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Adaptive studies on a Walking Tractor for Smallholder Farming Operations

Kasambula V., Okurut S. and PadolinaC.L.
Agricultural Engineering and Appropriate Technology Research Institute
P.O.Box 7144 Kampala, Uganda

Abstract

Mechanisation of farm operations translates into improved labour productivity, land use and timeliness of desired operations. A single axle Walking Tractor (and its accessories) is being adaptively developed at AEATRI as one way of improving mechanisation of farm operations at small-scale level. The first prototype was designed, fabricated and tested to adaptively develop it to suit the prevailing physical set up of the small fragmented acreage typical of the Ugandan farmers. Data to determine performance characteristics was collected and assessed after testing the walking tractor on tillage of the heavy clay soils in Luwero District and on lighter sandy loam soils in Kumi District. Results from the tests indicate that major changes to decrease the strenuousness of operating the tractor will require extensive modification and fabrication of many parts and components. It is, therefore, practical to design and construct more prototypes along recommendations of all essential stakeholders. This implies extensive modification of the present prototype. Successful development and dissemination of the single axle-walking tractor will increase the level of mechanisation of farm operations on typical small-scale Ugandan farms there by contributing to the Plan for Modernisation of Agriculture (PMA).

Key words: Adaptive studies, Walking tractor, Small holder farming operations

Introduction

For about eighty years now government has been trying to mechanise farm operations through tractorisation. This effort has been characterised by importation of oversize and non-standardised tractor models for small household farms. This has resulted into high costs of operation and long "dead times" of expensive equipment. To contribute to the modernisation of agriculture as a way of improving upon the present agricultural production, it is vital to develop and/or adapt simple and affordable motorised technologies to mechanise farm operations for small-scale farmers.

In Uganda, the agricultural sector contributes an estimated 43% of the GDP and an estimated 85% of the export earnings. A big number of the country's industries, including textile, timber, tobacco, food processing and leather industries are also agro-based. Agriculture therefore remains the base for the country's economic growth.

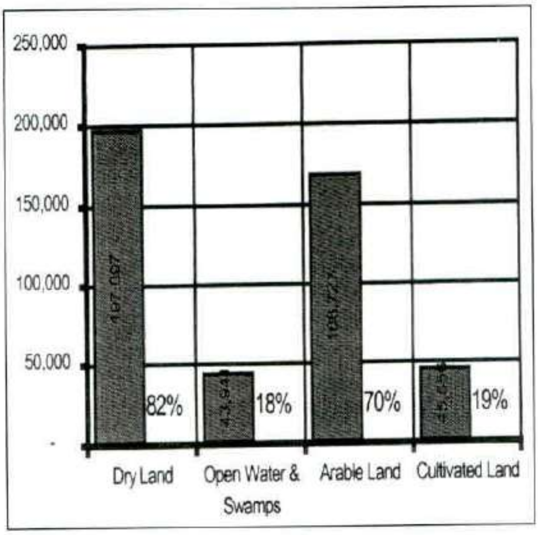
The country's climate is characterised by annual average rainfall of 1200 mm, mean minimum temperature of 17°C, mean maximum temperature of 28°C, average daily sunshine of 6 hours, and average humidity of 78%. It is generally favourable for all kinds of agricultural production.

The country's total surface area is 241,038sq. of which 197,097 sq. km is dry land and 43,942sq. km is open water and swamps. Arable land is estimated to be 168,727sq. km, which is 70% of the total area of the country. Only 45,556sq. km, which is 27% of arable land, is under cultivation. Despite the high water potential the country is endowed with (18% of the country's area), only 0.3% of the arable land is currently under irrigation.

Table 1: Surface distribution in Uganda

	Dry land	Open water swamps	Arable land	Cultivated land
Surface area, sqkm	197,097	43,941	168,727	45,566
Percentage	82%	18%	70%	19%

Fig. 1: Surface area distribution



Out of the country's estimated population of 22 million, 88% comprising about 2.5 million households, live in rural areas and are engaged in agricultural production based on family labour largely contributed by women and youth. These households produce 94% of the sector's output on an average farm size of 2.5 hectares. Their essential tools of production (e.g. the hand hoe, machete, etc.) are simple, rudimentary and labour intensive.

