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Evaluating the planning and implementation process of water harvesting and irrigation systems from an innovation systems perspective. Lessons from Lare and Gilgil, Kenya.

Master thesis
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ABSTRACT

Agriculture is the main occupation in Kenya, and 80 % of the population rely directly or indirectly on this sector. Most of the farmers have rain-fed agricultural systems, although 80 % of land is considered semi-arid or arid and is therefore not suitable for this type of agriculture. Thus enhancing irrigation and water harvesting systems can bring forward increased yields and an improved use of the existing water resources, which can cause an increase in food security as well as a decrease in water scarcity.

According to the Agricultural Innovation System (AIS) approach, innovation builds on interactions between research and economy, the behavioural pattern of all organisations involved and an environment that enables interaction and knowledge transfer. Furthermore it has been concluded that economic welfare always involves environmental and social sustainability. Innovation refers to the use of knowledge to bring about social or economic change. The AIS approach also states that stakeholders and their demands need to be included in the innovation process as their requirements signalise in which direction innovation needs to be guided.

This thesis aims at depicting how farmers in Lare and Gilgil, two locations in Kenya, have adopted water harvesting and irrigation systems in their farming system and whether one can speak of innovation as defined in the AIS approach. Therefore not only should it outline which measures have been taken to use the existing water resources for agricultural as well as domestic purposes in an improved way, but it should also illustrate if these measures have led to economic or social change. Based on the AIS approach, the main actors involved in triggering the measures and the steps taken to enable interaction and knowledge transfer during planning and setting up water harvesting and irrigation systems were identified, focusing especially on the farmers' role during the whole planning and implementation process. In order to get a picture of available water resources, potential changes and crop water requirements, transect walks were conducted, existing hydrological data was evaluated using SPSS and crop water requirements were calculated using CROPWAT.

Various stakeholders from the private and public sector were involved in triggering water harvesting and irrigation systems both in Lare and Gilgil and many steps were taken to enhance interaction and knowledge transfer. Although the level of stakeholder interaction and knowledge transfer varied between single farmers, a multiplicity has adopted water management measures. The thesis suggests that farmers include traditional knowledge when implementing water management systems. Furthermore it argues that if multi-level interaction and knowledge transfer were improved and if access especially to financial resources was enhanced, farmers could make even better use of the available water resources.

Keywords: Water harvesting, irrigation, water availability, crop water requirements, knowledge transfer, indigenous knowledge, agricultural innovation systems

ZUSAMMENFASSUNG

Rund 80 % der kenianischen Bevölkerung sind direkt oder indirekt vom Landwirtschaftssektor abhängig. Die meisten Bauern und Bäuerinnen betreiben Regenfeldbau, obwohl 80 % des Landes als halb-trocken oder trocken eingestuft sind und daher nicht für diese Art von Landwirtschaft geeignet sind. Die Etablierung von Bewässerungs- und Regenwassersammlungssystemen kann daher höhere Erträge und eine bessere Nutzung der vorhandenen Wasserressourcen begünstigen, was wiederum zu einer Erhöhung der Ernährungssicherheit und einer Reduktion der Wasserknappheit führt.

Gemäß dem Zugang der Landwirtschaftlichen Innovationssysteme (LIS) entwickelt sich Innovation aus Interaktionen zwischen Forschung und Wirtschaft, den Verhaltensweisen aller beteiligten Organisationen und einem Umfeld welches Interaktion und Wissenstransfer ermöglicht. Des Weiteren wurde darauf geschlossen, dass wirtschaftliches Wohlergehen immer mit ökologischer und sozialer Nachhaltigkeit in Verbindung steht. Gemäß dem LIS Zugang bezieht sich Innovation auf die Nutzung von Information, um soziale oder wirtschaftliche Veränderungen hervorzurufen. Außerdem bedarf es alle Akteure und deren Bedürfnisse im Innovationsprozess mit einzubeziehen, da diese signalisieren in welche Richtung Innovation geleitet werden muss.

Diese Arbeit zielt darauf ab zu zeigen, wie Bäuerinnen und Bauern in Lare und Gilgil, zwei Gebieten in Kenia, Regenwassersammlungs- und Bewässerungssysteme implementiert haben und ob diese Systeme Innovationen darstellen. Es wurde ermittelt wer die Maßnahmen hervorgerufen hat und welche Schritte gesetzt wurden, um Interaktion und Wissensaustausch während des Planungs – und Implementierungsprozesses von diesen Systemen zu fördern. Besonderes Augenmerk lag dabei auf der Rolle der Bäuerinnen und Bauern während des Prozesses. Um ein Bild von den vorhandenen Wasserressourcen, Veränderungen im Wasserdargebot und vom Pflanzenwasserbedarf zu bekommen wurden Transekte durchgeführt, hydrologische Daten mit SPSS ausgewertet und der Pflanzenbedarf mithilfe von CROPWAT ermittelt.

Zahlreiche Akteure aus dem privaten und öffentlichen Sektor waren sowohl in Lare als auch in Gilgil bei der Entwicklung von Regenwassersammlungs- und Bewässerungssystemen beteiligt und unterschiedliche Schritte wurden gesetzt, um Interaktion und Wissensaustausch zu ermöglichen. Obwohl der Grad der Interaktion und des Wissenstransfers zwischen einzelnen Bäuerinnen und Bauern unterschiedlich war, hat eine Vielzahl von ihnen wasserwirtschaftliche Maßnahmen gesetzt. Obwohl der Pflanzenwasserbedarf nicht durch den natürlichen Niederschlag gedeckt werden kann, ist der Gebrauch von Bewässerungssystemen noch nicht weit verbreitet.

Diese Arbeit soll zeigen, dass Bauern und Bäuerinnen traditionelles Wissen bei der Implementierung von Wassersammlungs- und Bewässerungssysteme einbringen. Die vorhandenen Wasserressourcen könnten noch besser genutzt werden, wenn Interaktion und Informationsaustausch in alle Richtungen sowie der Zugang insbesondere zu finanziellen Ressourcen verbessert werden würde.

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LIST OF ABBREVIATIONS

AICAD – African Institute for Capacity Development

AIS – Agricultural Innovation System

CIA – Central Intelligence Agency

EU – Egerton University

FAO – Food and Agriculture Organization of the United Nations

GDP – Gross Domestic Product

JICA – Japan International Cooperation Agency

KARI – Kenya Agricultural Research Institute

KWAHO – Kenya Water for Health Organisation

SEI – Stockholm Environment Institute

UNEP – United Nations Environment Programme

UNDP – United Nations Development Programme

WGF – Water Governance Facility

WRMA – Water Resources Management Authority

1 INTRODUCTION

Kenya, with a total of 493 m³ of internal renewable freshwater resources per capita, can be classified as a severely water scarce country (World Bank. 2011, Pereira 2009). Nonetheless, the country is far from taking full advantage of the available water supplies (Mogaka et al. 2006). According to Alila and Atieno (2006, p. 3) roughly 80 % of Kenya's population live in rural regions and live directly or indirectly off agriculture. According to various authors (Alila and Atieno 2006, p. 3, FAO 2012a, Frenken 2005, p. 290), not only do the livelihoods of the majority of Kenyans depend on agriculture, but the economy on the whole relies on this sector. Therefore it is crucial to enforce the development and long term performance of the agricultural sector (Alila and Atieno 2006, p. 3). According to the UNEP report *Facing the Facts: Assessing the Vulnerability of Africa's Water Resources to Environmental Change* (2005), Kenya has faced several droughts in the past decades. Both the intensity and frequency of droughts are likely to increase, and Kenya is going to face severe water scarcity in the upcoming years due to a decrease in rainfall and an increase in water demand (UNEP 2005).

Kenyan farmers predominantly have rain-fed production systems and are therefore dependant on the two annual rainy seasons. Due to the existence of a number of different agro-ecological zones, the efficiency of rain-fed agriculture has a high variance (Government of Kenya 2010). Only around 12 % of Kenya's total land area is considered well suited for growing crops, while land considered semi-arid or arid makes up around 80 % of the overall area (Kabubo-Mariara and Karanja 2007). Enhancing irrigation and rain water harvesting measures can lead to improved yields and a more efficient use of existing water resources and can thus improve food security and reduce water scarcity (Kiome 2009).

This thesis is an integral part of the WATERCAP project "Strengthening universities capacities for mitigating climate change induced water vulnerabilities in East Africa", funded by the Austrian Partnership Programme in Higher Education and Research for Development - Appear. The aim of WATERCAP is to fight climate change induced water vulnerabilities in Uganda and Kenya by emphasizing partnerships between different stakeholders who are involved in developing strategies to increase water reliability and reduce uncertainties in agricultural production, thus enabling food security. Strengthening these partnerships should enable innovation capacity as well as mutual learning and knowledge transfer, which are critical factors in finding strategies to cope with water scarcity (Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) 2010).

This thesis aims at contributing to the WATERCAP goal by evaluating the current situation in two research sites with respect to water availability and potential changes in the rainfall quantity, crop water requirements, water management measures, identifying responsible authorities in water related questions as well as to describe the planning and implementation process of existing water management measures in an agricultural innovation systems perspective.

According to the Agricultural Innovation System (AIS) approach, innovation builds on interactions between research and economy, the behavioural patterns of all organisations involved and an environment that enables interaction and knowledge transfer. Furthermore it has been concluded that economic welfare always involves environmental and social sustainability. Innovation refers to the use of knowledge to bring about social or economic change. The AIS approach also states that stakeholders and their demands need to be included in the innovation process, as their requirements signalise in which direction innovation needs to be guided (World Bank. 2007).Therefore the stakeholders involved in the development of water harvesting and irrigation measures are identified, and the role of farmers, the use of their knowledge in the planning and implementation process as well as the innovation capacity of the measures are analysed.

1.1 Objectives of the thesis

This thesis aims at finding out whether farmers in two Kenyan research sites are affected by water scarcity and whether they have adopted any water harvesting and irrigation systems to manage the existing water resources in an improved manner. It also depicts the farmers' requirements with respect to water resources for agricultural purposes. Furthermore hydrological data was collected and evaluated in order to identify the potential amount of rainwater that can be harvested, the crop water requirements and also if changes in climate have taken place over the past decades. The objectives can be summarized as follows:

1. To evaluate the current situation of the research sites in terms of water availability and crop water requirements and potential changes of water availability over the past decades
2. To describe the research sites in terms of natural resources, land use and water management measures
3. To identify existing water harvesting and irrigation systems and their innovative capacity
4. To identify both the male and female farmers' water requirements, their role in the planning and implementation process and how water harvesting and irrigation systems are used
5. To identify the actors involved in triggering existing agricultural, water-related measures with special focus on water harvesting and irrigation systems and the main actions that were taken to enable interaction and knowledge transfer between all stakeholders, both men and women, during the planning and implementation process

1.2 Research questions

The main research questions can be formulated as follows:

1. What is the current state of water availability and crop water requirements and has the quantity changed?
2. How can the existing conditions in terms of natural resources, land use and water management measures be described?
3. Which irrigation and water harvesting systems have been implemented and have these systems brought about innovation?
4. How are the farmers' water requirements, capabilities and knowledge taken into account in the planning and implementation of water harvesting and irrigation systems and how are the existing systems used?
5. Who was involved in the development and which actions were taken in enabling interaction and knowledge flow between all stakeholders in the planning and implementation process of these two water related measures: Water harvesting and irrigation systems?

2 Literature Review

2.1 Agriculture in Kenya

2.1.1 Basic information and farming systems

Agriculture plays a very important role in Kenya's economy, as 19 % of the country's GDP result from this sector and approximately 75 % of the national labour force works in the field of agriculture (CIA 2012). Furthermore agriculture accounts for 65 % of the country's export earnings. In addition, agriculture indirectly administers another 27 % to the GDP, considering its interrelation with other branches such as the manufacturing, service and distribution sector (FAO 2012a). Around 80 % of the country's inhabitants live in rural areas and directly or indirectly depend on agriculture (Alila and Atieno 2006, p. 3). Considering these Figures, not only do the livelihoods of the majority of Kenyans depend on agriculture, but the economy on the whole relies on this sector. Therefore it is crucial to enforce the development and long term performance of the agricultural sector (Alila and Atieno 2006, p. 3). The strong interconnection between agriculture and the overall economy results from limited natural resources available, the poor development of the industrial sector as well as the dependence of other sectors' well-being on that of agriculture, such as tourism, which only flourishes when appropriate food supply is ensured (FAO 2012a). Around 80 % of the people working in the agricultural sector are made up of smallholder farmers (Frenken 2005).

Kenya's agricultural branch can be divided in to six sub-categories, comprising food crops, industrial crops, horticulture, livestock, fisheries and forestry. As little as 16% of Kenya's land area reveals medium to high potential as well as can rely on continuous and sufficient rainfall for agricultural purposes. This area is mainly used for business oriented agriculture, comprising 31 % cropland, 30 % grazing land and 22 % forests. The remaining 17 % of land are used for markets, infrastructure, game parks and urban centres (Government of Kenya 2010).

Major food crops grown in Kenya comprise maize, cassava, sorghum, millet, wheat, potatoes, sweet potatoes, bananas, fruits and vegetables. Maize is the staple food of the majority of the Kenyan population and therefore takes up a large part of the agricultural land. In 1998, 1.5 million hectares out of 3.12 million hectares occupied by food crops were covered by maize. Cash crops include tea, coffee, horticultural crops, pyrethrum and cotton (Frenken 2005).

About 84 % of Kenya's total area is considered arid or semi-arid, making it unsuited for rain-fed agriculture, as precipitation occurs in insufficient amounts or is very unevenly distributed (Government of Kenya 2010). Nonetheless, the country's agricultural production system is mainly rain-fed (Frenken 2005), which means that crop yields are reliant on the country's two annual rainy seasons (Government of Kenya 2010).

In zones of high humidity and elevation, rain-fed agriculture accounts for constant and efficient yields, whereas in regions of medium elevation there is a high risk of crop shortfall due to an uncertainty in the rainfall amount and distribution (Government of Kenya 2010). The low rainfall zone consists of arid and semi-arid regions, having an average rainfall of 400 mm per year. Farmers in this region usually have a mixture of crops and livestock, which are often not suitable for rain-fed agriculture and the existing soil conditions (Government of Kenya 2010). Due to the existence of large semi-arid and arid areas, the investment in irrigation and water harvesting systems to serve agricultural purposes is unavoidable. This step could lead to providing food security for a rapidly growing population as well as bring about economic stability (Blank et al. 2002).

2.1.2 *Development of the Agricultural Sector*

According to the Kenyan Government Report *Agricultural Sector Development Strategy 2010 – 2020* (2010, p. 1), economic growth during the first two decades after gaining independence in 1963 showed an upward trend. Agricultural revenues rose and as a result there was an average economic growth of 7% per annum. Due to a call from the first president, Jomo Kenyatta, encouraging the population to "return to the farms", there was a rise particularly in small-scale agriculture. This shift towards agriculture led to an expansion of agricultural areas due to the fact that sufficient land was available and technology was used more adequately. Furthermore the government promoted research and agricultural extension and implemented agricultural organisations for farmers, agricultural inputs as well as for marketing and credits (Government of Kenya 2010).

This trend, however, could not be maintained. From 1990 onwards a decline in agricultural growth could be observed, resulting from decreased investments in the sector, less support and interest in agricultural expansion and research as well as from inadequate management and dissolution of agricultural institutions. The budgetary allocation to the agricultural sector had declined from 13 % to 2 % (Government of Kenya 2010). This development resulted from a change in policies which were initiated by a World Bank Report written in 1981 by Elliot Berg on *Accelerated Development in Sub-Saharan Africa: A Plan for Action.* as a reaction to a decline in Kenya's overall economy and the country's high debts, which were a result of an imbalance in trade due to unfavourable trade policies and a fast growing population. The report recommended that the private sector in key industries had to be strengthened as well as that exports and market reforms be prioritized. As a result the World Bank moved financing from the agricultural sector to the public sector and aid became earmarked (Banutu-Gomez 2011, Mihevc 1995). The World Bank promoted Structural Adjustment Programs (SAPs) which should enhance trade, growth in the private sector and increasing financial capacity. The SAPs did not automatically promote agriculture as was assumed and the induced reforms did not deliver the expected results. Aid from the World Bank and other western countries did not bring about sustainable development because of various reasons like lack of participation of African management in the process, lack of long term strategies and lack of coordination between the various donors (Akaki 2003).

From the year 2000 onwards, and especially after 2003 when the government decided to reinvest in agriculture, the sector started recovering and growing anew. From then onwards, 4.5 % of the country's GDP was allotted to the agricultural sector. Agriculture faced another setback in 2007 due to violence after the general elections and in 2008 due to the financial crisis, causing food and fuel prices to rise (Government of Kenya 2010).

2.1.3 *Agricultural Policies and Strategies since 2003*

Policies affecting the agricultural sector have an influence on the overall economy. These policies result from governmental decisions that have an impact on fluctuations in input and output prices, costs and revenues, public expenditures for agricultural production and the allocation of resources (Alila and Atieno 2006).

Kenyan agricultural policies lay value on food security, an equal distribution of food, increased agricultural efficiency as well as production, higher earnings particularly for smallholders, irrigation to ensure consistency in agricultural performance and marketing measures (Alila and Atieno 2006).

1. Economic Strategy for Wealth and Employment Creation (ERS)

In 2003 the newly elected government decided to prioritise the recovery of the agricultural sector by abandoning the former policy on poverty reduction and appointing new policies on economic recovery. The Economic Strategy for Wealth and Employment Creation (ERS) was introduced in 2003, shifting the focus from poverty reduction and food security to economic welfare as means to mitigate poverty and ensure sufficient food supplies. Agriculture was identified as one of the main pillars to help the economy recover. For that reason the government started reinvesting in agricultural research and reviving the former agricultural institutions. The ERS can be seen as the starting shot for the revitalisation of agriculture with the final aim to reduce poverty (Government of Kenya 2010).

2. Strategy for Revitalising Agriculture (SRA)

In 2004 the government came up with the Strategy for Revitalising Agriculture (ARS) as a supporting instrument to the ERS, its aim being "To transform Kenya's agriculture into a profitable, commercially-oriented and internationally and regionally competitive economic activity that provides high-quality, gainful employment to Kenyans" (Government of Kenya 2010), p. 6). The government aimed at triggering a shift from subsistence agriculture to agriculture with profitable and business oriented character. The strategy provided directions and a list of actions necessary to reach this transformation.

The SRA compiled the following changes necessary to approach the vision set up by the ERS (Government of Kenya 2010):

- Inspection and alteration of the existing judicial, regulatory and institutional conditions
- Reorganisation and privatisation of semi-governmental institutions
- Meliorated transmission of research and consulting services
- Enhanced access to agricultural inputs with good quality and monetary services
- Better accessibility to internal as well as external markets
- Implementation of new policies and programmes regarding food security

Vision 2030

As the ERS was planned only for five years and ended in 2007/08, a new strategy to pursue the aims of the ERS needed to be developed. The government came up with a strategy named Kenya Vision 2030 with its focus on Kenya's long term development. The main aim of this vision is to turn Kenya into a wealthy country with a high living standard by 2030. The vision is based on three main pillars, namely the economic, the social and the political pillar. As in the ERS and the ARS, Vision 2030 confers an important role to agriculture in working towards an improvement of the country's economic wellbeing. In order for the agricultural sector to contribute to the country's overall economic growth, the government puts an emphasis on converting subsistence agriculture into business – oriented, innovative and up-to-date agriculture (Government of Kenya 2010).

This change should be triggered by

- Rebuilding important institutions in agriculture, wildlife, forestry and livestock to foster agricultural growth
- Developing new land use policies for an improved use of arable land
- Developing new irrigation schemes in order to utilise more area for agriculture
- Increasing crop yields, livestock and trees
- Improving the accessibility to markets for smallholder farmers by improving the supply chain organisation
- Improving crop, livestock and forestry goods before passing them on to the market

According to Vision 2030, the four major challenges lie in increasing agricultural productivity, extending land used for agricultural purposes, optimising the supply chain as well as improving the farmer's access to markets and in adding value to the agricultural produce to make it more competitive on the international market (Government of Kenya 2010, p. 7).

3. Agricultural Sector Development Strategy 2010 - 2020

The Agricultural Sector Development Strategy ASDS was formed under the new government elected in 2008. It can be considered a leading document on national level for governmental agricultural entities as well as for all other stakeholders. The main aim of this strategy is to get both the private and the public sector more deeply involved in the challenges agriculture is facing. Furthermore the legal document considers ongoing amendments in policies and institutions, the structure of the new government, goals and achievements from the ERS and ARS as well as the content of Vision 2030. It also incorporates regional and international initiatives. It builds on the achievements of former strategies and recognises agricultural revival. It should enable further progress and development on a path that has already been set, its final goal being the achievement of poverty reduction and food security (Government of Kenya 2010).

The ASDS should ensure that the ministries of the agricultural sector enable and stimulate the use of most recent technologies and procedures by farmers, processors, producers and marketers. It also prioritises the efficient management of resources such as land, water, inputs and monetary resources (Government of Kenya 2010).

This strategy includes all agricultural policies, regulations and programmes which will be implemented by the government sooner or later and should lead to the final goal of food security and decreased poverty and unemployment (Government of Kenya 2010).

2.1.4 Agricultural Land and Agro-Ecological Zones

Agro-ecological zoning allows areas to be grouped according to their development potentials and constraints and is considered an important tool for rural land use management. According to the Food and Agriculture Organization, agro-ecological zones are defined "[...] on the basis of combinations of soil, landform and climatic characteristics" (FAO 1996a, p. 2).

Important parameters used for the classification of land are the crop requirements with respect to climatic and edaphic factors on the one hand and management practices applied in the area in which the crops are grown on the other. The zone classification takes place on the basis of the similarity of constraints and potentials and is used as a means to identify steps necessary to improve the land use situation, either by enhancing production or by counteracting land degradation (FAO 1996a).

If zoning is complemented by land use information in the form of land utilisation types and their ecological requirements, it can be used to assess available land resources. Agro-ecological zoning is applied to evaluate the land suitability and possible yields and when combined with additional information such as land tenure, land availability, infrastructure and costs, more exact and extensive analyses in natural resources and land use management can be undertaken. One of the main outputs of agricultural zoning are maps showing the zonal structure as well as land suitability and an appraisal of potential crop areas, production and yields (FAO 1996a).

Jaetzold et al. (2010, p. 16b) provide a detailed overview and classification of agro-ecological zones shown in Table 1.

Kenya can be divided into seven ecological zones, being the Tropical Alpine, Upper Highland, Lower Highland, Upper Midland, Lower Midland, Lowland and Coastal Lowland. Furthermore the country can be split into three major production areas, taking rainfall into consideration (Government of Kenya 2010):

1. High rainfall zone: This area is characterised by an annual precipitation above 1000 mm. It takes up around 20 % of the total usable agricultural land and comprises mostly food, cash crops and livestock. Main export goods resulting from this zone are tea, coffee, vegetables, potatoes, pyrethrum and around 75 % of milk products. Around 50 % of the population live in this zone.
2. Medium rainfall zone: In this zone the annual precipitation adds up to 750 to 1000 mm. About 30 to 35 % of the total production area is ascribed to this zone. Roughly 30 % of Kenya's population live in this area. The medium rainfall zone is used mainly for growing drought-tolerant crops and keeping cattle and small livestock. High migration from the high rainfall zone towards this region can be recorded.
3. Low rainfall zone: In this region precipitation amounts to 200 to 750 mm annually. Approximately 20 % of the country's population live in this zone. It comprises 80 % of the total livestock and around 65 % of wildlife.

Main Zones Belts of Z.	0 Ann. av.r. > 1.25 PET (perhumid)	1 (humid)[2]	2 (subhumid)[2]	3 (semi-humid)[2]	4 (transitional)[2]	5 (semi-arid)[2]	6 Ann. av.rainfall = 0.1 - 0.25 PET (arid)[2]	7 Ann. av.rainfall =less than 0.1 PET (perarid)[2]
TA **Tropical Alpine Zones** Ann. mean 2 – 10°C	Glacier Mountain Swamps	I Cattle – Sheep Zone			II Sheep Zone			* (High altitude deserts)
UH **Upper Highland Zones** Ann. mean 10 – 15° Seasonal night frosts	Forest Zones	Sheep-Dairy Zone	Pyrethrum-Wheat Zone	Wheat-Barley Zone	U. Highland Ranching Zone	(U. H. Nomadism Zone)[5]		
LH **Lower Highland Zones** Ann. mean 15 – 18° M. min. 8 – 11° normally no frosts		Tea-Dairy Zone	Wheat/Maize[3]-Pyrethrum-Zone	Wheat/Maize[3]-Barley-Zone	Cattle-Sheep-Barley-Zone	L. Highland Ranching Zone	(L.H. Nomadism Zone)[5]	
UM **Upper Midland Zones** Ann. mean 18 – 21° M. min. 11 – 14°		Coffee-Tea Zone	Main Coffee-Zone	Maize[4] and Marginal Coffee Zone	Maize[4]-Sunflower Zone	Livestock – Sorghum Zone	U. Midland Ranching Zone	U. Midland Nom. Zone[5]
LM **Lower Midland Zones** Ann. mean 21 – 24° M. min. > 14°		L. Midland Sugarcane Zone	Marginal Sugarcane Zone	Maize[4] and Cotton Zone	Maize[4] and Marginal Cotton Zone	L. Midland Livestock-Millet Zone	L. Midland Ranching Zone	L. Midland Nom. Zone[5]
L Lowland Zones **IL Inner Lowland Z.** Ann. mean > 24° Mean max. > 31°		* (Rice-Taro Zone)	* (Inner Lowland Rice-Sugarcane Zone)	* (Inner Lowland Cotton Zone)	* (Sorghum-Groundnut Zone)	Inner Lowland Livestock-Millet Zone	Inner Lowland Ranching Zone	Inner Lowland Nom. Zone[5]
CL Coastal Lowl. Z.6) Ann. mean > 24° Mean max. < 31°		* (Cocoa-Oilpalm Zone)	Coastal Lowland Rice-Sugarcane Zone	Coconut Cassava Zone	Marg. Cotton[7] and Cashewnut-Cass. Zone	Coastal Lowland Livestock-Millet Zone	Coastal Lowland Ranching Zone	Coastal Lowland Nom. Zone[5]

1) Inner Tropics, different zonation towards the margins. The T for Tropical is left out in the thermal belts of zones (except at TA), because it is only necessary if other climates occur in the same country. The names of potentially leading crops were used to indicate the zones. Of course these crops can also be grown in some other zones, but they are then normally less profitable.
2) No strict thresholds due to the different rainfall requirements of the leading crops of the main zones resp. different distribution of rainfall during the year see General Part.
3) Maize in small farms normally
4) Maize is a good cash crop here, but maize also in LH 1, UM 1-2, LM 1-2, L 1-4, and partly in the better subzones of LM 5 and L 5.
5) Nomadism, semi-nomadism and other forms of shifting grazing.
6) An exception because of the vicinity of cold currents are the tropical cold Coastal Lowlands cCl in Peru and Namibia. Ann. means there 18 – 24°C.
7) In unimodal rainfall areas growing periods may be already too short for cotton.
* Not occurring in Kenya.

Table 1: Agro-Ecological Zones (Source: Jaetzold et al. 2010, p. 16b)

2.2 Water Use in Agriculture in Kenya

The water withdrawal in Kenya amounted to 2.7 million m³ in 2002 of which 80 % was used for agricultural purposes and livestock, 17 % for domestic purposes and 4 % for industries. The demand was estimated to increase up to 5.8 million m³ in 2010 as the population is increasing (Frenken 2005).
Water for agricultural purposes is scarce, just as water in Kenya is in general, due to the fact that the existing water resources are unevenly distributed, both spatially and temporally, and that a part of the water resources such as the groundwater in the north-eastern region and in the Rift Valley area are not suited for agricultural purposes due to their chemical composition. Due to the high fluctuations in rainfall, Kenya is affected both by floods and by droughts (Mulinge et al. 2007).
Due to an unequal distribution of the water resources between and within Kenya's basins, water use conflicts between agriculture, livestock, environment and wildlife are common in certain areas (Frenken 2005). According to Mulinge et al. (2007, p. 15), another problem is the water supply as women have to walk far distances to fetch water.
The UNDP points out that the current water situation needs to be addressed by invigorating the development and management of water resources on local, national and regional level, and that water management doesn't solely restrict itself to the development and implementation of policies, but also applies to the provision of information, access to water and affordable technologies (UNDP Kenya and UNDP WGF 2007).

2.2.1 Water management, policies and legislation related to water use in agriculture

Kenya's government has made several efforts to improve the management and stop the degradation of water resources. It has recognised that water is not only essential for securing the population's livelihood, but also plays a key role in the achievement of economic as well as social wellbeing (Mogaka et al. 2006). The need to manage water is embedded in multiple papers on development policy issues, starting with the Sessional Paper No. 10 of 1965 (Republic of Kenya 1965, cited in Mogaka et al. 2006)
Other legal papers that incorporate water management issues comprise of the National Development Plans from 1974, 1994a, 1997, and 2002c established by the Republic of Kenya, the Sessional Paper No.1 of 1986 called Economic Management for Renewed Growth, the policy of 1992 on the evolution of land considered arid and semi-arid, the National Poverty Eradication Plan (1999-2015); the Sessional Paper No.2 of 1996 about Industrial Developments until the year 2020, the National Water Master Plan (1992), the National Environmental Action Plan (NEAP) and the Country Strategy on Integrated Water Resources Management (IWRM) (Mogaka et al. 2006).
The National Water Master Plan aimed to review existing laws concerning the management and use of water resources in Kenya and led to the establishment of the Water Act 2002 (UNDP Kenya and UNDP WGF 2007).

The Water Act 2002 brought about significant changes in the legal framework concerning water management issues. The main achievement was to divide the water agenda into water resources management and provision of water services. This led to the division of competencies regarding policy making on the one hand and everyday administrative and regulatory issues on the other. Further it was made possible to transfer certain duties to other subordinated state organs and the inclusion of non-governmental institutions in both the management of water resources as well as the provision of water services. The main developments comprise the splitting of water resources management and provision of water services, the division of competencies regarding policy making on the one hand and everyday administrative and regulatory issues on the other, the transfer of certain duties to other subordinated state organs and the inclusion of non-governmental institutions in both the management of water resources as well as the provision of water services. Furthermore the act triggered the development of a Human Rights Based Approach (HRBA) in the field of water within the Government of Kenya. The HBRA aims to promote the right to water as well as sanitation to all people, irrespective of their personal circumstances such as income or social standing (KWAHO 2009).

The Water Act 2002 declared the Ministry of Water Resources Management and Development (MWRMD) as the general organ responsible for water governance. This ministry focuses on stakeholder involvement, privatization, marketing and decentralisation. Furthermore the act set the pace for the development of the Water Resources Management Authority (WRMA), who is responsible for the governance of rivers, lakes and aquifers as well as for water contamination, and also for the formation of the Water Services Regulatory Board, responsible for the provision of water by licensed water service suppliers (Frenken 2005).

Different organisations both from the private and public sector are responsible for issues concerning irrigation. The Water Act 2002 appointed two institutions directly under the MWRMD, one being the National Irrigation Board (NIB) which is engaged in the development of national irrigation plans and the other one being the Irrigation and Drainage Department (IDD), which deals with the encouragement of smallholder irrigation. The management of water and land resources within river basins is appointed to the River Basin Development Authorities (RBDA), which are a part of the Ministry of Regional Development. However, the progress in the field of irrigation is being enabled not only by public institutions but also by various private organizations (Frenken 2005).

In order to promote long-term management and efficiency of irrigation plans, water users associations (WUA) were established, independent of who was involved in the initial promotion of the irrigation scheme. The WUA are responsible for governing smallholder irrigation plans. Most of the irrigation equipment and the water rights belong to the water users (Frenken 2005).

The act clearly states that all surface and ground water resources belong to the state and that any abstraction and use of water is only allowed if a licence has been applied for and issued (UNDP Kenya and WGF 2007).

The issuing of water permits and assignment of water to users according to the amount of available water is carried out by water appointment boards. The magnitude of water use is the decisive factor for the water charge and the length of the permit. The irrigation permit has to be renewed after five years and the permit charge depends on the surface area which has to be irrigated. There are two conditions which should be observed by holders of irrigation permits, one being that only the flood flow of the stream should be utilised for irrigation purposes, and the other one being the construction of a storage basin which should hold enough water to irrigate the area specified in the permit for 90 days. Both these conditions are often ignored as irrigation is necessary especially in the dry months where there is low stream flow, and building a reservoir exceeds the financial means of most of the farmers (Frenken 2005). According to Frenken (2005, p. 9-10), there is no national policy and legal framework for the management of irrigation schemes, but it is currently being developed. The lack of an overall national irrigation policy results in different organizations implementing individual irrigation plans which do not complement each other. In order to cope with these problems, a Draft Irrigation Policy was developed in 2001 and furthermore a Draft Irrigation Strategic Plan dealing with developments from 2003 to 2008 is under development.

Figure 1 shows an overview of the institutional framework that has resulted from the Water Act 2002.

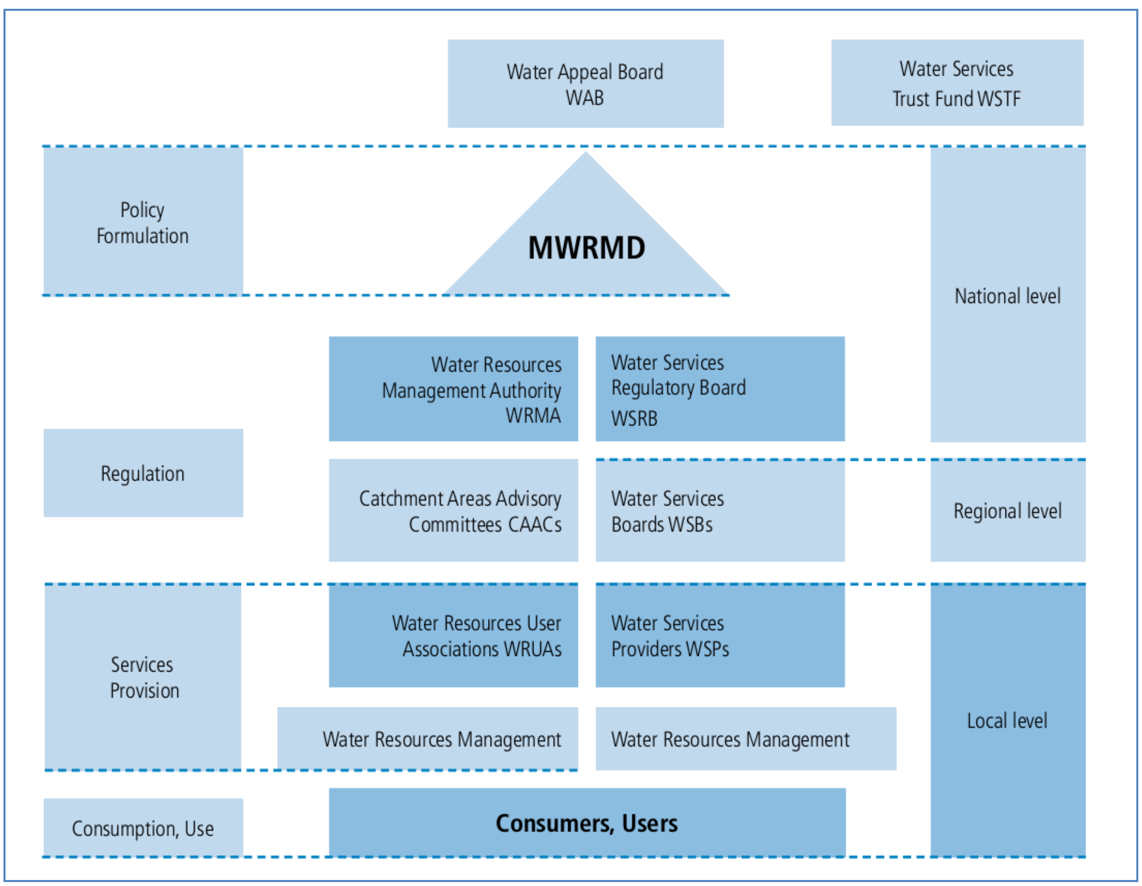


Figure 1: Institutional setup under the Water Act 2002 (Source: UN-Habitat 2011, p. 3)

2.3 Irrigation Systems in Kenya

2.3.1 Definitions and classifications

Irrigation is practiced in order to supply plants with adequate amounts of water in times of insufficient rainfall (Brouwer et al. 1988). If applied correctly, this practice can lead to highly improved crop yields. In arid areas, irrigation has two beneficial effects. Together with the irrigation water, important nutrients are supplied to the crops, and due to the water flow into the soil, salts are leached or diluted. Farm productivity and crop yield are dependent on the duration, frequency and type of irrigation (Walker 1989). Dougherty and Hall (1995, ch. 4) explain that irrigation can also have negative environmental impacts such as salinization, alkalization, soil acidification and water logging. In order to prevent these effects, certain measures need to be taken, including regular drainage and leaching of salts.
Irrigation systems that are widely used include surface, sprinkler and drip irrigation systems. Based on these three categories, one can differentiate between the following irrigation methods (Brouwer et al. 1988):

1. Surface Irrigation

In surface irrigation, surface water flows and spreads into the field by the force of gravity (Walker 1989). Water enters the field from a farm channel, either through pipes or small passages which are placed in the bank of the farm channel. The phase in which water spreads over the entire field until it is contained by earth dykes is called advance phase. During this phase, water close to the channel will already start infiltrating while the area farthest away from the channel is not yet reached by the water flow. This means that water is unevenly distributed when applying surface irrigation. In order to enable a more equal distribution, the water supply has to be continued until it reaches the end of the field and is able to infiltrate into the soil. Nonetheless, the water near the farm channel is likely to percolate into deeper zones while that at the end of the field may not have enough time to infiltrate and will thus will run off (Kay 1986)

- Basin Irrigation

Basin irrigation is commonly used for small fields (Walker 1989). Water flows into a flat field, surrounded by low dams which prevent water from running off the field. This method is applicable to crops which are not adversely affected by being covered by water over longer time periods (Brouwer et al. 1988). The inflow is unregulated and unguided (Walker 1989).

- Border Irrigation

The principle of border irrigation is similar to that of basin irrigation, only that it is applicable to long, sloping fields, rectangular or moulded in shape with an open lower end where water can run off freely. One field can be divided into many inclined borders, which are supplied with water from the field head ditch placed at the upper end of the field, where checks are dug manually. When the water supply is stopped, the water will flow off from the top to the bottom of the field. Border irrigation is suited for various crops, but not for such which require water to remain on the surface for some time (Walker 1989).

- Furrow Irrigation

Water is conveyed in the field through small channels known as furrows and flows in the direction of the highest gradient, refilling the soil water reservoir by spreading both in horizontal and vertical direction, while it is flowing down the slope. As opposed to basin irrigation, the flow into each channel is controlled and guided and doesn't flood the entire field surface (Walker 1989).

2. Sprinkler Irrigation

Sprinklers act similar to natural rainfall. Water is usually pumped to a sprinkler system through pipes and is then emitted into the air where the water falls on the plants and the soil surface in the form of drops. While sprinklers can be applied to a variety of field plants and trees, it should be noted that those with large outlets are not suitable for fragile crops such as lettuces as they could get damaged due to the big drop sizes which are produced by the sprinklers. These systems are best suited for sandy soils but can be applied to various soil types. They are normally operated in a way that the average supply rate from the sprinkler is lower than the infiltration rate of the soil in order to prevent runoff and standing water. In order to prevent blockages of the sprinkler outlets and crop damage, the water needs to be filtered. The main parts of a sprinkler irrigation system are a pump unit, pipe mainlines and sub mainlines, sockets and sprinklers. The overall goal of sprinkler irrigation is to saturate the crop root zone by applying water homogeneously. The wetting pattern of rotary sprinklers is circular with more of the water entering the soil close to the sprinkler and less entering at the outer boundary of the circular area. Therefore a number of sprinklers have to be placed next to each other so that their wetted areas overlap in order to reach a homogeneous saturation. Furthermore the influence of wind has to be taken into consideration when deciding on the spacing between the sprinklers, as it blows away the drops and thus reduces the uniformity. Another factor which has to be considered is the operating pressure of the sprinkler. If the pressure is too low the sprinkler won't break the water into drops and it will just fall on one spot at the outer area of the wetted circle. Low pressure can occur when the pipes get worn out and the friction in them increases. Also if the pressure is too high, the performance will be poor as because a thin spray which falls close to the sprinkler reduces the radius of the spray (Brouwer et al. 1988).

3. Drip Irrigation

When using this irrigation method, water is emitted through pipes which are placed on the soil and have emitters. Water is applied more often than in other irrigation systems and due to that high soil moisture and good growing conditions can be established. Due to the high investment costs this system is usually applied for crops with high value. It is most suited for different row crops such as vegetables and trees. Drip irrigation can be applied to all soil types. In order for water not to run off or accumulate on the surface, the supply rate has to be adapted according to the soil type. Similar as in sprinkler irrigation it is very important that the water that is fed to the drip pipes is clean and free from sediments, algae, dissolved chemicals like iron which precipitate as well as remnants of fertilizer, as the drip emitters or outlets are very small ranging from 0.2 mm to 2.0 mm and will get blocked otherwise. As single plants are supplied with water by drip irrigation, this method is very suitable for areas which have water shortage. Normally a drip irrigation system is made up of a pumping device, a control unit which consists of valves and regulators for pressure and discharge, a filter and a fertilizer tank, pipe mainlines and sublines, laterals and emitters. Drip irrigation saves water due to reduced deep percolation, surface runoff and evapotranspiration losses (Brouwer et al. 1988).

2.3.2 *Applicability*

The choice of irrigation system depends on a number of factors (Walker 1989):

- Suitability:

The irrigation method needs to function alongside with other farming procedures such as preparation of land, crop planting and harvesting.

- Cost effectiveness:

Some systems with high initial and running costs may require little labour and use water economically, while other systems with low initial and operation costs may require a high amount of labour and water uptake. Furthermore some systems are limited to certain types of soil and topography. Maintenance costs, life expectancy and other yearly costs like energy costs should also be considered when choosing an irrigation system.

- Topography

Especially for surface irrigation topography plays an important role, the two most important factors being field gradient and its structural unity (Walker 1989). Sprinkler and drip irrigation systems have a better performance on steep and irregular slopes as they hardly require land levelling (Brouwer et al. 1988).

- Soil properties

The type of irrigation that is chosen is strongly influenced by the soil's moisture - holding capacity, infiltration rate and thickness. Sandy soils with low moisture-holding capacities and high infiltration rates will have to be tackled differently than soils with high clay content and high water-holding capacities. Also other properties such as the interaction between soil and water which is influenced by physical, biological and chemical characteristics has an influence on the hydraulic characteristics of the soil.

Furthermore the soil will influence factors such as erodibility and crusting, which are also important factors when planning an irrigation system (Walker 1989).

- Climate

Drip or surface irrigation is preferred in areas with strong winds, as drops emitted from the sprinkler are likely to be blown away. In areas where irrigation is not required throughout the year, sprinkler and drip irrigation could be more efficient than surface irrigation because their use can be adjusted more easily to the on-farm conditions (Brouwer et al. 1988).

- Water quantity and quality

Both the water quantity and water quality influence the choice of irrigation method. If there is only a small discharge available, it is advisable to supply the crops frequently with little amounts of water. In general the water use efficiency is higher for drip and sprinkler irrigation than for surface irrigation, which makes these methods more suitable for areas with water scarcity. If the water contains a lot of sediments, surface irrigation should be preferred over drip and sprinkler irrigation as the water outlets are likely to get clogged by the sediments. If there is high salt content in the water, drip irrigation is more suited because less water is emitted to the soil, especially in comparison to surface irrigation. When looking at the leaching characteristics, sprinkler irrigation is more efficient than surface irrigation (Brouwer et al. 1988). Water with low quality needs to be supplied more frequently than water of high quality (Walker 1989).

- Crop type

Not only the quantity of water, but also the way in which water is applied to crops, influences the crop yield. The irrigation system changes the external conditions such as temperature and humidity. The effect of these influences varies according to the crop type and needs to be considered when choosing an irrigation system (Walker 1989). While surface irrigation can generally be used for all crops, drip and sprinkler irrigation systems are used for crops of high value as their investment costs are high. Drip irrigation is suitable for single crops or row crops, but not for plants which grow very close to each other such as rice (Brouwer et al. 1988).

- Social conditions

Whether or not new irrigation systems are adapted will strongly depend on the individual community and if any forms of irrigation have already been practiced (Brouwer et al. 1988). Problems may arise when introducing new, uncommon systems. It could happen that farmers don’t adopt the new methods, or that maintenance is not carried out correctly and the system fails. It may be more effective to revitalise old, traditional irrigation systems than to introduce unknown ones (Walker 1989).

- Necessary labour

A large amount of labour is required when constructing, operating and maintaining a surface irrigation system. When implementing drip or sprinkler irrigation systems, no land levelling is necessary and the operation and maintenance of the system require less labour (Brouwer et al. 1988).

- External influences such as national policies

The development of irrigation systems is influenced by external factors such as national policies which indirectly favour the use of one irrigation system or another (Walker 1989).

2.3.3 *Typical systems and practices in Kenya*

Kenya's irrigation history dates back to 400 years, when the main method used was spate irrigation. Drainage systems came into existence in the 1930s. Water from natural springs was collected and was used to irrigate short term crops in the dry seasons. In the 1950s, when new land boundaries and land allotments came into existence, a large part of swamp area was drained and turned into agricultural land (Muthigani 2011).

While furrow irrigation and wild-flooding systems can be considered traditional Kenyan irrigation methods, other schemes and technologies were brought to the country from outside. First influences came from Arab merchants who introduced rice planting to Kenyan farmers. During the late nineteenth century labourers from the Indian subcontinent brought to Uganda to construct the railways started using irrigation systems to grow Asian vegetables. The tradition of growing typically Asian vegetables has remained, but is nowadays carried out by Kenyan farmers. Irrigation as a method was stimulated once again by the colonial government during the Second World War, because the British army was in need of food. In that period, the growing of vegetables was enforced with the support of diversion systems that are still being used (Blank et al. 2002).

Modern irrigation systems emerged together with cash crop farming, generating items such as coffee and pineapples. In the 1950s a number of irrigation plans were established as a result of a wide, agricultural recovery programme set up by the African Land Development Unit (ALDEV) in 1946. In 1966 the National Irrigation Board (NIB) came into existence, its main task lying in the management of national irrigated land in the hand of tenants. In order to enhance smallholder irrigation schemes, the Small Scale Irrigation Unit was formed in 1978 as a subgroup of the Ministry of Agriculture (Muthigani 2011).

From 1970 onwards, large-scale business farmers primarily producing coffee increased their irrigation performance, using mechanical water withdrawal and overhead sprinkler systems. Especially in the horticultural sector farmers started investing in water saving irrigation systems such as drip irrigation systems (Muthigani 2011).

Apart from farmers who possess large scale agricultural production systems comprising crops such as coffee and rice, single farmers, especially those growing export crops like coffee or horticultural crops, have started creating their own irrigation systems. 42 % of Kenya's irrigated area can be ascribed to business-oriented, private and large-scale production farms, 40 % to smallholder farms and 18 % to government-operated plans (Government of Kenya 2010).

The state is not able to manage large-scale surface irrigation systems any longer as its capacity has been exhausted. On the one hand this development has led to a breakdown or desertion of government-supported irrigation plans. On the other hand, smallholder farmers have partly taken over the responsibility of operating and preserving irrigation schemes, although the managerial framework is missing. Old rules concerning water assignation and distribution have expired, meaning that new policies and plans are needed to help farmers manage the water resources in a sustainable way (Blank et al. 2002).

Irrigation plans in Kenya can be divided into three groups (Blank et al. 2002):

- Smallholder irrigation systems where individuals or groups of farmers divert water from streams to their plots, mostly containing crops used for their own consumption or local markets.
- Large-scale irrigation systems built, managed and preserved by the government, where smallholder farmers are not incorporated in the management processes and are highly dependent on the government for the supply of inputs as well as the distribution of crops.
- Agro-industrial irrigation of crops with a high value, such as flowers, where the private sector or single persons are responsible for the development and financing of the crops. In this group, pump based systems together with sprinkler and drip irrigation are common and necessary to enable high yields.

Changes and developments in irrigation systems that took place in the last decade have made the categorisation of irrigation into these three groups more difficult (Blank et al. 2002).

Blank et al. (2002, p.1) point out that new irrigation technologies comprising sprinkler and drip irrigation systems as well as various pumps such as treadle or motorized ones are being presented to and acquired by farmers at a high pace, enabling a far more efficient use of water and therefore also enabling the cultivation of larger amounts of land. The use of these systems is likely to lead to an increase in farmers' incomes as well as to the utilisation of new water resources which were not accessible before, especially by female farmers, as these resources could not be diverted without the use of pumps.

Drip irrigation is in use since ten years, mainly in the field of horticulture and flower cultivation for exporting, making it an established irrigation method. The most common drip irrigation methods comprise bucket, drum and eight-acre schemes. The bucket kit can be considered the fundamental drip irrigation element. This technology was introduced by two missionaries in 1988 and was further promoted by the Kenya Agricultural Research Institute (KARI) and various NGOs. It is made up by two tubes of 15 meters length comprising 100 drip transducers that are able to supply water to 100 crops. The bucket kit method is efficient for self-supply, bearing the option to sell the excess crops. The drum method raises the irrigation capacity by the factor five while the eight-acre scheme enables a capacity that is twenty times as high as that of bucket schemes (Blank et al. 2002). Figure 2 shows how the area under irrigation has changed since 1975.

