Assessment of the impacts and Adaptive Capacity of the Machobane Farming System to Climate Change in Lesotho

African Technology Policy Studies Network
RESEARCH PAPER | No. 16

Sissay B. Mekbib
Adesola O. Olaleye
Motlatsi N. Mokhothu
Masia Johane
Spirit B. Tilai
Taddese Wondimu

Assessment of the Impacts and Adaptive Capacity of the Machobane Farming System to Climate Change in Lesotho

Sissay B. Mekbib
National University of Lesotho, Lesotho

Adesola O. Olaleye
National University of Lesotho, Lesotho

Motlatsi N. Mokhothu
National University of Lesotho, Lesotho

Masia Johane
Department of Livestock Marketing and Registration, Lesotho

Spirit B. Tilai
National University of Lesotho, Lesotho

Taddese Wondimu
National University of Lesotho, Lesotho

AFRICAN TECHNOLOGY POLICY STUDIES NETWORK

The African Technology Policy Studies Network (ATPS) is a multi-disciplinary network of researchers, private sector actors and policy makers promoting the generation, dissemination, use and mastery of science, technology and innovation (ST&I) for African development, environmental sustainability and global inclusion. ATPS intends to achieve its mandate through research, capacity building and training, science communication/dissemination and sensitization, participatory multi-stakeholder dialogue, knowledge brokerage, and policy advocacy.

Published by the African Technology Policy Studies Network
P O Box 10081, 00100 GPO Nairobi Kenya

ISBN: 978-9966-030-31-3

Table of Contents

Acknowledgement

This paper was produced as part of the implementation of the African Technology Policy Studies Network (ATPS) Phase VI Strategic Plan, 2008 – 2012 funded by ATPS Donors including the Ministerie van Buitenlandse Zaken (DGIS) the Netherlands, Rockefeller Foundation, amongst others. The authors hereby thank the ATPS for the financial and technical support during the implementation of the program. The Authors specially thank the ATPS Climate Sense Program Director, Dr. Kevin Urama (ATPS); and the Program Coordinators including Prof. Francis Mutua (ATPS Kenya); Dr. George Owusu Essegbey (Council for Scientific and Industrial Research (CSIR), Ghana), Prof. Eric Eboh (ATPS Nigeria), Dr. Nicholas Ozor (ATPS), and Ms. Wairimu Mwangi (ATPS) for their technical support during the research process.

Abstract

Lesotho is a landlocked country within South Africa with a population of less than 2 million people and is highly vulnerable to climatic changes. Agriculture remains a major source of income for more than 80% of rural population in Lesotho. The arable land is only about 9% of the total land area of 30,355 square kilometers and the current crop yields are about half the level achieved in the late 1970s. Despite its contribution to Lesotho's development, the rural economy has been languishing due to poor land management and farming practices. Among other things, the overall decline is attributed to poor weather; declining fertility of land and poor management of water resources. Communities living in marginal lands and whose livelihoods are highly dependent on natural resources are among the most vulnerable to climate change. The Machobane Farming System (MfS) is a farm practice with high adaptability and resilience to climate change that was developed by Dr Machobane in the late 1950s. Fields of farmers practicing the MfS remained green throughout the year. Although there are discernible challenges for its wide application, the MfS is a very disseminative and friendly farming system combining indigenous knowledge and technology for high and sustainable production of variety of crops throughout the year. In this study besides documenting the historical, current status and future prospects of the Machobane Farming System and of its adaptability and resilience to climate change, we also assessed the physicochemical and microbial characteristics of its soil, and presented the challenges and vulnerability of the farming system.

Key words: Machobane Farming System, Indigenous farming technology, Climate change, Adaptability, Traditional knowledge

1. Introduction

Of the many environmental problems facing mankind today, climate change remained as a global concern for its increasing number of impacts on all aspects of human lives. In Africa, climate change affects agriculture production through increased water stress, reduced suitable areas for production and decrease yield potential. The situation is even getting worse in countries with low income populations that practice subsistence agriculture. In this piece of work, the adaptive and resilient nature of Machobane Farming Systems compared to other non-Machobane Farming System were studied and documented in the different agro-ecological zones of Lesotho.

1.1 Background information

The Kingdom of Lesotho is a country located in the southern part of Africa with the land area of 30,355 sq km, of which 15% is considered arable (Flannery, 1977). It is situated within the Southern African plateau at an elevation of between 1,500 m and 3,482 m above sea level. It is divided into four agro-ecological zones (Table 1) based on climate and elevation: Lowlands (17%), Senqu River Valley (9%), Foot-hills (15%) and Mountains (59%) (Cauley,1986). Currently, approximately 9% of its land area is arable, the remainder of the country being dominated by rangeland suitable for extensive livestock production (Bureau of Statistics and Planning, 2007). The highest population pressure is found in the lowlands of the country, where the estimated arable land is concentrated and this is compounded by the problem of serious soil erosion, land degradation and increasing population pressure (BoSP, 2007). Rainfall is sporadic and drought, hailstorms and winters can be quite severe. Even the estimated arable land is declining because of the thin layer of soil, limited vegetation and the high mortality of farmers caused by HIV/ AIDS. Lesotho loses about 40 million tons of soil annually due to wind and water erosion (Flannery, 1977). While weather is partly to blame for the soil erosion, poor land management and an ancient land tenure system also play their part. Lesotho has been described as one of the least forested countries in sub-Saharan Africa. Trees are cut down for firewood and new shoots are eaten by animals, causing further soil erosion and making even less land available for agriculture.

Naturally, the agro-ecological location of the country made it so vulnerable to many effects of climatic changes. The northern and central lowlands are characterized by large deposits of rich volcanic soils, while the southern lowlands are characterized by poor soil and low rainfall. The foothills, on the other hand consists of very fertile land that is associated with high agricultural productivity. The drainage patterns of the mountain regions has produced deep river valleys, gorges, and gullies. However, it forms the main livestock grazing area in Lesotho. The soils of the Senqu River valley on the other hand remained the most unproductive in the region (Cauley,1986).

The 2007 Intergovernmental Panel on Climate Change (IPCC) report confirmed that climate change is already happening and that communities living in marginal lands and whose livelihoods are highly dependent on natural resources are among the most vulnerable to climate change and have to develop strategies for coping with these phenomena. These communities have valuable knowledge about adapting to climate change, but the magnitude of future hazards may exceed their adaptive capacity, especially given their current conditions of marginalization.

In pursuit of commitments under the Climate Change Convention, Lesotho has developed the National Adaptation Program of Action (NAPA) on climate change under the UNFCCC in 2007 (Ministry of Natural Resources, 2007) and identified technology needs in agriculture because it contributes the most important to the national economy and on the livelihoods of majority of the population (LMS, 2004). The NAPA process identified eleven adaptation options, most of which address land and water management and agricultural production, following the finding that chronic food insecurity is likely to be further deepened through climate change (MoNR, 2007).

1.2 Problem statements

Lesotho is one of the countries vulnerable to climate changes due to her geographical location and agro-ecology. It is therefore imperative for Lesotho to examine various technological possibilities in agriculture that will form part of the country's adaptation strategy to reduce its vulnerability to climate change. Evaluation of the different types of farming practices (systems) in a condition where the existing arable land (9%) is even more decreased from time to time is crucial. Successful adaptation reduces vulnerability and it depends greatly on the adaptive capacity of an affected system, region, or community to cope with the impacts and risks of climate change. On the other hand, enhancement of adaptive capacity can reduce vulnerability and promote sustainable development across many dimensions (IPCC 2003).

The Machobane Farming System developed by Dr Machobane is one of the farming systems in Lesotho with high adaptability and resilience to climate change because of its convenient practice and disseminative traditional knowledge to the farmers using existing natural resources (Robertson, 1994). However, there are uncertainties or challenges to the MfS such as intensive nature of the farming activity, input to expand the system; training to build nurseries, training to harvest water, pest control methods, etc as a system to a wider community.

1.3 Objectives

The present study was therefore made based on the following objectives:

General Objectives:

1. to understand the technical features of MfS and develop scientific ground to exploit its full benefits in comparison to other farming systems.
2. to develop a base line information for sustainable use of the MfS as its principle can be applicable to smallholder farming areas in tropical Africa.

Specific objectives:

> to identify perceived causes of poor crop production by households

> to collect information on current traditional pest control practices

> to develop important pest list and type of crop diseases in the major cropping zones of the country

> to determine the physicochemical characteristics of both MfS and non-

Machobane Farming System soils from the different agro-ecological zones of Lesotho

- to determine the soil microbiota as soil fertility indicator from both MfS and non-Machobane Farming System soils from the different agro-ecological zones of Lesotho
- to determine and analyze the trend of detailed meteorological data from the nearest stations
- correlating the basic field agronomic features, cropping practices, and meteorological data from the nearest station.

1.4 Justification

In due course of climatic change, some of the agricultural farming fields practicing Machobane Farming System remained unaffected and appeared green throughout the year. However, no study has been conducted that explain why the Machobane fields are green while non-Machobane fields are dry in years of poor rainfall. There is also currently no explanation on the impact of the MfS on the soil's capacity for retaining moisture and making it available for plant growth. Thus, being a good farming practice, knowing the impact of the MfS on the soil's capacity for retaining moisture and making it available for plant growth appears an issue of concern.

1.5 Structure of the paper

This paper is organized based on the data obtained from field and laboratory work to substantiate the adaptive and resilient nature of the Machobane Faming System. Data analysis, including validation was done using SPSS and SAS software. In some cases, results and findings are presented in descriptive format.

2. Literature Review

2.1 Climate change impacts on farming systems in Lesotho

As the case is true in many other developing countries, in Lesotho, more than 80% of the population livelihood rely on subsistence agriculture by raring animals and/or crop farming. Only nine per cent of the land is arable in the rocky, mountainous "Kingdom in the Sky". Even this figure is declining because of the thin layer of soil, limited vegetation and farmers dying of AIDS (European Forum on Rural Development Cooperation, 2002).

Naturally, Lesotho is critically vulnerable to climate change scenarios because of its agro-ecological location. Rainfall occurs mainly during the summer season but is extremely variable in quantity and time. Lesotho usually receives 85% of its annual rainfall between the months of October and March. Data from Lesotho Meteorological Services reported that rainfall levels in September 2006, the beginning of the planting season, were 57% lower than average. Although late rains commenced in October and remained constant through December, rainfall amounts declined as from January 2007 and decreased dramatically during February and March as compared to the 30-year average for Lesotho (EM-DAT, 2008). A shift in precipitation patterns ultimately brings a shift in sawing and harvesting seasons to which unexpected disastrous situations could happen before crops are harvested in the field. Assessment of historical data since 1961 to 1994 predict warmer future climatic conditions over Lesotho being lower precipitation in spring and summer and a higher precipitation in winter and autumn (MoNR, 2007).

On the other hand, an increase in precipitation in winter may suggest an increase activity in frontal systems which may result in heavier snowfall and strong devastating winds often bring disasters and human suffering posing significant risks for agricultural production in Lesotho. Every year, wind and water carry 40 million tons of soil from Lesotho (European Forum on Rural Development Cooperation, 2002). Rainfall is higher in the mountains and foothills and may favor the animal farming, but, the cropping season is much shorter due to the early outset of frost which will be exacerbated by climate change. The lowlands areas are significantly drier and crop failure from drought is very common.

