Asian and Pacific Workshop on Whole-process Mechanization of Potato

27-28 June 2016
Kunming, China

United Nations ESCAP
Economic and Social Commission for Asia and the Pacific
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*The shaded areas of the map indicate ESCAP members and associate members.**

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Executive Summary

Today, the potato is the world's third most important food crop after rice and wheat in terms of human consumption, and by far the most important root and tuber crop, consumed by a billion of people across the world[1]. It is cultivated in more than 125 countries and can be used as a staple food, as a cash crop, as animal feed, and as a source of starch for many industrial uses[2]. Potato is a highly productive crop with a yield two to four times than the food quantity of grain crops per unit area; potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals[3]. Potato crop with short duration varieties of 80 to 90 days can fit well in various intensive cropping systems. It also has the advantages of high protein content and long storage time. Moreover, potato cultivation and post-harvest activities constitute an important source of employment and income, especially in developing countries. Celebrated in 2008, the United Nations International Year of the Potato (IYP) highlighted the important role of the potato in agriculture, the economy and world food security.

Presently, more than half of global potato production comes from developing countries[4]. The production of this crop in Asia and the Pacific has increased faster than the average level of the world[5]. In 2013, the value of potato crop production in this region accounted for 61.5% of the global outcome[6]. However, the average potato productivity in the developing countries in Asia is only 17.9 tons/ha[7], much lower than the average productivity (over 40 tons/ha) in most developed countries in Europe and North America[8]. In addition, the annual per capita potato consumption in Asian and Pacific countries are still modest (38 kg/year, 2011) when compared to Europe (84 kg/year, 2011) or North America (58 kg/year, 2011)[9].

In light of the above, it is recommended that every effort should be made to realize the full agricultural potential of this crop in the region. However, it is important to highlight the difficulty to overcome certain challenges that Asia-Pacific needs to improve the potato yield, such as the shrinking quantity of arable land, reduced water availability, changing climates and expanding biotic and abiotic stresses. As projected, if the global temperature increases between 2.1 and 3.2 C, the global potential potato yield decreases by 18% to 32% (without adaptation) and by 9% to 18% (with adaptation)[10]. Therefore, the full potential of potato in the region could be achieved only through the adoption of improved varieties and appropriate production technologies.

Agricultural mechanization has proved itself irreplaceable in increasing agricultural production, productivity, and profitability and thereby helps to eradicate poverty and hunger and improving farmers' livelihoods in general. For instance, compared with labour and livestock operation, the efficiency of land preparation, planting, and harvesting applying machinery in potato production could be enhanced respectively for 40 percent, 80 percent, and 60 percent in

1 International Potato Centre website, available at http://cipotato.org/potato/#sthash.mgnQmL8G.dpuf

2 FAO, 2009, Sustainable Potato Production – Guidelines for Developing Countries, available at http://www.fao.org/3/a-i1127e.pdf

3 International Potato Centre website, available at http://cipotato.org/potato/facts/

7 Scott GJ, Suarez V., 2012, The Rise of Asia as the Centre of Global Potato Production and Some Implications for Industry, Potato J (2012) 39 (1): 1-22, available at http://epubs.icar.org.in/ejournal/index.php/PotatoJ/article/viewFile/32257/14421

8 FAO website, available at http://www.fao.org/potato-2008/en/world/index.html

China[11]. However, the development of agricultural mechanization in general, among the Asian-Pacific countries is comparatively low and features with vast disparity. This is, in particular, the case for whole-process mechanization in potato production, covering ploughing, planting, plant protection, harvesting, post-harvest storage and processing.

Sharing the experiences, and good practices and building partnerships with national and international organizations will enhance our capacity to address the challenges and emerging issues for the whole-process mechanization of potato production in this region. The scarcity of financial and human resources calls for better integration of regional resources in order to respond to growing demand for whole-process mechanization of potato production in an environmentally, economically and socially sustainable manner. China is the world's biggest potato producer, with output in 2013 of 89 million tons accounting for over 24 percent of the global harvest, or 49 percent of the production in Asia[12].

The China International Potato Expo is an annual international potato exhibition convened in China since 2010. At this juncture, on 27- 28 June 2017, CSAM organized the “Asian and Pacific Workshop on Whole-process Mechanization of Potato Production”, in collaboration with the Agricultural Mechanization Chapter of China Society for Agricultural Machinery and the Agricultural Trade Promotion Centre of the Ministry of Agriculture of China in parallel with the “China International Potato Expo 2016”. Around 120 participants from 13 countries, i.e. Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam, participated in the workshop and exchanged knowledge and best practices on potato and root crop mechanization in the Asia Pacific region. The participants were also invited to attend the Potato Industry Development Forum where Chinese and Dutch experts illustrated the latest signs of progress in potato production and visited the “China International Potato Expo 2016.” The workshop concluded with a field visit, where participants had the occasion to observe different factories and establish links for future collaborations with local businesses.

The Proceedings synthesize the presentations of the country representatives illustrating common challenges and constraints of the participating countries, such as small and fragmented land holdings; limited purchasing power of the farmers; and low development level of potato mechanization; and underline the need for small, efficient, affordable, and high-quality machinery for the whole value-chain of potato production. As a result of the fruitful discussion it was proposed that a regional cooperation mechanism be established for research and academic institutions on tuber and root crops mechanization in the region. Potential activities could include technology transfer, information sharing, joint research, value-added production, and capacity building. CSAM will discuss the proposal with key stakeholders and explore the feasibility for such a cooperation mechanism.

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11 China Nongjitong webiste, available at http://www.nongjitong.com/zhuanti/2014tudou/

12 China Industry Information website, available at http://www.chyxx.com/industry/201501/302276.html

List of Abbreviations

AMD	Agricultural Mechanization Department
ANTAM	Asian and Pacific Network for Testing Agricultural Machinery
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
CEAT	College of Engineering and Agro-industrial Technology
CSAM	Centre for Sustainable Agricultural Mechanization
CVC	Cassava Value Chain
DFTQC	Department of Food Technology and Quality Control
DLS	Diffused Light Storage
DOA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nations
GoN	Government of Nepal
ICAERD	Indonesian Center for Agricultural Engineering Research and Development
ICAR	Indian Council of Agricultural Research
IRSAM	Institution for Rental Services of Agricultural Machineries
MARDI	Malaysian Agricultural Research and Development Institute
NAMEA	Nepal Agricultural Machinery Entrepreneurs Association
NARC	Nepal Agricultural Research Council
PARC	Pakistan Agricultural Research Council
ReCAMA	Regional Council of Agricultural Machinery Associations in Asia and the Pacific
RNAM	Regional Network for Agricultural Machinery
SDC	Swiss Development Cooperation
SMFI	San Miguel Foods Inc.
TCRC	Tuber Crop Research Centre
ULV	Ultra-Low Volume
UPLB	University of the Philippines Los Baños
URC	Universal Robina Corporation
UTD	Up-to-Date

Opening Remarks

Ms. Katinka Weinberger
Officer in Charge
Centre for Sustainable Agricultural Mechanization
United Nations Economic and Social Commission for Asia and the Pacific

Distinguished Speakers;

Representatives of CSAM member States;

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, I would like to extend my warm welcome to the Asian and Pacific Workshop on Whole-process Mechanization of Potato Production.

At the outset, let me express my appreciation to our Chinese partners and co-organizers – the Agricultural Mechanization Chapter of China Society for Agricultural Machinery and the Agricultural Trade Promotion Centre of the Ministry of Agriculture of China for their commitment and dedication with incredible energy and performance in organizing this workshop and I am pleased that the Asian and Pacific Workshop on Whole-process Mechanization of Potato Production can be held in China, the world's biggest potato producer in the period of China International Potato Expo 2016.

Potato is the world's third most important food crop after rice and wheat in terms of human consumption and by far the most important root and tuber crop consumed by millions of people across the world. Potato plays an important role in agriculture, the economy and world food security. Compared to grain crops, the potato has the advantages of higher productivity, higher protein content, less water consumption, shorter growing duration, sound adaptability to various cropping systems, and greater potential to create post-harvest employment and increase income. Food security remains an urgent issue that countries must address. Asia and the Pacific has the highest concentration of hungry people while the region is also challenged with resource and environmental constraints. Thus, regional efforts shall be made to achieve the full potential of potato in addressing hunger and food security in the region.

Agricultural mechanization has an important role in increasing agricultural production, productivity, and profitability. As the only UN agency devoted to sustainable agricultural mechanization in the region, CSAM would like to continue and enhance its role of catalyst and incubator to initiate and nurture extensive and fruitful regional cooperation on sustainable agricultural mechanization among all stakeholders in the region and beyond.

We believe the Asian and Pacific Workshop on whole-process

Mechanization of Potato Production can play an important role 1) to share knowledge, information and good practices of whole-process mechanization in potato production; 2) to establish network and linkages; and 3) to develop cooperation actions and mechanisms with your peers.

I understand that there will be ample opportunity to listen to your insightful thinking and success stories of your respective agencies and countries in whole-process mechanization of potato production in the sessions today and tomorrow and I have been impressed by the number of contributors to the various sessions.

Ladies and Gentlemen,

I would like to wish you every success to your deliberations and a pleasant stay in the beautiful Kunming City.

I look forward to learning about the outcomes of this meeting in due course.

Thank you.

I. Plenary Session

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Accelerating the Development of China's Whole-process Potato Mechanization

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Deputy Director General
National Agro-mechanization Technical Extension Station
Ministry of Agriculture of China

I. Introduction

Mechanization became an essential issue in modern agriculture production process. As a major agricultural country, China starts to recognize the importance of mechanization and actions have been taken from both government and nongovernment sides to accelerate mechanization development. In this paper, we would focus on potato production mechanization under three aspects, recognizing the positive results and challenges of potato production mechanization, consolidating efforts to solve the major challenges in Whole-process potato production mechanization, and exploring the essentials of potato production mechanization.

II. Background

1.1 Current condition for the potato production

Currently, potato planting is around 83.6 million acres with an annual yield of 19.1 million ton nationwide. Chinese potato production accounts for a quarter of the total global potato production and ranks first in global potato production.

1.2 Development of potato production in the 21st century

There are a series of policies and laws in China to support the potato production mechanization including Law of the People's Republic of China on the Promotion of Agricultural Mechanization, the annual Document NO.1 on the State Council, and agricultural machinery subsidy policy. In the same time the market demand also plays an important accelerator role.

The fundamental strategy to support the potato production mechanization is "led by the government and participated by different parties". Under this outline, the Chinese government starts its actions through four major paths: research and innovation, administrative promotion, technical guidance, and demonstration support.

Researching and innovation: The key programme of the Tenth "Five-Year Plan for Economic and Social Development of the People's Republic of China (Five-Year Plan)" focuses on research & development (R&D) of the key facilities in the whole-process potato production. The Eleventh "Five-Year Plan" attached great attention on research & demonstration of the technology of mechanized digging and harvesting. The Special R&D Fund of the National Public Welfare Industry prioritizes for the study of upgrading the key technologies and facilities in tuber and root crops. Other supports also include National Modern Agriculture Program on Potato Industry Technology System and provincial & enterprise's research programmes.

Administrative promotion: In October 2006, the Ministry of Agriculture (MOA) issued the Comment on Accelerating Potato Industry Development. Later, MOA developed the National Planning of Advantaged Agricultural Products (2008-2015). In 2009, the National Potato Production Mechanization Meeting was held in Inner Mongolia. In 2011, potato production machinery was listed as the key technology for promotion in 2011.

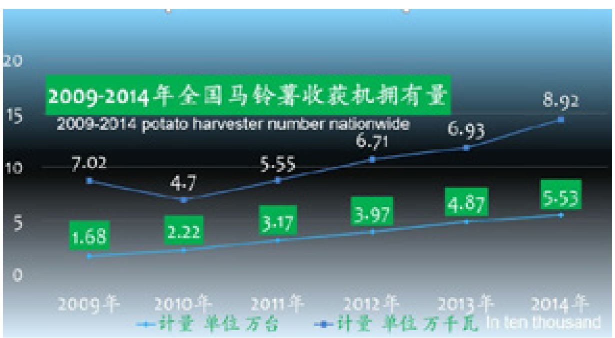
Technical guidance: Technical guidance is provided according to the pertinent industry standard, local standard and technical regulations.

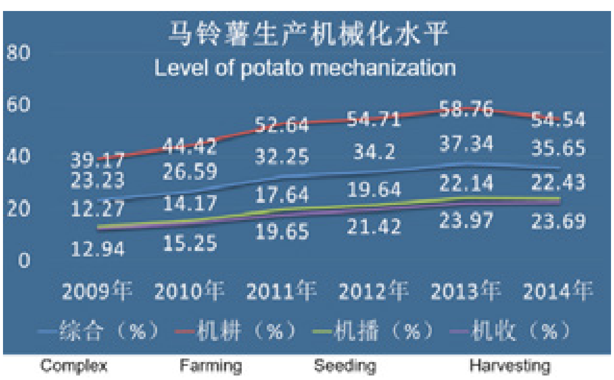
Demonstration support: Government provides subsidies and support for the demonstration of appropriate technology and facilities covering equipment purchasing subsidy, operation subsidy, production subsidy, demonstration implementation support and demonstration base construction support.

III. Positive Results and Challenges of Potato Production Mechanization

1.1 Progress

There are more than 30 manufacture factories with more than 100 various products. Below is the development of potato harvesters and level of potato mechanization from 2009-2014.

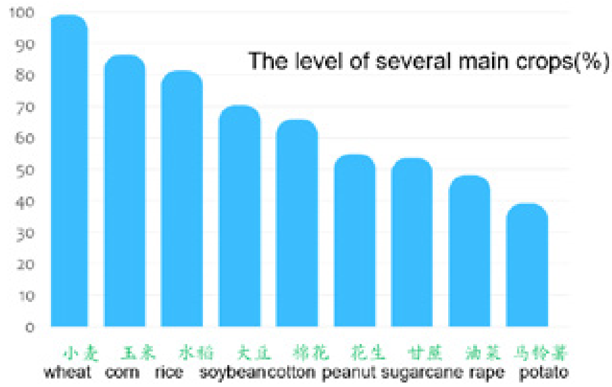




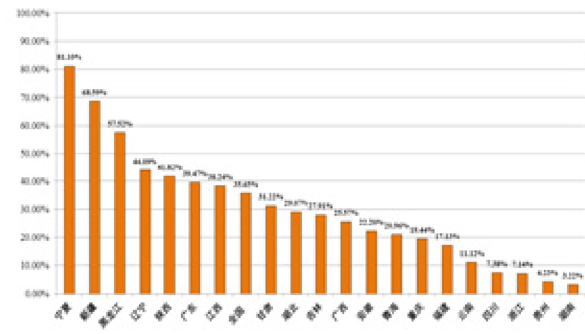
As a result, the yield increased 500 kg/acre; production cost saved 600 RMB/acre; and efficiency increased 10 times.

1.2 Challenges

Comparatively, the overall potato production mechanization rate is not as high as other crops shown below.



Another challenge is the unbalance development among different provinces.



Potato mechanization level in different provinces in 2014（%）

Meanwhile, there are four constraints for Whole-process potato mechanization including: 1) efficient supply of suitable machinery; 2) combination of machinery and agronomy; 3) the change in running businesses; and 4) the linkage among storage and transportation.

Despite the above-mentioned challenges and constraints, China has great opportunities for the development of potato production mechanization under favorable and enabling environment of the national efforts for achieving the "Four Modernizations of Agriculture, Industry, and National Defense" and transition period from rural labor force to mechanization for agricultural production.

IV. Consolidating Efforts to Solve the Major Challenges in Whole-process Potato Production Mechanization

Agricultural production relies greatly on machinery. Hence farmers' demand for machinery increases. Mechanization influences farmer's wellbeing as well as the development of the industry. Additional mechanization leads to the revolution of variety breeding, cultivation model, production method and operation method.

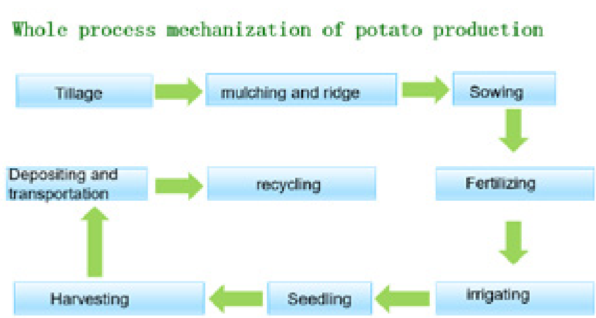
As estimated, the cost and benefit of potato production in China from 2010-2014 is showed below:

Mechanization helps to reduce the costs of the labor force. According to the Guiding Suggestion of MOA on Promoting the Whole-process Mechanization of the Main Crops, efforts shall be focused on 9 main crops and 5 main economic plants; and production processes of tillage, planting, harvesting, plant protection, and drying. The development goals of the potato industry by 2020 in line with the "Comment on Accelerating Potato Industry Development" is that the planting area reaches 100 million acres and 30% of total potato production are consumed as a staple food.

V. Exploring the Essentials of Potato Production Mechanization

There are six fundamental concepts under this section. These are: integration, diversity, comprehensiveness, systematism, sustainability and dynamic.

a. Integration: It is essential to take the whole supply chain as whole, integrate the technologies of good seeds, good methods, good machinery and good market together, and give farmers the Whole-process support and solution packages in the whole value chain. For example, the Whole-process mechanization of potato production covers the following steps:



b. Diversity: In terms of diversity, it is better to develop different planting methods and machinery as per the specific features of different provinces. For instance,

- **In the North:** Focusing on large and medium-sized planting and harvesting technology; integrated demonstration and land preparation; joint harvesting and phased harvesting; efficient and accurate pesticide application and straw processing technology.
- **In Central China:** Focusing on small sowing and harvesting technology; integrated demonstration of potato mechanized planter; small potato harvester; efficient and accurate pesticide application and straw processing technologies.
- **In the Southwest:** Focusing on hilly and small mechanized planting techniques and harvesting technology; integrated demonstration of small potato phased harvesting machine; small potato planting machine; straw processing; and other mechanization technologies.
- **In the South:** Focusing on small sowing and harvesting technology; integrated demonstration of potato mechanized planter; small potato harvester; efficient and accurate pesticide application and straw processing technologies.

The agricultural operation is also encouraged to be run by different players via land renting, trusteeship, and shareholding arrangement, and to develop the various operation types including self-supporting type, cooperative type, and service providing type.

c. Systematism: It needs to consider the whole-process potato mechanization in a systematic manner, for example, to emphasize advancement, adaptability, and safety altogether; to consider the technology for both the fore-rotating and subsequent crops; the matching issues of machinery for pre-production, production, and post-production; and to view the issue from an overarching perspective including technologies, operators, operation scale, administrative arrangements, etc.

d. Sustainability: The sustainability of the pertinent policies and technologies shall be emphasized. It is significant to exert the major role of the market to guide the development of potato production mechanization. The economic, social and environmental benefits shall be considered simultaneously as well as the utilization rate of land, labor and nature resources.

e. Dynamics: A dynamic model shall be developed for the Whole-process potato mechanization considering various factors including time and space, relative stability, radiation effects, and gradual progress of the model. The model shall cover solution selection, trial and pilots, large-scale application, and regular monitoring and improvement.

VI. Solution for Whole-process Potato Mechanization

To find solutions to improve the whole mechanization process, it is needed to consider in an integrated manner covering the supporting arrangement, operation mechanism, operation regulations and standards, available machinery, equipment, technology model, processing route, and applications areas. From the policy

item	Unit	2010	2011	2012	2013	2014
Net benefit	Yuan	1058.13	1000.75	1072.37	1315.74	1000.09
Total benefit	Yuan	2989.16	2218.02	2233.65	2761.37	2430.48
Average yield	KG	1708.07	1819.27	1670.6	1641.42	1753.44
Total cost	Yuan	1131.03	1214.27	1161.28	1355.46	1400.39
Direct cost	Yuan	799.19	869.43	760.08	783.56	839.13
Planting fee	Yuan	264.93	333.36	313.96	326.23	339.60
Fertilizer fee	Yuan	160.16	207.02	195.55	160.02	184.8
Indirect fee	Yuan	41.03	40.33	22.82	43.08	37.55
Manpower cost	Yuan	290.81	304.51	370.38	528.82	491.98
Family labor	Yuan	249.14	260.49	339.31	329.61	321.84
Employ fee	Yuan	41.67	44.02	39.07	199.21	168.70

Cost and Benefit of National Potato Production (2010-2014)

perspective, it shall be an integrated effort including supply side reforms, targeted policy support, and coordinated system innovation.

a. **Supply-side reforms:** From the whole image, the current main conflict is the insufficient supply of innovative machinery with high demand of modern agriculture equipment. The only solution is to make significant progress on the efficiency and quality of the machinery supply system through technology innovation, product innovation, service innovation, operation method reform and innovation, and human resource development.
b. **Policy support:** The subsidy and other supporting policies shall be focused on the whole mechanization process of the main crops including machinery purchase subsidy, demonstration sites development, technology innovation, operation subsidy, supporting innovative and capable operators and regular performance evaluation.
c. **Coordinated system innovation:** Sound development of whole-process potato mechanization shall engage all the stakeholders and make coordinated efforts, for example, to establish multi-stakeholder consultation teams and committees; to encourage the private sector to play the major role for innovation together with the other players; demand-oriented research; a combination of various funding methods covering hiring and renting; public-private partnership; government investment; and establishing consultation mechanisms of all key stakeholders for major issues, among others.

VII. Conclusion

In summary, the Whole-process potato mechanization is achievable due to high market demand and solid government support together with research, administrative promotion, technique guidance and demonstration. It would benefit not only one industry but the whole agriculture machinery sector.

The Whole-process Mechanization of Potato Production in India

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I. Introduction

Potato (Solanum tuberosum L.) is a major food crop grown in more than 125 countries of the world. Popularly known as 'the king of vegetables', potato, has emerged as the fourth most important food crop in India after rice, wheat, and maize. Dry matter, edible energy and edible protein content of potato make it a nutritionally superior vegetable as well as a staple food throughout the world. Because of being a short duration crop, it produces more quantity of dry matter, edible energy and edible protein in less duration of time than cereals like rice and wheat.

Potato is a highly nutritious, easily digestible, wholesome food containing carbohydrates, proteins, minerals, vitamins and a high-quality dietary fibre. A potato tuber contains 80% water and 20% dry matter consisting of 14% starch, 2% sugar, 2% protein, 1% minerals, 0.6% fibre, 0.1% fat, and vitamins B and C in an adequate amount. Thus, potato provides more nutrition than cereals and vegetables (Singh, 2014 a).

The world production of potatoes in 2013 was about 368 million tons. Just over two-thirds of the global production is eaten directly by humans and the rest is being fed to animals or used to produce starch. This means that the annual diet of an average global citizen included about 33 kg of potato. However, the local importance of potatoes is extremely variable and rapidly changing. It remains an essential crop in Europe (especially eastern and central Europe), where the per-capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia. China led the world in potato production, and nearly a third of the world's potatoes were harvested in China and India. The geographic shift of potato production has been away from wealthier countries toward lower-income areas of the world, although the degree of this trend is ambiguous.

II. Present Trend of Potato Production in India

India has diverse soil types and agro-climatic conditions. Successful potato cultivation requires night temperatures of 15-20°C with sunny days. Indian sub-tropical plains offer optimum conditions for potato cultivation, where 85-90% of potatoes are grown during short winter days from October to February. The hills account for less than 5% of the total potato production during long summer days from April to September/October. The plateau regions of south-eastern, central and peninsular India constitutes about 6% area where potatoes are grown mainly as a rain-fed or irrigated winter crop. On the basis of the diverse soil, climate and other agronomic features, the potato growing areas in India can be divided into eight zones. These zones lay in two major potato growing areas i.e. north Indian hills and north Indian plains, while southern and north Bengal and Sikkim hills and plateaus are three special problem areas.

Nearly 85% of the potato crop of Indian plains is grown during winters having short photoperiod (with about 10-11 h sunshine) and the crop duration is also limited to 90-100 days because of short and mild winter. The mornings usually have fog, which further reduces the sunshine hours posing severe constraints on photosynthetic activity. Besides, the post-harvest period consists of long hot summer, which creates storage problems.

All these problems highlight the need for suitable varieties and technologies for growing potatoes under the sub-tropical conditions of India. The area, production, and productivity under potato crop increased by 770%, 3020%, and 250%, respectively during the last 65 years (Table 1). India now ranks second in potato production (48.10 million ton) in the world with an average yield of 23.13 t/ha (2014-15).

Table 1: Area, Production and Yield of Potato in India

Year	Area (million ha)	Production (million tonnes)	Yield (t/ha)
1949-50	0.239	1.54	6.59
1959-60	0.362	2.73	7.55
1969-70	0.496	3.91	7.89
1979-80	0.685	8.33	12.15
1989-90	0.940	14.77	15.71
1999-00	1.340	24.71	18.44
2003-04	1.270	23.12	18.20
2009-10	1.840	36.58	19.92
2014-15	2.076	48.10	23.13

Source: Directorate of Economics & Statistics, Govt. of India

With the improvement in the living standard of people in India, the dietary habits will shift from cereals to vegetables. Under such a situation, it is estimated that India will have to produce 78 million tons of potato by 2050. This target could be achieved only by improving the productivity level. The productivity of potato in India is quite low (23.13 t/ha) as compared to that of Belgium (49.0 t/ha), New Zealand (45.0 t/ha), UK (39.7 t/ha) and USA (38.3 t/ha). This is due to a shorter crop duration in India. There is a wide variation in the agro-ecological setting in different parts of the country, which results in wide variations in the productivity levels in different states (Table 2).

Table 2: Area, Production and Yield of Potato in Major States of India during 2014-15

States	Area		Production		Yield (t/ha)
	(000’ Hectares)	Share (%)	(000’ Tons)	Share (%)	
Uttar Pradesh	604.30	29.21	13,137.54	28.59	21.74
West Bengal	412.20	19.92	12,027.00	26.17	29.18
Bihar	318.99	15.42	6,345.56	13.81	19.89
Madhya Pradesh	136.01	6.57	3,048.00	6.63	22.41
Assam	99.18	4.79	1,706.04	3.71	17.20
Others	469.05	24.09	9,017.93	21.09	16.46
Total	2,068.95	100.00	45,950.85	100.00	22.21

Source: Horticulture Division, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi (3rd Advance Estimate)

Potatoes are usually grown from small tubers, called seed potatoes. Seeds selected are free from diseases. Either a small tuber as whole or a piece of a large tuber containing at least one 'eye' is planted. Large tubers are treated with Emison and then cut into pieces having 2-4 'eyes' on each piece. Potatoes require good sunlight to grow and prefer a slightly acidic soil with a pH of 5.8-6.5. The soil is dug to a depth of 250-380 mm and covered with a mixture of soil and compost (50-75 mm) at the bottom. Seeds are planted into soil and the depth of soil allows good roots and foliage development. As the potatoes grow up, more soil and compost are added.

Several profitable potato-based inter-cropping and crop rotations have also been identified for different regions of the country. Potato can be profitably intercropped with wheat, mustard, and sugarcane. These cropping systems have helped in the maintenance of soil fertility and have improved the fertilizer economy, crop yield and gross returns.

III. Status of Mechanization in Potato Production in India

Potato is a highly voluminous and labour intensive crop which requires about 600 man-h/ha for different operations, if done manually. Seed (2.5-3.5 t/ha) and produce (25-30 t/ha) are perishable in nature and need quick and careful handling to avoid damage of tubers, especially during planting, harvesting and post-harvest operations (Singh, 2014 b). Although, in agriculturally developed countries production of potato was highly mechanized during the 1950s and 1960s, in India, the importance of mechanization felt in the 1970s and different machines were developed at Indian Council of Agricultural Research (ICAR) and agricultural universities. These machines were slowly adopted in Punjab, Haryana, Western Uttar Pradesh and in some other potato growing areas which helped in increasing potato production and bringing brown revolution in India.

Though basic machines like semi-automatic planters, inter-row cultivators, ridgers, sprayers, digger plows, digger elevators etc. are being used in India during the last couple of decades, in recent years, a significant development in research and development have taken place and a variety of new designs of machines have been added to the existing pool. Following are some of the recent advances in the mechanization of potato production in India.

3.1 Field Preparation Equipment

Deep soil tillage saves potato crop to some extent from water logging and drought conditions and result in 10-15% extra yield. Sub-soiler can be used for non-inversion deep tillage to a depth of 300-350 mm in dry field condition before planting the potato crop (Figure 1). Besides, disc harrows, cultivators, plankers recently rotavators/roto-tillers have started becoming popular with potato growers to obtain fine tilth in one operation.

Figure 1: Sub-soiler for Deep Tillage and Roto-tiller for Field Preparation.

Figure 2: Laser Guided Land Leveller

Precise land levelling is required to optimize water use efficiency, to improve crop establishment and to reduce the irrigation time. Laser land leveller is suitable for levelling the potato field within certain degree of desired slope (Figure 2).

3.2 Planting Equipment

Traditionally, potatoes are planted manually or with animal-drawn aids in most parts of India at 500-600 mm row to row spacing and 100-200 mm plant to plant spacing. The potato planter performs the functions of furrow opening, seed metering, seed placement at proper depth and formation of ridges to cover seed tubers. Two, three or four-row semi-automatic potato planters have been developed, commercialized and are being used by the farmers for sowing small potatoes or tubers with eyes in ridges on mechanized farms. The capacity of such a machine is low (0.15 ha/h) because of the slow speed of operation as the feeding of potato is done manually. In north-western areas, revolving magazine and belt cup type planters are popular where farm workers sit behind the machine and put seed tubers in revolving cells or belt cups. Seed pieces are dropped in line and are covered by ridge making units of the machine.

The tractor-drawn belt type semi-automatic potato planter ridger was demonstrated to farmers on a large scale by NDUAT, Faizabad Centre of AIRCP on FIM (Figure 3). The machine has a field capacity of 0.2 ha/h at forwarding speed of 2.15 km/h. The effective working width, planting depth and fertilizer placement depth of the machine are 1,200 mm, 213 mm and 54 mm, respectively. The machine saves 75% in labour (Pandey et al., 2006).

In recent years, automatic potato planters have been successfully designed and are being adopted by farmers. Automatic potato planters with picker wheel type mechanism are commercially available. These machines automatically pick up seed tubers and drops in lines which are covered by ridgers. In addition, they have more capacity, minimum missing and planting can be done at night. Moreover, these machines are also provided with fertilizer application units.