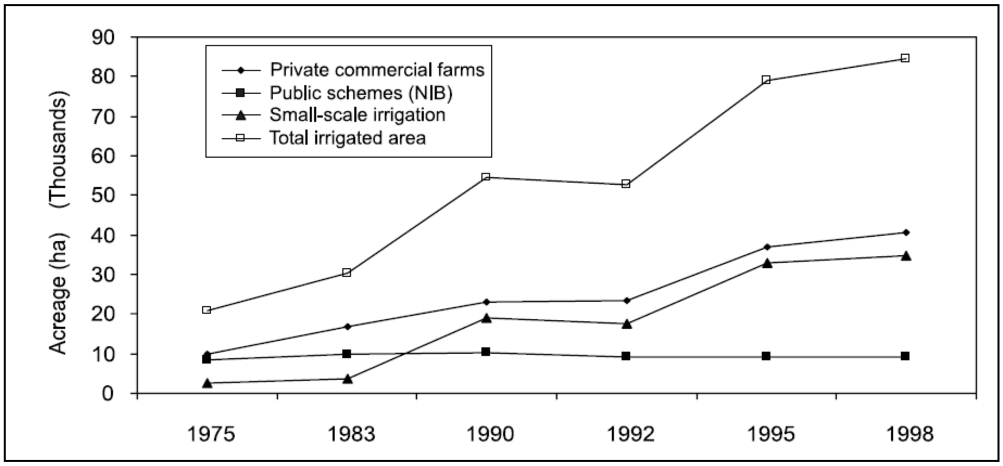


Figure 2: Trend in irrigation development in Kenya (Source: Blank et al. 2002, p. 43)

Smallholder farming has become business-oriented, enabling farmers to step away from traditional crops to those of higher value, suitable to be distributed on vegetable and fruit markets. This shift was achieved mainly by farmers who had formed linkages with marketing agents or agro - industrial companies selling crops like tomatoes and organic vegetables (Blank et al. 2002).

Irrigation can lead to an efficient use of available water resources and to an increase of income for those who are able to use the new technologies (Blank et al. 2002). It can also increase the amount of land suitable for agricultural purposes, especially in the medium rainfall zone. In 2003, irrigated land made up only 1.5 % of Kenya’s agricultural area, but contributed around 3 % to the country’s GDP and approximately 18 % of the value of the total agricultural produce (Muthigani 2011).

2.3.4 Challenges in irrigation development

In order to make use of irrigation systems in an efficient and sustainable way, a number of hurdles need to be overcome. A balancing act between fair access to water, sustainable water and land use, agricultural development and poverty reduction through higher generation of food and cash crops needs to be accomplished (Blank et al. 2002).

The main challenge lies in the proper management of irrigation schemes. As the government is no longer capable of managing large-scale surface irrigation schemes, new managing strategies need to be established. Due to the government’s missing capacities and the emergence of irrigation systems developed and managed by individuals, it no longer has the exclusive power over the existing water resources. This could lead to an exhaustion of both surface and groundwater water resources as well as to fights over the available water and inequalities in water distribution. Furthermore former general public water rights could be suppressed by the development of irrigation schemes by individuals, resulting in a hindered access to water for poor and unprivileged farmers who don't have the financial means to engage in new irrigation technologies (Blank et al. 2002).

Environmental impacts on soil and water have to be considered when planning an irrigation system, and measures need to be taken to mitigate the adverse effects which arise from irrigation (Dougherty and Hall 1995, ch. 4).

After having exhausted both its financial and work force capacities in the past decades, the government has recently put an emphasis on incorporating the private sector in the planning, operation and maintenance of irrigation schemes, thus promoting the liberalisation and privatisation of this field as well as the commodification of the agricultural sector. Its focus has been set on pointing out the benefits that arise from these systems and appealing for participation, i.e. through cost sharing. The aim of the government lies in stepping back from the role of exclusive decision maker, thus promoting policies that strengthen the collaboration between the public and the private sector as well as the advantageous involvement of the private sector in order to create a long lasting, self-preserving system (Blank et al. 2002).

According to Blank et al. (2002, p.7), alongside government supported irrigation schemes, attention needs to be paid to small-scale irrigation systems which can be easily understood, afforded as well as implemented, operated and maintained by poor farmers.

One of the main problems in adapting small-scale irrigation systems is the farmers' lack of financial means to purchase them. This is why in addition to providing new technology, strategies that enable better access to the necessary capital need to be developed. Famers face difficulties in obtaining credits, as financial institutions consider them worthy of credit only if they have depth security, which is not the case most of the time. Another reason why irrigation developments have been stagnant is the missing legal framework providing policies that enable an environment suitable for these developments. Furthermore there is a lack in coordination between the different protagonists involved in planning and implementing irrigation schemes, as an institutional framework is missing to provide a clear code of practice in the handling of the limited water resources (Blank et al. 2002).

New technologies alone will not change the financial situation of the farmers. It is essential that the farmers produce goods that meet the market requirements in order to achieve a high returns on investment. Marketing strategies may include growing and selling products in the off-season period where food prices are high and the competition from rain-fed production is absent, or focusing on products that are primarily exported. In order for farmers to benefit from the goods they manufacture, they need to have an insight into market developments as well as access to farmer associations and other networks. This requires regular technology adaption as well as continuous knowledge transfer (Blank et al. 2002).

2.4 Water Harvesting Systems in Kenya

Critchley and Siegert (1991) describe water harvesting as a “rudimentary form of irrigation”. It can be seen as a cheap alternative to irrigation systems and is recommended especially in semi-arid and arid areas as it is a way to supply the soil and plants with water that would normally run off and thus improve and secure the crop yield. Not only water but also soil can be harvested by this method.

Furthermore negative effects such as erosion and flooding can be reduced by harvesting rainwater (Liniger et al. 2011).

2.4.1 Definitions and classifications

Water harvesting is the “collection of runoff for its productive use”. This includes the use of rainwater for domestic purposes and livestock, for supplying crops, trees and runoff and for providing ponds. Rainfall can be harvested from ground surfaces and roofs as well as from water courses which are either transient or discontinuous. The collection of water from the soil surface and from roofs is known as rainwater harvesting while water obtained from the discharge of water courses is known as floodwater harvesting (Critchley and Siegert 1991).

The three main components of water harvesting systems are an impervious or hardly permeable gathering area where water accumulates and runs off, a transport system made up of pipes, ditches, channels or the like, and a storage device where water can be kept or directly used, like a tank, earth dam or the soil itself (Liniger et al. 2011).

Water harvesting systems can be divided into roof water harvesting, in-situ rainwater harvesting, micro-catchments, external or macro-catchments and small dams or ponds (Liniger et al. 2011).

1. Roof water harvesting systems

Water that is harvested from roofs is primarily used for domestic purposes due to its relatively good quality (Liniger et al. 2011). Roofs made from corrugated iron sheets or tiles are most suited for roof water harvesting as they neither contaminate, nor absorb the water that falls on the roof, whereas roofs made from palm-leafs or covered by grass are not suitable for rain water harvesting systems. The amount of water collected from roofs is proportional to the roof area and can be calculated by multiplying the rainwater that falls on the roof by the catchment area and then removing 15 % of that value due to evaporation losses. In order to use the roof water efficiently, the size of the storage tank has to be appropriate. If the tank dimensions are too small, water may overflow in times of high rainfall due to the fact that the inflow rate is higher than the extraction rate. Thus the rainfall quantity that can really be used is also influenced by the tank efficiency (Thomas and Martinson 2007).

The water quantity (Q) gathered on the roof and being conveyed by the gutters to the tank inlet can be roughly estimated as follows (Thomas and Martinson 2007):

$$Q = 0.85 \times R \times A$$

where R is the annual total rainfall in mm, A is the catchment area and 0.85 is the factor considering evaporation losses and losses that occur between the roof and the storage tank.
To calculate the real available water quantity (U) the storage efficient has to be considered (Thomas and Martinson 2007):

U = E x Q

where E is the storage efficiency with a value always smaller than 1, which depends on the tank size, the climate and the water drawing pattern. A higher extraction rate improves the storage efficiency E, but the reliability is reduced as the water in the tank is used up and it is uncertain when the next rainfall is going to occur.
In order to transport water from the roof to the storage tank, a network of gutters and downpipes which transport the water directly to the rank inlet are required (Thomas and Martinson 2007).

2. In situ rainwater harvesting systems

This method also falls under conservation measures. Water is gathered and stored within the soil and is prevented from evaporating and running off by different measures. These measures include tillage practices, mulching and cover crops (Liniger et al. 2011). The best suited areas for in situ rainwater harvesting are topographic declines (UNEP 1997).

3. Micro-catchments

Micro-catchments are systems which are normally placed directly on the field and can be holes, pits, small dams or bunds established to collect surface runoff from within the crop field. Their catchment area is small reaching up to a maximum of 1000 m², and the cropping area has a maximum of 100 m². The ratio catchment area to cropping area lies between 1:1 and 10:1. In addition to the water harvesting measure, agronomic practices are common especially for annual crops and trees, including composting to increase fertility (Liniger et al. 2011).

4. Macro-catchments

These systems are marked by large catchment sizes and are usually not placed on the cropping field. High amounts of water can be collected and stored by constructing check dams and diversion channels to collect flood water from ephemeral rivers, roads or ditches. The catchment to crop area ratio is between 10:1 and 1000:1 (Liniger et al. 2011).

5. Small dams and ponds

These constructions are small basins to collect and store water from different surrounding surfaces such as roads, hills, open grasslands or rocky sites. The water is used for domestic purposes, livestock and irrigation (Liniger et al. 2011).

2.4.2 *Applicability*

Factors influencing the adoption of roof water harvesting systems can be summarized as follows (Thomas and Martinson 2007):

- Roof suitability

The roof needs to be made from a hard material such as tiles, plastic or metal sheets which don't absorb or contaminate the water. Palm leaf or grass roofs are not suitable for water harvesting. The larger the roof area, the more rain water can be collected.

- Costs

The roof water storage tank will be the highest financial expenditure in most roof water harvesting systems. The tank efficiency rises with the tank size, but so do the costs as well. The relationship between expenses and efficiency needs to be analysed and the size should then be chosen to fit the user's requirements and financial means. The annual water yield in % of annual rainfall multiplied by roof area varies very strongly according to tank size and can be 25 % for a very small tank and 75 % for a very large tank.

- Annual rainfall

The rainfall amount that gets into the gutters should be adequate, meaning that at least the designed annual water use per person can be covered.

- Air pollution

Areas with high air pollution are unfavourable for roof water harvesting systems, as the water can get contaminated as well.

- Social conditions

A successful implementation of sustainable roof water harvesting systems depends on how well the social and cultural aspects of the community are integrated into the implementation process. The role of both men and women should be known when designing and implementing roof water harvesting systems, and special focus needs to be put on women during the planning process, as they are often the final users of these systems and are also responsible for their operation maintenance (Worm and van Hattum 2006).

The choice of water harvesting system for agricultural purposes is based on the following factors:

- Precipitation

The overall amount of rainfall is a major factor when planning water harvesting systems. But more importantly properties such as the rainfall duration, intensity and frequency need to be considered as they have a higher influence on the performance of the system. Areas considered arid or semi-arid have high periodic fluctuations in rainfall. As the suitability for a water harvesting system does not only depend on adequate frequencies but also on other factors such as the duration of dry seasons between the rainy periods, it is difficult to decide on a reference level for the frequency distribution. Rainfall duration and intensity are of high importance due to the fact that runoff occurs only if the rainfall intensity is higher than the infiltration rate, or if the soil water storage capacity is exceeded by the combination of rainfall duration and intensity (Reij et al. 1988).

- Vegetation

On the one hand vegetation reduces the amount of runoff due to interception and transpiration processes. On the other hand it causes a heavy reduction of erosion occurrence compared to unplanted soil. Also other factors such as soil crusting are positively influenced by the presence of vegetation. Plants reduce the runoff velocity and thus enable infiltration rates much higher than those of bare land (Reij et al. 1988)

- Crop water requirements

The water harvesting system needs to be designed according to the water demand. The amount of water required by a crop will vary according to the crop type, which doesn't only have an influence on the water demand but also on the length of the growing season. While certain crops may need less water than others on a daily basis although they are both in the same growth stage, they may have a longer total growing season and thus require more water in total (Critchley and Siegert 1991).

- Soil requirements

Fertile and deep soil with a good water holding capacity is ideal as cropping area, while soil with a low infiltration rate is suitable for a catchment area. The following soil characteristics have an influence on plant growth:

  - Structure

The soil structure describes the size of soil complexes which are made up of single aggregated soil particles. Crop development is favoured in "loamy" soils with high organic matter content.

  - Texture

The soil texture is a measure for the predominant particle size. One can differentiate between soils which are made up mainly by sand, silt or clay. With respect to water holding capacity, available nutrients and biological processes, soils with high silt content, also referred to as “loamy” soils, are best suited for water harvesting systems, as they provide good conditions for crop growth (Critchley and Siegert 1991). Loam contains sand, silt and clay (Soil Science Society of America 2008).

- Depth

Water harvesting systems are preferably built in deep soils as they have a high water holding capacity and high nutrient content. Soils with depths smaller than one meter are not recommended for water harvesting systems.

- Infiltration rate

In the catchment area low infiltration rates and thus soils with high clay content are suited as they generate high amounts of runoff. On the other hand cropping areas should have fairly high infiltration rates in order to prevent water accumulation on the soil surface and permit water to enter the crop root zone. The infiltration characteristics of the cropping area should be the determining factor if a water harvesting system should be established or not.

- Available water capacity

The available water capacity (AWC) is defined as “the depth of water in mm readily available to crops after a soil has been thoroughly wetted to “field capacity” (Critchley, 1991, Ch. 2.3.8). This factor indicates how well the soil is able to hold moisture and therefore make it available to the crops.

- Soil productivity

Apart from water availability, the soil quality plays an important role in crop growth. Therefore in case of low soil quality it is necessary to take measures to improve the fertility in order to enhance crop development.

- Salt content

Soils with high contents of sodium or soluble salts are not suitable for the establishment of water harvesting systems as they can adversely affect plant growth and also reduce the amount of available water for crops.

- Construction suitability

Not all soils are suitable for building earth structures such as dams or bunds. Soils that get fissures when they dry as well as soils which are very erodible and such of poor quality should be avoided when constructing water harvesting systems.

- Slope

Gradients of more than five % are unsuited for water harvesting systems as they cause a non-uniform runoff and require high efforts in constructing earth structures.

- Costs

In many cases the most expensive component in water harvesting systems is the earthwork and stonework. Considering roof water harvesting systems the storage tank will be the main capital expenditure.

- Social conditions

In order to implement water harvesting systems successfully, it is important to consider social and cultural aspects which are typical of the people living in the respective area. All water sources within the area should be considered and the costs and benefits of all resources need to be identified. It is important to consider the people's requirements when a water harvesting system is being planned. Furthermore the citizens need to be involved in the development of water harvesting systems in order for them to be a success. Water harvesting systems can also be influenced by land tenure. Farmers who only own a small plot may be unwilling to set up a water harvesting system on adjacent land which does not officially belong to them. Another problem is the management of land with complicated rights of ownership and use as well as commonly owned land. Farmers may not be willing to establish water harvesting systems on land which is used by other farmers at the same time. Land use management in general has an influence on the effectiveness of water harvesting systems. These systems can help improve neglected and unattended land by making it fertile and planting crops, but they only have a positive effect if other land management measures such as grazing controls are implemented simultaneously.

2.4.3 Typical systems and practices in Kenya

Although traditional water harvesting techniques date back to 4000 years in different parts of the world (UN-Habitat 2005), there is little information available on the historical development of water harvesting systems in Sub-Saharan Africa. Nonetheless farmers possess indigenous knowledge on water harvesting techniques that has been passed on from generation to generation, which indicates that water harvesting systems in Kenya are traditional to a certain extent. Especially in semi-arid and arid areas water harvesting has been an indispensable technique to overcome severe water shortages (Black et al. 2012). As a reaction to recurring droughts, water harvesting systems have gained more importance since the 1970s. Especially in the past ten years efforts have been made to promote water harvesting systems in order to reduce the adverse effects of drought such as crop failure and land deterioration (Critchley and Siegert 1991).

There is evidence for the existence of rainwater harvesting systems in Kenya since the beginning of the twentieth century. During the 1970s and 1980s the material recommended for rain water tanks was corrugated iron sheets, but due to its corrosive characteristics which promote leakages, this type was soon neglected. The use of ferro-cement as tank material started around 1980 and is considered the most popular substance since then due to its longevity and affordability. Also concrete tanks became popular in the 1980s and are still being used to a large extent. In general rainwater tanks are becoming more and more common throughout Kenya (Black et al. 2012).

Apart from rainwater tanks, micro-catchment systems such as water pans, ponds and dams are counted among common water harvesting techniques in Kenya. These constructions vary from small, manually constructed pans to huge, community based earth dams. While earth dams were implemented in Kenya by white settlers, water pans such as the *hafirs* in north-eastern Kenya are considered a traditional water harvesting method. These constructions are primarily used to store big amounts of water to supply livestock and irrigate crops. Typical methods to increase the soil moisture content include *negarims*, bunds, pitting techniques, basins and ridges for single plants and furrows as well as basins and water spreading for entire crop fields (Malesu et al. 2007). *Negarims* are diamond shaped, closed micro-catchments which are separated by earth bunds which prevent water from running off. Often these catchments are constructed for plants in arid areas with moisture deficits. *Zai* pits, also called infiltration pits, are small holes that are dug to retain water and are shown in Figure 3. Usually crops with high water requirements are planted directly in these pits. *Zai* pits are often positioned at the end of *negarims* in order to store the runoff from the micro-catchments (Black et al. 2012).

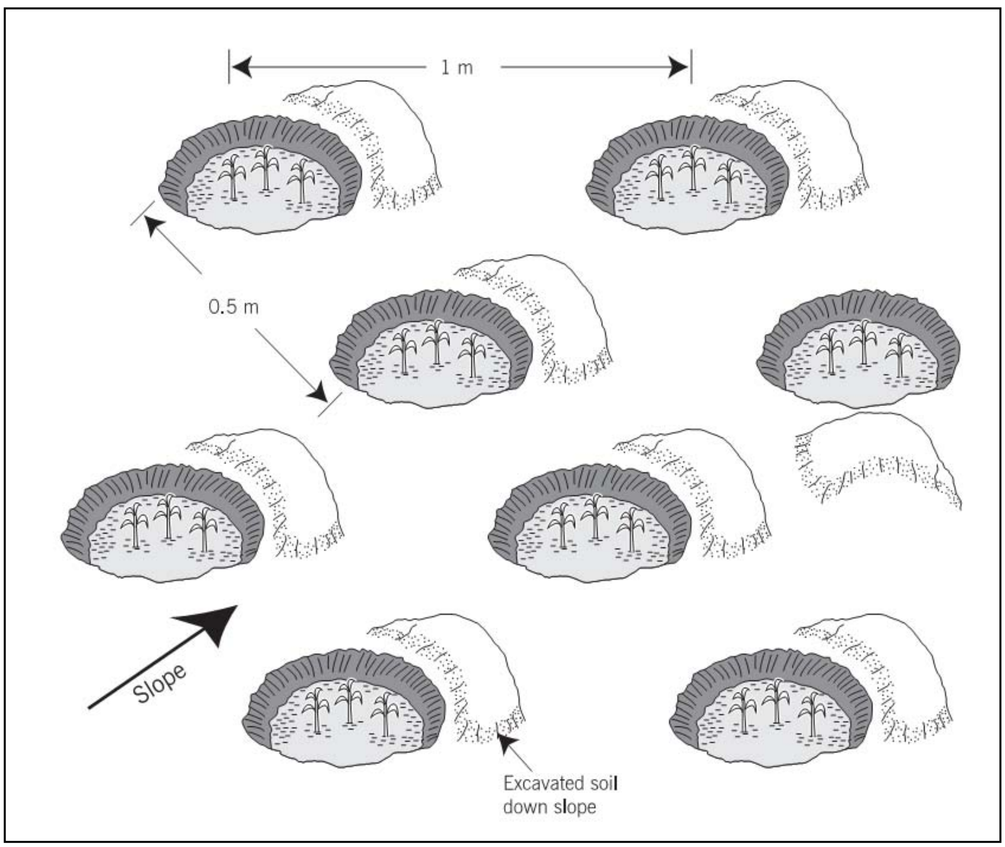


Figure 3: Zai pits used for water harvesting and conservation (Source: Malesu et al. 2007, p.84)

Spate irrigation is also considered a traditional water harvesting technique. High river flows or seasonal floods are diverted via canals constructed as ditches or bunds and are spread on the fields.
Another traditional method found all over the country is based on taking advantage of high water tables at topographic low points or dried river beds or river banks by planting crops such as arrowroots, potatoes or rice in those areas (Malesu et al. 2007).
Collecting runoff from roads and paths and conveying it directly to the cropped area or into a storage structure has become popular over the years. Open channels are usually dug to convey the water and are often accompanied by earth or stone bunds in order to avoid soil erosion (Black et al. 2012).
One more water and soil conservation technique is known as *Fanya juu* shown in Figure 4, which is a terracing method where a ditch is dug out on a slope and the soil is placed above the ditch as an embankment. Soil and water are prevented from running off by the embankment and furthermore water is stored within the ditch. This technique promotes a natural formation of terraces. The furrows are often planted with high water demanding crops such as bananas (Black et al. 2012).

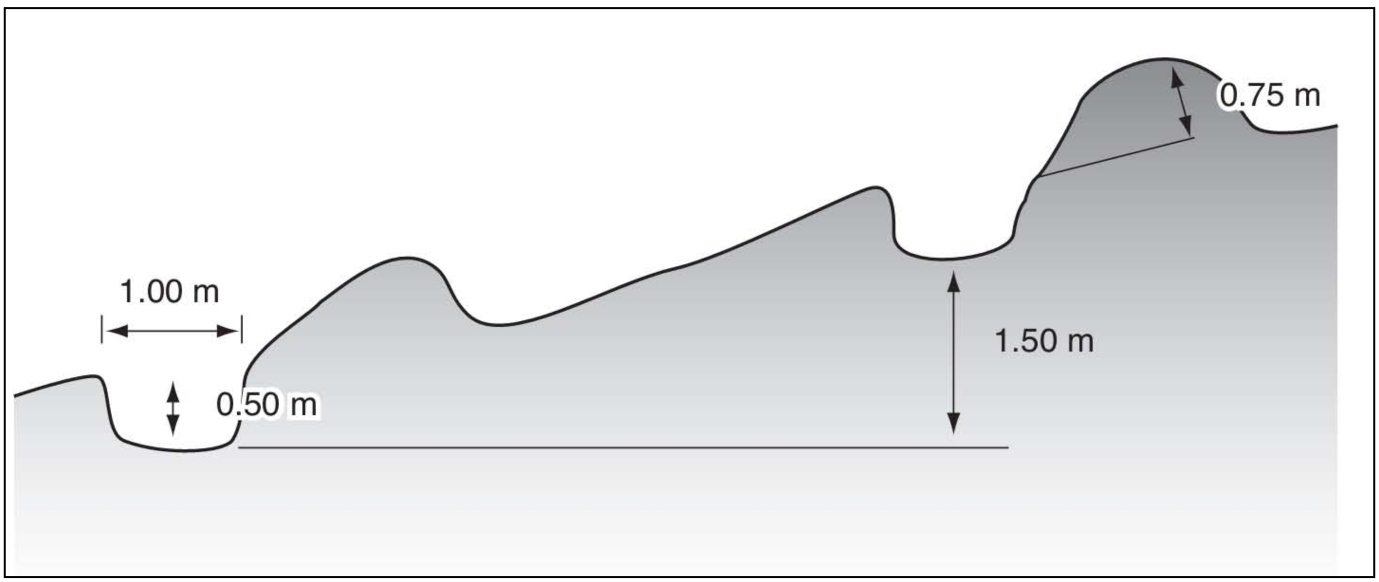


Figure 4: Fanya juu (Source: Malesu et al. 2007, p.72)

Often these different techniques are combined with each other by Kenyan farmers, which make a classification of water harvesting systems into single groups difficult (Malesu et al. 2007).

2.4.4 Challenges in water harvesting system development

Critchley and Siegert (1991) point out that many projects have been unsuccessful due to lacking combination of affordability, efficiency and acceptance by farmers or pastoralists. This circumstance arises due to a lack of technical knowhow on the one hand and too little consideration of socio-economic factors of the respective area on the other hand (Critchley and Siegert 1991).

Drechsel et al. (2005, p. 7) points out that socio-economic factors can be a more prevalent constraint to adopting rainwater harvesting systems than bio-physical conditions such as soil texture or slope of an area. Social, economic as well as cultural aspects play a role in whether or not a system is adopted. The efficiency of the measures, the assumed advantages arising from new technologies and the available resources will determine the farmers' decision whether to implement water harvesting systems. Furthermore the decision will be based on the farmers' attitude, whether or not they are willing to try out something new and take a risk, the political situation and whether or not they would get support from other stakeholders. In addition to financial means, farmers need to have sufficient labour in order to implement certain measures. When labour is limited, farmers are not likely to invest in a new measure which requires additional labour. Not only hired labour but also the amount of labour the farmers themselves can or want to invest in a new project needs to be considered. This factor is influenced by the expected benefit of the measure and how motivated the farmers are to try out something new (Drechsel et al. 2005). The Stockholm Environment Institute and the UNEP (2009, p. 61) point out that although the benefits of rainwater harvesting have been studied and depicted, there is still a lack of combined knowledge on factors such as investment costs, losses and benefits of rainwater harvesting or its impacts on biophysical and socio-economic factors for various reasons. Furthermore they explain that in order to overcome this information gap, knowledge needs to be disseminated to all kinds of end users in various ways and that networking is the key to sustainability of water harvesting systems. In order to promote water harvesting systems, facilitating policies as well as an institutional framework which deals with education, technical support and capacity building need to be established.

2.4.5 Agricultural Innovation

According to Ernst et al. (1998, p.12-13) innovation is the process where organisations "master and implement the design and production of goods and services that are new to them, irrespective of whether they are new to their competitors, their country, or the world".

Innovation is neither equivalent to technology or science, nor to the creation of knowledge alone, but rather relates to the use of knowledge to bring about social or economic change. Furthermore innovation comprises different kinds of changes such as technological and organisational ones and can be caused in various ways (World Bank. 2007).

In the past decades, the opinion of what agricultural innovation represents has changed considerably, and so have the procedures of supporting innovation. In the early 1980s the "National Agricultural Research System" (NARS) was established to manage the financial means allocated to agricultural progression. The focus of the NARS was set on extending research delivery by providing support and investing in areas such as management, capacity, infrastructure, human resources and policy making on national level. In the later 1980s an emphasis was put on improving the handling of existing public research organisations, for example by promoting better conceptual designs and an improved management of finances. The NARS is considered a “linear” or “transfer of technology” model where new knowledge and technology is generated due to a science push and a market pull and assigned to different problems (World Bank. 2007), as shown in Figure 5.

As a result of the lability and diseconomies of many public research organisations due to the one-sided NARS approach, the “agricultural knowledge and information system” (AKIS) came into existence in the 1990s, acknowledging that innovation is not driven by research alone. Although the AKIS lays value on research supply as well, its focus is broader, taking into account the plurality of agricultural knowledge and the connection between research, knowledge acquisition and expansion as well as the identification of the farmer’s needs for the development of new technologies (World Bank. 2007).

There are different reasons why agricultural research systems have not brought about the desired social and economic transformations. First of all, as a result of the founding of centralised research institutions, the transfer of technology and the dissemination process have often proven to be inefficient. Furthermore research priorities have not been placed correctly, considering economic gains. Another problem that results from the linear model is a weak demand for research products, reflected in low adoption of technology by farmers, due to the fact that the technologies don’t appeal to them or fit their requirements (Hall et al. 2006).

The notion of these problems has led to a new approach known as agricultural innovation system (AIS), which recognises that innovation is an interactive process and sets its focus more on the demand for technology and research and on factors and changes necessary in order to apply the knowledge and technology that has been generated. These factors include the emergence of new competencies, interconnections, attitudes and practices, institutional structures and policies. Innovation is put into a social and economic context and goes far beyond discovery and invention (World Bank. 2007).

An innovation system can be described as consisting of “…organisations, enterprises and individuals that together demand and supply knowledge and technology, and the rules and mechanisms by which these different agents interact” (World Bank. 2007, p.5).

The outdated linear model suggests that innovation takes place due to a science push, where basic science produces science that is automatically transferred and used and thus leads to economic change, isolating research from all other organisations, or a market pull, where market needs trigger the generation of knowledge which again automatically leads to innovation (World Bank. 2007).

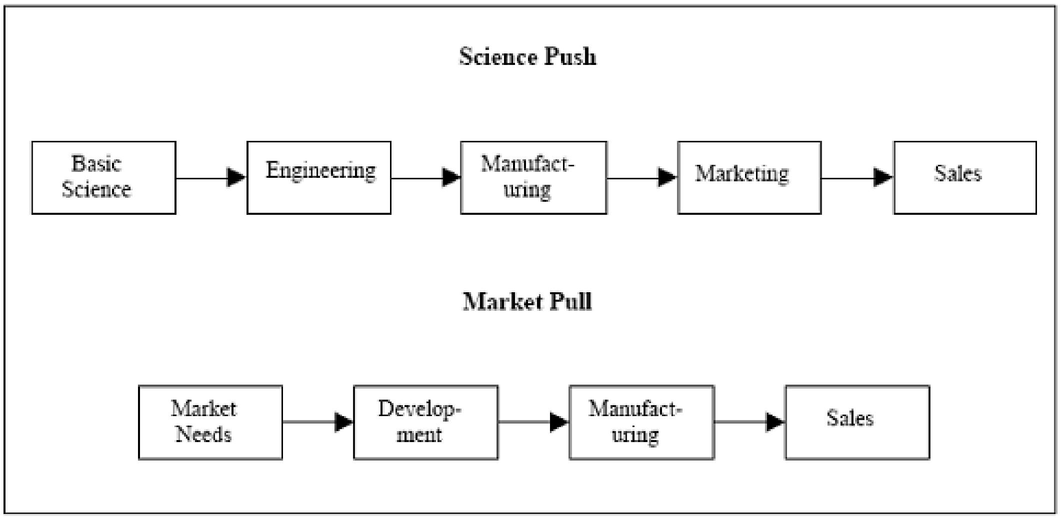


Figure 5: Linear model of science push and market pull (Source: Arnold and Bell 2001, p. 6)

Considering new insights, innovation builds on interactions between research and economy, the behavioural pattern of all organisations involved and an environment that enables interaction and knowledge transfer. The Agricultural Innovation Systems approach states that this knowledge transfer needs to be established between all individuals and organisations in order for innovation to take place, as each of them possesses a different type of knowledge that can be related to social, economic, political, institutional and policy aspects. Furthermore it has been concluded that economic welfare always involves environmental and social sustainability. The new conception of innovation systems provides the following findings (World Bank. 2007):

- Shifting the focus from production (and therefore outputs) to innovation (i.e. the application of all types of knowledge) is necessary to promote the desired economic or social changes (World Bank. 2007).
- Interaction and learning processes are essential for triggering innovation. For this interaction to take place, organisations need to be linked to each other to combine different sources of knowledge, both tacit and codified (World Bank. 2007).
- Interaction, knowledge transfer and learning can only take place if linkages between all actors are formed (World Bank. 2007). These linkages have different knowledge bases and can be of different natures. In a partnership for example, two or more organisations may decide to develop a product together or to exchange their knowledge, whereas in another type of linkage one organisation may just acquire the goods or services from another organisation (Hall et al. 2006).
- As opposed to the former linear model, where public research organisations were placed in the centre of promoting innovation, other actors and roles outside the government have gained importance in the agricultural innovation systems approach. Actors can have more than one role

and furthermore roles can change and new ones can emerge, as the innovation is a dynamic process (World Bank. 2007).

- The likeliness of innovation to take place depends on the practices and attitudes of the actors which in turn strongly influence the interactions between them. While some organisations may have the custom to interact, others may be used to working isolated from the other actors. Some organisations may be more willing to take risks than others. Also the sharing of information will be more common in some organisations than in others. The variety of practices and attitudes implies that actors may react differently to a set of innovation triggers (World Bank. 2007).
- Policies, especially in combination with other policies, play an important role in generating innovations. They influence the practices and attitudes of the actors and therefore have to be dealt with in a thorough way (World Bank. 2007).
- Stakeholders and their demands need to be included in the innovation process. Their needs signalise in which direction innovation needs to be guided (World Bank. 2007).
- Innovation is a dynamic process in which learning and capacity building are essential for promoting innovation. Habits and practices that so strongly influence the innovation process can also be considered learnt manners and need to progress in order for innovation to take place. This change in behaviour often doesn't only require new working methods, but also new linkages (Hall et al. 2006). These new methods should enable organisations to acquire new knowledge and at the same time make a better use of the entire available knowledge (World Bank. 2007).
- In order to deal with external shocks it is helpful to enforce behavioural patterns that allow a rapid and dynamic response to new circumstances (Hall et al. 2006).
- All actors possess their own knowledge, be it local and context-related knowledge of farmers, referred to as tacit knowledge, or generic knowledge possessed by scientists and other knowledge producing actors, also known as codified knowledge. Innovation can only take place if knowledge flows in all directions, meaning that local knowledge is transferred from farmers to scientists and not only generic knowledge from scientists is brought to farmers, as it often is the case in reality. In this case of one-sided knowledge transfer, one could speak of an asymmetric knowledge flow. A symmetric knowledge transfer requires a good connection and interaction between those possessing local knowledge and those offering generic knowledge (World Bank. 2007).

Innovation processes and relationships	Restrictive attitudes and practices	Supportive attitudes and practices
Interacting, knowledge flows, learning	- Mistrust of other organizations - Closed to others ideas - Secretiveness - Lack of confidence - Professional hierarchies between organizations and disciples - Internal hierarchies - Top-down cultures and approaches - Covering up of failures - Limited scope and intensity of interaction in sector networks	- Trust - Openness - Transparency - Confidence - Mutual respect - Flat management structure - Reflection and learning from successes and failures. - Proactive networking
Inclusiveness of poor stakeholders and the demand side	- Hierarchies - Top-down cultures and approaches	- Consultative and participatory attitudes
Risk taking and investing	- Conservative	- Confidence - Professional incentives

Table 2: Attitudes and practices that influence innovation processes and relationships (Source: World Bank. 2007, p.18)

According to Arnold and Bell (2001), relevant actors and actions in an innovation system can be assigned to five components, comprising the demand component, business systems, education and research systems, intermediate organisations and enabling structures. Not only the actors, but also the performance of the links between them plays an important role in enabling a well functioning innovation system (Arnold and Bell 2001). Figure 6 provides an overview of components and linkages of an agricultural innovation system.

The Agricultural Innovation System Approach emphasizes the importance of women in an innovation system which primarily aims at improving the livelihoods of all people involved, especially that of disadvantaged members of society (World Bank et al. 2009).

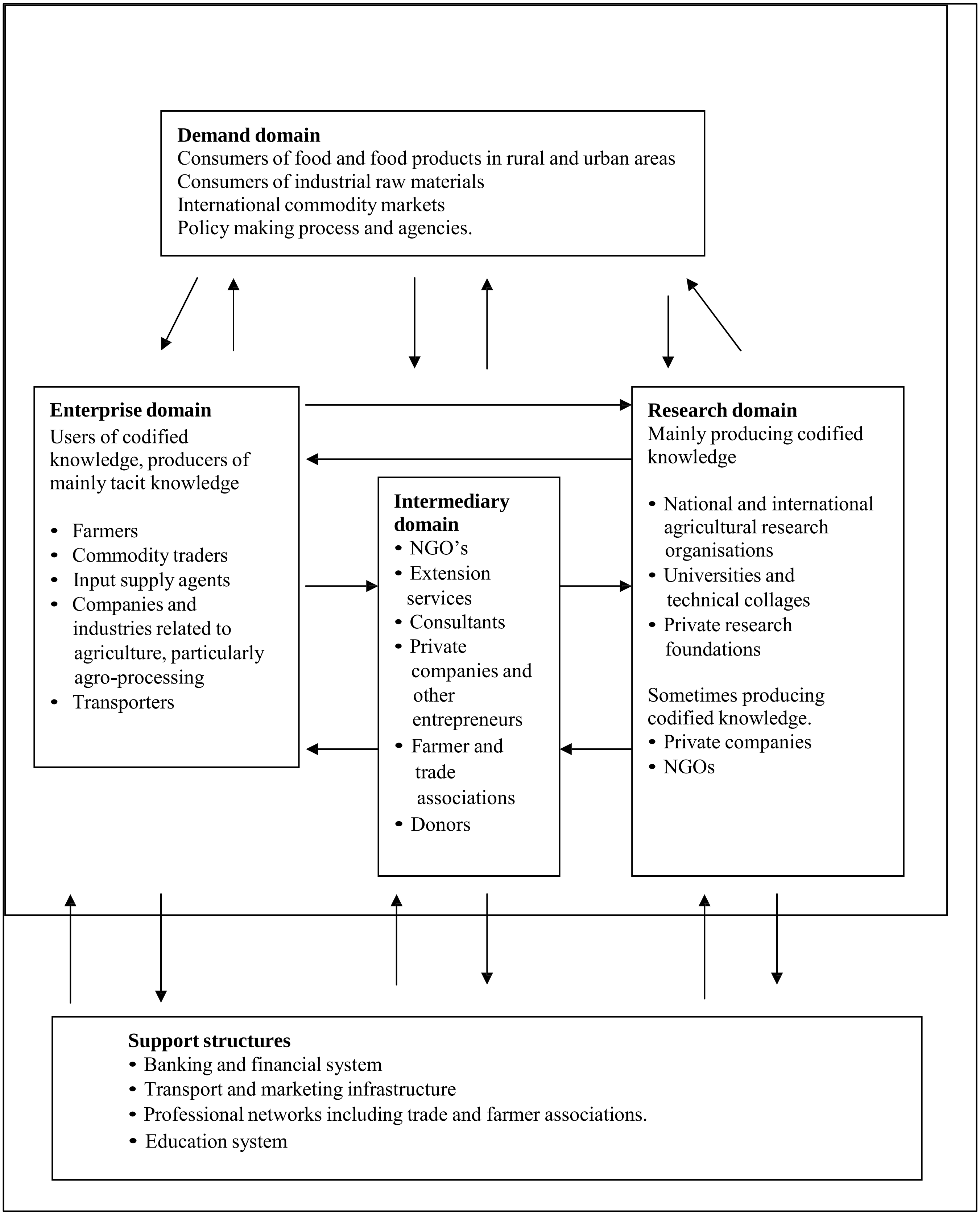


Figure 6: Elements of an agricultural innovation system (Source: Arnold and Bell 2001, modified by Hall et al. 2006, p.22)

3 RESEARCH SITES

Investigations were carried out in two research sites called Lare Division and Gilgil Division in Nakuru County. The exact location of these divisions within Nakuru County is illustrated in Figure 7.

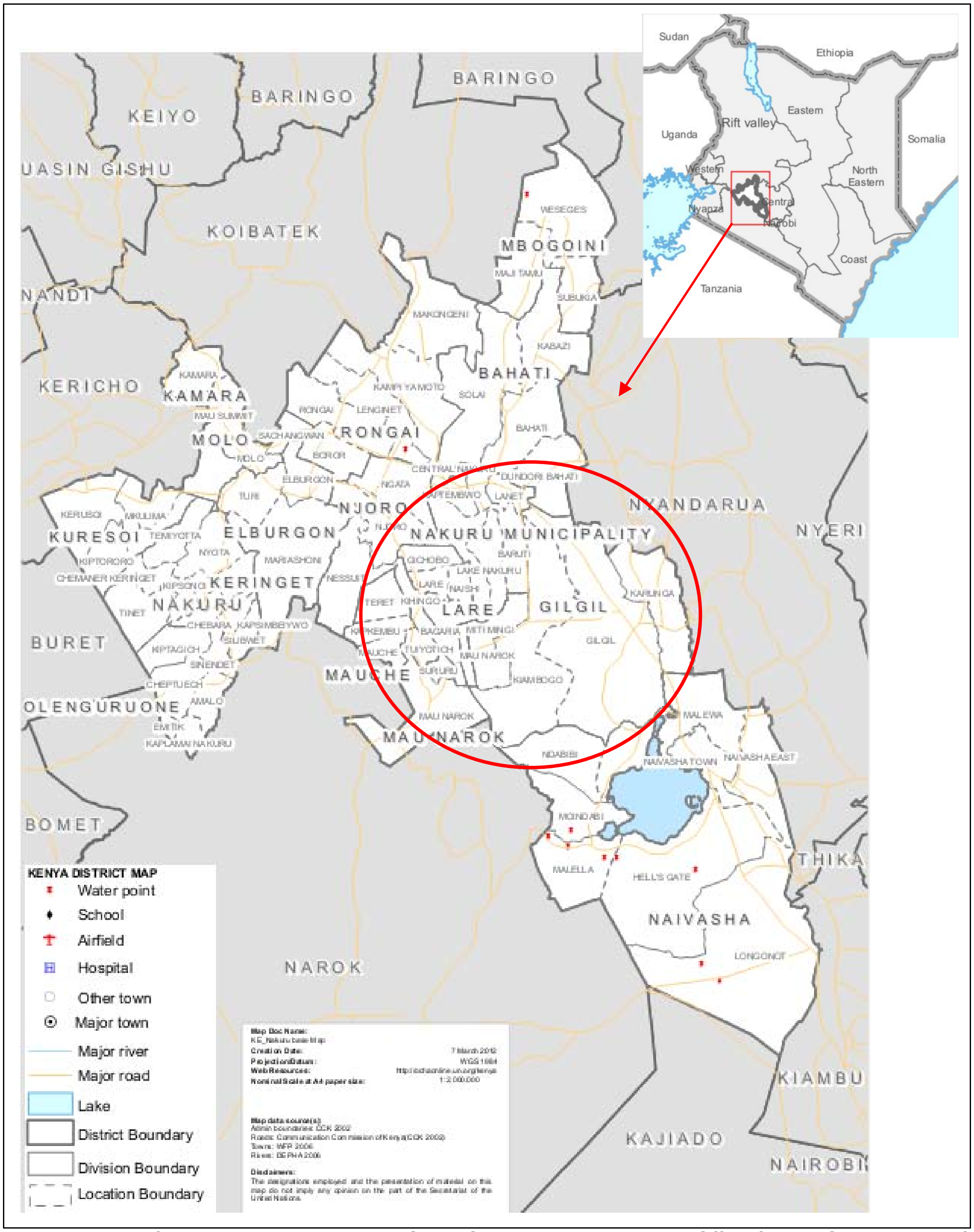


Figure 7: Map of research areas Lare and Gilgil (Source: United Nations. Office for the Coordination of Humanitarian Affairs. 2012, modified)

3.1 Lare Division

3.1.1 *Biophysical characteristics*

3.1.1.1 Location

Lare Division is situated in the Rift Valley province of Kenya and is part of Nakuru County. It has a size of approximately 134 km² (Naaminong et al. 1997) and is subdivided into four administrative locations named Gichobo, Naishi, Lare and Bagaria (Kenya National Bureau of Statistics 2010, cited in Jaetzold et al. 2010), as shown in Figure 8.

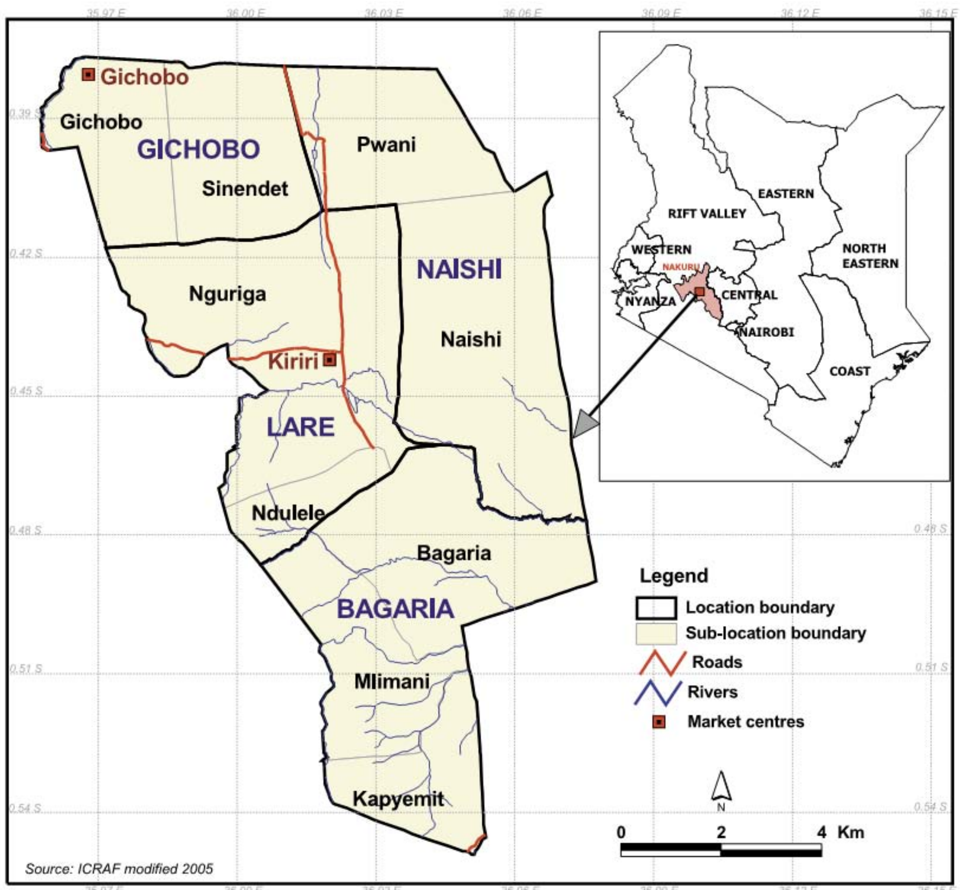


Figure 8: Map of Lare Division (Source: Malesu et al. 2006, p. 4)

3.1.1.2 Climate

Lare receives an average rainfall amount of 600 to 1000 mm per year. Although generally unpredictable, most of the rainfall occurs during the two rainy seasons, which are known as *long rains* in March and *short rains* in October (Malesu et al. 2006). Lare faces recurring droughts every three to five years (Naaminong et al. 1997). According to rainfall and temperature data obtained from the nearest weather station (KARI Njoro, NPBRC), the mean annual temperature varies between 15 and 18 degrees Celsius and the mean annual rainfall is 959 mm. Figure 9 shows the rainfall and temperature distribution for Njoro in 2012.

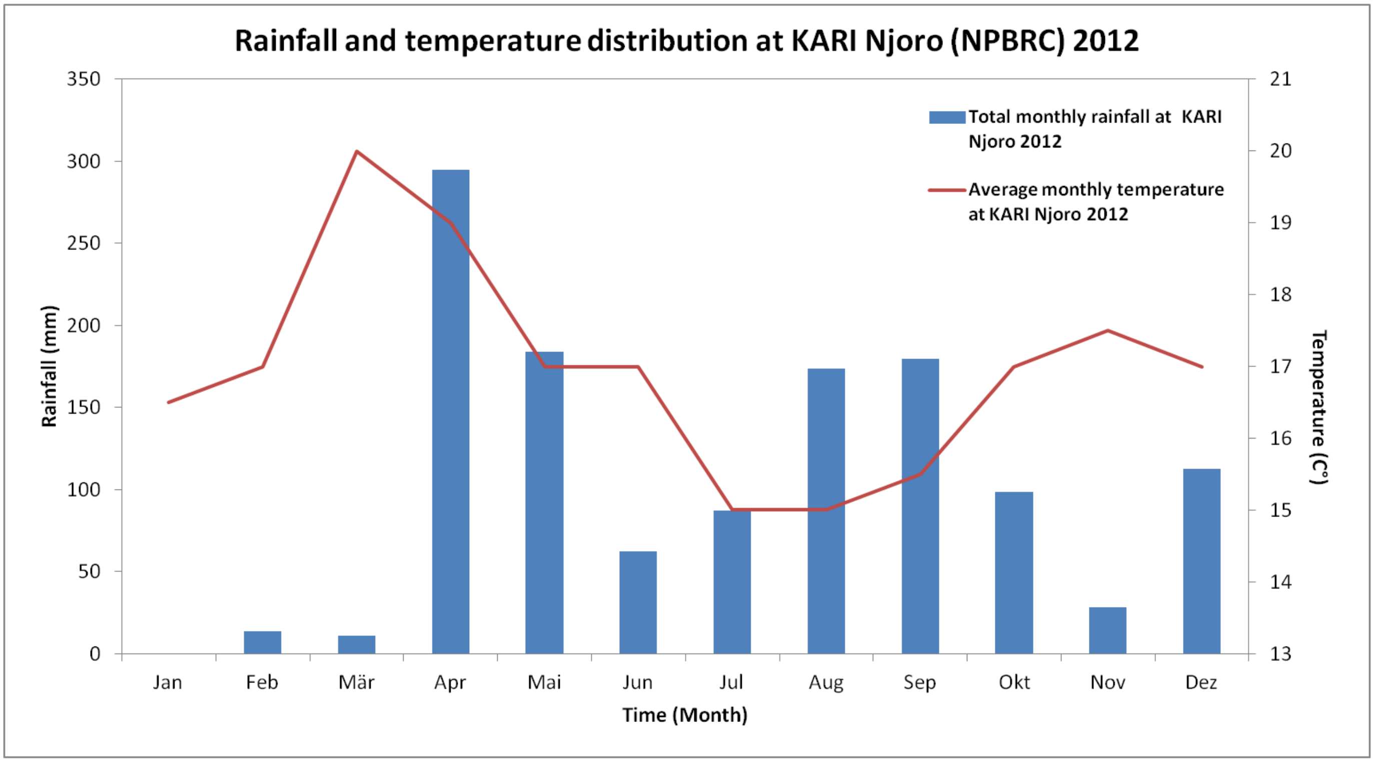


Figure 9: Rainfall and temperature distribution at KARI Njoro in 2012 (Source: Rainfall and temperature data NPBRC 2012, own illustration)

According to Naaminong (Naaminong et al. 1997, p. 12) Lare can be subdivided into four agro-ecological zones, namely LH2, LH3, UM4 and UM5. The zonal distribution within Lare is shown in Figure 10.

