

Green Biotechnology

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— Editors —

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Preface

Biotechnology is a broad area and its development is dependent on relationship with various disciplines of science. The term “Biotechnology” derives from three Greek words: *bios* - life; *techno* – technology and *logos* - thinking. There exist a vast variety of definitions of Biotechnology. Presumably the most general one is given by the United Nations Convention on Biological Diversity, 1992, which states that “Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.” Biotechnology has diverse applications. From producing food to designing baby, biotech today is considered as million dollar industry. Today industry and researchers use biotechnology as a tool in their process to a greater extent in a diverse manner.

This diversity has, in turn, brought about the need for a system to classify biotechnology uses based on common features or final purpose. As a result, nowadays there exist **five** main groups in biotechnological applications, which have been identified by a color system.

Red Biotechnology brings together all those biotechnology uses connected to medicine which includes producing vaccines and antibiotics, developing new drugs, molecular diagnostics techniques, regenerative therapies and the development of genetic engineering to cure diseases through genetic manipulation. It also includes reproductive technologies.

White Biotechnology comprises all the biotechnology uses related to industrial processes - that is why it is also called “industrial biotechnology”. It includes the use of microorganisms in chemicals production, the design and production of new materials for daily use (plastics, textiles, etc.) and the development of new sustainable energy resources such as biofuels.

Green Biotechnology is focused on agriculture as working field. It includes creating hybrid varieties, new plant varieties and transgenic plants of agricultural interest using modern biotechnology, producing biofertilizers and biopesticides etc.

Purple Biotechnology deals with different domains of Intellectual Property such as Patents, Trademarks, Copyrights and Geographical Indications. It is connected with inventions and trade in biotechnology, especially in an economically globalised scenario, where technology transfers by way of intellectual property protection is now part of global trade.

Blue Biotechnology is based on the exploitation of aquatic and marine resources to create products and applications of industrial interest. Sea has covered $\frac{3}{4}$ of the planet where diversity of sea creatures is enormous. The researcher has explored a huge portion of the ocean and a lot of species, yet many mysteries are waiting to be discovered.

The present book on the topic "**Green Biotechnology**" aimed at finding out the issues and challenges in plant and agriculture field and how they can be addressed. The contributions were invited from the people involved in plant and agriculture field as well as people involved in regulatory framework of issues pertaining to plant and agriculture biotechnology. The articles have covered the substantive matter from India and abroad. We believe that this edited book will be useful not only to scientific community but also to others who are involved in policy making.

Editors

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Chapter 18

Climate Change Impacts on Crop Production and Smallholder Farmer Livelihoods in Limpopo Province, Northern South Africa

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ABSTRACT

Climate change and variability directly influences the food supply and livelihoods of billions of people, particularly smallholder farmers who depend on climate-sensitive rain-fed agriculture. This study investigated the impacts of climate change on crop production and smallholder farmer's livelihoods in Mopane and Vhembe districts, Limpopo province, South Africa. Hundred and fifty questionnaires were administered to smallholder farmers who were subsistence farmers who produced for household consumption and only seldom sold; those who were farming for both household consumption and selling the surplus; and those who were mainly selling referred to as 'food producers' because their primary goal was to produce for the market. Eight focus group discussions were conducted for further probing. Transect walks were done with a small group of farmers to triangulate the above mentioned tools. The study findings highlighted that most smallholder farmers especially women (64 per cent), regarded crop production as a way of life. The effect of climate change among farmers have been experienced through decline of productivity compromising food security and livelihood options of farmer's as 73 per cent depend on the income generated from sales of agricultural produce. The findings also highlighted that smallholder subsistence farmers perceived prolonged droughts (56.4 per cent) as the main shock stressing crop production. They also indicated that droughts often lead to low crop yield and high crop failure (73.3 per cent). In response to the prevailing climatic conditions, smallholder farmers

used their indigenous knowledge as it was regarded as accessible and available based on trust, convenience, cost effectiveness and reliability. However, there is a need to consider integration of indigenous knowledge system-based, climate-smart agricultural approaches and interventions with scientifically derived information to empower subsistence farmers with adequate adaptive capacity to better respond to climatic challenges.

Keywords: Smallholder farmers, Climate change, Food security, Livelihood, Climate-smart.

Introduction

In many parts of Africa, the current climate is already marginal with respect to precipitation and further warming in semi-arid areas and it's likely to be devastating to agriculture (8). Climate may change more rapidly than expected and is projected to have complex, long term effects on the environment. According to (13) climate change brings about substantial losses especially to smallholder farmers whose main source of livelihood is derived from agriculture.

