropping Patterns Management: Supported farmers to adopt right crop combination and/or cropping patterns. The concept of zero tillage has been introduced wherever feasible after one crop. Inter cropping and multi-cropping with legumes have been integral parts of crop management. Crop diversification through diverse cropping practices is another attribution that could impart resilience to climate change impacts.

c) Use of Crop Residues: Encouraged farmers to harvest paddy and wheat after the crops reach one foot or above from the ground. This not only minimizes use of fertilizer but also helps maintain moisturization in the field.

d) Energy Smartness: Supported farmers to conduct residue management and land consolidation.

e) Nutrient & Fertilizer Management: Encouraged farmers to use bio fertilizer instead of chemicals through partnerships with Integrated Pest Management (IPM) groups. Cowshed management is the part of nutrient management strategy, which is the source of organic fertilizer. In cowshed management, the policy encourages farmers to collect cow dung and urine as fertilizers and bio-pesticides.

f) ICT Services and Linking Farmers to Experts: Introduced ICT based information flow mechanism. Selected farmers have been linked with a call centre who provides information on weather through a recorded voice call. In addition, the farmers can make a call to the call centre and get required information from experts.

g) Gender Friendly Community Institutions: Established farmers group and encouraged capacity development; invited farmers to join small-scale saving credit cooperatives where they can share their problems with agriculture practices. By far, this measure has helped women and marginalized communities to build confidence and develop leadership. Focus was set to be about gender and social inclusion. The existing cooperative has been mobilized for this purpose.

h) Invited farmers to Alternative Energy Promotion Centre (AEPC) / Nepal Biogas Program for biogas plant installation with national biogas support and subsidy. It has also linked AEPC to small-scale solar panel for electrification.

i) Crop and Cattle Insurance: Encouraged farmers to sign up for crop and livestock insurance subsidy program.

j) Exposure Visit: One-week visit to Samastipur and Vaishali districts of India was organized for three project staff and 12 farmers (7 women and 5 men) from the pilot sites. The team observed and learnt about the climate change adaptation practices in Borlaug Institute of South Asia (BISA) farm and Climate-smart Villages (CSV) sites of Samastipur, India. They learned about water smart practices (direct seeded rice, maize based system, raised beds and precision land leveling), nutrient smart technologies (site specific nutrient management (SSNM), legume integration (green seeker, nutrient expert decision support tool for maize and wheat), carbon smart technologies (zero-tillage and residue management), energy smart technologies (zero-tillage, residue management and directly seeded rice), weather smart interventions (weather forecast, index based insurance, seeds for needs, crop diversification and agro forestry), and knowledge smart intervention (ICTs, gender empowerment and capacity development). In BISA farm, the team learned about benefits of different machines for Climate-smart agricultural practices. They leant about combo turbo seeder/happy seeder, multi crop planter machine, thresher, punch planter, bed shaper, clincher, laser land leveler, residue cutter, maize sheller, dish machine, combine harvester, zero tillage machine, and plot planter.

Issues and Challenges

- Geographical setting
- Awareness of Climate-smart technology and related mechanization
- Low investment from public and private sector for CSA and mechanization
- Limited access to machineries, spare parts and after-sales services
- Weak organization setup in the government system working in CSA and mechanization
- Reliable energy supply
- Youth migration to urban and aboard leaving old age and women
- Credit facility and high interest rates from financial institutions
- Monsoon dependent agriculture

- Unavailability of weather forecast (Weekly, Monthly, Seasonal, Annual)
- Natural calamities; Floods, Land Slides, Cold & Hot Weather, Drought and Earthquakes. Recurrent climate related hazards

Conclusion

- Besides good policy and strategy, implementing agencies should give priority to CSA and sustainable agricultural mechanization
- Country has conducive policy environment to address problems and issues related to climate change, and government has put thrust by taking several policy initiatives as included in ADS
- Country is highly vulnerable to climate change (ranked 12th most climate-vulnerable country in the world); Climate-smart technology is crucial to the mitigation of the impacts
- High priority should be given to factors affecting climate change and its mitigation
- Technology reducing climatic hazards should be encouraged
- Replication or adaptation of CSV's outcomes at other locations should be encouraged
- Adopt suitable technology from other countries and do adoptive research based off of local condition
- Organizational coordinated effort should be build up based on lesson learnt to combat the effect of climate change through climate friendly activities
- Ministry of Agricultural Development is committed to work in collaboration with I/NGOs, private sector, and other development partners in the implementation of ADS for addressing the climatic venerability and climate change to achieve the ADS vision and national goal of food and nutrition security and improved livelihoods in the country

Pakistan
Climate-smart Agriculture and Mechanization in Pakistan

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I. Introduction

Pakistan relies heavily on agricultural practice. 68% of country's population living in rural areas directly or indirectly depends on agriculture for their livelihood. The industry is a dominant sector of Pakistan economy. It accounts for 21% of the country's GDP and takes up about 43.7% of the total work force. It contributes substantially to Pakistan's export earnings. The four major crops (wheat, rice, cotton,and sugarcane) on average contribute 31.1% to the value added in overall agriculture and 7.1% to GDP. The minor crops account for 11.1% of the value added in overall agriculture.

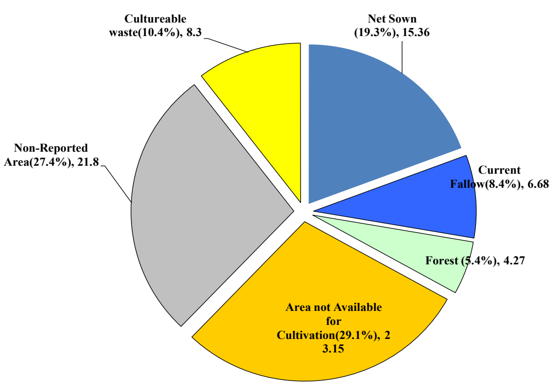

Figure 1: Land Utilization

Country Profile of Pakistan

Pakistan spans 79.61 million ha, with a population of over 194.3 million. The average rainfall is 127 ~ 1,250 mm per year.

Figure 2: Administrative Divisions of Pakistan

II. Management of Straw in Combine Harvested Wheat Fields

Wheat Straw Chopper

Wheat is the main crop of Pakistan. Its grain is used for human consumption and its straw can be fed to animals. It is grown on 8 million ha land. The recently introduced combine harvesters for wheat harvesting mainly deal with grains but the straw is left in the field. Although combine harvesters facilitate the harvesting of wheat, they collect grains only, leaving the stubbles standing in the field. Due to unavailability of proper technology to clear the fields for sowing of subsequent crop, farmers are compelled to burn these stubbles. It has given rise to following issues:

- Environmental pollution associated with fire hazards;
- Loss of precious soil organic matter; and
- Loss of wheat straw "bhoosa" a valuable cattle-feed.

Challenge was to develop a wheat straw chopper to harvest the standing stubbles and chop them into "bhoosa". PARC introduced a tractor mounted wheat straw chopper-cum-blower and tested it in various field operations. PARC provided technical assistance to private manufactures and signed agreements with five local manufacturers for its commercialization. Currently more than 15 private manufactures are producing this machine. Around 7,000 units were in operation during 2016. It is benefiting the country worth Rs.820 million annually and is helping to reduce environmental pollution. It saves 500 kg/acres of wheat straws for cattle feeding.

Figure 3: Wheat Straw Burning

Figure 4: Straw Chopper in Operation in the Field

III. Management of Rice Straw in Combine Harvested Paddy Fields

a) Zero-tillage Drill

Rice is grown on 2.5 million ha in Pakistan. Land preparation for wheat in rice-wheat rotation is an energy-intensive and time-consuming process. For this reason, wheat sowing usually gets delayed, especially in basmati growing areas, resulting in low yields. Therefore, the concept of zero-tillage sowing method was considered. PARC has made intensive efforts in introducing this technology in the country. Sowing of wheat in zero-tillage culture minimizes the intercrop gap and crop yield is substantially improved.

The Agricultural and Biological Engineering Institute (ABEI) formally, Farm Machinery Institute (FMI) of the Pakistan Agricultural Research Council Islamabad designed and developed low cost and light zero-tillage drill to suit farming conditions. Fifty hp tractors operate these machines with a capacity of 1 acre/hour. It saves diesel, which is used for land preparation and irrigation. It also increases wheat yield by preventing 1% yield loss/per day if wheat is sown after 25 November every year.

More than 25 manufacturers are currently producing this drill and over 7,000 operating units of the machine are available with farmers in the country. Its per annum benefit to the country is $ 5.855 million. This technology is successful if paddy is manually harvested (stubble free field).

Figure 3: Burning of Rice Straw before Wheat Sowing

Figure 4: Zero Tillage Drill

Figure 5: Pak Seeder

b) Pak Seeder

The use of combine harvesters is becoming more prevalent. Mostly European self-propelled combine harvesters are imported in the country. It is estimated that about 12,000 units of such combines are in operation, and more than 50 percent of rice crop is harvested using these combines especially in Punjab Province. These machines cut paddy crop at the height of 40-80 cm and leave behind a swath of loose residue, which clog the openers of existing zero-till drills.

Residue management is a major problem in rice-wheat system of the country. Residue is either removed or spread in the field in order to overcome this problem. However, farmers prefer to burn it as an easy method of land clearance for subsequent crop. Burning of residue not only results in loss of nutrients in the soil but also poses a great threat to the natural environment, human health, and economic loss when smog restricts road and air traffic. Residue appears to be the only organic matter available to most rice farmers. Incorporation of crop residue into the soil enhances soil fertility since it supplements soil nutrients. Burning rice residue causes almost a complete loss of 25%Nitrogen, 20%Phosphorus, and 50-60% Potassium and Sulphur. The Agricultural and Biological Engineering Institute (ABEI) formally, Farm Machinery Institute (FMI) of the Pakistan Agricultural Research Council Islamabad have designed and developed a direct drilling seeder, called Pak Seeder, to suit farming conditions in rice-wheat areas.

This machine cuts the stubbles, picks up the loose straw lying in front of each opener of the zero till drill, chops them into small pieces, and spreads uniformly between the rows. It is a PTO driven tractor mounted eight-row machine and is suitable for most tractors available in the country. Its effective field capacity is one acre an hour. Efficient use of Seeders can ensure in-time sowing of wheat, save operating cost, moisturize soil, decay crop residue, control non-chemical weed, reduce environmental pollution, and improve soil aeration and fertility.

IV. Natural Resource Saving Technology

Fertilizer Band Placement Drill for Wheat

In Pakistan, phosphate fertilizer in wheat is conventionally applied by broadcast method before sowing crop. This is a wasteful method of fertilizer application as only 15-25% of the applied phosphate is utilized by wheat crop. The seed-cum-fertilizer drills currently used in Pakistan place fertilizer either too far from the seed or in direct contact with it. In the former case, fertilizer use efficiency is hampered and has relatively high rate of ammoniated phosphate fertilizer (like DAP) which affects the seed germination and crop yield.

To solve the mentioned problems, a fertilizer band placement drill was developed at The Agricultural and Biological Engineering Institute (ABEI) formally, Farm Machinery Institute (FMI) of the Pakistan Agricultural Research Council Islamabad. The drill was field tested and evaluated. This drill places fertilizer 5 cm away and 5 cm deeper than the seed. The crop roots utilize fertilizer since it is applied very effectively and 60-70% of the applied phosphate is utilized by wheat crop. Field experiments have confirmed that this drill saves 50% phosphate fertilizer comparing to broadcast method. In addition, about 10% more grain yield was obtained in plots where 50% fertilizer doze (40 kg DAP/acre) was band placed using this drill than where full recommended phosphate doze (80 kg DAP/acre) was applied through broadcast.

More than 8,000 units are in operation and by using this technology, and the country is saving Rs. 6.8 billion annually since expense on DAP fertilizer is reduced.

Figure 6: Fertilizer Band Placement Drill

Figure 7: Field Trials of Fertilizer Band Placement Drill

V. Future Focus

We will put more emphases on precision agriculture, make efforts to optimize the use of inputs such as fuel, water, seed, fertilizer, and chemical, and use energy efficient and environment friendly mechanical technologies. We should conduct more researches and enable developments on machines that can achieve intellectualization such as computer controllers, variable rate technology, farm GIS and data management, zone management, and telemetric machinery operating whose information is available on internet and crop sensors.

Philippines
Agricultural Mechanization Technologies for Sustainable Philippine Agriculture and Fishery Production Systems

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I. Introduction

The Philippines is an agricultural country influenced significantly by the effects of climate change. Different anthropogenic activities undertaken by humans have been recognized as contributors of climate change. This climate phenomenon affects agricultural production systems by changing rainfall patterns, temperature variability and extreme weather conditions. The use of climate resilient agricultural mechanization technologies is therefore necessary to sustain agricultural and fishery production systems in view with climate change for food production and meet the requirements of the ever-growing population.

Of the total population of 103.5 million living and deriving food from 9.671 million hectares of agricultural land and 1.83 million square kilometers of water resource, the effect of climate change to the Filipinos is substantial. About 11.801 million Filipinos are employed in the agricultural sector and the derived products contribute about 10% of the total gross domestic product of the country. Apart from rice and corn being the staple food of Filipinos, other crops such as coconut, sugarcane, and some high value crops are produced by the agricultural sector. Moreover, the protein requirement of the normal Filipino diet comes from livestock, poultry and fishery which are also produced by the agricultural and fishery sectors (country stat., 2016). However, the production may change drastically due to the negative impact of climate change, if no interventions are undertaken.

The introduction of suitable, innovative and climate resilient agri-fishery mechanization technologies (AFMTs) will, among others, enable the agri-fishery sector to cope up with the adverse effects of climate change, thus sustain food productivity. These AFMTs could contribute in full utilization of products and by-products; cultivate on a sustained production of uplands, hilly lands, swamplands and other non-arable lands; intensify and diversify farming systems which will, in turn, generate employment; reduce or minimize post-harvest losses; increase the value added to farm and fishery products through secondary and tertiary processing; and help bring equity among Filipinos in the access to basic production resources. These AFMTs can also reduce the contribution of agriculture to climate change.

This paper aims to present how differently institutions are involved in research, development and extension of innovative and climate resilient agri-fishery mechanization technologies in the Philippines; the developed AFMTs resilience to climate change by these research and development institutions; and the current RDE efforts on precision agriculture as a response in mitigating the adverse impacts of climate change on the agri-fishery sector.

Table 1. Country Background

Item	Description	Data
Geographical Location	Latitude : NL	4.7 ° N
	: SL	21.5 ° N
	Longitude: EL	117 ° E
	: WL	127 ° E
Meteorological conditions	Temperature	Min. 26.1 o C Max. 28.4 ° C
	Annual Precipitation	2,000 mm/year
Agricultural Conditions	Total Area	300,000,000 km^2
	Total Land Area	298,170,000 km^2
	Total Water Area	1,830,000 km^2
	Agricultural Land	9,671,000 km^2
	Arable Lands	4,936,000 km^2
	Permanent Cropland	4,225,000 km^2
	Forest Land	74,000 km^2
	Other Lands	307,000 km^2
	Agricultural Farms	4,820,000 farms (2002)
Agricultural Conditions	Staple Foods	RICE: (2015) Area Harvested: 4.656 million ha Production: 18.150 MMT Farm gate Price: P18.04kg
		CORN: (2015) Area Harvested:2.562 million ha Production: 7.518 MMT Farm gate Price: P12.01/kg
	Other Staples	Root Crops and Plantain
	Other Major Crops	Sugarcane, Coconut
	Top Export Crops	Coconut Oil (18%), Banana (17%), Tuna (7%) Pineapple & Products (7%)
Population and Employment	Total Population	103.500 million
	Total Employment	38.65 million
	Employment in Agriculture	11.801 million (share 31%)
	Wage Rates	P 252-454 plantation (2016)
Social Conditions	Official Language	English & Filipino
	National Language	Filipino
	Religion	Christians / Muslims
Economy (2015)	GNI at Current Prices	P 13,851 Billion
	GDP at Current Prices	P 11,584 Billion (10% in agriculture @ 7.18% growth)
	GVA at Current Prices (agriculture and fishing)	P1,293 Billion
Mechanization Level (Quick Index)	For Rice For All crops	2.32 hp/ha 1.23 hp/ha

Source: Country Stat. psa.gov.ph, 2016

II. The Philippine Climate-smart Agriculture and Fisheries

With the advent of climate change issues and challenges, the agricultural sector has also laid down their plans for a Climate-smart agriculture and fisheries sector. Figure 1a shows the development plan during the Aquino (2010-2016) and the current administration (Duterte -2017-2022) for a Climate-smart Agriculture and Fisheries sector. The introduction of climate resilient AFMTs in the agri-fishery sector can ensure the production of food, feed, fiber, timber and other agricultural and bio-materials for food sustainability, security and sufficiency as well as farm prosperity as presented in Figure 1b.