Jaetzold et al. (2010, p. 16b) describe these zones as follows:

LH2:

Lower Highland Zone with mean annual temperature between 15-18 °C, sub-humid, also known as Wheat/Maize-Pyrethrum Zone

LH3:

Lower Highland Zone, with mean annual temperature between 15-18 °C, semi-humid, also known as Wheat/Maize-Barley Zone

UM4:

Upper Midland Zone, with mean annual temperature between 18-21 °C, transitional, also known as Maize-Sunflower Zone

UM5:

Upper Midland Zone, with mean annual temperature between 18-21 °C, semi-arid, also known as Livestock-Sorghum Zone

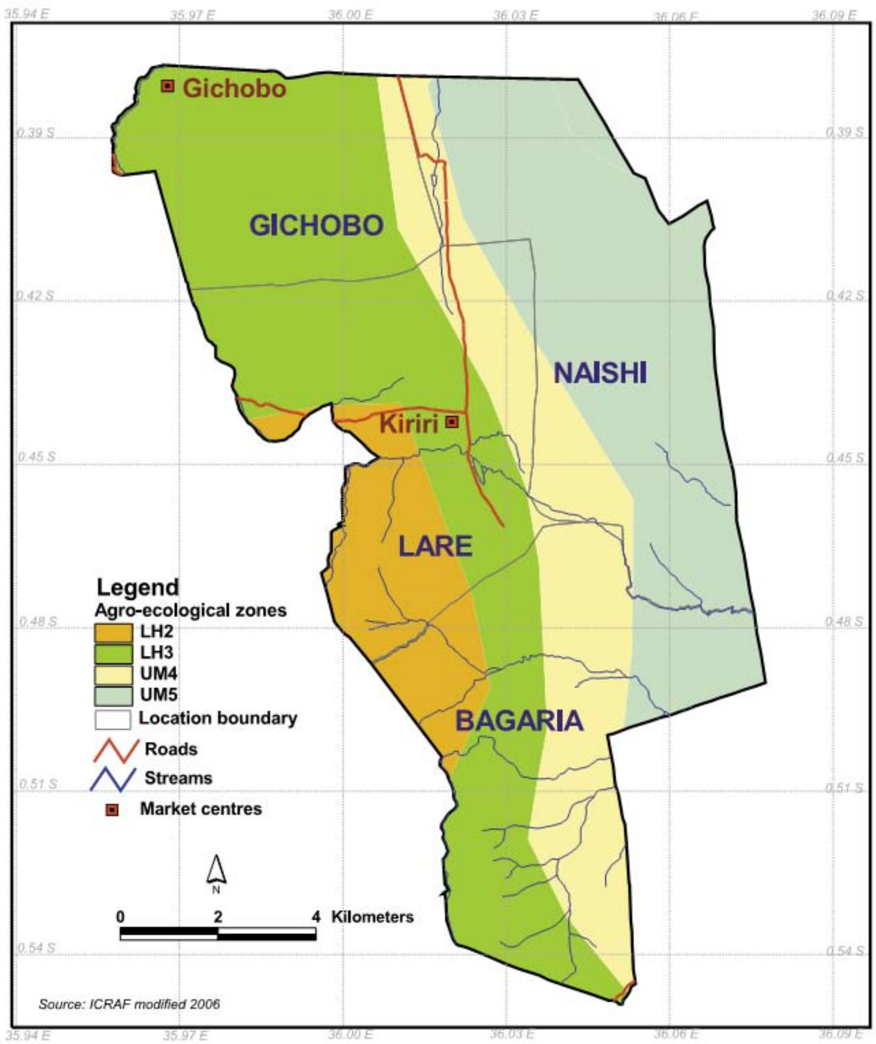


Figure 10: Map of Agro-Ecological Zones in Lare (Source: Malesu et al. 2006, p. 6)

The cropping seasons and suitable crops according to the agro-ecological zones are described in Table 3.

Agro-Ecological Zone		Cropping Season		Good yield potential - Examples	Fair yield potential - Examples
LH2	Maize / Wheat - Pyrethrum Zone	One very long cropping season, dividable into two variable cropping seasons	1st rainy season starts mid March	Late maturity maize and wheat, potatoes, beans and sunflowers	Finger millet, beans, tomatoes
			2nd rainy season starts end of June	Kales, cauliflower, carrots and beetroots.	Peas, potatoes, cabbages
			Whole year	Black wattle	Pyrethrum, tea
LH3	Wheat/(Maize)-Barley Zone	One very long to long cropping season, dividable in two variable cropping seasons	1st rainy season starts beginning of Marcl	Wheat, barley, late maturity maize	Potatoes, beans, cauliflower
			2nd rainy season starts around July and August	Barley	Medium maturity wheat, beans, tomatoes
			Whole year	Black wattle	Avocados, strawberries
UM4	Maize-sunflowers Zone or Upper Sisal Zone	One long to very long cropping season, dividable in two variable cropping seasons	1st rainy season starts end of March	Late and medium maturity maize, sunflowers and beans, cold tolerant sorgum	Finger millet, pigeon peas, potatoes, egg plants
			2nd rainy season starts end of June	Sunflowers	Beans, potatoes, sunflowers
			Whole year	Sisal, eucalyptus trees	Pawpaws, mangoes
UM5	Livestock-Sorghum Zone	One (weak) short cropping season, intermediate rains, and a (weak) very uncertain second rainy season	1st rainy season starts beginning of March	No good yield potential except with add. irrigation (partly possible)	Cold tolerant sorghum
			Whole year		Sisal, Marama Beans

Table 3: Agro-Ecological Zones in Lare (Source: Jaetzold et al. 2010, pp.109-118, modified)

3.1.1.3 *Soils and Topography*

The soil types in Lare change according to elevation and vary between fragile loam and sandy loam. Furthermore the soils are moderately deep, well drained and volcanic. The soil colour can range between brown and grey depending on the drainage characteristics of the respective area. The location is characterised by slopes (Malesu et al. 2006). The soil types found in Lare Division are shown in Figure 11.

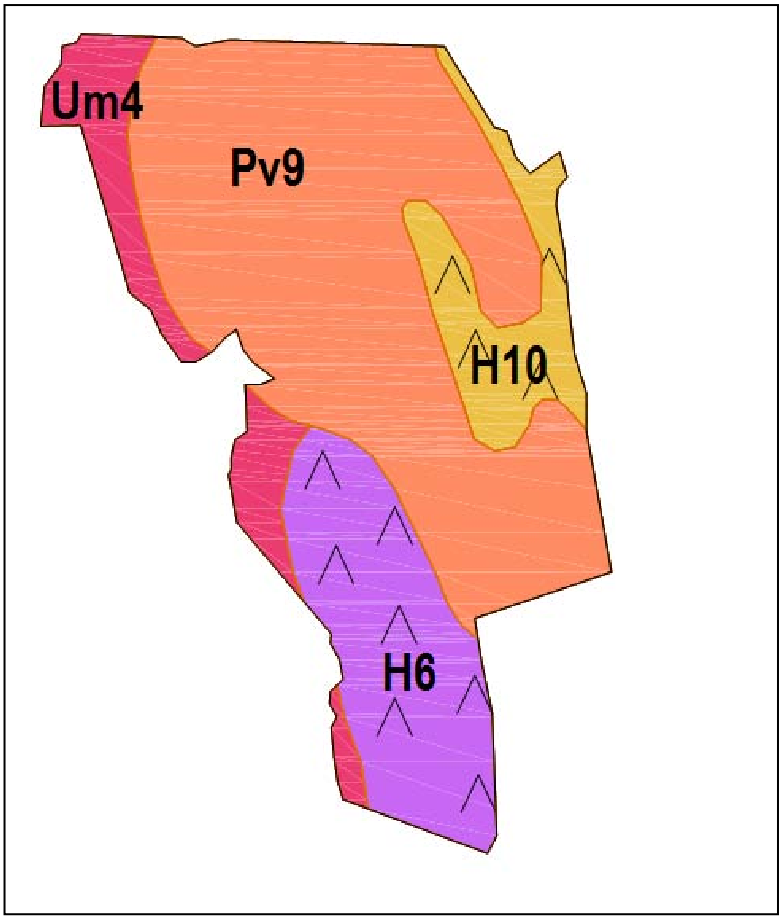


Figure 11: Soil types in Lare Division (Source: Sombroek et al. 1982, modified)

The soil types are described by Sombroek et al. (1982, pp. 18-33) as follows:

H6:

Complex of

- Well drained, deep to very deep, dark brown to greyish brown, friable and smeary clay loam with a thick humic topsoil (Mollic ANDOSOLS)
- Somewhat excessively drained, shallow, strong and rocky soils of varying colour and consistence and texture (dystric REGOSOLS, lithic phase with ferralic CAMBISOLS, lithic phase and rock outcrops)

H10:

Complex of well drained to moderately well drained, shallow to moderately deep, dark brown, firm, strong clay loam to clay in places with humic topsoils (Eutric REGOSOLS) partly with lithic phase; with Verto-Luvic PHAEOZEMS, partly lithic phase

Pv9:

Well drained, moderately deep to deep brown, to dark brown very friable loam to sandy to clay loam (Vitric ANDOSOLS)

UM4:

Well drained deep to extremely deep, dark red, friable clay with a thick humic topsoils (mollic NITOSOLS with Nitro-luvic PHAEOZEMS)

3.1.1.4 Vegetation and land cover

The vegetation around Lake Nakuru consists of trees such as Acacia, Olea and Euphorbia as well as bushland and grassland communities (Republic of Kenya 2010). The main land cover types found are agricultural land, forests and shrubland (Malesu et al. 2006). As shown in Mwetu (2010), the distributions of these land cover types have gone through drastic changes, with forest land decreasing since 1973 and being turned into grassland and agricultural land.

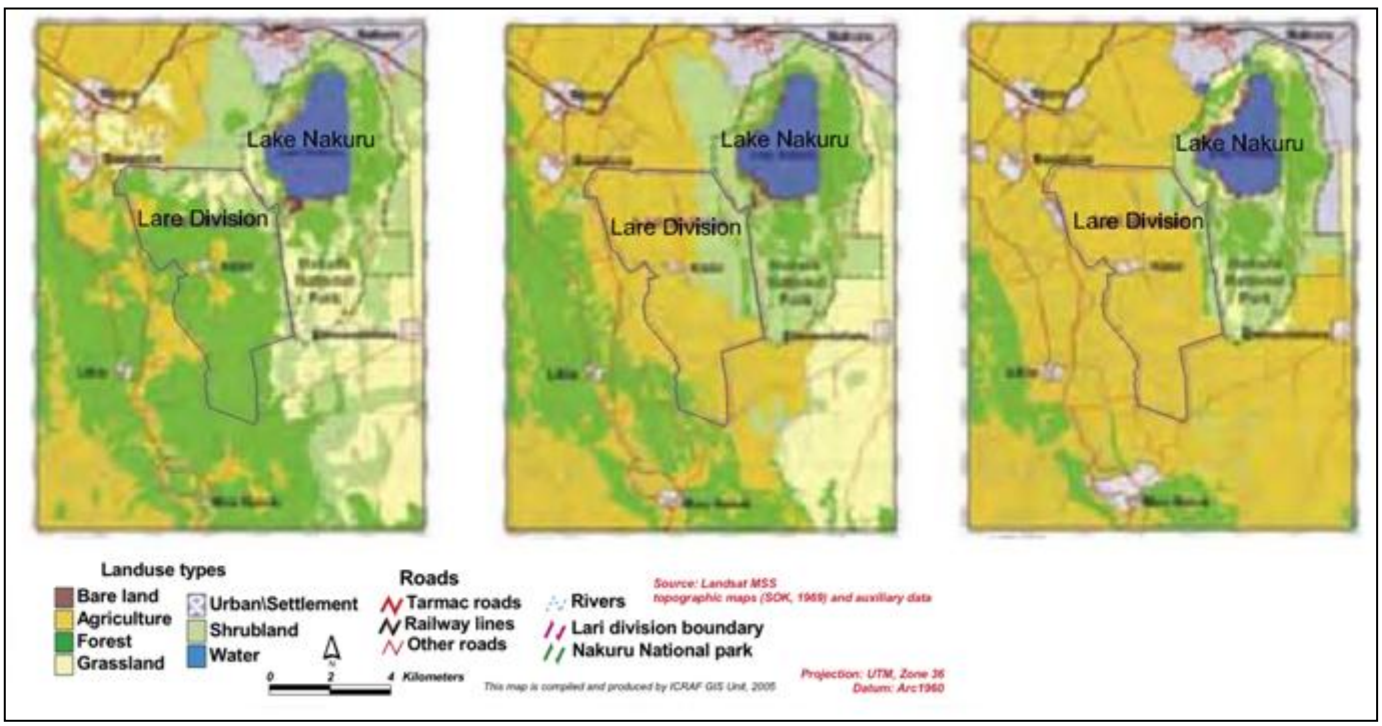


Figure 12: Land cover maps of Lare and its surrounding from 1973, 1986 and 2003 (Source: Malesu et al. 2006, p. 12, modified)*

*poor map quality already existed in the original version in Malesu et al. (2006, p.12)

3.1.1.5 Hydrology

Lare is crossed by various streams as shown in Figure 13, which originate from the Mau forest. The main river which passes through the area flows into Lake Nakuru. The majority of these streams are seasonal (Malesu et al. 2006).

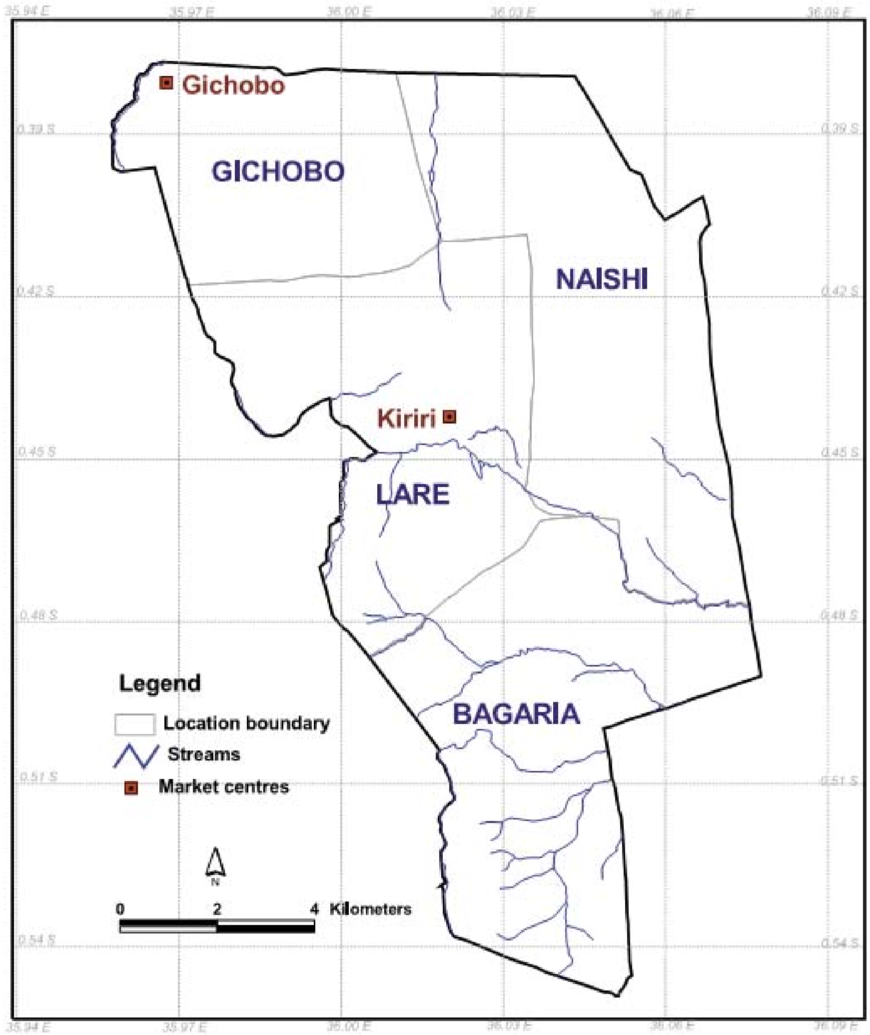


Figure 13: Streams in Lare Division (Source: Malesu et al. 2006, p. 11)

3.1.1 Socio-economic characteristics

3.1.1.1 Demography

DIVISION/ Location/Sub location	**Male**	**Female**	**Total**	**Area in Km²**	**Density**
LARE	**14499**	**15322**	**29821**	**139,1**	**214**
Bagaria	3877	4236	8113	40,5	200
Bagaria	2670	2926	5596	23,2	241
Kapyemit	723	786	1509	8,7	174
Milimani	484	524	1008	8,7	117
Gichobo	2980	3159	6139	23,4	262
Gichobo	1374	1435	2809	11	255
Sinendet	1606	1724	3330	12,4	268
Lare	4767	5018	9785	35,5	276
Lare	3152	3407	6559	26	252
Ndulele	1615	1611	3226	9,5	341
Naishi	2875	2909	5784	39,7	146
Naishi	1887	1959	3846	26,4	146
Pwani	988	950	1938	13,4	145

Table 4: Population in Lare Division (Source: Kenya National Bureau of Statistics 2010, cited in Jaetzold et al. 2010, p. 141, modified)

According to the Kenya National Bureau of Statistics (2010, cited in Jaetzold et al. 2010, p. 141), the number of inhabitants in Lare Division is around 30000. The distribution of males and females according to location is shown in Table 4.

3.1.1.2 Land use

The most common land use type in Lare is mixed farming, with maize, beans, wheat and vegetables such as peas as main crops grown, and cattle as main animals reared. Livestock are of high significance in the area, as their products are used for domestic as well as commercial purposes and thus influence the income of the inhabitants as well as the economy in the location (Malesu et al. 2006).

3.1.1.3 Land tenure

Land tenure changed when people began settling in Lare around 1978. Former forest areas were cut down and turned into private, purchasable land. Sizes of single farms vary between four and ten hectares, but there is a trend to further land splitting as the population in the division is increasing. Certain areas have stayed public and are being used for community facilities such as schools, markets and community dams (Malesu et al. 2006).

3.1.1.4 Water resources

Most homesteads don't have tap water and are therefore dependent on water from seasonal rivers, bore holes, roof catchments, water pans and water dams both for domestic use as well as for feeding their livestock (Malesu et al. 2006). As water scarcity is prevalent both for livestock and drinking purposes (Naaminong et al. 1997), there has been a high adoption rate of water pans (Malesu et al. 2006). The increase in water pans in the division is shown in Figure 14.

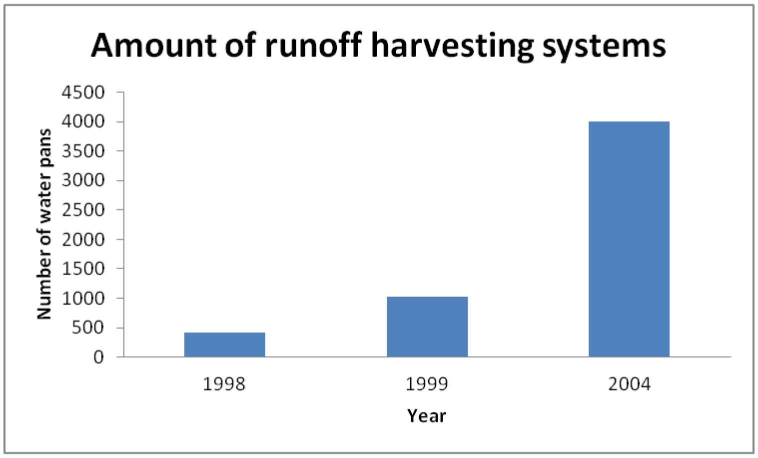


Figure 14: Increase in the number of water pans from 1998 to 2004 (Source: Malesu et al. 2006, p. 10, own illustration)

While 409 water pans were identified in 1998, 1030 runoff harvesting systems were estimated in 1999 and around 4000 water pans had been built up to 2004 (Malesu et al. 2006).

3.2 Gilgil Division

3.2.1 Biophysical characteristics

3.2.1.1 Location

Similar to Lare Division, Gilgil Division is situated in the Rift Valley province of Kenya and is part of Nakuru County. It is subdivided into two administrative locations called Gilgil and Karunga and four sub-locations known as Gilgil, Eburu and Mbaruk in Gilgil location and Karunga in Karunga location ((Kenya National Bureau of Statistics 2010, cited in Jaetzold et al. 2010, p. 147).

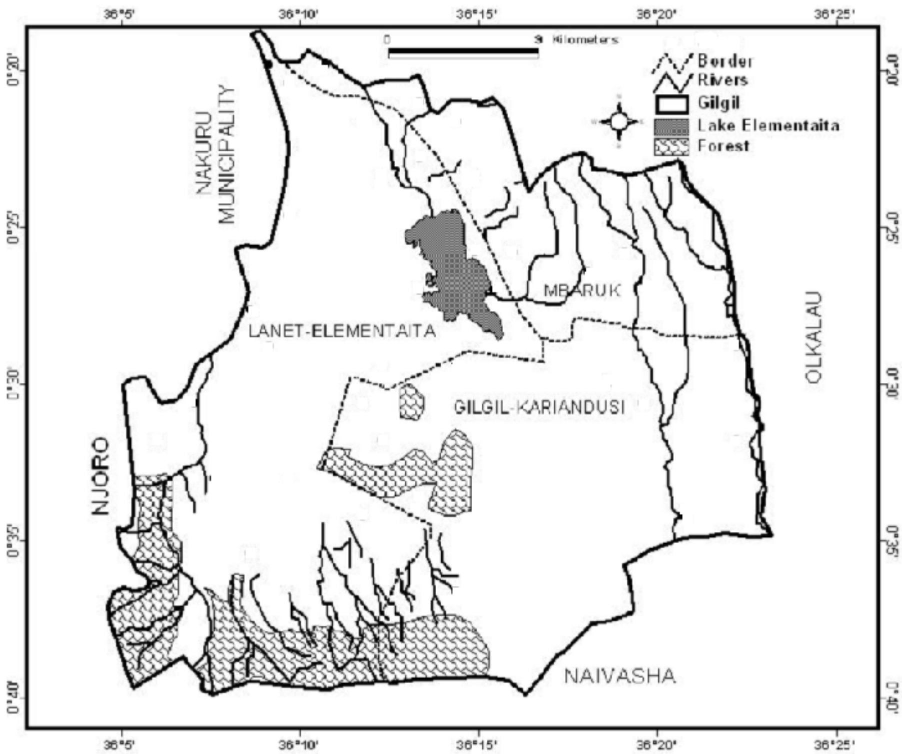


Figure 15: Map of Gilgil Division (Source: Wambu and Muthakia 2011, p. 38, modified)

3.2.1.2 Climate

The rainfall pattern in Gilgil is bimodal with rainy seasons from April to June (long rain) and from October to November (short rain) (Sparvs Agency Ltd 2008). Rainfall data was obtained from the nearest weather station, Soyambu Wildlife Conservancy, and temperature data was obtained from Nakuru MET station (cited in Jaetzold et al. 2010, p. 104). The mean annual rainfall at Soysambu Wildlife Conservancy amounts to 725 mm, considering data from 1948 to 2012, and the mean annual temperature lies between 18 and 20 degrees Celsius. Figure 16 shows the rainfall distribution at Soysambu Conservancy in 2012 and the average temperature distribution of Nakuru MET station between 1993 and 2008 (cited in Jaetzold et al. 2010, p. 104).

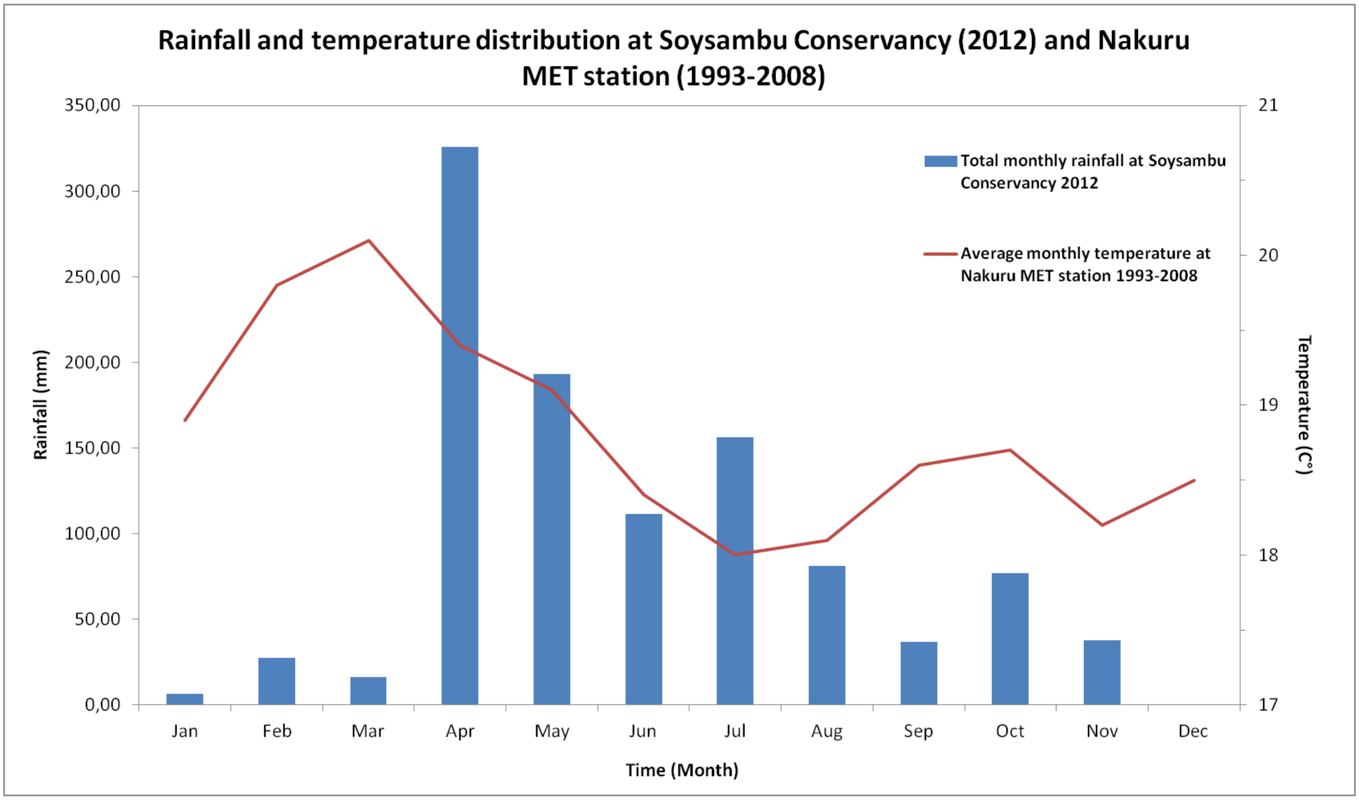


Figure 16: Rainfall distribution at Soysambu Wildlife Conservancy in 2012 and temperature distribution at Nakuru MET station between 1993 and 2008 (Source: Rainfall data Soysambu Wilflife Conservancy 2012 and temperature data from Nakuru cited in Jaetzold et al. 2010, p. 104, own illustration)

The main agro-ecological zones found in Gilgil are UH2, LH3 to LH5, and UM4 to UM6 (Jaetzold et al. 2010) and are shown in Figure 17 and described in Table 5.

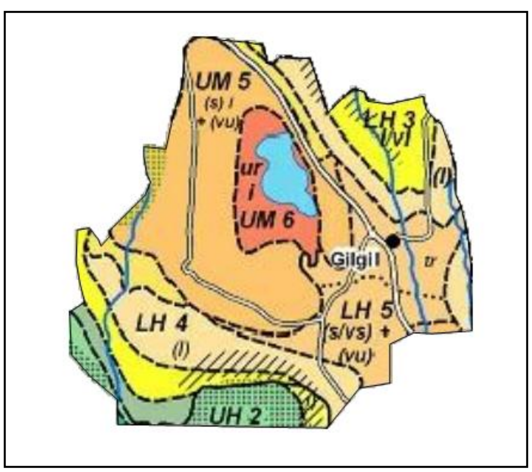


Figure 17: Map of Agro-Ecological Zones in Gilgil (Source: Jaetzold et al. 2010, p. 106, modified)

Jaetzold et al. (2010, p. 16b) describe these zones as follows:

UH2:

Upper Highland Zone, with mean annual temperature between 10-15 °C, semi-humid, also known as Pyrethrum-Wheat-Zone

LH3:

Lower Highland Zone, with mean annual temperature between 15-18 °C, semi-humid, also known as Wheat/Maize-Barley-Zone

LH4:

Lower Highland Zone, with mean annual temperature between 15-18 °C, transitional, also known as Cattle-Sheep-Barley-Zone

LH5:

Lower Highland Zone, with mean annual temperature between 15-18 °C, semi-arid, also known as Highland-Ranching-Zone

UM4:

Upper Midland Zone, with mean annual temperature between 18-21 °C, transitional, also known as Maize-Sunflower Zone

UM5:

Upper Midland Zone, with mean annual temperature between 18-21 °C, semi-arid, also known as Livestock-Sorghum Zone

UM6:

Upper Midland Zone, with mean annual temperature between 18-21 °C, arid, also known as Upper Midland Ranching Zone

<table>
<tr><th colspan="2">Agro-Ecological Zone</th><th colspan="2">Cropping Season</th><th>Good yield potential - Examples</th><th>Fair yield potential - Examples</th></tr>
<tr><td rowspan="3">UH2</td><td rowspan="3">Wheat-Pyrethrum Zone</td><td rowspan="3">One very long cropping season, dividable into two variable cropping seasons</td><td>1st rainy season starts end of March</td><td>Very late maturity wheat, medium maturity barley, oats, beans, peas, potatoes</td><td>Very late maturity maize (risk by frost in valleys and higher plateaus</td></tr>
<tr><td>2nd rainy season starts beginning of July</td><td>Medium maturity barley, oats, rapeseed, peas, vegetables i.e. cabbages, kales</td><td>potatoes, kohlrabi</td></tr>
<tr><td>Whole year</td><td>Pyrethrum, strawberries, collard greens (Sukuma wiki)</td><td>Plums, pears, apples</td></tr>
<tr><td rowspan="3">LH3</td><td rowspan="3">Wheat/(Maize)-Barley Zone</td><td rowspan="3">One very long to long cropping season, dividable in two variable cropping seasons</td><td>1st rainy season starts beginning of March</td><td>Wheat, barley, late maturity maize</td><td>Potatoes, beans, cauliflower</td></tr>
<tr><td>2nd rainy season starts around July and August</td><td>Barley</td><td>Medium maturity wheat, beans, tomatoes</td></tr>
<tr><td>Whole year</td><td>Black wattle</td><td>Avocados, strawberries</td></tr>
<tr><td rowspan="3">LH4</td><td rowspan="3">Cattle-Sheep-Barley Zone</td><td rowspan="3">One long to very long cropping season, dividable in two variable cropping seasons</td><td>1st rainy season starts end of March</td><td>Late and medium maturity maize, sunflowers and beans, cold tolerant sorgum</td><td>Finger millet, pigeon peas, potatoes, egg plants</td></tr>
<tr><td>2nd rainy season starts end of June</td><td>Sunflowers</td><td>Beans, potatoes, sunflowers</td></tr>
<tr><td>Whole year</td><td>Sisal, eucalyptus trees</td><td>Pawpaws, mangoes</td></tr>
<tr><td rowspan="2">LH5</td><td rowspan="2">Livestock-Sorghum Zone</td><td rowspan="2">One (weak) medium to long cropping season and intermediate rains and a (weak) very uncertain second rainy season</td><td>1st rainy season starts beginning of March</td><td rowspan="2">No good yield potential except with add. irrigation (partly possible)</td><td>Cold tolerant sorghum</td></tr>
<tr><td>Whole year</td><td>Sisal, Marama Beans</td></tr>
<tr><td rowspan="3">UM4</td><td rowspan="3">Maize-sunflowers Zone or Upper Sisal Zone</td><td rowspan="3">One long to very long cropping season, dividable in two variable cropping seasons</td><td>1st rainy season starts end of March</td><td>Late and medium maturity maize, sunflowers and beans, cold tolerant sorgum</td><td>Finger millet, pigeon peas, potatoes, egg plants</td></tr>
<tr><td>2nd rainy season starts end of June</td><td>Sunflowers</td><td>Beans, potatoes, sunflowers</td></tr>
<tr><td>Whole year</td><td>Sisal, eucalyptus trees</td><td>Pawpaws, mangoes</td></tr>
<tr><td rowspan="2">UM5</td><td rowspan="2">Livestock-Sorghum Zone</td><td rowspan="2">One (weak) medium to long cropping season and intermediate rains and a (weak) very uncertain second rainy season</td><td>1st rainy season starts beginning of March</td><td rowspan="2">No good yield potential except with add. irrigation (partly possible)</td><td>Cold tolerant sorghum</td></tr>
<tr><td>Whole year</td><td>Sisal, Marama Beans</td></tr>
</table>

Table 5: Agro-Ecological Zones in Gilgil (Source: Jaetzold et al. 2010, pp. 107-123, modified)

3.2.1.3 Soils and Topography

Soils in Gilgil are volcanic with some thin organic layers in between. Soil thickness and type vary throughout the area. There is a small portion of fertile, deep soil in the higher, eastern area of Gilgil, while the major part of the area is sodic, saline or both, strongly weathered and acidic (Alamirew et al. 2007). The area is characterised by rocky rupture lines, volcanic exposures and craters (Republic of Kenya 2010). Figure 18 illustrates the soil types and their distribution in Gilgil Division.

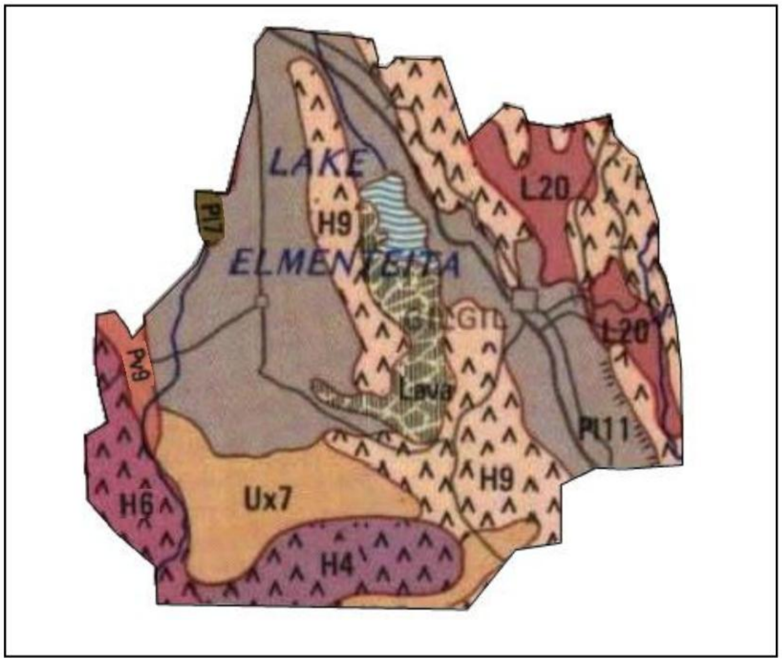


Figure 18: Soils in Gilgil Division (Source: Sombroek et al. 1982, modified)

The soil types found in Gilgil are described by Sombroek (1982, pp. 17-35) as follows:

H4:

Somewhat excessively drained, shallow, dark brown to brown, friable and slightly smeary, rocky and stony, clay loam (ando-eutric CAMBISOLS, lithic and stony phase; with rock outcrops)

H6:

Complex of

- Well drained, deep to very deep, dark brown to greyish brown, friable and smeary clay loam with a thick humic topsoil (Mollic ANDOSOLS)
- Somewhat excessively drained, shallow, strong and rocky soils of varying colour and consistence and texture (dystric REGOSOLS, lithic phase with ferralic CAMBISOLS, lithic phase and rock outcrops)

H9:

Well drained, shallow, dark reddish brown, friable, very calcareous, bouldery or stony, loam to clay loam; in many places saline (LITHOSOLS; with calcic XEROSOLS, lithic, bouldery and saline phase and rock outcrops)

L20:

Well drained, moderately deep to very deep, dark brown, friable and slightly smeary, clay loam to clay (ando-luvic PHAEOZEMS)

Pl7:

Imperfectly drained to poorly drained, very deep, dark greyish brown to dark brown, firm to very firm, slightly to moderately calcareous, slightly to moderately saline, moderately to strongly sodic, silt loam to clay; in many places, with a humic topsoil; Subrecent lake edges of the Central Rift Valley (undifferentiated SOLONETZ, saline phase)

Pl11:

Complex of

- Well drained, moderately deep to deep, dark brown, friable and slightly smeary, fine gravelly, sandy clay loam to sandy clay, with a humic topsoil (ando-haplic PHAEOZOMS)
- Imperfectly drained, moderately deep to deep, strong brown, mottled, firm and brittle, sandy clay to clay (Gamblian lake of the Central Rift Valley), (gleyic CAMBISOLS, fragipan phase)

Pv9:

Well drained, moderately deep to deep brown, to dark brown very friable loam to sandy to clay loam (Vitric ANDOSOLS)

Ux7:

Well drained, shallow, dark brown, friable, strongly calcareous, strongly saline and moderately sodic, stony loam; with a stone surface (dissected older piedmont plain) (calcaric REGOSOLS, stone-mantle and saline-sodic phase)

3.2.1.4 Vegetation and land cover

The vegetation around Lake Elementaita is made up of tree species such as Acacia and Euphorbia and various bushland (i.e. Rhus natalensis) and grassland (i.e. Cynodon dactylon) communities (Republic of Kenya 2010). A high amount of former woodland has been cleared or turned into bush and grasslands as a result of farming, grazing and fires. The natural vegetation is at risk of getting even more diminished due to its use as firewood and for charcoal production (Sparvs Agency Ltd 2008).

3.2.1.5 Hydrology

The main rivers which flow through Gilgil Division are Gilgil, Kariandusi and Malewa Rivers (Bergner et al. 2009). River Kariandusi emerges from the Kariandusi hot springs situated in the eastern part of Gilgil

Division. Lake Elementaita is part of Gilgil Division and is fed by the Kariandusi hot springs as well as by Kariandusi River and another stream known as Meroroni River (Republic of Kenya 2010). The streams found in Gilgil are shown in Figure 19.

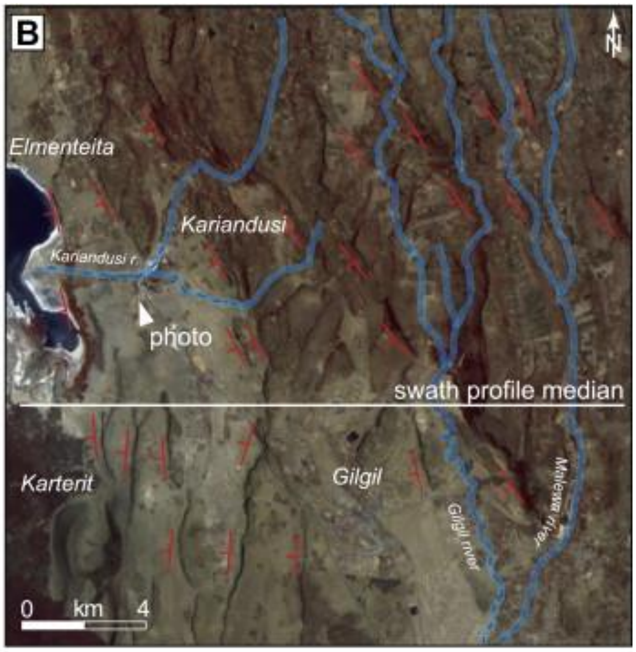


Figure 19: Streams in Gilgil Division (Source: Bergner et al. 2009, p. 2812)

3.2.2 Socio-economic characteristics

3.2.2.1 Demography

Considering the population census of 2009, the number of inhabitants in Gilgil Division is approximately 93000. The average population density is 160 persons per km², ranging from 29 persons per km² in Eburu Sub-location to 565 persons per km² in Gilgil Sub-location. The average number of family members per household is 4 (Kenya National Bureau of Statistics 2010, cited in Jaetzold et al. 2010, p. 146), resulting in an average availability of agricultural land of 2.53 ha per household. This is a theoretical figure, though, as not the entire land is used agriculturally and most of it has low potential (Jaetzold et al. 2010). Due to a population increase in the entire county, the number of inhabitants in low potential zones and rangelands and especially around Lake Elementaita has increased (Republic of Kenya 2010). The exact distribution of male and female inhabitants is shown in Table 6.

DIVISION/ Location/Sub location	**Male**	**Female**	**Total**	**Area in Km²**	**Density**
GILGIL	**47839**	**45213**	**93052**	**581,5**	**160**
Gilgil	36989	34378	71367	425,6	168
Gilgil	25498	22105	47603	84,3	565
Eburu	3394	3767	7161	245,9	29
Mbaruk	8097	8506	16603	95,3	174
Karunga	1085	10835	21685	155,9	139
Karunga	1085	10835	21685	155,9	139

Table 6: Population in Gilgil Division (Source: Kenya National Bureau of Statistics 2010, cited in Jaetzold et al. 2010, p. 146, modified)

3.2.2.2 Land use

Some of the major land use types found in Gilgil Division are farming, ranching, mining, forestry and settlement. The most common land use type is ranching, as farming in lower parts of the area is uneconomical due to unpredictable and unevenly distributed rainfall. Due to the climatic conditions only 30 % of land considered arable can actually be used for farming. 50 % of the total land is considered agro-ecological zones UM5 and LH5, which are hardly suitable for agriculture. Although there is a high risk of crop failure, large amounts of maize are grown in this area. In 2009 only around 20 % of the mean maize yield could be harvested due to the rainfall conditions. Farmers also grow beans and use irrigation to grow vegetables both for domestic and commercial purposes (Sparvs Agency Ltd 2008). There are a few ranches and large scale farms which produce a high quantity of flowers and plants such as grapes using irrigation as well as milk and meat, which is of high importance to the local population and the national economy (Jaetzold et al. 2010). Especially in Elementaita and Kikopey livestock production is high. Furthermore people in the area are involved in charcoal production and in collecting sand and salt from Lake Elementaita for commercial purposes. The area is also used by nomadic Maasai for livestock grazing and salt consumption. Overgrazing is a common problem due to a high demand of forage for both livestock and wildlife and often leads soil erosion after periods of drought (Sparvs Agency Ltd 2008).

The higher areas are more humid and are thus more suitable for small-scale farming. A large variety of vegetables are being planted in those areas (Jaetzold et al. 2010).

3.2.2.3 Land tenure

Increased settlement in Gilgil location began around 1982 and land was split into single plots. Today farm sizes range from around two to five acres. During the time when people started settling in the location there was still a large number of trees, but as the population and cultivation increased over the years the forest areas diminished. Furthermore the level of Lake Elementaita was higher than it is nowadays and a high quantity and variety of wildlife used to be common, which don't exist in this area any more (Sparvs Agency Ltd 2008).

3.2.2.4 Water resources

The main water sources are the hot springs in the area, which are used for drinking, domestic purposes, livestock feeding and irrigation. Also the water from surrounding rivers is abstracted for these purposes (Sparvs Agency Ltd 2008). According to Wambu and Muthakia (2011, p. 37) groundwater is also an important water source, and rainwater harvesting is not widely practiced. They state that the fluoride content in water taken from boreholes is high, but the content in river or stream water is low compared to high fluoride content rivers in other parts of the country. Therefore it is possible to use this water both for domestic and industrial purposes with a low risk of fluorosis (Wambu and Muthakia 2011)

4 METHODOLOGY AND DATA COLLECTION

Before conducting the actual surveys in Lare and Gilgil, the sites were visited in order to get a general impression of the prevailing circumstances and to get into contact with people who could assist in planning the transect walks and choosing farmers for the semi-structured interviews. Furthermore an interview pre-testing was conducted in order to ensure that the questions were comprehensible and sensible. Before doing the actual interviews in the research areas, the questions were restructured and modified.

4.1 Transect walks

In order to get a comprehensive picture of the research sites and existing water management measures with a special focus on water harvesting and irrigation systems, transect walks were conducted in Lare and Gilgil Divisions. As single locations in Lare differ both in bio-physical as well as socio-economic characteristics, two transect walks were undertaken, one of them in Lare Location together with the Assistant Chief of Lare Location and the other one in Kiriri Location together with the Chief of Lare Location. One transect walk in Gilgil was conducted in Gilgil Location together with the Agricultural Extension Officer of Gilgil Division. Figure 20 gives an overview of the transect walk locations within the divisions, while Figure 21 and Figure 22 show the exact routes of the transect walks.

1. <u>Location of transect walks within the divisions</u>

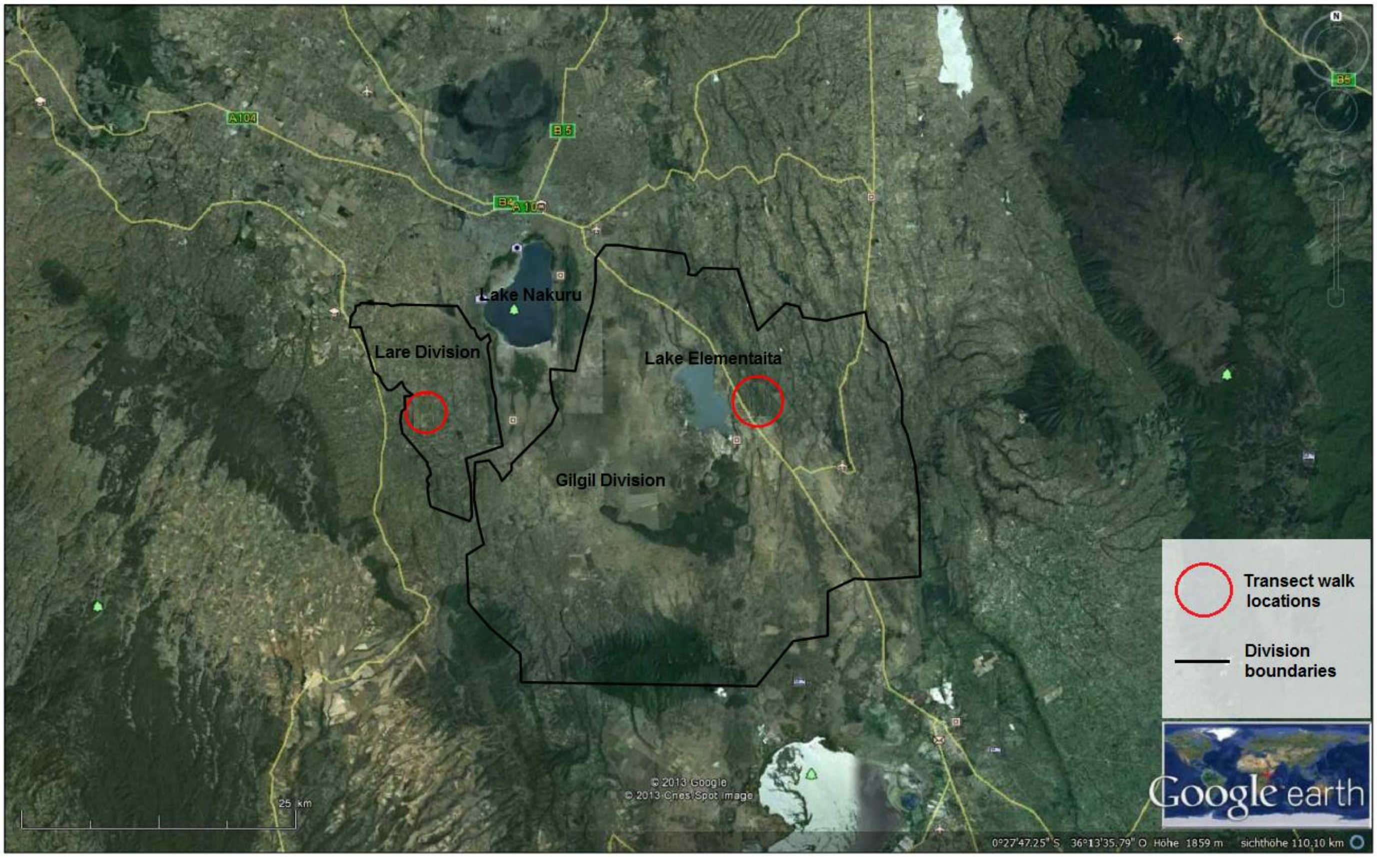


Figure 20: Overview map of transect walk locations in Lare and Gilgil (Source: Google Earth 2013b, modified)

2. <u>Location of transect walks in Lare Division</u>

Figure 21: Location of transect walks in Lare Division (Google Earth 2013c, modified)

3. <u>Location of transect walk in Gilgil Division</u>

Figure 22: Location of transect walk in Gilgil Division (Source: Google Earth 2013a, modified)

According to the World Bank (2012, pp. 1-4) a transect walk is “a tool describing and showing the location and distribution of resources, features, landscape, main land uses along a given transect” (p. 1). Various aspects within a village can be identified using this tool. For example the interrelation between topography, soils, cultivation or natural vegetation and settlement structures can be analysed. Furthermore the main problems and opportunities can be analysed by talking to different local analysts, based on characteristics found along the given transect. Another feature which can be identified is the use of local practices and technologies. A transect walk is a research tool used to gather information about the existing local circumstances. The main working steps when doing a transect walk can be summarized as follows:

1. <u>Choose local analysts</u>

This step involves selecting key informants to talk to during the transect walk in order to get a picture of the locals’ opinion about existing resources and their community in general. This selection is based on the research objectives and the depth of analysis.

