ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

RESOURCES AND NUTRIENT FLOWS IN SMALLHOLDERS' FARMING SYSTEM OF KUMBURSA VILLAGE, ADA'A DISTRICT, CENTRAL ETHIOPIA

BY BOGALE GELANA DERESSA

JUNE, 2014

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This is to certify that the thesis prepared by Bogale Gelana, entitled: “Resources and Nutrient flows in smallholders’ farming systems of Kumbursa village, Ada’a District, central Ethiopia” submitted in partial fulfillment of the requirements for the Degree of Master of Art in Geography and Environmental Studies, specialization: Land resources Management complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Abstract

Inappropriate use of available resources and low nutrient application are among the major causes behind the current low agricultural productivity in the highlands of Ethiopia. To curb soil fertility depletion in these areas, it requires quantifying of available resources that are responsible for nutrient import into and export out of the farm system. The objective of this study was therefore to assess the resources and nutrient; nitrogen (N), phosphorus (P) and potassium (K)) flows at field and farm scales in Kumbursa village, Ada'a district central Ethiopia. Through stratified random sampling three farm wealth groups (rich, medium and poor) were distinguished based on farm size, number of oxen and grain stocks. From a total of 258 households 120 Households were interviewed using structured questionnaire. Soil, organic fertilizer sources, crop yield and crop residue samples were collected and analyzed for their nutrient content. The SPSS software and excel have been used for data analysis. The inflow resources are chemical fertilizer and animal feed concentrate while the outflow resources were crop yields and manure. At farm scale the amount of resources and nutrients flows into a farm system were more than the outflow of resources and nutrients from a farm system. The nutrient balance for animal production system and household were positive. This study also indicates that total input to farm fields of all three macronutrients does not counterbalance nutrient removal through crop yields and crop residues. The nutrient balance for crop production sub system was -93.46 kg N, 5.8 kg P and -97.47 kg K/ha/yr. The study clearly identifies the need for the development of integrated nutrient management systems to reduce the high rates of nutrient depletion. Three possible measures can be suggested first reduce crop residues removal from crop fields and improve livestock feed through improved forage management. Secondly, introduction of efficient energy sources to reduce use of cattle dung for fuel and consequently increasing manure availability for field application. Thirdly, application of more chemical fertilizer to the field,

Key words: soil fertility, resource flow, nutrient flow, nutrient balance, nutrient mining Sustainable agricultural production.

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List of Acronyms

ADAO	Ada’a District Agricultural Office
ADF	African Development Fund
CSA	Central Statistics Authority
DARC	Debrezeit Agricultural Research Center
DAP	Di Ammonium Phosphate
FAO	Food and Agriculture Organization
FHH	Female House Hold
FYM	Farm Yard Manure
GDP	Gross Domestic Product
GIS	Geographic Information System
FSU	Farm Soil Unit
Ha	Hectare
HH	House Hold
IFDC	International Fertilizer Development Center
ILRI	International Livestock Research Institute
IFPRI	International Food Policy Research Institute
MHH	Male House Hold
MoRAD	Ministry of Agriculture and Rural Development
MoA	Ministry of Agriculture
NPK	Nitrogen Phosphorus Potassium
NRC	National Research Council
NRCS	National Resource Conservation Service
NSMA	National Service Meteorological Agency
OC	Organic Carbon
OIDA	Oromia Irrigation Development Agency
OM	Organic Matter
PPU	Crop production Unit
PPS	Primary Production System
RU1	Manure
RU2	Manure peat

SNV	Netherlands Development program
SOM	Soil Organic Matter
SSA	Sub Saharan Africa
SPS	Secondary Production System
SPSS	Stastical Package for Social Science
SPU	Animal Production Unit
TLU	Tropical Livestock Unit
UN	United Nation
UNDP	United Nation Development Program
UNEP	United Nation Environmental Program
WB	World Bank

Chapter One

1. Introduction

1.1. Back ground

Resources and soil nutrient flow imbalances in farm system has been posing a serious problem to the sustainability of agricultural production both at global and regional scale. Developing countries are still facing critical problems with food shortages mainly because of insufficient external and internal inputs to the farm and subsequent soil nutrient depletion (Henao, 1999). In Africa poor resource management and consequent decline in soil fertility has remained to be one of the most limiting biophysical factors to low agricultural productivity (Bayu et al., 2005; Hartemink, 2006).

Soil erosion and soil nutrient mining through continuous cultivation of crops coupled with low application of external and internal sources of nutrients is singled out as the major cause of nutrient depletion in the region (Stoorvogel and Smaling, 1990). The average intensity of fertilizer use throughout SSA (roughly 8 kilograms per hectare) remains much lower than elsewhere (e.g., 54 kg/ha in Latin America, 80 kg/ha in South Asia, and 87 kg/ha in Southeast Asia) (Jayne, 2003).

Because of low investments in soil fertility in many places in Africa, nutrient balances, are usually negative contrasting with results from countries like USA and China, where nutrient inputs by far exceed respective outputs (Virtuosic et al., 2009)..

Nutrient mining has been estimated to average 660 kg of nitrogen (N), 75 kg of phosphorus (P) and 450 kg of potassium (K) per hectare per year during the last 30 years from about 200 million hectares of cultivated land in 37 countries in Africa and losses of 130 kg N, 5 kg P and 25 kg K per ha per year have been reported in the East African highlands (Stoorvogel and Smaling, 1990; Sanchez *et al*., 1997; Smaling *et al*., 1997).

Resource mismanagement and degradation as well as inefficient utilization of available resources have remained to be responsible factors for low and stagnant socio-economic development in most developing countries. Limited access to clean energy and pure water supply in SSA has resulted in inefficient labor use, wastage of resources as well as increased workload on women and children (NBPE, 2008).

Rural households in Ethiopia have been more and more extensively dependant on traditional biomass fuel for household energy due to scarcity and unaffordable prices of firewood and charcoal. Large scale reliance on traditional biomass energy has been causing a number of environmental and socio-economic problems among which are excessive deforestation, loss of biodiversity, soil fertility depletion and loss of agricultural productivity, food insecurity and hunger, and poor societal health (Zebider, 2011).

Consumption of traditional fuels has negative environmental, economic and health impacts. That is, increased use of firewood and charcoal leads to deforestation, leading to ecological imbalance, and increased use of agricultural residues and animal dung deprives the land of essential nutrients that are necessary for soil fertility. Furthermore, smoke from the use of fuel wood and dung for cooking contributes to acute respiratory infections. This latter problem, i.e. indoor air pollution is worse in poor Ethiopia where households' houses are not equipped with separate living and cooking places (Nebiyu, 2008).

On the other hand combustion of wood and dung generally is incomplete, they have low energy efficiency. Smoke, toxic gases and small particles are emitted to the atmosphere causing pollution to the environment and health problems to the household (NBP 2007). Various health related problems of many rural and some urban households in SSA are associated with excessive smokes released from traditional biomass burning plus unventilated traditional kitchens and houses (Getachew et al., 2006; NBPE, 2008; Edwards et al., 2010).

Like other SSA countries, agricultural productivity in Ethiopia suffers from loss of soil nutrients due to land degradation. Nutrient balance studies carried out in sub Saharan Africa (SSA) indicated high rate of soil nutrient mining in Ethiopia (Nandwa and Bekunda, 1998; Stoorvogel et al., 1993).

All the soil macro-nutrients showed negative balances and the prediction was twice as high as the average value for SSA, indicating the severity of nutrient depletion in Ethiopia (Haileselassie et al., 2005). The cropped area is subject to severe losses of nutrients through soil erosion and removal of dung and crop residue for fuel (Haileslassie et al., 2005).

.One of the responsible factors for soil fertility deterioration in Ethiopia is its large scale dependence on traditional biomass fuel due to lack of alternative modern source of energy. Biomass supplies up to 94% of total national energy consumption and up to 99% of rural energy consumption of the country. Overall, the main sources of energy include woody biomass (78%), dung (8%), crop residue (7%) and petroleum (5%) (Getachew *et al* 2006). The high demand for fuel wood has led to large scale deforestation and therefore to damages like erosion, desertification, decreased soil fertility and increased danger of flooding. As the population growth in Ethiopia causes an acute scarcity of fuel wood, households are turning to dung and crop residue for energy (Woldeamlack, 2003).Thus they lose their fertilizer benefits for agricultural production.

Livestock manure constitutes the most important source of nutrients and organic matter for the maintenance of soil fertility in the low-input farming system of most Ethiopian highlands. Recently, however, a cattle manure which is processed into dung-cakes is overwhelmingly taken away from the farm to the urban market constitutes the most important resource for soil fertility maintenance. However, most farmers process a good portion (90%) of their manure into dung-cakes and sell it at the market. On average a farm household around Debirebirhan exports about 43.5 kg N, 9.0 kg P, and 41.4 kg K y-1 through the sale of the dung-cakes (Akililu, 2006).

If the required growth in food supplies is to be achieved, fertilizer input into agricultural land must be targeted and organic matter has to be recycled by avoiding any waste or loss to the wider environment (Smith et al., 2013). Hence, sustaining the nutrient base calls for measures that combat the loss of nutrients. The objective of this study was to quantify resources and nutrients (N, P and K) at field and farm scales in smallholders' farming system of kumbursa village, Ada'a district, central Ethiopia.

1.2 Statement of the problem

Agriculture is the basis of Ethiopian economy, accounting for 46% of its GDP and 90% of its export earnings and employing 85% of the country's labor force (UNDP, 2002). About 95% of the agricultural output originates from subsistence smallholder farms (ADF, 2002). However, most of the environmental problems facing the country are associated with subsistence agriculture-related activities (UNEP, 2002), resulting from inappropriate land management practices and low external and internal nutrient inputs (UN, 2002).

Efforts to raise agricultural productivity in the farming systems of Ethiopia dominated recent policy interventions (Assefa, 2005). The government has promoted several agricultural sector improvement programs through its extension services to enhance the productivity of small holding farms that now have to compete with the needs of the growing population and current socio-economic development of the country. Despite the efforts made by the government, still crop productivity is greatly hampered by inadequate application soil fertility amendments, removals of nutrients through crop harvest and crop residues, use of animal manure for fuel and growth in human and livestock populations that has led to an expansion of cultivated land and shortened fallow periods which, in turn has accelerated land degradation and decreased soil fertility for crop production (IFAD, 2008).

Agricultural practices of smallholders with low external and internal inputs carry the risk of depleting soil nutrient stocks, seriously threatening future agricultural production potentials (Elias et al., 1998; Stoorvogel and Smaling, 1990). Blank recommendation of chemical fertilizer for Ethiopia is 200kg (100kg/ha DAP and 100 kg/ha Urea) (EDRI, 2011). But the average consumption of chemical fertilizer for Ethiopian farmer is 17kg/ha (FAO, 2009). The gap between the recommended rate of application and consumption rate is a clear indicator of unbalanced between inflows and outflows of resources and nutrient in a smaller holders' farming system of Ethiopia.

In Ethiopia, soil nutrient depletion is the main biophysical factor limiting increases in per capita food production for the majority of small farms (Sanchez et al. 2002). But it seldom gets low public attention since it is a gradual process and not associated with catastrophes and mass starvation (Haileselassie, 2005). On the other hand, Ethiopia is characterized by diverse climatic conditions, soil types and topography, resulting in a wide variety of farming systems, each with its specific nutrient management system, and the associated rates of nutrient addition or depletion (Assefa,2005). As a result, it is not well known how nutrient management practices are affected by spatial and temporal scale embedded in the livelihood of rural households (e.g. crop selection, labour, source of energy, finance, the location of a farmer's plot within the landscape and other socioeconomic issues of the farming systems (Elias et al., 1998; Byrne et al., 2006). A high heterogeneity in management, together with different biophysical, socio-economic and across each agro-ecosystem makes difficult blanket recommendations to overcome soil fertility problems in Ethiopia (Snapp et al., 2003). Thus, acknowledging heterogeneity in resource flows and their nutrient contents, and moreover quantifying them at different spatial scales, is the first step in making suitable recommendations to the different agro ecologies (Snapp et al. in Haileslassie, 2005).

The annual nutrient deficit in Ethiopia has been calculated to be -41 kg N, -6 kg P and -26 kg K ha^{-1} yr^{-1} (Stoorvogel and Smaling 1990). However, a more diversified picture of nutrient mining appears when studying the nutrient balance at the farm, field and plot level as compared to the national level. It is obvious that the national figures are hard to relate to a specific farming system. This is particularly important for Ethiopia since the agricultural landscapes and production systems are variable with regard to topography, agro-ecological characteristics, ethno-history and culture that influence agricultural practices and nutrient management (Balesh., 2005: Haileselassie ,2005).

Quantitative knowledge on the resources and nutrients in a farm system helps to understand the state of soil degradation and may be helpful in devising nutrient management strategies. It is also useful for policy-makers, extension workers (agricultural advisors), and farmers for planning and on-farm nutrient management and sustainable agricultural production (FAO, 1996).

However, there has been limited number of literature in previous studies regarding the resource and nutrient flows (Eyasu, 1998; Assefa; 2005; Amare, 2005; Balesh; 2005 and Hailu, 2010) have studied soil nutrient balance and have reported nutrient mining, possible causes and implications. However, none of them have thoroughly linked the problem of soil nutrient depletion with carbon removal and financial resources of the households and the studies were limited to certain areas of Ethiopia.

So this study is intended to fill the gap in existing literature regarding this silent form of soil nutrient mining by primarily focusing on quantification of resources and nutrients and the impacts of nutrient depletion on sustainable agricultural production of farm households of Kumbursa village, Ada'a, District, Central Ethiopia.

1.3. Objective of the study

1.3.1. General Objective

The general objective of this research is to quantify resource and nutrient flows in small holders' farming systems of kumbursa, Ada'a District, central Ethiopia.

1.3.2. Specific Objectives

Based on the above general objectives, the following three specific objectives have been formulated.

- To identify households' farm resources, those are responsible for nutrient import into and export out of the farming systems and flows within the farming system,
- To quantify nutrient flows both at farm and field scales and its implications on sustainability of nutrient management and
- To assess current soil fertility status of the study village.

1.4. Research questions

Based on the above objectives, the following research questions have been forwarded so as to guide the proper data collections and analysis.

- What are the most common household farm resources responsible for nutrient import into and export out of the farming systems and flows within the farming systems? How much are they?
- What amount of nutrients flowing within, into and out of the farming system?
- What is the current soil fertility status of the study village?

1.5 Scope of the study

The study was conducted in Kumbursa village, Ada'a, District, Central Ethiopia. It is carried on quantification of resources that are responsible for nutrient import into and export out of the smallholders' farming system. The study was also carried out to quantify nutrient flows focusing on NPK and Organic carbon. The study is delimited only to partial nutrient balance analysis.

1.6 Significance of the study

Quantification of resource and nutrient flow study at farm/field level is a tool for evaluation of different farming systems from the perspectives of sustainable nutrient management and agricultural production. It is also useful for policy-makers, extension workers (agricultural advisors), and farmers for planning and on-farm nutrient management and sustainable agricultural production. In this regard the output of the research may serve as an indicator for management interventions and optimization of resource allocation at farming system level, as it indicate the quantity and direction of flow of resources and nutrients which take place among different sub farming systems (crop production, animal production and household) systems and finally it may initiate other researchers who are interested in carrying out further research in the area.

1.7 Limitation of the study

Like any research this study was conducted with some limitation. The first limitation was time. Since it is applied research it requires data that has to be generated through laboratory analysis. It was hard to get appropriate laboratory that can perform sample analysis The laboratory result was delayed because of that I was faced shortage of time for result analysis and discussions.. The second limitation was the study focuses on only partial nutrient flow analysis that only considers the nutrient import through chemical fertilizer and organic sources as (IN1 and IN2) and crop yield harvest and residues, manure as (Out1 and Out2). This study does not consider full nutrient flow analysis that should consider all possible sources of nutrients in to and out of the farm system because of time, available data and skill.

1.8 Organization of the Thesis

This thesis is divided in to five chapters. In the first chapter, the introduction of the paper is presented. This covers background of the study, statement of the problem, objectives of the study, research questions, scope of the research, significance of the study and organization of the thesis. Chapter two presents the literature review which encompasses theoretical literature review, empirical literature review related to soil fertility management practices and the conceptual framework of the study. Chapter three provides research methodology. Chapter four discusses with results and discussion of the thesis and finally, chapter five presents conclusion and recommendations.

Chapter Two

2. Review of Literature

2.1. Conceptual frame work

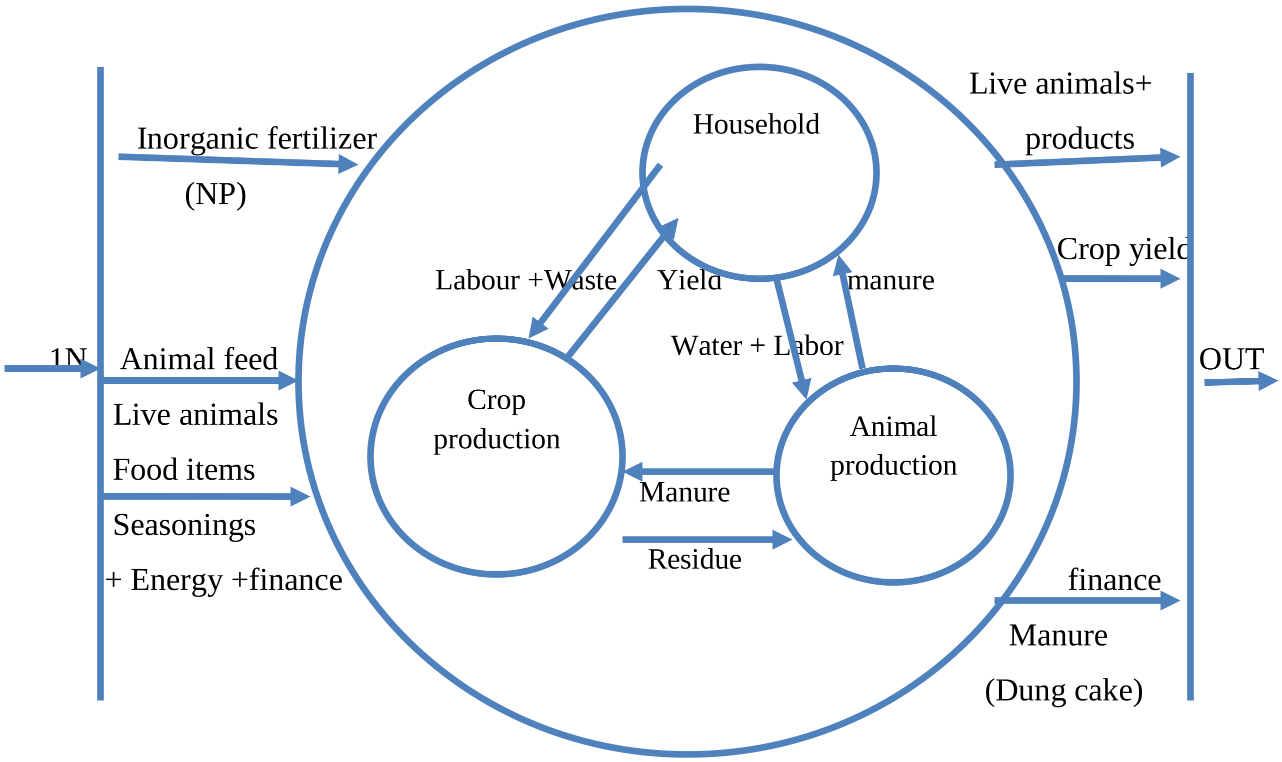


Fig 2.1 Conceptual frame work that analysis farm system resource flows within the subsystems and external systems, Source: mental map of the author

Social and economic factors are critical in understanding patterns of resources flow and nutrients in a farm system (Balesh, 2005). In the above farm system model there are three distinguishable sub-systems: the crop production sub system, the animal production sub system, and the household system. In farming systems there are various types of interacting: (i) flows in to the farm system from the external system and out flows from the farming system to the external, (ii) flows within its subsystems.

