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No 3: Frugal Innovation for Inclusive
Development: A Case Study on Power Tillers in
Tanzania

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This is a publication of the Centre for Frugal Innovation in Africa (CFIA), a research centre within the strategic alliance between Leiden University, Delft University of Technology and the Erasmus University Rotterdam in the Netherlands. The CFIA studies frugal innovations in relation to economic transformations in Africa. Our aim is to identify the conditions under which frugal innovations are more likely to improve the lives of consumers and producers at the Middle and Bottom of the Pyramid.

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1. Introduction

The Leiden-Delft-Erasmus (LDE) consortium in collaboration with REPOA are developing a research project aiming to understand the role of innovation, technology transfer and technology networks in Africa's economic transformation. This role is articulated using the notion of frugal innovation. In its literal meaning, the term frugal is related to scarcity of resources, be it financial, technical capability, or institutional. The application of this notion in this project is broadly along the same lines. Frugal innovation is viewed as a process of transforming products from their technical complexities while retaining their basic functionality. This process is mainly targeted at reducing product costs or making them adaptive to operating conditions of marginal populations or relatively poorer consumers. Frugal innovation or frugal engineering as is sometimes referred to, can apply to any product or service. For example, General Electric Company developed a hand-held electrocardiogram (ECG), which reduced ECG test to about one dollar per patient (The Economist, 2012). Important considerations in understanding the process of frugal innovation are both technological dimensions and institutional dimensions, which together affect the process of technology (or products and services) transfer, adaptation and its social and economic impacts. Thus it concerns value-sensitive design and marketing strategies that bring sophisticated products within the reach of relatively poorer consumers, referred to in this project as the Bottom of the Pyramid (BoP).

It is acknowledged that the majority of the BoP lives in Africa and mainly in rural areas. In Tanzania for example, more than 74% of the labour force is engaged in agriculture, and poverty is more pervasive in rural areas. According to Household Budget Survey (2012), 33% of rural households live below the poverty line. Since the majority of rural households are predominantly smallholders engaged in labour intensive agriculture, design of interventions geared to improved productivity is considered critical if earnings are to be raised and poverty reduced. One important element to address in this respect is production technology which includes mechanization of farming activities. It is no wonder therefore that the pilot phase of the project elected to focus on introduction and utilization of power tillers among smallholders with particular reference to Tanzania despite the fact that frugal innovation is applicable to many other types of products.

Power tillers are considered as an appropriate technology for most smallholder farmers and this has been made possible by reengineering. The use of power tillers in Tanzania was accelerated following the announcement of the “Kilimo Kwanza” initiative meaning “Agriculture First” in 2009. This case study provides an analysis of the institutional processes underlying their introduction and adoption, and the design features reflecting suitability of the innovation of power tillers in relation to their expected contribution.

This report is organized as follows. Section two discusses the objectives of this study, its underlying hypothesis, and the research questions. Section three discusses the methodology applied, and section four presents the findings. Section five discusses overall contribution of this study to the research theme on frugal innovation, and section six contains the conclusions.

2. Research objectives, hypothesis and research questions

The research programme on frugal innovation is intended to inquire the conditions under which frugal innovations are more likely to stimulate development in the African context. While it is a general consensus that frugal innovation can be beneficial to the firms and the poor, there is a knowledge gap on what really can be considered to be frugal innovation/engineering, its institutional processes, and how and when the benefits can accrue to firms and the majority of the people in the BoP, or the majority of the people in sub-Saharan Africa.

This kind of research involves analyses of consumer preferences and how reengineered products suit their needs or otherwise in terms of the design features; and the process by which the products are introduced, marketed, and institutionalized. The two are not necessarily mutually exclusive, and often interlinked if the innovation process is to translate into a viable business model. The objective of this case study is to provide a rapid analysis of the notion of frugal innovation in application to the introduction of small, hand-operated tractors, commonly known as power tillers as solution to technological problem of the smallholder farmers that lead into low output and productivity. It will focus on the innovation in terms of the key design features of the product and institutional platform underlying it, and the results it has generated. It is anchored on the broader hypothesis of the research programme, that is, locally **embedded knowledge and technology networks are important elements in successfully re-engineering high-value products for low-value but high-volume markets**. The interpretation here is that some firms that manufacture tractors, while have moved into more modern and sophisticated machines, they have at the same time re-engineered those products and technologies to produce simpler and cheaper machines that can be afforded and applied by low income and unsophisticated smallholders.

