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

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Abstract

Lesotho is a landlocked country within South Africa with a population of less than 2 million 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 in the late 1950s by Dr Machobane. 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 present the challenges and vulnerability of the farming system.

Key words: Indigenous farming technology, Climate change, Adaptability, Traditional knowledge, Subsistence farming

1. Introduction

Of the many environmental problems facing mankind today, climate change remains 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 System compared to other Non-Machobane Farming Systems were studied at different agro-ecological zones of Lesotho.

The Kingdom of Lesotho is a country located in the southern part of Africa with the land area of 30,355 sq. km and of which 15% of the land was arable by 1977 (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 (Figure 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 AIDS. Lesotho loses around 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 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.

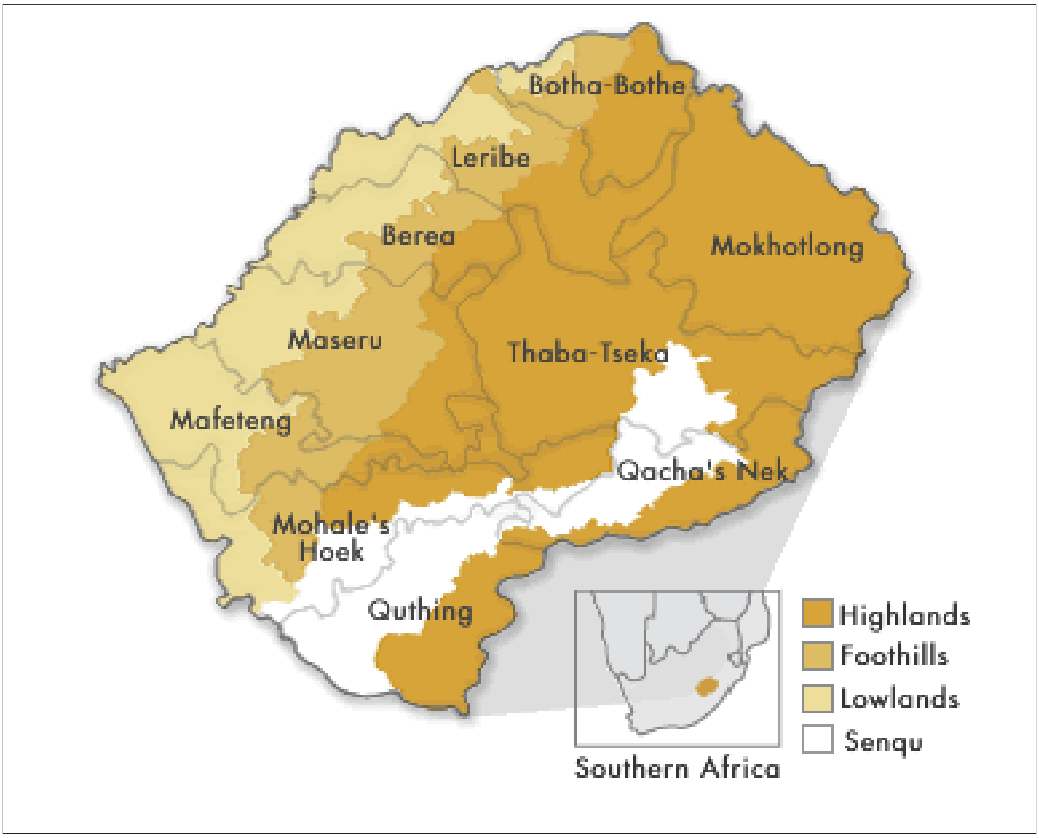

Fig. 1. Agro–ecological zones of Lesotho: the study area.

Naturally, the geographical location and agro-ecology of the country makes it so vulnerable to many effects of climatic changes (BoSP, 2007). 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, consist of very fertile land that is associated with high agricultural productivity. The drainage patterns of the mountain regions have 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. It further underscored that communities living in marginal lands 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 United Nations Framework Convention on Climate Change (UNFCCC) in 2007 and identified technology needs in agriculture because it contributes the most to the national economy and to the livelihoods of majority of the population (Lesotho Meteorological Service, 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.

