SUSTAINABLE FARMING THROUGH MECHANIZATION: DEVELOPMENT OF A BUND MAKING MACHINE

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Abstract

As the decreasing rural population of Sri Lanka is becoming increasingly responsible for feeding the growing urban population, increase in productivity of agriculture has become an essential feature in stepping towards sustainability. As younger generation avoids the cultivation, the labour shortage has become very significant. To motivate the young people in to agriculture, mechanization plays a vital role. This paper describes about one such mechanization, which is done on replacing manual bund making process in low land paddy fields. Bund making is usually done in two steps using the mamotee; bund clearing and mud plastering. Hence two separate attachments have been developed for the two steps separately.

For bund clearing, a simple cutter with a height adjusting mechanism has been developed and tested. This attachment is designed for a two-wheel tractor as it was the most preferred tractor among Sri Lankan farmers.

A new concept was tested for bund plastering, as a direct attachment to the tractor. A closed rectangular channel which has a curve along its length has been suggested to convey mud towards the bund. The flowing ability of mud was supposed to be utilized in this new concept. Mechanizing the mud plastering process would be an entirely a new innovative concept and lot of empirical investigations are needed during the testing of the attachments. The two attachments were fabricated with a minimum cost and field-testing was conducted to check the proper functionality of the two attachments.

The bund clearing attachment worked successfully though several modifications were to be made. The mud plastering concept failed during testing. Approximately about 30-fold productivity gain in terms of time consumption is expected with the introduction of this mechanization compared to the conventional methods currently used by the farmers.

Key Words: Bund, Mechanization, Plastering, Clearing

1. Introduction

Sri Lanka has been an agricultural based country for centuries. The country's agriculture mainly depends on rice production and it was responsible for 30.5% of employment in the country in 2005, down from 36.8% in 1995[1]. At present the number has decreased much more as the younger generation refuses to perform hard work related to cultivation. As population in urban areas increases, the demand for food has been rapidly increased and the countries own food production has failed to cope with this growing demand within the past few years. As a result a sizable amount of rice is imported to the country, annually. To overcome this problem and to achieve sustainability in agriculture, development in the agricultural inputs was started to implement lately. One of the main areas of this is development of the agriculture related technologies. Among them, mechanization of agricultural activities plays a main role which could eventually give a solution to the growing labour shortage in agriculture. It also facilitates to increase the productivity of cultivation and create an efficient environment. Farm mechanization should be done in order to develop appropriate technologies to suit local conditions which are compatible with the socio-economic and field conditions available in Sri Lanka.

Paddy cultivation is mostly performed by the rural population of Sri Lanka. Around 879,000 farmer families are engaged in paddy cultivation each year and it represent 20% of country's population [2]. These people are rarely exposed to the modern advanced technologies. They are less adaptive to the expensive lifestyles due to their very low income. They mostly engage themselves within their villages and live a very simple life.

In this background, implementing new farm machinery could be a very challenging task. Even though there are lot of farm machineries introduced to farmers each year, only a very few of them become popular among the community [3]. Many of them failed due to the following reasons. Most of these machines are very expensive and due to scarcity of spare parts farmers are reluctant to buy such products. Difficulty in maintenance and handling can also be a major reason among them. It is also important to notice what facts the local farmers are mostly attracted when they are purchasing farm machinery. They often prefer engine driven mechanisms. Two wheel tractors is one of the most popular machinery among Sri Lankan local farmers. They also pay attention to the cost as well as the applicability of the machine to various activities. If the manual task takes lot of time and energy, they would prefer to go for an engine driven mechanized solution. That was the reason why the rotary tilling attachment and threshing machines have become very useful to the farmers. As successful machineries are implemented to cater the needs of farmers, the younger generation would be more encouraged to step in to cultivation. With successful mechanizations, people can be employed as operators, instead of labours. Hence it will eventually ensure the sustainability of the national food production.

Each task done during the paddy cultivation happens to be very hard and time consuming. Bund (or paddy dikes) preparation is one such difficult task which local farmers had been practicing it manually for centuries.