Inorganic fertilizer (the immediate source of nutrient for crops), animal feed, salt, food items, finance and energy flow from the external to the farm system. On the other hand crop yields, live animals and products, manure (dung cake), energy and finance flows out of the farm system.

The major internal resources flows were crops, crop residue, manure, household waste and labour and water. Crop yields and crop residues flow from crop production sub system to the household and animal production sub systems. Manure flows from animal production sub system to the household sub system which is later used as fuel and small proportion is sold to market. Household waste flows in to the crop farm system near the homestead. Labour flows from the household to both crop and animal production sub systems. Water flows from household to animal subsystem. Whenever resource inflow in terms of nutrient balances is negative the sub systems is losing nutrients on the other hand positive nutrient balances indicate that the nutrient is accumulating ,

2.2. Soil fertility dynamics and its determinants

Soil fertility is the quality of a soil that enables it to provide adequate amounts of nutrients in a proper balance for the growth of specified plants or crops. Soil fertility is a complex process that involves the constant cycling of nutrients between organic and inorganic forms. Fertility can be naturally occurring or through adding fertilizers. Soils fertility is dynamic process. Soil fertility is affected by processes such as, additions, transformation, translocation, and removal of materials. Materials can be transported into the location where a soil is forming. When plants die on to the surface, they decompose adding organic matter to the soil. Human add materials to the soil (inorganic fertilizer, compost, lime) or remove material from the soil, (crop yield harvest, crop residue, animal manure). Soil translocation occurs by water infiltrating through the soil is transferring materials from upper to lower portions of the profile. Burrowing animals like earth worms, ants, etc., move soil materials within the profile. Burrowing animals create passage ways through which air and water can travel promoting soil development. Easily dissolved elements like calcium carbonate can be removed from the soil profile with rain climates. Soil depletion occurs when the components which contribute to fertility are removed and not replaced, and the conditions which support soil's fertility are not maintained (Hilhorst and Muchena, 2000)

2.3 Soil fertility management

When a particular crop is grown on the same parcel of land year after year the land may become exhausted of one or more nutrients. If such exhaustion occurs, nutrients in the form of fertilizers must be added to the soil. The sources of plant nutrient were mineralization of parent material, chemical fertilizer application and organic fertilizer sources. The soil fertility at farm scale depends on nutrient management by farmers, manipulation of nutrient stocks and flows, nutrient inputs in the system through organic and inorganic amendments, nutrient export via crop harvest and crop residue removal, and conversions within the production systems (Deugd et al., 1998).

2.3.1 Organic matter

Soil humus is the organic fraction of soil derived from the decayed tissue of plants and animals, and from animal excreta (Teklu, 2005). Soil organic matter contains approximately 58% organic carbon. Organic matter content in a soil has a major influence on the physical and chemical properties of soils. As it breaks down, it releases nutrients in a form which can be taken up by plants and crops, so it increases the availability of nutrients that affect yield. Organic matter also helps to bind soil particles together that improve the physical properties of the soil making it easier for roots penetration. Tillage becomes easier and soil becomes well-drained. The binding effect also reduces wind and water erosion and also improves the water holding capacity of the soil (Gurung et al, 1997). The major organic fertilizers used for soil fertility amendment includes manure, compost, crop residues and house waste.

Manure

Since time immemorial animal manure is the prime source of the soil fertility management to improve way for many farmers of Ethiopia. Traditionally, it is used as fertilizer to ameliorate soil fertility depletion in any parts of Africa in general and Ethiopia in particular. For example, the study conducted by Elias (2002) reported that 87 percent of Kindo Koisha (Southern Ethiopia) farmers apply animal manure. This is because applying animal manure has residual effect in the soil (Elias, 2002: Tegene, 1998). The effect varies based on the amounts applied. However, it is dependent on the availability of livestock and family labor for transporting into their fields (Elias, 2002). But today it is also extensively used as source of household energy (Assefa, 2005).\

Compost

Compost is the final product obtained from the decomposition of the organic matter, wastes from preparing food and gardening, sweeping up leaves, collecting manure, straw and grass clippings etc. It enhances soil fertility, soil structure and water storage capacity for two or more years, unlike chemical fertilizer (Fentaw, 2010)

Crop residue

Crop residues include the above ground biomass of plants remaining in the field grains, tubers and other products have been collected. The crop residues are incorporated into the soil and /or left as mulch (Elias, 2002). It is a way of directly recycling nutrients into the soil taken by the plants from the soil earlier. It is used for soil protection and soil fertility improvement (Smith and Elliott, 1990). Normally in Ethiopia crop residues are removed for animal feed (Edwards and Hailu, 2006; Elias, 2002). About 42 percent of farmers in Kindo Koisha apply crop residues for improving their soil fertility. While others immediately plough fields to protect roaming of animals due to the free range grazing practices (Elias, 2002)

Crop residues protect soil from the direct impacts of rain, wind and sunlight leading to improved soil structure, reduced soil temperature and evaporation, increased infiltration, and reduced runoff and erosion. While some studies suggest that plant roots contribute more carbon to soil than surface residues (Whitbread et.al,2003), crop residue contributes to soil organic matter and nutrient increases, water retention, and microbial and macro invertebrate activity. This effect typically leads to improved plant growth and increased soil productivity and crop yield (NRCS, 2006).

Household waste

Organic wastes from the house commonly are added to soils as sources of plant nutrients and to improve the physical properties of the soil. The common house waste added to the soil is ash (Barbaric, 2006).

2.3.2 Inorganic fertilizer

In Ethiopia, farmers' uses only DAP and Urea fertilizers due to the fact that Ethiopian soils are deficient of Nitrogen and Phosphorus nutrients (Samuel et al., 2000). These two fertilizers were recommended since their nutrient content of Nitrogen and Phosphorus is high compared to other types of chemical fertilizers (Takashi and Ayumi, 2010). According to Alemayehu (2008) about 10 Percent of the total land of Ethiopia is under crop cultivation , but fertilizer is applied only on 40 percent of the cultivated land and the rate of application is below the optimal level (Eyasu, 2009). The blank recommend inorganic fertilizer for Ethiopia is 100kg of DAP and 50kg Urea per hectare (Eyasu, 2002). Recently, the blank recommendation for cereal crops is 100kg DAP and 100kg Urea (EDRI, 2011) But the average fertilizer application for Ethiopia is 17Kg/ha (FAO, 2009).

2.4 Farming system

Farming system is a decision making unit comprising the farm household, cropping and livestock system that transform land, capital and labour into useful products that can be consumed or sold. Farm as the main unit of analysis has been used in this study, as this is where the farmer and other household members decide on soil fertility strategies and activities (Fresco and westphal, 1988).

"Farming system consists of several enterprises like cropping system, dairying, piggery, poultry, fishery, beekeeping etc. These enterprises are interrelated. The end product and wastes of one enterprise are used as inputs to others. The waste of dairying like dung, urine, refuse etc. is used for preparation of FYM, which is an input in cropping systems. The straw obtained from the crops is used as fodder for cattle's are used for different field operations for growing crops. Thus different enterprises of farming systems are highly interrelated (Millar, 1990).There are 3 distinguishable sub-systems within the farm system: the crop production system, as defined primary production system (PPS), the animal production system, as defined secondary production system (SPS), and the household system (HH) (FAO, 2011).

The crop production system

Soils constitute the bulk of plant nutrients in the crop production system, and are the primary source of fertility for crops. This fertility store can be seen as the farm's capital, which may be increased or depleted. Crops and pasture are the outputs of farming which transform nutrients, water, light, labor and other inputs during their growth. A crop production system usually includes different crop species and weeds that are all competing for the same stock of nutrients, which may include additions of mineral and/or organic fertilizer. Crop products such as food, feed or fiber are a source of nutrients that can be used by household members, fed to animals, sold or exchanged. Crop residues are another source of nutrients that can be put to various uses, such as fodder for livestock, roof straw for houses, fuel for household energy sale at the market or bedding in kraals, etc (FAO, 2011).

The animal production system

Animals spend time in a pen or *kraal*, and/or grazing fields where they graze/fed fodder and generate an important source of manure. Animal products are a source of nutrients that may be consumed by the household or sold at the market. Herds of animals transform plant biomass into animal products, such as: meat, milk, eggs, hides, etc.), and Excrement: faces and urine (FAO, 2011).

The household system

Household members are a group of people who live together and are usually related through kinship and marriage. The household is the centre where many decisions are made about the allocation of labour, capital and land, and about farm management. Food in terms of resource and nutrient flow analysis, food constitutes a significant source of nutrients which is either purchased or produced on-farm. Considerable amount of the nutrients consumed remains in the human body. House refusals: This is either used as animal feed or becomes part of the household's waste, which is generally collected in a heap and taken out to the fields. Another important ingredient of waste is ash from cooking fires (FAO, 2011).

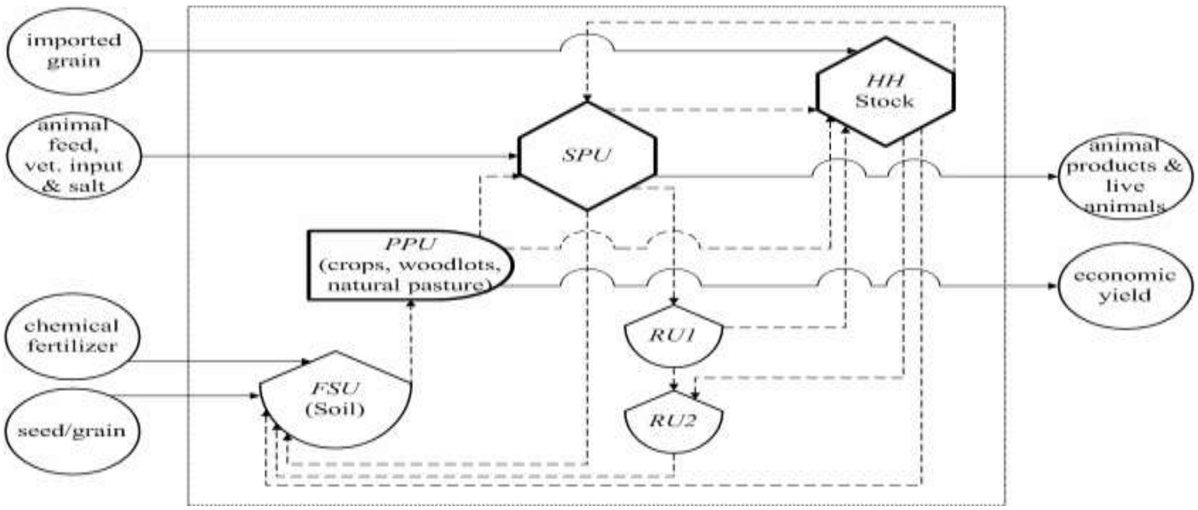


Figure 2.2 Inflows and outflows over the farm boundaries ('farm gate flows') (Solid lines) and farm scale internal flows (broken lines).

Source: Assefa, 2005

The sold lines in the above figure shows inflows of resources into the farm system while the broken lines shows internal flows of resources within the sub systems of the farm system.

2.5 Nutrient flow and balances

2.5.1 Nutrient flow

Nutrient flow analysis can be used to give insight into the impact of farmer management decisions on soil fertility in his or her farm. Farmers transport material that contains nutrients - be it harvested products, manure, fertilizer or straw that is used to build roofs. Some processes may lead to a loss in nutrients, e.g. burning of straw will result in complete loss of carbon and nitrogen. Estimating nutrient flows is a useful way to find out if farmers' crop management practices are sustainable, i.e. are outputs of nutrients balanced by a sufficient level of inputs (FAO. 2003).

Nutrient transfer occurs as removals (output) from one source or system to supply (input) another. In a simple undisturbed system, plants grow utilizing soil nutrients and when they die, nutrients return to the soil through litter for reuse. If herbivore is introduced into the system only party of the nutrients may return to the soil from the plants directly to litter. Unfortunately, if the animal move out of the designated boundaries, the nutrient will be lost unless there must be a deliberate effort to return the excreta if nutrients are to be recycled. Nutrient transfers are not only influenced by the conditions and process within the system but also by circumstances and controlling forces outside the system. In this case, unequal transfers between the nutrient pools may cause the system to be nutrient accumulating or nutrient depleting (Erisman, 2004).

A nutrient balance for a 'system' consists of the sum of nutrient inputs minus the sum of nutrient outputs. This system always represents a particular spatial scale, and it can range from a small soil aggregate to the entire globe. In agricultural activities, nutrients are added to the systems (via fertilization), nutrients are exported from them (via harvesting yields or collecting crop residues), and other nutrients are either added by environmental processes (e.g. atmospheric deposition, nitrogen fixation) or lost (e.g. nutrients in eroded soil particles, leaching). Hence, by calculating the net difference between the amount of nutrients that are entering a system (i.e. inputs) and the nutrients that are removed (i.e. outputs) a nutrient balance (i.e. Σ inputs – Σ outputs) can be obtained (Smaling and Dixon, 2006).

The method usually starts by predefining concrete spatial-temporal borders for limiting the dimension where calculations will take place, which is followed by the estimation of the nutrient flows of interest. In general, flows can be estimated by direct measurements, calculated by pedo-transfer functions or obtained from surveys, databases and/or literature (Oenema and Heinen, 1999).

Negative nutrient balances indicate that the system is under nutrient deprivation and will degrade with time if the same trend continues; although the time to degradation will depend on inherent soil fertility (i.e. soil nutrient stocks) (Bindraban et al., 2000). Positive nutrient balances, on the other hand, indicate that nutrients in the system are accumulating, and even leading to pollution risks if accumulation is excessive (Virtuosic et al., 2009).

Nutrient balances are *partial* when they only consider flows of inputs (e.g. fertilizers) and outputs (e.g. crop produce) that are easy to measure, and are normally regarded as more useful for farmers. Other balances cover a wider range of inflows and outflows, including atmospheric deposition of nutrients, fixation, sedimentation, erosion, leaching and gaseous losses, among others. Such types of balances are calculated in the multi-scale nutrient called full scale nutrient balance.

Inflows 1 and 2 plus outflows 1 and 2 are normally used for calculating partial balances at field scale, because they are relatively easy to determine and strongly influenced by resource allocation and management decisions. Since they show the degree of human involvement, capital and labour allocation, income generation and food security, Smaling *et al.* (1997)

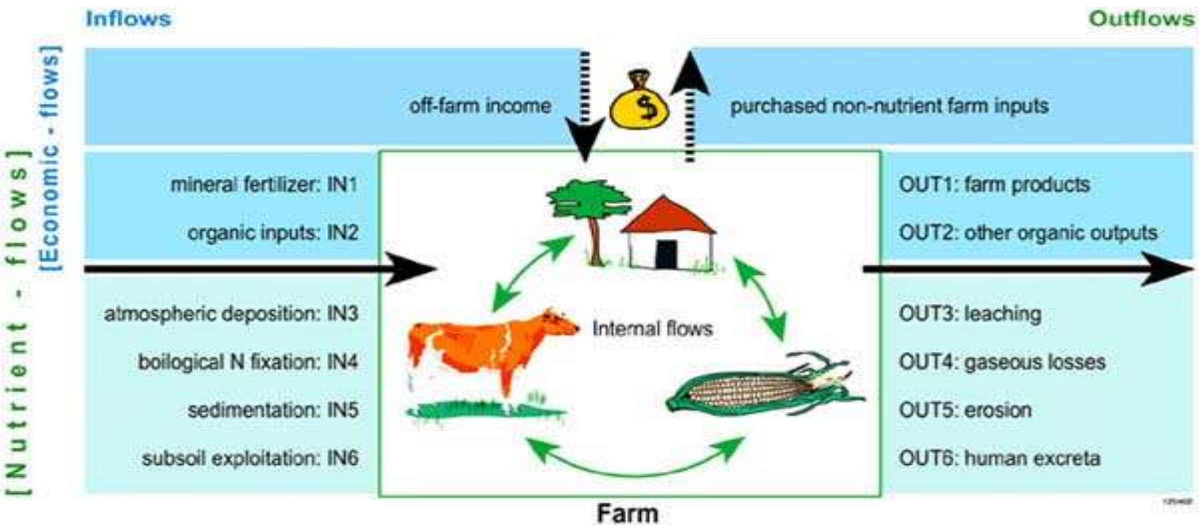


Fig 2.3 Nutrient and economic flows that influence the nutrient balance and farm income

Source FAO, 2003

2.5.2 Nutrient balance

Many countries in Africa are net exporters of nutrients. They export agricultural products carry with them more nutrients than they import in the continent as fertilizer, food or animal feed. During the past 30 years an average of Nutrient mining has been estimated to 660 kg of nitrogen (N), 75 kg of phosphorus (P) and 450 kg of potassium (K) from about 200 million hectares of cultivated land in Africa (Bindraban et al., 2000).

Soil nutrient balances in Sub Sahara Africa appear to be a contributing factor for its poverty (Brady, 14th edition). The estimated nutrient balance for the year 2000 varies among Sub Sahara African countries. it ranges from -2 to -60 kg N, -10 to 0 kg P and -2 to -48kgK/ha. The average nutrient balance was -33kgN, -4kgP and -25kgK/ha for the same year (IFDC, 2001).

A number of district level studies have been conducted using data from farm and village level analyses .For example study from Kisi district, Kenya found consistently negative balances for all major nutrients at the aggregate district level (Smaling et al., 1993). Similar results have been found in Mali, where aggregate nutrient losses are reported for all districts, except the cotton growing zone where imports of inorganic fertilizer compensate for harvest exports and other losses (Powell and Coulibaly, 1995). Soil nutrient depletion is more intense in the crop production system of the smallholder farmers in eastern Uganda. Harvesting of crops for food and the surplus for sale are the most important sources of nutrient flow in the crop production system (Esilaba, Nyende, Nalukenge, Byalebeka,. Delve, and Sali, 2005).

