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Mechanization of Rice Production in Anuradhapura District of Sri Lanka: Current Status and Future Potential

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Abstract

Background: Increase in productivity of agriculture has become an essential feature in stepping towards sustainability. The younger generation avoids the cultivation, leading the labour shortage to become a significant challenge. To motivate young people into agriculture, mechanization plays a vital role. Therefore, this study was conducted to identify the degree of mechanization of rice cultivation activities in the Anuradhapura district and to assess the future mechanization potential.

Methods: Primary data were collected through a comprehensive questionnaire and personal interviews. Farmers were randomly selected from the Divisional Secretariats in the Anuradhapura district based on the stratified random sampling method. Data were collected through pre-tested questionnaires from 220 rice farmers.

Results: Mechanization level was 100% in land preparation and threshing in rice cultivation. Meanwhile, highest mechanization requirement in rice cultivation was identified for bund making (100%), transplanting and weeding (97%), power chemical application (92%), and power spraying and weeding (92%). The highest mechanization capacity was reported in irrigation scheme based rice fields, while the lowest was reported under rain-fed rice cultivation.

Conclusions: Bund making, transplanting, weeding, power chemical application activities have the potential to be mechanized in Anuradhapura district, Sri Lanka. Rice transplanting approaches need to be popularized to increase the mechanical weeding, reduce weedicide application and increase mechanization.

Keywords: Anuradhapura District, Farm Machinery, Mechanization, Rice Cultivation

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INTRODUCTION

Sri Lanka has been an agricultural-based country for centuries. However, the agricultural sector was the least contributing subdivision to the Sri Lankan economy, with a 7.5% contribution as of 2017 [1]. Around 40% of the arable land in Sri Lanka is devoted to rice cultivation, alongwith around 26% of the labour force involved in the agriculture sector [2]. The country's agriculture mainly depends on rice production, which was responsible for 30% of employment in the country in 2005, down from 37% in 1995. The UNDP/FAO rain-fed rice research and development project, which was in operation from 1984 to 1989, proposed a new classification of rice-growing environments, which is based on the surface water source, supply, and use. According to the classification, three major categories were introduced as: rice land under major irrigation schemes; rice land under minor irrigation schemes, and rain-fed lands [3].

The history of agriculture contains many examples of using tools, but only in recent times that the highest rate of machine use has been reported. Agricultural mechanization is the application of agricultural machinery in land preparation, transplanting, irrigation, chemical application, fertilizer application, harvesting, and threshing to produce crops. Decreasing manual labour requirements is an important aspect of farm mechanization. Less labour is needed to complete the cultivation process of a mechanized farm, compared to a traditional farm. Mechanization in agricultural operations can increase the income of farmers and promote the economic interests of agriculture. Additionally, greater accuracy and higher productivity in ploughing and preparation of rice surface can lead to greater efficiency in mechanical transplanting. Further, the use of certain implements has eliminated the production procedures, which shortened the labour demand period [4].

Rice cultivation includes multiple interdependent activities to complete in a timely and efficient manner. They are land preparation, sowing or planting, harvesting, fertigation and chemigation. Land preparation includes bund preparation, primary tillage or plowing to cut, break, and invert the soil partially or completely, harrowing, or secondary tillage to cut the weed, break the soil clods, mix them, and leveling.

Bunds help to keep the irrigated water in the field and supports irrigation management. Primary tillage destroys weeds, insects, and pests, while aerating the soil [5]. Furthermore, it increases the seedbed depth, increases the water holding capacity, and improves soil health [6]. Secondary tillage further destroys immerging weeds and helps to level the seedbed. Leveling allows for the efficient application of water to conserve irrigated water, while improving surface drainage, reducing soil erosion, allowing efficient weed management, and improving crop stand and crop establishment [7].

In rice transplanting, rice is grown in the nursery, pulled, and transported to the leveled field to establish. This practice provides a higher yield, while easing the weeding. Timely fertilizer application helps to manage weeds, improve yield, and reduce fertilizer costs [5-6]. Chemigation controls weed, pests, and increase yield. Harvesting is the process of collecting mature rice grain from the crop. Harvesting activities include reaping, stacking, handling, threshing, cleaning, and hauling. Reaping is the process of cutting rice straw with a mature pinnacle above the ground. Threshing is the process of separating rice grain from the crop. Cleaning involves separating useful rice with unwanted substances including immature grain, stone, and straw [7].