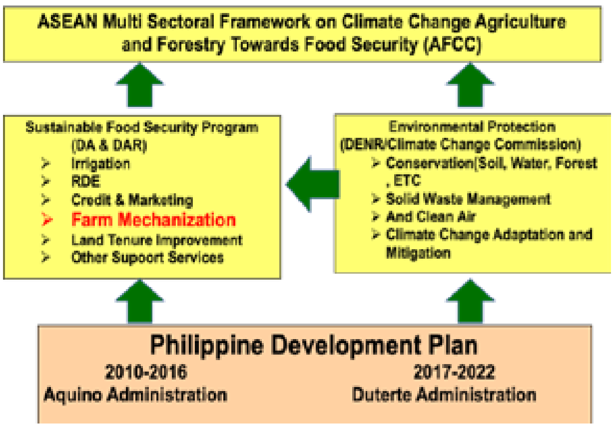

Figure 1a: The Philippine Climate-smart Agriculture and Fisheries framework

Figure 1b: The Key Results in the Introduction of Afmts in the Agri-Fishery Sector

Source: Rico, 2016

III. Institutions Involved in the Development of Climate Resilient AFMTs

The RDE network in producing AFMTs for different agricultural crops and fishery consists of various agencies directly or indirectly involved in innovative research and development of climate resilient AFMTs (Figure 2) (as adopted from Amongo, et al. 2015). The agencies can generally be categorized into implementing and funding agencies. Implementing agencies can be further categorized as Research Development Institutions (RDIs) under the government or private agencies; Higher Education Institutions (HEIs) represented by state universities and colleges (SUCs) and International Agencies (AIs) based in the Philippines. There are cases, however, in which implementing agencies are also funding agencies.

a) Implementing Agencies

Government Agencies- *Bureaus under the Department of Agriculture (DA)*

The Bureau of Plant Industry (BPI) is an agency of the government under DA that is responsible for serving and supporting the Philippine plant industry sector. BPI envisions the country's agriculture sector to be composed of vibrant crop-farming communities, and to produce quality, accessible, and globally competitive agricultural crops that are profitable for the Filipino. Its mission is to conserve and develop Philippine plant genetic resources and ensure the protection and development of the plant industry. Its development efforts in mechanization are the improvement of farm equipment and ancillary structures for the plant industry. BPI strives to satisfy the needs of its stakeholders in the areas of crop research, protection and production, crop utilization and analytical services, seed quality assurance, plant quarantine, and agricultural engineering services.

The Bureau of Fisheries and Aquatic Resources (BFAR) is a government agency that is responsible for the development, improvement, management and conservation of the country's fisheries and aquatic resources. It was reconstituted as a line bureau by virtue of Republic Act No. 8550 (Philippine Fisheries Code of 1998). The bureau is under the Department of Agriculture. Its mission is to improve fisheries productivity within ecological limits and empower stakeholders towards food security, inclusive growth global competitiveness and climate change adaptation. Its vision is to be an excellent institution in sustainable fisheries management and services by 2016.

The Bureau of Animal Industry (BAI) was established on January 31, 1930 pursuant to Republic Act (RA) No.3639 dividing the Bureau of Agriculture into two distinct entities: The Bureau of Plant Industry and the Bureau of Animal Industry. BAI underwent several changes and is currently composed of seven technical divisions, namely: The Animal Health Division (formerly the Regulations and Control Division), the Animal Feeds Standard

Division (formerly the Animal Feed Control Division), the Dairy Development Division, the Livestock Development Division (formerly the Livestock and Poultry Propagation Division), the Laboratory Services Division, the Marketing Development Division, and the Research Division. BAI's function as stipulated in EO No. 292 s. 1987, are to:formulate programs for the prevention, control and eradication of animal diseases and for the development and expansion of the livestock and poultry industries to meet the growing requirement of the growing populace; recommend specific policies and procedures governing the flow of livestock product through the various stages of marketing as well as the proper preservation and inspection of such products; coordinate and monitor the activities and projects related to livestock and allied industries; prescribe standards for quality in the manufacture, importation, labeling, advertising, distribution and sale of livestock, poultry and allied industries; and recommend plans and programs, policies and regulations to the Secretary of Agriculture and provide technical assistance in the implementation of the same.

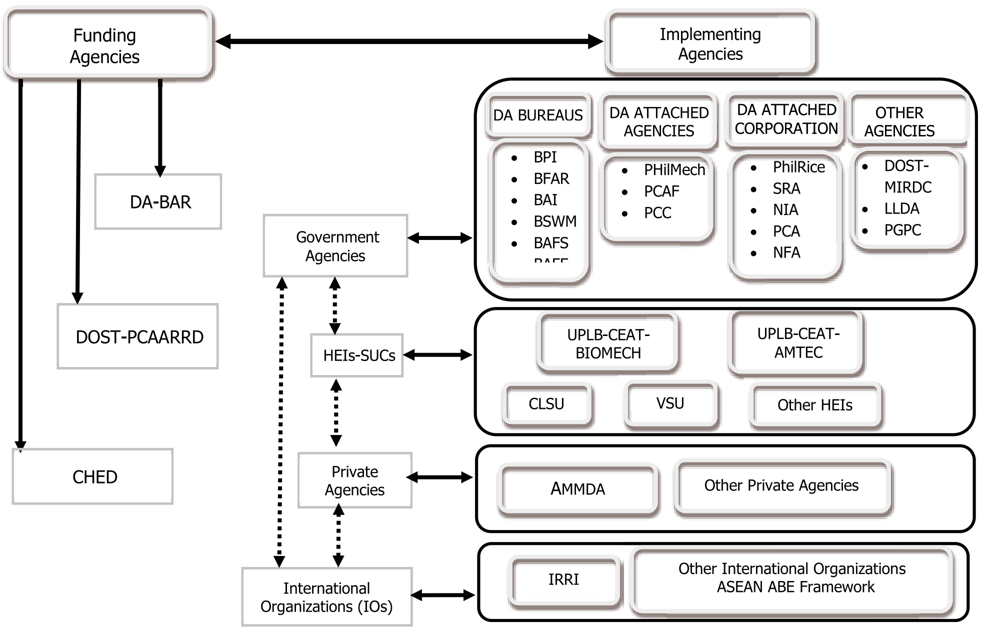

Figure 2. RDE Network for Agri-fishery Mechanization

The Bureau of Soil and Water Management (BSWM) is the bureau tasked to implement projects on soil and water conservation particularly in the agricultural sector. In 2011, BSWM reported that from 1974 to 2010, it had completed more than P5 billion worth of irrigation projects for farming communities that could not be served by large irrigation systems. The BSWM reported that it had undertaken four types of irrigation systems: small water-impounding projects (SWIPs), small diversion dams, small farmer reservoirs (SFRs), and shallow tube wells (STWs). (as presented by Amongo et al, 2015)

The Bureau of Agricultural and Fisheries Standards (BAFS) is a new Bureau created by the enactment of RA 10601 otherwise known as the Agriculture and Fishery Mechanization Act of 2013. BAFS is tasked to establish quality safety and performance standards of AFMTs used in the agriculture and fishery sector. Its programs include standards development and updating; testing and evaluation of AFMTs; standards regulation and enforcement; and registration, classification, accreditation of Manufacturers, Fabricators, Assemblers and Importers and other stakeholders and the Registration of Ownership of Agricultural and Fisheries Machinery in the agricultural and fishery sector (IRR of RA 10601, 2013).

The Bureau of Agricultural and Fisheries Engineering (BAFE) was also established based on RA 10601 to ensure that support services and institutional development in support to the AFMech Law of 2013 is implemented. These include: facilities and equipment acquisition assistance; establishment of agricultural and fisheries Machinery Service Centers; implementation of the Contiguous Farming and Infrastructure Support; Agri-Fisheries Mechanization and Engineering Resource Network; Institutional Strengthening; Credit and Marketing Support and Policy, Planning and Project Monitoring (IRR of RA 10601, 2013).

Government Attached Agencies

The Philippine Center for Postharvest Development and Mechanization (PHilMech) is one of the Department of Agriculture's (DA) attached agencies that are currently a major player in RDE activities on AFMTs. It envisions being the premier center for postharvest and mechanization development for globally competitive and sustainable agriculture and fishery sectors. Its mission is to empower the agriculture and fishery sectors by increasing resource-use efficiency and productivity, reducing losses, and adding value to the produce through RDE. Its general mandate aims to generate, extend, and commercialize appropriate and problem-oriented agriculture and fishery postharvest and mechanization technologies (www.PHilMech.gov.ph, 2013). Moreover, PHilMech's more active efforts in mechanization, particularly in the design and development of rice production mechanization technologies and technologies for other agricultural commodities, were brought about by the change of its mandate together with the change of its name from the former Bureau of Postharvest Research and Extension in 2010 (as presented by Amongo et al., 2015) .

The Philippine Council for Agriculture and Fisheries (PCAF) (formerly the National Agriculture and Fishery Council (NAFC)) is established, "to ensure participatory broad-based decision making in agriculture and fisheries by providing quality services to its nationwide network of private sector-led consultative councils toward the formulation of sound policy and program recommendations for sustained countryside agricultural and fishery development." It envisions itself "as an effective and efficient catalyst and generator of private-sector commitment and participation in developing the agriculture and fisheries sectors as a basis of a vibrant national economy." PCAF values people empowerment and good governance (www.nafc.da.gov.ph/mv.html, 2013). The agricultural and fishery mechanization, food crops, fisheries, and livestock committees are the important sectoral committees of NAFC. These committees have an important role in RDE of AFMTs in terms of their discussion and endorsement of significant mechanization projects for approval and implementation by DA (as presented by Amongo et al., 2015).

The Philippine Carabao Center (PCC), an attached agency of the Department of Agriculture (DA), was established by virtue of Republic Act 7307 in 1992, PCC became operational in 1993, taking momentum from the gains and achievements of earlier programs. It has a network of 13 regional centers strategically located in various parts of the country. The Center aims to achieve "better nutrition, higher levels of income and improved general well-being of the overwhelming sector, the rural farming families...through the conservation, propagation and promotion of water buffalo as important source of milk and meat, in addition to draft power and hide." In 2008, PCC also pursued an additional mandate as the national lead agency for livestock biotechnology research and development in the Department of Agriculture as contained in DA Administrative Order No. 9, 2008. Its R&D efforts help address technology and policy gaps. Essentially, it seeks to overcome the constraints in building more efficient and profitable buffalo-based enterprises.

DA Attached Corporations

The Philippine Rice Research Institute (Philrice) is the country's leading government agency in rice science and development. It envisions a competitive, sustainable, and resilient farming sector through the utilization of clean, green, practical, and smart technologies. In the past several years, PhilRice has focused its efforts on improving rice production and increasing land productivity. Current research and development (R&D) programs are focused on coping with climate change, high-value products from rice and its environment, farming without fossil fuel, intensified rice-based agri-bio systems, and future rice.

Two of the 13 divisions of PhilRice that are directly involved in RDE in rice mechanization are the Rice Engineering and Mechanization Division (REMD) and the Technology Management and Services Division (TMSD). The REMD helps other agencies improve the country's level of mechanization and modernize rice production and postharvest operations through the design, development, manufacture, and marketing of location-specific farm machinery for rice production and postproduction operations that cater to the needs and locations of farmers.

The Sugar Regulatory Administration (SRA) was created in May 28, 1986 to promote the growth and development of the sugar industry through greater participation of the private sector and to improve the working conditions of the laborers. Furthermore, Republic Act 9367 s. 2006 (Biofuels Act of 2006) mandated SRA, as member of the National Biofuels Board (NBB), to develop and implement policies supporting the Philippine Biofuels Program and ensure security of domestic sugar supply. The vision of SRA is to be “an empowered government organization that ensures long-term viability, environmental sustainability and global competitiveness of Philippine sugarcane industries through greater and significant participation of the stakeholders.” And its mission is “to provide stakeholders of the Philippine sugarcane industries with pro-active and effective policies, regulatory, R&D and extension services.”

The National Irrigation Administration (NIA) focused on the nationwide existence of efficient irrigation systems that are environmentally sound and socially acceptable, located in strategic agricultural areas, capably managed by viable and dynamic irrigators’ associations, profitably producing good quality rice and other diverse crops, progressively improving the welfare of farm families and rural communities, and sustainably supporting the food production program of the government; and for the agency to be transformed into a financially independent organization that operates at its full potential. With its employees enjoying compensation and benefits comparable to other service-oriented government corporations, it attains prominence as a leader in irrigation management in the Asian region, and excellence as a well-managed government corporation.

NIA’s mission is the development and management of water resources for irrigation and provision of necessary services on a sustainable basis consistent with the agricultural development program of the government. The objectives of NIA are to (a) develop and rehabilitate irrigation systems in support of the national food production program, (b) provide an adequate level of irrigation service on a sustainable basis in partnership with farmers, (c) provide technical assistance to institutions in the development of water resources for irrigation, (d) support economic and social growth in the rural areas through irrigation development and management, and (e) improve and sustain the operation of NIA as a corporation and service-oriented agency (www.nia.gov.ph, 2013, as presented by Amongo et al., 2015).

The Philippine Coconut Authority (PCA) is the sole government agency that is tasked to develop the industry to its full potential in line with the new vision of a united, globally competitive and efficient coconut industry. Its mandate is to promote the rapid integrated development and growth of the coconut and other palm oil industry in all its aspects and to ensure that the coconut farmers become direct participants in, and beneficiaries of, such development and growth. It establishes the legal basis for PCA's sole stewardship and responsibility over the coconut and other palm oil industries for the benefit of the coconut and oil palm farmers. It envisions a developed and globally competitive coconut and other palm oil industry that contributes to food security, improved income, and enhanced participation of all stakeholders by 2020.

The National Food Authority (NFA), as a government corporation, envisions itself “to be at the forefront in providing excellent needed services to the grains marketing industry towards global competitiveness and committed to ensuring food security.” Its missions include (a) pursuing and accelerating the integrated growth and modernization of the food marketing industry, (b) providing excellent services towards attaining food security and the stabilization of the supply and price of rice, (c) assisting the food marketing industry to move towards global competitiveness, and (d) empowering rice farmers. NFA has a Technical Research and Development Services Department, which conducts activities on rice mechanization.

The Philippine Grains Postproduction Consortium (PGPC), formerly the Philippine Rice Postproduction Consortium, is an alliance of government agencies involved in the improvement of the grains postproduction industry. The consortium was originally established in 1999 and was renamed to PGPC in 2012 through Executive Order (EO) 59, signed by President Benigno S. Aquino III to include other grains such as corn, dalai, and sorghum. The present member-agencies of the consortium include the National Agricultural and Fisheries Council (NAFC) of DA, NFA, PhilMech, PhilRice, and the University of the Philippines Los Baños (UPLB), with the International Rice Research Institute (IRRI) as a collaborating international agency. The Institute of Agricultural Engineering of the College of Engineering and Agro-industrial Technology (IAE-CEAT) is the official UPLB representative unit in the PGPC. The PGPC’s RDE thrust has focused on postproduction mechanization (e.g., development and pilot testing of the PGPC dryer) (PGPC 2013 as presented by Amongo et al., 2015).

The Laguna Lake Development Authority (LLDA) was organized by virtue of Republic Act No. 4850 as a quasi-government agency with regulatory and proprietary functions. Through Presidential Decree 813 in 1975, and Executive Order 927 in 1983, its powers and functions were further strengthened to include environmental protection and jurisdiction over the lake basin’s surface water. In

1993, through Executive Order 149, the administrative supervision over LLDA was transferred from the Office of the President to the Department of Environment and Natural Resources (DENR). Some of the powers and functions of the LLDA is to catalyze Integrated Water Resource Management in the Laguna de Bay Region, showcasing the symbiosis of man and nature for sustainability, with focus on preserving ecological integrity and promoting economic growth with equitable access to resources.

State Colleges and Universities (SUCs)

The Center for Agri-fisheries and Biosystems Mechanization (BIOMECH) formerly Agricultural Mechanization Development Program (AMDP) of UPLB-CEAT has been supporting the three major functions of the university for 37 years, viz., instruction, research, and extension. Since 1979, it has developed, designed, tested, and promoted affordable farm machinery for farmers; conducted technology and information dissemination through exhibits, pilot testing, demonstration of machines, and publication of extension materials (bulletins, refereed and non-refereed journals, leaflets, etc.); and conducted training for different target beneficiaries.

With the overall goal of improving the farmers' quality of life, BIOMECH continues to develop more affordable technologies; provide technical assistance; and promote farm technologies to improve farm operations, reduce farmers' drudgery, and provide value-added to farmers' crops. The center's rice mechanization R&D efforts have yielded technologies that include upland and lowland power tillers and implements, mechanical rice transplanter, lowland weeders, thresher, rice harvester, and village-scale rice mill (AMDP, 2013 as presented by Amongo et al., 2015).

BIOEMCH is being supported by the Institute of Agricultural Engineering which is one of the Centers of Excellence in Agricultural and Biosystems Engineering programs.

The Agricultural Machinery Testing and Evaluation Center (AMTEC) of CEAT-UPLB was established in 1977 by virtue of a Memorandum of Agreement between DA and UPLB. This was in recognition of the need for an official testing agency to promote a self-reliant agricultural machinery industry that would cater to the needs of Filipino farmers (AMTEC, 2010 as presented by Amongo, et al., 2015).

AMTEC envisions the establishment of a national center that will test and evaluate the performance of agricultural and fisheries machinery to the benefit of Filipino farmers and fisherfolk. Its current mission is to establish standards of performance of machinery; conduct laboratory and field tests of machinery; evaluate the results using rationalized criteria; and disseminate the information to concerned agencies, farmers, and fisherfolk (AMTEC, 2010, as presented by Amongo, et al., 2015). However, testing of machines is voluntary, and only manufacturers participating in government bidding for agricultural machinery are required to submit their machines for testing. Furthermore, AMTEC is not mandated to issue certificates of performance for machines tested.

AMTEC has been active in performing its role. To date, about 193 standards have been developed and adopted through its leadership. Moreover, 263 machines were tested from 2006 to 2009, consisting of prime movers, irrigation machinery, production machinery, and postharvest equipment (AMTEC 2010, as presented by Amongo, et al., 2015).

As stipulated in RA 10601, BIOMECH is mandated to lead and coordinate all RDE activities in Agri-Fisheries Mechanization of all academic institutions in the country. On the other hand, AMTEC is mandated to lead as the National Testing Center of AFMTs in the Philippines.