Soil nutrient balances at small spatial scales at two agro-ecological zones (highland and lowland), in southern Ethiopia at Kindo kasha representing four socio-economic groups of farmers in terms of their resources (rich, medium, poor and very poor), reveals that the N balances were negative for all household groups, while the P balance was positive for most farms. Poorer farmers had lower N depletion rates, which may seem contradictory. However, they can compensate for lower mineral fertilizer inputs by intensive soil enriching and nutrient conserving practices, including: rational use of available manure; systematic management and recycling of crop residues; collection of leaf litter; and improved soil conservation. The differences between the farm components were very large. The enset, taro and darkoa (homestead) fields received many inputs and therefore had a positive or neutral balance, but the shoka (out fields) had very negative balances owing to low input (Elias.,1998).

Macro nutrient depletion in Ethiopia mostly caused by continuous cropping without replenishing, leaching, crop residue removal, low level fertilizer use, deforestation, and inadequate run-off management (Chilot et .al 2002). Soil nutrients balances study at national and regional level, reported large variations in the nutrient balances of different cropping systems, ranging from nutrient accumulating systems (e.g. enset, Ensete ventricosum) to cropping systems including most cereals (e.g. teff, Eragrostis teff) with strongly negative nutrient balances . Nutrients are annually taken away through crop harvest and residues or lost in processes such as leaching and erosion which far exceed the nutrient inputs through fertilizers, deposition and biological fixation. The cropped area is subject to severe losses of nutrients through soil erosion and by removal of dung and crop residue for fuel (Haileslassie et al., 2005). Current levels of organic fertilizer input are much lower than required to maintain a dynamic equilibrium in soil organic matter content. Thus, availability of organic inputs is a crucial constraint for attaining sustainability in terms of nutrient elements (Assefa. 2005). Partial balances of the macronutrients, nitrogen (N), phosphorus (P) and potassium (K) study at farm level in Northern highlands of Ethiopia indicate that soil nutrient depletion proceeds at an alarming rate at both ‘farm field’ and plot scales. Nutrient depletion rates differ significantly among farmer wealth groups, with the highest rates recorded for the rich farm group, followed by the medium and poor farm groups (Assefa, 2005).

Soil nutrient balance study at small holders’ farming system of Jimma zone shows that N, P and, K added to the crop farm through inorganic and organic sources were much less than nutrient removed out of the system. Poor integrated soil fertility management practices, in effective use of locally available nutrient and high cost of commercial fertilizer become the cause for unsustainable agricultural production in the area (Abebayehu, et.al, 2011).

Nutrient flows and balances study result among different groups of farmers in the smallholder farming system in Gare Arera, central Ethiopia shows that rich and medium wealth group farmers could afford to apply mineral fertilizers and increase nutrient inputs from organic sources as they have more access to manure and other organic materials for compost production. While, Poor farmers do not have such choices in the absence of a credit scheme and live stock as manure sources (Balesh. 2005).

2.6 Household energy and Agriculture

Ethiopian economy is mainly depending on agriculture. Agriculture directly supports about 85 percent of the population (CSA, 2007). Shortage of firewood forces the farmers to use dung and plant residues as fuel instead of using as organic fertilizers. The losses of crop production from burning of dung and soil erosion are estimated at over 600,000 tons annually, or twice the average yearly request for food aid in Ethiopia (Edwards and Hailu, 2006).

Chapter Three

3. Research Methodology

3.1. Description of the Study Area

3.1.1. Location and topography

Ada'a district is located in East Shoa zone of Oromia regional state of Ethiopia. The District covers a total area of 1610.5 km^2. The district constitutes a total of 23 Peasant Associations (PAs) and Ude is the Peasant association where the study village /Kumbursa/ is found. Kumbursa is located at distance of about 55.5 km East of Addis Ababa between $8^0$41'11'' and 8^o42'49''N, and 39^o 00'29 and 39^o 01'44''E covering about 640 hectares (Figure 3.1),

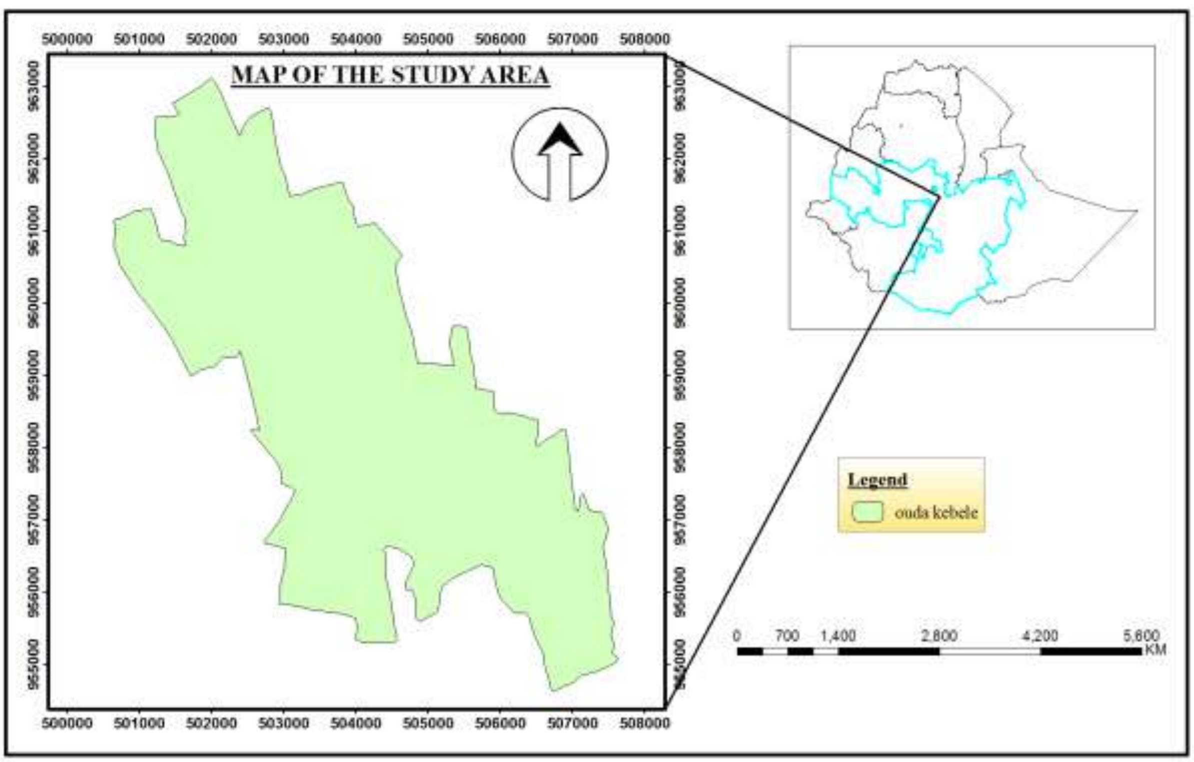


Fig 3.1 Map of the study area (Ethio GIS, 2007)

Altitudes in this district range from 1500 to 22000 meters amsl. The district is characterized by 'Woina dega' traditional agro climatic zone which ranges from 1500–2200 meters amsl (ADAO, 2010) and 'Kumbursa has an altitude of1888-1992 meters amsl (Field survey, 2014).

3.1.2. Rainfall and temperature of the study area

Precipitation in the area originates from South-West equatorial air stream, which moves northwards (NMSA, 2005). Rainfall data of 49 years of the district indicated that the area has extended wet season from March to September with mean monthly rainfall varying from 51 to 210 mm (Figure 3.2). The rainfall distribution pattern is uni-modal with highest amount occurring between June to September (74% to the mean annual precipitation) with a total annual average of 818.16 mm The annual temperature of the District ranges from 16.33^{0}C to 19.71^{0}C,with a mean annual 18.14 ^{0}C. The hottest months are March, April and May (Figure 3.2).

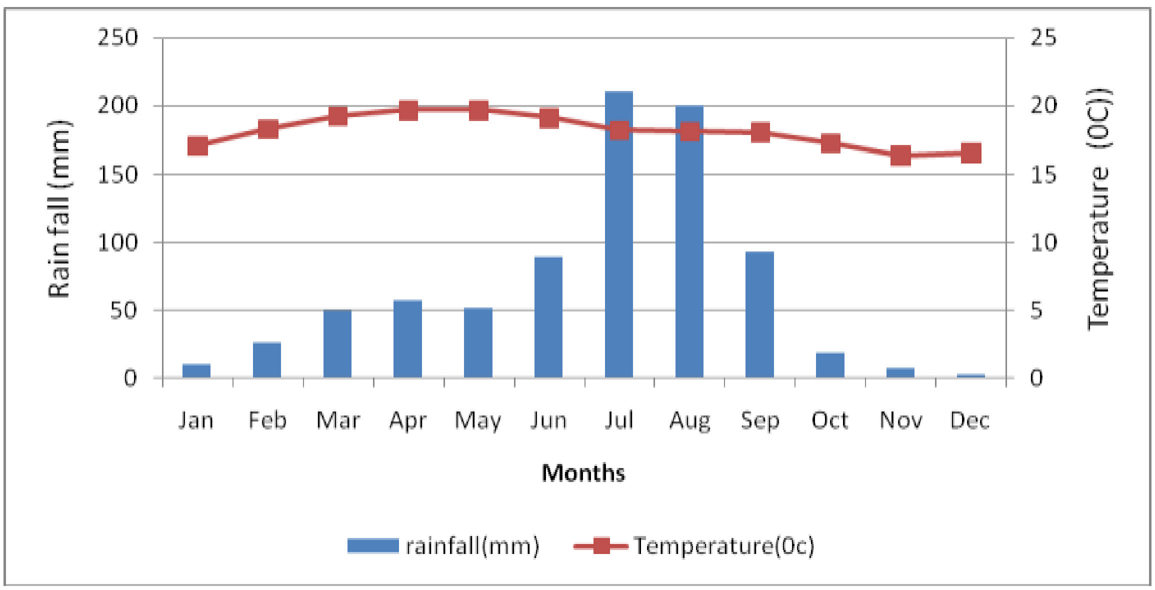


Fig.3.2. Monthly rainfall (mm) and mean monthly temperature (^{0}C) of Ada'a District, average of 49 years (1965 – 2013; DARC, 2013)

3.1.3 Soil

The single major soil type is Vertisol (black cotton soil) which covers about 60.8% of the district. The study village has this soil unit. Other soil types are Cambisols and Luvisols (23.5%) and Rendzinas and Pharoses (14.7%) (DARC, 1998). The average soil depth is between 0.65 to 1.05m with medium infiltration rate and medium water holding capacity (OIDA, 2002). Texturally the soils of the area are classified as sand silt (3%), clay (88%) and clay loam (9%) (ADAO, 2005)

3.1.4. Land Use/ Land Cover

The dominant land use type in Ada'a District is cropland which covers 51% while degraded land, settlement/building, forest land, and water body and pasture/grazing land account for 19.2%, 8.9%, 7.4%, 7.1% and 6.4% of the total land area respectively (AD A O, 2010). The land cover is dominated by scattered trees and shrubs which are found around settlements, in farmlands, and shrubs, trees and grasses in the closure areas. Important forest includes the government-protected Dirre-Garbicha and the Tedecha and Ude community forests (ADAO, 2010),

3.1.5 Farming system

The agricultural activities carried out in the area include both crop production and animal husbandry, in which the latter plays a complementary role. The farming system in the area is therefore, denoted by close interdependence & integration of crop cultivation and animal husbandry, where the production and productivity of one is not separated from the other.

The agro-ecology in the District is best suited for diverse agricultural production. There are a number of rivers and crater lakes that are being used for irrigated agriculture, particularly for horticultural crop production. The District is nationally known for its best quality Teff production, which dominates the agricultural production system. Wheat is also cultivated in sizeable quantities in medium to high altitude areas. Pulse crops, especially chickpea, are grown in the bottomlands and on residual moisture in selected areas. Lentil is also grown to a lesser extent. Horticultural crops, mainly vegetables, are produced under irrigation. Livestock production is an integral part of the production system. Production of cattle, donkey, sheep, goat and poultry is a very common practice (ADAO, 2010).

3.1.6 Demographic characteristics and household's Livelihood

The District has an estimated total population of 355,343, of whom 175,788 are men and 179,555 are women. With an estimated area of 1,610.5 km2, Ada'a district has an estimated population density of 220.64 people per square kilometer, which is greater than the Zone average of 181.7(CSA, 2007). Ude peasant association has 835 households of which 258 households are in the study village /kumbursa.(ADAO,2010).

Sedentary mixed farming is the main stay of farmers in the District. The People of the area practice various livelihood and income generating activities mainly crop production and animal husbandry in addition to petty trading and daily labor. Crop production plays a major role in income generation in the area and cereals such as teff, wheat, pulse crops such as lentil and chickpea are the major crops grown. Especially, the area is known for its quality teff production nationally. Crop production is mainly rain fed. The farmers also keep cattle, equine, but small numbers of sheep & goats are kept by few farmers. Hillside areas are used as communal grazing land (ADAO, 2010).

3.2 Research Design

The study followed both qualitative and quantitative method of data handling and analysis. Research instruments such as sampling, household questionnaire, personal observation, key informant interviews, and focus group discussions were used to get reliable data. Laboratory sample analysis and document reviewing were also used based on the nature of the specific objectives of the study.

3.2.1. Selection of the study sites

Kumbursa is the village where improper use of resources has been under way .that should be used for soil fertility amendment. Recycling of organic matter into cropland is limited due to the competing demand of crop residues for livestock feed and animal manure for household energy. Hence this village is one of the hotspot areas where nutrient mining is expected. Therefore, it is important to conduct this research to assess resources and nutrient flows out of and into the smallholders' farming system of the specified village.

3.2.2. Sampling technique

Households of the village were classified in to three different wealth categories (rich, medium and poor), depending on the local community's criteria and the socio-economic conditions of the households in the village. The criteria used were land holding size, oxen number and the stock of grain for seed, consumption and market.

Farmers in the 'rich' group possessed land > 3 ha, oxen ≥ 5, and had excess production in stock to cover the requirements for seed, consumption and market, farmers in the 'medium' group possessed 1-3 ha, 2-4 oxen and sufficient production in stock to cover the requirements for seed, consumption and market, and the 'poor' group possessed land holdings <1 ha and owned one or no oxen, and had insufficient grain in stock for seed, consumption and market. Through stratified random sampling proportionally 22 households from the rich, 73 from the medium and 25 from the poor group were selected from the households of the village. The community's classification has been validated with the data collected during the pilot survey.

Table 3.1: Total households and Sample size by *wealth category, Kumbursa village, Ada'a district, central Ethiopia, 2014.*

Wealth category	Total Number of Household Heads			Number of Sample Households					
	MHH	FHH	Total	MHH	%	FHH	%	Total	% the sample size
Rich	25	7	32	19	19.6	3	13.64	22	18.33
Medium	119	53	172	58	59.79	15	20.54	73	60.83
Poor	45	9	54	20	20.61	5	20	25	20.83
Total	189	69	258	97	80.83	23	19.17	120	100

Source: field survey, January 2014

3.2.3. Data sources and data collection Instruments

Both primary and secondary data were generated by employing quantitative and qualitative methods. The quantitative methods involve the use of household survey while the qualitative methods used include focus group discussion, key informant interview and direct personal observation.

Primary Data collection

The following techniques were employed to generate the primary data.

Household Survey

Questionnaires developed for this purpose was used after pretesting to generate reliable data. During the household interviews, information was obtained on the family size, land holding size, number of cattle, amount of inorganic and organic fertilizer used, amount of crop and straw harvested, amount of crop sold and/ or consumed, labour, sources and amount of energy utilized and finance.

Farmers also gave information on different production compartments, different land utilization type, and their major farm products and destinations. resource flows were quantified by asking farmers and through direct observation on the farm or in the household. The inflows were investigated by asking farmers the quantities of mineral fertilizers (IN1), organic inputs such as manure (IN2) entering the farm annually. The outflows included harvested crops (OUT1a) and animal products (OUT1b) and crop residues (OUT2a), and animal manure (OUT2b) leaving the farm. Farmers quantified in their own units, such as sacks, bags and donkey load etc.., which was later, converted to standard metric amounts. Also all classes of farm animals will be counted and converted to TLU for each farmer; a field observation was conducted randomly to check the different land utilization type, the number of plots under each farmer, and the surface area of each plot that was owned by the farmers.

Key Informant Interview

A key informant interview is important in getting information pertinent to soil nutrient management practices. Through such instrument, information regarding the views of experts from District Agriculture office, District energy office and Development Agents (DAs) were collected,

Focus Group Discussion (FGD)

The focus group discussion was used as one of the critical sources of primary data in addition to the household surveys. One focus group discussion, involving eight participants was conducted in the village. For this, checklist interview guide was prepared to get deep information regarding energy source and utilization; household expenditure and the work load on household members.

Participants were composed of both men and women selected from the entire three farmer's wealth categories (rich, medium and poor).

Personal Observation:

Direct personal observation and measurements was made. The observation encompassed visit of topography, vegetation cover, settlement pattern and the overall aspects of farm management practices and of the study area. Sample measurements were made on plot size, fuel wood and, dung cake consumed /week, manure dropped per cow/day. Thus, the researcher's opinion based on his visit of the study area was included in the analysis**.**

Sample collection for laboratory analysis

From the selected households, composite samples of soil, household's organic materials (cattle manure, dung cake, donkey manure, compost and animal feed concentrate), farm products (grain yield and crop residues) were collected so as to analyze the nutrient contents of these resources. Thirty six composite soils samples, 0-20 cm depth, were collected from representative land utilization types of teff, chickpea, wheat and homestead for the analysis of organic carbon, NPK contents. Similarly 12 undisturbed soil samples were collected using core sampler for the analysis of bulk density. Fifteen composite samples three samples from each of cattle manure, dung cake, donkey manure, compost and animal feed concentrate were collected and analyzed for NPK and OC content. Twenty seven composite samples of grain yields 9 samples from each of teff, chick pea and wheat and 27 composite samples of crop residues were collected and analyzed for their NPK and OC content. All collected samples were analyzed at Debrezit Agricultural research center soil and plant analysis laboratory using standard procedures.

Soil organic carbon was determined by the wet oxidation method (Walkley and Black 1934). Available P was determined with the Olsen method (Bray and Kurtz 1945), while total N was determined by Kjeldahl digestion, distillation and titration. Exchangeable K was analyzed using an atomic absorption spectrophotometer following an ammonium acetate extraction. Bulk density was determined by the measurement of the wet weight of each core and converting to dry mass equivalent per unit volume of the soil using moisture data and the known volume of the core. Plant P and K were analyzed by dry ashing method using spectrophotometer and atomic absorption and TN was analyzed by Kjeldahl digestion, distillation and titration and organic carbon was calculated from the ash (Sahlemedhin and Taye, 2000).

