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Swedish University of Agricultural Sciences

Faculty of Landscape Architecture, Horticulture and Crop Production Science

Future yield performance of ZS265 and ZS263 maize varieties and information dissemination for adaptation to climate change.

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Foreword

The reality of the agro-ecosystems status in developing countries dawned on me during my experience working as a farm manager in the rural regions of Zimbabwe after I had completed my university degree in Algeria where I was exposed to a diverse world of intensive farming. In Zimbabwe I saw a different face of agriculture, I was exposed to the inequalities that exist in the farming systems; gender issues, livelihoods challenges and the unpredictability of climate through drought and floods and a host of other elements. These inequalities and challenges made me realise that the knowledge I had acquired in my bachelor's degree was not going to enable me to achieve my goal of being a major player in the rural agricultural development sector in Zimbabwe. This inspired me to want to further my studies and equip myself further with skills to successfully tackle rural poverty and elevate the livelihoods of people through innovations that can be adapted by small holder farmers (who make the highest portion of farmers in the world) with minimal needs for economic capital.

In my quest for self-betterment, I enrolled for the Agroecology Master's programme. In the two years I was on the programme I have acquired a new thinking perspective and a more holistic approach to farming systems. I feel that it is critical to have a holistic mind-set, to be able to contribute ideas that culminate and effectively disseminate crucial innovations to rural communities. In the process, keeping in mind the economic, social and natural dimensions of agro-ecosystems, their linkages and feedbacks. With this mindset, solutions are designed with consideration of effects both positive and negative in a three-dimensional format and along the food value chain. The case studies and farm visits during the master's study period have also broadened my thinking and acceptance of feasibility in application of agroecological principles from conservation tillage in large scale farms over a thousand hectares to success case studies of small scale farms such as that of the Stora Fårvallsslätten in Sweden and Rancho Ebenezer in Nicaragua.

I have developed holistic thinking capacities, gained more environmental awareness, learnt agroecological principles and a handful of tools that measure sustainability indicators such as the SAFA tool (Sustainability Assessment of Food and Agriculture systems), MASC tool (Multi Assessment of Cropping System) and the Life Cycle Assessment tool (LCA). At the end of my master's studies, I yearned to acquire a deeper understanding of the resilience and sustainability in time of agricultural innovations and technologies with this research study. It is my hope that it contributes to resilience building and sustainable agricultural development in the Zimbabwean maize cropping system, as we not only aim to develop new technologies for farmers but as researchers we also aim to develop technologies that will sustain productive agricultural systems through time. I also hope to leave a positive mark for having made successful contributions to the Zimbabwe Agroeconomy.

Sweden, November 2017

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First and foremost, my utmost gratitude goes to Dr G. Carlsson and Dr E.S. Jensen who supported me through the processes that enabled me to finish my master's degree program at the Swedish University of Agriculture, Alnarp. I will always be indebted to my supervisors, Dr G. Carlsson, Dr S. Spendrup and Dr D. Parsons who provided constructive advice, support and guidance during the whole period of academic research. I also extend my gratitude to Mr Parsons who was very patient and tireless in teaching me how to use the APSIM crop model, but was also very supportive in the process of simulations which helped me to finish my thesis on time. I have gained skills in yield forecasting, a key asset to my professional being. My gratitude also goes to the management of the department of Biosystems and Technology at the Swedish University of Agriculture in Alnarp, for giving me a working space within their facilities that enabled me to rub shoulders with other researchers.

My sincere thanks go to the Crop Breeding Institute (CBI) of Zimbabwe, in particular the Principal Director of the Department of Research and Specialist Services (DR&SS); Mr Sikhosana who granted me permission to base my work on their field research. I am also very conscious of and grateful for all the help from Mr P. Matova, the Chief Maize Breeder at CBI, who facilitated access to information and timeously compiled data for the Drought Tolerant Maize for Africa that I needed for this academic research work.

My deep gratitude also goes to my back-up team, my family, the Mutaviris' for both financial and moral support during my master's program and studies in Sweden. My brother Alex and sister Sekai for their time in proof reading my texts, my sister Nyarai and uncle Muvavi and brother in law Tinashe for their time in conducting questionnaire surveys. Finally, my parents for their prayers and unwavering encouragement during tough times. Final thanks are sent to my friends and classmates Robin, Michal, Johan, Fotue and Monica for finding kind and motivational words when I felt overwhelmed, and Neza who helped me tie all the last pieces together.

Summary

In an effort to design a sustainable maize cropping system in Zimbabwe, attain food security and build resilience against climate change, achievements in crop breeding are evident by the introduction of Drought Tolerant (DT) maize varieties. The study aims to analyze the impact of climate change on DT maize varieties that are characterized to be drought tolerant and yield productive under future climate conditions. The study integrates the social dimension of agroecosystems and sustainability by analyzing challenges faced by the Agricultural Technical and Extension Services (AGRITEX) of Zimbabwe in disseminating information on DT maize to farmers. As resilience building is characterized by the systems' capacities to self-organize and still retain same functions when undergoing stresses, shocks and its ability to increase and build the capacity for learning and adaptation (socio-ecological resilience) (Gibbs, 2009).

To analyze the response of DT maize productivity to climate change, the modelling approach was used. The crop model Agricultural production systems simulator (APSIM) was calibrated and validated with data from the Crop Breeding Institute research site, Makoholi located in the Agro-Ecological zone IV of Zimbabwe. Climate parameters input were based on downscaled RCP 8.5 and RCP 2.6 scenarios of AE zone IV of Zimbabwe. Relative to the baseline climate (1980-2005), in the near future climate (2020 – 2045) a mean annual maximum temperature rise of 6.1°C in RCP 8.5 and 3.3°C in RCP 2.6 was projected. The total growing season rainfall was projected to have higher variability in climate scenario RCP 8.5 and lower variability in climate RCP 2.6. The Root mean square error (RSME) indicated that APSIM could simulate the yield and days to tasselling of the two DT maize varieties for the growing season 2010-2012. Relative to ZS265 the inter-percentile range of yield change of ZS263 by +38%, +16% and +12% in the RCP 8.5, RCP2.6 and the baseline, respectively. A questionnaire survey was distributed to extension workers utilizing both quantitative and qualitative questions. Results obtained from 15 respondents indicated that hindrances and challenges in dissemination of information by AGRITEX on DT maize to farmers as an adaptation strategy was mainly due to financial, financial allocation and institutional (malfunctioning or non-existing communication channels between the research subsystem and their extension subsystem) challenges.

To ensure food security in Zimbabwe in the coming decades under climate change and variability, it is required to find and analyze integrated approaches to implement alongside crop breeding strategies i.e. DT maize varieties, through agroecological crop management practices and principles, and improved social information systems which integrate the different knowledge subsystems in the same level.

Keywords: APSIM, extension worker, drought tolerant, socio-ecological, AGRITEX, resilience.

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List of abbreviations

AGRITEX - Department of Agricultural Technical and Extension Services.

AIAS - African Institute for Agrarian Studies.

AIS – Anthesis to Silking Interval.

APSIM - Agricultural Production Systems simulator.

AR - Assessment Report.

CCA- Climate Change Adaptation.

CCAFS - Climate Change Agriculture and Food Security.

CMIP5 - Coupled Model Inter-comparison Project Phase 5.

DFID - Department of International Development.

DTMA – Drought Tolerant Maize for Africa.

GMB – Grain Marketing Board.

GCM - Global Circulation Model.

FEWS - Famine Early Warning Systems.

FAO - Food and Agriculture Organization.

FSSSA - Forum for Food Security in Southern Africa

IPCC - Intergovernmental Panel on Climate Change.

IPSL-CM5A-LR - Institute Pierre-Simon Laplace.

NASA - National Aeronautics and Space Administration.

MoAMID – Ministry of Agriculture, Mechanization, and Irrigation Development.

RCP - Representative Concentration Pathway.

SAFA - Sustainability Assessment of Food and Agriculture systems.

SSA – Sub- Saharan Africa

WATCH - WATer and global Change.

WFO - World food program.

WFDEI - WATCH Forcing Data ERA-Interim data

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1 Introduction – contextual setting

1.1 Sustainability and Agroecology Concept

Sustainable development is defined by the Food and Agriculture Organization (FAO) (2014), as;

> Sustainable development has been defined by FAO as "*the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*". (FAO Council, 1989).

In line with sustainable development, sustainable agricultural intensification sought out to produce more with less. It is defined by Pretty, and Bharucha, (2014), as the increase in agricultural production per unit land coupled to reduced impact on the environment, while **creating resilience,** maintaining and conserving the ecosystem. Sustainable agriculture applies methods, principles and advances from various agricultural disciplines such as agroecology, precision farming and climate-smart agriculture. Agroecology is defined by Wezel *et al.,* (2009), as a science, movement and practices.

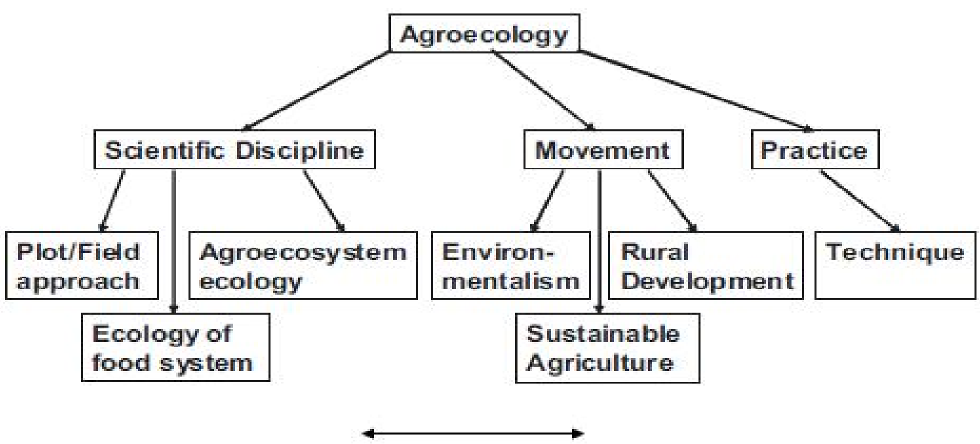

Figure 1: Diversity of current types of meanings of agroecology (Wezel, *et al.*, 2009).

This present thesis is framed and motivated by the concept of agroecology as a science; it's holistic approach to farming systems. It is based on two (social and environmental) of the three pillars of sustainability and agroecology as per the definition of the FAO (2014), above and Francis *et al.*, (2003), respectively. Francis *et al.*, (2003), defines agroecology as "the integrative study of entire food systems encompassing social, economic and ecological dimensions". The study or analysis of whole farming systems is defined by Gamble *et al.,* (1996), as an analysis of the integration and interrelationships of perspectives and components within and outside the farming environment. All together with their connections, the perspective gives the full holistic picture of the system. The external influence perspective[1] will be analyzed in this thesis in twofold; firstly, the environmental influence of climate change on the maize production system of Zimbabwe. And secondly, a brief outlook of the external impact of challenges in the information dissemination system of the cropping system. The general integration and interrelationships of these social and environmental external perspectives will be discussed and linked to the economic betterment of the system through ecological and social resilience principles.

The concept of agroecology as a practice is integrated into the thesis following the definition of agroecology by Gliessman (2015); agroecology is the application of ecological concepts and principles to the design and management of sustainable food systems. Natural selection is the ecological and natural way of plants to adapt to abiotic and biotic changes in nature. In this paper, the science of crop breeding is explored, as it is the human artificial, accelerated and direct version of natural selection. Gliessman (2015:186), urges that physical and biological limiting factors adapted against in agroecosystems are not static, therefore the agroecological perspective and sustainable way in crop breeding is to breed for durable adaptation in crop plants. The stability in time of the resilience to climate change of the newly developed maize varieties in Zimbabwe will be analyzed in this paper by simulating their yield production in the future climate scenarios.

The roots of ecological and sustainable agricultural systems extend beyond the science and practices into the realm of social, governmental, organizational and rural developmental systems, hence Wezel's part definition of agroecology as a movement. Agroecology as a movement encourages the adoption of participatory and action-oriented approaches (Mendez *et al.,* 2013) and, enhancement and taking advantage of local knowledge (Altieri and Nicholls, 2005). This concept of agroecology as a movement is not explored in the methodology of the thesis but only incorporated into the discussions on resilience building

1.2 Zimbabwean Context

Maize is the mainstay of food security in Zimbabwe, while small grains (sorghum, millets) and tubers (sweet potatoes, cassava and yams) play a less significant role in household food security (FFSSA, 2001). The cropping system has been under a series of setbacks in the past years, with maize production reaching an average low of 0,7 ton per hectare at national level in the year 2014 (The world bank, 2015). Figure 1 below demonstrates the annual production of maize in the past 56years, with a drastic and maintained low from the year 2000. This plummet in production is attributed to several factors. Some of these factors, both external and internal factors on the maize cropping system of Zimbabwe are described below based on the four dimensions of the Sustainability Assessment of Food and Agriculture Systems (SAFA tool).

[1] The external influences perspective is an analysis of the climate and socio-economic factors on the farming system (Gamble *et al.,* 1996).

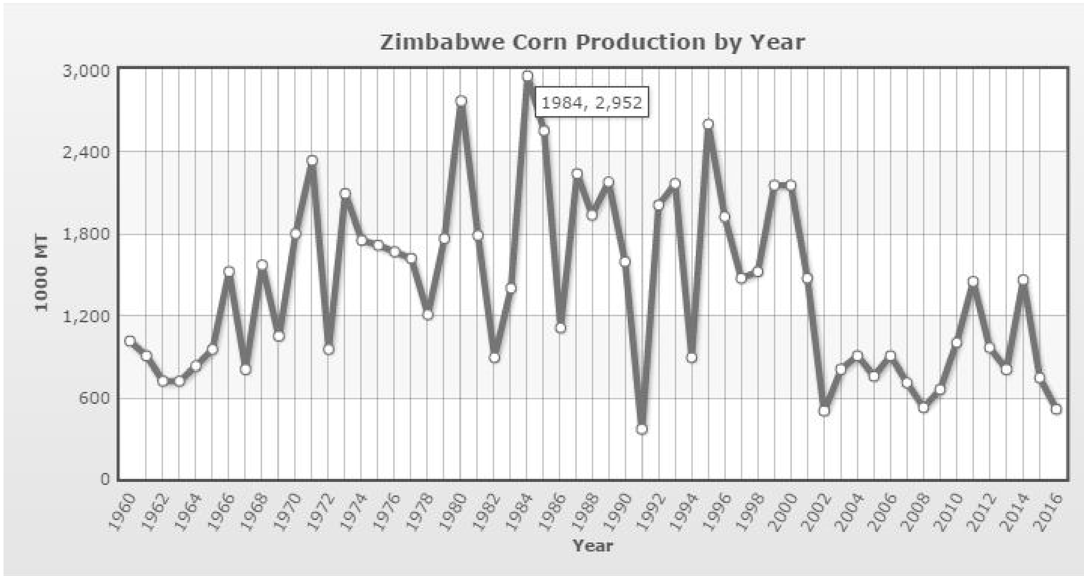

Figure 2: Maize yield production in Zimbabwe from year 1960 to 2016 (Indexmundi, 2017).

Politics and policy perturbations (Governance): Today's Zimbabwean Agricultural Policies are more inclined to supporting tobacco and cotton production leading to an antagonistic effect on the production of the food crops. For example, a 5% export incentive is paid to cotton farmers by the Ministry of Finance. According to the 2017 statistics obtained from the Ministry of Agriculture by the Famine Early Warning Systems network (FEWS, 2017); 17% more farmers have shifted towards tobacco farming and 50% more land has been cropped with cotton as compared to the case in 2016. FEWS (2017), also reports a reduction in cropped area for maize, sorghum and groundnuts by 18%, 23% and 22% respectively below the five-year average.

Economic perturbations: The Zimbabwean government introduced a new grain marketing policy, the statutory Instrument No//235A of July 16, 2001, which gave a monopoly to the Grain Marketing Board (GMB). Due to the parastatal's failure to pay farmers for their delivered produce, farmers slowly diverted from maize production to the more cash lucrative and instant paying tobacco (FFSSA, 2001; AIAS, 2006 and Masukure 2005). In a study by Dekker and Kinsey (2006), 20.6% of the farmers interviewed pointed out that lack of seasonal capital to buy farming inputs as the second largest constraint in their cropping system after erratic rainfall patterns.

Social perturbations: The Forum for Food Security in Southern Africa (FFSSA) (2001), states that farmers lack knowledge, training and appropriate managing skills for crop husbandry, hence, suboptimal yields. Low knowledge input through extension services is indicated and evident in several studies amongst the farmers, leading to suboptimal utilization of fertilizers (FAO, 2006), poor selection of crop varieties relevant to the agro-ecological region (Rurinda *et al.*, 2013) and low efficiency in using accessible farm machinery (FFSSA, 2001).

Environmental (natural) perturbations: Pests are amongst the leading natural perturbations in the Zimbabwean maize cropping system. Migratory pests for example the Fall armyworm

(*Spodoptera frugiperd)* of American origin is stated by the FEWS (2017), to be the cause of up to 10% yield grain losses that were recorded in Southern Africa in 2016. Poor soil fertility is also one of the natural factors affecting maize productivity in Zimbabwe. FAO (2006), states that 70% of the soil texture in Zimbabwe is sandy and acidic also characterized by numerous nutrient deficiencies; namely nitrogen, phosphorous sulfur, magnesium (Mg), potassium (K) and micronutrients such as zinc (Zn). Fertilizers amendments are scarce and expensive due to liquidation of fertilizer companies hence low availability and usage (FEWS, 2017).

Focus of study – As described above, the Zimbabwean maize cropping system faces several perturbations, and these are linked or have a negative effect from other factors within the Zimbabwean agricultural system as whole. The study will only focus on two of these perturbations, namely climate change and lack of information in farmers.

1.3 Thesis outline

Figure 3 below is a summary of the thesis; its approaches and detail per chapter of the thesis.