2.1.1 Crop farming systems

Crop production is one of the most important components of the farming systems in Lesotho throughout all livelihood zones. Maize (63%) dominates the area under cropping followed by sorghum (28%) and wheat (12%), while beans and peas accounts for (5%) and (3%) share of area planted respectively (BoSP, 2007). The North and South western Lowlands, the Senqu River Valley, the Foothills and Mountain regions are the main cropping regions in the country. The amount and distribution of precipitation and other climatic conditions of the area is an important factor in crop production activity. The south western lowlands are the more susceptible areas to erratic agro-climatic conditions in the region.

Maize is the basic staple food crop of the people as it contributes 40% to the daily diet. Sorghum is the next important cereal used in preparation of porridge, traditional beer brewing and preparation of animal feed. Beans and peas have been grown for long as cash crops and are major sources of protein in the local diet. The area under cultivation, production, and yields are very erratic and closely related to rainfall patterns. Other factors such as soil infertility, inadequate use of organic fertilizers, inefficient technologies that are characterized by untimely planting, poor land preparations inadequate weeding, and delayed harvesting are also major factors that greatly affect crop production in Lesotho.

The domestic production of fruits and vegetables is a source of livelihood for at least 10% of the population in the foothills, lowlands, and Senqu River Valley (MoNR, 2007). However, this potential has been marginalized by skewed climate extremes and hazards such as hail, frost, and extreme temperatures, which could even become more severe under climate change conditions.

Currently, six farming systems or technologies are practiced in Lesotho, namely:

block farming (Integrated Regional Information Network, 2009), mono-cropping (traditional farming), conservation farming (Soil and Water Conservation and Agro-forestry Program, 2001), keyhole garden (Taylor, 2008), double digging [a 24 inch (610 mm) deep trench] and the Machobane Farming Systems (Machobane and Robert, 2004). Data depicting the percentage of farmers engaged in each farming system is not available. The farming systems are promoted with the obvious goal of assisting the rural livelihoods, conserving the environment, and generating income. However, the response of the farming systems to climate change impacts, adaptability and resilience property remains a crucial factor for consideration.

2.1.2 Animal husbandry

In Lesotho, livestock production plays an important role for both economic and social reasons next to crop production and it contributes 30% to agricultural gross domestic product (Turner, 1993). The sub sector consists mainly of cattle (25%), sheep (45%) and goats (30%) (BoSP, 2002). Other livestock kept include horses, donkeys, pigs and poultry. Cattle are mostly raised for subsistence livelihoods including draught power, milk, fuel (dung), and meat.

Livestock are reared around homesteads for half of the year due to seasonal changes (onset of winter), management practices (shearing, dipping) or to minimize the risk of theft. Thus most stock have inadequate ration during long periods of the year in terms of poor nutritive value of fodder and forage. Farmers have no tradition of fodder husbandry on arable land or conserving fodder as silage or hay. This leads to insufficient dry matter intake for livestock. Though in some remote areas, rangelands are under-grazed due to remoteness, most village pasture areas support high stocking rates and are severely degraded. The range land deterioration as a result of overstocking, in turn affects the livestock productivity amongst other factors such as lack of proper feeding, disease control, poor breeding practices and stock theft.

The livestock sub-sector is less prone to erratic climatic conditions as compared to the arable agriculture. Good rains positively affected rangelands and the water flow in streams and rivers on which livestock depend. However, the productivity of the sub-sector is severely affected by failure to maintain an appropriate balance between range resources and animal population and by adherence to traditional management practices (World Bank, 2001). A trend of declining in the number of livestock and its output is attributed to declining of animal nutrition that has mainly resulted from degrading and overgrazing of rangelands (Messner, 1989).

2.2. Vulnerability of the farming systems and challenges encountered

Although agriculture accounts for only 15% of Lesotho's gross domestic product, it is the main source of livelihood for about 60% of the population. Agricultural productivity is affected greatly by climate changes. As droughts have always been a part of the climate in Southern Africa, its frequency in Lesotho has increased significantly over the past few years. And because of its high elevation (1388-3482m) above sea level, Lesotho is heavily influenced by a variety of competing weather systems, leaving the country prone to natural disasters, drought and desertification, loss of biological diversity and land degradation. In accordance with Article 4 of the United Nations Framework Convention on Climatic Change (UNFCC), these conditions indicate Lesotho as a country highly vulnerable to climate change.

Lesotho has experienced the growing impact of global warming, as seen from the increasing frequency of natural disasters, droughts, and emerging signs of progressive desertification, fragile characteristics of its soil and terrain, erratic climatic conditions (including changing patterns in rainfall periods and the risk of shorter growing seasons), increased poverty levels, and the relative deprivation of the inaccessible mountain region which makes up more than 60% of the country. Out of a population of 1.8 million people, 56% live on less than $2 per day, many in the rural areas where about 82% of Lesotho's people are found engaging primarily in subsistence rain-fed agriculture and informal trade (MoNR, 2007).

Lesotho experienced a prolonged dry spell and high temperatures during the critical period of the 2006/07 cropping season (January – March 2007) which resulted in large-scale and irreversible damage to the maize and sorghum crops. The absence of rains during January to March was the main cause of the damage to yields, coupled with an excessive dry spell that has prevailed since December 2006 (EM-DAT, 2008).

Migration of the male working force to South African mines and industry had a large impact upon mountain communities (Arnalte, 2006). Besides this, the lack of resources and the inappropriate farming techniques, such as monoculture, resulted in declining yields and therefore, food insecurity for many families in the mountain kingdom.

The increase in the density of livestock is causing land degradation across the country due to the over-grazing of pasture. Over-grazing coupled with deforestation for firewood, has lead to severe erosion and associated loss of soil fertility. The particular situation in the mountains gets aggravating for the isolation of communities. Inherently poor communication and lack of transport infrastructure make it more difficult for advice and extension agents to reach the mountain communities. Then, people in the mountain remain unaware of alternative management techniques which could improve the fertility of their land and their food security.

2.3 Measures taken by the Government of Lesotho

As a member of the international community, Lesotho has signed the UNFCCC at the Earth Summit in Rio de Janeiro in June 1992 and of its ratification in 1995. However, there are no national coordinated policy to deal with such pervasive problem directly (BoSP, 2007). The country puts more priority on adaptive measures because of its extreme vulnerability to the adverse effects of climate changes. This includes: promotion of renewable sources of energy for the residential and commercial sectors, the promotion of energy efficient devices, the encouragement of energy switching to cleaner sources such as electricity, reforestation of indigenous forests, aforestation of gullies and degraded lands and rehabilitation of wetlands.

In addition, other different programmes such as Disaster Management and Poverty Alleviation Programmes, which include social funds, special employment schemes, restoration and resettlement schemes are implemented for households that are affected by development activities.

2.4 Climate change adaptive strategy

Climate change predictions are still too coarse to give highly specific guidance. Drought-affected areas are likely to expand, and the poor have the least capacity to adapt to the increasing severity of weather events that are expected (United States Agency for International Development, 2007). To adapt to increasing weather variability, buffering and diversification strategies such as cropping systems change (Philip et al., 2007), water harvesting and small-scale irrigation (USAID, 2007), integrated crop management, diversification with higher-value crops, Government policies and longer-term development pathways to build the resilience of smallholder farmers (Hazell and Haddad, 2001; Pender et al., 2001),

2.5 The Machobane Farming System and its requirement

The following are key features of the Machobane Farming System, signifying its basic behavioral and technical requirements to adopt as an agricultural farming system.

2.5.1 Behavioral requirements

i) self reliance; farmers must be convinced that can achieve food security without external assistance: it is their will that makes the difference;
ii) appreciation of the resource base; farmers must be convinced that they can improve crop production by fully exploiting their resource base;
iii) readiness to do hard work;
iv) learning and teaching by doing; farmers must be trained on their own fields and farmer trainers must be ready to do work along with them;
v) spontaneous technology spreading; farmers learn from their farmers;
vi) Machobane farmers have the duty to help their neighbors.

In Lesotho mountain areas, most crops are grown on permanently terraced land. Due to poor soil structure, inadequate soil fertility management and erratic rainfall, land productivity is low and subject to wide fluctuations. According to Machobane, these constraints can be overcome by rational exploitation of the resource base and minimizing the need for purchase inputs. In the MfS, it is considered that intensive cropping of one acre is sufficient to ensure food security for an average family of 5 members (1/3 of the area conventionally thought necessary).

Commonly, seven basic crops are grown in Lesotho: maize, potatoes, sorghum, wheat, peas, beans and curcubits (pumpkins and melons). These crops are relay-intercropped in a 1-acre (0.4 ha) plot and the cropping pattern allows food crops to be produced almost all the year round. To reduce the likelihood of total crop failure, and increase productivity the Machobane farming system takes the following basic technical applications into account:

2.5.2 The technical bases

i) The use of organic fertilizers.
ii) Perennial vegetation cover.
iii) Cropping pattern adequate to the varying climate.
iv) Natural pest control.
v) Relay harvesting allowing for almost year-round harvest.

Although the specifics of this farming system may be appropriate only in the temperate climate of Lesotho, many of the principles outlined here are also applicable to smallholder farming areas in tropical Africa.

i) Use of organic fertilizers

The Machobane Farming System uses animal manure and wood ash as fertilizer. For the initial land preparation, approximately 300 wheelbarrowfuls are used per hectare (120 per acre; one wheelbarrow contains about 25 kg). Depending upon the type of soil, different mixtures of organic material are applied as required. About the same amount of organic matter is applied to the field before each cropping season. By the fourth year, the fertility of the soil will have improved, and less organic fertilizer will be needed each cropping season then after. Plant leaf litter and/ or remains (mulching) can also be used as effective soil cover to maintain moisture and decomposing material to the plant.

ii) Perennial vegetative cover

The Machobane Farming System ensures complete crop cover throughout the year, because winter crops (e.g., wheat and peas) are planted in April–May (for harvest in January–March), and summer crops (e.g., maize, beans and sorghum) are planted in August–October (for harvest in November–December). Because the system uses minimum tillage (complete plowing of the field is only done once every 5 years), soil movement is minimized. Crop residues are left in the field, allowing humus to build up. Because there are always crops in the field, grazing of livestock is not possible.

iii) Cropping pattern adapted to varying climate

Lesotho's climate is temperate, with a warm summer and a cool winter. Late or early frosts, hail and seasonal drought are not uncommon. The Machobane system allows for the planting of cool-weather crops, such as peas, wheat and potatoes, which perform well in the winter conditions. In the summer months, maize, beans, pumpkins and other crops are intercropped (Figure 1 and 2). However, because Lesotho can experience drought in the summer, drought-resistant crops like sorghum (aptly known as the "camel of the plant kingdom") are also planted to reduce the risk of crop failure.

iv) Seedbed preparation and planting

In the first planting season, the 0.4 ha (1 acre) field is ploughed. The plot is then harrowed or disked to prepare the soil completely. A spade or hoe can be used to make the furrows or rows where the seed is to be planted. In April, the winter crops (wheat and peas) are planted. A double row of wheat is planted, with 30 cm between the two rows. Then a gap of 2 m is left, and a double row of peas is planted, again with 30 cm between the rows. Then comes another gap of 2 m, followed by a double row of wheat, a 2-m gap, another of peas, and so on (Figure 1).

Figure 1: Machobane Farming System: double row of wheat and vegetables.

In August, the first batch of potatoes is planted in the 2-m gaps between the rows of wheat and peas; only half of the field is planted at this time. Starting in November, the rest of the field is planted with a second batch of potatoes.