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.

The Machobane Farming System (MfS) is one of the farming systems in Lesotho with high adaptability and resilience to climate change. The system was developed long time ago by Dr Machobane for its convenient practice and disseminative traditional knowledge to the farmers using natural resources existing around (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.

The present study was therefore designed to evaluate the adaptive and resilience nature of the Machobane Farming System compared to other farming practices to climate change in Lesotho.

2. Literature Review

2.1 Climate change impacts on farming systems in Lesotho

Like in many other developing countries, in Lesotho, more than 80% of the population livelihood relies on subsistence agriculture by raring animals and/or crop farming. Rainfall occurs mainly during the summer season but is extremely variable in quantity and time due to climate change (European Forum on Rural Development Cooperation, 2002).

A shift in precipitation patterns ultimately brings a shift in sawing and harvesting seasons to which unexpected disastrous situations could happen before crops 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 (Ministry of Natural Resources, 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 (EFRDC, 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 dominated. In terms of the area planted, it is dominated by maize (63%) followed by sorghum (28%) and wheat (12%), whereas beans and peas account 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 percent 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 even could be more severe under climate change conditions.

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 homestead pasture lands 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.

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 UNFCCC, 2000, these conditions indicate Lesotho as a country highly vulnerable to climate change.

A prolonged dry spell and high temperatures during the critical period of the 2006/07 cropping season (January – March 2007) resulted in large-scale and irreversible damage to 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 (Emergency Events Database, 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.

2.3 Measures taken by the Government of Lesotho

As a member of the international community, Lesotho ratified the UNFCCC Treaty in 1995. However, there is 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, and are important. Government policies and longer-term development pathways to build the resilience of smallholder farmers (Hazell and Haddad, 2001; Pender et al., 2001), are also urgently required.

2.5 Farming technologies: the Machobane Farming System

2.5.1 Requirements

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 are not available. The farming systems are promoted with the obvious goal of assisting the rural livelihoods, conserving the environment, and generating income. However, their response to climate change impacts, adaptability and resilience property remained a crucial factor for consideration of the farming systems as a best farming practice in the rural livelihood of Lesotho.

The Machobane farming system is an intensive cropping system, using crop rotation, relay cropping, and intercropping practices with the application of manure and plant ash. The farming system was established as a system by Dr. James Machobane, a Mosotho agronomist, who first conceived this “farming system” around 1950s and experimented on his own land for 13 years before attempting to launch it amongst his fellow farmers (Machobane and Robert, 2004). Although he had no formal agricultural training, Mr. Machobane developed a very complex, integrated farming system designed to improve the productivity of small-scale farmers in Lesotho. The following are key features of the Machobane Farming System signifying its basic behavioral and technical requirements to adopt as an agricultural farming system.

2.5.1.1 Behavioral requirements

The behavioral requirements for farmers are:

i) self-reliance; farmers must be convinced that they 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 cucurbits (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:

2.5.1.2 The technical bases

The following are the technical bases that are required in Machobane Farming System to increase productivity.

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.

2.5.1.3 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 (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.

2.5.1.4 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.

2.5.1.5 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 (Fig. 2 and 3). 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.

2.5.1.6 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 (Fig. 2).

Fig. 2. 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 (Fig. 3). After the first batch of potatoes are harvested in December, vegetables such as rape, cabbage, and spinach can be planted.

Fig. 3. Maize intercropping with pumpkin and watermelon: Mountains (Mantsonyane).

2.5.1.7 Crop management practices

2.5.1.7.1 Tillage

Once the crops are in the field, minimum tillage is done using a spade or a hoe. A hand-pushed ripper (Fig. 4) 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.