The country's wide range of agro-ecological characteristics should yield a variety of tropical, semi-arid and temperate crops and livestock products.

- This potential is under exploited because Uganda's agriculture is constrained, among others, by:
- Labour intensive farm operations of land tillage, on farm transport and primary crop processing using rudimentary tools,
- Farm production based on family labour that is characterised by gender biased division of labour, inequitable access to resources, and, gender differentiated distribution of accrued benefits,
- ***Total dependence on rainfall and no irrigation.***

This leads to production for mere subsistence with no surplus for sale to improve household income.

Initiatives on Farm Mechanisation in Uganda

For about eighty years now, government has put some effort into mechanising farm operations through tractorisation. In the year 1922, the Cotton Growing Corporation presented three Austin tractors to the Sironko Valley Cotton scheme. In 1936/37, a paraffin tractor was used at Bukalasa. During the same period, a small crawler and other American equipment were used to terrace fields of Kawanda and Serere Agricultural Research Institutes.

In 1947, a special development section was formed to investigate mechanisation of farm operations through use of Tractor Hire Services, (THS). The THS scheme started in the central region and spread more rapidly in the northern region where pressure on land was comparatively less. Tractorisation through THS became increasingly popular to farmers from 1950 onwards. Pre-Independence Government policy encouraged provision of mechanical cultivation in suitable areas of the country and private ownership and hire of tractors to others. Incentives for acquisition and use of tractors were put in place. They included a 25% subsidy on tractor cost, no tax on tractors, implements and spare parts, free repair labour with owners providing only spare parts and access to fuel and lubricants for agricultural tractors imported under the "Farmers' Pack".

During the first decade of Independence, the THS rapidly expanded. Tractor numbers increased from 51 in 1961 to 1,286 units by 1965. 1,250 additional units were imported in the period 1966 to 1970. The number of group farms rose to 40 by 1965 and received 200 tractors during 1966 to 1970. 17 class-one and 66 class-two agricultural mechanisation workshops were set up countrywide. A Diploma course in agricultural mechanisation was launched at Arapai Agricultural College in 1965 to produce tractor hire personnel while a training centre started at Namalere Mechanised Division to impart skills of tractor operation and maintenance to personnel. Despite all this, interest in THS and Group Farms drastically declined due to high operation costs, long "dead machine time", poor management, and inadequate transparency and accountability.

During the early 1960s, the Department of Agriculture of Makerere University under took the development of a light multipurpose tractor targeting smallholder farmer needs. However, the exodus of Ugandans of Asian origin from Uganda in 1971/72 adversely affected this effort when it was in its final stages. During the second decade of Independence, the new Government imported 600 new tractors despite low interest in THS by previous Government. Busitema National College of Agricultural Mechanisation in Tororo was established in 1971 to train technicians for mechanisation. Economic constraints during the decade led to decline in THS and group farms.

During the third decade of Independence, Government policy shifted away from THS to private ownership of Tractors and their equipment. 3021 tractor units of over 150 different makes and models were recorded in the 1980 National Tractor Census, of which fleet 68% were then operational. 604 new tractors were imported by Government and 522 by the private sector during 1988/1989. Private ownership of tractors was emphasized by Government despite demands to the contrary by farmers. Consequently, tractors and equipment belonging to the THS were sold to individual farmers in anticipation of effective utilisation.

During the same period, the first Mechanisation Strategy Formulation was attempted in Uganda. In 1983, tractors were allocated to districts and were later vandalised due to turmoil. In 1987, tractors were allocated on loan to RC III administrations in selected Districts. Poor management led to early machine breakdowns and non-recovery of the loan.

During the fourth decade of Independence, a B.Sc. Agricultural Engineering course commenced at Makerere University (1990). The Agricultural Engineering and Appropriate Technology Research Institute, AEATRI, was established (1994) under National Agricultural Research Organisation, NARO, to carry out research, development, and dissemination of agricultural engineering technologies. Privatisation and liberalisation of the economy through divestiture of public enterprises led to increased participation of the private sector in the importation, sales, ownership, after sales service and overall utilisation of tractors.