Nutrient input from mineral fertilizer was calculated using data obtained from the village. Both DAP and Urea was taken into account for farm household input estimation. Urea is chemically composed of 46% of N, while DAP contains 18% of N and 46% of P (FAO, 2008). In order to estimate the amounts of livestock manures, the total livestock population of the households was converted to Tropical Livestock Units (TLU) using a conversion factor for each livestock type. Then, based on information from data collected manure production was calculated using dry weight manure productivity index. The quantity of manure produced was converted to nutrient using the nutrient content of the product obtained from laboratory analyses results.

Nutrient Outputs Soil erosion, leaching, nitrogen denitrification and volatilization, through harvested crop yields, crop residues and manure used for fuel are usually the major pathways of nutrient losses from agricultural soils, which could be analyzed through full nutrient balance analysis. In this study the quantity of crop yield, crop residue and manure were considered, since most decision by farmers were made on these resources. The quantity of crop was obtained from the household survey and crop residue was calculated from the crop harvest index ratio obtained from demonstration fields and literatures. The quantity of manure was calculated from TLU using a conversion factor for each livestock type. The quantities of these resources were converted to nutrients using laboratory analyses results.

3.2.4. Administration of the Questionnaire

The questionnaires were administrated by trained data collectors and the researcher who are speakers of the local language of the study area. A brief orientation and training was given for data collectors before the actual data collection. During data collection strict supervision and control was done to increase the quality of the questionnaire.

3.2.5. Data-analysis

Nutrient balance study follows starting by the identification of the key inputs and outputs in various farm components and sub-components of a bounded system boundary. The various resource and nutrient inputs and outputs were defined through farmer-led analysis estimation. Flows of nutrients (Nitrogen, Phosphorus and Potassium), and Organic Carbon were quantified through nutrient content analysis of the resources flows, whereby balances are calculated for each of the identified nutrient ‘currencies’. To facilitate the analysis of a farm system and its nutrient flows, the following steps were followed: The major resources of the farm system were identified, paying particular attention to different stocks and sources of fertility. Grouping of the stocks and sources of fertility in to sub-systems and identification of their respective boundaries was done. The resource flows that link the different sub systems of the farm system were identified. Addition of the measured or estimated resource flows was done. The estimated amount of nutrients within each resource flow was translated from quantities of matter into quantities of nutrients based on data base collected from the study site nutrient content analysis.

The data obtained from household interview, field observation, and laboratory analysis was analyzed and summarized in to tables and graphs by using Microsoft office excel spreadsheet and Statistical Package for Social Studies (SPSS) version 20 to quantify and characterize the production factors available on the farm *i.e.*, overview and characteristics of land size, livestock, crop yield and crop residues, nutrient balance per crop and for the entire farm, flows between the sub system (crop, animal, and household), fertilizer use, crop-livestock reactions, nutrient sinks and sources. Qualitative data generated from key informant interview, focus group discussion and secondary sources was analyzed by narrative description.

Chapter Four

4. Results and Discussion

4.1 Socio-economic and demographic Characteristics of the Sample Households

4.1. 1 Sex and age of the respondents

Participants were composed of both sex selected from the entire three farmers' wealth categories (rich, medium and poor). About 81% and 19% of respondents were male and female headed farmers respectively. The minimum age of the respondent was 28 while the maximum age was 78. The modal age group of respondents is 41-50 years old, accounting for 37.5% of the respondents (Fig 4.1). About 27.5, 17.5, and 14.2% of the respondents were from the age groups between 51-60, 30-40, and 61-78 respectively (Fig. 4.1).

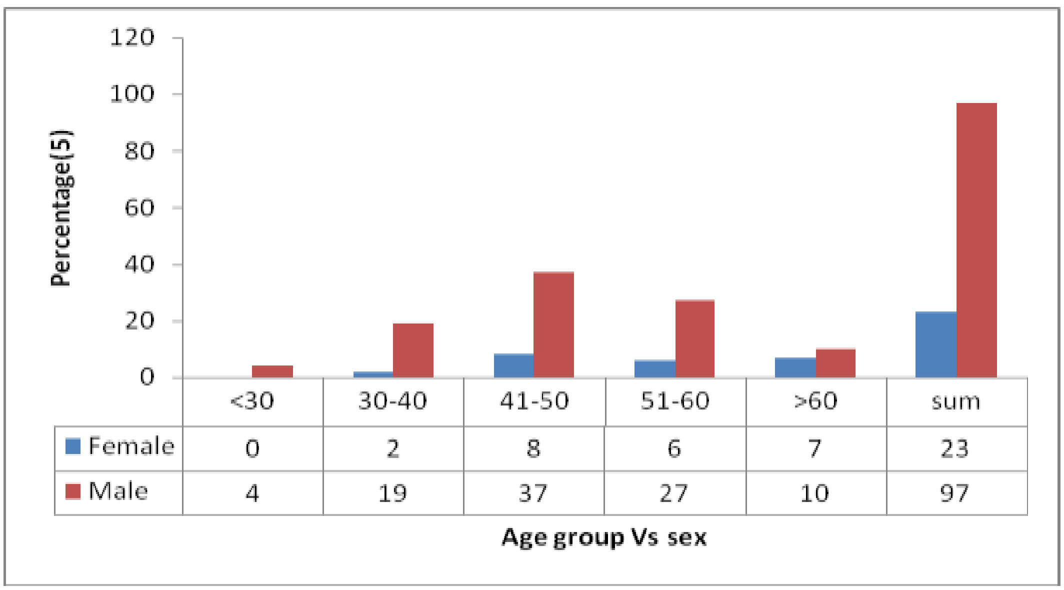


Fig 4.1 Percentage distribution of the respondents by their sex group, Kumbursa, 2014

Source: Field survey, 2014

The average age of the respondents is 48 years. That means on average the respondents are in the category of active labour force, which could have positive implication in terms of coordinating family labor and soil fertility management. Like many other rural villages of the country, most households of Kumbursa village is dominated by male headed households.

Therefore, decision on soil fertility management is done by male than females. But there is no difference on use of resources and nutrients between male and female headed households.

4.1.2 Educational level

Educational status of 33.3and 31.7% of the respondents was illiterate and read and write respectively, while 16.7 and 10.8% of the respondents attended Junior high school and elementary school. Those with Secondary high school and higher education (diploma) educational level were only 6.7 and 0.8% of the respondents respectively (Fig 4.2).

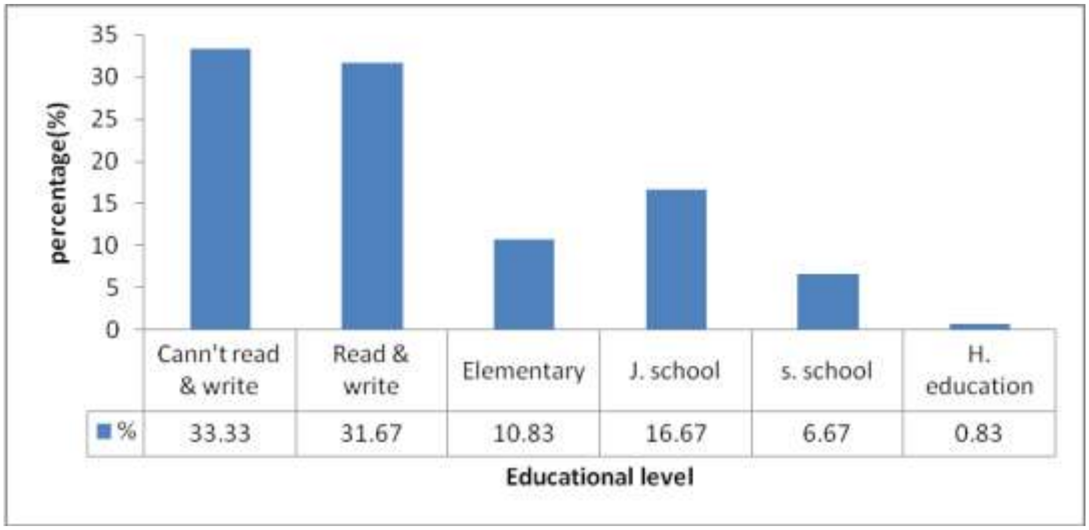


Fig 4.2 Percentage frequency distribution of respondents by their educational level, Kumbursa, 2014

Source, Field survey, 2014

In general, about 78% of the respondents are illiterate and can read and write only. This, in turn, could have its own implication on household's resources and soil nutrient flow management practices.

4.1.3 Marital status

About 71.7, 17.5, 5.8 and5% of the respondents are married, widowed, divorced and single respectively (Fig4.3). Since significant number of household heads (71.7%) are married, they may get the support of their spause so as to involve in managent of resource and nutrient flows of the household, while the other groups (single, widowed or single) may be disadvantageous in this regard.

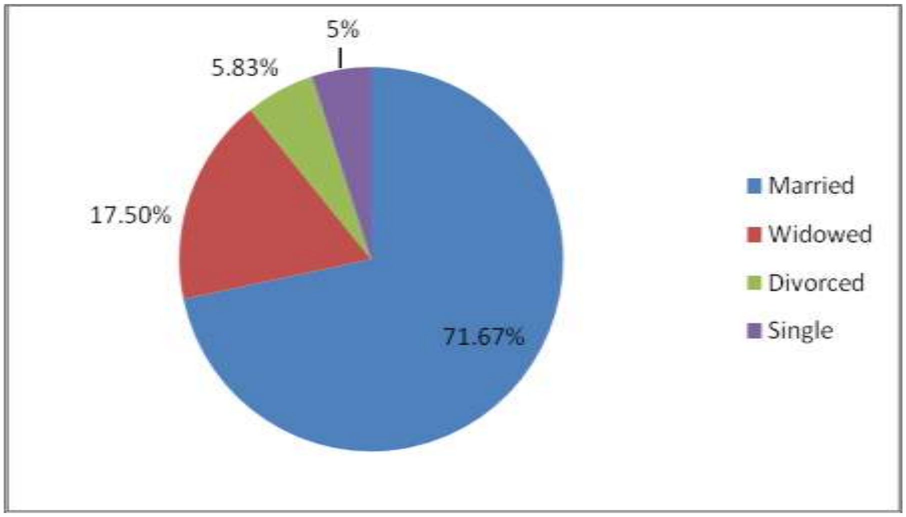


Fig 4.3 Percentage frequency distribution of marital status of the respondents, kumbursa,Juanury 2014

Source: Field survey,2014

4.1.4 Family size

The total family size of the respondents was 739, of which male and female members of the households of the respondents were 384 and 355 respectively. The average family size of the respondents by wealth category is 6, 6 and 7 for poor, medium and rich respectively. The mean value for the respondents is 6. Family size determines the labour force of the households, which are important in all agricultural activities.

4.2 Quantification of selected resource flows

4.2.1 Labour force

In the study village about 61% (16-60 years old) represents active labour force (Fig.4.4). This is greater than the national average which is about 52% (CSA, 2007). The families in the age group between 6-15 years (28.96%) can also perform some activities. They look after cattle, collect firewood, fetch water and perform similar agricultural activities.

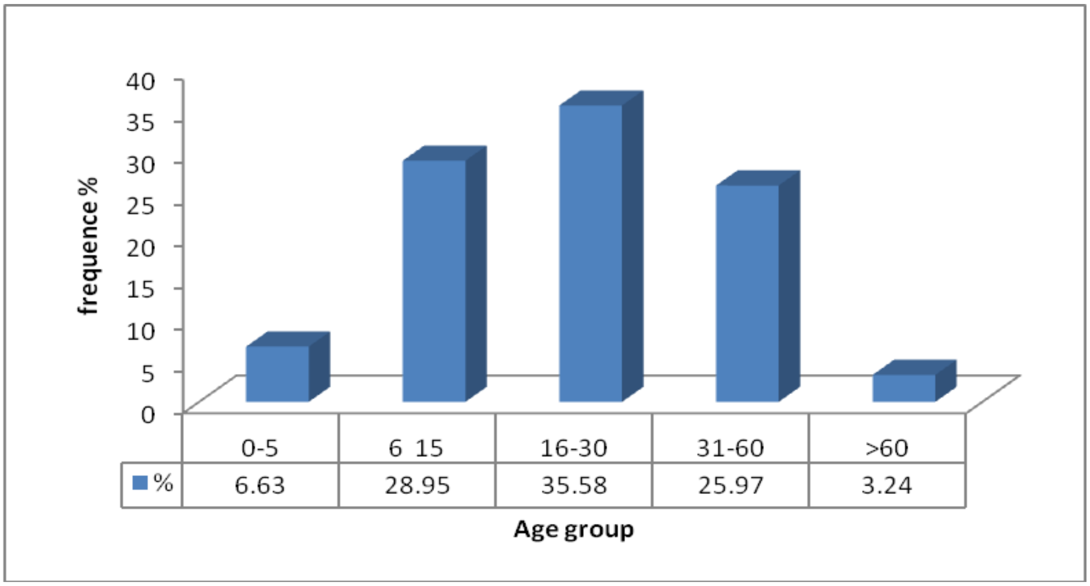


Fig. 4.4 labour force of the respondents in kumbursa village, Juanry, 2014

Source field survey, 2014

Labour is one of the most important socio-economic characteristics that influence soil fertility management. Transportation and application of organic fertilizer such as manure and compost to the distant plots require human labour and transportation.. 90% of the family members' age is between 6 - 60 years. The age group < 6 and >60 years is only 10% of the total.

4.2.2 Land holding size

The average land holding size for the poor, medium and rich farm group is 1.08, 1.5 and 3.36 hectares respectively, and these differences are statistically significant ($P< 0.05$). The average land holding size of the respondent's is 1.75 hectares. This is much larger than the national average land holding size, which is nearly one hectare (CSA, 2007).

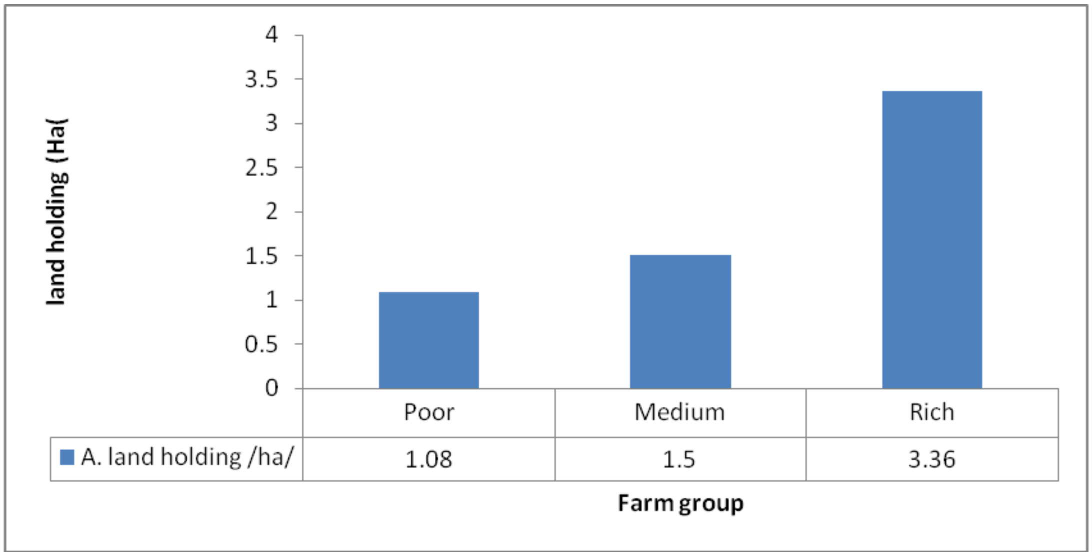


Fig 4.5 Average land holding size (ha) by farm wealth category, kumbursa village

Source: Field survey, 2014

There is significant variation among the different wealth categories of the village in terms of landholding sizes. Rich households have significantly highest holding size than medium and poor wealth farm groups, and land holding size of medium wealth farm group is significantly higher than land holding size of poor wealth group ($P < 0.05$). The land holding size influences the wealth status of the households. Those households that have large land size are rich because they produce more crop yield than those households that own smaller land sizes. The resource and nutrient outflow and inflow to the farm systems of rich households are high compared to the medium and poor households.

4.2.3 Livestock holding size

A Tropical Livestock Unit (TLU) is an animal unit used to aggregate different classes of livestock. One TLU equals an animal of 250 kg live weight (FAO, 1987). To convert different animals to TLU, the numbers of different animals were multiplied by the corresponding conversion factors as follows: cattle 0.7, sheep/goat 0.1, horse=0.8, donkey=0.5 and chicken=0.01(http://www.fao.org/wairdocs/ILRI).

In the study village the average livestock (TLU) holding for rich, medium and poor farm groups was 8.36, 4.05.and 2.53 respectively, and the differences are statistically significant ($P < 0.05$) (Fig 4.6).

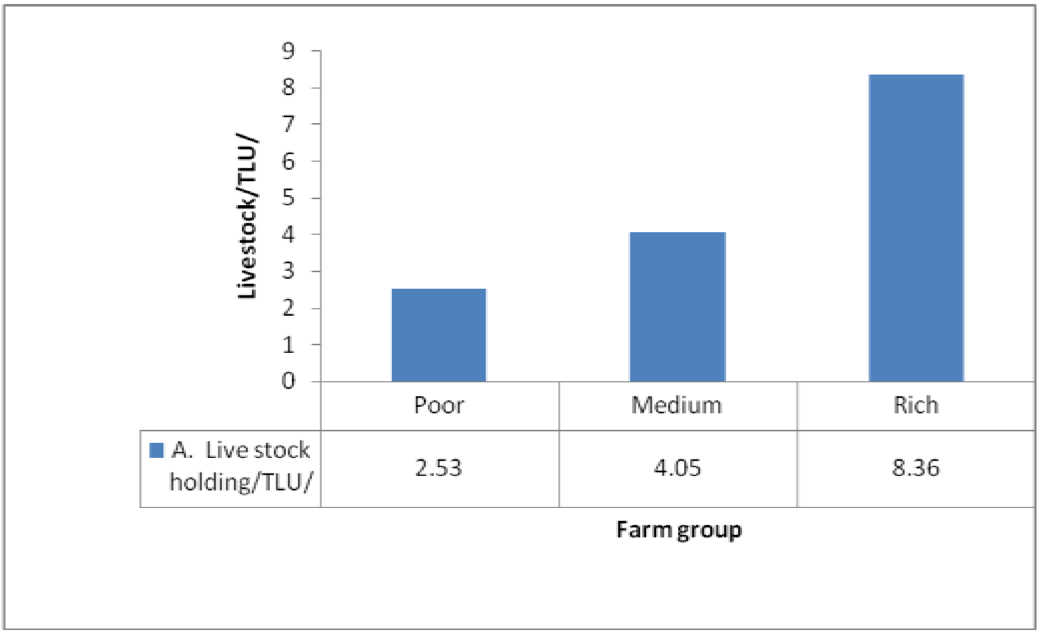


Fig 4.6 Average livestock holding (TLU) by farm wealth group in Kumbursa village

Source: Field survey, 2014

Having large size TLU means that there is an opportunity to produce more manure which may be used for soil fertility amendment. But in the study area nearly 90% of the manure produced is used as source of household fuel and 7.8% is sold to the market, whilst only 2.2% is used for soil fertility amendment.