This broader hypothesis is operationalized in this case study through a hypothesis that **the introduction of power tillers as means to help smallholders to improve their output and productivity have not succeeded because of both limitations on technical design and neglect of institutional dimensions**. The limitations of technical design relate to the efficacy of these machines under different soil types, terrain, and climatic conditions. The institutional dimensions relates more to the process by which the power tillers were introduced in Tanzania, mechanisms by which they reach the intended targets, and how they are put into use by recipients. Like any generic innovation, it is difficult for frugal innovation to occur under normal conditions that guarantee firms and entrepreneurs to take risks in new areas and where the target

markets are those at the BoP, in the absence of institutional mechanisms to offset uncertainties. Some institutional actions, however, can also become counterproductive, if interests of different institutional actors are not aligned. Understanding broader institutional settings surrounding this particular frugal innovation and its outcomes is as important as understanding its technical dimensions.

This hypothesis is explored by an attempt to answer the following research questions:

- How were the power tillers introduced and adopted by the smallholders in Tanzania?
- What are the elements in the design of power tillers that make them suitable (or unsuitable) for the smallholders under different agro-ecological conditions?

3. Research methodology

The first question led the study to exploring institutional aspects of this innovation. This included the processes by which this technology was evaluated and why it was considered relevant for Tanzania. Investigation was made on the decision making process and the incentives of different actors in the process. Specifically, the following aspects were pursued:

- a) The process of identification of technology and decision to import vis-à-vis customization by local firms
- b) How the initiative was financed (role of the government, the private importing agent, local government authorities/district councils, farmer organizations, and individual farmers)
- c) Institutional coordination through the chains - from acquisition to knowledge on use of power tillers, maintenance, utilization

To obtain relevant information for this kind of institutional analysis, interviews were carried out with key informants at different levels of government departments responsible for policy decisions and implementation and those from the private sector. Specially, these included the Ministry of Agriculture, Food Security and Cooperatives (MAFSC), National Service Business Unit (SUMA), Regional Administration and Local Government Authorities, selected District Councils and the importing agents and suppliers of power tillers.

The second question was intended to examine key design features of power tillers in relation to the functions they are intended to perform. Thus technical information was obtained from key suppliers where key design attributes were identified. These attributes were taken into account to examine performance on the ground on key functions under different agro-ecological conditions. Semi-structured interviews (Appendix 1) were held with officials working in target Districts and with farmers selected randomly in those districts. The selection of these districts was based on the distribution of the estimated 4,571 power tillers supplied in Tanzania as shown in **Table 1**. It has been shown that significant number of these power tillers was supplied in six out of 21 Regions of Tanzania mainland.

Table 1. Distribution of power tillers by region

S/No	Region	No. of units	% of total
1	Mbeya	1073	23.47
2	Morogoro	327	7.15
3	Iringa	306	6.69
4	Shinyanga	246	5.38
5	Rukwa	242	5.29
6	Mtwara	217	4.75
7	All others	2160	47.25
Total		4,571	100.00

Source: Ministry of Agriculture Food and Cooperatives.

While the study could have been made more robust by selecting a sample from all regions, budgetary limitations and time constraints made it prudent to select fewer areas. Two districts were selected from two regions that have the highest number of power tillers, namely Mbeya and Morogoro. This selection was considered helpful as it increased the likelihood of reaching a good number of farmers from whom to draw different experiences at reasonably low logistical costs. From each of these two regions, one district was selected, based primarily on the same criterion, that is, a district with the largest number of power tillers. For Mbeya, this was fairly straight forward. Mbarali district represented 97% of the 1073 power tillers in the region. In Morogoro region, Ulanga, Kilosa and Kilombero Districts accounted for 27%, 23%, and 19%, of the 327 power tillers in the region respectively. However, farmers in Kilombero District engage in production of paddy, just as farmers in Mbarali, but the difference in supply of power tillers is significant. This led to the choice of Kilombero district.

The objective of the field survey in the Districts was to obtain information relating to:

- a) Key design parameters and how they relate to expected and current use;
- b) Support mechanisms related to knowledge of use, maintenance, and operating costs;
- c) How the power tillers have contributed to changing livelihoods of the smallholders – productivity increase, reduced transport costs, improved acreage under cultivation, increased income; and if not, reasons thereof and the source of this failure.

In Mbarali District respondents were drawn from two Divisions, namely Rujewa and Ilongo. In Rujewa Division 45 farmers were interviewed, whereas in Ilongo Division only 15 farmers were interviewed. All respondents in Mbarali were farmers owning power tillers on individual ownership management. **Table 2** shows the distribution of the sample in Mbarali.

Table 2. Respondents in Mbarali District

S/No	Division	Ward	Respondents
1	Rujewa	Madibira	30
		Mapogoro	15
2	Ilongo	Hambolelo	5
		Chimala	5
		Itambolelo	5
Total			60

Source: Survey data

In Kilombero District data were collected from 47 respondents owning power tillers. The respondents were drawn from three Divisions, namely Ifakara (15 farmers), Mang'ula (16 farmers) and Mngeta (16 farmers) as shown in **Table 3**. Six of the respondents were farmers owning power tillers under farmer group management, and 41 respondents were farmers owning power tillers on individual ownership management. The farmer groups have individual members ranging between 15 and 22 farmers and are all gender sensitive.

