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Farm Mechanization of Small Farms in Ethiopia: A Case of Cereal Crops in Hetosa District

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ABSTRACT

Farm machinery utilization for small farm holders in Ethiopia is not prominent. Reliance on draught animal technology and low productivity had been observed. It has been a question to most of the people why our agriculture relies on animal power, and people agree that this has to be changed. But how to change should come about. Based on these problems the study aimed to investigate the existing conditions of small-holders farm mechanization and to evaluate the effect of using agricultural machinery on crop production particularly on main cereal crops. In order to achieve the objective of this study, different methods were used. Data were collected from randomly selected 90 farmers using stratified random sampling techniques. In order to see the effect of farm machinery on crop production, linear regression was used. In addition, three mechanization models i.e. Model 1: traditional farming; Model 2: Semi- mechanized farming; and Model 3: Mechanized farmings were developed. They were compared in terms of machine-hours, man-hours, draught animal-hours, labor required, land and labor productivity. Furthermore, these models were compared by the mechanization input and output energy consumptions. In addition, mechanization status of the study area and existing farm machineries time and use dependent costs and economic feasibility of owing farm machinery were determined.

The results indicated that using farm machineries and associated technologies has a positive and significant effect on cereal crops productions. Among three models, traditional wheat farming was more labor intensive by 86.7% and 88% than the semi-mechanized and mechanized farmings respectively, and the number of days required for the complete farm operations was greater for the traditional by 72.2% and 94.4% than those required for the mechanized and semi-mechanized farming respectively. It was found that mechanized farming was labor and time saved technology more than the traditional and semi-mechanized farming. Mechanized and semi-mechanized farming played a significant role by reducing the operations hours of cereal crops which have timeliness effect on production. It was found that the mechanized and semi-mechanized farming were more land and labor productive than the traditional farming. Labor productivity was increased by 94.2%, 95.6% and 61.42% for wheat, barley and maize farm operation respectively when the traditional farming was mechanized. Besides, productivity by the mechanized and semi-mechanized productions was more than those by the traditional production. Hence, traditional farming was not economical.

However, from the energy prospective, total input energy for the semi-mechanized farm for wheat was more by 95.47% and 77.14% than those by the traditional and mechanized farmings respectively. Energy efficiency and productivity by the mechanized and traditional farmings were more than those by semi-mechanized production. Finally, low mechanization level, improper machinery handling, over-utilization, high repair and maintenance, and fuel and oil costs were identified. However, this study found impressive results which could invoke and inspire farmers in the study area to own tractors so as to get return in a short period. The last but not the least, choice of farm machinery for the framers in the study area is crucial. Hence, it is recommended that the government to design proper mechanization policies which could change current traditional farming systems of small farm holders to power assisted ones.

Key words: farm mechanization, mechanization modeling, farm machinery, energy, cereal crops

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INTRODUCTION

Geographically, Ethiopia is the largest country in the horn of Africa with a total land size of 1.127 million km^2. The population is estimated to be 93.3 million (CSA, 2013) with an average growth rate of 2.63% per annual. As in other many developing countries, the Ethiopian economy depends predominantly on agriculture and about 85% of the populations are rural dwellers while the remaining 15% is in urban. There are 111.5 million hectares of land in Ethiopia, 74.5 million hectares of which is suitable for agriculture and 13.6 million hectares of which is currently under production. According to Ethiopian Central Statistical Agency (World Bank, 2013/14), agriculture contributes about 40.2% for the country gross domestic product (GDP) and it also accounts for 80% of total employment. Crop agriculture accounts for about 29% of GDP followed by livestock for 12% and for forest at 4%. Agriculture is predominantly in the hand of small farmers working on individual small holdings mainly for house hold consumption. The holdings have remained fragmented and insufficiency (Temesgen et al., 2001).

Despite the big potential, agriculture in Ethiopia is characterized by very low productivity and the average grain yield for main cereal crops is less than 1 ton per hectare. Mostly farm power is draft oxen and human muscle in the land preparation, planting (CIMMYT, 2014 & Deribes et al., 2014) and post-harvest operations, for main cereal crops, which is the main cause of low productivity. Food shortage in the country is increasing. The low productivity in agricultural production has made it difficult to attain food self-sufficiency for the country. The solution to low productivity of agriculture is to improve the traditional farming practices (Azerfegn and kassa, 2008). According to CSA (2014), the population of the country is increasing with an alarming growth rate of 2.63% per annum. This number is expected to reach 117million by the year of 2030 (The world fact book, 2012).

Agricultural mechanization is an important link in achievement of effective growth in agricultural production. However, the greatest source of farm power in Ethiopia for land cultivation, seed bed preparation, harvesting, and threshing sticks on human and animal power. According to World Bank (2003), in Ethiopia about 14 million oxen were routinely used for cultivation. The country has been using these draft oxen since dated back 2000 BC (FAO, 2007). In general, the majority of small farm holders have been cultivating their lands manually except some parts of wheat growing regions of Arsi and Bale high lands (CIMMYT, 2014). This is a clear indication that the country's agriculture is characterized by its low level of mechanization which can't soundly gear towards the technological advancement. But in other nations, increasing advent of mechanized farm equipment dramatically increased agricultural productivity over the past hundred years. For example, in 1900, 40% of USA population worked to feed the county. Today it is only 2% by mechanized farming (Fawccet et al, 2007).

One of the keys to success in food production in Asia and Latin America has been farm mechanization but in contrast, the use of tractors in sub-Saharan Africa has actually declined over the past 40 years and compared with other world region, their use in sub-Saharan African today is very limited. Tractor use over the same period in Asia has increased tenfold. For example, mechanization levels of Philippine and Japan were 0.15 kW/ha and 2.25 kW/ha respectively in 1968, while in 2005, the values were raised to 1.02 kW/ha and above 7 kW/ha respectively. Similarly, since 1997, other Asian countries like Korea, China, India and Bangladesh, farm powers required were 3.08 kW/ha, 2.91 kW/ha, 0.75 kW/ha and 1.17 kW/ha respectively (AGMACHIN, 1998 & Soni and Ou, 2010). In 2009, the number of tractors, power tillers and combine harvesters in Korea were 258,662, 714,537 and 79,561 respectively (Kim, 2013). Total arable land was 10 million hectares during this time (Kim, 2011). Based on these facts, mechanization levels for the tractor, power tiller and combine harvester were 25.6, 71.5 and 7.9 respectively. But in Ethiopia, currently this power is 0.1KW/ha which is incredibly by far less than Bangladesh's fifteen years back power level.

It is clear that agriculture in Ethiopia is the largest sector and back bone of the economy. It accounted 90% of export and 85% of labor force (World Bank, 2013). Therefore, no doubt to every one as agricultural performance has significant effect on output and the corresponding income and poverty level for the majority of the population. The improvement of agriculture is then paramount in poverty reduction as an action that increases agricultural production will insure availability and access to food and improve farm income and thus reduce poverty.

The country has great potential to agriculture because of its vast area of fertile land, diverse climate, generally adequate rainfall and large labor pool. Despite this potential, however, Ethiopia agriculture for many decades remained undeveloped. This is due to quite a lot of factors. The largest shares were low level of mechanization inputs and low level of technologies. The shortage of farm power has been identified as one of the limiting factor to increasing crop production in several sub-Saharan African countries (FAO, 2001 & 2006).

In Ethiopia, 75 million hectors of land is suitable for agriculture. Out of these, 15 million hectares were only utilized while the remaining 60 million hectares remains unutilized (CSA, 2012). Despite of this huge land, the government hasn't used this opportunity to utilize the land with mechanical means /farm power/ in order to alleviate food deficit and supply raw agricultural products to agro industry found in the nation to lesser extent. Currently, the government of Ethiopia realizes the importance of agricultural sector for the country and formulated its economic strategy to agricultural development lead industrialization policy (ADLI), however, the strategy doesn't support mechanization of small farms as a policy.

Nowadays, food security is considered to be a need as well as a right, taking account of a measure of democratic governance (Mohammad, 2014). In addition, food security is perceived as factor laying the foundation of independency and freedom of the nation (Rokhoddin and et al., 2004). Food security is the corner stone of the developed society as well as being essential element of its member's mental and physical element. Although food security is a multidimensional and multidisciplinary concept, being closely related to the national interest and national security of the society, the agricultural sector, in any country plays the most important role (Clarke, 2000). In fact food self-sufficiency for one nation is the issues of live and death unless giant economy and well industrialized country which doesn't rely on agriculture and capable enough to import required food crops.

In such conditions where the population of the world grows with an alarming rate, the role of mechanization in agricultural production should stand out than before. Attention should be given to modern mechanization technologies in order to enhance agricultural productivity and achieves sustainable development (Almassi et al., 2008). In fact, the wide mechanization of agriculture in the developed countries has been widely recognized as key element producing high standard of living (Reid et al., 2003). For the economic stability of developing countries like Ethiopia whose 90% of the farmers hold less than 2 hectares (CIMMYT, 2014), more attention must be paid to small farm holders who are a majority (Yohanna, 2004) by means of mechanization through which land use intensification and productivity of labor achieved (IFPRI, 2015). Small farm mechanization could pave the way for food security in the light of sustainable development (Bakhado, 2010) by providing farmers with new facilities such as cropping, time lines of production process, improvement of the quality of the agricultural operations in order to meet local food required.

1.1. Background and justification

According to United Nations projection, in 2040, the world population will be over 9 billion. In the coming two decades, 50% more food, 45% more energy, and 30% more water will be needed in the world. With the same circumstance, in Ethiopia, the number of population is increasing with an alarming rate. According to World Bank (2012), by the year of 2030, the number of population will be 117 million. In existing situation, the country is characterized by high growth rate of population, low productivity of food crops due to low modernization of agriculture, and high food scarcity.

On the contrary, for the last ten years since the country implemented the agricultural development lead industrialization (ADLI) policy (strategy views agriculture as an engine of growth), incredible achievement has been recorded with double digit agricultural GDP. Because of new economic policies and strategies, and introduction of new extension packages increased use of fertilizer and improved seeds; relative improvement in crop production was observed. But, this achievements and agricultural production unbalance with rapidly growing of population. The fact shows that at same parts and urban areas of country, the population has been facing shortage of food supply. As one of tangible evidence, Ethiopian revenue and customs authority 2014 data base shows that the country imported 59.66 million kg (596.6 thousands quintal) of durum wheat from India in the year of 2014 in order to fill the gap happed in the county in this regard.

Awulachew et al. (2007) reported that Ethiopia has 300 billion m^3 of water potential, 75 million hectare cultivable land, 3.7 million hectare irrigation potential and suitable agro ecology. Despite of the availability of all these natural resources, achieving agricultural productivity growth can’t be possible without developing and disseminating improved agricultural technology which increases small holder, improving rural house hold welfare required effort to yield enhancing resource

In Ethiopia, Out of 85% rural community, farmers holding lands less than 5 hectares were accounted 89.8% (CSA, 2011). Their yields per hectare for major cereal crops were less than one ton in average. This figure is very much less than that in most other developing countries. Elias et al (2013) revealed that average wheat observed from extension participants was less than extension target (43-58) by one third of quintal per hectare. The farmers have been relying on traditional farming practice which produces poor yield output per hectare. Small farm-holder agriculture is extremely labor intensive and drudgery of farm work is another factor limiting productivity.

Farm equipment utilization is observed less due to less attention of government to promote farm equipment and lack of mechanization policy. As CSA (2014) data shows, the number of farm equipment is very few in the country. The ratio of farm machine to the 1,000 hectare is 0.5 for tractors and 0.1 for combine harvesters by the year of 2014. Attention to small farm holder utilizing farm power is more likely less due to the aforementioned facts. They have less insight to and knowledge about benefit of farm equipment and its effect on crop production in all aspects in Ethiopia.

The problems are becoming serious because alarming rate of drought animal price, and high demand of food crop at national level due to scarcity of cereal crop production to the controversy of sufficient and suitable arable land and proper agro ecology of the country. It has been a question to most of the people why our agriculture is rely on animal power, and agree that this has to be changed. But how to change should come about. Most importantly, in Ethiopian condition, the effect of farm machinery on the production, socio economic of small farm holder, and profitability issues need to be thoroughly investigated. Hetosa district was selected as study site because this area is found in main cereal crops-based systems of Arsi highlands, where cereal pre and post harvesting are mainly done using tractors and combine harvesters along with animate power. Smallholder farmers in this area are relatively better in terms of agricultural mechanization level which the study thought better to represent other rural areas of the country.

Empirical and analytically supported examining with scientific approach and location, specific attention is given to mechanized agriculture for small farm-holders, by precisely indicating the importance of using farm machinery for production and productivity along with indicators of yield variation of two forms of farming. Since agriculture is energy user and energy producer as well, the relation between agriculture and energy is mutually dependent. Hence, mechanization energy consumption was also considered. Finally, from output of this study, small farm holders’ awareness expected to increase. Other stockholders and government will be awarded and considered results and recommendation in order to shift small holder farm production from manual and subsistent to market oriented, available, stable and accessible agriculture and promote economy scale of small farm holders.

1.2. Objectives of the Study

The general objectives:

The main objectives of this study were to investigate the existing conditions of small holder’s farm mechanization, to evaluate the impact of farm machinery on production output at different mechanization levels and to suggest methods of increasing their income using appropriate combination of mechanization technology.

Specific objectives:

On the basis of general objective, the following specific objectives were drawn:

- To assess the farm mechanization status of small farms as a case study.
- To identify the effect of using agricultural machinery for cereal crop production based on a statistical method.
- To model farm mechanization for small size farm holders to transform manual labor operating farm to powered machine operating one.
- To determined mechanization input and output energy for the models.
- To determine farm machinery management and related costs.
- To estimate farm machinery owing cost and return from custom hiring services.
- To recommend appropriate mechanization policy direction to national policy makers and suggest short and long term cost effective mechanization option for small farm holders.

CHAPTER 2

LITERATURE REVIEW

2.1. Agricultural mechanization review

According to Wikipedia, agricultural mechanization is a process of using agricultural machinery to mechanize the work of agriculture, greatly increasing farmers work productivity. Agricultural mechanization enhances the use of tools, implements, and machine for the agricultural land development, crop production, harvesting, and preparation for storage and on farm processing (Rijk, 1999 and FAO, 2007).

Agricultural mechanization is application of mechanical technology and increase power to agriculture largely as a means of inhuncing the productivity of human labor (FAO and UNIDO, 2008). Rjik (1999) reported that as agricultural mechanization includes three main power sources: human, animal and mechanical and the manufacturer, distribution, repair, maintenance management, and utilization of agricultural tools, implements, and machines are covered under this disciplines with regards as to how to supply mechanization inputs to the farmer in efficient and effective manner. According to FAO (2008), mechanization includes the use of tractors of various types as well as animal powered and human powered implements and tools and internal combustion engine, electrical motors, solar power, and other methods of energy conversion.

Agricultural mechanization implies the use of various sources of improved farm tools and equipment to make farm operation mechanical. This could have been introduce machinery in to an industry, enterprise etc., especially in order to replace manual labor. Because, using machinery reducing human drudgery, increasing productivity, and improving timeliness of agricultural operations such as planting and harvesting, and reducing peak labor demands are among the most prominent (Jayasuriya et al., 1986). Farm work is physically demanding and the working conditions are often harsh. It is less strenuous to drive a tractor than to till the soil with a spade all day long. A tractor pulling a plow can cultivate a larger area than a human with a spade in the same amount of time, thereby increasing productivity and timeliness (ASABE, 2011).

Mechanization technology keeps the change with industry growth of the country and socio economic advancement of farmer whereas declining interest in agriculture of the land owner and non- availability of the agricultural labor for field operation may be one of the major socio economic issues in the highly industrialized nation, increase land and labor productivity with dignity are the mechanization requirement of the developing country. Mechanization is therefore, location specific and dynamic. The quality of input of mechanization and consequently land and labor productivity in both situations may differ considerably (Goffid and Rijk, 1980; Singh, 2000; Singh and Chandra, 2002).

FAO (2013) also added agricultural mechanization as a process of utilization different combination of power, tools and equipment for production process overtime. Farming system typically move from hand tool technology to the selective use of draught animal or tractor for certain operation. The ability to mechanize is determined in part by nature of the operation as well as other technological, economic and financial and environmental consideration. It passes through three mechanization level. These three levels of mechanization have its own degree of sophistication. For example, for land preparation: hand tools technology (the simplest and most basic level of agricultural mechanization) which requires tools and simple implements like hoe, spade etc. Draught animal technology refers to the implement (steel plow, spike harrow, disc harrow and 'Maresha') and utilization of animal muscle as the main power source while mechanical power technology refers to the highest technology level in agricultural mechanization. It consists of all machinery which obtained its main power from the other sources other than muscular power. Inclusively the technology requires power tiller, two wheel and four wheel drive tractors along with disc plow, harrow disc, mold board plow and cultivators (Rijk, 1989; Marteza, 2014).

2.2. Effects of Mechanization on production and productivity

Mechanization of the production also covers the sphere of mental labor. Its main goal is to raise labor productivity and free human from heavy, labor intensive and fatigue operation. Mechanization production promotes rational and economic use of raw and processed materials and power, reduction of prime cost and improvement of product quality. In addition to improvement and replacement of the equipment and production process, mechanization of production is closely linked to a rise in a level of workers skill and production organization and to the use of method of scientific organization of labor. Mechanization of production is one of the main avenues of technical progress. It insures development of productive force and services as a material base for raising the efficiency of public production, which is being developed by intensive method. Mechanization also imparts capacity to the farmers to carry out farm operations, with ease and freedom from drudgery, making the farming agreeable vocation for educated youth as well. It helps the farmers to achieve timeliness and precisely meter and apply costly input for better efficacy and efficiency (Kulakarni, 2009).

So far had been explained in so many literatures as mechanization plays a great role in agricultural production, mechanization may provide a direct increase in land productivity by increasing yields or reducing losses, increasing crop intensification or expanding cultivated area (Duff, 1986). Improved farm implements and machines from time to time may aimed to for different farm operation to increase productivity of land and labor through timeline of operation , efficient use of inputs, improvements in quality of produce , safety and comfort of farmer and reduction in loss of produce and drudgery of farmer (Hunt,1983).

Timeliness is an important factor in agricultural production. Completing certain farming operations such as planting and harvesting in a timely manner increases yields and improves profitability. Farming operations are seasonal with fluctuating labor demand. More labor is needed during planting and harvesting than during other periods of plant growth. This fluctuation in labor demand creates labor management problems. With mechanization it is possible to reduce peak labor demand and maintain a more stable labor force on the farm (ASABE, 2011).

Several authors have studied the status of mechanization with references to the intensity of power or energy availability and its impact in increasing the agricultural and labor productivity (Zangneh and Banaeian, 2014). Power availability in different countries demonstrated that productivity was positively correlated with potential unit farm power (Giles, 1975). NCAER (1981) assessed the impact of tractorization on the productivity of the land i.e. yield and cropping intensity and economic growth (income and employment). Ghadiryanar et al, (2009) studied on the effect of tractor supply in Iran agriculture from micro plan point of view. Their studies shown that tractor has a significant effect on the crop yield and planted areas. In line with this, Xinan et al. (2005) and Singh (2000) depicted that the use of modern technology during recent decades resulted in raped growth of farm production. Tractor and farm machinery are important example of this modern technology.

The end objective of farm mechanization is to enhance the overall productivity and production with the lowest cost. The trends in the European and Asian countries were, however, distinctly different. Rijk (1989) reviewed the growth of mechanization in different Asian countries and suggested computer software (MECHMOD) for the formulation of strategy for the mechanization policy based on the economy of using animate and mechanical powers for different field operations.

Several studies (Zangneh and Banaeian, 2014; Ghadiryanfar et al., 2009; Rasouli, et al., 2009) have been conducted on the impact of mechanization on the farm production, productivity, cropping intensity, human labor, employment as well as income. They concluded that farm mechanization enhances the production and productivity of different crops due to timeliness of operation, better quality of operation and precision in the application of the input. NCAER (1980) in his study on mechanization of sorghum and cotton, 72% and 7% yield (gap) increment was shown compared to traditional farm. Productivity increases on tractor owning and tractor hiring ranged between 4.1 to 54 percent. The percent was comparatively low on custom hiring farm as compare to tractor owning farms due to higher level of input and better control on time lines of operation. Mandal (1975) added in his report that average increase of productivity on farm with renting tractors was reported to be less than tractor owned farm but much greater than that of traditional bullock and these values were 11.8%, 13% and 16% for paddy, sugarcane and ground nut respectively. There is no doubt of mechanization for productivity increment among researchers report. Fawcett (2007), in his study addressed that increasing advents of mechanization farm equipment drastically increased agricultural productivity over the past 100 years.

Farm mechanization boosts farm income than traditional ways of farming or animal drawn farming in developing country (Adamade et al., 2014) which was confirmed by other studies. However, long ago, NCAER (1980) in his study reported that tractor owner and user derived higher gross income per hectare compare to traditional bullock farm and above 63% higher than bullock while average net return per hectare basis was reported to be 152%.

Many researchers reported that a tractor is a very important mechanical machine to reduce human and animal drudgery and enhance agricultural productivity and profitability on accounts of time lines of operation, better quality and more efficient of work and more efficient utilization of crop input (Verma, 1986). Singh and Singh (1975) reported that tractor operated farms give a higher yield of wheat in paddy and sugar cane and produced a higher overall gross output per hectare than non-tractor operated farms. Mandal (1975), have also reported that tractor owned farms obtained productivity of paddy, sugar cane and ground nut by 4.1 to 28.3%, 13.1to 34% and 9.8 to 54.8% with average value of 15.8%, 23.2%, and 31.8% respectively than traditional bullock.

Mechanization generally enhanced human capacity leading to escalation and increased productivity as a result of timely planting, weed control, harvesting, and post harvesting and accessibility to the market. In addition to the above point, FAO (2007) confirmed that it reduces exhaustive work and making agriculture more attractive for the people.

2.3. Ethiopian agriculture

Ethiopia lies within the tropic between $3^{o}24'$ and $14^{o}53'$ North; and $32^{o}42'$ and $48^{o}12'$ East. Land mass has a total area of 1.13 million km^2. Land covers 1.12 million km^2. It‘s 99.3% is a land area and the remaining 0.7% is covered with water body (MoWR, 2010). It has arable land area of 10.01% permanent crop covers 0.65% which other covers 89.34% (Silash et al, 2007).

The population was estimated at about 93 million (CSA, 2013) which puts at the second in Africa followed by Nigeria (Awlachew et al, 2005). 85.3% of the population is leaving in rural while the remaining is in urban (CSA, 2013). Growth domestic product (GDP) in Ethiopia expanded to 10.3% in the year 2013/14. Agriculture is the leading sector in Ethiopia economy which accounts 40.2% of total GDP as compare to industry (14%) and service sectors (46.2%) (World Bank, 2013/14 & Ethiopia Economic Outlook, 2014). The share of agriculture declined from 46% (2005) to 40.2% (2013/14). Although agricultural share of GDP has declining steadily over the past decades, it continue to be the back bone of

Ethiopian economy which is contributing about 80% employment and 70% of export earnings in 2013/14.

Agricultural sector had been facing a number of problems limiting its potential. Vulnerability to exogenous shock like environmental and climatic oriented, especially food creation is relied on rain fed made one of the critical challenges (Awlachew et al, 2007, Ethiopia Economic Outlook, 2014 and African Development Bank, 2010). Market institution is very weak, however, the price is more likely to increase since Ethiopian Commodity Exchange (ECX) intended to disseminate daily price of each item to farmers. Increasing price of mechanization input such as fertilizers, selected seeds, chemicals, (pesticide and herbicides) which are crucially important (Asfaw et al., 2012).

Low mechanization (agricultural technology) practices, over cultivation in densely populated high land, low attention to conservation agriculture continued to constrain agricultural output growth (Benin, 2006). Improving productivity, profitability and sustainability of small holders farming is therefore the main path ways to get out poverty (World Development Report, 2008). The country is at grass root level in mechanization. Achieving agricultural growth and development and thereby improving rural house hold welfare requires increase effort to provide yields enhancing resources (Goshu et al., 2012).

Hassena et al. (2000) confirmed that prior to 1960 livestock to production was the dominant farming systems in the study area. Since 1960, farmers have shifted from live stock to crop production. The sizes of the farm become decreased with increased population and crop land has been divided among more peoples. Hence, due to introduction of mechanized farming (using tractor and combine harvester as farm power) and short coming of farm land the number of draught animal significantly decreased.

Asfew et al. (2012) reported that achieving agricultural productivity growth cannot be possible without developing and disseminating improved agricultural technology that can increase productivity to small holders farmers. Likewise other African countries, Ethiopian agriculture faced lack of adequate farm management practices and low level technology and modern mechanization input usage are the major obstacles to sustain agricultural production in the country (FAO, 2010 & Elias, 2013). They added in their study that farmers advisors (extension workers) can also played a significant role to increase production and productivity by creating awareness to farmers how to use mechanization input. Evidence from the report shows average teff observed farm extension participants (16quintal/ha) was less by 1/3 from extension set target (43-58 quintal/ha) for wheat (Elias et al., 2013).

2.4. Cereal crop mechanization

Cereals such as tef, wheat, barely, maize, sorghum, and millet are the most important field crop and chief element in the diet of most Ethiopian. Cereals are still has dominance in crop production. According to CSA (2014/15) data report, cereals accounted 87.31%. Out of total land crop area, 80.78% was used for cereals production.

Cereals crops mechanization is at infant stage in Ethiopia. In existing condition, commercial crops are intended to mechanize in some other regions. Cereal one is concentrated on the two regions of Ethiopia. Almost 80% of the total areas under cereal were Amhara and Oromia regions to the north west, west, south west of the capital (Addis Ababa). This area included adverse area set of condition of agricultural production (Dia and Nim-prat, 2005; Taddese et al., 2006). Shortage of farm power and mechanization level witnessed as the main element. Giles (1975) reported that power availability in different countries demonstrated that productivity was positively correlated with potential unit farm power. According to Seyoum (2009), Ethiopia’s yield level was lower than the average yield in least developed countries defined by United Nations however higher than east Africa.

Even though, very limited study found about cereal crop mechanization of Ethiopia, Tirfessa (2013) addressed lack of mechanization technology adoption was one of the crucial factors to improve productivity of production. In line with declining both rural population and share of agricultural GDP, rising cost of wage of laborers, and rising cost of oxen make the country in demanding mechanization. However, there is a bottle neck problem which hinders track to mechanization. Guush (2014) and Tirfessa (2013) addressed the following challenges: 1) lack of mechanization policy which promotes farm machinery for agriculture; 2) financing of mechanization which related to loan and concern over risk; 3) technical challenge which related to skill, maintenance capacity, testing and evaluation of machinery. These two studies addressed the importance and challenges of general farm mechanization of Ethiopia. None of the studies yet addressed about small farm holders mechanization and their social economic, mechanization option and existing condition of farm mechanization since it is dynamic and location specific.

2.5. Farm mechanization in Arsi province: scenario of cereal crops

Arsi province is found within the highest elevation zone where predominantly wheat, barley and teff are grown (USDA, 2015). Cereal crops farming in Arsi province is generally labor intensive for small scale. However, in some locations of Arsi such as Asasa, Etheya and Lole, there had been in good progress of using of agricultural machine especially for wheat production (Hassena et al., 2010).

Though agricultural machinery was not introduced in most of regions of Ethiopia, it is not new to farmers who leave in Arsi's aforementioned districts. Mechanization was introduced during establishment of Chilalo Agricultural Development Unit (CADU) in 1969. Since then Arsi farmers had been using mechanical thresher (combine harvester) due to interest arose (Jonsson, 1972).

Before five decades farming system had changed/shifted from livestock dominant to crop production. But the land size becomes decreased as a population increased and sharing house hold land owner to its family (youngsters). Though land size decreases, since 1960, cereal crop yield increased because of decreasing loss of yields (Amdessa, 2015) which was affected by manual operation.

Since 2002 wheat yield seemed to increase due to government encouraging farmers to use improved seed and distribution of fertilizers (USDA, 2015). This encouragement confirmed that mechanization was exclusive of initiatives. Although, farm mechanization of cereal crop assisted with tractor and combine harvester started in Arsi along with set of CADU in 1969, in other African countries it was introduced 1940 in the period of leading to independency thereafter.

2.6. Draft animal technology

Draught animal is the prestigious in Ethiopia for those whose economy is based on agriculture particularly on crop production. From the existing condition, farmers use oxen, mule, horse and donkey as motive power for farm work. According to World Bank (2003), farm power in Ethiopia, like other sub-Sahara African countries relies on animate power. Agricultural and Food Engineering Technical report (FAO, 2007) depicted that the use of draft animals date back to 2000BC in Ethiopia. In Ethiopia about 14 million oxen routinely used for cultivation (World Bank, 2003).The major contribution of farm animal to the agricultural production in Ethiopia is through the draft power provided by oxen. However, these oxen only work for about 60 days a year and the rest of the time they are not used for productive agricultural purposes (Gryseels and Anderson, 1983). The annual working cycle of an ox is characterized by short periods of high intensive labor and long periods of idleness, with about 15% of the feed intake actually used for work and the remainder being just dedicated to maintenance (Wilson, 2003).

Oxen mostly take one year to be trained. The training starting at the age of two and that the working life lasts only about 4-5 years (Spies, 1994). Hence, the farmers should try to look for alternative power sources for the reason the investments on animals concerning training time and feed could not bring better returns. Specially in a country like Ethiopia, where drought occur repeatedly and stays for a long period of time, the life of draft animals has been certainly in vulnerable (EIAR, 2006).

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter discusses the research methodology, location and description of the study site. Physical and socioeconomic situation, agricultural production, mechanization status and technology used were determined. It also focuses on data types and data sources, methods of data collection and analysis. The chapter also discusses the methodological approaches and specific data gathering techniques used. It spells out the sources of data used in the evaluation of the socio-economic impact of mechanization (Agricultural machinery and modern farm tools) on the livelihoods of farmers in Hitosa district. Agricultural mechanization modeling technic and comparative analysis among models on impact of mechanization on productivity, visibility and appropriateness for small farm holders on the basis of current situation was determined. Energy consumption analysis and cost benefit analysis of each mechanization model for three main cereal crops were also discussed. Farm machinery management, fixed and variable costs, machinery basically tractors and combine harvesters owning and return duration from the investment were also determined in the area under study.

3.2. Study site

This study was conducted in east Africa; Ethiopia, Oromia regional government, and in Hetosa District. The study area is located in the Arsi zonal administration of the Oromia Region which is about 175 kilometers from the capital, Addis Ababa. This district lies in between 7°57′N latitude and 39°7′E longitude with an elevation of 2,430 meters. As it was stated in the introduction section, the area was prominent for mechanization than other areas of the region since 1969 (Hassena et al, 2000). Moreover, the study site found in main cereal crops-based systems of Arsi highlands, where cereal pre and post harvesting are mainly done using tractors and combine harvesters along with animate power. Smallholder farmers in this area are relatively better in terms of agricultural mechanization level which the study thought better to represent other rural areas of the country.

Basically categories of farms are depend on the countries. The small farm holders basically in the study area refer to those farmers owning small based plot of land on which they grow subsistence crops regardless of limited resource of lands relative to others large and commercial farm holders in the sectors.

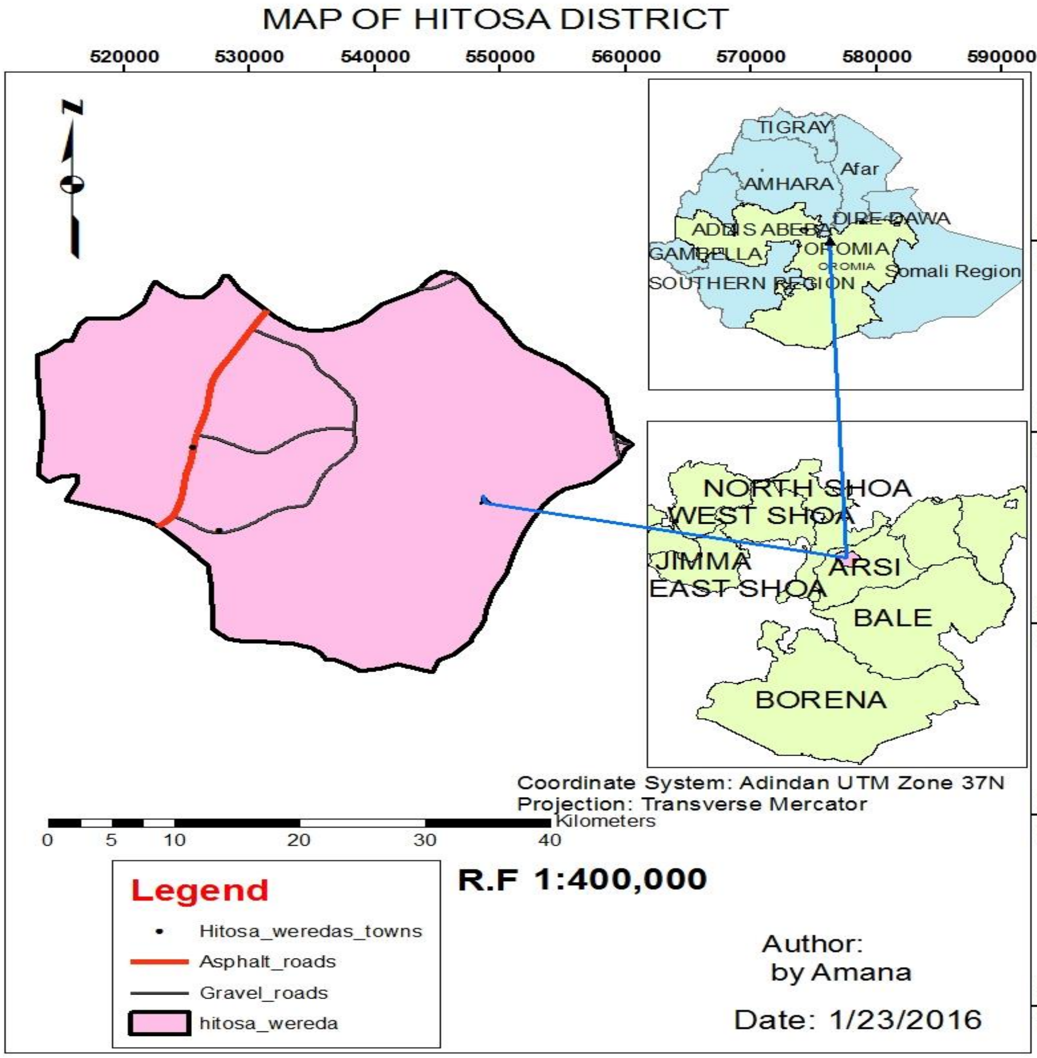


Figure 3.1.Study area map

Etheya is the capital of Hetosa district until today. According to 2007 national census total population of Hetosa was 144,282 of whom 72,535 were males and 71,747 were females. Population density was 209.1 per km^2. The average household is 5 people (CSA, 2012).

The district has 125,802 rural and 22,791 urban populations. The total land area of the district is 68,999 km^2. Topographic area is mostly flat and sloppy in which the altitude ranges between 1200-1500 meters above the sea level. The area's agro ecology is mid and low lands. The area gets rain fall during summer and that extends from the beginning of April to the end of November. The mean annual rainfall of the district is 1,500 mm. Considerable rainfall is received from June to August. The annual temperature ranges from 18 to 24^oC**.** The daily temperature is high from November to March and sometimes reaches to 30^oC.

District practices mixed farming. Various cereal crops like wheat, barely, and maize, are widely produced while tef and mallets are rarely produced. Wheat and barley are dominant crops. Because of the dominance of cereal crops, suitable topography, and long term exposure and awareness about using farm machines of the district, mechanization has been practiced to some extent than other districts. Hence, the district was selected under this study to investigate small holder farm mechanization.

3.3. Research method

It was also included quantitative (the study was preferred quantitative one because of its output clearly understandable and self-description to many readers) and qualitative approaches to data analysis. A regression model was developed for decision analysis of mechanization inputs particularly farm machineries and other variables' effects on production.

Modeling of cereal crops mechanization is done for small farm holders who were in the study area. Comparative analyses among different mechanization models (manual, semi-mechanized and mechanized) were thoroughly applied. Determination of farm machinery management like fixed and variable costs were tested using different models and the outputs were simulated. Comparative analysis was conducted between theoretical and actual values of the cost variables. Farm machinery owning and return duration from investment analysis were carried out.