In October, the summer crops are planted in a complex intercropping pattern of maize, beans, sorghum, pumpkin and watermelon. In the 30-cm spaces between the double rows of wheat and peas, a single furrow is dug. Maize and beans are planted in this furrow, with 30 cm between the maize plants, and 15 cm between the beans.

Every 4 m, two pumpkin seeds are added to the maize and bean hill. In every other row, watermelon is planted rather than pumpkin. Finally, sorghum is sown along the entire furrow (Figure 2).

Figure 2: Maize intercropping with pumpkin and watermelon: Mountains (Mantsonyane)

After the first batch of potatoes are harvested in December, vegetables such as rape, cabbage, and spinach can be planted.

v) Crop management practices:

Tillage

Once the crops are in the field, minimum tillage is done using a spade or a hoe. A hand-pushed ripper (Figure 3) can also be used to open the furrow to plant the summer and winter crops. New crops can then be planted without harming the standing crops.

Weeding

Weeds in the field should be controlled as they can harbor insects and pests, and can also compete with plants for moisture, light and nutrients. The first weeding is done with a hoe immediately after crop emergence to break up and aerate the soil around the crops and to kill the weeds. The second weeding is done when the crops are about 1 month old. Crop residues are left in the field, helping to improve soil fertility and hindering weed growth.

Figure 3: A hand push ripper to open the furrow

Earthing the potatoes

The first earthing is done when the potatoes are at their first stage of flowering. A very small quantity of soil is gathered around the plant at this time. The second earthing is done at the second budding: a little more soil is ridged around the plant. The third earthing is done at the third budding, and ridging is done to cover half the plant with soil. With the fourth earthing, two-thirds of the plant is covered with the soil.

Natural pest control

Natural pest control is encouraged in the system, while chemical pesticides are discouraged. Since some crops act as natural repellents to certain insects, the intercropping practice contributes to pest control. The deliberate crop rotation helps to break the life-cycle of insect pests. Regular weeding throughout the year helps to control pests and diseases. Also, some plants can create an unsuitable environment for insects; for example, the pumpkin plant has hair which is irritating. Pest-control home remedies may also be used.

Relay intercropping

The relay intercropping practice offers many advantages. For example, because the crops are sown at different times there is little competition during the growing period. Time spent weeding one crop helps prepare the soil for the crop that will follow. Available land is maximized with the production of several species.

Relay harvesting

The relay intercropping system allows for staggered harvesting of crops throughout the year, manually. No machinery is used for harvesting. The winter crop of peas can be harvested in November (as green peas) and in March (as grains). Wheat is harvested starting in January. The first batch of potatoes is harvested from late November to March; the second batch is harvested starting in April. The potatoes are harvested as soon as the leaves and stems have become dry using a spade or digging fork.

Harvesting the large number of summer crops begins late in the year. Green maize can be harvested in December–January, and green beans in December–February. Watermelons can be harvested starting in February. From March to May, pumpkins should be harvested. Beans in grain form are harvested from April to the end of June; rape, cabbage, and spinach can be harvested during the same period. Grain or dry maize and sorghum are harvested in June–July.

2.6 Current status of the Machobane Farming System

As part of its broader initiative in African countries affected by drought and desertification, the International Fund for Agricultural Development (IFAD) helped the government of Lesotho to establish the Soil and Water Conservation and Agriculture Program (SWaCAP) as an intervention to encourage conservation based agricultural production practices (Consolidated Applied Program, 2007). In the 1991-1992 cropping season, SWaCAP persuaded Dr. Machobane to get involved in reinstating the MfS, an effort which succeeded in reintroducing the MfS with 22 participating farmers producing variety of plants such as potato, maize, sorghum, wheat, bean, pumpkin, and watermelon seed. The number of new farmers continued to increase rapidly, reaching about 1600 farmers by mid-1996. The project also promoted soil ripping to break up subsurface compaction and Bana grass to reduce sheet erosion between bunds and provide fodder. It was noted that significantly high adoption rates of the MfS were linked to farmer-driven extension initiatives (CAP, 2007). Currently, however, among many other factors, due to less support provided and lack of work force, the practicality and disseminative role of the MfS is weak.

3. Research Methodology

The Study Area

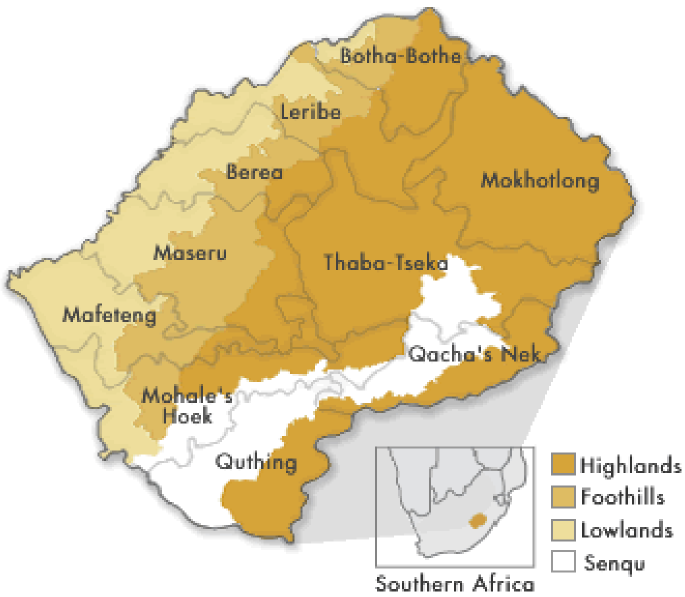


Figure 4: The study area: agro-ecological zones of Lesotho

The study area covers the four agro-ecological zones of Lesotho: the Highlands, Foothills, Lowlands and Senqu River Valley as depicted in figure 4.

3.1 Data Collection and Analysis

3.1.1 Objective 1 - 3: Identification of the perceived causes of poor crop production by households

Fieldwork data collection was undertaken using informally structured questionnaires and field interviews with respondents. In total, 400 households

[100 from each of the four agro-ecological zones of Lesotho] were interviewed. The questionnaire comprised of four major parts. The first part covers data on the household characteristics [name, education, marital status and family size…]. The second part covers data on food security and poverty alleviation practices that comprise household livelihood, the farming system used, household expenditure, soil fertility, irrigation practices, pest and disease control strategies, crop diversity and productivity, and natural resource conservation practices. The third part covers data on climate change and adaptation practices, which comprises of the detailed aspects of climate change impacts and hazard type and occurrence. The fourth part refers to Government and civil society's intervention and their involvement in climate change and its impact by providing support at community level.

3.2.2 Objective 4 & 5: Determination of soil physicochemical and microbiological characteristics

Undisturbed soil samples were collected from five districts [ThabaTseka-Mants'onyane (Mountain), Leribe-Pitseng (Wet lowland), Buthat Bothe (Foothill), Quthing (Senqu River valley) and Mohale's Hoek (Dry lowland) of the four agro-ecological zones in Lesotho. From each of the selected farmers' fields (Machobane and non-Machobane) samples were collected from the mini-pits at the depth of 0-20cm to determine the bulk density (Blake and Hartge, 1986) and water reaction (Klute, 1986). Samples were collected according to pedological horizons based on slope/ relief of the area. Data about type of vegetation around each mini-pit, position of the mini pit on the slope, type of parent materials in the area and soil texture was recorded according to USDA method.

3.2.2.1 Soil physico-chemical analyses

Air dried samples were used to determine the proportion of gravel (>2mm) in the soil. The <2 mm fraction were determined using hydrometer method as an index of soil micro-aggregate stability The total N, organic carbon, available phosphorus (P), exchangeable cations and micro-nutrients, soil pH and cation exchange capacity were determined using the method described in Badamchian (1984).

3.2.2.2 Soil microbiology analyses

Soil samples from different agro-ecological zones of Lesotho were collected from five locations of Machobane and non-Machobane farming plots using (A4 size) brown paper bags. The samples were kept frozen at 4°C in the fridge until processing. As good indicator for soil fertility, the population dynamics of Bacillus strains as plant growth promoting rhizobacteria (PGPR) and strains of non-symbiotic nitrogen fixing bacteria (NfB) were determined using the methods described in Foldes et al (2000) and Kennedy et al. (2004) respectively.

3.2.3 Objective 6: Meteorological data analysis

Meteorological data on rainfall and temperature were collected from Lesotho Metrological Service (LMS) for the period of from 1923 to 2006. This data were analyzed using SAS statistical package.

3.2.4 Objective 7: Correlation of basic field agronomic features and cropping practices

From each of the agro-ecological zones visited, 10 – 12 members of the community were selected to participate in discussion groups. The selection criteria for participating farmers were based on their active participation in the farming activity and recommendation by the Extension Department of the Ministry of Agriculture. The lead questions that were used for discussion were: type of farming system, disease and pest control mechanisms the community currently using, climate change impacts to their farming system, adaptation strategies that they are using to climate change and collective measures to be under taken for future adaptation were raised and discussed at various agro-logical zones of the study area in Lesotho.

3.3 Climate change adaptation policy issues relevance to Lesotho

A workshop was conducted to discuss climate changes adaptation policy issues in Lesotho. The workshop involved an open dialogue with stakeholders from various sectors in Government, representatives of Non-Governmental organizations (NGOs) and farmers (private and association holding firms).

3.4 Statistical analyses

Summary statistics – CV, standard errors, skewness etc. were used to summarize all soil data collected. Students' t-test was used to compare the difference between the soil properties at each section of the slope positions using the PROC Means of the Statistical Analysis Systems (SAS Version 8), 2001. The subsets of topography and soil fertility data were analyzed and summarized by the principal component analysis (PCA) using the PRINCOMP procedure of SAS. Principal components (PC's) were calculated based on correlation matrix. The mean separation analyses were conducted using Duncan's Multiple Range test at $P<0.05$.

4. Results & Discussion

4.1 Objectives 1-3: Identification of perceived causes of poor crop production by households

4.1.1 Respondents gender cross tabulation with farming systems

More than 66.8% of the respondents of which 51% were male and 49% females were found to practice the Machobane Farming System. Of the remaining 33.2% of respondents that do not practice Machobane Farming System, about 56% of them were females (Table 1) at all. This finding could be attributed to the intensive nature of Machobane faming practice which requires more labor compared to other farming practices.

Table 1: Respondent gender cross tabulation with Farming Systems

	Response	Respondent Gender		Total
		Male	Female	
Do you use a Machobane Farming System?	Yes	132 (51%)	127 (49%)	259 (66.8%)
	No	56 (43.4%)	73 (56.6%)	129 (33.2%)
Total		**188**	**200**	**388**

4.1.2 Soil fertility management

More than 88% of the respondents were subsistence farmers producing maize (81%) as a main staple food followed by beans (52%), sorghum (30%) and vegetables (29%).

Although the application of fertilizer is still supported by others, most of the respondents advocate on farm manure application, inter-planting and incorporation of farm crop residues as main strategy to improve soil nutrient. In their faming system, more than 64% of the respondents were found to utilize manure (64%) followed by the application of commercial fertilizers (32.8% and wood ash (30.8%) to ameliorate the soil quality. The use of organic manure and ash as has been practiced by the community is an encouraging situation that could be adopted widely.

As there are many cattle in Lesotho, adopting a centralized way of getting manure from other kraals to the farm practitioner through cooperatives and/ or any support by extension workers can benefit the wide application of organic farming in the country. Many of the respondents that use manure prefer fully composted sheep manure for application. Results from soil microbiology analysis, supports this fact by showing that, activity of microorganisms in the farming systems applying manure increased soil pH (Fig. 10) and ameliorated soil fertility.