Table 3. Respondents in Kilombero District

S/No	Division	Ward	Respondents
1	Ifakara	Kibaoni	9
		Ifakara	5
		Lumemo	1
2	Mang'ula	Kiberege	2
		Mang'ula	7
		Kisawasawa	4
		Mwaya	3
3	Mngeta	Mngeta	16
Total			47

Source: Survey data

4. Findings of the study

The study reveals a number of institutional and design aspects of power tillers hitherto unknown to the policy development fields, or at least documented in a systematic manner. Each of these findings is discussed here under in turn.

Institutional processes of product introduction: *Top down, state-led induced innovation*

Tractor mechanization for cultivation, farm transport, and processing took off in Tanzania since around 1950s. Initially these tractors were used on foreign owned estates growing tea, coffee, sisal, tobacco and wheat. By the early 1960s the number of tractors rose to around 1600 units. The number of tractors increased fast because of the emergence of a number of private commercial Tanzanian farmers with medium to large scale farms. The Tanzanian farmers used tractors mainly for production of maize in Iringa, wheat in Arusha and cotton in Shinyanga, and by 1970 there were about 17,000 tractors (Kjaerby, 1986).

The evolution of the use of the hand hoe in agriculture in East Asia in the 1960s was mainly driven by land tenure considerations. Due to the small sizes of farms, Japan and India invented small, hand operated tractors, initially designed for use in rice paddling, gradually replacing hand hoes. The focus of mechanization in Tanzania, however, was mainly on four wheeled tractors. The modernization approach adapted as part of the First Five Year plan in 1964, for example, aimed at opening up new areas for modern and mechanized farming, through supply of tractors and machinery. However, implementation of the schemes under this approach failed for various reasons, including the lack of sufficient preparation and overcapitalization relative to returns (Mmari, 2012). The reliance on manual power has continued to dominate agriculture in Tanzania and also other countries in sub Saharan Africa (FAO, 2008). While the use of engine power increased by 500% between 1961 and 2000 in Asia, it increased by only 28% in SSA during the same period (ibid).

In Tanzania, partially due the early tractor failure, the second government plans from 1969 stressed on the use of draft animal power instead of tractors in an effort to transform farming from manual or human power dependency to animal power, with establishment of animal breeding centre in Mwanza region for producing bulls that could endure longer working hours and produce high power. The use of animal power, however, was confined to pockets around

the country, and became insufficient as the population grew and the area under cultivation increased. Although the use of tractors continued to expand on the state-owned large scale farms, on the whole, the population of tractors decreased from 17,000 units in 1970 to less than 6,000 in 1990s due to a variety of reasons (FAO, 1997).

Experimentation with alternative forms of mechanization started in 1965 on a hand operated garden tractor imported from the Netherlands for training purposes, but no efforts were further made to introduce the technology at the level of farmers' fields. The first trial runs were initiated in the 1990s, when ten power tillers were acquired by the mechanization department of the Ministry of Agriculture from Japan under the Food Security for the Underprivileged Farmers project, commonly known as "2KR" project. The staff of the Ministry had to rely on the user's manual as they had no formal training. The trials and promotional activities were first undertaken in Morogoro region, which led to the request for twenty additional power tillers from Japan. This marked the beginning of the use of power tillers in Tanzania, albeit at a very small scale. The Ministry sold these power tillers at a subsidized price equivalent to two-thirds the CIF value at Dar es Salaam.

In 2002, the Ministry introduced additional districts for promotion of power tillers, including Mbarali district. More power tillers were requested, for which 120 units were delivered under the same project. The Ministry required all regions to indicate their needs for power tillers, but the response turned to be very low. Subsequently, the Ministry decided to allocate six units to each region. The Ministry then organized a heavy campaign to promote the use of power tillers in the regions, working with regional leaders and local government authorities. Mbarali district responded well. The agricultural training institute located at Igurusi village in Mbarali district took up the challenge to support farmers, particularly for setting up irrigation schemes for rice production. The institute offers diploma programmes in irrigation and land use planning. The initiation of these irrigation schemes sparked the demand for power tillers in Mbarali district, which partly explains the prevalence in their use compared to the other districts.

The increase in the number of power tillers in many other districts comes in the wake of a directive from the Prime Minister to all District Councils in 2010 following the adoption of Kilimo Kwanza initiative, for each to procure 50 power tillers each year. In turn, the councils would distribute these machines to small farmers and farmer groups. Under this arrangement, farmers would contribute 20% of costs while Councils, under the District Agricultural Development Plans (DADPs) would subsidize 80% of the cost. Many district councils

responded, although most procured them in phases due to budgetary constraints.