The tractor operated automatic potato planter was demonstrated to farmers on a large scale by CCSHAU, Hisar Centre of AICRP on FIM (Figure 4). The machine has a field capacity and field efficiency of 0.4 ha/h and 75-80%, respectively at an operating speed of 2.5-3.0 km/h. The fuel consumption is 4.0 l/h. There it is a saving in labour of 60-70% over the traditional manual method. The machine is available with semi-automatic and automatic planting mechanism costing Rs. 45,000/- (US$ 700) and Rs. 60,000/- (US$ 930), respectively (Singh, 2010 b).

The tractor (34 kW) operated vertical belt paired row potato planter has been evaluated by PAU, Ludhiana Centre of AICRP on FIM, to plant potato tubers on beds (Figure 5). The field capacity of the paired row planter is 0.24 ha/h at an average forward speed of 2.5 km/h. The approximate cost of vertical belt paired row potato planter is Rs. 85,000/- (US$ 1,320) and the cost of operation is Rs. 2,700/ha (US$ 40/ha). It helps farmers in saving quality potato seed from damage. There is a saving of 47.31% in cost of operation as compared to revolving magazine type semi-automatic potato planter (Mehta et al., 2016).

Figure 3,4: Tractor Operated Automatic Planter in Operation in Haryana State.

3.3 Inter Row Cultivation Equipment

Potato, being an underground crop, is highly responsive to inter-row-cultivation. Traditionally, after 21 days inter-row cultivation is performed with a cultivator (Figure 6), fertilizer is applied manually and earthing up operation is done with 3 rows or 5 rows ridgers. This involves multiple entries of tractors into the field.

Figure 5: Vertical Belt paired Row Automatic Potato Planter

A self-propelled power weeder (4.1 kW diesel engine) is also useful in row crops, horticultural and vegetable crops for weeding (Figure 7). The speed of power weeder ranged 2.3-2.5 km/h with an effective working width of 550 mm giving field capacity of 0.10

to 0.13 ha/h. The cost of self-propelled power weeder is about Rs. 40,000 (US$ 620) and the average cost of weeding is Rs 1,000/ha (US$ 15/ha). The equipment saves 90% operating time and 30% in term of cost of weeding as compared to hand weeding.

Figure 6: Spring Tyne inter Row Cultivator

Figure 7: Self-propelled Power Weeder

The tractor operated (26 kW and above) fertilizer band placement cum earthing up machine was designed and developed at GBPUAT, Pantnagar (Figure 8). The machine is suitable for simultaneous placement of fertilizer, earthing up and cutting of weeds in crops such as maize, sugarcane, potato etc. having more than 0.50 m row to row spacing. The field capacity of the machine was 0.56 ha/h with field efficiency of 82.4%. There was considerable saving in fertilizer, time and labour over the traditional method.

Figure 8: Fertilizer Band Placement cum Earthing up machine

3.4 Plant Protection Equipment

Effective management practices have been devised for major potato diseases and insect pests in India. Late blight is the most common disease of potato which occurs almost every year in the hills and plains. Besides chemical control measures, several late blight resistant varieties have been developed. Cultural and biological control measures have also been developed to control diseases and insect pests. The development of late blights forecasting systems for hills and plains has enabled early warning mechanism for the appearance of late blight disease. For many decades, the choice of sprayers was limited. These are manually operated low capacity equipment (Figure 9). The performance of these machines depends upon the operator's endurance. Recently, high capacity tractors operated sprayers have been developed which are more efficient, give consistent performance and can cover a large area in short span of time to save the crop from deadly diseases like late blight. The effective field capacity, field efficiency, fuel consumption and cost of operation of the tractor mounted sprayers are 1.12–1.25 ha/h, 75%, 5.5 l/h, and Rs. 800/ha (US$ 12/ha), respectively (Figure 10).

Figure 9: Single Nozzle and Multi-nozzle Hand Operated Sprayers

Figure 10: Tractor Operated Boom and Air Assisted Sprayers

3.5 Harvesting Equipment

Potato digging is a cumbersome process as soil-potato ratio is 31:1 and requires 600 man-h/ha if done manually (Verma, and Garg, 1971). Manual harvesting of potato is done by digging with the help of a shovel, a potato hook, and a spading fork. It is very expensive, time-consuming and of low capacity. It may damage the potatoes during digging operation. Manual harvesting of potatoes by kudali or khurpa (local tools) have a possibility of causing damage to around 13-15% (Singh and Singh, 1997).

Pre-cutting of wines and pre-sprinkling of water is used to reduce the possibility of damaging the potatoes.

In the semi-mechanized process of harvesting potatoes, digging is done by any machine or plough and collected manually. Sometimes, potatoes are also harvested by a bullock drawn disk plough, an animal-drawn potato digger (Figure 11) and tractor mounted cultivator but these are not commonly used because they cause more damage (up to 20%) to potato tubers as compared to manual methods. The harvesting operation is repeated four to five times for maximum recovery of tubers from the field using bullock drawn disk plough or tractor-drawn cultivator.

Figure 11: Animal Drawn Potato Digger

The tractor operated potato digger was demonstrated on a large scale by CCSHAU, Hisar Centre of AIRCP on FIM (Figure 12). The machine has a field capacity and field efficiency of 0.2-0.3 ha/h and 60-70%, respectively. The costs of machine and the cost of operation are Rs. 40,000/- (US$ 620) and Rs. 1,000/ha (US$ 15/ha), respectively.

A root crop harvester-cum-elevator has been developed for digging of potato, onion, garlic and carrot crops (Figure 13) (Mehta et al., 2013). The field capacity of the machine for potato digging is of 0.24 ha/h at a forward speed of 2.41 km/h. The possibility of damaging potato tubers is 1.92%. The approximate cost of the machine is Rs. 40,000/-(US$ 620).

The potato harvesters (combine) carry out a series of tasks in one operation, and can be tractor-mounted, self-propelled, or trailed type. Those that are trailed are power driven by a tractor to which they are attached. While simple harvesters resemble side-loading elevator diggers, more complex models include complex processes including electronic separation mechanisms.

The farmers of Gujarat, India, have imported a tractor operated (> 40 kW) offset-trailed type single row potato harvester of 2-ton hopper capacity from Germany (Figure 14). The compact and maneuverable potato harvester is suitable for medium and large size farms. It gently separates haulm from crop and drops potatoes from a low height. The large picking table of the machine with enough space to pick up the trash ensures a clean harvested crop.

3.6 Grading and Seed Treatment

Potato grading and treatment have been done manually for the last couple of decades. However, during the last few years, graders (Figure 15) and seed treatment machines have been developed to mechanically carry out these operations. But, the adoption of these machines in India is low because of needing to make a huge initial capital as compared to cheaper manual grading and treatment machine.

3.7 Potato Handling

In the production of potatoes, during the seeding and producing the potatoes are moved from one place to another 6-7 times before sending it to market. This requires a large number of farmers and it is very time-consuming. Furthermore, as the material is shifted in baskets and trays over the head, it involves a lot of drudgery to the workers. Alternative potato handling methods have been developed to reduce drudgery, time and labour requirement during the operation. For small farmers, 50 kg and 200 kg capacity trolleys have been developed. One person can move double or triple the load without much drudgery. For large size farms, pallets of capacity 500 kg to 1,300 kg have been developed which are used with the help of a fork lift for potato handling. All these machines are slowly being adopted by farmers in India.

Figure 12: Tractor Operated Potato Digger

Figure 13: Root Crop Harvester cum Elevator

Figure 14: Potato Combine Harvester in Operation in Gujarat State of India

Figure 15: Potato Rubber Spool Grader

3.8 Storage

In India, 85% of potatoes are produced in winter and stored during the long hot summer. Potatoes are required to be stored at 10-12° C for food purposes and at 2-4 ° C for seed purposes. The surplus potatoes in a season are stored in cold storages at 2-4° C in the country. This makes stored potatoes unfit for processing and loses preference for table purposes due to the accumulation of sugar content. There are a lot of traditional low-cost and non-refrigerated storage structures (essentially based on evaporative or passive evaporative cooling) in use in India with varying degrees of success. In non-refrigerated storages, sprout suppressants are being used to prevent excessive weight loss and shrinkage due to sprouting.

These new machines are helpful in timely planting, inter-row cultivation, spraying, harvesting, grading, and seed treatment. As by using these machines, different farm operations can be completed well in time. Therefore, cultivation of other crops in the system is not delayed and farming in general and cultivation of potato, in particular, can become a good business proposition.

3.9 Potato Export

Although India contributes 7.55% to the total world potato production, its 0.7% share in world's potato export is quite insignificant. India has also the natural advantage of exporting fresh table potatoes from January to June when the supply from European countries dwindle. It can also supply fresh potatoes round the year because India has an important diversity of agro-climates and potatoes are grown throughout the year in different parts of the country.

Many developing countries are becoming much more integrated into the international potato trade due to globalization. With the phasing out of quantitative restrictions on agricultural commodities, the imports and exports of potato would be based on the differences in price and production cost between the importing and exporting countries. Due to the low production cost in the country as a result of availability of cheap labour, India will have competitive advantage in the international potato trade.

IV. Challenges and Constraints Faced for Whole-process Mechanization of Potato Production in India

The challenges and constraints for whole-process mechanization of potato production in India are as follows:

1. Seed treatment for quality potato crop production requires 24 hours dipping in a tank before planting. The loading and unloading of seeds in the tank is a highly labour intensive operation and need to be mechanized.
2. Low-cost planters are needed for planting of cut seeds of potato

for growing crop for table purpose.

3. There is a need to keep tubers well covered with soil or mulch from planting to harvesting of potato to protect it from disease and pest problems.
4. Low-cost potato digger cum elevator or potato combine are required for mechanization of potato harvesting.
5. There is a need to develop lightweight farm tools and equipment to mechanize potato cultivation in hilly regions of the country.
6. There is a need to expand the scope of potato processing industries in India and also to diversify the processing to produce flour, cubes, granules, flakes, and starch.

V. Suggestions for Increasing the Regional Cooperation on the Whole-process of Mechanization of Potato Production in Asia and the Pacific

The countries of Asia-Pacific can help each other in identifying the mechanization gaps and share knowledge, information and good practices of potato mechanization in each country. The countries in the region can help India in providing technical know-how and low-cost technologies particularly for mechanization of potato harvesting and processing. India can also provide support to member countries in the transfer of technical know-how and improved farm equipment and machinery for potato production and processing. It can also help member countries in the formulation of standards for testing of potato cultivation machinery and their testing to promote regional trade.

Current Situation and Countermeasures of Mechanized Production for Potato in Yunnan Province, China

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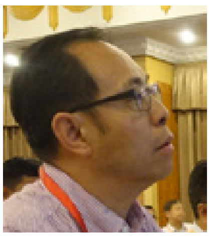

Abstract

Potato is one of the major crops in Yunnan province. It is one of the most important Yunnanese food crops and cash crops. In order to promote the development of the potato industry, reduce labor intensity, increase farmers income and improve the economic benefits of potato planting, it is important to introduce mechanized production methods. The present production situation and mechanical application situation of the potato in Yunnan province will be described at first. Then, the main factors restricted mechanized production of potato and the problems existed in agricultural machinery for potato production will be analyzed. In the end, based on the local situation in Yunnan province, some improved measures and countermeasures will be explicated.

I. Current Situation and Regional Distribution of Potato in Yunnan

Currently, land dedicated to potato crops can be seen everywhere. Since potato is an excellent source of nutrition and vitamins, potatoes are named as "underground apple", "new staple", and "top 10 healthy food" by people. Yunnan, a big potato producer province, ranks top on the potatoes' production yield and cultivated land area in China. In 2014, Yunnan had 11 million mu for potato cultivation that brought 14 million tons of fresh tuber yield. 3 million mu were assigned for winter-planting. Because of Yunnan's advantageous climate, the planting of potato can run for four seasons, which provides sufficient supplies to people's daily diet and profits for the enterprises on the value chain. This unique advantage creates remarkable profits for the entities and enables Yunnan's potatoes to be exported to Guangdong, Guangxi, Sichuan, and Guizhou. In addition, the potatoes are exported to other countries, such as Vietnam, Myanmar, Thailand, and Australia. Now, Yunnan becomes a major production base for export of potatoes to South-East Asia.

II. Mechanized Production Situation

In 2015, the area of mechanical plowing, mechanical sowing, and mechanical harvesting for potatoes was 2.45 million mu, 0.12 million mu, and 0.16 million mu respectively. The overall mechanization rate in Yunnan is of 31%. In that province, there are 215 sets of potato-sowing machines and 382 sets of potato-harvesting machines.

Traditionally, the production of potatoes applies human-sowing process, which resulted in a disorganized spacing of land. By applying mechanized production, time and cost are reduced effectively. Also, it lowers the intensity of labor and maintains the sowing qualities.

In 2011, the city of Shaotong introduced 3 sets of machines named 2MB-1/2 2-row with Big Ridge for-Potato-Growth from Qingdao Hongzhu Agricultural Mechanization Co., Ltd. They used the machines for sowing testing. It is noteworthy that the sowing area achieved by this machine was 66.72hm2. However, these sowing machines are still under the stage of importing, testing, and remodeling, and they have not yet been used broadly.

The premise to achieve mechanical harvesting is mechanical plowing. The traditional way to harvest potato by manually is very inefficient. Considering this problem, Yunnan introduced machines for sowing and harvesting and did the testing and promotion on the machines. In 2011, Shaotong Agricultural Promotion Station introduced one potato-killed seedlings machine and one harvester. In October 2012, the region of Yimen introduced a harvester that matches the hand-hold machine and did the on-site testing and promotion. Currently, the farmers in Yunnan are more and more familiar with the mechanized technique of potatoes and soon the potato harvester will be introduced and tested.

III. Demonstration Base for the Mechanized Potato Planting

Recently, the Yunnanese government invested 3 million RMB in 3000-mu mechanized potato planting base for demonstration. The model base was co-developed by Dapo Village in Zhanyi County and Yunnan Chengxing Agricultural Development Co., Ltd. To achieve mechanized production for potato entirely, the base operated 60 sets of machines, including potato harvesters, large sized sprinkler irrigation machines, plant protection equipment, etc. It developed the whole mechanized process for potato production, from sowing, fertilizing, irrigating, to spraying, harvesting, and sorting. Eventually, this model base became the first one that achieved the full implementation of the mechanized production process for potatoes in Yunnan. The demonstration also brought over 10,000 mu along this mechanized production.

IV. The Problems Along the Mechanized Production

4.1 Natural Conditions Restrictions

Since 94% of Yunnan is a mountainous area and the main production area for potato is on the mountain or half-mountain area, hence it is not advantageous to mechanize production due to the steep slope. In addition, in poor mountainous area, it is hard for farmers to access the innovation and new production methods. Low economic conditions, farmers' backward conception, and lagging techniques have seriously hindered the development of mechanization.

Furthermore, viscous soil, as a mineral resource, has also become an obstacle to the potato's mechanization production. The main characteristics of viscous soil are its plasticity, water-absorbability, expansibility, and absorbability. Due to its plasticity, the production will require the larger powerful engine during the process. The viscous soil not only increases mechanical resistance and power consumption, but also creates abrasion and lowers the reliability and safety.

4.2 Mismatch between Agricultural Mechanization and Agronomic Techniques

Since farmers plant potatoes in four seasons in Yunnan, they apply different agronomic techniques including intercropping, interplanting cultivation technique, deep-planting, etc. While the farmers spent a long time to develop agronomic technique and field management at the same time, agricultural mechanization was being ignored.

Besides the problems mentioned above, there are other difficulties needed to be resolved to achieve mechanization. Meanwhile performance still has problems in mechanical sowing, harvester, and large-scale operation.

V. Recommendations and Way Forward

5.1 Strengthen Policy Support and Financial Investment

By reinforcing the policy support and investments, the mechanized production for potato will develop more rapidly and effectively. First, the government should ensure that policies to be implemented in the manner of leading the way, especially focusing on the leading enterprises, agricultural entities to promote standardization and mechanization of planting. Besides, the compensation scheme should also coordinate the policies to encourage more farmers and entities to implement the mechanization process.

5.2 Coordinate Agricultural Mechanization and Agronomic Techniques

Since the potato-planting system is diverse and complicated, it is important to coordinate agricultural mechanization and agronomic techniques and ultimately achieve sustainable development. First, the quality of production should be improved to promote stability and adaptability, especially on sowing and harvesting. Second, there should be a higher combination of the agronomic techniques and mechanization in order to match with each other. It is also important that there is a higher production of machinery to meet the needs of the agronomic techniques. In addition, the government should have more budget on research and development entities to expect a breakthrough in this area.

5.3 Establish Demonstration Base for the Mechanized Planting

A demonstration base of mechanized potato planting is always the most effective way. The base will not only help to present the standardized model but also enable the exploration of new mechanical techniques and matching strategies. Besides, by cooperating with different organizations, the base will also be a center for training and technical guidance. In this case, farmers will get a first-hand experience about new techniques and explore the advantages of mechanization.

5.4 Develop Practical Machinery

In recent years, Yunnan's development on mechanization of potato planting is noteworthy and the technique has been promoted and applied in many areas. However, due to the unique soil and complicated planting system, the introduced machinery is, occasionally, unadaptable to Yunnan's planting environment. So, it is necessary to develop machinery that can be adapted to the local conditions.

Considering Yunnan's unique soil and terrain features, digging parts can be improved in many aspects. For example, a digging shovel can be applied to multiple plates to reduce abrasion and resistance. Also, according to the viscidity of the soil, the shape of the shovel can be changed from a triangular shape to a trapezoid to expand the contact surface. The new shape will enable shovels to cut into soil more easily, and meanwhile, maintain the intensity.

For the detach component, it can be improved in its amplitude, longitude, speed, and shape of the grid bar. Since those elements are all significant, it will be necessary to consider each other and optimize the design by conducting a vast number of testing and motion simulation.

5.5 Support to Build up Professional Cooperation

Building up more professional cooperation in terms of potato planting will be important for the commercialization of potatoes. Professional cooperation can also motivate more farmers to get involved in.

Conclusion

To sum up, there is still room for improvement in the mechanization production of potatoes in Yunnan. It is important to selectively introduce and learn the most updated techniques and machinery from domestic and foreign manufacturers. In addition, the potato-planting machinery should also be further developed to adapt to Yunnan's regional condition, particularly focusing on the difficulty of sowing and harvesting. The implementation and achievement of mechanization will accelerate potato production and contribute to the agricultural development in Yunnan.

The Whole-process Mechanization of Sweet Potato Production in Malaysia

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I. Introduction

Sweet potato is among the top seven staples in the world and is followed after wheat, rice, maize, potato, barley, and cassava. Currently, the world largest cultivated area for sweet potato is in China, with more than 3.5 million hectares, or almost 43% of the total world production (Table 1).

Sweet potato is a minor food crop in Malaysia. The area under root or tuber crops production is small as compared to the major plantation crops of the country such as oil palm rubber, cocoa, and fruits. Among the root crops, sweet potato ranks second after cassava. A total of 1,309 hectares were planted with sweet potatoes in 2009 and the area has slowly increased to 2,505 hectares in 2013. The yield of sweet potato increased from about 13,495 Mt in 2009 to 26,688 Mt in 2013 (Table 2). The comparison between production, yield and planting area shows that the yearly production of sweet potato increased linearly with the increase in planting area (Figure 1).

Sweet potato is mainly grown in the states of Johor, Perak, Selangor, Kelantan, Pahang, and Terengganu. The growing areas on mineral soil are in Johor and Pahang. However, in Perak sweet potato is planted on sand tailings soil. Sweet potato is mostly planted on cleared peat moss soil in Selangor, while in Terengganu and Kelantan, there are mostly plantings on bris, sandy beach deposits which is typical on the east coast of Peninsular Malaysia. Intermittently, some sweet potato is planted in abandoned paddy areas or in during off-season in Kedah, Kelantan, and Terengganu.

Sweet potato has a great advantage in growing well on marginal soils such as bris, tin-tailings, acid sulfate soil and drained peat. This needs to adopt certain recommended soil amendments. This means that the sweet potato will not compete with the other crops for fertile and better-quality soils. Marginal soil in Peninsular Malaysia alone covers some 1.67 million hectares, with 870,000 ha of peatland and muck soil 433,000 ha of idle paddy land, 165,000 ha of bris 110,000 ha of acid sulfate soil and 91,000 ha of sand tailings. The nutrients contained in bris soil is lower and there is a need to improve the process by using the organic fertilizers. R&D on this soil type showed that for agricultural use, this soil needs to be sustained with the organic fertilizers or manure such as pomes to improve the soil nutrition. The minimum capacity of the soil fertilizers or manure is about 20 ton per hectare.

Table 1: Top ten sweet potato producing countries in the world

Country	Production	
	Area (hectares)	Volume (Tons)
China	3,524,505	79,090,068
Nigeria	1,115,000	3,400,000
Tanzania	675,000	3,100,000
Uganda	550,000	2,587,000
Indonesia	161,850	2,386,729
Vietnam	135,900	1,364,000
Rwanda	112,346	1,081,224
India	111,800	1,132,400
United States of America	45,810	1,124,230
Ethiopia	39,076	1,354,911
Total top ten	**6,471,287**	**96,620,562**
World	**8,240,969**	**110,746,162**

Table 2: Area and production under tuber crops during the years 2009–2013

Year	Cassava (ha)	Cassava (mt)	Sweet potato (ha)	Sweet potato (mt)	Coco yam (ha)	Coco yam (mt)
2009	3,075	68,508	1,309	13,495	656	6,366
2010	2,708	37,183	2,176	23,054	348	2,887
2011	2,596	33,206	2,229	26,582	385	2,802
2012	3,053	40,998	2,386	25,417	384	3,183
2013	3,205	43,048	2,505	26,688	403	3,342
2014	-	-	-	-	-	-

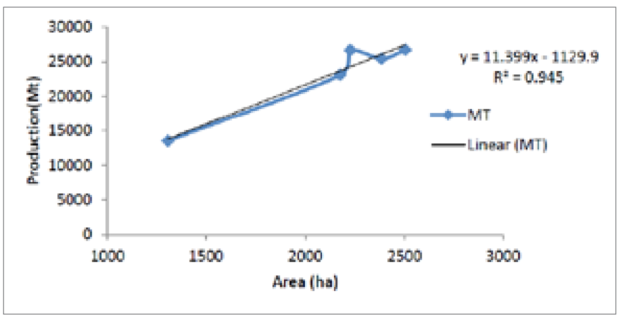

Figure.1: Production (Mt) and area (ha) of sweet potato production

A range of cultivated varieties, differing in root and flash color, flesh texture and root shape, are grown mainly for the fresh food market. Nevertheless, as much as 40% may be used in processing: mainly as a thickener in the manufacture of tomato and chili sauces, baby foods, and snack food such as 'kerepek'(crisps) and 'cakar ayam' (sugared and fried strips). Fresh sweet potato is bought to be eaten boiled, steamed or fried, and to prepare some traditional Malaysian cakes and tea time snacks. This crop is used not only for direct fresh consumption but also as a raw ingredient in food processing. Sweet potato flour can be used as a partial substitute of wheat flour in bakery and pasta products.

Research on Sweet Potato

Research on sweet potato has been held at MARDI since 1971. Many varieties of sweet potatoes have been released in the year 2000 such as Bukit Naga, Kuala Bikam, Gendut Jalomas, and Telong which are readily available in the market. The latest variety, VitAto, was released in middle 2007. This variety was mostly grown by farm owners and growers in bris soil, mainly in coastal areas about 5 km from the coast. It is known as a very vigorous variety and able to produce a good yield in bris soil area.

Sweet potato can be planted all year round, with supplemental irrigation and different varieties during the dry season, normally in February to July. Planting time depends on the variety grown and season. Normally from August to December, it is the rainy season and sometimes the area becomes flooded. For this period, even sweet potato is not advisable. Sweet potato and tubers are very sensitive to flooding and become rotten when the tuber is submerged in water for more than three days. The yield of sweet potato depends on the variety and season, which are the principal factors limiting growth and development of tubers. These are also dependent on the planting time and inter-cropping rotation.

Most of the sweet potato produced is marketed fresh. The marketing system follows the pattern of farmers-collectors-truckers-wholesalers-retailers-consumers. By far the most prevalent is the consigning method of selling whereby the product is consigned by the farmers through the local collectors or transport agents (or truckers) for sale in the terminal market with prices known only after scaling at such market.

Some new varieties developed by MARDI such as VitAto have the potential to be processed commercially into flour due to their high starch. There is a potential demand for sweet potato flour in the food processing industry and highlight the need to increase production. Hence, the machines for field operations are needed to plant sweet potatoes on a larger scale for the flour industry.

Currently, increasing agricultural production face difficulties in finding labour. With a proper machinery, such as a tractor with an air-conditioned cab, the laborious and hazardous jobs can be done safely, in a comfortable and fast manner. Such a change in the field working environment will bring about new perspectives when looking at farming as an enterprise in the near future. The main objective of this paper is to present a new approach to sweet potato production in Malaysia.

II. Status of Mechanization in Sweet Potato Productions

Shortage of labor in the agricultural sector is a well-known and accepted fact in the country. In view of this, mechanization is needed urgently in the sector. The traditional manual method of growing sweet potato involves a great amount of labor. A large amount of labor is required for digging, planting and weeding operations. For commercial sweet potato cultivation, mechanization and the other labor–saving technologies are needed. The mechanization system in Malaysia was developed by adopting the available prime mover and implements. However, some improved implements were developed modified making a complete package of sweet potato cultivation. The implements are used for the land preparation, planting of seedling, maintaining and harvesting of the crop.

Machinery System for Production of Sweet Potato

Several machines are available for various field operations in sweet potato production. A proper selection and adaptation of the machinery for sweet potato production makes field operations more efficient, more comfortable and safer. Commercial sweet potato production has to rely on the machinery for efficient management, especially in the future when the sweet potato becomes an industrial crop. Some of the mechanized field operations are shown in Table 3 and discussed below.

Table 3: Machinery availability, problems and requirements for sweet potato production

Operation	Machine requirement	Availability
1. Land Preparation a. Tillage (rotor) b. Rotor + Ridger	Rotovator Rotovator + ridger	Suitable on bris soil, attached to a 30 hp 4 w tractor. Setting for ridger 1 016 mm for tractor operation.
2. Planting a. Planting materials b. Planting spacing c. Planting method	Mechanical aid 1,016 x 240 mm, 40,000 plants/ha Transplanter attached to a 30 hp 4 w tractor, planting on beds, 1.3 m wide.	Cuttings 300 mm long, short internode, 8 nodes per cutting. Available
3. Fertilizer applications a. NPK (granular/ powder) b. Organic fertilizer (dry and granular/powder)	Spreader with some modifications Spreader with some modifications	Available Modified, suitable for dry applications
4. Pesticide spraying	Boom sprayer attached to a 30 hp, 4 w tractor.	Available, tractor tracks follow the furrows during sprayer.
5. Water management a. Irrigation b. Drainage	Any type of sprinkler available, depending on field conditions Ridger or disk furrow	Available Available
6. Harvesting a. Vine slashing b. Root digger c. Root collection	slasher or bale roller - Vibrator digger - Modified Houlon destroyer digger - Some use of plough/mechanical implements but damage is high. Trailer attached to a tractor and manual collection	Needs some modifications Still under research/ manual collector is still needed Available

Land Preparation Machinery

The first step in sweet potato production is the clearing of land. Large-scale land clearing can be done by bulldozers while small scale bush clearing can be done with a backhoe. The same machines can also be used for constructing farm roads and drains. After clearing, the land needs to be prepared for planting. Land preparation involves ploughing, harrowing, roto tilling and ridging operations. Land preparation is important for improving soil structure and removing the weeds. Standard four-wheel tractors can perform land preparation operations (1, 2 and 3). Machinery for land preparation in problematic soils such as tin-tailings and bris soils is similar to those used for mineral soils, except for ploughing (Table 3). The soil structure in these problematic soils is loose. For land clearing, a bucket scraper attached to a tractor can be used. A rotovator and a ridger can be applied simultaneously during the land preparation. The bed size is 1.3-meter-wide for single-row planting and 1.5-meter-wide for double-row planting.

Figure 1: Land Preparation by a Disk Plough

Figure 2: Land Preparation by a Rotor Ridger

Figure 3: Double Disk Harrow for Bed Making

Figure 4: Organic Fertilizer Applicator

Organic Fertilizer Applicator Machine

The organic fertilizer applicator is locally designed. It can apply organic fertilizer at the center of the bed (or ridge) before planting. This machine is designed by MARDI for application of dried chicken manure along the bed. The machine is attached to the tractor, and the fertilizer is dropped along the bed and worked in by a PTO - tractor shaft (Figure 4).

Planting Machinery

The normal practice is to cut planting materials (250-300 mm long cuttings) from existing crops or from plants specially raised in a breeding center. The cuttings are then planted by hand. This method requires up to 150 man-hours per hectare. Manual planting is slow, affecting the time required, as well as the cost for planting, especially when carried out on a large scale.

Figure 5a: Single row Planter

Figure 5b: Crop –Transplanted Using Single Row Planter

A mechanical transplanter can reduce the amount of labor used and shorten the time required for planting. The transplanter also plants in a more uniformed manner (Figures.5b and 6b). An adapted single row and double-row vegetable transplanter can be used for planting sweet potato seedling (Figures. 5a, b and 6 a, b). Two operators are needed to operate a single row planter;

one for planting, and another for driving the tractor, while three operators are needed for a double row planter: two for planting and one for driving the tractor. Both machines can plant one hectare in 6-8 h and 4-6 h, respectively, depending on the experience of the operators and the driver in synchronizing the operations.

Figure 6a: Double Row Planter

Figure 6b: Crop Transplanted Using Double-Row Planter

The cuttings have first to be wilted before using the transplanter. The application of the fertilizer is undertaken simultaneously with planting using the same machine. Granular fertilizer is applied in a band along the planting row. The planting system has to match the machine setting. For a double-row transplanter, the spacing between the rows within a bed can be adjusted to a minimum of 500 mm apart, and the spacing between plants within 250-350 mm.