3.4. Method of data collection

3.4.1. Data collection for descriptive statistics and analytical model

The study was used primary and secondary sources of information. The relevant primary sources contain original, raw, un-interpreted and unprocessed information. Primary data were obtained in the form of structured interview from selected 90 farmers in the study area. This data were used for descriptive analysis of socio economic conditions of the study area. Collected data from these 90 farmers were also used as input for analytical model (a multiple linear regression model) which used to determine the effect of farm machinery on the cereal crops production.

3.4.1.1. Sampling technique

Twenty farmers associations in the Hetosa district were included in the sampling. From each farmers association farmers were selected by systematic random sampling technique. The farmers were clustered according to geographical location because the district consisted of many villages and the sample had to be representative of the whole district. Finally 90 farmers were selected by stratified random sampling technique. It was the most convenient in this study because it gave every farmer an equal chance of being selected. Since majority of the farmers are illiterate being unable to give response by writing on questionnaire paper, structured interview was prepared. Prior to conducting the interview, three enumerators were trained on how to make interview and handle respondents. Content wise brief understanding of structured questionnaires for enumerators were a part of this training. Then interview was conducted based on structured questionnaire. The responses of the respondents were recorded by three paid enumerators.

All existing farm machineries in the district were taken using random sampling in order to collect actual machinery (tractors and combine harvesters) cost data which was used for model validation.

3.4.1.2. An analytical model to evaluate effect of farm machinery on cereal crop production

A linear regression model was used to determine the factors which are most likely to influence production of cereal crop at study area. On top of this, the model needs to determine the effect of using agricultural machines such as tractors and combine harvesters on production in the form of input and output relation. The study identified eight crucial independent variables; tractors and combines harvesters, age of house hold head, education, farm size, family size, weed control technology, and field condition. We selected the linear regression model, because the dependent variable is continuous and the model is best determine a cause and effect relationship between the parameters without put and computationally easier to estimate. Hence, the model was specified as follows using the same ways as Gujarati (2008).

In order to estimate multiple linear regression function, Y is dependent variable which represents production value that depends on eight independent variables (parameters). Some independent variables are continuous and the remaining variables are categorical (dummy variables). A general form of multiple linear regression model was expressed as follows:

$$\mathrm{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon_0 \qquad 3.1$$

Where: Y= production of crop (response /dependent variable) in quintal per house hold

β_o=intercepts/constant

$\beta_1, \beta_2, \beta_3, \ldots, \beta_8$ =Coefficients

X_3 X_5, and X_6= Continuous input variables which determine dependent variable.

X_1, X_2.X_4, X_7 and X_8=dichotomous input variables which determine dependent variable.

X_1 =access to tractor (0 = not accessible; 1 = accessible);

X_2 =access to combine harvester (0 = not accessible; 1= accessible);

X_3= age of the house hold head (yr);

X_4= education (0 = illiterate; 1 = educated);

X_5=farm size (ha); the number of hectares the farmer has;

X_6=family size (number of family above 10 years old)

X_7= weed control technology (0=manual weeding; 1=herbicide)

$X_{8=}$ field condition (0=sloppy field; 1=plane field)

ε_0 = error term.

3.4.1.3. Linear regression model specification

Farmer's access to tractors (X_1): The accessibility of tractor services was measured in terms of a farmer's closeness to tractor owner, tractor hire enterprises' station and level of mechanized vicinity, and is grouped as accessible and non-accessible otherwise. It was hypothesized that the accessibility to tractor services increases interest to use tractor and farmers who use it more likely to produce higher than draft power.

Farmer Access to combiner (X_2): The accessibility of combine services was measured in terms of a farmer's closeness to combine owner, combine hire enterprises' station and level of mechanized vicinity, and was grouped as accessible and non-accessible. It was hypothesized that the use of combine harvester services could increase interest to use combine harvester and farmers who use it more likely to produce than draft power.

Farmer's age (X_3): Younger farmers may have greater access to modern farming (mechanization) because they have had greater access to education, and thus they would be more aware of new harvesting technologies. Older farmers might not have access to this information or post-harvest losses. It was hypothesized that with increasing age of a farmer, the less likely to use a farm machines and more likely stick to use animate. Hence, younger age has more likely positive effect on production.

Farmer's education level (X_4): Formal schooling enhances a farmer's ability to perceive, interpret, and respond and accept to understand modern mode of farming. Hence, education was hypothesized that the probability that literate farmers could use farm machinery and produce more from unit hectare is higher than illiterate farmers. Education level was a categorical variable. The categories are illiterate (non-schooled, basic education and elementary 1-5), educated farmers who attended grade 6 and above.

Farm size (X_5): It was hypothesized that as a farmer's wheat area increases, he/she is more likely to use an agricultural machinery to ensure that farm operations are completed on time so that production is more likely to increase than small farm size.

Family size (X_6): Larger households have sufficient labor required to manually harvest wheat. Thus, a larger family size would be expected to decrease the probability that a farmer use farm machinery. Hence, it was hypothesized that small family house-hold more likely to use farm machinery which has a positive effect on the production.

Weed control technology ($\boldsymbol{X_7}$): Weed controlling would increase output yield depending up on the type of weeding. It was hypothesized that, yields more likely increases when farmers use mechanized spray/herbicide than manually weeding.

Field condition (X_8): Field condition determines the amount of crop yield per hectare. It was hypothesized that plane fields are more likely to have higher yield per hector than slope field.

3.4.2. Data collection for mechanization modeling

The other important data were those that are used for mechanization modeling. After the models were developed, data were collected from 90 farmers which were mentioned under section 3.4.1. Additional data were also collected from 70 agricultural extension service providers, 5 agricultural bureau extension services and input supply team, 2 mechanization input supply enterprise (Hetosa union). It was also collected from owners of draught animal and farm machinery custom hiring service providers. Frequent field observation for 40 days and field survey was a key element for this modeling.

3.4.2.1. Modeling mechanization for small farm of cereal crops production

Tirfesa (2013) and Guush (2014) stated that agricultural mechanization in Ethiopia was depending on animate power which is supposed to be the main cause of food self-insufficiency in the region. Except stating low level of mechanization and productivity, none of the studies have compared and contrasted among mechanization (from traditional to fully mechanized farm operation) in all parametric aspects in the form of mechanization models.

Thus, this study used three mechanization models particularly for main cereal crops production. The models are developed based on the existing facts in the farmers, farming community, farm machinery and draught animals customs hire service providers.

3.4.2.1.1.Economic determination

Economic analysis was performed using equations 3.2-3.4 (Pishgar et al., 2012, Demircan et al., 2006).

Total production value = yield (kg/ha) × price (USD/100 kg) 3.2

Net return = total production value (USD/ha) − total production cost (USD/ha) 3.3

$$\text{Crops productivity} = \frac{\text{yield(kg/ha)}}{\text{total production cost (USD/ha)}} \qquad 3.4$$

3.4.2.1.2. Energy analysis for mechanization models

Agricultural mechanization models were developed for main cereal crops as shown in the above section 3.4.2 from Table 3.1-3-3. Comparative analysis among the models needs to be conducted in order to identify the most energy saving model. All the energies determined are those required to the farm one hectare. Although separate descriptive analysis was made for each model for the sake of comparison, human (daily laborer and machinery operator) and animal energies, farm machinery energy (tractor, power tiller etc.), fuel energy (particularly diesel fuel), seed (wheat, barley and maize), and fertilizer energies are used as input energies. Output yield (seeds) energy is used as output energy.

The data used in the study are taken from the models (each Table 3.1-3.3). The energy equivalents to each input and output are listed in the Table 3.4. The data were converted into convenient energy units and expressed by MJ/unit.

Total input energy, total output energy, energy ratio and energy productivity required per hectare were determined in order to identify the model which utilized energy at minimum level as compared to the others. In order to calculate each input and output energies, the study followed the same method used by Sedaghat et al. (2014) and Mohammad et al. (2011).

Table 3.1. Mechanization input and output energy conversion for cereal crop production

	Energy variables /inputs/	Units	Energy equivalent (MJ/unit)	Reference
Input energy	Human labor	Hour	1.96	Sedaghat et al., 2014; Ozkan et al., 2004; Mohammed et al., 2011
	Oxen	Hour	8	Ozkan et al.,2004
	Horse	Hour	10.1	Thomas (2015)
	Machinery	Hour	62.7	Singh et al., 2002; Sedaghat et al., 2014; Mohammed et al., 2011.
	Diesel fuel	Liter	56.31	Sedaghat et al.,2014
	Chemical fertilizers:			
	Nitrogen(N)	kg	66.24	Sedaghat et al.,2014; Yilmaz et al.,2005
	Phosphate(P_2o_5)	kg	12.44	Esengun et al.,2007; Rafie et al.,2010
	K_2o	kg	11.15	Esengun et al., 2007; Sedaghat et al.,2014
	Seed (wheat, barley and maize)	kg	14.7	Sedaghat et al., 2014; Mohammed et al., 2011;Demercan and Eknici, 2006
Output energy	Grain (Wheat, Barley and Maize)	kg	14.7	Sedaghat et al., 2014; Mohammed et al., 2011;Demercan & Eknici, 2006
	Straw	kg	12.5	Ozkan et al., 2004; Sedaghat et al., 2014; Mobtaker et al., 2010

3.4.2.1.3. Human labor as input energy

Man power energy: This energy consists of energy used by draught animal, farm labors and machine operators. Labor energy considered in this analysis is 15 years old and above who is economically active and matured enough in agricultural community. Hence, labor and animal energies were calculated by the equations 3.5-3.7 as follows:

$$\mathrm{E_{Moh}} = \sum_{i=1}^{n} \frac{1.96}{A} \times \mathrm{N_{Li}} \times \mathrm{T_{Oi}} \times \mathrm{D_{Oi}} \times \mathrm{N_{Oi}} \qquad 3.5$$

$$\mathrm{E_{MOx}} = \sum_{i=1}^{n} \frac{8}{A} \times \mathrm{N_{Li}} \times \mathrm{T_{Oi}} \times \mathrm{D_{Oi}} \times \mathrm{N_{Oi}} \qquad 3.6$$

$$\mathrm{E_{MOH}} = \sum_{i=1}^{n} \frac{10.1}{A} \times \mathrm{N_{Li}} \times \mathrm{T_{Oi}} \times \mathrm{D_{Oi}} \times \mathrm{N_{Oi}} \qquad 3.7$$

Where, E_{Mo}, $\mathrm{E_{MOx}}$, $\mathrm{E_{MOH}}$: human and animal energy (oxen and horse) in manual operation (MJ/ha);

N_{Li} : Number of labor or animal (ox and horse) required to complete the farm in each farm operation (i)

T_{Oi}: Daily working hours for operations 'i' (hr/day);

D_{Oi}: Work days that are needed in each farm operation 'i' (day);

N_{Oi}: Operation repetition per year;

A: Farm size (ha);

Energy used by machine operators was calculated by the following equation 3.8:

$$E_{mo} = 1.96 \times \text{machine hours} \times \sum_{i=1}^{n} \frac{N_{Oi}}{Ca_i} \qquad 3.8$$

Where; Ca_i: field capacity of the machine for i operation (ha/hr);

N_{Oi}: Operation repetition per year (a single season was considered in this study);

E_{mo}: Energy used by machine operators (MJ/ha)

Farm machine capacity determination:

Capacity of the machines (power tiller, tractor or combine harvester) for i operation (ha/hr) were determined by the following equation 3.9 used by Hunt (2001) and Romanelli et al. (2009).

$$Ca_i = \frac{W \times V \times \eta}{10} \qquad 3.9$$

Where; w: Working width of the machine (m);

V: Travelling speed of the machine (Km/h);

η: Field efficiency (decimal)

3.4.2.1.4. Fuel energy determination:

Fuel consumption rate of the tractor, combine harvester, power tiller and truck were determined by the following equation 3.10 (Grisso et al., 2004 and ASABE standards 2006, 2011).

$$Q_i = SFCV \times P_t \qquad 3.10$$

Where; Q_i: Fuel consumption rate (L/h);

P_t: Machine horse power (kW);

SFCV: Specific fuel consumption (L/kW·h).

Hence, fuel energy used by the farm tractor was determined by the following equation:

$$E_{fuel} = \frac{56.31 \times Q_i}{Ca_i} \times \text{machine hours} \qquad 3.11$$

Where; E_{fuel} : used energy as fuel (MJ/ha) and 56.31is energy used per liter of diesel fuel.

3.4.2.1.5. Farm machinery energy determination:

Farm machinery input energy was determined using equation 3.12 as follows by considering 62.7 MJ energy as hourly operation.

$$E_M = 62.7 \times \text{machine hours} \times \sum_{i=1}^{n} \frac{1}{Ca} \qquad 3.12$$

Where; E_M: Farm machinery energy (MJ/ha);

Ca:Field capacity of farm machinery (ha/hr);

3.4.2.1.6. Total input energy

Input energy was determined by multiplying used input items by equivalent energy in Table 3.4. Total input energy was determined from the total sum of energy used in particular model. For instance, the total input energy used manual operation is the sum of labor energy, draught animal energy, seed energy and fertilizer energy.

3.4.2.1.7. Output energy

Final crop yields were multiplied by the equivalent amount of energy (Table 3.4) in order to get total output energy in MJ/kg.

3.4.2.1.8. Determination of energy indicators

Net energy, energy ratio, energy productivity, and energy efficiency for the three models were determined by using equations 3.13, 3.14, and 3.15 (Mohamed et al. (2011), Rafiee et al. (2010); Hatirli et al. (2005); Khan et al. (2012); Fadav et al. (2011); Ebrahim et al. (2013), Morteza et al.(2012); Lorzadeh et al. (2011)).

$$\text{Net energy} = \text{output energy } (\text{MJha}^{-1}) - \text{Input energy } (\text{MJha}^{-1}) \qquad 3.13$$

$$\text{Energy productivity} = \frac{\text{Yield } (\text{Kgha}^{-1})}{\text{Input energy } (\text{MJha}^{-1})} \qquad 3.14$$

$$\text{Energy efficiency} = \frac{\text{Output energy } (\text{MJha}^{-1})}{\text{Input energy } (\text{MJha}^{-1})} \qquad 3.15$$

3.4.3. Data collection for machinery management and cost determination

The relevant farm machinery population data were collected from government organization such as district's agriculture and rural development office and Central Statistical Authority (CSA) of the study area. Data of selected farm machinery types, models, horse power, make and origin were taken from their owners. Agricultural machinery services and their maintenance condition were considered for data collection. Practices for preventive maintenance and intervals of changing items like fast running parts data were collected. Similarly, machine parts other than fast running and replacement interval data were also collected from machinery owners. Most importantly, machinery management data for various fixed and variable cost such as machinery initial price, purchased year, service life, machinery utilization data, time related cost, use related costs like repair and maintenance cost and fuel and oil costs data were collected from owners of the machine. Tractors average annual hectare plowed data were collected. Aforementioned machinery's service charge rate per hectare from custom hiring service data were also collected for the best determination of machinery costs and income analysis.

Secondary data is useful for background information and for the researcher to get a better understanding of the study area. Different source document information such as journals and standards like ASABE were used as input information for the thesis.

3.4.3.1. Mathematical formulation for determination of cost of agricultural machinery

The study tried to investigate agricultural machinery management conditions in the study area. Parallel to this, costs of agricultural machinery were also determined. Several studies (Hunt (1983), Witney (1995), Norvel (2007), Bowers (1992), Goense (1995) ASAE (1999)) categorized cost into two categories. These are annual owner ship cost (depreciation, interest and insurance) which occurs regardless of machine use and operating cost (repair and maintenance cost, fuel and oil cost, labor cost) which vary directly related with the amount of machine use.

3.4.3.1.1. Depreciation cost determination using straight line method

This study used straight line depreciation method because with this method, an equal reduction of value is used for each year the machine is used. Depreciation cost was calculated using remaining value formulas estimated based on the values of used farm equipment. Calculate remaining value as a percentage of the list price for farm equipment at the end of *n* years of age and after *h* average hours of use per year using the following equation 3.16 (Hunt,1983).

The owner of farm machinery in the study area used this method because it's simple and straight forward. It is most suitable for estimating costs for the entire life of the machine (Witney, 1988) while declining balance method depreciated machine at faster rate during early age of the machine than older age. The annual depreciation charged can then be considered as the sum which must be set aside each year in order to replace the machine with identical model at the end of the period of ownership (Norvel, 2007).

$$\mathrm{AAD} = \frac{\mathrm{P-S}}{\mathrm{L}} \qquad 3.16$$

Where: AAD= average annual depreciation (USD)

P= purchased price of the machine (USD)

S= salvage value of machines which is 10% of current list price(USD)

L= economic life of the machine (USD)

3.4.3.1.2. Determination of interest cost

Interest is a large expense item for agricultural machinery. It is a direct expense item on borrowed capital. The annual interest rate can be varying depending on the organization and country but usually in the range of six to twelve. In Ethiopian condition this rate is 9.5% for agricultural machinery purchased by borrowed money from a bank. Hence, the study used the following equation 3.17 (Edward, 2009 and Hunt, 1983) in order to determine the interest cost.

$$\mathrm{In} = \left[\frac{P+S+D}{2}\right] \times \mathrm{IR} \qquad 3.17$$

Where: In= Interest cost (USD)

P=Purchased price (USD)

S=Salvage value (USD)

D=depreciation (USD)

IR=interest rate

3.4.3.1.3. Determination of tax and insurance

Tax differs from country to country. Tractors and combine harvesters may have yearly cost for registration plate in same countries (Goense, 1995). VAT and sale taxes are to be included in the purchase price. Bowers (1992), described tax, a paid on farm machinery for place that do have property as for other properties. The cost estimated equal to one to two percent of purchased price of the machine at the beginning of the year often is used.

Generally, there was no cost for insurance for agricultural machineries owned by farmers in the study area so does elsewhere except for large state and private owned farms. Inclusive of tax and insurance 2% was used to determine aforementioned costs. For the sake of calculation, the study followed the equation 3.18 and 3.19 which was used by Hunt (1983) and Bowers (1992).

$$T = \left[\frac{\mathrm{P}}{2}\right] \times 0.55 \times \mathrm{TR} \qquad 3.18$$

$$\mathrm{I} = \left[\frac{P+S+D}{2}\right] \times IR \qquad 3.19$$

Where: I and IR= Insurance cost (USD) and insurance rate respectively

T and TR=tax (USD) and tax rate respectively

P=Purchased price (USD)

S=Salvage value (USD)

3.4.3.1.4. Determination of variable costs for agricultural machinery: repair and maintenance cost

This study compiled data from repair and maintenance costs for tractors and combine harvesters owned by the farmers in the western Arsi zone, Hetosa district. The area was prominent for mechanization than other areas of the region since 1969 (Hassena et al, 2000) so that the existing farm machinery are taken to investigate repair and maintenance costs.

Farm machinery in the study area is owned by farmers and farmers union. Those machineries which were owned by the union are not included in determination of repair and maintenance costs. The study considered tractors (Massey Ferguson-398; Fiat New Holland-110-90, NTAF-Belarus-825, Styer-9094) and combine harvesters (Class Combine, John Deer, and New Holland). The capacity of these farm machineries was ranged from 67.5 kW to 120 kW. Service life and annual use hours of these machines are different. In order to determine RMC of each machine, accumulated life time of use was considered based on the annual hour of use.

Accumulated repair and maintenance costs were determined using the ASABE Standard (2011) and the model proposed by Witney (1995).

$$\mathrm{ARM_n} = \mathrm{RF1} \times \mathrm{CLP_n} \times \left[\frac{\mathrm{AH_n}}{1000}\right]^{\mathrm{RF2}} \qquad 3.20$$

Where: ARM_n= accumulated repair and maintenance costs for n years as a function of accumulated hours,

CLP_n = current list price,

AH_n= accumulated use of hours (working hours accumulated by each machine),

RF1 and RF2= dimensionless coefficients that affect the shape of the interpolating curve.

RF1=repair factor one (0.007 and 0.003 for tractors and heavy machineries and 0.04 for self-Propelled combine harvester) and describes the amount of RMCs;

RF2= repair factor two (2 for both tractors and heavy machineries and 2.1 for self-propelled combine harvester) and represents the distribution of RMC during the estimated-life of a machine.

N= Number of years (age of machine) in which RMC is to be determined,

1000= Conversion factor.

Theoretical RMC model uses accumulated annual hour of use of each tractor and combine harvester. For actual RMC, data were collected from each tractor and combine owners. Collecting data from each machine owner was tedious and tiresome because cost recording systems for purchased spare parts, fast running items and consumable materials, lubricant and payment for repair crew etc. were not organized in a systematic way for most machinery owners in the study area. Hence, the study used data from those owners who have better recording systems as compared to the others.

The actual annual hour of use of tractors and combine harvesters varied from machine to machine (tractor and combine). The variation perhaps comes from the difference in capacity of the machinery, owner's activity to attract the customer and demand of the machinery which forced the machine to be operated over time during peak period. Based on these data cost comparison was conducted. Estimated repair cost versus actual cost was analyzed. Projected regression graph was used to indicate if actual costs are more than, or less than, or equal to estimated cost. If not equal, by how much has it deviated?

The study also analyzed farm machinery's time of replacement by the function of critical repair and maintenance costs being and becoming out of owners control due to frequent failure. Finally regression analysis of data for tractors was done using power and polynomial functions. The regression model which has the highest coefficient of determination (R^2) was selected as the best fit model for predicting actual RMC.

3.4.3.1.5. Determination of fuel and oil cost

All the tractors and combine harvesters found in the study area were diesel type. This consumption for tractors and combine harvesters can also be determined by the amount of energy demanded at the drawbar or through the PTO. In order to relate the energy requirements and the farm machinery fuel consumption, it is important to consider load on the machine. The machines loads vary from heavy operations like subsoiling and plowing at dry field to light and routine tasks.

Fuel consumption of individual tractor could vary even for particular operation over duty cycle because of different factors. Following the method used by Hunt (1983), average annual fuel consumption and associated annual hours of machine use were determined in order to analyze the fuel cost. Hence, fuel consumption the four tractors used in the study area was measured by the average amount of fuel consumed during specific year when the machines were on operation and the cost was determined using national average fuel price.

Depending on the type of fuel used and the amount of time the machines used fuel and lubrication costs usually represent at least 16%-45% of the total cost (Bowers eta al., 1999). The study used annual average fuel required for each tractor and combine harvester. However, fuel consumption varied on the operation of the machines. Thus, fuel cost determination was based on the actual power (kW) for the machines.

Some studies (Grisso et al, 2004, ASABE standard EP496.3, 2006 and ASABE Standards D497.7, 2011) estimated diesel fuel consumption which was calculated from the equation 3.21.

$$Q_{avg} = 0.305 \times 0.73 \times Max.PTO.P = 0.223 \times Max.PTO.P \qquad 3.21$$

Where: Q_{avg}= average diesel fuel consumption (L/h);

Max.PTO.P = maximum PTO power (kW)

Numerical value 0.73 comes from the fact that a diesel tractor uses approximately 73% as much fuel in volume as a gasoline tractor and 0.305 come from average fuel consumption data estimated from the varying PTO power tests in the Nebraska Tractor Test Laboratory (NTTL) reports (Bowers, 2001).

Equation 3.21 did not give average annual fuel cost unless the average fuel consumption is multiplied by the amount of hour the machines used per year and fuel cost per litter (USD/litter). Since aforementioned studies didn't directly estimate average annual fuel cost rather than estimating average fuel consumption, it was preferred to use the model proposed by the Hunt (1983) for this particular study as shown in equation 3.22.

$$DFC = MAX\ PTO\ KW \times 0.223 \times \text{price of diesel} \times \text{hours of use} \qquad 3.22$$

Where: DFC - Diesel engine fuel cost (USD/year),

MAX PTO KW- maximum PTO power (kW),

0.223-a constant (conversion factor to convert horse power to kilowatt as a function of fuel consumption rate (L/kWh))

Average annual fuel cost was determined using equation 3.22. Average annual hour of use was collected from the owner's data record. Finally the calculated result was compared with the actual fuel cost incurred by the particular machine. Cost of oil, lubricant and oil filter were included in repair and maintenance cost except crank case oil or engine oil (ASABE standard EP496.3, 2006). Hence, average annual oil costs were calculated as 15% of the average annual fuel cost of tractors.

3.4.4. Breakeven point determination

Breakeven point is one of the important methods to identify profitability and losses of the farm machinery. It is also found to be crucial to determine the service years or hectare at which the owner of the machinery will get return from investment. The ultimate goals of the farmers were to maximize profit. Hence, the farmers perhaps will decide to buy or to hire tractor. Breakeven point can be expressed in terms of income from the hiring services of tractors in order to cover costs. Moreover, BEP is the point at which the total income from the tractors equal to the total costs. It can be expressed by the following equation 3.23 (Parminder et al., 2012).

$$BEP = \frac{\mathrm{FC}}{\mathrm{HC} - \mathrm{TVC}} \qquad 3.23$$

Where: BEP- Breakeven point in hectare.

FC- Fixed cost (USD); it include all cost components related to time.

HC- Hiring cost or custom hiring rate per hectare (USD/ha).

TVC-Total variable cost (USD); this included repair and maintenance costs and fuel and oil costs.

3.4.5. Data analysis

Actually, data analysis is the most important part to make the research meaningful and easily understandable for any other readers and researchers. Therefore, in this study collected data were analyzed using Minitab, STATA, and SPSS statistical soft wares. On top of these, the relation between variables and parameters was analyzed using excel software. Collected data were interpreted and analyzed in the form of table, pie charts, bar graphs, and regression graphs.

Based on the research questions and finding of the study, collected data were interpreted in descriptive method such as average and percentage values; and statistical methods such as f-test, and two-sample t-test were used to describe and analyze the household level characteristics including the state of resource ownership, farm production machinery, farm activity and related entity of the sample households. Multiple linear regression function was used to determine the relationship of farm machinery and associated variables with crop production.

CHAPTER 4

4. RESULT AND DISCUSSION

4.1. Mechanization of small holders farming characteristics

4.1.1. Demographic statistics of the small farms

Selected respondents of Hetosa districts were interviewed to find their background which related to age, sex, and level of education, marital status, house hold head, and source of income. These features are found to be important in terms of clearly showing the diverse background of the respondents and their effect mechanization as well as socioeconomic aspects.

According to the response of interviewee, the mean age of the respondents was 44.11 with standard deviation, minimum and maximum age of 10.8, 30 and 75 respectively. Ages between 27.5 and 32.5 (N=15) has high frequency followed by age between 37.5 and 42.5 (N=20). 92.2% (N=83) of the respondents were male while the female respondents were accounted 7.8 %(N=7). Thus, majority of the sampled farmers were middle aged, which could result in a positive effect on production.

Table 4.1. House hold age descriptive statistics

	Number	Minimum	Maximum	Mean	STD
House hold age	90	30	75	44.1	10.8

The respondents who attended secondary education in the area were 8.7% (N=8) while those who attended pre-secondary education (6-10) were 32.2 % (N=29). The proportion of first cycle (1-5) is the highest with 42.2 (N=38). The farmers who were considered as illiterate accounts 16.6% (N=15) with exception of few who were attended informal education. Even though the number of illiterate was many more, when compare with the national average, the study area is falls within educationally advantageous part of Arsi zone which affects agricultural activities in the area.

We could see that the cumulative proportion of farmers who went to school was 83.1%. Therefore, most of the farmers can read, write and more likely know about farm mechanization which is crucially important to maximize their production. The majority of the respondents were married (88.8%) while unmarried respondents were comparably very few (11.20%) and considered as younger.

Table 4.2. Basic house hold family characteristics

Entity required	No.	Minimum	Maximum	Mean	STD
Total family members	90	0	20	6.3	3.3
Male family members	90	0	10	3.3	1.9
Female family members	90	0	10	3.0	1.8
Family members above 10 & below 60	90	0	14	4.8	3.1

0=those who don't have family required

The respondents' average family size in the area was 6.3 with minimum, maximum and standard deviation of 0, 20 and 3.3 respectively. The mean values of male and female family members were 3.3 and 3.0 respectively. The difference was not apparent. The average number of family members whose ages were above 10 and below 60 was 4.8 which are more likely productive age and potential labor force for production.

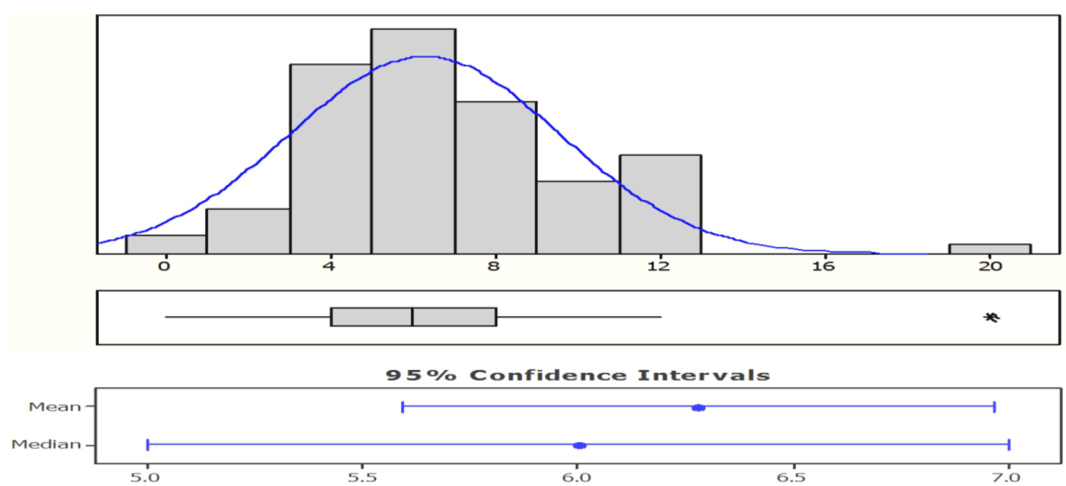


Figure 4.1.Farmers family size

When we refer to Central Statistics Authority data from 2004/5 to 2010/11, the national average of family size was 4.8. Therefore, farmers in the study area have larger family size than the national average.

Table 4.3. Household head and economic engagement characteristics

	Frequency	Percent	Valid Percent	Cumulative
Female	9	10	10	10
Male	81	90	90	100
Crop production	56	62.2	62.2	62.2
Other business	1	1.1	1.1	63.3
Mixed farming	33	36.7	36.7	100

Table 4.3 shows that the proportion of male headed household is 90% which is by far higher than female headed household. Traditionally females are more responsible to indoor than outdoor activity like farming which belongs to males. In rural community, in most cases, when male is not in household, female might not have access to receive information about new technology and machine use for farming to increase production.

In Ethiopia, 85% of the economy basically depends on agriculture. This is also supported by this study where by 98.9% of the farmers in the study area was engaged with agriculture while only 1.1% engaged with other businesses. Among the total respondents, 62.2% (N=56) and 36.7% (N=33) are engaged with crop production and mixed farming (crop and animal production) respectively. Farmers in the study area are rarely engaged with others businesses.

According to Berhanu (2004), small holder farming in Ethiopia was dominated by mixed farming. In contrast, this study revealed that the majority of the respondents in the study areas were engaged with crop production than mixed farming. Hence, the district seems to be favorable for crop production than animal rearing.

4.1.2. Farm size and farm level characteristics

Land is one of the crucially important inputs for the rural community whose livelihood depends on farming. These days, owning lands in such a rural area is sometimes considered as live and death due to the above fact. On top of owning land, its size has one of the determinant factor for agricultural mechanization unlike industry and service sectors are mainstay in the urban areas. The study reveals that all the respondents in the study area were owner of the land although the size of the holding has a great variation from household to household.

Table 4.4. Possession of land by hectare

Land holding in ha	Frequency	Percent	Land holding in ha	Frequency	Percent			
							Mean	1.83
.5	13	14.4	2.3	2	2.2	Summery		
.63	2	2.2	2.5	6	6.7		minimum	0.5
.75	6	6.7	2.8	1	1.1			
1.0	13	14.4	3	8	8.9		maximum	6.0
1.3	2	2.2	3.5	7	7.8			
1.5	10	11.1	5.5	2	2.2		Sd.dev	1.18
1.8	1	1.1	6.0	1	1.1			
2.0	16	17.8	Total	90	100		SEmean	0.12

Table 4.4 shows the mean value of land holding size was 1.8 hectare with the minimum and maximum observed holdings per house hold of 0.5 and 6 hectares respectively. The majority of land holders have less than 2 hectares (approximately 70%). In general, percentage of land holding size between 1.0 and 2.0 hectares in the study area was greater than the mean value of the national level while percentage of land holding size less than half hectares (14%) was by far less than the national average value (35.93%). However, the amount of land holding in the study area at middle scale was slightly higher than the national holding size in hectare. The proportion of fragmented lands was very high, which has negative implication for modern farm mechanization in the study area.

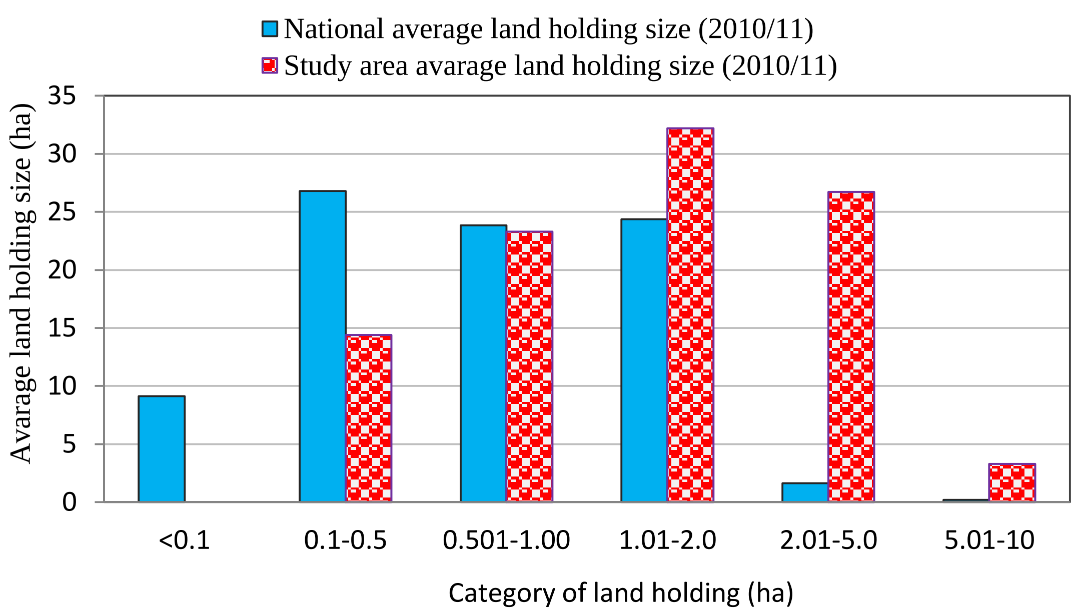


Figure 4.2. Land holding size in hectare

Farmers who have better experience of farming are supposed to have better skill and knowledge because experienced farmers have a better engagement with farming than non-experienced one. Chiremba and Masters (2003) reported similar idea as farming experience is better predictor of good farming performance.

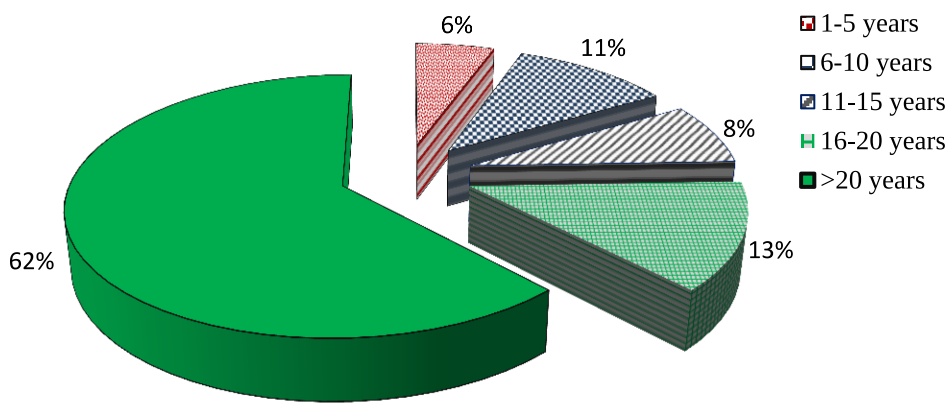


Figure 4.3. Farmers farming experience in the Hetosa district

Figure 4.3 revealed that 6% of the farmers age was within the range of 1-5 years farming experience whereas 11%, 8%, and 13% within the range of 6-10, 11-15 and 16-20 years farming of experience respectively. 62% of the respondents have more experience which accounts more than 20 years of farming experience. Therefore, in the study area, majority of the farmers have better farming experience. Experienced farmers along with long duration in the framing are more likely to produce and get better income from production which enable them to purchase farm machineries than non-experienced one.