The Central Luzon State University (CLSU) is a state university, one among the three Centers of Excellence offering the Agricultural and Biosystems Engineering in the Philippines. It has a Research, Extension and Training (RET) Office that continuously conducts RDE activities towards contributing to countryside development (www.clsu.edu.ph, 2013). The office also contributes to CLSU's active RDE in agricultural engineering for various agricultural commodities. The RET Office envisions "research as frontier center and program for empowering participating individuals and groups to improve their quality of life." It aims to develop packages of appropriate technologies, processes, and systems adaptive to sustainable agro-industrial production. The central goal is to serve as a continuing source of appropriate technologies, knowledge, information systems, management schemes, and services concerning the uniqueness of the university in agriculture, fisheries, and environment that will meet the requirements of agro-industrializing communities (www.clsu.edu.ph, 2013, as presented by Amongo, et al., and 2015).

The Philippine-Sino Agricultural Center for Agricultural Technology (PhilSCAT) is a collaborative project between the Republic of the Philippines (RP) and the People's Republic of

China (PRC), executed by DA of the RP and the Ministry of Commerce of the PRC. Its lead implementing agencies are CLSU (for the RP) and Yuan Longping High-Tech Agriculture Co., Ltd. (for the PRC). Partner agencies of PhilSCAT include PhilMech, PhilRice, the Agricultural Training Institute (ATI), and the DA-Regional Field Office III. PhilSCAT has an Agricultural Engineering and Mechanization Unit, which offers custom services to farmers within the vicinity of the Center at a prevailing rate. Its custom services include seedbed preparation, transplanting, threshing, harvesting, bagging, drying, and milling (www.philscat.orgfree.com, 2013 as presented by Amongo, et al., and 2015). Over the years, it has conducted mechanization projects in collaboration with its partner agencies.

The Visayas State University (VSU) is also one of the oldest institutions located in Baybay Leyte which offers agricultural engineering program and. It is one of the Centers of Excellence offering the Agricultural and Biosystems Engineering. The mandate of the University is primarily to provide advanced instruction and professional training in agriculture, science and technology, education, and other related fields, undertake research and extension services, and provide progressive leadership in these areas. The university shall ensure that it retains its original mandate as a primarily agricultural institution. Its vision is to serve as premier university of science and technology in the Visayas and its mission is to provide excellent instruction, conduct relevant research, and foster community engagement that produce highly competent graduates necessary in advancing the well-being of the country.

The Visayas State University is a recognized Zonal University in the Visayas, a leading Research Institution, and the only Green University in the Visayas. It is also the only University accredited by the Department of Tourism as a tourist destination. Moreover, VSU is the National Research Center of three important crops, namely: 1) The Philippine Rootcrops Research and Training Center (PhilRootcrops), (2) National Abaca Research Center (NARC), and the (3) National Coconut Research Center-Visayas. Each research center is well-equipped with facilities covering production, including tissue culture laboratories; and processing of food and non-food products. Each Research Center has developed new varieties and technologies in their respective mandates. VSU is also housing a number of Regional and Institutional Research Centers including the; (1) Renewable Energy Research Center (RERC), (2) Plant Oil Technology Research Center, and (3) The Philippine Carabao Research Center. VSU is also assigned as the leading regional research institution in the different agricultural commodities including fruits and vegetables, grains and cereals, small ruminants, and environment (as presented by Amongo, et. al., 2014).

There are other higher educational institutions involved in RDE for AFMTs as presented in Table 2. These institutions basically offer the baccalaureate Agricultural Engineering program while the three Centers of Excellence (COEs) namely: IAE-CEAT UPLB, CLSU and VSU offer the BS Agricultural and Biosystems Engineering, Master of Science, and Doctor of Philosophy programs in Agricultural Engineering.

Table 2: Distribution of HEIs Offering the BSAE Program

ISLAND GROUP	REGION	LOCATION OF HEIS	HEIS (NO.)
Luzon	NCR (National Capital Region)	Caloocan	1
	CAR (Cordillera Administrative Region)	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**

ISLAND GROUP	REGION	LOCATION OF HEIS	HEIS (NO.)
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
	ARMM - Autonomous Region in Muslim Mindanao		0
		Subtotal	**14**
		Total	**48**

Source: Amongo et al., 2013

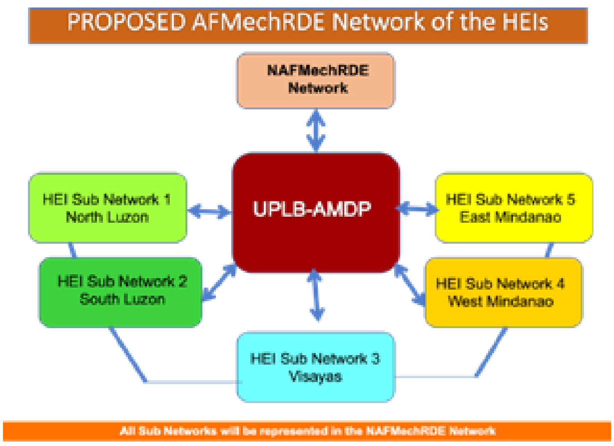

Figure 3. Proposed AFMech RDE Network for HEIs
Source: AMDP, 2014

Private Agencies

The Agricultural Machinery Manufacturers and Distributors Association Foundation, Inc. (AMMDA) is composed of members that are involved "in the manufacture, assembly, distribution and servicing of farm machinery, namely 4-wheel tractors (standards and compact) and their implements; power tillers and their attachments; irrigation equipment; postharvest equipment; processing equipment; gasoline and diesel engines; crop maintenance and protection equipment; and other agricultural machinery".

AMMDA members are either distributors or manufacturers. Manufacturer-members fabricate local-made hand tractors, threshers, shellers, flatbed dryers, pumps, drilling rigs, shredders, and decorticators, among others. Hand tractor attachments and threshers/shellers are manufactured in volume by AMMDA manufacturer-members. The average volume of production of hand tractors and threshers/shellers amounts to 20,000–30,000 and 15,000–20,000 units respectively. Other machines are fabricated to order. Some manufacturers have up-to-date fabrication equipment, and at least five members have computers and CNCs (Canapi, 2010 as presented by Amongo, et al., 2015). AMMDA also conducts short-term R&D activities for the improvement and adaptation of commercially available machinery to suit local conditions.

One example of other private institution is the Benito M. Domingo (BMD) Cornworld, a successful enterprise that started land consolidation efforts for rice and corn crops in Isabela Province. Mr. B.M. Domingo, head of Cornworld in the early 2000s, was tapped by the government to assist in the preparation of the loan proposal package and project feasibility study for the machinery requirement of a clustering and mechanization project for an organized cooperative in Isabela. BMD Cornworld also provided a technology demonstration of a 4-wheel tractor, planter, sprayer, and harvester for corn production in the area. After loan was approved for the DA program, it provided the cooperative with assistance for the acquisition and delivery of equipment from a United States (US)-based supplier, Dee Implements. It also assisted in establishing the demonstration farm of the cooperative and conducted training for farm machine operators in land preparation, planting, fertilizer and herbicide application, and harvesting. It also conducted monitoring of the operation of the acquired machines during initial implementation of the project (Larona, 2006).

International Organizations

The goals of the International Rice Research Institute (IRRI) postharvest projects framework include food security and poverty reduction through value addition. The objectives of the projects are to reduce postharvest losses and increase farmers' incomes, strengthen public-private extension systems, and coordinate/ facilitate policy dialogue for sustainable development of the postharvest sector. In general, in terms of mechanization, IRRI focuses on applied science and technology to improve the postharvest sector. Other pillars of operation that IRRI utilizes for its RDE in postharvest include multichannel extension/business models, multi stakeholder platforms and learning alliance, and multi-stakeholder collaborations (NARES: PhilRice, NFA, etc.; NGOs; civil society; consortia; and others) (IRRI, 2011 as presented by Amongo, et al., 2015).

Formerly known as the United Nations Economic and Social Commission in the Asia and the Pacific (UNESCAP) Regional Network for Agricultural Machinery, (established in 1977, renamed in 2000 the Regional Network of Agricultural Engineering and Machinery, then renamed again in 2006 the UN-Asia and the Pacific Center for Agricultural Engineering and Machinery) the Center for Sustainable Agricultural Mechanization (CSAM), which was formally launched in 2012, plays an important role in agricultural development in the Asia-Pacific region. The change in the name reflects the commitment of CSAM to contribute to the achievement of the United Nations Millennium Development Goals, particularly Goal 1: Eradicate extreme poverty and hunger; Goal 3: Promote gender equality and empower women; Goal 7: Ensure environmental sustainability; and Goal 8: Develop a global partnership for development.

To achieve its goals, CSAM has laid down two major work programs, namely (a) the Sustainable Agricultural Mechanization Strategies (SAMS) in collaboration with the Food and Agriculture Organization, which aims to achieve the dual goals of increasing food productivity against the background of rapid population growth, reduction of rural labor as a result of urbanization, and dwindling natural resources, and reducing the impact on the environment; and (b) the Asian and Pacific Network for Testing Agricultural Machinery (ANTAM), a regional network aiming to promote intraregional trade in safe and quality agricultural machinery for the benefit of both farmers and manufacturers (UNESCAP 2012, as presented by Amongo, et.al., 2015).

The BIOMECH serves as the Philippine's focal point who actively participates in the implementation of its two work programs. The BIOMECH has been a part of crafting the SAMS program, while AMTEC is involved in the implementation of the ANTAM.

Moreover, under the implementation of the strategic plan of action on ASEAN Food Security and Climate Change mitigation, the ASEAN Agricultural and Biosystems Engineering (ABE) framework was formulated in 2013 and being spearheaded by the Philippines. One of the major components of this ASEAN ABE Framework is the promotion and implementation of sustainable agricultural mechanization in the context of climate change mitigation.

b) Funding Agencies

Government Agencies

The Bureau of Agricultural Research (BAR), one of the staff bureaus of DA, was established to lead and coordinate the national agriculture and fisheries R&D in the country. It is committed to consolidate, strengthen, and develop the agriculture and fisheries R&D system for the purpose of improving its effectiveness and efficiency by ensuring customer satisfaction and continuous improvement through work excellence, teamwork and networking, accountability, and innovation. Its vision centers on a better life for the Filipinos through enhancing capabilities in agriculture and fisheries R&D. Its mission is to attain food security and reduce poverty by making agriculture and fisheries sectors more technology-based. The BAR was created by virtue of EO116, signed in 1987. In the EO, the government addressed the lack of coordination and integration of agricultural research and development among the existing bureaus, councils, and agencies. Thus, the BAR was created under the Research, Training, and Extension Group (www.bar.gov.ph, 2013 as presented by Amongo, et al., 2015). The BAR also provides funds or grants for the RDE program within its thematic thrusts.

In the early 1980s, the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) of the Department of Science and Technology (DOST) crafted short- and long-term plans for agricultural engineering R&D. In 1981–1990, 50% of the studies conducted focused on the design and development of machines for rice production and processing. Other studies were on benchmark surveys, piloting, packaging, and impact evaluation of technologies that were concentrated on rice. The main agencies responsible for most of the studies related to rice were UPLB, PhilRice, PhilMech, CLSU, BPI, IRRI, DOST, and the DOE (Resurreccion, 2001).

With the rationalization of DOES, the overall long-term goal of PCAARRD became to reduce poverty incidence, attain food security and global competitiveness, and address related environmental issues and concerns. PCAARRD's commitment and its programs, projects, and activities are anchored on the Philippine Development Plan 2011–2016 and Philippine Agriculture 2020.

More specifically, PCAARRD aims to achieve the President's Social Contract to the Filipino people as stipulated in EO43. It has four banner programs: strategic R&D, R&D results utilization, policy research and advocacy, and capability building and R&D governance. These banner programs address the key result areas of the national goals and commitments as embodied in the Social Contract of the Philippine President.

The Commission on Higher Education (CHED) is the key leader of the Philippine higher education system, effectively working in partnership with other major higher education stakeholders in building the country's human capital and innovation capacity towards the development of a Filipino nation as a responsible member of the international community. CHED's mandate focuses on the national government's commitment to transformational leadership which sets education as the central strategy for investing in the Filipino people, reducing poverty, and building national competitiveness.

CHED also provides research funds or grants to higher education institutions (HEIs) for RDE in line with its program on Centers of Excellence and centers of development. The grants may be used for upgrading research and instructional facilities and implementing RDE projects upon approval of CHED as the funding agency.

The mentioned institutions from the government and private sectors also comprise the Research and Development Institutions (RDIs) and (HEIs) for the development of AFMTs which are innovative and climate resilient machinery and technology. Figure 4 shows the RDE Framework for the development of AFMTs as stipulated in RA 10601.

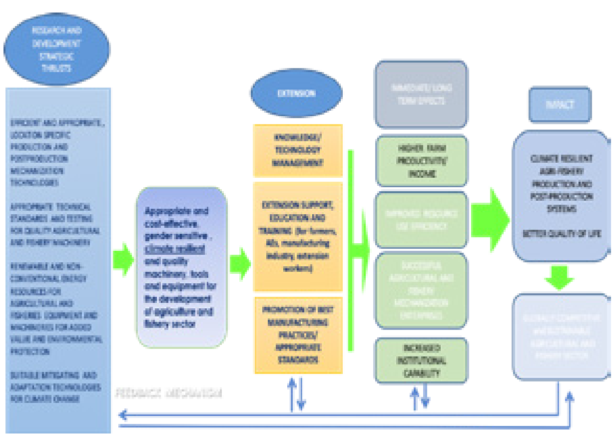

Figure 4: The National Agriculture and Fisheries Mechanization RDE Conceptual Framework

Source: Pasalo, 2016

IV. Biomech Developed Agriculture and Fisheries Mechanization Technologies

In the Philippines, the technologies used by farmers in the different farm operations are presented in Table 3. The top three AFMTs utilized by rice and corn farmers include power tillers, rice threshers and rice mills. The need to develop other appropriate and climate resilient technologies has been the goal of most of the research institutions in the country.

Table 3: Farm Machinery Population, 2012 (Estimate)

Agricultural Machines	Number 2012
Agricultural Tractors	
1) 4-wheel Tractor	9,306
2) Power Tiller	1,000,000
Paddy Threshers	
1) Rice Thresher	74,551
2) Pedal Thresher	20,149
3) Multipurpose Thresher/Sheller	6,259
Mechanical Harvester	
1) Combine Harvester	50
2) Reaper	100
Post-Harvest Machinery	
1) Corn Sheller	5,340
2) Flat Bed Dryers	2,620
3) Recirculating/Columnar Mech. Dryer	1,330
4) Corn Mill	2,340
5) Rice Mill (Single Pass)	24,420
6) Rice Mill (Multi-Pass)	904

Source: AMTEC and www.unapcaem.org as cited by Rico, 2016

The Center for Agri-Fisheries and Biosystems Mechanization has developed AFMTs for different crops and inland aquaculture to increase farm production. BIOMECH envisions to Excel in RDE committed to agri-fisheries and biosystems mechanization in the Philippines responsive to the challenges of food security, energy sustainability, environmental protection, climate change and globalization. It has four major RDE thrusts as presented in Table 4.

Table 4: BIOMECH RDE Thrusts

AREAS	SPECIFIC RDE AREAS
Food Security	Crop, livestock and fisheries production mechanization technologies Aquaculture engineering Alternative food sources mechanization Postharvest mechanization Food and feed processing technology Precision agriculture and smart farming Contiguous farming system
Energy Sustainability	Energy-efficient technologies Renewable energy technology
Environmental Protection	Agro-waste management and utilization GIS for Mechanization (Agricultural Mechanization Planning and Monitoring) Soil and water conservation technologies
Climate Change	Land and water resources engineering Climate change mitigation and adaptation

AMDP now BIOMECH has produced different AFMTs through the years as follows:

The UPLB Hand Tractor

The UPLB Hand Tractor (Figure 5) uses two surplus automotive differentials for the necessary reduction and power transmission. It can utilize lower power engines than the existing local ones because of its improved power transmission system. The technology is lower in cost than existing designs because of its simplicity, fewer and less expensive manufacturing operations, lower power and labor cost, and less investment on tooling. Its lightness translates to easier and better field handling (AMDP, 2009).

Figure 5: SUPLB Hand Tractor Using Surplus Automotive Differential

The Mini Hand Tractor

The UPLB Mini-Hand tractor (Figure 6) is a low-cost pull type hand tractor that can be used in marginal areas and even in hilly or rolling areas. It can be also utilized as a garden tractor for primary and secondary tillage operations in a greenhouse. Its available instruments include plow, harrow, cultivator, seeder/planter or furrower. The tractor is very light (53 kg without the engine). While many versions of hand tractors require intensive physical strengths, this machine has a good maneuverability in rolling or hilly terrains and can be easily operated by women. It operates on a single axle and a power transmission consisting of belt, pulley, and chain-sprocket. Its power source is a 3.5 hp gasoline engine (AMDP, 2009).

Figure 6: Mini Hand Tractor

UPLB Hand Tractor (with steering clutch)

The UPLB Hand Tractor (Figure 7) with steering clutch is a simple pull type hand tractor that uses a single split-type axle. The plowing attachment is a single-bottom moldboard plow. Its steering mechanism uses the idler and dog type steering clutch for easy maneuverability especially on rocky or stony field upland conditions. It weighs about 141.0 kg (without engine) and can be operated by one person. The power transmission uses belt, pulley, and chain-sprocket. Its power source is a 7.46 kW (10 hp) engine (AMDP, 2009).