Weed Management Machinery

Weeds in sweet potato fields can be controlled by a tractor-mounted single and double rows inter-row cultivators which cultivates between the rows of sweet potato (Figures. 7a, and b). These inter-row cultivators can be attached to a fertilizer applicator and a ridger. The ridger is used for lifting up the soil as well as pulverizing the soil and working in the fertilizer. If required, weeds or grass in the middle of the beds can be limited by using a boom sprayer to apply the weedicide. This boom sprayer has to be used at the early stage of planting, or before planting to control grass seed germination (Figure 8). Other operations used in the bris soils include the double disks harrow to cultivate the weeds between the rows, beside that it can reshape the planting bed (Figure 9).

Figure 7a: Spreading Granular Fertilizer along Sweet Potato and Row Weeding

Figure 7b: Weeding between Rows for Single Row Sweet Potato Planting

Figure 8: Pesticide spraying using an air-conditioned tractor

Figure 9: Double disk harrow used for inter- rowing and reshaping the planting bed

Pest and Disease Management Machinery

Pest and disease management is one of the major considerations in the operating of large-scale production of sweet potato. During the outbreaks of diseases, control measures have to be taken fast. Delays in controlling the disease spread may cause substantial damage to the sweet potato yields. A tractor-mounted boom sprayer or power sprayer is one of the machines usually dedicated to sweet potato pest and disease management (Figure 8). Both single and double-row planting are effective in terms of speed of operation and savings in chemicals. With a machine, the height and angle of the spraying can be controlled according to the height of the crop from the ground and the canopy structure. With the help of a tractor PTO shaft, chemical droplets can penetrate deep into the canopy preventing insects from breeding inside.

Irrigation

Irrigation is needed at an early stage of crop germination especially during the dry season. It should be applied regularly at least two weeks after planting until the crop is established. When sweet potato is grown on sandy soils, there is usually a need to irrigate when there are prolonged periods of rainless days. An irrigation system which has been broadly used is the overhead sprinklers system (Figure 10). On peat, there is often no need for irrigation because of the higher water retention capacity of the soil.

Figure 10: Sprinkler System Applied During the Crop Establishment

Fertilizer Application Machinery

Fertilizer application in the field can be done with a tractor-mounted row fertilizer spreader (Figures. 7a and b). The machine applies the granular fertilizer on both the left and right sides of the tractor. The operation is relatively fast and suitable for a large field. Alternatively, a fertilizer hopper attached to the planter can apply fertilizer at the same time as the planting operation.

If the weeds have germinated within the rows, the inter-row cultivator can be used simultaneously with the fertilizer applicator. Fertilizer leaching can also be minimized by mixing it into the soil. An optimum maintenance and fertilizer application ensure that maximum yields can be obtained. Observational studies on sweet potato showed that the crops grew faster and produced higher yields with organic fertilizer.

Vine Slashing Machinery

The tractor-mounted flail or shredder with a specially designed blade is suitable for large scale use for slashing the sweet potato vines before root harvest (Figures. 11a and b). The flail blade design is suitable for the use on crops grown on beds such as sweet potato. The vines and weeds on the beds can be shredded into smaller pieces by a heavy-duty shredder. The pieces are then left on the ground to decompose.

Figure 11a: Slashing Sweet Potato Vines

Figure 11b: Vines and Leaves before

Harvesting and In-field Handling

Harvesting sweet potato from small fields for the fresh market is generally done manually. Some machines such as a cangkul (hoe) and other hand tools are available. One method for easy manual harvesting is slashing the vines from the roots and rolling up the vines along the beds. The Assam fork or Cangkul Mata Tiga is used to dig up the roots. By using this method, the roots can be lifted with the fork and placed on one side for the collection by another group of workers. This traditional technique is slow and strenuous (Figure 12a).

Figure 12a: Manual Harvesting

There are three types of harvesting machines which can be used in sweet potato harvesting. The first type is simple and locally fabricated. This machine has three strong steel tines to dig up the roots. The implement is attached to a medium-sized tractor and pulled along the bed. The roots are lifted up and left on the bed. A group of collectors follows the tractor and collects the roots. The tine design consists of parallel blades adjusted to a certain angle to dig the roots (Figure 12b).

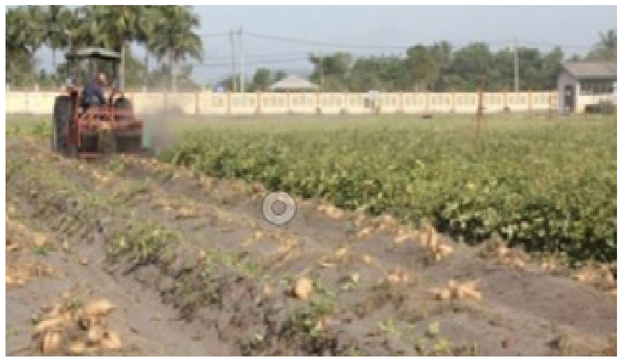

Figure 12b: Root Digger Lifter

A second type is a digger-lifter machine. This machine is imported and needs to be attached to the prime mover (a standard tractor). The machine is pulled by the tractor, and the digger digs into the soil and lifts up the roots by a conveyor mechanism. The conveyor conveys the roots and drops them at the back. Like that, any soil and gravel that drops passes through the conveyor links. A group of collectors follows at the backloading the roots into a trailer. The problem with this machine is that the soil may be deposited on the roots and cover them, causing the collectors to miss some of the roots (Figure 12c).

Figure 12a: Manual Harvesting

The third type is a digger-lifter and elevator. This machine is a modification to the imported potato harvesting machinery. This machine can be used for harvesting sweet potato with major modifications. This machine can be attached to a tractor greater than 60 hp. The machine can do three operations simultaneously. The first operation is digging the roots, the second is lifting up the roots and shaking them loose from the soil, and the third is facilitating root collection (where one or two people standing at both sides of the machine will collect the roots). The collected roots will then be put on both sides of the elevator and be conveyed to the end and dropped into baskets (Figure 12d).

Figure 12b: Root Digger Lifter

A tractor-trailer is suitable for in-field handling on a large farm. A smaller farm may use a wheelbarrow or other carts. The use of a shallow container is better than a deep container as the latter poses a greater possibility of sweet potato roots being bruised when they are loaded. Sometimes a farmer uses bamboo baskets for handling sweet potato.

Machinery Available and Cost Considerations

Table 4 compares the estimated production cost of a hectare of sweet potato on mineral soils, sandy soils and drained peat by manual means and on mineral soils by machines. It can be seen that a machinery system on sandy soil, such as tin tailings and bris soil would achieve a savings of about US$ 0.02/kg, or assuming a root yield of 20 tonne, total savings amounting to US$ 400 per ha on sandy soils as compared to a manual production system. In addition, the working hours for the mechanized system could be further reduced if the process of cutting of vines is mechanized.

Table 4. Estimated costs (RM) of producing 1 ha of sweet potato on mineral soils, sandy soils and drained peat by manual means and on mineral soils by machines.

Cost item	Manual production			Mechanical production on mineral soils
	Mineral soils	Sandy soils	Drained peat	
Land preparation(contract)				
2 rounds of tillage	400			400
1 round of tillage		200	200	
1 round of ridging	200	200	200	200
Planting				
Planting materials+	800	800	800	800
Labour* for planting	240	240	240	120**
Fertilizer application				
5 t of dolomitic lime			400	
Labour for lime application			75	
2.5 t of chicken dung	300			300
10 t of chicken dung		1,200		
Labour for chicken dung application	75	150		45**
Chemical fertilizers				
34 N, 34 P2O5, 67 K2O	185		185	185
17 kg CuSO4.5H2O			55	
Labour for application	75		75	30**
80 N, 60 P2O5, 120 K2O		735		
Labour for 3 applications			225	
Weed control				
4.2 Lof alachlor	90	90	90	90
Labour for spraying	150	150	150	30**
Pest control				
16 kg of endosulfan granules	50	50	50	50
Labour for application	150	150	150	45**
1 Lof malathion	15	15	15	15
0.5 kg of benomyl	35	35	35	35
Labour for spraying	150	150	150	45**

Irrigation				
At plant establishment	180	180	180	180
Additional		180		
Harvesting				
Yield of 20 t @ RM33/t	660	660	660	150**
Total cost	3,755	5,410	3,710	2,720
Cost per kg roots (RM)	0.19	0.27	0.186	0.136

+ Non-recurrent cost after 1st crop of sweet potato
* Labour cost: RM15 per man-day.
** Machine operator paid RM15 per hour

The Needed Assessment of Sweet Potato Production Mechanization

Currently, Malaysia is focusing on bringing back the agricultural sector to contribute to the GDP. The government has changed the name of Ministry of Agriculture to Ministry of Agriculture and Agro-based Industry in order to change people's attitude towards agriculture.

Mechanization is necessary for the commercial sweet potato production. It is an advantages against manually operated process in the increase of productivity, field efficiency and output quality. Sustainable continuous production and labor dependency reduction can be achieved through the application of the mechanization system. Readily available prime mover and implements can be adopted in the sweet potato production. However, the implements need to be tested to ensure their reliability, stability, durability, functionality, and cost–effectiveness. Some implements have to be developed or existing ones have to be modified to suit the local conditions. Finally, the application of a complete mechanization package for sweet potato production should consider its technical feasibility and economic viability.

III. Challenges and Constraints Faced for the Whole-process of Mechanization of Sweet Potato Production

- Machinery for sweet potato production is expensive and farmers are not able to purchase them.
- Machinery for tuber crops is not suitable to work in wet soil conditions, e.g. rainy season.
- Poor facilities and resources for training on machineries, lack of skilled trainers for training.
- The recognition of trainer standards is not uniform.
- The lack of skilled labor in agriculture mechanization and automation.
- Limited transfer of technology.
- The young generation is not interested in agriculture.
- Farmers landholdings are small, between 1- 2 ha, and not suitable for farmers to own the machinery.
- There is a need for new machines to be developed for application in the peat soil.
- Increasing agricultural production will face difficulties in finding the labor force. The only alternative is to replace the labor with machines. However, the problem still stands on how to attract the young and skilled operators to handle the machinery.

IV. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

Skilled labor force can be developed through training courses for field machinery handling. In this regard, countries in Asia and the Pacific have the know-how on how to give the training courses to the service providers, farmers or entrepreneurs for mechanization in the field of production of sweet potato.

The machinery courses can benefit the workers by teaching them on how to handle the field machinery for sweet potato production. It also can attract the young people to work in the agricultural sector and machine operations. The training courses to the young farmers should be established under the guidance of the agricultural agencies.

V. Conclusion

A complete machinery system based on a standard four–wheeled tractor has been developed and tested for mechanized commercial sweet potato production in the marginal soil (bris and tin tailing soil). Almost all field operations in the production of sweet potato can be mechanized. Even though certain operations still have to be done partly by manual methods, mechanized production can save a substantial amount of labor and costs of field operations.

Mechanized production involves a large amount of capital, and there is no universal machinery system applicable to all farming situations. Therefore, careful planning is needed for machinery to be used optimally in the field. Understanding and accepting the new changes in field design and agronomic practices will enable sweet potato cultivation to be fully mechanized in the near future and increase sweet potato share in the world production.

The Whole-process of Mechanization of Root Crop Production in the Philippines

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I. Introduction

Root crops are one of the most important food crops in the country after rice and corn. Due to their ability to thrive in varying agro-ecological conditions, they have served as a major alternative food source in the majority of the regions in the country. The most commonly planted root crops in the country are cassava, sweet potato, yams, and potato. Apart from their use as food, root crops also serve as raw materials for the production of animal feeds, starch, and other derived industrial products.

Currently, about 300,000 ha of agricultural land is devoted to the production of root crops. Most of these areas, however, are in marginal areas commonly not suitable to the more popular staples such as rice and corn. Cassava accounts for a considerable percentage in terms of area and production. Current area of production is about 216,775 hectares (Table 1) with a production volume of about 2.5 million tonnes in 2014. This has shown a constant increase during the last ten years.

Next to cassava, sweet potato ranks as the second most planted root crop, accounting for 88,968 hectares area (Table 1). Similar to cassava, sweet potato is a very versatile crop where tertiary products can be produced. Tubers are commonly eaten boiled or sweetened or used as condiments for native recipes. The leaves are also used as a vegetable, either boiled or as ingredients for native dishes. It has also been used for the manufacture of sauces, pastes, and juices.

Potato (white) for now is the third most popular tuber crop in the country, accounting for only about 7,800 hectares area (Table 1). These are commonly found in the highlands or mid-elevated areas like Benguet, Davao, Cotabato, and Bukidnon, with Benguet accounting for more than 60-75% of the total production. It is commonly used as a vegetable crop. Other uses include food items such as chips, noodles, or French fries, and industrial material like granules, flour, and starch.

Table 1: Area (ha) and Production (t) of Various Root Crops.

Year	Cassava		Sweet Potato		Potato		Yam	
	t	ha	t	ha	t	ha	t	ha
2005	1,677,564	204,784	574,629	120,638	70,160	5,497	29,256	5,890
2006	1,756,856	204, 578	566,773	118,829	69,461	5,450	30,074	5,999
2007	1,871,138	209,633	573,734	117,584	118,497	7,939	29,265	5,839
2008	1,941,575	211,657	572,655	116,465	121,311	7,994	24,185	5,212
2009	2,043,719	215,933	560,516	114,380	119,159	7,904	22,567	4,929
2010	2,101,454	217,622	541,265	109,438	124,671	8,129	21,906	4,744
2011	2,209,684	221,235	516,338	103,704	120,574	8,171	17,844	2,974
2012	2,223,182	217,259	516,907	101,087	119,570	8,096	16,429	2,688
2013	2,362,561	217,146	528,250	94,844	117,722	7,890	14,770	2,621
2014	2,540,254	216, 775	519,855	88,968	119,140	7,868	15,260	2,616

Source: PSA

The current potato value chain is basically composed of sub-chains based on the type of product produced: (1) the food, (2) feed, (3) starch and flour. Locally produced potatoes are commonly sold fresh in the market while others are processed into chips (crisps), extruded products or into French fries. However, the bigger fast food joints that commonly have a nationwide chain of stores import their entire requirement for French fries. The fast food chains Jollibee and McDonalds, the nation's two biggest fast food joints, have imported 31,757 Mt in 2006 and are well established in many provinces (Wustman, 2010).

The potato supply chain is basically composed of only a single chain which is the food chain. The chain has basically three major stakeholders: farmers (producers), retailers and processors. Logistics, however have a vital role to play as most farms are in remote highland areas, especially in the mountainous areas of Benguet. Most production areas are small and fragmented farms in such similar terrains in other areas of the country with relatively the same climatic conditions. Large scale operations used to produce a substantial volume of high-quality raw materials for potato production is still a new approach in the Philippines. Transport is carried out by horses (highland fields to villages), trucks (village to cities) and ships (Mindanao to Manila). Retailers sell fresh potatoes in the local market or supermarkets. Potatoes sold in supermarkets are usually wrapped in plastic bags with package sizes varying from a few hundred grams up to about a kilogram.

processors of potatoes into chips are well established. Liwayway and Universal Robina Corporation (URC) both operate potato chip processing plants. About 20,000 t of potatoes are annually processed into chips. Annually, these two companies import raw material amounting to about 17,000 Mt, with URC using 12,000 Mt while Liwayway using about 5,000 t Liwayway imports 100%, while URC imports about 75% and sources about 25% locally (Wustman, 2010). Apart from the use of potato, Liwayway or the more commonly known as Oishi food snack brand also uses cassava starch and flour for the production of some of its food snacks.

The current sweet potato value chain is basically composed of sub-chains based on the type of product produced: (1) the food, (2) feed, (3) starch and flour. The food sub-chain (around 95%) essentially dominates the whole value chain in the country (Roa, 2014). The rest of the production (5%) is mainly utilized for feeds and other uses.

Value chain for sweet potato has four major stakeholders: producers, traders, retailers, and processors. Sweet potato production is currently done by small farmers or in commercial production by cooperatives and private companies. Large scale operations are being done in Nueva Ecija, Tarlac and Albay provinces. Produced for commercial operations, sweet potato is distributed to feed mills, food processors and retailers. Retailers sell fresh sweet potatoes in the local market or supermarkets. In a small and semi-commercial scale, about 40%, of the produce goes to the retail market, for food processing and as seed material and farmer's own consumption, respectively (Roa, 2014). Sweet potato is further processed into dried chips, native delicacies, noodles and other food products. In the retail market, some restaurants serve sweet potato fries as an alternative to French fries.

The current cassava value chain (CVC) is basically composed of four sub-chains based on the type of product produced: (1) the food, (2) feed, (3) starch and (4) flour. There are five marketing channels within the CVC namely, (1) home consumption, (2) native food and delicacies, (3) feeds, (4) starch, and (5) flour. Figure 1 is the visual representation of the CVC showing the different marketing channels. The feed sub-chain essentially dominates the whole CVC as it accounts for about 70% of the total cassava produced in the country. San Miguel Foods Inc. (SMFI) and its subsidiary feed company B-MEG generally drives not only the feed sub-chain, but the whole CVC due to its sheer size of operation and the demand for cassava as raw material for animal feeds. Most of the current producers of the crop went into cassava farming with the feed market as a point of entry. The recent entry of CP Company of Thailand, however has brought about a new player in the feed market channel.

Although there are other feed millers in the country, it is only SMFI that has continually used cassava as a substitute as well as the main ingredient for its various feed formulations. The feed mills generally require cassava either as dried chips or granules.

Next to the feed chain, the starch sub-chain accounts for about 20 to 25% of the total production of cassava in the country. Presently there are only five operational starch plants in the country with capacities ranging from 50 to 150 t/day. Unlike the feed channel, the starch channel only requires one form of product which is fresh cassava tubers. Cassava, which is highly perishable, needs to be processed within 2 to 3 days, after which deterioration sets in, that includes a reduction in the total starch content. Thus, most cassava starch mills are located in close proximity to the production area.

The food and flour sub-chains accounts for the smallest percentage of the total cassava produce. This is anywhere from only 5 to 10% of total production. The food sub-chain has generally two marketing channels, one for home consumption and another one for native food snacks and delicacies. The other food marketing channel which is for native snack foods and delicacies is generally scattered all over the country. This includes the households that consume cassava as staple who sell to this channel their surplus produce. Most of the products are cassava cakes, sweets, and other delicacies. In this marketing channel, cassava is sold as either fresh tubers or cassava grates. The cassava flour sub-chain is basically backyard and village level operations. Although cassava has been proven to be a good substitute for wheat flour, it has not been consistently used in mainstream bakery operations. Thus, only small bakeries or home-based operations use cassava flour at the moment.

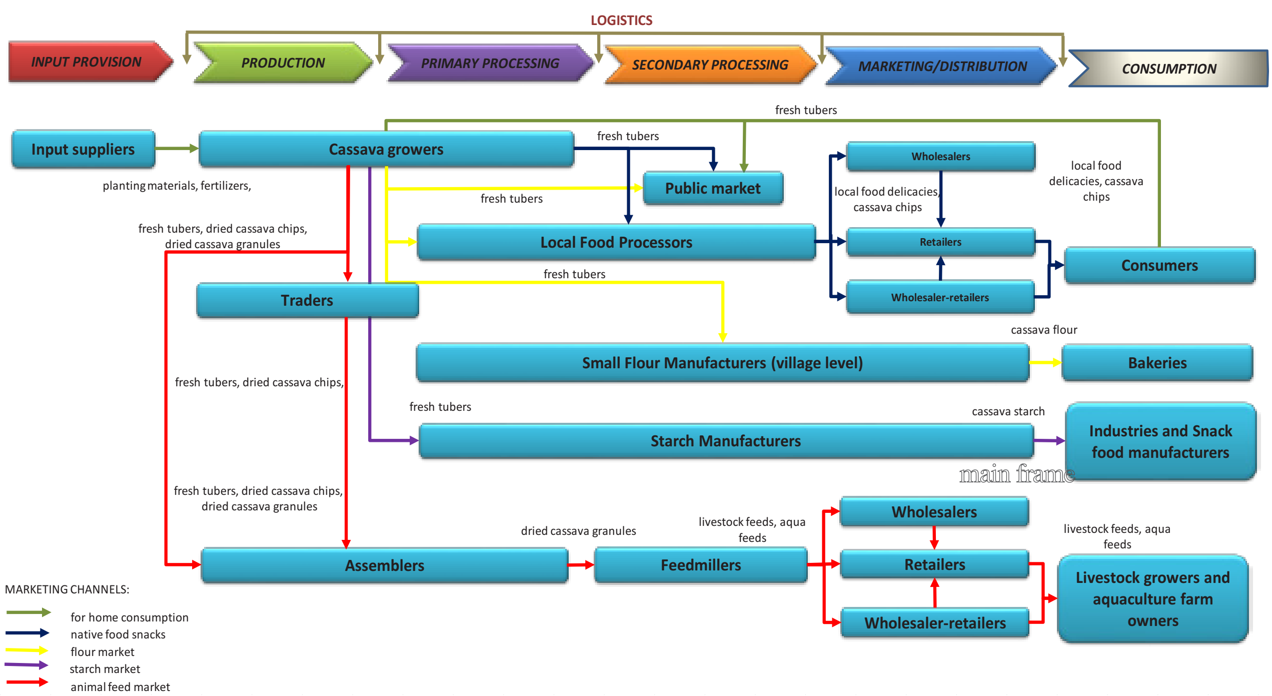

Figure 1: General Cassava Value Chain Map of the Philippines (Source: UPLB, 2015)

II. Status of Mechanization in Root Crops (Tuber) Production in the Philippines

The production of tuber crops such as potato, sweet potato, and cassava in the Philippines from planting to harvesting, is a mostly manual operation. The initial field operation in the production of cassava starts with land preparation. The use of animals (Figure 2) and small tractors for land preparation and weeding is common. Since most of the potatoes are produced in CAR, wherein most areas are sloping, raised seedbed preparation is done manually using hoes. The prevailing practice in land preparation for cassava production is via the use of four-wheel tractors with trailed or mounted plows or harrows. Since cassava production is still basically dominated by smallholder farms (0.5 to 1.0 ha), tractor plowing is used on the relatively large areas and those on relatively flat terrain. When tractors are used for land preparation, three operations are commonly performed—plowing, harrowing, and furrowing, using different implements. There are custom operators from the private and the local government units that provide these services. Farmers who have smaller lots, or have production areas in rolling and hilly terrain and have less disposable funds opt to use animal-drawn plows and harrows for land preparation. The depth of plowing is also shallower than that for tractor plowing.

Figure 2: Land Preparation Using Animal for Potato Production
Source: Bowman, 2012

Some farmers also practice applying organic fertilizer, where it is applied before or after land preparation or during planting. This is often applied manually using bare hands or with the use of small hand tools. During the land preparation, the organic fertilizer is mixed with the soil as the implements work the soil. When applied during planting the organic fertilizer is applied in close proximity to the plant and then covered with soil.

Inorganic fertilizers are applied during planting and 3-4 months after planting. Depending on the results of the soil analysis, varying types of fertilizers are applied. This is commonly a manual operation where the fertilizers are applied in rows, where the small canals are made near the plant hills. This is then covered with soil. In the case of hill planted stalks, the fertilizer is dibbled 30-50 mm away from the hill and then covered with soil.

Herbicides are also being increasingly used in cassava plantations, especially in Mindanao. These are sprayed in between the rows with the use of manual sprayers. Both pre- and post-emergence herbicides are being used. The use of herbicides saves farmers from manual weeding which is costlier and time consuming.

Farmers who opted not to use herbicides practiced weeding and cultivation (Figure 3). Off-barring is commonly done with the use of animal drawn plows and other implements. Hilling up is done three months after planting and coincides with the application of fertilizer. This is also done with the use of animal drawn plows.

Figure 3: Weeding and Hilling up for Potato
Source: Bowman, 2012

Harvesting tubers can be made manually with a spading fork or any pointed tools, standard hoes or weeding hoes. Small-scale harvesting is carried out with manual tools. It is necessary to lift the tubers carefully to avoid damages, and to shake them to remove soil. The indigenously made cassava lifters are used in some areas which are basically levers that have teeth to hold the cassava stem.

Depending on the marketing channels for which the cassava tuber will be sold, harvesting is done from 8 months to 1 year. Cassava harvesting is still exclusively a manual operation, where the tubers are uprooted by sheer pulling force applied by the workers. This is one of the most laborious, time consuming and drudgeries operation in the production of cassava. This is also one of the more critical operations since after harvest there is the onset of root deterioration after 2-3 days. Once uprooted, the tubers are cut from the plant, gathered in piles and placed in sacks. The Philippine Center for Postharvest Development and Mechanization

(PHilMech), in collaboration with the Agricultural Engineering Research Institute (AERI) of Thailand, has developed a cassava digger to reduce the drudgery of manual digging or uprooting of cassava tuber. The digger, attached to a 90 hp tractor, was designed as a tractor-drawn harvesting implement. The implement digs up the soil of up to 300 mm deep and reduces labor requirement from 20 laborers to 6 laborers per hectare.

Figure 4: The PHilMech Cassava Digger.

The post-harvest operations done on the other tubers vary depending on the marketing channels where the tubers are to be sold. After harvest, the potatoes are brought to a common area for grading, washing, and packing. Grading, washing, and packing are done manually. This is the same with sweet potato.

For home consumption of sweet potato and cassava, the common operations involved are cleaning/washing, peeling, and boiling (cooking). After boiling, this can be eaten or reduced into rice-like crumbles to serve as staple carbohydrate food.

For potatoes and sweet potatoes distributed to large restaurants and food processors, the process flow involves: washing/cleaning-peeling-chopping/chipping-bagging. Washing could be manual or mechanical. The washer-peeler available in the market washes the tuber and at the same time removes the cork skin. Available machines usually use perforated rotating drum design. Example of this is the AMDP Root Crop Washer-Peeler (Figures 5 and 6). It was tested and evaluated by Capito (2009) with optimum conditions and indicated that 75 kg cassava tubers can be washed in five minutes at a drum speed of 50 rpm. The cleaning efficiency obtained was 89.7%, peeling efficiency was 77.4%, parenchyma

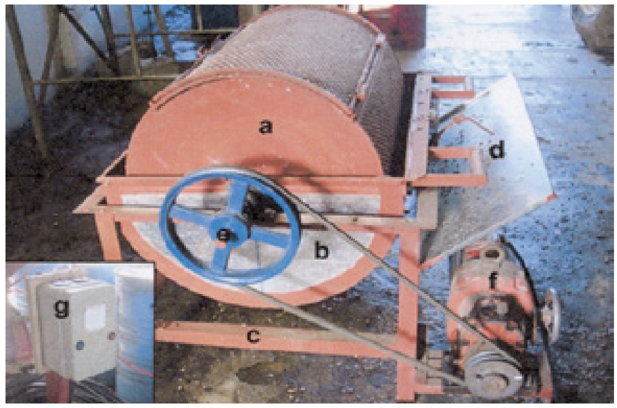

Figure 5: The prototype AMDP Root Crop Washer-Peeler
Source: Capito, 2009

Figure 6: The AMDP Root Crop Washer-peeler
Source: Pangan, 2016

Peeling is usually done manually using hand tools (peelers) for potato and sweet potato. A sweet potato peeler is available in the market. It has a mechanical rotary type peeling unit (made in China). The input capacity was 72.5 kg/h using newly harvested sweet potatoes with zero damage (AMTEC, 2016). In restaurants and food processors (small scale), cutting, chipping, or slicing were done manually using knives.

For sweet potato as feeds, chipping or cutting sweet potato roots into thin slices should be done to facilitate efficient drying, handling, and storage. Chipping is done to avoid jamming the grinding machine during feed milling operations. The desired size of chips should not exceed 15 mm in thickness and 100 mm in length. An example of a mechanical chipper is the one developed by the Bureau of Plant Industry. The BPI root crop chipper has a rated capacity of 0.3 tonnes per hour when operated by pedal, and 1.5 tonnes per hour when operated by a 3-horses power gasoline engine. Its cutting blades are mounted on a vertical disk located opposite to a feed hopper. These blades are adjustable, allowing roots to be chopped to desired thickness, from 5 mm to 20 mm thick, and from 100 mm to 180 mm long.

Figure 7: Manual peeling of tubers for snack food sub-chain.

Figure 8: Root crop (tuber) slicer for production of chips.
Source: http://www.jjeenterprises.com

For the cassava starch marketing channel, the priority of the farmers is to deliver the tubers to the mill in the shortest period of time where root deterioration has not set in. The tubers are commonly brought to the mill and placed in plastic sacks. The starch milling process is a standardized operation, where the only difference is the type of technology used in starch extraction. The process flow for milling commonly involves washing/cleaning-peeling-chopping-rasping-pressing/dewatering-drying-milling-sifting-bagging. The capacities of plant range from 20 t/day to 250 t/day with different levels of sophistication. Some plants even have energy co-generation facilities that make use of the wasted water to produce biogas that could supply part of the power requirement of the plant.

In the cassava feed marketing channel, acceptable products are fresh tubers, dried cassava chips (peeled or unpeeled), or dried cassava granules (peeled or unpeeled). Post-harvest operations done for cassava tubers in the feed marketing channel are washing/cleaning, peeling, chipping, drying and granulating. The washing/cleaning of the tubers involves the removal of soil particles and dirt to prevent contaminating the fleshy part of the tuber in succeeding operations. Peeling involves the removal of the brown outer layer and the pale white waxy layer of the tuber. Chipping involves cutting of the tubers into smaller chips to hasten drying. Drying is the removal of excess moisture to prevent deterioration of the chips. Granulating is a further size reduction into smaller bits as required by the feed milling companies.

Currently, there are small capacity washers, peelers, chippers and granulators that are being used by the farmers and processors in the feed sub-chain. Except for granulation, all the other operations are still predominantly done manually where there are no available machines or where there are requirements of excess farm labor. A cassava granulator (Figures 9 and 10) was designed by AMDP, IAE, CEAT. The AMDP cassava granulator is composed of a hopper, drum cover, drum, grate, discharge trough and prime mover (560 W (3/4 hp) electric motor). In a study by Aliangan (2014), the AMDP Cassava Granulator was tested at different blade clearance and drum speed settings, and cassava days after harvest (DAH). Results showed that blade clearance has no effect on the capacity, percent granule size <12.7 mm and power consumption. The optimum working conditions of the machine were 2 days after harvest, 16-mm blade clearance and 900 rpm drum speed with 1,076 kg/h capacity and 77% granule size less than 12.7mm.