It is usually done in two steps at the beginning of the each crop season. First, the bund should be cleared from weeds and grass during initial plough. Then the bund should be plastered with a layer of mud after the second plough [4]. Good bunds help to limit water losses by seepage and under bund flows. Bunds should be well compacted and any rat holes should be plastered with mud. An average farmer would take approximately 30 mins for single side bund clearing and 45 mins for single side bund plastering of an 18 m long bund. Therefore, the main objective was to mechanize this bund making process, since it could be very helpful for farmers to save time, physical energy and make their work easy. The attachments for bund clearing and plastering should consist of the following features:

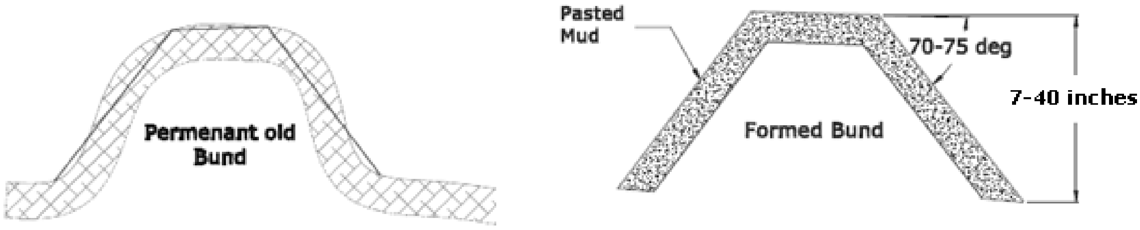
- Low cost
- A very simple mechanism which any farmer could understand
- Efficient than the manual bund preparation process
- Easy to operate for the local farmers
- Durable and which bear the rough conditions in the paddy field
- Easily maintainable
- Spare parts available

Mainly it should be developed to an affordable price so that any farmer could hire it during their cultivations.

2. Material and Methods

2.1 Literature Review

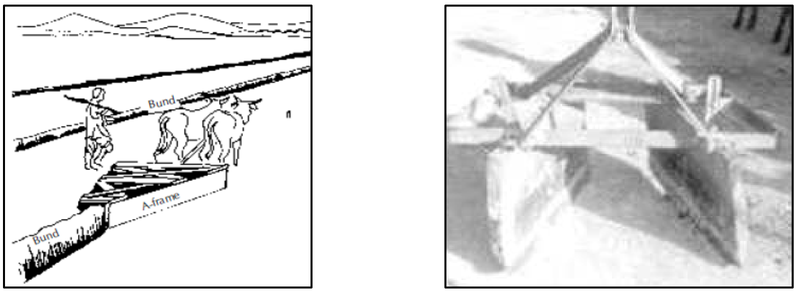
During bund clearing, usually the weeds are removed and the bunds are cut into an angle as shown in Fig 1(a). Then mud was plastered to create a uniform layer on the bund. This mud would moderately consist of water so that the mud can successfully retain on the slanted surfaces of the bund. The mamotee is used to lay a mud clod on the slanted surface of the bund and it was shaped up to form a uniform layer of mud as shown in Fig1 (b).



(a) *(b)*

Fig1: Bund clearing & bund plastering

During literature survey, several existing methods of bund making were found. Fig 2(a) shows one simple method for bund making, which is drawn by bullock [5]. Fig 2(b) shows the same method which was modified to drawn by the tractor [6]. But this method has been used to prepare new bunds in places where there are no bunds available.



(a) *(b)*

Fig 2: Bund forming using an A-frame

(a) Bullock drawn (b) Tractor drawn

However, there was a modern attachment for 4-wheel tractors for bund preparation, which is made in China as shown in Fig 3. But it costs more than Rs.600, 000. Therefore, it was not economically feasible for the Sri Lankan farming community since local farmers do not frequently use four wheel tractors for paddy cultivation.