Figure 7: UPLB Hand Tractor W/Steering Clutch

BIOMECH/AMDP Plow Mounted Corn Seeder

The AMDP plow-mounted corn seeder (Figure 8) is developed for upland corn marginal farms. The seeder is mounted on the frame of the moldboard plow. The distance between hills in a row (75 cm row distance) can be adjusted from 25 cm or more by changing the combinations of the chain-and-sprocket assembly that connects the ground wheel to the metering device. The technology is simple and low-cost, and can be operated by women. Its capacity is approximately 0.25 hectares per day at 1 to 3 seeds (open pollinated variety) per hill or a seed requirement of about 20 kilos per hectare. The furrowing and planting operations are combined into one operation, which makes the technology more efficient. The technology had been extended in Siquijor, Zamboanga del Sur, and Cebu provinces.

Figure 8: BIOMECH/AMDP Plow-Mounted Seeder

AMDP Pneumatic Corn Planter

The AMDP Pneumatic Corn Planter (Figure 9) can be used for planting hybrid corn and legumes such as soybean and white bean. It has a pneumatic metering device which uses blower with vacuum to pick up seeds. It provides minimal mechanical seed damage; is less sensitive to shape; and has better singling of seeds. It is mounted to a four-wheel tractor mounted and ground wheel driven using two 2 tires. It accomplishes seed metering, seed placement, depth control, soil covering and pressing with adjustable seed spacing. The planter can be equipped with fertilizer or herbicide applicator (Orozco, 2011; CEAT, 2011).

Figure 9: AMDP Pneumatic Corn Planter

UPLB Single-Row Organic Fertilizer Applicator

The UPLB Single-Row Organic Fertilizer Applicator (Figure 10) is a two-wheel tractor-drawn single-row fertilizer distributor. It can apply organic fertilizer (e.g. chicken manure) at 1 ha/day. It is attached to a toolbar and hitched to a hand tractor. The operator controls the applicator through a pedal that raises or lowers the ground wheel. The toolbar also has a furrow opener which can be raised and lowered through a hand lever. The machine consists of the major components: hopper, auger-type metering device, power trans-mission, and ground wheel. The power transmission is ground wheel actuated through chain and sprockets, intermediate vertical shaft, and a three-ring joint connector. It is equipped with a positive displacement metering device, adjustable metering rate, and a furrow opener. It weighs about 88 kilograms without the tractor and can be operated by one person (AMDP, 2009).

AMDP Mini Corn Mill

The AMDP Mini Corn Mill (Figure 11) can be fabricated using locally available materials. The machine is compact and portable and consists of a degerminator and pin-type milling assembly. It has replaceable milling screens to mill different corn grit sizes. The milling capacity is 50 -150 kg/hr (1.15 - 4.88 mm particle size). The machine requires 3.73 kW electric motor as power source and one operator (AMDP, 2009).

Figure 11: AMDP Mini Corn Mill

AMDP Pneumatic Dryer for Coconut Meat Residue

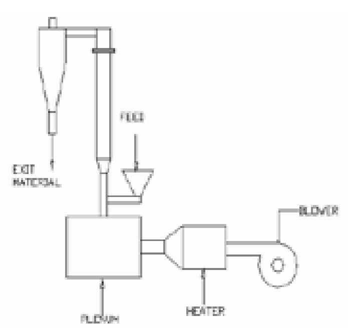

Figure12: Schematic diagram of the AMDP Pneumatic Dryer

A pneumatic dryer is capable to function under high temperature with high velocity, high thermal efficiency, and short duration of drying. In pneumatic drying, wet material is mixed with the stream of heated air and is conveyed through the drying duct where high heat and mass transfer rapidly to dry products. The AMDP-developed pneumatic dryer (Figure 12) is designed to improve drying system for coconut meat residue. The use of pneumatic dryer can be integrated in the production of cooking oil, virgin oil, and flour. While producing these products, coconut meat is pressed to extract coconut milk and its by-product ("sepal") weighs about 50% of the original amount. The residue was previously regarded as waste. The interest in the technology (Rodulfo, 2011) increased when a study of the Department of Science and Technology (TIPS, 2005 as cited by Rodulfo, 2011) found that when "sapal" is processed into flour, it has a significant amount of dietary fiber, which helps control diseases such as cancer, cardiovascular illnesses, and diabetes.

Village Level Ethanol Production System

This Village Level Ethanol Production System technology (Figure 13) may better rural livelihoods since it can be a dependable source of energy and fuel. Ethanol can be used as fuel in modified gasoline engines which can provide electricity for lighting purposes when coupled to generator. It can also be used as fuel in modified gasoline engine as power source for power tiller, irrigation pump, thresher, and other agricultural machines that require power. The equipment including the distilling apparatus is low cost, easy to fabricate and assemble, and can be operated by one person. It can be used to distill fermentation broth (beer) from different feed stocks such as starchy materials (corn, cassava, sakwa), saccharine materials (sugarcane, molasses, fruits) and coconut toddy (tuba). The distilling capacity is about 1 liter of anhydrous ethanol, 170 proof (85%). Fuel wood, bagasse, rice hull or any available farm by-products can be used as fuel to serve as heat source of the apparatus (AMDP, 2009).

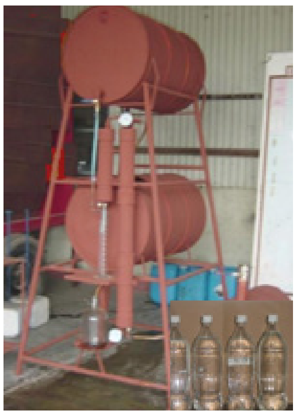

Figure 13. Village-level Ethanol Production System

Faculty-based projects

Backyard Airlift Aquaponics System

Hydroponics and the growing plants without soil have been combined with aquaculture in integrated systems commonly referred to as aquaponics (Figure 14). The fish waste provides nutrient source for the growing plants. The plants together with screen and gravel biofilters serves as treatments of the water for its recirculation and reutilization. The system can be an efficient and

Figure 14: Backyard Airlift Aquaponics System

space-saving method to grow fish, vegetables, herbs, flower plants, and can be integrated in gardens. The aquaponics system will also enable users to produce their own fresh food for consumption or possibly for sale (UPLBAA, 2011).

Anthropometric Survey of Farmers in the

Calabarzon Area

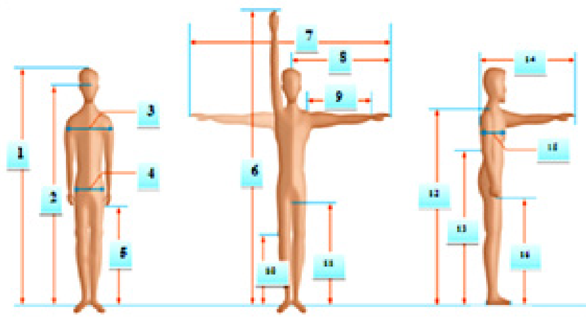

Figure15: Illustration of Measurements of Respondent in Standing Position

The primary objective of this project is to develop an anthropometric profile of farmers in the CALABARZON area that are essential in machine and workstation design. The anthropometric data shall provide designers the information that will "fit the machine to the user" by analyzing the profile of the population to be served. Figure 15 shows an illustration of the measurements of respondent in standing position. The available information will ensure that the designed machines will not provide discomfort and danger to the user. As of 2013, a total of 836 farmers (429 male and 407 female) from CALABARZON were measured for anthropometric data. Efforts are continuing to achieve the data requirement that will represent the population devoted for agriculture at the regional and eventually at the national level. Moreover, there is also a need to evaluate the existing machine designs based on users' dimensions and modify the machines to increase the man-machine system's efficiency (Amongo and Onal, 2014).

Mechanization of Heat Treatment of 'Carabao' Mango for Quarantine Disinfestations and Disease Control

The `Carabao´ mango is one of the major export products of the Philippines. Disease management on the farm and postharvest heat treatments are recommended to address postharvest diseases such as anthracnose and stem end rot. Hot water treatments at 52-55°C for 10 min, which were previously implemented to fight these diseases, had been gradually replaced by the hot water dip (HWD). HWD has a shorter treatment time of 1 min at 60°C. The current hot water tanks used for heat treatment have low capacity and fruit handling is done manually. The current needs of the industry are designs with mechanized handling and greater capacities to meet larger fruit volume (Yaptenco et al, 2013).

Figure 16: Rendered View from an Autocad Drawing of the Designed Lifting Device (Yaptenco and De Ramos, 2012).

The objective of the project is to develop a mathematical model of the temperature distribution in `Carabao´ mango fruit during heat treatment; and develop a mechanized system for heat treatment of 'Carabao' mango against postharvest diseases and/or insect pests. A prototype mechanical lifter for loading and unloading of a 20-crate hot water tank was field-tested (Figure 16). Hot water treatment (52-55oC, 10-min dip) of two batches of fruit were prepared and weighed prior to hot water treatment. Result showed that the lifter could handle the fruit weight (466 and 465 kg) during loading and unloading of the hot water tank. Improvements on the design were made based on the field test. The study also developed a program using the Visual Basic programming language to model fruit temperature during heat treatment (Yaptenco, et al, 2013).

Design, Testing and Installation of Micro-Hydro System

The utilization of micro hydro systems to produce electricity and mechanical power is one of the major potential sources of renewable energy. One important application of micro hydro systems is its utilization as an alternative source of power in the farm. The micro hydro-power systems power rating is 100kW or less. A 100kW system will produce 100 standard units of electricity in an hour. Micro hydro systems have been popular in less-developed countries for a number of years and are making rural communities avail electrification in areas with hydro-power potential but without a grid network. The study found that most micro hydro generation systems in the country are imported. Such systems are usually utilized for electric generation mainly for household consumption especially in the off-grid areas. One major problem of these imported machines is after sale services since the generator system is imported. The general objective of the project is to design a localized micro hydro system as source of farm power. The project had already developed test standards for micro-hydro generator. The developed system had been installed in an area to determine its performance (Figure 17) (Amongo et al, 2014).

Figure 17: Assembly and Installation of Micro Hydro Set Up.

Field Testing of AMDP/ABPROD RICE HULL FURNACE

Rice hulls or husks are widely used as source of heat for power generation or heating for agricultural processing operations such as drying. AMDP/ABPROD had developed a furnace model using rice hulls as power source (Figure 18) for flatbed dryers and recirculating dryers for fruits and vegetables, and paddy grains. The furnace had to undergo field testing in a rice-milling operation processor, or trader conditions, where high utilization rates can occur and demand for higher efficiencies are required. The flatbed dryer and furnace were field tested at Ferdie's Rice Mill, Brgy. San Ignacio, San Pablo City (Casas, 2013).

Figure 18: AMDP Rice Husks Furnace for Fruits and Grain Drying

Design and Installation of WECS at PSFI Training Center, Rizal Province

Wind energy conversion system (WECS) is a system that converts wind energy to either mechanical energy or electrical energy.

According to Schalager and Weisblatt (2006) (as cited by Onal 2013), harnessing wind energy for electricity generation was not given much interest until the first oil crisis in the 1970s. The technology of using wind energy for electricity generation is relatively new though rapidly growing (Fanchi 2005 as cited by Onal 2013). This can be resulted from the threat of all-time possible fossil fuel crisis.

Figure 19. Wind Profile Generation at PSFI for WECS Design.

Site characterization is important in the design process of any WECS. Wind atlases for the whole country are available. However, the data were presented in vast areas, which are not usually suitable for specific areas. Also, the wind profile generated in these atlases were measured at low heights (usually at 2 meters above the ground), which is not suitable for most WECS applications because the suitable wind speed is usually found at higher elevations. Thus, there is a need for site characterization before the development of any wind energy conversion systems. The general objective of this project is to develop a localized wind energy conversion system (WECS) for mechanical and electrical generation at PSFI Training Center in Pililla, Rizal (Onal & Amongo, 2014).

Automation and Design Improvements for the SINAG

(Solar Incubation for Agriculture) System

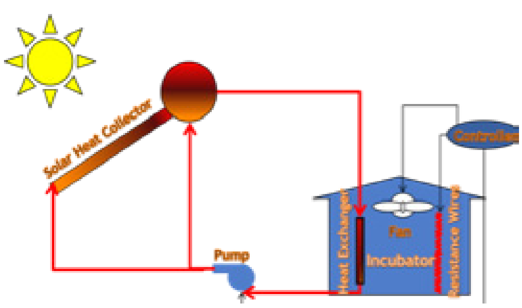

Figure 20: Illustration of the SINAG System

The new project is an off-shoot of a previous DOST project entitled Development of SINAG: a solar assisted egg incubation system (Figure 20), aimed to provide the poultry industry a technology suited for small to medium scale egg production system. Project results showed that 72.6% of the electrical energy could be conserved by the SINAG system. Despite the favorable result, design modifications of the system are still needed to further improve the system. The objective of the project is to further improve the design of the SINAG prototype through automation design of a more energy efficient heat collection and heat delivery system to the incubation space (Paras Jr., 2016).

Design and Development of a Machine Vision System for Sorting Mango

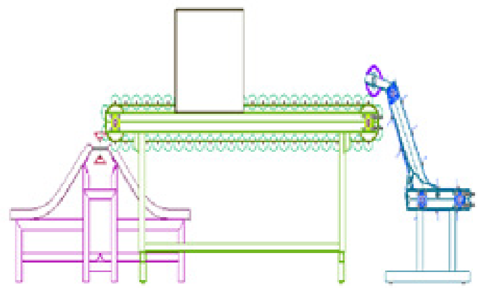

Figure 21: Illustration of a Machine Vision System for Sorting Mango

The main objective of the project is to design and develop a machine vision system for quality sorting of mango. It aims to enable a computer software to a) extract characteristic features such as fruit area, diameter, length, perimeter, circularity, and defects from images of mangoes, b) build a rotary conveyor system to handle, c) classify mangoes according to ripeness, shape, and defects, d) test and verify the developed software under static condition; and e) evaluate the performance of the system using three feeding rates.

Hydroponic Green Forage Production for Crossbred Dairy Buffaloes

Figure 22: Hydroponic Corn Seedlings

The hydroponic green forage production (Figure 22) in comparison to traditional field forage production has numerous advantages as follows: (a) continuous supply of fresh green forage especially during drought period, (b) efficient and conservative watering system for growing forage, and (c) higher land area productivity.

These advantages may bring higher returns for buffalo raisers with good herd management. Crossbred buffaloes can sustain higher milk production (7 to 10 liters per day) when provided with comfortable environment and adequate nutrition, among other factors. Dairy buffalo farms may experience shortage in forage supply due to climate change-induced events like flooding and drought. Hydroponic green forage production system is an alternative forage production system that can be introduced to buffalo farms to ensure continuous supply of high-quality green forage. The project aims to develop a hydroponic green forage growing system, and determine the feeding potential of hydroponic corn sprouts as green forage for crossbred dairy buffaloes (Saludes and Ballaran, 2014).

V. Other efforts on precision agriculture and fisheries technologies in the Philippines

The Department of Agriculture formulated a Policy and Implementation Program on Climate Change, which highlights the general impacts of climate change in the Philippines. It also identifies the general impacts of climate change in agriculture and fisheries sector. Moreover, it outlines the policy imperative, which underlines the important aspects of including climate change concerns in all areas of public policy, particularly in research, economic and social policies. The DA climate change program has the vision of "a climate risk-resilient Philippine Agriculture and Fisheries with healthy, safe, prosperous and self-reliant farming and fishing communities and thriving productive ecosystems". Its goal is "to build the adaptive capacity of farming and fishing communities and increase the resilience of natural ecosystems to climate change and optimize adaptation with mitigation opportunities towards sustainable development".

The general adaptation and mitigation measures to climate change were given as guidelines in implementing the required policy instruments to address climate change risks. These policy instruments include 1) climate information system for agriculture and fisheries, 2) research and development for adaptive tools, technologies and practices, 3) fully engaged extension system, 4) repair and improvement of irrigation systems and establishment of SWIPS and SFRs, 5) climate-resilient agri-fisheries infrastructures, 6) regulations to ensure effectiveness and safety, and 7) windows for financing and instruments for risk transfer.

Precision agriculture is categorized under policy instrument 3) research and development for adaptive tools, technologies and practices. Under this category, precision agriculture is referred to "a fine-tuned agricultural production that considers planting dates based on weather predictions, planting designs that considers sun and wind exposures, varieties highly suited to the soil and weather patterns, and the delivery of water and other inputs at the right time and right amounts. Research on this area should be done on a crop-by-crop or species/breed-by-species/breed basis for livestock production and aquaculture as well as by location including urban areas".

Following guiding principles included in the DA Policy and Implementation Program on Climate Change, DA agencies included R&D on Precision Agriculture and Fisheries Technologies that will adapt and mitigate the negative impacts of climate change. Some of these efforts are provided in the following discussions.

Philrice

PhilRice in 2015 presented its National R&D Highlights on Coping with Climate Change Program. Among others, the following major activities were undertaken.