Some of the cassava granulator available in the market includes:

- The Kolbi KG16B combine cassava granulator/shredder model was tested using cassava tubers with a moisture content of 55.00%. The granulator/shredder model is composed of a blade with a shaft speed of 620 rpm, and 8.5 kW diesel engine which consumes 1.0 liter per hour. It was determined that the capacity of the cassava granulator was 7,848 kg/h (AMTEC, 2016).
- The RU RUGRAN4500-16 cassava granulator model was tested using cassava tubers with a moisture content of 65.90%. The model is composed of a blade with a shaft speed of 1,195 rpm, and 5.97 kW diesel engine which consumes 1.07 liters per hour. It was determined that the capacity of the cassava granulator was 14,391 kg/h (AMTEC, 2016).
- The ACT Super Granulator is a closed-cylinder, horizontal single-shaft cassava granulator with rotating blades and powered by a 7.1 kW water-cooled diesel engine. The measured input capacity was 10,457 kg/h using freshly harvested cassava while the fuel consumption of the diesel engine was 2.0 l/h (AMTEC, 2016).

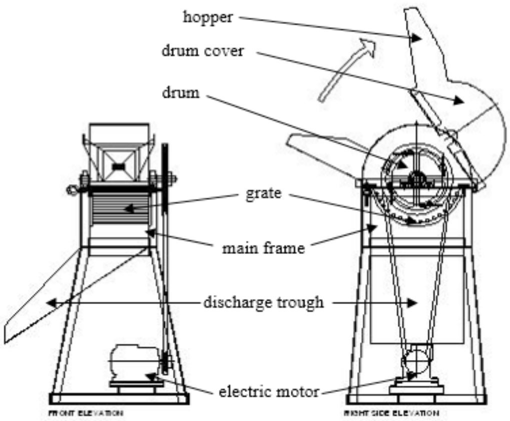

Figure 9: Final design of the AMDP cassava granulator.
Source: Pangan et al., 2013

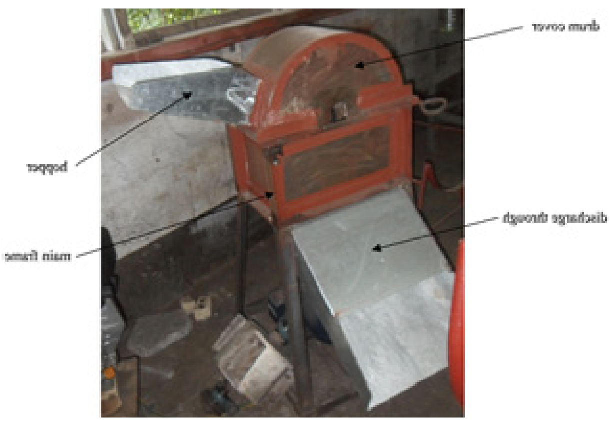

Figure 10: The AMDP Cassava Granulator Showing Its External Parts
Source: Pangan et al., 2013

Under optimal conditions (dry and sunny weather for sun drying), small-scale primary processors produce high-quality unfermented cassava flour that meets the specifications of industrial users within one day. Drying has been identified as the major tool for expanding the processing of cassava into high quality cassava flour.

Local processors expose cassava mash on a polythene sheet directly under the sun. This is referred to as "sun drying". Drying at rural or domestic levels cannot be done artificially because of the high capital investment in equipment and energy required and hence, natural sun drying is done.

Sun drying has several inherent drawbacks, such as susceptibility to damage due to inclement weather, slow drying rates, and contamination. Because of these limitations and the high cost and low utilization of more efficient traditional dryers, the adoption of a modified sun drying process, solar drying, has been considered for drying high quality cassava flour in rural areas.

The Philippine Center for Postharvest Research and Mechanization (PHilMech) developed a dryer for cassava granules to be processed into animal feeds. The AGRICOMP-PHilMech Cassava Belt Dryer (Figure 11) is a continuous flow-type dryer for granulated cassava. The dryer uses a biomass furnace as a heat source. The measured input capacity was 893.4 kg/h while output capacity was 395.2 kg/h. The moisture content reduction was 40.2%/hour (from 51% to 10.8%). The measured average temperature was 97.9° C with drying system efficiency of 42.9% (AMTEC, 2016).

Village level and backyard feed milling machines are also commonly used. These are mostly composed of hammer mills and other size reduction equipment and mixers. Bagging is usually done manually in such small-scale operations.

The AMDP in UPLB has an existing hammer mill. The AMDP Hammer mill can mill various organic materials and has been tested to mill cassava flour, copra, and even corn shells. The mill's screen can be changed to vary the size of the powdered granules. It utilizes a 3.75 kW electric motor as a power source, weighs 60 kg, and measures 700 x 900 mm. It is easy to operate by a single person and has low maintenance. It has an input capacity of 200 kg/h. Large capacity models are available. Some of the cassava mills available in the market include:

- The LAKAS-AGRITECH Cassava Pulverizer is a hammer-type mill powered by a 4.8 kW gasoline engine. The screen has 0.6 mm perforation of stainless steel sheet. The measured output capacity was 84.5 kg/h at 1,765 rpm with 89.6% recovery. The fuel consumption of the gasoline engine was 0.67 l/h (AMTEC, 2016).
- The FFC23 Disk mill is an attrition-type mill powered by a 4.85 kW gasoline engine. The screen has 0.6 mm perforation of stainless steel sheet. The mill was tested as cassava pulverizer with a measured input of 39.9 kg/h at 3,615 rpm shaft speed. The fuel consumption of the gasoline engine was 1.28 l/h (AMTEC, 2016).

The flour sub-chain has similar equipment with the starch sub-chain. However, in the country, only small village level equipment exists. The Visayas State University has developed a technology package that can produce cassava flour and dried grates (Figure 12). The package basically consisted of mechanical washer/peeler, mechanical chipper, cassava grater, presser, spinner, pulverizer, flour mill and dryer. The flour was used as a partial substitute for wheat flour to make breads and pastries. These machines have two systems of producing cassava flour. One system used dried cassava chips while the other system used dried cassava grates. On the other hand, cortex peel has to be removed if the tuber is to be processed into food products. There was no available machine for removing the cassava cortex. Cortex removal is always done manually using a knife.

Figure 11: The AGRICOMP-PHilMECH Cassava Belt Dryer.

Figure 12: The VISCA Cassava Flour and Grates Technology Package
Source: Roa, 2014

III. The Need to Assess the Root Crops (Tuber) Production Mechanization in the Philippines

The various operations in the production and post-harvest processing of tubers (potato, sweet potato, and cassava) can be mechanized to increase capacity, increase efficiency, reduce cost, reduce labor drudgery and reduce overall cost. There should however, be a thorough assessment of the various sub-chains for root and tuber crops to determine proper capacities, final product form and cost of operation. On the production operations, mechanization interventions can more or less be uniform across all the sub-chains. It is in the post-production and processing stage where there will be a variety of machines that will be needed to produce the desired product sellable in the specific marketing channel.

Fertilizer Application

The application of fertilizers, especially organic fertilizers would benefit from the use of spreaders. This will allow a more uniform application rate and more effective mixing of the organic fertilizer into the soil. The initial application could be done during the tail end of the land preparation operations before furrowing is done. This will also spawn greater utility of the four-wheel tractor. This, however, will only be applicable for relatively flat areas and larger cluster areas.

Planting

Planting is still largely a manual operation across all farms. Generally, this includes the furrowing operation and the actual dropping and covering of the planting materials. Potato planting should be simultaneous with bed preparations. There are also areas where inorganic fertilizers are applied during the tuber planting operation.

Cassava planters can also be employed in the relatively flat and larger clusters areas, where several rows can be planted simultaneously. In countries such as Brazil and Thailand, tractor-drawn planters are basically sugarcane planters adapted for cassava planting. This is basically semi-automatic, as operators are involved in placing the stalks into the planting mechanism where it is cut, dropped, and covered. Other models have fertilizer attachments that will allow simultaneous application during planting.

Harvesting

The most tedious and most laborious operation in the production is harvesting, especially cassava. Due to the nature of the root crop, manual harvesting becomes costly and time consuming. Depending on the marketing channel the tubers are to be used, care should be taken to prevent damaging the roots or else deterioration of the roots will set in. In some cases, roots are left on the field leading to yield loss. Mechanical harvesters basically loosen the soil around the roots that make it easier for the harvesters to uproot and cut the tubers. This increases the field capacity and allows faster harvesting of the tubers.

For potato and sweet potato harvesting, an accessory for vine cutting (topper) would be an ideal on field attachment as this will allow faster harvesting.

Cassava harvesting, especially for large or deep roots, the sheer force needed to uproot them takes a toll on the energy of the harvesters. This is also one of the harder operations to mechanize since one cannot see the pattern of root formation, as it is below the ground.

A root cleaning accessory would be an ideal on field attachment as this will allow initial removal of the soil particles after the tubers are cut from the plant part. The roots will be already relatively clean before they are transported to the starch plant or chipped for the feed marketing channel.

Packing

Apart from the harvesting operation, packing the tubers before transporting entails a lot of time and labor. Potatoes as well as sweet potatoes (food sub-chain) are usually packed in transparent plastic bags. It will be ideal if mechanized packing will be a part of the grading and washing system.

In the feed marketing channel of sweet potato and cassava, the tubers are placed in sacks, then chipped, then placed in sacks, then dried, then granulated, and then placed in sacks again before they are transported to the feed mills. This system incurs a lot of cost and labor, and ultimately, income loss to the farmer or processor. With the use of larger handling systems, tubers or chips need not be placed in sacks before transport. By eliminating the sacking operation, much time, labor, and cost will be saved. Since cassava is generally transported in bulk, this kind of moving system will be more efficient in the long run.

Depending on the marketing channel the tubers are intended for, the postharvest operations differ in terms of the number of succeeding operations done and on the type of product desired by the market. In mechanizing the operations, the requirements of the market are critical factors to be considered so that the farmers are assured of a good income. Most of the discussions below will present post-harvest mechanization of sweet potato and cassava. Potato is consumed largely in the Philippines as a vegetable, while cassava is processed into food, feeds and other products, while sweet potato is consumed as food and processed into feeds (Table 2).

Post-harvest operations in the food sub-chain will depend on the marketing channel that is being addressed. The two marketing channels are the home consumption and the native food snacks and delicacies. Tubers for home consumption basically are just boiled or cooked so hand peelers and even sharp knives will be adequate.

Cassava Peeling

The removal of cassava cortex for food consumption is still a manual operation. Cortex removal is always done manually using knife.

Drying

The major practice in drying chips is through solar drying, which takes around 2-3 days depending on the intensity of the sunlight. The problem, however, is during the wet months. Available mechanical dryer for chips, grates and granules has low capacity (less than 100 kg per hour).

Table 2: Root Crops: Supply Utilization Accounts by Commodity, Year and Item

	SU Production	SU Imports	SU Gross Supply	UT Exports	UT Feeds and Waste	UT processing
Cassava						
2005	1,677,564	0	1,677,564	488	100,654	1,408,744
2006	1,756,856	3,150	1,760,006	591	105,411	1,477,909
2007	1,871,138	0	1,871,138	881	112,268	1,571,016
2008	1,941,575	0	1,941,575	848	116,495	1,630,211
2009	2,043,719	0	2,043,719	982	122,623	1,715,899
2010	2,101,454	24,500	2,125,954	1,011	126,087	1,784,952

	SU Production	SU Imports	SU Gross Supply	UT Exports	UT Feeds and Waste	UT processing
2011	2,209,684	5,845	2,215,529	1,098	132,581	1,860,122
2012	2,223,182	78	2,223,260	583	133,391	1,867,049
2013	2,361,561	15,877	2,377,438	182	141,694	1,996,895
2014	2,540,254	10,439	2,550,693	361	152,415	2,142,279
White Potato						
2005	70,160	10,579	80,739	0	3,508	17,540
2006	69,461	7,742	77,203	0	3,473	17,365
2007	118,497	5,257	123,754	0	5,925	29,624
2008	121,311	5,459	126,770	0	6,066	30,328
2009	119,159	1,758	120,917	0	5,958	29,790
2010	124,671	6,276	130,947	0	6,234	31,168
2011	120,574	8,176	128,750	0	6,029	30,144
2012	119,570	6,299	125,869	0	5,979	29,893
2013	117,722	4,362	122,084	0	5,886	29,431
2014	119,140	1,337	120,477	0	5,957	29,785
Sweet Potato						
2005	574,629	0	574,629	b/	28,731	0
2006	566,773	0	566,773	2	28,339	0
2007	573,734	0	573,734	4	28,687	0
2008	572,655	0	572,655	2	28,633	0
2009	560,516	0	560,516	3	28,026	0
2010	541,265	0	541,265	3	27,063	0
2011	516,338	0	516,338	4	25,817	0
2012	516,907	0	516,365	5	25,845	0
2013	528,250	0	516,365	6	26,413	0
2014	519,855	0	516,365	21	25,993	0

Note: SU – Supply; UT – Utilization; b/ - Less than 1 metric ton

Source: PSA

Tubers sold in the feed sub-chain undergo several transformations before they are used as raw materials for feed formulations. Farmers also have the option to sell produce to this marketing channel either as fresh tubers, dried chips or dried granules. Each form of product fetches different prices, which is basically a form of value addition to the farmers. Although currently there are machines that are being used for drying, several considerations can be examined to optimize the current designs to better match the requirements of the value chain. The major practice in drying chips and granules is through solar drying, where the chips are laid out in cement pavements or PU mats or plastic sacks where they are allowed to dry from 2-3 days, depending on the intensity of the sunlight. The problem again is during the wet months. Although most sweet potato and cassava plantations time their harvest during the dry months, this will eventually change as the feed sub-chain grows and demand for the product increases. The effects of climate change also factor into this as there are certain production areas where climate patterns have constantly changed. Although mechanical drying is still much more expensive on a peso/kg basis, there may be promising indigenous dryers that may be modified to allow drying of cassava during the wet months.

In some regions, farmers make use of what is known as the tapahan, a dryer basically used for copra making or drying of coconut meat. These are basically direct fired natural convection dryers. The main concern however is the possible smoke contamination. But since the tuber product is basically for animal feed such technology may be optimized to include blowers and reduce the smoke from the furnace. With such lower cost dryers, the problem of drying during the wet months will be arrested.

IV. Challenges and Constraints Faced for Whole-process Mechanization of Root Crops (Tuber) Production in the Philippines

The main constraint in the mechanization of potato in the Philippines is the limited and fragmented production area. As shown in Table 3, only CAR (mainly Benguet) has the largest area for white potato production, followed by Davao Region and Northern Mindanao. There were other small patches of land suitable for potato production scattered around the country (Table 3). On the other hand, sweet potato and cassava could be planted in the areas not covered by the main crop like rice, corn, and sugarcane.

Another constraint is the low production volume. As shown in Tables 3 and 4, the average yield in CAR is about 16.8 Mt/ha compared to 47.15 Mt/ha of USA in 2014 (FAO). Due to low volume production, imports from the USA, Canada, Australia, and New Zealand of potato frozen material is still cheaper. Low production volume is also a constraint for sweet potato and cassava. The main cause for this is the lack of good seed/plant material. Good seed/plant material will result to higher yield, thus lowering production cost and raw tuber cost. Another cause of low production volume is the pest and diseases of root crops (tubers).

Another constraint is the transport problems and lack of storage facilities. Especially in Benguet, the road network is the main problem due to mountainous terrain. Transport of root crop harvest in Benguet sometimes uses low capacity tramline. On the other hand, it is costly to transport products from the Davao Region and Northern Mindanao to Luzon. The big market for tubers is in Luzon and where most of the processors are located. Moreover, no storage facilities were available for fresh root crops (tubers) in the Philippines.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Root Crops (Tuber) Production in Asia and the Pacific

The cooperation could involve the research, development, and extension of the design and adaption of existing machines for tubers like potato, sweet potato and cassava. The precursor of CSAM which was named RNAM (Regional Network for Agricultural Machinery) used to have a program called mutual exchange of prototypes. Under this program machines that have been proven commercially and technically viable in a member country are provided to another country for testing and possible adaptation.

Machines could include planters, fertilizer applicators, harvesters, packers, peeling machine for cassava (cortex removal), and dryer (food and feed). Constraints to mechanization should be considered, like small farm sizes and inadequate extension program and technology transfer mechanisms. Small farm sizes and fragmented farms have always been an issue with the implementation of mechanization project. It defies the principle of economies of scale. The average farm holdings in the country is 1.29 has (PSA, 2015). In Benguet, most areas planted with potatoes are in sloping and hilly sections. Small machinery could be adapted to increase productivity. There is also the lingering issue of labor displacement in most subsistence farms where the only source of income is farming.

The benefits derived from mechanization are still unclear to some farmers. Extensive demonstrations and training on the operation and maintenance of the machines at the farmers/operators' level should be undertaken to promote mechanization. One approach used in extension projects is the participatory approach. Farmers/end users were involved in the planning, design and implementation stages.

This workshop is very important to address the challenges and constraint in the mechanization of potato production as well as root crops (tubers). The experiences and knowledge shared could be used to properly address the different challenges and constraints.

Table 3: Area Planted/Harvested for White Potato, Geolocation and Year in Hectares.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CAR	3,502.00	3,456.00	5,900.00	5,932.00	5,824.00	6,068.50	6,115.50	6,083.00	5,892.00	5,884.90
ILOCOS REGION	..	..	..	..	..	..	..	..	..	..
CAGAYAN VALLEY	75.00	75.00	78.00	76.00	79.00	70.00	69.00	66.00	64.00	64.00
CENTRAL LUZON	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	..	..
CALABARZON	..	..	..	..	..	..	..	..	..	..
MIMAROPA	..	..	..	..	..	..	..	..	..	..
BICOL REGION	1.00	1.00	1.00	1.00	..	..	..	..	..	..
WESTERN VISAYAS	..	..	..	..	..	..	..	..	..	..
CENTRAL VISAYAS	19.00	19.00	22.00	20.40	19.30	20.80	21.00	18.00	12.50	3.00
EASTERN VISAYAS	..	..	..	..	..	..	..	..	..	..
ZAMBOANGA PENINSULA	..	..	..	..	..	..	..	..	..	..
NORTHERN MINDANAO	531.00	548.00	556.00	562.00	573.00	568.00	560.00	550.00	543.00	537.00
DAVAO REGION	1,293.00	1,280.00	1,310.00	1,322.00	1,329.00	1,329.00	1,330.00	1,303.00	1,300.00	1,300.00
SOCCSKSARGEN	75.00	70.50	71.25	79.25	78.75	72.10	74.45	74.78	78.03	78.85
CARAGA	..	..	..	..	..	..	..	..	..	..
ARMM	..	..	..	..	..	..	..	..	..	..

Note: Data not available

Source: PSA

Table 4: Volume of Production for White Potato, Geolocation and Year in Metric Tons.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CAR	53,069.00	52,204.54	100,752.49	103,303.09	101,060.68	107,181.98	103,135.41	102,433.67	100,758.09	102,255.24
ILOCOS REGION	..	..	..	..	..	..	..	..	..	..
CAGAYAN VALLEY	284.21	447.87	528.09	521.33	536.16	440.87	443.05	421.39	427.25	448.25
CENTRAL LUZON	2.49	2.50	2.57	2.61	2.65	2.64	2.62	2.63	..	..
CALABARZON	..	..	..	..	..	..	..	..	..	..
MIMAROPA	..	..	..	..	..	..	..	..	..	..
BICOL REGION	0.56	0.14	0.14	0.13	..	..	..	..	..	..
WESTERN VISAYAS	..	..	..	..	..	..	..	..	..	..
CENTRAL VISAYAS	52.46	62.05	58.29	56.55	51.94	55.87	57.52	54.90	33.68	7.21
EASTERN VISAYAS	..	..	..	..	..	..	..	..	..	..
ZAMBOANGA PENINSULA	..	..	..	..	..	..	..	..	..	..
NORTHERN MINDANAO	6,662.50	6,744.89	6,778.01	6,945.00	7,025.00	6,870.00	6,745.00	6,550.00	6,355.00	6,145.00
DAVAO REGION	9,476.96	9,436.48	9,811.21	9,841.47	9,859.42	9,557.85	9,601.08	9,512.70	9,511.42	9,633.77
SOCCSKSARGEN	612.00	562.25	566.36	641.31	623.50	561.97	589.05	594.55	636.20	650.55
CARAGA	..	..	..	..	..	..	..	..	..	..
ARMM	..	..	..	..	..	..	..	..	..	..

Note: Data not available

Source: PSA

The Whole-process Mechanization of Potato Production in Thailand

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I. Overview of Potato Supply Chain in Thailand

General Overview and Production

Potatoes were introduced to northern Thailand during the late nineteenth century either from Burma or Yunnan Province, China. The crops were first introduced by a group living in the highland areas of southern China, and these potatoes were valued for their disease and drought resistance but criticized for their small tubers, bitter taste, and dark color when fried. Alu, which is also the Hindi term for potato, is a local kind of potato. In Thailand it is generally called manfarang ("foreign tuber"). About 1905 attempts had been made to cultivate potatoes. The result of the experiments was good, but with a lack of local acceptance hence the project was soon abandoned. Small quantities were imported, but for the exclusive use of European residents in Thailand. After that, some of the potato varieties were imported from different countries and tested in the local conditions. The first location of lowland potato production was in Chiang Mai province, the Northern region of Thailand. Table potatoes have been cultivating since the 1960s.

By 1970's, Thai farmers imported about 200-300 tons of potato seed per year. Two types of potato varieties were cultivated: table potato and processing potato. In 1976, a factory was set up to produce potato chips to catch the early trend of snacks business. However, the firm faced an unstable and limited supply of raw material. To solve the problem, the firm started to make contracts with growers based in Chiang Mai in 1987. However, the planted area was limited to less than 2,000 ha until 1986 (Figure 1).

At the beginning of 1990, rapid expansion led to a nearly 5-fold increase in the area within only 20 years (Figure 1 and Figure 2). This occurred because of 2 reasons:

1) The production of vegetables, including potato, was expanded to displace opium production in the upland regions of northern Thailand. It was caused by the collaboration among the Royal Project Foundation, Maejo University in Chiang Mai, and the JR Simplot Company in the U. S. This effort to produce Russet Burbank for processing was later abandoned because the growing season was too short for existing cultivars and the unskillful potato growers.

2) Contract farmers got technology transfer from processing firms regarding variety, seed input rate, level and type of chemical fertilizer application, plant protection materials, pest control as well as cultural practice. The accumulated knowledge and experience have paved the basis for growers to develop the technique for tuber seed storage which allows the early-season planting when desired.

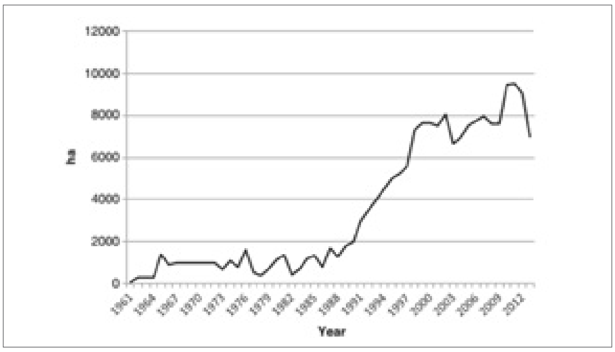

Figure 1: Potato Planted Area of Thailand from 1961 through 2013
Source: FAO Stat by Kittipadakul, P and et.al., 2016

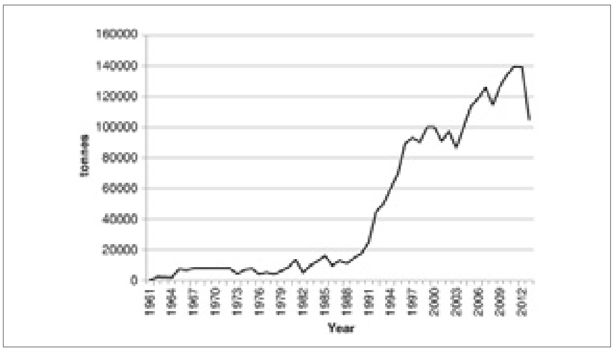

Figure 2: Potato Production Thailand from 1961 through 2013
Source: FAO Stat by Kittipadakul, P and et.al., 2016

Northern Thailand has always been the major production centre for potatoes. In 1970s and 1980s this area accounted for as much as 80 percent of the production. In 2015, the total production area was 7,117.7 ha and about 97.6 per cent of planted land was in the north, the remained land located in the Northeast (Figure 3). The national production reached 109,251 tons in 2015. Despite the fact that potato snacks are not traditional fare for the Thais, potato consumption and demand in Thailand far outstrips domestic production.

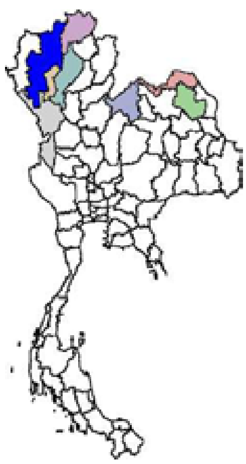

Figure 3: Filled Color was the Plated Area of Potato in Thailand

Geography and Production Zones

Potatoes are primarily grown in Chiangmai and Chiangrai Provinces which are located in the mountainous regions of northern Thailand. The average temperature during the main growing season in the northern and northeastern highlands is around 15-20°C. The average annual rainfall in Chiangmai is 1,057 mm, while the humidity is 74 percent (Arunsit, 1977). There are 2 kinds of lands in Thailand:

1. Hills (800-1,500 meters above sea level, or masl), are divided into two subzones: foothill areas between 800-1,000 masl, and areas above 1,000 masl. Potatoes are produced in the hills mainly under rainfed conditions and are grown year-round but primarily during the wet, summer season. Yields in the hills are estimated to be about eight tons per hectare and the seed is locally produced.

2. Lower lying valleys, such as the Chiangmai valley situated at around 300 masl, where potatoes are grown after rice on flat paddy land from imported seed during the cool, dry season, with productivity around eleven tons per hectare. (CIP, 1976; Sikkhamondhol, 1980).

Commercial Production

Farms in Thailand range in size from 0.08 to 1.6 ha, with an average size of 0.5-0.8 ha. In 2005, there were 11,412 potato growers in Thailand. In lowland areas, potatoes are grown in rotation with rice. If there is enough water, farmers choose to grow sweet corn, followed by rice and then potato. The potato crop is planted directly after the rice is harvested, so that rice is grown in the wet season and potato is grown in the drier months. In highland areas, rotational crops are corn and soybean. Sometimes farmers also cultivate pepper or tomato, but it often leads to diseases in the potato crops. Growers in North Thailand typically grow corn, onion, and rice in addition to potato (Singh 2005).

Contract farming is widely practiced in Thailand (Singh 2005). In the Chiang Mai Province, contract agreements between 3000 growers and Frito Lay Thailand, and another 3,000 growers and Berli Jucker Foods are arranged through brokers, farmer groups and the Potato Growers' Cooperatives. Typically, companies employ brokers to work with farmers to provide seeds and to work with them in order to deliver everything that is needed for processing. Contract farming is credited with the rapid increase in production in the early twenty-first century (Singh 2005).

The major potato processing company in Thailand is Frito Lay Inc., and 30 percent of production is planted for the cultivar Atlantic. The remaining land is planted to Frito Lay varieties, which are generally more resistant to late blight and early blight than Atlantic.

The Potato Supply Chain in Thailand

Potato is a crop with short distribution channels. 90 percent of the production (Atlantic cultivar) goes to processing firms located in the north and only 10 percent (Spunta) goes to fresh food markets. Table potatoes for fresh cooking supplied in the markets are from both domestic and import sources whereas processing potatoes are mainly from domestic production.

1. The Supply Chain of Table Potatoes

The main planting area of table potatoes is in Chiang Mai Province, which accounts for almost 90 percent of the total production. All the potatoes purchased by Spunta are stocked in cold storage. Local assemblers were not keen to learn the sizes of demand by final buyers. Figure 4 illustrates the marketing distribution channels showing that Bangkok wholesalers absorb 90 percent of table potatoes, which subsequently go to hotels/restaurants and retailers. It was revealed by the assemblers that in spite of the supply control, prices of table potatoes fluctuated from year to year depending on movements in tourism.

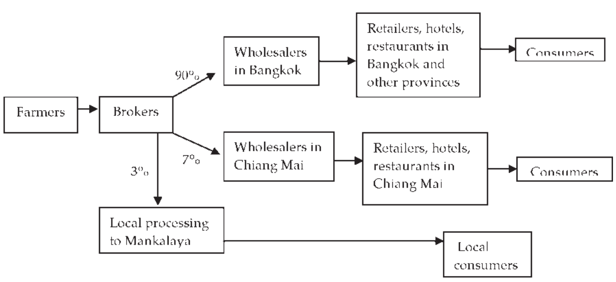

Figure 4: Marketing Distribution Channels of Table Potatoes in 2006

2. The Supply Chain of Processing Potatoes

Brokers play a significant role in the supply chain of processing potatoes. Generally, most of the growers who produced processing potatoes were contractors who supplied raw materials to processing food industries via brokers or directly to the firms. Most of the potato chips produced by these firms were distributed to middle and high-level markets such as supermarkets and convenience stores across the country (Figure 5).

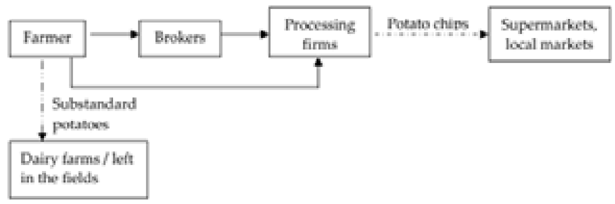

Figure 5: Marketing Distribution Channels of Processing Potatoes in 2006

The survey revealed that the chain of potatoes in San Sai District is rather different from other areas. In 1987, when processing of potatoes was first introduced to San Sai area, farmers signed contracts with the firms. However, as observed by Wiboonpongse and Sriboonchitta (2005), marketing practices of potato growers in this district have gradually changed. Presently, 95 percent of potato growers in this district no longer sign contracts with processing firms but sell their potatoes to brokers at prevailing market prices (Figure 6).