2.5.1.7.2 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.

Fig. 4. A hand push ripper to open the furrow.

2.5.1.7.3 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.

2.5.1.7.4 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.

2.5.1.7.5 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.

2.5.1.7.6 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 for Sub-Saharan African countries affected by drought and desertification, the International Fund for Agricultural Development (International Fund for Agricultural Development, 2001) helped the government of Lesotho establish the Soil and Water Conservation and Agro-forestry Program (SWaCAP, 2001), as an intervention to encourage conservation based agricultural production practices. 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 (Consolidated Appeal Program, 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 a bit weakened.

3. Objectives

In view of the short-comings noted under the section on literature review, this study focuses on the following seven specific objectives:

i) to identify perceived causes of poor crop production by households;
ii) to determine the physicochemical characteristics of both MfS and non-Machobane Farming System soils from the different agro-ecological zones of Lesotho;
iii) 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;
iv) to collect information on current traditional pest control practices;
v) to develop important pest list and type of crop diseases in the major cropping zones of the country;
vi) to determine and analyze the trend of detailed meteorological data from the nearest stations;
vii) correlating the basic field agronomic features, cropping practices, and meteorological data from the nearest station.

4. Justification

There is a greater need to practice more robust farming systems in Lesotho and elsewhere around the globe considering the increased climate change impacts. Under the circumstances, farmers need to explore alternative systems such as planting crops like sorghum, which are more resistant to changing weather patterns, instead of maize. Nevertheless, there has to be a fundamental and revolutionary change in the way that agriculture is practiced. Improved farming practices like crop rotation, and the more novel concept of conservation agriculture - which minimizes soil disturbance, applies more precise timing for planting, and utilizes crop residue to retain moisture and enrich the soil - would need to be widely promoted (IRIN, 2009).

There is a need to boost government commitment in terms of budget allocation to the agricultural sector. In 2003 the Southern African Development Community leaders met in Maputo (Mozambique) and committed to allocating at least 10% of their national budgetary resources to agricultural sectors, but Lesotho has only managed allocating around 3% annually towards meeting the target set in the Maputo Declaration on Agriculture and Food Security (IRIN, 2009). An alternative promising approach to boosting crop production and combating climate change impacts embraces the introduction and implementation of innovative indigenous farming technologies such as the MfS.

In general, the Machobane Farming System 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. 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.

5. Research Questions

On the basis of the objectives, the following are the research questions whose answers are sought in this study.

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?

v). What are the important pest list and type of crop diseases in the major cropping zones of the country?

vi). What are the characteristics of the meteorological information within the study area?

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

6. Characteristics of the Study Area

The study area is situated at an elevation of between 1,500 and 3,482 m above sea level. It is divided into four agro-ecological zones (Figure 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 and with the highest population pressure (Bureau of Statistics and Planning, 2007).

The lowlands areas are significantly drier and crop failure from drought is very common. The northern and central lowlands of the study area are also 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 consist of very fertile land that is associated with high agricultural productivity. The soils of the Senqu River valley on the other hand remained the most unproductive in the region (Cauley, 1986).

Rainfall occurs mainly during the summer season but is extremely variable in quantity and time due to climate changes. Lesotho usually receives 85% of its annual rainfall between the months of October and March. The mountains and foothills usually receive higher rainfall and may favor the animal farming. The cropping season is much shorter due to the early outset of frost. The 30-year average rainfall distribution reportedly shown to decrease (57%) in September 2006, the beginning of the planting season, and decreased dramatically during February and March 2007 (EM-DAT, 2008).

Currently, there are six farming systems practiced in Lesotho, namely: block farming (IRIN, 2009), mono-cropping (traditional farming), conservation farming

(SWaCAP, 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 are not available. The farming systems are promoted with the obvious goal of assisting the rural livelihoods, conserving the environment, and generating income. However, their response to climate change impacts, adaptability and resilience property remained a crucial factor for consideration of the farming systems as a best farming practice in the rural livelihood of Lesotho.