Clearly, the introduction of power tillers was influenced by the government, supply driven from the top, although in Mbarali district, demand was complimented by the introduction of the irrigation farming schemes. The initiatives from the agriculture training institute at Igurusi in Mbarali were also a catalyst for the irrigation scheme development. As will be seen subsequently, agro-ecological conditions and farming practices had an influence on differential demand. The decision to promote the use of power tillers country wide in the late 2000s in the context of “Kilimo Kwanza” did not take into account technical characteristics of power tillers and the differences in agro-ecological conditions as determinants of their effectiveness. The political and administrative dexterity prevailed over technical considerations.

Response of private sector to changing demand for power tiller use

Initial supply of power tillers by private traders was pioneered by Auto Sokoni Limited, an importer of various agricultural machinery operating in Dar es Salaam and other urban centres in Tanzania. Auto Sokoni had in stock few units of power tillers made by AMEC group of China, to whom they had been agents. Soon after the demand in Mbarali district surged, Auto Sokoni responded by importing more units and opening up supply branches in Mbeya and Iringa regions, from where they could serve rice farmers and others in the neighboring districts.

More and more traders began to import power tillers from China, and others dealt with spare parts. For the earlier make of power tiller-KUBOTA from Japan supplied through the project under the Ministry, the supply of parts that were originally supplied with the machines was running out of stock. The coordinators of the project had an earlier agreement with International Motors, an agent of Toyota to provide dealership for spare parts, but because the market segment was small relative to their main segment, they opted to pull out of the agreement. So the supply of parts for these machines became problematic. This problem made the Chinese-made machines more popular, because spare parts were readily available. New problems have, however, emerged in the supply of parts. As is the case for other types of machines, genuine parts are often more expensive than generic ones, making consumers to prefer cheaper ones. Unaware of significant quality differences, some owners of power tillers have been exposed to cheaper parts that are of lower quality, resulting to frequent malfunctioning. These are supplied by different traders who stock machinery and auto spare

parts. In addition, many other types of power tillers have been introduced in the market, including those from India, Korea, and Thailand. For most smallholders who choose to buy power tillers, the main driver of the choice of type is the price, although the experience of previous owners of power tillers also dictates these choices.

Ownership of power tillers by groups or individuals

There are three categories of owners of power tillers. The first are individuals who purchased these machines on their own from suppliers. The second are the individuals who benefited from the loan or the subsidy scheme, and the third are farmer groups who acquired their machines through a subsidy scheme from the District Council. The first category was influenced more by need arising from their agricultural activities, while the rest were more supply driven. As the data and the institutional process of introducing power tillers suggest, owners in Mbarali district acquired their machines mainly by purchasing them on their own or through their already established Savings and Credit Cooperative Societies (SACCOS). Survey data shows that majority of power tillers in Kilombero district were acquired through the support of the District Councils, and so are owned by farmer groups, a condition preferred by District Councils as a way of reaching many farmers. Under this system, farmer groups pays 20% of the machine cost, while 80% is subsidized by the District Council. It has not been possible to establish directly whether ownership type matters for the outcome. It appears, however, that, individual ownership is most likely influenced by demand by owners rather than driven by supply, and so it is more likely to be associated with more positive outcomes.

Embeddedness of local knowledge in product design and adaptation to local needs

Effectiveness of power tillers is influenced in part by the design, but also knowledge of those operating them. Conventionally, these machines are known as two-wheel, hand operated tractors. Three features determine their effectiveness. First is the ease of control, so that more engine power is used more on tilling or any other intended use than in operation. Thus, the design and the engine power are not expected to exceed 14 horse power. The second is convenience to the operator, such as the ease of reach to the command tools, and third is the comfort of the operator. If conditions for the correct application of these machines are not met, it is likely to discourage its use or lead to modification by users and suboptimal use.

In terms of their functions, power tillers derived their name essentially from power tilling, but tilling is just one component, albeit the main component. The Rotovator, also known as rotter hoe is the key implement that was designed for tilling light soils, applied for functional time and energy that human power could not produce. Other operations that power tillers undertake, also hand operated are ploughing, harrowing, ridging, and water pumping, but additional equipment have to be acquired by the owners for these purposes. Another operation, the only operation that provides for a seat for the operator is trailing.

Survey results revealed that all farmers in Kilombero and Mbarali districts own plough (disc/mouldboard). However farmers in Kilombero district also own trailer (93%), rotovator (80%), cage wheels (59%) and harrow (56%). Whereas in Mbarali district farmers own cage wheels (92%), trailer (82%) and rotovator (72%). Water pump and transplanter are not as common and would seem to play a minor role in agricultural production. There have been various modifications undertaken by farmers or owners of power tillers to suit some local needs, that is locally driven re-engineering, which suggests that the products were not initially re-engineered or designed for adaptations in different agro ecological conditions. Most significant modifications are done on implements, as reports 74% of respondents in Kilombero. In fact, most modifications are reported in Kilombero than in Mbarali, and seem more prominent on the trailers with the aim of increasing carrying capacity, a reflection of desires for using these machines for transportation. Some modifications are also undertaken on the hitching system, which is the way some implements are attached to the machine. 35% of owners reported to have modified implements in Kilombero as compared to 12% in Mbarali. Some of these modifications are done without regard to the power generation or intended designs, contributing to failures, frequent breakdowns or even injuries.