The impact of grading has contributed to changes in the supply chain. Potatoes must have the following characteristics to be purchased by processing firms:

- size (no less than 4.50 cm in diameter)
- specific gravity no less than 1.082 or FL solid no less than 17.1
- skin texture - an absence of peel due to premature harvesting
- no adulterated things
- no defect from nematode attack wound from harvesting and insect attack, greenish skin, abnormal shape, serious bruise, rotten output, germinating or hollow core.

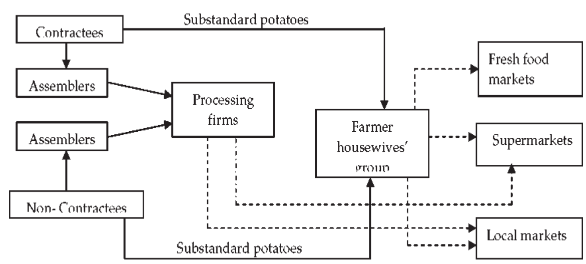

Figure 6: Marketing Distribution Channels of Processing Potatoes in San Sai

90 percent of the total production from San Sai District is graded as a good quality (large and medium sizes) and is delivered to processing firms. Oversized potatoes are sold in the fresh food market for good prices and the under-sized ones are sold for cattle feed (1-2 baht/kg) or to the local fresh market at lower prices

to become valuable domestic seed (12 baht/kg). Others of an unacceptable size (smaller than 4.5cm) are kept in cold storage for seed. Moreover, defective potatoes (accounting for 5-10 percent of total production) are absorbed by housewives' processing groups to produce potato chips. Thereby, the value is added to substandard potatoes and there is an increase in women's employment.

II. Status of Mechanization in Potato Production in Thailand

Cultural practice and machinery used for different farm operations for potato production as the following:

Potato seed: Several seed-transmitted diseases are prevalent on the potato crop in Thailand. The most significant pathogens are potato virus Y, Phytophthora infestans, and Ralstonia solanacearum. Some growers save tubers for its use as a seed. However, these growers face a high level of disease in potato production, which undoubtedly reduces its quality. Most potato seeds (4,500 mt annually) is imported from a number of countries, including Australia, the Netherlands, Scotland, and Canada. Each year Spunta is imported from the Netherlands, while Atlantic is from Scotland and Australia. However, there are some efforts to develop a tuber seed production system in Thailand, a current project initiated by a prominent grower from north of Chiang Mai (San Sai District) focuses on importing early generation pathogen free seed from Scotland, growing this seed for two generations in a remote area at high altitude, with rigorous disease management practices including fungicide and insecticide sprays, and removal of symptomatic plants. In the third year, seeds are produced near the main production area, and sold in the fourth year to local growers for commercial production. As long as virus incidence remains below 5 percent, it is more cost-effective to use fourth-year rather than third-year tubers as a commercial seed. Northern production regions in Thailand offer good potential as a seed potato hub in Southeast and South Asia, since rainfall and consequently disease incidence, is lower than in other regions.

Land preparation: Three activities of common practice of land preparation are primary tillage, secondary tillage and furrowing. Primary tillage is done by using 4-wheeled tractor attached with a disk tiller (Figure1 (a)) instead of standard disk plow which is deeper tillage. This was due to the local custom with less fuel consumption. Secondary tillage is done by using 4-wheeled tractor attached with rotary tiller about 1-2 pass to get small soil clod suit for potato. Furrowing was done by using power tiller attached with rotary tiller or ridger to make furrow depending on planting method.

Figure 7: Land Preparation by Using Tractor Attached with Disk Tiller for Primary Tillage (a) and Forrowing Using Power Tiller Attached with Ridger (b)

Planting: There are 3 common planting practices; non-furrow (Figure 8a), on furrow (Figure 8b) and a double row on seedbed (Figure 8c). Whole seed tuber or cutting seed were put on the prepared furrows by labor. Machinery was used for land preparation to make the furrow. In this operation, machine was used just for covering soil back over the seed tuber. This operation is labor intensive and high cost. Potato planter is not used.

Figure 8: Common Practice for Planting Potato

Crop care and crop protection:

Weed control: Weed was controlled by using of pre-emerging herbicide after finish planting. Machinery used is knapsack sprayer which available both manual and power knapsack sprayer.

Insect and disease: Chemical control is commonly used. It is used depend on symptoms and problem faced. Machinery used is knapsack sprayer, which is similar to function of weed control and be available both manually and by power.

Fertilizer Application: Both chemical and manure fertilizers were used. They were applied at the same time to put seed tuber in the furrow during the planting operation.

Irrigation: Furrow irrigation is common practice while sprinkler irrigation is also available in some area where water supply is limited.

Harvesting: Moldboard plow type potato harvester is usually attached to power tiller (Figure 9). At Figure 10 and 11 you can find plow type potato harvester that is attached to power tiller and 4-wheel tractor respectively.

Figure 9: Plow Type Potato Harvester Attached to Power Tiller

Figure 10: Potato Harvester Attached to Power Tiller

Figure 11: Potato Harvester Attached to 4-wheel Tractor

However, these harvesters were just lifting up the tubers from under the soil to on the soil, then collecting tubers to net sack and move out the field were done manually hence it was labor intensive. (Figure12). Research and development of harvester is high required because labor shortage tends to be critical.

Figure 12: Collecting Tubers to Net Sack and Move Out of the Field Require Huge Amount of Labor

Postharvest: Most farmers sell their potatoes immediately or soon after harvesting because they lack storage facilities and must pay back their loans. However, postharvest technology was considering to be important because of the effect on tuber quality, deterioration and price of potato. The following technology may be required viz., grading facility or machine and processing of substandard potato to increase price and value added.

III. The Need Assessment of Potato Production Mechanization in Thailand

- Potato seed is mainly imported causing problems potato seed quality and high price which is result of high production cost, limited input, and production yield.
- The technology of domestic potato seed production is available but the capacity doesn't meet the consumption. Various tools and technologies to facilitate the potato seed production are required.
- Arable area for potato production is limited, therefore increasing of productivity and seeking for a new arable area as well as production efficiency improvement are highly required.
- Mechanization for a specific operation in potato production is still lacking; research and development of new agricultural machinery as well as performance improvement for existing machines are highly required.
- Post-harvest technology is needed to maintain quality, grading and simplify processing of substandard potato.

The following is a list of machinery/ technology required to support potato production and its rank.

Item	Machinery/ Technology	Rank
1	Machinery to be used for supporting potato seed production. Appropriated disease-free greenhouse, with apparatuses to facilitate seedling after culture process, system to control environment and irrigation, tuber grading and storage.	1
2	Potato planter for piece tuber type and whole tuber or capable for both.	3
3	Facility and management system for seed storage for farmers groups.	8
4	Appropriate tools for crop care operation viz., fertilizer application, weed control, insecticide control and disease control.	5
5	Machinery for harvesting operation which contributes highly to total production cost.	2
6	Grading facilities.	4
7	Appropriate technology of packaging and transportation.	7
8	Machinery and technology for processing and utilization of potato for farm level or farmers' group especially for substandard potato.	6

IV. Challenges and Constraints Faced for Whole-process Mechanization of Potato Production in Thailand

Challenges:

- Domestic production doesn't meet the high domestic demand and lack of chance to export potato tuber and processing products.
- Lack of technology for domestic potato seed production has a good result which would reduce seed import, seed cost, production cost and improve farmers' income.
- Increasing the capacity and efficiency of domestic potato seed production.
- Specific planting zone for potato seed shall be established.
- Lack of mechanism to absorb unemployed labor, housewives and farmers' group for potato production.
- Research and development of agricultural machinery shall be strengthened to support potato production and to solve of labor shortage problems.

Constraints Faced:

- Potatoes are grown at the hilly areas in small plot which constrain the utilization of agricultural machinery and implements.
- Growers are small farm holders. Usage of the machines are limited by cropping system and seasoning therefore holding and investing in a machine is not economically efficient.
- The labor shortage tends to be high and this situation becomes critical for coming years.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

1. All countries are better to reduce imports of seed, but to
   - To improve yields of their own varieties;
   - To creat special seed production and marketing of in-vitro plants, mini-tubers and different generations of tuber seed.
2. The efficient operation of seed supply, quality control, and distribution system.
3. Research and development of appropriate agricultural machinery to increase production efficiency, to improve cost reduction, and to address labor shortage problem.

II. Country Presentations

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Bangladesh
Whole-process Mechanization of Cassava Production in Bangladesh

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I. Overview of Potato Supply Chain in Bangladesh

Potato plays an important role in the economy and food security of Bangladesh. Potato is the third most important crop in Bangladesh. Potato growing season is from mid-October to the end of March. At present, nearly 0.47 million ha of cultivable land is under potato cultivation and the country produces 9.2 million metric ton of potatoes with an average yield of 19.6 t/ha. The cultivable area, production and yield of potato in Bangladesh are given in Table 1.

Table 1: Year Wise Area, Yield, and Production of Potato in Bangladesh

Year	Cultivable Area (Million ha)	Potato Yield, (t/ha)	Potato Production (Million ton)
2007-8	0.5	17.75	9.2
2008-9	0.46	14.54	6.75
2009-10	0.47	17.8	8.4
2010-11	0.46	18.1	8.32
2011-12	0.43	19.8	8.31
2012-13	0.44	19.37	8.6
2013-14	0.46	19.37	8.95
2014-15	0.47	19.65	9.25

Using high yielding varieties and improved production technology, potato production can be further increased up to 30.40 t/ha. Many institutes and private sectors are working on this aim. For instance, Tuber Crop Research Centre (TCRC) of BARI developed about 80 potato varieties to meet the demand of producers facing different environment. BARI produces breeder seed potato for farming and supplies to national authorized seed producer. Bangladesh Agricultural Development Corporation (BADC) is responsible for multiplying and selling to the farmers.

Table potatoes grown in Bangladesh are the most suitable variety for export and are mostly produced either on a contract farming basis or by exporter leased land. Some larger exporters are however buying potatoes from the open market. Processing varieties are also usually grown through contract farming or on the land leased by the processor. Different potato varieties have different routes to the market. Local table potatoes are sold directly by the farmers at the local market. High yielding table potatoes are sold to a trader who sells them at the local market or puts them in cold storage. During the last few years, potatoes are exported to different countries.

The challenges faced during potato production are as follows:

Firstly, the quality seeds are not available in sufficient quantity. Only 5% demand for high-quality seed could be met for both private and public sectors; and the remaining 95% is of low-quality seed potato produced by the farmers themselves. Apart from formal government sector, there are growers who are supported by the private sector in seed potato production as well as in general potato production such as KONIKA Seed Company, ADAKHP, BRAC, SYNGENTA Foundation, and PRAN Agro Ltd. etc.

Secondly, potato production in Bangladesh created storage problems. The number of potato cold storage in Bangladesh increased from 77 in 1975 to 382 in 2013. However, distribution of the cold storage is not uniform throughout the country. In some areas, cold storage space remains underused, whereas in other places all the potatoes cannot be stored. As a result, potato storage charges differ considerably between districts to districts.

In addition, there is an acute shortage of labor during the peak planting and harvesting operations, which causes a delay in potato planting and harvesting.

The appropriate policies and programs such as promoting small-scale mechanization, potato storage, and developing of effective potato marketing channel can make potato production sustainable and income growth of farmers.

II. Status of Mechanization in Potato Production in Bangladesh

Potato cultivation in Bangladesh is mostly done by traditional methods. Only a few private companies use potato machinery like potato harvesters and graders on their farms. The land for potato production is prepared by small power tillers which are very common tillage tool in agricultural works. Recently, the usage of medium size tractors (40-55 hp) is also increasing for this operation. Irrigation is done 3-4 times by shallow tube wells. There are deep tube wells and improved water distribution channels in the government and seed producing farms. Table 2 shows the agricultural machinery involved during farming operations.

Table 2: Major Agricultural Machinery Engaged in Potato Farming Activities

No.	Name of Machinery	Number of Machinery	Remarks
1	Power tiller	700,000	Multi-purpose use in addition to soil tilling
2	Four-wheel tractor	35,000	Custom hire use
3	Shallow tube well	1,549,711	Groundwater as well as surface water pumping
4	Deep tube well	203,741	Ground water irrigation
5	Sprayer	1,300,000	Mostly knapsack type
6	Diesel engine	2,500,000	Agricultural activities

Potato Planting and Fertilizing

Potato planting is usually a manual operation. Generally, farmers open a furrow by pulling an indigenous plough maintaining row spacing of 500 mm for cut piece seeds and 550 mm for whole tuber seed. Seed to seed distance is 150 mm and 200 mm for cut piece seed and whole tuber seed, respectively. Basal doses of fertilizers are also applied besides the planting line. Finally, the seeds are covered with a spade and the beds are made. Recently, BARI developed two-wheel tractor (Power tiller) driven potato planter (Figure 1) and have started to use it in the farmers' field. It is suitable for soil tilling and placing the potato seeds at pre-determined spacing simultaneous. However, the operation is limited to cover only one hectare per day. There is a big prospect of expansion but no such initiatives are taken. There are a few imported potato planters in the private potato farms and academic institutes. Considering the big size of the machine and the small size of the landholdings, those planters are not being used in the farms.

Figure 1: Power Tiller Driven Potato Planter

Pesticide Spraying

Farmers apply chemicals into the potato field by knapsack sprayers. Some contract growers (The ones who lease the land from the owners on a season basis) who are comparatively large farmers, use power sprayer in their farms. Generally, they spray field 4-6 times to control disease and pests. Farmers need sprayers of good quality.

Potato harvesting operation is done by manual labor. Generally, farmers use indigenous plough to open the potato beds and in some cases farmers use a bullock drawn plough. Finally, exposed potatoes are picked by hand. In this operation, there are still some potatoes left under the soil; so farmers use local special hand tools to dig the soil and collect the potatoes. Local female laborers also take part in the harvesting operation. Recently, BARI developed a two-wheel tractor (Power tiller) driven potato harvester; and farmers accepted it considering the performances (Figure 2). It digs the potato beds; the high rotating conveyor chain carries soil with potato, and potatoes are exposed on the surface. Finally, potatoes are picked by hand. Farmers are also in need of potato harvesters.

Figure 2: Power Tiller Driven Potato Harvester

Potato Grading

Generally, farmers grade and sort potatoes by hand. Large farmers and seed producing farms, especially BADC (Bangladesh Agricultural Development Corporation), grade the potato using locally made potato graders. The efficiency of these graders is low.

III. The Need Assessment of Potato Production Mechanization in Bangladesh

Agricultural labor availability is decreasing day by day in the rural areas due to increased income in off-farm works. Labor shortage is critical for potato production. Potato growers as well as contract growers of Cold Storage Association need the machinery to mitigate the labor shortage impact and make potato production steadier. Planting and harvesting operations are crucial for mechanization in Bangladesh. The potato seed production farms and the potato processing industry need a full package of equipment like potato graders, potato slicers along with potato planting and harvesting machinery. The estimated numbers of potato machinery required are shown in Table 1.

Table 3: The Estimated Numbers of Appropriate Potato Machinery Needed in Bangladesh

No.	Name of Potato Machinery	Numbers Required	Suitable Potato Growing Areas of Bangladesh
1	Small potato planter	2,000	Munsigonj, Rajshahi, Joypurhat, Bogra, Rangpur, Dinajpur, Nilphamari, Lalmonirhat, Jessore, Panchagore, Thakurga, Comilla
2	Small potato harvester	2,000	
3	Power duster cum sprayer	10,000	
4	Potato grader	5,000	

IV. Challenges and Constraints Faced for the Whole-process Mechanization of Potato Production in Bangladesh

The major constraints for potato mechanization are as follows:

1. Lack of appropriate small potato planting and harvesting machinery for small fragmented land at an affordable price for the farmers;
2. Prices of potato produced are not stable, which discourages the farmers from capital investment;
3. Inadequate number of skilled machinery operators and mechanics in rural areas;
4. Machinery manufacturers are not technically sound for manufacturing potato machinery;
5. Credit support for agricultural machinery is not farmer-friendly;
6. There is a need for the policies on mechanization issues (Such as subsidies on agricultural machinery with easy access for farmers); and
7. Inadequate funds for potato machinery research.

Major Challenges

1. How to introduce small potato planters and harvesters to farmers;
2. How to make these machines available to the farmers with affordable price; and
3. How to link the potato machinery with the dealers, manufacturers, agri-business personnel.

V. Suggestions for Regional Cooperation for the Whole-process Mechanization of Potato Production in Asia and the Pacific

1. Formulation of sustainable guidelines for potato mechanization and implementing the strategy at a farmer's field;
2. Introduction and interchanging suitable potato machinery among the region with a fair price;
3. Open market policies for marketing of produced potatoes in the region; and
4. Capacity building of the farm machinery engineers, manufacturers, machinery operators, and progressive farmers with respect to the potato machinery and mechanization.

Cambodia
Whole-process Mechanization of Potato Production in Cambodia

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I. Overview of Cassava Supply Chain in Cambodia

Cambodia is a country with nearly 80% of the population living in the rural areas and 71% of the population dependent on agriculture and livestock for their livelihood. Beside the rice cultivation, cassava is a main subsidized crop which farmers grow in the country especially in high land area. Cassava is grown in all provinces. It is mainly grown in two corridors i.e. the Thai border (Battambang, Bantey Meanchey, and Pailin), and the Kampong Cham. The two largest provinces, Battambang and Kampong Cham, account for almost 90% of the total production of cassava in Cambodia.

The estimated production (root fresh) of cassava in 2015 (crop year 2014/15) was 11.94 million ton which has increased from 7.93 million ton in 2014. The raise in production was due to the expansion of the planted area and to a higher yield. Moreover, Farmers' response to the price increase, was due to growing contract schemes of some private companies combined with favourable weather and government policies.

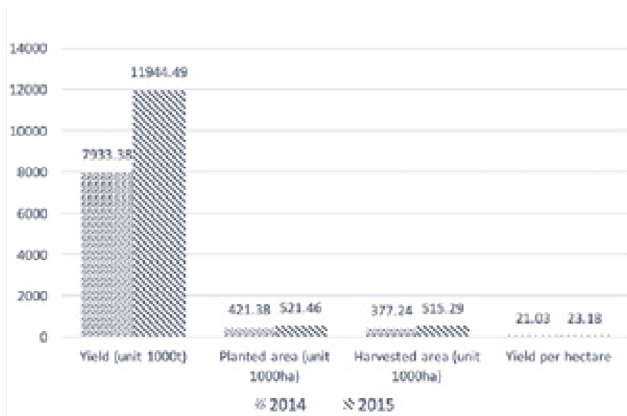

Figure 1: Cassava Production in Cambodia from 2014 to 2015
Source: AFSISNC, 2015

In Cambodia, where cassava is the second most important agricultural crop after rice, production of the starchy root is also geared up from the foreign market, mainly Thailand, China, and Vietnam. Due to lack of processing facilities of cassava, Cambodian farmers sell the dried cassava chip and flour to these markets, where it is processed into food, textiles and paper products.

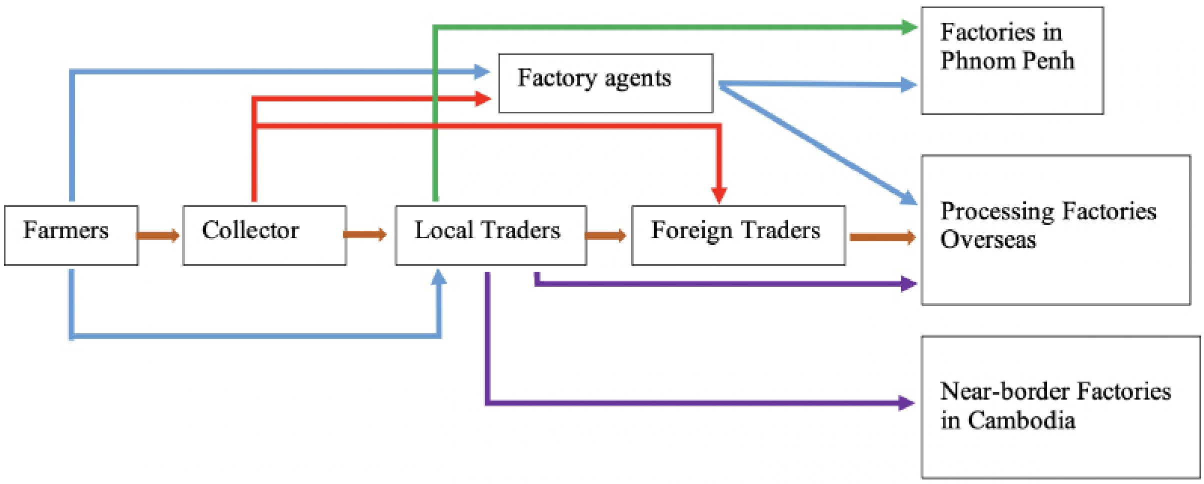

Figure 2: Flow of Cassava Trade (Hing Vutha, 2009)

The main components of Cambodia's cassava value chain are farmers (both small-scale and large-scale), collectors, traders and processors.

- Farmers: There are no statistics available concerning the number of cassava farmers. This number is certainly much smaller than rice producers, by far Cambodia's largest crop, which is cultivated by a total of 2.25 million farmers. However, the number of cassava farmers must still be large given it is Cambodia's second-largest crop; and that it is very labor-intensive requiring several short periods of time for planting and harvesting. Farmers typically grow cassava with other crops, such as maize and soybeans, for home consumption and as a source of income. Cassava farmers tend to have small or medium-size plots of land (typically 2 to 5 ha), although there are also large farms of 50 hectares or more. Most cassava producers are self-employed, though there are also cassava farmers undertaking contract-farming for factories.
- Collectors: The fresh or dried cassava from the farms is either sold directly to the processors or sold through a network of collectors, middlemen and traders to factories in Cambodia, Vietnam, and Thailand. Most collectors and traders are Cambodian, but they may represent foreign customers who have warehouses in Cambodia that only serve Thai or Vietnamese factories. Cambodian traders are not only specialized in cassava but also in general commodities i.e rice, corn, cashew nuts, soybeans, mung beans, and sesame depending on the season.
- Processors: There are currently about a dozen of cassava processors in Battambang, Kampong Cham, Kandal, and Phnom Penh. The first processor in Cambodia was established in 2001, and four have been established since 2008. Most of these companies are joint ventures with Thai, Vietnamese or South Korean partners, and tend to be specialized in a single product (cassava starch, animal feed, or bio-ethanol).

II. Status of Mechanization in Cassava Production in Cambodia

Agricultural mechanization in Cambodia has been increasing widely since the 1990s especially in land preparation, irrigation, threshing, and harvesting. The increase rate of tractors during the last 10 years was about 13% annually (4,247 units in 2006 and 11,960 units in 2015). The number of power tillers significantly increased at a compound annual growth rate of about 27% during the last 10 years (29,706 units in 2006 to 228,659 units in 2015). In Cambodia, the characteristics of agricultural machinery utilization depend mainly on the farm size, crop types, and terrain. Power tillers are used throughout the country by the smallholding farmers. Large tractors are preferred by the owners of rubber, cassava and sugarcane plantations, and other concessional land granted by the government. The northwestern region (Pailin, Battambang, Banteay Meanchey) is characterized by a large land size per household.

Equipment and machinery from land preparation to harvesting are important for the whole cassava production. The stages of cassava production are:

Land preparation – tractor (60-90 hp) operated 5/7-disc plough is used on a large area. For the small area, farmers use only the power tiller for land preparation. In general, the farmers plough two times for land preparation for loosening the soil and making the rows to plant.

Planting – manual labor is still used for cassava planting in Cambodia. The stem is cut by a wood cutting machine before planting. The planting needs 4 people per hectare and the expenses are about USD 50 per hectare.

In the growing stage, the fertilization, weeding and spraying herbicide depends on the manual labor. Usually 3 to 5 people are needed to do all these tasks for one-hectare area per day.

Harvesting - the farmers cut the branches and collect them to put under the shade and start digging the root during the months of November to February. There are two ways of harvesting the roots, one is using labor force with digger and another one is using the tractor with digger implement. The cut root is dried before packaging and transporting for storage or export to abroad.

Drying - Fresh cassava is dried under sunlight for two to three days. When the cassava is dry enough (moisture content 12% - 15%), it is packaged in the sack and transported to processing place or exported overseas, such as to South Korea, Japan, China and the European Union.

Table 1: Implements Required for Field Operation

No	Operation	Power Source	Implement
1	Land preparation	Tractor, Power tiller	Disc plow, Rotary, Plow
2	Creating ridge	Tractor, Power tiler	Ridger
3	Cutting stem for planting	Manual labor	Cutting machine, Wood Cutting
4	Planting	Manual labor	Hoe
5	Weed control	Manual labor	Hoe, Knapsack sprayer, Hand weeder
6	Fertilizer and pest control applications	Manual labor	Knapsack sprayer
7	Cutting stem	Manual labor	Knife
8	Harvesting root	Tractor, Power tiller	Digger

Figure 3: Mechanization of Cassava Production (Battambang, 2016)

III. The Need Assessment of Cassava Production Mechanization in Cambodia

Cassava mechanization is important and necessary for Whole-process production. Some of the farm machinery workshops are still relatively small, and the technical skill of the producers is low. Most of the farm machineries are imported from abroad. Further, there are no national regulations or experts in controlling the quality and safety of the machine. There is a need to improve technical skill to develop equipment/machinery for cassava production to increase production and yield. Moreover, mechanization is crucial when the labor force in the countryside move to work abroad to countries such as Thailand, South Korea, Japan, and Malaysia. Climate change is also influencing the cassava production in terms of water supply and solar drying. Therefore, it is required to equip with water pumping machines and drying machines for cassava production. In the Whole-processing of cassava production, most of Cambodia farmers manually carry out planting, pest control, fertilization, and harvesting operations, which results in low yields and high losses. Therefore, it is absolutely necessary to use the farm machinery like diggers, dryers, chopping machines, and modern storage facilities such as silos in order to increase yield and minimize losses.

Digger

Ridger

Figure 4: Tractor Operated Implements for Cassava Production

IV. Challenges and Constraints Faced for Whole-process Mechanization of Cassava Production in Cambodia

Most of the Cassava machinery used in Cambodia are imported from abroad and especially from neighboring countries such as Thailand and Vietnam. In Cambodia, local workshops can produce only a small fraction of small machines since the producer does not have an adequate knowledge, skill and technical support from national experts. Therefore, cooperation between national technical experts and local machinery producers is necessary to connect and support the producers in developing their workshops and strengthening the quality of machinery and its safety conditions. The local production faces fierce competition with farm machinery imported from neighboring countries with a high-quality and low-price product.

Since 2015, the number of cassava chopping machines produced is decreasing because the demand of the farmers in Battambang province for this machine has been met. Moreover, the workshop producing the machine is not improving their product and lack of training and innovation. Therefore, most of them have no creative ideas on how to develop the product. The process of development includes only reverse engineering machinery imported from Thailand and China. Most cassava production in Cambodia is in small scale or family level production. Machinery usage in cassava production is still underdeveloped as compared with other countries. Most of the Cambodian farmers still operate cassava production manually. Due to this, cassava yield is still low, and the loss remains high. Therefore, mechanization development for this production is necessary for Cambodia and it plays an important role to increase the yields and farmers' income.

Local Chopping Machine

Imported Chopping Machine

Figure 5: Cassava Chopping Machines

Suggestions for Regional Cooperation for Whole-process Mechanization of Cassava Production in Asia and the Pacific

- In terms of the regional cooperation for whole-process mechanization of cassava production in Asia and the Pacific, I would like to make some suggestions on how to develop the root crop production mechanization;
- Keeping and improving regional or bilateral cooperation among Asian countries, particularly cooperating on Research and Development of root crops mechanization;
- Transferring the skill, technology, and knowledge from researchers to farmers and other stakeholders;
- Transferring innovative technologies and practices of root crop mechanization across the Asia-Pacific region; and
- Holding regional workshops and conferences on root crop mechanization regularly.

China
Experimental Study on Potato Harvester with Integrated Type of Vibrated Digging and Separating

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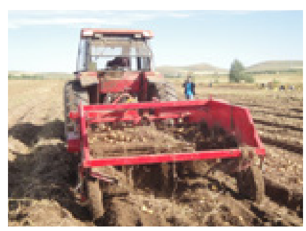
I. Study on the Potato Planting Mode and the Distribution of Potato in the Field

The study focuses on one season ridge planting mode in north China with ridge spacing of 80-100cm and ridge height of 25-30cm, while the depth of distribution of potato of 15-25cm and width of 45-60cm.

II. The Condition and Problems of Current Potato Harvesters in the Market

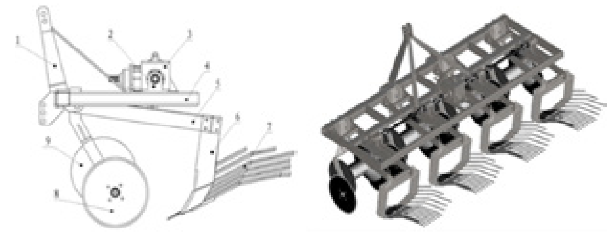
Currently, there are four main issues on potato harvesting, which respectively are: 1) a large amount of soil digging, high resistance, and high energy consumption; 2) long time friction between potato and separation chain harms the potato; 3) complicated structure of machinery, long length, inflexible motion, and no hanging mode; 4) the separation chain is easy to damage in rocky fields.



III. The Structure and Working Principle of the New Vibratory Integrated Digging-Separating Potato Harvester

According to the real practical experiment, the four issues mentioned above were addressed and solved from the design level. Firstly, the working principle of the digging shovel was studied to solve the problem of high resistance. Second, the harvester components were lowered to reduce resistance and energy consumption. Third, potato-soil separation and potato vine separation were developed. Fourth, the issue of breaking skin was solved and the quality of potato harvesting was increased.

The structure and working principle of the whole machine is showed below:



There are two major features of the new design. The vibratory obtrapezoid digging shovel greatly reduces the amount of soil digging and tillage resistance up to 30%. The combination of potato-soil separation grating and the vibratory shovel forms the no-sieve separation device simplifies the separation mechanism, reduces the potato motion distance and time on the separating sieve, and reduces the rate of injury.

That solved the problem of high resistance force, lowered the resistance and energy consumption of the harvester components, solved the issues of breaking skin and increased the quality of potato harvesting.