4.1.3 Soil conservation practices

The application of terracing as a conservation practice to control of soil erosion followed by counter farming and intercropping is depicted in Figure. 5 below. The development and construction of permanent water ways and furrow diversion is regarded as a means to minimize soil erosion problems in the community.

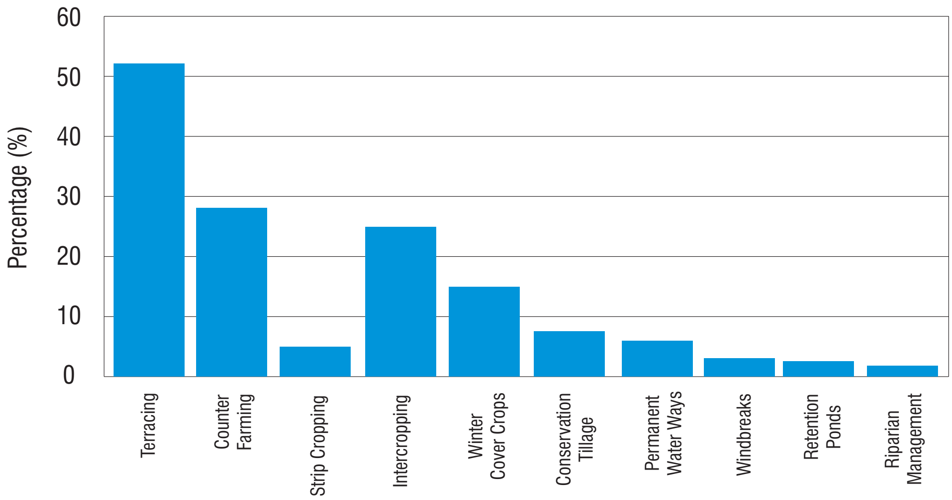


Figure 5: Soil conservation practices

4.1.4 Agricultural inputs availability

Amongst the many factors that affect agricultural productivity, the survey data revealed respondents reaction as climate variability (81.8%) followed by no availability of local/ improved seeds (55.8%), no availability of irrigation water(47.7%) and lack of money to hire labor and buy inputs (41.2) as major factors that limit their activity (Table 2).

Table 2 : Factors affecting agricultural productivity: case processing summary

Factors affecting agricultural productivity	Cases Valid	Percentage (%)
High cost of land for expansion	78	19.7
No availability of labor (Family/non-family)	66	16.7
High cost of non-family labor	60	15.2
Non-availability of irrigation water	189	47.7
No availability of local/ improved seeds	221	55.8
No availability of machine hire services	115	29.0
Lack of money to hire labor, buy inputs etc.	163	41.2
Lack of market or low prices	61	15.4
Climate variability	324	81.8

4.1.5 Pest prevalence and control

Insects were identified as the major pests followed by fungal and bacterial infections that cause great damage to respondents crop plants (Fig. 6). Stock Borer (Busseola busca), and Bagrada Bug (Bagrada hilaris) were identified as the major insect pests followed by Aphids that causes great damage to the leaf (>55%) and stem (51.5%) parts of crops, respectively.

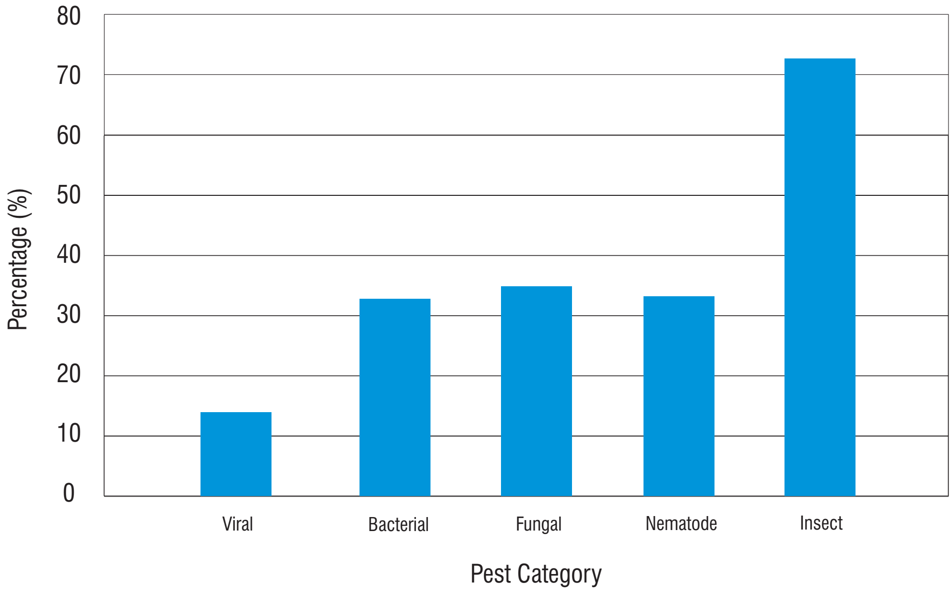


Figure 6 : Crop Pest Categories

To control pests, about 44% of the respondents depend on application of commercial pesticides, whereas 30% use traditional pesticides on their farms. The formation of concoction from various plant materials and other inputs was alluded to during the Focused Group Discussions.

Table 3: Effects of climate change manifestation on agricultural productivity and community material loss as indicated by respondents

Effect	Climate Change Factors						
	Drought (%)	Flooding (%)	Mud slide (%)	Storm surge (%)	Hail (%)	Freezing (%)	Evapo-ration (%)
Crop loss	91.7	57.6	5.3	41.9	70.2	49.5	27.8
Spread of disease	72.2	22.5	1.3	12.9	41.7	21.5	12.4
Livestock mortality	53	26	2.3	27	36.9	31.1	8.3
Property loss	14.4	28.8	2.5	34.1	29.8	10.4	4.8
Fertility loss	48.5	41.7	2.3	22.0	40.4	12.9	7.1
Microbial crop infestation	34.1	9.6	0.5	7.8	15.4	9.6	4.8
Pest infestation	54.8	8.8	0.5	7.8	15.2	8.6	5.3

4.1.6 The Farming Systems

Different farming systems, including Machobane Moldboard, Conservation Broad Casting and Keyhole gardening are practiced by communities as discussed in the Focus Group Discussion (FGDs) in the areas visited (Table 4). These Focus Group Discussions (FGDs) were held between 21st and 25th of August 2010.

The different types of crops that are grown at different agro-ecological zones and the types of disease/pest that commonly affect them are also listed in Table 5.

4.1.7 Community understandings of climate change

Participants from all agro-ecological zones have noticed that climate is changing. Long period of drought, exceptionally heavy rain fall and drought have been noticed by all focus group participants. In the mountains area of Mantsonyane, farmers used to experience early frost due to climate changes, which some respondents thought could be due to the construction of Mohale dam, such problem is now a bit improved. In the other agro- ecological zones, farmers have noticed the change in climate by a shift in sawing season, early frost, wet and dry seasons and extremely high temperatures.

The eminent shift in planting season has excluded certain crops like peas and beans in the mountain areas. The changing climate has also decreased yield because of poorly developing buds; pest infestation, drought, flooding and hail storms. In the Mountain and the Foothill villages practicing Machobane Farming System noticed that it is less affected by a climate change. Sustenance of fertility from the soil that slowly release nutrients to the farm and conservation of the moisture content in Machobane Farming System make its resilience to climate change noticeable. In the Senqu River valley, participants noticed that no particular crop was resistant to climate change.

4.1.8 Adaptation strategies by the communities in response to climate change

Specific measures taken against changing of climate conditions have varied from one village to the other. In the mountains some participants mentioned that they were running trials to find out as to which crops would be more suitable to the shifting and short growing period. In the dry Senqu River valley, mulching and returning residue on to the fields was observed to be the best way of conserving

Table 4: Benefits and disadvantages of different farming systems practiced in three selected agro-ecological zones

Agro ecological zone (village)	Farming system	Numbers practicing	Benefits	Disadvantages
	Machobane (MfS)	5	• conserves moisture and creates less need to buy inputs • Ensures optimal use of farm by- products; nothing is wasted. • produce taste much better and there is possibility of growing traditional vegetables, which are not likely to be grown on other farming systems	• Participants did not mention any drawbacks of the system
	Moldboard ploughing	11	• all residue can be turned under • ensures large scale farming/relatively	• soil and moisture not conserved with hard soil clods
	Conservation farming	2	• no spade used • soil is not disturbed and hence no weed infestation and makes construction of strips is easier	• holes are to be dug and this is a labor intensive step
Senqu River Valley (Mokanametsong)	Keyhole garden (KH)	6	• conserves moisture • low cost inputs used • Easier to manage	• It is labor intensive initially • small scale production system
	Machobane (MfS)	2	• conserves moisture, no need to buy inputs and ensures optimal use of farm by- products; nothing is wasted. • variety of vegetable can grow in a pieces of plot with a possibility of growing traditional vegetables	
Mountains (Mantsonyane)	Moldboard Mixed (MfS and Crop rotation)	11	• less expensive with less labor because it is animal traction ploughing • conserves moisture and there is no application of fertilizers to grow maize because of crop rotation • effective maize-peas - wheat rotation adopted after long trials which have increased maize yield.	• There is still a need to apply MFS inputs for vegetable cultivation
	Key hole garden (KH)		• not well known but it is being introduced	
Foothills (Pitseng)	MfS	4	• variety of vegetables can be cultivated in piece of land/farm year ro und. • crops/ vegetables resist disease • sustain fertility from the soil that slowly release nutrients • improve the quality/characteristics of the soil.	
	Moldboard ploughing	11	• ploughing is always at shallow depth • reduce work load to the user	
	Conservation farming	3	• not labor intensive • it can maintain soil moisture and ma kes nutrients available • cost effective	
	Broad casting Key hole	11	• It is an old practice when resources such as seed are limited. • used for small scale farming such as front or back ya rd farms • works year round and sustainable • produce all types of crop ; it is best for vegetables	

Table 5: Different crops grown and pests/ diseases that commonly affecting them in the agro-ecological zones given

Agro-ecological zone (village)	Crops	Pests and environmental factors	Pest control method
1.Senqu valley (Mokanametsong)	• Maize • Sorghum • Wheat • Beans • Vegetables	• Cut worm (*Agrotis spp*)and stalk borer (*Busseloa busca)* • Aphids (Hoaba* and Boroku*) • Rust and smuts • Blight	- *Tigatus minuta* and *Aloe*, Onion and Pepper concoction - They also claim using pharmaceuticals such as Acaricides (Dezzel NF*), Fast take, Avalanche* and Cut worm. They used these chemicals as pesticides to control animal diseases such as sheep scab as well.
2. Mountains (Mantśonyane)	• Maize • Sorghum • Wheat • Beans • Peas • Lentils • Vegetables	• Cut worm (and stalk borer (*B. busca)* • Drought • Drought • Frost • Frost • Frost	- These crops are grown in all farming systems. - All farming systems are said affected by disease and pests - Herbicides used on small areas like gardens - Use of *Aloe*, soap lather, seholobe*, moroko oa joala*, seholobe and mosali mofubelu* - Using concoction of smelling types of herbs mixed with chillis • The concoction is applied during pest outbreaks • Main advantage of this mixture lies in its being non-poisonous. • also some buy commercial pesticides for field crops such as sorghum, wheat and maize
3. Foothills (Pitseng)	• Maize • Sorghum • Wheat • Beans • Potato • Tomato • Beet root • Green pepper • Spinach • Cabbage	• Cut worm (*Agrotis* spp) • Cut worm (Observation is that Sorghum was not affected by worms in the previous years) • Gradabug* (on vegetables) • Aphids (on vegetables)	• Farmers use any pesticides as per their economy for application from the nearby available markets whenever there is an outbreak. • These days, however, the application frequency and dose of pesticides increased from time to time. • They also use a mix of plant concoction (different herbs) such as *Aloe*, *Rhamnus prinoides.*

moisture (Table 6). They have also proposed water harvesting and construction of small dams for irrigation during dry period as an effective adaptive measure towards climate change. In the foothills at Pitseng village participants mentioned several adaptive measures such as:

- Ploughing the land while the plant residue is still there
- Avoid burning of plant residues in order to conserve soil moisture and not destroy the nutrients.
- Establishment of appropriate sawing season for different crops in response to the shifting sawing season to cope with a climate change.
- Farmers used to saw maize in August but, due to climate variability, they have established the sawing season for maize to be towards the end of July instead.
- Farmers still run trials for other crops and vegetables.