Understanding the status of mechanization level in Sri Lankan rice cultivation is essential to introduce improved and efficient mechanized solutions. Mechanization is essential to face the skilled agricultural labor shortage, while establishing food security in the country. Therefore, this survey was planned to understand the status of mechanized rice cultivation in Sri Lanka. The general objective of this study was to identify the degree of mechanization of rice cultivation activities in the Anuradhapura district, with an emphasis on the level of mechanization, mechanization capacity, power per unit area, while evaluating the future mechanization potential.

METHODOLOGY

Location

This study was carried out in Anuradhapura District from June to September in 2018. Anuradhapura is one of the major rice cultivation districts and reported the highest rice production (365,988 MT) during the 2015/2016 *Maha* season, accounting for about 13% of the rice production of the country [8].

Sampling and Data Collection

The stratified random sampling approach was used in sample collection. Data were collected through a pre-tested questionnaire from 220 rice cultivation farmers from randomly selected Gramaniladhari divisions of 22 Divisional Secretariats of Anuradhapura district. The structured questionnaire was pre-tested using 15 rice farmers. In the survey, nine rice cultivation steps were focused as: Land preparation (LP), Bund Making (BM), Seedbed preparation (SB), Transplanting (TP), Weeding (WD), Power Weedicide Application (PWA), Power Pesticide Application (PPA), Harvesting (H) and Threshing (T).

Data Analysis

Mechanization Level

The following index (Equation 1) was used to determine the ratio of mechanized operations at different agricultural stages, separately [5].

$$ML = \frac{AM}{AC} * 100 \qquad (1)$$

Where,

ML : Mechanization Level (%)
AM : Mechanized Cultivated Area (ha)
AC : Total Cultivated Area (ha)

Power per Unit Area

This Index (Equation 2) shows the average power available per unit of cultivated agricultural land. The unit used to describe this index is horsepower per hectare ($hpha^{-1}$) [9].

$$PPA = \frac{PA}{AC} \qquad (2)$$

Where,

PPA : Power per Unit Area (hpha-1)
PA : Total Machinery Power (hp)
AC : Total Cultivated Area (ha)

Labour Capacity

Operations carried out exclusively by human power were determined by using the Equation 3 [9].

$$LC = 0.1\ H\ \frac{TH}{AC} \qquad (3)$$

Where,

LC : Labour Capacity ($kWh\ ha^{-1}$)
0.1 : Human Power in (kW)
H : Number of Operators
T :Time devoted to Manual Operations (hours)
AC : Total Cultivated Area (ha)

Mechanization Capacity

The mechanization capacity that corresponds to the use of machinery with mechanical energy sources under direct human control, was evaluated using the Equation 4 [9].

$$MC = RP\ \frac{TM}{AC} \qquad (4)$$

Where,

MC : Mechanization Capacity ($kWh\ ha^{-1}$)
RP : Rated Power of Machines (kW)
TM : Time Used (hours)
AC : Area of Land (ha)

Mechanization Index

Mechanization Index (Equation 5) is the ratio of mechanical energy used by rice machines over the total farm operational energy including human labour and mechanical energy [10].

$$MI = \frac{MC}{(MC + LC)} \qquad (5)$$

Where,

MI : Mechanization Index (kWhha-1)
MC : Mechanization Capacity (kWh ha^{-1})
LC : Labour Capacity (kWhha^{-1})

Mechanization Requirement

This index was calculated using the simple mathematical relation, as shown in Equation 6 for each agronomical operation [9].

$$MR = 100 - ML \qquad (6)$$

Where

MR : Mechanization Requirement (%)
ML : Mechanization Level (%)

RESULTS AND DISCUSSION

The important indicators for power per unit area and mechanization level were computed to determine the level of mechanization of rice fields in the Anuradhapura district. The mechanization level of land preparation in all Divisional Secretariats of Anuradhapura district was 100% (Table 1).

Farming operations generally include energy-intensive and control-dependent operations. The importance of timely land preparation and cost-intensiveness of manual land preparation have led to the popularization of mechanical land preparation in the entire district. However, any type of mechanical process was not used in the preparation of bunds (Table 1). As no other alternative method has been developed to fulfill bund preparation, new machinery is required to be designed, developed and evaluated to mechanize the bund preparation in rice land preparation [8]. The average mechanical seedbed preparation in the Anuradhapura district was 30% (Table 1). People who owned tractors denoted a higher tendency of seedbed preparation.