Effectiveness of power tillers

While power tillers were introduced in many districts through administrative directives, it is clear that they fit in certain production situations but not in others, a fact that was not keenly considered in this decision process. As a result, applications are different and so are the outcomes. The striking differences in the rate and type of use of power tillers in Mbarali and Kilombero districts underscore this point. While both districts produce paddy, farmers in Mbarali district practice irrigation using runoff water and water from rivers through irrigation schemes. Irrigation schemes were gradually developed and formalized under the supervision of district authorities in the 1990s. The schemes constitute irrigation organizations

of small farmers, organized on issues of water rights and access to credit. The key agro-ecological feature is that clay soil is usually hard to till by hand hoe when dry, and hence the popularity of power tillers in terms of power and affordability. Power tillers, however, cannot operate effectively on hard clay soils. It is for this reason that power tillers have been used more extensively for field activities in Mbarali district compared to Kilombero district, and outcomes are different. By 2013, Mbarali district had about 44,000 acres under 80 smallholder irrigation schemes. The schemes vary in size, but the average of 3,000 smallholder farmers cultivates approximately 2,000 hectares of land.

On the contrary, farmers in Kilombero district have continued to rely on rain-fed farming, so that the use of power tillers for ploughing is limited to a short period between the beginning of rains and planting time when soils are less hard. This has made the use of these machines less prominent for field operations in Kilombero district than in Mbarali district. **Table 4** shows the activities under which power tillers operate in the two districts.

Table 4. Usage of Power Tillers in Mbarali and Kilombero Districts

	Activities	Mbarali		Kilombero	
		Responden	%	Responden	%
1	Farming	60	100	7	17
2	Transportation	46	77	31	66
3	Irrigation	6	10	0	0
4	Threshing	2	3	0	0
5	Grounded	0	0	8	17

Source: Survey data

Clearly, Mbarali farmers use power tillers more directly on agricultural related activities than is the case with farmers in Kilombero district. Even though 77% of owners in Mbarali use these machines for transportation, in most cases it is for transportation of farm inputs or produce to or/and from the farm, as explained by farmers as well as the District Agricultural and Livestock Officer. To the contrary, most transportation in Kilombero district is treated as a business in its own right and is not necessarily connected to farming activities. In Kilombero district, farmers complain that these machines do not generate enough power to till the dry hard soil. This concern has also been echoed elsewhere including by ministry officials.

It can also be seen that, a significant proportion of power tillers in Kilombero district were reported as being grounded. This is further corroborated by many formal complaints by Kilombero district farmers through the Council. Documentary evidence on power tiller malfunction availed by farmers as well as District Council vis-a-vis the supplier confirms dissatisfaction of farmer groups on the functioning of these machines. In one such communications in April 2011, the supplier was required by District Council to pay a visit to the district in order to inspect and fix problems of these machines, cited to emanate from three sources, namely technical specifications; operational; and manufacturer shortfalls. A subsequent letter addressed to the District Executive Director from the chairperson of farmer group in Kiburutubu Ward confirmed that the technician from the supplier went to the site to inspect the machines and agreed with the observed problems, promising to fix those in their capacity.

In terms of the contribution of power tillers to agricultural output and productivity, and the original intention of their use, results vary between the districts, reflecting the differences in the intensity of use of power tillers in the primary farm activities. **Table 5** shows the response of farmers in the two districts with respect to improved agricultural productivity, mainly in terms of improvements in crop yields per unit of land.

In Kilombero district, respondents in farmer group category indicated that power tillers had not increased their agricultural productivity because the farmers in the groups do not use them for agricultural activities. For the case of the individual farmer's category, almost 50% of the respondents indicated power tillers to have improved agricultural productivity. The overall results however, indicate that 57% of the respondents have not been able to improve their agricultural productivity. As explained earlier, this has been attributed to the fact that power tillers fail to generate sufficient power to be able to plough the soils of the area.

Table 5. Improved agricultural productivity

S/No	Response	Kilombero District				Mbarali District	
		Group	Individual	Respondent	%	Respondents	%
1	Yes	0	20	20	43	55	92
2	No	6	21	27	57	5	8