Some functions of livestock in the study area

Cattle and donkeys are the two dominant livestock in the village. The average cattle holding size for rich, medium and poor is 8, 4 and 2, and the average donkey holding size is 3, 2 and 1 for rich, medium and poor farm group respectively. A few households also keep sheep, goat and poultry. Having oxen and donkeys are considered as a necessity since both play dominant roles in crop production. Oxen are used for traction and threshing while donkeys are used for transporting harvested crops to the threshing place, transporting produce agricultural products to the home and to the market, it also transports water to the household, dung cakes to the market and animal feed to the homestead.

Fig 4.7 A farmer transporting harvested chickpea from field to homestead in kumbursa (photo by the Author, 2014)

Fig 4.8 A farmer threshing teff using oxen in Kumbursa village (photo by the Author, 2014

The livestock production activity of the study area is entirely depending on stall feeding whereby all crop residues are used for animal feed. It was only in rare cases that the farmers of the village use crop residues for other purposes than feeding their animals. In addition to the crop residues, some farmers (61.67%) purchased animal feed concentrates and salt for their animals.

Fig.4.9. A woman providing feed and water to penned cows in her home compound (photo by the Author, 2014)

4.2.4 Inflows of resources and nutrients to the farm system

Resources that flow to the farm system include chemical fertilizer, animal feed concentrate, food items, and live animals.

Chemical fertilizer

For all three farm groups, inflows into the farm include chemical fertilizer, veterinary products, animal feed and salt, purchased grain and other food items. Inflows of the inorganic fertilizers, Urea and Diammonium phosphate (DAP), restricted to cereal crop fields. 75 kg/ha urea and 100kg/ha (54 kg N and 46 kg P $ha^{-1)}$ for the rich, 65 kg /ha urea and 100 kg/ha DAP (51 kg N and 46 kg P $ha^{-1)}$ for the medium; and 50 kg/ha Urea and 100 kg/ha DAP (43 kg N and 46 kg P $ha^{-1)}$ for the poor farm group, respectively. There is a deference in fertilizer consumption among the farm wealth categories. These differences are statistically significant ($P< 0.05$).

Animal feed concentrate

Animal feed concentrate, salt and veterinary products and salt were imported to the animal's production system. Inflows of animal feed concentrate to livestock production system were 5000kg .(125 kg N, 39 kg P 65 kg K $ha^{-1)}$ for the rich; 2423kg(60 kg N,19kgP and 32kgK $ha^{-1)}$ for the medium; and 2159kg (54 kg N, 17 kg P and 32kgK$ha^{-1)}$ for the poor farm group per year respectively. All farm groups purchased other food and light sources from the market, after selling crops their stock and/or live animals and bi-products.

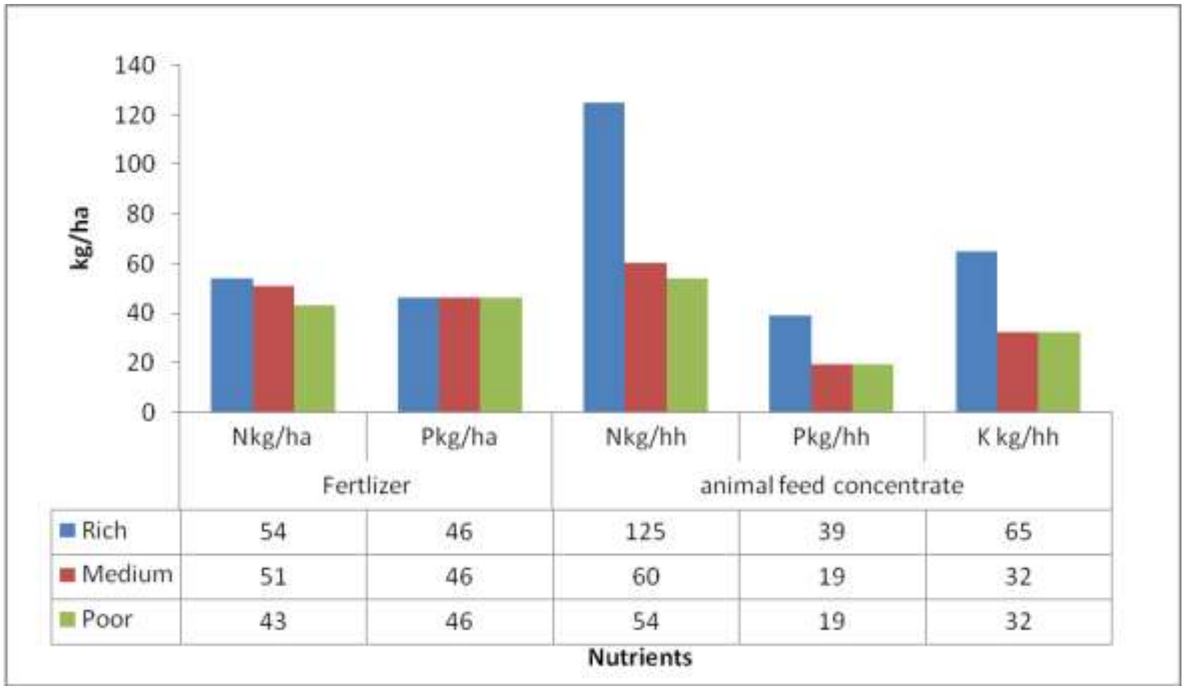


Fig 4.10 Inflow of nutrient in to the farm system, Kumbursa village

Source: Laboratory result, 2014

4.2.5. Out flows of resources and nutrients from the farming system

Farm system outflows consisted of grain from stock, dung cake, live animals and livestock products, i.e. eggs, skins and hides sold as a source of cash to buy chemical fertilizer, food items and clothing, for school fees and materials, and for land tax. However, for the purpose of quantifying the nutrient contents, crop yield and dung cake sold to the market were quantified. The other resources (live animals and livestock products, i.e. eggs, skins and hides) sold to the market were considered as a source of cash output in financial analysis.

Crop yield

The average amount of crop yield sold to the market was 5498 kg .(158 kg N, 26 kg P and 49 kg K $ha^{-1)}$ for the rich; 2383 kg(70 kg N,11kgP and 22kgK $ha^{-1)}$ for the medium; and 2166 kg (67 kg N, 11kg P and 21kgK$ha^{-1)}$ for the poor farm group per household per year respectively

Manure

The average amount of manure sold to the market was 669 kg .(10 kg N, 3 kg P and 14 kg K ha^{-1}) for the rich; 328 kg (4 kg N,1kgP and 7 kg K ha^{-1}) for the medium; and 241 kg (4 kg N, 1kg P and 5kgKha^{-1}) for the poor farm group per household per year respectively.

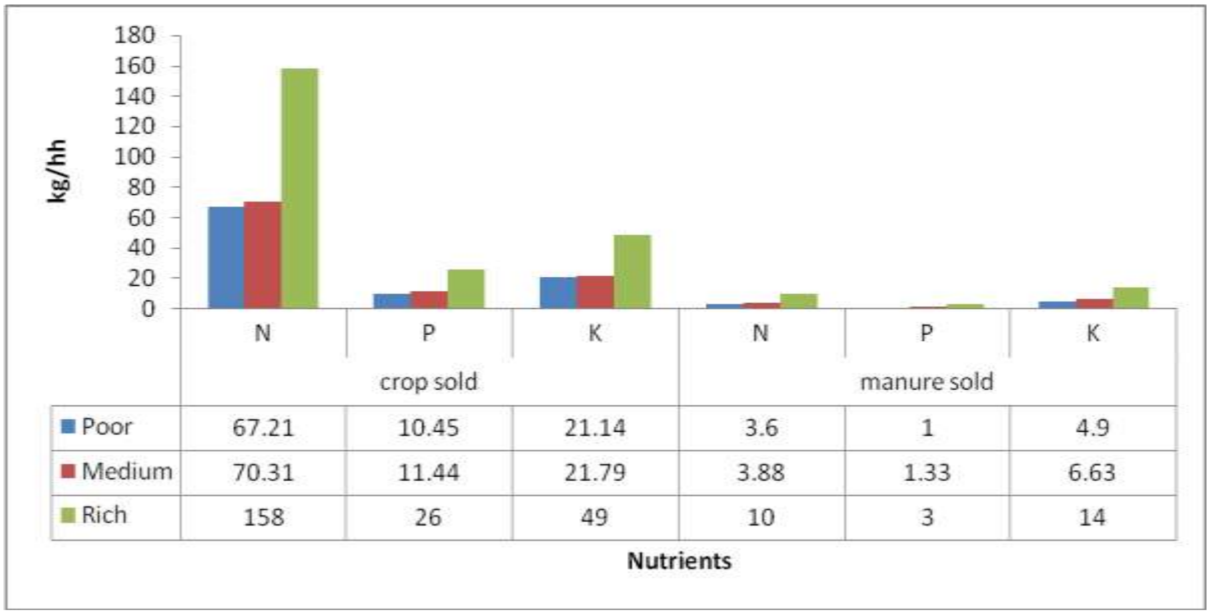


Fig 4.11 outflow of nutrients from farming system, Kumbursa village

Source: Laboratory result, 2014

4.2.6 Internal flows of resources and nutrients

In the study area, three major sub farming systems were identified: the crop production, animal production and household system. The major resources flows from the crop production sub system were crop yields and crop residues. And the destinations are both the household and animal production sub systems Animal production sub system depends on stall feeding. There is no communal grazing or pasture land. Animals were confined to the homestead and fed on crop residues throughout the year. Manure flows from animal production sub system to the household sub system which is later used as fuel and small proportion is sold to market. House waste flows in to the crop farm system near the homestead. Labour flows to both crop and animal production sub systems.

Crop yield: Crop yield was exported to household sub system for household consumption and/or for market as a source of cash. The average amount of crops transferred to the household was 8009 kg .(262 kg N, 44 kg P and 83 kg K $ha^{-1)}$ for the rich; 6591 kg(130 kg N, 32 kg P and 65 kg K $ha^{-1)}$ for the medium; and 6484 kg (215 kg N, 33 kg P and 66 kg $Kha^{-1)}$ for the poor farm group per household per year respectively.

Crop residue: In the study village, nutrients are also exported from farm fields through the removal of crop residues. Nearly 90% of the crop residue is removed from the field and total feed to animals. The crop residue of some crops like chickpea is totally removed through harvesting by uprooting.

Fig 4.12 Chickpea field left bare ground due to uprooted harvesting

Photo by the author, 2014

Crop residues are exported to animal production sub system as animal feed. The average amount of crop residue exported to the animal production sub system was 8844 kg .(83 kg N, 10 kg P and 168 kg K $ha^{-1)}$ for the rich; 8463 kg(73 kg N, 10 kg P and 147 kg K $ha^{-1)}$ for the medium; and 4067 kg (42 kg N, 5 kg P and 110 kg $Kha^{-1)}$ for the poor farm group per household per year respectively. This is equivalent to 2 quintals of urea for the rich, 1.5 quintals of urea for the medium and 1quintal urea for the poor farm group.

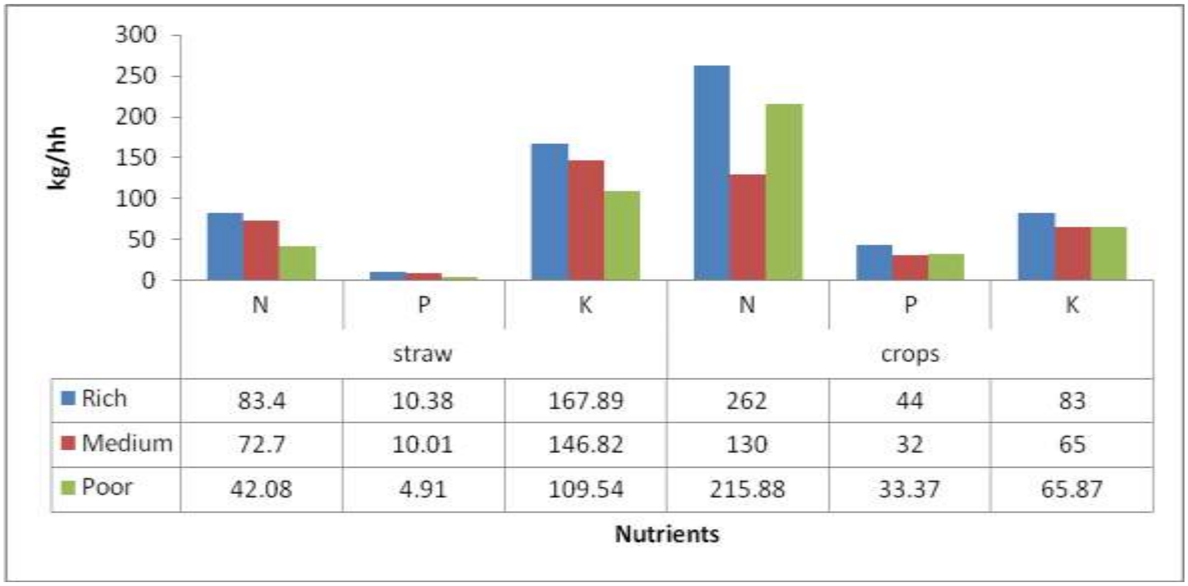


Fig 4.13 Internal flows of nutrients within the sub farm system

Source: laboratory result, 2014

Household waste

In the study area on average 0.5kg, 0.33kg and 0.17kg of waste was produced per day by the rich, medium and poor households respectively. The major proportion of the household waste is ash which is produced through burning of manure and firewood where by major part of nitrogen and organic carbon is lost. Inorganic form of phosphorus and potassium is retained to a large extent in the ashes. However, for cultural and awareness reasons, only a small proportion of the ash is recycled as fertilizer. Major part of the ash produced through burning of biomass is simply accumulated along side of fences in the homestead.

Manure as source of household energy

The households in the study village use chemical fertilizers as a main soil fertility improvement. Crop rotation is commonly practiced with a sequence of cereals with pulses. Chemical fertilizers (DAP + UREA) are used only for cereal crops production. Pulses are produced without application of fertilizers. Farmers in Kumbursa rarely use animal manure or other organic wastes to improve soil fertility. On average, 2.2% (112.2Kg) of manure was used as compost to apply near the homestead. This is equivalent to 1.69 kg N, 0.46 kg P and 2.29KgK per annum. 7.8% (398.8 kg) of manure was sold to the market as dung cake, which is equivalent to 5.98 kg N, 1.63

kg P and 8.13 Kg K per annum. The rest 90% (4601.1kg) per household per annum was used as fuel.. This is equivalent to 76. Kg N, 20.96 kg P and 104.3 kg K per household per year. This amount of N was not recycled because of loss through burning (fig 4.15).

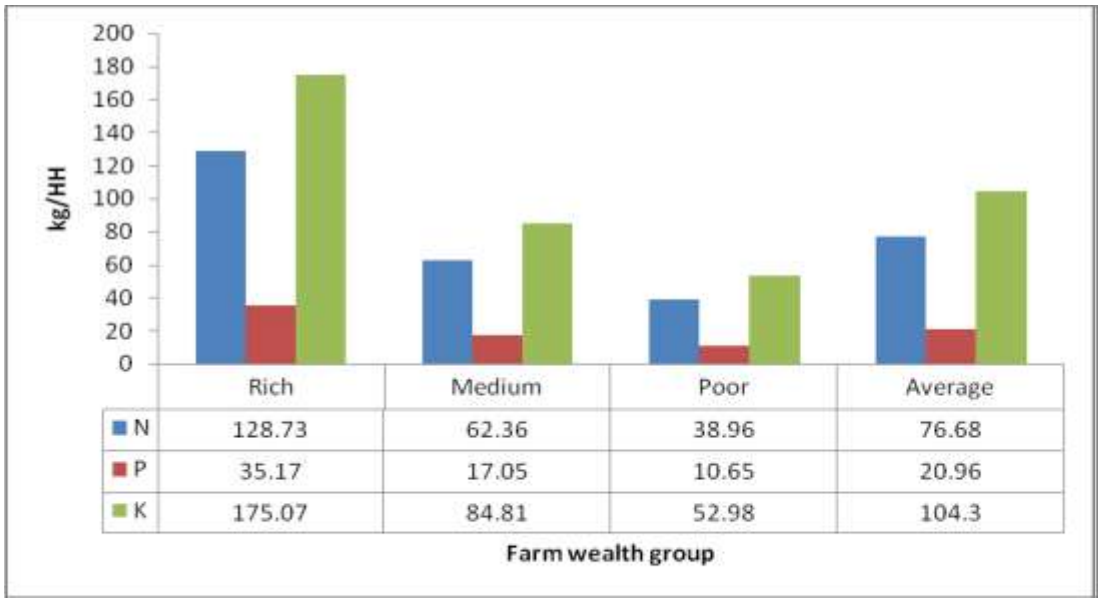


Fig 4.14 internal flows of nutrients through manure as source of household energy in Kumbursa
Source: laboratory result, 2014

Fig 4.15 Dung cake prepared and stored for later use at Kumbursa village
Sources: photo from the author, 2014

Firewood and charcoal as Source of household Energy

In the study village, the average consumption of firewood for fuel per household was 21kg/week, 84 kg/month and1008kg/year. This is equivalent to 20 donkey load (MoA, 1996). The cost of one donkey load was Eth birr 50. Therefore, the yearly firewood consumption rate is estimated to Eth birr 1000 per household. But the households in the study village use their own trees (eucalyptus) by cutting from their own compound. Therefore, there is no financial expenditure for firewood and the distance to collect firewood was almost zero. The average charcoal consumption is 12kg/month and this is nearly ½ of a sack which costs 120 Eth birr.

4.2.7 Financial resource analysis across farm wealth group

The financial analysis of the households of kumbursa shows that the difference between the output and input in terms of cash (Eth. Birr) is a substantial amount so that all the three farm groups can afford to buy inorganic fertilizer for soil fertility amendment(fig 4.18). From the household survey it is understood that on average the rich farmers applied 100kg/ha of DAP and 75kg/ha of urea for teff field and100kg/ha DAP and 100kg/ha Urea for wheat. The medium farm wealth group applied 100Kg/ha of DAP and 65Kg/ha of Urea for teff and 100Kg/ha DAP and100Kg/ha Urea for wheat. The poor farm group applied 100kg/ha DAP and 50kg/ha Urea to teff and 100Kg/ha DAP and 75kg/ha Urea for wheat. This is much more than the national average which is 17kg/ha (FAO, 2009). This result is contrast to previous study results done by Balesh T, 2005 and Hailesilie, 2005 that showed a significant difference among groups of farmers (rich, medium and poor) in the smallholder farming system in application of mineral fertilizers and organic fertilizer from organic sources. The rich and medium farm group can afford to buy inorganic fertility and has more access to manure and other organic materials for soil nutrient improvement. While, Poor farmers do not have such choices in the absence of a credit scheme and live stock as manure sources (Balesh T., 2005). Similarly analysis of the household survey clearly shows that a much smaller fraction of farmers classified as poor (16%) were applying DAP and Urea, while the majority of households classified as ‘rich’ (86%) did use mineral fertilizer and manure (Haileslassie,2005).