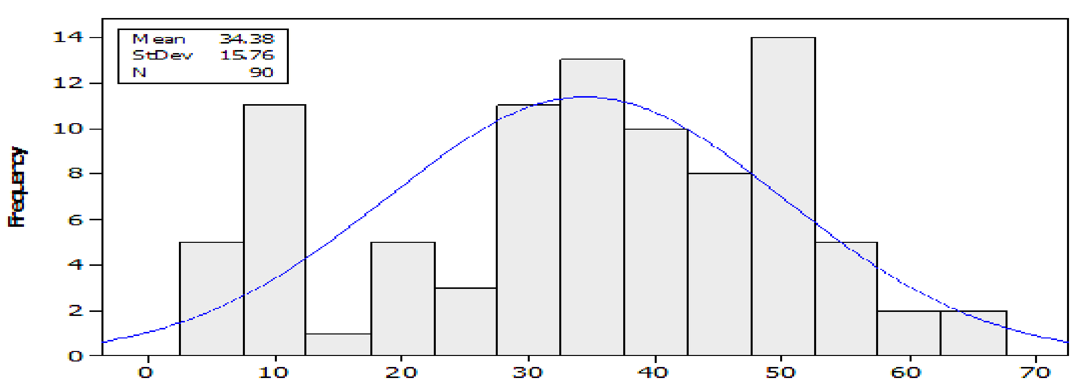


Figure 4.4. Respondent’s duration of living in the Hetosa area as the function of farming experience

Regarding soil type, 83.3 % of the soil in the study area is Andosol. This soil is popular for cereal crop especially for wheat production. Its nature is fertile and black in color. On top of this, the nature of topography of the land is plane and rarely sloppy. Because of the above mentioned facts, the study area is convenient for farm mechanization and center of cereal crop production. Hence, using modern draught animal technology or farm machinery for pre-harvest as well as postharvest couldn't be constrained in the study area.

4.1.3. Agricultural products

Major crop can determine the type of technology the society uses in the particular area for crop production. In most cases where many diversity crops are available, mechanization is rarely used while in the areas where specialized crops are available, in most cases, mechanization can be used. The results in the study area as shown in the Table 4.5 reveals that 84.4 % (N=76) of the farmers produced cereal crops (wheat, barley and maize) while 15.6% (N=14) of the respondents are engaged with production of both cereals and pulses mainly beans.

Table 4.5. Major crop in the study area

Type of major crop	Frequency	Percent	Cumulative percent
Cereals	76	84.4	84.4
Cereals & pulse	14	15.6	100.0
Total	90	100.0	

The pie chart in Figure 4.5 depicts that out of the total respondents who were solely produced cereal crop, wheat crops producers were taken the largest share in the entire district which accounted 73.3%. From the result one can understand that wheat is a dominant and specialized crop in the district, which is convenient for mechanization which increases production to change the income of the farmers.

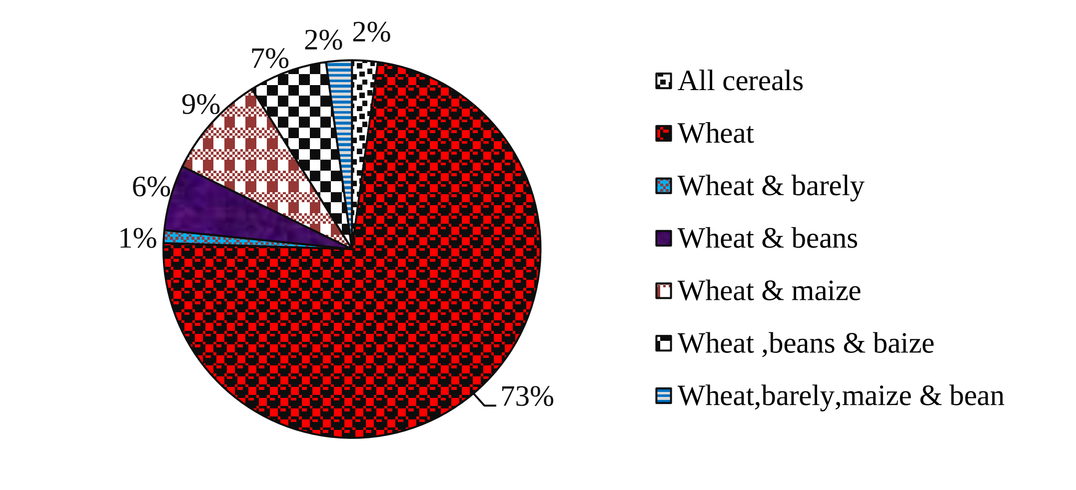


Figure 4.5.Type of cereal crop often produced in the study area

Farmers who produced more than two crops at a time in their field such as wheat and maize; wheat, beans and maize; wheat and beans; wheat, barley, maize and beans; and wheat and barley are 8.89%, 6.67%, 5.56%, 2.2% and 1.11% respectively. But few respondents in the study area produced all types of crops in their farm field at a time. Hence, specializing wheat in the study area helps many farmers hire/buy/rent similar machine in order to operate their farm.

Table 4.6. Wheat crop yield (kg/ha) in 5 years in Hetosa district

Year	N	Mean	STD	Minimum	Maximum
2010/11	90	3340	981	1600	6000
2011/12	90	3479	1027	1500	6500
2012/13	90	3467	965	1800	6500
2013/14	90	3464.4	871.4	1800	6000
2014/15	90	3684	1075	2000	6400

FAOStat data base (2014) shows that in many developed countries like USA, Australia, and South Korea average wheat crop yields are within the range of 5000-7000 kg per hectare whereas in the study area five year data taken from CSA (2007), average cereal crop (wheat) yields per hectare, as shown in the Table 4.6, were 3340 (2010/11), 3479 (2011/12), 3467 (2012/13), and 3464 (2013/14) kg per hectare respectively. But the national five years average wheat yields shown in the Figure 4.8 are 1750, 1839, 1890, 2134, and 2220 respectively. The national average wheat yield is by far very low than most developed countries. This is perhaps due to traditional farming practices and lack of mechanization which decreases production in the most Ethiopian region.

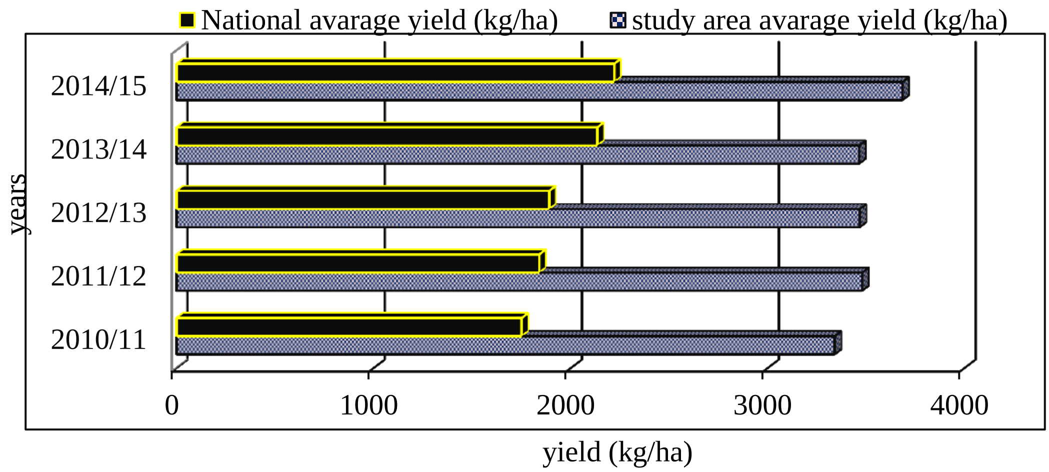


Figure 4.6. Comparison of five years national and study area wheat yield (source: CSA (2014/15))

Comparing with the national average wheat yield kg per hectare, the mean value of the five year wheat yield in the study area has a significant difference which is 3486 kg per hectare (study area) and 1966 kg per hectare than national average. The two sample t-tests at 5% significant level confirmed that there is no significant variation among five year national and study area yields. Study area has high wheat yield per hectare than national mean value. Hence, F-test at 5% significant level reveals that there is highly significant difference between national and study area yields. In general higher wheat yield was observed in the study area due to being and becoming mechanized farming which is also supported by Hassena et al. (2000).

4.1. 4. Farm powers

Agricultural mechanization in Ethiopia can be divided into three distinct level of technology: hand-tools technology, draught animal technology, and engine-powered technology. Now days, even though the contribution of hand tools for crop production has no significant effect, the majority of the farmers in the study area have different types of traditional hand tools. As indicated in the Table 4.7, 95.6 % of the farmers have traditional plow (Maresha) which is used to till land but only few farmers lack this tool. With the similar condition, 93.3% of the respondents in the study area have wooden beam in which Maresha is attached at the tail end and yoke at the front end. In the case of farm tools when the farmers have Maresh along with beam they are supposed to have yoke. Because these aforementioned farm tools (Maresha, beam and yoke) have integrated function. Hence, from the Table 4.7, similar response of availability of yoke (93.3%) was observed to approve this fact.

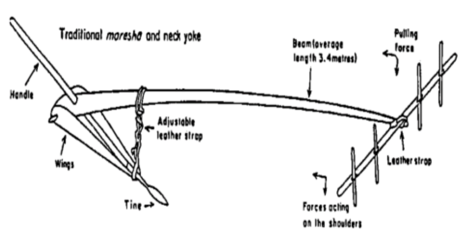
In rear case, when framers don’t have any of the three tools, they are more likely to borrow them from the neighbor farmers. Sickle is the other hand tool technology which is crucially important for farmers to harvest their crop manually. However, it is observed that the majority of the farmers harvest their crops with combine harvester. 95.6% of the respondents in the study district have sickles. It seems that, the sickle tools have more than two functions. Either they can use it for crop harvesting or forage (grass) cutting for their livestocks.

Table 4.7. Traditional farm tools in the study area

Farm tool variables		Frequency	Percent	Valid Percent	Cumulative Percent
Maresha	Available	86	95.6	95.6	95.6
	Not available	4	4.4	4.4	100.0
Beam	Available	84	93.3	93.3	93.3
	Not available	6	6.7	6.7	100.0
Yoke	Available	84	93.3	93.3	93.3
	Not available	6	6.7	6.7	100.0
Sickle	Available	86	95.6	95.6	95.6
	Not available	4	4.4	4.4	100.0
Hoe	Available	85	94.4	94.4	94.4
	Not available	5	5.6	5.6	100.0
Spade	Available	28	30.8	30.8	31.9
	Not available	62	68.1	68.1	100.0
Shovel	Available	59	65.6	65.6	65.6
	Not available	31	34.4	34.4	100.0
Cart	Available	13	14.4	14.4	14.4
	Not available	77	85.6	85.6	100.0
Row crop planter	Available	34	37.8	37.8	37.8
	Not available	56	62.2	62.2	100.0

Hoe, spade and shove are also commonly used as hand-tool technology in the study area. The results in Table 4.7 reveal that 94.4% of the respondents have hoe while 30.8% and 65.5% of them have spade and shovel respectively. It was observed that from the farmers in the study area hoe and shovel are mostly used for repair and maintenance of their beam, yoke and cart whenever they broken or encountered problem. In addition to these, tilling with hoe is the most popular to few farmers who have small and fragmented land (not convenient to use draught animal and tractor). It is versatile hand tool and mechanization technology that is locally made by artisans with different shapes like flat blade, size and curvature. Hoe’s shape depends on the type of job required. Farmers use narrow and short bladed one for maintaining tools while long and wide bladed is used for primary and secondary tillage operation and land bedding, ridging, as well as row crop cultivation so as to remove weeds.

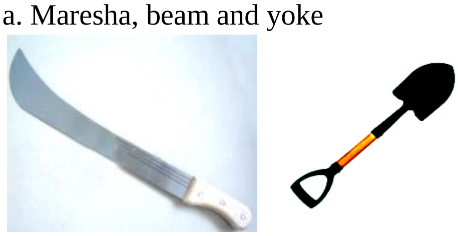
The results in Table 4.7 also show that very few respondents which account 14.4% have cart. It seems that the majority of the respondents in the study area lack this equipment. The most commonly used one in the study area was two wheeled cart which is used to transport mechanization inputs and outputs during pre and post-harvest operations. But most of the farmers transport mechanization inputs (seed, fertilizer etc.) using either horse or donkey. The rest has been using carts by paying service charge for cart owners.



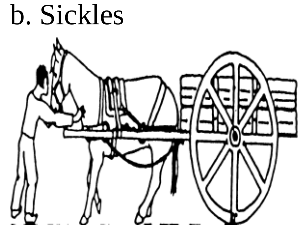
a. Maresha, beam and yoke

b. Sickles

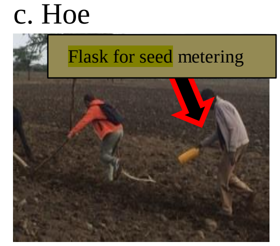
c. Hoe



d. Shovels and spade from left to right



e. Cart



f. Row crop planter

Figure 4.7. Traditional farm tools

The study reveals that only 37.8% of the farmers in the study area have row crop planting equipment. However, the types of planters they used for wheat are not the actual mechanically assembled dibbler tools which have seed metering unit, but it can be made from any locally existing jar and flask with orifice to meter seed as shown in Figure 4.7f.

In the study area, however, horses, donkeys and mules are not used; oxen are most commonly used as draught animal. Table 4.8 reveals that 24.4% of the farmers in the study area haven't oxen. Among those respondents who had oxen as draught animal, 32% of them had only single ox while the lesser have more than two oxen. This result proves that owing draught oxen by breading (18.9%) was less than by buying (65.5%). Therefore, decreasing the number of draught animal in the district was one of the indicators of the existence of alternative power source like tractor and combine harvester due to good potential of mechanization than elsewhere in Ethiopia. Even though the size of the land decreased, mechanization has a great impact on the number of draught animal.

Table 4.8. Availability and affordability of draught animal power in the study area

Draught animal owing condition		Frequency	Cumulative Percent
Owning oxen	No owning	22	24.4
	Owning	68	100.0
Number of oxen the respondents have	Farmers with no ox	22	24.4
	Farmers with 1 ox	29	56.7
	Farmers with 2 oxen	25	84.4
	Farmers with >2 oxen	14	100.0
How to owning oxen	By breeding	17	18.9
	By buying	59	84.4
	By both buying & breeding	3	87.8
	No oxen farmers	11	100.0
Owning oxen drawn implement	Farmers who don't have oxen drawn implement	63	70.0
	Farmers who have oxen drawn implement	27	100.0

Among oxen drawn implements such as oxen drawn traditional plow, modified plow/ Marasha, animal drawn cart, modified mold-board plow, animal drawn seed drill machine and human pushed small wheel/cart, only 30% of the farmers had oxen drawn traditional plow. None of the farmers have the rest of implements. This showed that in the study area shortage of modified technologies which used to improve production as alternative to tractor-drawn implements were happened. Besides to this, neither of the respondents in the study area have both tractor and walky tractor (power tiller). The result shows that either the farmers in the study area don't have initial capacity to buy farm tractor or they may not have awareness of return from the tractor investment. Hence, they are more likely to rent farm power for both pre and post-harvest operations.

4.1.4.1. Determination of rental based farm power for pre and post-harvest operations

Many farmers have been using both draught animal and farm machinery (tractors and combine harvesters) by renting from machinery and draught animal owners during normal and peak operation period. However, the owners of farm power give priority for themselves at any operation period. Those farmers who rented pay service charge depending on the time of operation i.e. they pay maximum amount during peak time and normal payment during normal operation period.

Figures 4.8 reveal that there was no full mechanization in the study area for any operation (say pre and post- harvest). Mixed operation was observed in using rental based farm power. During first round operation primary tillage operation, majority of the farmers used tractor (61.11%) to turn soil upside down while some farmers (38. 89%) used draught animal. They used tractor than draught animal because in upland (dry land) farming, it is common to maintain tilling top soil layer at minimum of 20 cm depth to bury surface plant residue for better decay of surface soil while this operation couldn't be maintained by shallow top soil turning upside down by draught animal. At this study area, primary tillage (first round operation) couldn't be attempted in dry land (tight top soil) unless the land (top soil) becomes soft to be plowed by animal power at the early rainy season; however, the depth of plowing still had a constraint.

In contrast, the results in Figures 4.8 b, c and d show that the majority of the farmers in the study area used draught animal (oxen) for the second round primary tillage (72.22%), harrowing (70%) and seed covering (71.11%) respectively while about one-third of the farmers in all aforementioned operation used tractor in this regard. The preference of farm power highly depends on the following factors: 1) season and weather condition, 2) required depth of plow, 3) nature of plant residue and 4) timeliness operation and yield (output).

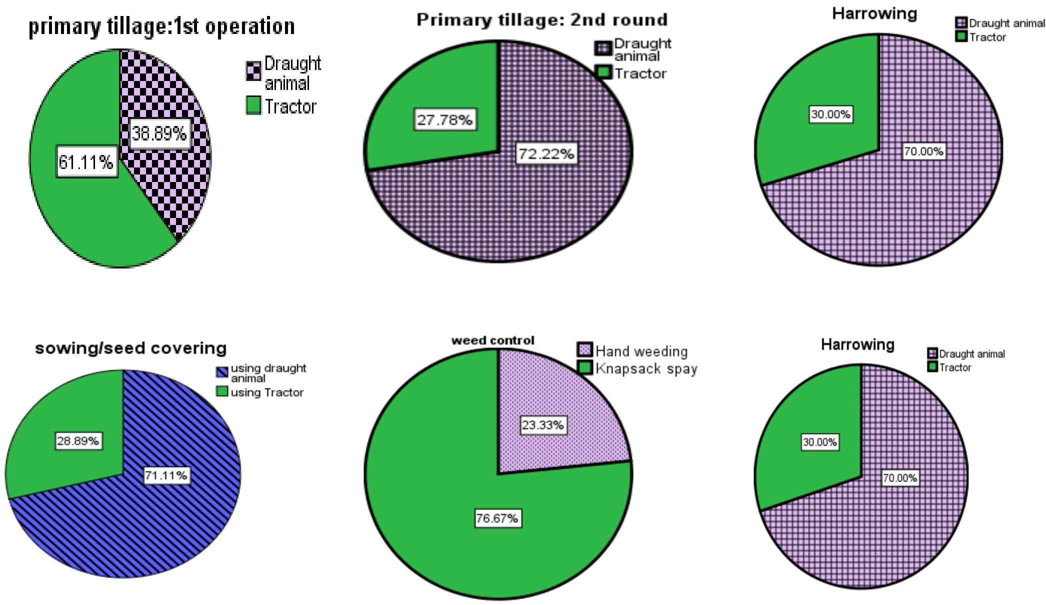


Figure 4.8. Rental based farm power used for pre and post-harvest operations

Farmers in the study area suggested that when the top soil is turned by tractor in the dry season, the inverted top soil layers had many clods so that they more likely use tractor for the subsequent operation to pulverize it into pieces in order to prepare better seed bed for the crop. When draught animals are used for the second operation of primary tillage, where tractor is used in the first and the field has clods, the soil couldn't be mixed and the clods remain as it is. Hence, most of the seed covered could be buried by clod which has negative effect on the crop yield.

Figures 4.8e and 4.8f reveal, weed control and harvesting between mechanized and traditional operations have significant difference. The Majority of the farmers (76.67%) in the study area used mechanized way of weed control while only one fourth of them used traditional hand weeding. Similarly, 92.22% of the farmers in the study area used mechanized harvesting. The number of farmers who used manual harvesting was declining from time to time. Comparative study conducted by Hassena et al. (2000) eight years ago in similar district showed that 41% of the farmers were using manual harvesting. This time, the percentages of the farmers who were using manual harvesting in the similar district (where the study is conducted) were only 7.78%. This shows that, there is a highly significant difference between two periods with eight years g

4.1.5. Farm operations in a year

Therefore, farmers in the study area are radically shifting from manual to mechanized harvesting. During manual harvesting of cereals, especially wheat and barley, it requires stacking in the field. After sometimes transporting to the threshing plot and threshing are done by animal power mostly cattle. The process is continued to winnowing, transporting and storing final yield which requires long time and labor intensive. On top of this, yield losses in every step are also one of the other determinant factors which affected the farmer's decision on shifting from manual to mechanized harvesting.

Table 4.9 and Table 4.10 show the timing of farm operations from primary tillage to the final harvesting cereal crops. Weather manual or mechanized operation and timing are important for better crop yield at normal and constant weather conditions. The results in Table 4.9 reveal that 62.2% and 54.4% of the farmers in the study area perform primary and secondary tillages respectively. According to this result, for the majority of the farmers, month of July is the time of sowing while August is the time of weed control which accounted 63.3% and 67.8% respectively. Similarly, November is the month of peak period for the majority of farmers who had been using both manual threshing (61.1 %) and mechanized harvesting (67.8%) methods. But some of the farmers (22.2%) who are said to be early beginners started their harvesting in the month of November. However, among farmers who used manual threshing, 36.7% of them thresh their cereals in December because of the fact that manually threshed cereals can be heaped and stored for some times.

Table 4.9. Period of farm operations in a year.

Operation type	Time of operation	Frequency	Valid percent	Cumulative percent
Primary tillage	March	34	37.8	37.8
	April	56	62.2	100.0
Secondary tillage	April	25	27.8	27.8
	April & May	5	5.6	33.3
	May	49	54.4	87.8
	May & June	11	12.2	100.0
Sowing	August	3	3.3	3.3
	July	57	63.3	66.7
	June & July	30	33.3	100.0
Weed control	Missing value	1	1.1	1.1
	August	61	67.8	68.9
	July	6	6.7	75.6
	July & August	22	24.4	100.0
Harvesting/ reaping	December	7	7.8	7.8
	November	61	67.8	75.6
	October	2	2.2	77.8
	October & November	20	22.2	100.0
Threshing	December	33	36.7	36.7
	November	55	61.1	97.8
	November & December	2	2.2	100.0
Transporting and storage	December	35	38.9	38.9
	November	53	58.9	97.8
	November & December	2	2.2	100.0

Hence, timely operation of land may not be attained mostly in traditional farming since it takes much time. The scenario seems hard for those who don't have their own farm power. In order to achieve greater timeliness operation, mechanization could be an answer. Because machines usually work faster than human and animal power and farmers can create timeliness related benefits which has a great effect on increasing yield. Therefore, farmers in the study area confirm that timely performed farm operation has a greater yield than that performed late.

Table 4.10. Farm operation calendar in Hetosa district

Operations	Operation months in a year for cereal crops											
	Januar	Feb	Marc	Apri	Ma	Jun	July	August	Sep	Oct.	Nov.	Dec
Primary tillage												
Secondary tillage												
Sowing												
Weed control												
Harvesting												
Threshing												
Transporting & storage												

4.1.5.1. Infrastructure of farm mechanization

Physical Infrastructure is essential for agricultural development in developing county like Ethiopia and so does in the study area. Particularly roads, irrigation, energy, telecommunication, and machinery service center (garage) are crucial for rural. The study revealed that insufficient infrastructure was identified as a bottleneck for effective utilization of agricultural inputs and limited them to supply out with better options. Currently road infrastructure is vital for farm machinery accessibility but it was limited to 68 km dry weather roads, and 161 km all weather roads. However, KOICA had been carried out integrated rural development projects like road, and energy (biogas) in some village which could be a model in the study district.

Table 4.11 shows that the respondents in the study area have an average distance of 4.4 km from the main road. The minimum distance was as close as 0.25 km while the largest distance was as far as 14 km from the main road which is categorized comparably as remote area. The mean value to the main road is one of the indicators of moderate closeness of the farmers to the main road that have better access to the infrastructure and transport facilities. They could have also access to the farm machinery like tractor and combine harvester for their farm operations on timely basis, supplying mechanization inputs to the farm land and transporting end products from the field. On top of this, farmers who have access to the main road have a better opportunity to negotiate or supply their end products to the market center either to wholesaler or retailer with better price. In other way round, the availability of transportation facilities might have help reduce long market distance constraint, offering greater depth in marketing choices.

Table 4.11. Farm machinery accessibility from farm

Description	Number	Minimum	Maximum	Mean	STD
Distance from main road (km)	90	0.3	14	4.4	3.4

The other facility/infrastructure crucial for farm mechanization is machinery service center. In the study area, there was no well-equipped machinery service center which provides technical repair and maintenance services except minor ones. Rather, each machinery has its own dealer. For example, Reis Engineering was a dealer of Massey Ferguson; Kaleb Farmers House was a dealer of Claas combine harvester; Gadab Engineering was a dealer of John Deere combine harvesters; government owned Adama Agricultural Machinery Industry was a dealer of NTAF-Belarus and YTO; and Adab Engineering was a dealer of Fiat New Holland tractors and New Holland combine harvesters. Almost all these dealers are located in the capital except Adama Agricultural Machinery Industry. Out of these dealers, some of them provide after sale service only for one year according to warrantee period. After one year, the farmers should try to maintain/repair them by themselves. Hence, integrated rural infrastructure is very important for farm machinery accessibility and associated problems.

4.1.6. Level of farm mechanization in study site

Mechanization index or mechanization level can be measured by the tractor and combine harvester availability in an area. Based on this concept suggested by Mohsen (2014) and Shamabadi (2013), the total farm machinery population in the Hetosa district was investigated and given in Table 4.12.

There is big variation in the level of mechanization in different regions of Ethiopia. In south eastern Ethiopia, particularly Arsi and Bale and central northern Gojam regions, farm mechanization was introduced for cereal crops in the early 1980 during Derg regime. But in some parts of Ethiopia like Gambella and Wollaga regions, cereal crop mechanization has been introduced within the last ten years. In the rest of the regions, particularly the norther and eastern regions mechanization has not been satisfactory due to constraints like hilly topography at the north, and very hot climate at the east.

Table 4. 12. Number of agricultural machines in the study area

Owner	Machine	Quantity	Brand	Horse power	Year of purchase
Hetosa union	Tractor	1	Belarus	110 hp	2011
		2	Massy Ferguson	90 hp	2011
		1	Farm track	80 hp	2012
	Combine harvester	1	John deere	160 hp	2008
		2	Claas combine	120 hp	2013
		1	New Holland	120 hp	2014
Private farmer	Tractor	2	Massey Ferguson	104 hp	1998
		2	Fiat new Holland	120 hp	1998
		3	NTAF-Belarus	90 hp	1998
		1	Styer	101 hP	1993
		2	TYO	110 hp	2012
	Combine harvester	2	John Deere	135 hp	2011
		1	New Holland	120 hp	2008
		1	Claas Combine	150 hp	2011

In the study area, mechanization was introduced at the inception of Chilalo Agricultural Development (CADU) in 1977 (Hassena et al, 2000). Since then farmers have had access to farm machinery especially for cereal crops production.

As shown in Table 4.12, there were about 22 registered farm machineries in the study area and out of which tractor accounted 63.6% while combine harvesters accounted 36.6%. Farmers were found to be using known brand tractors such as Belarus, Massey Ferguson, Farm Track, Fiat New Holland and Styre tractors while TYO (china origin) was newly introduced tractors. However, farmers had a complaint on Steyr and TYO due to their frequent failures. Despite the complaint the government has been importing so many tractors (TYO) due to the cheaper price as compared with others. When compared with tractors, the number of combiner harvesters was very limited. Mostly, John Deere, New Holland and Class were being used in the study area.

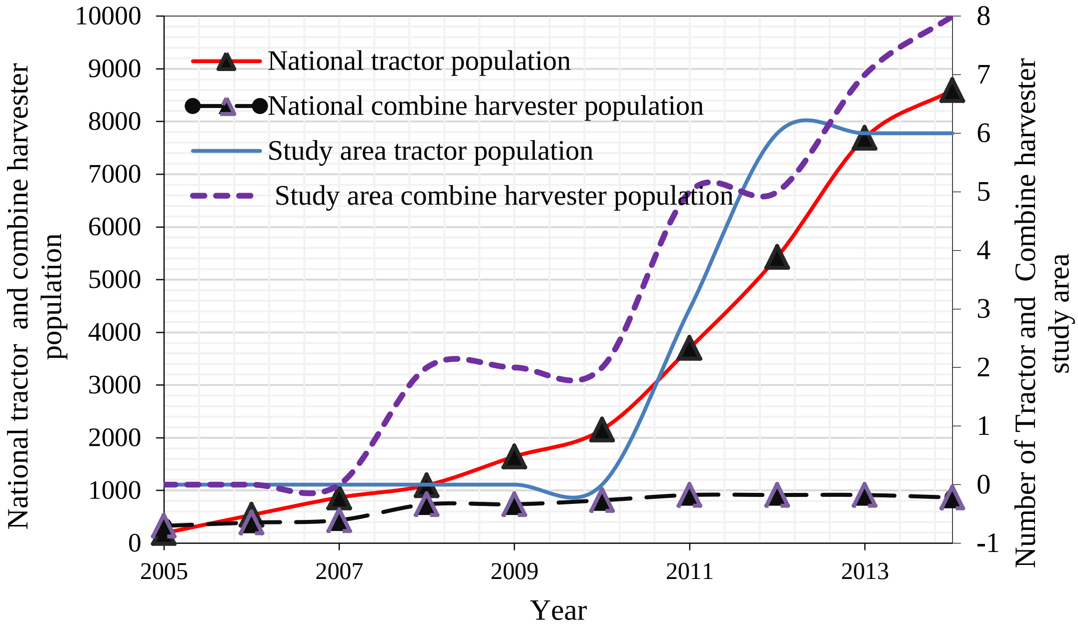


Figure 4.9. Farm machinery populations

Figure 4.9 depicts that the number of combine harvesters and tractors at national level was very limited before 2007. For the last 10 years, the number of tractors and combine harvesters was increased drastically in the study area. A number of tractors increased by about 8 fold from 2007 to 2014. Although the government has been importing a lot of machinery, farm mechanization is still in nascent stage and needs significant support and emphasis from the government.

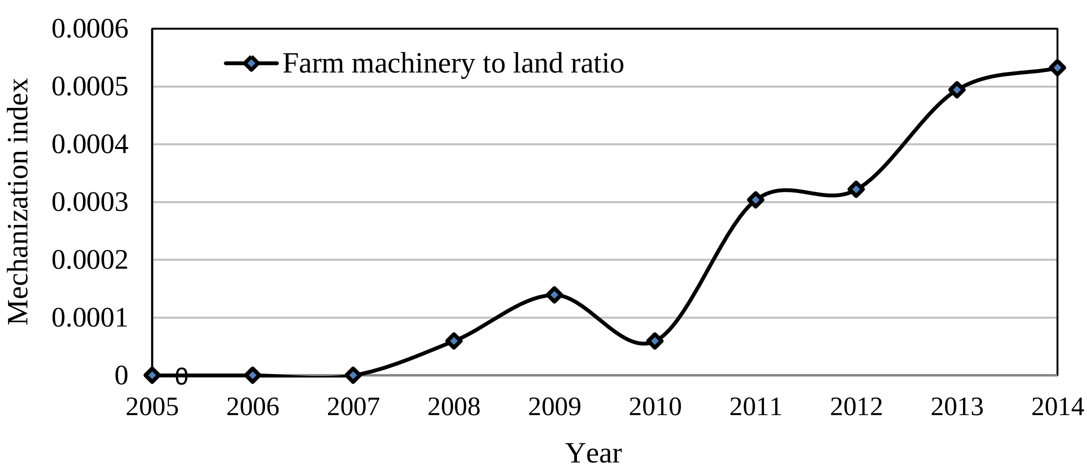


Figure 4.10. Mechanization index in Hetosa district

Mechanization level indicators confirmed that by 2014 (see appendix B) the ratio of tractors to 1000 hectares was 0.5 at national level; whereas, in the study area the value was as low as 0.23. These simply mean that 1 tractor works for 2000 and 4500 hectares at national level and study area respectively. In line with this, mechanization indicators shown in Figure 4.10 confirmed that the ratio of farm machinery to cultivable land increased linearly from 2007 to 2009. In the meantime, this ratio declined during the period from 2009 to 2010. The ratio of farm machinery to land has increased impressively from 0.01% in 2010 to 0.053% in 2014. The lower ratio refers to the lower mechanization level of the study area. Low level of mechanization can be characterized by low level of production without considering other factors (FAO, 2004).

4.1.6.1. Farm machinery condition: Origin and makes of agricultural machinery in study site

Different types of machinery with different makes and origins are available in Hetosa district. As shown in Table 4.13, there are eight main machinery makers for both tractors and combine harvesters. These machineries have different origins and are made with different level of quality and complexity. Each machinery is composed of different systems and components which require different to repair and operate.

Table 4.13. Makers and origins of tractors and combine harvesters

Type of farm machinery			Model	HP	Make	Origin
Tractors	1	Massey Ferguson	398	104	AGCO	America
	2	Fiat New Holland	110-90	120	FIAT motors corporation	Italy
	3	NTAF-Belarus	820	90	NTAF-Belarus	Russia
	4	Styer	9094	101	Styer	Austria
	5	YTO	404	110	YTO	China
Combine harvesters	6	John Deere	8000	135	John Deere company	America
	7	John Deere	7000	160	John Deere company	America
	8	New Holland	80-66s	120	FIAT motors	Italy
	9	Claas Combine	Dominator 68's"	150	Claas	Germany

The result in the Table 4.13 shows about five types of tractors with different origin and make: Massey Ferguson, Fiat New Holland, NTAF-Belarus, Styer, and YTO. Even though the level of complexity is different from tractor to tractor, their general systems could be similar, but in the case of combine harvesters, the systems consisted of tremendous amount of hydraulics, chains, gears and grain transporting units. Above all, different sensor technologies which detect grain moisture content and the like are equipped with combine harvesters. The level of complexity also varies from maker to maker. For example, the older model of John Deere combine was simple and easily maintainable but nowadays due to technological advancement, the complexity of the systems increases from time to time as a result of which, perhaps, it is difficult for persons who have less knowhow to handle, operate and maintained the combines.

Therefore, more technical repair crews with new technologies are required. To maintain these machines, it requires many well trained technicians who have theoretical and technical back ground of machinery with adequate experience and skills.

4.2. Estimation of agricultural machinery effect on crop production

Linear regression function was used to determine mechanization input parameters and output relationship on the effect of farm machinery and mechanization technology as shown in the Table 4.14. The value of linear regression of R-square in the model indicated the association between explanatory variables and response variables. It was also measured the percentage of response variable/ production variation explained by linear model. Hence, 61.47% variation was explained by aforementioned eight parameters included in the model while the remaining variables/factors which were not included in the model might be explained. The variation of the model (F-statistics) was statistically significant) $p<0.01$). The sum of error square of the model was a more than the sum of square residuals. The root mean squared error which measured the differences between the values predicted by the model and the values actually observed was small (7.6).

The regression coefficients of the accessibility of famers to the tractor (X_1), combine harvester (X_2), education (X_4), farm size (X_5), weed control technology (X_7) and field condition (X_8) were positive which indicated that unit increase in each of these variables could increase production of cereal crop output yield while age of house hold head (X_3) and family size (X_6) regression coefficient were negative which indicated that a unit increase in this parameter has negative effect on crop yield output.

Among mechanization input parameters which affected wheat crop production, having access to use combine harvester (P<0.01), education (P<0.05), firm size (P<0.01) and weed control technology (P<0.01) have highly significant effect on crop yield output. The implication of significant effect of combine harvesters was perhaps due to reduction of post-harvest losses which could be happened possibly during manually operation. The result in Table 4.19 showed accesses to use tractor for farm operation has no significant effect on crop production. However, the response has positive using tractor as farm power. Farmers who have large farm size have a positive and significant effect on final yield output than small farm size farmers. Age of house hold head has negative effect on production. It was hypothesized that younger farmers may have greater access to modern farming (mechanization) because they have had greater know how and awareness of farming technologies than older one. But the result revealed that age has a negative significant effect and the null hypothesis was rejected.