2. <u>Give explanations and orientation</u>

An introduction and explanation to the local analysts about the exact objectives and goals of the transect walk and discussions is very important. It is also necessary to make sure that the key informants understand and are comfortable with the discussion topics.

3. <u>Conduct a transect walk and create a diagram</u>

A route needs to be selected together with local analysts and planned in such a way that all features of interest are seen during the walk. The route needn’t be a straight line but can be winding if this enables the view of all features.

The transect walk commences at one end of the area, and after covering a certain distance, for example when seeing a special feature, or after a defined interval (for example every 100 meters), or at the beginning of every new zone (change in topography, landscape or land use), a break is taken in order to record the distance and to discuss about the key characteristics and observations made in the respective section. The discussion can be triggered and relevant information can be gathered by asking targeted questions. It is essential to take notes and record whatever information is of importance and to make sketches if necessary.

It is not necessary to stick to the planned route, if taking another way aids in gaining important and interesting information. Enough time should be taken during the transect walk to identify specific features, and the observations can be complemented by interviews with people who live along the transect route.

After the transect walk has been completed it is advisable to sit together with the local analysts and discuss and record what had been observed during the walk. After that a diagram of the transect walk and the information gathered on the way is prepared. It is best to draw the diagram on a large piece of paper. The respective zones that were perceived during the walk are noted down on the top of the diagram, and the main features identified such as vegetation, land use and so on are listed in vertical direction. Then the diagram is completed by filling in details of each feature.

4. Analyze the diagram

This step involves interpreting the information gathered in the diagram, and questions such as which resources are abundant and which ones are scarce, how do these resources change along the transect, where do people acquire water, where do livestock graze etc. should be answered.

5. Close the activity

This step involves explaining to the local analysts once more what is going to be done with the information, asking about their perception on the tool in terms of usefulness, advantages and disadvantages, and thanking them for their time and efforts.

4.2 Semi-structured interviews

In order to get a comprehensive picture of the research sites and existing water management measures with a special focus on water harvesting and irrigation systems, transect walks were conducted in Lare and Gilgil Divisions. As single locations in Lare differ both in bio-physical as well as socio-economic characteristics, two transect walks were undertaken, one of them in Lare Location together with the Assistant Chief of Lare Location and the other one in Kiriri Location together with the Chief of Lare Location. One transect walk in Gilgil was conducted in Gilgil Location together with the Agricultural Extension Officer of Gilgil Division.

Both the semi-structured interviews with farmers and experts were carried out using an interview guide containing core questions of interest and thus providing an interview framework. The interviews were recorded with a recording device and transcribed at a later point. The sample of farmers was chosen through key informants who were the Location Chief in Lare Division and the Agricultural Extension Officer in Gilgil Division and consisted of 10 farmers each. The prerequisite was that the sample consisted of at least as many female as male farmers and that all interviewees possessed at least one of the following systems: Water pans, water tanks or irrigation systems. The interviewees for the expert interviews were chosen according to the actors involved in the irrigation and water harvesting projects in both research sites and their availability. In Lare, the experts consisted of the Agricultural Extension Officer, the Location Chief and the water harvesting Project Coordinator. In Gilgil, the Agricultural Extension Officer and project coordinators both from JICA and the Ministry of Water were interviewed.

Semi-structured interviews were conducted to find out about the general situation of farmers in the research areas, for example if they are facing water scarcity and if the amount of available water both for domestic and agricultural use has changed over the past years. Furthermore the interviews aimed at finding out if and how farmers use water harvesting and irrigation systems to handle the existing water resources in an improved manner, and what role they played in the planning and implementation process of those measures. It was also intended to find out about the typical work-sharing as well as knowledge-sharing within families, and which role women play in the decision process and management of water harvesting and irrigation systems. Ten farmers were interviewed in both research sites, out of which four were men and six were women in Lare, and five were men and five were women in Gilgil. Most of the interviews needed to be translated, which was done by the Assistant Chief of Lare Location in Lare and by the Agricultural Extension Officer of Gilgil in Gilgil. The interviews in Lare were conducted in Lare location, Nguriga Sub-location, and the ones in Gilgil were conducted in Gilgil location, Mbaruk Sub-location.

Expert interviews were carried out to identify the stakeholders involved in triggering water harvesting and irrigation systems and what role these parties played. Furthermore these interviews should enable an identification of steps that were taken to promote interaction and knowledge transfer between all stakeholders, focusing especially on the farmer's role in the process. The interviews were also conducted to find out which role female farmers played in the implementation of measures and how they were represented in the different stakeholder groups.

Rainfall data was collected from Kenya Agricultural Research Institute (KARI), Njoro and consisted of monthly rainfall records from 1949 to 2012, and from Soysambu Conservancy, which consisted of monthly rainfall records from 1948 to 2012. These data were statistically analysed to find out whether there has been a significant change in the annual rainfall amounts over the past decades. Furthermore the rainfall probability of exceedence was calculated, as this measure is needed to evaluate whether the crop water requirements are met and if, when and how much irrigation is necessary for optimal crop development.

Interviews are a common method used in qualitative research. Their aim is to get a picture of the interviewee's living environment and an interpretation of this information. An important characteristic of semi-structured interviews is that they contain a number of questions and themes of interest which are defined prior to the interview, but that it is possible to modify, extend or change the sequence of these questions during the interview in order to round off the answers and get a complete picture of the interviewee's story (Kvale 1996).

As described by Kvale (1996, p. 125)

"The research interview is an interpersonal situation, a conversation between two partners about a theme of mutual interest. It is a specific form of human interaction in which knowledge evolves through a dialogue"

The framework of a semi-structured interview can be established by using an interview guide, which contains an overview of the topics of interest and a collection of possible questions. It depends on the interviewer how closely he or she will stick to the interview guide. Interviews can be evaluated according to a thematic and a dynamic component. While the thematic part focuses on the context of the interview with respect to the conceptual framework of the study itself and the latter analysis, the dynamic part focuses on the interaction that takes place during the interview. The questions should enable good interaction between the interviewer and the interviewee and create a positive environment in which the interviewee can speak freely about his or her feelings and experiences. The questions should be easily understood, free from scientific language and short (Kvale 1996).

Certain steps need to be taken before actually conducting the interview. It is necessary to be aware of the exact subject matter of the interview, its purpose as well as to be clear about which interview technique is going to be applied. It is also important to bear in mind how the interviews are going to be analyzed and how the findings are going to be verified and recounted (Kvale 1996).

In order to create an enabling atmosphere in which the interviewees talk freely and openly about their experiences and lives, a number of actions need to be implemented. Before starting the interview, a short briefing about what the interview is about, the purpose and the interview process needs to be carried out. The interviewees are asked if they have any questions concerning the interview. The first few minutes of the interview are essential and will decide upon how the whole interview is going to proceed. By listening carefully to the respondent and showing interest, respect and understanding towards what is being told, a good interaction between interviewer and respondent can be promoted and the interviewee will feel comfortable to answer the questions freely, and at the same time the interviewer will be open and clear about what he or she wants to find out. After the interview has been carried out, a debriefing takes place where the interviewer can summarize the main aspects of the interview, the interviewee can respond to these observations and can ask some more questions which may have arisen during the interview (Kvale 1996).

Once the interviews have been recorded and transcribed, Schmidt (2004) provides a strategy to analyse qualitative guideline interviews, which is based on a combination of different suitable analysing techniques and has five main steps. This strategy was used to analyse the semi-structured interviews.

1. Generating analysis categories based on the material

The creation of analysis categories starts with reading the gathered material in an intensive and repeated manner. This material is defined as the interviews which were completely and accurately transcribed. The goal is to note down themes and individual aspects of each interview transcript which can be broadly connected to the research questions. It is not necessary to come up with identical topics in each interview. Although at this point the interviews should not yet be compared to each other, it is useful to note similarities and differences between interviews for the following analysing steps. It is important to try not to filter the material in a way that it coincides with the own theoretical presumptions, for example by overlooking certain text passages. On the basis of the located themes and aspects, analysis categories are formulated.

2. Creating a coding guideline

Based on the analysis categories a guideline is created which contains a detailed description of the single categories. For each category single characteristics are defined. With the help of this guideline the gathered material should be coded. This means that the respective text passages of an interview are assigned to the best suited category.

3. Coding the material

Based on the coding guideline, each interview is assessed and categorised by assigning the material to single analysing categories. Each interview is codified under all categories of the coding guideline. This means that the analysing categories which were extracted from the material in the previous analysing step are now applied to the material. This step aims at reducing the amount of information in order to be able to compare the single cases with respect to dominant tendencies. Each passage from an interview is assigned to an analysing category and further to a single characteristic within the category which is well defined.

4. Quantifying material overview

This step aims at assembling the findings of the codification by displaying them in the form of a table. This overview is made up of frequency indications of certain analysing categories. These frequency distributions give a first impression of the tendencies found in the material. They are not yet the results, but give information about the "database".

5. Detailed case interpretation

The profound case interpretation is the last analysing step. The goal of this step could be to find new hypotheses, to test hypotheses, to differentiate concepts, to develop new theoretical considerations or to review the existing theoretical framework.

4.3 Analysis of rainfall data and crop water requirements

4.3.1 Descriptive statistics

In order to get a picture of the average annual rainfall amount, the annual rainfall distribution as well as the variability of rainfall over the years, rainfall data was statistically evaluated using the program SPSS.

4.3.2 Trend analysis

To find out whether the rainfall data follow a certain trend or not, the following steps were taken:

- Normality test

Annual rainfall amounts were tested for normality by using graphical methods, including normal distribution plots and histograms and by using the Kolmogorov-Smirnof and Shapiro-Wilk Tests.

- Test for homogeneity of variances and means

In order to find out whether there has been a significant change of variance or mean over the years, or if the data are expected to come from the same distribution, the rainfall data was tested by using T-Test and Levene's Test.

- Autocorrelation

In order to find out whether the variables rainfall and year were independent of each other, their autocorrelation was tested.

- Trend test

To test if the data was following a significant trend, linear regression and the Kendall-Tau rank correlation were used.

4.3.3 Evaluation of crop water requirements

In order to find out whether the crop water requirements are fulfilled by natural rainfall or if supplementary irrigation is necessary, data was evaluated using the FAO CROPWAT program Data required for CROPWAT includes climate data (temperature, humidity, sunshine and wind speed) to calculate reference evapotranspiration ET_o, rainfall data, information on crops and cropping patterns (crop type, planting and harvesting dates, crop coefficient, growth stage lengths, rooting depth, critical depletion fraction, yield response factor) and soil data (total available water, maximum infiltration rate, maximum rooting depth and initial soil moisture depletion) (Smith 1992).

4.3.3.1 Climate data

Climate data from Nakuru was acquired from the FAO CLIMWAT program, which is a climate database that provides basic climate data necessary for CROPWAT, including temperature, humidity, sunshine and wind speed. From this data, evapotranspiration ET_o is automatically computed by the program.

4.3.3.1 Evapotranspiration

The FAO CROPWAT Program uses the FAO Penman-Monteith Equation to calculate evapotranspiration.

FAO Penman-Monteith Equation

This equation combines the Penman-Monteith Equation with the equations for aerodynamic resistance (r_a) and surface resistance (r_s) with regard to a specified crop of 0,12 m height, a surface resistance of $70 ms^{-1}$ and an albedo of 0.23. The FAO Penman-Monteith - formula can be computed as follows (Allen et al. 1998):

$$ET_o = \frac{0.408\, \Delta (R_n - G) + \gamma \frac{900}{T + 273} U_2 \left(e^o - e_a\right)}{\Delta + \gamma (1 + 0.34 U_2)}$$

where

ET_o is the reference evapotranspiration [mm day^{-1}],

R_n is the net radiation at the crop surface [MJ m^{-2} day^{-1}], G is the soil heat flux density [MJ m^{-2} day^{-1}],

T is the mean daily air temperature at 2 m height [°C],

U_2 is the wind speed at 2 m height [m s^{-1}],

e is the saturation vapour pressure [kPa],

e_a is the actual vapour pressure [kPa],

e – e_a is the saturation vapour pressure deficit [kPa],

Δ is the slope vapour pressure curve [kPa C^{-1}], and

γ is the psychrometric constant [kPa C^{-1}].

4.3.3.2 Rainfall data

The average monthly rainfall which is required for the use of CROPWAT was acquired from KARI Njoro (NPBRC) and from Soysambu conservancy. Effective rainfall was calculated with the "fixed percentage" method in CROPWAT, where 80 % of rainfall is considered effective. In this study, effective rainfall is defined on the basis of crop water requirements and therefore as the amount of water that is useful in supporting crop production. Effective rainfall can therefore be considered as the amount of rainfall that remains in the root zone, which is equivalent to the quantity left over after subtracting the volume of rainfall lost in the form of surface runoff, evaporation and deep percolation (Brouwer and Heibloem 1986) The amount of effective rainfall is dependent on various factors, the most important ones being the rainfall properties such as intensity and amount, other meteorological factors such as radiation and humidity, land and soil properties, soil water characteristics, ground water properties, management methods and crop characteristics (Dastane 1978).

4.3.3.3 Crops and cropping pattern

Crop types, planting and harvesting dates were acquired during the semi-structured interviews with farmers. Once this information is provided, CROPWAT gives typical values for the other crop data required such as crop coefficient k_c and stage lengths. The crops for the analysis were chosen according to those most commonly grown by the interviewed farmers and include maize, kidney beans, potatoes, tomatoes and kales.

4.3.3.4 Soil data

Information on typical soil types in the areas was acquired from literature and during the transect walks. Once the soil type is known, which to a large extent is clay and clay loam in both research areas, CROPWAT provides characteristic values for data such as total available water and maximum infiltration rate.

4.3.3.1 Crop water requirements

The crop water requirements were calculated for a normal year, which is characterised by a rainfall amount that is exceeded with a probability of 50 % (Smith 1992).

From the data described above, CROPWAT is able to compute the irrigation water requirements as the difference between effective rainfall and crop evapotranspiration under standard conditions (ET_c).

The program provides a table which shows the crop water requirement covered by natural rainfall and the irrigation requirements per decade, which is equal to ten days, as well as the irrigation requirements for the total growing period.

5 RESULTS

5.1 Water availability, crop water requirements and changes in rainfall quantity

5.1.1 Results from semi-structured interviews with farmers

In Lare location the interviews were carried out with six women and four men. Their ages varied from 29 to 79 years and the family sizes ranged from five to fourteen members. The number of female members in each household ranged from one to ten members. All the farmers who were interviewed belonged to the Kikuyu tribe. The farmers´ level of education lay between primary level standard six and completion of secondary school. All the farmers stated that each of their children went to school. Only one child who was physically disabled did not attend school.

Seven are the owners of the farm while two lady farmers stated that the farm belongs to their parents and one lady said that the farm belongs to her father. Six farmers said that they or their parents had got their farms through a settlement scheme. Two lady farmers inherited the land from their parents. One lady and one gentleman bought the farms. Nine farmers shared the opinion that their children would take over the farm when they retired at some point. One lady said that she didn't know if her children would take over the farm, depending on if they would move out and have their own place.

In Gilgil location interviews were conducted with five female and five male farmers aged between 21 and 71 years. Family sizes varied from two to ten members, with a number of female members ranging from one to six members. All farmers who were interviewed belonged to the Kikuyu tribe. The farmers' levels of education lay between primary level, standard two, and completion of secondary level. All farmers stated that each of their children went to school or were already working, or would go to school once they had reached the correct age. Seven interviewees are the owners of the farm, two young male farmers state that the farm belongs to their mothers and one male farmer states that the farm belongs to his father. Nine farmers stated that they or their children would take over the farm at some point and one male farmer explained that he cannot tell whether his children would take over the farm.

a. Water availability

The interviewed farmers in Lare plant their crops for the first time between March and April and for the second time between September and November, except for one farmer who plants a second time between June and August. All farmers declared that the reason for planting crops in those periods is because the rain starts at that point.

Similarly all farmers in Gilgil use April as first and August as second planting period because these are the times when the rain starts. Their rainfall observation fits together well with the collected data from Soysambu Conservancy.

Nine farmers in Lare have one to two planting seasons and one has three to four, while four farmers in Gilgil have one or two planting seasons and six have three to four planting seasons. The only farmer in Lare who plants new crops three to four times a year irrigates his crops.

b. Crop water requirements

All interviewees in Lare grow maize and beans. Furthermore seven farmers grow potatoes, four farmers grow cabbages and kales, three farmers grow tomatoes, two farmers grow carrots, spinach, wheat, sweet potatoes, onions, cassavas and bananas and only one grows sun flowers, peas, sorghum and soya beans. While one lady farmer grows only maize and beans, two male farmers grow ten different crops. All other farmers grow between four and six crops at a time. All farmers in Gilgil grow maize and beans as well as cabbages, furthermore eight grow kales and tomatoes, six grow papayas, four grow spinach, sweet potatoes, potatoes, carrots, cassavas, three grow oranges, passion fruit and bananas, two grow onions, tree-tomatoes, mangoes and garden pees, and one grows capsicums, lettuces, citruses, avocados, arrowroots, plums, green beans, black nightingshades, custard apples and coriander. The variety of crops being grown per farmer ranges from five to sixteen different plants. Eight farmers grow between eight and twelve different crops, one farmer grows five crops and one farmer grows sixteen crops. The crops and their distribution according to research site are illustrated in Figure 23.

Farmers in Lare mentioned that the main reasons for growing these crops is that they are common and can be used for domestic use as well as for selling purposes, while those in Gilgil explained that the crops they grow do well on the market and are also suitable for home consumption.

In Lare four farmers plant all their crops only once per year while four others have two planting seasons. Another interviewee usually has two planting seasons as well, but in the year 2012 he was continuously planting new crops due to the uncommon rain pattern. Another male farmer plants crops three to four times a year and beans twice a year. Maize and beans are usually only planted once a year. In Gilgil, eight farmers plant maize and beans once a year, while two farmers have two planting seasons for those crops. Six farmers plant their vegetables every three to four months throughout the year, while four farmers have only one planting season for vegetables. One farmer mentioned that he would like to plant his vegetables more than one time in a year, but that there is not enough water to do that. The amount of planting seasons is shown in Figure 24.

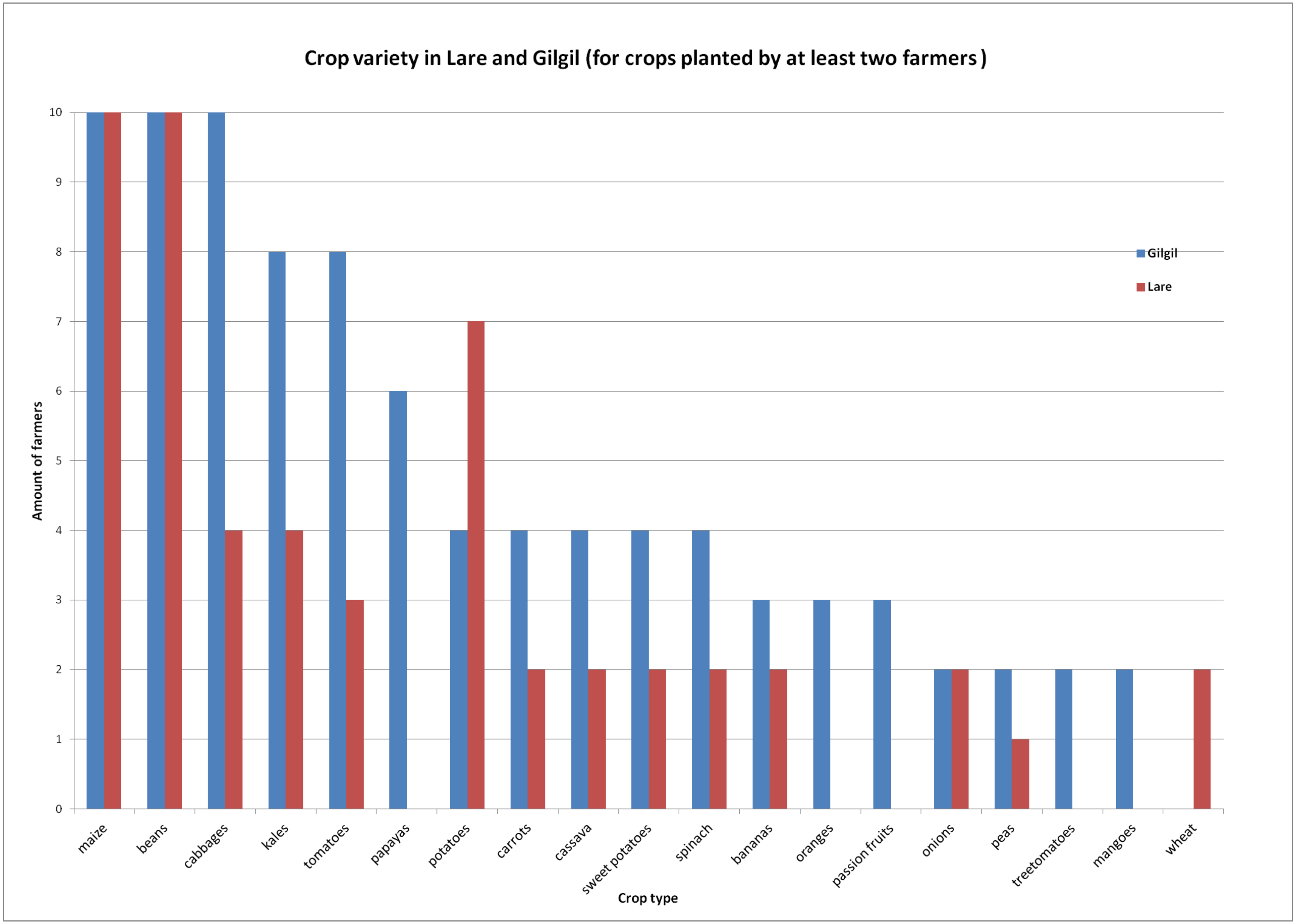


Figure 23: Crop types grown by farmers in Lare and Gilgil (Source: Semi-structured interviews with farmers, own illustration)

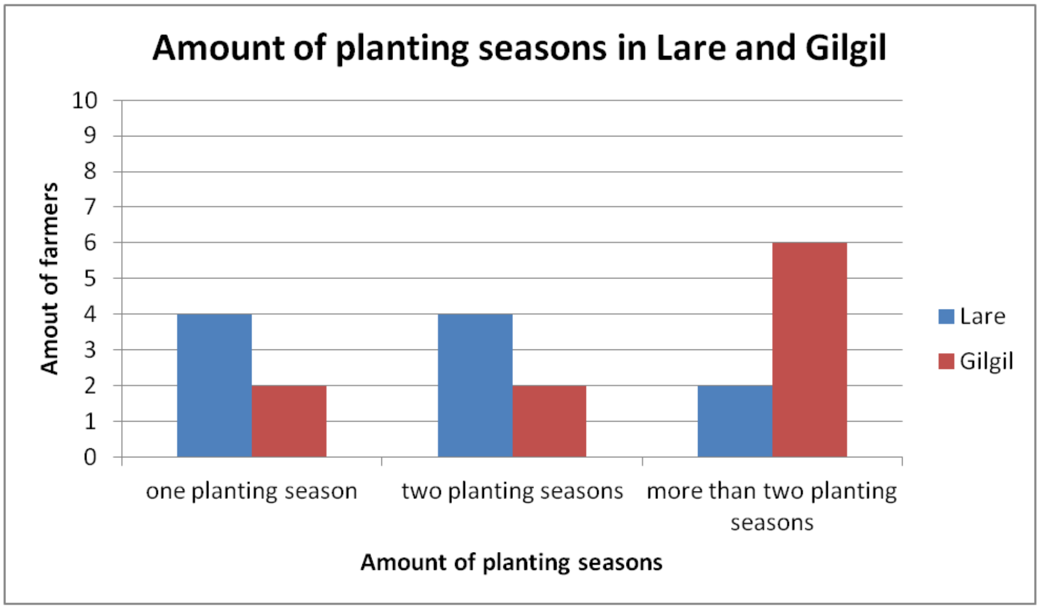


Figure 24: Planting seasons in Lare and Gilgil (Source: Semi-structured interviews with farmers, own illustration)

c. Perceived changes in rainfall amounts

Eight farmers in Lare shared the opinion that the amount of rainfall has increased over the last five years. One of them thought that although the year 2012 was marked by high amounts of rain, in general the rainfall quantity has reduced tremendously over the last decades. One farmer remarked that due to the excess rains his water pans were almost overflowing in 2012. Two farmers stated that they couldn't make out any change in the rainfall pattern over the past five years. In Gilgil, nine farmers think that the rainfall amount has increased over the last five years. Only one farmer said that in 2011 and 2012 the rainfall amount was less and that in general the rainfall has decreased over the years.

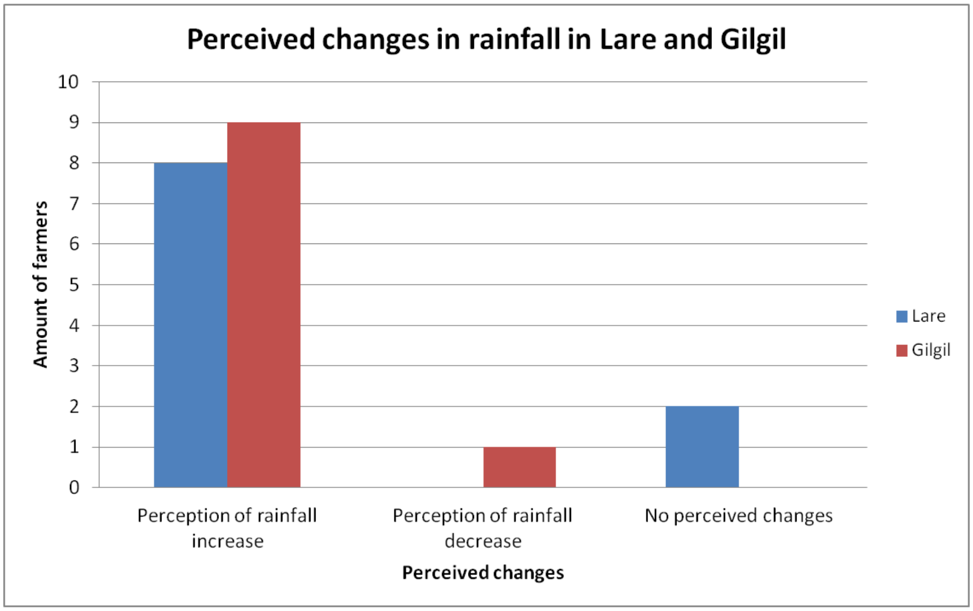


Figure 25: Perceived changes in rainfall in Lare and Gilgil (Source: Semi-structured interviews with farmers, own illustration)

Seven farmers in Lare thought that the year 2012 was cooler than the previous years. One farmer expressed that 2012 was warmer than the year before. Also in Gilgil seven farmers think that the temperature has decreased in the last years, while two stated that there hasn't been any change in temperature and one farmer feels that it has become warmer. The perceived changes in rainfall are shown in Figure 25, while those in temperature are depicted in Figure 26.

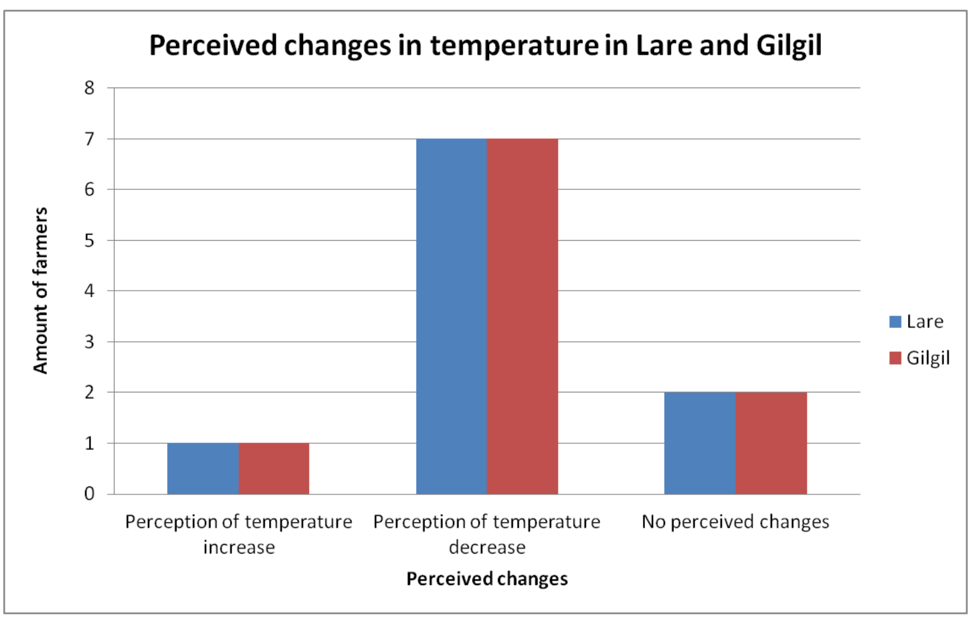


Figure 26: Perceived changes in rainfall in Lare and Gilgil (Source: Semi-structured interviews with farmers, own illustration)

Four farmers in Lare mentioned that the negative effects of these changes in climate were bad or delayed maize harvest due to the prolonged rains and sicknesses such as colds and malaria.
Despite these negative effects of climate change the farmers also benefitted from the increase in rain. Seven farmers adapted to the changes in climate by altering their cropping patterns, implementing more planting seasons and planting a larger crop variety. Three farmers said that they haven't changed their planting patterns due to the change in rainfall. In Gilgil six farmers have increased the amount of planting seasons due to higher rainfall quantities. One farmer has planted new crops for the first time. The farmer who thinks that the rain has decreased said that he had to use more irrigation water in order for the crops to develop well this year. Two farmers haven't changed their cropping patterns due to the increased rainfall.
Eight farmers in Lare shared the opinion that the changes in climate could be linked to the change in tree cover, while two farmers couldn't explain the changes. In Gilgil six farmers stated that the changes in climate have taken place due to an increased planting of trees which has occurred since people started settling in the area. One farmer stated that it is just a natural change of climate, and that he doesn't think that the change has something to do with the planting of trees as he hasn't noticed any increase in trees. Three farmers can't tell why these changes in climate are happening.

5.1.2 Results from rainfall data analysis

5.1.2.1 Lare Division

1. Descriptive statistics

			Statistic	Standard error
Annual rainfall data KARI Njoro (1949 - 2012)	Mean		959,44	26,49
	95% confidence interval of median	lower boundary	906,50	
		upper boundary	1012,38	
	5% truncated mean		957,93	
	Median		949,95	
	Variance		44916,65	
	Standard Deviation		211,94	
	Minimum		552,90	
	Maximum		1512,30	
	Range		959,40	
	Interquartile range		335,10	
	Skewness		0,15	0,30
	Curtosis		-0,51	0,59

Table 7: Descriptive statistics annual rainfall data KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

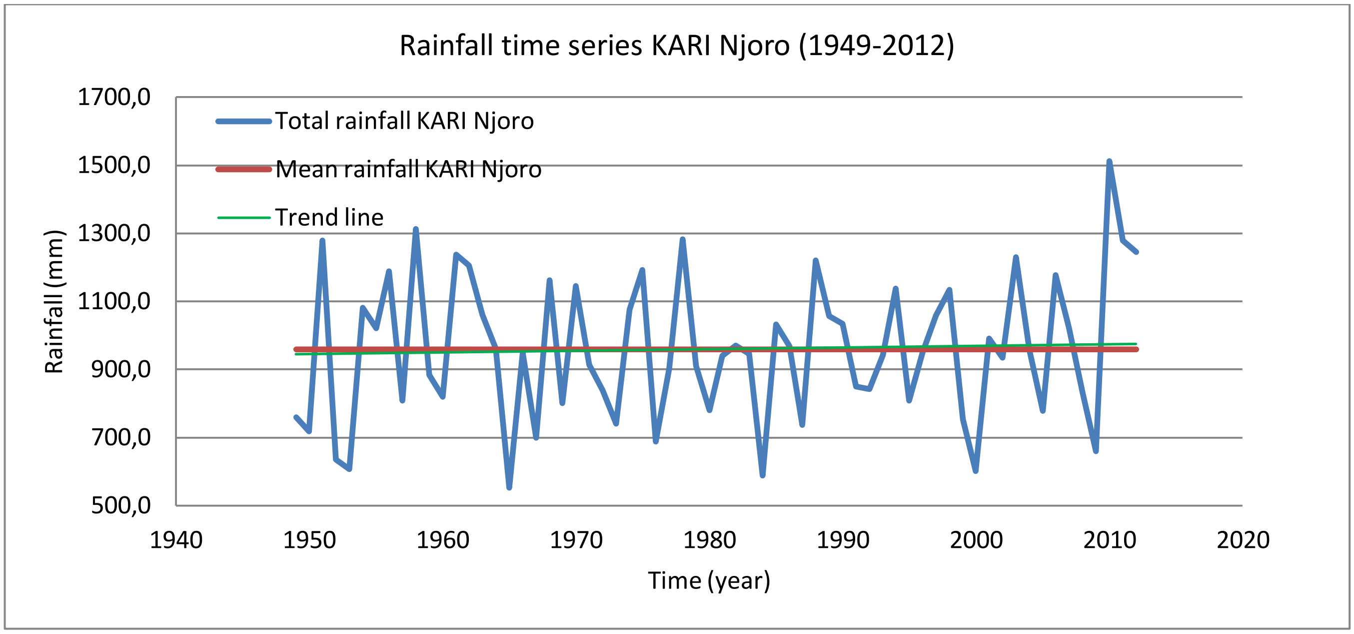


Figure 27: Time series of annual rainfall data KARI Njoro (1949-2012) (Source: Rainfall data NPBRC, own illustration)

According to Table 7, Lare has an average annual rainfall of 959.44 mm a median of 949.95 mm and a standard deviation of 211.94 mm. The annual rainfall values range from 552.90 mm to 1512.30 mm. The skewness and curtosis have values close to zero. From the time series plot shown in Figure 27 it is possible to identify rainfall minimums which occur every three to five years. The lowest amount of annual rainfall occurred in 1965 (552.90 mm), but also in the years 1984, 2000 and 2009 the rainfall amounts were fairly low (587.70, 600.50 and 659.60 mm respectively.

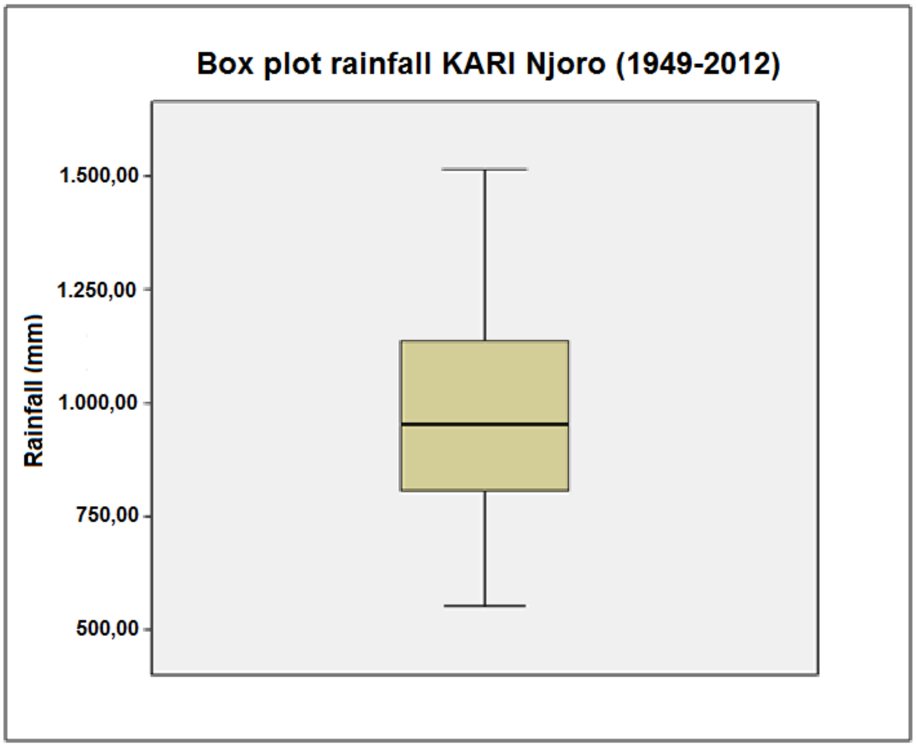


Figure 28: Box Plot of annual rainfall data KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Figure 28 shows that the rainfall data from KARI Njoro have a low variance considering the box length. 50 % of the data lie within a range of 335.10 mm (interquratile range). Furthermore the box plot shows that although the amount of rainfall in 2010 was higher than in all previous years (1512.30 mm) the value is not an outlier.

2. <u>Trend analysis</u>

a. <u>Normality test</u>

- Graphical Methods – Histogram and Q-Q Diagram

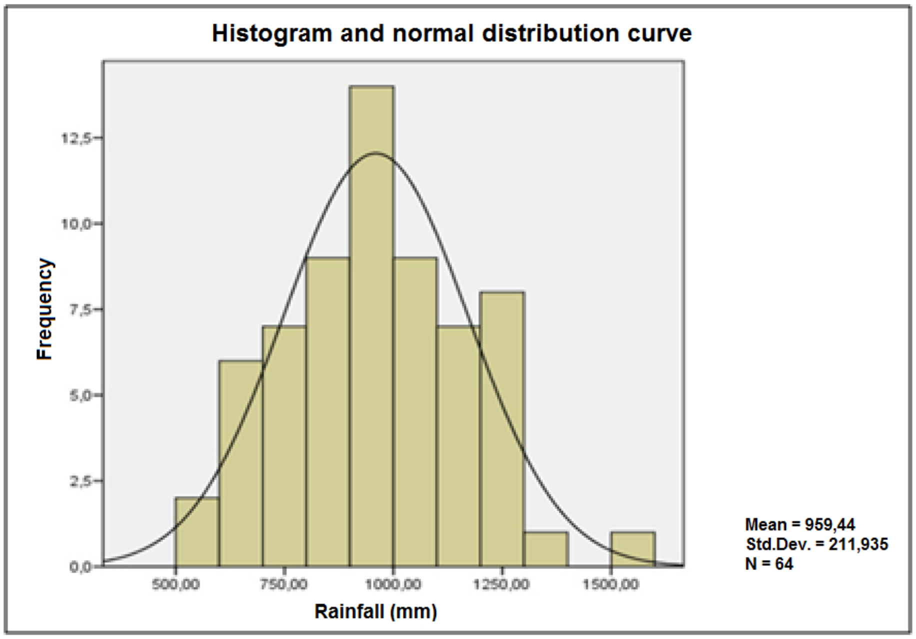


Figure 29: Histogram of annual rainfall KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Figure 29 shows that in most of the years from 1949 to 2012 the annual rainfall amounts ranged between 900 and 1000 mm. The normal distribution curve that was fitted to the data shows a good match, indicating that the data is normally distributed.

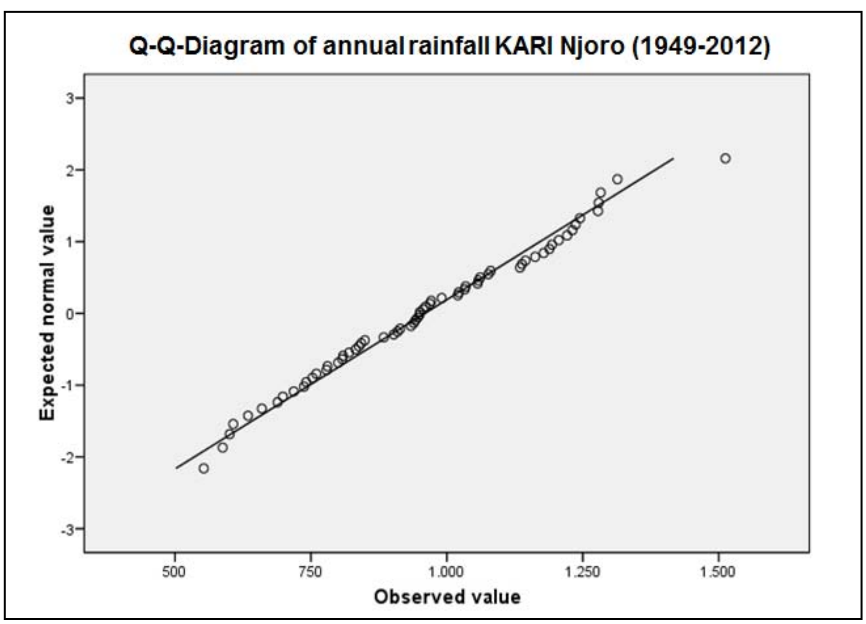


Figure 30: QQ-Plot of annual rainfall KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

In Figure 30 the observed values were plotted against the expected normal value, forming a more or less straight line and thus indicating normal distribution.

- Statistical Tests - Kolmogorov-Smirnov and the Shapiro-Wilk Tests

Rainfall	Kolmogorov-Smirnov		
	Statistic	df	Significance
	0,061	64	0,200
	Shapiro-Wilk		
	Statistic	df	Significance
	0,984	64	0,569

Table 8: Kolmogorov-Smirnov and Shapiro-Wilk Tests for annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Table 8 shows that both the Kolmogorov-Smirnov and the Shapiro-Wilk test have a significance higher than the chosen level of signigicance of 0.05 which indicates that the data are normally distributed.

b. <u>Tests for homogeinity of variances and means</u>

- Levene's Test and T-Test:

Rainfall		T-test for equality of means						
		T	df	Sig. (2-sided)	difference	error of	Confidence	
							Upper	Lower
	Variances are equal	-0,572	62	0,570	-30,44687	53,26929	-136,93067	76,03692
	Variances are not equal	-0,572	61,748	0,570	-30,44687	53,26929	-136,93933	76,04558
		Levene-test for equality of variances						
		F	Significance					
	Variances are equal	1,086	0,301					
	Variances are not equal							

Table 9: Levene's and T-Tests for annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Table 9 shows that the significance level of Levene's Test for the homogeneity of variances is 0.301 and therefore greater than 0.05, just as the T-Test for the homogeneity of means, which is 0.570. This indicates that the rainfall data is homogenous, thus the variances don't change significantly over time.

c. Correlation

		Rainfall	Year
Year	Pearson Correlation	1	0,139
	Significance (2-sided)		0,275
	N	64	64
Rainfall	Pearson Correlation	0,139	1
	Significance (2-sided)	0,275	
	N	64	64

Table 10: Correlation between annual rainfall and year at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

The correlation according to Pearson is shown in Table 10 and is 0.275 which is greater than 0.05 and therefore not significant. This means that there is no significant statistical connection between the rainfall amount and the respective year.

d. Autocorrelation

			Box-Ljung-Statistic		
Lag	Autocorrelation	Standard error	Value	df	Sig.
1	-0,061	0,122	0,248	1	0,618
2	-0,179	0,121	2,434	2	0,296
3	-0,048	0,120	2,595	3	0,458
4	0,119	0,119	3,596	4	0,464
5	-0,029	0,118	3,654	5	0,600
6	-0,182	0,117	6,070	6	0,415
7	0,132	0,116	7,353	7	0,393
8	0,112	0,115	8,292	8	0,406
9	-0,099	0,114	9,043	9	0,433
10	-0,066	0,113	9,388	10	0,496
11	-0,176	0,112	11,846	11	0,375
12	0,007	0,111	11,850	12	0,458
13	0,047	0,110	12,032	13	0,525
14	-0,015	0,109	12,050	14	0,602
15	0,033	0,108	12,143	15	0,668
16	0,084	0,107	12,767	16	0,690

Table 11: Autocorrelation of annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Table 11 shows an autocorrelation significance of above 0.05, and Figure 31 shows that the boundaries of the 95% confidence interval are not exceeded. Both these illustrations indicate that the data are not autocorrelated, which means that rainfall data are not dependent on each other. Rainfall from a later year is not related to the rainfall from an earlier year.

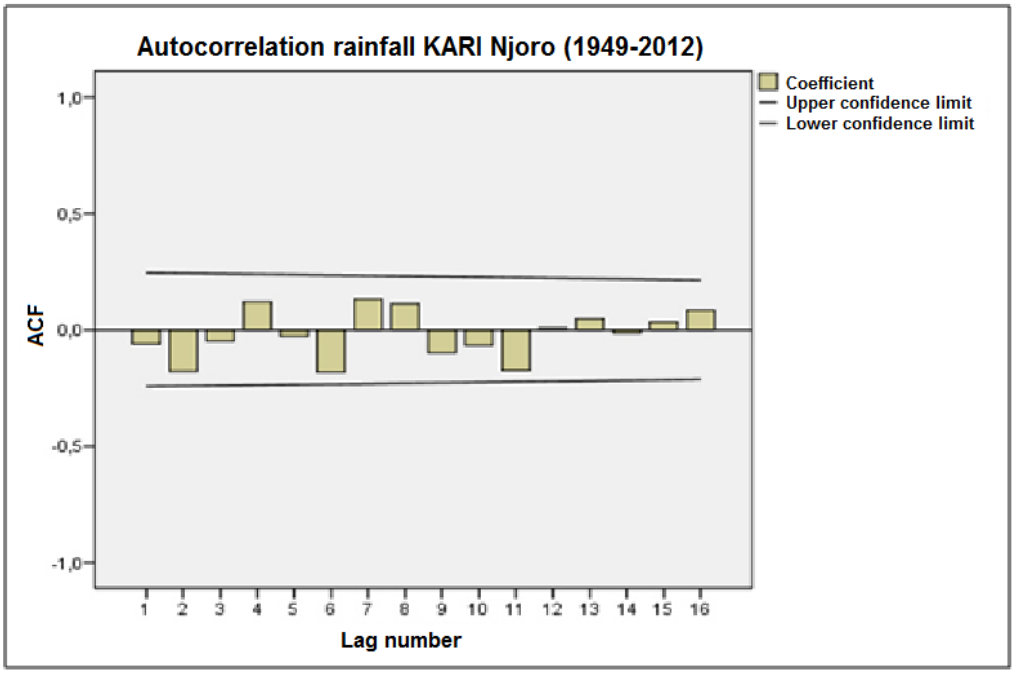


Figure 31: Autocorrelation of annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

e. Trend test

- Linear Regression:

		Non-standardized coefficients		
Model		B	Standard error	
Rainfall	(Constant)	-2.163,879	2.835,547	
	Year	1,577	1,432	
		Standardized coefficients Beta	T	Significance
			-0,763	0,448
		0,139	1,102	**0,275**
	R	R-squared	Corrected R-square	Standard error of estimate
	,139(a)	0,019	0,003	211,57

Table 12: Regression model and correlation coefficient of annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Table 12 shows that the significance of Beta is 0.275, which is higher than 0.05 and thus indicates that there is no significant relationship between the rainfall amount and the respective year, and therefore no significant trend. Furthermore and the correlation coefficient R is 0.139, indicating a very weak relationship between rainfall amount and year. R² is 0.019 and the corrected R² value is 0.003. The corrected R² value expresses that only 0,3 % of the variance can be explained by a statistical relationship between rainfall and year.

- Kendall-Tau Rank Correlation:

			Year	Rainfall
Kendall-Tau-b	Year	Correlation Coefficient	1,000	0,079
		Sig. (2-sided)	.	0,354
		N	64	64
	Rainfall	Correlation Coefficient	0,079	1,000
		Sig. (2-sided)	0,354	.
		N	64	64

Table 13: Kendall-Tau Rank Correlation Coefficient of annual rainfall at KARI Njoro (Source: Rainfall data NPBRC, SPSS Inc. 2006)

Similarly, Table 13 shows that the significance of the Kendall-Tau rank correlation has a value of 0.354, which is higher than 0.05 and thus indicates that there is no significant trend in the data.