IV. The Effect of the New Potato Harvester in the Field

The new potato harvester has better performance and solves most of above-mentioned issues. The 47.8kw horsepower harvester could work over four rows at the same time. The loss rate reduces to 2% and the obvious rate achieves 98%. The leakage rate is 0.13%. The most impressive feature is that the damage rate reduced to 0.06% with a production efficiency of 0.55 hm2/h

V. Conclusion

The new integrated vibratory digging-separating potato harvester solved the key problems, such as high resistance in digging, low efficiency in potato-soil separation, damaged skin and so on. It integrates seedling processing, digging, removing soil and collection in potato harvesting. It has a simple structure, lightweight, low working resistance force, high production efficiency and low damage rate.

Indonesia
Whole-process Mechanization of Potato Production in Indonesia

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I. Overview of Potato Supply Chain in Indonesia

Indonesia is a minor producer of potato. The potato production in 2014 was around 1.32 million ton with an average yield of 17.3 t/ha. Over the last decade, Indonesia import has dramatically increased (14.082 ton in the first quarter of 2016). Potato is an important component of highland (more than 1,000-meter altitude) vegetable production systems across Nanggroe Aceh Darussalam, North Sumatera, West Sumatera, Jambi, West Java, Central Java, East Java, South Celebes, North Celebes, NTB and Papua (Figure 1).

Potato marketing in Indonesia is dominated by general trading and contract farming schemes. General trading refers to an informal and flexible relationship between sellers and buyers in which the commodity price is finalized in an agreement. The trader's positions in determining prices are usually higher than the farmers as the farmers have loans for buying seed, fertilizer, pesticide, and household goods. On the other hand, contract farming is an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices.

In general, there are two types of potato marketing channels according to the two potato varieties grown in Indonesia, i.e. granola and atlantic. Granola refers to a common marketing channel between farmers who produce granola varieties and traders who sell to the main markets for household consumption. Atlantic refers to a marketing partnership between farmers' groups who produce atlantic varieties and food processing company materials for potato chips. The partnerships are conducted without a formal agreement between the company and the farmers.

The supply chain in the Indonesian horticulture industry is not efficient (Figure 2). Marketing costs are relatively high, while the community's access to formal financing institutions is quite low. Most traders made partnerships with farmers to maintain supply continuity, and in the meantime, farmers could get capital for input productions and marketing securities.

Almost all of the Indonesian potato producers (98.5 percent) use non-certified seed, mostly to produce potatoes for home consumptions and traditional retail markets. Only 1 percent of potato producers use certified seed to produce quality tubers for sale to the supermarkets, while 0.5 percent remain is imported seed to produce potato for large scale industry. The organizational structure of potato seed multiplication in Indonesia is presented in Figure 3.

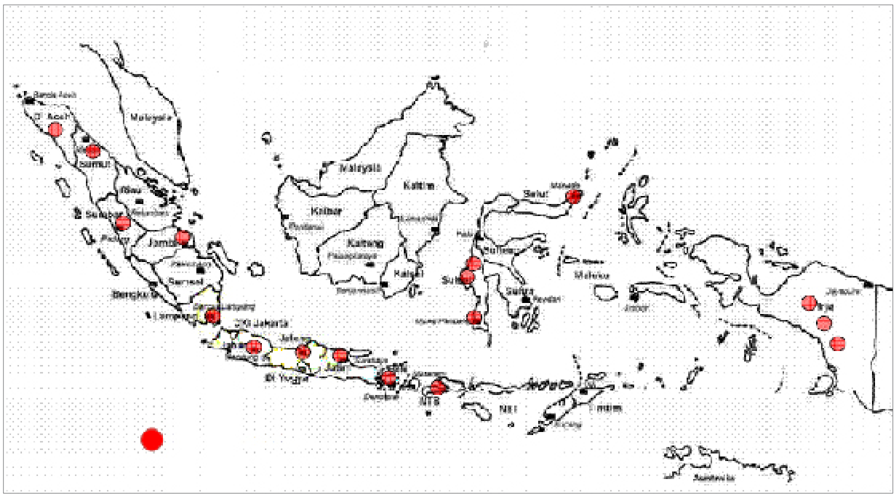

Figure 1: Potato Production Areas in Indonesia

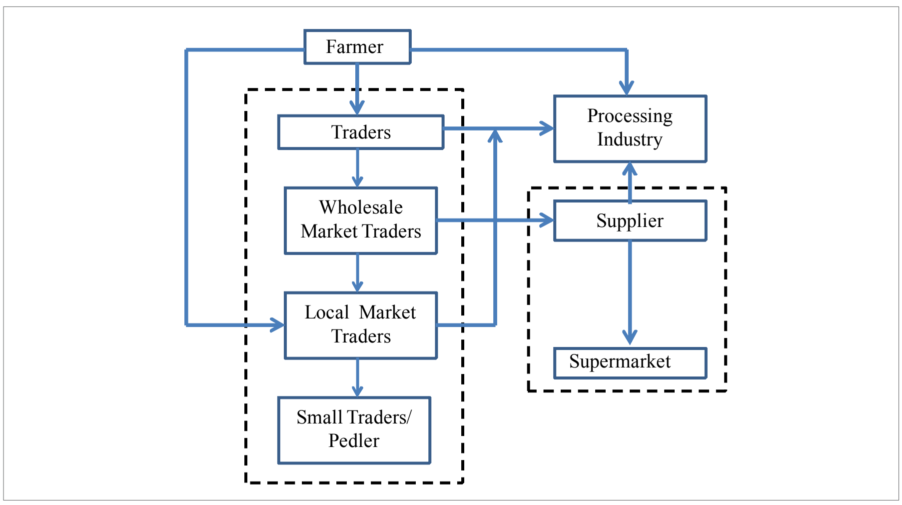

Figure2: Potato Market Chain in Indonesia

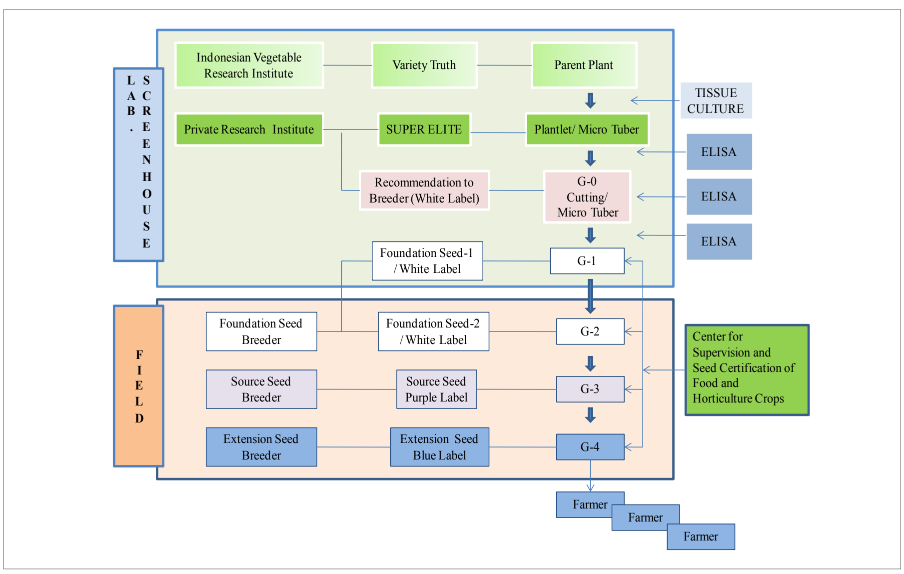

Figure 3: Organizational Structure of Potato Seed Multiplication

II. Status of Mechanization in Potato Production in Indonesia

Cultivation of potato in Indonesia is mainly limited by factors such as relatively steep slope, soil sensitivity to landslides and erosion, high rainfall, and infrastructure especially farming road. Potato production in Indonesia is a small-scale production, with individual producers typically growing potatoes in less than 0.5 ha area. Lack of labor in the region is the major reason to encourage mechanization. However, the mechanization is currently only directed to big producers, farmers' groups or the Institution for Rental Services of Agricultural Machineries (IRSAM or UPJA in Bahasa). Some big producers or seed companies use hand tractors or four-wheel tractors for land preparation, mulching machines, aero-hydroponic methods, green houses and screen houses, sprinkler irrigation, sprayers for pesticide application, grading machines, cold storage houses for seed.

The Indonesian Center for Agricultural Engineering Research and Development (ICAERD) has developed several types of machinery for potato production, as follows:

2011: Potato harvester (walking type)
Potato grading machine (roller type)
2012: Potato planter (walking type)
2013: Potato screen house and aero-hydroponic method for potato seed production
Potato grading machine (belt type)
2014: Potato slicer machine (various types)
2015: Potato peeling and washing machine

There are several types of machines that can be developed to support potato production such as manure spreader and cultivator. Status of Mechanization in potato production in Indonesia is briefly presented in Table 1.

Table 1: Status of Mechanization in Potato Production in Indonesia

Fact of Potato	process Activities	Agricultural Machinery and Facility
Harvesting area in 2014: 76,291 ha Need of seed: 1.5 t/ ha	Seed production	Screen house/green house Irrigation (Fertilizer-irrigation, sprinkler, mist, aero-hydroponic) Warehouse/cold storage, pest control, aeration Grading machine, transportation (for klift, three cycle/truck)
Potato production in 2014: 1.32 million tonne with an average yield of 17.3 t/ha. Potato consumption in Indonesia (2015): 4.76 kg per capita per year. Consumption of potatoes increase up to 10 kg per capita per year by 2021.	Potato production	Land preparation (hand/four-wheel tractor), furrower, manure/fertilizer spreader, potato planter, weeder, sprayer for pest control, irrigation (pump, sprinkler), harvester, transportation (three cycle/truck)
	Postharvest handling of potato	Aeration, grading, cold storage and transportation (forklift, three cycle/truck)
	Potato processing	Washing & peeling machinery, slicer machinery, deep fryer, packing

III. The Need Assessment of Potato Production Mechanization in Indonesia

In Indonesia, the number of supermarkets is increasing significantly, which means a growth in demand that has outpaced the supply response. There is a lack of good quality product available on a continuous basis. Consumption demand of potatoes is believed to continue to rise. As an alternative food source, the level of potato consumption in Indonesia is still low, at 4.76 kg per capita per year. The government is targeting to increase the consumption of potatoes up to 10 kg per capita per year by 2021.

However, there are many challenges faced by potato producers. Generally, labor shift to other more prospective sectors, causes a scarcity of labor for agriculture. Potato production requires a massive labor force for every activity (Table 2). Mechanization is projected to play a main role in solving this problem. Mechanization of potato production system needs serious assessments to minimize the risks for further development by in terms of ecological, economic, social, technological and institutional aspects.

Table 2: The Labor Requirement for Potato Cultivation per Hectare in Pangalengan, Indonesia

Activities	Labor (work man day)		Average
	Production of certified seed	Production of non-certified seed	
a. Land preparation, including making furrow and initial fertilizer application	209	103	156
b. Planting and furrow covering	41	44	42.5
c. Cultivation including embroidery, weeding, irrigation and spraying pesticide	174	239	206.5
d. Farm watchman	136	0	68
e. Harvesting	79	75	77
f. Transportation to the road	112	42	77
Total	751	503	627

Note: all converted to man labor, woman labor is calculated as equal to 0.8 man labor

The rate of urbanization also has an impact on an increasingly scarce availability of young workers in agriculture, as they are involved in industrial activities in urban areas. This condition boosts the dominance of older rural farmers who undertake agricultural cultivation. Therefore, the challenge for future needs is in making agricultural activities more attractive to the young generation. One is the development of agro-industries, as well as promoting mechanization for potato production.

Good planning with measurable implementation is needed to minimize problems. As the concept of sustainable development becomes very important, it is also important to remark that the government is able to functionally involve in providing information, building infrastructure, promoting growth and creating institutional frontier environment, which ultimately can help to achieve the objectives continuously.

Efforts to develop agricultural mechanization are not separable from institutional support, as adopting, learning, developing and implicating the technology should be in accordance with the socio-economic conditions of agriculture in Indonesia, helping its delivery to the public, demonstrating and conducting training to the community so that these technologies can be applied and provide tangible benefits to the development of agriculture.

IV. Challenges and Constraints Faced for Whole-process Mechanization of Potato Production in Indonesia

Demand for potato from industry and consumption are increasing year by year as a result of the increasing population and welfare. Therefore, the Strategic Plan of the Ministry of Agriculture of Indonesia projected a production growth of potato of 2 percent/year. To implement this plan, selected-mechinery is practiced to enhance productivity, add value and competitiveness. However, there are still several constraints in the potato value chain that affect mechanization in potato production, such as:

- Trust - Competition within the Indonesian potato value chain has resulted in that a lack of trust among the different stakeholders.
- Product availability - Lack of availability of good quality product on a continuous basis within the value chain has resulted in Indonesian potato producers are unable to capitalize on evolving market opportunities, such as supermarkets and food courts.
- Low market share - Indonesian potato producers' low market share has inhibited their ability to respond to evolving demand.

The main constraints of potato, especially Granola-variety value chain are on the production side, as there is little scope to improve traditional market chains, and the modern sector (supermarkets) remain too small to justify attention. The most frequently mentioned constraint by the producers are low yields and high production costs, which relates to potato seed quality and cost, and also to crop management issues especially the relatively high use of agro-chemicals during crop production cycle.

The issues related to potato seed are (a) high cost and limited supply of good quality certified seed tubers; (b) locally produced of uncertified seed tubers from the clean meristem culture is not stable and also of high cost; (c) the farmer practice of using seed retained from previous harvests, over several cycles results in gradually increasing disease pressures and lower yields over time.

Moreover, the use of agro-chemicals can be a negative factor for the environment, especially at high application rates/frequencies, and issues such as worker protection, water resource contamination, and safe disposal of containers are all valid. Additionally, there are increasing environmental regulations for the productive use of highlands.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

Suggestions for regional cooperation for whole-process mechanization of potato production are as follows:

1. Strengthening regional cooperation in collaborative research and development, information sharing, harmonization of standards and testing procedures, capacity building, technology transfer and trade facilitation and investment.
2. Strengthening networking in the establishment of business and enterprise friendly policies, laws, and regulations as well as physical and institutional infrastructures which encourage commercial activities and entrepreneurship in farming, input supply, product handling, processing and marketing as well as manufacturing.

Myanmar
Whole-process Mechanization of Potato Production in Myanmar

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I. Overview of Potato Supply Chain in Myanmar

Among the sixteen introduced potato varieties around 1915, three varieties such as Up-to-Date, Great Scott, and Ally have been widely accepted and remain as the dominant varieties in Myanmar. Among the three varieties, the Up-to-Date (UTD) is by far the most popular variety in spite of its susceptibility to late blight. According to the report of the Myanmar Agricultural Services (MAR 1990), "The cultivar UTD presently occupies nearly all of the potato growing area. Ally is the second most widely grown variety, and local varietal mixtures are also planted throughout the country" (CIP/Burmese Mission 1982).

A review of Myanmar's potato production system by a team of scientists from Myanmar and CIP in 1982 resulted in the introduction of germ plasm of over fifty cultivars from the Philippines, Bangladesh, and the Netherlands. A series of thirteen experiments were performed to assess relative performance under varying conditions, including: fertility responses; yields under varied cultural practices such as spacing, mulching, and planting depth; seed source and selection; and a comparison of tuber storage in Diffused Light Storage (DLS) vs. semi-dark and dark storage (MAS 1990).

Germ plasm evaluations were undertaken utilizing management practices not generally available to farmers in Myanmar, such as applications of manure and synthetic fertilizers, and the spraying of fungicides and insecticides. There was a wide variation among the newly introduced cultivars, but very few consistently out-yielded Up-to-Date. In one trial, UTD out-yielded 23 promising foreign varieties in previous evaluations. In general, the results were very inconsistent given environmental variables, such as early season rainfall and late season blight severity. In general, UTD has proven to be well suited to Shan Hills, given its proven capacity under sub-optimal conditions and good storability. On-going germ plasm evaluation and selection are focused on late blight resistance, not a strong factor for UTD.

In Myanmar, potato production is concentrated in three areas: vizthe Shan Hills (60 - 70 percent) to the east of the country; areas adjacent to rivers in the Magwe, Sagain, Mandalay, and Kachin states (25 percent); and the Chin Hills (8 - 10 percent) to the west. The Shan Hills area is clearly the major potato production region and contributes to 75 percent of the national total production.

Potato is grown year-round in four distinct seasons/regions in Myanmar i.e. irrigated spring (from January to April), early monsoon (from April to August), late monsoon (from August to November) and minor winter crop (from November to February). Potato grown at early monsoon is a minor crop and the seed is kept from a previous crop or purchased from wholesalers. Late monsoon is the major potato growing season and especially in Southern Shan Hills and Chin Hills. The seed is derived from the April harvested irrigated crop and uphill fields. The minor winter irrigated crop is grown in the alluvial plains, the seed is derived from the August harvest of the early monsoon crop planted in April.

According to Haverkort (2013), there is no official seed system and currently no professional production of quality seed potatoes. Farmers keep some late monsoon crop yield for the early ones. All seeds for the winter and late monsoon crop are bought from traders, who themselves buy their potatoes as ware potatoes. After grading and storing, they sell the smallest ones as seed potatoes to farmers. Some disadvantages of this system are the varietal mixture and the high incidence of diseases such as late blight and brown rot.

Modern disease-resistant varieties are thus urgently needed for the development of the Myanmar potato sector. In the coming years, the demand for ware potato varieties (fresh consumption) as well as (crisps and other snack food) processing varieties will increase. By using high-quality seed potatoes, combined with the use of other improved inputs (fertilizers, pesticides, irrigation water, and (small) machines), the production rate can be doubled in the coming years. This growing demand for ware potatoes and potato-based products provide good business opportunities to improve storage and to set up a processing industry.

According to the report of the Dutch team (2015) as shown in Figures 1 and 2 and data from Myanmar Agriculture at a Glance (2015) as shown in Table 1, nowadays Myanmar produces approximately 600,000 tonne of potato on 40,000 ha and the present consumption is about 10 kg per capita indicating that population of 60 Mio production and consumption are in balance and grows rapidly. Given the consumption patterns in the other parts of Asia, it is expected that demand will increase considerably over the coming years. The production and consumption will grow rapidly. It is therefore a real cash crop for growers, for which they need to invest in seed, labour, fertilizer and crop protection.

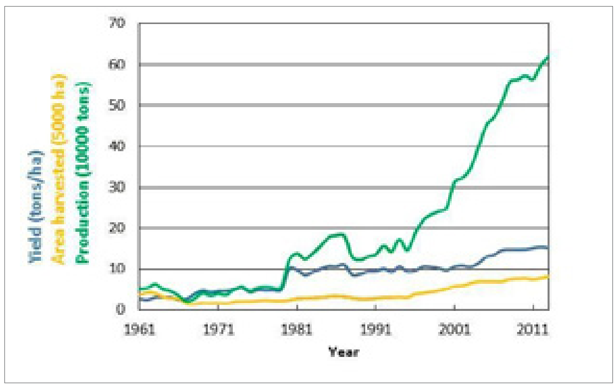


Figure 1: The Yield, Area and Production of Potato In Myanmar between 1961 and 2013

Source: Report of the Potato Mission of the Netherlands Industry and Knowledge Institutions to Myanmar, 2015

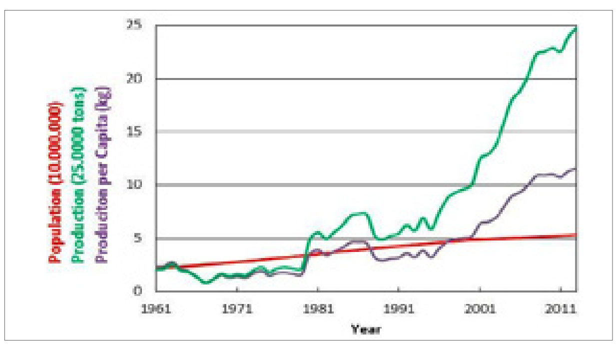


Figure 2: Development of Potato Consumption in Myanmar between 1961 and 2013

Source: Report of the potato mission of the Netherlands industry and Knowledge institutions to Myanmar, 2015

Table1: Sown Area, Yield and Production of Potatoes in Myanmar

Year	Sown ('000 ha)	Harvested ('000 ha)	Yield (Mt/ha)	Production ('000 Mt)
1995/96	19	19	9.64	187
2000/01	29	29	10.87	319
2005/06	35	35	13.76	478
2009/10	38	38	14.76	563
2010/11	39	39	14.8	573
2012/13	37	37	15.16	560
2013/14	36	36	15.05	549
2014/15	37	36	15.11	551

Table 2: Cost of Cultivation for Potato

Cost of Production for per acre (Kyats)							
Year	Family about	Hired Labour	Material Costs	Total	Yield (kg/ha)	Production Cost for 1 ha	Production Cost for 1 t
2011/12	-	175,500	94,140	269,640	2,078	666,280	320,634
2012/13	-	213,300	104,240	317,540	2,078	784,641	377,592
2013/14	-	216,000	107,240	323,240	2,118	798,726	377,049
2014/15	-	216,000	107,240	323,240	2,118	798,726	377,049

II. Status of Mechanization in Potato Production in Myanmar

Agricultural mechanization in Myanmar is changing from conventional farming to mechanized agriculture:

The main functions of Myanmar Agricultural Mechanization Department (AMD) are as follows:

1. Reforming farmland for mechanization.
2. Distributing farm machineries to farmers by the installment payee.
3. Providing services for tillage, planting and harvesting through the hiring system.
4. Conducting training to not only departmental staffs but also to farmers for farm machinery operation and maintenance in AMD training centers and stations.
5. Researching for the farm mechanization development and farm machinery development in Myanmar.
6. Reforming to terrace farming by substituting shifting cultivation in hilly regions.

The Agricultural Mechanization Department (AMD) is the leading farm mechanization sector in Myanmar, undertaking the following strategies:

1. Strategy for Farm Land Reform

AMD is supposed to reform the current farm land into bigger continous block, and design for farm road and appropriate irrigation and drainage system.

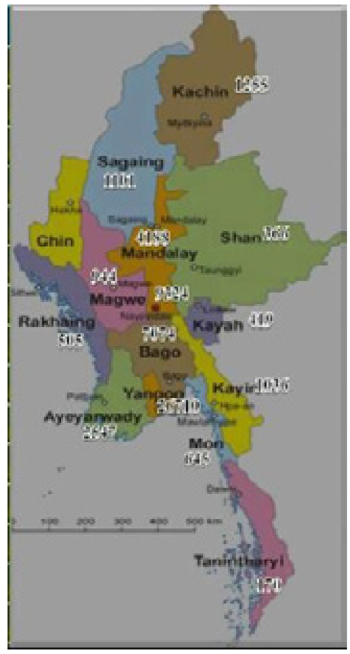
2. Mechanized Farming Strategy

AMD will make efforts to enhance farmers' income and livelihood by increasing qualified farm products and reducing losses through the utilization of farm mechanization system. The first priority is to make complete provision of farm machinery and services on land preparation, harvesting and threshing.

Table 3: The Progress of Land Consolidation by 2015

No.	Location	Area (acre)
1	Kachin State	1,255
2	Kayar State	419
3	Kayin State	1,036
4	Sagaing Region	1,101
5	Tanintharyi Region	170
6	Bago Region	7,074
7	Magway Region	944
8	Mandalay Region	4,188
9	Mon State	645
10	Rakhine State	505
11	Yangon Region	26,710
12	Shan State	366
13	Ayeyarwaddy region	2,547
14	Naypyitaw Council Area	9,324
	Total	56,284

Figure 3: The Progress of Land Consolidation by 2015



In Myanmar, rice is a staple food and land consolidation is shown in Table 3 and Figure 3 while agriculture implements are shown in Table 4. These implements are mostly used for rice production and some for other crops grown in Myanmar. For potato production in Myanmar, two machines are mostly used, namely tractor for land preparation and potato lifter or harvester at harvesting time. Most of the potato production is conducted manually and nearly 60 percent of the tubers are damaged.

Table 4: Agricultural Implements

								('000 Number)
SN	Particulars	1995/96	2000/01	2005/06	2010/11	2012/13	2013/14	2014/15
1	Draught cattle	6,808	8,096	8,868	10,316	10,490	10,596	10,698
2	Tractor	9	11	11	11	13	14	17
3	Spike harrows	2,834	2,987	3,126	3,182	3,200	3,196	3,211
4	Inter cultivator	132	156	179	190	197	198	199
5	Plough share	2,758	2,873	3,018	3,085	3,064	3,077	3,078
6	Rotary harrow	435	518	571	632	628	626	622
7	Cart	1,674	1,759	1,795	1,769	1,776	1,769	1,763
8	Other harrow	411	452	479	492	497	496	503
9	Seed drill (harrow)	71	83	93	94	96	97	98
10	Seed drill (plough)	14	17	21	23	23	23	23
11	Water pump	72	142	179	208	231	242	262
12	Power tiller	17	57	97	160	218	243	275
13	Harvester	4	3	3	2	2	2	3
14	Thresher	6	19	29	42	55	62	70
15	Combine harvester	1	1	0.1	0.23	0.64	0.76	1.78

Source: 2015 Myanmar Agriculture at a Glance

III. The Need Assessment of Potato Production Mechanization in Myanmar

Small farmers are leaving farming due to poor return. In such a situation, it would be advantageous to think of modernization and mechanized farming. Potato farmers in Myanmar can produce good products, but the rudimentary warehouse and distribution system often cause poilage of potatoes before distributing to market. Long-term plan for applying machinery. Custom hiring services are still needed to enhance the access to machinery for small-scale farmers who cannot afford to buy farm machinery.

The level of utilization of farm machinery at various stages of crop processing is still low as compared with other potato producing and exporting countries. The varieties of the equipment is not enough to meeet the needs of agriculture. There are also vast opportunities to develop of farm machinery for precision and protected agriculture, hill agriculture, horticulture, recovery and management of crop residues, non-farm application like efficient rural transport, etc. Good land preparation is important in potato farming. The soil needs to be conditioned and free of weeds. The seedbed former, also known as the rotary ridger, prepares the soil by mechanical means to give bed a consistent till and good aeration. Potato growing farmer in Myanmar need facilities such as seedbed former, planter, seed bed maintainer and the potato lifter, or harvester for potato production. These four implements have to work together to produce the desired results. Individual small farmers can benefit from mechanization by using the services of agricultural contractors or joining together to purchase equipment for common use.

IV. Challenges and Constraints Faced for Whole-process Mechanization of Potato Production in Asia and the Pacific

In Asia and the Pacific region, potato is a commercial crop both for fresh consumption and processing. Better varieties with integrated crop management practices will increase yield and provide higher productivity to the farmers. The availability and marketing of healthy potato seed, processing varieties, ware potato for fresh consumption and potato post-harvest technology are important for farmers in all potato producing countries in the region.

Most countries in Asia and the Pacific region are densely populated and still growing. The pressure on land is among the highest in the world, with the available arable land as low as 700 m^2 per capita. More than half of the population in Asia and the Pacific is heavily dependent on the agricultural sector for living. In Myanmar, up to 70 percent of the population involves in agriculture whereas in China more than 60 per cent still lives in rural areas despite the accelerated urbanization during last two decades.

With agro-industrialization, potato processing quality has become an important factor. Varieties suitable for French fries and snack foods are rewarded with higher prices from processing companies. China has made significant investments in starch production in large processing plants in north of Myanmar, but producing coarse starch is also a popular way of processing potatoes among poor farmers. There is a need for technology to facilitate poor farmers in the emerging processing market.

The biggest challenge is the high cost of transport and the poor condition of transport infrastructure - rural roads, rural-urban highways, border crossings, and ports. The second challenge is the seasonal nature of potato production. There is a large need to invest in affordable small greenhouses in the cool mountain areas. Irrigation in the dry zone and hills, cold storage at urban and export market points are needed. This will extend the season and allow farmers and traders to have more bargaining power, flexibility and options in domestic and export markets.

The final very important challenge is the need to develop both rural and urban wholesale markets. There is a need to develop wholesale markets as collection points and conduits to cities for the development of value chains in Asia and the Pacific region. Mechanization is the surest way of improving yield. Farmers who have embraced mechanized agriculture and use high quality seeds, as well as appropriate fertilizers, are assured of increased production. They are also guaranteed lower production costs and higher profits.

Nepal
Status of Potato Production and Whole-process Mechanization in Nepal

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I. Introduction

Potato is an important crop in Nepal. It is grown all over the country, in terai (plain), hilly and high mountain areas from the lowest point of 70 m above Mean Seal Level (MSL) to the highest of 4,400 m above MSL. It is one of the staple crops for people living in the mountain areas, and an ingredient of vegetable dishes in hilly and terai region of Nepal.

Potato is the 5th crop by area coverage in the country (205,725 ha). The government has given a priority for the development of the potato sector. The National Potato Research Program (NPRP) of Nepal Agriculture Research Council (NARC) and the National Potato Development Program (NPDP) of the Department of Agriculture (DoA) are working for the technology delivery and technology dissemination, respectively. Programs are designed for varietal development, seed production, seed distribution, pest management etc. Two government farms are also working in special regards for seed production. Research on Potato mechanization is being carried out by the Agricultural Engineering Division of NARC, whereas extension is being done by the Directorate of Agricultural Engineering (DoAEngg).

Potato processing industries are established and supervised by the Department of Food Technology and Quality Control (DFTQC). There were various projects from different development organizations in the past working on potato. The Swiss Development Cooperation (SDC) Project during 80's technically supported NPRP with advance controlled glass house and net shed for quality seed potato production and their distribution in Nepal. Exhibitions are organized by the local governments, farmers' groups, co-operatives and the private sector in collaboration with the governmental and non-governmental agencies in many potato growing areas.

II. Status of Potato Production

The area of the potato cultivation is increasing, but the pace is rather slow. Production and productivity are also experiencing an increase. The total production is around 2,817,512 t with a productivity of 13.69 t/ha. The use of good quality seed, fertilizer and irrigation facility is increasing thus leading to a productivity improvment. Stage will decrease the cost of production. However, a large area of the crop is still under rain-fed condition, so the production and the productivity are largely affected by the rainfall too. Its consumption is about 75 kg/head/annum. Its national productivity is still low (13.69 t/ha) in 2015. It is nearly self-sufficient for fresh consumption (88-90% around). The rest of the amount is imported mainly from India and Bhutan.