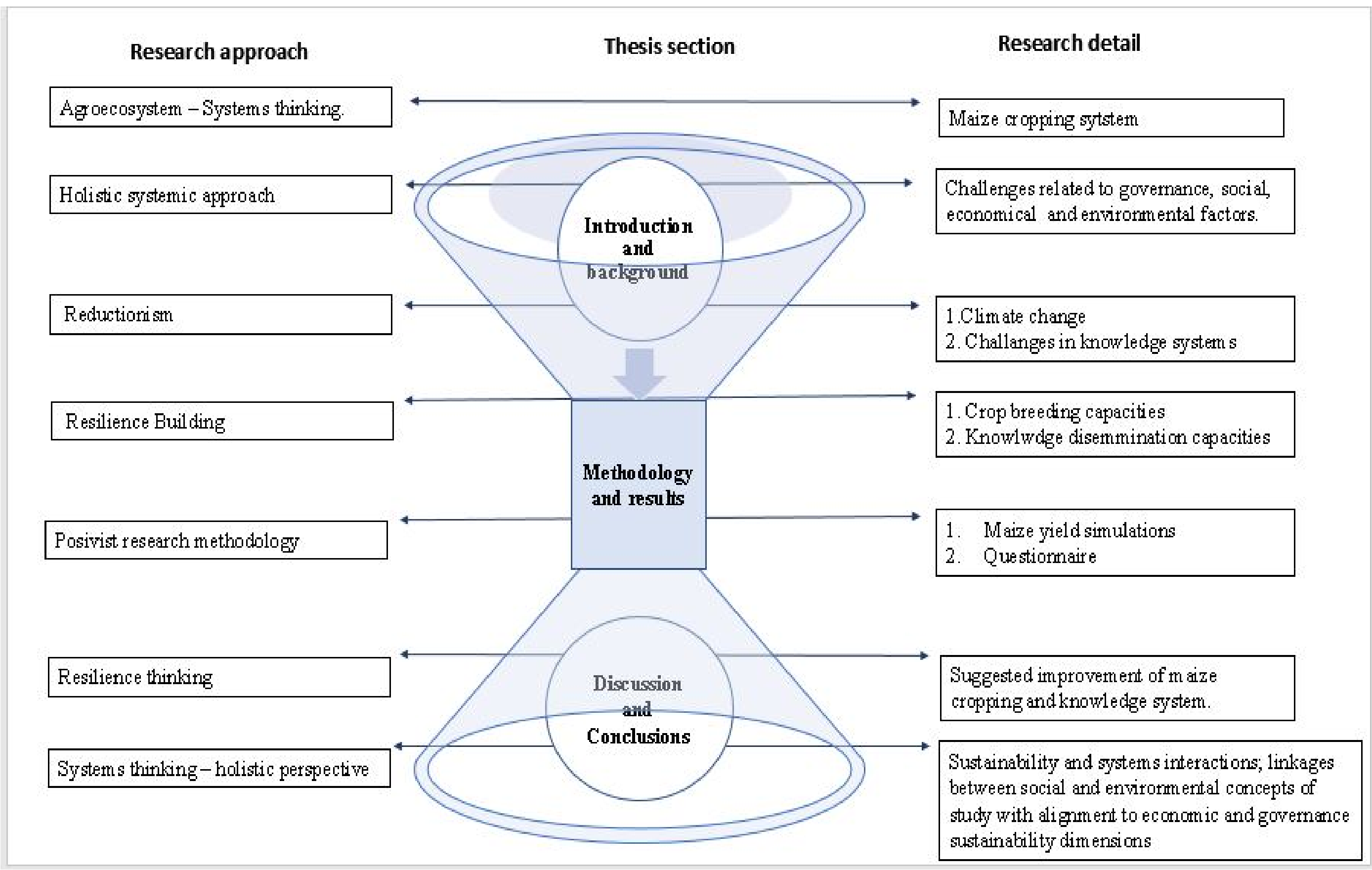

Figure 3: Thesis outline and description (Author, 2017).

2 Problem statement

2.1 Climate change

The importance of climate change as a constraint to farmers in Zimbabwe's is reflected in studies such as that by the African Studies Centre of the Netherlands. The study was carried out across 18 sites in Zimbabwe in 193 small holder farmer households and results revealed that 25,6% and the largest proportion of the 297 constraints mentioned by farmers for the cropping season 2009-2010 was unreliable, erratic, low, late rainfall (Dekker and Kinsey, 2011). Climate change is an external influence perspective named climate and risk /opportunity perspective by Gamble *et al*., (1996), in of the whole farming systems or agro-ecosystem analysis concept. Climate change poses both risk and opportunities to the agro-ecosystems. In the case of maize production in Southern Africa, Rurinda *et al.*, (2015), estimate that responses of maize to the changing climate can be as wide as -40% to +10%. Climate risk is categorized into three categories by Misti *et al.*, (2015), in the baseline report on Economic Development and Climate Change in Zimbabwe.

1. <u>Decline in precipitation</u>

Cairns *et al.*, (2013), state that according to 21 global climate models of the SRES A1B[2] emissions scenario, a decrease in rainfall of -5 % in Southern Africa during the main maize growing seasons is estimated by the year 2100. However, Rurinda *et al.*, (2015), Chikodzi *et al.*, (2013), and Misti *et al.*, (2015), indicate a large uncertainty and spatial variation (variability) in rainfall projections for Southern Africa instead of an average decrease in precipitation. The rainfall variability is stated to be characterized by a change of the onset of the rainy season and an unpredictability of the end of rainy seasons with rainfall periods extending into June and July and sometimes ending much earlier in March. Lastly, a reduced frequency of rainy days coupled with increases in rainfall intensity masking climate change signals as averaged total rainfall across the country will look normal.

2. <u>Increased Temperatures</u>

Over the past period of 1962-2000, the mean daily maximum temperature in Zimbabwe has increased by 0.2°C – 0.5°C per decade and is further projected to increase by 2-4°C by 2100 according to the global projections by the Intergovernmental Panel on Climate Change (IPCC 2013). Lobell *et al*., (2011), reported that each 1 degree increase above 30°C day temperatures reduces maize yield by 1,7% under drought conditions.

3. <u>Increase in Frequency of Extreme Weather Events, Floods and Droughts</u>

Zimbabwe has been experiencing crop losses due to the increased frequency of cyclone induced floods, e.g. Cyclone Eline in 2000, Japheth in 2003, Favio in 2007 and Dineo in 2017. The UNDP (2015), indicates that six of the ten biggest natural disasters between 1991 and 2013 in Zimbabwe

[2] SRES A1B - Special Report on Emissions Scenarios (SRES), a balanced emphasis on all energy sources (A1B).

were caused by drought and furthermore, fourteen countrywide droughts occur bi-annually. In Southern Africa, 40% of the maize growing areas face occasional drought, while 25% face frequent droughts leading to 10-25% and nearly 50% yield losses, respectively (Fisher *et al.*, 2015). Drought is defined by Gitz and Meybeck (2012), as a "prolonged absence or marked deficiency of precipitation". Figure 4 below, illustrates the types of droughts and their impacts over time, from the onset of drought to realization of impacts.

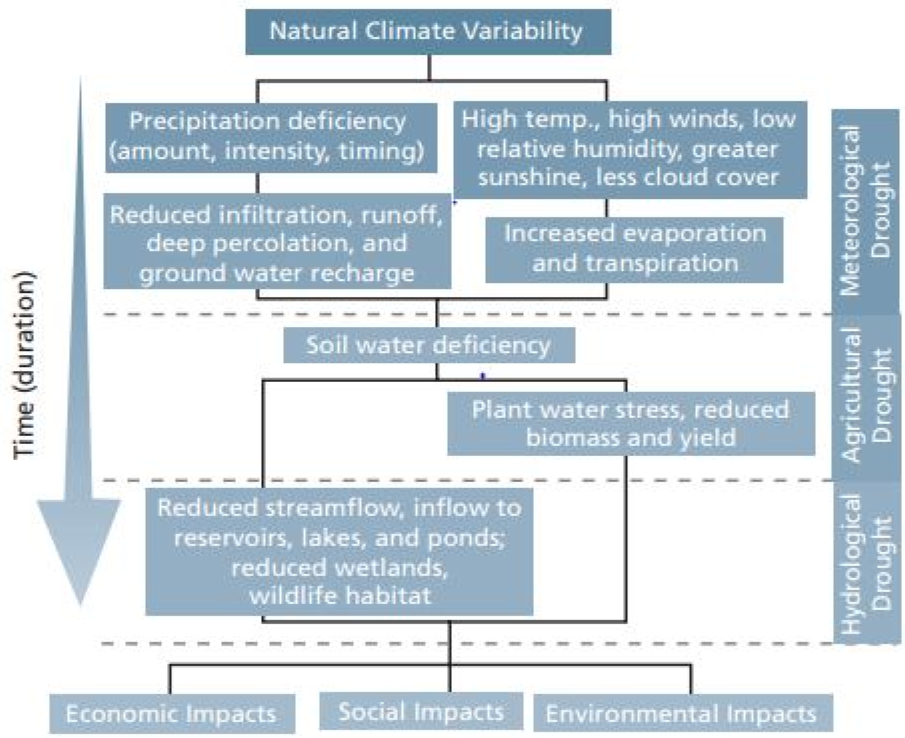

Figure 4: Types of droughts and their impacts over time, from onset of drought to realization of impacts (Ramamasy and Baas,2012).

According to Ramamasy and Baas (2012), the reduction in rainfall for a specified period (meteorological drought) reduces the quantity of soil moisture to meet the needs of a particular crop at a particular time (agricultural drought), which in turn induces biotic water stress. A combination of increased temperatures, frequent droughts and rainfall variability reduces soil water availability for crops, increases evapotranspiration and induces negative bio-physical effects on the crops which then contributes to lower yields. Altin *et al.*, (2012), and Aslam *et al.*, (2015), give estimate losses of maize yield due to drought at various stages of maize for example at;

- Pollination stage - pollen shedding is accelerated, and silking is delayed by drought prevalence for four consecutive days during the pollination stage and this increases the anthesis-silking interval followed by 40–50 % yield losses.

- Grain filling - drought stress during kernel development is responsible for 20–30 % yield losses mainly due to under sized kernels.

Consequently, due to reduced maize yield productivity, climate change presents risk to lives and livelihoods (economic and social impacts) at the individual level and to the economy at the regional and national levels, as food security in Zimbabwe is highly dependent on maize production.

The exposure and sensitivity of a system (e.g. a community) to an environmental change risk (e.g. drought) reflects the likelihood of the system experiencing the particular conditions and the occupancy and livelihood characteristics of the system which influence its sensitivity to such exposure" (Smit and Wandel, 2006).

The shortfalls in maize production have led to food insecurity, for example in the lean season between January and March 2017, 4.1 million people were estimated to be food-insecure because of the El Niño-induced drought (WFP (2017), FEWS (2017)). Given that the country's agro-ecological regions have been shifting over the years, it is of paramount importance to build, implement and adopt adaptation strategies for improved maize productivity under climate change stresses. Much of Zimbabwe is comprised of semi-arid agro-ecological regions IV and V (see table 1 in chapter 5), which are characterized by low and erratic rainfalls and poor soils. According to the UNDP (2015), studies have found that climate change has caused some regional shifts to drier agro-ecological zones IV and V. Findings from a study by Wuta *et al.,* (2015), point to an increase in the size of agro-ecological zones IV and V by 5.6% and 22.5 %, respectively and a decrease by 49 % and 13.9% of agro-ecological zones II and III, respectively, which are the main food producing areas in Zimbabwe. The shifting of the agro-ecological zones boundaries to regions already characterized by low and erratic rainfalls, observed in this study strongly points to evidence of risk due to increased area affected by climate variability, further escalating the climate stresses in maize production and thus problems of food insecurity.

The exposure of the maize cropping system to climate change stresses in a rain fed agricultural system is dire to prevent and yet innovations and strides can be taken to reduce the systems sensitivity to these stresses. These climate adaptation strategies employed by farmers in Zimbabwe include planting short season varieties, dry planting, moisture preserving techniques, and crop diversification to name a few (Muzamhindo *et al.,* 2015).

2.2 Information Dissemination

Agricultural technology transfer depends on a holistic agricultural knowledge system that comprises a research subsystem, the extension subsystem, farmers subsystem and information subsystem. A national agriculture information system ensures that information generated by agricultural agencies, institutions and researchers is collated and made available to a wider audience including farmers through channels which include the extension system.

(Mugwisi, 2013)

In the agroecosystems analysis, agricultural knowledge generated outside the farmers subsystem is considered as external influence perspective, its disposition to farmers influences their decision making and ultimately the development of the farming systems. With the adoption of Drought Tolerant (DT) maize varieties developed in the Drought Tolerant Maize for Africa Project by a researcher's subsystem as the main strategy to building resilience against and adapting to climate change investigated in this study. The effectiveness of the information dissemination to farmers about these new varieties developed for climate change is important. Mugwisi (2013), states that one of the main challenges affecting the adoption of new technologies by farmers is lack of information.

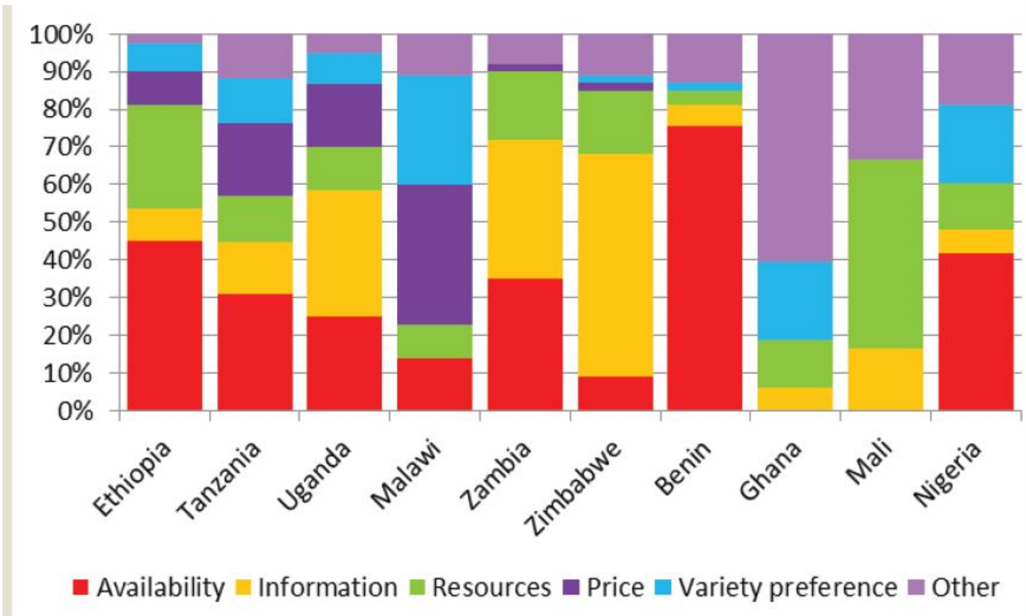

Figure 5: Constraints to adoption of DTMA varieties in selected countries. Constructed by the authors from DTMA surveys in 2013/14 (Fisher *et al.,* (2015).

This section of the social concept of the thesis is based on the results of the research study done by Fisher *et al.,* (2015), on the challenges faced by farmers on the adoption of DT maize in Eastern and Southern Africa. The study was carried out by the Oregon state university, Tanzania agricultural institute and CIMMYT (Kenya, Southern Africa region and Ethiopia), in six countries (Ethiopia, Tanzania, Uganda, Malawi, Zambia and Zimbabwe) and involved measuring the DT maize adoption rates and their determinants. Of the six response choices given (seed availability, information, resources, seed price, seed attributes and other). The results indicated that 59% of the farmers in Zimbabwe lacked information on DT maize and this is the largest factor that hindered the adoption of DT maize (see figure 5). With these results in mind a short literature review was conducted to have insight into challenges in the information dissemination challenges in Zimbabwe.

In the information subsystem of Zimbabwean agriculture information dissemination from the research subsystem is provided to farmers by extension services providers such as public-funded institutions, non-governmental organizations (NGOs), commodity processors, farmers' associations, and private agrochemical input suppliers. This study will focus on the public-funded institute called Agricultural, Technical and Extension Services (AGRITEX), a department under the Ministry of Agriculture, Mechanization & Irrigation Development of Zimbabwe. The flow of information in the communication process to farmers follows four main approaches of the AGRITEX as described by Hunyani-Mlambo (2002), and Mugwisi (2013);

-the use of the Master Farmer training approach,

- the radio listening group approach**,**

-group development areas approach comprising general development interest groups, commodity interest groups,

-the farming systems research and extension approach centered on problem solving, and interdisciplinary, is farmer-oriented and iterative with an emphasis on onsite trials, demonstrations and field days as a way of facilitating linkages among the farmers, researchers and extension workers.

Agriculture extension[3] plays a significant and catalytic role in technologies and improved strategies information transfer process both from researchers to farmers and vis-à-vis. Several studies indicate that when farmers have access to information their tendency to adopt improved strategies is increased. Results from a study in the Chiredzi area of Zimbabwe by Muzamhindo *et al.,* (2015), carried out in 97 households through interviews, indicated that access to extension services positively influenced a household's decision to adapt to climate change and variability. 63.5% of the farmers with access to extension services adopted adaptation strategies, these findings are consistent with findings of other researchers such as Deressa (2009), and Mudzonga (2012), Legesse *et al.,* (2013).

Acknowledging the positive effect to adoption of adaptation strategies yielded by access to extension services it is important to note the challenges faced by the AGRITEX institute hindering this positive outcome. Some of the challenges as indicated by antecedent studies include;

- Financial challenges - According to Hanyani- Mlambo (2000), Zimbabwean government agencies have experienced drastic financial cuts and tight budgeting since 1991 when the government started implementing World Bank and International Monetary Fund (IMF) backed economic reforms. Hanyani-Mlambo (2002), further states that the ever-dwindling operating budget and lack of transport, severely limits the contact of AGRITEX officers with farmers.