Due to their socio-economic position, smallholder farmers are among the most disadvantaged and vulnerable groups affected by climate change and variability (2). Smallholder farmers in the southern African region are set to be most affected by these climate variations due to poor access to information, access to technology and dependency on climate sensitive agriculture (18, 20, and 21). Therefore, the impact of climate change and variability threatens and weakens the already vulnerable smallholder farmers whose main source of livelihood is rain fed agriculture.

According to (13) smallholder agriculture is the engine of rural economic growth and the main source of most smallholder farmers' livelihoods. (11) Estimates that there are about 500 million smallholder farms in the world; in Asia and sub-Saharan Africa smallholder farmers produce up to 80 per cent of the food consumed and support up to two billion people. However, global climate change has increased vulnerability leading to poverty and human food insecurity. According to (8) in South Africa the agricultural sector contributes 3.4 per cent to the Gross Domestic Product (GDP) and employs 30 per cent of the labour force, and for the third quarter of 2010 Primary agriculture contributed about 3 per cent to the GDP of South Africa whose nominal value was estimated at R667 billion (4). Regardless of the great contribution agriculture to the economy, it could be greatly affected by climate related disasters such as erratic rainfalls, floods and extended dry seasons.

In South Africa rural smallholder farmers are vulnerable to climate change and according to (10),(5) and (19), it is expected to increase food insecurities and worsen the poverty status among rural communities, affecting all four dimensions of food security, which are food availability, accessibility, utilization and stability, as well as livelihood assets. As indicated by (13), smallholder farmers' production systems are directly threatened by the increasing temperatures that cause heat stress on plants, reducing water availability and lowering overall productivity.

The changing climate poses a negative impact on overall productivity; soil fertility due to the very hot temperatures accompanied by dry winds leading to

erosion, wilting of plants and poor production (7). The (9) highlighted that soil is very vital for the provision of nutrients for plant growth, carbon storage as well as the regulation of water cycle. The increase in temperature and changing of precipitation patterns negatively affects soil quality which results in loss of soil organic matter. This action negatively affects the soil fertility as rising of air temperatures are likely to speed-up the natural decomposition of organic matter and increase the rates of other soil processes (1). (8), also highlighted that yields could fall quite dramatically in the absence of adaptation measures. This degrades soils which are critical for crop production subsequently compromise food quantity and quality. Majority of smallholder farmers in rural areas have no or primary level education, therefore it is difficult for them access information on new technologies on soil management (6). These farmers mostly practice mono-cropping, which is disadvantageous as it degrades soils even more. Climate change has also impacted on the erratic rainfalls in South Africa and Limpopo is no different to the effects with the current drought the country is facing.

The Limpopo province in South Africa is relatively dry with an annual average rainfall of 400mm (15). The (15) highlighted that in Limpopo province, drought is a very serious problem as the province is semi-arid area with low and erratic rainfall. The impact of low rainfall in this region has resulted in loss of livestock, shortage of drinking water, low yields and shortage of seeds for subsequent cultivation. The loss of these natural assets among smallholder farmers minimize their ability to cope with the climatic changes, hence they are vulnerable to climate change. The (6) highlighted that increasing temperatures in South Africa may support expansion of the borders of vector and water borne diseases (*e.g.* malaria and cholera), and that climate change may also potentially trigger new and emerging infection epidemics and environmental toxins caused by disruptions to human well-being and to agricultural and natural ecosystems. It is for these reasons that the mitigation and adaptation to climate change should be given attention.

In various South African rural areas, smallholder farmers are generally found in remote areas, making it difficult to reach because roads are either in poor condition or non-existent. Smallholder farmers' adaptation to climate change at a local level faces poor infrastructure as part of the main challenges due to erratic rains causing floods, destroying buildings, eroding roads and bridges. As a result, there is long transportation time with high costs, due to inadequate transport infrastructure. According to (16) transportation of produce to the markets on time is one of the key constraints for smallholder farmers in rural areas. This therefore, results in loss of quality and late delivery to the markets, leading to produce being sold at lower prices or rejected, so, this means a lack of sustainable income for the smallholder farmers, which affects their livelihoods as well as their food security (3).

According to (14) the negative impacts of climate change can be significantly reduced through adaptation strategies. Therefore, there is a need for investments to improve agricultural productivity under the risk of climate change. This paper investigates the impacts of climate change on crop production and smallholder farmer's livelihoods in Mopane and Vhembe districts, Limpopo province, South Africa.