Table 4.14. Properties of parameter estimates of multiple linear regression model for wheat crop production.

Production.	Coef.(β)	Std. Err	t	P>|t|	95% Conf. Interval	
Tractor accessibility	3.47438	2.559675	1.36	0.178	-1.618569	8.56733
Combine accessibility	8.324037	3.079985	2.70***	0.008	2.195834	14.45224
Age of house-hold head	-.0048625	.1072683	-0.05	0.964	-.2182927	.2085677
Education	6.285321	2.40277	2.62**	0.011	1.504563	11.06608
Firm size	4.010641	.8668048	4.63***	0.000	2.285972	5.735311
Family size	-.3221629	.3428936	-0.94	0.350	-1.004414	.3600878
Weed control technology	6.823291	2.508623	2.72***	0.008	1.831917	11.81466
Field condition	1.787837	2.089019	0.86	0.395	-2.368656	5.94433
constant	11.59161	4.97704	2.33	0.022	1.688858	21.49436
Number of obs.	90					
F(8, 81)	16.15					
Prob > F	0.0000					
R-squared	0.6147					
Adj R-squared	0.5766					
Root MSE	7.6903					

Note**:** *=significant at P<0.10; **= significant at P<0.05; ***significant at P<0.01

Table 4.15. ANOVA table for parameter estimates of multiple regression model

Source	SS	df	MS
Model	7641.70	8	955.213
Residual	4790.39	81	59.140
Total	12432.1	89	139.686

The result in Table 4.14 showed that using farm machinery and associated technologies have a positive effect on cereal (wheat) crop production. Moreover, accessibility to combine harvester was crucially important factor to get higher yield output. Result in Table 4.14 revealed that coefficients of combine (8.3) was positive very large. Though not significant, tractor was also positively influenced the response variable. This indicated that using these farm machineries for crop production were significantly influenced yield out. On other hand farmers who had better access to combine harvester and tractor found to be beneficiary than those who didn't have access.

As explained above, education also had positive significant effect on crop output yield. Positive and strong education coefficient (6.2) noticed confirms, educated farmers could use farm machinery and are more likely to produce higher yield per unit hectare than illiterate farmers. Education was believed to be a key success for a farmer to respond and accept to understand modern mode of farming. Farm size had also significantly influenced crop output. The result depicted that farmers who had large farm size could produce more crop output than small size holders. The coefficient of family size (-0.32) was negative and very small. Those farmers who had small family size have a negative effect on production output. Hence, null hypothesis was rejected in this regard. Similarly, younger age was negatively influenced on crop output yield. Elder and experienced farmers perhaps had a tendency to influence production.

Weed control method had also positive impact on production. The coefficient of weed control technology (6.8) was positive and very strong which indicated that using knapsack type spay (mechanized means) had highly significant influence on production than manual weeding. There was a wide gap between production level of those farmers who used weed control technology and those with manual weeding.

Lastly, farm field's topographic condition was important factor which affects production output. Coefficient of field condition (1.7) showed that regular terrain or plane fields were positively influenced production of crop than irregular or sloppy fields. This indicated that there is natural limit for farmers who have sloppy field. Beside natural constraints like soil erosion, accessibility to the farm machinery hiring services is also very limited for farmers who have sloppy field due to concern over turn of field machines. As one of the better option in the case of using modern technology, Power tiller/walky tractor/ can be used instead of using four wheeled machinery (tractor and combine harvester) to overcome problem related to sloppy field.

4.3. Development of farm mechanization models

The study used three models:1) traditional farming mechanization model which uses animate as a motive power; 2) semi-mechanized farming mechanization model which uses walky tractor (power tiller) as a motive power. This model used intermediate technology so called semi-mechanized because of the combination of human and machine used in such a way that human power is used to push power tiller forward alongside of operation; 3) mechanized model which is supposed to use farm machinery (tractors and combine harvesters) in all pre and post-harvest operations.

Model 1. Traditional farming (draught animal and human as motive power)

- Model 1 represents Table 4.16A to Table 4.16C.This model represents the traditional farming by human and animal powers in Ethiopia. Following were assumed in this model to reflect the current farming practices and the data collected in the Arsi region. The collected data and farming practices used to estimate man power, animal power and production cost required per unit hectare by the model 1. Oxen are hired with his owner on the basis of working 6 hours per day for primary tillage, secondary tillage and seed covering operations. One operator drives oxen to work and another is an assistant. One extra person as a seed broadcasting expert is required for every 4 pair of oxen so that 9 persons are working for wheat and barley seed covering operations. Hiring a pair of oxen costs 8.77 USD per day regardless of working load and time; 2.31USD for a pair of oxen and 3.26 USD for each of two operators.

- Labor and oxen work 8 hours a day for post-harvest operations of three main crops. Labor cost per days is 2.31 USD for hand weeding (except for maize), threshing and transportation, 3.226 USD for normal operation and 3.69-4.62 USD for the peak time operation in the seed covering and harvesting seasons respectively. To get threshing operations done a day 10 pair of oxen and 12 labors for wheat, 8 pair of oxen and 10 labors for barley, and no oxen but 10 laborers for maize required per one hectare. Horse is usually hired to transport the harvested crop to threshing and storage place. A pair of horses can transport 15 quintals of wheat and 10 quintals of barley a day and are paid 4.62 USD for each.
- Three labors also need to work 2 days for loading and unloading 3000 kg and 2000 kg of harvested wheat and barley crops on the horse and property staking them in farmer's storage or ware house. But for maize crops five labors are needed a day to staking 2500 kg in farmer's storage. Labor and oxen requirement were determined in the model 1 of Table 4.16A to Table 4.16C
- Total cost of labor was calculated as sum of labors per operation multiplied by unit cost per day. Total oxen cost was calculated as a pair of oxen cost multiplied by number of days required for operation. Average wheat, barley and maize yields were 3000, 2000 and 2500 kg per hectare respectively.

Table 4.16A. Input values of wheat farm operation for the model 1

Wheat operations	Primary tillage		Secondary tillage	Sowing/ drilling	Weeding /weed control/		Post-harvest operation			Total
parameters	1st round	2nd round	Seedbed preparation	Seed covering	cultivation	Hand weeding	Harvesting & heaping	Threshing &winnowing	Transporting and storage	
No of days required for oxen	4	3	3	4	-	-	-	2	2	18
Oxen hour required	24	18	18	24	-	-	-	80	32	196
No of man required	8	6	6	9	-	20	15	12	6	82
Man-hour required	48	36	36	54		160	120	96	48	598
Cost for oxen	9.23	6.92	6.92	9.23	-	-	-	23.08	9.23	64.63
Cost of labor	25.85	19.39	19.39	41.55	-	46.16	55.40	27.70	13.85	249.10
Cost per operation	35.08	26.31	26.31	50.78	-	46.16	55.40	50.78	23.08	313.73

Model 1-Input Cost			Operation cost	Yield Output Income	Total Return
Wheat Seed	Fertilizer	Total input	B=313.73USD	C=3000 kg/ha*(39.24 USD/100kg) =1177.2 USD/ha	C-(A+B)= 688.04 USD
200kg*(55.4USD/100 kg)=110.80 USD	100kg=64.63 USD	A=175.43 USD			

Table 4.16B. Input values of barley farm operation for the model 1

Barley operations	Primary tillage		Secondary tillage	Sowing/ drilling	Weeding		Harvesting & heaping	Threshing &winnowing	Transporting & storage	Total
Parameters	1st round	2nd round	Seedbed preparation	Seed covering	cultivation	Hand weeding				
No of days required for oxen	4	3	3	4	-	-	-	2	2	18
Oxen hour required	24	18	18	24		-	-	64	32	180
No of man required	8	6	6	9	-	20	15	10	6	80
Man-hour required	48	36	36	54	-	160	120	80	48	582
Cost for oxen	9.23	6.92	6.92	9.23	-	-	-	18.46	9.23	60
Cost of labor	25.85	19.39	19.39	41.55	-	46.16	55.40	23.08	13.85	244.67
Cost per operation	35.08	26.31	26.31	50.78	-	46.16	55.40	41.54	23.08	304.67

Model 1-Input Cost			Operation	Yield Output Income	Total Return
Barley Seed	Fertilizer	Total input	B=304.67 USD	C=2000kg/ha*(36.93 USD/100kg) =738.6 USD/ha	C-(A+B)=258.5 USD/ha
200kg*(55.4USD/100 kg)=110.80 USD	100kg=64.63 USD	A=175.43 USD			

Table 4.16C Input values of maize farm operation for the model 1

Maize operations	Primary tillage		Secondary tillage	Sowing /drillin	Weeding			Post-harvest operation			Total
	1st round	2nd round	Seedbed preparation	Seed covering	Cultivation	Hand weeding		Harvesting & heaping	Threshing & winnowing	Transporting & storage	
parameters						Early stage	Premature stage				
No of days required for oxen	4	3	3	3	4	-	-	-	-	-	17
Oxen hour required	24	18	18	18	32	-	-	-	-	-	110
No of man required	8^	6	6	6	8	16	14	20	10	5	99
Man-hour required	48	36	36	36	64	128	112	160	80	40	740
Cost for oxen	9.23	6.92	6.92	6.92	9.23	-	-	-	-	-	39.22
Cost of labor	25.85	19.39	19.39	27.70	25.85	51.70	45.24	92.33	32.31	16.15	355.91
Cost per operation	35.08	26.31	26.31	34.62	35.08	51.70	45.24	92.33	32.31	16.15	395.13

Model 1-Input Cost			Operation cost	Yield Output Income	Total Return
Maize Seed	Fertilizer	Total input	B=395.13 USD	C=2500 kg/ha*(27.7 USD /100 kg)=692.5 USD/ha	C-(A+B)= 154.27 USD/ha
50 kg=46.16 USD	150 kg/ka*(64.63USD/ 100 kg)=96.94 USD/ha	A=143.1 USD			

100 kg =1quintal, M=model

a. Typical traditional farming for wheat and barley crops production

b. Typical traditional farming for maize crop production

Figure.4.11. Traditional farming for main cereal crops

Model 2. Semi-mechanized farming

Model 2 represents by Table 4.17A to Table 4.17C. In this model, power tiller, knaps sack type sprayer, [B] combine harvester and [©]truck were used to carry out tillage, weed control, harvesting and transportation respectively. Power tiller of 15 kW in horse power and 0.125 ha/h in average field capacity were most commonly used in the study region. Following were found from the results of the interviews and collected data.

- Power tiller requires 8 hours operation per hectare for each of the first round primary tillage, the second round primary tillage, the seed bed preparation and the seed covering. Combine harvester and truck require half an hour of operation for the harvesting and transportation respectively. Knap-sack type sprayer requires 6 hours of operation for the weed control.
- Hiring cost power tiller was 46.16 USD for first round primary tillage and 23.08 USD for second round primary tillage, secondary tillage of seed bed preparation and sowing respectively for wheat and barley crops operations. Hiring costs of combine harvester was 2.3 USD per 100 kg while truck cost of loading and transporting was 0.46 USD per 100 kg. Similarly hiring cost of manual maize sheller was 0.46 USD per 100 kg.

- Dibbler was used for seed covering of maize crop. Hiring cost of dibbler was 2.3 per day. Weed control of maize crop didn't use knap-sack type sprayer but hand hoe was used to remove weed after cultivation. Manual sheller was also used for threshing maize crop.
- Labor cost of primary tillage, secondary tillage, winnowing, transportation and storage was 3.23 USD while 4.61USD for peak time operations of seed covering and harvesting of wheat and barley operations. But hiring cost of knap-sack type sprayer along with owner was 5.54 USD per hectare. Extra one person during seed covering was required as seed broadcasting expert for all crops.
- Average wheat, barley and maize yields were 3200, 2300 and 3000 kg per hectare respectively.

Table 4.17A to Table 4.17C show work hours and costs required for one hectare farming by the model 2 in terms of machine and man-hours based on the above practices.

Table 4.17A. Input values of wheat farm operation for the model 2

Wheat operations	Primary tillage		Secondary tillage	Sowing/ drilling	Weeding		Post-harvest operation			
parameters	1st round	2nd round	Seedbed preparation	Seed covering	cultivation	Weed control	Harvesting	Threshing & winnowing	Transporting & storage	Total
No. of days required for power tiller	1	1	1	1	-	-	½ hr[B]	-	½ hr[c]	5
No. of power hours required	8	8	8	8	-	-	½ hr	-	½ hr	33
No of man required	1	1	1	2	-	1	1	4		11
Man hours required	8	8	8	16	-	6	1	24.5		71.5
Cost for power tiller	46.16	23.08	23.08	23.08	-	46.16	73.86	-	14.77	250.23
Cost of labor	3.23	3.23	3.23	9.23	-	5.54	4.61	12.92		41.99
Total Cost per operation	49.39	26.31	26.31	32.31	-	51.7	78.48	12.69		292.22

Model 2-Input Cost			Operation cost	Yield output income	Total return
Wheat Seed	Fertilizer	Total input			
200 kg/ha*55.40 USD/100 kg)= 110.8 USD/ha	100 kg/ha*64.63 USD/100 kg)= 64.63 USD/ha	A=175.43 USD	B=292.22 USD	C=3200 kg/ha* (39.24 USD/100 kg)=1255.68 USD/ha	C-(A+B) =788.03 USD

Table 4.17B. Input values of barely farm operation for the model 2

Barley operations / Parameters	Primary tillage 1st round	Primary tillage 2nd round	Secondary tillage Seedbed preparation	Sowing/dri... Seed covering	Spraying cultivation	Spraying Weed control	Post- harvest operation Harvesting	Post- harvest operation Threshing & winnowing	Post- harvest operation Transporting & storage	Total
No of days required for tractor	1	1	1	1	-	-	½ hr[B]	-	½ hr[C]	5
No of power hours required	8	8	8	8	-	-	½ hr	-	½ hr	33
No of man required	1	1	1	2	-	1	1	3		10
Man hours required	8	8	8	16	-	6	1	16.5		63.5
Cost for tractor	46.16	23.08	23.08	23.08	-	46.16	53.09	-	10.61	255.26
Cost of labor	3.23	3.23	3.23	9.23	-	5.54	4.61	9.69		38.76
Cost per operation	49.39	26.31	26.31	32.31	-	51.7	57.7	20.3		294.02

Model 2-Input Cost			Operation cost	Yield Output Income	Total Return
Barley Seed	Fertilizer	Total input			
200 kg/ha*55.40 USD/100 kg)= 110.8 USD/ha	100 kg/ha*64.63 USD/100 kg)= 64.63 USD/ha	A=175.43 USD	B=294.02 USD	C=2300 kg/ha*36.93 USD/100 kg)=849.39 USD/ha	C-(A+B)= 379.74 USD/ha

Table 4.17C. Input values of maize farm operation for the model 2

Maize operations / parameters	Primary tillage 1st round	Secondary tillage Seedbed preparation	Sowing/ drilling Seed covering	Weeding cultivation	Weeding Weed control (1st & 2nd)	Post-harvest operation Harvesting	Post-harvest operation Threshing & winnowing	Post-harvest operation Transporting & storage	Total
No of days required for tractor	1	1	4[z]	2			1		9
No of power hours required	8	8	32	12	-	-	8	-	68
No of man required	1	1	8	4	20	10	6		50
Man hours required	8	8	64	24	160	80	48		396
Cost for power tiller	46.16	23.08	9.23	4.61	-	-	13.85	-	96.93
Cost of labor	3.23	3.23	36.93	12.92	64.63	46.16	19.39		186.49
Cost per operation	49.39	26.31	46.16	17.53	64.63	46.16	33.24		283.42

Model 2-Input Cost			Operation	Yield Output Income	Total Return
Maize Seed	Fertilizer	Total input			
50 kg=46.16 USD	150 kg/ka*(64.63USD/	A=143.1 USD	B=283.42 USD	C=3000 kg/ha*27.7 USD/100 kg)=831 USD/ha	C-(A+B)= 404.48 USD/ha

Figure.4.12. Typical semi-mechanized farming model for cereal crops

MODEL 3. Mechanized farming

Model 3 represents by Table 4.18A to Table 4.18C. In this model tractor was used instead of power tiller while the other machines remained as the same as model 2. Tractors most widely used in the study area were found to be 75 kW horse power and have an average field capacity 0f 0.5 ha/h. The work hours and costs for hiring knap-sack sprayer, combine harvester and trucks were the same as those in the model 2 for wheat and barley crops. [z]Dibbler was most commonly used for maize planting. Weed control and post-harvest operations were the same as model 2 for maize crop. Utilization of tractor was found as follows:

- Tractor requires two and half hours of operation per hectare for the first round and the seed bed preparation respectively, and two hours for the seed covering.
- Costs to hire a tractor for primary tillage and seed bed preparation for all three crops were 55.40 USD and 30 USD respectively and seed covering cost for wheat and barley crops was the same as seed bed preparation. Dibbler hiring cost was 2.30 USD per day for maize planting. Hiring cost maize sheller was 0.46 USD per 100 kg. Weed control of maize crop didn't use knap-sack type sprayer but hand hoe was used to remove weed after cultivation.
- Service charge for machine operator as labor cost was 3.23 USD for primary tillage, seed bed preparation, harvesting and transportation of wheat and barley crops operations. Similar cost was used for first round and seed bed preparation of maize operations. But operator and assistant labor cost of seed covering was 4.61 USD only for two hours operation of wheat and barley crops while the same operation of maize crop was 4.61 USD per day. Threshing and transportation shared common labor.
- Average wheat, barley and maize yields were 3500, 2500, 3200 kg per hectare respectively.

Table 4.18A to Table 4.18C show work hours and costs required for one hectare farming by the model 3 in terms of machine and man-hours based on the above practices.

Table 4.18A. Input values of wheat farm operation for the model 3

Wheat operations parameters	Primary tillage		Secondary tillage	Sowing/drilling	Weeding		Post-harvest operation			Total
	1st round	2nd round	Seedbed preparation	Seed covering	Cultivation	Weed control	Harvesting	Threshing & winno-wing	Transporting & storage	
No of days required for tractor	2:30hr	-	2:30 hr	2 hr	-	-	½ hr[B]	-	½ hr[c]	<1day
Power hours required	2.5	-	2.5	2	-	-	0.5	-	0.5	8
No of man required	1	-	1	2	-	1	1	4		10
Man hours required	2.5	-	2.5	4	-	6	1	24.5		40.5
Cost for tractor	55.40	-	30	30	-	46.16	80.79	-	16.15	258.5
Cost of labor	3.23	-	3.23	4.61	-	5.54	-	12.92		29.53
Cost per operation	58.63	-	720	750	-	105.56	80.79	29.07		288.03

Model 3-Input Cost			Operation cost	Yield Output Income	Total Return
Wheat Seed	Fertilizer	Total input			
200 kg/ha*(55.40 USD/100 kg)= 110.8 USD/ha	100 kg/ha* 64.63 USD/100 kg)=64.63 USD/ha	A=175.43 USD	B=288.03 USD	C=3500 kg/ha*(39.24 USD /100 kg)=1373.4 USD/ha	C-(A+B)= 909.94 USD/ha

*, 1 USD ≈21.66 ETB (2015)

Table 4.18B. Input values of barley farm operation for the model 3

Barley operations Parameters	Primary tillage		Secondary tillage	Sowing/ drilling	Weeding		Post-harvest operation			Total
	1st round	2nd round	Seedbed preparation	Seed covering	cultivation	Weed control	Harvesting	Threshing & winnowing	Transporting & storage	
No of days required for tractor	2:30hr	-	2:30hr	2hrs	-	-	½ hr	-	½ hr	<1day
Power hours required	2.5	-	2.5	2	-	-	0.5	-	0.5	8
No of man required	1	-	1	2	-	1	1	3		9
Man hours required	2.5	-	2.5	4	-	6	0.5	16.5		32
Cost for tractor	55.40	-	30	30	-	46.16	57.71 *	-	11.54	230.81
Cost of labor	3.23	-	3.23	4.61	-	5.54	-	-	9.69	26.3
Cost per operation	58.63	-	720	750	-	105.56	57.71	-	21.23	257.11

Model 3-Input Cost			Operation cost	Yield Output Income	Total Return
Barley Seed	Fertilizer	Total input			
200 kg/ha*(55.40 USD/100 kg)= 110.8 USD/ha	100 kg/ha* 64.63 USD/100 kg)=64.63 USD/ha	A=175.43 USD	B=257.11 USD/ha	C=2500 kg/ha* (36.93 / USD/ 100 kg)=923.25 USD/ha	C-(A+B)= 490.71 USD/ha

Table 4.18C. Input values of maize farm operation for the model 3

Maize operations	Primary tillage		Secondary tillage	Sowing /drilling	Weeding		Post-harvest operation			Total
Parameters	1st round	2nd round	Seedbed preparation	Seed covering	cultivation	Weed control	Harvesting	Threshing & winnowing	Transporting & storage	
No of days required for tractor	2:30hr	-	1/4	4^z	2	-	-	1	-	~8
Power hours required	2.5	-	2.5	32	12	-	-	8	-	57
No of man required	1	-	1	8	4	20^Q	10	4		48
Man hours required	2.5	-	2.5	64	24	160	80	32		365
Cost for tractor	55.40	-	30	9.23	4.61	-	-	14.77	-	114.01
Cost of labor	3.23	-	3.23	36.93	12.92	64.63	46.16	*12.92		180.02
Cost per operation	58.63	-	720	46.16	17.54	64.63	46.16	27.69		294.03

Model 3-Input Cost			Operation cost	Yield Output Income	Total Return
Maize Seed	Fertilizer	Total input			
50 kg= 46.16 USD	150 kg/ka*(64.63USD/100 kg)=96.94 USD/ha	A=143.1 USD	B=294.03 USD/ha	C=3200 kg/ha*(27.7 USD/100 kg) =886.4 USD/ha	C-(A+B)= 449.27 USD/ha

Figure.4.13. Typical mechanized farm operations for cereal crops of third model

4.4. Comparison of mechanization models

Mechanization model developed has three categories: model1 for traditional type mechanization, model 2 for power tiller type mechanization, model 3 for tractor assisted modern mechanization operation. Model 1 type mechanization uses traditional tools which are supposed to be in the museum in the developed countries. On top of these, draught animal technology and mechanization tools which pulled by draught animal (oxen, bullock, donkey and horse etc.) are one of the parts of this model. Hand tools such as hoe, spade, shovels, sickles, and other tools which had been pulled by draught animals such as arid plow (Marasha), beam, yoke and etc., have been considered as type one mechanization model.

As it is mentioned above, model 2 mechanization includes intermediate technologies which are neither traditional nor fully automated. Rather these technologies were manipulated by human power. Basically such technologies are designed for small farmer holders who have no capacity to purchase big machine. It is said to be intermediate because it seems a transitional technology from traditional to fully automated (self-propelled machines) like tractors, combine harvesters and other similar farm machineries. For example, walky type tractors and threshers are categorized as model 2 type mechanization tools. Walky type tractors or power tillers are pushed by human power (operator) toward the direction of the farm field. In most cases such power tiller has no seat space for operator and the direction is also guided by the operator since it doesn't equip with steering systems. Similarly, threshers are moved from field to field either pulled by draught animal or human being. Particularly, threshers alike walky type tractors are equipped with wheels which are used to move elsewhere in the field as required.

Model 3 type mechanization technologies are modern farm powers which are propelled by themselves without assistance of external power. Such technologies include tractors and combine harvesters which range from small to large horse power. The size of the machine to be used depends on the several factors such as capacity of farmers, the size of the field, the nature of terrain and soil condition and weather condition. Basically in the model 3, most of the mechanization technologies require skilled operator (technicians).

Other important element supposed to be considered was irrigation. Ethiopia has a significant irrigation potential from both available land and water resources. It is one means by which agricultural production can be increased to meet the growing demands in Ethiopia (Awulachew et al. 2005). A study also indicated that one of the best choices to consider for food self-sufficiency is expanding irrigation development on various scales, through river diversion, constructing small dams, water harvesting structures, etc. (Robel 2005). In its part, traditional and mechanized irrigation required labor and machine like diesel pump and associated facilities. However, cereal crop farming in the study area found to be rain-fed and mono cropping. Irrigation was not nominal to the district. Therefore, all irrigation and related issues were not considered in the models analysis.

These three mechanization modeling have their own roles for small farm holders for farm operations. Hence, in these three models for all farm operations i.e. pre and post-harvest operations were included. Parameters such as the number of days required to complete farm operation per season, number of labor required, and cost required for manual operation, power tiller and tractor (mechanized) operations were thoroughly compared and analyzed.

4.4.1. Work days required for cereals production

Figure 4.14 shows the total number of days required for wheat production by model 1 were 18 days while the number of days required by models 2 and 3 were 5 and 1 respectively. Similarly, in the case of model 1 the numbers of days required for complete operation for barley field were 18 days while the number of days required by model 2 and model 3 were 5 and 1 respectively.

Table 4.19. Three mechanization modeling comparisons

parameters	Model 1: Traditional			Model 2: Semi-mechanized			Model 3: Mechanized		
Main crop	Whea	Barel	Maize	Wheat	Barely	Maize	Wheat	Barely	Maize
No. of days	18	18	17	5	5	9	1	1	8
No. labor	82	80	99	11	10	50	10	9	48
Power cost	64.63	60	39.22	250.23	255.26	96.93	258.5	230.81	114.01
Labor cost	249.1	244.6	355.9	41.99	38.76	186.49	29.53	26.3	180.02

The result in Table 4.19 reveals that the number of days required for both barley and wheat crops are the same in the three models. In the case of maize farming, different numbers of days are observed in wheat and barley framings by three models but the numbers of days required for maize operation by model 2 and 3 are more than those for wheat and barley by 44.4% and 87.5% respectively. The result reveals that the number of days required for maize farming in one complete operation is significantly higher than those for wheat and barley crops.

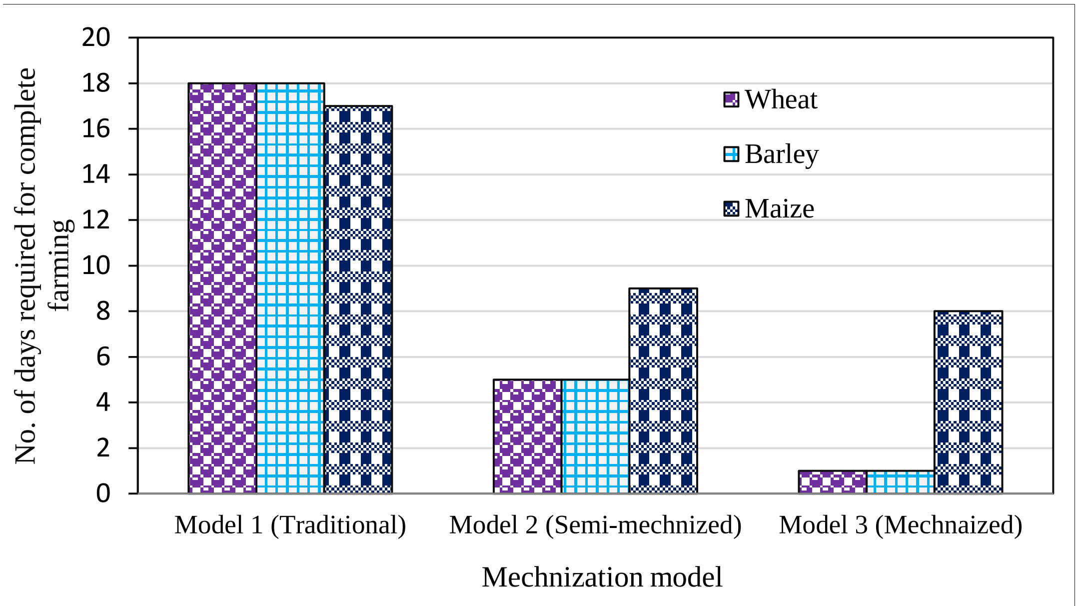


Figure 4.14. Work days for cereals production of three models

In other way round, three mechanization models in terms of days required and saved for one complete farm operation are taken into consideration. The result in Table 4.14 indicated that 72.2% of days could be saved by using model 2 than model 1 and 94.12% days were saved by using model 3 than model 1 in wheat productions while 80% of days could be saved using model 3 instead of model 2 of similar crop. The number of days saved in barley crop was same with wheat crop by comparing three models but the result is not similar with maize crop because many days were required for three models. In maize crop production, farmers could save 47.1% of days by using model 2 than model1 while 52.9% of days could be saved by model 3 than model 1. The number of days saved by using model 3 of maize crop production was 11.1% as compared to model 2.

Table 4.20. Percentage of days saved

Model category		Model 2 to 1	Model 3 to 1	Model 3 to 2
Cereal crops operation	Wheat	72.2%	94.4%	80%
	Barely	72.2%	94.4%	80%
	Maize	47.1%	52.9%	11.1%

Comparative analysis for three cereal crops with in the models revealed that the number of days required for maize crop was higher than wheat and barley crop in all of the three models while the number of days required in model 1 was almost the same. Comparative analysis for three cereal crops among the model i.e. model 1, model 2 and model 3 showed highly significant differences by the number of days to complete farm operation. This analysis indicated that the duration of farming in the model. Farming duration plays crucial role in agricultural operations. As the length of the operation days increases, the effect on crop production could be not good. Timely operation is paramount for production. Hence, tractors and power tillers are more likely help timely accomplishment of farm operation than manual operation.

The results in Table 4.21 revealed that 598 man-hours and 196 oxen-hours were required for wheat crop operations by model 1 while man-hours and oxen-hours required for barely farming were 582 and 180 respectively, and 740 man-hours and 110 oxen-hours for maize operations. When we look at model 1 results in Table 4.27, man-hour required for maize crop was more than those for wheat and barley crop by 19.2% and 21.4% respectively.

Larger man hour for maize crop was due to the increased of man-hours by 41.1% during weeding operation. But man-hours (160) for the model 1 of wheat and barley crops were less than that of maize crop operations. Oxen-hours required for wheat and barley operations for the model 1 were more than maize by the 43.9% and 38.9% respectively. Maize farming oxen-hours were slightly lower (110) than those of wheat and barley crops. Since traditional farming didn’t require machine-hours it wasn’t considered in the analysis. When model 1 to model 2 and model 2 to model 3 were compared in terms of man-hours for wheat crop, they showed a striking result. Man-hours required in model 1, model 2 and model 3 were 598, 71.5 and 40.5 respectively. Larger man-hour in model 1 indicated that traditional farming is labor intensive than semi-mechanized and mechanized farming operation.

In other expression, traditional farming of wheat crop required more time than mechanized and semi-mechanized by 93.2% and 88% respectively. When comparing three models in terms of labor required, nearly similar results were observed for barely operation.

Table 4.21. Man, oxen and machine hours required per operation

Man-hour (A), oxen-hour (B), machine-hour (C)			Primary tillage		Secondary tillage	Sowing /drillin	Weed control		Post-harvest operation			Total
			1st round	2nd round	Seedbed preparation	Seed covering	cultivation	weeding	Harvesting & heaping	Threshing & winnowing	Transporting & storage	
Model 1	Wheat	B	24	18	18	24	-	-	-	80	32	196
		A	48	36	36	54	-	160	120	96	48	598
	Barely	B	24	18	18	24		-	-	64	32	180
		A	48	36	36	54	-	160	120	80	48	582
	Maize	B	24	18	18	18	32	-	-	-	-	110
		A	48	36	36	36	64	240	160	80	40	740
Model 2	Wheat	C	8	8	8	8	-	-	½ hr	-	½ hr	33
		A	8	8	8	16	-	6	1	24.5	-	71.5
	Barely	C	8	8	8	8		-	1/2	-	½ hr	33
		A	8	8	8	16	-	6	1	16.5	--	63.5
	Maize	C	8	-	8	32	12	-	-	8	-	68
		A	8	-	8	64	24	160	80	48	--	396
Model 3	Wheat	C	2.5	-	2.5	2	-	-	0.5	-	0.5	8
		A	2.5	-	2.5	4	-	6	1	24.5	-	40.5
	Barely	C	2.5	-	2.5	2		1	0.5	-	0.5	8
		A	2.5	-	2.5	4	-	6	0.5	16.5	--	32
	Maize	C	2.5	-	2.5	32	12	-	-	8	-	57
		A	2.5	-	2.5	64	24	160	80	32	-	365

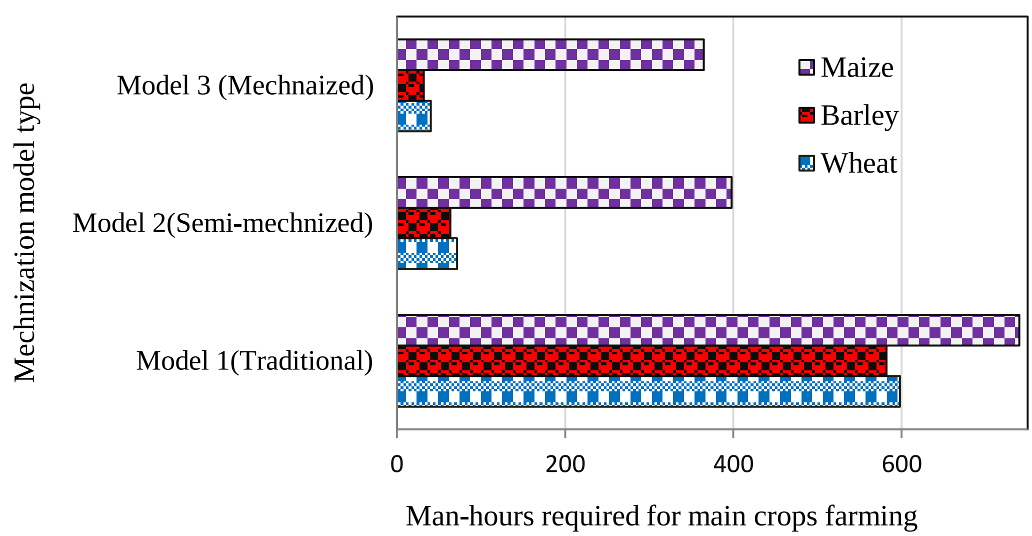


Figure 4.15. Man-hours required for cereals production of the three mechanization models

The results in Table 4.21 and Figure 4.15 showed that man-hours required for three cereal crops i.e. wheat, barley and maize operations decreased surprisingly from traditional to mechanized operations but man-hours required for maize operation by two models (mechanized and semi-mechanized farming) didn't show high degree of variation. The main reason for the increased of man-hours in model 1 as compare to model 3 and model 2 for maize operation was long time of operation, particularly, during weed control and harvesting. When model 1 and model 3 were compared regardless of man-hours required, model 1 seemed to be higher by two fold than model 3. Hence, shifting of farm power from manual to mechanized farming decreases man-hour and increases instead machine hours.

4.4.2. Labor required for the cereals production of mechanization models

Table 4.22 shows labor required by three models. The results revealed larger number of labor was required by model 1 for all cereal crops than by model 2 for the same crops. Similarly, larger number of labors was also observed in model 1 relative to model 3 while relatively proportional labor forces were observed in model 2 and model 3. Using mechanical power for farm operation saves labor. Due to shifting of labor from animate power to mechanical power, the number of labor forces required by two models declined by 86.58% and 87.8% respectively. It also depicted that 9% of the labor was saved by mechanized farming as compare semi- mechanized wheat framing. Similarly, 90% and 51.5% of labors were saved by model 3 than by model 1 for barley and maize crop operation respectively.

Table 4. 22. Total number of labor in each model

Model category		Model 1 (traditional)	Model 2 (semi-mechanized)	Model 3 (mechanized
Cereal crop operation	Wheat	82	11	10
	Barley	80	10	8
	Maize	99	50	48

Table 4. 23 Saved labor comparisons between three models

Model category		Model 2 to 1	Model 3 to 1	Model 3 to 2
Cereal crop operation	Wheat	86.6%	87. 8%	9%
	Barely	87.5%	90%	20
	Maize	49.5%	51.5%	4%

In the case of barley crop, the number of labor required was slightly lower than in wheat (N=82) and maize (N=99) crops in model 1. But larger percentage of labor was observed in model 1 than in model 2 and model 3. Declining of labor forces was observed both in Models 2 and model 3 due to shifting of power from animate to mechanically operating one.

As it was observed from the barely crop results in Table 4.23, 87.5% of labor was saved due to shifting of power from model 1 to model 2 and model 3 respectively while 49.5% and 51.5% of labor were saved for of maize crop by shifting model 1 to model 2 and model 3 respectively.