5.1.2.2 Gilgil Division

1. Descriptive statistics

			Statistic	Standard error
Annual rainfall data Soysambu Conservancy (1948-2012)	Mean		729,80	21,24
	95% confidence interval of median	lower boundary	687,37	
		upper boundary	772,24	
	5% truncated mean		729,99	
	Median		741,25	
	Variance		29326,58	
	Standard Deviation		171,25	
	Minimum		369,50	
	Maximum		1136,40	
	Range		766,90	
	Interquartile range		239,30	
	Skewness		-0,06	0,30
	Curtosis		-0,28	0,59

Table 14: Descriptive statistics annual rainfall data at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

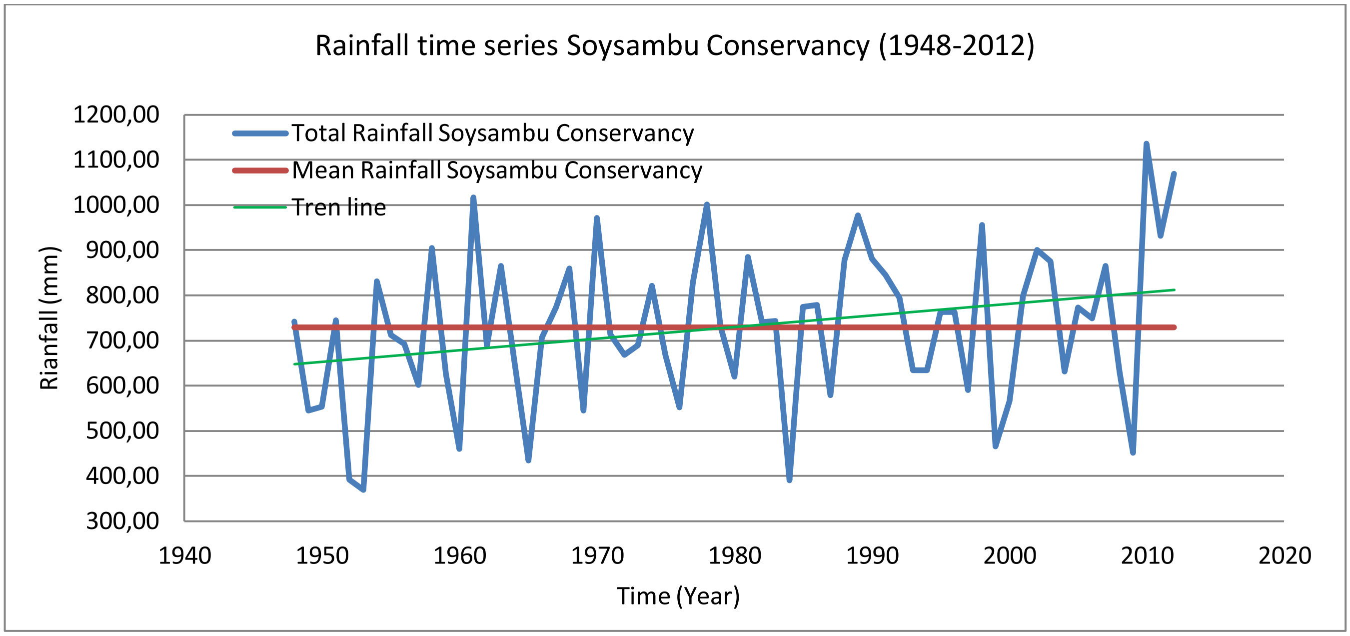


Figure 32: Time series of annual rainfall data at Soysambu Conservancy (1948-2012) (Source: Rainfall data Soysambu Conservancy, own illustration)

As shown in Table 14, Gilgil has an average annual rainfall of 729.80 mm, a median of 741.25 mm and a standard deviation of 171.25 mm. The annual rainfall values range from 369.50 to 1136.40 mm. The skewness and curtosis have values close to zero. From Figure 32 it is possible to identify rainfall minimums which occur every three to five years. The lowest amount of annual rainfall occurred in 1953 (369.50 mm), but also in the years 1952, 1965, 1984 and 2009 the rainfall amounts were fairly low (391.56, 434.90, 390.20, 451.20 mm respectively).

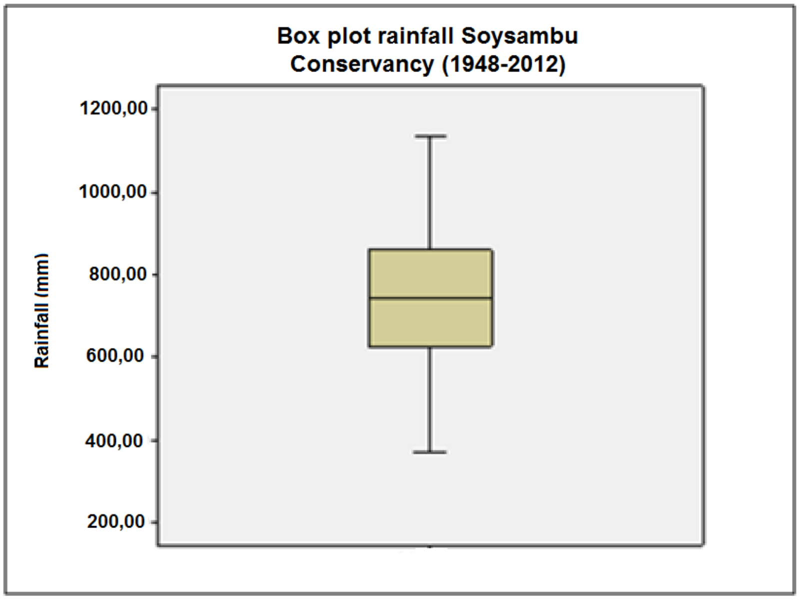


Figure 33: Box plot of annual rainfall data at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Figure 33 shows that the rainfall data from Soysambu Conservancy have a low variance considering the box length. 50 % of the data lie within a range of 239.30 mm (interquartile range). Furthermore the box plot shows that although the amount of rainfall in 2010 was higher than in all previous years (1136.40 mm) the value is not an outlier.

2. Trend analysis

   a. Normality test

   ➢ Graphical Methods – Histogram and Q-Q Diagram

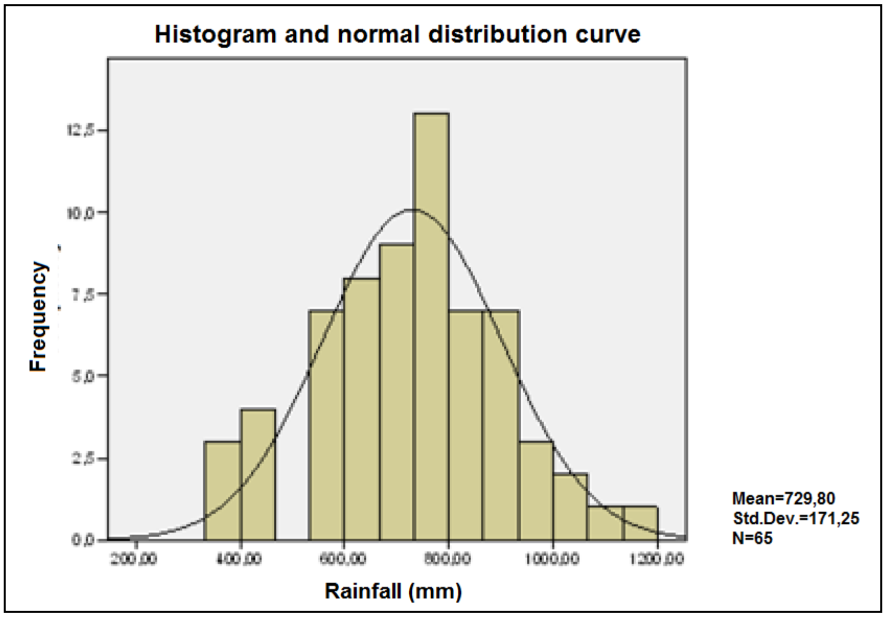


Figure 34: Histogramm of annual rainfall Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Figure 34 shows that in most of the years from 1948 to 2012 the annual rainfall amounts ranged between 700 and 800 mm. The normal distribution curve that was fitted to the data shows a good match, indicating that the data is normally distributed.

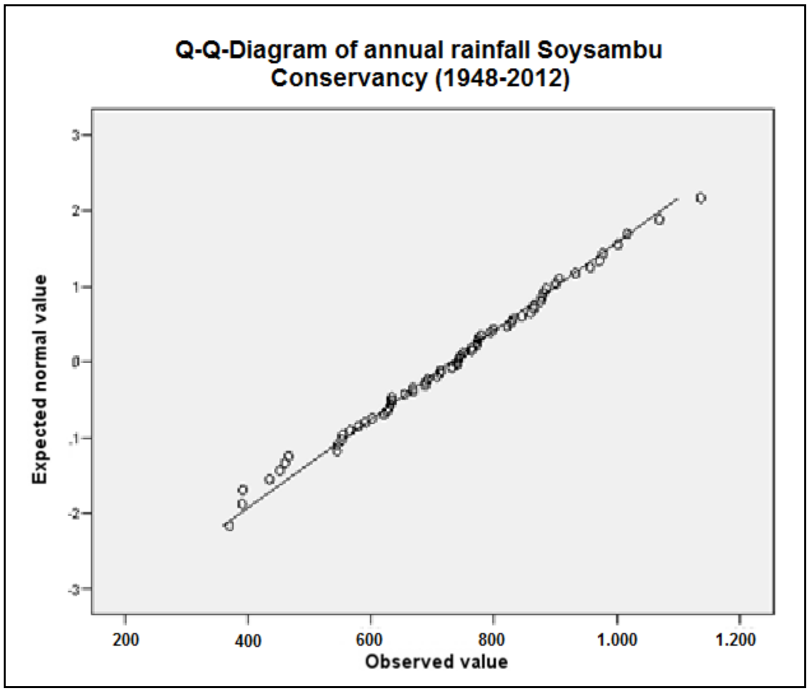


Figure 35: QQ-Plot of annual rainfall Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

In Figure 35 the observed values were plotted against the expected normal value, forming a more or less straight line, thus indicating normal distribution.

- Statistical Tests - Kolmogorov-Smirnov and the Shapiro-Wilk Tests

Rainfall	Kolmogorov-Smirnov(a)		
	Statistic	df	Significance
	0,047	65	0,200
	Shapiro-Wilk		
	Statistic	df	Significance
	0,991	65	0,910

Table 15: Kolmogorov-Smirnov and Shapiro-Wilk Tests for annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Table 15 shows that both the Kolmogorov-Smirnov and the Shapiro-Wilk test have a significance higher than the chosen level of signigicance of 0.05, which indicates that the data are normally distributed.

b. <u>Homogeneity of variances and means</u>

- Levene's Test and T-Test:

Rainfall		T-test for equality of means						
		T	df	Sig. (2-sided)	difference	error of	Confidence	
							Upper	Lower
	Variances are equal	-1,380	63	0,172	-58,29569	42,22949	-142,68460	26,09321
	Variances are not equal	-1,377	61,592	0,174	-58,29569	42,34352	-142,95034	26,35895
		Levene-test for equality of variances						
		F	Significance					
	Variances are equal	0,055	0,815					
	Variances are not equal							

Table 16: Levene's and T-Tests for annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

According to Table 16, the significance level of Levene's Test for the homogeneity of variances is 0.815 and therefore greater than 0.05, just as the T-Test for the homogeneity of means, which is 0.172. This indicates that the rainfall data is homogenous, thus the variances don't change significantly over time.

c. <u>Correlation</u>

		Rainfall	Year
Year	Pearson Correlation	1	,284(*)
	Significance (2-sided)		0,022
	N	65	65
Rainfall	Pearson Correlation	,284(*)	1
	Significance (2-sided)	0,022	
	N	65	65

Table 17: Correlation between annual rainfall and year at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

According to Table 17 the Pearson correlation has a significance of 0.022 which is smaller than 0.05 and therefore significant. This indicates that there is a **significant statistical connection** between the rainfall amount and the respective year.

d. Autocorrelation

Lag	Autocorrelation	Standard error	Box-Ljung-Statistic Value	df	Sig.
1	0,009	0,121	0,006	1	0,940
2	-0,107	0,12	0,793	2	0,673
3	0,045	0,119	0,933	3	0,818
4	0,068	0,118	1,267	4	0,867
5	-0,022	0,117	1,303	5	0,935
6	-0,189	0,116	3,933	6	0,686
7	0,166	0,115	6,014	7	0,538
8	-0,013	0,114	6,026	8	0,644
9	0,064	0,113	6,345	9	0,705
10	0,033	0,112	6,433	10	0,778
11	-0,069	0,111	6,819	11	0,814
12	0,108	0,11	7,785	12	0,802
13	0,002	0,109	7,786	13	0,857
14	-0,067	0,108	8,174	14	0,880
15	0,075	0,107	8,661	15	0,895
16	0,053	0,106	8,913	16	0,917

Table 18: Autocorrelation of annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Table 18 shows an autocorrelation significance of above 0.05 for all lags, and Figure 36 shows that the boundaries of the 95% confidence interval are not exceeded. Both these illustrations indicate that the data are not autocorrelated, which means that rainfall data are not dependent on each other. Rainfall from a later year is not related to the rainfall from an earlier year.

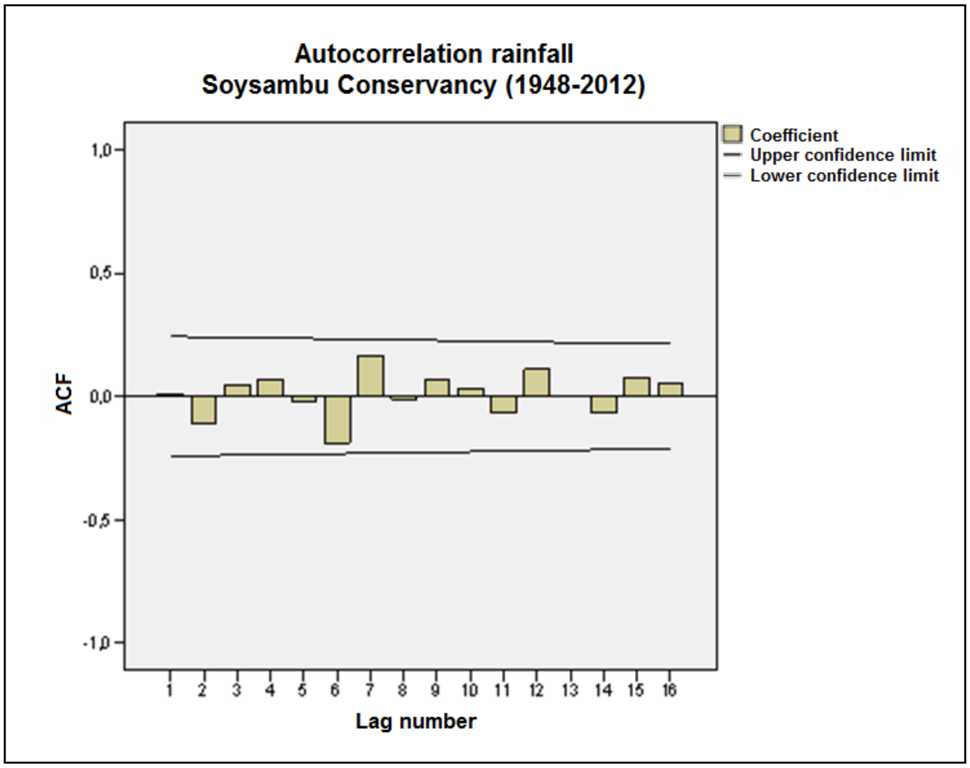


Figure 36: Autocorrelation of annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

e. Trend test

- Linear Regression:

Model		**Non-standardized coefficients**		
		B	Standard error	
	(Constant)	-4.364,643	2.166,385	
	Year	2,573	1,094	
		Standardized coefficients Beta	T	Significance
			-2,015	0,048
		0,284	2,352	**0,022**
	R	R-squared	Corrected R-square	Standard error of estimate
	,284(a)	0,081	0,066	165,49

Table 19: Correlation coefficient of annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Table 19 shows that the significance of Beta is 0.022, which is lower than 0.05 and thus indicates that there is a significant relationship between the rainfall amount and the respective year, and therefore a **significant trend**. Furthermore the correlation coefficient R is 0.284, indicating a weak relationship between rainfall amount and year. R^2 is 0.081 and the corrected R^2 value is 0.066, which means that 6.6 % of the variance can be explained by a statistical relationship between rainfall and year.

- Kendall-Tau Rank Correlation:

			Rainfall	Year
Kendall-Tau-b	Rainfall	Correlation coefficient	1	,188(*)
		Sig. (2-sided)	.	0,026
		N	65	65
	Year	Correlation coefficient	,188(*)	1
		Sig. (2-sided)	0,026	.
		N	65	65

Table 20: Kendall-Tau Rank Correlation Coefficient of annual rainfall at Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, SPSS Inc. 2006)

Similarly, Table 20 shows that the significance of the Kendall-Tau rank correlation has a value of 0.026, which is lower than 0.05 and thus indicates that there is a significant trend in the rainfall data.

5.1.3 Results from crop water requirements analysis

The crop water requirements for Lare and Gilgil were calculated with CROPWAT, using the rainfall that is exceeded with a probability of 50 %, which is equivalent to the average rainfall and is expected in a normal year. The irrigation requirements are given in mm per decade, which is equivalent to ten days (Smith 1992).

5.1.3.1 Lare Division

For typical climatic conditions, a normal rainfall year, red, loamy soil, crops planted in April have the following crop water requirements:

1. Maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,3	1,9	19,0	31,7	0,0
Apr	**2**	Init	0,3	1,92	19,2	37,6	0,0
Apr	**3**	Deve	0,45	2,98	29,8	35,9	0,0
May	**1**	Deve	0,71	4,99	49,9	34,0	15,8
May	**2**	Deve	0,98	7,14	71,4	33,5	37,9
May	**3**	Mid	1,21	8,49	93,4	29,7	63,7
Jun	**1**	Mid	1,23	8,29	82,9	24,2	58,7
Jun	**2**	Mid	1,23	8,0	80,0	20,1	60,0
Jun	**3**	Mid	1,23	7,5	75,0	22,0	53,1
Jul	**1**	Late	1,17	6,58	65,8	24,3	41,5
Jul	**2**	Late	0,9	4,63	46,3	25,4	21,0
Jul	**3**	Late	0,59	3,04	33,4	27,7	5,7
Aug	**1**	Late	0,38	1,98	6,0	9,6	0,0
					671,9	**355,5**	**357,2**

Table 21: Irrigation requirements for maize with rainfall data from KARI Njoro (Source: Rainfall data NPBRC, CROPWAT)

The crop water requirement of maize is 671.9 mm as shown in Table 21. Maize needs to be irrigated from its developing stage in early May up to the late maturity stage end of July. While 355.5 mm can be covered by natural rainfall, an additional amount of 357.2 mm needs to be supplied through irrigation.

2. Kidney Beans

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0,4	2,5	25,3	31,7	0,0
Apr	2	Init	0,4	2,6	25,6	37,6	0,0
Apr	3	Deve	0,5	3,6	36,0	35,9	0,2
May	1	Deve	0,8	5,6	55,7	34,0	21,7
May	2	Deve	1,1	7,7	76,7	33,5	43,2
May	3	Mid	1,2	8,2	90,2	29,7	60,6
Jun	1	Mid	1,2	7,9	78,5	24,2	54,4
Jun	2	Mid	1,2	7,6	75,8	20,1	55,8
Jun	3	Late	1,2	7,1	70,9	22,0	48,9
Jul	1	Late	0,9	5,1	50,7	24,3	26,4
Jul	2	Late	0,5	2,7	23,9	22,8	0,0
					609,5	**315,7**	**311,1**

Table 22: Irrigation requirements for kidney beans with rainfall data from KARI Njoro (Source: Rainfall data NPBRC, CROPWAT)

The crop water requirement of kidney beans as shown in Table 22 is 609.5 mm. Kidney beans need to be irrigated from their developing stage in early May up to the late maturity stage at the beginning of July. While 315.7 mm can be covered by natural rainfall, an additional amount of 311.1 mm needs to be supplied through irrigation.

3. Potatoes

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0,5	3,16	31,6	31,7	0
Apr	2	Init	0,5	3,2	32	37,6	0
Apr	3	Deve	0,53	3,55	35,5	35,9	0
May	1	Deve	0,74	5,14	51,4	34	17,4
May	2	Deve	0,96	6,99	69,9	33,5	36,4
May	3	Mid	1,15	8,09	88,9	29,7	59,2
Jun	1	Mid	1,17	7,88	78,8	24,2	54,6
Jun	2	Mid	1,17	7,6	76	20,1	56
Jun	3	Mid	1,17	7,13	71,3	22	49,4
Jul	1	Late	1,17	6,57	65,7	24,3	41,5
Jul	2	Late	1,08	5,61	56,1	25,4	30,7
Jul	3	Late	0,94	4,87	53,6	27,7	25,9
Aug	1	Late	0,81	4,23	33,9	25,5	2
					744,8	**371,5**	**373,0**

Table 23: Irrigation requirements for potatoes with rainfall data from KARI Njoro (Source: Rainfall data NPBRC, CROPWAT)

The crop water requirement of potatoes as shown in Table 23 is 744.8 mm. They need to be irrigated from the development stage in early May up to the late maturity stage end of July. While 371.5 mm can be covered by natural rainfall, an additional amount of 373.0 mm needs to be supplied through irrigation.

4. Tomatoes

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0,6	3,8	38	31,7	6,3
Apr	2	Init	0,6	3,84	38,4	37,6	0,8
Apr	3	Init	0,6	4	40	35,9	4,1
May	1	Deve	0,68	4,74	47,4	34	13,4
May	2	Deve	0,82	5,98	59,8	33,5	26,3
May	3	Deve	0,97	6,82	75	29,7	45,3
Jun	1	Mid	1,12	7,53	75,3	24,2	51,1
Jun	2	Mid	1,17	7,6	76	20,1	55,9
Jun	3	Mid	1,17	7,13	71,3	22	49,3
Jul	1	Mid	1,17	6,58	65,8	24,3	41,5
Jul	2	Mid	1,17	6,06	60,6	25,4	35,3
Jul	3	Late	1,14	5,91	65,1	27,7	37,3
Aug	1	Late	1,02	5,32	53,2	31,9	21,3
Aug	2	Late	0,9	4,66	46,6	35	11,6
Aug	3	Late	0,82	4,17	12,5	8,3	0
					824,9	**421,2**	**399,6**

Table 24: Irrigation requirements for tomatoes with rainfall data from KARI Njoro (Source: Rainfall data NPBRC, CROPWAT)

Table 24 shows the crop water requirement of tomatoes, which is 824.9 mm. They need to be irrigated from the initial stage in early April up to the late maturity stage in August. While 421.2 mm can be covered by natural rainfall, an additional amount of 399,6 mm needs to be supplied through irrigation.

5. Cabbages

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,7	4,43	44,3	31,7	12,6
Apr	**2**	Init	0,7	4,48	44,8	37,6	7,2
Apr	**3**	Init	0,7	4,66	46,6	35,9	10,7
May	1	Init	0,7	4,89	48,9	34	14,9
May	**2**	Deve	0,73	5,33	53,3	33,5	19,8
May	**3**	Deve	0,79	5,58	61,3	29,7	31,6
Jun	**1**	Deve	0,86	5,76	57,6	24,2	33,4
Jun	2	Deve	0,92	5,94	59,4	20,1	39,4
Jun	**3**	Deve	0,98	5,93	59,3	22	37,4
Jul	**1**	Mid	1,03	5,8	58	24,3	33,8
Jul	**2**	Mid	1,06	5,46	54,6	25,4	29,3
Jul	3	Mid	1,06	5,47	60,2	27,7	32,5
Aug	**1**	Mid	1,06	5,52	55,2	31,9	23,3
Aug	**2**	Mid	1,06	5,5	55	35	20
Aug	**3**	Late	1,05	5,38	59,1	30,6	28,5
Sep	1	Late	0,98	4,94	49,4	24,6	24,8
Sep	**2**	Late	0,93	4,6	9,2	4,1	9,2
					876,5	**472,2**	**408,4**

Table 25: Irrigation requirements for cabbages with rainfall data from KARI Njoro (Source: Rainfall data NPBRC, CROPWAT)

The crop water requirement of cabbages as shown in 25 is 876.5 mm. They need to be irrigated from the initial stage in early April up to the late maturity stage in September. While 472.2 mm can be covered by natural rainfall, an additional amount of 408.4 mm needs to be supplied through irrigation.

5.1.3.2 Gilgil Division

For typical climatic conditions, a normal rainfall year, red, loamy soil, crops planted in April have the following crop water requirements:

1. Maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,3	1,9	19,0	25,2	0,0
Apr	**2**	Init	0,3	1,9	19,2	30,5	0,0
Apr	**3**	Deve	0,5	3,0	29,8	28,2	1,5
May	**1**	Deve	0,7	5,0	49,9	25,1	24,8
May	**2**	Deve	1,0	7,1	71,4	23,6	47,8
May	**3**	Mid	1,2	8,5	93,4	22,5	70,9
Jun	**1**	Mid	1,2	8,3	82,9	21,3	61,6
Jun	**2**	Mid	1,2	8,0	80,0	20,0	60,0
Jun	**3**	Mid	1,2	7,5	75,0	19,5	55,6
Jul	**1**	Late	1,2	6,6	65,8	18,4	47,4
Jul	**2**	Late	0,9	4,6	46,3	17,5	28,8
Jul	**3**	Late	0,6	3,0	33,4	19,2	14,2
Aug	**1**	Late	0,4	2,0	6,0	6,6	0,0
					671,9	**277,5**	**412,6**

Table 26: Irrigation requirements for maize with rainfall data from Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, CROPWAT)

Table 26 shows the crop water requirement of maize, which is 671.9 mm. Maize needs to be irrigated from its developing stage in late April up to the late maturity stage end of July. While 277.5 mm can be covered by natural rainfall, an additional amount of 412.6 mm needs to be supplied through irrigation.

2. Kidney Beans

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,4	2,53	25,3	25,2	0,1
Apr	**2**	Init	0,4	2,56	25,6	30,5	0
Apr	**3**	Deve	0,54	3,6	36	28,2	7,8
May	**1**	Deve	0,8	5,57	55,7	25,1	30,7
May	**2**	Deve	1,05	7,67	76,7	23,6	53,1
May	**3**	Mid	1,17	8,2	90,2	22,5	67,8
Jun	**1**	Mid	1,17	7,85	78,5	21,3	57,3
Jun	**2**	Mid	1,17	7,58	75,8	20	55,8
Jun	**3**	Late	1,17	7,09	70,9	19,5	51,4
Jul	**1**	Late	0,9	5,07	50,7	18,4	32,3
Jul	**2**	Late	0,51	2,66	23,9	15,7	6,4
					609,5	**250**	**362,6**

Table 27: Irrigation requirements for kidney beans with rainfall data from Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, CROPWAT)

The crop water requirement of kidney beans as shown in Table 27 is 609.5 mm. They need to be irrigated from the development stage late April up to the late maturity stage in July. While 250.0 mm can be covered by natural rainfall, an additional amount of 362.6 mm needs to be supplied through irrigation.

3. Potatoes

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,5	3,16	31,6	25,2	6,4
Apr	**2**	Init	0,5	3,2	32	30,5	1,5
Apr	**3**	Deve	0,53	3,55	35,5	28,2	7,3
May	**1**	Deve	0,74	5,14	51,4	25,1	26,3
May	**2**	Deve	0,96	6,99	69,9	23,6	46,3
May	**3**	Mid	1,15	8,09	88,9	22,5	66,5
Jun	**1**	Mid	1,17	7,88	78,8	21,3	57,5
Jun	**2**	Mid	1,17	7,6	76	20	56
Jun	**3**	Mid	1,17	7,13	71,3	19,5	51,8
Jul	**1**	Late	1,17	6,57	65,7	18,4	47,3
Jul	**2**	Late	1,08	5,61	56,1	17,5	38,6
Jul	**3**	Late	0,94	4,87	53,6	19,2	34,4
Aug	**1**	Late	0,81	4,23	33,9	17,5	11,9
					744,8	**288,4**	**452**

Table 28: Irrigation requirements for potatoes with rainfall data from Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, CROPWAT)

The crop water requirement of potatoes as shown in Table 28 is 744.8 mm. They need to be irrigated from the initial stage in early April up to the late maturity stage in August. While 288.4 mm can be covered by natural rainfall, an additional amount of 452.0 mm needs to be supplied through irrigation.

4. Tomatoes

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,6	3,8	38	25,2	12,7
Apr	**2**	Init	0,6	3,84	38,4	30,5	7,9
Apr	**3**	Init	0,6	4	40	28,2	11,7
May	**1**	Deve	0,68	4,74	47,4	25,1	22,3
May	**2**	Deve	0,82	5,98	59,8	23,6	36,2
May	**3**	Deve	0,97	6,82	75	22,5	52,5
Jun	**1**	Mid	1,12	7,53	75,3	21,3	54
Jun	**2**	Mid	1,17	7,6	76	20	56
Jun	**3**	Mid	1,17	7,13	71,3	19,5	51,8
Jul	**1**	Mid	1,17	6,58	65,8	18,4	47,4
Jul	**2**	Mid	1,17	6,06	60,6	17,5	43,1
Jul	**3**	Late	1,14	5,91	65,1	19,2	45,9
Aug	**1**	Late	1,02	5,32	53,2	21,9	31,3
Aug	**2**	Late	0,9	4,66	46,6	23,7	22,9
Aug	3	Late	0,82	4,17	12,5	6	1,6
					824,9	**322,5**	**497,4**

Table 29: Irrigation requirements for tomatoes with rainfall data from Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, CROPWAT)

Considering Table 29, the crop water requirement of tomatoes is 824.9 mm. They need to be irrigated from the initial stage in early April up to the late maturity stage in August. While 322.5 mm can be covered by natural rainfall, an additional amount of 497.4 mm needs to be supplied through irrigation.

5. Cabbages

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	**1**	Init	0,7	4,43	44,3	25,2	19,1
Apr	**2**	Init	0,7	4,48	44,8	30,5	14,3
Apr	**3**	Init	0,7	4,66	46,6	28,2	18,4
May	**1**	Init	0,7	4,89	48,9	25,1	23,8
May	**2**	Deve	0,73	5,33	53,3	23,6	29,7
May	**3**	Deve	0,79	5,58	61,3	22,5	38,9
Jun	**1**	Deve	0,86	5,76	57,6	21,3	36,3
Jun	**2**	Deve	0,92	5,94	59,4	20	39,4
Jun	**3**	Deve	0,98	5,93	59,3	19,5	39,9
Jul	**1**	Mid	1,03	5,8	58	18,4	39,6
Jul	**2**	Mid	1,06	5,46	54,6	17,5	37,1
Jul	**3**	Mid	1,06	5,47	60,2	19,2	41
Aug	**1**	Mid	1,06	5,52	55,2	21,9	33,3
Aug	**2**	Mid	1,06	5,5	55	23,7	31,2
Aug	3	Late	1,05	5,38	59,1	21,8	37,3
Sep	**1**	Late	0,98	4,94	49,4	19,2	30,2
Sep	2	Late	0,93	4,6	9,2	3,5	9,2
					876,5	**361,1**	**518,9**

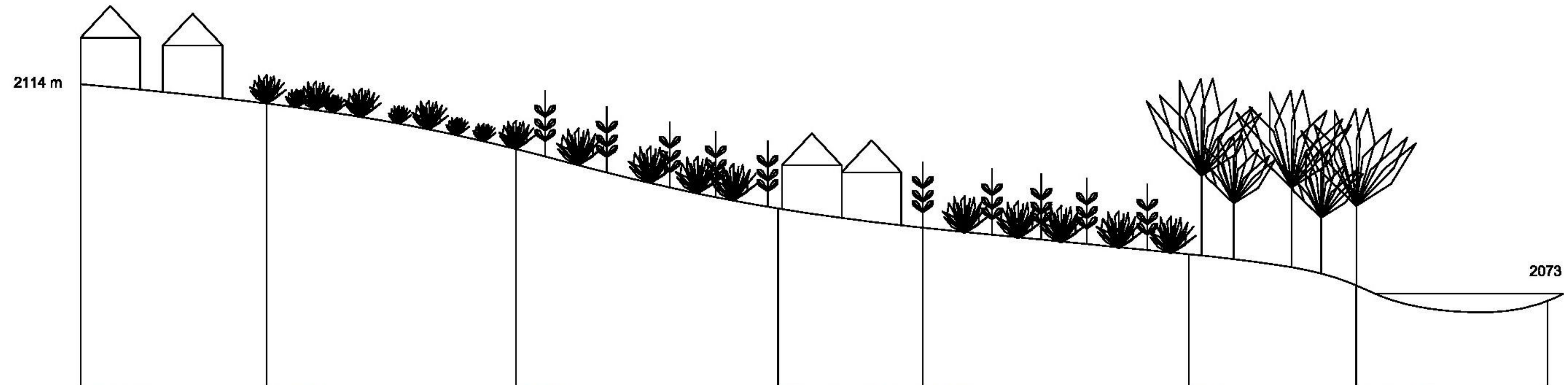
Table 30: Irrigation requirements for cabbages with rainfall data from Soysambu Conservancy (Source: Rainfall data Soysambu Conservancy, CROPWAT)

The crop water requirement of cabbages as shown in Table 30 is 876.5 mm. They need to be irrigated from the initial stage in early April up to the late maturity stage in September. While 361.1 mm can be covered by natural rainfall, an additional amount of 518.9 mm needs to be supplied through irrigation.

5.2 Natural resources, land use and water management measures

5.2.1 Results from transect walks

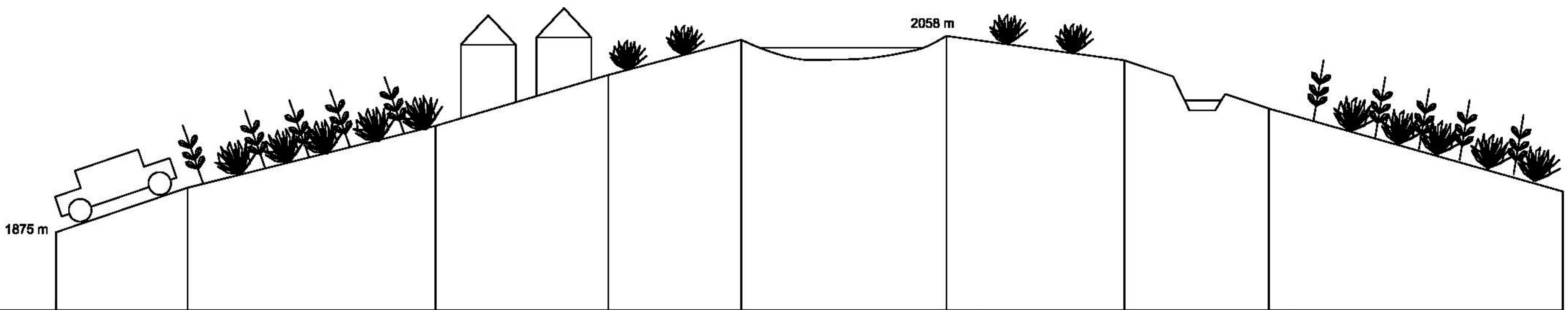
5.2.1.1 Transect walk Lare



Land use	Homestead	Home garden	Crop field	Village centre, market	Crop field	Forest	Community dam
Soil	clay loam	clay loam	clay loam	clay loam	clay loam	clay loam	
Water management	rain water tanks (200 to 10000 litres) - aluminium, steel, plastic or stone - domestic use	irrigation with water from the pans (mainly buckets, hose pipes and single drip irrigation systems), in situ rainwater harvesting (trenches constructed around the garden)	surface runoff collection in water pans - different shapes and sizes, in situ rainwater harvesting (trenches constructed around the plots), irrigation with water from the pans (mainly buckets, hose pipes and single drip irrigation systems)	communal water tank made from stone, 10000 litres, community boreholes, water kiosk, culverts under main road to prevent flooding	surface runoff collection in water pans - different shapes and sizes, in situ rainwater harvesting (trenches constructed around the plots), irrigation with water from the pans (mainly buckets, hose pipes and single drip irrigation systems)		community dam - fed both by rain water and a seasonal river, use of water from the dam for domestic purposes as well as irrigation
Soil conservation	trench inlet to homestead comprises a screen to collect eroded soil	construction of terraces - planting of napier grass to prevent soil transport	construction of terraces - planting of napier grass to prevent soil transport		construction of terraces - planting of napier grass to prevent soil transport	planting trees and growing tree seedlings, soil harvesting - collection of soil at a screen and redistribution on the field	
Vegetation	grassland and bare soil	tomatoes, kales, spinach, cabbage, carrots, pees, grassland	maize, potatoes, beans, cassava, arrowroots, vegetables i.e. kales, spinach, cabbages, tomatoes	sodom apples, eucalyptus, acacias, jakaranda trees, cactuses, grassland	maize, potatoes, beans, cassava, arrowroots (drought-tolerant), vegetables such as kales, spinach, cabbage, tomatoes	Acacias, Eucalyptus, Grevaria, Cypresses, Sisal, grassland	trees, grassland
Social/economic indicators	houses made from mud and metal sheets, single stone and wood houses, mainly aluminium and plastic tanks, single stone tanks	some kitchen gardens comprise exotic plants such as chick peas, others have common vegetables	varying crop types - exotic, expensive crops vs. commonly grown, available crops, plot sizes vary between 2,5 and 10 acres		varying crop types - exotic, expensive crops vs. commonly grown, available crops, plot sizes vary between 2,5 and 10 acres		
Crops		maize, potatoes, beans, cassava, wheat, sweet potatoes, bananas, vegetables such as kales, spinach, cabbage, carrots, tomatoes, pees, sugarcane, onions.	maize, potatoes, beans, cassava, arrowroots, vegetables i.e. kales, spinach, cabbages, tomatoes	maize, beans, potatoes, kales, tomatoes, arrowroots	maize, potatoes, beans, cassava, arrowroots (drought-tolerant), vegetables such as kales, spinach, cabbage, tomatoes	various tree seedlings	
Livestock	cattle, sheep, chickens, goats, rabbits			cattle, sheep, goats			
Problems	soil erosion during heavy rains, lack of sufficient amounts of water for animals and plants	lack of sufficient amounts of water for optimal crop development	lack of sufficient amounts of water for optimal crop development, destruction of crops due to heavy rainfall	National Cereals and Produce Store – closed because no funds to run it, now brokers buy bags of cereals (à 90kg) from famers at a very low price (2000 KES), soil erosion during heavy rains			
Opportunities	increased water availability for animals can increase production of milk	use of rainwater for irrigation purposes can lead to higher yields and income generation, planting of drought tolerant crops may increase food security	increased use of rainwater for irrigation purposes can lead to higher yields and income generation	increased use of terraces can decrease the negative effects of soil erosion, better road quality could lead to more people buying goods directly from the farmers	water from community dam can be used for irrigation purposes and to feed livestock, fish have been placed in the dam water - new source of income		water from community dam can be used for irrigation purposes and to feed livestock, fish have been placed in the dam water - new source of income

Figure 37: Results from transect walk in Lare (Source: Data collected from transesct walk, own illustration)

5.2.1.2 *Transect walk Gilgil*



Land use	Road	Crop field	Homestead	Bare land	Natural spring	Bare land	River	Crop field
Soil	sandy loam	sandy loam	sandy loam	clay loam	clay loam	clay loam		sandy loam
Water management		piping system from natural spring to farms, crop irrigation with spring water - mostly use of hose pipes and sprinklers, ferro cement tanks to store spring water	piping system from natural spring to homestead, use of spring water for drinking purposes and for livestock feeding, fish ponds, rain water storage tanks	large (community) stone tanks to store spring water, piping system from natural spring to farms	construction of a spring catchment, construction of a piping system (6 main pipes) transporting water to the community storage tank	piping system from natural spring to farms	direct water abstraction for domestic use and irrigation	piping system from natural spring to farms, crop irrigation with spring water - mostly use of hose pipes and sprinklers, ferro cement tanks to store spring water, water pans - use of water for irrigation purposes, soil water harvesting - excavation of earth, insertion of plastic lining, refilling and planting crops on that area
Soil conservation	trenches to enable water flow into the farms - reduction of soil erosion	terracing - planting of napier or vetever grass to prevent soil transport		terracing - planting of napier or vetever grass to prevent soil transport		terracing - planting of napier or vetever grass to prevent soil transport		terracing - planting of napier or vetever grass to prevent soil transport
Vegetation	grassland, wild shrubs	maize, beans, potatoes, cassava, fruits, vegetables, grassland	grassland and bare soil	grassland, wild shrubs	Acacias, Eucalyptus, Grevaria	grassland, wild shrubs		maize, beans, potatoes, cassava, fruits, vegetables, grassland
Social/economic indicators	no investment in road construction	varying crop types - exotic, expensive crops vs. commonly grown, available crops, plot sizes vary between 2 to 4 acres	mainly mud houses, mainly aluminium and plastic tanks, single stone tanks	very few homesteads, plot sizes vary between 4 and 10 acres		very few homesteads, plot sizes vary between 4 and 10 acres		varying crop types - exotic, expensive crops vs. commonly grown, available crops, plot sizes vary between 2,5 and 10 acres
Crops		maize, beans, potatoes, cassava, millet, sorghum, arrowroot, fruits e.g. bananas, mangos, papayas, passion fruit, vegetables e.g. kales, spinach, cabbage, tomatoes, pees, sugarcane, onions, beet roots		maize, beans		maize, beans		maize, beans, potatoes, cassava, millet, sorghum, arrowroot, fruits e.g. bananas, mangos, papayas, passion fruit, vegetables e.g. kales, spinach, cabbage, tomatoes, pees, sugarcane, onions, beet roots
Livestock			cattle, sheep, chickens, goats, rabbits		kettle, sheep			
Forestry/Agroforestry		planting of various fruit trees such as mango, papaya and passion fruit trees			various trees such as Acacias, Eucalyptus and Grevaria have been planted around the spring catchment			reforestation has begun
Problems	high soil erosion leading to poor roads	lack of sufficient amounts of water for optimal crop development	spring water has a high fluroide content causing health problems for the farmers	lack of sufficient amounts of water for optimal crop development	low spring catchment protection - no fencing	lack of sufficient amounts of water for optimal crop development	very low flow in the dry season (january to march) especially for users downstream	lack of sufficient amounts of water for optimal crop development
Opportunities	increased water diversion into the farms is likely to reduce soil erosion	adoption of rainwater harvesting techniques to supplement the water from the hot springs	adoption of rainwater harvesting techniques to use rain water instead of spring water for drinking purposes, increased water availability for animals can increase production of milk	adoption of rainwater harvesting techniques to use rain water instead of spring water for drinking purposes, planting of drought tolerant crops may increase food security	spring water catchment can be protected if fenced	adoption of rainwater harvesting techniques to use rain water instead of spring water for drinking purposes, planting of drought tolerant crops may increase food security	adoption of rainwater harvesting techniques - less direct abstraction from river	adoption of rainwater harvesting techniques to supplement the water from the hot springs and river

Figure 38: Results from transect walk in Gilgil (Source: Data collected from transesct walk, own illustration)

5.3 Existing irrigation and water harvesting systems and their innovative capacity

5.3.1 Results from semi-structured interviews with farmers

In Lare, each farmer who was interviewed possesses at least one water pan and water tank. All farmers collect surface runoff from the road in their water pans through small trenches that they have dug on the road, enabling the water to flow into their farms. They all also collect rainwater from their roofs in water tanks. All interviewees stated that they supply their livestock with water from their water pans. Only three male farmers irrigate their crops. They use water from their water pans for irrigation purposes. One of them irrigates the vegetables in his green house, which is usually operated when the dry season comes. Another farmer uses buckets, hose pipes, sprinklers and a drip to irrigate his crops. He has a manual pump to transport water from his pan to his crops. The third one uses buckets and hose pipes to irrigate his plants. He also has a manual pump to transport water from his pans to the crops through the hose pipes. In Gilgil on the other hand nine farmers use water from the Kikopey hot springs to feed their livestock, while one farmer gets piped water from the Malewa River. Eight farmers collect rainwater in a tank and one of them also has a water pan. All farmers irrigate their crops, nine of them with water from the hot springs and one with water from the Malewa River. They have a piping system from the spring to a storage tank and another connection from the tank up to their farms. Also the lady farmer who gets water from the Malewa River has a piping system up to her home. Four farmers use sprinklers for irrigation, two farmers have sprinklers and hose pipes and four farmers use only hose pipes. Two farmers commented that they prefer using the hose pipe instead of the sprinkler because a larger area can be irrigated with the hose pipe and water is not sufficient to use the sprinkler. Two farmers stated that they would prefer drip irrigation, but that they don't have the finances to get the system.

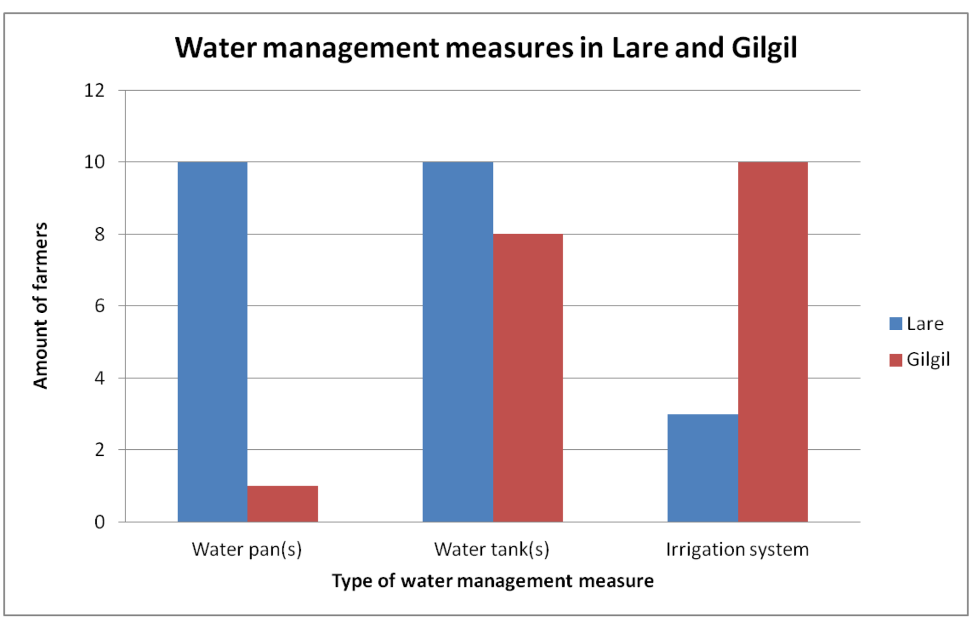


Figure 39: Water management measures in Lare and Gilgil (Source: Semi-structured interviews with farmers, own illustration)

The water management measures used by farmers in Lare and Gilgil are illustrated in Figure 39.
Nine farmers in Lare said that the main reason for starting with rainwater harvesting was a lack of water and that the nearest water source was ten to twelve kilometres away. Similarly all farmers in Gilgil stated that the main reason for starting with rainwater harvesting and irrigation was a lack of sufficient water and crop failure.
All interviewees in Lare and Gilgil think that their water harvesting and irrigation systems are useful in mitigating the problems listed above. Benefits mentioned are a higher availability of water, improved food security, reduction of time and effort used in search of water, reduction of water borne diseases, improved yields and increased crop variety.

5.4 Farmer's requirements, capabilities, knowledge and role in the planning, implementation and use of water harvesting and irrigation systems

5.4.1 Results from semi-structured interviews with farmers

a. Farmers' requirements with respect to water for agricultural and domestic use

Although all farmers in Lare think that having some type of water harvesting or irrigation system for crop development is very important, most of them don't collect enough water in their pans to practice irrigation. This circumstance is marked by the responses of the farmers. One woman farmer stated, "If it is possible for people around one can even donate a small farm and a pan can be dug. Then people can be able to feed themselves. People could then do irrigation." The lady suggested that if more water was available, it would be possible to practice irrigation. Also all the farmers in Gilgil thought that the use of an irrigation system is very important for crop development, but all of them stated that they would require more water for irrigation purposes than they are currently receiving from the hot spring.
Nine farmers in Lare and seven in Gilgil possess cattle while all farmers in Gilgil and seven in Lare possess chickens. Furthermore seven farmers in Lare and one farmer in Gilgil have sheep, four farmers in Gilgil and three in Lare have goats. All the farmers use their crops and livestock products both for home consumption as well as for selling. The farmers in Lare supply their animals with water collected in their water harvesting systems and those in Gilgil get water from the hot springs.
Six farmers in Lare and eight farmers in Gilgil have enough water to supply their animals. Whether the farmers have enough water for their animals depends on the amount that is available from various water resources and on the water demand, which again is influenced by the number and type of livestock possessed by the farmers. While the farmers in Lare need between 20 and 400 litres per day, those in Gilgil require only 10 litres to 80 litres. The farmers in Lare who lack sufficient water buy additional water in the dry season for their animals, and one of the two farmers in Gilgil who doesn't have enough water exchanges water with his neighbours, while the other one doesn't acquire any additional water.

Eight farmers in Lare would like to have more support from their government. Seven of those farmers primarily require financial support and five would also need more technical advice on different topics such as irrigation practices, water resources management and farm management in general. Financial support is required in order to get piped water, build dams for irrigation purposes and water tanks. In Gilgil all farmers stated that they need more support from the government. All of them require financial support and eight need technical advice. Nine farmers in Gilgil explained that if they had the financial means they would construct water pans and water tanks, while one farmer stated that he would buy a proper lining for his water pan. One lady mentioned that she would like to have technical advice on crop husbandry, pest and disease control and on marketing. On the whole thirteen out of twenty farmers would like to have more information and technical advice about different subjects related to agriculture as shown in Figure 40.