Presently, Government has launched the Plan for Modernisation of Agriculture, PMA, in Uganda as one of the strategies for eradication of poverty. This includes among others the establishment of the National Agricultural Advisory Services (NAADS) whose mission is to increase farmers' access to information, knowledge and technology for profitable agricultural production.

Justification

The Government's economic strategy is to modernise and commercialise agriculture leading to eradication of poverty. Deployment of farm implements that will improve farm productivity and add value to farm labour will contribute to this strategy. Labour requirement for production remains the main input to a given farming enterprise. Due to the smallholder-nature of a typical Ugandan farmer, improvement in the mode of agricultural production in the country has been insignificant. Essential farm operations of land preparation, planting, weeding, harvesting, and on-farm transportation are still being accomplished through use of labour intensive rudimentary tools like the hand hoe, the axe, the machete, the slasher, the sickle and head or back portage. This always leads to untimeliness of tillage operations and poor agricultural productivity.

The current government has striven to mechanise farm operations through formulating and implementing enabling policies. Some of the policies succeeded to some extent but many failed due to unfavorable developments in the cultural, social, political and economic settings of the country. It is difficult for the farmer who has low purchasing power and works on small fragmented uneconomical acreage to acquire, use and maintain state of the art tractors and their accessories. Besides, the practice of using oversize and non-standardised tractor models for small household farms has resulted into high costs of operation and long "dead machine times" of expensive equipment.

The Ox-plough has been developed and popularised in the northeastern and eastern parts of the country where the topography is largely flat, the soils are light sandy loam and the culture for use of animal draught power is conducive. Where the land is hilly and the soils are heavy, as is typical of other regions of the country, higher tractive forces are necessary. Furthermore, negative cultural beliefs on the use of cattle as beasts of burden have hindered the use of animal draught power in these parts of the country. Nevertheless, more technology development work is under way on the ox-plough to improve upon its performance parameters for areas where it is accepted.

To improve upon the present agricultural labour productivity it is vital to develop and disseminate simple and affordable technologies for primary and secondary farm operations. AEATRI, under the Farm Power and Implements Programme, a single axle tractor is being developed for smallholder farming operations that will increase capacity and timeliness in the desired farm operations.

Goal

The goal is to modernise Agriculture in Uganda by improving the level of mechanisation of farm operations.

Purpose

To improve productivity of labour, land and other necessary inputs at smallholder farm level.

Objectives

To adaptively develop a single-axle-walking tractor (and its accessories) that is simple to fabricate, operate and maintain it should be characterised by the following attributes:

- Affordable to the small scale farmer or a group of low earning farmers in terms of initial capital, operating and maintenance costs,
- Compatible to the prevailing physical set up of the small fragmented acreage typical of the Ugandan farm and,
- Easy to operate by all gender.

Research Questions

Evaluate advantages and disadvantages of the available technologies for adoption to local conditions

- Determine the technical efficiencies associated with use of the walking tractor.

- Determine productivity rates and cost effectiveness on utilisation of the walking tractor.
- Social–economic responsiveness to the use of the technology.

Methodology

Following a research priority setting exercise carried out during the AEATRI planning and review workshop (April 1999 at Maganjo) a single-axle walking tractor prototype from the Philippines (Courtesy of C.L Padolina), was selected to be adaptively developed for the Ugandan conditions. To determine its performance characteristics the developed tractor has been tested on heavy clay soils in Luwero district and on lighter sandy loam soils in Kumi district.

A test sheet was developed to collect the following data:
- Location of experiment site,
- Test conditions (landscape/topography biomass cover, soil type & condition, previous crops cultivated and when done)
- Equipment and implement identification data,
- Performance data,
- Social–economic responsiveness,
- Recommendations.

Following the field-tests, a few modifications recommended by Farmers have been carried out to improve performance. Major design changes recommended by Farmers are yet to be carried out.

Experiment design

Representative test sites were selected from AEATRI contact farmers' fields. Sub-county extension staff was co-opted to prepare the farmers for the experiments. Test plots were then carefully laid out to enable taking off data as the walking tractor continuously made plowing passes. The following data was taken:

- Depth of cut, width of cut, total area covered.
- Time taken to make one pass going, one pass returning, turnings, stoppages and reasons why.
- Fuel consumption,
- Operators performance (farmers were particularly encouraged to operate the tractor)
- Group discussions were then held immediately after the fieldwork to exhaustively discuss the technology.