[3] Agricultural extension is the process of transferring agricultural information and technology to farmers for use in production and marketing decisions and similarly transferring information from farmers to researchers (Mugwisi, 2013).

- Organisational errors - Bureaucracy and long channels of communication, Lack of self-discipline: few can work without supervision and high staff turnover leaves some projects/programs unfinished (Hunyani – Mlambo, 2002).
- Lagging information between research and extension departments - 94.8% (163 extension officer's responses) pointed to lack of communication between the department of research and that of extension services of the Ministry of Agriculture as a challenge on acquisition of new agricultural knowledge in a study survey carried out by Mugwisi (2013).

2.3 Aim and research question(s)

According to the Resilience framework (see next chapter), when adaptive capacities (DT maize varieties) are input into a system under stress (climate change stress) there exists a range of possible outcomes of the system; from the system bouncing back better to a total collapse. The primary aim of this research study is to predict the productivity in the time dimension of Drought Tolerant (DT) maize varieties released by the Crop Breeding Institute of Zimbabwe through the Drought Tolerance Maize for Africa project. The secondary aim is building on to results and literature of antecedent studies on challenges faced by AGRITEX, the study aims to further apprehend the challenges appraised by AGRITEX in information dissemination of DT maize varieties to farmers in Zimbabwe, as effective information dissemination contributes to higher adoption rates of DT maize. The research overarching question is;

What is the adoption and productivity response of DT maize varieties in the Zimbabwean maize cropping system to climate change?

In an effort to answer the overarching question the research focuses on the following subsidiary questions:

1. In the near future (2020-2045), what is the productivity of ZS263 and ZS265 DT maize varieties in the region IV of the Zimbabwean cropping system under RCP 2.6 and RCP 8.5 climate scenarios?

Three analytical elements of the productivity of ZS263 and ZS265 will be represented in relation to the above question; yield performance impact and comparative yield performance between the short (ZS263) and medium (ZS265) season varieties. The second subsidiary question aims to investigate information transfer in the knowledge system for implementing new DT maize varieties in smallholder agriculture in Zimbabwe:

2. What are the extension workers' perspectives on challenges faced by AGRITEX leading to lack of information on DT maize varieties by farmers?

3 Conceptual framework

The flow of the research was guided using a conceptual framework, which gave guidance to the conduction and direction of the research thesis, and gave clarity of concepts and their relationships within the research thesis. The conceptual framework for this study is based on the basic resilience theory framework of the Department of International Development (DFID) illustrated in the figure 6 below. There exists a more comprehensive Zimbabwean resilience conceptual framework by the United Nations Development Program (UNDP) (see appendices 1), which is inclusive of the absorptive, adaptive and transformative capacities. This was not used for this study as the focus of the study is adaptive capacities.

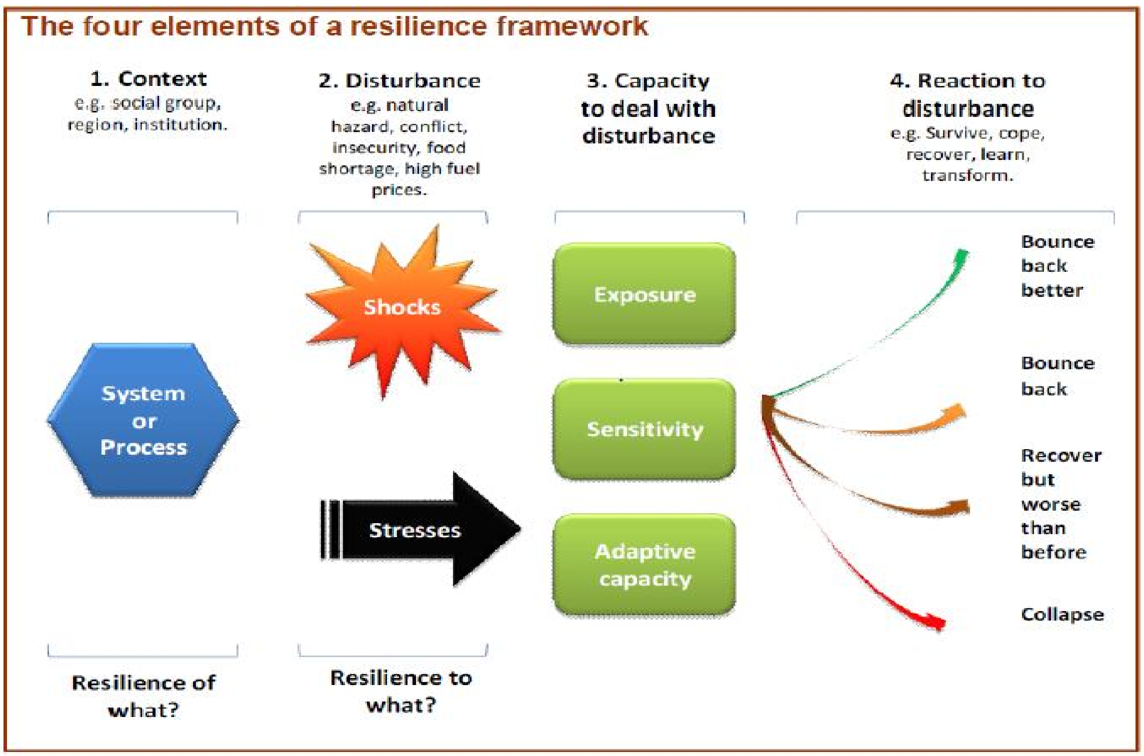

Figure 6. Components of a disaster resilience framework (DFID, 2011).

The four elements of the framework are context, disturbance, adaptive capacity and reaction to disturbance of the system and are described below according to the DFID (2011), and Combaz (2014);

1. **The context:** Whose resilience is being built?
   The context of this study is the socio-ecological resilience of the Zimbabwean maize cropping system. The focus is the resilience of the adaptive capacities of new drought tolerant maize varieties across time and the challenges of adoption of these varieties within the information subsystem of the Zimbabwean agriculture.

2. **The Disturbance**: What shocks (sudden events like conflict or disasters) and/or stresses (long-term trends like resource degradation, or climate change) the group aims to be resilient from?
   The disturbance in question for this study, is climate change. Stresses caused by climate change on the maize cropping system cause vulnerability to the system for example reduction of yield due to drought, heat, shorter growing season and rainfall uncertainties. Gitz and Meybeck (2012), characterize vulnerability as a complex concept that needs to be considered across scales and across various dimensions. The regional scale was used to analyze the drought tolerant maize varieties in Zimbabwe and the national scale was used for identifying challenges of the extension services, these scales respectively cover the ecological and social dimension of the maize cropping system.

3. **The capacity to respond**: What is the ability of a system or process to deal with a shock or stress?
   The response to stresses of a system depends on exposure (the magnitude of the stress), sensitivity (the degree to which a system will be affected), and adaptive capacity. Gitz and Meybeck (2012), state that exposure to stresses due to climate change are hard to control and yet sensitivity can be reduced for example by using drought tolerant varieties. Adaptive capacity allows actors (individuals, communities, regions, governments, organizations or institutions) to anticipate, plan, react to, learn from shocks or stresses and adjust to a disturbance (DFID, 2011).

4. **The reaction**: What is the response to disturbance?
   According to Smit and Wandel (2006), adaptations can be anticipatory or reactive based on their timing. The system has four pathways that it can take as a response to a disturbance, and these are;
   - Bounce back better – the systems' capacities are enhanced, stresses reduced, and future stresses can be dealt with.
   - Bounce back to normal - pre-existing conditions prevail.
   - Recover, but worse than before – reduced capacities of the system.
   - Collapse – fatal reduction of capacities and inability to deal with future disturbances.

The thesis will focus on the third and fourth elements of the resilience framework; where the capacity to respond to climate change for transformational changes is investigated through a study of the challenges of the actors (extension services) to enhance adaptive capacities of farmers adopting drought tolerant maize varieties. The reaction element, is studied through simulations of drought tolerant maize varieties as to how they will respond to future stresses.

4 Social-ecological resilience

Resilience is a pre-condition to sustainability (see figure 7 below). Maleksaeidi & Karami (2013), state that an agroecosystem is deemed sustainable when it is resilient; its social, economic and social dimensions can adapt to the changes, absorb stresses and shocks on the system.

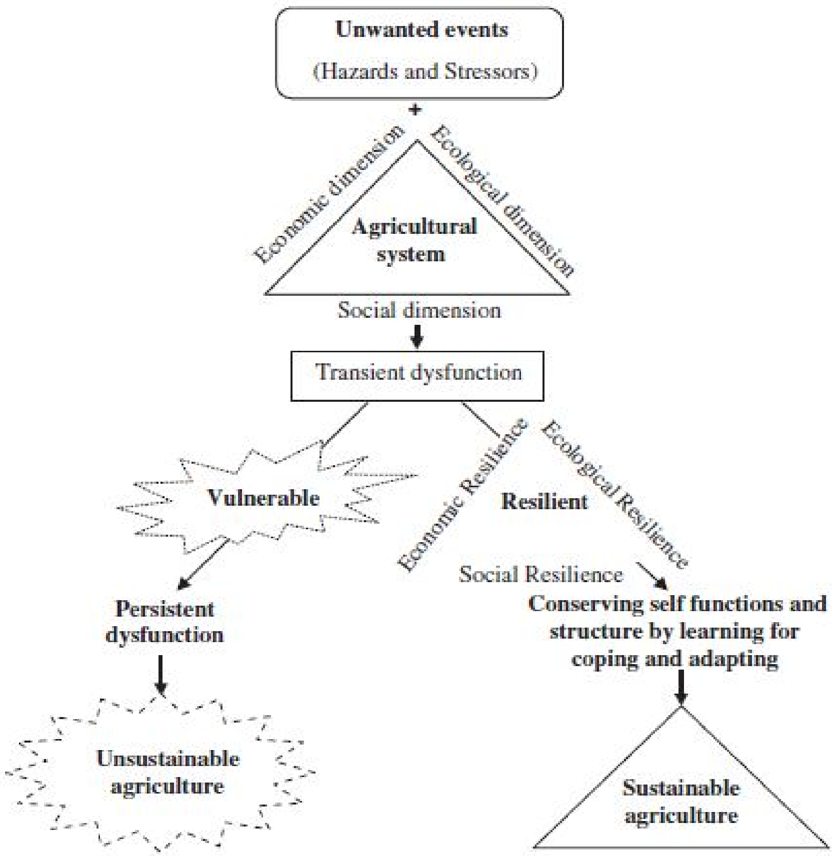

Figure 7: Relationship between sustainable agriculture and social-ecological resilience (Maleksaeidi & Karami, 2013).

The concept of resilience has been continuously developed upon the early definitions such as one by Holling, (1973); resilience is a measure of the ability of a system[4] to absorb changes of state variables, driving variables, and parameters, and still persist. Rockström (2009), states that the sudden and random shocks from nature result in reorganization of the playing field on which all biological life forms depend. Since food systems are by nature ecological, economic and social;

[4] A system is a set of interacting and independent components that form an integrated whole, in interaction with the environment and other systems (Gitz and Meybeck, 2012).

resilience thinking has emerged as a tool to understand and analyze socio-ecological systems[5] known as social-ecological resilience.

> *Social-ecological resilience is understood as "the capacity of a system to absorb a disturbance and/or reorganize while undergoing change to still retain essentially the same function, structure, identity, and feedbacks"*
>
> (Walker *et al.*, 2004; and Maleksaeidi and Karami, 2013).

According to Folke (2006), not only does the concept resilience of a social-ecological system focus on the ability of a system to persist in the face of a disturbance but also integrate the idea of a***daptation***, learning, innovation, novelty and self-organization. Adaptation is one of the three capacities of resilience building; absorptive, adaptive and transformative capacities (UNPD, 2015). Adaptive capacity is "the ability of a system to prepare for shocks and changes in advance or adjust and respond to the effects caused by the stresses" (Maleksaeidi and Karami, 2013). Smit and Wandel (2006), name the two dimensions to adaptive capacities in a socio-ecological system, to be the ability to cope with shocks and the adaptability to change (time dimension).

4.1 Ecological Dimension of Socio-ecological Resilience

Darwin's great insight

The key is man's power of accumulative selection; nature gives man successive variations man adds them up in certain directions useful to himself, in this sense he may be said to make for himself a useful breed (Darwin 1859, p. 30).

The evolutionary process of plant adaptation[6] is an ecological adjustment of plants in response to environmental conditions for instance, an actual or expected climatic stimuli, their effects or impacts. According to Gliessman (2015), in nature plant adaptation occurs through natural selection (increased populations of individuals that present advantageous traits to the environment) and in agricultural societies the process is accelerated by humans by directed selection. Genetic change for environmental adaptation is directed by selecting desirable traits for cultivation and production, and creating new gene combinations, resulting in some novel and desired phenotypes; the process known as crop breeding.

"Any recipe for confronting the challenges of climate change must allow for mitigation options and a firm commitment to the adaptation of agriculture, including through the conservation and sustainable use of genetic resources for food and agriculture."

The Declaration of the World Summit on Food Security (FAO, 2009).

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[5] Social-Ecological Systems are defined as social systems that are inseparably linked to and embedded in ecological systems, where changes do not occur in a predictable and linear manner, and with the potential to exist in more than one stable state in which their function, structure and feedbacks are different (Walker & Salt, 2006 and Folke, 2006).

[6] Plant adaptation refers to the development of genetic or behavioral characteristics which enable plants to cope with environmental changes, to survive and reproduce (Smit and Wandel, 2006).

In a quest to increase the gene pool for crop breeding for climate change both international and local genetic resources are being harnessed by breeders through germplasm exchanges. Convections on improving access and benefit-sharing of plant genetic resources have been set, such as the International Treaty on Plant Genetic Resources for Food and Agriculture by the FAO. This treaty according to Toledo and Manzella (2012), is an instrument of facilitation of germplasm exchanges in an international extensive network of research institutes in over 127 countries, it expands the currently narrow genetic base of crop varieties. Benefiting from this treaty, climate change adaptive plant breeding projects for tolerance to drought, floods, and extreme temperatures, (all these of climate change phenomenon's) have been established. The crop varieties released from these projects are an effort to build resilience to climate change. One such project is the Drought Tolerance Maize for Africa (DTMA) conducted by CIMMYT and CGIAR in various African countries which breed new drought tolerant maize varieties from germplasm sourced both internationally and locally in its respective African countries.

Long- term Ecological Resilience

Once an adaptation strategy is formulated and in the process of adoption, its ability to stay resilient in the time dimension should be evaluated to map out its future stability and productivity. A system is resilient when it is less vulnerable to shocks ***across time***, and can recover from them (Gitz and Meyback, 2012). Ecological resilience in the time dimension is the main concept analyzed in this paper through yield simulations of the DT maize varieties in future climate scenarios. The breeding for new maize varieties in Zimbabwe against climate change was and/or is carried out under current climatic conditions. And yet, climate change is defined by continuous change and uncertainties over the years. Therefore, these varieties are developed under the anticipation and insight to hold out in the future of climate change. Several approaches and tools are used to assess the future of crop production systems for example, the crop simulation models, empirical models, crop yield forecasting and yield transfer functions (Fisher *et al.,* 2015).

4.2 Social Dimension of Socio-ecological Resilience

According to the Former Vice-President of Knowledge Management and Sustainable Development (Bindu, 2012), to build resilient transformational changes in a system, firstly knowledge adaptation strategies must be put in place. The Resilience Alliance donates this to the social dimension of social-ecological resilience in systems (Gibbs, 2009). The social dimension of resilience refers to the ability of the individuals, groups, institutions and their production systems to build and increase the capacity for learning adaptations in ecological system to reduce society's vulnerability to external shocks and disturbances (Maleksaeidi and Karami, (2003), Redel, (2008), and Smit and Wendel, (2006)). Folke *et al.,* (2003), further prioritize the ability of a system to initiate solutions to problems and its capacity to self-organize the solutions into the knowledge system as a factor to building resilience.

Climate change awareness amongst Zimbabwean farmers is high (Dekker and Kinsey, 2011), but their knowledge of adaptation through improved varieties maize is low Fisher *et al.*, (2015). The outcome of adaptive capacities depends on numerous factors such as availability of resources, economic cost of capacity, infrastructure, technology, political decision, perceived attitudes by farmers, institutional environment, information resources, and knowledge transfer (Fisher *et al.*, (2015); Smit and Wendel, (2006); and, Maleksaeidi and Karami, (2013)). Information resources, and knowledge transfer are inherent of the social capital, one of the five capitals of the Livelihood framework for rural sustainability by the DIFD (2001); Human capital (skills), physical capital (infrastructure, machinery), natural capital (land, water), financial capital (savings, credit) and social capital (social adherence, communities). Diversified livelihoods, knowledge accumulation, and improved social capital of farmers enriched with abilities to make proactive and informed choices about alternative livelihood strategies is key to early adoption of adaptation strategies in this context drought tolerant maize varieties are a result of improved adaptive capacity from One of the aims of the Zimbabwean strategic resilience framework is to enhance resilience through improved climate change adaptation (*CCA*)[7] practices in vulnerable communities, and the aim is stated;

> *Promoting informed decision-making by addressing gaps in knowledge about adaptation and developing CCA platforms as 'one-stop shops' for Zimbabwe-specific information on appropriate adaptation strategies.*
> (UNDP, 2015).

The social networks serve as the web that seems to tie together the adaptive governance system. According to Eriksen *et al.*, (2010), a social system is delineated by social boundaries that are non-absolute and relative to a kind of social context or activity and connected through networks and interaction channels which serve as relationships between its actors. In the context of crop breeding as a resilience approach, three boundaries are delineated in the social structure of knowledge system of Zimbabwe. These are research institutes and organizations, extension services and farmers. These subsystems of the social systems adapt the notion of Holon's where in a social system each subunit is a social hierarchy and is structured, stable and functional (Ostrom, 2005).