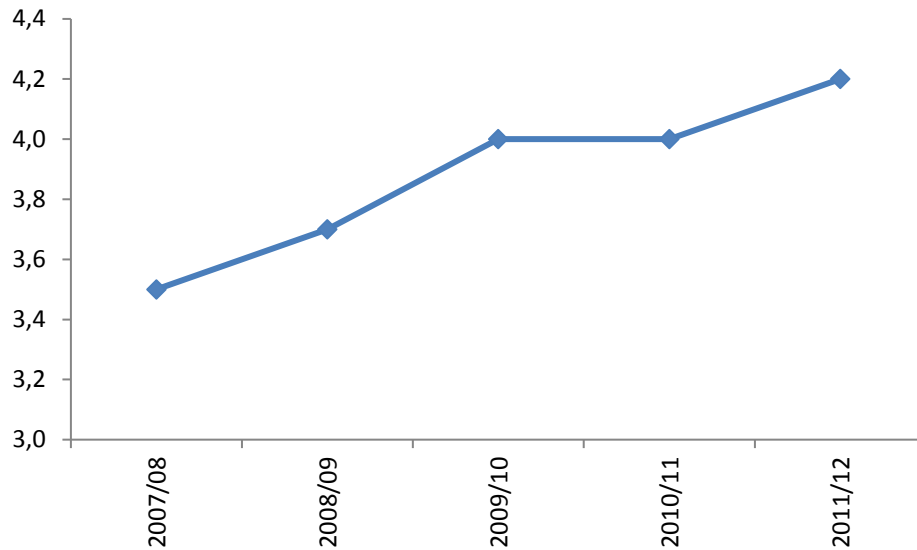
Source: Survey data

For the 43% of respondents in Kilombero district who indicated to have improved their agricultural activities associated the power tillers with the ability to prepare a good seed bed. Hence farmers use these machines to transplant paddy contrary to previous planting technique where they used to plant by broadcasting.

On the contrary the majority of respondents (92%) in Mbarali district, claim to have improved their agricultural productivity through the use of power tillers as they are now able to prepare their farms better and on time with the use of rotovators. The extra income obtained is used for purchasing fertilizers, which is applied on their farms. As a result the amount of paddy produced per unit area has increased considerably.

The few farmers (8%), who claimed not to have improved their productivity, associate the failure to late planting and failure of using sufficient fertilizer on their farms, rather than on machine malfunction. Data provided by District authorities in Mbarali corroborates farmer's claims on increased productivity, especially of paddy, as shown in Figure 4.1

Figure 1. Productivity change (yields) in Mbarali in tonnes/hectare 2007/8-2011/12



Data Source: Mbarali District Council

While productivity is reported to have increased as a result of the use of power tillers in some areas, it is possible that some other factors may have contributed. However, the available data cannot provide a detailed analysis of these other factors. In addition, the sample size is not large enough for disaggregate by categories of land size, gender, or prior income for analysis of significant variations.

In terms of transportation cost the results in **Table 6** shows that 91% of the respondents in Kilombero and 80% in Mbarali districts have reduced their transport costs. The trailer has a seat, which allows the user to ride behind the power tiller instead of walking as for the case of ploughing, harrowing, and puddling. Power tillers are therefore used to transport different goods including produce, firewood, water, building materials, etc. The 9% (Kilombero) and 20% (Mbarali) of the respondents claiming not to have benefited do not own power tiller trailers.

Table 6. Reduced transport costs

S/No	Response	Kilombero District				Mbarali District	
		Group	Individual	Total	%	Respondents	%
1	Yes	3	40	43	91%	48	80%
2	No	3	1	4	9%	12	20%

Source: Survey data

In terms of area under cultivation, **Table 6** shows that a majority of the respondents (57%) in Kilombero district have not increased their area under cultivation because they use their power tillers mostly for haulage. Farmers who claimed to have increased their area under cultivation (43%) in Kilombero district reported to do so because of flexibility in their operations in terms of timing and reduced drudgery.

In Mbarali district 80% of farmers responded to have managed to increase the area under cultivation (**Table 7**). The increased areas vary from 1 ha to between 2 and 3 ha and few farmers have increased from 2 to 5 ha of paddy production. This has been attributed to availability of irrigation facilities (schemes) as well as possession of power tillers and tillage implements mainly ploughs and rotovators. Although farmers in Mbarali district appeared to have increased the area under cultivation they reported to be facing a new challenge related to transplanting. Transplanting in Mbarali district is mainly done manually by using hired labour. With an increase in cultivated area, the demand for hired labour has gone up, resulting in increased labour costs. Therefore farmers in the area are looking for alternatives. Currently farmers are working closely with Mbarali district council to explore ways of acquiring rice transplanters that will be powered by power tillers. While these effects are seen as challenges, they are also a result of positive externalities arising from the application of this farming technology, as it has created additional avenue for increasing area under cultivation and farmers' incomes. Reduced transport costs and increased farmer incomes accruing from transportation services can also be considered as positive externality.