1. Coping with Climate Change Program

This Program started in 2013 with the goal of helping the country attain food self-sufficiency amidst the challenges caused by climate change. The following projects are being implemented:

Project 1: Generating and managing local knowledge and information on climate change

a. *Analyzation on the impact of climate on rice using long term data at PhilRice Central Experiment Station*
b. *Identification of the growing degree-day (GDD) requirements at different phenological stages of public hybrid rice parental and other inbreeds*
c. *Impact of increasing temperature on rice insect pests and natural enemies*

Project 2: Developing technologies that would help farmers adapt to or manage the impact of climate change

a. *Optimal planting dates based on recent agro climatic indices for rice and rice-based crops in Ilocos region*
b. *Design and development of prefabricated components for a low cost, easy to build and typhoon-resistant multi-purpose farm structure*
c. *Irrigation by capillarity: development of an efficient method of irrigation for extreme drought*

Project 3: Enhancing rice farmers' resilience by providing them opportunities to produce additional sources of food and income

a. *Maximizing the use of the continuous rice hull (CtRH) carbonizer in generating additional sources of income for enhanced climate change resiliency of rice-based farming communities*
b. *Rice-duck-based farming system for enhanced climate change resiliency of farming households*

2. Incorporating Decision Support System for Agrotechnology Transfer (DSSAT) in RDE Projects

In PhilRIce, efforts are being made in integrating DSSAT as component parts of their RDE projects. Researchers are trained on the application of a software program consisting of crop simulation models on rice science and technology. DSSAT integrates the effects of soil, crop phenotype or traits, weather, and management options on crop yield and allows software users to ask 'what if' questions by conducting virtual simulation experiments on a computer within minutes. Moreover, the agri-tool can simulate how specific crop varieties perform under different environmental conditions. Technologies need to be developed to provide recommendations for farmers to achieve the maximum potential of their land. Through the agri-tool software, information on appropriate crop management strategies and expected yield performance can be easily predicted by simply calibrating the parameters like soil, climate, and farm inputs.

3. Farming without Fossil Energy Program

Another program being implemented by PhilRice is the Farming Without Fossil Energy. Generally, the program aims to substantially or entirely remove use of fossil fuels as energy source in rice and rice-based farming by developing alternative energy sources and inputs to come up with sustainable and cost-effective rice and rice-based farming systems. It will explore use of biomass waste, wind, sun, water and plants to develop processes and technologies that would aid in reducing dependence on fossil fuels in rice and rice-based farming operations. Likewise, the program will identify available rice production technologies that are resource use-efficient. The program includes projects on:

Development of Renewable, Alternative, Diversified and Decentralized Energy Resource System for and from Rice-Based Agriculture

a. *Adaptation of Low External Energy Input in Rice-Based Farming*
b. *Evaluation and utilization of alternative and potential non-fossil fuel based (nFFB) nutrition for rice farming*

PHilMech

Some of the projects of PHilMech on AFMTs are the following:

1. Cold chain system for high value crops
2. Computer Vision System for the Physical Quality of Milled Rice
3. Coconut Water Pasteurizer/Chiller
4. Far Infrared and Convection Heating System for Dried Mango
5. Controlled Atmosphere for Philippine Mango
6. Rubberized Conveyor for Onion Sorting
7. Soybean Sorter
8. Soybean Postharvest and Mechanization system
9. Soybean Processing System

DA also launched its program entitled: Strengthening the Implementation and Adaptation and Mitigation Initiative in Agriculture (AMIA) (DA-AMIA Brochure, undated), which features a climate resilient bunker-based storage systems for seed production, water harvesting, and sustainable agricultural productivity. It also focuses on key factors in agriculture and fisheries such as 1) policies on research and development, 2) policies on agricultural extension, 3) analysis and evaluation on renewable energy utilized in the production systems, 4) the best practices and disaster risk reduction and management due to typhoons, drought and floods in agriculture, and 5) the language of disaster in major language groups in farming and fishing areas in the Philippines (AMIA, 2016).

These projects were done by DA in response to the challenges of climate change in the agricultural and fisheries production systems of the country.

PCAARRD-DOST

1. Improving Rice Planting, Harvesting and Milling in the Countryside

DOST PCAARRD embarked on a project to address the economic losses from rice production and postproduction operations in the country through the Strategic S&T Program for Rice, wherein one of the components is the Rice Mechanization Program. The Rice Mechanization Program is expected to contribute to the reduction of rice harvesting and threshing losses from 4.2% to 1.8% in 2020. It will also help lower the losses from drying paddy rice, from 5.8% to 3.8% in 2016.

The program includes the development of harvester, transplanter and compact rice mill by the DOST-Metals Industry Research and Development Center (DOST-MIRDC) and the Department of Agriculture-Philippine Center for Postharvest Development and Mechanization (DA-PhilMech). MIRDC and DA-PhilMech also developed and tested rice transplanting and harvesting attachments that can be mounted and dismounted from the hand tractor. These affordable implements will help increase the utilization of hand tractors and can potentially reduce the cost of farm level mechanization.

2. Training on Design, Tools and Techniques for Precision Agriculture/Smart Farming

The Cavite State University (CavSU) hosted the PCAARRD-sponsored Training on Design, Tools and Techniques for Precision Agriculture/Smart Farming on 4-8 June 2012, Cavite State University, Indang, Cavite. The training aimed to provide the researcher-participants with knowledge and skills on the use of existing tools and techniques to S&T projects especially in the agriculture, aquaculture, and natural resources sectors. Twenty researchers from eight regions in the country representing the academe (SUCs and private) and national agencies under the DA and DOST participated in the training. The lectures/discussions were the following: 1) Smart Farming/Precision Agriculture Models at the National and Global Level - with emphasis on hydroponics and aquaponics, 2) Basic Engineering Processes/ Flow Charting in the Design Process Practical Application of Robotics, 3) Fundamentals of GIS and Remote Sensing, 4) Development of Microcontroller Applications to Agriculture, 5) Practical Pneumatics and Hydraulics, and 6) Machine Vision for Quality Evaluation of Rice and Corn. Hands-on sessions included application of the principles learned in developing mini projects such as environmental monitoring system, brooder temperature controller, irrigation control, flood control/monitoring, and automatic sizer.

Conclusion

The increasing interest over the years on the utilization and application of agriculture and fisheries mechanization technologies has been raised due to many challenges including climate change, energy security, food sufficiency and security, environmental protection and conservation, and population growth, among others. Such real challenges are being faced not only by the Philippines but also by other countries located in Asia and the Pacific region and even the world.

In seek of logical responses, regional and government planners, RDE practitioners, and other concerned stakeholders took steps to address these challenges and problems. On the government side, strong policy commitment and guidelines are necessary towards achieving the vision of a climate risk-resilient Philippine Agriculture and Fisheries Sector. On the RDE side, technology innovations and climate resilient agriculture and fisheries mechanization technologies are imperative to adapt and mitigate the impacts of the combined effects of the challenges of climate change.

In the Philippines, necessary policy environment in the agriculture and fisheries sector is in place for implementation. RDE efforts have already been pursued by research, development and extension agencies on AFMTs. (e.g. National Building Code 1972, AFMA Law 1997, IP Code 1998, Solid Waste Management 2000, Biofuels Act 2006, Renewable Energy Act 2008, Climate Change Act 2009, AFMech Law 2013, SIDA Law 2014, ABE Law 2016)

However, there are also inadequacies in the implementation structure on the development and implementation and promotion of AFMTs in the grassroots level. Although these are initially being pursued under the AFMech, there is a need to strengthen the other stakeholders particularly at the local government units' level.

Indeed, the greater challenge lies on the technology innovators and technology change agents to comprehensively and cohesively develop and extend capacity building of AFMTs, which will help empower farmers and communities to achieve farming efficiencies and productivity in a safe and healthy environment.

Republic of Korea
Current Status of Agricultural Engineering Research and Climate-smart Agricultural Policy in Korea

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Agricultural Engineering in Korea has played an important role in the improvement of food self-sufficiency rate to uplift the country from the poorest countries to one of the rich countries. It has a leading role in the phenomenal development to overcome the barley hump, a serious food shortage until the 1950s. However, great efforts have been made to develop agricultural-engineering-based agriculture based on accumulated technology and compressed experience for rural development to enhance the economic strengths of Korea in international community. Before it is too late, we need to learn valuable development experiences and technologies to address national interest, create new employment opportunities and secure overseas food for future use.

Globalization refers to the fact mutual dependence in the international community is increasing and countries are progressing as a single system. Boundaries of each nation and state are weakened, which is a phenomenon that will continue to happen since the world is connected to one. It means that the interdependencies among nations and states will deepen. To promote the globalization of Korean Agricultural Engineering, it is necessary to consider what mutual dependence and a single system of Agricultural Engineering mean.

From this point of view, in this paper, the present position of Korean Agricultural Engineering was presented by reviewing peer-review papers published on journals of Korean Societies of Agricultural Engineering (KSAE) and Agricultural Machinery (KSME). Additionally, recommendations have been made for the globalization of Korean Agricultural Engineering.

Past and Present of Korean Agricultural Engineering

After the 1900s in Korea, Agricultural Engineering can be characterized by five eras as shown below.

1. 1900-1945 was the time that modern irrigation works were established with some irrigation associations, and agricultural water management system was introduced to farmers. Agricultural infrastructure modernization during this period underwent a rather dark time.
2. 1946-1969 was the time that water management worked for overcoming poverty and food shortages. Because of an insufficient agricultural infrastructure, serious food shortages were experienced every year. Because of floods and drought, the infrastructure development and reclamation projects have been very actively conducted in full-scale since the 1960s.
3. 1970-1989 was the time to achieve self-sufficiency of

rice that is an agricultural base to expand promotion of large-scale agricultural development projects and ongoing agricultural-based business.

4. 1990-1999 was the time to focus on raising agricultural competitiveness as investment and maintenance base of agricultural production in order to correspond to the era of globalization. Investment was also made for the improvement of large-scale farming and farming and fishing communities.
5. 2000 to the present, while human and agriculture and nature are coexisting, the focus has become to ensure the quality of rural life. For this reason, it has placed farming and fishing community development, restoration of the natural and ecological environment that has been damaged in the development with full commitment, and the emphasis on the top facility agriculture in order to develop export agriculture. For this reason, farming and fishing community development and restoration of natural and ecological environment have been achieved with full commitment. In addition, the importance of export agriculture has been emphasized on the top level.

During time 1) and 2), financial status was not enough to meet and support the country's demand based off of liberation and colonial rules. Accordingly, full-scale agricultural development was not carried out. However, from time 3), financial status of the state got better thus some efforts were put into the rural areas and investment plans were made. Agriculture and industry technologies dramatically developed as a consequence of the Saemaul Movement, which showed that civic movement could be promoted to vigorous agricultural development. For this reason, Korea was able to succeed in agriculture and rural modernization in which the Agricultural Engineering technology had greatly developed within a short period of time of less than 50 years. At the same time, efforts were also made to restore, protect, and conserve natural ecosystems while advancing farming and rural development.

Researches of Korean Agricultural Engineering

Like many other Asian countries, Korean Societies of Agricultural Engineering (KSAE) and Korean Societies of Agricultural Machinery (KSME) have made significant contribution to the development of rural area as well as agriculture for more than 50 years. In this subchapter, publications on those two journals will be introduced to show current status of researches that are actively conducted in Korea. Figure 1 shows the major sessions of KSAE with number of published papers for 2014-2015. KSAE has 6 working groups in total which are: water management, soil engineering, agricultural buildings, rural development, rural information, and local environment. About 42& of KSAE's published papers were about agricultural water utilization; 21% about subgrade and agricultural land engineering, and 17% about agricultural facility and structure. Studies on agricultural buildings such as greenhouse and livestock houses have been greatly supported by Korean government recently because more than 64% of land is mountain area with very distinguishable seasons. There are many important limitations restricting productivity of agricultural products in these areas. Only protected cultivation can guarantee an annually stable production of high-quality agricultural products. Figure 2 shows that the published papers of each working group were categorized using some typical keywords.

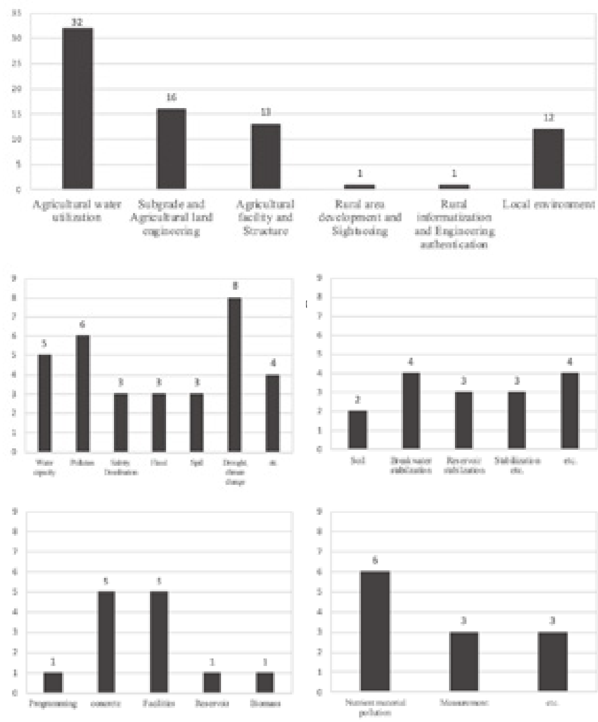

Figure 2: KSAE Published Papers of 4 Research Fields Categorized Using Some Typical Keywords

Figure 3 shows the major sessions of KSME with number of published papers for 2014-2015. KSME has 5 working groups in total, namely: off-road machinery system, agricultural environment system, agricultural process and food engineering, biological engineering, and information and complex technologies. About 33% and 37% of KSME published papers were about off-road machinery and process and food engineering, which indicates the two leading research fields. While studies on off-road machinery have been led by commercial companies more than universities, food processing has been very hot topic. Those studies have brought a lot of benefits to farmers and related industries, much more than simply selling agricultural products. Figure 4 shows that the published papers of each working group were categorized using some typical keywords.

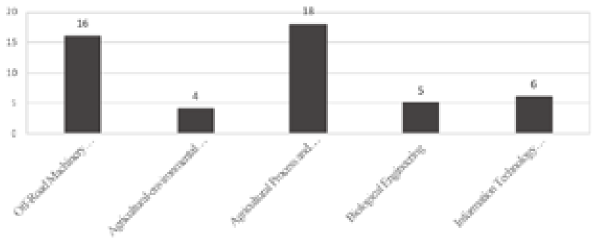

Figure 3: KSME Published Papers for Totally 5 Research Area from 2014 to 2015

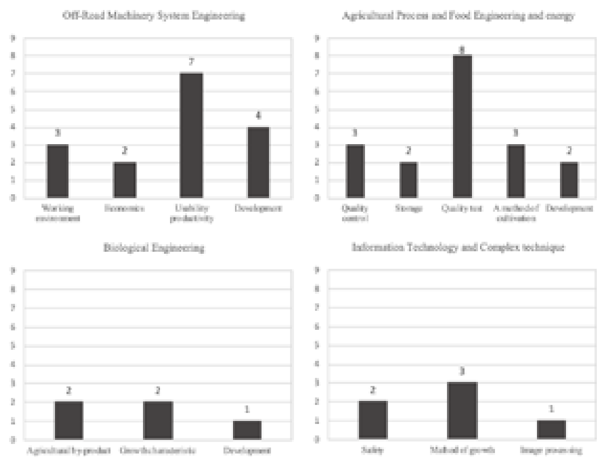

Figure 4: KSME Published Papers of 5 Research Area Categorized Using Some Typical Keywords

Climate-smart Agricultural Policy

- Necessity for establishing Climate-smart agricultural policy designed for Korea considering regional uniqueness
- Candidate for Climate-smart agriculture technology designed for agricultural conditions of Korea
- Policy considerations for vitalization are classified as follows
    - Research/technology development
    - Economic means
    - Regulatory means
    - Promotion/education
    - Support for organizing joint activities of producers

1. Research/Technology Development (R&D)

- Develop technology that can be used practically (disease and harmful insect control, soil nutrient management, energy saving, water management technology)
- Develop drought-/cold-tolerant varieties
- Develop GHG MRV (measurement, reporting, verification) technology
- Develop weather forecast technology for agriculture

2. Economic means

- Support farmers to have a stable income
- Vitalize value chains and related agricultural market
- Make investment and provide loans to buy agricultural equipment
- Promote consumption by using policies currently enforced as Climate-smart agricultural policies including crop insurance, direct payment program for eco-friendly agriculture, carbon offset program through emission trading scheme (being planned) and certification program for low-carbon agricultural and livestock products

3. Regulatory means

- Direct regulation about environmental standards (Regional Nutrient Quota System, GHG Emission Target Management Scheme, setting up standard for applying chemical fertilizers, monitoring regulations for environmental standards)
- Regulation by using levies (scheme for agricultural water fee, carbon tax, levy on fertilizer/agricultural chemical/surplus livestock animal waste)
- Policies currently enforced that can be used as Climate-smart agriculture policies- GHG Emission Target Management Scheme, and standards for applying chemical fertilizers

4. Promotion/Education

- Train CAS research and technology experts
- Train farmers specialized in CSA
- Establish systematic CSA education program
- Build comprehensive CSA consulting system designed for local situations
- Policies currently enforced that can be used as Climate-smart agriculture policies-technology education, early warning system model project

5. Supporting organizations for producer's communal activities

- Strengthen the power of producers association
    - Provide support to hold events related to CSA

- Provide support for activities based on regional community
  - Provide support to build cooperative unit and district (districts for environment-friendly agriculture, etc.)

Considerations under the Trend of Globalization

Globalization at Agricultural Engineering field has brought inevitable infinite competition. There are needs to solidify development experiences and technical capabilities and utilize them in the real world. Globalization can be a product of economic, science and technology, socio-cultural, and political power. It is also receiving criticism that the world restructuring is focused on economic powers.

It is also true that exclusive development of economic and technology requires massive capital, technology, and professional services. There are myriads of instances demonstrating that globalization is cast sweeping influences across different aspects of life. Such a phenomenon is particularly obvious in the development of smartphone, electronic components, automobile, pharmaceuticals, and agricultural seeds. However, there is also evidence indicating that globalization has deepened the gap between rich and poor in all nations. Accordingly, in the foreseeable future, there is also possibility that a regression to protectionism from the free trade principle will take place. Thus, cooperation of collaboration among all stakeholders from experts from agriculture and industry areas would be crucial in ranking up the Korean Agricultural Engineering in the world.