Table 4.24. Number of labor required for operation

	Operations / Crops	Primary tillage		Secondary tillage	Sowing/ drilling	Weed control		Post-harvest operation			Total
		1st round	2nd round	Seedbed preparation	Seed covering	Cultivation	Weeding	Harvesting & heaping	Threshing & winnowing	Transporting & storage	
Model 1	Wheat	8	6	6	9	-	20	15	12	6	82
	Barely	8	6	6	9	-	20	15	10	6	80
	Maize	8	6	6	6	8	30	20	10	5	99
Model	Wheat	1	1	1	2	-	1	1	1	3	11
	Barely	1	1	1	2	-	1	1	1	2	10
	Maize	1	-	1	8	4	20	10	3	3	50
Model	Wheat	1	-	1	2	-	1	1	2	2	10
	Barely	1	-	1	2	-	1	1	1	2	9
	Maize	1	-	1	8	4	20	10	1	3	48
Total		30	20	24	48	16	114	74	41	32	39

Among the pre and post-harvest operations in the three models shown in Table 4.24, weed control was the most labor intensive operation followed by harvesting and seed covering respectively while cultivation was the list labor required followed by second round tillage operation and seed bed preparation. As aforementioned, the number of labor in weed control was high, however, labor costs for all models except model 3 (barley and wheat farming) were within the normal range (Figure 4.16). But during two peak operations (seed covering /sowing/drilling/ and harvesting), the demand of the labor is very high as compared to other operations as shown in the Figure 4.16.

The labor costs were high during peak operation due to three reasons: 1) laborers give an attention to their own farms than seeking job elsewhere which makes labor shortage, 2) competition of the farmers to accomplish operation within time so as to reduce time lines related costs, 3) increasing labor cost during this period is considered as a trend by both farmers and laborers. Increasing cost during peak operation than normal operation has not only been seen in human labor alone but also on both draught animal and mechanical power (tractor, combine harvester, threshers etc.).

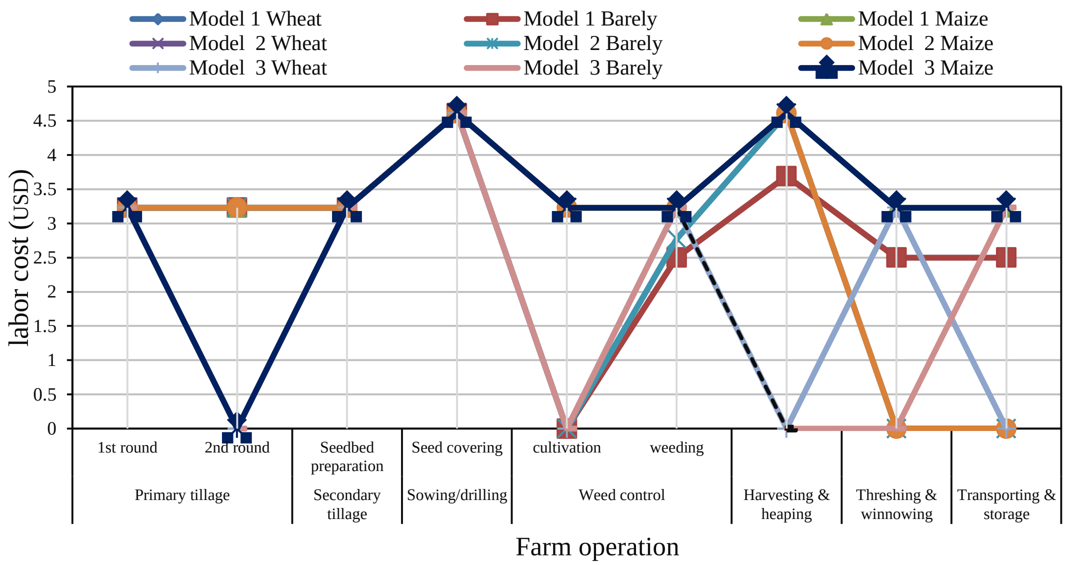


Figure 4.16. Peak time operation and its corresponding labor cost

Generally, increasing additional cost during peak operation has increased overall operational cost which has a negative impact on total cost and return from investment.

4.4.2.1. Validity test for labor force required

Validity test requires checking of mechanization model developed with the actual mechanization so as to check how best the model works and is functional. Validity testing for pairwise labor force required between traditional and mechanized farm operations was checked as shown in Tables 4.25 and 4.26.

The results in the above mentioned Tables revealed that the mean value of labor required in the primary tillage was 8 for traditional and 1 for mechanized farm operations. Paired difference t-test showed that there is highly significant difference between mean value of traditional and mechanized labor with p=0.000 and t=30. Pairwise secondary tillage labor force required for traditional and mechanized farm operations were 5.7 and 1.4 persons per hectare respectively but high standard deviation was observed for traditional labor force than for mechanized one with mean variation between two labor forces are highly significant at 5% significant level. The labor force required for model 1 (traditional farming) was 6 while the number of labor required for its counterpart was 1. This does mean that there was no significant variation in the same operation (with in mechanized and traditional) while still a significant variation between traditional and mechanized operations as it was discussed under section 4.4.2.

Table 4.25. Pairwise test for labor required between traditional and mechanized

Paired operation comparison (wheat		N	Mean	Std.Deviation	Std. Error Mean
Pair 1: Primary tillage	Traditional	90	7.844	2.0163	.21254
	Mechanized	90	1.277	.4504	.04748
Pair 2: Secondary tillage	Traditional	90	5.711	1.6909	.17825
	Mechanized	90	1.466	.5648	.05954
Pair 3: Harrowing	Traditional	90	6.477	2.9726	.31334
	Mechanized	90	1.433	.5203	.05485
Pair 4: Sowing	Traditional	90	8.588	2.2330	.23538
	Mechanized	90	2.022	.9359	.09865
Pair 5: Weed control	Traditional	90	17.96	6.6000	.69571
	Mechanized	90	1.155	.3645	.03842
Pair 6: Harvesting	Traditional	90	15.25	4.1855	.44119
	Mechanized	90	1.488	1.2829	.13523
Pair 7: Threshing	Traditional	90	10.61	3.9935	.42095
	Mechanized	90	1.888	.8271	.08719
Pair 8: Transport & storage	Traditional	90	5.533	1.7171	.18099
	Mechanized	90	1.744	.6101	.06430

Similarly for harrowing operation there was no significant variation among mechanized labor force. But relatively high standard deviation among traditional labor proved that there was high variation of utilization of labor force per hectare. Paired difference t-test showed that there was highly significant variation between mechanized and traditional labor forces with p value of 0.000 at 5% significant level.

As compare with other operations, mean value of paired difference of weed control had high standard deviation (7.358). The result in Table 4.26 shows mechanized farm operation required few labor force and was fast done to save time while traditional farm operation required many labor forces per hectare for weed control. As farmers in the study area proved, hand weeding was labor intensive because thorough weeding was required to eliminate different types of weeds.

Table 4.26. Paired samples labor test for mechanized and non-mechanized farm operations

Paired wise labor comparison between two farm operations (wheat crop)		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair 1: Primary tillage	Traditional-mechanized	6.566	2.061	.2172	6.135	6.998	30.224	89	.000***
Pair 2: Secondary tillage	Traditional-mechanized	4.244	1.800	.1898	3.867	4.622	22.360	89	.000***
Pair 3: Harrowing	Traditional-mechanized	5.044	3.057	.3222	4.404	5.685	15.654	89	.000***
Pair 4: Sowing	Traditional-mechanized	6.566	2.412	.2543	6.061	7.072	25.820	89	.000***
Pair 5: Weed control	Traditional-mechanized	16.811	6.702	.7064	15.407	18.215	23.796	89	.000***
Pair 6: Harvesting	Traditional-mechanized	13.766	4.250	.4480	12.876	14.657	30.725	89	.000***
Pair 7: Threshing	Traditional-mechanized	8.722	4.167	.4393	7.849	9.596	19.853	89	.000***
Pair 8: Transport & storage	Traditional-mechanized	3.788	1.706	.1798	3.432	4.146	21.071	89	.000***

***=highly significant at a 5% significant level, P=0.000

Next to the weed control, harvesting in traditional operation was highly determinant task which required many manpower whereas its counterpart required very few labor forces per hectare while threshing and transport operation required relatively few labor. However, paired difference of labor t-test in Table 4.26 shows highly significant variation (5% significant level) between traditional and mechanized labor for harvesting, threshing, and transporting and storage.

When we looked into labor force required for traditional and mechanized operations, the number of labor required was almost similar but slight variation was observed because real labor force was location specific than the developed models.

4.4.3.Cereals production costs and incomes for the mechanization models

The cost is one of the decision variables to determine productivity of labor, land and power used as a mechanization input. The model developed for small scale farm households were compared in terms of man-hours, oxen-hours, machine-hours and work days required per hectare. But cost for selected seeds, fertilizer, and operations were also considered as mechanization input. Parallel to aforementioned cost variables, the total cost per hectare for each model was determined in order to identify relatively cost effective model.

The results in Table 4.27 showed that the amount of seeds and fertilizers for all types of models were similar. For example, wheat, and barley seeds used per hectare for traditional, semi-mechanized and mechanized farms were two quintals per hectare. But the quantity of maize seed for traditional, semi-mechanized and mechanized operations was the same. The costs for the wheat and barley selected seeds were equal (110.8 USD) whereas selected maize seed required 46.16 USD per hectare. Similarly, the amounts of fertilizers used per unit hectare are equal for all type of models.

Table 4.27. Summary of input costs, operation costs, incomes and returns from the models

Item cost (USD/ha)	Model 1: Traditional			Model2:Semimechnized			Model 3: mechanized		
Main crop	Wheat	Barley	Maize	Wheat	Barley	Maize	Wheat	Barley	Maize
Input (seed cost)	110.8	110.8	46.16	110.8	110.8	46.16	110.8	110.8	46.16
Input (fertilizer	64.63	64.63	96.95	64.63	64.63	96.95	64.63	64.63	96.95
Operation cost	313.73	304.67	395.13	292.22	294.02	283.42	288.03	257.11	294.03
Total cost	489.16	480.1	538.24	467.65	469.45	426.53	463.46	435.54	437.14
Output	1172.2	738.6	692.5	1255.68	849.39	831	1373.4	923.25	886.4
Return	688.04	258.5	154.27	788.03	379.74	404.48	909.94	490.71	449.27

Along with mechanization input costs, operation costs for each model for all main crops were taken in to consideration. According to the results in Table 4.27, operation costs by model 1 for both wheat and barley crops were higher than by model 2 and model 3 for the same crops. Operation cost for wheat and barley decreased from traditional farm operation to semi-mechanized and mechanized operations respectively.

Percentage of variation of operational costs among the models was calculated for each main crop. Empirical evidence from Table 4.27 showed that operation cost for wheat farm by model 1 is higher than that by model 2 by 7% while percentage cost variations of model 1 with model 3 seemed to be closed (8.19%) with percentage of variations by model 1 to by model 2. But, very little difference (1.43%) of operational cost was observed between model 2 and model 3. Hence, costs decreased whenever the farm power was shifted from manual to mechanized. The total cost for wheat farm operation had a similar trend.

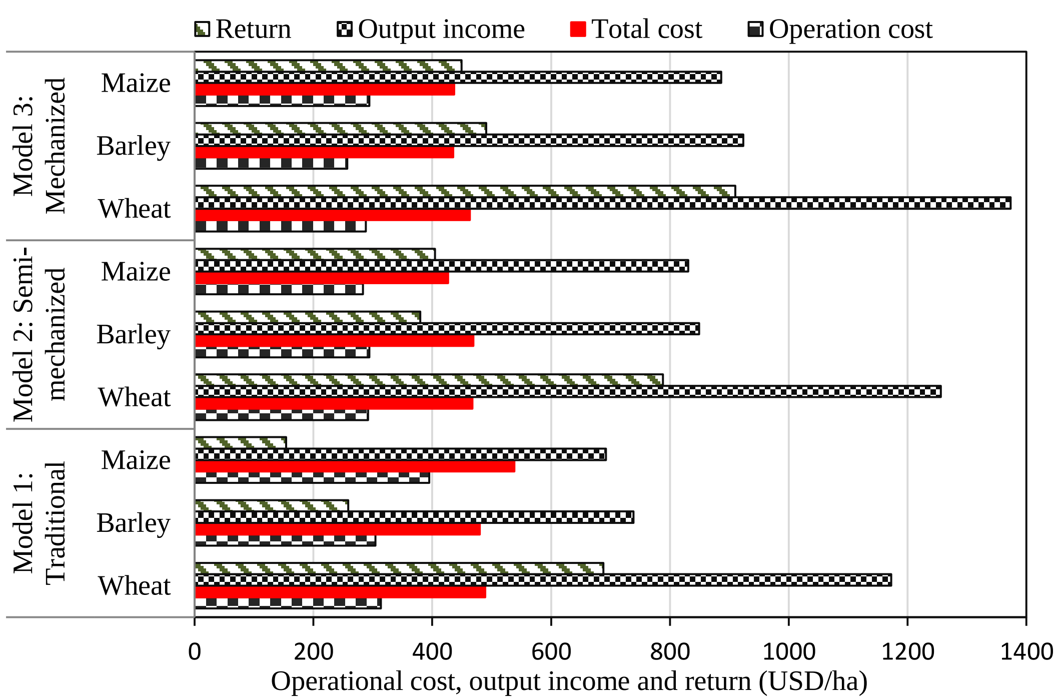


Figure 4.17. Cost comparison among the models

In contrast to operation cost, the results in Table 4.27 showed yield per-hectare increased in mechanized farming than in traditional farming. The return by the model 3 for wheat farm was higher by 24.4% than by the model 1 and 13.4% higher than by semi-mechanized farm operation.

In the case of maize and barley farms, operation costs were decreased while output and return were increased in mechanized farming than by traditional farming. The results in Table 4.27 depicted that the returns from semi- mechanized of barley and maize farming are higher by 31.92% and 61.85% respectively than traditional farming one. Similar scenarios are observed in mechanized farming. Producing higher yield in mechanized farm than traditional one perhaps resulted from better seed bed preparation. This idea was also confirmed by Gills and Clayton (1983) in their study of mechanization. Clayton (1983) added, if properly used, tractor will certainly produce better seed bed than hand labor particularly on heavy soil. Increasing yield on mechanized farm may also result from timely farm operation due to that machine works faster by far than animal and human being.

Taking other factors constant, most importantly, tractor can plow deeper than drought animal arid plow so that turning of top soil upside down mixes and pulverizes so as to maintain better water infiltration and air movement in the soil which perhaps create conducive atmosphere for crop growth so does higher yield per hectare.

The study also proved that traditional farm operation (model1), where human and draught animal are primary motive power, used a large number of labor per hectare whose costs were readily increased from 0.26 USD/day (Hassena et al, 2000) fifteen years back for harvesting operation (wheat crop) to 3.23 USD/day on average which more likely increased cost for manual operation than for mechanized farming.

More importantly, Figure 4.17 revealed that wheat has higher return in all models than the remaining two crops (barley and maize). Hence, it could be thought that most of the peasants in the study area have an interest of producing wheat than other crops.

Table 4.28. Crops productivity for the three models

Crops	Economic variable	Traditional	Semi-mechanized	Mechanized
Wheat	productivity	6.13	6.84	7.55
Barley	productivity	4.15	4.89	5.74
Maize	productivity	4.64	7.03	7.32

In addition to the aforementioned facts, economic parameters such as benefit to cost ratio and productivity were crucial and the determinant factors to compare models. Hence, benefit to cost ratios by model 3 was more than those by model 1 and 2 for the three crops productions (Table 4.28). It was known that productivity is a measure of total production per hectare to that of the total production cost per hectare. The productivity of the three crops by the traditional farming was lower than those by semi-mechanized and mechanized farming. Therefore, besides saving labor and time, mechanizing small-farms holder made them economical and productive.

4.4.3.1. Validity test for mechanization input required

Validity test for the model developed included three main inputs: Seed (kg/ha), Fertilizer (kg/ha) herbicide (lit/ha) and their corresponding cost. The seed and fertilizer required per hectare for traditional and mechanized farm operation were found to be equal i.e. 200 kg/ha for wheat seed and 100 kg/ha for fertilizer in all the models. But the actual data results taken from the field to check the model is shown in Table 4.29 and revealed that on average wheat seed required per hectare was 205.7 kg for traditional and 196.7 kg for its counterpart. However, the mean value (201 kg/ha) for the two operations was almost equal with in the model developed (200 kg/ha).

Results of paired sample (traditional and mechanical power) t-test on mechanization input for wheat operations were given in Table 4.30. The calculated t-value (1.56) was smaller than the t-tabulated (1.987) which indicated statistically no significant variation between mechanized and traditional operations for wheat seed (p=.122) at 5% significant level. As the results showed in Table 4.29 almost similar standard deviations were showed by the traditional (37.6 kg/ha) and mechanized (36.6 kg/ha) farm of wheat seed application per hectare. Though mean values of wheat seeds were similar and high standard deviations were showed in the case of the mechanized as well as traditional farming. Slightly significant variation was showed between traditional and mechanized farming by the fertilizer application. However, the quantity of fertilizer in kg almost closed to each other. These variations may come from individual differences in the amount fertilizer used by the farm and farmers and perhaps also due to better fertilizer placement in mechanized than in traditional farms.

Table 4.29. Paired samples statistics for mechanization inputs

Mechanization input		Mean	N	Std. deviation	Std. Error mean
Pair 1:seed	Traditional	205.72	90	37.615	3.9650
	Mechanized	196.77	90	36.606	3.8587
Pair 2:Fertilizer	Traditional	105.38	90	17.437	1.8380
	Mechanized	99.83	90	13.870	1.4620
Pair 3:Herbicide	Traditional	.9083	90	.32768	.03454
	Mechanized	.8111	90	.33164	.03496

Alike seed and fertilizer, herbicide required per hectare were almost similar for both in model and actual field application. But the actual pesticide amount per hectare for the wheat productions showed no statistically significant variation between the mechanized and traditional wheat productions.

Table 4. 30. Paired Samples test for mechanization inputs

Mechanization input comparison for traditional and mechanized wheat operations		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair1: Seed	Traditional-mechanized	8.944	54.388	5.733	-2.447	20.336	1.560	89	.122^{NS}
Pair 2: Fertilizer	Traditional-mechanized	5.556	24.153	2.546	.496	10.614	2.182	89	.032**
Pair 3: Herbicide	Traditional-mechanized	.097	.473	.049	-.002	.196	1.948	89	.055^{NS}

Note: ** is statistically significant; ^{NS} is non-significant at 5 % (0.05) significant level

Hence, it could be said that the developed models best suit for farmers, farm enterprises and policy makers to choose a farm-power as mechanization input. The appropriate choice and subsequent proper use of mechanized inputs have a significant effect on agricultural production and productivity and on the profitability of farming.

In most cases, the application of advanced tools, draft animals, or machines do not by themselves lead to increasing yields but usually reduces the cost of production and counteracts peak periods of labor shortage. However, the benefits achievable by using advanced and improved inputs such as, better seed, fertilizers, herbicide and pesticides cannot be fully realized without an increased application of farm power. CIGR (1999) confirmed that in agricultural production, farm power was only one input along with land, fertilizer, seed, crop chemicals, and so forth. It also added, the level of its use is one of a mix of management decisions a farmer has to make in order to increase agricultural production, income and labor productivity.

4.4.4. Labor and land productivity measure in the models

Three models were compared in terms of labor productivity for all three main crops. It was measured as a total farm output (final yield) divided by the total sum of men (labor) hour equivalent for the farm operations (Shafi, 1984). The results of each model for three main crops are indicated in Table 4.34.

Table 4.31. Labor and land productivity comparison for three models of main crops

Models	Wheat			Barley			Maize		
	Out Put (kg/ha)	Total Labor	Produ ctivity	Out Put (kg/ha)	Total Labor	Produ ctivity	Out Put (kg/ha)	Total Labor	Produ ctivity
Mode	3000	598	5.02	2000	582	3.44	2500	740	3.38
Mode	3200	71.5	44.75	2300	63.5	36.22	3000	396	7.57
Mode	3500	40.5	86.42	2500	32	78.13	3200	365	8.76

100 kg is equivalent to 1 quintal

Increasing labor productivity was observed when labor force in traditional farming substituted with machinery. The result in Table 4.31 revealed that labor productivity increased by 94.2%, 95.6% and 61.42% for wheat, barley and maize farm operation respectively when the traditional farming was mechanized.

These days, in most of the Ethiopian regions, many youngsters who are categorized as potential labor force in rural areas are in secondary education while unproductive age groups are even in elementary schools nearby their homes. Most of the secondary schools are found in urban and semi-urban areas which perhaps far away from rural areas. Rural exodus had been observed practically due to aforementioned reasons which made labor shortage in the rural farming community. Besides, other factors such as being and becoming of industrialized urban areas, many young people are seeking better job in the factory. Followed by booming Ethiopian economy for last consecutive ten years, many of young people organized small and micro enterprises to create jobs of their own in most of big and small towns. Migration of not only literate but also illiterate people from the rural areas seeking for better life and facilities in the urban has been caused labor shortage in the farming. In fact, for most of the peoples rural farming is arduous and by very nature drudgery.

Hence, introduces mechanized farm operation could be one of the solutions to the rural labor exodus for employment in other sectors of the economy so that the remaining labor can work along with machine.

Land productivity can be obtained by dividing farm output by farm size which indicates production per the existing land. In line with this, shifting farm power from traditional to mechanized operation makes the farmers more productive. The results in the Table 4.31 reveal higher yield output per hectare in mechanized farm operation than traditional farming for all main crops. A study on 'mechanization effect on farm practices in Kwara State, North Central Nigeria', conducted by Duada et al. (2012) confirmed that with the introduction of mechanization, there is a positive impact on farm productivity and income, where farmers accept the use of tractor in their farming activities. Duada et al. (2012) added that application of modern agricultural technology enables the cultivation of more lands and ensures timeliness in operation and better tillage. Similarly, Singh and Singh (1972) concluded that tractor farms gave higher yields of wheat, paddy and sugarcane and produced a higher overall gross output per hectare than non-tractor farms. NCAER (1973) compared the values of annual farm output per hectare under different levels of mechanization. The output per hectare was found to increase as the level of mechanization increased from non- mechanized farms to mechanized farms.

4.5. Energy use analysis: input and output relationship

Agricultural input has a lot of energy which is categorized as renewable and non- renewable source of energy. Human, animal and seed are under category of renewable source of energy whereas machinery and its fuel, draught animal, fertilizer and herbicide are under the category of non-renewable source of energy. Both energies are limited unless properly used and managed. In order to think better way to optimize the consumption of these energies from the prospective of farm operation, three models were compared in terms of energy use and analyzed in detail as below.

4.5.1. Input and output energy analysis for the model 1

The result in the Table 4.32 and Figure 4.18 shows total input and output energies by Model 1 for the three main crops. As shown in Table 4.32, energy used by draught animals for wheat and barley production is more than that for maize while labor energy per hectare required for maize production is greater than those for both wheat and barley productions. But seed as input energy used for both wheat and barley is more than that for maize production because the amount of seed needed per hectare of maize field is by far greater than the amount of wheat and barley seeds needed for one hectare.

Table 4.32. Input and output energies for the three main crops by model 1

Traditional farming for main crops		Wheat	Barely	Maize
Input energy	Draught animal energy (MJ/ha)	2947.2	2691.2	1760
	Labor energy (MJ/ha)	759.4	721.3	1419.1
	Seed energy (MJ/ha)	2940	2940	735
	Fertilizer energy (MJ/ha)	6624	6624	9936
Total input energy (MJ/ha)		13270.6	12976.5	13850.1
Total output energy (MJ/ha)		44100	29400	36750
Net energy (MJ/ha)		30829.4	16423.5	22899.9
Energy efficiency (%)		3.32	2.27	2.65
Energy productivity		0.23	0.15	0.18

When three crops were compared from the perspective of total sum of input energy, maize required more energy than wheat and barley by 4.2% and 6.3% respectively in manual operation. Since wheat farm produces higher yield per hectare than the remaining two crop farms, its total output energy per hectare is more by 33.33% and 16.66% than barley and maize field farms. Similarly energy efficiency and productivity of wheat production is higher than barley and maize production.

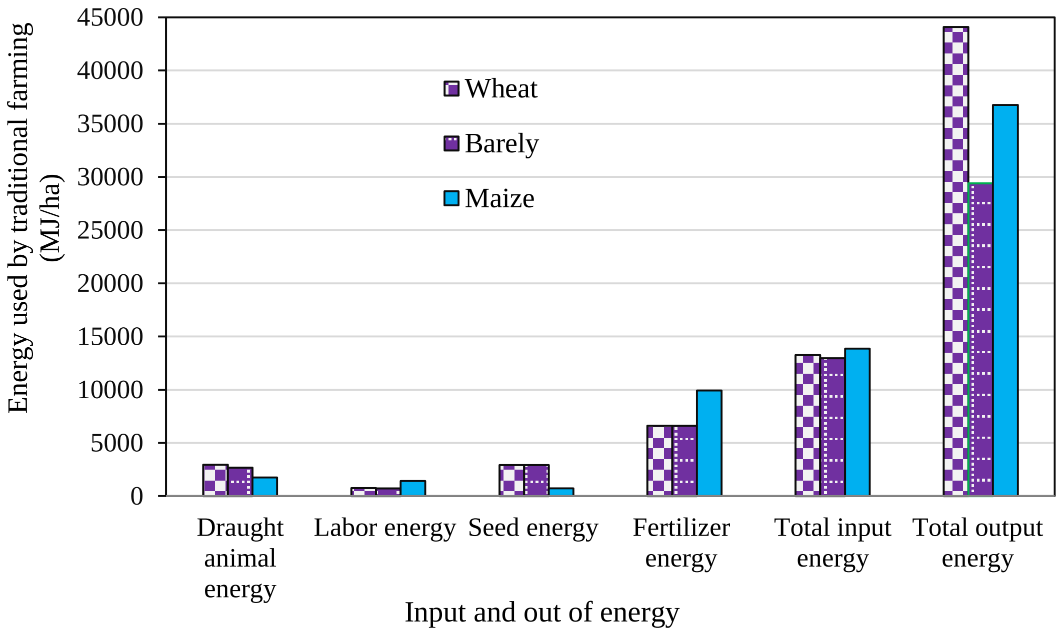


Figure 4.18. Energy used for production of three main crops by model 1

4.5.2. Input and output energy analysis for the model 2

Like model 1, farm power for model 2 has some variations. Power tiller was supposed to be primary source of power and powered by fuel; however, it is also pushed and steered by manpower. The amount of input energy used was measured as sum of machines and its fuel energies. Hence, the result indicated in Table 4.33 for the model revealed that wheat and barley crops required more energy by 50.33% than that of maize production whereas the two crops used the same amount of energy. Comparative analysis from the perspective of labor energy showed, maize crop used more energy by 41.4% and 43% than wheat and barley crops respectively. Labor energy required per hectare is related to the number of persons engaged with entire crop operations. The amount of seed and fertilizer energies used for the model 2 was equal to that for the model 1 because equal quantities of seed and fertilizer were used for two models.

Table 4.33. Input and output energies for the three main crops by model 2

Semi-mechanized farming (model-2)		Wheat	Barely	Maize
Input energy	Machinery energy (MJ/ha)	16082.55	16082.55	8217.6
	Fuel energy (MJ/ha)	49004.18	49004.18	24109.62
	Labor energy (MJ/ha)	577.22	561.54	984.84
	Seed energy (MJ/ha)	2940	2940	735
	Fertilizer energy (MJ/ha)	6624	6624	9936
Total input energy (MJ/ha)		75227.95	75212.27	43983.06
Total output energy (MJ/ha)		47040	33810	44100
Total yield (kg)		3200	2300	3000
Net energy (MJ/ha)		-28187.95	-41402.27	116.94
Energy efficiency (%)		0.63	0.45	1.00
Energy productivity		0.04	0.03	0.07

The results in Table 4.33 and Figure 4.19 showed that although, the total input energy for maize crop is lower than the two crops. Net energy, energy productivity and energy efficiency of maize is higher than the wheat and barley. In line with this, increasing maize output per hectare resulted in better energy efficiency and productivity.

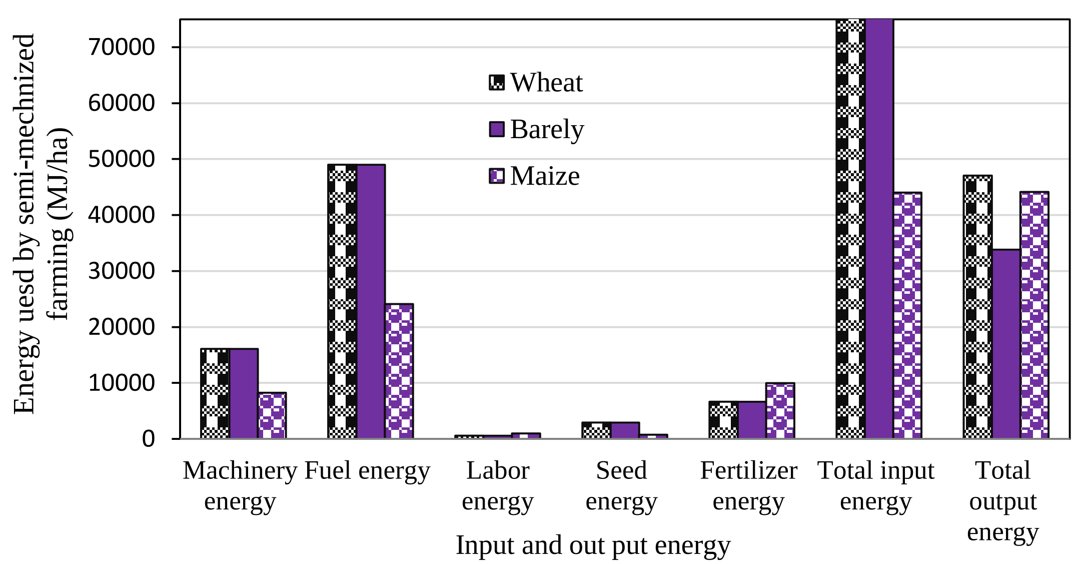


Figure 4.19. Energy used for the production of three main crops by model 2.

4.5.3. Input and output energy analysis for the model 3

The result in Table 4.34 revealed that input energy by farm machines and its fuel for the wheat and barley was more than that for maize by 31.3%. In other way round, instead of using machine energy, more of labor energy was used for maize production than that of the wheat and barley by 91.14% and 89.59% respectively. The amount of labor energy, machinery energy, total input energy, and output energy used for wheat production was not consistent with Sedadgat et al (2014). However, seed for wheat and barley, fertilizer, and total input energies of maize production confirmed similar results aforementioned studies. The differences were perhaps due to difference in estimated ranges of hectare, ways of energy used and geographical location of the two study areas.

Table 4.34. Input and output energies for the three main crops by model 3

Mechanized farming (model-3)		Wheat	Barely	Maize
Input energy	Machinery energy (MJ/ha)	909.15	909.15	819
	Fuel energy (MJ/ha)	13969.78	13969.78	9417.85
	Labor energy (MJ/ha)	91.14	75.46	725.2
	Seed energy (MJ/ha)	2940	2940	735
	Fertilizer energy (MJ/ha)	6624	6624	9936
Total input energy (MJ/ha)		24534.07	24518.39	21633.05
Total output energy (MJ/ha)		51451	36750	47040
Total yield (kg)		3500	2500	3200
Net energy (MJ/ha)		26916.93	12231.61	25406.95
Energy efficiency (%)		2.10	1.50	2.17
Energy productivity		0.14	0.10	0.15

Seed and fertilizer energies used in model 3 were similar to those in the models 1 and 2 because equal amount of seeds and fertilizers were used for the three models. Seed effect was reflected on total input energy. Seed energy increased total input energy. But the difference in total output energies among three main crops occurred due to the difference in production outputs. Energy efficiency and productivity of maize production was higher than those of the barley and wheat productions.

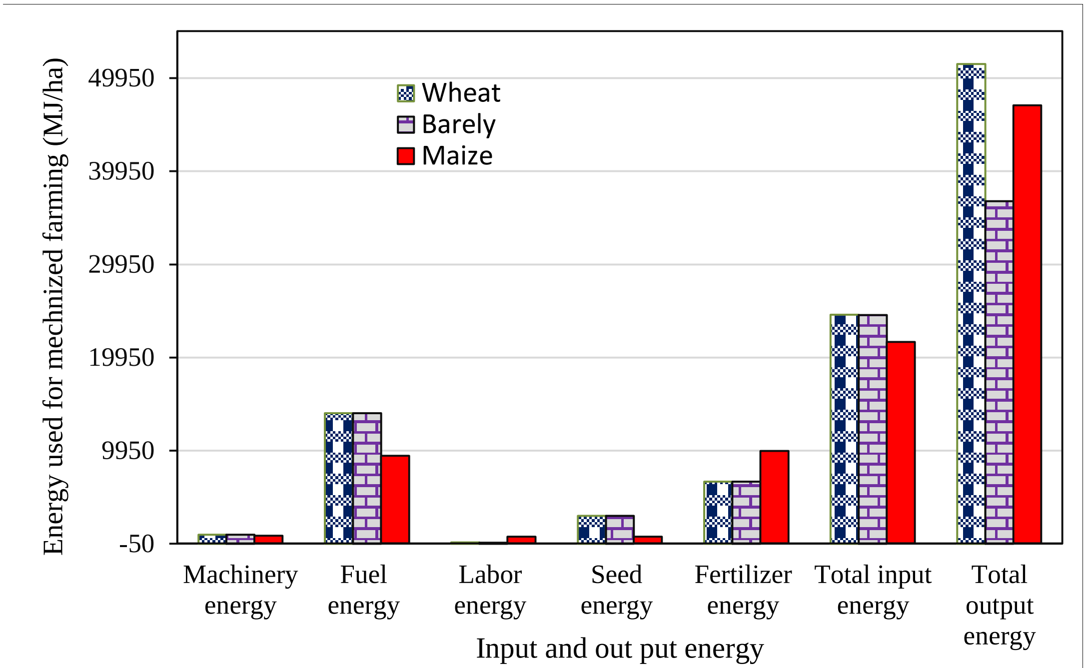


Figure 4.20. Energy used for the production of three main crops by model 3

4.5.4. Energy consumption comparison for cereals production of three models

4.5.4.1. Energy for wheat production

Under section 4.5, comparative analyses were made for energies used by three models for the three crops. Under this section, energy comparison was done among the models each of the crops. Hence the result in Table 4.35 shows that energies used by animal and farm machines with its fuel for the models 1, 2, and 3 were 2947.2, 65086.73 and 14878.92 MJ/ha respectively. From this result model 2 required 95.47% more energy than model 1 and 77.14 % more than model 3 for wheat production whereas model 3 required 80.19% more input energy than model 1. From this result, model 1 was identified as the least energy consumer as compared to model 2 and 3. But for small farm holders who want rental services, the model 3 could be better choice. However, the details of the profitability, economic and cost component will be treated later.

Table 4. 36. Energy used for wheat production

	Wheat farming energy	Model 1	Model 2	Model 3
Input energy	Draught animal energy (MJ/ha)	2947.2	0	0
	Machinery energy (MJ/ha)	0	16082.55	909.15
	Fuel energy (MJ/ha)	0	49004.18	13969.78
	Labor energy (MJ/ha)	759.4	577.22	91.14
	Seed energy (MJ/ha)	2940	2940	2940
	Fertilizer energy (MJ/ha)	6624	6624	6624
Total input energy (MJ/ha)		13270.6	75227.95	24534.07
Total output energy (MJ/ha)		44100	47040	51451
Net energy (MJ/ha)		30829.4	-28188	26916.93
Energy efficiency (%)		3.32	0.63	2.10
Energy productivity		0.23	0.04	0.14

Use of more energy by the models 2 means that energy value for power tiller and mostly of its fuel are more than tractor. Because power tiller took long time to finish a hectare operation and consumed more fuel energy than tractor. Tractor worked the same operation with lower than 69% hour than that of power tiller. In line with this diesel fuel was observed as the largest share in energy demand by the semi-mechanized and mechanized models for wheat production which accounted 67.2% and 93.5% respectively. This result is consistent with Anderea et al (2014) who reported in their study that in high mechanized systems and operation used fuel demands higher energy mega joule per liters.