Fully mechanical transplanting is very efficient in large plots than in small plots, because maneuvering the machine over bunds or in irregular shaped plots is difficult compared to larger plots. The average level of mechanization for rice transplanting was 3% in the Anuradhapura district. Among surveyed Divisional Secretariats, only farmers in Rajanganaya had adopted mechanical transplanting at a notable level of 56%. The small size of the rice fields, high cost of rice transplanting associated with machine renting and fuel, technical issues associated with their operating, unskilled labor, lack of efficient transplanting experience, and problems in the preparation of seedlings were identified as the major barriers for mechanized rice transplanting.

There are three weeding methods available in rice cultivation as chemical weeding, manual weeding, and mechanical weeding. Manual and mechanical weeding reduce the chemical cost and is environmentally friendly. However, manual and mechanical weeding is possible only in row-planted rice fields. Therefore, mechanical weeding was reported by only the farmers, who had followed rice transplanting. However, mechanical weeding is not possible within the crop rows and is limited to plants with 2-4 leaves. However, mechanical weeding is less labor-intensive than manual weeding, but difficult to be practiced in hardened soil or less water available soil.

The average mechanization level for rice weeding in the Anuradhapura district was also very low (3%). This concluded that mechanized rice weeding technically depends on the mechanization of transplanting. Therefore, transplanting should be mechanized before mechanizing the rice weeding operations. Table 1 shows the mechanized weeding and mechanized transplanting levels among the farmers in the Rajanganaya Divisional Secretariat as 56% and 56%, respectively.

The average power sprayer usage level in the Anuradhapura district was 9% (Table 1). These Divisional Secretariats are fed under major irrigation systems and the

Table 1: Mechanization Level (%) of Various Farming Operations in Rice Fields of Anuradhapura District

Divisional Secretariat	Mechanization Level (%)								
	Land Preparation	Bund Making	Seedbed Preparation	Transplanting	Weeding	Weedicide Application (Power Sprayer)	Pesticide Application (power Sprayer)	Harvesting	Threshing
Epologama	100	0	23	0	0	0	0	100	100
Galenbidunuwewa	100	0	25	0	0	0	0	100	100
Galnewa	100	0	33	0	0	23	23	100	100
Horowpathna	100	0	30	0	0	0	0	96	100
Kebithigollewa	100	0	19	0	0	0	0	100	100
Kahatagasdigiliya	100	0	27	0	0	0	0	73	100
Kekirawa	100	0	32	0	0	0	0	100	100
Medawacchiya	100	0	42	0	0	0	0	89	100
Mahavilacchiya	100	0	53	0	0	0	0	95	100
Mihinthale	100	0	0	0	0	34	34	97	100
Nacchaduwa	100	0	17	0	0	0	0	100	100
Nocchiyagama	100	0	29	0	0	24	24	100	100
Nuwaragampalatha East	100	0	21	0	0	21	21	100	100
Padaviya	100	0	42	0	0	16	16	100	100
Palagala	100	0	39	0	0	0	0	100	100
Palugaswewa	100	0	35	0	0	0	0	94	100
Rabewa	100	0	29	0	0	0	0	100	100
Rajanganya	100	0	44	56	56	23	23	100	100
Nuwaragampalatha Central	100	0	26	0	0	16	16	100	100
Thalawa	100	0	21	0	0	7	7	100	100
Thirappane	100	0	38	0	0	0	0	100	100
Thabuththegama	100	0	30	0	0	21	21	100	100
Average ML	100	0	30	3	3	8	8	97	100
Average MR	0	100	70	97	97	92	92	3	0

average land size of above Divisional Secretariats are higher than that of others. Most farmers were using manual knapsack sprayers for chemical application. The high price of power sprayers also demotivates the development of mechanization options for power sprayers. The average mechanization level of rice harvesting operation was desirable at 98.8% (Table 1). The pre-harvest losses due to pests and unfavourable weather conditions on extended over maturity and high cost of manual harvesting have contributed to the mechanization of harvesting [9]. The mechanization level of land preparation in all Divisional Secretariats was recorded as 100% (Table 1).

Power per Unit Area

The power per unit area for land preparation was 42.1 hpha^{-1}. Two-wheel tractors and four-wheel tractors were mostly used for land preparation. However, no power-generated machines were used for bund preparation. The highest power value per unit area was for threshing (87.3 hpha^{-1}). Low power values per unit area were recorded in transplanting as 4.3 hpha^{-1}, weeding 1.9 hpha^{-1}, and power sprayer for chemical application as 0.3 hpha^{-1} (Table 2).