Farmers are mainly using seed potato produced from potato seed producer/ farmers' group. The seed is either stored in a rustic store (natural) in high hills areas, or in cold storage in mid hills areas and terai. A quite remarkable quantity of seed potato of 141 t (2013/14) is being imported from India. Basic seeds produced from a tissue culture or from true potato seed are multiplied to certified seed by the seed producers which is ultimately used for ware potato production.

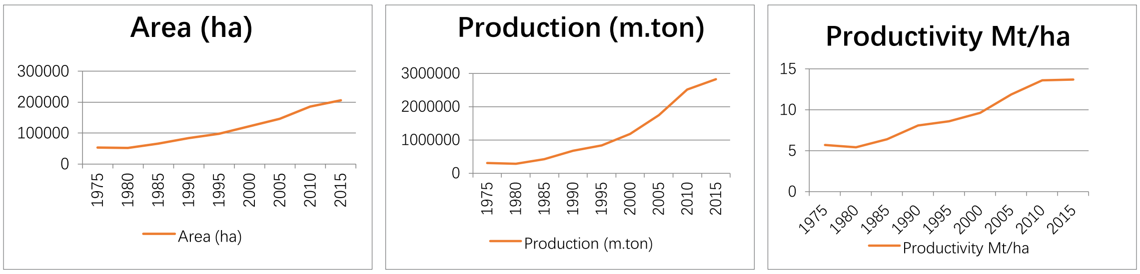

Figure 1: Area, Production and Productivity of Potato in Different Years (NPDP, 2015)

1. Potato Crop Varieties:

More than 10 varieties are recommended for potato growing. The preference of farmers towards the varieties is different in different parts of the country. It also differs from the market preference. In remote areas, still, quite old/local varieties are in use. The preference of farmers of different localities is listed as follows:

- Western terai and hills - Kardinal, Desiree, Khumal white
- Central and western Mid hills - Janakdev
- Kaski and Nuwakot districts - MS 42.3
- Hills of Dolakha, Sindhupalchok, Ramechhap districts-Rosita, Khumal red
- Kavre, Bhaktapur and Kathmandu districts-Kardinal, Desiree, Janakdev
- Ramechhap and Okhaldhunga districts-Chisapani red
- Eastern terai-Kufri Sindhuri, Kardinal

2. Seasons of Potato Growing in Nepal

Due to the geographical advantage, potato can be grown year-round in Nepal. In southern terai and foot hills it is grown in winter to early spring whereas in hills and mountains in late spring and autumn season.

Table 1: Seasons of Potato Growing in Nepal

S.n	Season	Planting time	Harvesting time
1	Winter season	Sept-October	January-Feb
2	Early Spring	January-February	April-may
3	Late spring	March-April	June-August
4	Autumn season	July-August	September-October

3. Potato Trade in Nepal (MoAD, 2013/14)

Seed potatoes, fresh potatoes and the processed potatoes are imported in Nepal mostly from India and Bangladesh. A quite a few amounts of these are exported too. A detail of export and import in the year 2013-14 is presented below (MoAD, 2014).

Table 2: Potato Trade in Nepal

		Import		Export	
S. No.	Item	kg	Values Rs	kg	Values Rs
1	Potato seeds	141,180	2,419,479	300	6,000
2	Fresh potatoes				
	Potatoes fresh or chilled	215,034,005	4,140,642,487		
	Potatoes	3,402,117	74,945,545	13,300	133,000
	Total	218,436,122	4,215,588,032	13,300	133,000
3	processed potato products				
	Flour, meal of powder of potatoes	24,900	1,475,408	18,730	2,383,363
	Flakes, granules, pellets of potatoes	451,079	31,116,829		
	Potato starch	802	42,125		
	Potato chips	162,417	88,964,349	34,255	86,349
	Potatoes prepared or preserved otherwise than by vinegar of acetic acid frozen	160,308	17,064,931		
	Total	799,506	138,663,642	52,985	2,469,712

·Note: NRs 106 = 1$

III. Overview of Potato Supply Chain

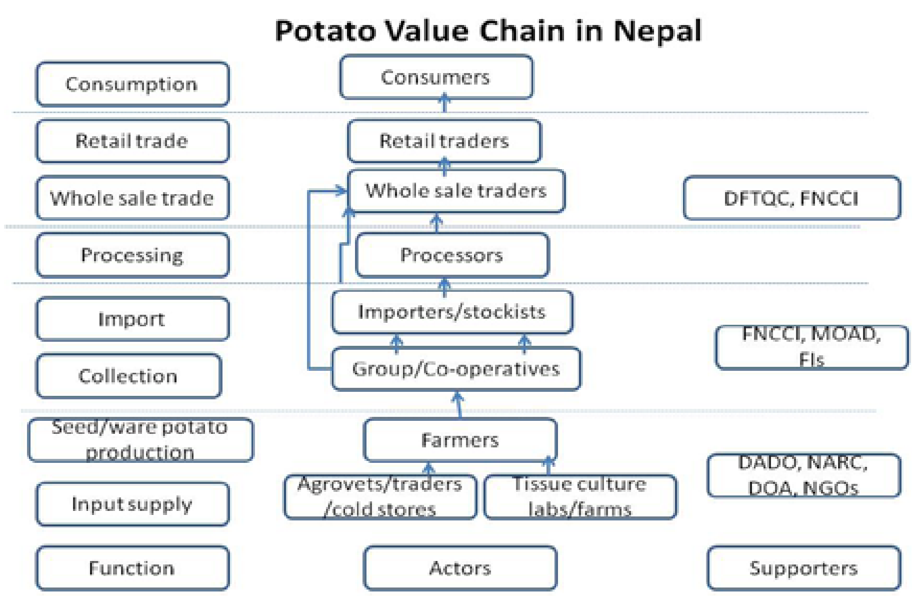

Figure 2: Potato Value Chain in Nepal

The potato supply chain in Nepal can be divided into two sectors, one is the seed sector and another is the ware potato sector. Pre-basic seeds are produced by tissue culture labs (NARC and Private) and screen houses. True potato seed is produced by horticulture farms. Some of them are imported from India. These seeds are grown by seed potato producer farmers to produce certified seed potato. Afterward, the potato goes to ware potato producer farmers. The seed potato is stored either in rustic stores (high hills) or in cold storages (mid hill and terai) before the planting season.

Potato produced by farmers in the villages is collected by farmers group/co-operatives or traders and supplied to the big wholesale markets/stockists. Some amount of potatoes is stored in a cold storage for a few months. A small part of the potato is imported from India, Bangladesh, and Bhutan. These wholesalers supply to the retailers, thereafter potato is delivered to the consumers. The wholesalers may also direct their supply to the processors to produce chips and other products.

There are at least 34 potato processors which produce chips, finger chips and other products.

IV. Status of Mechanization in Potato Production

1. General Agricultural Mechanization

Most of the agricultural operations in the country are labour-intensive. As the productivity of both crop and livestock is low, the labour is less lucrative. The application of mechanization is limited for selected operations only. Agri-mechanization in Nepal getting attention in recent years the commercialization of agriculture and also due to the shortage of labour. The below table shows the household usage of various machinery/equipment as per the National Sample Census of Agriculture, CBS, 2012.

Table 3: Equipment for Agricultural Operations

Machinery/Equipments used	No of Households	% Households
Iron ploughs	1,073,441	28.02
Tractor & Power tillers	920,371	24.03
Thresher	803,154	20.96
Pumping sets	548,203	14.31
Sprayers	574,014	14.98
Shallow tubewells	367,744	9.56
Deep tubewells	159,725	4.17
Treadle 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 the Agricultural Mechanization Promotion Policy on 13 August 2014 and showed the direction for its development in the country. The drafting of the Agricultural Mechanization Promotion Operation Strategy is in process. This strategy will serve as a guide map to implement relevant policies more effectively. The Agricultural Development Strategy (ADS), approved by the Government of Nepal (GoN) on 26 July, 2015 has a special section mentioning the private sector involvement in boosting agricultural mechanization. In the new Constitution of Nepal (2072) approved on 20 September, 2015 the emphasis was given to promote the agricultural production. 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.

The Agricultural Engineering Division under Nepal Agricultural Research Council (NARC) is working for the research and development of agricultural machinery. The Directorate of Agricultural Engineering under the Department of Agriculture is working for the dissemination of the technologies to the farmers, conducting trainings for farmers and entrepreneurs and facilitating for the establishment of workshops and custom hiring centers in the country. The use of machines is high in terai region and low in the hills and mountains due to the geographical difficulties. Most of the machines are imported from China and India, while some local manufacturers have started the production of the machinery in the country.

2. Mechanization in Potato Production

Even though potato cultivation in the country has a long history, mechanization in potato production is in the primitive stage as compared to other countries. Mechanization of the whole production process is increasing due to the increasing demand, commercialization and farm labour scarcity caused by the migration to cities and aboard.

Present operation-wise mechanization status for potato production can be stated below.

- **Seed Preparation**
  To ensure the production of good quality seed, 4 tissue culture labs (one in the government sector and 3 in the private sector) are in operation and two other tissue culture labs are under construction. There are 6 screen/net house linked with these labs for producing pre-basic seed potato.

- **Land Preparation**
  The use of four-wheel tractor driven plough, mold board plough, disc harroe are common. The number of four-wheel tractors and two-wheel driven potato planters in use are limited, while the demand is increasing.

- **Water Management**
  Most of the irrigation water is supplied from channels, shallow and deep tube well. Electrical, diesel, petrol and some places

solar pumps are used for water lifting where irrigation facilities are available. The use of drip irrigation system and the use of sprinklers is increasing in hilly terrain.

- **Intercultural Operation**
  Weeding is mostly done manually, while some of the hand tool and mechanical weeders are being used in some areas. For pest management, different spraying equipment and duster are commonly used for pesticide and fungicide application, with the rate of almost 100%.

- **Harvesting**
  Harvesting is mostly done manually. However, some four-wheel and two-wheel tractor driven digger are used in terai area. Some local manufacturers have started producing such equipment.

- **Post-Harvest**
  Grading and sorting are done manually. In some areas, cleaning, grading and sorting are done mechanically. Manually operated potato grader has been introduced recently in major potato growing areas.

- **Transportation**
  Transportation of product from farm/field to collection center or storage is done with the trailer attached to four-wheel and two-wheel tractors.

- **Processing**
  Value adding potato processing is initiated by at least 34 processing factories by producing chips and other products.

- **Storage**
  For storage of seed potato, 44 cold stores are established in terai and mid hill areas with an estimated capacity of 86,400 t, out of them 40 cold stores are in operation. 50% of the electricity tariff is being subsidized by the Government. In high altitude areas, 200 rustic stores (Natural) with the estimated capacity of 1,710 t is constructed out of which 171 are in proper operation. The construction and running of 10-40 metric t capacity rustic stores are increasing in high mountain areas. The Nepalese Government has launched interest subsidy for 5 years for establishments of the new cold store to be financed by banks with minimum electricity demand charge.

V. The Need Assessment for Potato Production Mechanization

Potato production mechanization is necessary for Nepal due to several reasons:

- The continued shortage of farm labour
- Commercialization of potato sector
- Increased cost of production
- Demand for good quality virus-free seed potato production
- Very few tissue culture labs
- Inadequate infrastructure for good quality seed potato storage
- Increasing demand for machinery
- Establish well-equipped training and testing centers
- ToT in house and aboard for the machineries presently used in the country.
- Educate sufficient numbers of mid-level technicians for effective mechanization.
- The establishment of local manufacturing/assembling units to reduce the costs of agricultural machineries import.
- Human resource development for entrepreneurs and cooperatives for custom hiring service.
- Attract young people in the agricultural mechanization sector and make it as a prestigious occupation to address agriculture human resources migration to urban, abroad and non-agricultural sectors.

VI. Challenges and Constraints Faced by the Whole-process Potato Production

There are several constraints faced by the whole-process potato production in the country. The geographical setting is one of the major constraints. In most of the areas of hills and mountains, the use of heavy machineries is not possible, only small and handy machines can be used. The land fragmentation is increasing day by day that makes mechanization difficult. There are only 15 agricultural engineers in DoA and 25 in NARC to look over the whole country which cause a weak organization in the government system.

There is also no mid-level manpower production for Agricultural Engineering like in other fields, including civil, electrical, mechanical engineering. Migration of youth to urban areas and abroad leaves workforce pool consisting of senior-aged and women for agricultural practices. Credit facility and interest rates from financial institutions makes it harder to attract the youth into the field. Among other constraints, some that could be listed: low volume of investment from public and private sector for the mechanization; low awareness of available technology around the globe; unavailability and limited access to the machinery in many parts of the country; unavailability of spare parts and after-sale services; establishing training and testing centers requires a lot of money; inadequate infrastructure facility to conduct effective training for staff, farmers or mechanics, and lack of energy resource availability.

VII. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

In view of the difficulties and the opportunity for whole-process mechanization of potato in Nepal, regional cooperation is expected in the following areas: capacity enhancement of existing human resources (Agri. Engineers/sub-engineers) through training/visits/traveling seminars; exchange of new innovations on agricultural mechanization among the member countries of CSAM through strengthening linkages; coordination among the organization/institute involved in agricultural mechanization in the South Asian Association for Regional Cooperation (SAARC) regions; establishment of support for Training and Testing Center by development partners; strengthening of ANTAM activities throughout the region; cooperation among different stakeholders in this field; establishment of network and linkages among agencies and individuals involved in whole-process mechanization of potato production in member countries; regional project for farm machinery research and development; technology generation and validation; a regional project to support farmers financially and technically to mechanize their potato farming; a regional network of traders to increase access to machineries and spare parts; regional collaboration in organizing international expos.

Additionally, it is anticipated that CSAM continues to organize regional meetings and seminars for coordination and cooperation in the area of Agricultural Mechanization. Developed countries provide more support for developing countries through scholarship provisions.

Pakistan
Overview of Potato Supply Chain in Pakistan

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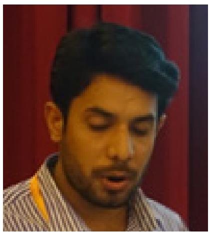


I. Introduction

Potato is one of the most important and common food crops in of the world. This crop has the potential to bridge the demand gap for food and cereal production of the increasing population. Potato is the world's leading vegetable crop and is grown in 79% of the world's countries. In Pakistan, potatoes are grown on 138.50 thousand hectares. The production is estimated at 3,141.40 thousand ton with an average yield of 22.7 tonnes per hectare. Almost 86% of potato area and production of Pakistan is located in Punjab province i.e. Okara, Sahiwal, Kasur, Sialkot, Sheikhupura, Jhang, Narowal, Pak pattan, Gujranwala, T.T Singh, Khanewal and Lahore. The shares of the remaining provinces are 9% in KPK, 4.5% in Baluchistan and 0.5% in Sindh. Three crops of potatoes viz autumn, spring and summer crops are being cultivated in Pakistan. In the plains of Punjab and Khyber Pakhtunkhwa, generally, two crops are raised in a year, i.e. autumn and spring crops while the third one is cultivated in the hilly areas of KPK during the summer season. In Pakistan, the high-altitude northern area (Batakundi 2,650 m, and Skardu 2,250 m) is the main seed producing area and supply seed to the rest of the country (Pakistan Economic Survey 2012-2013).

Potato Supply Chain

The potato supply chain in Pakistan can be categorized of three types.

1. Local consumption
2. Industrial consumption
3. Exports

1. Local Consumption

Local consumption has a major share in the total production. In Pakistan, 99% of local need is being fulfilled by local production. Supply chain starts from the farmer who usually sells the potato to the middle man after harvest, if market prices are reasonably good. If the prices in the market are low, the farmer stores the potato in cold storage on a rental basis. Some farmers also approach to the bulk vegetable & fruit market (Mandi) directly. In bulk vegetable & fruit market there are several shops of agents (arhti) who purchase the potato from the farmers or middle man through a bidding process. Then this potato is transported to the bulk vegetable & fruit market of major demand areas, i.e. big cites. Some portion is sold out at the market to the local retailers by the agents through a bidding process. The potato in the markets of big cities is also sold out to retailers. The retailers sell potato to the consumers in street shops.

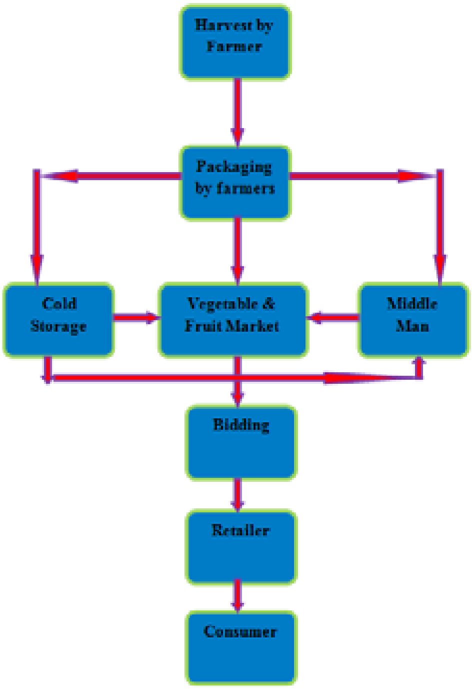


Figure 1: Supply Chain of Domestic Consumption

2. Industrial Consumption

The industries involved in making by-products of potato also purchase the potato from the farmers, although the share of purchases does not consume much in terms of production volumes. However, farmer selling the potato to the industry usually gets a better price than the conventional farmer. The major industry of potato by-products in Pakistan is "Lay's". There are also some other local industries but their consumption is not so big. The industry provides special seed to the farmers and also instructs the farmer about the production technology of the crop. After the harvest, the industry purchases the whole production of the farmer and stores it into their cold storage. Some portion of the potato is directly used in processing and other is stored in the storages. After the processing of potato products, it is then sold by the company through their own marketing network.

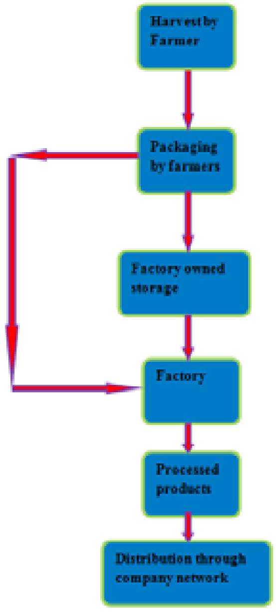


Figure 2: Supply Chain of Industrial Consumption

3. Exports

Pakistan also exports some potato to the other countries/regions like Sri Lanka, Iran, Afghanistan, well-equipped, Hong Kong, etc. The potato is purchased by the export agents through a middle man, local vegetable markets, or directly from the farmers. This potato is then graded, repacked, and the potato is transported to the export market i.e. Karachi. The exporter purchases the potato according to the quality of the crop. The prices change according to the export demand in the market. The potato is then exported to different countries.

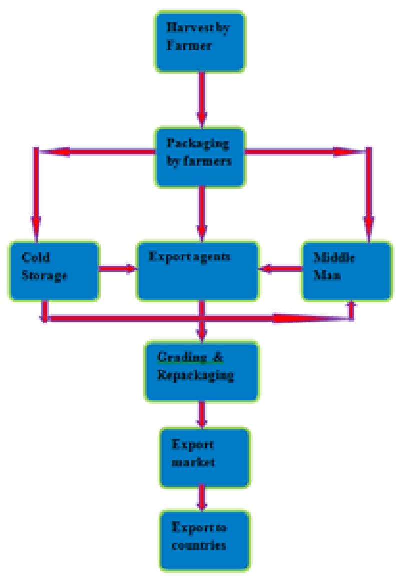


Figure 3: Supply Chain of Export

II. Status of Mechanization in Potato Production in Pakistan

Currently, the farmers of Pakistan are using the following essential machinery and equipment for potato production.

Primary Tillage Implements:

Mould Board Plough

In Pakistan, mould board plough is the most important implement for primary tillage in canal irrigated or heavy rain areas where too much weeds grow. The objective for ploughing with a mould board is to completely invert and pulverize the soil, up-root all weeds, trash and crop residues and bury them under the soil. In Pakistan, the mould boards are mostly designed to cut down the soil and invert it to the right side, completely burying the undesired weed growth which is subsequently turned into manure after decomposition.

Figure 4: Mould Board Plough

Disc Plough

A Disc plough is commonly used for deep ploughing in root-infested, sticky, stony and hard soils. It mixes remains of crops and weeds throughout the depth of ploughing, hence it is ideal for rain-fed areas suffering from soil erosion by water and wind. Spring loaded floating rear furrow wheel controls the side draft to ensure straight work and ease of handling by a smaller tractor. disc scrapers are also adjustable to ensure that the discs remain clean in all conditions.

Figure 5: Disc Plough

Secondary Tillage Implements:

Tine Cultivator

The tine cultivators used in Pakistan have a similar operation to the chisel plough but have different goals. It is used for 'complete' tillage operation and works near the surface and disturbs the soil in a careful manner by producing a staggering pattern. It stirs, pulverizes and aerates the soil before planting and does the weed control after planting. Mostly the farmers use it for preparation of proper seedbed, burying the crop residue and warming the soil.

Figure 6: Tine Cultivator

Disc Harrow

The disc harrow is used in Pakistan for high soil disturbance, proper handling of obstacles, breaking of large clods, harrowing after ploughing, chopping and mixing of crop residues into the soil for seedbed preparation. Disc harrow has a heavier weight per disc and thus has the penetration ability to break down large clods normally left after disc ploughing or chisel ploughing in hard grounds. It has a robust construction and used as mounted or trailed implement. The disc harrow prepares the seedbed leaving the soil in granular form which is the most suitable structure for plant growth. It aerates the soil, helps to conserve moisture for longer periods and eradicates weeds. In sandy loam soils, this implement can also be used as a primary tillage implement. The depth of ploughing is regulated simply by manipulating the offset angles of the gauges. By simply removing a pin, the mounted position can be converted into trailed position and vice versa.

Figure 7: Disc Harrow

Rotary tiller

The rotary tiller (Rotavator) carries out shallow tillage operation. The curved blades slice through the soil and chop surface residue while mixing all material in the disturbed layer. It also pulverizes the soil and buries weeds and crop residue. It suits both wet and dry fields.

Figure 8: Rotary Tiller

Ridger

In Pakistan, potato crop is sown over ridges with 2 or 3 ridges in a single run. The ridgers are used for making ridges for potato planting. The ones used in Pakistan are fully adjustable for giving different accurate row widths. To obtain the correct ridge profile and retain soil flow, the high grade mould boards are adjustable. The ridger can also be used for earthing up the crops sown in rows.

Figure 9: Ridger

Potato Planter Cum Fertilizer Applicator

In Pakistan, potatoes are sown manually or by 2 or 3 rows semi-mechanized planter, followed by fertilizer drill.

Figure 10: Potato Planter Cum Fertilizer Applicator

Some big farmers use cup type potato planters for planting cut or graded seed potatoes and other similar size tubers automatically. It plants the tubers from 6 cm to 13 cm apart in the rows and hills the row all at once. It is available as a one and two row model. Row spacing is adjustable from 26 cm and above. Fertilizer and Insecticide attachments are optional. The automatic potato planter could apply fertilizer while planting.

Hoeing and Intercultural Practices

Normally, a spade is used for intercultural practices. However, tractor mounted hoeing machinery is also used for removal of weeds and undesired plants. But in Pakistan, it is not so efficient for potato crop.

Spray Machinery

In Pakistan, knapsack hand sprayer, knapsack power sprayer, ULV (ultra-low volume) sprayer and tractor mounted boom sprayer are commonly used for spraying in the potato crop. The availability of these machinery depends on the budget of the farmers and type of disease to overcome. Mostly small farmers are using hand sprayer but mass-scale growers are using boom sprayer for the potato crop.

Figure 11: Hand Spray Machine

Figure 12: Boom Sprayer

Harvesting Machinery

In Pakistan, potato diggers are followed by the manual collection by small farmers, whereas mass-scale growers are using a potato harvester which is also followed by a manual collection for harvesting the crop.

The potato digger is mounted with rubber beam wheels with a vibrating mechanism. The potato diggers with coulters are used to dig one row of potatoes or other root crops. The machines can be attached to the centerline of the tractor or offset when straddling two rows and digging one. The standard diggers harvest the produce through dugging the soil and shaking the bulk of the soil through the chain. The type of chian in used according to the soil type and produce size. The hydraulic drive allows better matching of chain speed with digging.

The early spinners were horse drawn and powered by a land drive wheel connected by a gear box to the spinner mechanism. These machines were often adapted to be pulled by a tractor drawbar. Later versions were PTO driven and were mounted on the three-point linkage. The biggest problem is that the potatoes have to be picked up by hand from the field but it is a great improvement from digging with a fork.

Figure 13: Potato Digger

Figure 14: Potato Harvester

Potato Grader

Grading is done both manually and mechanically by the graders of different types and capacities.

Storage

It has been noticed that over the years, the production of potato has increased manifold, which led to a glut situation in the market. The practice of storage helps to stabilize the prices in the market. In Pakistan, storing potatoes for longer periods in normal temperature is not possible as it is an organic material. Through respiration, the changes occur due to heat, and the tubers will deteriorate due to heat and loss of dry matter. At optimum condition, the quality of potatoes remain good in storage for 3-5 weeks. The condition and health of the tuber in storage are important and it can be coupled with good management during storage. The following are the benefits of storage in our country:

- Minimum losses occurred due to tuber rotting disease.
- Appearance preserved by inhibiting the development of surface blemishes.
- Minimum moisture loss and softening.
- Minimum losses during sprouting.
- Damage prevention.
- Potato saved from color loss.

III. The Need Assessment of Potato Production Mechanization in Pakistan

To meet the increasing demand for food and to overcome the problem of labour shortage, it should be mechanized the Whole-process of potato production. It can help the farmer to get a better-quality production. In our country the majority of the farmers have a small land holding, they are using tractors less than 85 hp. The need is to design lightweight machinery which suits the majority of the farmers in Pakistan. The research and development in following areas of potato mechanization are needed in the country.

Seed cutter

Most of the farmers use hand operated tools i.e. knife for cutting the seedlings. This requires labour and ample time which usually results in low quality and wastage of seed. An intelligent seed cutting machine should be introduced and advertised among the farmers' community in Pakistan for better, uniformized and safe cutting of seedling.

Planter

In Pakistan, potato crops are being planted by manually fed tractor-driven planter. It results in an increase in labour cost, non-uniform seed distribution and wastage of time. A fully mechanized potato planter may resolve all these problems. The need of farming community is a light weight and fully automatic planter, which would pick tubers from its hopper and plant them.

Intercultural/ Hoeing Machinery

An intercultural operation is necessary for potato fields to tackle the issue of weeds. In Pakistan, hoeing and intercultural practices are mostly carried out manually by spade and other hand tools. This results in wastage of time and increases labour cost. To overcome these issues, a low horsepower self-propel hoeing machinery is the need of farmers.

Harvester

In Pakistan, farmers are harvesting potato crop with the help of a digger and followed by manual collection. This causes injury on the products, excessive labour costs, wastage of crops and time. This is the major issue which should be overcome for potato mechanization.

A self-propel potato harvester, which would contain a function of digging, cleaning, grading and packing in a single unit, should be introduced. The progressive farmers/growers of potato may find this machine an optimum solution to their problem. Furthermore, the service provider may also use the machine for providing services to the small farmer on a rental basis.

Stone Separator

In Pakistan, some soils in plain areas and the majority of soils in hilly areas contain stones, which damage the potato during harvesting. It is necessary to remove the stones from the field before sowing potato to protect them from injuries during plowing, harvesting and grading operations.

Cleaning and Disinfecting Equipment

Potato equipment and storages are exposed to a number of pests including fungi, bacteria, insects, nematodes, and weed seeds. Many of these pests can spread from tuber to tuber or field to field or in storage and cause problems in future crops if not eliminated or at least minimized.

A seed cutter is a common source of contamination. This occurs because the cutting blades are in use continuously during the cutting process transmitting sap, debris, and the associated pathogens from infected seed tubers to healthy ones. Potato pathogens can survive for a very long time in potato storages. There is a need for equipment which can be moved from field to field or even shared among growers.

Potato Grader

It has been experienced that the static units are not feasible under our existing conditions and there is a need for mobile grading units at the farm level. The end users are reluctant to bring their product to the grading sheds because it entails transportations charges.

The need could be realized to introduce a portable PTO mounted potato grader. The reductions per minute (rpm) of feeder, grader and conveyors are adjustable according to the materials to be sorted out. The marketing system will definitely improve for export and domestic purposes if the grader product is sold in market and grading is introduced through law. Tubers are graded for separate packaging, and superior grade could get high price.

IV. Challenges and Constraints Faced by Whole-process Mechanization of Potato Production in Pakistan

In Pakistan, there are still some constraints which limit potato production, processing and marketing. These include:

Small Size Land Holdings

The farmers have small land holdings i.e. on average 95% famers hold land less than 5 ha. These farmers cannot afford to pay the price of high-tech machinery involved in whole-process mechanization of potato. Usually, these farmers use machinery from the service providers. The service providers can be motivated/trained to enhance the adoption of machinery use.

Small HP Tractors

In Pakistan, 60 percent of the tractor are less than 50 hp. These tractors are not even capable of performing basic potato mechanization operations i.e. digging and planting. The planter and digger are used with the 85 hp tractor, which is the biggest hp tractor available in Pakistan. The advanced whole-process mechanization requires tractors above 100 hp, which are not available in the country.

Tractorization Instead of Mechanization

In Pakistan, most of the farm machinery is operated through the tractors. The self-propelled special machines for different crops are not very popular in Pakistan. The other factor is the high price of self-propelled special machines which hampers the adoption of these machines by small land holding farmers on individual ownership.

Lack of Technical Personnel

Advance machinery requires technical staff for its operation, repair and maintenance. But unfortunately, our farm workforce is unskilled and illiterate. So, it needs time to equip the farm work force with adequate technology for potato mechanization.

Inadequate Supply of Good Quality Seeds

The quality of seeds available in the country affects the yield of the potato tubers. The improved variety of imported seeds are used in a few places.

Inadequate Storage Facilities

The available traditional storage facilities do not allow to store the potato tubers for more than one month. This increases the loss of potato tubers and seeds. Therefore, farmers prefer to sell off their products soon after harvesting.

Diseases and Pests Management

The management of diseases and pests is one of the major problems faced by farmers. It reduces potato yield and may even destroy the crop once the farm is affected.

The High Cost of Production Inputs

The high cost of good quality seeds, labor and farming equipment is a major constraint to the quantity of potato produced. Many farmers cannot afford to buy the equipment which will increase their yield.