Table 7. Increased area under cultivation

S/No	Response	Kilombero District				Mbarali District	
		Group	Individual	Total	%	Respondents	%
1	Yes	0	20	20	43%	48	80%
2	No	6	21	27	57%	12	20%

Source: Survey data

Institutional support for user knowledge and maintenance

At the time of introduction of power tillers, very little knowhow existed on the use and maintenance of power tillers, neither at the Ministry and other institutions nor the farmers or operators of power tillers. As suggested by some officials, there were no sufficient preparations on the part of farmers on how to operate these machines under optimal conditions. Another

official from the supplying unit noted that, part of the complaints from farmers emanated from lack of preparations on the part of the users to understand conditions under which these machines could be put into use and to avoid unwarranted modifications.

Power tiller operators are important in making the technology useful to both small and medium scale farmers. The key responsibilities of operators are to operate power tillers and to carry out normal routine maintenance that prevents them from frequent breakdowns and major repairs. Employing a competent operator ensures better returns on the investment. Thus it is very important for an operator to be trained.

Results from Kilombero district show that very few power tiller operators (4%) acquired operation skills through formal training. This also applies to Mbarali district where it was revealed that none of the operators had an opportunity of attending formal training. The formal training in operating power tillers in Kilombero district was conducted at VETA - Mikumi for 3 weeks, but unfortunately the study could not adduce reasons as to why other operators (96% for the case of Kilombero) had no opportunity of attending the training.

The other operators in both districts acquired skills to operate power tillers through on job training for different periods of time ranging from one day to one year. Others acquired skills by being trained by suppliers of power tillers for one day. This was the case with operators of power tillers owned by farmer groups in Kilombero district. This could be one of the causes of grounding about 50% of power tillers owned by farmer groups.

Similarly there was no robust maintenance support system in many areas of the country. Repair and maintenance, therefore has been a challenging prospect, although it has evolved over time. Repair works and maintenance are measures taken to maintain and restore the performance of the machine. These measures aim at prolonging the life span of the machine. Repair works are undertaken to replace different parts of the machine. These include both scheduled and unplanned replacement of parts. The term maintenance can be defined as the work done to ensure that failure does not occur before a specified life span of the component has been reached. This includes cleaning, daily oil check, greasing, battery inspection, engine tuning and general check-up of the machine. Usually maintenance work is graded on daily and seasonal basis. To carry out repair works and maintenance it is therefore important to have a reliable source of spare parts and trained personnel.

In Kilombero district the study has revealed that spare parts for power tillers are obtained from different places including Ifakara, Mngeta, and Mang'ula villages. The distances from where the power tillers are based to spare part shops in these areas lie in most cases in the range of 1 km to 80 km. However if a spare part cannot be found locally it may be sourced from Iringa, Mbeya or Dar es Salaam.

Farmers in Mbarali district purchase spare parts mainly from Chimala and Madibira villages. Other places include Mbuyuni, Ubaruku, Mkunywa Kijijini, Rujewa and Mahango villages. On rare occasions farmers travel either to Iringa or Dar es Salaam to purchase spare parts. Chimala and Madibira villages are in the range of 0.2 to 30 km to most of power tiller owners.

Although Mbarali district subsequently developed better local capacity for maintenance of these machines, it presents an exception rather than the rule. First, because of high demand, the traders, especially Auto Sokoni Ltd moved in quickly to set up a supply base within the district, with several agents also selling spare parts. Second, the agricultural training institute located at Igurusi in Mbarali district imparted knowledge and skills through field demonstrations on irrigation. Combining this and the service from local mechanics working with private suppliers, maintenance capacity was built, which led the farmers in the respective areas to even modify some features of these equipment. The most common form of modification as noted earlier was mainly on the trailers in order to increase axle load. These included the replacement of original axles with stronger locally fabricated axles and a replacement of original rims with stronger and wider locally modified rims.

It can generally be concluded that power tillers are simple machines that can be easily repaired and maintained in rural areas using existing skills. Their reliability in terms of undertaking proper work according to specifications, however, and identifying genuine parts and undertaking appropriate modifications is doubtful. The potential for positive externality in raising local engineering skill base exist, but the linkage between manufactures, suppliers, farmers or machine operators as technology users is not robust enough to achieve full benefits of frugal innovation as its theory projects. It could not be established why this is the case, but two hypotheses can be project. First, the volumes of the machines supplied in Tanzania are too small relative to global share for the manufacturer to invest in the desired linkage. Second, national system of innovation is not robust enough to propel local adaptations of technologies and innovations. These may limit effectiveness of this technology and its demand in Tanzania the long run.

Design elements of power tillers that make them suitable

Power tillers in the study areas were found to be attracting young operators, a majority of whom are between 21 and 30 years old. This was revealed by 51% of the respondents in Kilombero and 60% in Mbarali districts. The fact that power tillers attract young people, this has a positive impact on reducing the rural to urban migration. The current trend has been for the educated and young people migrating from rural to urban areas to liberate themselves from drudgery associated with the hand tools technology in agriculture leaving the aged people in the villages.

The elements of power tillers that make them suitable include the source of power which is the engine rather than human, and the size of these units, which are smaller and cheaper. Power tillers have a mechanism for hitching different implements for different operations including tillage, pumping of water, threshing, transportation, etc. The provision of a seat also makes power tillers to be suitable for transportation purposes.