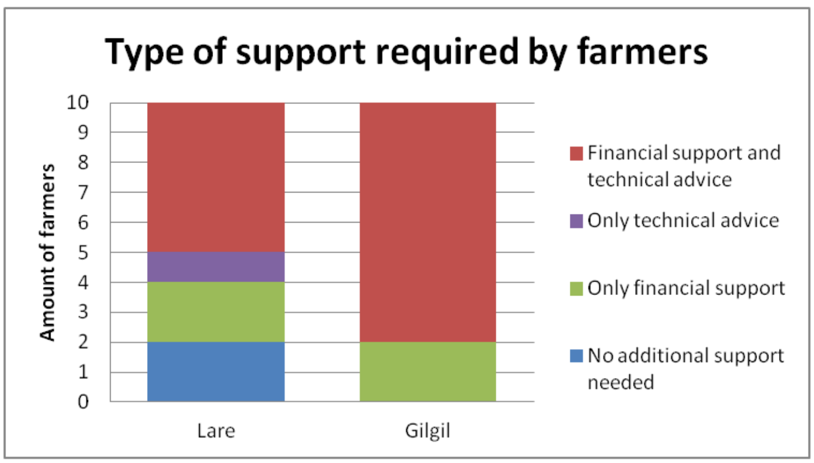


Figure 40: Type of support needed by farmers (Source: Semi-structured interviews with farmers, own illustration)

b. <u>Farmers' capabilities, role and knowledge used in the planning and implementation process of water harvesting and irrigation systems:</u>

Eight farmers in Lare stated that the development of water pans or water tanks took place due to their own effort and initiative and that they didn't get any technical advice. The two other farmers in Lare received advice on water harvesting from different institutions such as the Ministry of Agriculture, KARI and EU. Nine farmers stated that they didn't receive any training on how to construct, use and maintain water pans and water tanks. On the other hand only four farmers in Gilgil shared the opinion that they didn't get any training or technical advice on how to implement their water harvesting or irrigation systems while the other six were advised and trained by the African Institute for Capacity Development (AICAD), Japan International Cooperation Agency (JICA) and the Minstry of Agriculture. One of the farmers who didn't get advice on water harvesting remarked that this technique was already practiced by his parents. Three farmers claimed that it was their own idea to start irrigating their crops and harvesting water and one farmer stated that he got information about those methods in school. The amount of farmers who received trainings in both research sites is illustrated in Figure 41.

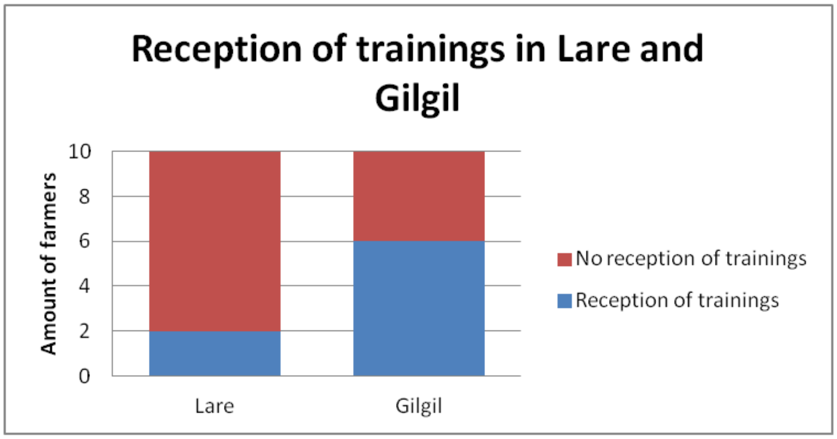


Figure 41: Amount of farmers who received trainings (Source: Semi-structured interviews with farmers, own illustration)

In Lare six farmers constructed their water harvesting systems only with the support of their families while the other four farmers out of which three were men hired labour and machines to construct their water pans. In Gilgil five farmers hired labour and the other five constructed the systems by themselves. The five farmers who hired labour were all women, two of whom were single parents.
Considering both research sites, out of the nine farmers who hired labour, three were men and six were women, out of which two were single parents. The amount and distribution of hired labour between men and women is illustrated in Figure 42.

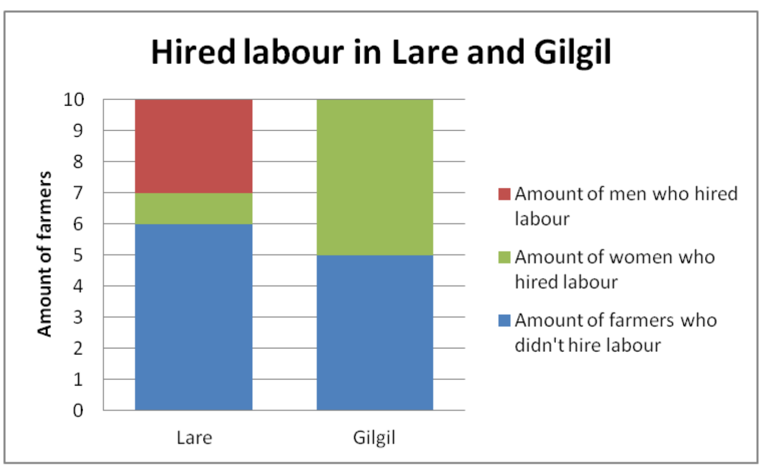


Figure 42: Amount if farmers who hired labour (Source: Semi-structured interviews with farmers, own illustration)

All farmers in Lare stated that they financed their pans and tanks themselves and didn't get any financial support. In Gilgil on the other hand six farmers financed their irrigation and water harvesting systems themselves, while one farmer got funds from JICA to buy a water tank, another farmer got financial support from the government to construct a water pan and two lady farmers took up a credit in order to construct or buy their systems. In both research areas the option of taking a credit was not considered by the majority. Out of the twenty farmers who were interviewed, only two female farmers took a credit to implement their water management systems. The mode of financing systems in both research sites is shown in Figure 43.

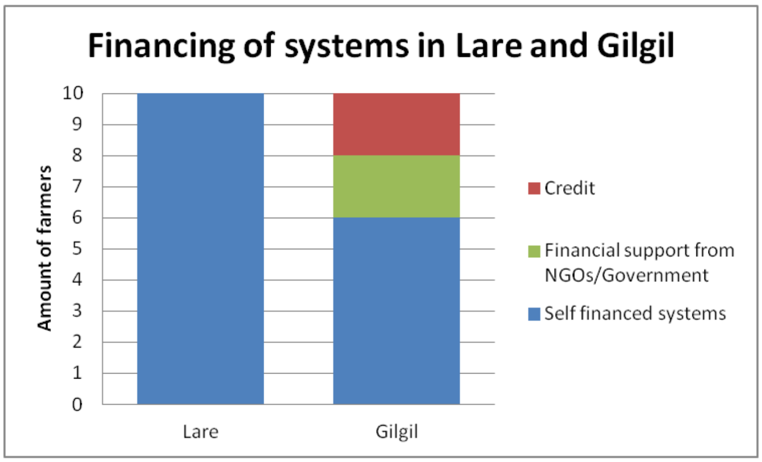


Figure 43: Modes of financing measures (Source: Semi-structured interviews with farmers, own illustration)

Seven farmers in Lare have the opinion that their knowledge and requirements are considered when new measures are being planned. Furthermore eight farmers explained that the interaction between them and the government is good. One male farmer stated that the communication could be better, but that at least sometimes they are asked about their requirements. Only one lady farmer stated that the communication between her and the government is not at all good.

The farmers who think that the communication between them and the government should be better are two of three farmers who think that their knowledge and requirements are partly or not at all considered and also share the opinion that they didn't get any technical advice or training on how to construct their water management systems. The two farmers mentioned are women. On the other hand five out of the seven farmers who thought that their knowledge is considered stated that they didn't get any training or technical advice on how to plan and implement their systems.

Five farmers in Gilgil think that their knowledge is considered when new measures are being planned. The other five people stated that it should be more considered or has not been considered at all. Three of those farmers stated that they also didn't get any training or technical advice from the government or another institution, while the other two did get advice. Only one of those farmers who thought that their knowledge was considered didn't receive any training on water management measures. Seven farmers have the opinion that there is good interaction between them and other stakeholders and include those five farmers who feel that their knowledge is considered when new measures are being planned. Two farmers explained that their knowledge is not considered when new measures are being planned although there is good interaction between them and other stakeholders. Three farmers who stated that the interaction and communication is not good belonged to those who also felt that their knowledge is not considered when new measures are being planned. All the farmers who feel that their knowledge is considered during the planning and implementation process of new measures think that there is good communication between them and other stakeholders and all farmers who claim that the interaction is not good belong to the group of farmers who feel that their knowledge is not considered.

Out of the five farmers who feel considered and included during the establishment of new measures and think that interaction was good, four got technical advice and trainings from AICAD and JICA for constructing their water management systems. Three farmers who feel that interaction is poor, belonging to the group of five farmers who feel that they are not considered, didn't receive any training, while the other two farmers did get technical advice.

Nine farmers in Lare stated that there is no farmers' organisation to represent them in any issues. One of them stated that there used to be cooperatives to represent the farmer's needs, but that the whole system failed and got wiped out. Only one farmer stated that there are many small groups in which farmers are represented. On the other hand eight farmers in Gilgil explained that they have a farmers' association in the form of farmer groups, and only two think that there is none. Six of those who think that there is a farmers' association have the opinion that the association is useful, while the two others, one man and one woman, don't really see any benefit in having the association. Based on the responses given by the farmers in Lare and Gilgil one can make out a clear difference in the perception of farmer representation.

The farmers' opinion and the relationship between interaction, knowledge consideration and reception of trainings are illustrated in Figure 44, Figure 45 and summarized in Table 31, while Figure 46 illustrates the perception of farm work division of male and female farmers.

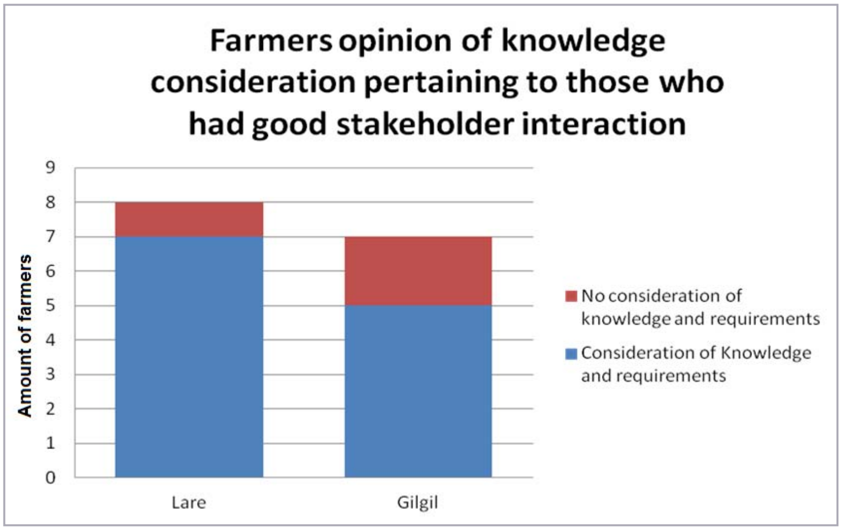


Figure 44: Relationship between consideration of knowledge and stakeholder interaction (Source: Semi-structured interviews with farmers, own illustration)

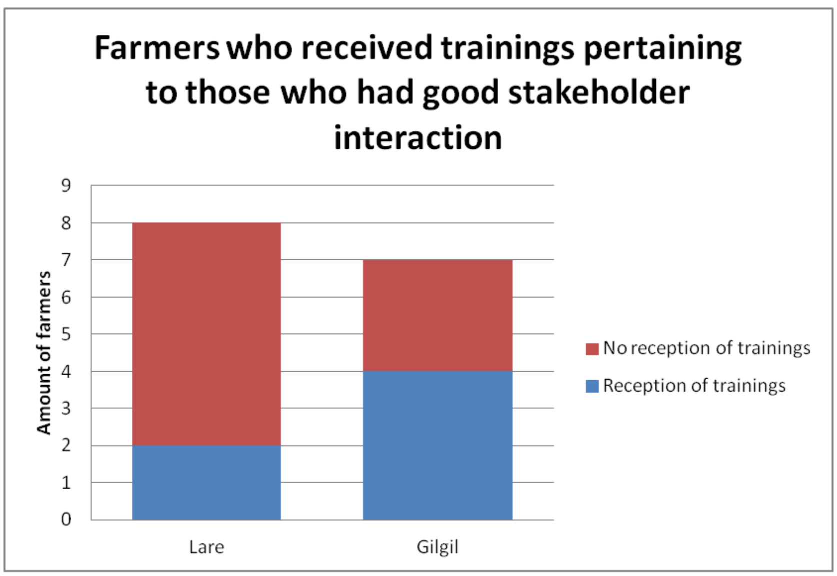


Figure 45: Relationship between stakeholder interaction and reception of trainings (Source: Semi-structured interviews with farmers, own illustration)

	Good interaction with other stakeholders		No good interaction with other stakeholders		Consideration of Knowledge and requirements		No consideration of knowledge and requirements		Reception of trainings		No reception of trainings	
	Lare	Gilgil	Lare	Gilgil	Lare	Gilgil	Lare	Gilgil	Lare	Gilgil	Lare	Gilgil
Total amount of farmers	10	10	10	10	10	10	10	10	10	10	10	
	8	7	2	3	7	5	3	5	2	6	8	4
Good interaction with other stakeholders					7	5	1	2	2	4	6	1
No good interaction with other stakeholders					0	0	2	3	0	0	2	3
Consideration of Knowledge and requirements	7	5	0	0					2	4	5	1
No consideration of knowledge and requirements	1	2	2	3					0	2	3	3
Reception of trainings	2	4	0	2	2	4	0	3				
No reception of trainings	6	3	2	1	5	1	3	2				

Table 31: Frequency distribution of selected categories (Source: Semi-structured interviews with farmers, own illustration)

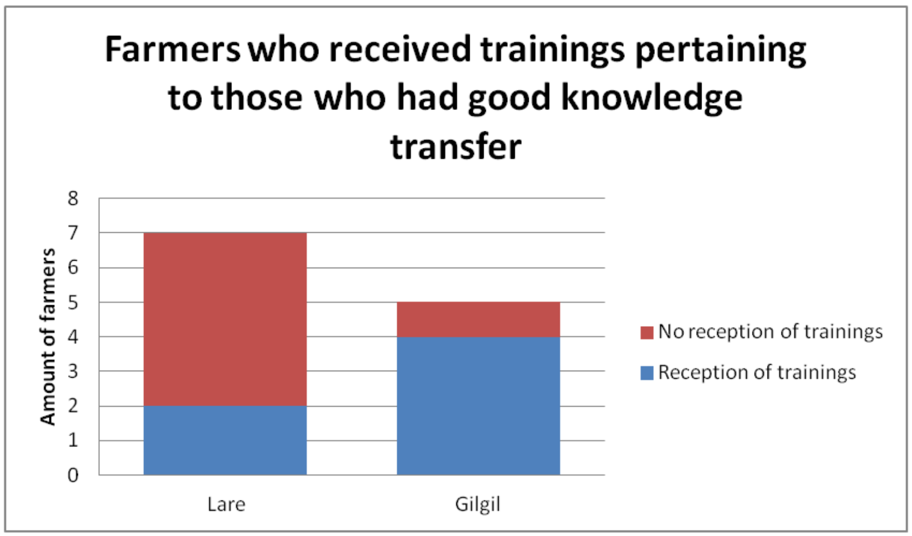


Figure 46: Relationship between knowledge transfer and reception of trainings (Source: Semi-structured interviews with farmers, own illustration)

c. Farmers' role in the use of water harvesting and irrigation systems

As shown in Figure 47, six farmers in Lare out of which four are men and two are women state that the whole family is engaged in working on the farm while the other four farmers who are all women stated that they do all the work by themselves. Three of them don't have husbands and the fourth lady's husband works outside. Two of the three men who irrigate their crops in Lare stated that it is them or their wives who take care of that task while the third man hires labour. In Gilgil five farmers stated that the whole family is responsible for irrigating crops, while the other five farmers out of which four are women stated that they do all the work by themselves. Two of those women don't have husbands and the husbands of the other two ladies have another job outside to sustain their families. It is noticeable that out of the nine farmers who stated that they did the work on the farm all by themselves, eight are female and one is male, and that the remaining eleven farmers who stated that the whole family was involved in farming activities were made up by eight men and three women. All the women who manage the farms by themselves are single parents or have husbands who are involved in off-farm activities. None of the men who were interviewed are single parents, and their main occupation is farming.

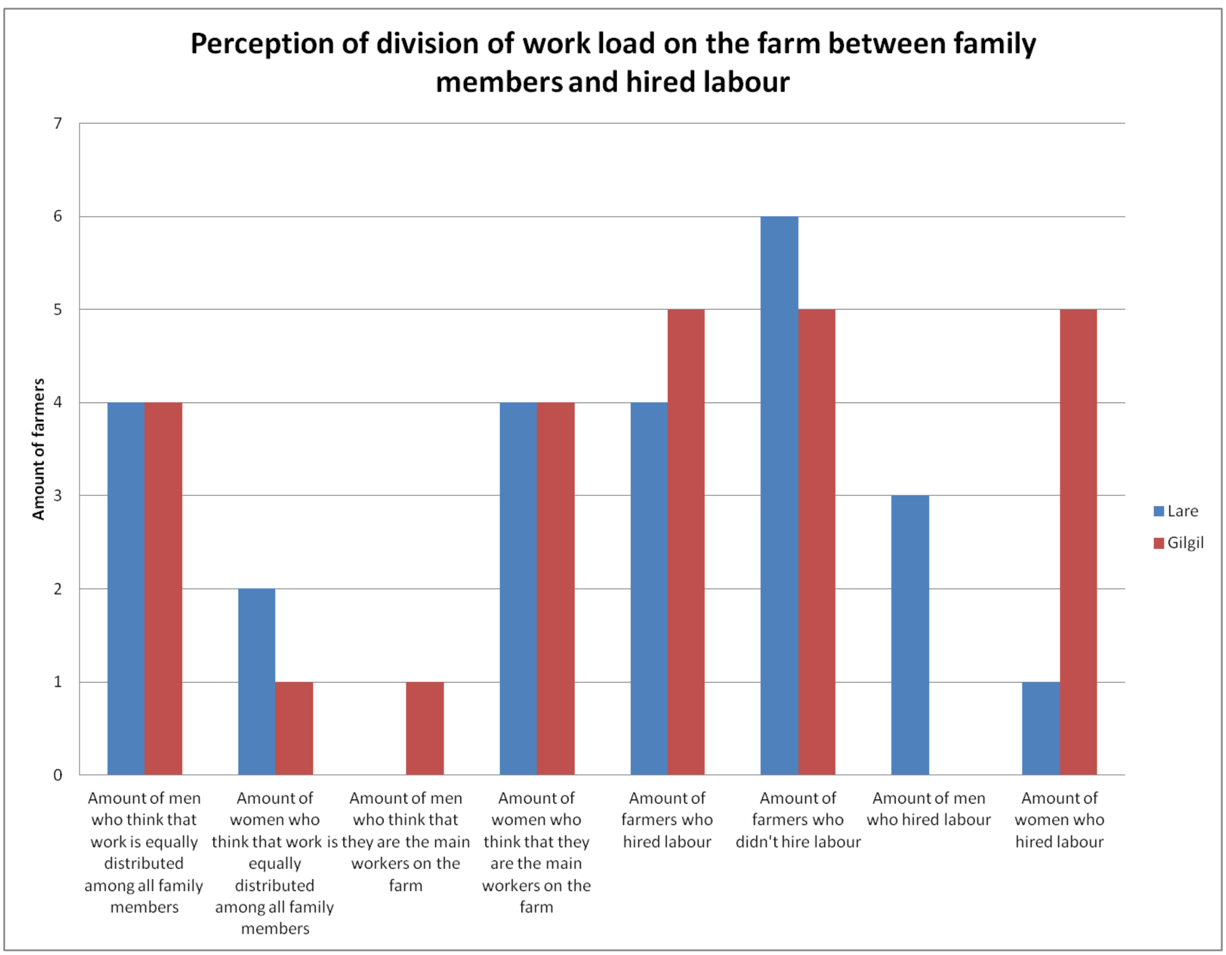


Figure 47: Perception differences between male and female farmers considering the division of work load in farming (Source: Semi-structured interviews with farmers, own illustration)

5.4.2 Involvement in the development and actions to enable interaction and knowledge flow

5.4.3 Results from semi-structured interviews with experts

Abbreviations:

Location chief of Lare Location: LC

Agricultural Extension Officer of Lare Division: AL

Project Coordinator from Baraka Agricultural College: BC

Agricultural Extension Officer of Gilgil Division: AG

Ministry of Water: MW

Project coordinator from AICAD: PA

a. Actors involved in triggering the development of water harvesting and irrigation systems

All experts interviewed in Lare shared the opinion that various stakeholders were involved in enabling the development of water harvesting and irrigation systems. The institutions mentioned were of private and public nature and included Baraka Agricultural College, GTZ (German Technical Cooperation), KARI (Kenya Agricultural Research Institute), ACK (Anglican Church of Kenya), Egerton University, ICRAF (World Agroforestry Centre), the Ministry of Agriculture and the Ministry of Livestock. All three interviewees stated that the farmers played an important role in triggering the measures, as they had approached the Ministry of Agriculture and demanded as they were suffering from water shortage. After that the Ministry of Agriculture got together with the other organisations mentioned in order to come up with solutions to mitigate the problem of water scarcity. AL explained that this was known as farmer-research extension linkage. BC explained that when the organisations were confronted by the Ministry, there was already an existing structure in place which was called the Lare extension staff and it was possible to reach out to the farmers through this organisation.

All the interviewees in Lare share the same opinion as to who was involved in triggering water harvesting and irrigation systems. The importance of farmers in the development of water management systems was also mentioned by all stakeholders.

In Gilgil the opinions of who was responsible for triggering the development of water harvesting and irrigation measures varied. AG explained that the measures arose through the farmers' own initiatives. On the other hand MW stated that it was the Ministry of Water who took the necessary actions to enable the development of water management systems. He explained that the idea of rainwater harvesting was introduced by the Ministry of Water in conjunction with AICAD, while irrigation measures were implemented primarily by the Ministry of Water. PA stated that AICAD triggered new measures through their capacity building programme after consultation with other stakeholders involved. These stakeholders comprise AICAD (in conjunction with JICA), the District irrigation office, the Kariandusi community, the District agricultural office, EU and WRMA. The African Institute for Capacity Development in conjunction with JICA (2010) documents that a participatory planning workshop was held after conducting a baseline survey in the research area to find out about the farmers' problems, needs and opportunities.

Experts in Gilgil don't have the same perception of who was responsible for triggering the development of water management measures. While PA stated that a variety of stakeholders was involved and called together in a workshop, MW mentioned only the Ministry of Water and AICAD, while AG spoke only of farmers who enabled the development of water harvesting and irrigation systems.

b. <u>Main actions that were taken to enable interaction and knowledge transfer between all stakeholders</u>

All experts in Lare shared the opinion that steps were taken to enable interaction and knowledge transfer between the stakeholders in Lare while the measures were being developed. They stated that the main steps included farmer's field days where different agricultural practices and methods were shown to the farmers as well as meetings, workshops, group discussions, trainings, demonstrations and follow-ups. There were also exchange visits to other locations where farmers had tried similar methods. BC concluded that after the farmers went out and constructed their water harvesting systems they had meetings to try and evaluate the measures. LC explained that the stakeholders didn't just bring new technologies, but that they used the farmers' knowledge as a base for any further planning. The farmers had an innovative idea and they were informed on how to implement their ideas. AL stated that there was a tool known as ITK, indigenous technical knowledge, which was used while planning the measures and made sure that the farmer's knowledge was included in the process.

Similarly all experts in Gilgil shared the opinion that steps were taken to enable interaction and knowledge transfer between the stakeholders while the measures were being developed. AG stated that a good number of farmers were called for workshops by AICAD and JICA and were encouraged to transfer their knowledge to people living in their surroundings. He stated that the interaction between the farmers and AICAD or JICA was very good, but that they primarily did trainings and didn't include the farmers in the planning process. There were also trainings and field trips organised by the Ministry of Water for the farmers. She thought that there was a good interaction between the Ministry of Water and the Ministry of Agriculture. On the other hand the interaction and knowledge transfer between AICAD and the Ministries of Water and Agriculture was not as good. She explained that the Ministry of Agriculture was called by AICAD only for a one day workshop and to run trainings for the farmers, but they weren't actually involved in the whole planning and implementation process of the measures and didn't know what was really happening in the field. This lack in communication led to a disruption of information and knowledge transfer between the agricultural extension officers and the farmers.

PA explained that there were several trainings and workshops that were conducted dealing with subjects such as irrigation and water management, livestock and soil conservation. There were also field days where farmers were taken outside to another village to see which measures farmers had implemented there. He stated that prior to these workshops and trainings they met with farmers in a hotel where all stakeholders got together and found out about the farmer's main problems and also their knowledge so that they could find out from what level they needed to build things up.

MW stated that there were several meetings, workshops, trainings, group discussions and demonstrations to enable interaction and knowledge transfer between all stakeholders, and that they were all done in a participatory manner.

Similarly as to who was involved in triggering the measures, the experts in Gilgil also had different opinions considering the interaction and knowledge transfer between stakeholders. Although all experts suggested that steps were taken to enable interaction and knowledge transfer, the quality of interaction wasn't equal between all stakeholder groups. AG mentioned that the interaction between the NGOs involved and the farmers was very good, but that the knowledge transfer between the Ministries of Water and Agriculture and the NGOs should have been better. On the other hand both PA and MW mentioned that there were several steps taken to ensure knowledge transfer between all stakeholders.

It can be made out that the experts in Lare have a more homogenous perception of who was responsible for triggering the development of new measures compared to those of Gilgil. While all three experts in Lare pointed out the importance of the farmers' role in triggering the measure, only the extension officer in Gilgil explained that the triggering of new measures happened through the farmers' initiatives. In Lare one could speak of a multi-stakeholder approach as various institutions both from the private and the public sectors as well as farmers were involved. In Gilgil on the other hand each expert mentioned different organisations which were responsible for triggering the development of water management measures. While PA mentioned a variety of stakeholders involved in the planning process, MW only spoke of the Ministry of Water and Irrigation and AICAD, and AG thought that it was mainly the farmers who were responsible for the development of water management measures.

In both research sites the experts perceived that farmers and their knowledge and requirements were considered. Nonetheless AG pointed out that farmers were primarily encouraged to visit workshops and trainings, but their knowledge was not really included in the planning process.

c. Inclusion of women in the decision, planning and implementation process of water management measures:

LC explained that women were very well included during the development of new measures. There were meetings and workshops where both men and women were invited before the process started. Furthermore he pointed out that women were invited through churches and that the turn-up proved that both men and women were interested. After those meetings the Ministry visited the families in their homes where they would talk to both men and women. They were invited in the planning process and were encouraged to practice water harvesting because they thought that if they had water near their homes it would reduce their problems and they could do other duties instead of searching for water. He explained that women were well represented in all stakeholder groups. Due to a directive of the government known as a third gender rule, it was assured that a third of the people in the management committees for water harvesting techniques was made up by women. He stated that women were also represented in other NGOs.

All three interviewees in Gilgil stated that both men and women were included in the planning and implementation process of water management measures. AG explained that the village elders were encouraged to select people from their villages according to certain features such as age and gender. He also stated that in most government plans and many projects, there is a slot which includes single parents, especially single women. He stated that although in general women are included, a single parent, especially a woman, is not well received in the community, which makes the inclusion of these women in the project difficult if they don't take their own initiative. MW stated that women were included in the process. They were encouraged to join in the demonstrations. Also PA explained that issues of gender were incorporated in the project from its initiation to its completion. Participants of meetings, workshops and training programmes were selected by AICAD with consultation of the village leaders. It was agreed by all the stakeholders that in each activity both gender be represented equally. All interviewees stated that women were represented in each stakeholder group.

Based on the responses in both research sites, women were encouraged to participate in various activities concerning the development of water management measures. Only AG pointed out that women, especially single women may face more difficulties in implementing water management measures than other farmers.

d. <u>Interaction and knowledge transfer between male and female farmers in the implementation process</u>

LC explained that it is often the men who do the implementation of the measures because it requires a lot of physical work. On the other hand irrigation and acquiring water for that purpose is a task that is handled by both men and women and they are often found working together. He also stated that there are cases where women are predominantly involved in the work of irrigation and farm management in general because many men work outside and the children will be out working or in school and colleges. Considering the decision on which measure should be implemented, the chief stated that according to African tradition the man is the decision maker and that that tradition has not yet stopped.

AG explained that women are more involved in agricultural practices as they are often the ones who stay at home and take care of the children. Work that needs to be done outside the home such as taking the produce to the market is normally done by men. MW suggested that in a female single-headed home it will be the woman who does all the work on the farm. For the very heavy work they normally hire labour or their sons help with that. But normally you will find that the man will be doing the heavy work like pipe connections, digging water pans, bringing the produce to the market, doing the chemical spraying while the woman will be responsible for tasks such as water provision and storage. PA thought that most of the activities are done in a participatory manner, for example all members of the family including the children participate in farm activities such as digging, planting, weeding, harvesting although there are some roles that are specific to the parents such as payment of school fees. Considering the decision on which measure should be implemented, AG suggested that it is the man who takes the decision. Also MW stated that it is actually the husband who has the last say, as he is the head of the house and owns the land, which makes his word final. He explained that if the woman has a good idea, she first has to convince her husband of that idea before it can be put into practice. PA stated that whoever is the head of the family decides on which measure will be implemented.

Considering the decision on which measure should be implemented, five interviewees suggested that the husband decides on which measure should be implemented. Only one interviewee explained that whoever is the head of the family makes that decision.

6 DISCUSSION ON RAINFALL DATA, CROP WATER REQUIREMENTS AND INTERVIEWS

6.1 Water availability, crop water requirements and changes in rainfall quantity

6.1.1 Rainfall data

Comparing the rainfall data of Lare and Gilgil, Tables 7 and 14 depict that Lare has a higher average annual rainfall (959.44 mm) than Gilgil (729.80 mm), resulting in an average difference of 230 mm per year between the two research sites. Also the median between the two sites has a difference of around 200 mm. Furthermore the annual rainfall values in Lare range from 552.90 to 1512.30 mm while those in Gilgil lie between 369.50 and 1136.40 mm, which shows that the lowest and the highest rainfall amounts observed in Lare are higher than the ones observed in Gilgil. In both research areas drought cycles can be identified which occur every three to five years, considering Figure 48. Furthermore in Lare and in Gilgil there were very high rainfall amounts in 2010 (1512.30 mm and 1136.40 mm respectively). The lowest amount of annual rainfall in Lare occurred in 1965 (552.90 mm), while the lowest value in Gilgil occurred in 1953. Both research areas had very low amounts of rainfall in the years 1984 and 2009.

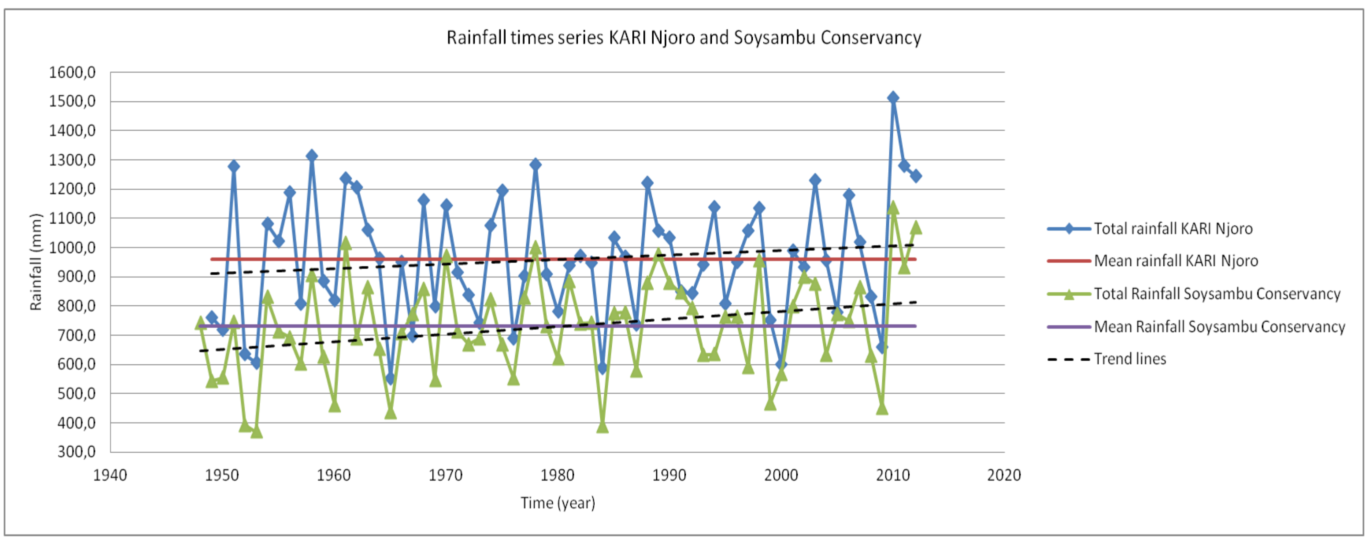


Figure 48: Comparison of annual rainfall amounts between Lare and Gilgil (Source: Rainfall data from KARI Njoro (NPBRC) and Soysambu Conservancy, own illustration)

Considering the statistical tests carried out (Tables 7 to 20 and Figures 27 to 36), both the annual rainfall data in Lare and Gilgil were assumed to be normally distributed. The Levene's and T-Tests indicated that the mean and variance in the rainfall data haven't significantly changed over time and that the entire data follows the same distribution. Furthermore the data in Gilgil and Lare are not autocorrelated.

Considering the Pearson correlation, in Lare there is no significant correlation between rainfall and the respective year. The linear regression model of Lare shows that there is no significant trend in the data, and the corrected R^2-value which is based on the sample size and is 0.003 indicates that 0.3 % of the variance can be explained by a statistical is relation between rainfall and year. The significance of the Kendall-Tau rank correlation is 0.35 and therefore higher than 0.05 and thus indicates that there is no statistically significant dependence between rainfall and year.

In Gilgil on the other hand there is a significant correlation between rainfall and the respective year considering the Pearson correlation. The linear regression model shows that there is a significant trend in the data. R has a value of 0.284 which implies medium significance, and the corrected R^2-value which is based on the sample size and is 0.066 indicates that 6.6 % of the variance can be explained by a statistical relation between rainfall and year. The significance of the Kendall-Tau rank correlation is 0.026 and is therefore lower than 0.05 and thus indicates that there is a statistically significant dependence between rainfall and year.

These findings indicate that there hasn't been a significant increase of rainfall in Lare, as opposed to Gilgil where rainfall has significantly increased.

6.1.2 Crop water requirements

Looking at the five crops chosen to evaluate the crop water requirements which are depicted in Figures 21 to 30, cabbages require the highest amount and kidney beans the lowest amount of water 876.5 and 609.5 mm respectively. In both research sites all crops require additional water through irrigation as the amount of natural water in the form of effective rainfall is not sufficient.

Lare and Gilgil were considered similar concerning the basic climatic conditions. Evapotranspiration data was acquired from Nakuru weather station and was used for both research sites, which indicates that the general crop water requirements in both research areas are the same. The variety in the amount of necessary irrigation water arises from the difference in rainfall amounts between Lare and Gilgil.

The results reveal that irrigation would be necessary in Lare and in Gilgil, but that the amount required is higher in Gilgil as the rainfall quantities are lower. The high irrigation requirements for crops such as tomatoes and cabbages explain why more farmers in Gilgil grow those crops compared to the farmers in Lare, as they irrigate their crops and those in Lare don't.

Even kidney beans and maize would require additional water, but as water is generally scarce, farmers don't irrigate these crops, leading to crop failure in times of low rainfall amounts.

6.1.3 Interviews with farmers

Considering the interviews, the majority of farmers in Lare and Gilgil felt that rainfall has increased over the past years. The farmers' perception of an increased amount of rainfall could be explained by a very high quantity of 1244 mm to 1512 mm in the years of 2010 to 2012 after receiving a very low rainfall amount of 660 mm in 2009. The probability of exceeding over 660 mm is approximately 92%, which means that this amount of rainfall occurs every 1.09 years, while a rainfall amount of 1512 mm, which occurred just one year later, is exceeded with a probability of around 0.60% and occurs only every 174 years. Looking at the rainfall data in Gilgil, there is also a trend towards more rainfall in the past years which is slightly significant. Furthermore the farmers in Gilgil experienced a very low rainfall rate of 451 mm in 2009, followed by rainfalls between 900 mm and 1000 mm in 2010 to 2012, which could have had an influence on their perception of a general change in rainfall.

Five farmers in Lare and six farmers in Gilgil shared the opinion that rainfall has increased as a result of increased planting of trees. Malesu et al. (2006, pp. 15-18) state that there has been a significant change in rainfall and that this change can be linked both to general climate change and to changes in land cover.

6.2 Existing irrigation, water harvesting systems and their innovative capacity

6.2.1 Interviews with farmers

Farmers in both research sites have adopted a number of water management measures comprising water harvesting and irrigation systems to cope with water scarcity. While water tanks to collect roof water can be found to a high extent in both research areas, water pans are common in Lare, while irrigation systems are mainly found in Gilgil. Farmers in Lare explained that the main reason for starting with rainwater harvesting was a lack of sufficient water that could be acquired nearby, while those in Gilgil suggested that irrigation came into existence mainly due to continuous crop failure.

Farmers living in Lare don’t have any permanent water source which supplies them directly in their homes. As they cannot rely on seasonal rivers and also cannot afford to pay for water from water kiosks on a regular basis, they harvest rainwater from roofs in water tanks for drinking purposes and collect surface runoff in water pans for domestic use, livestock feeding and partly for irrigation to cope with the problem of water scarcity.

In Gilgil on the other hand farmers get tap water from the Kikopey hot springs, but as the water quality is poor, all of them additionally collect roof water in tanks for drinking purposes. As opposed to Lare, there are no boreholes where water is collected and can be purchased. Farmers rely entirely on the water from the springs and use it for drinking, domestic purposes, livestock feeding and for irrigation.

All farmers in Gilgil irrigate their crops, as the climate is not suitable for rain-fed agriculture and the crops used to fail regularly, and four out of ten farmers in Lare use water from their pans for irrigation purposes, as they can increase their crop production through irrigation. Although farmers in Lare collect water in water pans and farmers in Gilgil have established a piping system to acquire water from the hot springs, not all of them have enough water to supply their animals and only two farmers, both from Lare, responded that they have enough water to irrigate their crops.

Mulinge et al. (2007, pp. 13-23) reflect the general situation of Kenyan farmers in terms of water availability and explain that water for agricultural purposes is scarce, just as water in Kenya is in general, due to the fact that the existing water resources are unevenly distributed, both spatially and temporally, and that a part of the water resources such as the groundwater in the north-eastern and Rift Valley area are not suited for agricultural purposes due to their chemical composition. Due to the high fluctuations in rainfall, Kenya is affected both by floods and by droughts.

The circumstances mentioned by Mulinge et al. (2007) make the importance of alternative water sources even more obvious. Black et al. (2012) explain that especially in semi-arid and arid areas water harvesting has been an indispensable technique to overcome severe water shortages. This observation accords with the farmers' high adoption of water harvesting systems to cope with water scarcity.

Critchley and Siegert (1991) explain that water harvesting systems have become more and more popular since the 1970s due to high drought frequencies. During the past ten years efforts have been boosted to promote water harvesting systems in order to fight against the adverse effects of drought such as crop failure and land deterioration. Although all farmers in Lare and Gilgil practice some type of water harvesting, only five farmers out of eleven who possess water pans use the collected water for irrigation purposes. Most of the water is used for drinking and domestic purposes.

According to the Government of Kenya (2010, p. 11), single farmers, especially those growing export crops like coffee or horticultural crops have started creating their own irrigation systems. Furthermore Blank et al. (2002) suggest that smallholder farming has become business-oriented, enabling farmers to step away from traditional crops to those of higher value, suitable to be distributed on vegetable and fruit markets. The situation depicted by the Government of Kenya (2010) and by Blank et al. (2002) is reflected by farmers in Gilgil who grow a variety of crops comprising different fruit and vegetables, but not for export but for home consumption and for local markets. In Lare on the other hand farmers have a smaller variety of vegetables and usually don't grow fruit, as they don't practice irrigation and these crops would fail. Nonetheless also those farmers sell the surplus crops on the market, though fewer amounts and a smaller variety of crops. Furthermore Blank et al. (2002) point out that new methods comprising sprinkler and drip irrigation systems as well as various pumps such as treadle or motorized ones are being presented to and acquired by farmers at a high pace. Farmers in Gilgil and also the few farmers in Lare who irrigate their crops are aware of new technologies such as sprinkler or drip irrigation systems and are also using those systems, thus affirming the developments mentioned by Blank et al. (2002).

Although there is potential for an even better use of water resources especially considering the low adoption of water pans in Gilgil and the sporadic use of collected water for irrigation in Lare, the measures which have been implemented so far have brought about drastic changes in the farmers' lives.

- Increase in water availability for drinking, domestic purposes and livestock feeding
- Increase in crop yields
- Increase in crop variety

- Improved food security
- Reduction of labour
- Reduction of time consumption

The positive effects of water harvesting and irrigation systems both in social and economic aspects such as improved food security and economic security are mentioned by various authors (Blank et al. 2002, FAO 1996b, Kiome 2009, Stockholm Environment Institute. and United Nations Environment Programme. 2009).

The World Bank (2007) suggests that innovation refers to the use of knowledge to bring about social or economic change. Considering the impacts that water harvesting and irrigation systems had on the farmers' lives, one can imply that their knowledge and the resulting systems that were created out of it have brought about social and economic change and that their systems have thus been innovative. The increase in general water availability for crops especially in Gilgil resulted in higher yields and the possibility to grow new crop varieties, which again improved farmers' access to markets and thus increased their incomes. Furthermore farmers both in Lare and Gilgil have more water to supply their animals, resulting in higher animal production and thus in higher incomes as larger amounts of eggs, milk and other products can be sold. The farmers are now also able to grow enough crops to sustain themselves, which means that food security has improved in both research sites.

All farmers have benefitted from the systems with respect to time consumption and labour, as they can spend the time used for acquiring water for other duties such as preparing the fields, planting or harvesting crops.

6.3 Farmers' requirements, capabilities, knowledge and role in the planning, implementation and use of water harvesting and irrigation systems

6.3.1 Interviews with farmers

The majority of farmers who were interviewed in Lare stated that they constructed water pans and water tanks due to their own effort and initiative and that they didn't get any technical advice from other stakeholders but used their own knowledge instead. One farmer stated, "...necessity is the mother of invention". Only very few farmers in Lare received advice on water harvesting from different institutions such as the Ministry of Agriculture, Kenya Agricultural Research Institute (KARI) and Egerton University. Nine farmers stated that they didn't receive any training on how to construct, use and maintain water pans and water tanks. Far more farmers in Gilgil shared the opinion that they got trainings or technical advice on how to implement their water harvesting or irrigation systems from NGOs.

In both research sites it is obvious that a high amount of farmers implemented new technologies even without interacting and sharing knowledge with other stakeholders. Farmers in Lare constructed their own water pans and water tanks while those in Gilgil constructed their own irrigation systems and also water tanks when they first settled there.

Interestingly, the majority of farmers in Lare shared the opinion that in general their knowledge and requirements are considered when new measures are being planned and that the interaction between them and the government is good, while at the same time most of them stated that they didn't get any training or technical advice on how to plan and implement their systems. Most of the farmers would like to have more technical advice on new technologies apart from financial support from the government. The farmers' responses imply that they are generally asked about their requirements and knowledge, but that many of them are not reached when trainings are being carried out.

The World Bank (2007) points out that all actors possess their own knowledge, be it local and context-related knowledge of farmers, referred to as tacit knowledge, or generic knowledge possessed by scientists and other knowledge producing actors, also known as codified knowledge. Innovation can only take place if knowledge flows in all directions, meaning that local knowledge is transferred from farmers to scientists and not only generic knowledge from scientists is brought to farmers, as it often is the case in reality. In this case of one-sided knowledge transfer, one could speak of an asymmetric knowledge flow. A symmetric knowledge transfer requires a good connection and interaction between those possessing local knowledge and those offering generic knowledge. Furthermore the Agricultural Innovation Systems (AIS) approach states that stakeholders and their demands need to be included in the innovation process as their requirements signalise in which direction innovation needs to be guided.

Rees et al. (2000) conducted a survey which affirms the difficulty for farmers to acquire codified knowledge. It suggested that especially in the field of technical information farmers feel that there is inadequate knowledge flow and an information gap. According to farmers and extensionists this problem is a result of an insufficient amount of extension staff as well as knowledge and skills possessed by them. Furthermore they point out that both farmers and extension workers are not content about the frequency and quality of interactions which provide technical information.

On the other hand only half of the farmers in Gilgil think that their knowledge is considered when new measures are being planned. The other five farmers claim that it should be considered more or has not been considered at all. Seven farmers explained that there was good interaction between them and other stakeholders and included those farmers who felt considered in the planning process. The high number of farmers who feel both considered and have good interaction with other stakeholders go in line with the opinion of the World Bank (2007), who suggests that knowledge transfer in all directions requires a good connection and interaction between those possessing local knowledge and those offering generic knowledge. Six farmers from both sites received technical advice on how to construct their water management systems, and include those who feel that their knowledge is considered as well as those who do not. The responses of farmers in Gilgil imply that although they receive technical advice, their knowledge may not be considered when new measures are being planned. In this case one could speak of one-sided knowledge transfer as explained by the World Bank (2007). Information only flows in one direction, from those offering generic knowledge towards those who possess tacit knowledge, without having the means to transfer it.

Although it seems that based on the literature found about the respective projects ((UNDP Special Unit for South-South Cooperation (2006), Malesu et al. (2006), AICAD in conjunction with JICA (2010)), a number of measures to identify farmers' requirements and knowledge as well as trainings and field days were carried out, not all farmers fully received support. (1) Either they felt included but they didn't receive any technical advice and assistance in the implementation process, or (2) they weren't included in the planning process and also not trained in the implementation of water management systems, or (3) they weren't included, but still received trainings and technical advice.

Gautam (2000, p. 14) comments that information is hard to acquire especially for farmers who are poor and that extension services are lacking consistency, regularity and adequacy and are generally focussed on farmers who are wealthy or own large amounts of land. Another interesting finding based on the surveys conducted by Gautam (2000) is that the main reason for not adopting recommendations is a lack of awareness and information. Regarding the survey, 80 % of those farmers who were aware of the recommendations by extension services adopted them.

Although on the whole less than half of the interviewed farmers received technical advice on how to implement water harvesting and irrigation systems and around half of them feel that their requirements and knowledge are considered when new measures are being planned, all farmers in Lare possess water pans and water tanks and some practice irrigation, and all farmers in Gilgil possess irrigation systems and water tanks or water pans. This shows that a lack of technical information and knowledge consideration doesn't hinder the farmers from adopting technologies.

The high adoption implies that farmers possess their own knowledge on water management systems. This is emphasized by different responses. For example one farmer in Gilgil explained, "We got the idea of roof water harvesting from our parents. They already did it, we didn't get any technical advice for that." Another farmer stated, "My knowledge should be more considered, because if people come and see what I have done on my farm, they can go home and do the same. Now they have come, you know, they want to teach me now and teach others. First of all they can come and see what I am doing. They recommend it or they cancel it. It is better if this is done. That's how we can start". According to Rhoades (1989) many technologies which are being promoted by researchers are based on traditional practices and methods that have been used by farmers for generations. He refers to these technologies as farmer-oriented ones which were the result of experimentation, where farmers were the creators of the technology. He explains that the farmers' knowledge and their essential role in innovation are not considered partly due to the fact that they never wrote down the findings and achievements that resulted from their innovations and partly because they were never mentioned in works written by authors from other fields such as economics or anthropology. Another reason for the negligence of farmer-led innovation can be seen in the general mind-set that was formed in the 1950s and 1960s and emphasized the benefits of western technology and science.

The fact that many farmers implemented innovative water management systems out of their own effort shows that innovation can also take place on the basis of the farmers' own existing knowledge. Although farmers have adopted a large number of measures, there is still potential for improvement as many farmers in Lare don't irrigate their crops and many in Gilgil don't possess water pans, and many complain that they don't have enough water for livestock feeding and for irrigation.

Nine farmers in Lare stated that there is no farmers' organisation to represent them in any issues, while eight farmers in Gilgil explained that they have a farmers' association in the form of farmer groups. Six of those who think that there is a farmers' association have the opinion that the association is useful, while the two others, one man and one woman, do not really see any benefit in having the association. Based on the responses given by the farmers in Lare and Gilgil one can make out a clear difference in the perception of farmer representation. Thompson et al. (2009, pp.1-3) explain that due to several reforms and policy changes many tasks such as input supply and marketing which used to be carried out by the government have now been appointed directly to farmers. This shift in responsibilities causes hurdles for farmers as they often lack resources and management capacity. Furthermore the farmers are lacking a common representative since the diminishment of cooperatives in the 1970s. This circumstance makes it difficult for farmers to actively contribute in the development of policies which affect them or to take advantage of new markets. In order for farmer organisations to be established or to expand their activities, support from external institutions including the government, public and the private sector is needed. The challenge lies in providing the right type and amount of support which enables the empowerment of farmers to contribute in agricultural policies and practices.

Farmers in Gilgil mentioned a lack of finances as primary reason why they don't have water pans. Although a lack of finances can be a constraint in adapting water harvesting measures, another reason for the low adoption of water pans in Gilgil could be the fact that farmers are used to getting water from the springs and haven't seriously considered the option of harvesting additional water. Maybe if interaction and knowledge transfer in the field of water harvesting was improved as explained by the World Bank (2007), more farmers would implement these systems.