The Machobane Farming System (MfS) is one of the farming systems in Lesotho with high adaptability and resilience to climate change. It was developed long time ago by Dr Machobane for its convenient practice and disseminative traditional knowledge to the farmers using natural resources that existing around.

7. Research Methodology

7.1 Fieldwork data collection and preliminary analysis

For fieldwork data gathering, informally structured questionnaires were used for interviewing people in the four agro-ecological zones (Fig. 1). Selection of households for interview was made based on their activities and experience in cultivation of crops.

7.1.1 Objective (i) - (iii): Focus Group Discussion

From each of the agro-ecological zones visited, 10 – 12 members of the community were selected to form a discussion group. The selection criteria for the participating farmers were based on their active participation in the farming activity and recommendation from the Extension Department, 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-ecological zones of the study area in Lesotho.

7.1.2 Soil sample collection

Undisturbed soil samples were collected from five districts [ThabaTseka-Mants'onyane (Mountain), Leribe-Pitseng (Wet lowland), Buthat Bothe (Foot hill), Quthing (Senqu River valley) and Mohale's Hoek (Dry lowland) of the four agro-ecological zones in Lesotho (Fig. 1). 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 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.

7.2 Laboratory work and data preliminary analysis

7.2.1 Objective (iv): Soil physico-chemical analysis

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 P, exchangeable cations and micro-nutrients, soil pH and cation exchange capacity were determined using the method described by (Badamchian, 1984).

7.2.2 Objective (v): Soil microbiota analysis

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 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 by Foldes et al. (2000) and Kennedy et al. (2004), respectively.

7.3 Objective (vi) and (vii): Meteorological data analysis

Metrological data mainly of rainfall and temperature were collected from Lesotho Metrological Service (LMS) that covers over a long period of time between 1800s and 2000s. Data was analyzed using SAS statistical package as described in 3.3.

7.4 Statistical analyses

Summary statistics – CV, standard errors, skewness etc. were used to summarize all soil data collected. Student t-tests were 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. 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. For all laboratory soil tests, the mean separation analyses were conducted using SAS Version 8 by Duncan's Multiple Range test at $P<0.05$.

8. Results

8.1 Fieldwork Data and Preliminary Analysis

8.1.1 Focus Group Discussion

During the discussion time, different types of farming systems were mentioned and their uses were thoroughly discussed. Different farming systems practiced in different areas were visited by the team members.

8.1.2 Objective (i) - (iii): Comparison between farming systems

When Machobane Farming System (MfS) was compared to conservation farming the focus group observed that they were the same in terms of yield. However, in the application of MfS to large scale farming system they also observed that MfS require more work as compared to other farming systems like conservation farming system and moldboard plowing. It was also observed that MfS was labor intensive and required a lot of input such as animal dung, ash and a special planter.

Majority of farmers consider the MfS the best because of variety of products that it accommodates. Although the farmers are aware of the known drawbacks of the moldboard farming system (MBfS), such as lack of soil conservation and the cost involved, they still practice it because of fear of risk in changing to a new system as against the traditionally practiced method and they have never come together to compare and discuss the advantages of available farming systems.

Participants also mentioned the reason for quitting MfS was not due to other motivation provided by others, but it was mainly due to lack of training given on its principles. They also mentioned that other systems which offer practical training attracted farmers, especially the once provided by proponents of the keyhole garden. In general, participants have rated MfS and Key hole garden the best methods, but have also mentioned that the scale over which these methods are applied is limited; hence the reluctance to practice these methods on a large scale.

8.1.3 Community understandings of climate change and their adaptation strategy

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 mountainous area of Mantsonyane, farmers used to experience early frost but, due to climate changes, which some 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. Too much rain has made weeding impossible.

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 mountains and the foothills villages Machobane Farming System noticed to be less affected by a climate change. Sustainance 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.