Seed and fertilizer energies, as shown in Table 4.36, were same because equal quantity of seed and fertilizer were used (kg/ha). However, in the case of labor energy there was a great difference among the models. Most of the farm operations in wheat productions were completed by labor for small farm holders by traditional operations. Hence, labor energy used in model 1 was 23.5% and 87.9% more than those in semi-mechanized and mechanized models respectively. Similarly, labor energy used in model 2 was 84.2% more than that of mechanized model. Labor energy used in traditional model was about 6% of the total input energy while the percentages of figures were not significant for those of model 2 and 3.

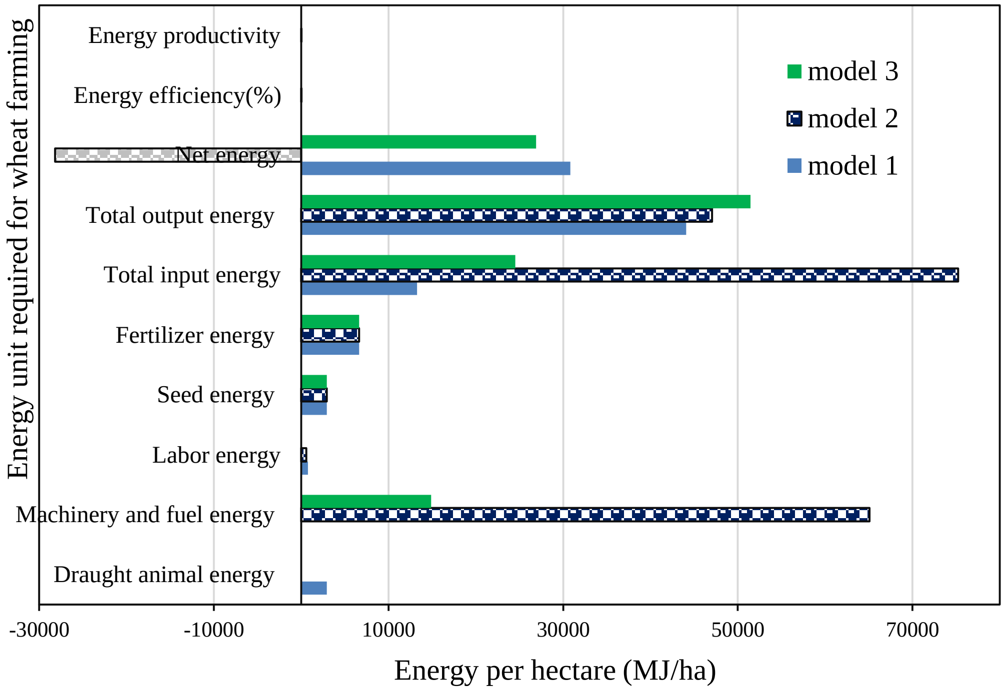


Figure 4.21. Inputs and outputs energy demand for wheat production processes

Less labor energy used in the mechanized and semi-mechanized operation means that the labor required in such systems was less due to the fact that most of the operations were carried out by machines. For instance, combine harvester can harvest, thresh, separate, clean and temporarily store until the grains gets discharged to carriage/storage area/, whereas, in manual operation all aforementioned production processes require large number of laborers. Therefore, in countries like Ethiopia where the growth is in fast track and labor is short due to rural exodus, technology for saving labor energy should be a good choice for small farm holders on the basis of their capacity.

The outcomes in Table 4.36 and Figure 4.21 revealed that the net energy for wheat production by model 2 was negative while the model 1 and model 3 showed opposite. The main reason for being negative was that the energy used by power tiller and its fuel were large when compared with those by two models. In the contrary, energy efficiency of traditional farming was higher than those of models 2 and 3 as showed in Table 4.36. The result revealed that the energy productivity of the manual operation was higher than relative to semi-mechanized and mechanized operations. Even though energy productivity and efficiency were higher for traditional farming, its significance from the labor and land productivity was very lower as compared to mechanized and semi-mechanized farming.

4.5.4.2. Energy analysis for barley and maize production

Table 4.37 and Table 4.38 show the input and output energies used for the barley and maize productions by the models 1, 2 and 3. Energy indicators such as net energy, energy efficiency and energy productivity are also given in the tables below.

Although the crops differ, a similar analysis can be applied to their productions and energies used. Draught animal energy used for the barley and maize productions had a difference of 931.2 MJ/ha. Energy used by drought animal was 2691.2 MJ/ha for barley crop production while 65086.73 MJ/ha by power tiller and 14878.93 MJ/ha by tractors.

Table 4. 37. Energy used for barley production

Barley farming energy		Model 1	Model 2	Model 3
Input energy	Draught animal energy (MJ/ha)	2691.2	-	-
	Machinery energy (MJ/ha)	-	16082.55	909.15
	Fuel energy (MJ/ha)	-	49004.18	13969.78
	Labor energy (MJ/ha)	721.3	561.54	75.46
	Seed energy (MJ/ha)	2940	2940	2940
	Fertilizer energy (MJ/ha)	6624	6624	6624
Total input energy (MJ/ha)		12976.5	75212.27	24518.39
Total output energy (MJ/ha)		29400	33810	36750
Net energy (MJ/ha)		16423.5	-41402.27	12231.61
Energy efficiency (%)		2.27	0.45	1.50
Energy productivity		0.15	0.03	0.10

The amount of energy used in the semi-mechanized farm operations for barley production was 95.86% and 77.14% more than that in the traditional and mechanized respectively. Similarly, energy demand for maize production by semi-mechanized farm operation was 94.6% and 68.3% more than that by the traditional and mechanized models respectively. In both crops, the semi-mechanized operations consumed more energy due to high energy value of fuel per liter whereas the traditional farm operations consumed less energy due to low energy rate per draught animals. Next to model 2, the model 2 consumed significant amount of energy. This is perhaps due to high fuel energy.

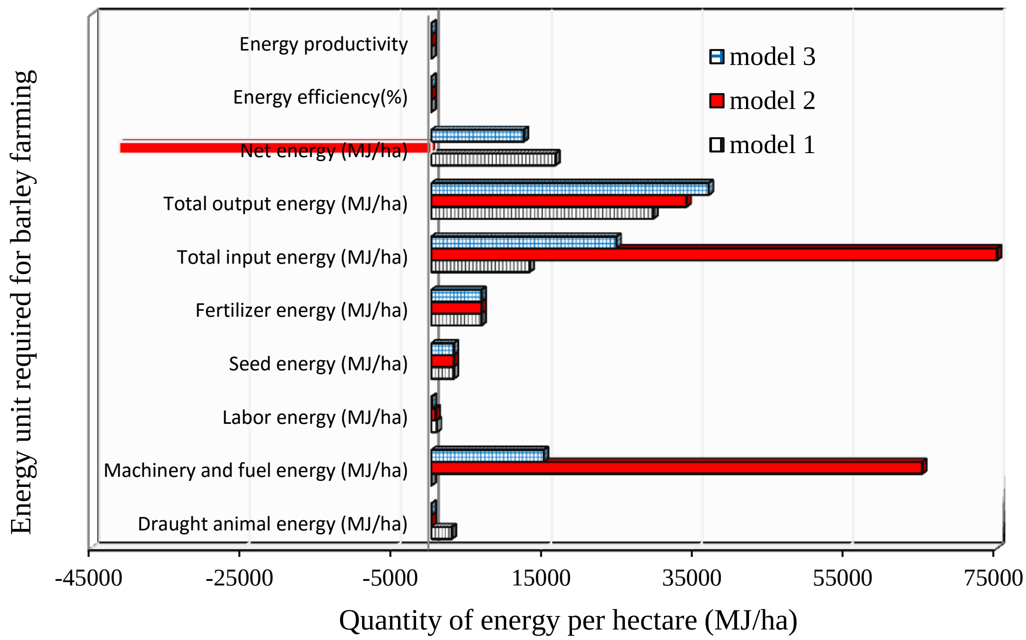


Figure 4.22. Inputs and outputs energy demand for barley production processes

Labor energies used by the traditional barley and maize productions were 721.3 MJ/ha and 1419.1 MJ/ha. They were 561.54 MJ/ha and 984.84 MJ/ha for semi mechanized, and 75.46 MJ/ha and 725.2 MJ/ha for mechanized models. Alike labor energy used for wheat production, labor energy used for barley and maize productions, by the model 1 was more than those by the model models 2 and 3. One can understand from this that shifting farm power from manual to semi- mechanized and mechanized operation decreased labor energy required for all of the three main crops.

Table 4.38. Energy used for maize production

Maize farming energy		Model 1	Model 2	Model 3
Input energy	Draught animal energy (MJ/ha)	1760	-	-
	Machinery energy (MJ/ha)	-	8217.6	819
	Fuel energy (MJ/ha)	-	24109.62	9417.9
	Labor energy (MJ/ha)	1419.1	984.84	725.2
	Seed energy (MJ/ha)	735	735	735
	Fertilizer energy (MJ/ha)	9936	9936	9936
Total input energy (MJ/ha)		13850.1	43983.06	21633
Total output energy (MJ/ha)		36750	44100	47040
Net energy (MJ/ha)		22899.9	116.94	25407
Energy efficiency (%)		2.65	1.00	2.17
Energy productivity		0.18	0.07	0.15

The total input energies for barely production were 12976.5 MJ/ha, 75212.27 MJ/ha, and 24518.39 MJ/ha for model 1, 2 and 3 respectively. Large input energy by model 2 resulted from the input energy used by fuel. Similarly, large input energy in model 3 was due to high energy value of fuel. In line with this, low energy efficiency and energy productivity were observed in model 2 than the remaining models.

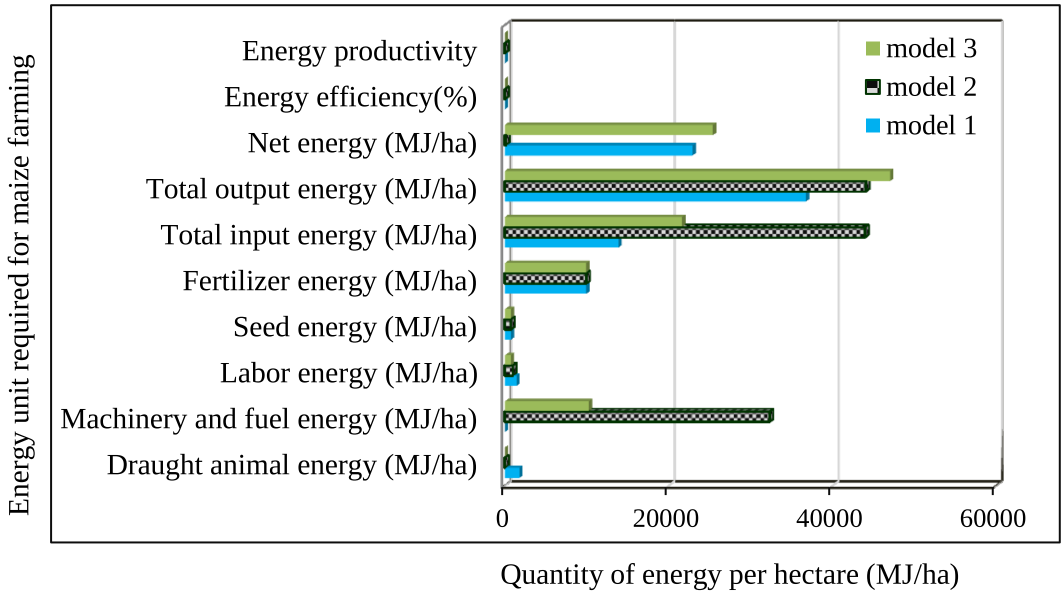


Figure 4.23. Inputs and outputs energy demand for maize production processes

The results in Table 4.38 revealed that energy efficiency and energy productivity of model 2 for maize production is low when compare to energy efficiency and energy productivity by the model 1 and 3. Above all, energy efficiency and energy productivity by the model 1 seem to be higher followed by the model 3 than that by model 2. By increasing crop yield and decreasing energy input, consumption of energy use efficiency can be increased. Similar studies by Lorzadeh et al. (2011) found that the total energy consumption in maize production was 29307.74 MJ/ha which is inconsistent with either of the models used in this study. Therefore, mechanized farming had shown reasonable machinery and labor energy as compare to model 1 and 2. Keeping in mind labor and land productivity rational paramount, model 3 could be good choice.

4.6. Farm machinery management and associated costs:

4.6.1. Farm machinery maintenance management

In agricultural production, availability of the machinery or getting ready for the job to be assigned is very important. This could be retained if farm machineries are properly handled and maintained. Agricultural machinery maintenance is crucial for successful agricultural production. It aims at guaranteeing availability of machines and related equipment for cultivation. In critical season, particularly during cultivation and harvesting, if machineries are not available, it results in loss of production. Hence, proper ways of machinery maintenance could have an advantage of not only keeping the machines at normal condition and increasing life span but also making the farmers get better income and return within short time.

Preventive maintenance is an extensive term which prescribes maintenance schedules recommended by the manufacturer that attempts to decrease the risk of system breakdown and total cost of maintaining the system. In general, preventive maintenance activities include inspection, cleaning, lubrication, adjustment, alignment, and/or replacement of sub-systems and sub-components that are fatigued. Table 4.39 and 4.40 showed that proper lubrication/changing oil and fast running items for different parts of machine were not taking place at correct recommended intervals.

For example, for Massey Ferguson 398 and Belarus 820 tractors, the time interval at which the engine oil and oil filter should be changed is 250 hours for both but the result in Table 4.39 and 4.40 indicated that the intervals by which the two items changed were 2400 and 1680 hours for the engine oil and 560 and 360 hours for the oil filter. These tractors worked in harsh, dust and dirt environment. If the tractors are supposed to work for 12 hours per-day, oil and its filter should be changed every 20 days. Similar conditions were observed for all other parts.

Table 4.39. Preventive maintenance and intervals of change of items for Massey and FNH

Machinery type		MF tractors-398		Fiat New Holland 110-90	
Machinery component	Parts to be changed	Recommended time interval (h)	Actual service Time(h)	Recommended time interval (h)	Actual service time(h)
Engine	Engine oil	250	2400	250	240
	Oil filter	250	560	250	240
Hydraulic system	Hydraulic	100	400	100	7956
	Steering oil	100	190	100	200
Fuel system	Fuel filter	500	1440	500	960
	Fuel injector	1000	3000	1000	2570
Transmission	Gear box	1000	6000	1000	11050
Differential	Final drive oil	1000	6000	1000	3050
Brake	Brake fluid	2000	3500	2000	7500

Table 4. 40. Preventive maintenance and intervals of change of items for Belarus and Styer

Machinery type		NTAF-Belarus-820		Styer-9094	
Machinery component	Parts to be changed	Recommended time interval (h)	Actual service time(h)	Recommended time interval(h)	Actual service time(h)
Engine	Engine oil	250	1680	250	-
	Oil filter	250	360	250	270
Hydraulic system	Hydraulic oil	300	360	300	400
	Steering oil	100	190	100	250
Fuel system	Fuel filter	500	560	500	600
	Fuel injector	600	600	600	700
Transmission	Gear box oil	1200	1250	1200	1250
Differential	Final drive oil	1200	1300	1200	1390
Brake	Brake fluid	2000	2050	2000	3000

Maintenance planning requires forecasting, timely inspection, repair schedule, repair mechanics, and spare part requirement. Various manufacturers recommend inspection program with fixed time replacement and cleaning of fast moving parts such as oil filter, air cleaner, seal, etc. and conditions for the replacement of other inspected parts.

The owners of the farm machineries in the study area are farmers. They didn't have technical knowledge about the machine they owned nor did the operators for the machine they operate. They rather focus on their short time profit than long time service of their machinery. Many of these people are illiterates who can neither read nor write. Even those who are fairly literate do not know how to read the owner's manuals of their machines. It is very necessary for the fulfillment of the objectives of maintenance that every operator should learn the correct operating and maintenance procedure of his equipment. A proper technical knowledge is vital for effective machinery handling.

Basically, some of the operators who handle tractors in the study area were illiterate and school dropouts. They have no idea about the life of the machinery. They run the tractor daily without care and maintenance. They think that the tractor is not due for maintenance until it can no longer start. But some of them used family member to handle their tractors. Few of the tractor owners use hired labor and well experienced operator to operate equipment. Such experienced operators knew what they could do. They maintained and handled the machines better than others family members. But the salary of such operators was higher than the others which are not appreciated by the owner of the machines.

In the study area machinery inspection is based on visual inspection, sound and vibration of a system. There is no inspection with instrument that enables the operators to know the status of machineries. There is no instrument that detects the condition of machinery such as compression tester, leakage tester, tachometer, exhaust gas analyzer etc. Hence, the inspections couldn’t be effective. Hence, well trained technical personnel, well organized service center and mobile garages in the vicinity should be located in order to maximize the utilization of machines.

Like other developing countries, Ethiopia is going to revolutionize its agriculture through mechanization without adequate attention being paid to machinery maintenance. As it was confirmed from the result in Table 4.39 and Table 4.40, maintenance will help greatly to decrease the unit cost of mechanization, increase machinery output and reduce downtime. A well-developed market system for harvest inputs will surmount the problem of glut at harvest time. This may bring more income to the farmer to buy spare parts and hire trained personnel to maintain his machinery.

4.6.2. Farm machinery utilization

Most tractors and combine harvesters are used seasonally during local cropping season of cereal crops with an average of 75 days. Some machinery particularly those which focused on hire services are used for about five months. Such type of tractor use is for two to three months per year in study area. At the end of July i.e. when farm operation ended, tractors moved to the vicinity of high land where farm operation was late and Bale zone which is 200 km far from study area. But tractors owned by Hetosa Union worked effectively for about two months only in the study area when the weather condition was convenient. Cooperative or union owned tractors and combine harvesters provide services to member farmers and provide surplus capacity to non-member farmers. The variation of working days among tractors and combine harvesters was due to the differences in local working seasons, climatic condition, geophysical condition and the service demand.

4.6.2.1. Effect of over utilization of farm machinery on economic life

The results in Table 4.41 show that same machineries particularly tractors were at maximum age while some of them were at minimum age. According to ASAE standard (1993) agricultural machinery data, estimated useful life of tractors and heavy equipment or four wheel drive tractors are twelve years or 10,000 hours and for sixteen years or 12,000 hours respectively.

Table 4.41. Service life of tractors and combine harvesters in the study area

Farm machinery			Model	HP	Purchased price	Purchased year	Useful life	Service life
Tractors	1	Massey Ferguson	398	104	21,776	1998	12	14
	2	Fiat New Holland	110-90	120	17,669	1998	12	14
	3	NTAF-Belarus	820	90	18,250	1998	12	14
	4	Styer	9094	101	18,640	1993	12	17
	5	YTO	404	110	-	2012	12	4
Combine harvesters	6	John Deere	8000	135	78,947	2011	12	5
	7	John Deere	7000	160	97368	2011	12	5
	8	New Holland	80-66s	120	71053	2008	12	8
	9	Class Combine	Dominator 68's"	150	73684	2011	12	5

It was observed from the result in the Table 4.41 that 60 percent of the tractors in the study area were above useful life by 16% while Styer-9094 tractors was beyond useful life by 41.66%. In the contrary, John Deere, Claas combine harvester and newly introduced Chinese made tractor were 4-5 years old. New Holland combine harvester was at middle of economic life. In short, 80% of the total tractors were beyond the economic life.

In an economic analysis, machinery depreciation is the one which depends on age and time of the machinery. In the analysis behind, it is considered fundamentally depreciation as a separate function of age and hours of use. That is ageing tractors without putting hours on it will cause it to depreciate at a certain rate and putting more hour on tractors without making it any older will cause it to depreciate at different rate. Hence, the result in Table 4.42 revealed that average working hours of both tractors and combine harvesters in the study area were below estimated hours of use (833 hours/year) which was estimated from 10,000 hours for 12 years. But the actual hours of machineries indicated in Table 4.42 were higher than average and yearly estimated hours of use.

Most of the farm machineries annual working hours were considerably lower than aforementioned hours. William (2002) and ASABE (1997) addressed annual working hours of tractors in USA were 200-400 which horse power ranging from 30 to 150 hp. Similarly Singh (2010) reported that most of the owners who were purchased new tractors in Indian condition used from 200 to 400 hours per annual. However, annual hour of use of used tractors were ranging from 100 to 300 hour per annual. The lowest annual hour of use of YTO tractor (Table 4.41) was 44.4% more hour of use than the highest annual hour of use (400 hr) of tractors mentioned by aforementioned studies.

However, these machineries were idle when there was no demand and off- operation for many months. But during perianal season both tractors and combine harvesters were working for a long period of time including night time when the field was clear to be seen under the moon besides head light. This scenario made the useful life of both tractors and combine harvesters shorter than predetermined hours.

For instance, Massey Ferguson-398, Fiat New Holland-110-90, NTAF-Belarus-820 and Styer-9094 tractors their actual hours of use were 960, 1248, 936 and 936 while their corresponding economic lives were 10.4, 8, 10.6, and 10.6 years respectively. For YTO tractors actual hour of use were less than those of the aforementioned tractors, the economic life was estimated to be 13 years. Likewise, above mentioned four tractors and, John Deere combine harvesters had longer hours of actual use and corresponding estimated economic life of 7.5 and 10.4 years. The annual hour of uses of tractors in the study area were similar with annual hour of uses of tractors under study in Iran field condition by Khoub (2008). Over utilization of farm machines in the developing countries perhaps due to shortage of farm machinery. However, over utilization has a negative technical implication where there is no proper machinery handling which resulted to a negative economical implication.

Table 4.42. Effect of annual working hours on machinery service life

Farm machinery			Model	HP	Purchased price	Purchased year	Useful life	Service life
Tractors	1	Massey Ferguson	398	104	21,776	1998	12	14
	2	Fiat New Holland	110-90	120	17,669	1998	12	14
	3	NTAF-Belarus	820	90	18,250	1998	12	14
	4	Styer	9094	101	18,640	1993	12	17
	5	YTO	404	110	-	2012	12	4
Combine harvesters	6	John Deere	8000	135	78,947	2011	12	5
	7	John Deere	7000	160	97368	2011	12	5
	8	New Holland	80-66s	120	71053	2008	12	8
	9	Class Combine	Dominator 68's"	150	73684	2011	12	5

From the above result it is possible to say that most of the owners of the tractors and combine harvesters put more hours on their machines than average estimated annual hours of use. This made the tractors and combine harvesters to lose their value at faster rate. Such accelerated depreciation of farm machineries resulted in shorter economic life than those of the machines which were operated under normal and for the estimated average annual hours of use.

4.6.3. Agricultural machinery cost management

4.6.3.1. Depreciation

All agricultural machineries whether on work or idle loose their values from time to time. In order to determine loose this in value purchased price and economic life of the machines are important. Although, different organizations use different ways of determination of depreciation like declining balance, double declining balance, and sum of year's digit, the straight line depreciation method is used in Ethiopia and so was for this particular study. As shown in Figure 4.24 tractors with different horse power, model, purchased price and useful life depreciated at different rate. Initial purchased price, age and accumulated hours of use usually are the most important factors in determining the depreciation and remaining value of a machine at any time.

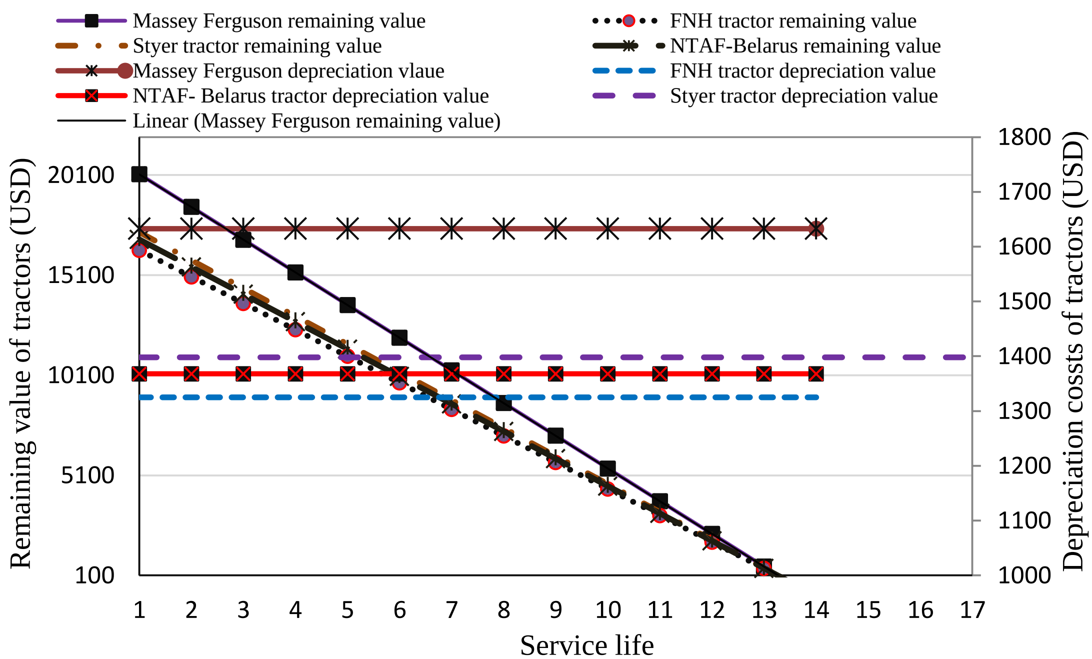


Figure 4.24. Depreciation and salvage value of different tractors

Figure 4.24, shows the depreciation costs of Massey Ferguson-398 and John Deere were larger than other tractors (Fiat New Holland, NTAF- Belarus, and Styer) and combine harvesters (New Holland and Class combine). Even though, the cost of depreciation of each tractors and combine harvesters varied depending on the initial price, observed depreciation cost is constant through life time (Figure 4.25).

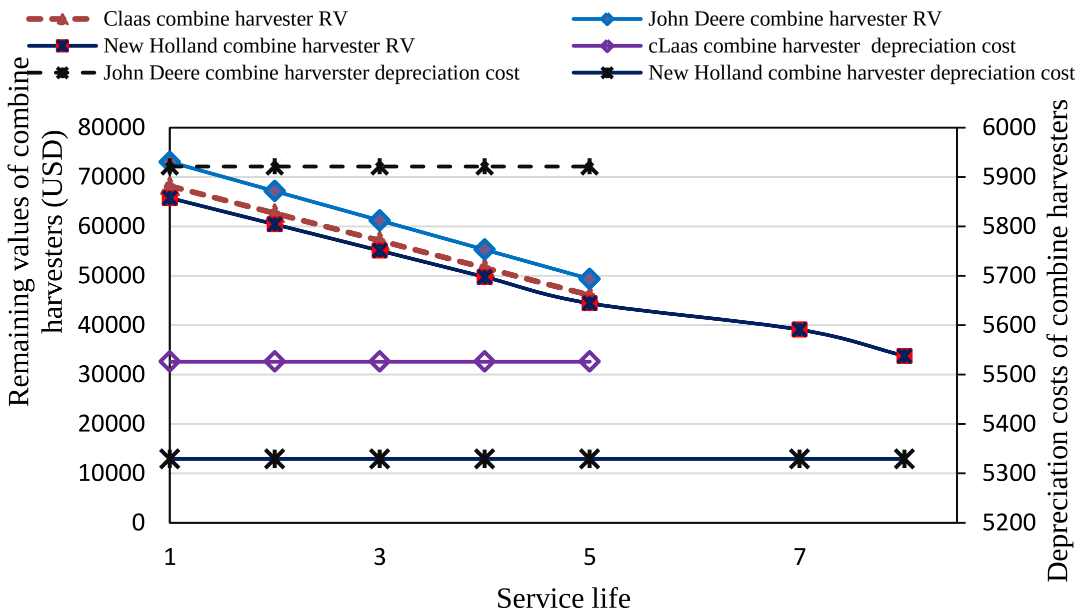


Figure 4.25. Depreciation and salvage value of different combine harvesters

Whenever declining balance method is used to calculate depreciation, in similar ways of Khoub et al. (2008) and Mohammad et al. (2012) on Massey Ferguson-285, a uniform rate is applied each year to the remaining value whereas the depreciation amount is different for each year. The value will be higher at early age and become decrease at older age. To the contrary, as the result shown in Figure 4.24, the remaining value of each machine gets decreasing through time while the value of depreciation remains constant and this cost is also higher in machinery cost components next to interest cost which is consistent with Mohammad et al. (2012).

4.6.3.2. Repair and maintenance cost

Repair and maintenance costs (RMC) are crucial in cost of owning and operation. Newly purchased farm tractors and combine harvesters start deterioration from the use of machines. Particularly in the study area, the environment was so harsh. Since the operation starts during early spring when the weather is so dry, a lot of dust makes the engine and its associated component to wear. On farm, frequent failures of machine systems and implement mechanisms had been experienced. Minor lubrication and daily service were required.

Failures of the machines and its mechanism during peak season increase cost of down time and decrease income (hiring service cost) for the machine owners. In order to minimize the cost of down time during peak season, effective repair and maintenance activities are necessary.

Figure 4.26 to Figure 4.29 revealed that RMC of all tractors in the study area were small at early life. As the ages of the tractors and combine harvesters increased, the costs became increased. This is consistent with the results of the study conducted on tractors by Rotz and Bowers (1991) and Calcante (2013).

Simulated and actual RMC of tractors and combine harvesters vary from machine to machine because of differences in horse power, type of machines, and annual hours of use and purchased price. Figure 4.26 to Figure 4.29 showed that theoretical RMCs of all aforementioned tractors (165849 for MF-389, 134573 for FNH, 139988 for Belarus, and 141964 for Styer) at a particular year (say at 8 years) were different due to above listed reasons. Similar results were observed in the case of the actual RMC

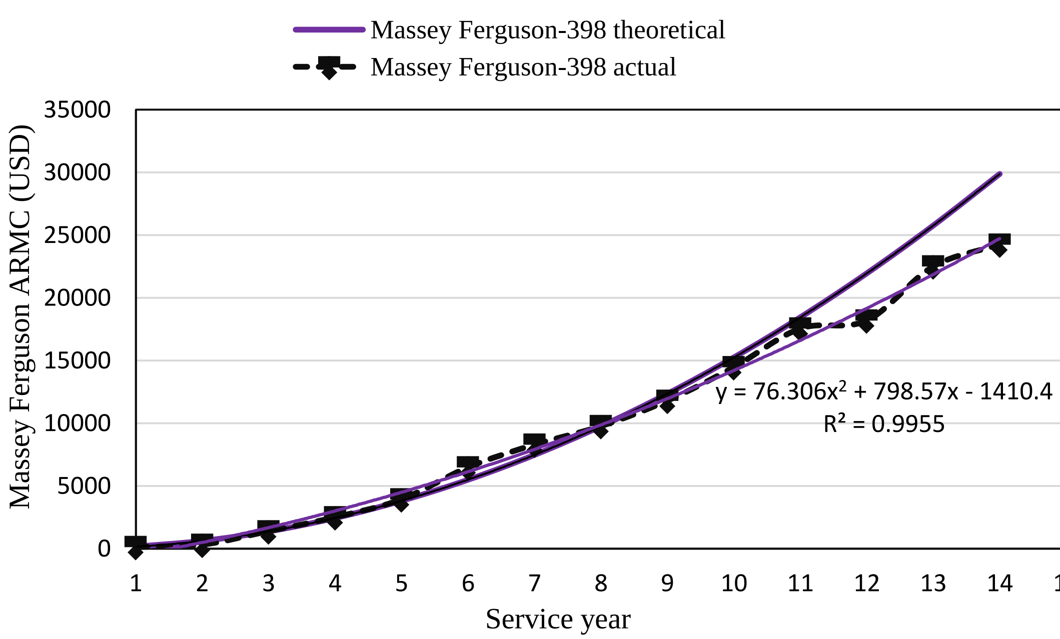


Figure 4.26. RMC of Massey Ferguson-398

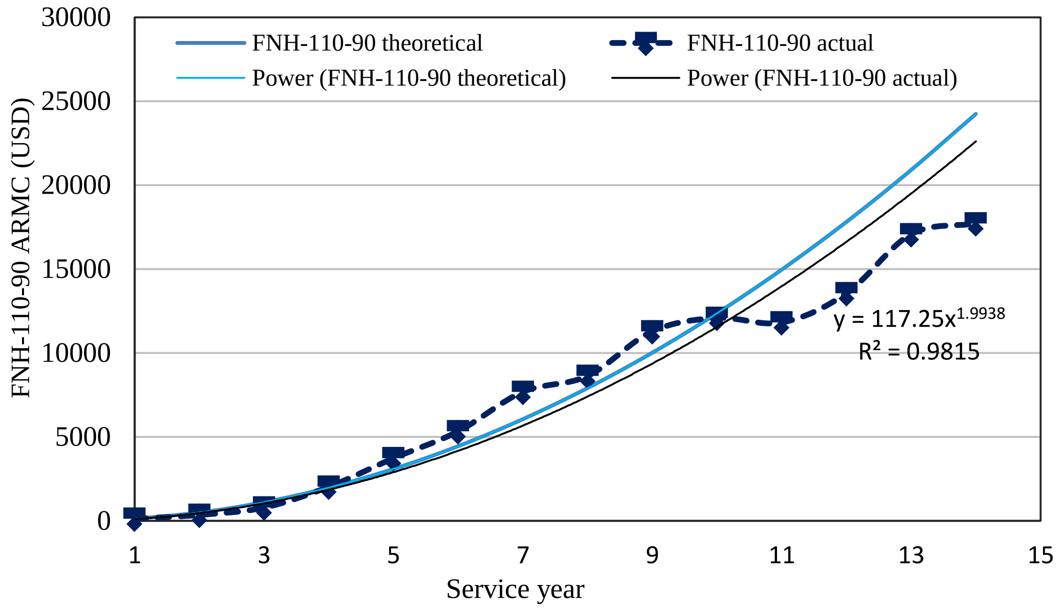


Figure 4.27. RMC of Fiat New Holland

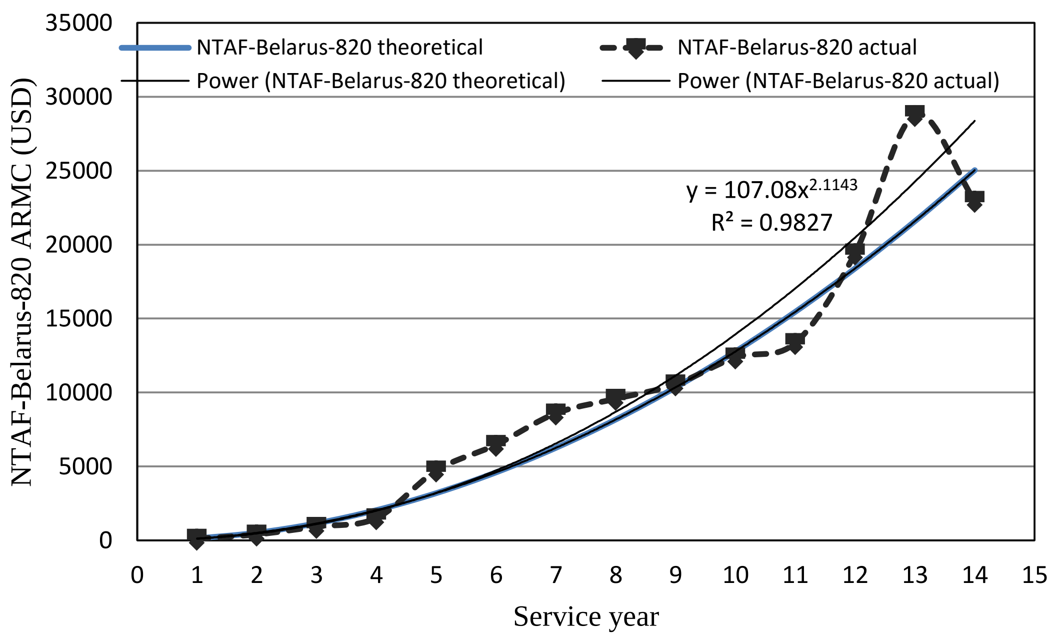


Figure 4.28. RMC of NTAF- Belarus

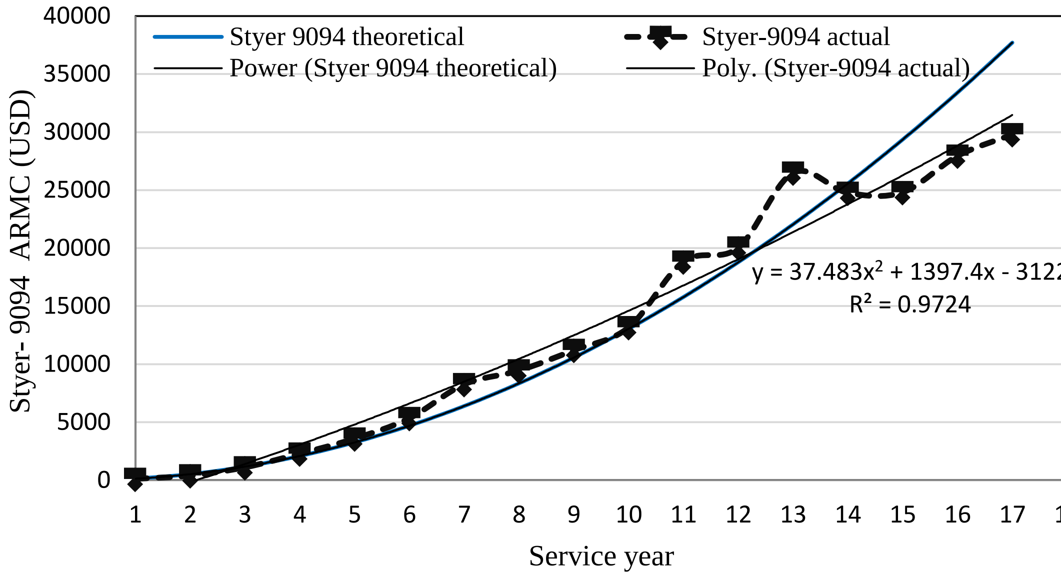


Figure 4.29. RMC of Styer tractor

Simulated and actual RMC for the tractors given in Figure 4.26 to Figure 4.29 indicated that actual RMCs were lower than simulated value at early age of the tractors. This could happen until half life time of tractors. Then RMCs gradually tended to exceed the simulated values. Because, when the machines become older they deteriorate and frequently fail due to poor maintenance. Besides to this, bad weather and irregular terrain in the study area makes the rates of wear, tear and series breakdown high. Most of machinery parts and implement mechanisms required replacement which consumed spare parts at faster rate and expensive cost of repairing resulted in high RMCs.