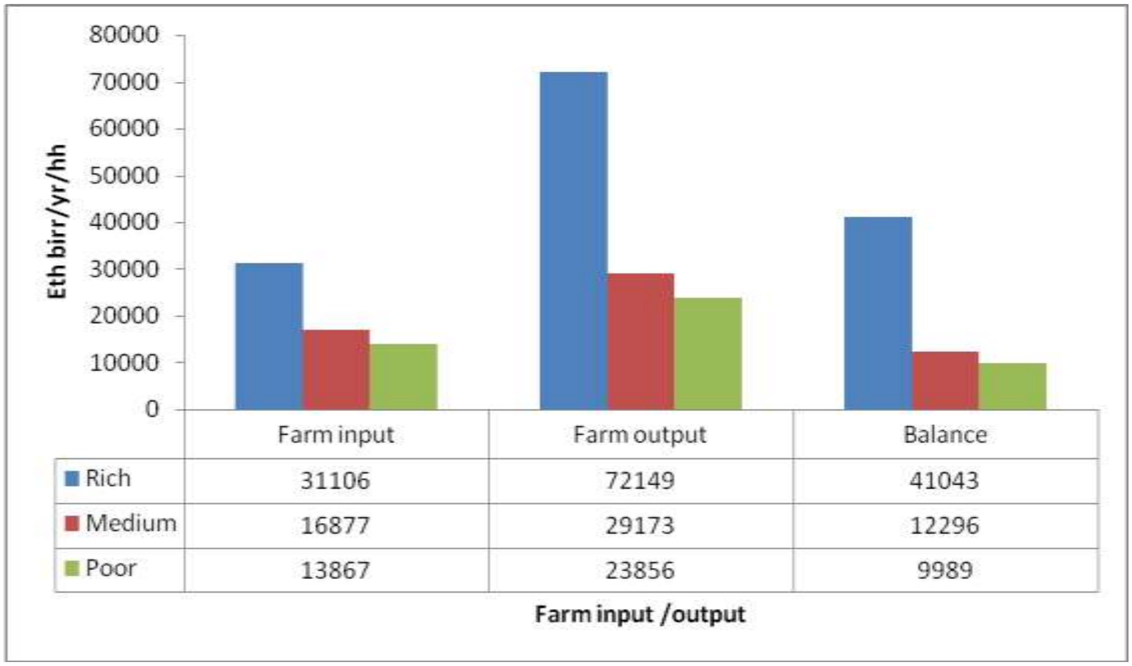


Fig 4.16 Household Financial analysis across farm wealth group in kumbursa village, 2014

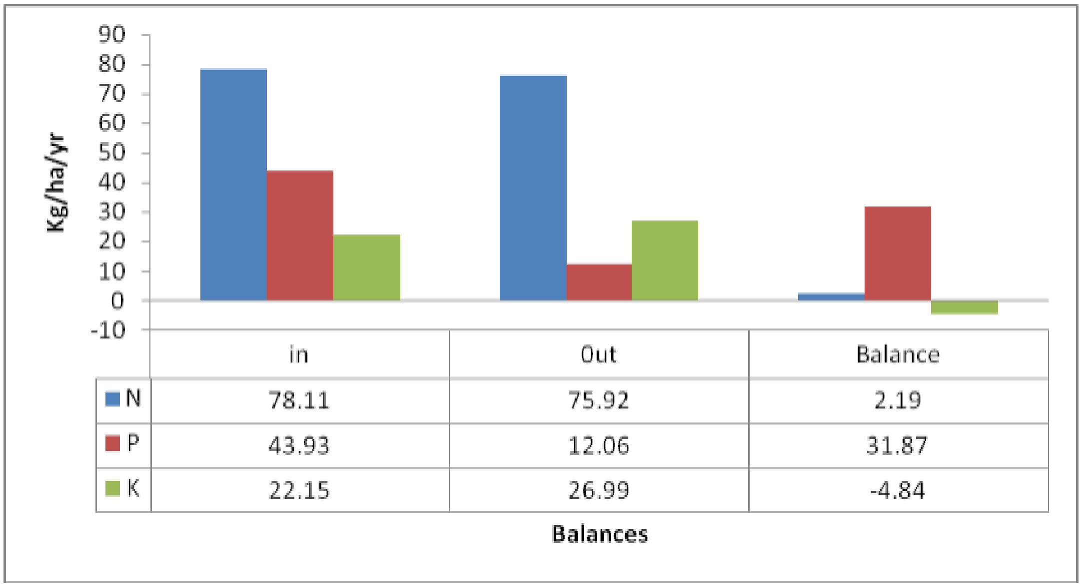
Source: Field survey, 2014

4.3. Quantification of Nutrient Flows

In agricultural activities, nutrients are added to the systems via organic and/or inorganic fertilization, and may be added by environmental processes (e.g. atmospheric deposition, and nitrogen fixation). On the other hand nutrients are exported from the systems via harvesting yields or collecting crop residues and may be lost via erosion, leaching and volatilization. Hence, by calculating the net difference between the amount of nutrients that are entering a system (i.e. inputs) and the nutrients that are removed (i.e. outputs) a nutrient balance i.e. (Σ IN+IN2 inputs – Σ OUT1 +OUT2).

4.3.1 Farm Scale Nutrient Balance Analysis

The total N imported (IN1 and IN2) into the farming system on average was 78.1 kg/ha/yr, while the export of the same nutrient (OUT1 and OUT 2) was 75.92 kg/ha/yr. Thus, the partial balance was 2.19 kg N/ha/yr (Fig. 4.6). Similarly the total P imported (IN1 and IN2) into the farming system on average was 43.93 kg/ha/yr, while the export of the same nutrient (OUT1 and OUT 2) was 12.06 kg/ha/yr, yielding a partial balance of 31.87 kg P/ha/yr. But the balance for K was -4.84 kg/ha/yr). The positive balance for N and P was mainly because on average farmers in the study area are applying sufficient inorganic fertilizer (100 kg DAP and 60 kg Urea/ha) for teff field and (100 kg DAP and 80 kg Urea/ha) for wheat field to counterbalance the nutrient losses caused by the removal of harvested products and crop residues. On the other hand, the negative balance for K was due to the fact that K is not a component of common inorganic fertilizer that are usually applied in the village as well as in Ethiopia.



	in	Out	Balance
N	78.11	75.92	2.19
P	43.93	12.06	31.87
K	22.15	26.99	-4.84

Fig 4.17 Farm Scale NPK balances in Kumbursa Village

Source: Laboratory result, 2014

Farming system level nutrient balance indicates only the aggregate and overall picture of the nutrient balance with little attention on sustainability of agricultural production. For detailed investigation of farm system sustainability it is necessary to split the farming system into a sub-system and workout the nutrient balance for each sub-system found within the larger farming system.

4.3.2. Sub Farm Scale Nutrient Balance Analysis

The balance for crop production sub farm system was negative for the three macro nutrients: N (-93.46 kg/ha/yr, P (-5.8 kg/ha/yr) and K (-99.47 kg/ha/yr). This is due to the nutrient losses caused by the removal of harvested products and crop residues from the crop production sub system. The balance for animal production sub system is positive N (+36.95 kg/ha/yr), P (+ 24.67 kg/ha/yr) and K (+36.92 kg/ha/yr).This is due to the high nutrient flow from crop residue and animal feed concentrate. Similarly the nutrient balance for household sub system is positive for the major macro nutrients: N (+59.89 kg/ha/yr), P (+13.39 kg/ha/yr) and K (+56.1 kg/ha/yr) as result of the internal flow of crop yields and animal manure to the household sub system. Even though the household imports large amount of nutrients from crop and animal sub farm systems part of it is consumed by the household and burned as fuel and finally nutrients are lost deep into the latrine as human waste and as ash. N, Organic Carbon and the organic form of P were lost through burring, While K and the inorganic form of P (the major part) may retain in the system (Fig 4.18).

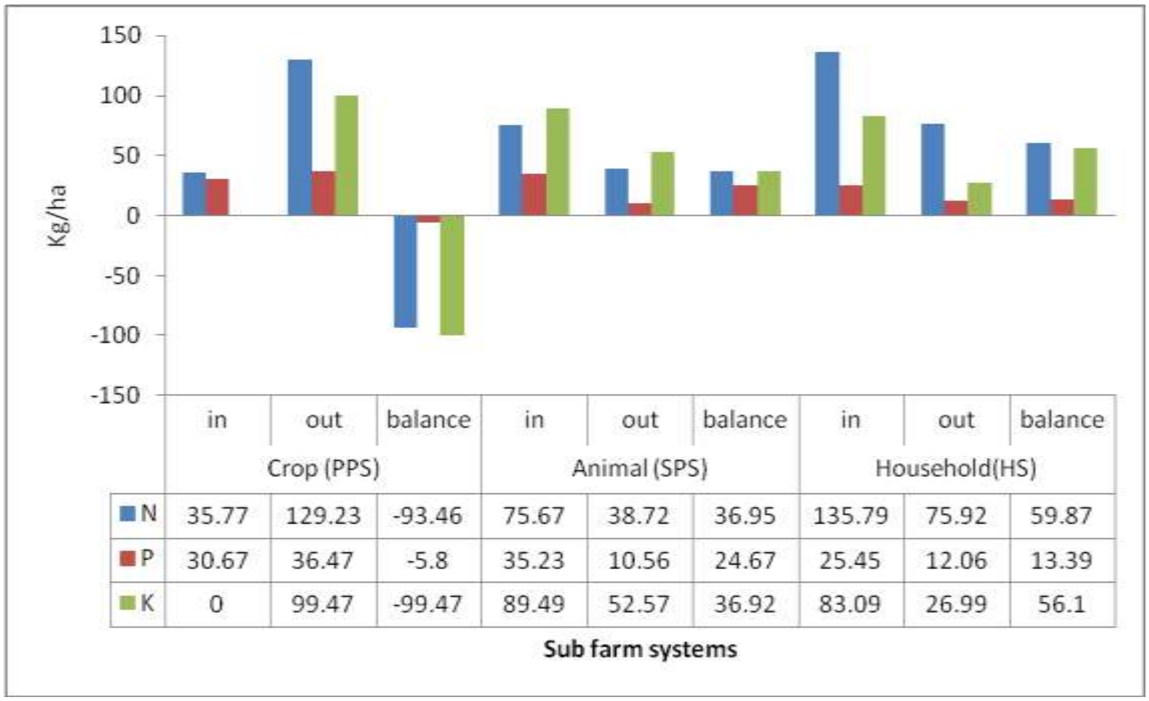


Fig 4.18 Sub Farm Systems Nutrient balance in Kumbursa village

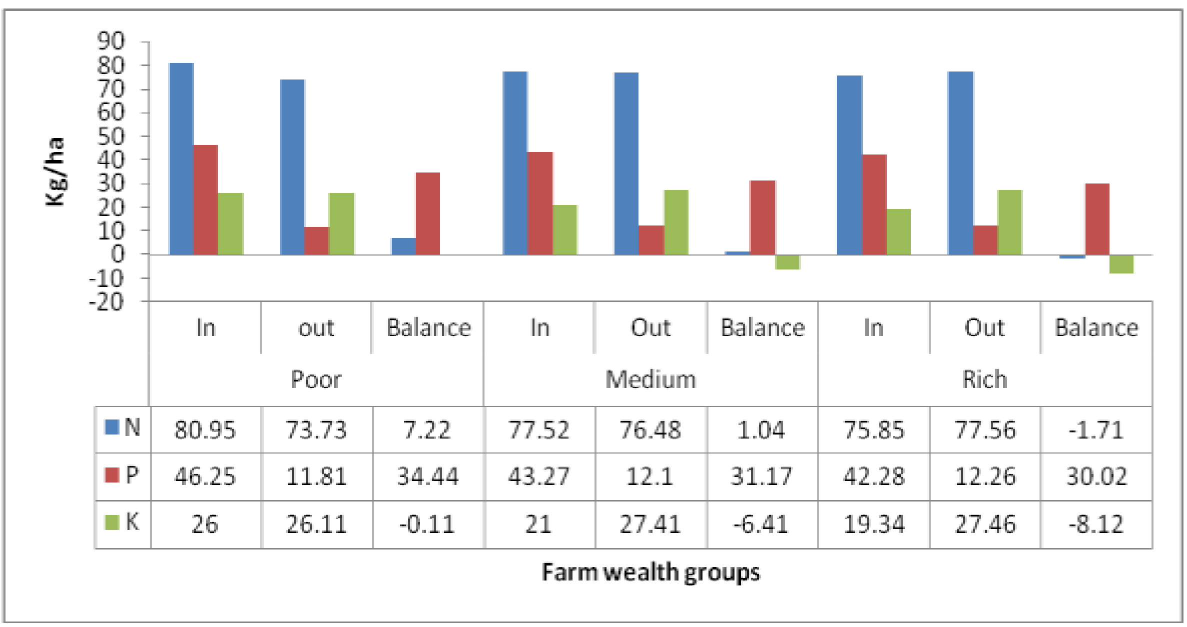
Source Laboratory result, 2014

Crop and livestock production sub-systems are not integrated in a sustainable manner as the recycling of nutrients from animal manure to cropland is interrupted by the use of dung cake for household fuel and for sale. Therefore, homesteads are areas of nutrient accumulation, while crop production sub-system is area of nutrient depletion in Kumbursa village.

4.3.3. Nutrient Balance Analysis across farm wealth groups

For all the three farm groups, inflows into the farm (Figure 4.8) include chemical fertilizer, animal feed, salt, and other food items. In this study, chemical fertilizer and animal feed purchased from the market were considered as inflow resources to the farming system. Chemical fertilizer (DAP and Urea) , animal feed purchased from the market was common for the three farm groups, Farm scale outflows consisted of grain from stock, live animals and livestock products, i.e. eggs, skins and hides, sold as a source of cash to buy chemical fertilizer, food items and clothing, for school fees and materials, and for land tax. For all farm groups, the highest outflows are through crop products.

N and P were positive for the poor and medium farm groups since export of these nutrients through crop yield and manure (dung cake) is low when compared to the rich farm wealth group. For rich wealth group both N and K are negative because of the high nutrient export to external (market) through crop yield and manure (dung cake), as the rich farm group produced more and sold these products to the market (external). This result was similar to the findings of Assefa, 2005. P is positive, for the three farm groups because of the low P content of crop yields and manure (dung cake) exported to external destinations (Fig 4.19).



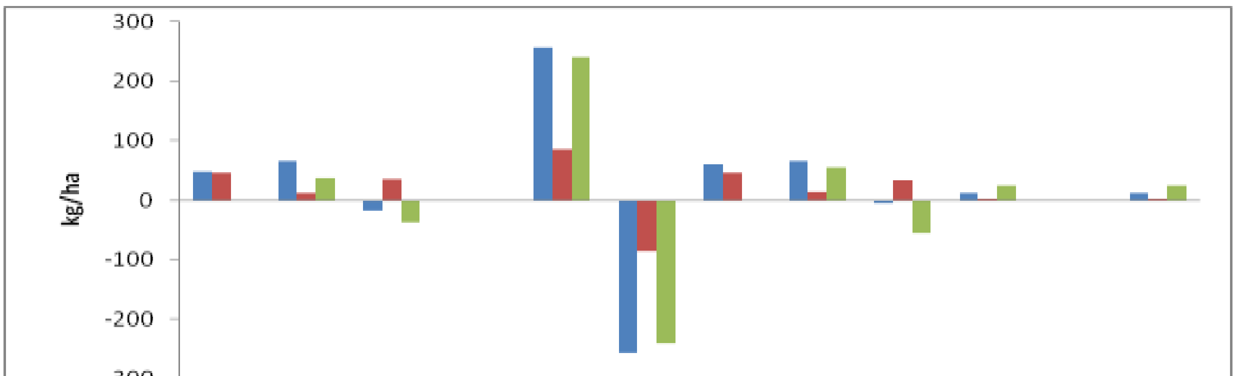
	Poor			Medium			Rich		
	In	out	Balance	In	Out	Balance	In	Out	Balance
N	80.95	73.73	7.22	77.52	76.48	1.04	75.85	77.56	-1.71
P	46.25	11.81	34.44	43.27	12.1	31.17	42.28	12.26	30.02
K	26	26.11	-0.11	21	27.41	-6.41	19.34	27.46	-8.12

Fig 4.19 Farm Wealth groups Partial Nutrient Balance Analysis for Kumbursa village

Source Laboratory result, 2014

4.3.4 Aggregate Field Scale Nutrient Balance Analysis

In the study area, the most important primary production units were teff, chickpea and wheat. In teff field, the highest negative balances were recorded for K (-37 kg /ha/yr) and N (-17 kg /ha). The N, P and K balance for chickpea were negative, with average values of -257kg/ha, -85 and -240 kg ha^{-1} respectively. The cause for negative balances of these nutrients in chickpea field was farmers do not apply chemical fertilizer to the chickpea field unlike teff and wheat. Similar to teff field, in wheat field, the two nutrients N and K were negative while P was positive. The positive balance of P for teff and wheat field was because of the low P content of crops and crop residues that are exported from crop fields. The N, P and K were Positive for homestead (+10.9, +2.04 and +24 kg ha/yr) respectively as a result of high import of nutrients through over left of crops residue and manure deposited in the homestead which is estimated to be10% of the total imported to the household sub farm system. In the study village on average 0.33kg of house waste is deposited in the homestead per day per household. Therefore, the homestead is the field where nutrients are continuously accumulated (fig 4. 20).



	In	Out	Balanc e	In	Out	Balanc e	In	Out	Balanc e	in	out	balanc e
	Teff			Chickpea			wheat			Homestead		
N	47.13	65.06	-17.9	0	257.4	-257.	60.16	65.19	-5.03	10.91	0	10.91
P	46	11.17	34.83	0	85.48	-85.4	46	12.65	33.35	2.04	0	2.04
K	0	37.16	-37.1	0	239.7	-239.	0	54.87	-54.8	24.09	0	24.09

fields

Fig 4.20 Aggregate field scale nutrient balance analysis in kumbursa village

Source: laboratory result, 2014.