8.1.4 Adaptation strategies made by the communities to environmental changes

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 moisture. 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:

- Plowing 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.

8.1.5 Future Measures (Collective Measures) to be implemented

Education and guidance of farmers by Government and Non-government to facilitate the use of organic farming through Machobane Farming System (MfS) and Conservation Farming was viewed to be an important future policy direction to adapt to changing climate conditions. Community based discussion forum to seek solutions to impacts of climate change was also considered an important milestone towards building adaptive measures towards climate change. Supply of special seeds that would resist drought and disease by government and NGOs has been viewed as another approach to overcome the problems imposed by climate change.

8.2 Objective (iv): Soil physicochemical analysis:

8.2.1 Soil texture

Silt and clay contents of the soil were found to be the most important fractions of soil texture. The silt and the clay contents of the soil determine the nutrient retention capacity of the soil. These sites can be grouped into two categories those with silt contents of > 40% (i.e. PMfS, PNMfS & TNMfS) and those with silt contents < 30% silt contents (i.e. MHNMfS, QNMfS, QMfS, TMfS, MHMfS, BBMfS & BBNMfS). The sand content from all sites tested can be grouped into three classes: those with sand contents >50% (i.e. MHMfS, BBMfS & 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).

8.2.2 Soil pH

Generally, the soil pH can be grouped into two classes. Those with pH >6.0 (i.e. TNMfS, QNMfS, MHMfS, MHNMfS, TMfS & QMfS) and those with pH < 5.0 (i.e. PNMfS, BBMfS, BBNMfS & PMfS). These sites had significantly different levels of acidity & alkalinity.

8.2.3 Organic Carbon

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

8.2.4 Available Phosphorus (P)

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

8.2.5 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 (i.e. PNMfS, BBMfS, BBNMfS & TNMfS) and those with lime rates < 10,000kg/ha (MHNMfS, QNMfS, MHMfS, TMfS, QMfS & PMfS).

8.3 Objective (v): Soil microbiology analysis

In soil microbiology analyses, the total count of both Bacillus spp and Nitrogen Fixing Bacteria (NfB) found to be higher between (1.96 x 105 - 5.4 x 105 cells/ml) in almost all Machobane Farming System practicing plots (Fig. 5 and 6). 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 as in nitrogen deficient soils (Colin, 2002) and has an over all ameliorative effect to the soil.

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 to be efficient and increase in number. Bacillus spp as they 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 (Gnanamanickan, 2003).