Materials and Methods

Description of the Study Area

The study was conducted in Limpopo province, Northern South Africa, within two district municipalities namely Mopani (23.31670 S, 30.71670 E) and Vhembe (22.93330 S, 30.46670E) (Figure 18.1). The Mopani District is situated in the North eastern part of the Limpopo Province covering an area of about 25 344, 13 km² in the province, with farming as the second largest employer in the district. However, this district is characterized by low rainfall (between 400mm to 900mm per year), resulting in limited water resources causing severe water shortages and regular drought conditions particularly in the lower-lying areas of the district. Vhembe district is located in a semi-arid area that is frequently affected by dry spells, often growing into severe drought.

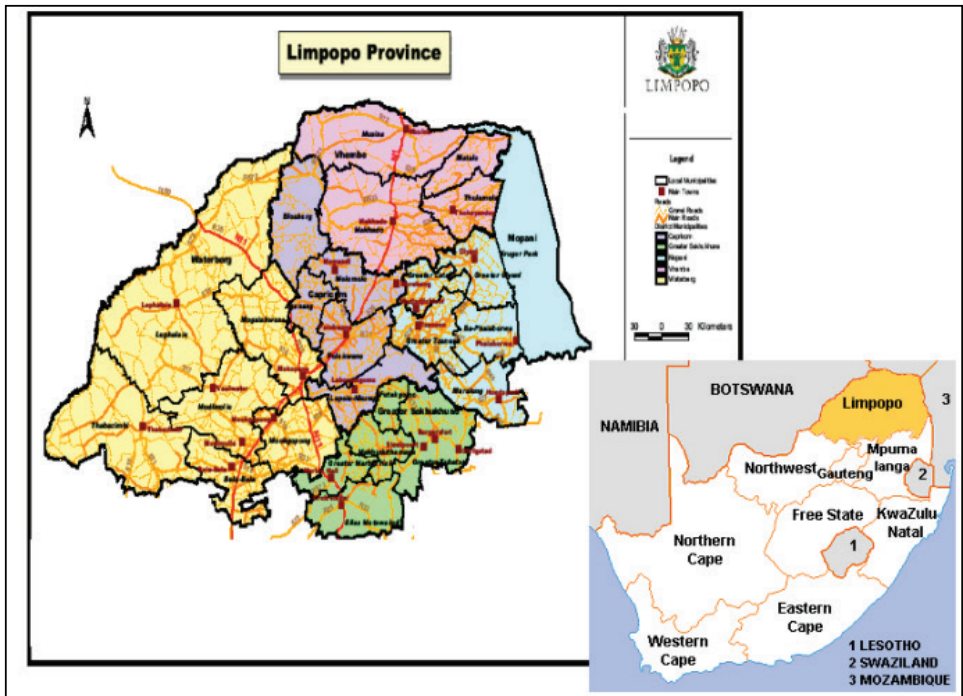


Figure 18.1: Location Map of the Study Area, Limpopo Province.

The district is the most northern district of Limpopo province with a rainfall pattern ranging between 246mm to 681mm per annum. Vhembe district covers an area of about 25 592 km² which is predominantly rural, with a population size of about 1, 294,722 people. As reported by the (15) the two district municipalities were the most vulnerable to climate change experiencing extreme climatic risk as well as high climate variability in the province.

Data Collection

Both qualitative and quantitative methods were used to collect data in the study. The quantitative research method was used to compare responses across the participants since they were asked identical questions in the same order to allow for significant comparison of responses across participants. On the other hand, the qualitative research method was used to seek understanding of the farmer's perspective or situation by regarding the participants as experts of their situation. This methodology was found appropriate for this study because the study aimed to find meaningful answers and experiences of farmers with regards to the impacts of climate change on crop production and variability on smallholder farmer's livelihoods and food security

A representative population of 150 smallholder farmers in Mopani and Vhembe districts participated in this study. The local extension officer of each local municipality provided a list of households and the smallholder farmers were randomly selected from each local municipality. The extension worker selected every fifth household in their area for administering the questionnaire. Focus group discussions as well as transect walk participants were also selected to be representative of the youths, women, and elderly and cheer leaders in both communities.

Data Analysis

A Statistical Package for Social Sciences (SPSS) version 23.0, Microsoft excel 2010 statistical package and STATA version 8 were used for questionnaire data analysis. Focus group discussions and secondary data were analyzed through content analysis by identifying themes, concept, patterns and trends.