On the other hand Farmers in Lare mentioned a lack of water as primary reason why they don't irrigate the crops. The fact that farmers in Lare collect water in pans but don't use it for irrigation purposes can be partly explained by the circumstance that not enough water would be left for other purposes. Nonetheless, if they seriously considered irrigating their crops, they could construct larger and a bigger number of water pans, given they can gather enough manpower to engage in the construction work. Efficient irrigation systems could help farmers both in Lare and Gilgil to become more business-oriented and generate a higher income which again could lead to a decrease in poverty and malnutrition. Drechsel et al. (2005, p.7) point out that the farmers' decision to adopt a new system will be based upon the nature of the technology itself, the perceived benefits and use of the technology as well as the available resources to implement the measure such as land, capital, knowledge and skills, which implies that farmers first of all need to be aware of available technologies and their potential benefits in order for them to adapt these measures.

Almost all farmers would like to have financial support from the government to implement water management measures. The fact that capital is a major constraint in the adoption of technologies is depicted by CBS (Central Bureau of Statistics) (2003) which states that in both research areas, 30 to 40 % of the people live below the rural poverty line. According to Alila and Atieno (2006, p. 4) the financial markets haven't developed in a way to support the farmers' investment in agricultural technology, denying them the necessary access to financial resources and thus being partly responsible for the low adoption of new agricultural technologies.

6.4 Involvement in the development and actions to enable interaction and knowledge flow

6.4.1 Interviews with experts

Based on the responses by the experts, various institutions belonging to the private as well as the public sector were involved in triggering the development of water harvesting systems in Lare and can be subscribed to all the domains mentioned by Arnold and Bell (2001), which comprise Baraka Agricultural College, KARI (Kenya Agricultural Research Institute), Egerton University and ICRAF (World Agroforestry Centre) belonging to the education and research group, and GTZ (German Technical Cooperation), ACK (Anglican Church of Kenya), Ministry of Agriculture and Ministry of Livestock belonging to the intermediate as well as enabling group. All interviewees stated that the farmers played an important role in triggering the measures by approaching the Ministry of Agriculture and demanding help as they were suffering from water shortage. The fact that various actors were present and aware of each other during the planning process of water harvesting measures can be seen as a step towards a multi-stakeholder approach as described by Adekunle and Fatunbi (2012, pp. 981-982). They explain that actors from agricultural research and development have recently proposed a multi-stakeholder approach where all actors carry out the task which they can do best in order to enhance the performance of the agricultural sector.

Furthermore Adekunle and Fatunbi (2012, p. 983) comment that innovation occurs when the various stakeholders involved in the process interact with each other and thus generate, apply and share knowledge. In Lare, various steps were taken to enable interaction and knowledge transfer between the stakeholders as suggested by Adekunle and Fatunbi (2012). The experts stated that the main steps included farmer's field days, exchange visits, meetings, workshops, group discussions, trainings, demonstrations and follow-ups.

All experts agreed that there was very good interaction between the stakeholders involved in the planning process and special focus was put on the inclusion of farmers. According to Malesu et al. (2006) adoption rate of water pans increased especially during 1999 and 2004, which implies that many farmers were reached by the water harvesting project which took place in 1999, and that farmers felt well included in the planning process of water harvesting measures.

The majority of the farmers who were interviewed in Lare didn't receive any information on water harvesting systems. The reason for that could be that all of them implemented their water harvesting systems between 1976 and 1992. In that period, the "linear" approach was popular, where research organisations were supported to create new knowledge and technology and assign it to different problems. As a result of the formation of centralised research institutions, the transfer of technology and the dissemination process often proved to be inefficient. Furthermore research priorities were not placed correctly considering economic pay-backs (World Bank. 2007). This implies that farmers who implemented their systems in that period of time were not reached and not considered when technology was being generated and transferred.

The farmers in Lare feel that the interaction between them and other stakeholders is good when new measures are being planned and that their knowledge is considered. At the same time most of the farmers would like to have better access to information, which suggests that there is still potential for improvement considering knowledge transfer in all directions as mentioned by the World Bank (2007).

In Gilgil the answer as to who was responsible for triggering the development of water harvesting and irrigation measures varied between only farmers being involved, the Ministry of Water together with AICAD, up to a wide range of stakeholders including AICAD, JICA the District irrigation office, the Kariandusi community, the District agricultural office, EU and the WRMA. It is noticeable that the perception of stakeholder involvement is not as homogenous as in Lare.

Adekunle and Fatunbi (2012, p. 982) state, "In the sphere of agricultural research and development, innovation system depicts a dynamic network of stakeholders interacting and learning together towards the generation, dissemination and continuous adoption of a technological output." Considering the very diverse perceptions of who was involved in triggering the development of water management systems in Gilgil, one can conclude that the interaction between all stakeholders wasn't good and therefore one cannot speak of an innovation system in Gilgil.

One major factor which could have an influence on poor stakeholder involvement and interaction in Gilgil could be a lacking legal framework providing policies which give a clear code of practice in the handling of the limited water resources. This framework could create an enabling environment for good coordination and interaction between different protagonists involved in planning and implementing irrigation schemes, as mentioned by Blank et al. (2002).

The situation in Gilgil depicts the problems that arise if various stakeholders are involved in the planning process of new measures, but don't properly interact with each other. Although all experts shared the opinion that steps were taken to enable interaction and knowledge transfer between the stakeholders while measures were being developed, the quality of interaction was perceived differently by each expert and varied between different stakeholder groups.

While an emphasis was put on knowledge transfer from various stakeholders towards farmers and resulted in various trainings, workshops and field days, less importance was given to knowledge transfer between the other stakeholders, and from farmers towards other stakeholders.

The problems which resulted from this asymmetrical knowledge transfer as described by the World Bank (2007) were single actors lacking in knowledge about actions carried out by other stakeholders, and that as a result knowledge could not be generated, applied and transferred in a joint manner. Farmers received ambiguous information from different sources, which could be one of the reasons why the adoption of certain measures such as water harvesting systems was low. Only half of the farmers in Gilgil thought that their knowledge is considered when new measures are being planned, although a good amount of them received trainings in various water management measures.

The findings in Gilgil show that the "linear" model where technology is generated and used to overcome different problems as mentioned by the World Bank (2007) doesn't encourage farmers to adopt new technologies and can be a reason for the low adoption of water harvesting systems in the area, although efforts were made to promote them.

The experts explained that there are typical duties on the field which apply to men and to women, but that the actual division of work depends on who is primarily responsible for the farm. This again depends on whether it is a single-headed household, or if one partner, which is usually the husband, has an off-farm activity. If women work on the field alone, they normally hire labour or their sons help.

Considering the decision on which measure should be implemented, five interviewees suggested that the husband decides on which measure should be implemented. Only one interviewee explained that whoever is the head of the family makes that decision. Srivastava et al. (1993, p. 148) explains that both men and women are involved in decision-making processes concerning agriculture, but that it depends on whether it is a male-headed or female-headed household and if the respective plot belongs to the male or the female farmer.

The perception that farmers' activities follow a pattern based on gender is shared by World Bank et al. (2009). There are tasks such as planting crops for domestic use, weeding, or poultry processing typically carried out by women and other tasks usually done by men, including the handling of crops that are sold, running equipment and handling tools. Furthermore women are responsible for processing food and caring for their family members and homes as well as for collecting fuel and water (FAO 2011).

Considering hired labour, Doss (1999) explains that access to labour depends on the number of family members who can be mobilized for agricultural labour and the availability of non-family labour. She states that female-headed households may face more problems in accessing labour as the available amount of male labour within the family as well as resources to hire labour may be limited. This circumstance could be the reason for the higher amount of labour hired by women compared to that of men in the research sites. The female farmers may require non-family labour due to the fact that they are not able to mobilize enough family labour.

According to Srivastava et al. (1993) the household structures as well as typical farming systems in Africa are going through changes. As male farmers are taking up off-farm activities due to social and economic factors such as land degradation and population growth, women have started doing tasks which were usually fulfilled by men. Around 34 % of households in rural Kenya are female-headed, and World Bank et al. (2009, pp. 315-317) explain that the number of these households is increasing. Furthermore the number of female labourers in agriculture considering both self-employed and wage labour exceeds that of male labourers in Sub-Saharan Africa. The FAO (2011, p. 24) points out that there are two types of female-headed households, the one in which a male partner is present and financially supports the family, but is engaged in off-farm activities and thus works away from their own farm, and the other type where there is no male partner which is the case for divorced and widowed women or those who were never married.

7 CONCLUSION

7.1 Water availability, crop water requirements and changes in rainfall quantity

Farmers in both research areas explained that the main problems before having water harvesting and irrigation systems were a lack of sufficient water and crop failure.

Irrigation is necessary in both research sites as the quantity of rainfall is not sufficient in order to meet the crop water requirements. Due to the fact that the average rainfall amount in Gilgil is lower than that in Lare, the irrigation requirements in Gilgil are higher for all crops.

Farmers are aware of the climatic conditions in their surroundings and use the rainfall seasons to grow their crops. The majority of farmers have the feeling that there has been an increase in rainfall in the past years. The majority also felt that the temperature has decreased over the past years. Based on rainfall data gathered at NPBRC and Soysambu Conservancy, there is no significant change in rainfall in Lare, and there is a slightly significant increase in rainfall in Gilgil. The farmers' perception of an increase in rainfall can be linked to uncommonly high rainfall amounts in the past four years.

7.2 Natural resources, land use and water management measures

Soil and vegetation:

The main soil types found in the research sites are clay loam in Lare and sandy and clay loam in Gilgil, and the vegetation consists of various bush, grassland communities and tree species such as Euphorbia and Acacia. The main crops grown comprise maize, beans and various vegetables and the main livestock kept are cattle, chickens and sheep.

Water resources and water management:

The main water sources found in Lare location are groundwater extracted from boreholes, rainwater stored either in tanks or in water pans and seasonal rivers. Furthermore there are large community dams fed by rainwater and river water. In Gilgil location on the other hand the main water source is spring water from the Kikopey hot springs brought to the farms through pipes from the spring catchment, rainwater stored primarily in tanks and seasonal rivers. There are no community dams or boreholes.

Water harvesting in Lare location is very common, especially water pans, water tanks and in-situ rainwater harvesting are found in the area. Water tanks vary in size and water pans vary both in size and shape. The main water harvesting technique found in Gilgil is the collection of water from the roof catchment in tanks. Water pans and in-situ rainwater harvesting is not very common. Various water tank sizes and materials can be found.

Land use:

Agriculture is one of the main land use types in Lare and Gilgil. In Lare, agriculture is mostly rain-fed, and irrigation is not commonly practiced. The main crops grown are maize, beans, potatoes and various vegetables. Also drought tolerant crops such as arrowroots are planted. Farm sizes vary between 2.5 and 10 acres. In Gilgil irrigation is very common, and many farms are equipped with hose pipes and sprinklers. The main crops grown are maize, beans, potatoes, various vegetables and fruit trees. Only the horticultural crops and fruit trees are irrigated while maize and beans are rain-fed. Water for irrigation purposes is acquired from the Kikopey hot spring and Malewa River through a piping system. A few farms have spring water storage tanks and water pans which are also used for irrigation purposes. Farm sizes vary between 2 and 10 acres. Agriculture is the main land use type in both areas.

Livestock:

The main animals kept in Lare are cattle, chicken, sheep and goats. In addition to the animals kept in Lare, farmers in Gilgil have fish ponds. Livestock products are used both for domestic purposes as well as for selling in both areas.

Based on the available natural resources, land use and water management measures, the major challenges can be summarized as follows:

Massive water shortage: Especially between January and March there is very little rainfall in both research areas. Even though people have adopted water harvesting systems, there is a need for farmers in Lare to buy water from the community borehole for domestic use and livestock. Water from the water pans and roof water is primarily used for domestic purposes and livestock, not for agriculture.

Even though most farmers in Gilgil get water from the spring, it is not enough to meet their demand both for domestic and irrigation purposes. Many haven’t yet adapted water harvesting measures, especially water pans. This means that once the water harvested from the roof is consumed, people don’t have any other option than drinking the water from the spring. Those who don’t even have water tanks always drink the water from the spring. This water has high fluoride content, causing negative effects on teeth and bones. In those times when the water from the hot springs is not enough to cover the demand, people only have the possibility to borrow water from their neighbours or get water directly from the river, as there are no boreholes around the area.

Unequal distribution of water: While farmers in Lare have free access to the water that they collect or buy from the surrounding boreholes, farmers in Gilgil get water from the springs in rations, as not all can be supplied at the same time due to insufficient water quantity. The number of people receiving water from one tank varies, and so does the amount of water that people can acquire, according to the tank or the pipe from which they get water.

Poor soil quality: In both areas the clayey soil doesn't allow water to infiltrate, causing high surface runoff and low replenishment of the soil, causing bad conditions for plants. All farmers need to use fertilizers or manure to ensure crop growth. The plant roots have difficulties penetrating into the soil due to its structure, so only plants which have lateral roots have the chance to grow optimally.
Erosion: Due to very poor infiltration and high rain intensities, the water that runs off causes a high amount of erosion, resulting in huge holes in the roads and soil degradation.
Lacking governance: The government in Gilgil only established pipes for a distance of 7 metres. The further connection needs to be undertaken by the farmers themselves. Also all the maintenance has to be done by them. The government hasn't established any source protection. There is a local committee who was elected by the community to supervise water extraction and act as middlemen between the farmers and the government. Whenever permission to tap water from the spring is needed, the committee takes care of it and contacts the government.
Low investment in equipment, implementation and maintenance: People in Gilgil use cheap plastic pipes which get destroyed easily, furthermore pipes are often not dug in but lie on top of the soil, especially in rocky areas. Animals often trample on the pipes, or they just burst when exposed to too much sun. When pipes are blocked or broken, the farmers exchange those parts by themselves, again using cheap material.
Poor/no catchment protection: The spring water catchment in Gilgil which is also a drinking water source is not protected. Farmers take their animals up to drink directly from the spring. There is no fencing or any other protection measure at the spring catchment.
High amounts of rain this year compared to previous years: Benefit: People use this additional rain for a second planting season. Disadvantage: Crops need to have a certain moisture content in order to be sold, due to the continuous rain the drying process takes longer, so crops cannot be sold as soon as normally possible.
Insufficient funds: The government is lacking funds to establish measures against erosion and soil degradation.

7.3 Existing irrigation and water harvesting systems and their innovative capacity

Farmers in Lare and Gilgil have adopted water management measures to make better use of the existing water resources. The main measure implemented in Lare is water harvesting, primarily water pans and water tanks, while in Gilgil most farmers practice irrigation and roof water harvesting in water tanks.
The reason why water harvesting systems and especially water pans are more frequently found in Lare Division can be associated with the lack of tap water in that area and thus the higher necessity to have these systems for every-day use. As most of the farmers in Gilgil on the other hand get piped water from the hot spring, having a water harvesting system is not as indispensable as in Lare, which could explain why only one of the interviewed farmers in Gilgil possesses a water pan.

The interviewed farmers mentioned that the benefits that arise from their systems comprise of a higher availability of water, improved food security, reduction of time and effort used in search of water, reduction of water borne diseases, improved yields and increased crop variety. All farmers stated that their systems are very useful to them.

7.4 Farmer's requirements, capabilities, knowledge and role in the planning, implementation and use of water harvesting and irrigation systems

Although water harvesting and irrigation systems have had a positive impact on the farmers' livelihoods, many are still confronted with water scarcity, especially in the dry season. More farmers in Gilgil mentioned water scarcity as the main problem, although they regularly get tap water from the hot springs. Paradoxically exactly the fact that farmers are continuously supplied by water from the hot spring could be one of the reasons for a more severe lack of sufficient water in Gilgil, as many farmers don't see the necessity or the urgency of constructing water pans.

Most farmers feel that they don't get enough financial support from the government, and the majority also thinks that they didn't have access to technical advice and information when they constructed their water harvesting and irrigation systems.

Although it seems that based on the literature found about the respective projects, a number of measures to identify farmers' requirements and knowledge as well as trainings and field days were carried out, not all farmers fully received support. (1) Either they felt included in the planning process of new measures, but they didn't receive any technical advice and assistance in the implementation process, or (2) they weren't included in the planning process and also not trained in aspects concerning the implementation of water management systems, or in single cases (3) they didn't feel included in the planning process but did receive trainings.

More farmers in Lare felt that their knowledge and requirements are considered when new measures are being planned, and the same amount of farmers in both research sites explained that the interaction between them and other stakeholders is good. On the other hand only two farmers in Lare stated that they were trained in water management systems while six farmers in Gilgil did so. This outcome shows that there is no clear relationship between knowledge consideration and receiving technical advice and information. Furthermore the majority of the farmers who thought that their knowledge and requirements are considered when new measures are being planned also stated that there is good interaction between them and other stakeholders.

Although on the whole only 8 out of 20 farmers received technical advice on how to implement water harvesting and irrigation systems, all farmers in Lare possess water pans and water tanks and some practice irrigation, and all farmers in Gilgil possess irrigation systems and water tanks or water pans. This shows that a lack of technical information doesn't hinder the farmers from adopting technologies.

Based on the interviews, interaction between the farmers and other stakeholders was generally good and many farmers felt that their knowledge is considered when new measures are being planned. This situation could be the reason for a high adoption of water management measures found in both research sites.

Furthermore the high adoption of water management measures implies that farmers possess their own knowledge on water management systems. This is emphasized by different responses. While the majority of farmers in Lare stated that they don’t have any farmer’s organisation that represents them as stakeholder group when new measures are being planned, the majority of those in Gilgil had the opposite opinion. The contradictory responses of the farmers in both research sites imply that farmer organisations are not evenly distributed throughout the villages.

The following conclusions can be drawn based on the interviews with farmers:

- The farmers’ perception of inclusion and knowledge transfer depends on whether their own knowledge is considered
- One-sided knowledge transfer in the form of trainings and technical advice from other stakeholders towards farmers doesn’t imply that good interaction between all stakeholders is perceived by farmers
- Consideration of the farmers’ knowledge and requirements goes hand in hand with the perception of good interaction between farmers and other stakeholders
- Knowledge transfer from other stakeholders to farmers seems to be inadequate although different projects are initiated to promote technical information
- Farmers possess their own indigenous knowledge on water management measures and implement them due to their own initiative
- Water management measures are most commonly self financed and only funded in rare cases, and credits are unlikely to be taken.
- Water management measures have a positive influence on the farmers’ livelihoods as they increase the amount of available water for drinking and domestic purposes and enhance food security.

7.5 Involvement in the development and actions to enable interaction and knowledge flow

According to the experts who were interviewed, various steps were taken to enable interaction and knowledge transfer between all stakeholders in both research sites.

It can be observed that although all experts shared the opinion that steps were taken to enable interaction and knowledge transfer between all stakeholders, the communication in Lare worked better than in Gilgil.

Interaction and knowledge transfer between stakeholders is often reduced to the relationship between farmers and other stakeholders and doesn’t imply the interaction between other stakeholders towards each other. Especially in Gilgil it seems that the main focus was set on enforcing a good interaction and knowledge transfer between individual stakeholders and farmers in the form of extension services, but not as much on the interaction between other relevant stakeholders towards each other.

Farmers and their knowledge and requirements were considered during the planning and implementation process of water management measures, and women were encouraged to participate in various activities concerning the development of water management measures. Nonetheless women, especially single women, may face more difficulties in implementing water management measures than other farmers.

Duties on the farm can be specifically subscribed to men and women. In a female-headed household, labour is more likely to be hired if there are no men in the household to do the heavy work.

In a male-headed household, the husband usually decides on which measure should be implemented.

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9 ANNEX

9.1 Rainfall and temperature data

9.1.1 Rainfall data KARI Njoro (NPBRC)

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC
1949	0,8	21,6	14,5	126,2	81,5	81,3	99,3	117,6	111,5	20,8	32,0	52,8
1950	24,6	0,0	66,0	116,8	48,5	63,0	130,3	103,1	62,0	51,8	30,2	22,1
1951	6,4	12,4	106,4	329,2	85,6	76,7	95,0	109,2	53,3	107,2	147,8	148,8
1952	0,8	20,3	6,9	143,8	145,3	17,3	58,9	84,3	52,8	38,9	54,6	10,4
1953	8,9	7,4	58,9	89,4	37,1	89,9	42,9	88,4	39,9	46,2	81,3	16,8
1954	0,0	17,8	6,1	235,0	244,9	156,7	153,7	77,2	49,3	77,5	45,5	16,8
1955	35,0	123,4	11,7	115,7	95,5	46,2	64,3	168,7	163,6	54,0	73,4	70,4
1956	116,1	49,3	81,3	103,6	68,1	114,6	104,9	274,8	87,1	76,2	75,4	37,1
1957	37,8	6,4	61,2	61,2	235,2	78,0	37,6	63,2	11,9	33,0	122,9	59,2
1958	57,7	129,0	148,1	120,1	217,4	42,9	167,9	126,5	121,4	70,9	34,5	77,2
1959	49,3	27,4	75,9	75,9	212,9	69,3	95,3	39,1	92,5	34,3	90,7	21,3
1960	9,7	17,5	116,1	67,1	111,3	17,0	31,2	227,1	94,2	59,4	44,2	25,4
1961	1,3	5,6	19,6	87,6	76,2	49,0	52,8	161,2	37,8	183,9	413,8	148,1
1962	83,0	8,4	83,3	121,7	133,4	100,1	135,6	87,1	89,7	188,4	116,8	58,4
1963	64,5	67,1	80,5	170,4	157,7	68,3	26,4	116,3	12,7	13,5	93,0	191,0
1964	1,5	43,4	47,8	248,9	121,7	41,7	77,0	111,3	82,8	74,2	71,4	39,6
1965	36,8	1,3	16,8	115,6	74,4	30,0	39,9	51,3	12,2	79,5	65,9	29,2
1966	3,6	46,2	59,2	200,9	56,4	92,5	104,6	97,8	105,2	50,5	124,0	9,4
1967	3,6	0,0	27,9	89,7	138,9	117,3	92,7	52,8	27,4	52,8	94,0	1,3
1968	0,0	156,0	174,6	286,4	99,4	34,3	126,2	66,4	25,8	29,5	100,6	63,2
1969	72,2	69,9	98,5	44,9	150,0	24,9	58,0	60,3	107,6	45,3	52,6	16,0
1970	136,3	14,0	130,5	181,9	154,9	64,6	76,2	127,4	65,7	59,6	108,6	24,8
1971	43,9	0,0	21,7	134,3	134,3	146,7	55,4	173,8	75,3	16,4	51,1	61,3
1972	17,8	138,9	14,4	21,6	152,7	62,3	90,7	128,7	37,1	59,4	107,7	6,9
1973	22,9	46,3	1,7	41,5	107,4	20,2	84,0	202,9	124,3	31,6	53,6	4,9
1974	10,8	14,1	114,8	199,6	70,6	61,1	115,1	284,3	95,7	49,7	43,9	16,7
1975	12,8	26,7	23,1	156,8	210,0	158,8	150,0	193,0	81,5	104,8	27,6	48,1
1976	3,9	27,5	11,0	110,1	77,5	32,4	102,5	138,9	96,4	24,4	33,7	30,3
1977	75,0	30,4	15,0	175,1	211,2	45,3	98,6	38,0	52,0	88,6	24,4	48,7
1978	85,7	100,7	195,3	161,2	61,8	56,8	133,3	157,8	88,8	102,2	23,9	115,5
1979	54,6	165,9	83,4	162,9	85,9	56,0	68,2	79,5	38,7	15,7	66,2	32,3
1980	39,3	19,8	75,4	127,5	221,7	75,8	18,4	51,4	14,1	18,7	113,9	4,3
1981	0,0	22,1	112,8	212,2	106,9	37,6	85,0	156,8	118,4	22,9	29,7	34,9
1982	7,0	21,1	4,9	144,1	131,8	40,3	42,8	247,9	28,6	94,5	139,9	68,2
1983	24,2	27,9	14,4	119,1	97,9	37,5	70,4	170,0	123,0	62,3	81,7	118,1
1984	1,3	15,1	6,8	106,5	29,1	34,3	63,2	64,7	60,0	80,4	91,4	34,9
1985	31,0	44,9	121,9	342,8	104,6	130,5	47,6	65,1	22,2	30,7	71,0	20,5
1986	0,0	5,4	27,4	145,6	92,4	156,9	149,1	113,6	154,7	31,3	44,3	48,4
1987	14,1	19,4	36,5	84,6	132,0	115,5	48,9	99,3	35,0	15,8	124,3	11,8
1988	95,5	8,5	45,3	273,9	156,4	116,9	98,1	142,5	105,2	85,4	36,8	56,7
1989	21,5	94,6	81,1	142,6	103,4	23,8	143,1	96,1	84,7	84,5	91,0	90,2
1990	77,6	121,5	156,4	137,4	90,1	60,8	94,7	79,9	45,2	83,8	40,8	46,3
1991	54,4	6,5	64,7	109,3	101,6	94,4	150,7	141,9	24,7	70,1	21,2	9,7
1992	14,2	8,3	37,1	131,1	103,8	93,2	94,4	96,2	50,6	83,8	64,9	64,9
1993	90,0	155,1	20,0	39,8	133,2	122,2	59,7	57,5	55,8	49,6	120,7	38,4
1994	0,0	22,6	75,6	142,5	124,4	159,8	270,9	107,2	40,4	68,0	124,1	2,5
1995	7,2	48,3	78,6	64,4	89,3	84,6	53,8	40,5	136,2	129,6	40,3	36,2
1996	20,5	54,1	102,0	28,1	57,0	130,2	166,7	127,7	141,4	20,6	94,1	7,2
1997	17,0	0,0	27,5	182,2	67,4	90,2	127,7	166,3	16,2	131,3	148,7	83,6
1998	136,1	77,6	39,7	112,8	250,2	69,1	72,8	117,6	112,2	91,4	54,5	0,6
1999	40,5	0,3	152,4	47,8	31,0	13,5	91,6	81,5	36,1	78,6	105,8	73,7
2000	4,2	1,4	0,8	55,9	34,2	86,2	65,5	136,6	24,6	68,6	67,7	54,8
2001	90,2	44,7	99,2	127,2	35,0	97,9	84,7	97,5	83,3	94,9	112,2	23,7
2002	28,8	18,7	135,5	126,1	154,4	83,8	38,3	54,5	19,0	43,6	30,0	201,3
2003	24,6	12,2	129,6	186,0	199,3	93,2	85,1	213,7	102,3	78,2	79,2	27,4
2004	102,2	17,3	85,1	169,1	158,8	57,2	58,3	116,9	50,0	48,5	43,3	49,9
2005	46,6	22,0	51,6	84,1	166,4	61,8	57,1	84,8	115,3	44,6	41,8	2,6
2006	15,3	13,0	68,0	122,1	98,3	64,7	50,3	127,6	27,4	29,5	269,6	292,3
2007	46,5	165,1	29,6	76,3	77,8	111,3	79,5	197,2	126	90,6	13	7,2
2008	20,6	4,2	70,6	112,7	62,3	49,8	89,8	86,4	83,2	155,1	94,0	3,5
2009	21,7	5,7	24,8	62,7	173,8	13,6	42,2	56,3	45,1	74,8	62,2	76,7
2010	42,9	157	184,1	140,4	180,8	51,9	166,1	240	172,2	109,9	53,1	13,9
2011	3,9	9,5	131,3	29,9	120,5	177,7	158,6	124,9	147,4	105,6	165,3	104,6
2012	0	13,6	11	295	183,7	62,1	87,3	173,7	179,4	98,3	28	112,7

9.1.2 *Rainfall data Soysambu Wildlife Conservancy*

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC
1948	24,00	7,00	80,75	82,25	118,75	70,25	85,75	82,50	116,25	16,50	32,50	24,75
1949	0,00	5,00	13,50	61,75	112,50	47,25	38,75	116,00	78,00	21,75	15,50	34,50
1950	72,75	3,25	47,25	102,75	62,00	47,25	41,25	53,50	60,00	31,75	21,50	10,75
1951	2,00	5,25	62,00	223,50	33,75	82,75	60,00	0,00	69,75	48,00	44,50	113,50
1952	0,00	6,50	0,00	44,75	89,50	3,75	18,00	27,06	42,50	107,25	37,75	14,50
1953	7,25	0,00	0,00	58,00	23,75	92,00	0,00	35,00	0,00	59,25	52,25	42,00
1954	12,25	5,75	1,00	112,00	191,50	105,25	107,50	41,50	130,50	54,25	10,50	58,75
1955	17,50	25,00	0,00	81,25	62,00	21,00	118,75	123,25	96,25	83,50	43,25	40,50
1956	33,00	125,00	29,50	63,25	74,00	44,75	40,50	101,00	65,50	78,00	22,50	15,00
1957	27,50	5,00	25,00	161,75	92,00	51,00	39,25	77,00	0,00	10,00	83,75	29,50
1958	59,50	65,00	37,50	45,75	172,00	54,75	183,00	72,25	25,00	97,75	22,00	71,00
1959	30,50	2,50	33,00	68,60	99,30	46,20	88,10	69,30	37,10	30,70	99,60	20,80
1960	36,60	36,80	80,80	34,80	17,50	29,20	18,50	94,20	63,20	25,70	13,50	9,70
1961	0,00	23,40	11,20	61,00	79,20	66,50	13,50	125,00	39,60	67,30	344,70	185,20
1962	24,60	1,50	67,10	110,00	75,70	80,30	7,10	29,70	142,20	58,70	39,40	51,80
1963	20,30	34,30	45,70	206,20	94,20	36,10	41,90	116,80	19,60	14,20	61,50	174,50
1964	16,00	14,00	57,70	140,50	52,10	30,50	97,00	63,20	70,10	75,90	37,30	0,00
1965	39,90	6,10	33,80	70,40	62,70	31,20	28,40	40,40	11,20	55,40	39,40	16,00
1966	5,60	5,80	33,30	107,40	164,60	63,80	88,60	13,70	21,10	108,20	89,70	5,10
1967	7,40	20,30	52,10	126,00	34,80	58,90	37,80	206,00	104,10	36,80	82,00	6,90
1968	0,00	84,80	69,30	199,90	33,50	66,30	30,00	109,70	51,80	41,90	130,60	41,70
1969	33,30	79,20	74,70	12,40	109,50	0,00	22,40	66,30	43,70	15,00	57,00	31,80
1970	198,40	18,70	97,90	177,40	82,20	92,00	44,20	44,30	53,60	61,20	68,60	33,10
1971	59,40	0,00	16,80	136,90	83,30	41,80	76,50	158,30	0,00	40,90	29,30	70,40
1972	46,50	100,80	19,70	60,50	28,10	103,30	45,50	96,90	23,50	66,10	74,30	2,80
1973	37,50	36,60	0,00	69,50	182,10	0,00	81,50	100,40	100,70	55,60	18,20	6,80
1974	3,10	6,20	46,40	90,00	119,40	71,70	135,20	53,10	161,80	50,80	49,80	34,20
1975	0,50	8,80	18,10	88,60	36,90	84,60	56,60	140,40	123,80	58,40	14,60	36,80
1976	4,30	13,70	14,60	67,70	59,30	49,90	75,60	55,50	55,60	25,30	74,00	56,40
1977	43,60	21,90	16,90	20,40	151,90	78,50	87,40	26,20	78,60	26,50	161,10	114,70
1978	93,10	119,40	101,80	106,80	32,30	15,90	49,80	99,90	165,30	78,90	45,20	93,00
1979	94,10	132,80	45,70	110,70	51,00	57,50	42,50	24,70	42,60	46,40	57,10	26,30
1980	22,80	25,10	24,10	103,70	157,60	55,10	49,60	35,40	9,60	26,90	82,30	28,30
1981	0,00	22,10	178,40	102,00	110,30	43,90	125,60	101,70	64,00	41,70	24,00	71,20
1982	7,70	9,10	1,10	130,40	49,40	57,10	53,70	112,50	64,50	74,20	112,90	67,60
1983	0,50	28,30	7,20	82,20	37,90	119,80	63,20	82,80	124,10	67,90	42,50	86,60
1984	5,40	9,90	6,00	48,40	7,50	20,30	26,70	55,90	53,50	45,10	73,00	38,50
1985	7,40	35,30	56,40	137,70	105,30	44,90	177,00	44,80	107,10	18,00	34,00	6,80
1986	1,30	14,80	49,40	105,90	142,90	51,80	77,60	94,30	26,50	78,70	40,20	95,40
1987	12,70	25,20	39,40	79,60	76,60	94,60	2,50	41,00	43,50	28,70	97,70	38,00
1988	71,70	15,10	45,30	243,60	121,50	63,60	94,10	55,30	41,10	88,00	37,10	1,70
1989	35,60	43,60	33,60	138,20	117,70	60,00	125,70	107,60	49,60	100,90	81,30	83,80
1990	76,80	78,50	172,50	146,70	51,90	20,20	90,90	64,10	18,50	74,30	50,80	35,10
1991	68,30	0,00	76,80	110,20	95,30	179,10	36,60	97,80	79,10	45,00	37,10	19,90
1992	11,50	3,50	40,70	109,60	53,00	97,80	62,30	123,30	92,30	78,00	43,80	78,00
1993	114,10	118,70	10,60	19,40	35,90	123,00	35,90	64,80	2,70	34,30	57,70	16,60
1994	0,00	5,30	14,60	91,90	98,00	121,70	47,90	60,70	41,40	33,50	76,50	42,60
1995	1,50	29,60	86,40	71,60	43,70	141,90	19,80	30,80	118,70	110,49	47,50	61,60
1996	30,70	68,70	26,90	18,30	58,80	215,10	138,60	88,40	43,00	29,30	36,40	9,70
1997	23,10	0,00	10,80	0,00	28,00	29,60	51,10	107,50	43,60	51,80	175,65	69,70
1998	8,20	171,40	96,80	49,90	78,10	171,30	55,90	59,70	42,70	109,80	69,39	43,00
1999	25,60	15,40	0,00	80,60	49,60	13,80	20,10	60,00	106,70	12,40	38,40	43,10
2000	0,00	0,00	0,00	80,20	27,50	71,70	70,70	59,00	47,00	49,00	90,80	69,80
2001	72,40	32,50	134,80	78,70	33,40	67,10	40,40	58,50	57,30	150,20	54,40	19,50
2002	103,60	13,30	82,10	181,70	135,60	27,80	29,10	56,10	18,50	50,00	72,20	130,40
2003	26,60	19,00	46,30	139,40	113,20	139,10	38,50	165,60	3,90	93,80	78,00	12,10
2004	49,60	5,80	89,90	101,50	63,90	23,70	46,90	55,50	57,50	38,80	63,40	35,60
2005	83,10	10,20	33,60	131,20	136,20	41,20	47,70	86,40	67,20	79,10	28,50	28,40
2006	4,00	6,50	110,20	67,50	65,70	58,30	17,30	77,60	19,20	10,80	175,90	136,60
2007	89,00	107,10	42,20	88,20	93,20	104,80	71,00	108,10	76,20	26,20	40,30	19,30
2008	23,60	2,70	116,90	88,50	27,30	24,10	60,10	55,90	68,70	60,10	91,50	10,00
2009	1,60	0,00	4,60	61,20	102,30	38,40	26,40	25,30	6,70	53,90	42,00	88,80
2010	19,50	59,70	175,20	134,30	94,70	95,80	63,20	66,60	103,40	113,50	144,70	65,80
2011	0,00	0,00	93,10	35,20	66,00	177,70	63,60	168,70	117,00	95,80	73,80	41,60
2012	6,50	27,30	16,20	325,90	193,10	111,40	156,30	81,10	36,90	76,80	37,80	0,00

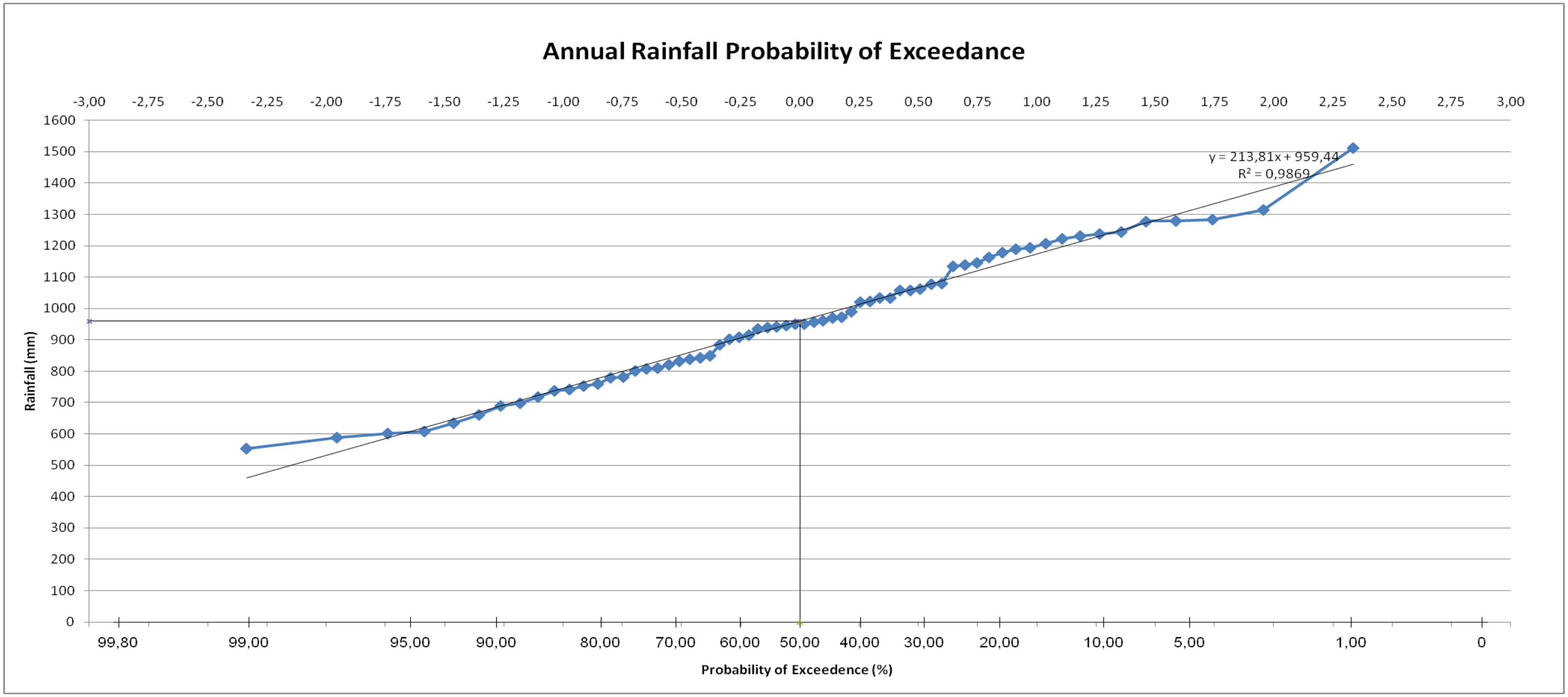
9.1.3 Temperature data KARI Njoro (NPBRC)

	January	February	March	April	May	June	July	August	September	October	November	December
1986	17,40	17,85	17,65	17,70	16,25	15,40	14,65	14,55	15,10	16,35	16,05	16,50
1987	17,30	18,25	20,85	18,20	17,05	16,30	15,45	16,25	16,90	17,50	16,95	16,90
1988	17,55	18,25	18,60	17,45	16,00	14,60	14,40	14,95	15,25	15,75	15,60	15,50
1989	16,50	16,35	17,45	16,45	15,65	15,15	15,25	14,80	15,55	15,50	15,70	16,40
1990	15,80	17,35	17,10	16,65	16,85	15,35	15,45	15,60	16,20	15,70	16,35	16,70
1991	17,40	18,10	17,95	17,15	17,25	16,60	15,50	15,55	16,05	17,50	15,45	16,65
1992	17,60	18,55	18,65	18,45	16,70	17,00	15,65	15,55	15,80	16,55	15,50	15,85
1993	15,70	16,45	16,85	17,00	17,15	16,70	16,60	15,35	16,05	16,80	16,70	16,75
1994	17,45	17,15	18,40	17,70	15,60	16,05	14,80	15,35	15,70	16,80	16,00	16,25
1995	17,80	17,60	17,65	16,90	16,40	16,55	15,25	16,40	16,15	15,65	15,90	14,80
1996	16,50	16,65	18,15	17,25	17,15	15,05	15,40	15,90	16,05	15,40	13,50	15,75
1997	17,75	17,60	17,40	16,85	16,00	14,90	14,40	15,75	15,75	15,90	16,15	15,60
1998	16,40	16,65	17,75	18,55	17,15	16,15	15,40	14,90	16,20	16,40	15,40	16,00
1999	16,75	17,15	17,65	17,15	15,80	16,90	14,25	15,15	16,00	16,00	15,90	16,25
2000	16,40	17,80	18,80	17,90	17,15	16,15	15,05	15,50	16,15	17,00	16,05	14,80
2001	16,90	17,40	16,80	15,75	16,65	15,15	15,25	15,15	14,90	16,00	14,65	16,15
2002	16,30	16,50	16,75	15,15	15,80	13,90	14,00	15,25	18,30	16,40	17,00	16,00
2003	15,55	16,25	16,80	16,65	15,50	15,25	13,15	14,50	14,40	14,40	14,60	15,35
2004	16,85	15,90	16,05	14,75	15,15	14,40	15,05	14,00	16,40	16,25	15,00	16,15
2005	16,40	17,90	15,40	16,50	14,90	15,45	13,40	15,00	15,65	16,25	15,40	16,65
2006	15,75	16,85	16,40	15,25	15,00	15,65	15,05	14,50	15,75	15,75	15,25	15,15
2007	15,00	15,75	15,50	16,50	16,00	14,75	14,40	14,70	15,70	15,30	15,15	16,45
2008	15,70	16,52	16,85	15,30	15,40	16,15	15,65	15,30	16,25	15,55	15,94	16,26
2009	16,98	17,23	18,45	17,50	16,60	15,64	15,21	16,97	16,54	15,85	16,05	16,56
2010	16,25	17,50	16,50	16,50	16,50	15,50	15,00	15,00	15,50	16,00	15,50	15,85
2011	16,50	17,00	17,50	17,00	16,00	16,00	14,50	13,50	16,50	16,50	15,50	15,50
2012	16,50	17,00	20,00	19,00	17,00	17,00	15,00	15,00	15,50	17,00	17,50	17,00

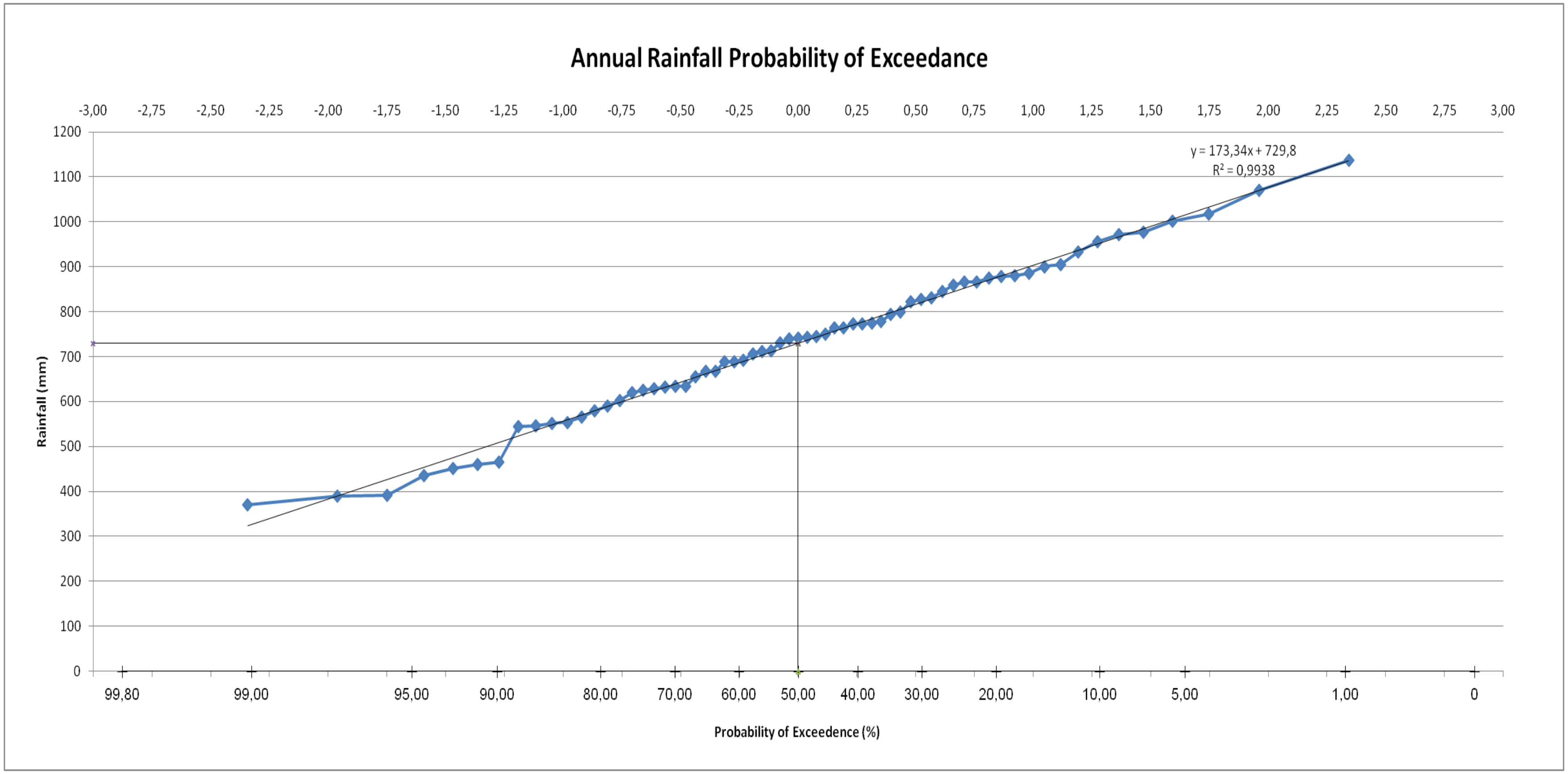
9.1.4 Temperature data Nakuru MET Station

	JAN	FEB	MAR	APRIL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC
Mean temperature	18,9	19,8	20,1	19,4	19,1	18,4	18	18,1	18,6	18,7	18,2	18,5

9.1.5 <u>Annual rainfall probability of exceedence in Lare</u>



9.1.6 Annual rainfall probability of exceedence in Gilgil



9.2 Transect Walks

9.2.1 Important features

- Which natural resources exist and which ones are scarce/ abundant?
- Whom does water belong to?
- Where is water abstracted for domestic/agricultural use?
- Which land use types are typical?
- How has the land use changed in the past years?
- How has the climate changed in the past years?
- What was done to adapt to changes in climate?
- Have there been any severe droughts or other climatic catastrophes in the past years such as flooding or frost?
- How do the topography, soil, vegetation and cultivation change along the path?
- Which livestock are kept and where do they graze?
- How have the crops and cropping patterns changed over the past years?
- What was the reason for these changes?
- How big are the plots?
- Which water management measures exist?
- How do the settlement structures look?
- Do people have gardens?
- What is grown in their gardens?
- When did the settlements come into existence?
- Which local technologies and practices are used?
- What are the main problems in the area?

9.3 Qualitative Interviews

9.3.1 Interview guideline for farmers

CROPS:

1. Which crops do you grow?
2. Why do you grow exactly these crops?
3. How often do you plant and harvest crops per year?
4. In which months do you plant crops?
5. In which months do you harvest your crops?
6. Why do you sow/plant your crops exactly in those months?
7. Which crops did you plant in the first planting period this year?
8. Which crops/ livestock products do you use at home?
9. Which crops/ livestock products are for market sale?

CLIMATE CHANGE:

1. Have you noticed any changes in rainfall in the last 5 years?
2. Have you noticed any changes in temperature in the last 5 years?
3. How did you react towards these changes?

4. What in your opinion is the reason for these changes in rainfall and temperature?

WATER FOR LIVESTOCK:

1. Do you possess livestock?
2. Where do you get water from to supply your animals?
3. How much water do you need for your livestock every day?
4. Do you have enough water to meet the demand of your livestock?

WATER FOR CROPS:

1. How important is having an IS/WHS for crop development?

1 – not important, 2 - little important, 3 – rather important 4 – very important

2. Since when do you have an IS/WHS?
3. What source of water did you use before having the IS/WHS?
4. Who was responsible for getting water from that source?
5. How did you get to know about IS/WHS?
6. What was the reason for setting up the IS/WHS?
7. What kind of IS/WHS do you use?
8. Where do you get the water from for IS/WH?
9. Do you also use water from your WHS for irrigation?
10. Who established (set up/built) the IS/WHS?
11. How were you involved in the establishment of the IS/WHS?
12. Were you asked about your requirements and opinion concerning the new system?
13. Did you get any technical advice on how to construct the IS/WHS?
14. Were you supported during the establishment of the IS/WHS?
15. Who supported you?
16. Did you receive any schooling on how to use/build the new system?
17. Who financed the IS/WHS?
18. What do you do when the system stops working?
19. Is there someone who helps you repair the system?
20. Do you maintain the system regularly?
21. When do you irrigate/ use water from the WHS for your plants?
22. Who in your family is responsible for supplying the crops with water?
23. Are you the owner of the IS/WHS?
24. Do you have a farmer's association?
25. Is the farmer's association useful?
26. Do you think the IS/WHS is useful?
27. What has changed due to the system?
28. Would you like to have more support from farmer associations/government to manage the resources in a better way?
29. What kind of support would you need?
30. Do you feel that your requirements and knowledge are taken into consideration when new measures are being planned?
31. How were you included in the planning process of the new measure?
32. Was there any interaction between you and the other people involved in this process?