There have been no unique (innovative) measures implemented in Senqu River valley agro-ecological zones. In the mountains and foothills, on-farm trials by farmers are ongoing to establish appropriate crops that can cope with shifting sawing season.

4.1.9 Future collective measures to be implemented

Education and guidance to farmers by Government and Non-government institutions is found to be an important future policy direction to adapt to changing climate conditions and this could include the use of organic farming through Machobane and Conservation Farming systems. Community based discussion forum to seek solutions to impacts of climate change was also considered an important milestone towards building adaptive measures to climatic changes. The supply of seed varieties that can resist drought and disease by government and NGOs is also viewed as an approach to overcome the problems imposed by climate change.

4.2 Objective 4: Determination of soil physicochemical characteristics

4.2.1 Soil texture

Silt and clay were found to be the most important fractions of the soil texture as shown in Figure 7 and 8. The silt and clay contents are very important for soil nutrient retention. These sites can be grouped into two categories those with silt

Table 6: Coping strategies to the effects of climate change

Protection to:	Climate Change Controlling Strategies							
	Flood protection (%)	Crop substitution (%)	Crop diversification (%)	Inter-cropping (%)	Settlement restriction (%)	Mulching (%)	Livestock restocking (%)	Replanting (%)
Crop loss	35.4	24.2	36.9	46.7	4.8	44.2	3.8	63.4
Livestock mortality	5.8	6.1	8.1	1.0	7.3	1.5	23.7	1.0
Property loss	8.1	5.1	3.3	1.0	2.3	1.0	2.3	0.5
Fertility loss	21.2	8.3	10.6	19.2	5.3	15.4	0.8	8.8
Pest infestation	8.6	15.2	21.7	21.5	0.8	8.1	1.8	16.7
Evaporation or freezing	13.4	4.5	6.8	6.6	0.5	11.9	1.8	4.5

contents of > 40% (PMfS) and those with silt contents < 30% (QMfS, TMfS, MHMfS, BBMfS). The sand content in all the sites can be grouped into three classes. Those with sand contents >50% (i.e. MHMfS, BBMfS and BBNMfS); those with sand contents between 35-48% (i.e. QMfS, TMfS, TNMfS, QNMfS) and those with sand contents ≤ 35% (i.e. PNMfS, MHNMfS & PMfS) (Fig. 7). Furthermore, the clay contents from all these sites can also be grouped into two groups. Those with clay contents >30% (i.e. TMfS, PNMfS, PMfS and MHNMfS) and those with clay contents < 25% (i.e. TNMfS, BBMfS, QMfS, BBNMfS, QNMfS and MHNMfS). These sites had significantly different levels of sand, silt and clay contents.

4.2.2 Soil pH

Generally, the soil pH can be grouped into two classes. Soils with pH >6.0 (i.e. TMfS, QMfS, MHMfS, BBMfS) and soils with pH < 5.0 (i.e. PNMfS and BBNMfS) (Fig 10). These sites had significantly different levels of acidity and alkalinity.

4.2.3 Organic Carbon

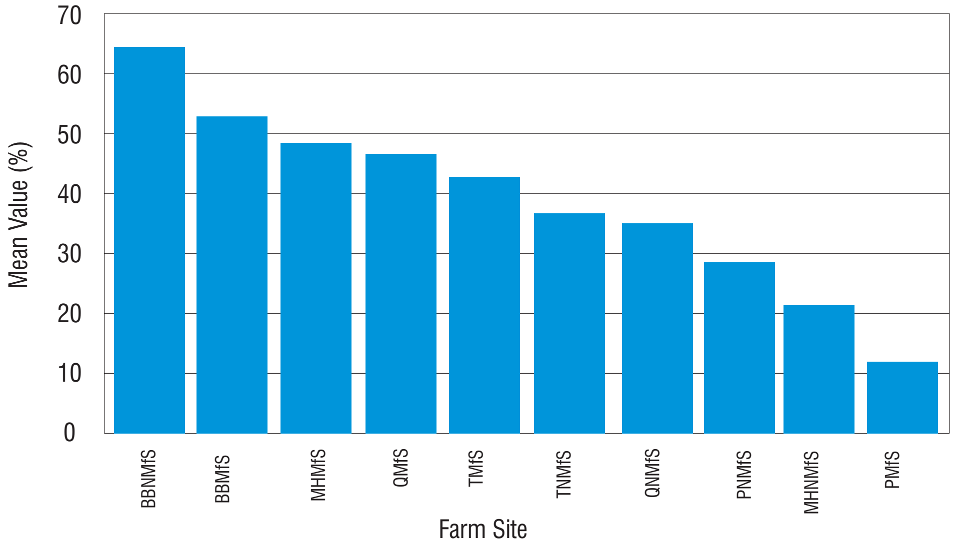
The organic "C" can be grouped into two classes. Those with org C < 1% (i.e. BBNMfS, PNMfS and QNMfS) (Fig 11). In addition others had org C > 1.5%. These sites had significantly different levels of organic carbon.

4.2.4 Available P

The available P were generally low and these could be grouped into two classes. Those with available P of >10mg/kg (i.e. BBMfS, MHMfS and QMfS) and the others had <5mg/kg of P (Fig 12). These sites had significantly different levels of available prosperous (P).

4.2.5 Lime rate

Results showed that sites can be grouped into two categories based on their lime requirements. These are sites with lime rate > 1,500kg/ha (MHMfS, TMfS, QMfS, PMfS) and those with lime rates > 10,000kg/ha (TNMfS, BBNMfS, PNMfS) (Fig. 13).



Legend: Acronyms stands for the following representation: BBNMfS = Butha Bothe non-Machobane Farming System, BBMfS = Butha Bothe Machobane Farming System, MHMfS = Mohale's Hoek Machobane Farming System, QMfS = Quthing Machobane Farming System, TMfS = ThabaTseka Machobane Farming System, TNMfS = ThabaTseka non-Machobane Farming system, QNMfS = Quthing non-Machobane Farming System, PNMfS = Pitseng non-Machobane Farming System, MHNMfS = Mohale's Hoek non-Machobane Farming System, PMfS = Pitseng Machobane Farming System.

Figure 7: Sand fraction. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05)