Experiment site 1

Village:	Nakikonge
Parish:	Nakikonge
Sub-county:	Makulubita
County:	Katikamu
District:	Luwero

Description of landscape/topography and biomass cover:
- Gently sloping terrain with uneven mounds of 300mm average amplitude.
- Tall tropical grass land recently slashed and cleared.

Soil description and conditions:

- Adequately moist heavy gravel red soils
- Previous crops cultivated and when done:
- Formerly sweet potato mounds left to fallow for 24 months

Experiment site 2

Village:	Morupedede
Parish:	Kacoboi
Sub-county:	Ongino
County:	Kumi
District:	Kumi

Description of landscape/topography and biomass cover:
- Generally, flat fallow/grazing land with short tropical grass.

Soil description and conditions:

- Adequately moist light sandy loam (mainly loam) soils
- Previous crops cultivated and when done:
- Fallow/grazing grass land for previous 24 months

Identification Data for Equipment and Implement

1. **Tractor description:**

   Make AEATRI
   Type prototype 1

2. **Engine Specifications:**

   Make: Yamaha
   ModelMZ 175 (R)
   Ignition electric/electronic
   Serial Number 7NN-107903
   Number of Cylinders 1
   Engine cc capacity 171cc
   Cooling system: air-cooled
   Rated Engine speed 2000rpm
   Rated Engine Power: max. 5.5hp at 4000rpm

3. **Fuel and Consumption:**

   Fuel type: Petrol
   Duration 3:20:31
   Amount, in lt.: 4.40
   Average fuel consumption lt./hr. 1.32 Lt./Hr

4. **Power Transmission Description:**
B79 V-belt primary transmission + lever roller belt tensioner clutch + chain and sprocket secondary transmission + steel cage final drive wheels.
Type: V-belt clutching transmission

Speeds	one
Forward:	one
Reverse:	zero

5. **Tyre Description:**
16 mm steel round bar cage with 1.5" x 1.5" x 4mm angle as treads

Diameter	500mm
Width 370mm	
Material	all steel

6. **Implement/Equipment Description:**
Draw bar description: hitched to the chassis and the equipment by way of a 25 mm high tensile steel drop bolt and a y bracket

Height above ground:	370mm
Distance to rear of driving wheel centre: 90mm	
Equipment make:	AEATRI plough
Equipment type:	mould board plough

7. **Adjustments and settings**

Set Depth of cut:	150mm
Set Width of cut:	240mm

Results and discussions

Positive aspects of the tractor

1. The tractor performs better than human muscle and draught animal power. An average of 0.12 acres/hr is ploughed using 1.3lt/hr. It takes about 8hrs to effectively plough an acre using about 10lts of petrol.
2. Most of the simple and routine adjustments and corrections made on the machine can be accomplished using simple hand tools.
3. The fast moving replacement parts and materials (mainly screws, bolts, nuts, simple fasteners and lubricants) are standardised and are readily available in the market.
4. The tractor is self-propelled while in the field and also when travelling short distances. For long distances, it can be ferried on the back of a 500-kg pickup truck. It measures 2300-mm length x 920-mm width x 1000-mm height.
5. The plough maintains an average depth of cut of 120 mm.

Negative aspects of the tractor

1. Operation of the tractor is highly strenuous. The average duration a single operator can run the machine is 8 minutes. For continuous work output, therefore, 3 to 4 people trained as operators are necessary switching over every 8 minutes. This is due to the following:
   - Intensive vibrations transmitted directly from the ground engaging tools (GET) to the operator,
   - Exertion of effort while guiding the plough along the furrow,
   - Stabilisation of the machine and lifting of the heavy weight in case the plough is stuck. This is especially so when the ground has not been leveled and cleared of grass, big roots and other obstacles prior to the ploughing exercise.
   - High operating/walking speed and poor control mechanisms for acceleration, deceleration and steering.