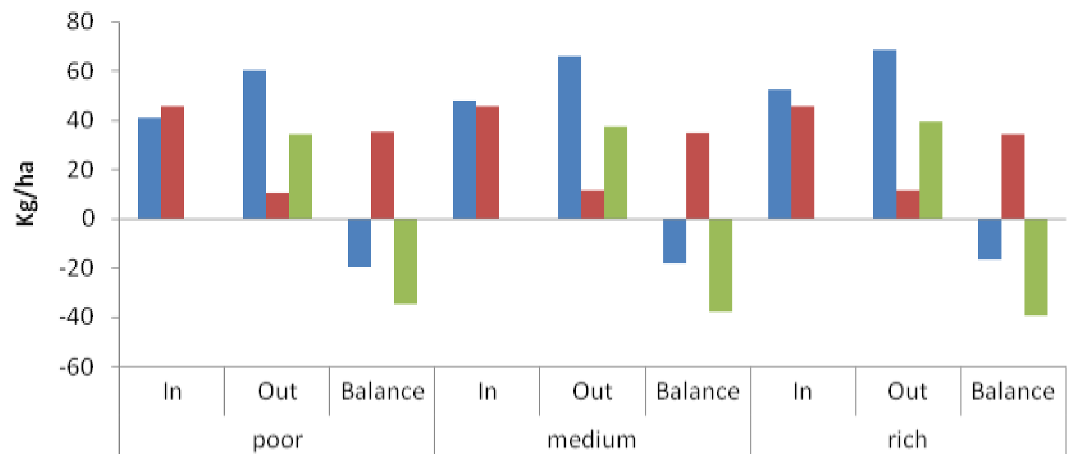
In the study village the homestead is mostly used as animal refreshment area. Some of the inflow like urine is not considered because it is difficult to quantify urine unless longtime nutrient monitoring is done. Similar to the inflow of nutrients through urine the outflow of nutrients used by permanent trees around the homestead is not considered in the partial nutrient balance calculation for the same reason.

4.3.5. Field Scale Nutrient Balance Analysis

The major crops produced in the village are cereals (teff, wheat) and pulses such as chickpea, lentil and faba bean of which dominant one is chickpea. The three crops namely, teff, chickpea and wheat constitute more than 90% of the cultivated land in the village. Nearly75% of the total crop produced in the village is sold to the market to buy inputs (fertilizer, pesticide), for labour payment, animal feed, food seasoning, tax and other household expenditure, while straw from crops are totally used for animal feed.

Teff Field Nutrient Balance Analysis

In the study area, fertility management at the field level was more determined by the crop grown than by the soil fertility category. Teff is highly valued as a staple and cash crop in the farming system. Another equally important reason that has initiated farmers of the village to produce teff despite its extensive labor demanding nature and low yield per area is the high value of its straw both for animal feed and for selling out to the nearby urban markets. Out of the total area under crops, 113.65 hectares (65.78%) is allocated for this crop. It is also given priority in all crop management practices like land allocation and preparation, fertilizer application and weeding frequency regardless of the low yield of the crop per hectare. In Ethiopia in general, specifically in the central highlands, 70 - 80% of the fertilizer purchased by smallholders is known to be applied to teff fields (Kenea et al, 2001). In contrast to this, in the study village, Kumbursa, more nitrogen and phosphorus were applied to wheat field than teff. This is because of farmers expect teff logging problem if they apply more urea to the teff field since teff straw was weaker than wheat.100kg DAP and 100kg Urea was applied to wheat field by both rich and medium farm groups, while 100kg of DAP and 75 kg of urea was applied to wheat field by poor farm groups. For teff 100kg DAP/ha and 75kg of urea, 100kgDAP and 65kg of Urea and 100kg of Dap and 50kg of Urea was applied to teff field by rich , medium and poor farmers respectively. Despite this, in the study area, N and K balances were negative for the three farm wealth groups, while P was positive for these farm wealth categories. The N balance for poor, medium and rich farm group was negative with average values of -19.46,-17.97 and -16.31kg/ha/yr respectively. Similarly, the K balance for poor. Medium and rich is -34.54,-37.63 and -39.35 kg/ha/yr respectively. While, the P balance is +35.62, +34.69+54.19 kg/ha/year respectively. This is due to the high nutrient removals of N and K through teff yield and its residues and low removal of P content of teff and its residue from the field (fig 4.21).



	poor In	poor Out	poor Balance	medium In	medium Out	medium Balance	rich In	rich Out	rich Balance
N	41	60.46	-19.46	47.9	65.87	-17.97	52.5	68.81	-16.31
P	46	10.38	35.62	46	11.31	34.69	46	11.81	34.19
K	0	34.54	-34.54	0	37.63	-37.63	0	39.35	-39.35

Farm wealth group

Fig 4.21 Teff field nutrient analysis across the farm wealth categories in Kumbursa village Source Laboratory result, 2014

Chickpea Field Nutrient Balance Analysis

Chickpea is the second important crop of the study area both with total production and area coverage 38.14 ha (22.05%). In the study area N, P and K balances are negative for the three farm wealth groups, The N balance for poor, medium and rich farm group is -251.5,-258.9 and -261.7kg/ha/yr respectively. Similarly, the P balance for poor. Medium and rich is -83.51,-85.99 and -86.93 kg/ha/yr respectively. And the K balance is -206.6, -207.62 and -209.8 kg/ha/year respectively. This is due to the high nutrient removals of N, P and K through chickpea and its residues from the field and zero application of N, P and K to the field compared to teff and wheat which makes the partial nutrient balance of the chickpea field negative (fig 4.22)

	In (poor)	Out (poor)	Balance (poor)	In (medium)	Out (medium)	Balance (medium)	In (rich)	Out (rich)	Balance (rich)
N	0	251.5	-251.5	0	258.93	-258.9	0	261.76	-261.7
P	0	83.51	-83.51	0	85.99	-85.99	0	86.93	-86.93
K	0	206.6	-206.6	0	207.62	-207.6	0	209.89	-209.8

Fig 4.22 Chickpea field nutrient balance analysis across farm wealth groups in kumbursa, Source: Laboratory result, 2014

Wheat Field Nutrient Balance Analysis

Wheat in the study area is the third important crop in terms of total production and total area 20.98 ha (12.14%) following chickpea. In the study village, more nitrogen and phosphorus was applied to wheat field than teff by all farm groups (100kg DAP and 100kg Urea) by rich and medium, while 100kg of DAP and 75 kg of urea was applied to wheat field by poor farm groups. Despite this in the study area N and K balances are negative for the three farm wealth groups, while P was positive for these farm wealth categories. The N balance for poor, medium and rich farm groups was -11.64, - 0,71 and -2.73 kg/ha/yr respectively. Similarly, the K balance for poor. Medium and rich is -53.98, -54.46 and -56.17 kg/ha/yr respectively. While, the P balance is +33.55, +33.44 and +33.05 kg/ha/year respectively. This is due to the high nutrient removals of N and K through wheat and its residues and low removal of P content of wheat and its residue from the field (fig4.23).

	poor			medium			rich		
	In	Out	Balance	In	Out	Balance	In	Out	Balance
N	52.5	64.14	-11.64	64	64.71	-0.71	64	66.73	-2.73
P	46	12.45	33.55	46	12.56	33.44	46	12.95	33.05
K	0	53.98	-53.98	0	54.46	-54.46	0	56.17	-56.17

Fig 4.23 Wheat field nutrient analysis across the wealth categories of Kumbursa village

Source: Laboratory result, 2014

Homestead Nutrient Balance Analysis

Homestead is the area where nutrient accumulation is expected. It is the area where over left crop resides, manure and house waste is deposited. The nutrient balance for the homestead was positive for all farm wealth categories with the highest value for rich farm wealth group as a result of the high amount of over left manure and crop residues and house waste disposal.

The homestead nutrient balance for N, P and K for poor, medium and rich is +3.36. +3.85 and +3.7kgN/ha/yr, +0.47, +0.68 and +0.89kgP/ha/yr and +7.01, +7.89 and .9.19kgK/ha/yr respectively. The nutrients imported as over left of crops residue and manure deposited in the homestead is estimated to be10% of the total imported to the household sub farm system. On average 0.33kg of house waste is deposited in the homestead per day per households of the study village. Therefore, the homestead is the area where nutrients are continuously accumulated (fig4.24).

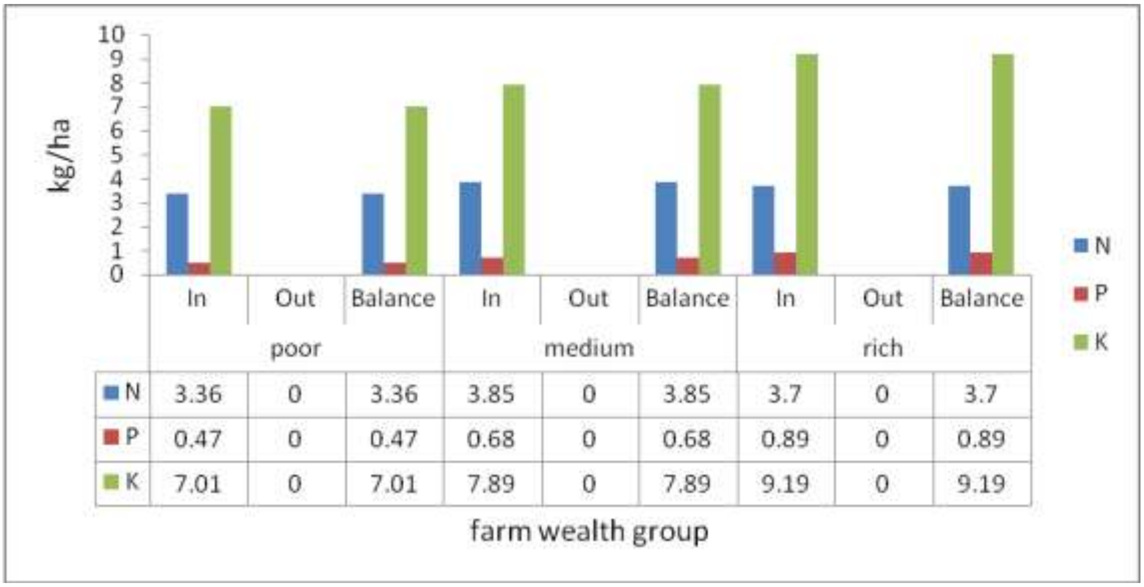


Fig 4.24 Homestead nutrient analysis across farm wealth groups in kumbursa village

Source: laboratory result, 2014

In the study village the homestead is mostly used as animal refreshment area. Some of the inflow like urine is not considered because it is difficult to quantify urine unless longtime nutrient monitoring is done. Similar to the inflow of nutrients through urine the outflow of nutrients through which is used by permanent trees around the homestead is not considered in the partial nutrient balance calculation for the same reason.

4.3.6. Organic Carbon flow Analysis

Organic carbon is one of the most important components of crop yield, crop residue and other organic sources such as manure. In crops and crop residue the proportion of organic carbon content ranges from 50-55 %. On average 5082kg/hh/yr of Organic Carbon is removed from the households of kumbursa village through household consumption, market, and feed of animals and as source of fuel (fig. 4.25).

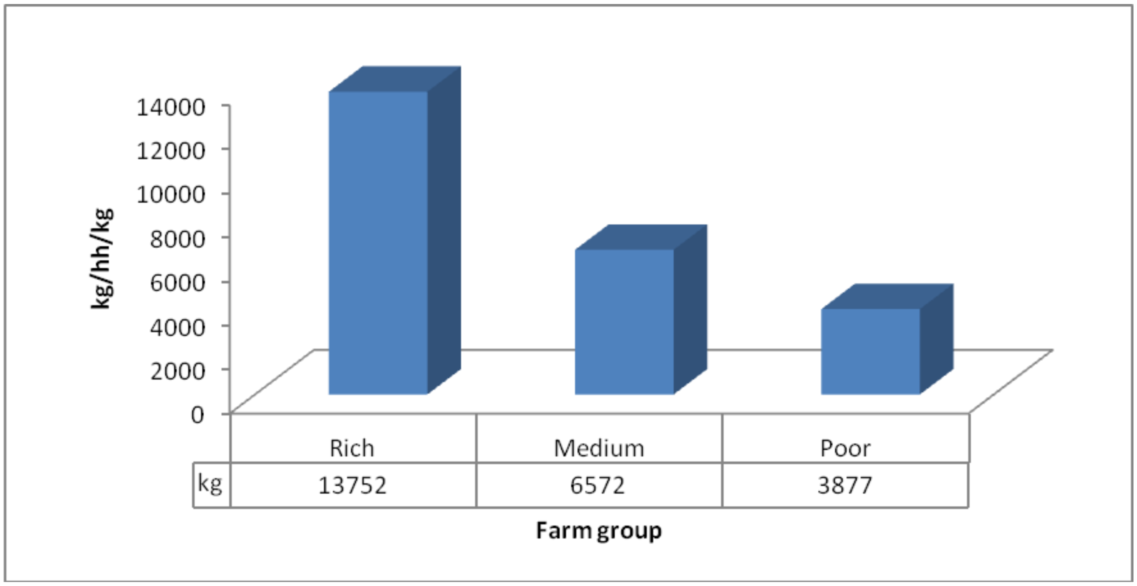


Figure 4.25 Organic Carbon flow analysis in kumbursa village

Source: Laboratory result, 2014

Organic carbon depletion rates differ significantly among different farmer wealth groups. The highest amount were recorded for the rich farm group (137527kg/hh/yr), followed by the medium (6572 kg/hh/yr) and poor farm group (3877 kg/hh/yr). These differences are associated with the differences in crop production, i.e., higher crop production by rich farm group, followed by the medium. The rich farmers have large land size as a result produce more yield and residue. Moreover the rich farm wealth group posses more livestock that produces more manure. On the other hand, the low rates of depletion of organic carbon in the poor farm group are partly associated with low crop production, and smaller number of livestock hence small amount of manure that directly related to lower carbon removal.

4.4 Soil fertility status of the study area

It should be noted that there is no worldwide accepted single criterion used for interpretation of analytical soil data. It all depends on the methods used and procedures followed in the determination of the properties in the laboratory and the intended use of the land or crops to be cultivated. Different field crops have different nutrient requirement and toxicity tolerant levels, which makes the definition of single criterion difficult. For this particular study the following criteria edited by J.R Landon (Booker Tropical Soil manual, 1991) was used as a reference to evaluate the natural soil fertility status of the study area.

Table 4.2 Critical values of Organic Carbon (OC), Total Nitrogen (N), Available Phosphorus (P) and exchangeable Potassium (K).,Kumbursa village, Ada'a District, Central Ethiopia.

Nutrient Rating	Nutrients			Exch.K Cmol/100g soil
	OC%	TN%	AV.P(ppm)	
Very High	> 20	> 1	> 22	> 0.8
High	10-20	0.5-1	13-22	0.5-0.8
Medium	4-10	0.2-0.5	6.5-13	0.3-0.5
Low	2-4	0.1-0.2	3-6.5	0.15-0.5
Very Low	< 2	< 0.1	<3	< 0.15

Source: Booker Tropical Soil Manual, 1991

Table 4.3 Organic carbon (OC) Total Nitrogen (TN), available P and Exchangeable K contents of the surface soil (0-20 cm) land utilization types in Kumbursa, Central Highlands of Ethiopia, 2014

Crop/homestead	Nutrients			
	OC (%)	TN (%)	Av. P (ppm)	Exch..K (Cmol/100g)
Homestead	2.56	0.28	17.8	2
Teff	1.46	0.103	4.11	1.67
Chickpea	1.5	0.13	16.6	1.44
Wheat	1.4	0.1	3.89	1.91

Source: Soil laboratory analysis, 2014

Organic Carbon content was very low in all crop fields teff (1.46%), chickpea (1.5%) and wheat (1.4%), while it was marginally medium in homestead (2.56%). Nitrogen content in the surface soil (0-20 cm) for homestead was medium (0.28%), while it was low for teff (0.103%), chickpea (0.13 %.) and wheat (0.10%). Available phosphorus of the surface soil (0-20 cm) land utilization types homestead and chickpea was high, homestead (17.8 ppm), chickpea (16.60 ppm),while it was low for teff (4.11 ppm) and wheat (3.89ppm) Exchangeable K of the surface soil is for the all land utilization type homestead (2.0 Cmol/100gsoil), teff (1.67Cmol/100gsoil),chickpea (1.44Cmol/100gsoil) and wheat (1.91Cmol/100g soil) is very high when compared to the reference explained in.(table 4.3). In general from this data it can be concluded that the contents of Organic Carbon, total Nitrogen and available Phosphorus are low in all crop fields while exchangeable Potassium is very high. The soil of the area is dominated by verity soil. It swells when wet and cracks when dry..The area is continuously cultivated and hence there is continuous nutrient mining through crop harvest and residue removal from the crop fields. Therefore applying these nutrients to crop fields is necessary to counterbalance the deficiencies, while potassium was sufficient as it was generally accepted that most Ethiopian soils are rich in Potassium.

Chapter Five

5. Conclusion and Recommendations

5.1 Conclusion

In the preceding chapter, resources quantification, nutrient balances and soil fertility status results have been presented and discussed. The most important findings of the study have been summarized and concluded below:

Resources that flow in to the farm system include chemical fertilizer, animal concentrate, food items, and live animals. Farm system outflows consisted of grain from stock, dung cake, live animals and livestock products, i.e. eggs, skins and hides sold as a source of cash. The major resources that are responsible for nutrient import to the farm system were chemical fertilizer and animal feed concentrate.

Crop yields and crop residues were flow from crop production sub system to Household and animal production sub systems respectively. Manure flows from animal production sub system to the household sub system. House waste flows to the crop farm system near the homestead. Labour flows from household to both crop and animal production sub systems.

The quantification of NPK at farm level was positive for N and P, while K was negative. This is due to the fact that potassium is not applied as chemical fertilizer in crop fields of the study area. NPK analysis for sub farm system shows that crop production sub system was negative for the three macro nutrients while, positive for both animal and household sub systems crop fields are negative because more nutrient is removed through resources (crop yield and crop residue).while there is accumulation of nutrients in the animal and household sub systems. N and K balances were positive for the poor and medium farm wealth group, while Negative for the rich farm wealth group. P was positive, for all farm groups. This is because of more resource flow to the market from rich farm group since the rich produced more and sold it the market.

Analysis of NPK at field scale shows that N and K were negative for teff and wheat fields, while P was positive. But N, P and K were negative for chickpea field. Chemical fertilizer was not applied for pulses such as chickpea. Similarly potassium was not applied as chemical fertilizer in crop fields as it was assumed that Ethiopian soils are rich in potassium.

Soil fertility analysis for the study area shows that organic carbon, total nitrogen and available phosphorus were low in all crop fields while exchangeable potassium was very high. Therefore, application of inorganic and organic fertilizer sources is important to replenish the low content of nutrients in the study area.