Resilient development is the desired outcome of the adaptation process, it is critical to evaluate the reason why lack of information is a great barrier in Zimbabwe towards adaptation of DT maize varieties amongst farmers. Extension services create bonds, bridges and linkages between the subunits of the agricultural knowledge system and integrate technologies, advances and practices within the multilevel of this social system. Identifying challenges faced in this linkage between AGRITEX and farmers will help design alternatives and remedies.

[7] Climate change adaptation (CCA) refers to the ability to anticipate and respond to the effects of climate Change (UNDP, 2015).

5 Materials and methods

The research study was carried out at the Swedish University of Agricultural Sciences SLU) in Alnarp. The thesis work was performed in collaboration with the Crop Breeding Institute (CBI) of Zimbabwe, correspondents with CBI were done through emails and/or skype. Simulation inquiries and assistance of the APSIM model were also done via emails, skype calls and physical meetings with Dr D. Parsons, a thesis co-supervisor and a professor at the Department of Agricultural Research for Northern Sweden; Crop Production Unit, SLU Umea.

5.1 Materials

This section of the thesis is a summary of information gathered as material used to employ the chosen methods for researching;

- the reaction element of the resilience framework of using Drought Tolerant (DT) maize varieties to manage climate risk of the climate and risk /opportunity management perspective of the maize cropping system in Zimbabwe.

- information dissemination system, which influences the adaptive capacities element of the resilience framework.

5.1.1 Drought Tolerant Maize for Africa

The natural science and agronomic component of the study is based on the results of the Drought Tolerant Maize for Africa (DTMA) project run by two CGIAR Research Centres; the International Maize and Wheat Improvement Centre (CIMMYT) of Eastern and Southern Africa, and the International Institute of Tropical Agriculture (IITA) of West Africa. The project was launched in 2007 and concluded in 2015 releasing 233 Drought Tolerant (DT) maize varieties across 13 Sub-Saharan Africa (SSA) countries. The new varieties underwent multi-location farm testing, a participatory approach with farmers in some SSA countries while trials were conducted in research fields in multi -location sites in the case of Zimbabwe.

5.1.1.1 The Zimbabwean context of DTMA project and research approach

This section is dedicated to a concise description of the execution of the experiment part of the DTMA project, only highlighting its overall specifics to bring forth principal points of the research project. The summary was synthesized from various sources; online sources of the Department of Research and Specialist Services (DR&SS) of Zimbabwe and the CIMMYT-DTMA webpage, verbal communication with Crop Breeding Institute, the maize breeding department personnel and various DTMA published papers e.g. DTMA (2015) volume four and Fisher *et al.,* (2015).

Research purpose – The purpose of the DTMA project was to identify maize germplasm with tolerance to drought through field evaluations in the different agro-ecological regions of Zimbabwe, aiming to provide appropriate maize varieties to resource poor smallholder farmers in drought prone environments of Zimbabwe.

Evaluation Sites - The field experiments were conducted in multi-location, on-station research sitesmanaged by the Crop Breeding Institute (CBI) of Zimbabwe represented in four out of five of the Agroecological (AE) regions in Zimbabwe in exception of region I. These sites included; Marondera, Gwebi, Harare, (region II), Panmure, Bindura, (Region III), Makhoholi, Matopos (Region IV) and Chisumbanje, Save Valley (Region V). AE region I, as described in the Agroecological Regional section of this paper is not prone to droughts and has the longest cropping period of all the regions; CBI does not have any research sites in this area.

Experimental Period – The DTMA field research experiments were conducted in these sites from the year 2008 till 2013.

Germplasm acquisition – the maize germplasm used in the field trials was obtained from CIMMYT, IITA, other CGIAR centres, and local maize varieties that were currently on the local market were sourced from their respective companies in Zimbabwe.

Drought Conditions – Three conditions for field trials included managed drought, random drought and optimal conditions. Cairns *et al.,* (2016), defines these drought conditions;

- Managed drought – the practice of withholding irrigation three weeks before anthesis and until three to four weeks after anthesis.
- Random drought – irrigating only at planting and emergence of the plants.
- Optimal conditions – natural drought conditions as the cropping season is aligned to the rainy season.

It is important to note that all the yield data for the varieties used in this study were obtained during the optimal conditions of the summer cropping season for each of the experimental years between November and May (Zimbabwe's main cropping period and season).

Data collection - The screening and evaluation of the germplasms for drought tolerance was achieved through measuring agronomic traits. Anthesis to Silking Interval (AIS) trait was measured as it is a dominant trait in developing drought tolerant varieties. It relates to earlier maturity of the crop variety leading to drought avoidance. Ngugi *et al.*, (2013), denotes the importance of this trait to the results of the experiments by CIMMYT in Mexico showing a high correlation between AIS and yield performance of maize under drought stress. Some other agronomic traits measured in this research project included;

- Anthesis date (date) - number of days from germination to flowering.
- Silking interval (days). the number of days from silk emergence till senescence of silks.
- Yield (ton/ha)
- Plant height (cm), ear height (cm), ear position (0-1), and the number of ears per plant

Project Output – the deliverables of this project were inbred lines and hybrids with tolerance to drought stress. A total of 22 DT varieties were released into the Zimbabwean cropping system, 19 hybrid varieties and 3 OPV's (Open Pollinated Variety) (DTMA, 2015).

5.1.1.2 DT maize varieties for this study

This study's performance data was obtained only from five varieties (ZS255, ZS261, ZS263, ZS265 and ZS271) that the CBI has Plant Breeder Rights to. Due to the ownership of Plant Breeder Rights for the other 17 varieties released in the project by other institutes, access to their data from the DTMA research was denied by the respective institutes. Intellectual Property Rights in plant breeding commonly known as Plant Breeders Rights (PBR) or plant patents are given to the developer of a new crop variety to protect their genetic material and intelligence, giving them an exclusive control over the variety´s information and who has access to it.

Choice of varieties for simulation analysis

DTMA (2015), highlights the adoption of DT maize varieties in the cropping season of 2015 in the DTMA research countries basing on the seed production data for 2014. In Zimbabwe, Pan53 was the most grown DT variety in 2015, covering >100 000 ha, followed by ZS265 and ZS263, with a cultivation coverage of >10 000 ha and >5 000ha respectively. ZS265 and ZS263 were released in 2010 and yet hybrids ZS261, ZS255 and ZS271 were released in April 2014 and were still at the Breeder's and Foundation seed bulking stages at the time of data release on adoption rates in 2015 (DTMA (2015), and DRSS (2017)). In this study only two varieties (ZS265 and ZS263) of the five varieties were analyzed in the crop simulation model (section 5.2.2). The choice of the two DT varieties was based on;

- **ZS265** - the ranking of adoption shown in the table below. Its high ranking gives relevance and indication to what is on the ground in the maize cropping systems concerning the new DT maize varieties and potentially, significance to outcomes of food security.
- **ZS263–** on its contrasting maturity characteristics. According to the CBI fact sheets ZS263 is the only variety characterized as early maturity as compared to the all other four varieties characterized as early to medium maturity varieties.

5.1.2 Zimbabwe's Natural Regions and research sites for the study

The natural regions in Zimbabwe are divided into five natural regions also referred to as Agroecological zones (AE). The AE zones are defined by *e.g.* their rainfall regime and soil quality. Chikadzi *et al.*, (2013) defines AE zones as land areas that poses a homogenous agro-climate, ecology, soil units and agricultural activities. The environmental distinctness of each AE zone has a considerable influence on the type of farming system present in that zone. It is important to note that the natural agronomic resources (optimum rainfall pattern, optimum temperature and soil quality) accountable for an optimum crop production environment declines from region I to V. The farming systems in the natural regions vary from specialised and diversified farming in region I, intensive systems in region II, to semi-intensive in region III and IV to extensive farming in region V (FAO (2006), Gambiza and Nyama (2000), Wuta *et al.*, (2012) and Chikadzi *et al.*, (2013)).

Table 1: A summary of the characteristics of each of the Agro-ecological zones in Zimbabwe.

	I	IIA	IIB	III	IV	V
Area covered						
% of total land area	1.8	7.6		18.7	37.8	26.7
Rainfall						
Annual rainfall (mm/yr)	> 1 000	700-1 050		500-800	450-650	< 450
Probability rainfall > 500 mm Oct. to April (%)	>90	>90	80 -90	70– 90	40-65	<60
Rainfall description	All months of the year	Reliable summer rains from Nov to March/April		Heavy rains, subject to seasonal droughts, severe mid-season dry spells	Frequent seasonal droughts and severe dry spells during the rainy season	Very erratic rainfall
Other characteristics						
Length of growing period (days)*	>165	150-165		135-150	105-135	<105
Topography	high altitude and steep slopes	mid-altitude areas		mid-altitude areas	low-lying areas	lowland areas below 900 m above sea level
Mean annual temp (°C)	15 -18	16 -19		18 -22	18 - 24	21 - 25
Soil Description						
Dominant soils	Red soil	Greyish brown sands and sandy loams derived from granitic rocks				Sands & sandy loams derived from granite & gneiss
Soil type	Acrisols, Ferralsols	Cambisols, Luvisols, Arenosols		Arenosols, Leptosols, Lixisols,	Luvisols	Leptosols, Luvisols, Solonetz
pH topsoil	4.4- 5.1	4.0-4.3	4.0 – 5.0	4.5 - 4.9	4.4 - 4.8	6.0 -7.0
CEC (me/ 100 g soil)	2.0 -2.6	1.5 - 5.0	1.0 - 3.0	1.0 - 4.0	2.0 – 5.0	Variable 10- 100
Available water holding capacity	High	Mid - low		Low	Low	Variable low-high

*Length of growing period- number of days with precipitation plus moisture stored in the soil exceed half the potential evapotranspiration (P>0.5PET).

Source: by Author adapted from FAO (2006), Gambiza and Nyama (2000), Wuta *et al.*, (2012), and Chikadzi *et al.*, (2013).

5.1.2.1 Choice of research site and Agroecological region for this study

"A regional approach may enhance the effectiveness and efficiency of resilience capacity-building programming in Zimbabwe by allowing for better contextualization of a defined area, which is required for good problem analysis (particularly at a systems level) and programming". (UNDP, 2015).

In regard to the importance of a regional approach as stated above, in the Zimbabwean resilience strategic framework, this approach was adopted to represent the area of study for the maize yield simulations. Makoholi site in region IV of the AE zones of Zimbabwe was the research site chosen for the APSIM simulation section of this thesis. The choice of the research site and region to be analyzed was based on the following aspects;

1) **Availability of yield data for the given years of study –** due to the complexity, longevity and multi-locational dimensions of the research within DTMA, the data quantity was voluminous and could not be completely retrieved. Therefore, only the site in region IV with a data set of three years yield data was selected.

2) **Importance of AE zone to climate change vulnerability –** as indicated in the problem statement the total land area for AE zones in Zimbabwe is changing. Several studies, for example by Wuta *et al*., (2012) and Chikadzi *et al.*, (2013), on re-classification of AE zones in conformity to climate change and variability indicate that the total area for region II and III reduced by 49% and 13.9%, respectively and an area increase of 5,6% was recorded for region IV. The study by Wuta *et al.*, (2012), was based on climate data from 39 weather stations across Zimbabwe. The alteration of areas in region II and III towards region III and IV respectively, gives an importance (in area) to region IV, which holds the highest total percentage area of 37.8% amongst all the AE zones in Zimbabwe.

5.1.3 Climate data

Climate data used for this study was obtained from the Climate Change Agriculture and Food Security (CCAFS) platform on its Global Circulation Model (GCM) downscaled data portal, which represents a set of scenarios carried out under the framework of the Coupled Model Inter-comparison Project Phase 5 (CMIP5) of the World Climate Research Programme (Emori *et al.*, 2016). According to Bjørnæs (2016), in 2014 the Intergovernmental Panel on Climate Change (IPCC) adopted four greenhouse gases concentration trajectories called the Representative Concentration Pathways (RCPs) for its fifth Assessment Report (AR5). The four RCPs are RCP2.6, RCP4.5, RCP6, 0 and RCP8.5 representing the least to the highest atmospheric concentration of greenhouse gases, and corresponding to warming potentials of +2.6, +4.5, +6.0, and +8.5 W/m^2, respectively.

Table 2: Summary of future (RCP2.6 and RCP8.5) and baseline climate data used in this study.

Parameter	**Description**
Location	Region IV, Zimbabwe
Location latitude	-19.7725
Location longitude	30.7680
GCM file set	GCM CMIP5 daily
Global circulation model (GCM)	ipsl_cm5a_lr
Scenario	RCP 8.5 and RCP 2.6
Period historical (baseline)	1980-2005
Period future	2020-2045
Climate Variables	Precipitation, Maximum, mean and minimum temperature, and solar radiation (pr,tasmax,tas,tasmin,rsds)
Observation data set	WFDEI
Observation data set years	1971-2012
Bias correction method	Quantile Mapping

Source: By Author (2017).

As stated in the summary table above, the rising radiative force pathway leading to 8.5 W/m2 in 2100 (RCP 8.5) and the peak in radiative force at ~ 3 W/m2 before the decline in 2100 (RCP 2,6) were selected for this study, to represent climate change extremes. The variables of the climate data obtained included minimum and maximum temperature, precipitation and radiation, short names listed as: "tasmin", "tasmax", "pr" and "rsds", respectively. The two RCPs for scenario modelling were input from a GCM named IPSL-CM5A-LR modelled by the centre of the Institute Pierre-Simon Laplace. The selection of the GCM was based on literature review from similar studies by Rurinda *et al*., (2015), who used the model as one of the GCM for their studies in Zimbabwe for maize crop modelling. A GCM is defined by IPCC (2017), as a tool used to simulate the response of the global climate system to increasing greenhouse gas concentration to the physical processes in the atmosphere, ocean, cryosphere and the land surface using a three-dimensional grid over the globe.

GCM calibration and bias correction methods - The GCM used in this study was calibrated using the Water and global Change (WATCH) Forcing data called the WFDEI observation data set, which consists of daily states of the weather for global half-degree land grid points applied to ERA-Interim data and extending into early 21st century (1979 – 2012) (CCAFS, (2017), and Navarro-Racines *et al.,* (2015)). In addition to calibration using observational data sets, three other different calibration approaches are employed in the interface in CCAFS-Climate portal; bias correction, change factor and quantile mapping. Quantile mapping was the method chosen for the correction approach, following advise by climate impacts specialist Mr J. Ramirez at the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Quantile mapping is described by Navarro-Racines *et al.,* (2015), as the bias-correction approach most appropriate for correcting more stochastic variables (e.g. precipitation and solar radiation), as GCMs do not capture realistic inter-annual variability associated with events such as El Niño and La Niña. Due to the importance of relations of the El Niño events and droughts in Southern Africa as described in the introduction chapter, capturing the variability to precipitation in GCM was eminent.

Experimental years' climate data – As the DTMA project was run from the year 2008 to 2013 the climate data for these years was obtained from the Climatology Resource for Agroclimatology (2017), website of the National Aeronautics and Space Administration (NASA). The same four climate variables as that of the baseline and future climate were obtained, these are minimum and maximum temperature, precipitation and radiation.

Limitations- Rurinda *et al.*, (2015), states that using an ensemble of GCMs increases confidence in projections as compared to individual models.

5.2 Methods

The following section of the thesis is a description of the two methods used in the study, questionnaires and crop modeling.

5.2.1 Questionnaires

The questionnaire survey method was used in this study to answer to the sub-research question -

What are the extension workers' perspectives on challenges faced by AGRITEX leading to lack of information on DT maize varieties by farmers?

Definition

A questionnaire survey is defined by Truman (2015) and Bernard (2006), as a series of identical structured questions that are exposed to all respondents of the study with an aim of obtaining statistically useful information on the topic of study. Questionnaires reduce the error of interview bias by having all the participants respond to the same set of questions.

Justification of method choice

The choice of using a questionnaire survey instead of interviews is based on the limited time frame of the study. A questionnaire survey analysis is more manageable in a shorter space of time by using statistical methods, giving a general view and state of the situation.

Survey protocol

The protocol used to actualize the questionnaire survey was adapted and tailored from the seven stages of research interviewing as listed by Kvale and Brinkmann (2008); Formulation of interview purpose, planning the interview, conducting interviews, transcribing, analyzing, verifying (validity and reliability of findings) and reporting. The first five stages are described in this chapter and the later are deliberated in the results and discussions chapter, respectively.

Questionnaire Design

The layout of the questionnaire document was tailored with inspiration from Dillman's questionnaire method called the Dillman Total Design Survey Method, as described by Bernard (2006). A professional look, defined by a front page with the name of study, organization of study and a one paged brief outline of the study or introductory letter (see appendices 2). The question order (most related to study first, less important questions and lastly demographic questions), formatting (standard convections) and length (below 10 pages). A letter of consent[8] or cover letter manifesting the voluntariness of the participants to the study, importance of respondent input and the confidentiality of their credentials (see appendices 3).

Formulation of questions

The formulation of the survey questions was built upon knowledge from similar studies on challenges faced by AGRITEX described in the problem statement. Associated questions were put under the same sections to give an ease and flow to the respondent, diving the questionnaire into five sections.

- Outreach indicator -. Scale-sets limit the scope of actions for action, but simultaneously it is the product of action (Eriksen, 2010); meaning the outreach scales and methods employed by AGRITEX administration determines the number of farmers that receive extension services. As stated in the problem statement AGRITEX faces organisational errors.
- Financial allocation – Since AGRITEX faces financial challenges, this section of the questionnaire seeks out an understanding of the financial resource allocation within the AGRITEX divisions and extension strategies.
- Professionalism - Chambers (1997) states that professionalism, social distance and power are the explanations of errors that stand out in the knowledge environment within development professionals; If extension workers are not educated on the hindrances in knowledge transfer caused by these social professional errors, this then creates significant limitations in the communication with farmers
- Information resources - This section of sought out information on the knowledge levels held by the extension officers on climate change and DT maize varieties, as indicated in the problem statement that there is poor communication between the research subsystem and the extension subsystem.
- Basic information – This section sought out demographic data on respondents

[8] An informed consent is defined by Kvale and Brinkman (2008), as an act of denouncing the main objective of the interview study by the researcher to the participant as well as their value of participation, assurance of confidentiality and voluntary participation.