Results and discussions

Negative Effects of Climate Change

The study findings highlights that the majority of individuals involved in rural agriculture were women (64 per cent) and they regarded crop production as a way of life, compared to 36 per cent men. These findings confirm the stereotype denoting agriculture as an activity for women, due to their perceived roles as custodians of families while men are usually involved in other cash-based activities to secure the livelihoods. Most of the farmers had income of \$100 or less per month mainly from farming 73 per cent (Table 18.1).

Farmers observed climatic and non-climatic shocks caused by climate change. According to the respondents 65 per cent of female farmers had no idea about the climate change concept. They were the most vulnerable group as they reported to have experienced very severe losses of agricultural based food over the past 10 years (54 per cent) whereas the losses for male farmers were moderately severe 46 per cent (Table 18.2).

Table 18.1: Household Source of Income

		Gender	
		Male	Female
Total household income Per month (\$)	Below 50	19	16
	51–100	52	64
	101–200	20	11
	Above 200	9	9
Source of income	Pension	58	
	Farming	73	
	Part-time job	5	
	Remittances	1	
	Social grant	13	
Total per cent of the different gender		36	64

Table 18.2: Loss of Crop Production Due to Climate Change

		Gender	
		Male	Female
Have you ever heard about climate change?	Yes	56	35
	No	44	65
How severe has the crop loss been over the past 10 years?	Very Severe	52	54
	Moderately severe	46	38
	Not severe	2	7
Total per cent of the different gender		36	64

The study findings revealed that different type of farmers had experienced different climatic shocks over the past ten years. Prolonged droughts were observed to have increased (51.3 per cent) as well as very hot seasons. About 5.3 per cent of the farmers observed increase in floods, and of them majority were subsistence farmers (7.4 per cent), with only 4 per cent of the farmers stated not to have observed any climatic changes (Table 18.3).

Table 18.3: Climatic Shocks Observed by Smallholder Farmers

Type of farmers	Floods	Prolonged Droughts	Very Hot Seasons	Haven't Observed Any Changes
Subsistence	7.4 per cent	56.4 per cent	29.8 per cent	6.4 per cent
Selling and consumption	0 per cent	44 per cent	56 per cent	0 per cent
Food producers	3.2 per cent	41.9 per cent	54.8 per cent	0 per cent

The respondents also highlighted the negative effects climate change had on the socio-economic aspect, emotional status as well as their food and nutrition security status (Table 18.4).

Table 18.4: Negative Effects of Climate Change on Limpopo's Smallholder Farmers

<i>Theme</i>	<i>Concept</i>	<i>Quotes</i>
Socio-economic effect on crop production	Declining crop yields	"Our production yield have dropped, so we experience food insecurities"
	Water scarcity	"there is no rain, hence no water, no crops"
	New pest and disease	"We keep on losing crops due to new pests such as aphid attacks"
Emotional effect	Loss of Hope	"We keep on losing our crops"
	Fear	"If these prolonged droughts persist and there's no rain, we are afraid wedie will of hunger and food insecurity"
	Helpless	"The issue of climate change is beyond our control, there's nothing we can do"
Food and nutrition security status	Food availability and access compromised	"We have not planted because there are no rains"
		"Last year we did not plant we were waiting for rains, and we suffered"

Discussions

Household Source of Income

The study findings confirm the (15) report that agriculture in Limpopo is viewed as a cornerstone of the rural economy because most farmers generate their livelihoods from it. In this study, agriculture was the main diversification strategy used by the farmers to complement their household income. The findings indicate that agricultural income was the major stabiliser and buffer of the household economic status (Table 18.1). As a result for these agriculture dependent vulnerable groups, any exposure to risks and minor changes in climate can have disastrous impacts to their household food security status and poses imbalances in livelihoods.

Loss of Crop Production Due to Climate Change

These findings are in agreement with previous studies that indicated that, in rural Limpopo the concept of '*climate change*' was virtually unknown among farmers (17). Although the concept of '*climate change*' was unknown, the farmers had their own understanding and some observations noted on what was happening (Table 18.2). According to the farmers the so called '*climate change*' was a day-to-day weather occurrence, that was observed through prolonged droughts and a significant decline in crop production due to lack of water. Therefore, there is also a need of weather stations (rain gauges) in the fields of these smallholder farmers communities as this will help them keep track of rain received yearly.