Mechanization Capacity

The highest total mechanization capacity of 58660.9 kWhha^{-1} (Table 2) was recorded inrice fields cultivated under major irrigation systems, followed by minor irrigation systems (19839.4 kWhha^{-1}). The rain-fed irrigation system reported the least total mechanization capacity as 15216.2 kWhha^{-1}, due to the low amount of land extent compared with the major and minor irrigation systems.

In major irrigation systems, transplanting and mechanical weeding accounted for 6.1 kWhha^{-1} and 2.8 kWhha^{-1} machine capacities, respectively. Meanwhile, zero machine capacity was recorded in minor and rain-fed rice cultivation systems. The machine capacities for power weedicide application in major and minor irrigation systems were 92.0 kWhha^{-1} and 7.7 kWhha^{-1}. However, there a Zero mechanization capacity for power weedicide application was observed in rain-fed irrigation systems.

Machine capacities for power pesticide application were 45.1 kWhha^{-1} and 3.0 kWhha^{-1} in rice fields under major and minor irrigation systems, respectively. Similar to the transplanting and mechanical weeding zero machine capacity was recorded for power pesticide application also in the rain-fed rice cultivation systems. The mechanization capacity of rice fields under major and minor irrigation systems were notably different from the rain-fed rice cultivation systems. Low mechanization levels for rice transplanting and weeding were observed in rainfed rice cultivation systems, compared with other agricultural operations, highlighting the need for more attention.

As shown in Figure 1, the mechanization capacity of major irrigation scheme based rice fields were found to be 58660.9 kWhha^{-1}, followed by 19839.4 kWhha^{1} and 15216.15 kWhha^{-1} for the minor irrigation scheme based rice cultivation and

Table 2: Mechanization Capacity of Rice Fields under Different Irrigation Systems and Power per Unit Area of Anuradhapura District

Step	Major Irrigation	Minor Irrigation	Rain Fed	PPA (hpha^{-1})
	MC kwhha^{-1}	MC kwhha^{-1}	MC kwhha^{-1}	
LP	31214.6	8197.06	4928.29	42.07
BM	0	0	0	0
SBP	623.23	394.67	162.38	26.51
TP	6.06	0	0	4.32
MW	2.79	0	0	1.85
PWA	92.03	7.73	0	.0.22
PPA	45.07	3.04	0	0.25
T	26677.08	11236.93	10125.48	87.29
Total	58660.85	19839.43	15216.15	

Note: LP: Land Preparation, BM: Bund Making, SBP: Seed Bed Preparation, TP: Transplanting, MW: Mechanical Weeding, PWA: Power Weedicide Application, PPA: Power Pesticide Application, HV: Harvesting, T: Threshing rain-fed rice cultivation systems, respectively. Rice fields under major irrigation systems represented a relatively higher amount of mechanization in rice cultivation, due to higher land extant/farmer, high labour intensity, and limited time for seasonal cultivation.

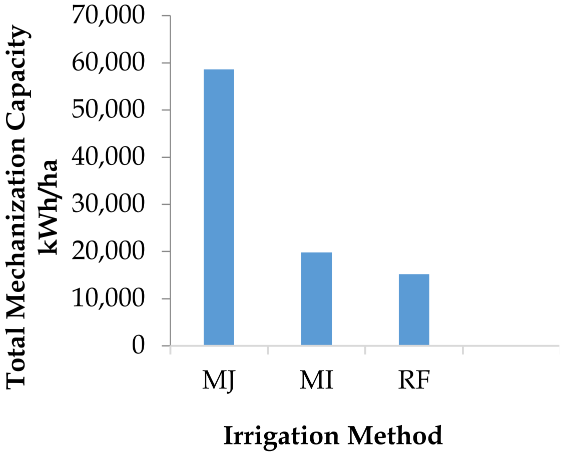

Figure 1: Total Mechanization Capacity under Irrigation System (kWhha^{-1})

Note: MJ: Major Irrigation, MI: Minor Irrigation, RF: Rain Fed

Mechanization Index

The highest mechanization index of 99.4% was determined for threshing, followed by land preparation (96.1%) indicating that such machinery has already reached the farmer-friendly level of mechanization (Table 3). The mechanization index of 7.0 and 1.6 for transplanting and power spraying, respectively indicated that such machinery has not reached the farmer-friendly level of mechanization, reflecting the need of introducing user-friendly and economically feasible machinery in such operations in rice cultivation.