1. The tractor cannot disengage the plough from the ground, especially during turning and while transporting the tractor to the field.
2. Due to difficulties in steering control to keep the plough along the furrow, the average effective width of cut is small (178 mm). For a sizeable area to be ploughed effectively many repeating passes have to be made.

Recommendations

Farmers proposals

1. Reduce the operating/walking speed to about $^3/_4$ of the present speed.
2. Incorporate practical and flexible acceleration control linkages.
3. Reduce weight of the machine as much as possible. Reduce the wheel width by 50% to facilitate manipulation when the machine is stuck and to improve on steering. Do not compromise on the traction.
4. Adjust the machine's centre of gravity to stabilise motion, at the same time maintain traction, and leverage for steering control.
5. Incorporate mechanical dampers while mounting the engine, the hand control bar, and the draw bar on to the machine chassis to absorb the intensive vibrations transmitted to the operator

Social–economic responsiveness

1. The tractor can be operated by children of 10yrs and above, female and male adults.
2. For the new technology to take hold, capital and running costs of the walking tractor should compare to those of the motorcycle which is the prevalent means of motorised transport in the rural areas today and also an area of investment.

3. Due to the high capital cost of the walking tractor, farmers proposed the following methods of acquiring it:

- Ownership by private person or persons for own use or hire at commercial rates,
- Ownership and appropriation by community based organisations (CBO),
- Government subsidy to sub-county units as a means of introducing and promoting modern technologies for commercial agriculture.

Research aspects

1. Participatory needs assessment involving stakeholders to determine farmers' farm power technology needs in general and walking tractor technology needs in particular,
2. Catalogue types and categories of walking tractor technologies available in the field and elsewhere,
3. Designing and fabrication of prototype walking tractors following farmers' recommendations,
4. On-station testing of the technology proto-types,
5. On-farm testing and evaluation with stakeholders, including technical and socio-economic evaluation,
1. Developing field-test linkages with interested potential fabricators and manufacturers,
2. Packaging of technology for mass production and dissemination through appropriate marketing channels.

Conclusion

The proposed recommendations will require fabricating and modifying many parts, which will lead to major

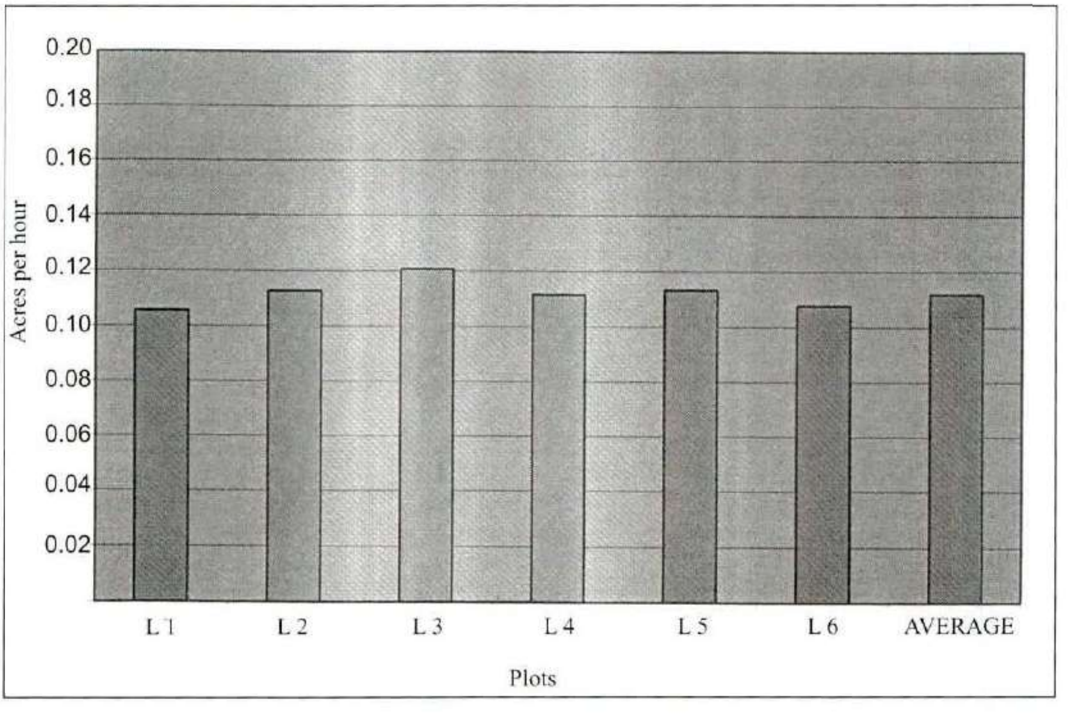


Fig. 1: Test results for Experiment Site 1 of Heavy grave soils in Luwero District