Structure of the questionnaire

The structured questionnaire used for this study was composed of two main types of questions; namely open-ended and closed questions (see full questionnaire in appendices 4).

Closed ended questions - these questions presented a set of already set responses to choose from, a yes/no answer choice, single choice questions, multiple choice questions (choose more than one answer) and scaled questions. A scale is defined as a device for assigning units of analysis to categorifies of a variable (Bernard (2006); Neuman (2011)). The type of scales used in this study included the following

- Descriptive rating scale - for example the AGRITEX officers were asked to mark their level of knowledge on climate change on a knowledge scale; no knowledge, low knowledge, adequate knowledge, considerable knowledge or substantial knowledge
- Numeric rating scale - for example the participants were asked to indicate an approximation of the percentage of farmers currently reached by AGRITEX on a percentage scale; 0 - 09%, 10-29%, 30-49%, 50-69%, 70-89% and 90-100%.
- Rank order scale – for example the participants were asked to rate some challenging factors according to this scale; 0 for not a challenge, 1 for the least important challenges, 2 for the averagely important challenge and 3 for very important challenges. This scale was coupled with the scoring tool, were each level of the scale was assigned a score of 0-3 from the non-challenging factors to the most important.

Biemer *et al.,* (2004), states that when using the scale as a choice of responses the best scale is between range of 5 to 11; respondents can discriminate between the scale values. For this study, a scale of five was the most used.

Open-ended questions – these are unstructured questions, where the respondent gives their own responses. For example, "How does the extension service transfer new knowledge about new crop varieties to farmers". Open-ended questions were used strategically as contingency questions as advised by Truman (2015); to follow up on some closed questions that required a specificity of "other option" and for when the respondent gives an answer to the previous question to explore motivations and explanations for choices on closed questions.

Question construction

Special attention and time was invested in the formulation of the questions. Biemer *et al.,* (2004), and Bernard (2009), state that question wording is a key factor in constructing a questionnaire, the respondent must be able to understand the question, words should not be ambiguous. The length of questions should be short and simple language but long enough to provide cues to stimulate memory search, less complex and appealing.

Sampling of respondents

A combination of purposive, convenience and referral sampling were used in this study. These sampling methods are non-probability sampling techniques. Non-probability sampling is described by Neuman (2011), as a process of selection of subjects of a study in a population without equal chances of selection. Bernard (2006), states that this is a useful method to be used when the population of study is difficult to reach. In the case of this study, because the survey is carried out from a different country, with no access to direct acquisition of contacts of the population, the non-probability sampling technique was fit to use.

Purposive sampling - a selection of specialized informants. Specialized informants are defined by Bernard (2006), to be survey participants that are selected to partake in a study due to their competence in the domain of study. The target population were extension workers from the department of Agricultural Technical and Extension Services (AGRITEX).

Convenience sampling – involves selecting participants from anyone within the target population who could be reached or readily available.

Chain referral or Network sampling – in this sampling technique a participant already located can recommend another individual who can be interviewed.

Administration of questionnaires

The method of admission of the questionnaires in this study was Self-administered survey, which was carried out via two channels; email and hard copies.

1. Via email - In this method, the questionnaire was sent to respondents via email with the letter of consent as the email body and invitation message for participation. An additional stage of contact and follow up was carried out, reminders were sent out after 10 days from time of sending the initial questionnaire. According to Bernard (2006), response rate increases by 1 - 9% if questionnaires are sent out for the second time.
2. Handouts – Copies of the questionnaire and the introductory letter were printed and distributed in person by intermediary persons as an attempt to increase the response rate. The intermediary persons had no link to the study, but merely offered support and kindness to the researcher to fortify study efforts. Handouts presented an advantage for face-to-face persuasion tactics. The questionnaires were either dropped off and later collected, or in some cases instantly filled out and handed back to intermediate person. These were then later scanned and sent to the researcher.

5.2.2 APSIM crop modeling

The crop modelling approach was taken to answer the research question;

"In the near future (2020-2045), what is the productivity of ZS263 and ZS265 DT maize varieties in the region IV of the Zimbabwean cropping system under RCP 2.6 and RCP 8.5 climate scenarios?"

Crop simulation modelling[9] is a way of quantifying long-term productivity of crops using yield data from field experiments and historical climate data against predicated future climate scenarios (Rurinda *et al.*, 2015). Examples of the models include DSSAT (Decision Support System for Agrotechnology Transfer), Cropping System Model and STICs (Multi-Disciplinary Simulator for Standard Crops) model (Masanganise *et al.*, (2012), Rurinda *et al.*, (2015)). In this study, to simulate the response of DT maize varieties to climate change, APSIM version 7.9 (Holzworth *et al.*, 2014), was used. Several studies on the Zimbabwean maize cropping system such as that by Carberry *et al.*, 2013 and Rurinda *et al.*, 2015 have used and validated the APSIM model.

Amongst the several maize base simulations in the APSIM model, Continuous Maize simulation was chosen, modified and used for this study. To evaluate the performance of the APSIM crop model yield (kg/ha), tasselling and maturity days outputs generated from simulations were compared to observed field experimental data for the seasons 2010-2012 of Makoholi research site located in AE zone IV of Zimbabwe. The main APSIM modules used in this study included the plant (maize), environment (meteorological input module, soil water, soil nitrogen and organic matter dynamic) and the management module. Changes in thermal time under the NW1-Local maize cultivar were made to create the two maize varieties in study ZS263 and ZS265. The phenology model in APSIM simulates maize development between growth phases, with each phase bound by distinct growth stages. It uses a thermal time target to determine the duration between development stages (Brown *et al.*, 2015). Specific changes in thermal time were made to the following stages;

- emerg_to_endjuv - this phase goes from emerging phase to end juvenile stage.
- flower_to_maturity - this phase goes from flowering to start grain fil to end grain fill.
- flower to_start_grain - this phase goes from flowering to start grain fill.

The simulation study focused on natural region IV, a semi-arid AE zone of Zimbabwe characterized by loam soil (see table 1 for full description of region). A generic African soil already existent on APSIM soil component named loam soil type (APsoil number 997) was used to represent the soils of AE zone IV of Zimbabwe (Dimes and Koo, 2010). Baseline information about local soils for the APSIM model was based on data from literature FAO (2006) and Chimanikire *et al.*, (2005). Specific changes of soil properties were made and kept constant for calibration and simulation trials i.e. the soil nitrogen (from the SoilN module) was lowered. FAO

[9] Crop Simulation Models (CSM) are computerized representations of crop growth, development and yield, simulated through mathematical equations as functions of soil conditions, weather and management practices (Hogenboom *et al.*, 2004).

(2006) indicate that the soils in this region (latitude $19^{O}50$' S and longitude $30^{0}46$') are deficient in nitrogen, phosphorous and sulphur. Since the principal aim of the study was to determine the climatic impact on DT maize varieties in the near future; a reset function was set at the start of each growing season so as to nullify the effect of continuous maize on the cropping system. Soil organic matter, nitrogen and water were re-initialized, since the observed data for calibration of APSIM was based on results data from field trials experimented on in optimal drought conditions in the DTMA project. The growing season for the APSIM clock was set on the uni-modal rainfall period of Zimbabwe, falling mostly during a wet season from October to April. Daily weather variables for both climate scenario RCP 2.6 and RCP 8.5, including rainfall, temperature (minimum and maximum) and solar radiation were retrieved from outputs of the GCM, described in climate data section of this thesis. Specifics for the management module were based on the DTMA project and farmers' management practices for the calibration and future simulations, respectively.

- Sowing dates - were static in both baseline climate and projected climate, as well as both calibration and simulations. Although a difference was set between the early maturing ZS263 which was set to plant between 15 December and 15 January. The 15 November to 31 December for the medium maturating ZS265 maize variety.
- Sowing densities **–** Plant density was set 4.4 plants/m2 for both calibrations and simulations.
- Fertilization dates **–** All nitrogen inputs were added as ammonium nitrate applied at sowing as starter fertilizer and as spilt application for top-dress fertilizer at 28 and 56 days after sowing for the calibration exercise. And for the simulations at 42 days after sowing.
- Fertilization rates - Basal application of compound D (7:14:7) was simulated at a rate of 175kg/ha, and Ammonium Nitrate top dressing (34.5% N) at a rate of 125kg/ha following the recommendation rates for maize in region IV of Zimbabwe. CBI (2017), states that recommending compound/maize fertilizer for region IV is 150-200kg/ha and 100-150kg/ha for ammonium nitrate top dressing. Calibration fertilization rates were set at 200kg/ha and 150kg/ha for compound D and ammonium nitrate, respectively.
- Harvesting rule **–** Maize grain was harvested at 12.5% moisture content and 90% of the Stover was removed from the field at harvesting.

5.3 Data analysis

Questionnaire survey- The closed-ended questions were analyzed via sums. Three steps were taken in analyzing the sums

- Coding - data analysis software (Excel) requires that all the information to be entered is given a numerical value that is a code that 'stands for' values that are in words. Binary variables were coded 0 and 1 e.g. Yes or No responses. nominal and ordered category variables will generally be numbered 1, 2, 3, 4, and so on.

- Assembling – All the responses from checked and coded questionnaires, were entered as values for each variable for each case into Excel creating a data matrix.
- Transforming – the data was transformed into percentages.

No statistical analysis was performed on the data due to the sparse number of respondents. Responses from the open-ended questions were analyzed using cues from content analysis, a qualitative analysis method employed in interviews. Analysis was done using common and recurring words and terms from the respondents' vocabulary. Using the key words, it provided the analysis with a quantitative (numerical) description.

Crop simulations - All the simulations were run by the APSIM model and the outputs for climate change period 2020–2025 and compared with the corresponding simulation under baseline climate conditions (1980–2005). The variability in annual yield production was characterized by calculating the inter-percentile range in box plots. The 75th percentile minus the 25th percentile as the box-plot range. To provide an ensemble effect of climate change on maize yield changes cumulative distribution functions (CDFs) were used to describe their probability distributions and analyze maize yield changes in future. Trend analysis of the DT maize yield and the relationship with the growing season rainfall was been performed. Regression analysis was carried out between annual maize yield and annual growing season rainfall. The detrended time series data for growing season rainfall for respective 25 years of the climate scenarios and the baseline climate were considered the explanatory variables, and maize yield was considered the dependent variable.

6 Results and analysis

This section of results will go through the presentation of the results and the analysis derived from them. The results from the questionnaire survey will be presented in sections as of the questionnaire. Climate data results and APSIM results will be conclude this chapter.

6.1 Questionnaire Survey

A total of 48 questionnaires were distributed to provincial, district and ward level extension workers in Zimbabwe, 17 through emails and 31 as handouts. 21 were returned (6 via emails and 15 handouts) achieving a return rate of 43.7%. However, errors were identified in 6 of the questionnaires and they were discarded. Therefore, usable returns amounted to n=15. The open-ended questions were summarized according to key words mentioned in the responses.

a. <u>Demographic results</u>

<u>Working experience</u> - Of the 15 respondents, 93.3% (n=14) have work experience with AGRITEX of 10 -15 years, which increases the validity of their responses due to their years of experience. Only one extension worker (6.7%) had an experience with AGRITEX of less than 10years (1year).

<u>Occupational level</u>- For this study the respondents were 6.7% (n=1) provincial, 20% (n=3) district and 73.3% (n=11) ward level extension officers, this distribution follows the population pattern of the AGRITEX technical hierarchy.

<u>Work location</u> - The respondents represented four of the ten provinces in Zimbabwe namely Matebeleland South, Matebeleland North, Midlands and Mashonaland West at response rates of 40%, 20%, 33,3% and 6.7% respectively. Matebeleland Province produced the highest number of respondents because physical handouts and follow-ups were done by the intermediary persons. Because of the respondent's population being concentrated in the Midlands and Matebeleland Province, the following responses are not representative of the whole country's AGRITEX workers perspectives but of Midlands and Matebeleland Provinces.

b. Extension services outreach results

The respondents indicated that the main approach for information dissemination applied is farm visits, which scored the highest responses of 47%. Field trials and multimedia platform (WhatsApp) was indicated to be of average importance with results of 17% and 20%, respectively. A lower use of other outreach approaches was indicated in the responses; phone calls (10%), radio and television (3%) and, flyers and handouts (3%). Results of a follow up open-ended question was consistent with responses indicated above. When asked how they transfer information to farmers, the key word in their responses were, field days (n=6), demonstration trials (n=4) and farmers training (n=4). One respondent stated that;

"*During field days you showcase different maize varieties from seed companies. Then we hold another field day were farmers see the performance of different varieties. We invite Sunday newspapers to take pictures and to listen to what is being said and be able to publish in the* *newspaper, this is to cater for the farmers who did not attend the field days"* (WLDW[10], Matebeland North province).

All respondents indicated that anyone is free to attend these field days and demonstration trials, with one open response from stating that attendance is *"self-initiative (extension merely sets conditions and individuals decide whether or not to attend"* (WLDW, Matebeland South Province). All respondents (100%) further indicated that these meetings are held in groups with farmers. Although, 66.6% of the respondents further indicated that meetings can be held with individual farmers, with one open response stating that *"if a farmer asks or needs individual solutions we attend to them individually"* (WLDW, Matebeland North Province). And another responding, "*Mainly in groups since farmers can not all be reached individually by the extension officer, though some can be reached individually but a very small proportion, the majority are reached through groups"* (DLEO[11], Matebeland North Province). 73% (n=11) of the respondents also indicated that there are two "other" options of holding meetings with farmers besides the open/free attendance groups and individual meetings. However, in these two other options there is selection of attendance.

1. Advanced master farmer training (n=9) - the attendance to this meeting is set by the basic condition of the ability of the farmers to read and write (n=4) and the farmers performance on set conditions (n=6). The set conditions are described by one respondent as "*farmers write exams and they are selected according to how they achieved"* (DLEO, Matebeland South Province).
2. Targeted farmers group (n=2) – for example pen fattening[12] farmers group, only farmers with a specific production system are invited. One respondent answered; *"sometimes specific farmer groups with their specific interest areas are reached as selected groups within the society"* (WLEW, Matebeland North Province).

Having established the question on extension approaches, the respondents were questioned on their experience and observation of factors that affected the pattern of attendance of farmers to meetings held by the extension services. The results for this question were disregarded as the responses were not uniform and consistent with the question and therefore, could not be correctly coded for data presentation. Lastly, on this section of the survey, the respondents were requested to indicate the approximate number of farmers reached by each extension worker. The responses are summarized in table 3, indicating an average outreach indicator ratio of between 1:500 and 1:800.

[10] WLEW- Ward Level Extension Worker
[11] DLEO – District Level Extension Officer
[12] Pen fattening involves the feeding of beef with a protein-based high energy diet for a period of 90 days to increase live weight.

Table 3: Outreach approximate of one extension worker to number of farmers (n=15).

Outreach ratio	Respondents (n)	Percentage (%)
1:100	1	6.7
1:500	5	33.3
1:600	3	20
1:700	2	13.3
1.800	3	20
1:900	1	6.7

One respondent further noted the national target of AGRITEX per extension in contrast to the current outreach status. He stated that the outreach ratio *"ranges from 500 to 600 households per extension worker. The national target as per AGRTEX strategic plan of 2015 is one extension worker to 300 households"* (PLDO[13], Midlands Province).

c. Financial allocation results

As described in the problem statement AGRITEX faces financial challenges. The following results section of the questionnaire reflects the perspectives of extension workers on allocation of financial resources by AGRITEX. To get an overview of financial allocation between the five AGRITEX branches, the respondents were requested to point out the branch that received the most funding, the results are summarised in table 4 below.

Table 4: Financial resource allocation within AGRITEX branches.

AGRITEX branch	Respondents (n)	Percentage (%)
Agronomy (Crops)	10	66.7
Training and Information	4	26.7
Land Use Planning	1	6.7
Agribusiness and Farm Management	0	0
Horticulture	0	0

According to the perspectives of 66,7% (n=10) of respondents, the Agronomy branch of the AGRITEX receives the most funding, followed by the training and information branch lastly land use planning branch. The extension workers were then questioned which one of the two factors took priority in the allocation of funds for reaching farmers between ease of access (area location) and area with most need for extension services. 93,3% (n=14) indicated that ease of access is highly prioritized in funding as compared to area with need for extension, a factor only chosen by one respondent. Lastly in financial allocation section, extension workers were requested to indicate a comparative overview of financial allocation of adaptation strategies. A larger portion of the

[13] PLEO – Provincial Level Extension Officer

respondents 73,3 % (n=11) indicated that information dissemination of new crop varieties does not receive as much funding as other adaptation strategies such as water harvesting and precision farming. The reason for this imbalance was noted by 3 extension workers as the lack of priority in dissemination of information of new varieties, they stated; "*It seems not important as others*" (DLEO, Midlands Province). and another noted *"priority appears to be on conservation tillage"* (WLDW, Matebeland South Province). One respondent denoted it to misallocation of funds to lack of knowledge on new varieties by the AGRITEX administration "*most of those in charge of allocation of resources do not appreciate or care so much about it* (crop breeding adaptive capacities). *They have very little contact with what is happening on the ground, that is importance to farmers and the economy"* (PLEO, Midlands Province).

d. Information resources results

All respondents indicated to have knowledge in DT maize varieties and climate change, with a larger portion of respondents indicating a low (40,0%) to adequate (46,6%) knowledge for both issues. Only one respondent (6,6%) had a highest knowledge level in climate change and 13,3% (n=2) considerable knowledge in DT maize.