When the tractors approach their economic life under accelerated depreciation, the actual RMC no longer continued to increase rather it started to decline except NTAF-Belarus tractors while simulated RMC continued to increase with power function($Y=aX^2$). According to the interviewed farmers (owners), declining of RMC was due to the following possible reasons:

- Inadequate supply of spare parts and high cost of existing spare part to replace.
- Idleness of machineries for a long time due to break down.
- Over operating of tractors without replacing spare parts due to concern over loss than benefit.

Generally speaking, ARM costs for tractors become equal to the purchased price at less than its useful life. Similar study conducted by Amana (2014) on sugar cane production machineries found that ARM costs for heavy equipment and tractors reached to the purchase price in less than less than half (4-6 years) of its useful life which is inconsistent with this study's result because of variability of working conditions. In mechanization for sugar production, most of the machineries were working during peak operation period for about 24 hours in order to supply cane to factory which operated the whole day without interruption whereas for the cereal crop production tractors were operated at most 14 hours per day; however, both machineries (cane and cereal production) showed similar result of RMCs because of frequent break downs and over utilization of machines without proper care.

RMC model proposed by ASABE Standard (2011) which was developed for agricultural machineries working in USA condition was used. According to this model estimated economic life of tractor is 12 years or 10,000 hours under normal operating condition. Maximum annual operating hours would be 833 hours. This number can go to an average of 970 hours per year (Pawlak et al, 2001) which perhaps balances after certain period of operation just to be in normal range. When annual average working hours are less than aforementioned maximum annual working hours, say 700 hours/year, estimated useful life of tractor would be 14 years which is beyond predetermined economic life. Such tractors perhaps mean technically obsolete and spare parts would be hard to find.

In most cases in developing countries like Ethiopia where farm machineries are imported from developed countries, average annual working hours are by far higher than the maximum estimated annual working hours which limited useful life of the tractors due to over utilization. In this condition, RMC model developed in USA condition no longer works in most developing countries. Therefore, either the model should be modified or new model applicable to the developing countries need to be develop.

4.6.3.3. Fuel and oil cost

Fuel consumption estimation is based on the average annual fuel consumption. Along with fuel cost, oil costs were also determined for aforementioned tractors and combine harvesters as 15% of their fuel costs (ASABE standard D497, 2006). In the study area, tractors and combine harvesters consumed diesel fuel. None of the machinery consumed gasoline. The results in Figure 4.30 to Figure 4.33 showed simulated and actual fuel and oil costs of tractors (Massey Ferguson-398, FNH-110-90, NTAF-Belarus-820, and Styer-9094), and combine harvesters (Appendix A). The result shows the variation between simulated and actual fuel and oil costs. The study found that fuel and oil costs increased with age.

Most importantly, actual fuel costs of Massey Ferguson-398 and Fiat New Holland-110-90 continued to increase than simulated fuel cost until half of tractor's economic life. Similarly, oil costs of both aforementioned tractors were higher than the simulated costs until the tractor reached to its useful life. In contrast with Massey Ferguson and Fiat New Holland, simulated fuel costs of Styer-9094 and NTAF-Belarus-820 tractors were higher than the actual one up to three to four years of service. Then, the actual fuel costs exceeded simulated fuel cost as shown in Figure 4.30 to Figure 4.33. The higher costs kept continued up to the predetermined economic life of the machines. The costs tended to decline since half of both machines useful life in a similar way to Massey Ferguson and Fiat new Holland tractors.

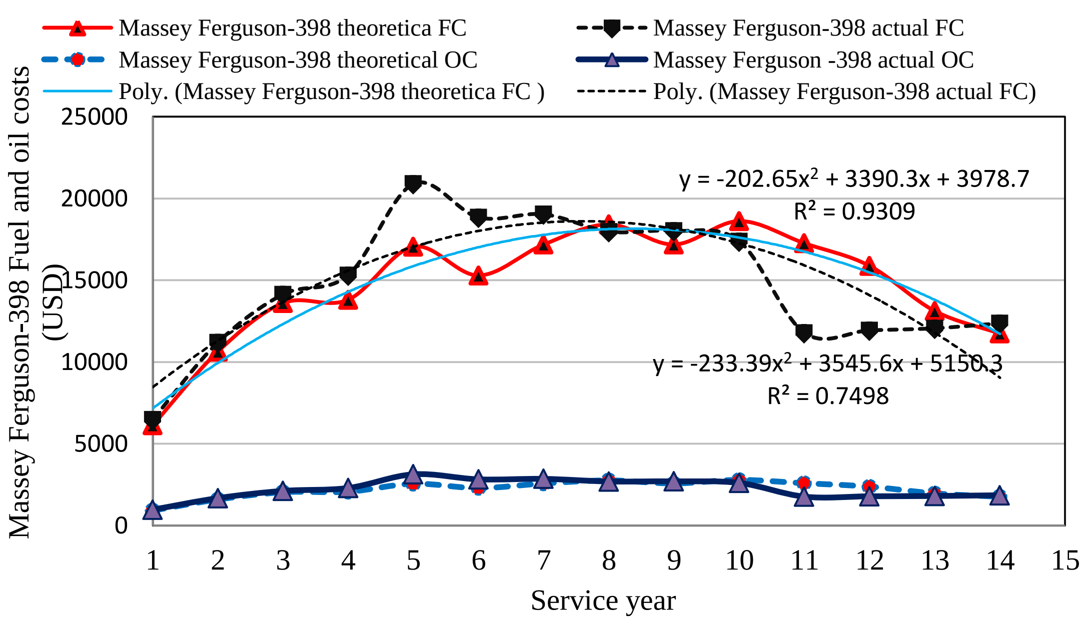


Figure 4.30. Actual and simulated fuel and oil costs of Massey Ferguson-398

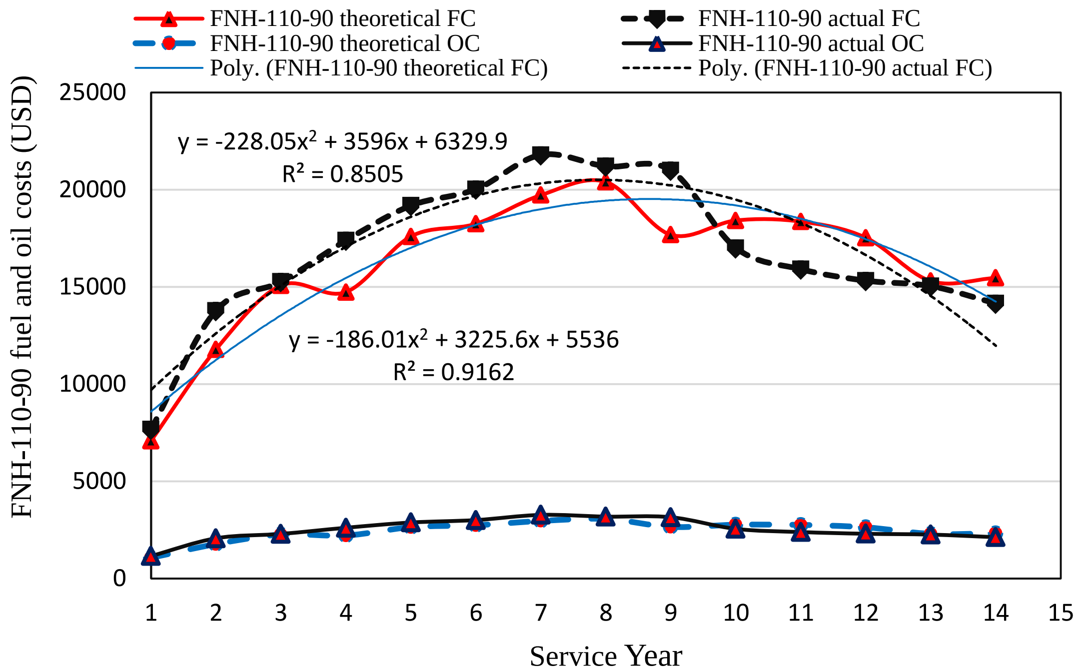


Figure 4.31. Actual and simulated fuel and oil costs of Fiat New Holland-110-90

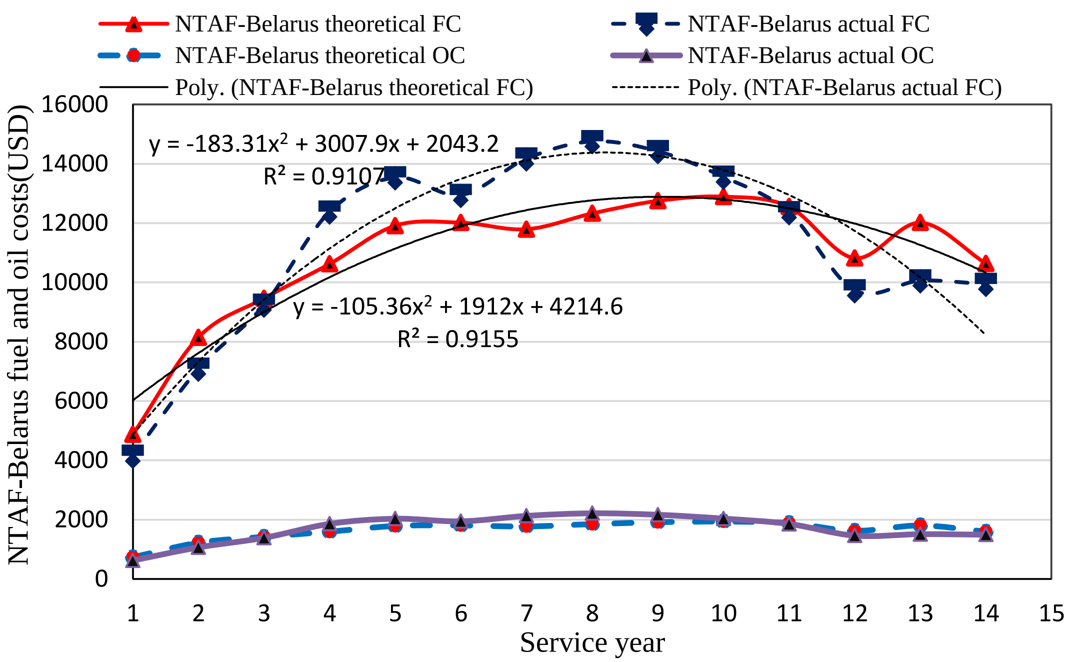


Figure 4.32. Actual and simulated fuel and oil costs of NTAF-Belarus

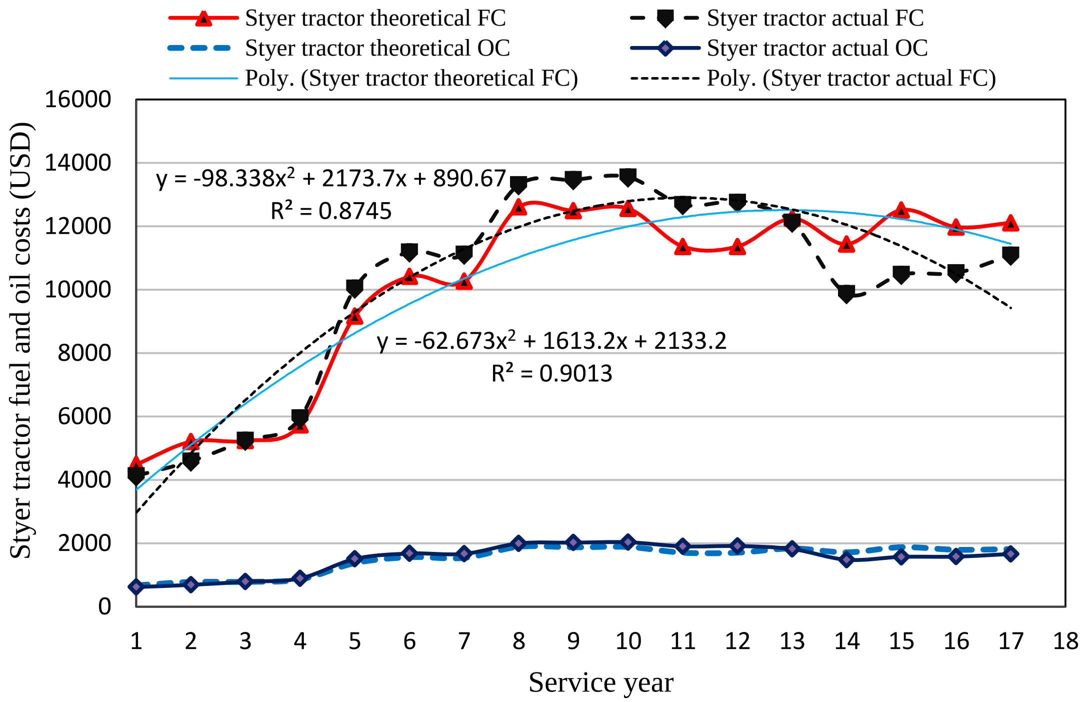


Figure 4.33. Actual and simulated fuel and oil costs of Styer -9094 tractor

In order to determine fuel cost as a function of service life of machines, least square regression method was used. Second order polynomial function was used to determine the relationship. Regression curve for the simulated and actual fuel costs of MF-398 were found as $y=-3967.6x^2+60276x+87555$ and $y=-3445.1x^2+57635x+57638$ respectively.

Generally speaking, actual fuel costs of MF-398 and FNH-110-90 tractors continued to increase up to 5 years and 7 years of use respectively and declined gradually. Simulated fuel costs of the both tractors were equal at the same service year. The simulated fuel costs, tended to exceed actual cost, and they declined along with tractors service life.

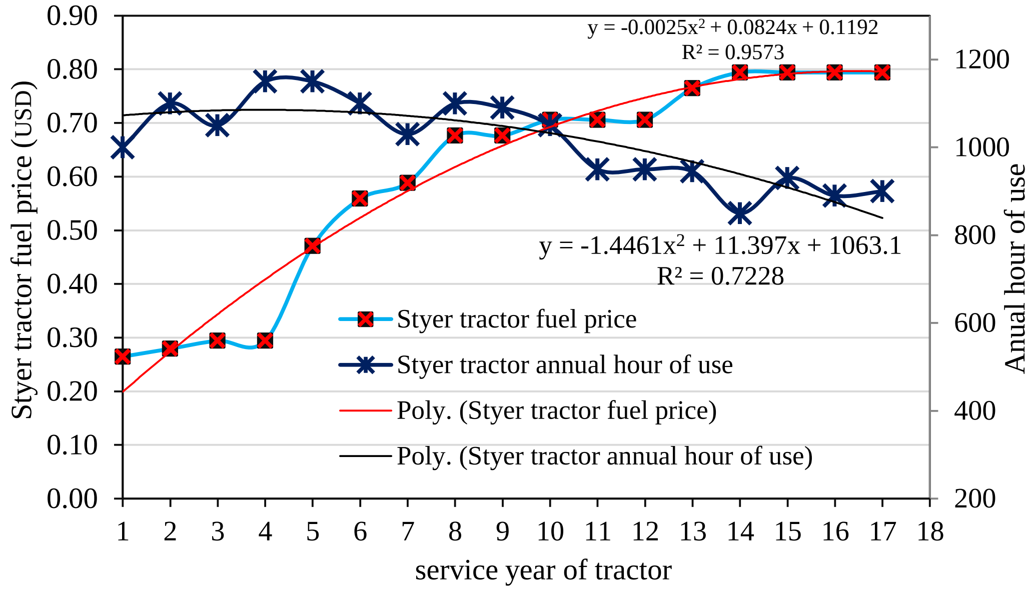


Figure 4.34. Effect of fuel price on total fuel cost for Styer tractor

Figure 4.30 to Figure 4.33 revealed that the actual fuel and oil consumption by the aforementioned farm tractors in the study area were very high perhaps due to poor maintenance, over utilization and improper care. Rising of fuel price from time to time has significant effect on the total fuel cost (Figure 4.34). Main machine components such as engine, pistons, piston rings, cylinder bores etc. require timely overhaul, reconditioning and maintenance. Because, these components are prone to wear due to high dust and dirts blown from the dry field operations. Hence, cylinder bore to piston clearance become increased which resulted to high blow by conditions. Performance efficiency of tractor and combine harvesters becomes low besides high rate of fuel consumption (William, 2002).

4.6.3.4. Total cost analysis of farm machinery

Total cost and variable costs increased with age of the tractors while accumulated fixed costs decreased slightly with age. Figure 4.35 shows the variation of total costs among tractors. This variation may come from the size and initial list price of the tractors.

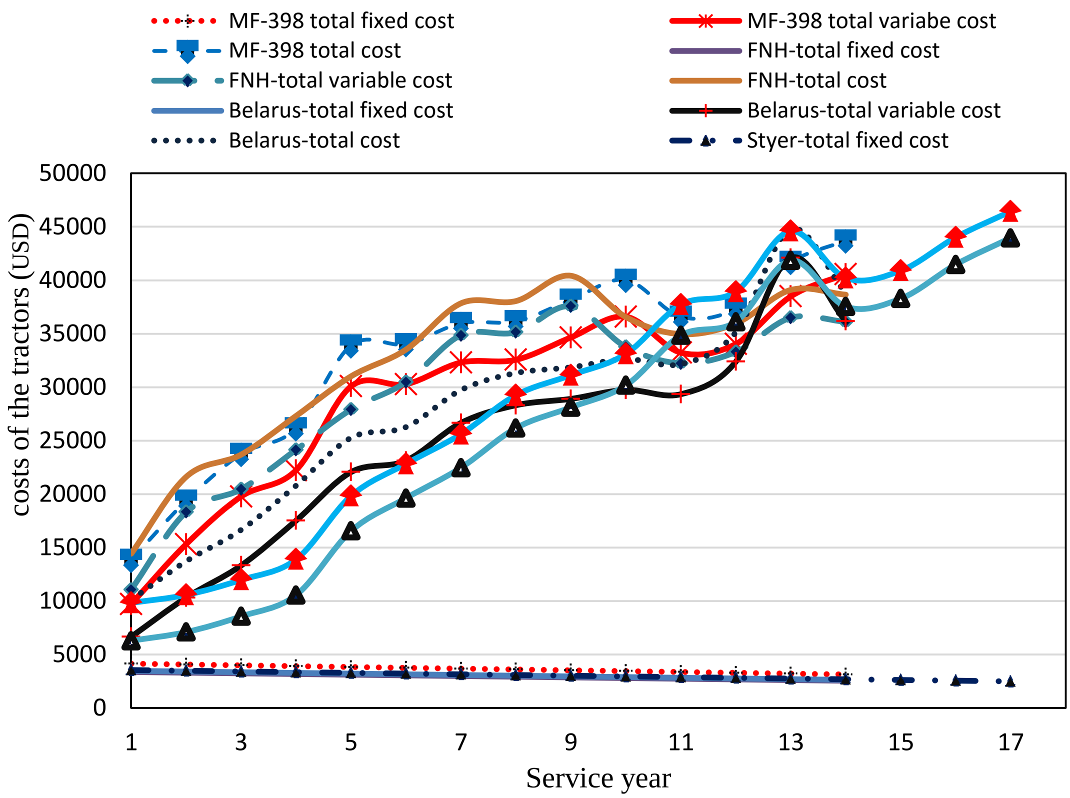


Figure 4.35. Total cost, total fixed cost, and total variable cost of tractors

As it was observed from Figure 4.35 that Fiat New Holland-110-90 (120hp) is bigger than the remaining three, however, total cost of Massey Ferguson-398 (104 hp) which is smaller in size to some extent than Fiat New Holland was competitive with the total cost. This result is partially consistent with the CIGR (2000), which suggested that a machine too large for the operation has a high price and excessive total costs. A very small machine has a low purchase price, but the total costs of its use may be high because of increased labor and timeliness costs. An optimum-size of machine having the least total costs exists between these two extremes.

4.6.4. Farm machinery replacement indicators

Replacing agricultural machinery which had been working in the dust and dirt conditions is very crucial for the optimum life. Replacing old machine by new similar one is usually performed based on its economic life. According to ASABE Standard D497 (2006), economic life of tractor is 12 years. But, economic lives of tractors (Table 4.43) in the study area were shorter than those by ASABE (2006).

Table 4.43. Replacement periods of tractors

Type farm Machinery		Service year of maximum fuel cost range	Average	Service year at max. RMC	Average attainable useful life	Estimated year of replaceme nt
Tractors	Massey Ferguson	5-10	7.5	11	10.4	9.6
	Fiat New Holland	7-10	8.5	10	8	9.6
	NTAF-Belarus	8-11	9.5	10	10.6	10
	Styer	10-13	11.5	13	10.6	11.5
	YTO	-	-	-	13.8	-
Combine harvesters	John Deere	-	-	-	7.5	-
	John Deere	-	-	-	10.4	-
	New Holland	-	-	-	7.57	-

The study found that economic life of a tractor has a direct relation with repair and maintenance cost. It was also found that the machinery replacement is based on three parameters:

1) service year when the tractors require maximum fuel cost (Figures 4.30-4.33)
2) Service year at which RMCs tended to decline and the simulated RMCs exceeded actual ones (Figures 4.26-4.29).
3) Average useful life where the machines are under accelerated depreciation due to overutilization (Table 4.42)

This study took an average of three parameters mentioned above and estimated replacement year for tractors. The replacement years for both Massey Ferguson-398 and Fiat new Holland-110-90 tractors were estimated to be 9.6 years, NTAF-Belarus-820 was 10 year and Styer-9094 was 11.5 years. A similar study was conducted by Abbas et al. (2012) to determine the replacement year of Massey ferguson-298 with in annual use of 500 hours in Iran farm fields and they found that the replacement was required at the age of 14 years that is after 6981 hours of operation which is inconsistent with this study. This difference may come from different geography and annual hours of use of these tractors.

According to this study, 12 years as an economic life may not work rather it could be taken as physical life. Hence, using these machines before the years recommended by this study could be economical. Using it beyond these life perhaps leads to excessive down time during farm operation due to frequent breakdowns and technologically malfunctions (ASABE Standard S495, 2006). Abbas et al. (2012) in their study confirmed that the useful life of farm tractors depends on intensity of RMCs, the amount of depreciation and interest costs. They also added, when the R&M costs are greater, the useful life will be shorter and increase in RMCs in the recent years greatly effects the useful time which is consistent with this study.

4.7. Economic feasibility of owning farm machinery

Almost all the farmers in the Hetosa district purchased tractors and combine harvesters for the sake of making businesses from the custom hiring services. Machinery owners can directly negotiate with farm owners or through a broker in advance at the beginning of the season. Farm machine, particularly tractor service rate in the study area is based on the crucial period. During peak operation, basically at the time of sowing and harvesting, the service rate was high. In contrast to this, during normal operational period and at the beginning of the season, the rate was at the normal range. Whatever the case, the rate was calculated on hectare basis. In most cases the rate is also affected by the field condition. The rate was high for fallow land and normal for previously cultivated field, distance from the main road and geophysical condition. Paman et al. (2010) found a similar situation, while conducting a study on economic potential of tractors hiring service in Indonesia condition, except that the size of the plot and weed growth on the field.

The charge rate was also affected by the competition between private tractor owners and Hetosa farmers union. There was no perfect competition among private owners. The union was balancing and normalizing the service charge rate. Due to concern over the union, the private tractor owners are forced unwillingly to maintain the common service charge unless aforementioned condition.

The charge rate varied from operation to operation. It was ranged from 50.78 to 60.02 USD for plowing with an average charge rate of 55.40 USD. For harrowing and sowing operations, it was about half of aforementioned service charge due to the fact that the required energy for compacted and undisturbed soil and tillage depth for former is higher than those for the later operation. The other mechanisms observed in the study area were that, the owner used to lower the charge rate below the one for the normal operation period for the farmers who were able to pay cash prior to plowing season. This makes the owner to collect more service charge than subordinating owners. The farmers could be benefitted from lower service charge and be guaranteed to get service in first line during either of peak operation so as to minimize timelines cost.

As it was seen in the last portion of mechanization level of the study area, there was shortage of farm machinery in the study area. Very limited framers have farm machinery. Majority of the farmers in the study area used to get service from these owners for their cereal crop productions rather than buying it because of different factors such as initial capital, lack of loan facilitation and support, fear of high initial cost of machinery, and lack of experienced operators and mechanic in the vicinity. Concern over return from a tractor investment within a short duration was the mainstay. It was confirmed that by the results from the feedback, majority of the farmers in the study area worried about return of tractor investment.

The study tried to investigate whether the owed tractors and combine harvesters basically in the study area have economic viability or nor. In this process, all the fixed and variable costs were determined as shown in the sections 4.6.3; revenue of tractors was estimated from the number of hectares plowed per year multiplied by service charge rate per hectare. In this condition, however, the owner plowed their own farms at the same rate with custom service. Average service charge rate (55.40 USD) per hectare was used for tractors shown in Table 4.44. Only those tractors owned by private farmers were used in this analysis. Average annual hectare plowed depends on the tractor’s performance, effective days per season in the study area and field capacity. For example, effective days of operation for MF-398 tractor in normal weather conditions were 60 days and its field capacity was 4 ha/day in average. It used to work half days. The numbers of customers have also an effect on the revenue of the tractors.

Table 4.44. Average annual hectare plowed by the tractors

Tractors model	MF-398	FNH-110-90	Berarus-820	Styer-9094
Average annual hectare plowed	240	312	200	156

Some studies (Paman et al., 2010; and Nazaie et al., 2014) used hectare as a breakeven point parameters but Parminder et al. (2012) used annual hours of use. In this study, annual hectare per tractor was used in order to determine profit or return from the tractor investment. Data were graphically analyzed on the basis of service life. Breakeven point was determined in terms of service year where the total cost is equal to the total revenue as shown in Figure 4.36.

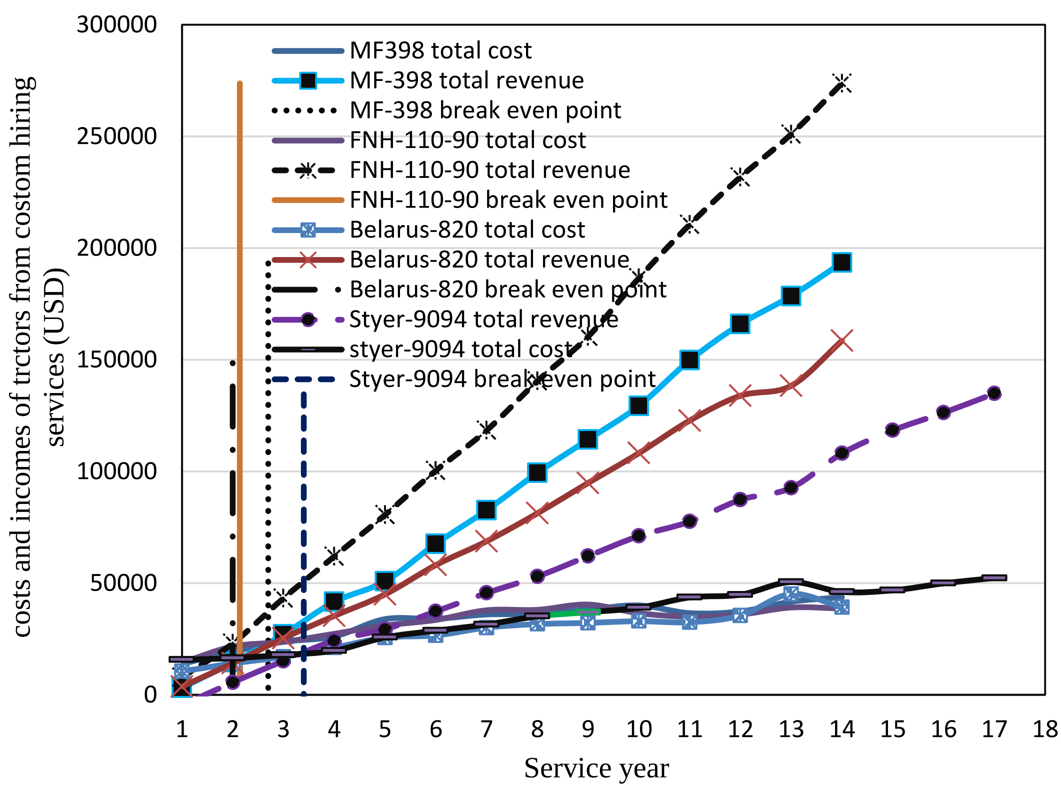


Figure 4.36. Acquisition cost pay back year of farm tractors

Figure 4.36 shows that break even hectares for Massey ferguson-398, Fiat New Holland-110-90, NTAF Belarus-820 and Styer-9094 tractors respectively were 2.7 (648 ha), 2.14 (667 ha), 2 (400 ha) and 3.4 (530 ha) years. After indicated years each tractor owners could got profit. Compared to longer economic life of the tractors, the owners get return from the investment at early age of tractors. This study found impressive results which could suggest that farmers in the study area would own tractors so as to get return in short duration. The result also revealed that the average pay-back period for each tractor was very short as compared to the economic life which is shorter than the expectation of the farmers in the study area. The implication of this result is that farmers will be more economical if they purchase tractors leaving aside worrying over tractors investment return.

CHAPTER 5

Policy Recommendation

5.1. Remarks to the government

In Ethiopia where 40.42% of its economy is based on agriculture, farm mechanization basically for cereal crop production is vital. Benefits of the mechanization in all aspects were confirmed in this study. The status of the study area would be the reflection of many regions in Ethiopia but the majority of the regions are in condition worse than the study area. Reliance on traditional farming is obvious. Currently many youngsters migrate to city. Their parents are becoming old. Potential to produce will be weak. Current strategies are agricultural lead industrialization. Agriculture which doesn't consider mechanization will be failed. County must feed rapid growing of population. Thus more food is required. Mechanization should be attention seeker than traditional farming to produce more food. Most probably severe situation will happen if the current situation will exceed. In order to increase farm productions, productivity and alleviate upcoming problems, this study recommends the followings to the government:

1) Develop mechanization policy and strategy which collectively deal with all crops. Mechanization policy is crucial for a country like Ethiopia which economy is based on agriculture. It facilitates the way to introduction, promoting and expansion of mechanized inputs. It also set out objectives and direction for current and future development and management of agricultural mechanization. The ultimate goals of policy are creating conducive environment for agricultural mechanization for increased productivity, capacitate research based technology and providing reliable and sustainable track to agricultural technology. Without strategy policy does nothing. Strategy matters most for wellbeing of policy. Hence, developing strategy is a key element in order to achieve preset objective of the policy. A number of mechanization strategies should be required during policy designation.
2) More than 95% productions come from small-holders farmers who have fragmented land less than 2 hectares. Appropriate mechanization technologies which consider the situation on the ground should be developed or supplied.

3) Small farm holders have no capacity to buy farm machinery. Always the government is upper hand. Hence, government should subsidize farm machinery and increase farmer's access to agricultural mechanization technologies. This can be done by two forms of subsidies. One, the government should encourage dealers/importers in order to import farm machinery duty free so that dealers will reduce selling price of the machines. The second one is direct subsidy. In this case, besides to facilitating loan, the government should supports farmers by providing some amount of money in order to motivate them.

4) Mechanization should be a part of rural integrated development program. Government should create conducive atmosphere that will ensure supply of mechanization input and farm power. Roads and other associated infrastructures are crucial.

5) Institutionalize repair and maintenance service center, on-field service provider and emergency mobile garage at least one at district level. Maintenance is crucial for mechanized sector. Maintenance activity ensures the availability of equipment and facilities and keeping the downtime to a minimum. It will support the effective operation process by eliminating and reducing the frequency and severity of farm machinery failure. Hence availability of fixed (garage) and mobile maintenance service center to the vicinity of mechanized agriculture is crucial for reliable machinery operation during period and vice versa.

6) Set up farm machinery repair and maintenance crew and operator training center. Along with this, middle level to high level professionals should be produced.

   Based on recent machinery and a technology employed on their construction there is a complexity of machinery system and some variation in operation, maintenance and safety improvement from time to time. To use and handle the newly purchased machinery properly, to understand machinery equipment function and mechanism, to have a power to find out the cause of a system trouble, to have ability to find and improve machineries minor and major defect sources, it is very important to train maintenance crews and operators in order to build them with knowledge and skill from time to time. This will ensures proper and effective maintenance and increase performance of maintenance crews and operators.

In order to communicate with machinery system, understand why failure occurs and suggests ways of avoiding failure occurring and minimize machinery breakdown, it requires educates and well trained operators. In order to minimize down time for a breakdown of farm machines during normal and peak time operation a great level of skill should be achieved through formal training.

Hence setting up training center for aforementioned skill is paramount in order make mechanization productive. Training center should be equipped with all facilities required for training. Apart from this, for intensive field training, machines and their implements with all its kind should be available at a place.

7) Establish R&D and technical advisory council with proper capacity frontier. RD in agricultural mechanization works on introducing new technology, testing and evaluation of technologies before adopting so as to best fit to a local situation works on innovation and improvement of existing products and processes. Hence, research and development plays great role in order to lead and support mechanization with scientific research and modern technology based systems. Technical advisory councils supposed to work on promoting appropriate mechanization inputs and provide continuous technical support for the farmers on how to use the technologies for better desired outcomes.
8) Establish mechanization, industry, environment and market value chain integrity. Agricultural products processing industries should be set up to a vicinity of farm. Farmers and the industries should have strong link. It is also better to work on the way farmers get more benefit from their produces by adding value on their product. Apart from this, environment issues need a great concern. Mechanization inputs should be environmental friendly and their effects should be a great minimum. All the details should be put during policy designing.

5.2. Recommended direction to farm machinery plan

98% of agriculture is on hand of small holders which have less than 5 hectares (CSA, 2014). The share of agricultural GDP is still paramount for the country’s economy. Moreover, enhancing food self-sufficiency through significant production and productivity increment from existing land has no choice (see appendix C). Transforming current animal and human led farm operations to modern and mechanically operated ones will be a key element. Hence, the study believed that policy and strategy would be too urgent tools. In fact change has to be radical even though can't bring it at a time. The following approach need to be followed.