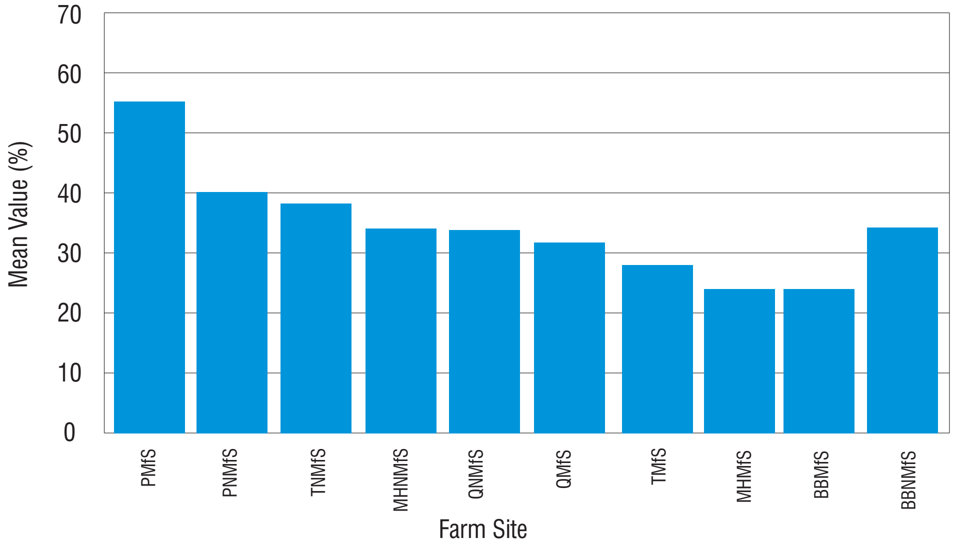


Figure 8: Silt fraction. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

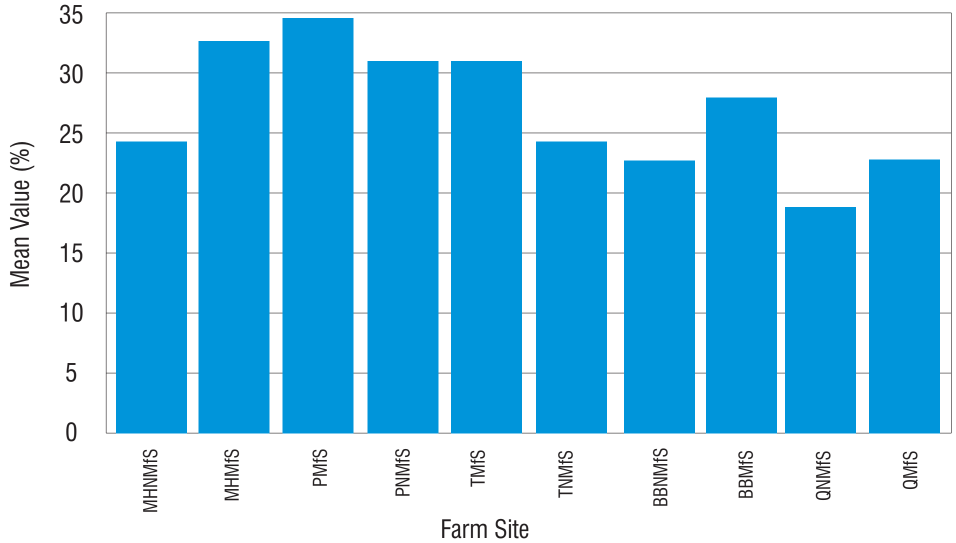


Figure 9: Clay fraction. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

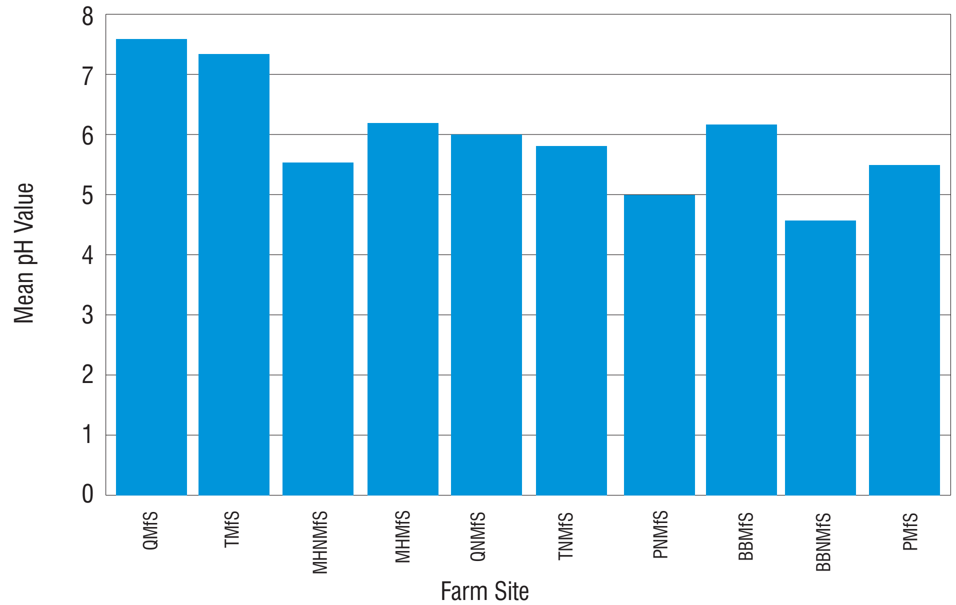


Figure 10: Soil pH. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

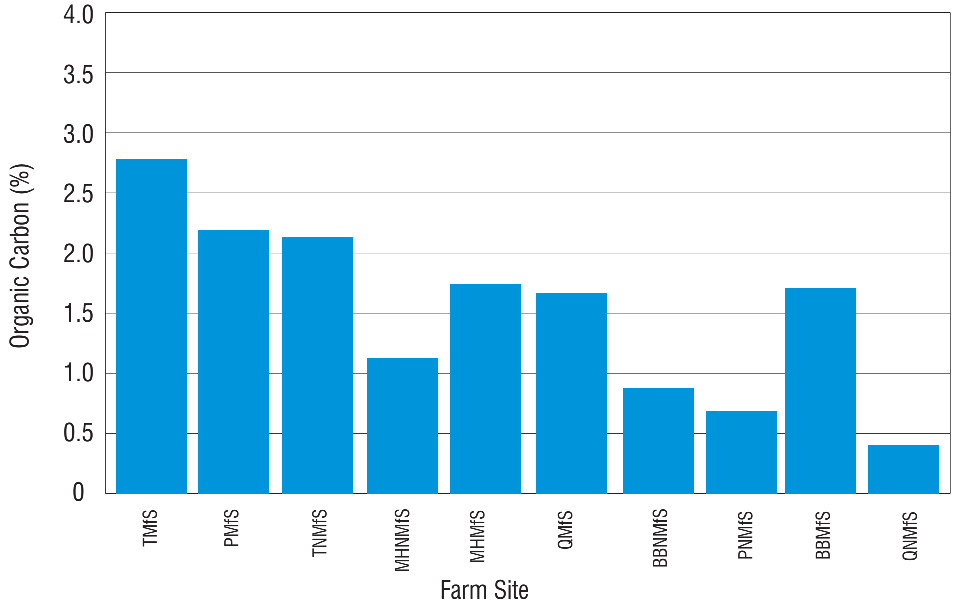


Figure 11: Organic carbon contents of soils practicing different farming systems. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

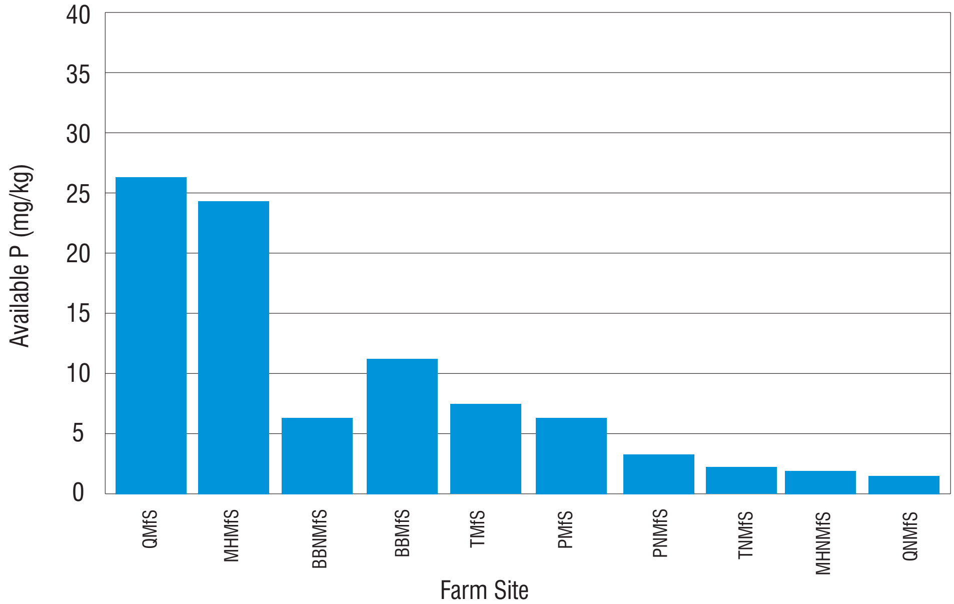


Figure 12: Available Phosphorus (P) in soils of Machobane and non- Machobane Farming practicing fields. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

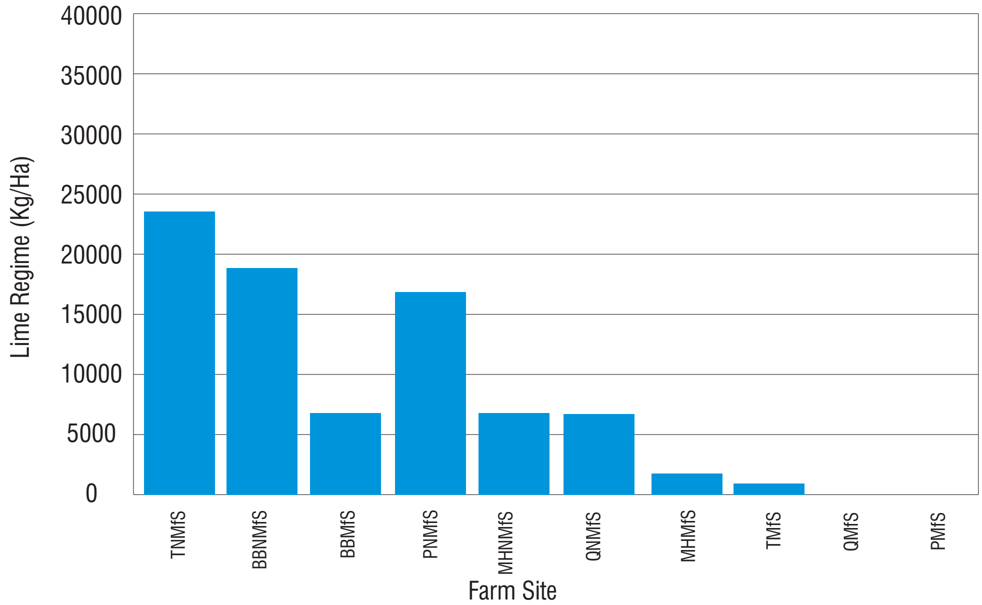


Figure 13: Lime Regime (Kg/ha) in different soils practicing Machobane and non-Machobane Farming Systems. Means with the same letter are not significantly different at Duncan's Multiple Rang Test and grouping (P< 0.05). Legend: refer to figure 7.

4.3 Objective 5: Determination of soil microbiota as soil fertility indicators

Soil samples brought from Machobane Farming practicing plots exhibited higher number of soil fertility indicator microorganisms compared to the non-Machobane Farming System soils. The total count of free living Nitrogen Fixing Bacteria (NfB) was 5.4 x 105 cells/ml followed by Bacillus spp (1.96 x 105cells/ml) (Fig 14 and 15). Soils rich in nutrients and carbon sources, not only increase number of microbial population, but also diversity of microorganisms (Colin, 2002; Carlos and Gabor, 2005). An increase in number could also be associated with the ability of the Bacillus spp to fix nitrogen in nitrogen deficient soils (Colin, 2002) and has an overall ameliorative effect to the soil pH. Significant differences were observed in soil pH improvement in some Machobane Farming System practicing farms (Fig. 7). The Bacillus spp as Plant Growth Promoting Rhizobacter (PGPR) is also known to exert a direct effect on plant growth by production of phytohormones, solubilization of inorganic phosphate, increased iron nutrition through iron chelating siderophores and volatile compounds that affect the plant signaling pathways (Joo et al., 2004).

They are also known for their migration to the aerial parts of the plant for the mediation of disease suppression activity (Gnanamanickan, 2003).

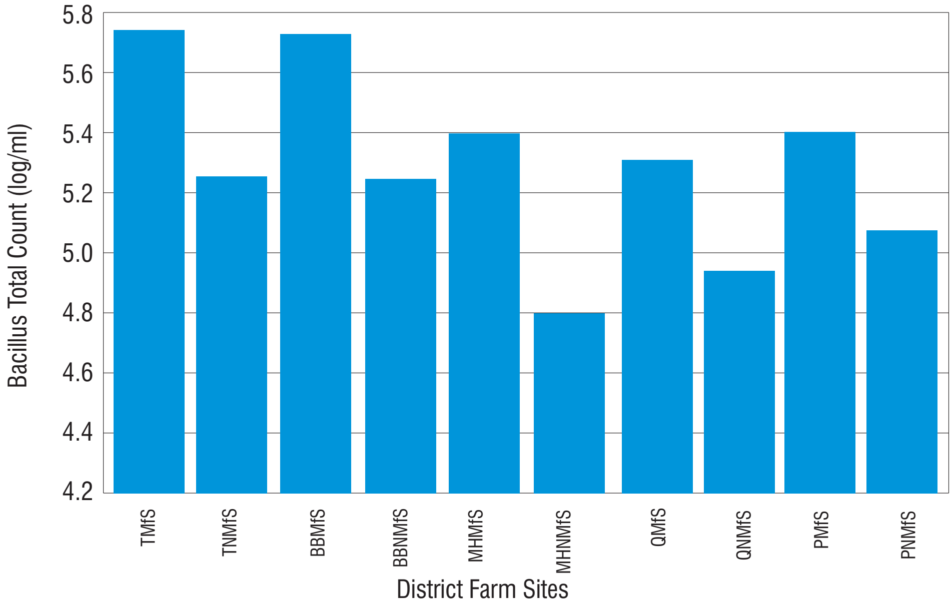


Figure 14: Total Bacillus count. Mean with the same letter are not significantly different by Duncan grouping at (P<0.05). Legend: refer to figure 7

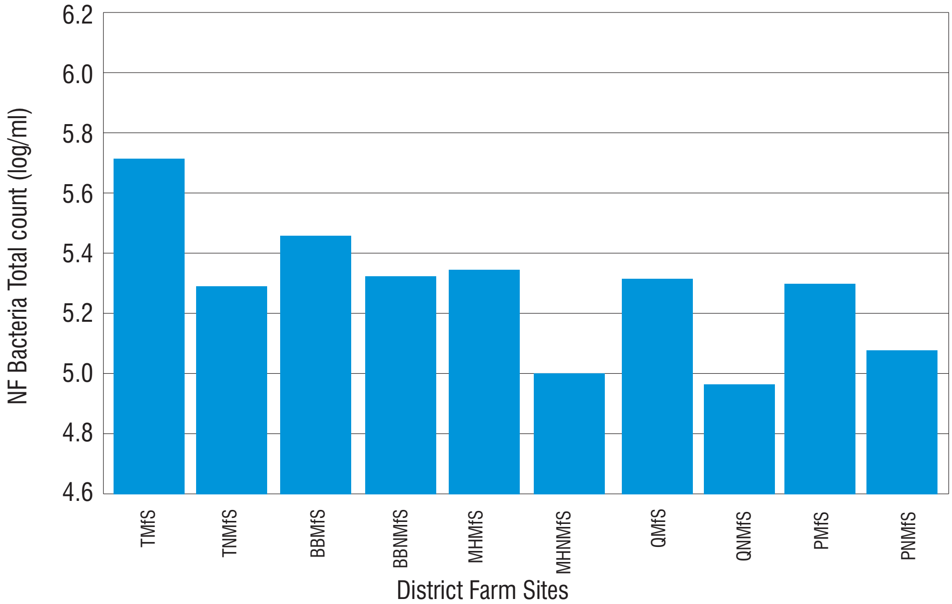


Figure 15: Total Nitrogen Fixing (NF) bacteria count. Mean with the same letter are not significantly different by Duncan grouping at (P<0.05). Legend: refer to figure 7.