Table 3: Mechanization Index

Cultivation Steps	MI(%)
Land Preparation	96.1
Transplanting	7.0
Chemical Application	1.6
Threshing	99.4

Note: MI: Mechanization Index

Mechanization Requirement

The mechanization requirement (MR) for different operations in rice cultivation in the Anuradhapura district was computed based on the current mechanization level of each operation. As the mechanization level of threshing and land preparation is almost 100%, the mechanization requirement of land preparation and harvesting equals zero (Table 4).

Table 4: Average Mechanization Requirement in the Anuradhapura District

Cultivation Steps	MR
Land Preparation	0
Seed Bed Preparation	70
Bund Preparation	100
Transplanting	97
Weeding	97
Power Spraying	92
Threshing	0
Harvesting	3

Note: MR: Mechanization Requirement

Due to the lower mechanization levels of transplanting and weeding, the highest mechanization requirement was reported for those operations as 97%, followed by power spraying (90.9%) and seedbed preparation (70.3%). This data underlines the insistence of removing barriers for the development of mechanization of rice weeding in the Anuradhapura district.

Labour Capacity

In computing the labour requirement on cultural steps, the ploughing was done only using tractors consuming 7 labour hours per hectare (Table 5). The mechanical seedbed preparation by tractors needed 3.5 labour hours, while 42 labour hours were required for manual seedbed preparation. Still, there are no machines developed for bund making in the Anuradhapura district thus, an average of 150 labour hours was required for one ha of rice land. The manual seed sowing (broadcasting) required an average of 49 labour hours per hectare of rice land.

Table 5: Average Labours and Machine Requirements for Mechanical and Manual Cultivations per Hectare

Steps	No of Labours	Mechanical Cultivation		Manual Cultivation	
		Type of Machines	Hours	No of Labours	Hours
PG	1	Tractor	7	-	-
SB	1	Tractor	3.5	6	7
BM	-	-	-	10	15
SS	-	-	-	7	7
TP	2	Transplanter	6	16	8
WD	1	Weeder	4.5	-	-
CA	1	Power Sprayer	2.5	1	6
HV	4	Combine Harvester	4.5	12	7
TH	4	Combine Harvester	4.5	-	-

Note: PG: Ploughing, SB: Seed Bed Preparation, BM: Bund Making, SS: Seed Sowing, TP: Transplanting, WD: Weeding, CA: Chemical Application, HV: Harvesting, TH: Threshing

The highest labour saving was found in mechanical transplanting, which required only 12 labour hours per hectare, while manual transplanting needed 128 labour hours for the same. The ability to maintain a uniform seedling spacing in mechanical transplanting, which facilitates mechanical weeding is an additional advantage.

The availability of effective sunlight by uniform plant spacing may enhance the higher tillering ability and unfavorable conditions for pests, reducing the cost for pest control. The power sprayer requires only about 2.5 labour hours per hectare, while manual spraying required around 6 hours. The labour requirement of 84 hours for manual harvesting followed by threshing has been reduced by the use of combine harvesters to 18 hours, due to simultaneous harvesting and threshing operations.

CONCLUSIONS

Results of this research indicated that except for tillage and threshing operations, a considerable gap is found in the current mechanization level resulting in the mechanization requirement of other operation steps. The mechanization level, mechanization capacity, and power per unit area for transplanting, weeding, power spraying denoted a very low value. There were no bund-making machines used in the Anuradhapura district. A zero mechanization capacity was reportd for transplanting and weeding in minor and rain-fed irrigation systems. Meanwhile, a zero machine capacity was recorded for power pesticide application in the rain-fed rice cultivation systems.

Mechanization of transplanting fascilitates the mechanization of weeding, while reducing the weedicide usage. This will be a solution to the agricultural labor shortage issue also. However, plot sizes need to increase to enable transplanting, which increases the demand for mechanized bund-making. The highest mechanization requirement was found to be 100% for bund making, followed by 97.1% for transplanting and weeding. The power spraying and seedbed preparation also required high mechanization requirements of 90.9% and 70.3%, respectively. Bund making, transplanting, weeding, power chemical application in comparison with other agricultural operations are uncomplimentary and require more attention than the other agronomic operations.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

WG[1]: Designed the research, supervised the study, interpreted the data, and wrote the manuscript. WG[2]: Collected the data and wrote the manuscript. NC: Supervised the study and reviewed the manuscript. All authors read and approved the manuscript.

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