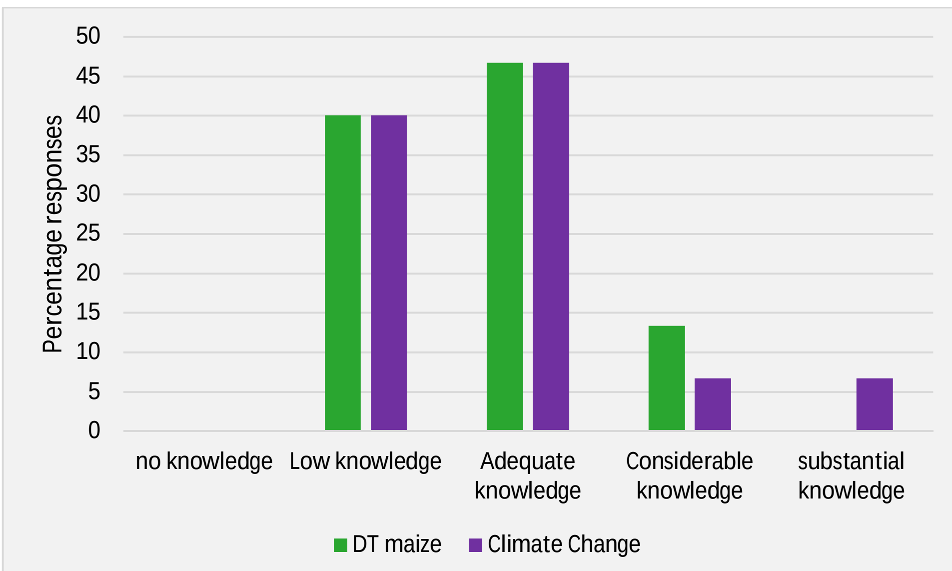


Figure 8: Knowledge levels of extension workers on DT maize and climate change.

In the problem statement it is noted that there is a disconnection between the research subsystem and the extension subsystem of the Ministry of Agriculture of Zimbabwe. The respondents were requested to state how they receive information about the newly developed crop varieties from the research institutes. n=3 respondents indicated that they do not receive any information from the research subsystem. One respondent stated: *"not applicable because results of researchers are not disseminated to extension workers"* (WLDW, Matebeland South Province). Other respondents stated that they acquire information from research articles (n=2), fact sheets (n=1), the internet (n=2) and seed companies open days (1). One respondent stated "*I attend open days at research* *farms such as Seedco, Ratray Arnold and Art farm when invited at my own cost, so depends on my financial position at the time of invitation. Sometimes seed houses do variety demonstrations at selected farmers' places and I attend the open day"* (PLDO, Midlands Province).

e. Professionalism results

To assess the extension workers' training in professional conduct, the respondents were questioned whether they received training on social skills for communication with farmers. 80% (n=10) responded that they do not receive this training. One respondent stated that; *"no, because there is no money to train us or send us to seminars"* (WLDW, Midlands Province). The rest of the respondents (20% (n=5)), indicated that they receive training in social skills. It is important to note that since all respondents who indicated that they received social skills training were from the Midlands Province.

f. Importance of challenges

To get an overall perspective of the extension workers on the level of challenges faced by AGRITEX, the respondents were requested to score listed factors according to their importance. Figure 9 below is a summary of responses of each challenging factor.

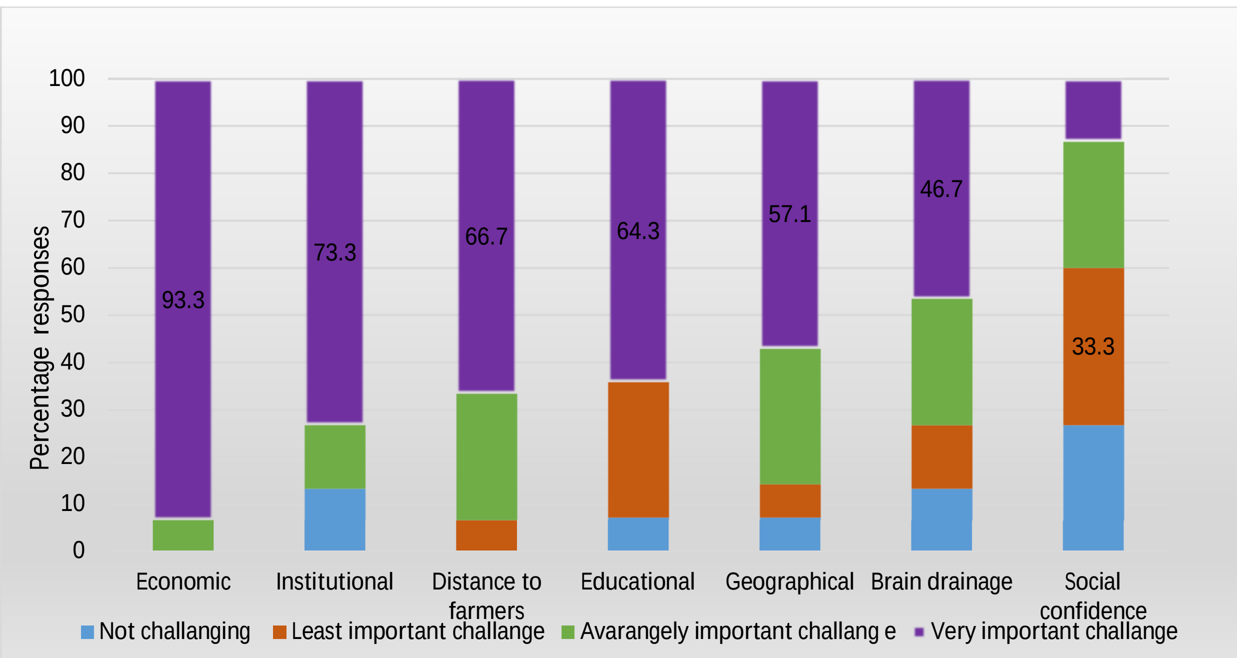


Figure 9: Levels of importance of challenges faced by AGRITEX

The results indicate that according to the extension workers perspectives the most challenging factors are financial and institutional factors. The highest number of respondents, 93.3% (n=14) indicated that financial challenges is the most challenging factor faced by AGRITEX.

A provincial level extension officer indicated to the educational challenges faced by extension workers by stating that *"Very little if any contact between the breeders and promotors of such technologies and the farmers and also the field extension personnel exists. There is need for an interface between researchers /breeders and field extension staff to update each other on the new technologies and the felt and observed needs and challenges of farmers in as far as adoption of the technologies and adaptation to climate change effects is concerned"* (PLDO, Midlands Province).

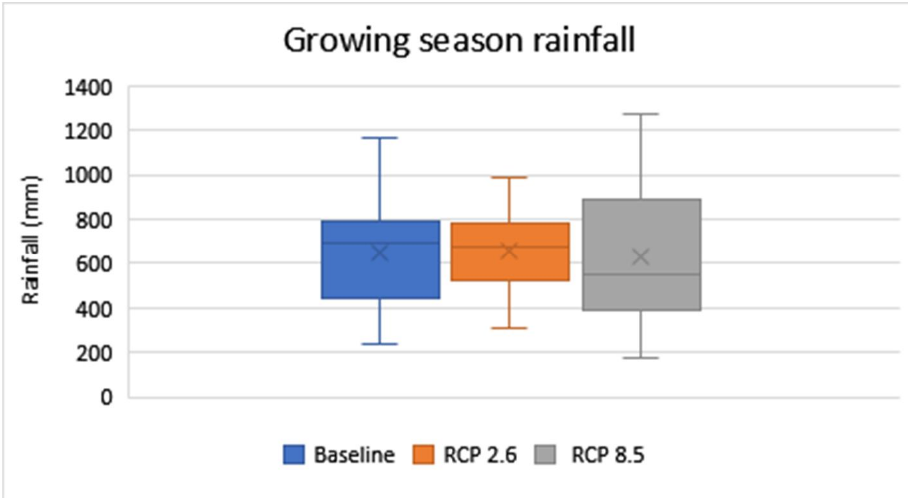
Three extension workers (n=3), added that farmers resistance to adoption to new varieties is a challenge as farmers tend to stick to old varieties.

Summary of questionnaire survey results

Although the questionnaire sought out national perspectives, the results are indicative of perspectives of extension workers from Midlands, Matebeland South and North Province. According to the results of extension workers who participated in this questionnaire survey, the major challenges evident from the responses were financial, institutional, information resources and educational. The results affirm that financial challenges are faced by AGRITEX, the results indicate a high outreach ratio of farmers per extension worker (500-600) far above the AGRITEX of 300 farmers per extension worker, the prioritization of areas with of ease of access as compared to need for extension services indicated by 93,3% (n=14) respondents, and the principal employment of extension service approaches of addressing farmers in groups. Institutional bias for financial allocation was revealed in the results as 73,3 % (n=11) respondents indicated that information dissemination of new crop varieties does not receive as much funding as other adaptation strategies. The results reveal an average level of knowledge on DT maize and climate change within the extension workers as respondents attributed this to malfunctioning or non-existing communication channels between the research subsystem and their extension subsystem. 80% indicated that they acquire information from research through searches of research articles, fact sheets, the internet and seed companies open days. Results gave an indication that the AGRITEX branch of Training and Information responsible for in staff training received a lower financial allocation than the Agronomy branch.

6.2 Climate Results

An increase in temperature was projected in the GCM, with a stronger increase in mean annual maximum temperature and a higher radiation force scenario of RCP 8.5 in region IV of Zimbabwe in the period 2020-2045. Relative to the baseline temperature, maximum temperature (Tmax) is projected to increase by 6.1 °C and 3.0 °C in climate scenario RCP 8.5 and RCP 2.6, respectively. Minimum temperature (Tmin) was projected to increase by 4.0 °C and 3.3°C in climate scenario RCP 8.5 and RCP 2.6, respectively. There was no significant difference in the increase in radiation between the two scenarios. RCP 8.5 had a mean annual radiation increase of 1.8 (MJ/m^2) relative to the baseline and 1.1 (MJ/m^2) for RCP 2.6. There was no significant difference in the mean growing season rainfall, totaled from October to April of each growing season. The mean growing season rainfall 649mm, 658mm and 629.984mm (marked x in the figure below) for the baseline, RCP 2.6 and RCP 8.5climate, respectively.



** x – average growing season rainfall.*

Figure 10: Projected growing season rainfall shown as box plots (5th, 25th, 50th (median), 75th, and 95th percentile), for the 1980-2005 baseline climate period and 2020 -2045 climate periods for RCP 2.6 and RCP 8.5 climate scenarios in region IV Zimbabwe.

It is important to note that the baseline and the RCP 2.6 climate scenario have a higher median growing season rainfall of 692mm and 673mm as compared to a lower median rainfall of 550mm in scenario RCP8.5. Results as depicted in the box plot above, indicate that a higher variability in RCP 8.5, which is characterized by the largest rainfall range of 389mm (25th percentile) and 893mm (75th percentile). A lower growing season variability is depicted in the baseline at 447mm – 790mm and lowest in the RCP 2.6 scenario at 521mm – 783mm. In conclusion, the GCM growing season rainfall was projected at a higher variability, a lower median and higher extreme rainfall (lowest and highest) for the RCP 8.5 relative to the baseline climate. Relative to the baseline climate, the growing season rainfall in the RCP 2.6 climate scenario was projected to be less variable and lower extremes.

6.3 APSIM-Maize calibration

The simulated and observed maize phenology and yield values for ZS263 and ZS265 varieties in Makoholi between growing season 2010 and 2012 was analyzed to validate the performance of APSIM. The simulation is considered excellent with a normalized RMSE of 10%, good if 10% - 20%, acceptable if 20% -30%, and poor if >30% (Zhang *et al.*, 2015). The simulated dates of flowering and maturity were close to the observed values with errors generally less than 10%. The RMSE of simulated flowering days after sowing was 7.6 (11.3%) and 1.4 (1.9%) days earlier for ZS263 and ZS265 respectively. Grain yield was reasonably well predicted for ZS265 with a RSME of -35.1 kg/ha and a bit more for ZS263 with RSME of -157.3 kg/ha RSME. The RMSE for days to maturity after sowing was also well predicated, 6.3 and 5.3 days earlier for ZS263 and

ZS265 respectively. The APSIM model performance was considered to be acceptable for the simulation of maize growth and yield at the study site considering possible errors in the observation data (e.g., imprecise soil parameters).

6.4 Drought Tolerant maize simulation results

6.4.1 Yield

The summary of the yield within the 25years modelled by APSIM is presented in figure 11 below. It presents yield variability of combinations of each of the two climate scenarios RCP 8.5 and RCP 2.6 during 2020 – 2045 and 1980–2005 baseline climate, at one AE region IV of Zimbabwe for each DT variety.

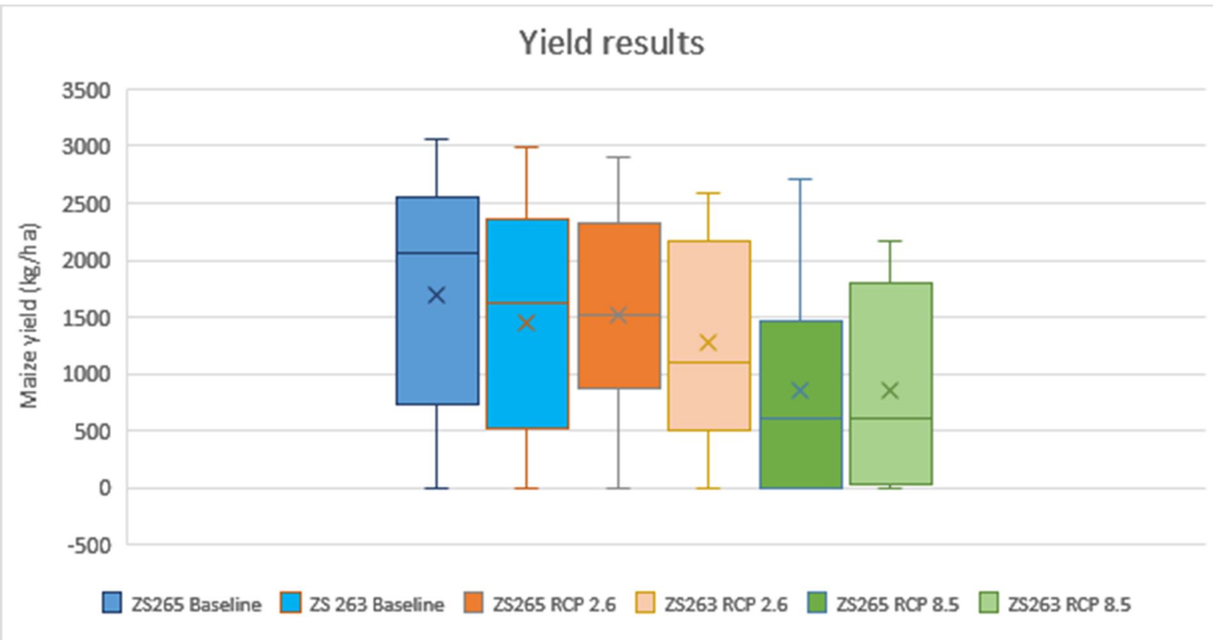
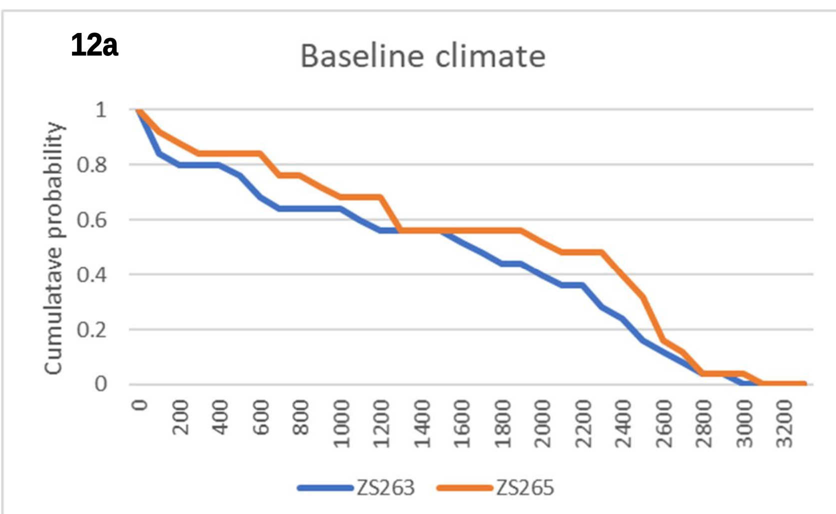


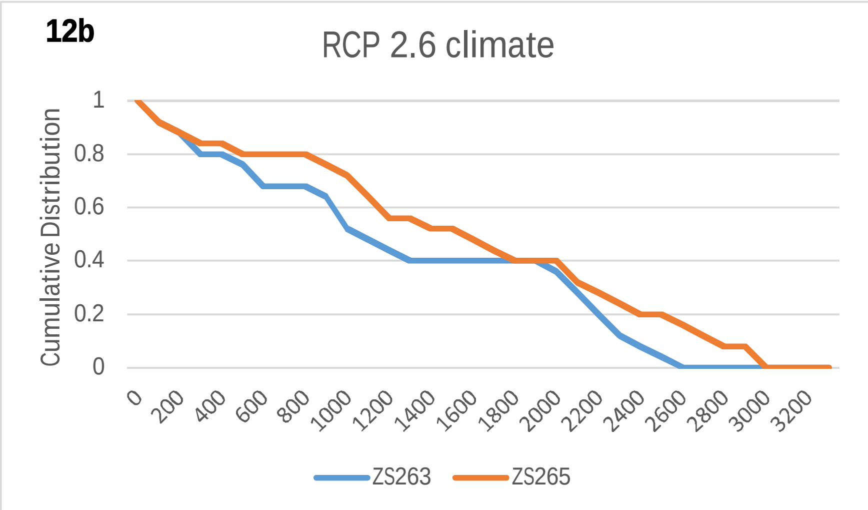
Figure 11: Simulated annual yield of ZS263 and ZS265, for the year 1980-2005 (baseline climate period) and 2020 -2045 climate periods for RCP 2.6 and RCP 8.5 climate scenarios in region IV Zimbabwe.