Climatic Shocks Observed by Smallholder Farmers

Smallholder farmers in the study areas were exposed to a number of shocks and stresses that affects their livelihoods. The farmers highlighted that they have been experiencing prolonged droughts, heat waves, increased dry seasons and reduced rainfall seasons which led to frequent livestock deaths, human disease outbreaks, crop failure, reduced yield and food insecurities over the past 10 years (Table 18.3). This was also highlighted by the key informants of the local municipalities.

Subsistence farmers perceived prolonged droughts (56.4 per cent) as the main shock stressing their production whilst other farmers were of the opinion very hot seasons were the significant shock (56 per cent). To further confirm these findings, during the conduct of the research, observations were made that the subsistence farmers had not planted anything because there were no signs of rain in areas such as Tzaneen and Maruleng.

Negative Effects of Climate Change on Limpopo's Smallholder Farmers

The focus group discussions held with the respondents highlighted that the climate change effects had a negative effect on the socio-economic aspects of the smallholder agricultural production, their emotional status as well as their food and nutrition status (Table 18.4).

As mentioned by the smallholder farmers the climate change over the past few years has resulted in prolonged droughts, reduced rainfall and very high temperatures which resulted in low crop yields. The smallholder farmers stated that lack of water for irrigation was another major challenge so the negative changes in rainfall patterns affected their livelihoods, because they end up delaying their planting seasons in anticipating for rainfall until it is too late in the season to plant. These findings support the (15) that Limpopo province has been experiencing extreme droughts, heat waves and reduced rainfall. These negative climatic effects compromise the well-being of the farmers as they experience food shortages.

As the respondents experienced erratic temperature changes and unpredictable rainfall they observed new pest and disease invasions. The "aphid attacks" of cabbage was one of the troublesome pests. Similar results were highlighted by (13) that smallholder farmers' production systems are directly threatened by the increasing temperatures that cause heat stress on plants, reducing water availability, lowering overall productivity and introducing new pests and diseases. According to the report by the (12) the invasion of crops by pests and diseases were caused by the rising temperatures and changes in precipitation patterns. Therefore, the increasing temperatures result in great loss of smallholder farmers' crop production. As some farmers highlighted during the FGDs even their indigenous ways of controlling pests seemed to be less effective, subsequently the new invasions infer some economic demands and unfortunately their knowledge seems to be limited on how to manage and control the pests (aphid attacks).

The negative effects of climate change have been seen to also affect the farmers emotionally. The prolonged droughts resulted in some of the farmers losing hope since they lost almost everything the previous year and it was still hard for them

to recover from the loss. The farmers highlighted that they were aware of their vulnerability status towards climate as they are highly exposed to the negative impact of climate change mainly rainfall shortages (drought). The farmers also stated that they are now more confused and living in fear, as they are not sure whether to continue farming or not, since there is less rain due to prolonged droughts. These farmers greatest fear is that the agricultural sector is the driver of their well-being, so they are bothered as unfavourable weather threatens their food security status and limits their livelihood options.

The focus group discussions revealed the smallholder farmer's willingness to progress and to adopt strategies that will mitigate the climatic stresses and threats. However they feel like the situation is beyond their control, thus feeling helpless since their indigenous knowledge which is cost-effective and most accessible seems to be outdated.

Conclusions and Recommendations

This study investigated the impacts of climate change on crop production and smallholder farmer's livelihoods in Mopane and Vhembe districts, Limpopo province, South Africa. The results of this study showed that in Mopani and Vhembe district municipalities agriculture is the back-bone and the primary source of the smallholder farmers' livelihoods. The study revealed that smallholder farmers in these municipalities were categorized in three groups: subsistence farmers who produced for household consumption and only sold seldom; then those who were farming for both household consumption and selling the surplus; and those who were referring to themselves as '*food producers*' because their primary goal was to sell to the market. However, the majority of smallholder farmers were not aware of climate change. Subsistence farmers more especially women were found to be the most vulnerable to climate change due to their high dependency on rainfall for their farming and lack of flexibility to employ different adaptation strategies.

Smallholder farmers were affected by prolonged droughts, reduced rainfall and invasion of new pests and diseases such as aphid attacks. In order to counter these effects, the majority of smallholder farmers in Mopani and parts of Vhembe relied on their indigenous knowledge for their farming practices since most of them suffered a serious lack of climate information that would help them adapt.

Therefore, there is need to bring awareness of the implications of climate change and to consider integration of indigenous knowledge system-based, climate-smart agricultural approaches and interventions with scientifically derived information to empower subsistence farmers with adequate adaptive capacity to better respond to climatic challenges.

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