Climate Limitations

Potatoes are grown only in temperate areas, restricting the areas where potato can be grown to increase the yield.

Activities of Middlemen

The high handling charges by the middlemen affect the price of the potato and middlemen also controls the market.

Marketing Problems

The poor transportation facilities from rural to urban areas, and the use of traditional baskets, sacks, and trays for the transportation damages potatoes.

Inadequate Funding of Research Work

Lack of funds for the research work on potatoes limits the opportunities of finding solutions to the problems faced by famers.

Inadequate Agricultural Equipment

Lack of agricultural equipment affects the production output, thus, leads to a reduced quantity of goods produced by farmers.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

Among Asia and Pacific countries, there is a gap of generations in farm mechanization. Some countries have fully mechanized approach in potato farming and some are still farming as in past decades. So, it needed to conduct cooperation among Asian and the Pacific countries. We face a serious problem to feed the most densely populated part of the world. The following suggestions may be helpful for regional cooperation among the countries in Asia and the Pacific in whole-process mechanization of potato production.

- In developed countries like Australia and Japan, farmers are using advanced machinery for potato farming and processing in large-scale fields. Similar machines should be developed in small size, which would be compatible with the small-scale farming communities like Pakistan.
- The import and export duty on these potatoes processing machinery must be removed or decreased so that machinery would be available for developing countries like Pakistan.
- There is a need to assess the type and size of the machinery required for every single machine, with regards to the local topographical conditions.
- Various conferences/workshops/seminars to promote the potato

mechanization should be held in different countries across Asia and the Pacific.

- Potato growing community of less mechanized countries should be educated about the production technologies of the whole-process mechanization of potato crop.
- Research cooperation for whole-process mechanization of potato should be established between the countries of Asia and the Pacific.

Sri Lanka
Whole-process Mechanization of Potato Production in Sri Lanka

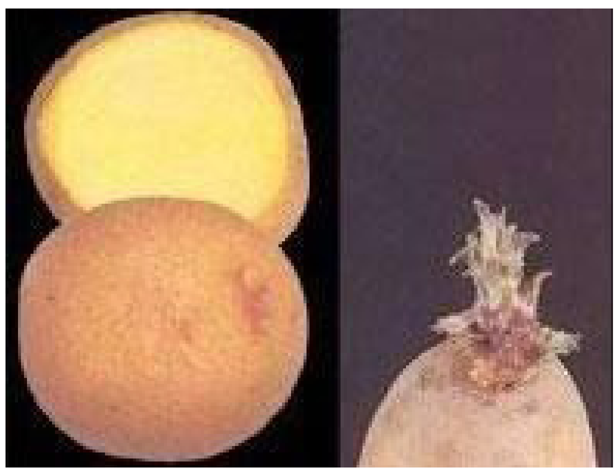
Mr. B.M.W.L. Balasooriya
Mechanical Engineer
Engineering Division
Department of Agriculture

I. Overview of Potato Supply Chain in Sri Lanka

Potato (Solanum tuberosum L.) originated in the Andes highlands in Peru and was introduced to Sri Lanka by the Europeans who settled in hilly areas in 1850's. At present potato is extensively cultivated in the district of Nuwara Eliya (Upcountry wet zone >1000m amsl) in two major seasons, "Yala" (Feb.- Jul.) and "Maha" (Aug.- Dec.) where annual rainfall is >2,500mm and temperature ranges between 10-15°C with the relative humidity of 80%. It is also widely grown in Badulla District (Upcountry intermediate zone- 1,000 to 1,500 m amsl) in paddy fields and high land during "Yala' and "Maha" seasons respectively. This area experiences the rainfall of 1,500 - 2,250 mm annually with 70% RH and 15- 22 °C range in temperature. Puttlam and Jaffna are the other two districts where the potato is grown, though to a lesser extent.

Potato is the most popular crop of upcountry farmers due to its high net return. In Sri Lanka, the Department of Agricultural (DOA) has taken measures to increase the local potato seed production to increase the potato crops.

Most farmers refuse to cultivate potatoes due to the lack of quality seeds in addition to the costs of production. If local seeds are available, it will help them to reduce the cost of production.

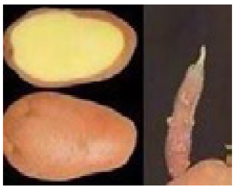


Farmers have to spend a lot of money to purchase imported seed potatoes.

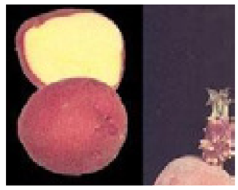
New technologies have been introduced to the farmers by the DOA to produce high-quality seed potatoes. According to the Senses and Statistics Department the total national potato production in 2009/2010 was 51,294 metric tons and the extent was 3,784 hectares. Potato production in 2008/2009 was 60,840 metric tons and the extent was 4,017 cultivated hectares. The Ministry of Agricultural has taken measures to encourage farmers to cultivate potatoes with the support of private sector institutions.

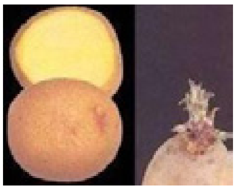
Recommended Varieties


Hillstar

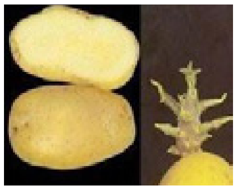

Desiree


Sante


Raja


Granola


Kondor


Isna

1. Potato-Recommended Varieties in Sri Lanka

1.	Name of the Variety:	Sita
2.	Scientists Involved:	Dr. Yogarathnum and Mrs. Velupillai
3.	Year of release:	1981
4.	Age of Optimum Harvesting time:	Late - 100- 110 days
5.	Pedigree:	Advanced generation line from (I-1085, India) CIP
6.	Pests and Disease Resistance:	Tolerance to late blight
7.	Crop Description:	
	a) Plant:	Anthocyanin discoloration is absent, green color leaves with many secondary leaflets Leaflets are very small and rough
	b) Flower:	White
	c) Tuber:	Short oval shape, yellow skin, white flesh, shallow eyes
	d) Sprout:	Green sprouts with weak pubescence
	e) Potential Yield:	20 - 25 t/ha

1.	Name of the Variety:	Krushi
2.	Scientists Involved:	Dr. Yogarathnum and Mrs. Velupillai
3.	Year of release:	1981
4.	Age of optimum Harvesting time:	Late - 100 - 110 days
5.	Pedigree:	Advanced generation line from (I-822, India) CIP
6.	Pests and Disease Resistance:	Tolerance to late blight
7.	Crop Description:	
	a) Plant:	Anthocyanin discoloration absent at the top of the stem and present at the stem base, dark green leaves with medium number of secondary leaflets
	b) Flower	White
	c) Tuber:	Round oval shape, yellow skin, white yellow flesh, medium depth eyes
	d) Sprout:	Color of the base red violet, tip light red violet, weak pubescence at the base and medium at the tip
	e) Potential Yield:	20 t/ha

1.	Name of the Variety:	Lukshmi
2.	Scientists Involved:	Mr. Abethunge and Mrs.S. Abethunge
3.	Year of Release:	1992
4.	Age of Optimum Harvesting time:	Late (110 days)
5.	Pedigree:	SE-11 x 260/39B
6.	Pests and Disease Resistance:	Moderately resistance to late blight
7.	Crop Description:	
	a) Plant:	Long stems
	b) Flower	White pink
	c) Tuber:	Round to oval shape, white skin with shallow eyes
	d) Sprout:	
	e) Potential Yield:	20 -25

1	Name of the Variety:	Manike
2	Scientists Involved:	Mr. Abethunge and Mrs.Abethunge
3	Year of release:	1992
4	Age of Optimum Harvesting time:	Late (110 days)
5	Pedigree:	Atzimba x 260/39B
6	Pests and Disease Resistance:	Moderately resistance to late blight
7	Crop Description:	
	a) Plant:	Long stems
	b) Flower:	White pink
	c) Tuber:	Round to oval shape, white skin with shallow eyes
	d) Sprout:	
	e) Potential Yield:	20 -25 t/h

2. Potato-commercial varieties

1.	Name of the Variety:	Desiree
2.	Scientists Involved:	-
3.	Year of Release:	-
4.	Age of Optimum Harvesting Time:	Moderately early to moderately late
5.	Pedigree:	Urgenta x Desesche
6.	Pests and Disease Resistance:	Good resistance to tuber blight
7.	Crop Description:	
	a) Plant:	Tall to medium, semi-erect stems, pronounce anthocyanin discoloration, dark green leaves
		Red-violet flowers
	b) Flower:	
	c) Tuber:	Long -oval shape, red smooth skin, pale yellow flesh, shallow eyes
	d) Sprout:	Large, broad cylindrical, intense to moderately intense red-violet and medium pubescence, many root tips, moderate to weak anthocyanin discoloration
	e) Potential Yield:	15-20mt/h

1.	Name of the Variety:	Granola
2.	Scientists Involved:	-
3.	Age of Optimum Harvesting time:	Medium late
4.	Pedigree:	3,333/60 x 267.04
5.	Pests and Disease Resistance:	Fairly good resistance to leaf blight moderate resistance to viruses A and Yn, resistance to pathotype A of the golden nematode
6.	Crop Description:	
	a) Plant:	Medium-length to tall, stems fairly thick, fairly spreading, pale purple; Leaves large, palish green, primary leaflets fairly large and narrow with fairly shallow veins
	b) Flower:	Darkish red - purple flowers
	c) Tuber:	Short - oval, yellow, fairly rough skin, yellow flesh, fairly deep eyes
	d) Sprout:	Fairly small, egg- shaped, red-purple, sparsely hairy, fairly large, open, deepish red- purple terminal buds; fairly small number of root tips
	e) Potential Yield:	20 -25 t/ha

1.	Name of the Variety:	Kondor
2.	Scientists Involved:	-
3.	Age of Optimum Harvesting time:	Moderately early to moderately late
4.	Pedigree:	KO61-333 x Wilja
5.	Pests and Disease Resistance:	Moderately good resistance to leaf blight, rather good resistance to tuber blight, rather good resistance to virus X and resistance to virus A
6.	Crop Description:	
	a) Plant:	Medium to short; stems semi erect to erect, pronounced to moderate anthocyanin discoloration, large to medium, dark green leaves
	b) Flower:	Red-violet flowers
	c) Tuber:	Very large, oval, red skin, moderately deep eyes, pale yellow flesh
	d) Sprout:	Large to medium, broad cylindrical, intense red-violet and strong pubescence, medium terminal bud with moderate to weak anthocyanin discoloration, few root tips
	e) Potential:	Yield 20 - 25 t/ha

1.	Name of the Variety:	Isna
2.	Scientists Involved:	-
3.	Age of Optimum Harvesting Time:	Moderately late
4.	Pedigree:	35/53/4718 x M.P.I. 44.335/128
5.	Pests and Disease Resistance:	
6.	Crop Description:	
	a) Plant:	No anthosyanin discoloration, large to medium, green leaves
	b) Flower:	White colour
	c) Tuber:	Short oval; yellow skin, yellow flesh, rather shallow eyes
	d) Sprout:	Purplish green base with green tip, weak pubescence at the base and medium at the tip
	e) Potential Yield:	20t/ha

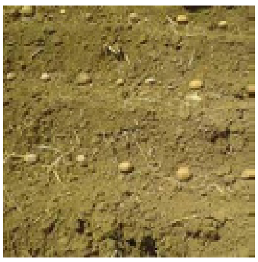
Agro Climatic Requirements

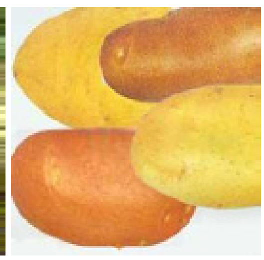
Potato can be successfully grown in upcountry, wet, intermediate, and dry zones at temperatures between 24 °C and 32 °C as well as in Puttalum and Jaffna districts during Maha. The optimum day temperature is 20 °C - 25 °C and a temperature difference between day and night should be 10 °C.

Time of Planting

Season	Location	Planting date
Maha	Nuwara Eliya Badulla (highlands) Jaffna, Puttlum Kalpitiya	Aug - Sept, Nov - Dec mid Nov - mid Dec, mid Oct - mid Dec
Yala	Nuwara Eliya Badulla	Feb - Mar, Jul - Aug

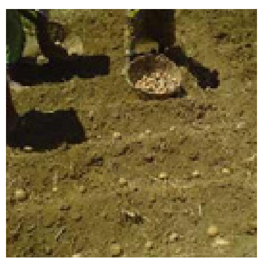
II. Status of Mechanization in Potato Production in Sri Lanka



As farmers are not economically capable of purchasing expensive imported machinery, almost no machinery is applied, and the Whole-process is done manually. The farmers are in need of small scale, less expensive machines, and have no need for large scale and expensive ones.






Government Farms are partially mechanized. No sufficient research has been carried out in this sector up to now, but recently the focus of attention has relocated towards this sector.

III. The Need Assessment of Potato Production Mechanization in Sri Lanka

1. Situation of Farm Mechanization in Sri Lanka

Land preparation	Planting	Threshing	Harvesting	Overall	Machinery produce	Level of mechanization
low	low	low	low	low	near nil	low

Sri Lanka has a written history of more than 2500 years, and it has been an agricultural-based economy since the beginning of its civilization. Hand tools and animal draught implements were used for the cultivation of the staple crop rice, since then the agriculture moved gradually to mechanization. Similarly, nowadays the reasons for moving toward mechanization include the need to meet the increased demand for food and the need to find an alternative to the labor-intensive work, because the cost of labor is continuously increasing. As labor migrates away from agriculture, the productivity of those who remain on the land needs to increase significantly. The percentage share of labor employed in agriculture decreased from 47% of total employment in 1990 to 36% in 1999. This shortfall can only be filled by mechanization. The world agricultural scenario indicates that food security is the paramount concern of every nation.

All of the technological advances in both developed and developing countries must gear towards increasing food production. Both the large-scale, specialized commercial agriculture and small-scale mixed semi-subsistence types of agriculture play vital roles to attain this objective. However, the average operational farm size in Sri Lanka is 1.0 hectare whereas in Asia it is ranging from 1 ha to 3 ha.

2. Status of Custom Hiring in Sri Lanka

There are several kinds of custom hiring systems being operated in the country. The most common type of machines involved in custom hiring are four-wheel tractors, combine thresher and combine harvester. The size and type of machines are different from region to region depending on the plot size, land holding capacity and the propaganda of the machinery suppliers. Table 1 provides an overview of the most commonly used machines in custom hiring and their average hiring rate per hour.

Table 1: Average Hiring Rate

Operation	Hiring rate ($)
Ploughing	120-140/ha
Reaping	95 – 115 / ha
Threshing	25 – 30 / ha
Combine harvesting	235 / ha

3. Supporting Policies

Most of the agricultural machines imported into the country are 100% free of import duty. This policy has been introduced to minimize the price of farm machinery and also to encourage farm mechanization activities in the country. Moreover, the government and the private banks operate soft loan schemes for machinery purchase. Custom hiring providers can enjoy these facilitations. Nonetheless, at the present, specific subsidiary packages or any other type of special assistance for custom hiring are not provided.

4. Social and Economic Benefits

Proper usage of agricultural machinery via custom hiring could benefit the farmers and the country as a whole in the following ways:

- The agriculture will become an attractive livelihood for younger generations;
- Cost of production will go down and profit margin will increase;
- Ability to maintain the quality of agricultural output;
- Crop yield and farmer income will be increased due to the increasing cropping intensity and reduced losses;
- Water-use efficiency will increase by farming in time;
- Healthy and happy farming communities will be established and maintained.

5. Challenges and Constraints

Custom hiring practices are not properly regulated, so that farmers rarely enjoy the benefits of new technology. The present system of custom hiring does not reach the objective of mechanization. Moreover, several machinery owners are reluctant to rent out their equipment, because of social problems caused by the use of the machines. There are many problems that can be observed in custom hiring system, both for farmers as well as for the machinery owners, specifically:

- The limited availability of hiring machines at close proximity to the farmers, united with insufficient number of the machines to meet the demand;
- High and inconstant hiring charges, united with financial hardships during the peak periods;
- Only high profit margin machines are available;
- Accepted quality level of work is not guaranteed (for example, in combine harvester operations rate of grain loss is as high as 20% - 30%).

6. Solutions and Suggestions

At the present, individuals carry out the hiring of farm machinery and this service is not so effective and is not properly organized. Therefore, government intervention is essential to provide sustainable, efficient and reasonable hiring facilities. A few decades ago, the government-controlled tractor-hiring units that were not sustained. After introducing tractors to the farmers, the units were terminated due to inefficient management and, especially, poor maintenance of the machines. Thus, it is suggested to establish government supported private machinery hiring units. The units can rent directly to farmers or to farmer's organizations. The machines made available by these units should match the capacity of the respective area. The machines kept at each hiring center should be selected based on the needs of the center's respective areas. The machines of hiring centers shall be operated by the operators rather than the farmers. Lastly, the government should regulate hiring rates and modes of charging according to the regulatory system included in the proposed farm machinery act.

IV. Challenges and Constraints Faced for Whole-process Mechanization of Potato Production in Sri Lanka

1. Technical Factors:

Potato's Biological Characteristics

Many constraints derive from the biological characteristics of the potato. These include the low multiplication rates of seed tubers and the technical difficulties and costs associated with maintaining seed quality through successive multiplications, owing to the potato's susceptibility to soil and seed-borne insect pests and diseases. Seed tubers are also bulky: two to three tonnes per hectare is the typical seed requirement. Stringent phytosanitary restrictions limit the movement of potato germplasm, seed tubers and fresh ware potatoes. Potatoes have high fertilizer requirements, but low utilization efficiency. Post-harvest, fresh potato tubers deteriorate quickly in tropical and subtropical environments, especially in the lowlands.

Lack of Efficient Seed Systems

Sri Lanka lacks efficient systems for the regular multiplication and distribution of certified seed tubers and the rapid deployment of new, improved varieties. Causal factors include the limited technical capacity of human resources, lack of managerial expertise and inadequate resource allocations to seed potato subsector in general. As a result, farmer-based seed systems are still common, and have managed to supply planting material over the years and contributed to expanding cultivation of the crop. Farmer seed systems face many challenges, but also offer an opportunity to improve seed supply of farmers with suitable trainings and guidance.

Diseases and Insect Pests

Diseases and insect pests are another major constraints. New strains of late blight have reached Sri Lanka and continue to spread. Late blight constitutes the most serious threat to the increasing potato production. Bacterial wilt is the second constraint, particularly in warmer and tropical regions. The impact of insect pests varies between regions. Major insect pests include aphids, tuber moths, leaf miners, Colorado potato beetle and Andean potato weevil.

2. Socio-economic Factors

High Production Costs and Lack of Credit

Compared to other food crops, production of potatoes is capital-intensive, requiring the purchase of large quantities of bulky seed and the application of high-cost inputs such as fertilizers and pesticides. With limited access to credit and few means of mitigating the risks of taking the loans, small-scale farmers find it difficult to practivce potato production.

Price Instability

With potato increasingly becoming a cash crop, small-scale potato growers are vulnerable to abrupt changes in input and output prices. Seasonal and year-to-year price movements can affect individual small growers who lack the financial resources and resilience of larger producers and cooperatives.

Inefficiency of Local Markets

Potato prices are usually determined by supply and demand, not as fluctuant as the prices of cereals in the internatinal markets. It is, therefore, a crop that can help low-income farmers and consumers to ride out episodes of food price inflation, such as the inflation experienced worldwide in 2007-08. However, the profitability of potato depends on efficient local markets and measures to control overproduction.

Limited Access to Higher Value Markets

To be successful, small-scale potato growers need access to profitable emerging domestic markets – such as the rapidly growing processing segment – as well as to potato export markets. However, access to domestic markets is often restricted by the marketing power of foreign suppliers, while export is constrained by trade barriers for processed products from the developing world in the developed countries. However, there are encouraging “success stories” that illustrate how small-scale producers can increase production and expand their market share. Recent legislation in the USA and Europe provide greater access to agricultural products from the developing world.

3. Policy and Institutional Factors

Neglect of the Potato Subsector

Little or no public investment is targeted at the integrated strategies for crop improvement, value addition, and marketing schemes or the potato production-processing-marketing chain. Sri Lanka lacks adequate potato seed production systems backed by certification and seed laws. Breeding rights are often not respected, reducing incentives for breeders to create new adapted and resistant varieties. In many areas, poor infrastructural facilities and poor access to markets are also the major challenges for the expansion of potato production and its profitability.

Inadequate Capacity Building Initiatives

The potato has not attracted private sector investment in the crucial area of seed multiplication and seed systems in Sri Lanka. Support for programmes diffusion of new varieties and for the scaling up of the existing integrated disease and insect pest management technologies and methodologies is generally inadequate. Programmes to upgrade the skills of potato growers need to be improved by government efforts to create, monitor and enforce regulations on pesticide use fertilizer residues into water supplies, which are the major constraints to the sustainability of potato production systems.

Lack of Support to Farmer Organizations and Entrepreneurs

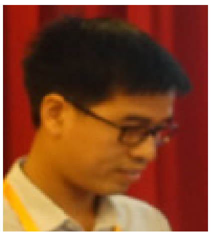
Support for potato farmer groups and associations and for local entrepreneurship is lacking in Sri Lanka. Efforts are being made by the public and the private sectors to improve seed quality, to promote variety development, and to transfer technology for integrated crop management to its contract growers.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

Although there was rapid economic development in Asia-Pacific countries in recent years, the purchasing power of farmers in this region remains low. Therefore, farmers in the developing and the least developed countries in the region cannot afford expensive agricultural machinery. At the same time, there are varying levels of agricultural machinery industries and use of their production across the region. China and India have emerged as centers for gigantic agricultural machinery manufacturers of the region. China has become a major producer of agricultural machinery along with its rapid development of agriculture. There are about 8,000 agricultural machinery manufacturers in China. Among them, 1,578 are large enterprises, including main machines manufactures as well as the spare parts producers. In India, the number of agricultural machinery manufacturers is more than 16,000. However, in some Asian countries, there is almost no agricultural machinery industry, such as Bangladesh, Cambodia, Laos, Nepal and Sri Lanka.

Vietnam
Whole-process Mechanization of Potato Production in Vietnam

Mr. Le Quyet Tien
Vice Director
Department of Agricultural Machinery
Vietnam Institute of Agricultural Engineering and Post-Harvest Technology (VIAEP)



I. Overview of Potato Supply Chain in Vietnam

A few years ago, the potato plants in Vietnam were grown mainly in winter on small and scattered lands with a lack of scientific and mechanized applications for its cultivation, which did not create a stable production.

In order to enhance the value of arable lands and to help create high-quality products to meet the needs of consumers, programs oriented on efficiency and sustainability of agricultural production and acceleration in the application of technological advances in production are gradually implemented.

In the Red River Delta, provinces of Hai Phong, Thanh Hoa, etc. have cultivated Marabel potato imported from Germany through a pilot project. The model of agricultural production has been implemented through "four pillars", including manufacturers, managers, scientists and entrepreneurs. In this model, joint-stock companies supply seeds, fertilizers of all kinds and plant protection products for farmers. Managers provide information to the farmers and create links.

II. Status of Mechanization in Potato Production in Vietnam

1. Soil Tillage and Planting Beds

This stage in Vietnam has been mechanized. Potato is a crop that can be grown on different soils without weeds and with careful plow. Ridegs are made as 20-25 cm high, 1.2 m long (including beds list) and 90 cm wide with a double rows of potato.

2. Seeds

Potato is stored in cold storage rooms at a number of local institutes and seed companies. The potato seeds imported from Europe as well as from China are mainly suitable for the winter season.

3. Sowing

There are 2 seasons for planting potato: winter season, from 15 October to 15 November; and Spring season from 15 November to 15 December. The planting seasons give the highest yield and do not affect the next crop that will be planted. Sowing is completely done by hands.

4. Harvesting

Potatoes can be harvested by machines manufactured by Vietnamese research institutes or imported from Thailand and China.

III. The Need Assessment of Potato Production Mechanization in Vietnam

The following are technology and research techniques applied in Vietnam:

- Single or twin beds;
- Raised planting beds; fertilization and weeds control;
- Prevention of excessive moisture of the soil;
- Mechanized tillage.

IV. Challenges and Constraints Faced by Whole-process Mechanization of Potato Production in Vietnam

In recent years, crop production has been influenced by climate change, unpredictable weather, and natural disasters leading to an increase of the production cost and benefit losses.

Another challenge is a shortage of labor. Farmers are seeking an employment at factories and in business sectors which would bring higher income.

One of the strongest constraints is fragmented arable lands (less than 400m²/person) that makes hard to apply mechinary that causes low quality and low quantity of the outputs and weak competition in the market.

V. Suggestions for Regional Cooperation for Whole-process Mechanization of Potato Production in Asia and the Pacific

- Strengthening the coordination and exchange of technology and equipment of research institutions specialized in mechanized potato production in Asia and Pacific;
- Funding research programs and promoting knowledge of mechanized potato production in Asia and Pacific;
- Creating cooperation and association to build large-scale manufacture of goods, providing a basis for the implementation of mechanization, transfer scientific and technological advances in agricultural sector.

ANNEX 1:
Programme of the Asian and Pacific Workshop on Whole-process Mechanization of Potato Production

27-28 June 2016

Yun'an Conference Hotel, Kunming, China

Asian and Pacific Workshop on Whole-process Mechanization of Potato Production	
Opening and Plenary Session	
PM - 27 June/Monday – Meeting Room No. 7, 2nd Floor, Yun'an Huitang	
13:30-14:00	**Opening Session** Moderator: Ms. Yu Kongyan, Deputy Director, Agricultural Trade Promotion Centre, Ministry of Agriculture of China Opening remarks: - Ms. Katinka Weinberger, Officer-in-Charge, Centre for Sustainable Agricultural Mechanization, ESCAP Welcoming remarks: - Mr. Li Anning, Deputy Director General, National Agro-mechanization Technical Extension Station, Ministry of Agriculture of China; Agricultural Mechanization Chapter, China Society for Agricultural Machinery - Ms. Yu Kongyan, Deputy Director, Agricultural Trade Promotion Centre, Ministry of Agriculture of China Keynote address: - Mr. Lu Xiaoping, Regional Director, Asia-Pacific Centre of the International Potato Centre
	Plenary Session Moderator: Mr. Liu Zhuo, Vice Secretary General, Agricultural Mechanization Chapter, Chinese Society for Agricultural Machinery
14:10-14:30	Accelerating the Development of China's Whole-process Potato Mechanization - Mr. Li Anning, Deputy Director General, National Agro-mechanization Technical Extension Station, Ministry of Agriculture of China; Agricultural Mechanization Chapter, China Society for Agricultural Machinery
14:30-14:50	The Whole-process Mechanization of Potato Production in India - Mr. Champat Raj Mehta, Project Coordinator, AICRP on Farm Implements and Machinery, Central Institute of Agricultural Engineering, Indian Council of Agricultural Research (ICAR)
14:50-15:10	The Whole-process Mechanization of Potato Production in Malaysia - Mr. Md Akhir bin Hamid, Researcher, Center of Engineering Research, Malaysian Agricultural Research and Development Institute
15:10--15:40	**Break**
15:40-16:10	Introduction of Potato Machinery Production in Yunnan Province - Mr. Ke Bin, Division Chief, Agricultural Mechanization Division, Department of Agriculture of Yunnan Province
16:10-16:40	The Whole-process Mechanization of Potato Production in the Philippines - Mr. Alexis Del Rosario, Engineer III, College of Engineering and Agro-industrial Technology (CEAT), University of the Philippines Los Baños (UPLB)

16:40-17:10	The Whole-process Mechanization of Potato Production in Thailand - Mr. Anuchit Chamsing, Senior Agricultural Engineering Specialist, Postharvest Engineering Research Group, Agricultural Engineering Research Institute, Department of Agriculture
17:10-17:30	Wrap up and Closure
18:00--19:30	Welcome Dinner
Country Presentations and Panel Discussion	
AM - 28 June/Tuesday – Meeting Room No. 6, 2nd Floor, Yun'an Huitang	
	Country Presentations Moderator: Ms. Yuee Feng, Programme Coordinator, Centre for Sustainable Agricultural Mechanization, ESCAP
09:00-09:15	Bangladesh - Mr. Md. Israil Hossain, Chief Scientific Officer & Head, Farm Machinery & Postharvest process Engineering Division, Bangladesh Agricultural Research Institute (BARI)
09:15-09:30	Cambodia - Mr. Sar Santy, Technical officer, Department of Agricultural Engineering, Ministry of Agriculture, Forestry and Fisheries
09:30-09:50	China - Mr. Song Jiannong, Professor, College of Engineering, China Agricultural University
09:50-10:05	Indonesia - Mr. Teguh Wikan Widodo, Research Engineer, Indonesian Center for Agricultural Engineering Research and Development, Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture
10:05-10:20	Myanmar - Mr. Myo Khaing, Staff Officer, Agricultural Mechanization Department, Ministry of Agriculture, Livestock and Irrigation
10:20-10:35	**Tea Break**
10:35-10:50	Nepal - Mr. Madhusudan Singh Basnyat, Officiating Program Director, Directorate of Agricultural Engineering, Department of Agriculture, Ministry of Agriculture Development
10:50-11:05	Pakistan - Mr. Muzammil Husain, Scientific Officer, Pakistan Agricultural Research Council
11:05-11:20	Sri Lanka - Mr. B.M.W.L. Balasooriya, Mechanical Engineer, Engineering Division, Department of Agriculture

11:20-11:35	Viet Nam - Mr. Le Quyet Tien, Vice Director, Department of Agricultural Machinery, Vietnam Institute of Agricultural Engineering and Post-harvest Technology (VIAEP)
11:35-12:45	Panel Discussion on potential cooperation mechanisms and actions among potato mechanization researchers and agencies Moderator: - Mr. Shang Shuqi, Dean and Professor of Electronic and Machinery College, Qingdao Agricultural University - Mr. Kanchan Kumar Singh, Assistant Director General (Engineering), Indian Council of Agricultural Research
12:45-13:00	Wrap up and Closure
13:00-14:00	Lunch Break
14:30–18:00	Field Visit - Yunnan Xiangjian Agricultural Equipment Co. Ltd. - Yunnan Power Co. Ltd.

ANNEX 2: Participants List

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