4.3 Objective 6 & 7: Metrological data trend analysis

The amount of precipitation and percentage change over years from 1923 to 2006 in Lesotho is depicted in Fig 9 and 10 below. The highest precipitation was recorded between 1954 and 1962 and this fluctuated irregularly as from 1963 to 2006 (Fig. 16). Results of the decadal change in rainfall were highest for periods of 1944-1953 and this trend decrease successively over years to the lowest between 1974 and 1983. The lowest precipitation change was recorded between 2003 and 2006 (Fig. 17).

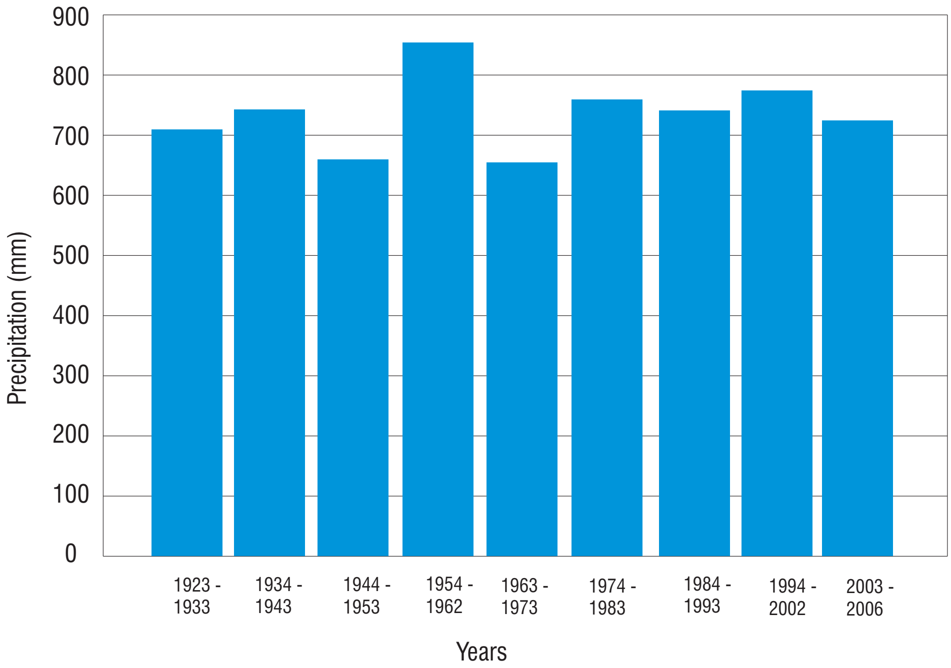


Figure 16: Precipitation trend in Lesotho from 1923 to 2006.

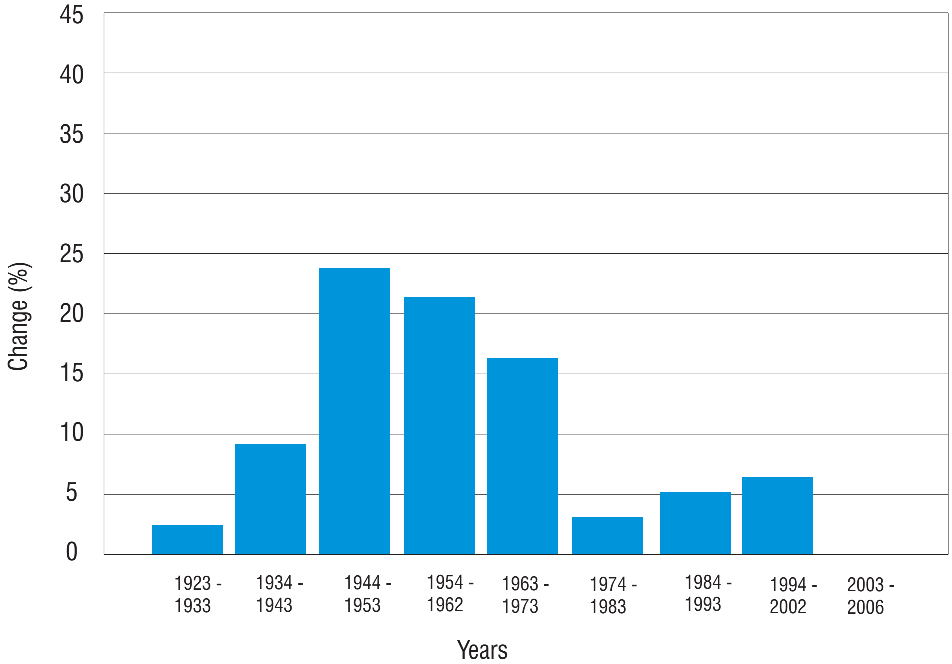


Figure 17: Percentage change of precipitation over years in Lesotho (1923 – 2006).

5. Policy Issues

Climate Change Adaptation Policy Issues Relevance to Lesotho: Opportunities to the Machobane Farming System

Lesotho is heavily influenced by a variety of competing weather systems because of its high elevation (1388-3482m above sea level). In accordance with Article 4 of the United Nations Framework Convention on Climatic Change (UNFCC), these conditions indicate Lesotho is highly vulnerable to climate change. The country is already experiencing the growing impact of global warming as seen from the increasing frequency of natural disasters, droughts, and emerging signs of progressive desertification, fragile characteristics of its soil and terrain, erratic climatic conditions including changing patterns in rainfall periods and the risk of shorter growing seasons. In Lesotho, more than 80% of the family livelihood comes from subsistence agriculture. In order to either take full advantage of new opportunities and potential that may come with climate changes, or avert human sufferings that may be associated with its adverse effect, more robust national coordinated, mitigative and/ or adaptive agricultural development policies should be in place to support indigenous farming systems based on the following policy research questions:

i) What are the perceived causes of poor crop production by households?
ii) What are the physicochemical characteristics of both MfS and non-Machobane Farming System soils from the different agro-ecological zones of Lesotho?
iii) What are the soil microbiota as soil fertility indicator from both MfS and non-Machobane Farming System soils from the different agro-ecological zones of Lesotho?
iv) What information is available on current traditional pest control practices

including important pest list and type of crop diseases in the major cropping zones of the country?

v) How do the basic field agronomic features, cropping practices, and meteorological data within the study area relate to each other?

6. Summary

More than 66% of the respondents in this study of which 51% were male and 49% female, were found to practice the Machobane Farming System. Of the respondents not practicing the Machobane Farming System, , a greater proportion (56%) were female l.

The study compared the Machobane Farming system (MfS) to other conservation farming practices in focus group discussions with farmers where it was observed that the farming systems resemble each other in terms of yield. However, the application of MfS to large scale farming requires more work and a lot of inputs such as animal dung, ash and a special planter. Majority of farmers consider the MfS as the best because of variety of products that it accommodates such as nutrient availability and maintenance of soil moisture. It also involves sustainable crop harvesting cycles throughout the year, which could be a good practice for family food security. In some cases farmers are still practice other farming practices such as the moldboard farming system (MBfS) despite of being aware of the known drawbacks such as lack of soil conservation and the cost involved. The farmers do not switch to other systems because of fear and the risks involved in changing to a new system from the traditionally practiced farming methods; besides, these farmers have not had the opportunity to come together to compare and discuss the advantages of alternative farming systems.

Participants from all areas visited have noticed that climate is changing. Long period of drought, exceptionally heavy rain fall and drought have been noticed by all focus group participants. In the mountain areas of Mantsonyane, they used to experience early frost but, due to climate changes, which they thought could be due to the construction of Mohale dam, such problem is now a bit improved.

However, the eminent shift in planting season has excluded certain crops like peas and beans in the mountain areas. The changing climate has also decreased yield because of poorly developing buds; pest infestation, drought, flooding and hail storms. In the mountain and the foothill villages, Machobane Farming System noticed to be less affected by climate change. Sustenance of fertility from the soil that slowly release nutrients to the farm and conservation of the moisture content in Machobane Farming System made its resilience to climate change noticeable.

In the mountains and foothills, they have been unique and innovative activities by farmers that involve on farm trials which is an ongoing process to establish appropriate crops that can cope with shifting of sawing season. In other agro-ecological zones: low lands, Senqu river valley and the Foothills, farmers have noticed the change in climate by a shift in sawing season, early frost, wet and dry seasons and extremely high temperatures. Too much rain has made weeding impossible.

In the analyses of soil physicochemical characteristics, samples obtained from the Machobane Farming System practicing fields showed a higher composition of Carbon (C) and Nitrogen (N) compounds compared to the non-Machobane Farming practicing soils, which is also with high lime rate requirements. Soil fertility indicator microbiota analyses on the other hand indicates that the total count of both Bacillus spp and Nitrogen Fixing (NF) bacteria found to be higher between (1.96 x 105 - 5.4 x 105 cells/ml) in Machobane Farming practicing soils compared to the non-Machobane Farming. Soils rich in nutrients and carbon sources, not only increase number of microbial population, but also diversity of microorganisms. An increase in number could also be associated with the ability of the Bacillus spp to fix nitrogen in nitrogen deficient soils and has an overall ameliorative effect to the soil pH (Cummings, 2005). Significant differences were observed in soil pH improvement in some Machobane Farming System practicing soils, which could be important criteria for sustainable use of such a farming practice to the benefit of subsistence farmers and is an environmentally friendly practice. The availability of humus (organic material) in the Machobane Farming System soils on the other hand serves as a very good source of carbon, which favor and energize the Nitrogen Fixing microorganisms including Bacillus spp in their nitrogen fixing activity and an increase in number. As most of soil Bacillus spp are endospore producing bacteria, they are tolerant to heat, desiccation and ultra –violet radiation so are able to survive for longer period of time in the soil. The Bacillus spp are also known for their migration to the aerial parts of the plant for the mediation of disease suppression activity.

From the overall trend of precipitation over years (1923 – 2006), the amount of rain and percentage change in Lesotho showed that the highest precipitation was recorded between 1954 and 1962 and this fluctuated irregularly as from 1963 to 2006. Results of the decadal change in rainfall were highest for periods of 1944 to 1953 and this trend decreased successively over years between 1974 and 1983. The lowest precipitation change was recorded between 2003 and 2006.

7. Challenges

Challenges to the Machobane Farming System

7.1 Resource limitation

As a guide principle to the Machobane Farming System, the practice involves the application of animal manure and plant ash as important elements to increase soil fertility. The availability of animal manure for some is difficult unless donated from external sources.