The results indicate that yield performance is consistent with climatic conditions, both varieties have higher yields in the baseline climate, lower in the RCP 2.6 climate and lowest in the R.P 8.5 climate scenario. All yields are simulated to be below 3000kg/ha in all climate scenarios and with the lowest extremes of no yield (0kg/ha). The lower percentile range (5th to 25th) has a higher range in the RCP 2.6 and baseline climate relative to the RCP8.5 climate. Both varieties have a higher yield range between the lower percentile 25% and the upper percentile 75% in the baseline climate, lower in RCP 2.6 and lowest in RCP 8.5. ZS265 indicates a higher yield range of 865kg/ha and 738kg /ha in RCP 2.6 and the baseline climate conditions, respectively as compared to ZS263 with a yield range of 500kg/ha and 865kg/ha, respectively. It is important to note that there is no significant difference in the mean maize yield (marked x) in the figure above between the two varieties within each climate. There is a significant difference in the median value between ZS265 and ZS263 in RCP 2.6 and the baseline climate conditions, and no difference in the RCP 8.5. To quantify and analyze these differences in yield, regression analysis was conducted in correlation to growing season rainfall (see section 6.4.2).

The inter-percentile range of yield change generally differed from the two DT varieties ZS265 and ZS263 by 38%, 16% and 12% in the RCP 8.5, RCP2.6 and the baseline, respectively. These results indicate a significance difference in performance of the two varieties under the worst climate scenario RCP8.5. The cumulative distribution functions graphs presented below present the maize yield changes among different combinations of climate scenarios and maize varieties.
The CDFs of simulated maize yield indicate that ZS65 has better performance in yield production under mild climate (fig.12a and 12b), and yet ZS263 has better performance in extreme climate scenario (fig.12c).

- In the baseline climate scenario (fig.12a) the median yield of ZS 265 is 21% higher than ZS263. ZS263 has both lower yield for the lower (0.25 probability) and higher (0.75 probability) quantile as compared to ZS265.
- In the RCP 2.6 climate scenario (fig.12b) the median yield of ZS 265 is 28% higher than ZS263. ZS263 has lower yield for the lower (0.25 probability) and higher (0.75 probability) quantile as compared to ZS265.
- In the RCP 8.5 climate scenario (fig.12c) the median yield of ZS 265 is similar to that of ZS263, with a minor difference of 0.83%. In this scenario ZS265 has both lower yield for the lower (0.25 probability) and higher (0.75 probability) quantile as compared to ZS265. ZS 265 has a higher variability in this climate scenario.





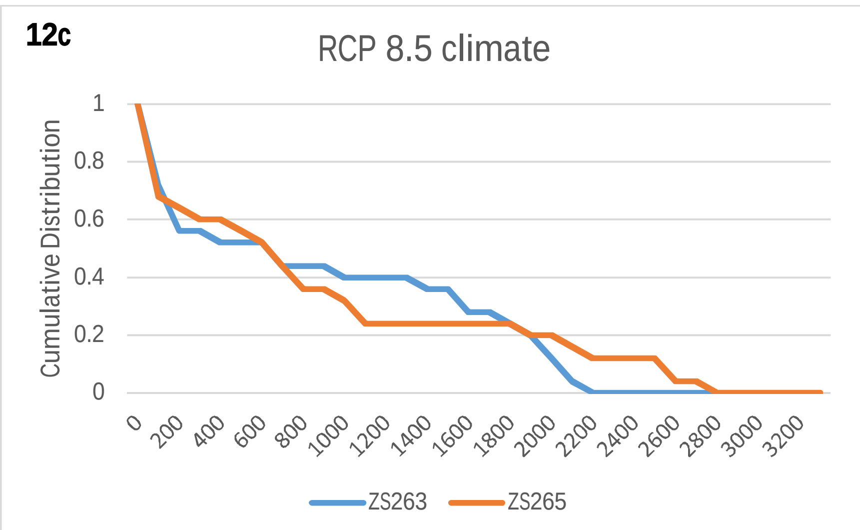
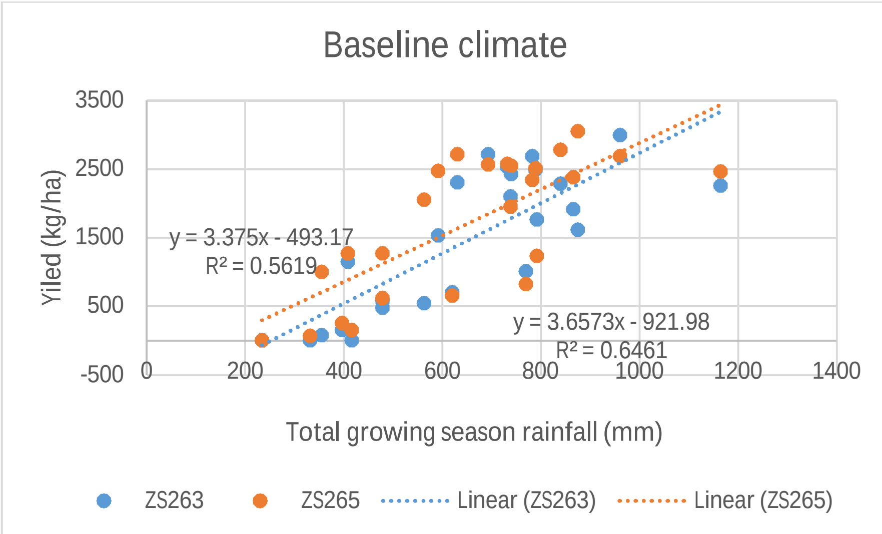
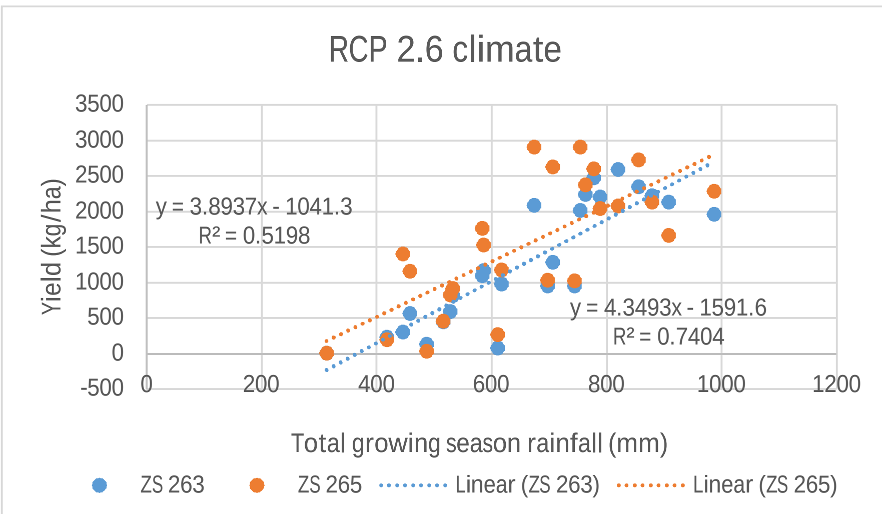


Figure 12: Cumulative distribution function of ZS265 and ZS263 maize for the year 1980-2005 (baseline climate period (12a) and 2020 -2045 climate periods for RCP 2.6(12b) and RCP 8.5 (12c) climate scenarios in region IV Zimbabwe.

6.4.2 Correlation of DT maize varieties to growing season rainfall.

All resulting CDF's showed the same tendency of better yield performance for ZS265 under climate scenario RCP 2.6 and the baseline climate. A regression analysis was conducted to investigate the correlation and amplitude of yield changes to the growing season rainfall of each climate scenario.


Baseline climate
Yiled (kg/ha)
3500
2500
1500
500
-500
y = 3.375x - 493.17
R² = 0.5619
y = 3.6573x - 921.98
R² = 0.6461
0
200
400
600
800
1000
1200
1400
Total growing season rainfall (mm)
ZS263
ZS265
Linear (ZS263)
Linear (ZS265)


RCP 2.6 climate
Yield (kg/ha)
3500
3000
2500
2000
1500
1000
500
0
-500
y = 3.8937x - 1041.3
R² = 0.5198
y = 4.3493x - 1591.6
R² = 0.7404
0
200
400
600
800
1000
1200
Total growing season rainfall (mm)
ZS 263
ZS 265
Linear (ZS 263)
Linear (ZS 265)

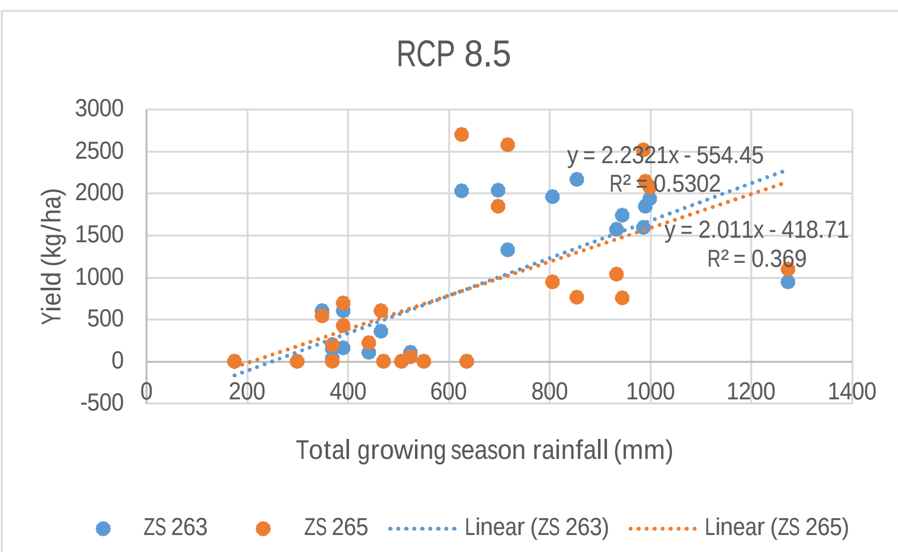

RCP 8.5
Yield (kg/ha)
3000
2500
2000
1500
1000
500
0
-500
y = 2.2321x - 554.45
R² = 0.5302
y = 2.011x - 418.71
R² = 0.369
0
200
400
600
800
1000
1200
1400
Total growing season rainfall (mm)
ZS 263
ZS 265
Linear (ZS 263)
Linear (ZS 265)

Figure 13: Relationship of yield to the growing season rainfall of ZS265 and ZS263 maize for the year 1980-2005 (baseline climate period (13a) and 2020 -2045 climate periods for RCP 2.6(13b) and RCP 8.5 (13c) climate scenarios in region IV Zimbabwe.

The results of the relationship between rainfall climatic variability and DT maize yields (kg/ha), reveal that there was a strong and positive relationship between the growing season rainfall and the maize. In fig. 12a and 13b, the results indicate a slightly steeper slope indicating that ZS2653 has a more direct response to the growing season rainfall. Fig. 13c confirms the CDF graph fig.12c where ZS265 has a lower yield performance in the extreme climate scenario RCP8.5.

Summary of simulation results.

The results simulated by the APSIM crop model indicate a large variability in of the 50% yield production for DT maize ZZS265 and ZS263 in the region IV of Zimbabwe. The simulated median annual yield is projected to be lower for both varieties in climate scenario RCP 8.5 and RCP2.6 relative to the baseline climate. ZS265 was simulated to be marginally better performing than ZS263 in milder climates and yet ZS263 performs better in yield production under extreme climate scenario. This was explained by the stronger relation of yield ZS265 to growing season rainfall.

7 Discussions and Conclusions

Current predictions of climate change impacts on maize yield, even though on average negative, remain largely uncertain. This uncertainty arises from inconsistencies in the predictions from both climate models and crop models. Masanganise *et al.,* (2012), affirms that there are still great uncertainties at regional and local level of confidence in climate models. The mean maximum annual temperature in region IV of Zimbabwe was predicted by GCM in this study to increase by 6.1°C and 3°C in the RCP8.5 and RCP 2.6. Relative to RCP 2.6 the growing season rainfall variability is predicted to be higher for RCP 8.5 climate scenario, composed of higher extremities of low and high rainfall in some years. These results conform to the literature review section on climate change phenomena described in the problem statement chapter. Cairns et *al.,* (2013), states that, adapting maize systems to future climates require the ability to accurately predict future climate scenarios to determine agricultural responses to climate change and set priorities for adaptation strategies. It is important to note that the simulation results generated in this study have a low confidence due to several limitations encountered in this study. The limitations that affected the calibration of APSIM include;

- The absence of yield and performance data for the whole DTMA project period for the two varieties in Makoholi research site.
- Absence of research site soil data during the DTMA project period, soil data and specifications relied on literature review.
- Use of one GCM for the climate data instead of a multi-GCM model.

Although it exhibits low confidence in results, the study is indicative or suggestive of the performance impact of climate change on DT maize. The results simulated in this study show that ZS265 and ZS263 maize mean yield is comparable within the three climates (fig: 11). ZS263 is simulated to have a higher variability in yield as compared to ZS265 across the three climates. The regression analysis further depicts that ZS265 the medium maturity variety is more dependent on growing season rainfall relative to ZS263 a short medium maturing DT variety (fig.12). This dependency is stated in this study as a preliminary conclusion as there is need for more analyses and simulations to establish this correlation of the DT varieties to rainfall and furthermore to maximum temperature. Traore (2014) and Rurinda et *al.,* 2015 suggests that although short season short duration varieties are perceived to be more climate robust because they are not dependent on a long growing season with ample rainfall, the temperature response of such varieties might counteract this positive characteristic.The median yield simulated for the baseline period (1980-2005) is 2058kg/ha for ZS265 and 1608kg/ha for ZS263. The results project that the yield median will decline in the AE zone of Zimbabwe by 75% and 67% in the climate extreme scenario of RCP8.5 for ZS265 and ZS263, respectively in 2020-2045. This decline is especially high and can be preliminary classified as Collapse of the Resilience framework (see conceptual framework). This reaction of a system is characterized by a reduction of capacities and inability to deal with future disturbances. The climate impact of ZS265 and ZS263 in climate scenario RCP2,6 was simulated to be less extensive as in RCP8.5. The projected yield decline was approximately 25% for both DT varieties compared to the baseline climate. According to the resilience framework a preliminary indicator can be taken for this reaction of the system to climate impact and recover, but worse than before, which is characterized by reduced capacities of the system. According to the results obtained from this study, when using the baseline climate yield results as a comparative standard the reaction of the Zimbabwean maize systems in the Resilience building concept is below ideal. According to Smit and Wandel (2006), two recovery pathways of a system under stress are;

- Bounce back better – were the systems' capacities are enhanced, stresses reduced, and future stresses can be dealt with.
- Bounce back to normal – were the pre-existing conditions prevail.

As the study focused on analyzing the crop breeding adaptation strategies, for ecological resilience, perspectives from extension workers were sought out. This secondary study was to investigate the challenges in the Zimbabwean agroecosystems in building and increasing learning capacities for learning and adaptation (social resilience of socio-ecological resilience).

The questionnaire results drawn from extension workers from Matabeleland and Midlands province of Zimbabwe gave an indication to the lack of financial resources for AGRITEX and inequalities in the allocation of this resource. Taking note of the correlation between the lack of funding into the information and training branch of AGRITEX responsible for equipping extension workers with knowledge and the level of knowledge of extension workers DT maize and climate change. There is evidence of challenges and disconnection between the subsystem that generates the crop breeding knowledge (research subsystem) and the extension services leading to the lack of knowledge by farmers. Mugwisi (2013), states that the perception within some sectors is that there is insufficient cooperation among agricultural extension service providers (despite their common ultimate goals) because these services are established without a built-in complementary relationship. This leads to the lags in transferring information from research to extension services (Hunyani -Mlambo, 2002). The results indicate that meetings with farmers are mostly held in groups due to the high outreach ratio of extension workers to farmers. Hunyani-Mlambo (2002), state that committee meetings, which are meant to bring all stakeholders together (farmers and extension workers), have often been a failure because of poor attendance, non-representation of some organizations or a lack of patience and commitment on the part of attending members. This linear information dissemination channel further hinders the financially crippled knowledge system of Zimbabwe in building socio-ecological resilience. There is need to formulate and implement integrated approaches to research and information dissemination.

❖ Diversify livelihoods to minimize risk exposure to shocks and stresses.
❖ Integrate local and scientific knowledge through appropriate practices and technology.
❖ Empower people and local organizations.
❖ Prioritize and enhance local food security in culturally appropriate ways.
❖ Guarantee equality of access to appropriate agricultural practices, knowledge and technologies.

Figure 14: Key social agroecological principles (Altieri and Nicholls (2005,) and Gliessman (2015)).

The key agroecological principles (fig 14) enhance local knowledge capacities and are recommend through the employment of Participatory Research methods in building social capital and knowledge. Participatory research methods are inclusive of the three knowledge subsystems (research, extension workers and farmers) under one platform. Eriksen (2010), states that scale sets limits to the scope of actions for action, but simultaneously it is the product of action. By presenting the knowledge system on the same platform the scale of outreach to farmers and extension workers in increased and the scope action of information dissemination also increased. The crop breeding institute of Zimbabwe has various locations of research sites across the five AE zones of Zimbabwe, participatory research projects, inclusive of farmers could be conducted in these sites. The participatory approach closes the knowledge gap between the knowledge subsystems and will help reduce the financial challenges that strongly affect the information dissemination system. The extension workers cease to play the role of information dissemination but take on the role of being facilitators. Anandajayasekeram *et al.,* (2008), state that working with and strengthening local farmers or community organizations furthers learning and adoption of alternatives and effectively empowers more people. Mutual trust and continuous open communication are invaluable in building such participatory interactions between farmers and other stakeholders. As indicated in the results, priority to extension services is given to locations with ease of access, with 57% responses denoting challenges to distance to farmers and 63% to geographical location of farmers.