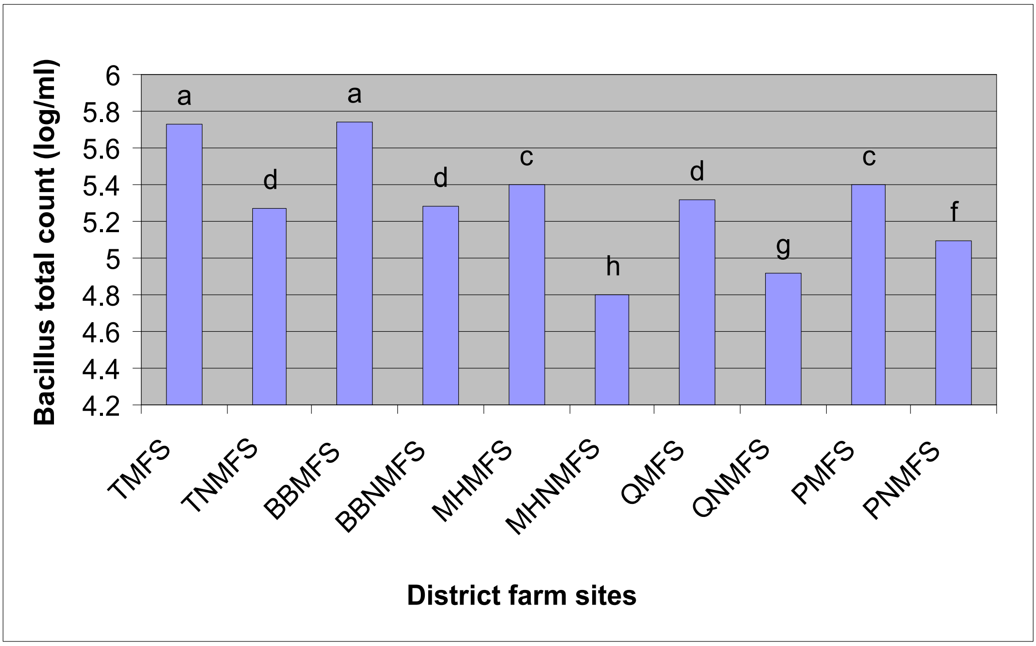

Fig. 5. Total Bacillus count. Mean with the same letter are not significantly different by Duncan grouping at (P<0.05).

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.

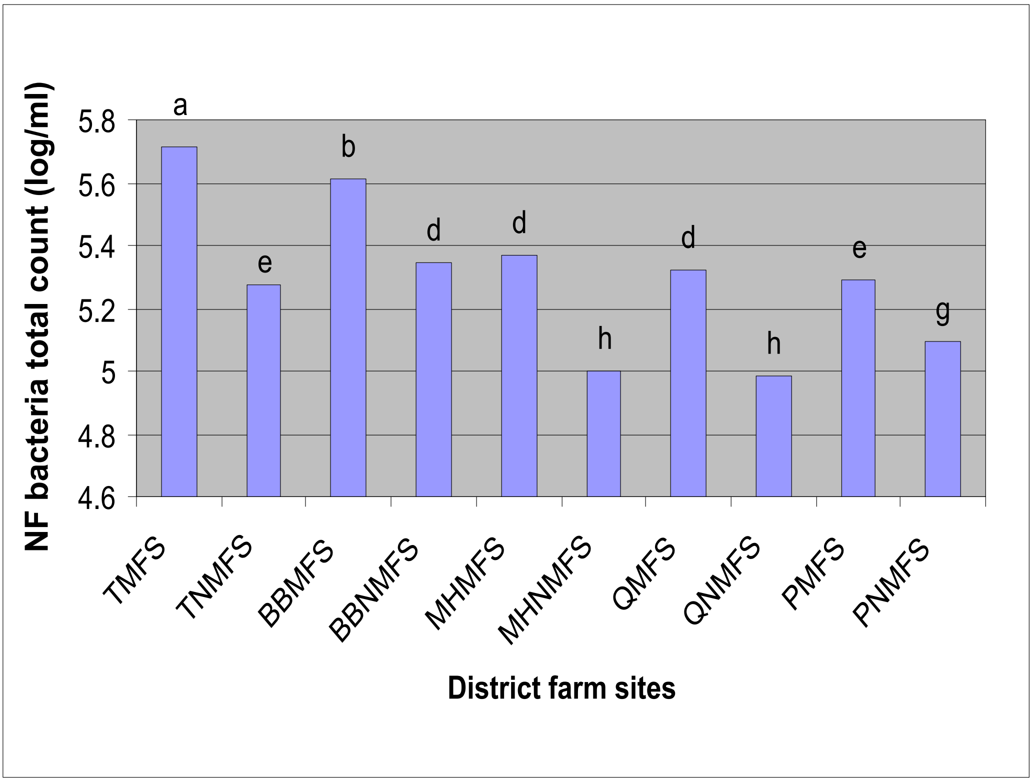

Fig. 6. Total Nitrogen Fixing Bacteria (NfB) count. Mean with the same letter are not significantly different by Duncan grouping at ($P<0.05$).