7.2 Competition over land

Livestock presents one of the biggest challenge for the MfS farmers. There is endless competition over land for grazing and land for farming. Basotho are very close to their animals, but there is problem with management of grazing. People stop cultivating because their fields are being grazed by other people's livestock. The Research and Science Development Agency (RSDA) cannot do much itself to improve the situation, but a new land tenure system probably could. Changes have been discussed for years, but the new government does seem set on reform. Meanwhile lack of ownership keeps people from making substantial investments in the land and from taking care of the environment. “Young people will run away from agriculture if there is no profit attachment”.

7.3 Nationwide Policies and Measures

For nationwide dissemination of the Machobane indigenous farming technology, there should be a centrally administered sector specific mitigative and/ or adaptive policy to support activities throughout the nation. As part of its initiative, the Machobane Agricultural Development Foundation has unique opportunity and duty to work for increased success of the Machobane Farming System.

8. Conclusion & The Way Forward

Lesotho has experienced the growing impact of global warming, as seen by the increasing frequency of natural disasters, droughts, and emerging signs of progressive desertification, fragile characteristics of its soil and terrain, erratic climatic conditions including changing patterns in rainfall periods and the risk of shorter growing seasons, growing levels of poverty, and the relative deprivation of the inaccessible mountain region which makes up more than 60% of the country.

In order to either take full advantage of new opportunities and potential that may come with climate changes, or avert human sufferings that may be associated with its adverse effect, more robust national coordinated mitigative and adaptive development policies should be in place for the best advantage of the poor.

More effort has to be done with strength towards improvement of productivity by way of several traditional and technological practices such as crop rotation, crop diversification and intercropping, good and sustainable irrigation practices, use of improved seed, traditional and integrated pest management practices, a shift in sawing season, the use of animal manure and ash are some of the good agricultural practices to be applied sustainably. Farmers' participatory discussions and soil samples analyses from Machobane and non-Machobane Farming Systems prevailed the potential of Machobane Faming System in ameliorating soil quality at all times throughout the year.

8.1 Empowering the mountain people

Empowering geographically isolated people such as mountain dwellers who lack support from central administration and technical advice is crucial to enable them take part in decision making activities within the local government administration. Recently introduced local government policies could be advantageous for mountain people. The NGOs and other organizations should take advantage of this policy and train the people in the mountain, the farmers, in administration and self-government, field farming practices, range land use and livestock production so that they can develop strategies that come from and are for the mountain communities.

8.2 Agricultural Policy development

There is a need to boost government commitment in terms of budget allocation to the agricultural sector. The Government must commit to allocating at least 10% of the national budgetary resources to agricultural sectors. Lesotho has only managed to allocate around 3% annually towards meeting the target set in the Maputo Declaration on Agriculture and Food Security (IRIN, 2009). Another promising approach to boosting crop production and combat climate change impacts is to embrace the introduction and implementation of innovative indigenous farming technologies such as the Machobane Farming System (MfS) as it has been verified and supported by some technical approaches. The MfS has more adaptive and resilient properties with the application of traditional and technological inputs to produce diverse crops throughout the year in the given plot/farm with several harvesting cycles. It is more economical and environmentally friendly that restores the soil fertility and improves crop production in quality and quantity.

To disseminate the knowledge to needy communities in the region, it's proposed that multi-faceted experience sharing program combining workshops, visitations to model farming systems in Lesotho, networking and distribution of the training manual and relevant literature material be promoted by concerned national and regional bodies. Such an approach is believed to play an important role in bringing a shift in social attitudes towards the improvement of farming systems in crop production.

8.3 NGOs, Regional and International Agencies

NGOs and other international agencies are playing important role in Lesotho of addressing the burning issues connected with poverty alleviation, HIV and AIDS, the management of ecology and the environment, among others. In these efforts, a greater role and concentration will be necessary not just to provide the urgently needed goods and services, but also to assist with the tools and training items to build local capacity and support sustainability. This implies a greater role and visibility for the technical agents and projects of NGOs, bilateral and multilateral agencies in all agro-climatic regions of Lesotho.

8.4 Science and Technology Policy

Biotechnology is one of the 'key technologies' that can benefit society in many ways, for instance by increasing the availability and enhancing the nutritional value of food grains, by eliminating the use of harmful pesticides, facilitating the manufacture of cheaper, safer and more effective drugs, by improving the quality of livestock, by increasing tree cover in the country and by treating material in a safe and eco-friendly manner. These benefits to society can extend to a wide range of sectors, such as Agriculture, Health Care, the Processing Industry and the Environmental Sector (United Nations Educational Scientific and Cultural Organization, 2006).

The Government of Lesotho through the Department of Science and Technology should strive to facilitate the development of biotechnology in the country by erecting high quality infrastructure through the strategy of encouraging research activities, developing human resources and establishing links between research institutions, academia as well as industry, and initiate biotechnology curricula in schools, colleges and the university.

References

Arnalte, L., 2006. A farming system for the mountains, [online]. Available at: web address (http://base.d-p-h.info/es/fiches/dph/fiche-dph-7060.html). [Accessed 29th September, 2010].

Badamchian, J., 1984. Laboratory manual recommended soil test procedures for soils of Lesotho. Ministry of Agriculture, Maseru.

Blake, G. R. and Hartge, K. H., 1986. Bulk density. In Klute A. (Ed). Methods of soil analysis (2nd Ed). Agronomy Monograph 9. ASA and SSSA, Madison WI. PP 363 - 375.

Bureau of Statistics and Planning, 2002. Lesotho Agricultural production survey. Maseru, Livestock report.

Bureau of Statistics and Planning, 2007. Lesotho agricultural situation report (1982-2004). Maseru.

Carlos, R. and Gabor, P., 2005. Biodiversity and Ecophysiology of Yeasts. Springer: Amazon.

Cauley, M., 1986. Benchmark soils of Lesotho: their classification, interpretation, use and management. Office of Soil Survey, Soil Conservation Division Ministry of Agriculture: Maseru.

Colin, H. R., 2002. Bacillus, Springer: Amazon.

Consolidated Appeal Program (CAP), 2007. Lesotho drought flash appeal. Maseru

Cummings, S. P., 2005. The role and future potential of nitrogen fixing bacteria to boost productivity in organic and low-input sustainable farming systems. School of Applied Sciences, (1)1, 1 - 10.

EM-DAT., 2008. The OFDA/CRED International Disaster Database, Université catholique de Louvain: Brussels.

European Forum on Rural Development Cooperation, 2002. Rural development: country report, [online] . Available at: web address (http://www.ruralform.info/en/montpellier_2002). Accessed on the 11th October 2010.

Flannery, R.D., 1977. Erosion phenomenon in Lesotho. Lesotho Agricultural College: Maseru.

Foldes, T., Banhegyi, I., Herpai Z., Varga, L. and Szigeti, J., 2000. Isolation of Bacillus strains from the rhizosphere of cereals and in vitro screening for antagonism against phytopathogenic, food-borne pathogenic and spoilage micro-organisms. Applied Microbiology, 89, 840-846.

Gnanamanickan, S. S., 2003. Biological control of crop diseases. CRC press: Amazon.

Hazell, P and Hadded, L., 2001. Agricultural Research and poverty reduction. A paper presented in food, agriculture and environment discussion, IFPRI: Washington DC.

International Fund for Agricultural Development, 2001. Rural report 2001: the challenge of ending rural poverty. Oxford University Press: Oxford.

Intergovernmental Panel on Climate Change, 2003. Climate Change 2001: impacts, adaptation and vulnerability. GRID-Arendal.

Intergovernmental Panel on Climate Change, 2007. Intergovernmental panel on climate change: synthesis report. Denarau Island, Nadi, Fiji. June 20 – 22, 2007.

Integrated Regional Information Network, 2009. Lesotho: a mountain of challenges, [online]. Available at: web address (http://www.irinnews.org/Report.aspx?ReportId=86910). Accessed 14th May, 2010.

Joo, G. J., Kim, Y. M., Lee, I. J., Song, K. S. and Rhee, I. K., 2004. Growth promotion of red pepper plug seedling and the production of gibberellins by Bacillus cereus, Bacillus macroides and Bacillus pumilus, Biotechnology letters, 26, 487-491.

Kennedy, I, R., Choudhury, A. T., Keeskes, M. L., Roughley, R. J and Hien, N. T. 2005. Non symbiotic bacterial diazotrophs in crop farming systems: can their potential for plant growth promotion be better exploited? Biological Nitrogen Fixation, Sustainable Agriculture and the Environment. 271 - 272.

Klute, A., 1986. Methods of soil analysis. Physical and meneralogycal methods, (2nd Ed). American Society of Agronomy, Madison, WI.

Lesotho Meteorological Services, 2004. Adaptation to Climate Change Technology Needs in Lesotho: Energy and Land Use Change and Forestry.

Machobane, J. J. and Robert, B., 2004. Drive out hunger: the story of J. J. Machobane of Lesotho. Jacana: Johannesburg.

Messner, H. H., 1989. A report on unit equivalents for livestock and their influence on National Carrying Capacity Estimates. Ministry of Agriculture: Maseru.

Ministry of Natural Resources, 2007. Lesotho's National Adaptation Program of Action (NAPA) on climate change. Submitted to the UNFCCC Secretariat.

Pender, J., Gebremedhin, B., Benin, S. and Ehui, S., 2001. Strategies for sustainable agricultural development in the Ethiopian Highlands. American Journal of Agricultural Economics, 83(5), 1231 - 1240.

Philip, D., Barry, S., Webb, P. and Winslow, M., 2007. How do poor people adapt to weather variability and natural disasters today? Human Development Report: Maseru.

Robertson A. F., 1994. Popular scientist: James Jacob Machobane and Mantsa Tlala, African affairs, 93, 99-121.

Soil and Water Conservation and Agro-forestry Program, 2001. Soil and water conservation and agro-forestry project, Lesotho.

Taylor, P., 2008. Lesotho's keyhole gardens: sustainable urban farming that feeds the community. Posted on Mother City Living: living green in Cape Town. [online]. Available at: (http://www.mothercityliving.co.za/20080624/lesothos-keyhole-gardens-how-urban-farming-can-feed-communities/). Accessed on 12 May 2010.

Turner, M. D., 1993. Overstocking the range: a critical analysis of the environmental science of Sahelian Pastoralism, Economic Geography, 69, 402 – 421.

United Nations Educational Scientific and Cultural Organization, 2006. Lesotho science and technology policy. 2006-2011, Stella srl, Trieste, Italy.

United States Agency for International Development, 2007. Adapting to climate variability and change: a guidance manual for development planning, US Agency for International Development, New York.

World Bank, 2001. World Development Report 2000/01 attacking poverty. World Bank, Oxford University Press.

The African Technology Policy Studies Network (ATPS) is a multi-disciplinary network of researchers, private sector actors and policy makers promoting the generation, dissemination, use and mastery of science, technology and innovation (ST&I) for African development, environmental sustainability and global inclusion. ATPS intends to achieve its mandate through research, capacity building and training, science communication/dissemination and sensitization, participatory multi-stakeholder dialogue, knowledge brokerage, and policy advocacy.

African Technology Policy Studies Network
Contact the Executive Director at
The Chancery, 3rd Floor, Valley Rd.
P O Box 10081, 00100-Nairobi, Kenya
Tel: (254 020) 2714092, 2714168, 2714498, 2723800
Fax: (254 020) 2714028

http://www.atpsnet.org

Science, Technology and Innovation for African Development

ISBN: 978-9966-030-31-3