Russia
Climate-smart Agriculture and Mechanization in Russia

Mr. Nikolai Vasilev
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NW MTS is one of the leading machine-stations that test agricultural machinery and technologies and is the westernmost station of Russia. Its projects mainly take place in Leningrad, Novgorod, Pskov and other areas of North-West Russia, including Kaliningrad oblast.

During the period from 1949 to 2015 NW MTS tested a sample of 4844 machines including 1581 experienced production and 2218 serial machines, imported 770, and recommended 275 models of machinesto the manufacture.

NW MTS has conducted tests for compliance with environmental regulation on the following topics:

- Amount of harmful emissions into the atmosphere;
- Opacity;
- Pressure propulsive ground.

Activities of the NW MTS:

- Testing of agricultural machinery;
- In a survey of agricultural machinery ordinary operation;
- Monitoring the quality of petroleum products used in the agro industrial complex;
- Testing of agricultural productions technologies;
- Information materials: articles, analytical materials.

NW MTS is the only systematic machine stations in Russia, which carries out equipment and technologies tests for cleaning and recycling of stones from the arable horizon; as well as testing of equipment and technologies for cultivation of agricultural crops on soils littered with stones.

Fodder for cattle in NW region

Stones cause critical damages to agricultural machines. Such damages often entail expensive repairs.

Along with the stone issue, in the fields of North West region of Russia, there is a problem of oversaturation of the fields with moisture. NW MTS monitors the climate condition in the region. In NW region, during the period from May to September in 2016, precipitation amount was 189% more than the amount in 2015 and 142% more than the amount in 2014.

Sri Lanka
Sustainable Small Scale Agricultural Mechanization in Tropical Countries

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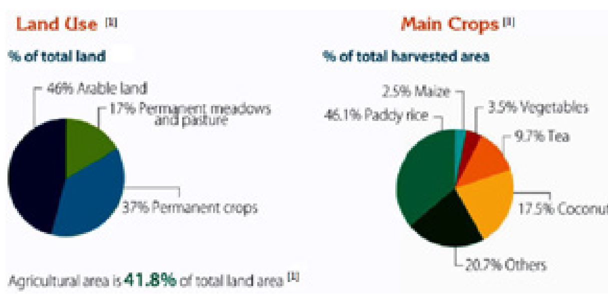
The Democratic Socialist Republic of Sri Lanka is situated on an island just off the southern tip of India, (between 50 55' and 90 50' North and 790 42' and 810 53' East; 432 km North to South; 224 km West to East). Most Sri Lankans live in rural areas. Therefore, special attention has been given to rural development and land reform. The urban population (21.5%) is mainly concentrated on greater Colombo and five other cities. But 70% of Sri Lanka's population lives in the south-western economically and climatically favored provinces, which only takes up 30% of the country's land. The dry zone accounts for 60% of the land but has only 20% of the population. Population density per square kilometer was 323 in 2004 (Annual Report Central Bank, 2014).

Land Use

- Agricultural land - approx. 2.6 million hectares (42%)
- Number of smallholder farmers - 1.65 million
- Average landholdings - less than 2 hectares
- Smallholder farmers are in charge of almost 80% of Sri Lanka's total annual crop production

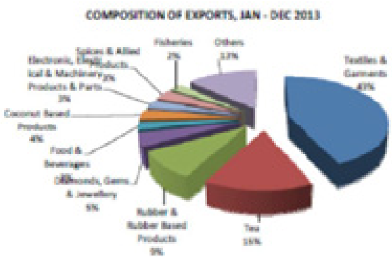
The agricultural area in Sri Lanka has increased gradually in the past decade. With the end of internal conflict, previously inaccessible territories have been converted into productive cropland. From 2003 to 2013, rice-harvested areas increased by 30.4% (911,440 to 1,188,230 hectares) and maize-harvested areas increased more than double (27,060 to 67,720 hectares).



Economic Relevance in Agriculture

- Contribution to National GDP – 12%
- Total Agricultural Imports - US$ 1,818 million
- Total Agricultural Exports - US$ 2,066 million

Sri Lanka's agricultural sector is performing below its potential. Overall, it achieves low levels of productivity and suffers a lack of diversification. Strengthening the agricultural sector will require overcoming major social, economic, environmental, and policy-related challenges. The country's staple crop, irrigated paddy rice, requires 1,500 mm of water annually. Irrigation systems and drought-resistant varieties are widely used in Sri Lanka; however, accessibility and affordability are limiting factors for smallholder farmers.



Water salinity poses another major threat since more than 45,000 hectares of agricultural land are affected by salinity due to improper irrigation techniques and poor drainage. In addition, soil degradation resulted from soil erosion challenges crop productivity and food security.

The overuse of inorganic fertilizers and chemicals endangers soil quality and compromises public health. In 2014, Sri Lanka imported 765,000 tons of inorganic fertilizer and approximately 8,200 of formulated pesticide products to support the agricultural system. More than 70% of imported fertilizers are used for paddy rice cultivation, owing in part to generous state subsidies for rice cultivation. This indicates that policies curtailing excessive use of synthetic fertilizer are required, which should focus on providing farmers recommendations of improved fertilizer management practices, promoting the use of judicious combination of organic and inorganic fertilizers, training farmers on nutrient management, and raising public awareness of environment protection.

Sri Lanka faces challenges in meeting its sustainability and productivity goals, particularly with respect to the livestock and chicken production systems. Practices such as silage challenges the agricultural sector in terms of the following aspects:

- Low levels of productivity
- Lack of labor/high cost of labor
- Change in weather patterns (i.e Maha 2016/17)
- Lack of diversification
- Salinity due to improper irrigation techniques
- Soil erosion challenges crop productivity
- High wastage during transportation (up to 40%)
- No proper markets

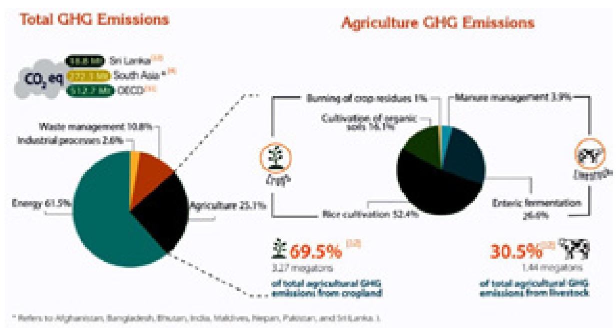
Climate Change Effect in Sri Lankan Context

- Over 19,900 cases of climate induced disease issues among the livestock are reported by 18 districts by May 2014
- Over 1.8 million Sri Lankans are affected by drought since 2013
- Sri Lanka's economic loss from floods alone has been USD 1 billion for 10 years (Humanitarian Bulletin, Sri Lanka, Issue 03 I Aug 2014)
- 87,281 ha of paddy lands were affected in Maha 2013/14
- Most agriculture-based livelihoods in the Dry and Intermediate Zones were affected

(Rapid Food Security Assessment in Districts Affected by Erratic Weather Conditions in Sri Lanka: Preliminary findings April 2014)

Green House Gas emissions

Agriculture accounts for 25.1% (4.71 megatons CO2 equivalent) of the country's total greenhouse gas (GHG) emissions, which is almost three times less than the energy sector (61.5%) but is more than the waste management (10.8%) and industrial sectors (2.6%) GHG emissions from cropland (mostly rice cultivation and cultivation of organic soils) account for 69.5% of total emissions, while the livestock sector (especially enteric fermentation) accounts for 30.5%.



Sri Lanka's Contribution for CSA

Sri Lanka was one of the first 50 countries to ratify the United Nations Framework Convention on Climate Change (UNFCCC) in 1993.

It became a signatory to the Montreal Protocol and the Kyoto Protocol in 2002.

Sri Lanka's Policies towards CSA

- The National Environmental Policy (NEP), 2003.
- The National Climate Change Policy (NCCP), 2012.
- The National Climate Change Adaptation Strategy (NCCAS), 2011–2016.

- The Action Plan for Haritha Lanka Programme, 2009.
- The Roadmap for Disaster Risk Management, 2005.

Sri Lankan Government Interventions for CSA

- The Department of Agriculture's (DOA) complementary programmes "crop germplasm collection" and "systematic crop comparison" are carried out by farmers in different agro-ecological regions, with the aim to improve access to new climate adapted genetic material. State protection is guaranteed.
- Price schemes, particularly in paddy rice, tea, milk, and chicken, have the potential to encourage the adoption of particular mitigation and adaptation practices such as livestock integration and crop diversification.

CSA Practices

- Short-duration and drought-resistant varieties
- Zero tillage
- Rainwater harvesting
- Micro-irrigation
- Soil conservation
- Practices include the introduction of salt-tolerant varieties
- Construction of ditches, contour planting, mulching, manure harvesting, and use of cover crops

CSA Practices – Where Mechanization Can Contribute

1. Planting with onset of rains
2. Water conservation
3. Zero tillage
4. Organic fertilizer
5. Rain water harvesting
6. Seasonal adopted planting time
7. Changing planting establishment methods –dry sowing

Planting with Onset of Rains

- Adjusting the cropping calendar by planting with the onset of rains
- Changing water patterns
- Rainwater supply can reduce energy needs for irrigation

Challenges:

1. Nonproductive conventional practices
2. Unavailability of labor/ high cost of labor

Mechanization Solutions

1. From animal drawn to tractor driven ploughs
2. From manual transplanting to motorized transplanting

Water Conservation

Challenges;

- Irregular land levels - farmers make small plots to maintain water levels
- Difficulty in mechanization
- Practice of flood irrigation
- Improper bund preparation due to labor shortage
- High water requirement for rice plant establishment

Mechanization Solutions

- Laser leveling
- Micro irrigation systems

Zero Tillage

- Minimum disturbance to soil – reduces soil erosion

Challenges

- Lack of suitable machinery

Mechanization Solutions

- Injector Planter

Organic Fertilizer

- Enhances soil quality, water retention and soil functions
- Potential to overcome climate shocks
- Reduces use of nitrogen fertilizer, thus reduces nitrous oxide emissions.

Challenges;

- Degrading takes longer time

Mechanization Solutions

- Use multi crop chopping machine to make small particles

Changing Crop Establishment Methods

– Dry Sowing

- Minimizes water use and conserves soil moisture, when combined with minimum or zero tillage

Mechanization Solutions

- Manual or tractor coupled seeders

Issues and Challenges in Adopting CSA

- Minimum government attention on CSA mechanization practices
- Lack of knowledge (policy makers, officers, farmers)
- Lack of resources (resource personnel, machinery, capital)
- Resistance to change

Conclusion

- As a small tropical island, climate change has substantial impacts on Sri Lanka's agriculture
- Findings of regional countries should be studied and adopted if suitable
- Investment towards CSAM should be immediately increased

Thailand
Sustainable Agricultural Mechanization in Thailand

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Abstract

Thailand is one of the world's biggest suppliers of agricultural production. Approximately 21 million ha or 40.9% of the total area is used for agricultural production. About 49.8% of the agricultural land is used for growing rice, 21.5% for field crops, 21.2% for fruit or horticultural crops, and 7.5% for others. Agriculture is an important sector since it is the largest source of employment of rural population of the country. About 46.6% of the total population is engaged in this sector. Mechanization plays a vital role in the present Thai agricultural production system. Labor shortage and necessity to reduce production cost are obvious issues faced by the country's agriculture practices. This paper presents an overview of agricultural mechanization in Thailand, the status of agricultural machinery industry, sustainable agricultural machinery concept and plan, and constraints to develop a sustainable agricultural machinery sector.

I. Overview of Agriculture and Mechanization Status

As an agricultural country, Thailand has approximately 21 million ha or 40.9% of the total area used for agricultural production. About 49.8% of the agricultural land is used for rice production, 21.5% for field crops, 21.2% for fruit or horticultural crops, and 7.5% for others. Agriculture is an important sector and the largest source of employment of rural population in the country. About 46.6% of the total population is engaged in this sector. Although the importance of agriculture has declined slightly due to the expansion of other sectors, its contribution continues to be above 10% of the country's GDP. Crop production is the most important sub-sector of agriculture. In 2010, it contributed approximately 61.8% of gross agricultural output of Thailand, followed by livestock (15.6%), fisheries (22.4%), forestry (0.02%), and others (0.18%). The five most important crops in terms of cultivated area and value of production in Thailand are rice, maize, sugarcane, cassava, and soybean with the area of 10.75, 1.11, 1.14, 1.03, and 0.16 million ha respectively. Rice, maize, and sugarcane are important domestic food commodities as well as foreign exchange earners. In addition, Thailand has other important crops such as rubber, maize, sugar cane, cassava, oil palm, etc.

Traditionally, Thai farmers used simple tools, animal drawn implements, and water wheels. Mechanization with power technology began in 1891 when the government imported steam power tractor and rotary hoes. However, they were found to be unsuitable for paddy conditions and also quite expensive (Sukharumana, 1982).

In the early 1920s, agricultural machines were imported for trial operation at the Rangsit Rice Station in the central plain region. During this period, the research and development in agricultural mechanization, however, did not progress much due to the lack of well-trained local personnel. Also, the onset of World War II disrupted all R&D in the country (Mongkoltanatus, 1993).

In 1947, a single axle tractor with rotary hoes powered by a 4.4 kW gasoline engine was imported, but its low chassis was unsuitable for swampy fields (Rijk, 1989). In the early 1950's, the government’s Rice Experiment Station promoted the use of 4-wheeled tractors by introducing contracting services. This project was unsuccessful.

In 1,955, 262 tractors were imported from various countries but the most popular were the Japanese 2-wheeled tractors or power tillers.

During 1956-1957, the number of imported tractors increased significantly, which stimulated local workshops to simplify the design of imported tractors to reduce cost and also make them suitable for local conditions.

In 1957, the Agricultural Engineering Division (AED) of the Ministry of Agriculture and Co-operative released the design of an axial flow pump, namely "debaridhi water pump" for local manufacture. This pump was subsequently commercially produced and widely adopted (Mongkoltanatus, 1991; Kaewprakaisaengkul, 1996).

In 1958, the Division released the design of a 4-wheeled tractor powered by a 25 hp engine, named "Iron Buffalo", to two private firms for commercial production (Chakkaphak, 1984). Firms stopped producing it because of the high manufacturing cost which makes it impossible to compete with imported tractors. In the same year, the first prototype of a rice combine harvester was designed. The cutting and threshing units were connected to the tractor (25 hp) and driven by a PTO shaft. However, this prototype was not commercially produced (Mongkoltanatus, 1991; Kaewprakaisaengkul, 1996). In 1960 and 1964, two firms, namely Ford and Massey Ferguson, established assembly lines for four wheeled tractors (Singh, 1983).

In 1964-1965, workshops around Bangkok area began to modify the design of imported 2-wheeled tractors by using trial and error method. Only one workshop succeeded in simplifying the gearbox and other parts of the tractor to suite local paddy field conditions. In 1966, a few firms began producing 2-wheeled tractors. The relatively low price and suitability to local conditions of these tractors comparing to the imported made them popular, and they were adopted widely in the central plain area. The high demand for these tractors resulted in establishment of many farm machinery firms in this region.

In 1967-1969, a firm producing 2-wheeled tractors in Ayudhaya province began manufacturing a simple 4-wheeled tractor, which was developed from a 2-wheeled tractor gearbox by adding two more wheels and a seat. It was powered by a 15 hp single piston diesel engine (Singh, 1983).

In 1975, the AED constructed the prototype for an axial flow rice thresher, which received its blueprint from the International Rice Research Institute (IRRI), then released it to a selected firm in Chachoengsao province for commercial production. Ten units were immediately sold, but it still was not as successful as expected. Later in 1975, a new blueprint was released to three firms for commercial production, and was widely adopted subsequently.

In 1977, a blueprint of a portable rice thresher was sent by IRRI to one firm to produce it, but it was not widely used due to its low capacity. In the same year, the Japanese combine harvesters (head feed type) were demonstrated to Thai farmers but the farmers were reluctant to accept them.

In 1978, a rice transplanter (12 rows and power operated) was imported from China by a local firm who also produced it, but they could not be sold in significant numbers. At the same time, the AED tested a Japanese reaper.

During 1981 and 1982, approximately 1,000 units of Chinese reapers were imported to the country. The variety kinds of long stem rice in Thailand were not suitable for reaping so farmers had to collect and bind the rice that are ready to harvest manually, which required more labor. Moreover, heavy weight machines were also major problem during field operations. Thus, these reapers were finally abandoned.

In 1985-1987, local firms around Bangkok started to fabricate a Thai-made rice combine harvester (Kalsirisilkp, 1993). Around the early 1990s, these firms successfully developed Thai-made rice combine harvester. It was accepted for use by farmers and popularly used in hiring services, especially in the central plain and then its use spread in other regions of the country (Krishnasreni and Kiattiwat, 1998). Thai combine harvesters have a capacity range from 0.42 to 0.9 hectares per hour (Kalsirisilkp, 1993; Krishnasreni and Kiattiwat, 1998). In 1997, there were about 2,000 units used mainly in the Central rice area of Thailand (Chamsing and Singh, 2000). Even though more design and development were needed to improve its performance, the Thai rice farming industry was satisfied with the combine harvester's performance (Krishnasreni and Thongsawatwong, 2004). Currently, they are being used across the country with high competition in hiring systems especially in the Central region. Hiring rate for harvesting rice in the Central region had decreased while remaining high in other regions.