8.4 Objective (vi) & (vii): Metrological data analysis

The amount of precipitation and percentage change over years (1923 – 2006) in Lesotho is depicted in Fig. 7 and 8 below. The highest precipitation was recorded between 1954 and 1962 and this fluctuated irregularly as from 1963 to 2006 (Fig. 7 and 8). 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. 8).

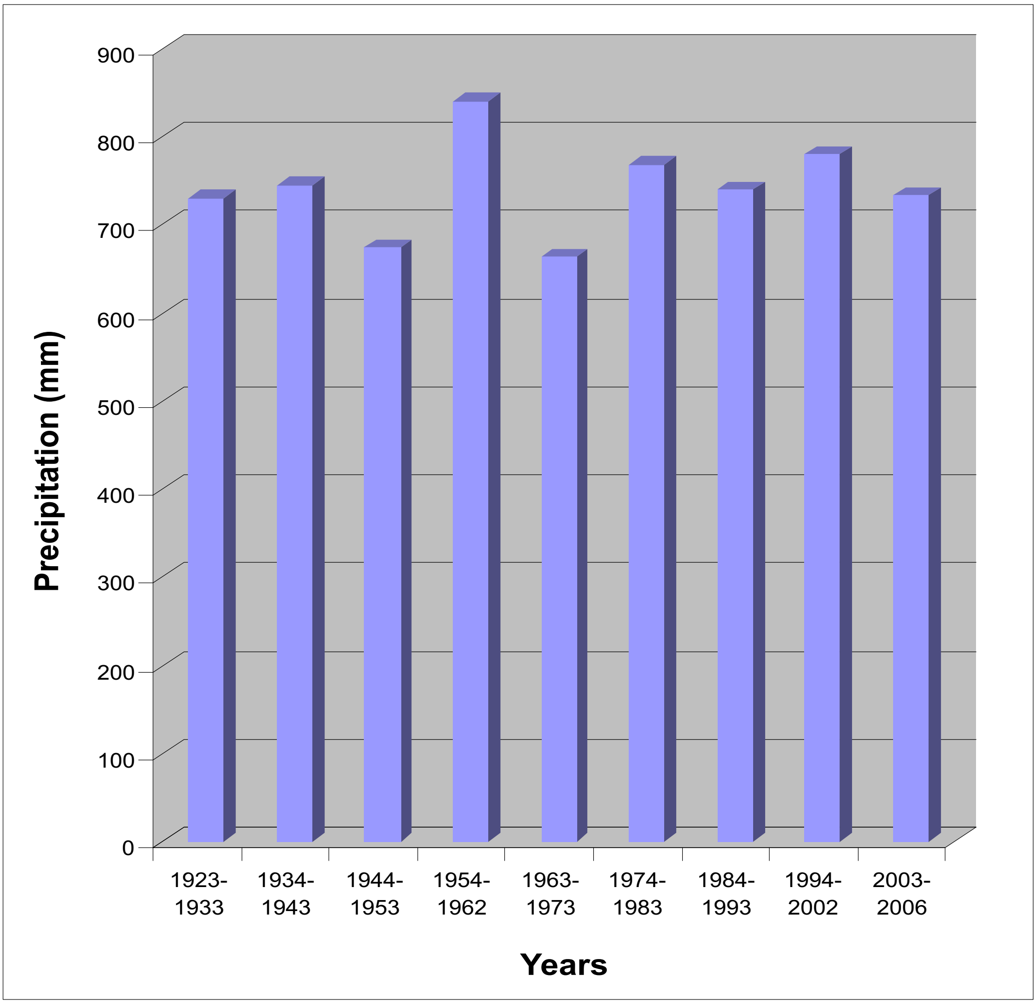

Fig. 7. Precipitation trend in Lesotho over years (1923 – 2006).