Fig 3: Bund forming attachment for 4-wheel
Tractors, made in China

This machine uses a rotary blade arrangement for breaking the existing bund or the ground and collects the soil and compresses it to form a new bund with a rotating drum. This was suitable only for dry or slightly wet soil. When the moisture content increases, the bund formation was not successful. The drum should rotate at a high speed to form a well compacted bund.

There was another attachment only for bund clearing built by a Sri Lankan farmer for 2-wheel tractors. It is shown in Fig 4 and the problem with this design was the inability to vary the height of the cutter. Only small bunds were able to clear by it.

Fig 4: Bund clearing attachment for
2-wheel tractors

According to the information found during literature; no one has yet developed a method for mud plastering. Therefore, the major requirements for the bund clearing cutter is the ability to cut the bund to an inclined shape while allowing adjusting the height. The mud plastering attachment should be able to convey the mud towards the bund and shape it to form a uniform layer of mud. By mechanizing the bund making process, the speed of the process can be increased up to the tractor moving speed (around 0.45 m/s speed).

2.2 Bund Clearing Attachment

To obtain a slanted cut in the bund, a cutter having straight blades, with an inclined cutter shaft was initially suggested, as shown in Fig 5.

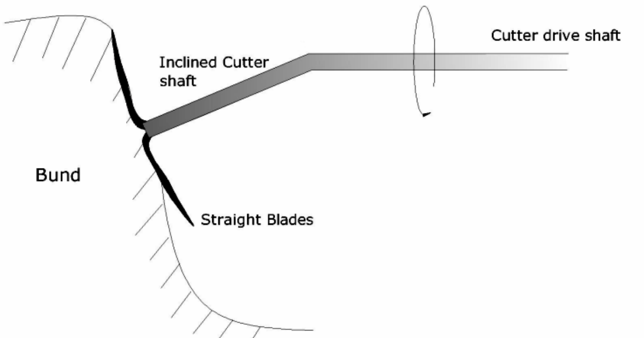


Fig 5: Cutter shaft inclined and straight blades

In order to clear the bund at different heights, there were three possible ways. These three possibilities were able to obtain by varying three parameters as shown in Fig 6.

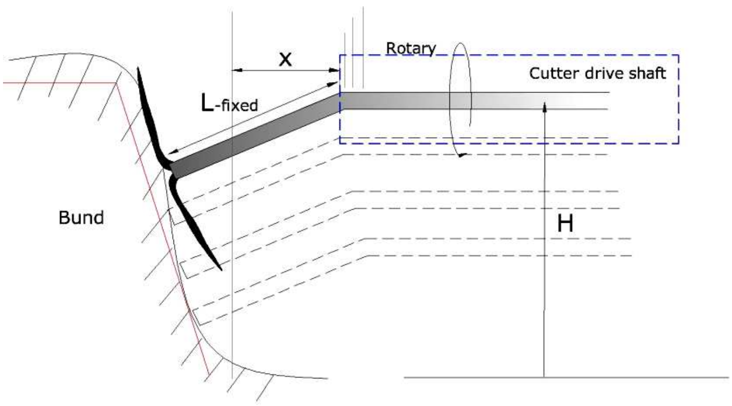


Fig 6: Fixed cutter shaft length (L) with variable height to the cutter drive shaft (H) and minimum distance from bund to the tractor wheel (x)

According to Fig 6, the three parameters were the height of the cutter drive shaft (*H*), the cutter shaft length (*L*) and the distance between the bund and the tractor mud wheel edge (*x*). One of the three parameters can made fixed and the other two can be varied and hence three possible ways can be obtained to adjust the height while cutting the bund to form slanted surfaces.

From these three possible ways, the configuration shown in the Fig 6 was selected. It is to have a fixed cutter shaft length (*L*) with a variable height (*H*) of the cutter allowing the operator to drive the tractor at various distances from the bund.