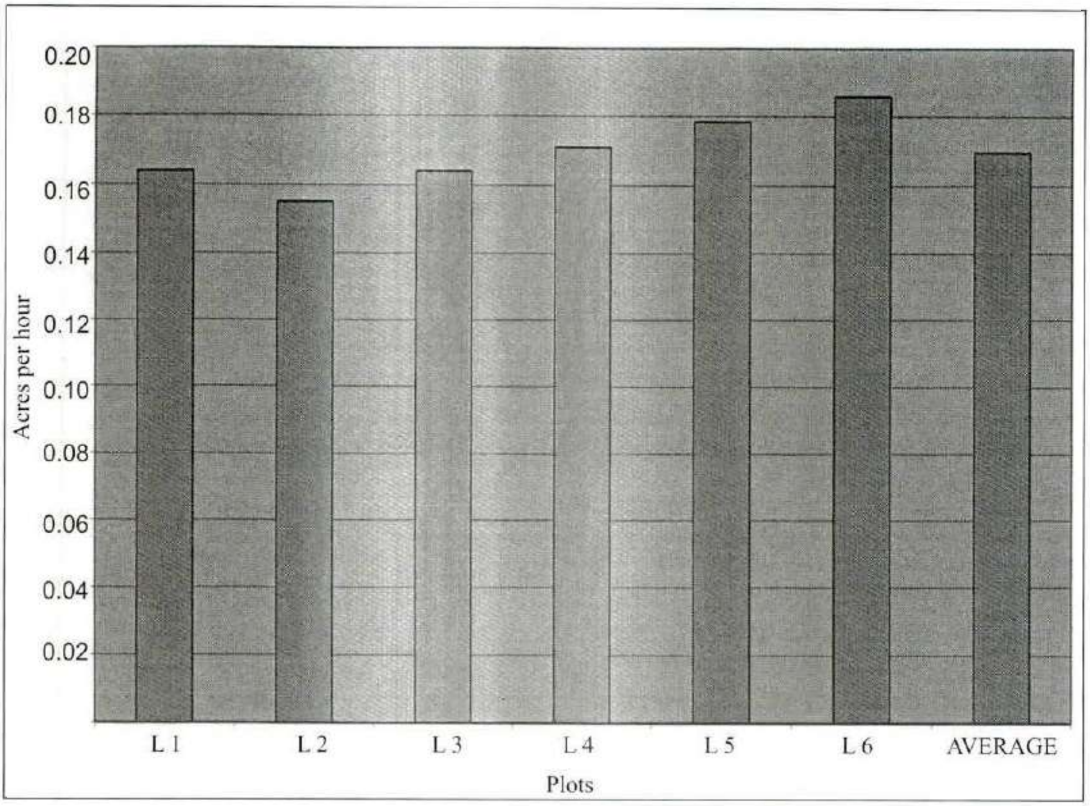


Fig. 2: Test results for Experiment Site 2 on Light sandy loam soils in Kumi District

The above graphical representation indicates that the walking tractor performs better on lighter sandy loam soils in Kumi District (0.17 acres per hour) than on heavy clay soils in Luwero District (0.11 acres per hour).

changes in design. It is, therefore, practical to design and construct another prototype along the above recommendations thus extensively modifying the present prototype.

The following are the requirements to have another prototype walking tractor fabricated.

1. Kinematics design and analysis of walking tractor mechanisms
2. Selection of materials basing on strength and weight requirements
3. Preparation of working detail drawings
4. Preparation of Bills of quantities
5. Fabrication of prototype
6. Testing with necessary modification Multiplication.