1) For short term mechanization plan (in the coming five years):

- Transforming from traditional to modern and semi-mechanized one; in this case using of draught animals will decrease by increasing power tiller from current 4,803 to 300,000 in the coming five years. This will increases power tiller to 1,000 hectares ratio from current 0.065 to 4.05 in the coming five years which will increases power ratio by 4628%.
- Transforming from traditional to modern and mechanized one; in this case using of animal and human power will decrease by increasing tractors from current 8,570 to 200,000 medium horse powers in the coming five years. This will increases tractors to 1,000 hectares ratio from 0.11 to 2.7 for the coming five years. The number of combine harvesters, dusters, cultivator, threshers and associated technologies like implements should be increased proportionally.
- Small farm holders don't have money to buy farm machineries. Even though mechanization strategy which supposed to be designed will have an answer, joint buying and using machinery could be possible choice. Hence, the farmers share all over head and variable costs of their machines. Such a strategy will increase the senses of belongingness to the farmers than renting some ones machines.

Therefore, five years believed to be transitional and training times from tradition to mechanized operations.

2) For medium and long term mechanization plan (in the coming ten years):

The study recommended appropriate mechanization policy and strategy which will uplifts current low level of mechanization technology and input in agriculture. Besides, resolving constraints which hindering a modernization of the agriculture and food production systems. Hence, the study recommended the following plans.

- Increasing power tiller from 4,803 to 600,000 so as to uplift mechanization level from 0.065 to 8.1. When this plan will achieves 123 farmers those average holding of 1 hectare or 61 farmers those average holdings of 2 hectares or 40 farmers those average holdings of 3 hectares will share a power tiller.
- Increasing tractors from 8,457 to 500,000 so as to uplift mechanization index from 0.11 to 6.7. This plan will benefit about 50 to 150 farmers those holdings from three to one hectare to share tractors in common.
- Machinery joint using mechanism mention under portion 5.2.1 will also works for this portion until the farmers will be able to own individually.

Therefore, this plan expected to increase usage of mechanical power and decreases animate power for farm operation. Apart from increasing crop production and releasing farmers from drudgery work, it will change the culture of farming community and farming environment. It will also expect to facilitate strong tie and synchronization between agriculture and industry which will pave the way to industrialization.

CHAPTER 6

Conclusion

This chapter gave conclusions arrived on the basis of objectives of the thesis and research findings. Hence, different mechanization input variables particularly which were believed to be crucial for the cereal crops production like farm machinery and related technologies were determined. The effect of agricultural machinery on cereals crop production was analyzed by the regression model. it showed that using tractors, combine harvesters, and weed control technology have a positive effect on cereal crop production. Other mechanization variables such as education, field condition and farm size have also found to have positive effect on cereals crop production. The study suggested that agricultural machinery and related crop production technologies should be used in order to increase production of cereal crops for small farm holders in the study area.

Among the three mechanization models, i.e. traditional farm (Model 1), semi- mechanized farm (Model 2) and mechanized farm (Model 3) which were developed for small farm holders, traditional farming was found to be time and energy consuming than the semi-mechanized and the mechanized farming. The mechanized farming found to be saved the working days by 94.4% and 80% than the traditional and the semi-mechanized farming respectively. Machine hours required for the mechanized and the semi-mechanized farming are by far smaller than oxen-hours required in the traditional farming.

The study found that the mechanized farming saved more labor than the traditional farming. Particularly in wheat crops, the mechanized and semi- mechanized framings could save labor by 87.8% and 86.6% respectively than the traditional farming. Man-hours required for the traditional wheat farming was very larger than the semi-mechanized and the mechanized farming by 93.2% and 88.1% respectively. Thus, in order to alleviate labor shortage for farm operations due to the rural exodus seeking for better jobs at urban, mechanization was found to be a better choice.

Above all, high total operation cost and total costs were found in traditional framing than the mechanized and semi-mechanized farm operations. In other way, the mechanized and semi-mechanized framings showed better income and net return from the production which have a positive effect for small farm-holder farmers. The study found that the mechanized farming was both more labor and land productive than the traditional framing.

In addition to different mechanization parameters, energy consumptions by three mechanization models were also investigated. The study found that total input energy consumption (MJ/ha) in semi-mechanized farming was higher than that by mechanized and traditional farming. Energy used by machines and its fuel by semi-mechanized model accounted higher share while in traditional model, energy used by draught animal accounted larger share followed by labor energy as compared to the total input energy. Net energy by the mechanized and traditional farming were positive while negative net energy was found by semi-mechanized farming which was caused by lose of energy. Traditional and mechanized productions were found to be energy efficient than that by semi-mechanized farming. Even though the traditional farming consumed low energy, mechanized farm was found to be economical than that by traditional and semi- mechanized farming. The result found that net return and productivity of mechanized farm were higher than those by the traditional and semi-mechanized farming.

It was known that the study area has a limited number of agricultural machineries particularly tractors and combine harvesters. Level of mechanization in terms of the number of machinery to cultivable land ratio was as lower as 0.23. Poor machinery handling, lack of scheduled maintenance services, poor after sale services, and lack of well-organized machinery service centers were found. In addition to these, the useful lives of machines were shorter than the predetermined ones by Standards (ASABE, 2011) due to over utilization of machinery in dirt and dust field conditions.

Ownership cost and variable cost are the two major cost components of farm machineries. Variable cost depends on the use of the machines. The study found that over utilization was observed in the study area as mentioned above. Most of the machine systems and implement mechanisms were frequently failed on farm during peak time operations. They were due to bad weather and irregular terrain so that the rates of wear and tear and break down become high. As the consequence, actual repair and maintenance costs were high up to the machine's half useful life. The actual costs of fuel and oil were found to be very high due to high fuel consumption.

In Ethiopia, there was agricultural development strategies which were basically focused on supplying improved seed and fertilizer. Mechanization of small-holder farming didn't get attention. No subsidy of the government for farm machinery to initiate small farm holders. Government and private owned dealer were importing and distributing tractors. Farmers who have a better capacity purchased and worked for custom hiring services. The study found that those farmers who purchased tractors and combine harvesters payed back within two to four years period. Since the return period was shorter than the half of economic life, farm machinery was found to be more profitable than the expectation of the farmers in the study area. If the government supports small farm holder facilitating subsidy and loan, farmers will be profitable, released from heavy labor and able to produce more from their land which could ensure food self-sufficiency.

Direction of future research work

This research has its own limitation. Testing and performance evaluation of imported agricultural machinery and in-depth investigations of fruit, vegetable and commercial crop mechanization areas need be covered with the next research consideration to fill the gaps mentioned.

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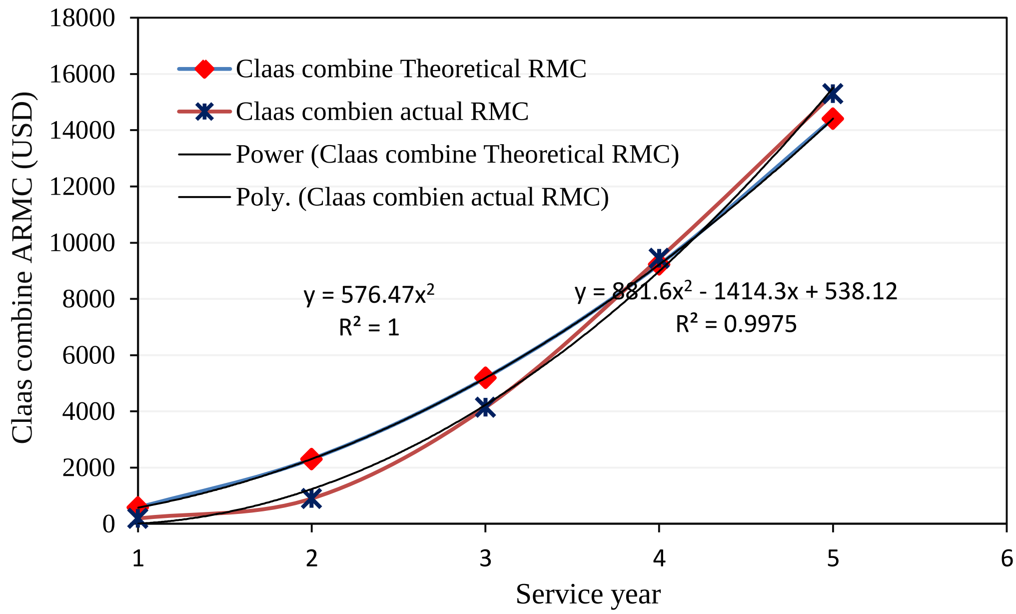
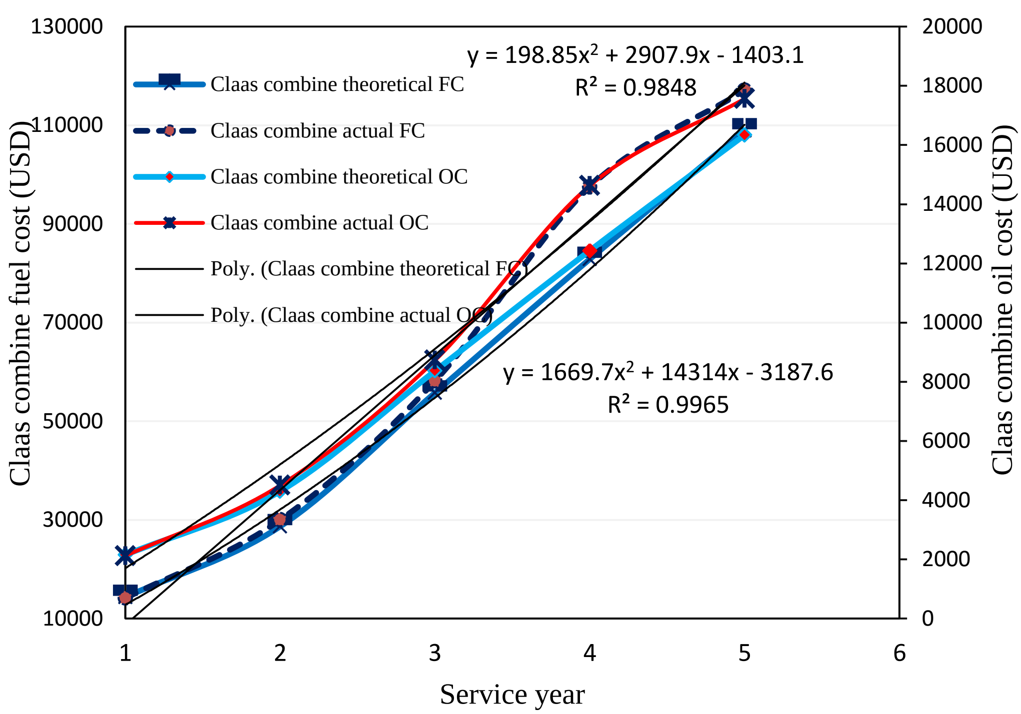
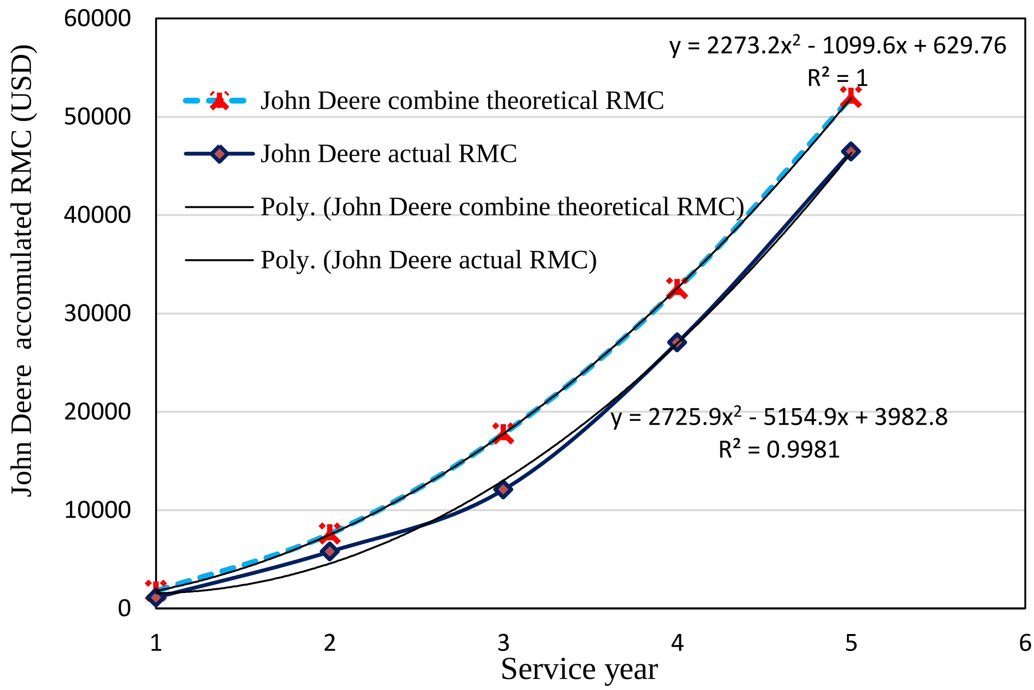
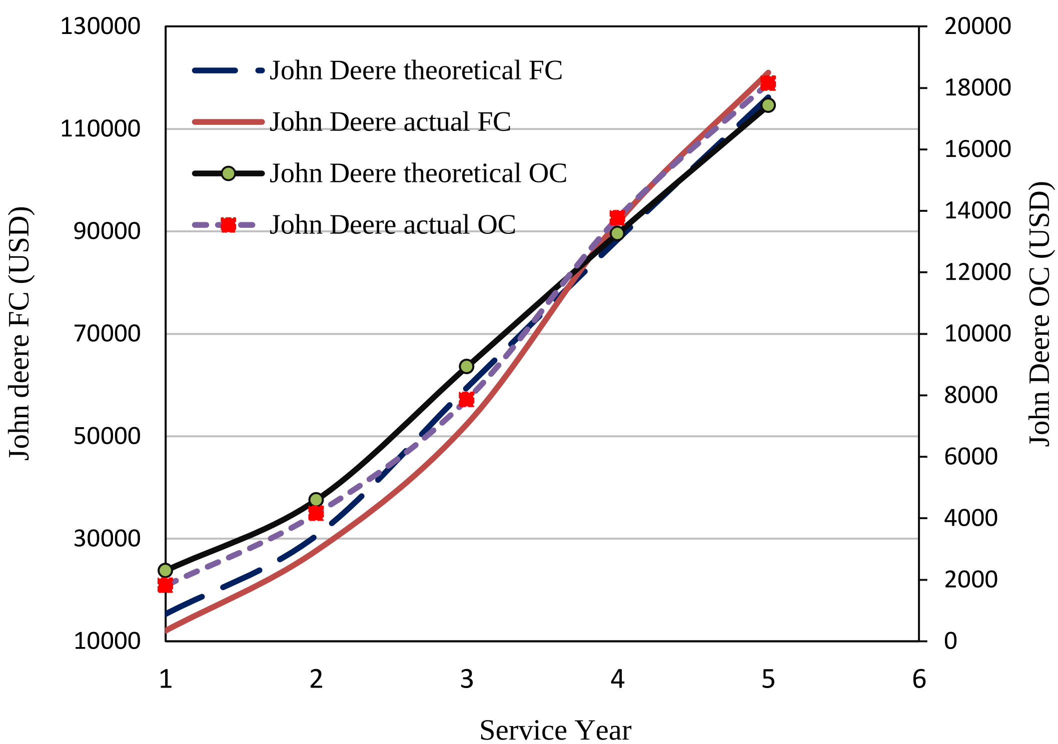
Appendix A

RMC, fuel cost and oil cost of combine harvesters

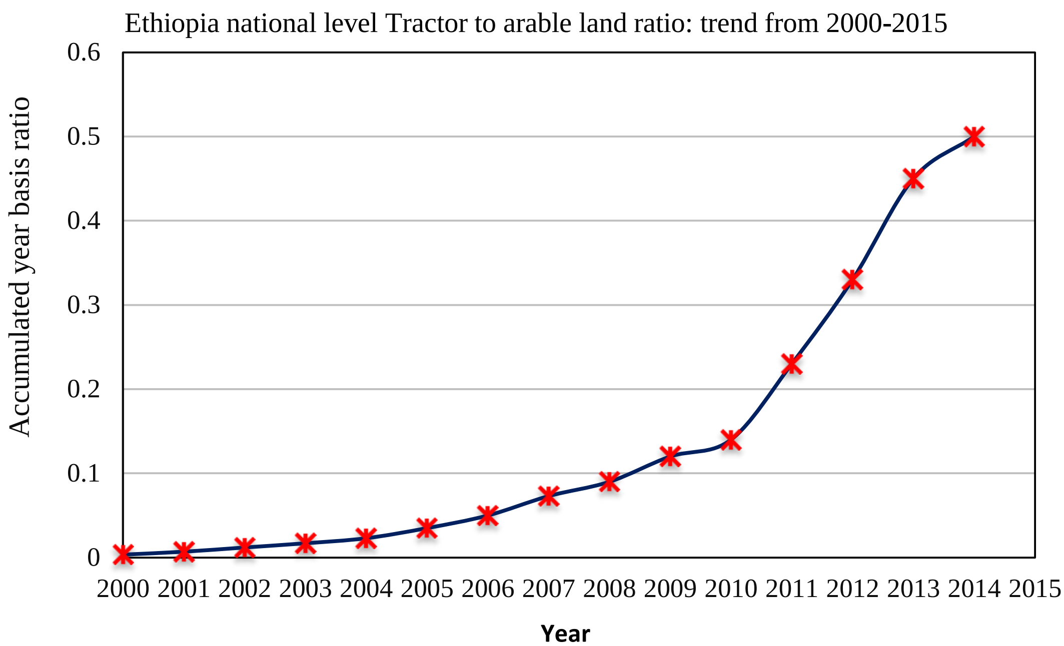




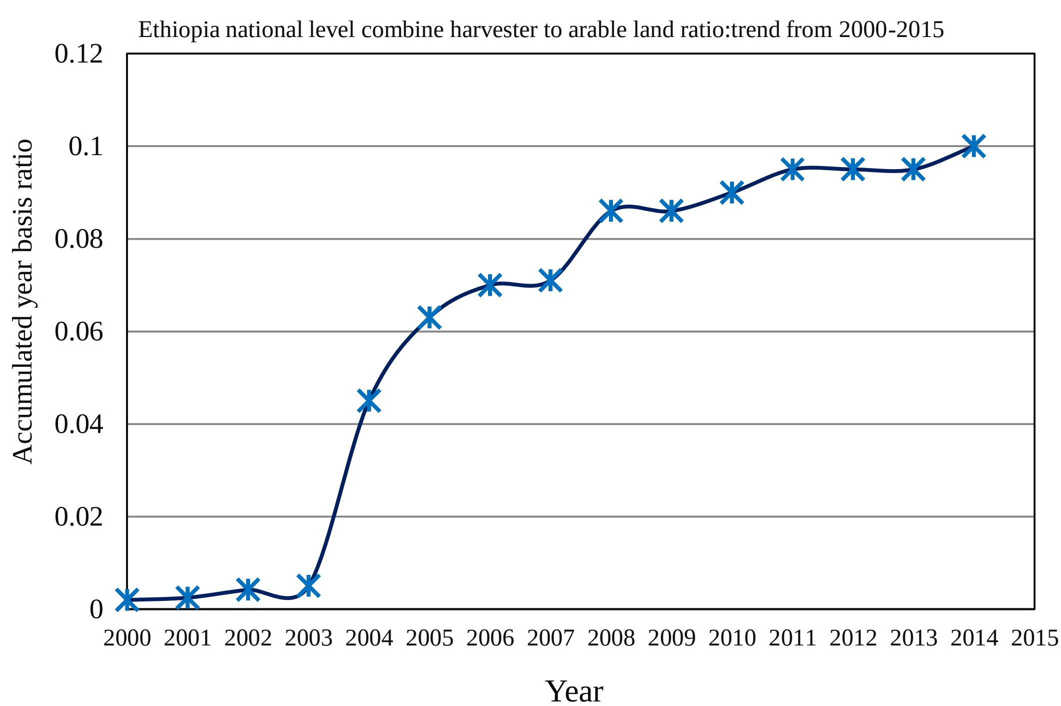

John Deere accomulated RMC (USD)
60000
50000
40000
30000
20000
10000
0
y = 2273.2x² - 1099.6x + 629.76
R² = 1
John Deere combine theoretical RMC
John Deere actual RMC
Poly. (John Deere combine theoretical RMC)
Poly. (John Deere actual RMC)
y = 2725.9x² - 5154.9x + 3982.8
R² = 0.9981
1
2
3
4
5
6
Service year


John deere FC (USD)
130000
110000
90000
70000
50000
30000
10000
John Deere theoretical FC
John Deere actual FC
John Deere theoretical OC
John Deere actual OC
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
John Deere OC (USD)
1
2
3
4
5
6
Service Year

Appendixs B



Ethiopia national level Tractor to arable land ratio: trend from 2000-2015
Accumulated year basis ratio
0.6
0.5
0.4
0.3
0.2
0.1
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year



Ethiopia national level combine harvester to arable land ratio:trend from 2000-2015
Accumulated year basis ratio
0.12
0.1
0.08
0.06
0.04
0.02
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year

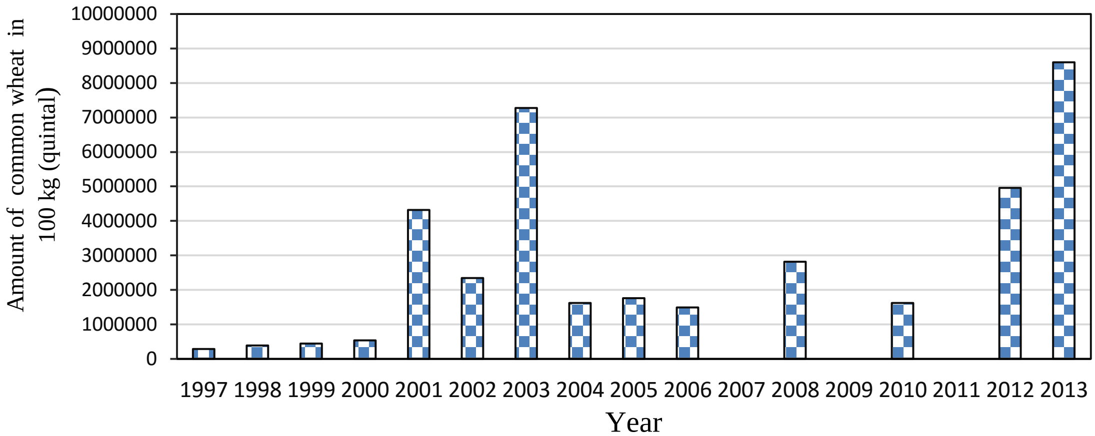
Appendix C

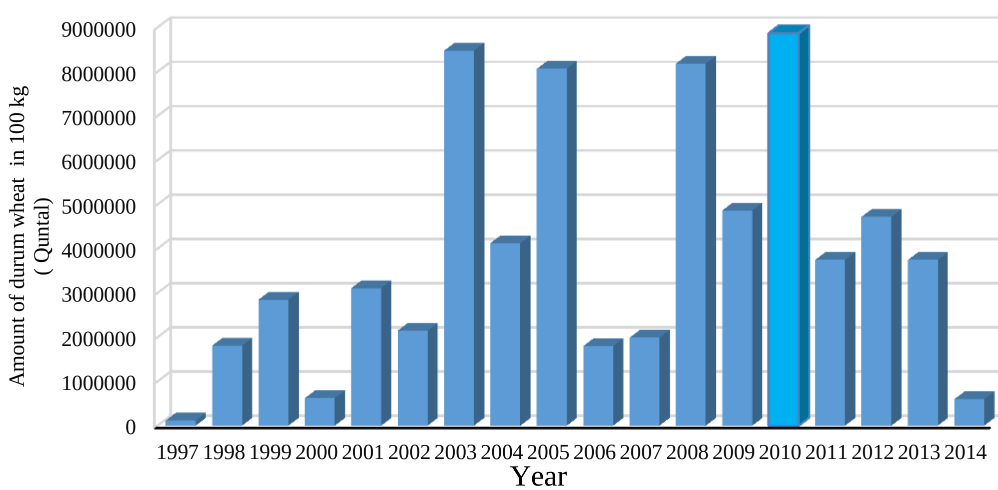
Trend of imported quantity of farm machinery for the last ten years

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Walky tractor	59	65	8	261	1589	148	2502	6	12	6
Tractor quantity	190	345	332	232	513	511	1546	1730	2258	913
Combine harvester	329	54	46	459	99	64	100	74	114	22
Implements	193,649	165	608,896	8,651	3,936	957	3,065	157,884	1,683	4,621

Imparted quantity of wheat for the last ten years

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Common wheat*	1,762,067	1,485,552	-	2,816,729	-	1,616,488	-	4,957,944	8,600,072	-
Durum wheat	8,063,948	1,797,506	1,988,883	8,183,771	4,865,710	8,870,451	3,745,785	4,719,587	3,745,785	596,693





Appendix C source: CSA and Ethiopia customs and revenue authority (2014)

Appendix D

Field Efficiency, Field Speed, and Repair and Maintenance Factors for Field Operations									
	Field Efficiency		Field Speed			EUL		Repair Factors	
	Range	Typical	Range	Typical	Typical	Est. Life	Tot. Life		
	%	%	mph	mph	km/h	hours	Cost%[a]	RF1	RF2
TRACTORS									
2WD & stationary						12,000	100	0.007	2
4WD & crawler						16,000	80	0.003	2
TILLAGE & PLANT									
Moldboard plow	70-90	85	3.0-6.0	4.5	7.2	2,000	100	0.29	1.8
Heavy-duty disk	70-90	85	3.0-6.0	4.5	7.2	2,000	60	0.18	1.7
Tandem disk harrow	70-90	80	4.0-7.0	6	9.7	2,000	60	0.18	1.7
(Coulter) chisel plow	70-90	85	4.0-6.5	5	8.0	2,000	75	0.28	1.4
Field Cultivator	70-90	85	5.0-8.0	7	11.3	2,000	70	0.27	1.4
Spring tooth harrow	70-90	85	5.0-8.0	7	11.3	2,000	70	0.27	1.4
Rotary tiller	70-90	85	1.0-4.5	3	4.8	1,500	80	0.36	2
Row crop planter	50-75	65	4.0-7.0	5.5	8.8	1,500	75	0.32	2.1
Grain drill	55-80	70	4.0-7.0	5	8.0	1,500	75	0.32	2.1
HARVESTING									
SP Combine	65-80	70	2.0-5.0	3	4.8	3,000	40	0.04	2.1
Forage harvester	60-85	70	1.5-5.0	3	4.8	2,500	65	0.15	1.6
SP Forage harvester	60-85	70	1.5-6.0	3.5	5.6	4,000	50	0.03	2
Sugar beet harvester	50-70	60	4.0-6.0	5	8.0	1,500	100	0.59	1.3
Potato harvester	55-70	60	1.5-4.0	2.5	4.0	2,500	70	0.19	1.4
SP Cotton picker	60-75	70	2.0-4.0	3	4.8	3,000	80	0.11	1.8
Mower-conditioner	75-85	80	3.0-6.0	5	8.0	2,500	80	0.18	1.6
Source: ASAE Standards 1993, American Society of Agricultural Engineers, St. Joseph, Michigan, 1993.									

Average Energy and Fuel Requirements for Selected Machinery Operations								
	PTO		Gasoline		Diesel		LP Gas	
Field Operation	hp-hrs/acre	kW-hrs/ha	gal/acre	lit/ha	gal/acre	lit/ha	gal/acre	lit/ha
Shred stalks	10.5	19.34	1	9.35	0.72	6.73	1.2	11.22
Plow 8-in deep	24.4	44.94	2.35	21.97	1.68	15.70	2.82	26.36
Heavy offset disk	13.8	25.42	1.33	12.43	0.95	8.88	1.6	14.96
Chisel Plow	16	29.47	1.54	14.40	1.1	10.28	1.85	17.29
Tandem disk, stalks	6	11.05	0.63	5.89	0.45	4.21	0.76	7.10
Tandem disk, chiseled	7.2	13.26	0.77	7.20	0.55	5.14	0.92	8.60
Tandem disk, plowed	9.4	17.31	0.91	8.51	0.65	6.08	1.09	10.19
Field cultivate	8	14.74	0.84	7.85	0.6	5.61	1.01	9.44
Spring-tooth harrow	5.2	9.58	0.56	5.23	0.4	3.74	0.67	6.26
Spike-tooth harrow	3.4	6.26	0.42	3.93	0.3	2.80	0.5	4.67
Planting row crops	6.7	12.34	0.7	6.54	0.5	4.67	0.84	7.85
No-till planter	3.9	7.18	0.49	4.58	0.35	3.27	0.59	5.52
Till plant (with sweep)	4.5	8.29	0.56	5.23	0.4	3.74	0.67	6.26
Grain drill	4.7	8.66	0.49	4.58	0.35	3.27	0.59	5.52
Combine (small grains)	11	20.26	1.4	13.09	1	9.35	1.68	15.70
Combine, corn & milo	17.6	32.42	2.24	20.94	1.6	14.96	2.69	25.15
Mower (cutterbar)	3.5	6.45	0.49	4.58	0.35	3.27	0.59	5.52
Avg fuel consump. per max pto hp (gal per hr)>			0.068		0.044		0.08	
Avg fuel consump. per max kW (liter per hr)>			0.345		0.243		0.406	
Source:machinery replacement strategy, by Wendel Boweres,Deeeree and company,1994.p.80,81								

Appendix E

QUESTIONNAIRE

<u>Purpose</u>: The main purpose of this interview (questionnaire) is to collect data pertaining to form mechanization of rural households. The interview will serve as a major input for a research conducted in pursue of academic purpose. Therefore, the respected respondents kindly requested to give us your genuine response to the questions included here below in the structured interview/questionnaire/. I would like to make sure that the response of the respondents is totally confidential/secured/. I would like to thank you in advance for your patience and cooperation. It was translated to local language.

Part I: General Information (for researchers use only)

1. Name of the respondent…………………………….
2. Name of peasant association…………… Name of the village…………………….

Part II: Household's characteristics

3. Age of respondent ……………………..
4. Sex; Male ☐, Female ☐
5. Education level; Informal education ☐ Grade 1-5 ☐, Grade 6-10 ☐ ,Grade 10 and above ☐
6. Marital status: Single ☐ ; Married ☐
7. If the answer for question #6 is married, number of family member……. Male ☐; Female ☐
   - Number of Family above 10 years and below 60 years ☐
8. House hold head :Male ☐ ; Female ☐

9. Source of income:
a)Crop production ☐ b) Livestock ☐ c)casual work & other business ☐ d)a & b ☐

Part III. Farm Level Characteristics

10. Do you have your own land? Yes…………….; No……………….

If the response is yes, total land in hectare /olmaa/?………………..

11. Distance of farm from main road………….km

12. Duration of living in this area in year…………………..

13. How long have you been since you engaged in to farming?

a)1-5 ☐ a) 6-10 ☐ c)11-15 ☐ d)16-20 ☐ e)21 & above ☐

14. a) How many hectares/olii/ of total land under cultivation? ....

b) Hectares /olii/of land uncultivated?..............

15. Your farm field condition (land scape): 1) plane field …… 2) sloppy field ……

16. Nature of soil of your field? Type ………………………….……………

PART IV FARM PRODUCTION CHARACTERISTICS

17. Type of farming of house hold: 1) crop production…... 2) livestock …….3) mixed…….

18. What is your major crop? Thick the items in box:-

Crop type	a) cereals ☐	b)pulses ☐	c)vegetables ☐	d)all ☐
If all, put in (%)	________ %	________ %	________ %	______ %

19. Cereal crop you often produce?

a)Wheat ☐ b)Barely ☐ c)Maize ☐ d)Teff ☐ e)Sorghum ☐ f)others ☐

20. How often you cultivate your land/produce crop/ in a year?

a)once a year ☐ b)twice a year ☐

21. If the response for #19 is cereals mentioned, please indicate quantity of yields.

Type of crop	Yield per hectare				
	2015/14	2014/13	2013/12	2012/11	2011/10
Wheat					
Barely					
Maize					
Teff					
sorghum					

PART V: FARM POWER (CROP PRODUCTION MACHINERIES)

22. Which Traditional farm tools do you have**?** Thick mark if exist and x-mark if not exist

Tool	Mark X	Tool	Mark X	Tool	Mark X	Tool	Mark X
Maresha		Yoke		Sickles		Hoe	
Beam		Spade		Shovels		Row Planter…	
Cart(Garii)							

23. Do you own oxen? Yes ☐ ; No ☐

24. If yes, 1) Single…………………2) Double……………..3) more than one pair…………….
Form of owning; 1) purchased….. 2) By breading…………………………………

25. Do you have oxen drawn implements? Yes ☐ ; No ☐

If the response for #25 is yes, indicate 'X' mark in box for implement you have and 'O' otherwise

Tool	Mark	Tool	Mark
Oxen drawn traditional plow		Modified mould board plow	
Modified plow/ Marasha		Animal drawn seed drill machine	
Animal drawn Cart(garii)		Human pushed small wheel/cart	

26. If your response for question #25 is no, what is your power source?

a)Donkey	☐	b)Horse	☐	c)Tractor	☐	d)power tiller/ walky tractor	☐

27. Do you access to the tractor? Yes ☐ ; No ☐

If the response is tractor, go to question #28 and if the response is walky tractor, go to Question #29

28. Do you own tractor? Yes ☐ ; No ☐ If yes, indicate:-
    a) purchased year____________________________
    b) purchased price___________________________
    c) Horse power______________________________
29. Do you own walky tractor? Yes ☐; No ☐ If yes, indicate:-

    a) Purchased year____________________________

    b) Purchased price___________________________

    c) Horse power______________________________

30. What means do you mostly used to control weed from your crop? 1) Hand weeding…………..
    2) Chemical (knap sack spray) ………………..
31. What is your harvesting method of your crop? 1)Manual(sickle)……….. 2) combine harvester……………
32. This question is only used for those who don't have their own farm power and based on hiring and rental power

A-animal T-tractor C-combine	Primary tillage		Secondary tillage		Weed control	Harvesting	Threshing
	Plowing 1	Plowing 2	Harrowing	Sowing			
Wheat field							
Barely field							
Maize field							

33. Time of farm operation(just to identify peak time of operation), and intensity of plowing

Operation	Sep	Oct	Nov.	Dec.	Jan.	Feb.	Mar.	Apl.	May	Jun.	July	Aug
Primary tillage												
Secondary tillage												
Sawing												
Weed control												
Harvesting												
Threshing												
Transporting and storage												

34. Sawing methods(variability test)

Crop type	Broadcasting	Yield (quintal/hectare)	Row planting	Yield (quintal/hectare)	remark
Wheat					
Maize					
Barely					

35. Quantity of(inputs) seed , fertilizer and chemical required per hectare

	Seed (kg/ha)			Fertilizer(kg/ha)			Herbicide(lit/ha)			Pesticide(lit/ha)		
	Wheat	Barely	Maize	Wheat	Barely	Maize	Wheat	Barely	Maize	Wheat	Barely	Maize
Traditional									NA			NA
Mechanized									NA			NA

36. labor required per operation

	Primary tillage	Secondary tillage	Planting/ Sowing	Weed control	Harvesting	Threshing	Transporting & storage	remark
Traditional								
Mechanized								

37. Yield comparison between different farm operation (yield variability)

Mechanized					Un-Mechanized			
		Wheat	Barely	Maize		Wheat	Barely	Maize
1	Tractor operation				Oxen			
2	Combine harvester				Human/sickles			
3	Thresher				Animal			
4	Seed drilling machine				Hand sowing			

Part VI. Financial Profitability Analysis

38. Pre and post farm operation (cost per hectare)

Operation type		Primary tillage	Secondary tillage	Sowing/ planting	Weed control	Pest/ herbicide	Harvesting & threshing	Cleaning, Transporting & storage	Total cost
Wheat	Manual								
	Mechanical								
Barely	Manual								
	Mechanical								
Maize	Manual								
	Mechanical								

39. Crop pattern in existing Land holding

- Total land holding in hectare……………………

Crop	Wheat	Barely	Maize	Tef	Sorgum	Beans	Peans	Potato	Fruit	Vegetable
Hectare										
ha (%)										