Kiplang'at (1999), argues that, "*The key to increased agricultural production ultimately lies in the nation's ability to disseminate relevant information to the farming community, to facilitate the effective adoption of new production techniques, application of agricultural inputs, decision making on markets, prices and methods of conserving water, soil and vegetable resources."*

With an understanding of the functions and use of agricultural information systems in helping informed decisions regarding crop management and climate resilience agricultural information interacts with and influences agricultural productivity. Agricultural productivity can arguably be improved by relevant, reliable and useful information and knowledge. Economic growth and theoretical studies underline that both the level and accumulation of human capital are crucial factors of production, and have competitive advantages in the growth processes. The livelihoods of the Zimbabwean farmers depend on the success and productivity of their cropping systems. The creation and dissemination of agricultural information (by extension services, research, and others) on climate change adaptation strategies is key to building the economic sustainability of their agroecosystem.

The combination of the results in this study (low and variable yield in future climate scenarios and evidence of information dissemination challenges) are suggestive of obstacles in building socio-ecological resilience using crop breeding adaptive capacities. Adaptation to climate change will require cross-disciplinary solutions, across the linked and imbedded subsets of the maize agroecosystems. With an introduction of alternatives using holistic and eco-centric paradigms in extension services, the system can be redesigned into a resilient and decentralized agricultural system.

7.1 Reflections on the research study

The present research thesis has given an indication of challenges in social resilience of the maize cropping system and the possible outcomes of yield and crop performance of ZS263 and ZS265 under future climate change. With these preliminary results from the study my personal reflection is their value inputted into the knowledge research field as part of a loop learning phenomenon.

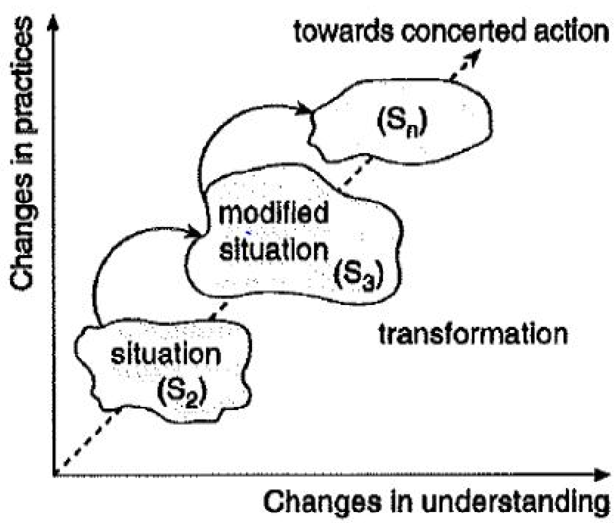


Figure 15: Situations characterized by complexity, uncertainty interdependence, multi-stakeholders and thus perspectives can be transformed through concerted action by stakeholders who build their stake holding in the process this leads to changed understanding (knowledge in action) and practices. (S=Situation) (Ison, 2008).

As demonstrated by Ison (2008), in fig.15, perspectives can be changed through changes in understanding and practises. In this study an understanding of the fatality of performance of crop breeding strategies of DT maize varieties, (ZS263 and ZS265) when independently adopted to adapt to climate change and build resilience was gained. Therefore, further studies inclusive of agroecological practices such as crop rotation, alternative staple food sources such as small grains millet and sorghum, crop diversity and agroforestry can be investigated to analyse the performance of the DT maize under future climate scenarios.

The ideology and theories of loop learning can also be incorporated into further studies for building social resilience. According sustainability tool of the FAO (2014), under the sub-theme Accountability and indicator – Responsibility, it is stated that,

"Senior management and/or owners of enterprise regularly and explicitly evaluate the enterprise's performance against its mission or code of conduct."

Organizational loop learning is characterized by regular reviews, monitoring and performance checks to identify ambiguities in fulfilling the institutional mission. Chambers (1997), further states that through organizational performance evaluations errors can be classified leading developmental learning within organizations. The results on the challenges faced by AGRITEX in the maize cropping system in this study serve as a step in loop learning. The climate resilience framework (fig.16) gives a visual summary of loop learning in climate resilience building and understanding vulnerability, a contribution outcome of this study to resilience building in Zimbabwe's maize cropping system.

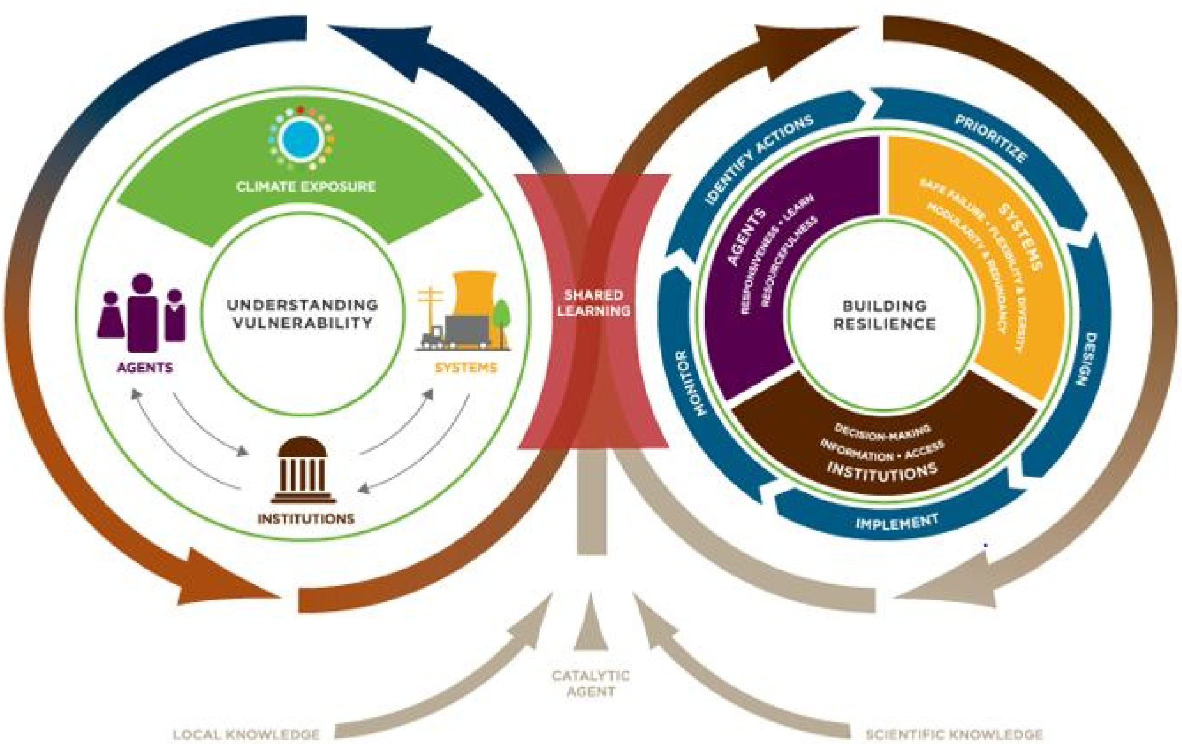


Figure 16: The climate resilience framework (ISET, 2017).

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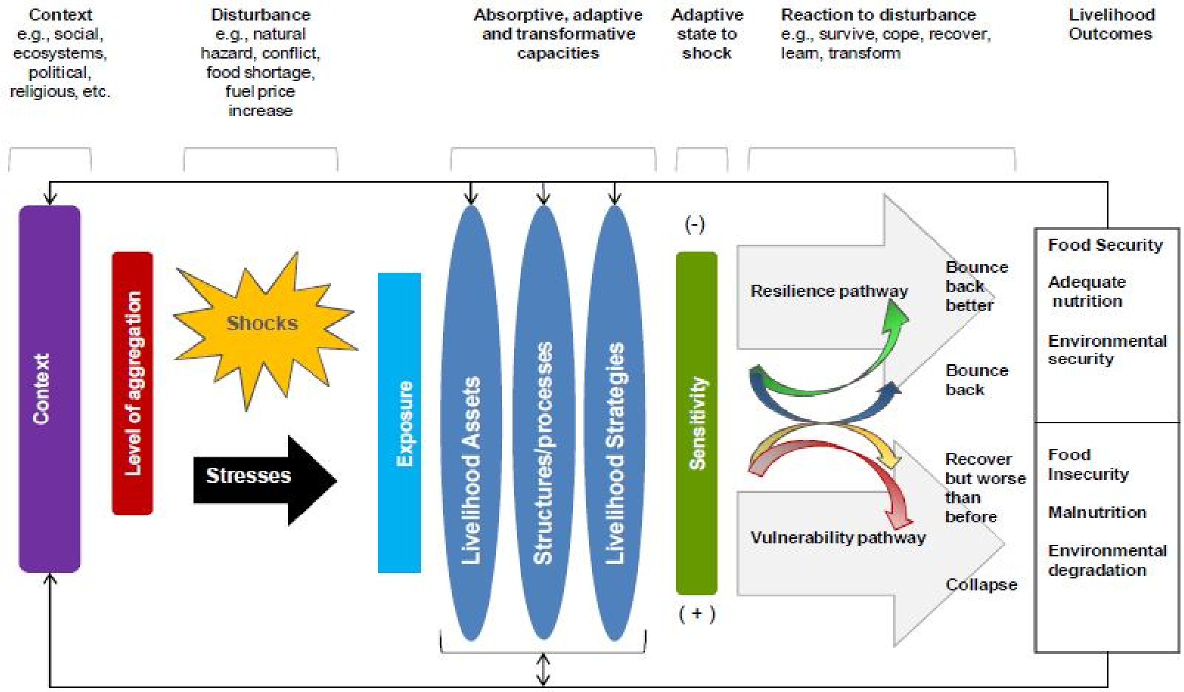
Appendices

Appendices 1: Zimbabwe Resilience Strategic Framework (UNDP, 2015).



Appendices 2: Introductory letter to the questionnaire survey.

Swedish University of Agricultural Sciences (SLU)

Department of Biosystems and technology

Master Thesis Degree in Agroecology

Building resilience against climate change in Zimbabwe's maize cropping systems

Amongst, the challenges faced in the maize cropping system in Zimbabwe, climate change is one of the predominant ones. In this study, the focus will be on the adaptation and dissemination of new maize germplasm with improved traits for drought tolerance. The study is based on the Drought Tolerant Maize for Africa (DTMA) project run by two CGIAR Research Centers; the International Maize and Wheat Improvement Center (CIMMYT (eastern and southern Africa)) and the International Institute of Tropical Agriculture (IITA(West Africa)), in collaboration with Crop Breeding Institute of Zimbabwe.

To build resilient transformational changes in a system, a sound knowledge system on adaptation strategies must be established if not in existence or solidified if it has any weak spots. Results from a study, namely: "Determinants of adoption of Drought tolerant maize for farmers to drought in eastern and southern Africa". indicated that 59% adaptation challenges of the DT maize varieties (e.g.; ZS 255, ZS 261, ZS 263, ZS265 and ZS271) in Zimbabwe were due to lack of information. In another study, "Factors Influencing Smallholder Farmers' Adaptation to Climate Change and Variability in Chiredzi District of Zimbabwe in 2015", the results indicated that access to extension services positively influenced a household's decision to adapt to climate change and variability.

Therefore, the aim of this questionnaire is to further gain perspectives from the (AGRITEX) extension workers on their views on challenges that are faced in delivering extension service to the farmers, building upon other surveys e.g. by "The information needs and challenges of agricultural researchers and extension workers in Zimbabwe" (Mugwisi, 2013). We are confident that your input will help us answer this question "What are the extension worker's perspectives on knowledge gap between research innovations (crop breeding) and the farmers?".

Thank you very much for taking part in this study.

NB// The validation of the results of the study will rely on the truthfulness of your answers.

For the fill-in questions answer in brief and **for the other option please fill in your new option**

Links for the studies mentioned above.

1. https://link.springer.com/article/10.1007/s10584-015-1459-2#Sec16
2. https://www.researchgate.net/publication/280831107_Factors_Influencing_Smallholder_Farmers%27_Adaptation_to_Climate_Change_and_Variability_in_Chiredzi_District_of_Zimbabwe
3. http://uzspace.uzulu.ac.za/bitstream/handle/10530/1204/The+information+needs+and+challenges+of+agricultural+researchers+and+extension+workers+in+Zimbabwe.pdf?sequence=1

Appendices 3: Letter of consent to the questionnaire survey.

Dear potential research participant,

You are being invited to participate in a research study I am conducting as part of my Master thesis in Agroecology degree with the Department of Biosystems and technology at the Swedish University of Agricultural Sciences (SLU) in collaboration with the Zimbabwean Crop Breeding Institute (CBI)**.** You will find more information about this study in the questionnaire.

Purpose: The purpose of this study is to analyse challenges faced by AGRITEX in transferring knowledge on climate change adaptive crop varieties to farmer's drought tolerant maize varieties. Your input and participation in this survey is indispensable as you possess the requisite working experience of the knowledge transfer system in Zimbabwe.

Procedures: If you decide to take part, your involvement would entail filling in the attached questionnaire and sending it back to us. This research will require about 15mins to 20mins of your time. The questionnaire can be conducted wherever you prefer, but without any other input apart from your own individual perspectives (no other people or research). see the attached document.

Confidentiality: The results from this study will be presented in thesis writing and will NOT contain any mention of your name, and any identifying information.

I very much look forward to your participation and thank you in advance for your assistance in this project.

If you require any information about this study, or would like to speak to the researcher, please see the contact information below.

Kind regards

MSc Vimbai Ruvengo

Agronomist
Agroecology master's student
Swedish university of Agriculture
Email: vigo0002@stud.slu.se or vruvengo@gmail.com
Skype name: vruvengo

Appendices 4: Questionnaire sample of the survey.

a) According to the studies mentioned above what do you think is/are the main challenge/s that cause lack of knowledge about drought tolerant maize varieties amongst farmers?

Answer...

b) In your opinion score following challenges that might be faced by AGRITEX according to the score rank listed below.

0 = **No** challenge
1= **Least** important challenges.
2= **Averagely** important challenge.
3= **Very** important challenge.

Factor		Rating
Economic	Financial challenges	
Distance to farmers	The remoteness of a farmer's location.	
Brain drainage	Not enough extension workers to reach all farmers	
Educational	Lack of information from the research centers to extension workers	
Social confidence	Lack of confidence in the extension service	
Institutional	Lack of good governance from the AGRITEX administration.	
Geographical	Accessibility to farm areas due to bad roads, mountains etc.	

c) In your opinion, what is the percentage scale of target farmers currently reached by AGRITEX in Zimbabwe on drought tolerant maize varieties? Mark with an 'X'.

0 - 09%	10-29%	30-49%	50-69%	70-89%	90-100%

Section A: Outreach indicators

a) How does the extension service transfer new knowledge about new crop varieties to farmers?

Answer......

b) How are meetings with farmers held? Mark with an 'X'.

In Groups	With individual farmers	Other

If other specify....

For the “other” option, if there is a selection process, what are the basis of selection?

c) Who is invited to attend? Mark with an ‘X’.

Anyone	Farmers selected within the societies (villages)	Other

If other specify......

Answer....

d) Outreach indicator: What is the current extension worker to farmer ratio for extension worker? (Approximate).

Answer....

e) Choose two of the most used communication method between extension officers and farmers? Mark with an ‘X’.

Internet		Field trials	
Phone		Radio and television	
Farm visits		Flyers and handouts	
Other (specify)			

f) In your experience and observation what which of these factors determines the pattern of attendance of farmers to extension service meetings?

Answer - 0= **Not** a factor 1= **least** effect

2= **Average** effect on attendance 3= **Most** effect on attendance

Age	Young farmers 20-40 years	
	Older farmers 40-60 years	
Educational level	Least educated (up to secondary level)	
	Below tertiary education (A level)	
	Above tertiary education (A level)	
Gender	Males	
	Females	
Social status	Rural farmers	
	Urbanized farmers	
Type of farmer	Subsistence farmer	
	Small holder farmer	
	Commercial farmer	

Section B: Financial allocation

a) Among the five branches of AGRITEX, which of these receive the most funding allocation?

[A] Agribusiness and Farm Management **[B]**Agronomy (Crops) **[C]** Horticulture
[D] Land Use Planning **[E]**Training and Information?

Answer ...

b) Does crop breeding adaptive capacities for climate change receive as much financial capital for knowledge dissemination as other adaptation capacities for example conservation tillage, water harvesting and precision farming? Mark with an 'X'.

Yes		No	

If not, what do you think are the reasons for this imbalance?

Answer......

c) How are resources allocated within the organization for reaching out to the farmers? Mark with an 'X'.

Area with most need for extension services	
Ease of access - Area location	
Other (specify)	

Section C: Information Resources

a) What is your current level of crop breeding knowledge on drought tolerant maize varieties?
b) What is your current level of climate change knowledge? Mark with an 'X'.

	no knowledge	Low knowledge	Adequate knowledge	Considerable knowledge	substantial knowledge
DT maize varieties					
Climate change					

c) How is information about new crop varieties transferred to you from the researchers?

Answer ......

Section D: Professionalism

a) Do you as an extension worker receive training on social skills for communication with farmers? Mark with an ‘X’.

Yes		No	

b) If yes score the following?

0= Not taught at all   1= Taught with no emphasis   2= Taught with great emphasis

Factor	Explanation	Score
Speech	The use of words that are used to communicate with farmers to be at same level as them	
Accessories	Dressing and technological devices that are demeaning to farmers.	
Behavior	Non - verbal and spiteful ways for example sitting on higher level while farmers sit on the ground	
Associates	Only association of extension agents with progressive farmers	
Avoidance	Extension workers shying away from some farming societies because of high level of social status differences.	
Other (Specify)		

Section E: Basic information

a) Period worked as an extension worker.

Answer …

c) In which region, do you work under?

Province	
District	

a) What is your extension services occupational level?

Provincial agricultural extension officer	
District agricultural extension officer	
Ward level agricultural extension worker	

b) Time taken to complete questionnaire.

Thank you for your participation

Answer…….