II. The Status of Agricultural Machinery Industry

At present, most of the agricultural equipment used in Thailand is locally produced. The most common machines include tractor, power tiller, disc ploughs, disk harrow, water pump, sprayer, threshing machine, reaper, combine harvester, cleaning equipment, dryer, rice milling machines, processing equipment, etc. However local machines produced from small manufacturer are not standardized in quality, efficiency, and durability. Some agricultural machines are imported from overseas by companies for Thai agricultural productions.

There is a growing market for 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. Due to labor shortage during harvesting season, especially for paddy rice and sugarcane, most farm owners or farmers are looking forward to using more efficient harvesters. It is obvious that agricultural mechanization in Thailand is at the turning point from labor intensive machines towards control intensive machines such as planting machines, irrigation system machines, powered sprayers, combine harvesters, dryers using biomass fuel, silo and storage handling, advanced and high-quality rice mill machines, etc. Eventually, these machines will be rapidly adopted by farmers or proprietors. However, more effort should be taken to develop modification and adjustment to suit the local condition.

The information in Table 1 was obtained from survey of the top 70 agricultural machinery factories in Thailand in 2001.

Table1: Major Products of Local Manufacturer in Thailand

Machine	Production in units per year
Two wheel walking tractors	80,000
Large tillage implements	3,000
Small tillage implement	90,000
Threshing machines	2,000
Combine harvester	600
Sprayers with hand operated	60,000
Irrigation pump	55,000

Sourse: The Agricultural Engineering Research Institute

In 2012, there were about 40,000 4-wheel tractors and 3,000 rice combine harvesters produced in Thailand.

According to the Department of Industrial Works, there were 2,809 factories who produce and repair agricultural machinery in 2009, as shown in table 2.

Table 2: Number of Agricultural Machinery Industry

Type of Machines	No. of Industry
Walking tractor	275
Tillage equipment	329
Planter	16
Sprayer	447
Harvesting machine	386
Others	164
Repair and maintenance	1,192

Source: Department of Industrial Work

III. Sustainable Agricultural Machinery Concept and Plan

The world population is projected to reach 9 billion by 2050. Therefore, managing agricultural production systems on a sustainable basis is one of the most critical challenges for the future of humanity. Technological advancements must be used to provide farmers tools and resources to make farming more sustainable. Concepts of modern technologies in agricultural systems have given an important role for the improvement of agricultural productions e.g. crop yield, livestock production, aquaculture production, and sustainable agriculture, in order to maintain food security.

It is found that modern agricultural technology can substantially improve agricultural production and sustainability. For instance, best management practices are widely applied nowadays. It relies on targeting many of their applications, not broadcasting as was done in the past. New disease resistant hybrids, biological pest control, reduced pesticide use, cultural practices that can reduce the incidence of pests and diseases, and better placement and reduced amounts of fertilizers are all being employed. Insect-specific chemicals and biological insect controls are now being utilized, instead of broad-spectrum pesticides, which reduce the number of sprays needed and therefore its capitals. Organic farming by using only organic fertilizer has helped farmers reduce costs and improve products. Crop models, GIS, and remote sensing can provide farmers precision agriculture information, which is a method that matches input needed with actual yields of different portions on the field. These tools also allow agriculture to manage land for both agriculture and wildlife.

More agricultural technologies should be adopted to enable the agricultural sector to feed an increasing world population. One of the technologies that it is hoped to increase yield is precision agriculture. Precision agriculture approaches agriculture practices such as industrial operations and aims to maximize yield by employing precise watering and fertilizing techniques by using data obtained from closely monitored variables, such as humidity and mineral levels in soil. Precision agriculture includes 1) precision planting, which involves planting seeds with different growth rates depending on the properties of the soil and matching seed genetics with soil conditions; 2) precision fertilizing, which modulates fertilization based on different soil properties; 3) precision spraying, which identifies highly weed-infested areas for targeted spraying, leading to a 60% reduction in the use of chemical pesticides; and 4) precision irrigation, which uses soil moisture and weather data to determine the rate of irrigation to keep soil moisture at suitable levels.

Thailand recently unveiled a 4.0 economical model to develop its economy to a valued-based one, according to Prime Minister Prayut Chan-O-Cha. Thailand 4.0 will change the country's traditional farming to smart farming, traditional SMEs to smart enterprises, and traditional services to high-value services. The aim is to create creativity and innovation through the application of technology. As the Nation comments, the challenge of this model is to get the country out of its middle-income trap. The government is hoping to see farmers become entrepreneurs and SMEs become startups and grow beyond their potentials without assistance obtained from the government. Smart farm in food supply chain is being promoted (Figures 1,2).

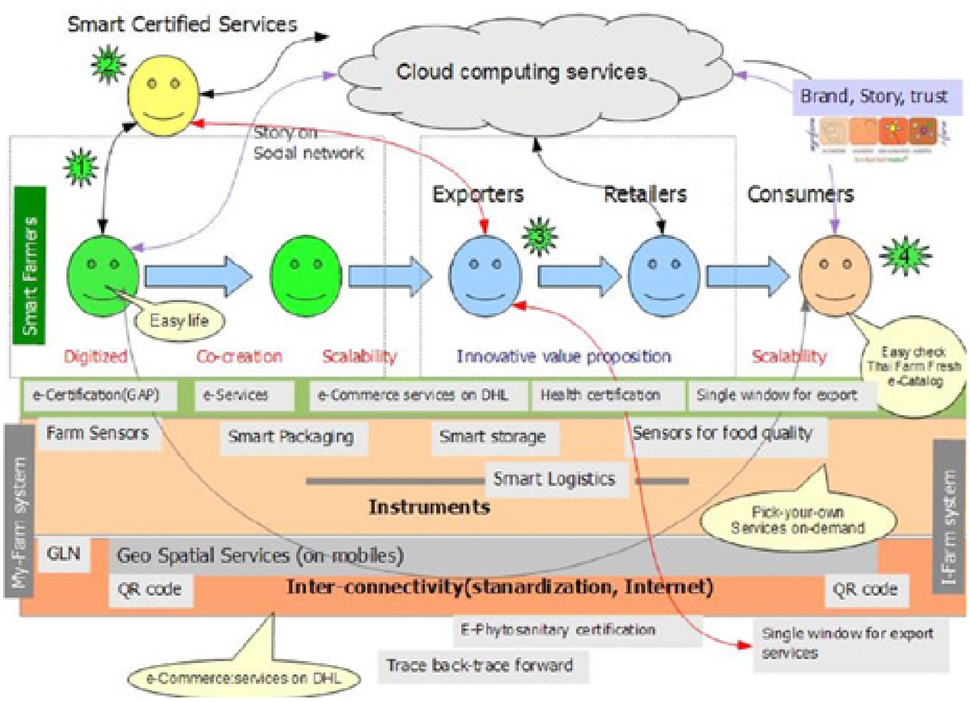


Figure 1: Smart Farm in Food Supply Chain.

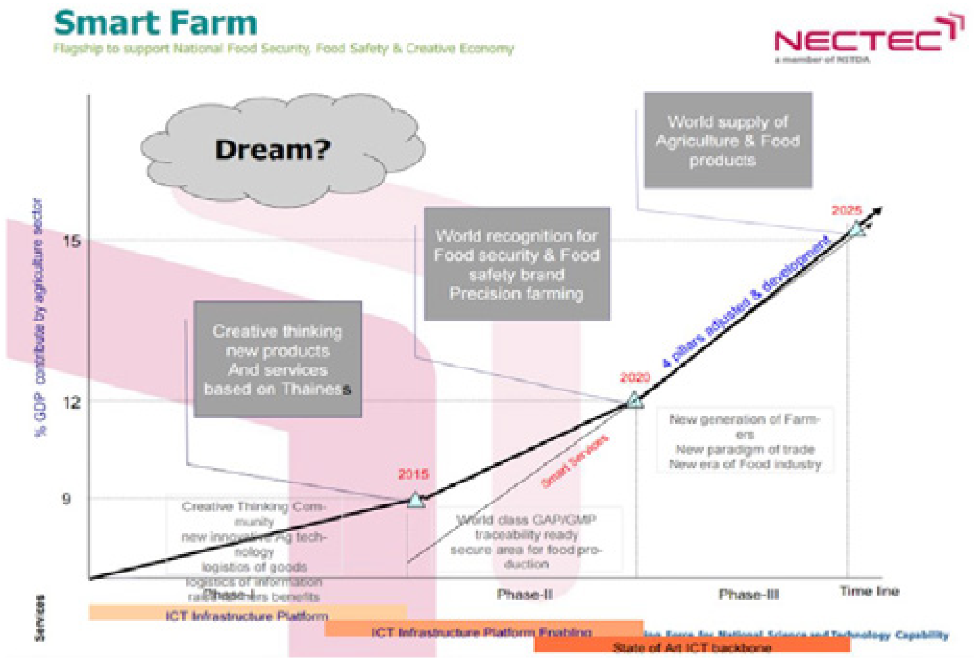


Figure 2: Smart Farm Flagship to Support National Food Security and Creative Economy

IV. Challenges and Constraints for a Sustainable Agricultural Machinery Sector

- Lack of appropriate technology at farm level.
- Small farm holder, labor shortage, and lack of financial support.
- Lack of collaboration with government institution.
- Rainfall during harvesting.
- Some parts of agricultural machinery were imported, which results in the high price of some agricultural machinery.
- Use of rice combine harvester required appropriate technology and machines for drying and storage.
- Plot size for crop production is rather small especially for rice production in the North and the Northeast. This decreases field capacity of agricultural machinery and increases energy consumption per unit area especially for big machinery.
- Average family members active in farm for all crop production and regions were little (i.e. about 2.0-2.6 persons/family or only about 45% of total family members). This resulted in labor shortage for farms as some family members were old or women. Therefore, custom service was observed for many or all farm activities.
- Problems pertaining land holding were size of planted area, land holding status, and high rental rate of land.
- Size of planted area for irrigated rice, rainfed rice, cassava and soybean (both wet and dry season soybean) production in the North and the Northeast were smaller comparing to that in the Central Thailand. Irrigation availability and socio-economic status of the region afftect farm income, potential to improve crop production efficiency, chance to successfully access loaned money, and holding of machinery.
- Farm operations of crop production in some regions still had low competition for custom service of machinery. This resulted in high hiring wage rate and low quality of work done.

- Problems of unnecessary ownership of machinery and finance for machinery acquisition were observed. Some farmers owned unnecessary machines which did not match with their farm works requirement, therefore low utilization rate of machines resulted in high fixed cost of machine and consequently increased cost of production. These problems were faced especially in rainfed rice production areas in all regions, and sugarcane production in the Northeast.
- Some parts of agricultural machinery were imported. Imported parts were similar to that of other machinery or vehicles. Therefore, import tax was charged at the same rate which was high for agricultural machinery. This results in high price of some agricultural machinery.
- Production technology for agricultural machinery of Thailand is still under development.
- Machinery for some farm operations and crops are still missing.
- Support from the government side in the past was little and was not focused on the requirements of users and producers.
- Governmental support for the development and the promotion for farm mechanization are still inadequate. Under-utilization of some agricultural machinery was noted.
- Irrigated area is limited and not equally spread throughout the country.
- Irrigation system is still in development phase. It restricts growing more crops per season. Inadequate water supply in dry season and lack of drainage system affect irrigated rice production.
- Landless farmers and small holding farmers cannot reach low interest rate loan from financial institutes. They still have to seek loan from other sources with high interest rate.

Vietnam
Results of Research Design, Manufacture and Testing of Maize Seeding Machine Following Minimum Tillage Method Suitable in Climate Change Regions

Mr. Tran Duc Tuan
Deputy Director
Research Centre for Agricultural Machinery and Aero-Hydraulic
Vietnam Institute of Agricultural Engineering and Post-Harvest Technology

I. Introduction

Vietnam is an agricultural country with a population of 90 million, 47.4 percent of which resides in the rural areas and involves in agriculture. Agriculture production contributes to 22 percent of the country's GDP. The rate of growth of the agricultural sector is 4.0% per year measured on a 10-year average. Livestock sector occupies about 27% while cultivation takes up 71%. The aim of this report is to introduce some recent agriculture mechanization and rural development in Vietnam.

Land area

The country has a total area of about 32 million hectares of which 22% are cultivable and about 85% of the cultivable land are paddy field areas.

Area for rice production of each household is very limited. For instance, average household arable land in Red River Delta is only 2,000 square meters, while average household arable land in the Mekong Delta is less than 14,000 square meters.

Table 1: Land Area by Land Classification

Land use	Area (Ha)
Agriculture land	9,345,400
Forestry land covered by trees	11,575,400
Homestead land	443,200
Specially used land	1,532,800
Unused land and river, spring, mountain	10,027,300
Whole country	32,924,100

Source: Statistical Yearbook 2011

Climate of Vietnam

Vietnam locates between 8° 30' to 23°22' latitudes and belongs to the tropical area. Average temperature is 22° - 28° C and the temperature is quite different between the north and south region. It also varies from 8° to 30°C in the highland in the central region.

Temperature

Vietnam is under monsoon climate and is influenced primarily by northeast and southeast winds. The climate is divided clearly into the southern and northern parts. The southern part is characterized by two seasons, a wet season from May to October and a dry season for the rest of the year. The northern part has four distinguishable seasons: summer, autumn, winter, and spring. Average air humidity reaches to 70%-80%, and average of rainfall is about 1,500-2,000 mm and 2,500-3,000 mm in some high mountainous areas. Floods are common in rainfall seasons.

II. Clime Changing at Vietnam

Climate change is one of the greatest challenges for farmers who have to cope with rising temperatures, strong and heavy rains, floods, droughts, storm, increase of water level, and high wave in sea. Annual average temperature increased about 0.5°C during the last 50 years (1958-2007) herewith winter temperature has increased faster. The annual rainfall has increased in the Southern climate zones by 20% over the last 50 years even though it has decreased in the Northern zone. Sea level also rises at the rate of about 2.8-2.9 mm per year.

Vietnam is one of the top 5 countries that are most vulnerable to climate changes. Most vulnerable sectors are agriculture, water resources, transport, trade, and education. The most vulnerable regions include Red River Delta and Mekong River Delta.

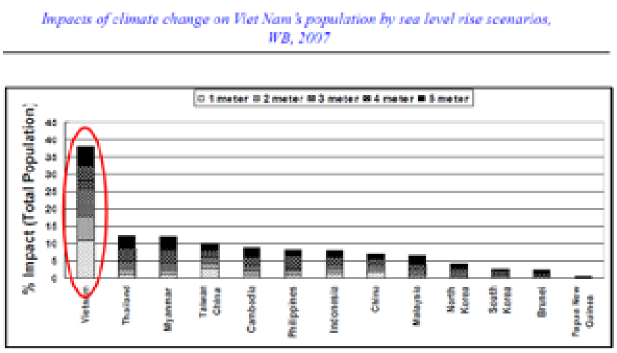


Figure 1: Impacts of Climate Change on Vietnam

III. Damages by Climate Change at Vietnam

In 2015, Vietnam was hit by series of natural disasters, which killed 154 people, injured 127 people, destroyed 35,233 houses, and damaged 445,110 hectares of rice and crops through landslides and sedimentation. Estimated total damage by natural disasters, which mainly focus on agricultural crop damage, erosion of roads, irrigation, power supply systems, telecommunications, mining, etc. was around 8,114 billion VND in 2015. Up to May 2016, estimated loss in the agricultural sector accounted about 400 billion VND, including 52,000 cattle deaths and destruction of 150,000 ha of rice.


Figure 2: Damage of Climate Change at Vietnam

From January to May 2016, 22 of 63 provinces have been affected by drought and invasive mangrove. Nine provinces in the Mekong Delta, hosting 288,259 households, experienced severe shortage of clean water for daily living.

IV. Solutions for Agriculture

The Government of Vietnam implemented a range of policies to tackle and mitigate the impacts brought by climate change. On 10 June 2013, the Agricultural Sector Restructuring Plans to Enhance Sustainable Development was signed. The regulations' main focuses are to prevent soil erosion, implement soil protection, provide proactive crop irrigation, select crops suited to climate change, adopt climates change-suited cropping patterns, create new species, modernized cultivation and stock breeding techniques, redistribute regional crop and livestock production to better suit changing climate conditions, provide additional incentives for agriculture, forestry and aqua farming, etc. (Figure below)

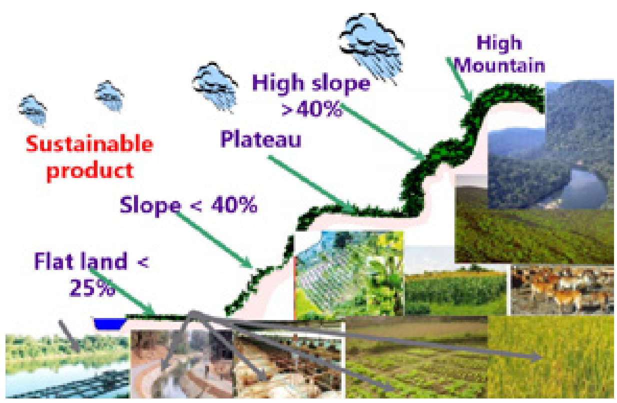


Figure 3: Sustainable Product at Vietnam

The whole Mekong Delta region has 112 thousand hectares of spring-summer rice production changed to other crops such as corn, dragon, black sesame, chili, pineapple, etc. that partly meet demand of the market, increase economic efficiency, and reduce effects of the lack of water. Conservation agriculture such as minimum tillage method or minimum mechanical soil is one of the solutions being applied in Vietnam now.

Figure 4: Conservation Agriculture Production at Vietnam

Some machines are applied for sugarcane, soy bean, maize, ect.

Figure 5: Machines Applied for Conservation Agriculture

Project "Research design, manufacture and testing of maize seeding-machine following minimum tillage method in climate change regions " is one part that helps the process of these decisions. The maize seeding machine GNTT-0.25 was produced.