To make the cutter simpler and avoid the use of a universal joint to incline the shaft, a horizontal cutter shaft was suggested. Mean time, to achieve a slanted cut at the

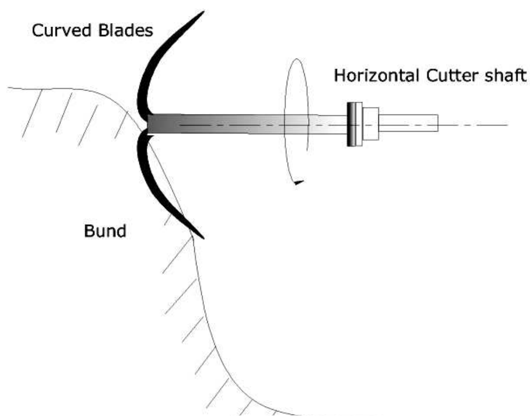


Fig 7: Horizontal Cutter shaft and curved blades

bund surface, the cutter blades were made inclined as shown in Fig 7.

To adjust the height of the cutter, a three gear wheel arrangement was suggested as shown in Fig 8. The dummy wheel is a free rotating wheel. To achieve various height levels, the driven wheel connected to the cutter shaft is rotated about the centre axis of the dummy gear wheel while the driver wheel is connected to the tiller blade shaft.

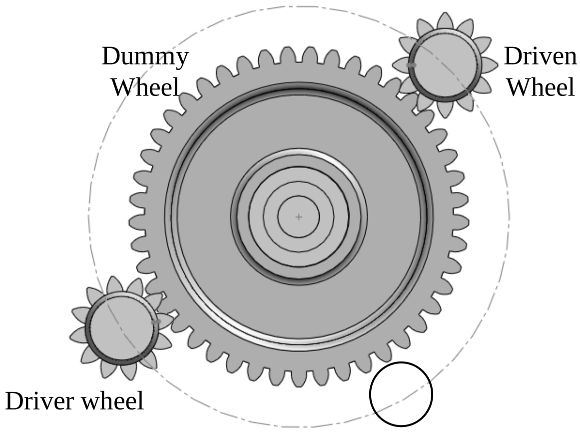


Fig 8: Height adjusting Mechanism

Fig 9 shows the fabricated bund clearing attachment. The fabrication was done with the commonly available materials (mild steel, sheet steel etc) and the total cost of fabrication was Rs. 24,000. The attachment was tested in a condition similar to the initial plough of the paddy field.

Fig 9: The fabricated Bund Clearing cutter

2.3 Bund Plastering Attachment

The suggested mud plastering technique is shown in Fig 10. The main purpose of this channel was to convey mud when it moves forward with the tractor and direct mud towards the bund. This was fabricated using steel sheets and the total fabrication costs Rs.6000. The channel was fixed to the tractor at the hitch point and tested at a similar condition after the second plough in the field.

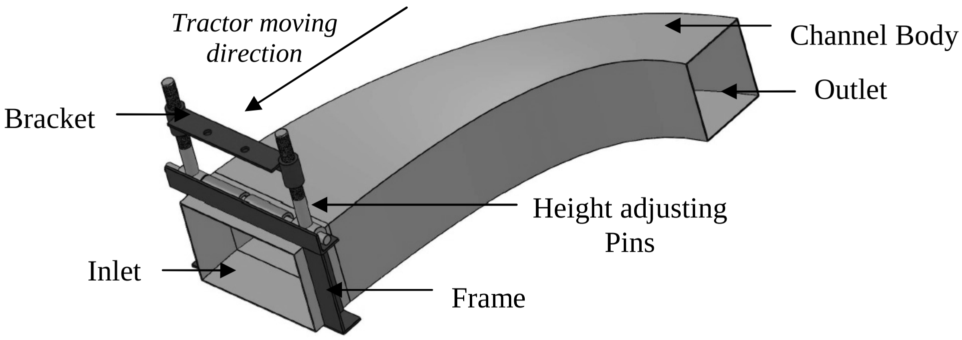


Fig 10: The Mud conveying Channel

3 Theory and Calculation

3.1 Maximum torque required for cutting action

The following parameters were assumed for the worst possible case,

No of blades in the Cutter (n) = 4
Blade span (s) = 22.5 cm
Maximum blade thickness (t_{max}) = 6 mm
Shear stress of the soil (τ) = 24 kPa

Cutter maximum operating speed (N_{max}) was considered as the tiller shaft speed at high rotary gear position and 1st main gear position [7].

$$N_{max} = 257 \text{ rev/min}$$

At any given moment, the cutter will only use half of the no of blades for bund clearing.
To calculate the torque generated due to cutting action, the blade profile was assumed to be on the periphery of a semi circle with a radii of half of the blade span (s). Fig 17 shows the approximate blade profile when viewed from the front.