5.2. Recommendations

The government formulated different policies to improve the lively hood of the rural population. Among the efforts made by the government, natural resource conservation and soil fertility management for sustainable agricultural production are the most important practices of the government. Despite the efforts made by the government, still crop productivity is greatly hampered by inadequate application of soil fertility amendments, removals of nutrients through crop harvest and crop residues, use of animal manure for fuel. In line with this the following recommendation were forwarded to strengthen the government effort so far on practices:

- Soil fertility management problem in the study village can be addressed both through the use of adequate soil fertility amendment inputs and minimizing organic nutrient losses. This can be done through application of chemical fertilizers and organic sources such as: manure, crop residues and domestic waste to the field.
- To feed the increasing population, the crop yields need to increase beyond the current level. This cannot be achieved without increasing the nutrient input. Both organic and mineral fertilizers have a role to play. Mineral fertilizers are expensive, hence it is better if future researches focus on how to increasing the use of organic fertilizer in smaller farming systems.
- Substituting the prevailing traditional household energy with modern and sustainable energy such as small scale household biogas digesters, rural electrification and energy efficient cook stoves can help to minimize the use of animal manure for fuel thereby increasing the availability of organic matter for soil fertility amendment.
- Provision of continuous training and awareness to the farmers on soil fertility management is advisable to improve the awareness of farmers for sustainable soil fertility management.

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ANNEXES

Annex 1: House Hold Survey Questionnaire

November 2013

Structured survey questionnaire

Addis Ababa University

Graduate Studies

College of Social sciences

Department of Geography and Environmental studies

A Questionnaire to be completed by Farmers of Ada'a District, Ude peasant Association, kumbursa village

Dear Farmers,

This questionnaire is designed to gather information for a study on small holder's farming systems of Ada'a District to quantify resources and nutrient flows.

I hope that the research outcomes will contribute to the way forward for sustainable management of available resources and improved household income, energy and soil fertility in land management practices

Please note your individual responses will be kept confidential, and only aggregated results from the whole survey will be used for the purpose of the study.

Yours faithfully

Bogale Gelana

Questionnaire for Farmers to quantify resources and nutrients flow, in small farming systems of Kumbursa village=, Ada'a District, Central Ethiopia

Enumerator: -------------------------------

Date of interview: ----------------------

PA's -------------------------

Village ---------------------

GPS coordinates at / near the farm of respondent

a. Latitude: ---------------- b. Longitude: ------------------- c. Altitude ----------------

1. General information

.Gender of the respondent: 1) Male 2 Female

Age of the respondent ______________________________

Marital status of the household head

1) Single 2) Married 3) Divorced 4) Widowed

1.4. Educational status of the household head

1) cannot read and write 2) can read and write 3) Elementary school 4) Junior secondary (7-8) 5) Secondary high school (9-12) 6) Diploma (or equivalent

1.5. Is the respondent head of the household?

1.Yes 2 No

1.6. Age and sex composition of the household family (including the household head)				
No.	Age	Male	Female	Total
1	0-5			
2	5-15			
3	15-30			
4	30-60			
5	60+			
	total			

2. Overall land holding and land use characteristics

2.1. Total size of land you own in ha (or in local unit) ___________________

2.2. In how many plots is your total land situated? ____________________

Plot	Area of plot		Current land use	Means of owning the land	Distance away from the home (in km or hr)
	Area	Unit			
1					
2					
3					
4					
5					

2.3. Do you have serious problem of land shortage?

1) Yes 2) No

2.4 If Q 2.3 is yes how do you solve the problem?

1) Rented 2) Crop Share 3) Gift 4) Other, please specify

3. Sources and utilization of fertilizers

3.1. Do you use soil fertility amendment inputs to your farmland?

1) Ye 2) No

3.2. If the answer for question 3.1 is yes, what types of inputs do you use? Multiple responses are possible.

1) Chemical fertilizers 2) Manure 3) Compost 4) crop rotation 5. Incorporate crop residues in the soil/field 6) specify, if any other _______________-

3.3. Rank your preference for the following inputs/ as per your preference to apply in your farm field (1 = most preferred and 5=least preferred)

No.	Input/inflow type	Rank	Reason for your preference
1	Chemical fertilizers		
2	Manure		
3	Compost		
4	Incorporate crop residues in the soil/field		
5	if any other		

3.4. Do you face any problem in applying these inputs to your field?

1) Yes 2) No

3.5. If the answer is yes, what is the problem?____

3.6. Please specify the type and amount of fertilizer used on different crops last season?

Plot	Crop grown	Area allocated in ha	Fertilizer used		
			Type of fertilizer	Amount Used kg/ha	Price /Qt
1			1. 2. 3. 4.		
2			1. 2. 3. 4.		
3			1. 2. 3. 4.		
4			1. 2. 3. 4.		

Code:- 1) Urea 2) DAP 3) Manure 4) Compost25.

3.7 Which of the following soil fertility amendment techniques do you use? Multiple responses are possible.

1) Crop rotation 2) Intercropping/mixed cropping 3) Agro forestry 4) fallowing

4. Crop and residue production

4.1. How much crop yield and residue you produced last season?

Plot	Crop grown	Area allocated (ha/)	Total yield in kg	Total crop residue in kg
1				
2				
3				
4				

5. Crop and residue utilization

5.1. For what purpose do you use the crop produced?

Plot	Crop grown	Utilization of crop product in kg		
		Used as house hold food	sold to market	Other uses
1				
2				
3				
4				

5.2. What do you do with the crop residue?

Plot	Crop grown	Utilization of crop residues in kg			
		Left on land for soil fertility improvement	Feed for livestock	Sold to market	Used as Firewood
1					
2					
3					
4					

6. Household animal production

6.1. What type and amount of animals do you own

Animal type	Number of animals
1.cows	
2. Oxen	
3.Heifers	
4. Calve	
5.sheep	
6.goats	
7.horses	
8.donkeys	
9..poultary	

6.2. Does your household graze animals away from the house?

1. Yes 2. No

6.3.if Q 6.2 is yes where do your animals graze?

1. On communal lands 2. On own pasture land

3. On own crop land residues 4. Others, specify

6.4. For how many (months of the year do) they graze on the above fields? Complete this information in the table below

No.	Grazing fields	Months of the year	Remark
1	communal lands		
2	own pasture land		
3	own crop land residues		
4	Others (specify)		

6.5 For how many hours of a day do your animals stay in:

1) Kraal___________________ 2) Field_____________________

7. Animal manure production and utilization

7.1. For what purpose do you use the animals waste (dung)? What portion per annum?

No.	Use of animal manure	Percent of the total (estimate)	Remark
1	As fuel for household energy		
3	As compost for farmland		
4	As fuel for market		
5	For house decoration		

8. Energy demand assessment

8.1. Who cooks most?

1. Female 2. Male

8.2. How many meals are prepared per day (incl. Breakfast, lunch and dinner)?

1. One 2. Two 3. Three 4. More than three

8.3. How many minutes or hours do you spend cooking per meal?

1. Breakfast____ 2.Lunch ____ 3. Dinner ____ 4. Lunch and Dinner ____

8.4. Do you boil drinking water?

1. Yes 2. No

8.5. How many rooms do you light during the night?

1. One 2. Two 3. Three 4. Four 5.more than four

8.6. How many hours do you light these rooms?

1 1-.2hs 2. 3-4hrs 3. 4-5 hrs 4. More than 5hrs

8.7. Household fuel supply source

Fuel source	Where does your household get fuel?	What is the distance of the fuel source from your household?	What difficulties do you face to get this fuel?	How does your household store the fuel?
Kerosene				
Candles				
Charcoal				
Firewood				
Cow dung				
Solar energy				
Alternative energy				

Thank you!

Annex 2 Checklists for Focus Group Discussions

Meals cooked and time spent per meal

a) breakfast--------------------

b) lunch-----------------------

c) Dinner--------------------------

Total--------------------------

Water consumption

a) Source of water--------------------------

b) Size of water vessel/jerkan//used--------------

c) Amount of water needed per day---------------

d) Time spent per day /minutes/---------------------

e) Frequency of water collection---------------------

f) Distance from the household--------------------

g) Who fetch the water----------------------------?

3. Cooking fuel

a) Source of fuel----------------------

b) Fuel wood used per week/kg/--------------cost----------

c) Dung cake used per week/kg/---------------cost----------

d) Do you sell dung cake? ---------------------------------

e) If yes, how much? -------------------------------------

4. Lighting

a) Source of light---------------------------

b) Volume used per week------------------------

c) Cost per week------------------------------

d) Distance to buy the light source-----------------

5. Household refusal utilization

a) What do you do with waste from the house? ---------------------------

6) Seasoning

a) Types of seasoning-------------------------

b) Cost of the seasoning used per week------------------------

7) What are the sources of finance for household expenditure? ------------------------

Annex 3 Checklist for Agriculture and Energy office experts' interview

Dear Experts of agriculture and energy of Ada'a District,

This questionnaire is designed to gather information on resource and nutrient flow in small holder's farming systems of Kumbursa village, Ada'a District to resources and(nutrient.

I hope that the research outcomes will contribute to the way forward for sustainable management of available resources and improved household income, energy and soil fertility in land management practices.

Please note that your individual responses will be kept confidential, and only aggregated results from the whole survey will be used for the purpose of the study.

Yours faithfully

Bogale Gelana

1. What are the sources of energy in kumbursa village?
2. Did farmers use organic fertilizer such as: manure and crop residues for soil fertility amendment? If not why?
3. Do farmers get training on soil organic source and their application? if yes how often?
4. What problems farmers face to use organic fertilizer sources?
5. Are there biogas users in Kumbursa? If yes pass to q6.\
6. Do you give training to the users of biogas digesters? If yes, How often and on which issues?
7. Do you make continuous follow up of the biogas digesters?
8. Do you make spare parts (bulb, gas tubes) available to the users of biogas digesters?
9. Do you maintain biogas digesters whenever there are technical problems?
10. Which model/s of biogas digesters are most preferred and why?
11. What are the major challenges you are facing in disseminating biogas digesters to the community?
12. Your general comments on how to exploit maximum benefits from biogas digesters.

Annex 4. Soil nutrient content

Land utilization type	Bulk Density (g/cm3)	%OC	%TN	Available P.(Olsen) (mg/kg	Total P (mg/kg	Ex K (mg/kg	Total K (mg/kg
Homestead	1.11	2.56	0.28	17.8	371	200	672
Teff	1.68	1.46	0.103	4.11	90	167	672
Chickpea	1.71	1.50	0.13	16.6	362	144.0	493
Wheat	1.58	1.4	0.097	3.89	85	191	603

Annex 5 organic fertilizer sources nutrient content

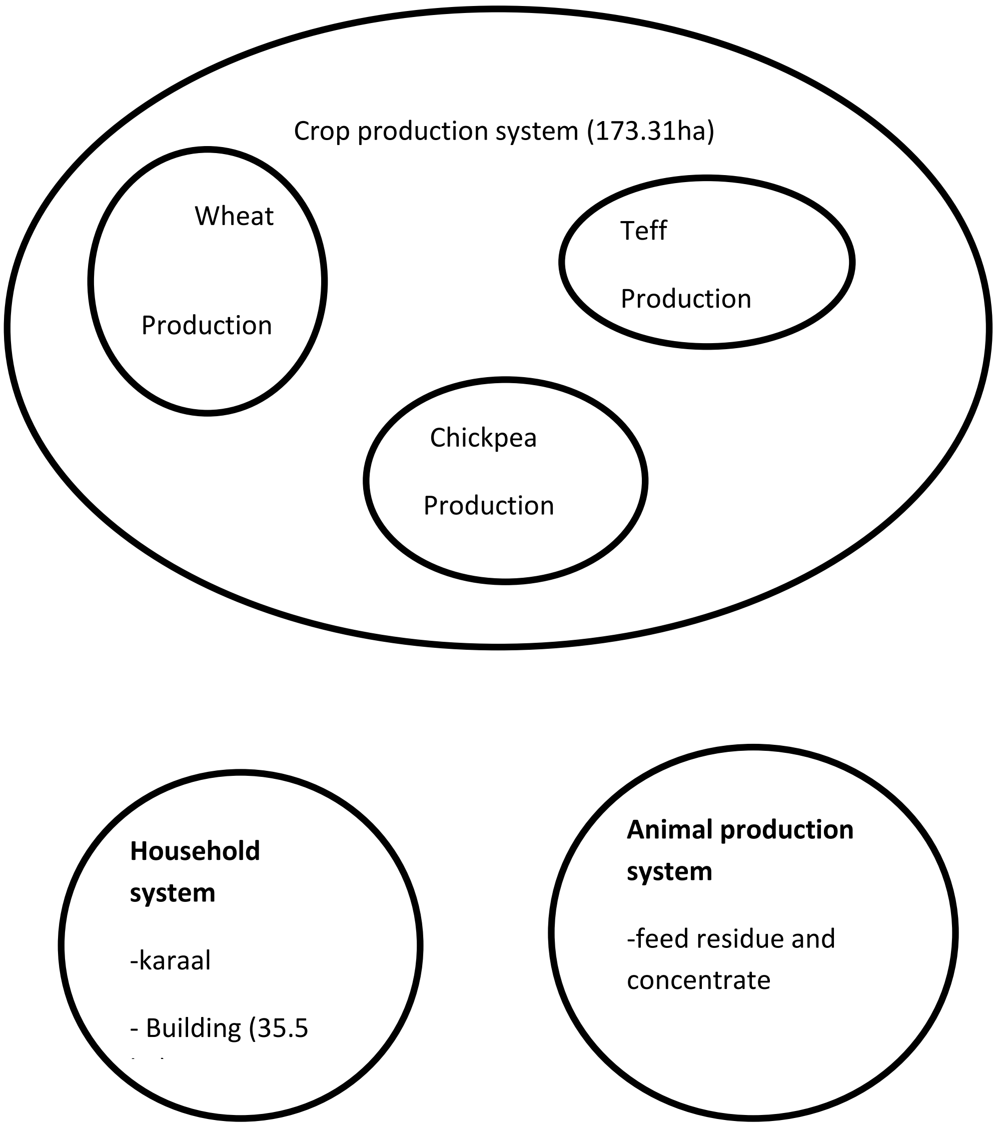
Organic source	%N	%P	% K	%OC
dung cake	1.7	0.46	2.28	56.8
cow manure	1.5	0.41	2.04	45.81
compost	0.74	0.73	0.7	56.8
Animal feed concentrate	2.49	0.78	1.3	55.36
donkey manure	1.87	0.2	0.03	56.79

Annex 6 Crops and crop straw nutrient content

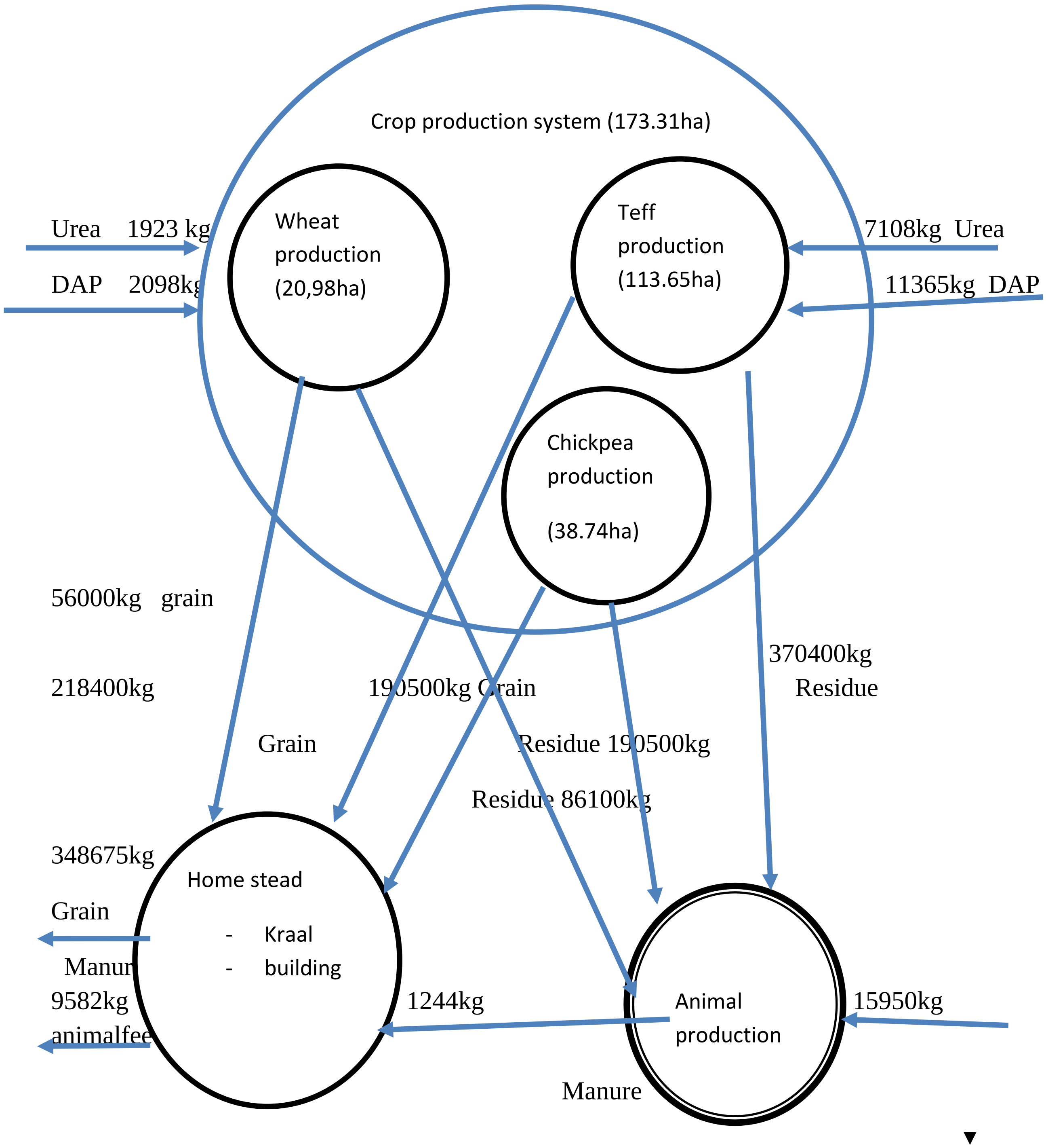
crop type	%N	%P	%K	%OC
teff	1.88	0.4	0.5	54.47
chickpea	4.41	0.61	1.5	54.29
wheat	1.94	0.34	0.46	54.53
Teff straw	1.01	0.13	0.9	52.45
chickpea straw	1.04	0.12	2.87	55.72
wheat straw	0.39	0.1	1.11	51.38

Annex 7 Resource flow map in Kumbursa village

Step 1 visualization of farming system



Step 2. Resource flow of the farming system



Annex 8. Average monthly rainfall and temperature of Ada'a district (1965-2013)

Months	Rainfall(mm)	Temperature (0C)
Jan	9.87	17.1
Feb	26.58	18.34
Mar	49.87	19.28
Apr	57	19.71
May	51.43	19.71
Jun	89.57	19.13
Jul	210.66	18.22
Aug	199.94	18.15
SePt	93.4	18.07
Oct	18.55	17.31
Nov	7.37	16.33
Dec	2.53	16.51