V. Research Design, Manufacture and Testing Machine

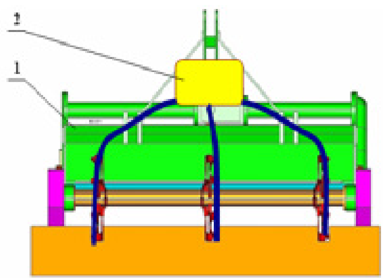


Figure 6. Principle of Machine

Technical requirements

The machine working on the field must simultaneously perform the following functions: local tillage at the sowing seed, make grooving, planting corn, filling and compacting soil.

The seeding unit is structured into separate clusters and driven independently, so the sowing distance can be changed to match the sowing patterns in production.

The working principle of the machine

The tillage unit sits on the seedbed according to the principle of active rotary, which is mounted in the front. Rotary is transmitted from the power take-off shaft of the tractor. On the drum of the rotary there are 3 clusters of rotary blades (there could be mounted more), and each cluster of rotary cutters has a working width of 150 - 250 mm, tillage depth of 120 - 150mm. The distance between group blades corresponds to the distance between two rows of corn.

The sowing unit is mounted just behind the rotary unit and works on the principle of tilting the disc. The number of sowing is 3, and the depth of sowing is 3 to 5 cm. The sowing unit is driven from the caster wheels. The machine is combined with tractors with a capacity of 30 to 35 HP.

Testing maize seeding machine GNTT-0.25

Methodology: Laboratory lay-out methods (field preparation) Testing and evaluation of maize seed machine was done according to the RNAM, (1985) standards; TCVN 2005. The data was summarized through laboratory lay-out methods (field preparation): testing and evaluation of maize seed machine were done based off of the RNAM, (1985) standards; TCVN 2005. The data was summarized, tabulated and analyzed with help of Microsoft Excel and SPSS.

Instruments and equipment used for testing machine

Distance measuring devices, time meters, soil depth measuring instruments, tools for measuring the size of piece soil, sowing depth instrument.

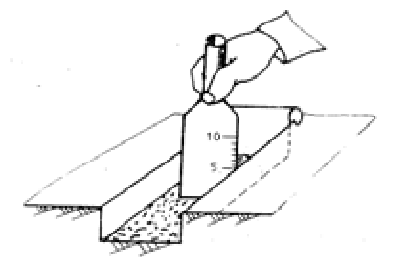


Figure 7: Sowing Depth Instrument

Test conditions.

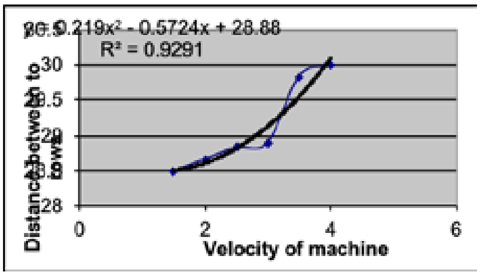
- Type of soil: mix soil
- The average hardness of the soil at a depth of 0 - 15cm: 9.87 12.46 kG / cm^2
- Average moisture of soil at depth 0 - 15cm: 22,0 - 23,0%
- Previous crop: rice planting
- Height of stem in the field: 10 - 15 cm
- Weed density remaining in the field: 400 - 550 g /m^2
- Seeder sowing: maize NK4300

Experiment on the field in Gia Lam district has 3 pots, each pot is

30 m x 60 m (1800m^2). Data was taken randomly, but it should be taken at least 10 meters far from the edge of the field.

Results and discussion

Machines for different speed flows were tested: 1.5; 2; 2.5 and 3 km / h. If the velocity of the machine is> 3 km / h, we see the distance between sowing seed increases, but it still meets technical requirements that is less than 30 cm.



The machine has been tested and the results of work were evaluated in real production conditions.

- Number of sowing rows: 3 rows
- Row spacing: 650 mm
- The distance between the seeding clusters: 280 - 290 mm
- Sowing depth: 40 - 60 mm
- Residual rate (seedless cavity) ≤ 3%;
- 1-grain cavity ratio: 86%
- Productivity: 0.25 ha / h
- Combined motive power 25 - 35 HP

Figure 10: Check the Quality of the Machine Working on the Field

VI. Conclusion

1. The machine works well and meets the technical requirements. Actual productivity is 0.25 ha / h and mechanical grain damage is minimal, with a ≤ 3%. residual rate (seedless cavity)

2. The machine has a simple structure and is easy to use. It adapts well to the manufacturing technology in our country.

3. The machine can sow maize at no-tillage soil conditions.

III. Summary of the Panel Discussion

Ways to Promote Climate-smart Agriculture More Efficiently through Agricultural Mechanization

Ways to Promote Climate-smart Agriculture More Efficiently through Agricultural Mechanization

Relationship between Agricultural Mechanization and Climate-smart Agriculture

In the following projects, it is taken for granted that agricultural mechanization contributes towards Climate-smart agriculture. One of the most prominent examples is the postharvest project (2009-2013) that represents collaboration between ADB and IRRI which aimed to adapt postharvest technologies (i.e. dryers, hermetic storage systems, quality tools) to local conditions and analyze potentials for local manufacturing. CORIGAP (closing rice yield gap in Asia with reduced environmental footprint) (2013-2020) intends to improve food security and gender equity and alleviate poverty through optimizing productivity and sustainability of irrigated rice production systems in China, Myanmar, Thailand, Vietnam, Indonesia, and Sri Lanka. BMZ rice straw management project is another important project which encourages Climate-smart agriculture.

As a further action contributing towards CSA, application of conservation tillage that can reduce greenhouse gas emission from soil, especially CO2, as well as reduce water erosion should be considered. Tillage Plus stubble cover prevents water evaporation, which helps to save more water in soil. Conservational tillage solves stubble burning issue that many countries face, and thus contribute to greenhouse. Low-cost mechanical dryer and combine harvester should be introduced and disseminated among countries. Laser land leveling, introduced in 2001, has led to more than 10,000 units in India and more than 2000 ha applied in Vietnam. Regarding rice straw management, after first demonstration and BM in Can Tho 2013 (ADB-IRRI project), rapid introduction of mechanized collection started under the frame of BMZ project.

Important Challenges in the Promotion of Climate-smart Agriculture through Agricultural Mechanization

Agricultural sector plays a very important role in Asian countries and face a lot of obstacles. One of the most difficult challenges is climate change. For instance, deformation of Mekong River caused by hydro-power leads to drought crisis, water scarcity, salinity contamination, etc. GHGE and environmental footprint that cause greenhouse effect and global warming should be reduced. Most countries burn straw which contributes substantially to greenhouse gas emission. These circumstances often reduce arable land and water availability. Additionally, agricultural sector faces other challenges, such as intensification and labor shortage, fossil fuel scarcity, inefficient use of energy and agronomic inputs, gaps of technology, low productivity, losses, and low sustainable production.

How to overcome these challenges and what role governments, private sector and farmers should take?

To overcome the challenges and to apply Climate-smart agricultural mechanization successfully onto agricultural production, cooperations between four main partners are crucial. The four partners include farmers, agricultural enterprises, governments and scientists, among which farmers and agricultural enterprises are the most important partners.

How to overcome challenges:

- Enable mechanization through SFLF;
- Solutions which emphasizes sustainability;
- Integrated system and value chain.

Roles of the four partners are:

Farmers and agricultural co-operatives: They are key elements in agricultural production. They have a decisive role in accepting or rejecting new methods, machines or technologies. There are no farming activities without farmers.

Agricultural enterprises (private sectors): In comparison with individual farmers or small farmers, private sector has more powerful capital for new investments in agricultural machines or technologies. They also have better business management knowledge and experiences. They could also be distributors of input materials such as seeds, fertilizer, and pesticides, or traders of agricultural products. Without these partners, agricultural productions could not be released to markets, and the value chains will be broken down.

Scientists, experts and specialists: These partners have the best knowledge of science and technology in comparison with the other partners. They can help farmers or private sectors select proper machines or technologies for the agricultural production, utilize new machines, new methods, and new technology; provide lectures for training courses, or help them set up pilot sites, business models, etc.

Governments: They play a mediate role to set up proper mechanisms for the cooperation between the 4 partners, to issue good policies supporting applications of Climate-smart agricultural mechanization, to provide subsidized budgets for pilot sites or business models to apply appropriate technologies/machines in the first stage, to strengthen agricultural extension agencies, etc. Governments play an important role in setting up mechanisms for the horizontal coordination between farmers and for the vertical coordination between different stakeholders of value chains.

To achieve great successes in the application of Climate-smart agricultural mechanization, business models of appropriate machines or technologies should be set up with participation of the four partners in which the private sectors should be a key and leading one. Efficiency and profit and income of the four partners resulted from new business models should be higher than those from the traditional or existing business models. In addition, profit brought by the new business models should be divided properly between the four partners. If so, new machines, technologies or the business models could be developed sustainably and be up-scaled widely in the future. Vietnam had so many successful examples of applications of modern machines, advanced technologies, good agricultural seeds, etc. in the agricultural production.

How Climate-smart Agricultural Mechanization Can Respond More Efficiently to the Needs and Demands of Marginal and Resource-poor Farmers Who Make Up the Bulk of the Farming Community in the Asia-Pacific Region?

Pro-poor policies, strategies and programmes that respond to the needs and priorities of the most vulnerable farmers should be developed. Proper attention should be paid to close gender gap and giving equal opportunities for women and men to access technologies, information, and other assets. It is also important approach the development of agricultural mechanization with consideration to equal rights among genders.

To achieve higher efficiencies, a number of measures can be considered, namely financial and credit schemes adapted to resource-poor farmers; increased access to accurate and timely climate information for planning planting, harvesting; creation of on-farm and off-farm jobs through the use of SAM in the rural areas and clean energy (solar energy, wind energy); promotion of social protection schemes; and development of infrastructure and extension services that reach remote areas.

ANNEX 1: Programme of the 4th Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific

23-25 November, 2016

Bao Son Hotel, Hanoi, Viet Nam

22 November	Arrival in Hanoi
23 November	Grand Ballroom, 3rd Floor
09:00-09:40	**Opening Ceremony** Moderator: - Ms. Tam Dinh, Vice Director General, Vietnam Institute of Agricultural Engineering and Post-Harvest Technology Welcome Address: - Representative of Mr. Le Quoc Doanh, Vice Minister, Vietnam Ministry of Agriculture and Rural Development Welcome Remark: - Mr. Pham Anh Tuan, Director General, Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP) Opening Address: - Mr. Katinka Weinberger, Chief, Environment and Development Policy Section, Environment and Development Division; Officer-in-Charge, Centre for Sustainable Agricultural Mechanization, United Nations Economic and Social Commission for Asia and the Pacific Opening Remark: - Ms. Li Yutong, Incoming Head, Centre for Sustainable Agricultural Mechanization, United Nations Economic and Social Commission for Asia and the Pacific
09:40-10:00	**Tea Break & Group Photo**
10:00-11:30	**Keynote Speeches** Moderator: Ms. Katinka Weinberger - Adapting Agricultural Systems in a Changing Climate: Climate-smart Agriculture and Sustainable Agricultural Mechanization Strategy – Ms. Mayling Flores Rojas, Agricultural Systems Mechanization Officer, Regional Office for Asia and the Pacific, United Nations Food and Agriculture Organization - A Road to Sustainable Agricultural Mechanization – the Experiences of Conservation Agriculture in China – Prof. Li Hongwen, Head, Conservation Tillage Research Centre, Ministry of Agriculture of China; Professional, China Agricultural University - Mechanization and Postharvest Management for Sustainable Rice Production – Mr. Hung Van Nguyen, Research Scientist, International Rice Research Institute (IRRI) - Collection and Uses of Rice Straw in the Mekong River Delta – Vietnam - Mr. Pham Van Tan, Deputy Director, The Sub-Institute of Agricultural Engineering and Postharvest Technology (SIAEP) of Vietnam
11:30-12:10	**Panel Discussion** - How can mechanization contribute better to Climate-smart agriculture? Moderator: Ms. Katinka Weinberger & Ms. Li Yutong <u>Panelists</u>: Ms. Mayling Flores Rojas; Prof. Li Hongwen; Mr. Hung Van Nguyen; Mr. Pham Van Tan - *What **evidence** do we have that agricultural mechanization contributes towards Climate-smart agriculture?* - *What are some of the **important challenges** that need to be addressed to ensure that agricultural mechanization can play a larger role towards Climate-smart agriculture?* - *How can these challenges be overcome and what should be the **role of governments, private sector and farmers?*** - *How can Climate-smart agricultural mechanization better respond to the needs and demands of **marginal and resource-poor farmers** who make up the bulk of the farming community in the Asia-Pacific region?*

12:10-14:00	**Lunch Break**
14:00-15:10	Country Presentation - Representatives of member countries briefing the efforts of respective countries to achieve Climate-smart agriculture and the proven practices and machinery Moderator: Ms. Li Yutong - Conservation Agriculture: A Climate-smart Agricultural Technology for Sustainable Crop Production in Bangladesh - Mr. Sultan Ahmmed, Director Member (NRM), Bangladesh Agricultural Research Council (BARC) - Biochar Production Technology in Cambodia and its Application on Agricultural Crops – Mr. Saruth Chan, Director, Agricultural Engineering Department, Ministry of Agriculture, Forestry and Fisheries of Cambodia - Agricultural Mechanization and Development of Sustainable Agriculture in China – Mr. Wang Guozhan, Division Chief, Department of Agricultural Mechanization, Ministry of Agriculture of China
15:10-15:30	**Tea Break**
15:30-16:40	- The Path and Cases on China's Sustainable Agricultural Mechanization – Prof. Yang Minli, Director, China Research Centre for Agricultural Mechanization Development; Professor, China Agricultural University - Leading the Way for Climate-smart Agriculture through Machinery and Practices in 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 - Climate-smart Agriculture and Mechanization in India - Mr. Krishna Kumar Singh, Director, Central Institute of Agricultural Engineering (CIAE), Indian Council of Agricultural Research
16:40-17:00	Wrap up of the 1st Day Session - Ms. Katinka Weinberger, Chief, Environment and Development Policy Section, Environment and Development Division; Officer-in-Charge, Centre for Sustainable Agricultural Mechanization, United Nations Economic and Social Commission for Asia and the Pacific
18:00-20:00	Dinner
24 November	**Grand Ballroom, 3rd Floor**
09:00-10:40	Country Presentation (Continued) Moderator: Ms. Li Yutong - Significance of Climate-smart Agriculture and Mechanization to Fiji - Mr. Ratu Penaia Vosawai, Senior Research Officer, Ministry of Agriculture of Fiji Islands - Lao Farmer's Experience on Resilience Agriculture by Introducing Rice Direct Seeding and Mechanization - Mr. Phatnakhone Khanthamixay, Head, Planning and Cooperation Division, Department of Agricultural Extension and Cooperatives, Ministry of Agriculture and Forestry of Lao PDR - Current State Research & Development on Rice Mechanization in Achieving Climate-smart Agriculture - Mr. Mohd Syaifudin Abdul Rahman, Deputy Director, Engineering Research Centre, Malaysian Agricultural Research & Development Institute (MARDI)

10:40-11:00	**Tea Break**
11:00-12:10	- Climate-smart Agriculture and Mechanization in Nepal - Mr. Madhusudan Singh Basnyat, Officiating Program Director, Directorate of Agricultural Engineering, Department of Agriculture, Ministry of Agriculture Development of Nepal - Climate-smart Agriculture and Mechanization in Pakistan - Mr. Tanveer Ahmad, Director/Principal Engineer, Agricultural and Biological Engineering Institute, Pakistan Agricultural Research Council - Agricultural Mechanization Technologies for Sustainable Philippine Agriculture and Fishery Production Systems - 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
12:00-14:00	Lunch Break
14:00-15:10	Moderator: Ms. Tam Dinh - Current Status of Agricultural Engineering Research and Climate-smart Agricultural Policy in Korea - Mr. Sung Je Hoon, Team leader, Rural Development Administration, National Institute of Agricultural Science of the Republic of Korea - Climate-smart Agriculture and Mechanization in Russia - Mr. Nikolai Vasilev, Engineer, FSBI North-West State Zonal Test Machines Station of Russia - Sustainable Small-Scale Agricultural Mechanization in Tropical Countries - Mr. B.M.C.P Balasooriya, Deputy Director, Farm Mechanization Research Centre, Department of Agriculture of Sir Lanka
15:10-15:30	Tea Break
15:30-16:20	- Sustainable Agricultural Mechanization in Thailand - Mr. Viboon Thepent, Senior Agricultural Engineering Specialist, Postharvest Engineering Research Group, Agricultural Engineering Research Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives of Thailand - Results of Research Design, Manufacture and Testing of Maize Seeding Machine Following Minimum Tillage Method Suitable in Climate Change Regions – Mr. Tran Duc Tuan, Deputy Director, Research Centre for Agricultural Machinery and Aero-Hydaraulic, Vietnam Institute of Agricultural Engineering and Post-Harvest Technology
16:20-17:00	Wrap up and Closure - Ms. Li Yutong, Incoming Head, Centre for Sustainable Agricultural Mechanization, United Nations Economic and Social Commission for Asia and the Pacific - Discussion on Follow-up Actions - Ms. Tam Dinh, Vice Director General, Vietnam Institute of Agricultural Engineering and Post-Harvest Technology
25 November	**Field Visit**
09:00-18:00	- Vietnam Engine and Agricultural Machinery Corporation - Tractors and Agricultural Machinery Company - Vietnam Institute of Agricultural Engineering and Post-Harvest Technology

ANNEX 2: Participants List

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