33. Do you think the farmer's knowledge should be more considered when new measures are being planned?

GENERAL INFORMATION ABOUT INTERVIEWEE:

1. What is your name?
2. Male/Female?
3. Which tribe do you belong to?
4. How old are you?
5. Did you attend school?
6. If yes, how many years did you go to school?
7. How many members live in your household?
8. How many of them are female?
9. How many children do you have?
10. Do all your children go to school?
11. How many of the children who don't go to school are male/female?
12. Are you the owner of the farm?
13. Who passed it on to you?
14. Will your children take over the farm at some stage?

9.3.2 *Interview guideline for experts*

1. Who was responsible for triggering the development of water harvesting/ irrigation systems?
2. Were any steps taken to enable interaction and knowledge transfer between all stakeholders in the planning and implementation process?
3. If yes, which steps were taken?
   □ Meetings □ Workshops □ Group discussions □ Training events □ publications □ joint activites □ other steps
4. How were farmers as core stakeholders included in the decision, planning and implementation process of the measure?
   □ Use of participatory tools to evaluate farmer requirements and include their knowledge □ Group discussions □ Training events □ joint activities □ other steps
5. Were both men and women included in the decision, planning and implementation process of water harvesting and irrigation systems?
6. Which steps were taken to ensure that both men and women attend meetings/workshops/trainings?
7. Were women represented in all stakeholder groups?
8. Which roles did women play in the stakeholder groups?
9. How is the work on the field usually divided between the family members?
10. Who in the family is usually responsible for water management for agricultural purposes?
11. Who in the family usually decides upon which measure should be implemented?

9.3.3 Evaluation matrix

9.3.3.1 Lare

Code	Farmer Male/Female	1 F	2 M	3 M	4 M	5 F
1	Crops grown	maize beans	maize beans tomatoes cabbages soya beans sunflowers kales potatoes sweet potatoes onions	maize beans cabbage carrots spinach wheat	maize beans potatoes vegetables	maize beans potatoes onions cabbages carrots
2	Reason for growing these crops	for family grow well in the existing climate	no reason - climate was unknown to them and they just tried planting a variety of crops those plants which grow well are continued, those that fail won't be planted again	they are usually the ones available to purchase it is the only crop that will do well here at the same time it's staple food	You can grow that what's common here. It is just like a custom to plant maize and beans.	for basic use
3	Livestock	chickens rabbits	chickens cows turkeys geese sheep goats	sheep cows	one cow	chickens cows goats sheep
4	Livestock products	eggs	milk, eggs, mutton	milk	milk	milk, eggs and mutton
5	Amount of planting seasons per year	1	1-2 depending on the rainfall pattern this year they are planting continuously due to the large amount of rainfall	1	it depends on the climate, but usually twice a year. maize we plant once.	1
6	Amount of harvesting seasons per year	1	2	2	it depends on the type of crops and on the season	1
7	Crop development time	7 months	5-8months	5-8 months	6-8 months	
8	Planting time	April	march-April	march-April	usually in march or April, and those who have a second planting season plant in august or September	in April
9	Harvesting time	December	December	beans - august maize - November/December	October or November	beans we will harvest between July and august maize will be harvested between October and November
10	Reason for planting time	rain starts in this month	rain starts in this month	rain starts in this month	because we have enough rain at that time	It's then when the rain starts
11	Home consumption	all products	all products	all products	all products	all products
12	Sale	all products	all products - all crops are planted for selling, one part is kept for home consumption and the rest is sold	surplus milk, sheep and vegetables from greenhouses	When I have enough I sell some. A part of the crops is stored for the dry season.	we sell the surplus
13	Change in rainfall	very heavy rain compared to 2010 and 2011	normally it rains from April to august, but this year the rain has just continued even in November	this year there was a high amount of rain, from early April all the way up to this time we never had a dry spell but in general the rainfall has reduced tremendously in the last years	It's almost the same as in the last years.	This year the rain was much more
14	Effect of change in rainfall	maize didn't grow well	maize couldn't be harvested at normal time because it is still wet maize needs to be dried in the house crops are getting rotten	harvesting wheat is more difficult because the fields are wet usually the wheat will get rotten	There were no negative effects. We planted more often than normally.	We had more planting seasons.
15	Change in temperature	very cold compared to previous years	very cold compared to previous years	cooler due to the high amount of rain the previous years were hot compared to this year	It's warmer	It wasn't so hot this year

Code	Farmer	6	7	8	9	10
	Male/Female	F	F	F	M	F
1	Crops grown	maize beans potatoes wheat kales	maize beans potatoes tomatoes kales	maize beans potatoes peas sorghum cassava	maize beans potatoes cassava sweet potatoes cabbages bananas tomatoes kales spinach	maize beans potatoes bananas
2	Reason for growing these crops	because they are marketable here	they are typical for domestic use	they are good for domestic use and for selling	they are for commercial and domestic use they grow well in this climate	we use them for home consumption and they are also good for selling
3	Livestock	chickens cows sheep geese	chickens cows sheep	chickens cows sheep	chickens cows and calves sheep	cows goats
4	Livestock products	milk, eggs, mutton	milk, eggs, mutton	milk, eggs	milk, eggs, mutton	milk
5	Amount of planting seasons per year	1	Potatoes I normally plant twice per year But maize and beans once per year.	2	3 or 4 times per year But the maize I plant once per year and beans twice per year	usually once per year but this year we planted twice.
6	Amount of harvesting seasons per year	1	2	2	3 to 4	1 to 2
7	Crop development time					
8	Planting time	in march	I plant maize, beans and potatoes in April. I plant potatoes a second time in September.	The first time is during the month of April and the second time in October	august, November and march	I plant the crops in march and maize, beans and potatoes a second time in June or July.
9	Harvesting time	between October and November	I normally harvest maize in November, but beans I harvest in august. Potatoes are normally harvested after three months.	Beans we harvest around July, August. Maize we harvest around November.	I harvest maize in November, and beans in august or July. The other crops I harvest every three months	I harvest in November, beans and potatoes after three months and maize after 6 months.
10	Reason for planting time	because the rain starts then	The rain usually starts in April so that's when I start planting. Also the second planting time of the potatoes is when the rains starts	That's the time when rain starts	I normally plant in those months because that's when the rain falls	because it's the season of the rain
11	Home consumption	all products	all products	all products	all products	we use most of the products at home
12	Sale	I sell the surplus maize an milk.	I sell the excess maize, milk and eggs	we sell the surplus of all products	all products	we only sell a little of the surplus
13	Change in rainfall	The last two years the rain has changed, it has increased.	I have not noticed any change.	It has changed because long time back it used to rain very little but now there's plenty.	There is excess rain, the water pans are almost full. The previous two years it wasn't as much as this year	this season we have heavy rain
14	Effect of change in rainfall					
15	Change in temperature	In this season now the nights are very cold. It wasn't like that before. But in the daytime it is very hot, hotter than normally	This year I experienced very cold nights and very hot days, hotter than normally.	Temperatures are low nowadays. A long time ago it used to be high.	Right now it is a bit cooler	It's cooler than in the last years.

Code	Farmer Male/Female	1 F	2 M	3 M	4 M	5 F
16	Effect of change in temperature		occurrence of malaria			
17	Adaption to changes in climate	change of maize type	second planting season only this year between September and October planting of beans, potatoes Napier grass and trees	many have started planting crops a second time around October, November but it is uncertain if they will succeed, depending on the continuity of rain, it's trial and error it must be a type of fast growing food crop	I didn't change anything.	we planted some potatoes in February, July and August. We usually don't plant at that time.
18	Reason for change in climate	lack of trees	I can't tell	Clearing of the vegetation leaving the whole place bare when rain comes the soil can't keep the moisture	I just can't explain that, but we think it's the way we are treating our forest, cutting trees. we spoilt the climate.	I think we have planted a lot of trees, that's why the rain is much now.
19	Water source for livestock	water pan	water pan	water pan water tank (roof water harvesting)	water pan	water pan
20	Water source for drinking					
21	Amount of water for livestock per day	60l; 20l/livestock	I don't know	it depends on the season between January and March each animal will require 30 to 40 litres because it is very hot and very dry In the rainy season the animals require less water because it is not so hot.	20 litres	100 litres
22	sufficient amount of water for livestock	yes	yes	no	yes, the water has remained for around 6, 7 years in the water pan.	no, we don't have sufficient water throughout the year.
23	other water sources			in the dry season, so from January to March there is need to buy water from the two boreholes nearby one borehole is from the catholic mission, the other one is public		From January to March the rainfall is less so we have no water. So we have to go far and get fresh water. It's piped water that comes from far away.
24	sufficient amount of water for irrigation					
25	reason for having enough water for livestock		It depends on the place you have come from. If you have come from a poor place you have to work hard so that you can have a better life Because if you have a problem with the water you have to work on that fast.			
26	Importance of WHS for crop development	very important	very important	very important	very important	very important
27	Type of WHS	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting
28	Time of establishment	1994	1991-1992	1976	1990	1981
29	Source of idea for WHS	own idea	own idea, I just thought of harvesting water there nobody told me about it	let me say that necessity is the mother of invention I was the first one who built a water pan like this one own idea	All the time we have been having visits from the ministry of natural resources, from Egerton, from KARI and others even from Nairobi. They came and gave some education and taught us about it. We had visits from the Ministry of Agriculture and from Egerton.	my parents had the idea and they just did it. My dad dug the pan
30	Reason for setting up WHS	Lack of water	Lack of water I saw many people suffering from lack of water I thought of putting water in every corner in order not to have the problem of searching water in far distances	the nearest source of water was 12 kilometres away and many couldn't walk such far distances	The ministry and Egerton taught us about the importance of having water pans. And the way they talked to us and they explained things we thought it was good for us to accept	Earlier we had to go far to get fresh water.
31	Water collection method	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater
32	Technical advice	no - own effort	no - own effort	yes, by the ministry of agriculture with my idea I went to the soil and water conservation services they did the surveying and checked the water levels while the bulldozer was working	yes, by the different organisations which came.	no, we didn't get any support.

Code	Farmer Male/Female	6 F	7 F	8 F	9 M	10 F
16	Effect of change in temperature			Sometimes it's cold and people get colds. When the climate is good you can feed your family as well as sell crops, so you cannot have much problems, because you have enough cash. So it's better now because we can grow more crops.		we can plant a second time, so it's good. The effect is positive.
17	Adaption to changes in climate	I haven't changed anything.	I haven't changed anything.	We have planted crops a second time	have changed my planting habit because now there is excess rain, especially this year. So I have almost planted throughout the year.	we have planted maize and beans a second time
18	Reason for change in climate	People have agreed to plant a lot of trees, so the rainfall has increased	People have again started planting trees, so that's why the weather has somehow changed. It is hotter now.	It's because of growing a lot of trees.	People have agreed to plant a lot of trees and that's why it is a bit cooler than before and there is more rain.	I cannot say something because this is God's wishes
19	Water source for livestock	water pan	water pan water tank	water pan	water pan water tank	water pan water tank
20	Water source for drinking					
21	Amount of water for livestock per day	100 litres	40 litres	20 litres	400 litres	200 litres
22	sufficient amount of water for livestock	yes, we have sufficient water, also in the dry season.	Yes, it is enough for the animals, even in the dry season. We have water throughout the year.	Because of rainfall for now we have enough.	The water is enough. I never have to buy water, I even sell water to the neighbours.	When there is no rain we have to buy water.
23	other water sources	But sometimes I have to buy additional water from the trading centre.	I never buy additional water.	But during the dry season we have to buy water from the boreholes, also for domestic use		
24	sufficient amount of water for irrigation					
25	reason for having enough water for livestock				I have three water pans and one water tank	
26	Importance of WHS for crop development	very important	very important	very important If it is possible for people around one can even donate a small farm and a pan can be dug. Then people can be able to feed themselves. People could then do irrigation.	very important	very important But we cannot make it.
27	Type of WHS	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting	water pan roof water harvesting
28	Time of establishment	1990	1985	2002	1987	
29	Source of idea for WHS	It was through my own initiative.	I got the idea through the neighbours	we were advised by the local leaders to build water pans	It was my own idea.	You know when we get a problem then we have an idea. It was our own idea.
30	Reason for setting up WHS	I was getting water from more than 10 kilometres away.	There was a problem of too little rainfall	It was just for drinking water, the boreholes were far away and we were advised by the village chiefs to construct small dams.	Earlier we had to go and buy water and we couldn't irrigate our crops.	There was a lack of water.
31	Water collection method	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater	surface runoff (road) rainwater
32	Technical advice	no, I didn't get any support.	no, I didn't get any support.	we were advised by the local leaders to build water pans but we didn't get technical advice	no	no

Code	Farmer	1	2	3	4	5
	Male/Female	F	M	M	M	F
33	Training/schooling	no	no I went to Baraka agricultural college and got information about the importance of planting trees	no	yes	no
34	Support - labour	no - only family	no - only family	yes - constructed by bulldozer	yes, the ministry of agriculture brought a tractor.	no, it was just my dad.
35	Financing	self financed	self financed	self financed	we paid for everything.	we paid for everything ourselves
36	Maintenance	regular maintenance - mud is dug out with help of neighbour (paid labour)	regular maintenance -experts are paid for maintenance	I've desilted the pan once and I found it expensive. I hired labour for that. So this time, last year before the rains started for this year I got one officer from the ministry of agriculture to come and see it. And he estimated how much it would cost to desilt it with a bulldozer now. But before starting with the desilting the heavy rains started so now we have to wait until the dry season comes for desilting We maintain the system regularly.	it never had problems, only last year when a road was built the trench got covered with mud, since then the water doesn't flow into the water pan, so we have to dig a new trench.	we do some work every two years
37	Irrigation	no	yes - water from pans is used for irrigation	yes - we use the water from the pans for irrigation we have two green houses. We usually operate those when the dry season comes. but it's very hard for people here to afford water for irrigation	no	we don't irrigate
38	Irrigation type		use of hose pipe use of watering can use of a manual pump			
39	Irrigation plan		yes, you have to have a plan of when to plant which trees and when to irrigate them Because you can't say that, I'm putting my naphales today and the rain is starting tomorrow There are fixed timings for irrigation I irrigate the plants every day			
40	Irrigated plants					
41	Irrigating person		My sons live far away so I can't rely on them So I have to do it, because I don't have any others. My wife helps me when I'm not near she does it	I don't have children around, they are grown people with their own families. So I've got to higher some labour for that.		
42	Farm ownership	yes	yes	yes	yes	my parents are the owners of the farm
43	Type of acquiring farm	I bought the farm	I bought it	I got it through the settlement scheme. The settlement fund trustee bought the land from the forest department and allotted it to us It used to be very unproductive forest land, so maybe the forest department didn't even sell it to the government but just gave it to them for free.	I got it through the settlement scheme	It was through the settlement scheme, we didn't pay for it.
44	Farmer association	no	no	We have a missionary institution here caring for the environmental welfare of the farmers around. That's the place where we congregate for any kind of development concerning agriculture around. Outside here we have organisations like Kenya Agricultural Research Institute and Egerton University Egerton College is very concerned here. We also have government officers like agricultural officers, vetenary officers, district agricultural officers, district veterinary officers as well as the the divisional agricultural officers, divisional forest officers and divisional veterinary officers. But we don't have an organisation for the farmers, there used to be cooperative unions to represent the farmers needs, but the whole system got wiped out, it failed.	We have many small groups who represent us. Currently I am not active but it helped me allot. Even today it helps me because I have learnt about it. If somebody is committed then we take all the advice how to do things and you get a lot of help and progress.	no

Code	Farmer Male/Female	6 F	7 F	8 F	9 M	10 F
33	Training/schooling	no	no	no	no	no
34	Support - labour	I had labourers come to dig my pan and got an expert to construct the water tank.	no, it was only the family.	we did it ourselves.	The government provided a bulldozer to a group of 30 farmers to dig the water pans.	We built it ourselves, just the family.
35	Financing	I paid for everything.	the family members financed it together.	we financed everything	I paid for everything, the fuelling of the bulldozer as well as the construction costs.	We financed everything ourselves.
36	Maintenance	I desilt the water pan every year around march with the help of labourers.	Every year we get someone to desilt the water pan.	We take out the mud every year by ourselves.	The water pan never dries, so there is no need for desilting.	We desilt it once a year, it's my family who does it.
37	Irrigation	no	no	no	yes	no
38	Irrigation type				I have a hose pipe and a money maker pump	
39	Irrigation plan				I irrigate the plants every second day. But I only irrigate when it is not raining, in the dry season.	
40	Irrigated plants				I irrigate the cabbages and the tomatoes	
41	Irrigating person				Sometimes I do it myself and sometimes I have labourers.	
42	Farm ownership	yes	yes	no, it' s my dad's farm.	yes	no, it's my parent's farm.
43	Type of acquiring farm	I inherited it from my parents	I inherited it from my parents	He got it through the settlement scheme	I got it through the settlement scheme	They got it through the settlement scheme
44	Farmer association	no, there is nothing	no	no	no	no

Code	Farmer	1	2	3	4	5
	Male/Female	F	M	M	M	F
45	Farmer association useful					
46	System useful	yes	yes	yes	yes	yes
47	WHS benefits	more water available during rainy season	you have some food, the area is looking better, you have some very positive changes			It saves time, earlier we had to spend time searching for water, but now we are free. We have water, we have everything when we have rain
48	Problems before WHS	no water available - she had to cover very far distances to get water	I had to go and fetch water from far places as there was no water.	the nearest source of water was 12 kilometres away and many couldn't walk such far distances There was no other source of water		We had to go far to fetch water, even now in the dry season we have to go and fetch water.
49	More support from government	yes	yes there is only support for the establishment of fish ponds but not for water harvesting for agricultural and domestic use	No, I feel supported by the government.	No, we get a lot of support.	yes
50	Consideration of knowledge and requirements	I feel that my knowledge and requirements are not considered I am all alone	We use our own knowledge Our knowledge is not considered and included there are field days where we can go to learn what also those farmers outside are doing And that is the place where we get some informations, some knowledges of things But this is not enough	I should say they are very much included Because when the people I have mentoned come here, they go and they call the farmers. And in fact most of the discusson that takes place is done by the farmers. It s not like a teacher and his puplis. The farmers are activated and they take a more active part than the peope who have come. So for that one I think we are very much ok.	It's good. You are included and you learn a lot and after learning it helps the farmers.	yes, it's considered
51	Type of support from government	more information on irrigation technologies financial support to get the irrigation equipment	Managing the farm, or managing the planting. We need some support and advices	No support needed	No support needed	financial support and also seeds, we are lacking seeds. Technical advice is ok.
52	Better interaction with government	yes, when new measures are being planned better communication	sometimes they ask us about our requirements Communication should be better but you know you can't just go there and say you want this and this unless you are asked They don't ask often enough, but sometimes they do ask and then you can say what you need.	There is good interaction. Only that the condition like I have said (considering lack of water and poor soil structure), but the government and other institutions are trying very hard to bring the farmers up	The communication is good Especially KARI and Egerton and the ministry came many times and taught us a lot.	yes, sometimes we have interaction. It is very helpful.
53	Biggest problem		It takes a long time to get back whatever you have invested in the farm What you sell can't be compared with what you invest You always go back behind, not in front. And maybe after ten years you have gotten back everything that you invested	it's lack of water and it's also the type of soil we have, it's not fertile. the soil cannot maintain the water If the rains fall here today, tomorrow you will come back and 24 hours from now you will not think that there was any rain that fell because no water goes into the soil top soil is about 6 inches, the moment these 6 inches are saturated with water, the rest will all run off And these 6 inches are clay. And clay loses water very fast. So in 24 hours the whole place is dry. So the main problems are the soil structure and the amount of rainfall. If we had enough water, maybe at least if every farmer had a small plot for irrigation, then we could do something around. The biggest problem is depending on unpredictable rainfall.		So right just now we are harvesting maize, you see, but we don't have any one to sell the maize to. We have brokers and they get what they want. Their prices are too low, so we have nowhere to sell the produce. And also a problem is lack of good seeds to plant at the right time.
54	Name	Maria Morino	Vincent Kabogo	David Matu	Joachim Dongo	Rosemarie Zerie
55	Tribe	Kikuyu	Kikuyu	Kikuyu	Kikuyu	Kikuyu
56	Age	54	75	79	74	32
57	Level of Education	sec - form 2	sec - form 2	O-Levels	sec - form 2	sec - form 3
58	Amount of members in household	6	14	6	13	11
59	Female members in household	3	I can't tell	4	10	4
60	Amount of children who go to school	all	two of three grand children, the third one is disabled	all	all	all children go to school
61	Children take over farm	yes	yes	yes whatever we have got here goes to my children	yes	yes
62	Other source of income	no	no	yes, we sell milk to a company called Brookside	no, it's only farming	no

Code	Farmer Male/Female	6 F	7 F	8 F	9 M	10 F
45	Farmer association useful					
46	System useful	yes	yes	yes	yes	yes
47	WHS benefits		The water is used for domestic purposes and for livestock. It is comfortable having water throughout the year.	Now diseases cannot spread because we have water. We also don't have to go far to get water.	I use the water to irrigate the farm and also for domestic purposes.	It's good for our harvest.
48	Problems before WHS	I had to go about 10 km to get water.	We had to go and get water from far places.	We had to go and get water from far places.	Before having the system I had to buy water.	Before we had to go and buy water.
49	More support from government	yes	yes	yes	yes	yes
50	Consideration of knowledge and requirements	yes, it's considered in the process.	yes, it is considered very much.	yes, it is somehow considered. But mostly we just get advice on how to do things.	yes, it is considered. There are organised groups. And the experts of the ministry of agriculture come and advice the farmers and so on. There are group meetings. It's very useful.	yes, it's considered.
51	Type of support from government	I need financial support and technical advice.	I need financial support and technical advice on how to manage the water resources.	Financial support, for example there is water running down from very far through water pipes . If the government could extend the pipes to the individual farms it would be a big help.	I need financial support and also technical support. If I had the money, I would buy a tank to pump water up and store it there and then I could irrigate through the force of gravity.	financial support and technical advice
52	Better interaction with government	There are meetings at the resource centre Mtakatifu Clara, The communication is good and those meetings are helpful. But we still need more support.	The interaction is good. We are sometimes advised to attend seminars at the resource centre Mtakatifu Clara. And there we get information about the advantages of things. We get new ideas. It is very useful.	The communication is good, sometimes there are farmer field days where you gather at a certain place and you are given advice on how to farm. That is very helpful, we get advice.	The interaction is good, but it should be even more. Group meetings should be twice or thrice a month instead of once.	The communication is good and it is very helpful.
53	Biggest problem	There is problem of inadequate rainfall. And also the other thing is the problem of marketing, selling the products. You sell your produce to the broker at a low price.	The problem is marketing, there are no brokers. Another problem is the lack of stratified seeds.	The change of climate can be the most effective problem because when it changes you cannot have anything to do. Sometimes when the climate changes like in the passed the government needed to assist people with food. The problem is the finances and also lack of seeds. We also lack enough pans to harvest all the water so it just runs off. So we don't have enough places or tanks to collect the water. And when you build a stone tank, sometimes it leaks. Like us we have two, but we cannot even harvest water from there.	There is a lack of stratified seeds. Also the water for irrigation is not enough. And marketing the produce is also a problem.	Sometimes we have drought We also lack finances It is difficult to buy seeds
54	Name	Anna Mugoni	Mary Wanjiro	Monica Mongore	Niera Kamau	Lilian Wanjiro
55	Tribe	Kikuyu	Kikuyu	Kikuyu	Kikuyu	Kikuyu
56	Age	50	29	40	55	39
57	Level of Education	prim - standard 7	prim - standard 7	sec - form 4	prim - standard 6	sec - form 4
58	Amount of members in household	I'm alone, I have children but they go to school or work somewhere else	7	9	5	5
59	Female members in household		2	4	2	1
60	Amount of children who go to school	all	all	all	all	all
61	Children take over farm	yes, I leave the farm to my children.	yes, the children will take over the farm.	Yes. According to constitution of Kenya nowadays you have to inherit, whether you're a man or a woman.	yes	No, I don't know. Perhaps. If they want they can go and get their own.
62	Other source of income				no	

9.3.3.2 Gilgil

Code	Farmer	1	2	3	4	5
	M/F	M	F	M	F	F
1	Crops grown	maize beans cabbage onions tomatoes capsicum oranges potatoes	maize beans cabbages kales tomatoes coriander lettuce potatoes spinach	maize beans cabbages kales carrots	maize beans cabbages kales tomatoes spinach cassava passion fruits treetomatoes avocados papayas	maize beans cabbages kales tomatoes carrots oranges citrus papayas
2	Reason for growing these crops	they do well in this climate, especially the onions the onions do very well on the market, they are the main source of income	The crops do well on the market, I grow them to get income.	they do well on the market	they take a short period to grow and also this small water, we can just put them easily and grow those crops I can get some to take within my family and also some income. They do well on the market.	they do well on the market and are for domestic use as well
3	Livestock	goats cows chickens sheep	cows chickens rabbits	chickens	chickens	cows chickens rabbits
4	Livestock products			eggs	eggs	
5	Amount of planting seasons per year	1 to 2 because of the monkeys which destroy the crops	3	maize and beans we plant once a year vegetables we plant every three to four months	maize and beans we plant once a year vegetables we plant every three to four months	maize and beans we plant once a year vegetables we plant every three to four months
6	Amount of harvesting seasons per year	it depends on the crops, the onions, cabbages, tomatoes and capsicums take 3-4 months, you take them out and plant others maize is harvested after 4-6 months beans take between 3 to 5 months depending on the variety	Vegetables are harvested after three to four months, kales after one month	Vegetables are harvested after three to four months, kales after one month	Vegetables are harvested after three to four months, kales after one month	Vegetables are harvested after three to four months we do crop rotation
7	Crop development time	depends on the crop				
8	Planting time	march or April	March, july and august. In march I plant maize and beans. And cabbages and other horticultural crops like tomatoes and lettuce in july. And in November I plant coriander and kales	maize and beans we plant in march or april	maize and beans we plant in april	maize and beans we plant in april
9	Harvesting time	the time is different depending on the crop		maize and beans we harvest in November, December		maize and beans we harvest in August
10	Reason for planting time	because the rainfall starts at that time	It depends on the market. When the crops are ready the market will be better in terms of sales, the amount of money. Maybe tomatoes, you can plant in December but there are so many tomatoes, because everybody planted. But maybe in the month of july, people don't have tomatoes	because that is when the rain starts		
11	Home consumption	all products, especially maize and beans, some milk and one quarter of the vegetables	a little of all products is used for home consumption	maize and beans and the other vegetables and eggs	I use all products for home	I use all products for home
12	Sale	all products, little milk and three quarters of the vegetables	the rest which is not consumed at home is sold	all vegetables, but not maize and beans	all products are sold	all products are sold

Code	Farmer M/F	6 M	7 F	8 M	9 F	10 M
1	Crops grown	maize beans cabbages kales tomatoes carrots arrowroots plums green beans sweet potatoes	maize beans cabbages kales tomatoes cassava bananas spinach papayas sweet potatoes black nightshade garden pees	maize beans cabbages kales tomatoes carrots potatoes onions sweet potatoes Papayas treetomatoes passion fruits	maize beans cabbages kales tomatoes cassava potatoes spinach sweet potatoes bananas passion fruits mangoes custard apples garden peas oranges papayas	maize beans cabbages cassava papayas mangoes bananas
2	Reason for growing these crops	they do well on the market and are for domestic use as well they do quite well in this area	they do well on the market and are for domestic use as well	they do well on the market and are for domestic use as well	they do well on the market and are for domestic use as well	it's for domestic use
3	Livestock	chickens rabbits	cows chickens goats	cows chickens	cows chickens goats	cows chickens goats
4	Livestock products					
5	Amount of planting seasons per year	maize and beans we plant once a year vegetables we plant every three to five months	maize and beans we plant once a year vegetables we plant once a year	maize and beans we plant once a year vegetables we plant once a year	maize and beans I plant twice a year The horticultural crops like kales, spinach, tomatoes, cabbage, she grows three times a year	maize and beans I plant twice a year vegetables we plant once a year because there is little water
6	Amount of harvesting seasons per year	Vegetables are harvested after three to five months we do crop rotation	once a year	once a year		Vegetables are harvested after three to five months
7	Crop development time					
8	Planting time	maize and beans we plant in march, april	maize and beans we plant in march, april, vegetables we plant in august	march	maize and beans I plant in march and august, vegetables I plant in January, July and November	maize and beans I plant in april and august
9	Harvesting time	beans we harvest in july or august, maize we harvest in october or november in order for them to get dry	beans we harvest in july, maize we harvest in august, september vegetables we harvest after 4 months	Maize and beans in August, September, the vegetables after three months	maize and beans I harvest in august and January vegetables we harvest after 4 months	maize and beans I harvest in august and January
10	Reason for planting time	it's when the heavy rains start		it's when the heavy rains start	it's when the heavy rains start	it's when the heavy rains start
11	Home consumption	I use all products for home	I use all products for home	I use all products for home	I use all products for home	I use all products for home
12	Sale	all crops are sold, not the livestock products	all products are sold	all crops are sold, not the livestock products	all products are sold	all products are sold

Code	Farmer	1	2	3	4	5
	M/F	M	F	M	F	F
13	Change in rainfall	there is much more rain than before	There was not enough rain before but now there is sufficient rain.	Last year the rainfall was very very low. This year was the same, in general there is less rainfall.	the rainfall has become more than the other years	the rainfall has become more than the other years
14	Effect of change in rainfall		I harvested a lot of maize this time, and potatoes	We used a lot of water for sprinkling so that the maize can do well.	I have planted some plants which I have never planted like pumpkins, irish potatoes and even sweet potatoes	
15	Change in temperature	now it is a little bit cool, earlier it used to be very hot	The temperatures are becoming low	There is no change.	sometimes it was so warm. The climate was hot. But during maybe from last year up it has changed so much, it's become cooler	
16	Effect of change in temperature					
17	Adaption to changes in climate	nowadays we are doing crop rotation	I am planting more times than the other years I have planted beans a second time in October and they are doing well.		I have planted some plants which I have never planted like pumpkins, irish potatoes and even sweet potatoes	I am planting more times than the other years
18	Reason for change in climate	we planted some trees	It's just climate change because now the trees, I am not seeing any difference from those days, they say that when there are more trees you get more rain, but there are not more trees		Maybe because in this area people have planted some trees.	Maybe because in this area people have planted some trees.
19	Water source for livestock	hot spring	I use water from the spring. But when there is a lot of water from the tank, I use that water	we get water from the river and from the rainfall	hot spring water	hot spring water
20	Water source for drinking	For drinking we actually wait for the rain, you can see I've got a tank here.	I used to use the water from the hot spring for drinking before I got my tank	we collect roof water in cans	when it rains I harvest roof water in a bucket and fill it in bottles, but when it is dry the water in the bottle keeps getting less and we are forced to drink spring water	hot spring water
21	Amount of water for livestock per day	I don't know	40 litres for one cow		10 litres for all chickens (8) per day	25 litres per animal
22	sufficient amount of water for livestock	yes, there is enough water throughout the year	yes, it's enough.		yes, it's enough	yes, it's enough because I have my own storage tank, otherwise water wouldn't always be enough because the storage tank on the top gets empty.
23	other water sources	with the hot spring I only use it in the shamba, for washing, cattle, everything, we don't drink it		water from the hot spring and the river	spring water	spring water
24	sufficient amount of water for irrigation	I get water throughout the year but the supply is very little, it's not sufficient			no it's not enough	no it's not enough, I could plant a larger area if I had more water.
25	reason for having enough water for livestock					
26	Importance of WHS for crop development	very important	very important	very important	important	very important
27	Type of WHS	irrigation system - piped water from the hot spring roof water tank	irrigation system - piped water from the hot spring roof water tank	irrigation system - piped water from the hot spring roof water tank water pan	irrigation system - piped water from the hot spring roof water tank	irrigation system - piped water from the hot spring roof water tank

Code	Farmer M/F	6 M	7 F	8 M	9 F	10 M
13	Change in rainfall	last year and this year the rainfall was more than the other years	the rainfall has become more than the other years	the rainfall has become more than the other years	the rainfall has become more than the other years	the rainfall has become more than the other years
14	Effect of change in rainfall	I haven't changed anything, because if it doesn't rain I use irrigation.	I planted more times and more crops I planted potatoes and tomatoes in november I also have maize which is germinating now	I planted a second time because of the rain	I don't wait to plant like in March and August, now they can even plant a bit earlier because they know that rains are coming more and even faster, there is a shift Now we plant maize twice a year	I haven't changed anything
15	Change in temperature	The temperature is the same	it's warmer	it's cooler	it's cooler	it's cooler
16	Effect of change in temperature					
17	Adaption to changes in climate	I haven't changed anything, because if it doesn't rain I use irrigation.	I planted more times and more crops	I planted a second time because of the rain	Now we plant maize twice a year	I haven't changed anything
18	Reason for change in climate	I can't tell	People have planted trees, even fruit trees, so I think that that is the reason for the change in climate.	I can't say why	people have come and settled and people have planted trees	I think it is because of the trees here. Before we came here it was plain land.
19	Water source for livestock	the main source is hot spring water, additionally we have a water pan	hot spring water	hot spring water, rain water	hot spring water	hot springs
20	Water source for drinking	the main source is hot spring water, additionally we have a water pan	hot spring water	hot spring water, rain water	rain water, but when it is over we have to use hot spring water	but the water is not good because of the fluoride is not enough, so when it is over we have to use spring water although the children are suffering with it because of the fluoride
21	Amount of water for livestock per day	30-40 l/day	40 litres a day	80 litres a day		80 litres per day
22	sufficient amount of water for livestock	yes	no. It's not enough.I get water from the neighbours when it's not enough. And if the neighbours are lacking water they get water from me. We get water from the same place but the water is rationed on different days. So if the neighbours have and I don't then I get from them, and the other way around	yes, because of the rainwater tank	yes	no. It's not enough. When there is no water the animals have to starve.
23	other water sources	spring water, surface runoff	spring water, rain water	spring water, rain water	spring water, rain water	spring water, rainwater
24	sufficient amount of water for irrigation	no, if I have more water I can do better			no	no
25	reason for having enough water for livestock	the pipes normally get water				
26	Importance of WHS for crop development	very important	very important	very important	very important	very important
27	Type of WHS	irrigation system - piped water from the hot spring water pan	irrigation system - piped water from the hot spring small metal drum - rain water	irrigation system - piped water from the hot spring rain water tank	irrigation system - piped water from the hot spring rain water tank fish pond spring water storage tanks	irrigation system - piped water from the hot spring rain water tank

Code	Farmer	1	2	3	4	5
	M/F	M	F	M	F	F
28	Time of establishment	2002 - irrigation	1999 - irrigation 2012 - tank	2012-irrigation system 1980-tank 2010 - water pan		2003-irrigation 2007-rain water tank 2005-spring water storage tank
29	Source of idea for WHS	JICA and AICAD came and taught us about this method and how to use water. By that time we did not know how to use water in the We got the idea of roof water harvesting from our parents. They already did it, we didn't get	JICA We were trained on water harvesting by JICA	It was AICAD who came here. They came to educate farmers. It's where we get ideas. We were also trained on roof water harvesting by AICAD Also for the water pan it was AICAD	we were taught on irrigation by JICA in collaboration with AICAD we were also taken to some other places to see and learn from them	it was my own idea, I didn't get any technical advice.
30	Reason for setting up WHS	The crops were not doing well before.	Now I am able to grow crops in the dry season I bought the tank because the water from the spring causes health problems for the bones	It was a lack of water. You know water here is very, very, very hard to get. That's why I decided to dig that water. One, it is very clean, second thing it's not good when the rain starts all the water flows down. That's why I decided to dig a water pan. So when it rains somehow I	there are problems that are forcing you to do it	There was a lack of water. It was very dry here when we came here, so we couldn't let that water go to waste.
31	Water collection method	establishment of piping system from the hot spring to the farm roof water tank	establishment of piping system from the hot spring to the farm roof water tank	establishment of piping system from the hot spring to the farm surface runoff (water pan) roof water tank	establishment of piping system from the hot spring to the farm roof water tank	establishment of piping system from the hot spring to the farm roof water tank
32	Technical advice	Yes, from JICA and AICAD	Yes, from JICA	Yes, from AICAD		no
33	Training/schooling	Yes, we were given trainings by Jica and we were shown how to do it, how to place things	I was trained by Jica on how to use irrigation	we were trained by AICAD		no
34	Support - labour	I did the labour myself, I fixed all the pipes. My family helped me.	I hired labour	I did everything myself	and did the piping system from the tank up to the hot spring, but from the tank there to our home we used our own means	I hired labour
35	Financing		I financed everything myself	The water pan was funded by the government But I financed the irrigation system and the roof water tank	We financed everything ourselves.	I financed everything myself the rotary club of Nakuru, they financed a small part.
36	Maintenance	I clean the pipes myself.	I get hired labour for the repairs. There are times where I have to do it more often because of animal trampling, but if it is not trampled it stays for a long time without repair	I do modifications. Maybe the pipe is blocked, there are plants inside, then I clean it. If it is leaking and I don't have money, I used to grease it. And then it will work. inside it only stays for two days. I would like to get a lining but I don't have the financial means.	we repair the system on our own in regular periods	I get labour to do the repairs and I do the checking because at times they break, they burst, so I have to keep checking about two or three times in a month
37	Irrigation	Yes	Yes	Yes	yes	yes
38	Irrigation type	hose pipe and sprinkler	sprinkler Before I had the system I used to use buckets	sprinkler Before getting a sprinkler I used to irrigate with the hose pipe I use the sprinkler because I don't have money to get something else. I would like to have drip irrigation but it's too expensive	sprinkler but a lot of water gets lost with the sprinkler, during the day the sun is very hot and the soil has a lot of sand. The sprinkler is getting useless because there is not enough water to use it. Only For now we are used to pipe irrigation because you can go and water a large place and use a very small time. But when you irrigate with that we would prefer drip irrigation but we don't before we used to use flood irrigation, but that takes a long time.	hose pipe, sprinkler sprinkler is not used because only a small area can be irrigated with it, so only use of hose pipe.
39	Irrigation plan	I rotate, each crop is irrigated once every two weeks	each crop is irrigated twice per week	I sprinkle after every two days	taught that the water remains in the soil for about three days.	three times a week, but not during the rainy season
40	Irrigated plants					

28	Time of establishment	2011 - water pan and irrigation system before that we didn't irrigate our crops we had less crops	2003 - irrigation 1985 - rainwater harvesting before that we didn't irrigate	2006 - irrigation 2012 - rainwater harvesting before it was only rain fed agriculture before I had the water tank I was just fetching from the river	2003 - irrigation 2008 - rainwater harvesting before I used to fetch water to irrigate the trees before I had the water tank I was just fetching from the river	1996 - irrigation 2011-rainwater tank before I used to fetch water from the trench, we didn't irrigate at that time
29	Source of idea for WHS	It was my own idea, I was working in shambas in the colonial times and saw what they were doing there.	I was trained in irrigation and water harvesting from JICA/AICAD	It was my own idea	agricultural extension officers showed us how to use it	It was not my idea, I learned about it in school
30	Reason for setting up WHS	There was a lack of water. When the rain comes, a lot of water runs off. So we think how to store it, how to catch it, otherwise the water goes off	I saw other people doing irrigation, and that got her also to start irrigating Earlier I had to go and fetch water from trenches nearby	We had too little water, so we had to get that	Before I used river water to irrigate the trees, it was tiresome, and I wanted to grow more crops	For one I needed something for me to eat and also maybe I can get something a little for my children to get education
31	Water collection method	establishment of piping system from the hot spring to the farm water pan	establishment of piping system from the hot spring to the farm roof water drum	establishment of piping system from the hot spring to the farm roof water tank		
32	Technical advice	no but if I need technical advice I can get it easily from KARI, agriculture office, if I go to crops officers, they are all able to help me.	yes	no	yes Agricultural extension officers	no
33	Training/schooling	no	yes JICA/AICAD did trainings	no	yes JICA	no
34	Support - labour	I got family, I got some big boys, I got them as a group and showed how we can do it ourselves because we have no money to get someone from outside, so it took some days to build it.	I hired labour	It was the family	I hired labour for the irrigation systems, the tanks I made myself	We didn't get labour. It was me and my family
35	Financing	I financed everything myself	I took a credit from a hardware	I financed everything myself	I took a credit from the bank	We financed everything ourselves I had to go and look for work outside, I am a soldier.
36	Maintenance	When it doesn't rain I can dry it and repair it, I do it every 2 years	I do the repairs myself after 3 months	Maybe after six months I do the repairs myself	I do the maintenance together with my husband Earlier we had to repair the pipes 30 times per year because the Maassai livestock used to trample on them, but now there is a rule which doesn't allow them to come near the pipes, so we maintain them once a year.	I maintain everything myself The Masai livestock often destroy the pipes
37	Irrigation	yes	yes	yes	yes	yes
38	Irrigation type	hose pipe	hose pipe	hose pipe	sprinkler	hose pipe I used to use sprinklers 5 years ago, but now the water is not enough because the population has
39	Irrigation plan	three days a week	twice per week	twice per week	once a week	three days a week
40	Irrigated plants					

Code	Farmer	1	2	3	4	5
	M/F	M	F	M	F	F
41	Irrigating person	All of us work in the farm, my wife and my children	I used to hire labour to irrigate the crops, but since I have the sprinkler I just exchange it myself when it is broken. I am the one who does it. husband.	It's just me.	It's me and my husband. If we don't have time we sometimes get hired labour for land preparation and planting and also for weeding.	It's only me. My husband works far away and the children are in school. I manage the farm.
42	Farm ownership	yes	yes	no, it' s my mother's farm	yes	yes
43	Type of acquiring farm	I bought it	I bought it			We bought it, me and my husband
44	Farmer association	spokesman of the village. There are many other groups.	Yes, we have.	Yes	and Jica, bus once the project has finished, everything comes to a stand	No
45	Farmer association useful	yes	It helps because when we were trained by Jica we were in groups and we still work together in a group, also when assistance is needed it comes in that group form	Yes	the group is still useful, we still have contact	
46	System useful	yes	It helps, but the sprinkler wastes a lot of water. I would want to buy drip irrigation but it's too expensive Now I don't have to use the spring water, I am having clean water	Yes	yes	Yes, but it would be even more useful if there was more water available.
47	WHS benefits	We have grown a good number of crops and it also saves time. I can plant crops throughout the year, so it helps.	I get higher yields and I sell three times. So it is a source of income	pan has a higher capacity than the sprinkler, because that water is rationed. The only problem is that the water from the pan is leaking.	You can plant throughout the year because you don't have to wait for the rain, you can irrigate the crops. So there is a market for the crops.	and only few horticultural crops. We couldn't rely on those. Now we have enough for home consumption and also we can be able to sell so it increases the income
48	Problems before WHS					
49	More support from government	We would like to have more support I take some more. Even the support we want some more. If some people come to help us we like that	Yes, I need support.	Yes	yes	yes
50	Consideration of knowledge and requirements	It should be more considered They come and ask us questions about what we know and don't know and then they train us It is demand driven. because they are far away and we have to go there.	It is considered. They came and my knowledge was included in the process We were called to a workshop and there we gave our views and the knowledge and our problems and the NGO used that as a trigger But I would prefer even more consideration.	Yes, it is considered	Yes some questions were written for us, they were brought to us and we answered those but it should be more considered	No, my knowledge is not considered. At first during trainings my requirements were not considered, but later on we could ask questions. The farmers are not consulted, AICAD just comes and teaches.
51	Type of support from government	technical support especially on animals and also general	Training	Financial support.	I know everything because we have also travelled, so I don't need technical advice.	assistance in trainings and also if it is possible for someone like this to assist with capital
		financial support	And I don't have enough money to do the things I want to such as drip irrigation, so she I needs financial support		I need financial support so that I can harvest water and store it somewhere.	A credit with low interest levels would be okay, we could pay it back.
52	Better interaction with government	yes it should be better were taken to include farmers, but normally the interaction is not good. JICA was an exception. Because they stayed in this area and we were taught thoroughly	There was good interaction.	Yes, the interaction is good.	Yes, the interaction is good. Especially the agricultural extension officer is coming here	Yes, the interaction is good.
53	Biggest problem	the first problem is the monkeys and wildlife in general, and then the water shortage and also the soil erosion has spoilt all the roads. So the market for crops is not very good because Another problem is that there are no hospitals here.	Shortage of water and capital to buy crop material such as pesticides	Water shortage	the first one is water shortage there are also insects that affect our plants. They are called spider mites.	Water shortage
54	Name	Vincent Kaniari	Mary Kaniuni	Paul Mboro Macharia	Rahel Wajera	Nancy Wanjiku
55	Tribe	Kikuyu	Kamba	Kikuyu	Kikuyu	Kikuyu
56	Age	71	36	21	39	50
57	Level of Education	primary level standard 8	primary level standard 8	secondary level form 4	secondary level form 3	secondary level form 4
58	Amount of members in household	it's me and my wife	6	6	4	4
59	Female members in household	one	three	5	2	1
60	Amount of children who go to school	all are studying outside or working	all	all	all	all
61	Children take over farm	That I can't judge. The shamba is their's, it's not mine. They may be coming back. They only come for the Christmas holidays. If they want	it is possible because I do the farming activities with the children, they help me.	Yes, I want to take over the farm.	Yes because if they don't get enough money to buy theirs they can just come here My husband has to work outside because the farm alone doesn't give us enough income	Yes, my son can take over if he wants to. He is interested in farming My husband has to work outside because the farm alone doesn't give us enough income
62	Other source of income					

Code	Farmer	6	7	8	9	10
	M/F	M	F	M	F	M
41	Irrigating person	My wife and me My children also help when they are not in school I am the manager	It's me, and my children help I don't have a husband to help, I do everything myself	My sisters	me and my husband actually I manage everything, because my husband is a teacher so maybe during the weekends he's here, but otherwise he's not here	My children and I and my wife We all work in the farm
42	Farm ownership	yes	yes	This belongs to my mum	yes	it is my Dad's farm
43	Type of acquiring farm					
44	Farmer association	Yes. We have some other farmers, we meet as a group and it depends how much you have for the fisheries. So there are 35 of us.	We have an association but currently it's there but it's not working at the moment	Not really	Yes, we have a group and we have a representative who goes and presents our needs	There is something but I can't see the reason, what they are doing
45	Farmer association useful	Yes because I meet with the others to get some ideas. But they don't do things in my farm. I do it myself	no		yes	no
46	System useful	yes	yes	yes	yes	yes
47	WHS benefits	Now we have water on the farm, we don't have to go somewhere to get it	When I irrigate I get more yields, she can even sell and get some income	Increase in harvesting and clean drinking water	Through the water tank, the water harvesting at least I have clean water now for drinking. And with the irrigation system my yields have improved	For one you can keep a means of getting something at least. And you can also manage to feed the country. First it's me and the family, second is the country.
48	Problems before WHS	before that we were suffering because of hunger but after that when we get the water we get food				We are able to eat, we are able to grow crops
49	More support from government	yes	yes	yes	yes	yes
50	Consideration of knowledge and requirements	They don't do it normally They have to face the farmer himself, in order to get the problems. Because you can teach everything but you have to understand it but it cannot help any farmer. My knowledge should be more considered, because if people come and see what I have done on my farm, they can go home and do the same. Now they have come, you know, they want to teach me now and teach others. First of all they can come and see what I am doing. They recommend it or they cancel it. It is better if this is done. That's how we can start	No, it is not considered We were just called and we were taught and we were told what to do.	Yes, it's considered. They come and do trainings.	Yes, it's considered. there were officers who came around and they interviewed us and talked to us and then after that all the people were told what the NGO wanted to do so we were involved and everything was done in our knowledge	No, it is not considered
51	Type of support from government	financial support and technical advice	financial support and technical advice	financial support and technical advice even a credit would be okay. But now it's very expensive	financial support and technical advice	financial support to build dams
52	Better interaction with government	Yes the interaction is good. We are having our agricultural officers, if I need any information, I get normally	No, intercation is not good. first of all I would like the people to come and talk to me, know what I want so that I can be able at least to give my needs. Now currently it is not being done, there is no good interaction between all stakeholders	Yes, it's good.	Yes, it's good.	No, intercation is not good. For us we don't have a choice. If some organisation like Jica comes and says let us do this or let us not do this it would have been better
53	Biggest problem	There is a problem to get water, get financial resources	There is no market. So now I have fruits but I don't even know where to sell them And also the transport to get to the market. Also pests are a problem	It's lack of water	It's lack of sufficient water The problem with that water from the spring is that it has a lot of fluoride.	It is kettle keeping, and we don't have veterinaries, so when something gets sick it takes time for the farmers to go there.
54	Name	Peter Kenyanjui Ndungo	Jane Wangari	Peter Kariuki	Alice Wairimu	Kidongo Vishuti
55	Tribe	Kikuyu	Kikuyu	Kikuyu	Kikuyu	Kikuyu
56	Age	70	40	23	40	50
57	Level of Education	primary level standard 8	primary level standard 2	secondary level form 4	secondary level form 4	Primary standard 7
58	Amount of members in household	7	6	10	7	7
59	Female members in household	1	4	6	3	4
60	Amount of children who go to school	all	all	all	all	all
61	Children take over farm	yes	yes	yes, I will take over	yes	yes
62	Other source of income					I am a soldier

Declaration of Honor

I hereby declare by word of honour, that this master thesis was written entirely on my own and I have not used outside sources without declaring the same in the text. Any concepts or quotations applicable to these sources are clearly attributed to them. This master thesis has not been submitted in the same or substantially similar version, not even in part, to any other authority for grading and has not been published elsewhere.

01.06.2013,

Date and signature