Apart from all these design features the technology was not fully accepted in all places where it was introduced. In some areas like Mbarali district the technology was well received, although numbers of modifications were also undertaken. In Kilombero district the technology proved to be somewhat of a failure as it could not perform as expected in primary activities in agriculture, principally because of key design of the engine power generating capacity for tilling hard soils.

5. Contribution of case study to the main research programme

The broader hypothesis of the main research programme is anchored on the important role played by embeddedness of local knowledge and technology networks in re-engineering of high-value products in ways that can make them attractive and useful by those in the BoP, potentially a high volume market for manufacturing firms. The absence of this embeddedness of local knowledge is likely to constrain successful re-engineering or even the adaptability of the products concerned. This case study have shown how the lack of embeddedness of local knowledge and agro-economic conditions in the design of power tillers have rendered them ineffective in areas that do not have complimentary interventions, notably the irrigation scheme. Local knowledge has been applied ex-post, mainly in modifying certain functions to suit other needs that were considered secondary, particularly transportation.

Not many efforts have been done to promote local assembly or customization of power tillers, except a failed attempt by one private company located in the Western Lake zone to produce power tillers. The Centre for Agricultural Mechanization and Rural Technology (CARMATEC) based in Arusha, a state institution established in 1981 should have played a leading role in identifying appropriate machines and technologies, or propose customization to make them work better for the intended purposes, but it seems to have played only a role in this particular process. Only a few machines that were procured directly through the Government tender or specific projects were passed through CARMATEC for testing and advice. The majority of these machines, especially those imported by traders did not use CARMATEC, perhaps because the law does not strictly require all imported agricultural machinery to be tested and approved by CARMATEC.

The study confirms the hypothesis of generalized failures related to technical design, reflected in the low power generation relative to dry clay soils that characterize many farming districts in Tanzania. The institutional limitations are also evident in the supply-driven approach, which was not conscious of agro-ecological differences and the importance of scaling up training on mechanization for users and its system for maintenance to achieve positive results. The demand of power tillers and the corresponding positive contribution to farm and livelihoods in Mbarali is not a reflective of routine institutional platform for promoting this innovation, as this is not

the case in many other districts for which power tillers have been promoted. In addition, the manufacturing firms have not responded to the needs arising from this diversity in the agro-ecological conditions in Tanzania.

6. Conclusion

This study on power tillers was carried out as a pilot project for a broad research project to be led by Leiden-Delft-Erasmus (LDE) consortium. The broad research project intends to focus on the role of innovation, technology transfer and technology networks in Africa's economic transformation, using the notion of frugal innovation. This pilot project was carried out in order to establish how different actors were involved in the introduction and application of power tillers in Tanzania. Overall, the study suggests that power tillers in Tanzania were introduced using top down, state-led induced innovation that was not adequately informed by technical and agro-ecological differences. As a result, power tillers were imported from different Asian countries and no reengineering was carried out in their designs to suit the local needs. In addition, no thorough preparation was put in place in terms of identifying the needs of users, training of operators, and setting up maintenance and service system. Frugal innovation entails more than just reducing the complexity and costs of products or services while retaining basic functionality. It also entails a functional interface between technological and institutional dynamics.

The end result is that in some places the technology was adopted with some modifications, whereas in others the technology was found not suitable for the purpose that was initially conceived. Local innovation resulted, however, as positive externalities, where secondary use of transportation and haulage of goods prevailed over primary farming functions. Power tillers can therefore provide solutions to primary concerns on agriculture mechanization for smallholders only where agro ecological conditions commensurate with the current technical design of power tillers. The study also suggests that the political economy of agrarian transformation needs to address the diverse needs of the farmers and package interventions that are appropriate to agro-ecological conditions and socio-economic environment that may be crop specific, market specific, or locational specific.

References

FAO (2008) 'Agricultural mechanization in Africa: Time for action. Planning investment for enhanced agricultural productivity'. Report of an Expert Group Meeting, January 2008, Vienna, Austria.

FAO (1997) Food and Agricultural Organization. Production year books Vol. 12(1958); Vol. 19 (1965); Vol 25 (1971); Vol. 40 (1986); Vol. 45 (1990); Vol. 49 (1995); Vol. 51 (1997). Rome, Italy.

Kjaerby, F. (1986) The development of agricultural mechanization in Tanzania. In: Boesen, J. (ed) Tanzania. Crisis and struggle for survival. Scandinavian Institute of African Studies, Uppsala, Sweden.

Mmari, D. (2012) Institutional Innovations and Competitiveness of Smallholders in Tanzania. PhD Thesis, International Institute of Social Studies.

The Economist (2012) First Break All the Rules: The Charms of Frugal Innovation. The Economist. 15 April 2010 (Retrieved July 06, 2012)