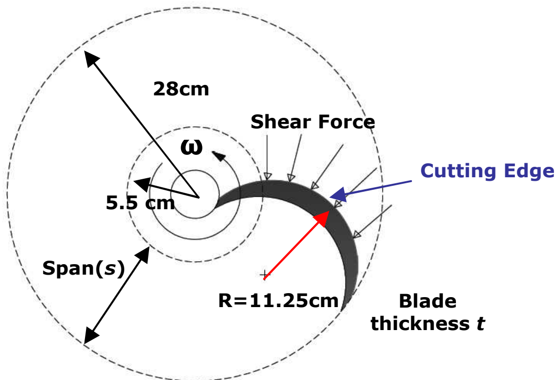


Fig 17: The approximate blade configuration at the maximum possible torque

$$\text{Total shear area } (A) = 2\,\pi\,R\,t$$
$$\text{Resultant shear force } (F) = \tau\,A$$
$$F = \underline{101.78 \text{ N}}$$

It was assumed that the resultant shear force acts along the centre point of the blade span. Then maximum torque required for cutting action would be,

$$\text{Maximum torque } (T_{max}) = F * R$$
$$= \underline{17.05 \text{ Nm}}$$

3.2 Maximum power required for cutting action

Since the maximum rotational speed of the cutter is 27 rad/s (257 rev/min), the maximum power required for cutting action [8] would be,

$$P_{max} = T_{max} * \omega_{max}$$
$$= 17.05 \text{ Nm} * 27 \text{rad/s}$$
$$= \underline{0.46 \text{ kW } (0.61 \text{ hp})}$$

The rated maximum power of the two wheel tractor is 12 hp. If a maximum of 20% transmission losses are taken, the minimum power supplied by the tractor transmission system would be ~ 9.6 hp. This would be more than enough for the cutting operation.

In addition a static FEM stress analysis was performed [9] using Solid work Simulation for the cutter blades to ensure safe operation with out failure.

4. Results

During testing, both attachments operated safely without any major component failure. The bund clearing cutter cleared the bund successfully and the height adjusting mechanism suit for the harsh conditions in the paddy field. But the inclination of the cutter blade was not sufficient to get a significant slanted cut in the bund. A mismatch in the cutter feed and speed was also observed which resulted in an improper cut along the bund, as expected.

The mud conveying channel concept failed during testing as the mud got stuck at the inlet of the channel.

5. Discussion

The above implementation was carried out under restricted condition due to financial and time limitations. As this is an ongoing work, to optimize the cutter blades to suit the purpose, several blade profiles and inclinations of the blade should be tested in the field as further study. The concept of the bund clearing cutter is entirely a new one and lot of trial and error tests should be carry out. In addition the ability of using the bund clearing cutter simultaneously with the rotary tiller should be investigated as it would be a significant method of increasing productivity in the land preparation during paddy cultivation.

One of the reasons for the failure in the mud conveying channel was the size of the channel at the inlet. So as further study, the inlet area can be increased and tested.

6. Conclusions

The mechanization of the bund making process is one of the important tasks to be done to achieve sustainability in paddy cultivation. As no similar method is developed to fulfil this task, a new conceptual design development and trial and error testings are required for improvement. The suggested design above is one such innovative concept and lot of further study is required to improve it. The successful mechanization of bund making process can provide an approximately about 30-fold productivity gain in terms of time consumption compared to the conventional methods currently used by the farmers.

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