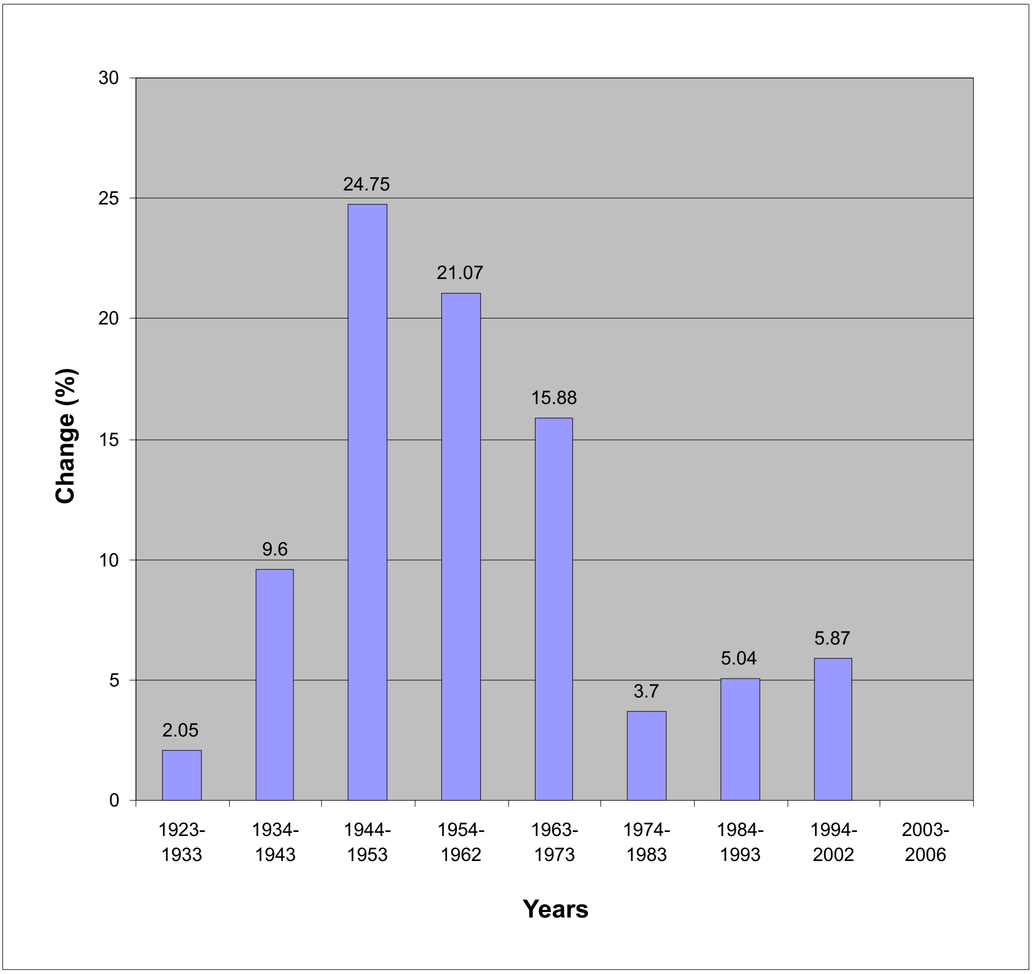

Fig. 8. Percentage change of precipitation over years in Lesotho (1923 – 2006).

9. Conclusions & Recommendations

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 improved outcomes for the poor. It is known that Lesotho has one of the most advanced soil conservation programs in Africa that involve terracing, grass stripping, and the construction of dams and irrigation canals to cope with the severe erosion problems. However, 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 sowing season, the use of animal manure and ash are some of the good agricultural practices to be applied sustainably.

9.1 Empowering mountain people to take part in local government

People living in the mountains are less supported from central administrative and technical advice because of their geographical isolation. Empowering them to take part in the local government is crucial. 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, range land use and livestock production so that they will develop strategies that come from and are for the mountain communities.

9.2 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&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 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.

9.3 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. By embracing biotechnology, implementation of developmental goals towards alleviation of poverty, food security, and improving human health and job creation is possible.

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