IMPACT OF CLIMATE CHANGE ON YIELD AND FARMERS' PRODUCTION BEHAVIOUR IN NORTHERN MAIZE BELT, NIGERIA

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By

ADAMU BUBA NDAWAYO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

March 2017

DEDICATION

This research is dedicated to the memory of my father Alhaji Adamu Ndawayo.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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Chairman : Professor Mad Nasir Shamsudin, PhD
Faculty : Environmental Studies

Climate change caused challenge for all sectors of economy, particularly rainfed agriculture, studies show that overall crop productivity in sub-Saharan Africa is likely to decline due to weather change effects. This has consequence for world food security in developing countries including Nigeria, with subsequent effect on yield harvest, reduction of farm income and total inefficiency in crop production. Maize production in Nigeria as in other developing countries is extremely vulnerable to changes in weather conditions (temperature, carbon-dioxide and rainfall). This problem can results to famine and poverty amongst farmers and low income earners, most countries were net importer of food. The main goal is to estimate the impact of climate change on maize yield and farmers' production behaviour in northern maize belt, Nigeria. With specific objectives of analysing and forecasting maize yield, evaluating and analysing farmers' perceptions on climate change with appropriate adjustment measures and determine production behaviour. Study method applied interdisciplinary approach by using decision support system for agrotechnology transfer crop simulation model (DSSAT – CSM) in forecasting maize yields until (2039) with secondary data of (temperature, rainfall and solar radiation) recorded between (1992 – 2015) period from institute of agriculture research Zaria (IAR) and managements data from national agriculture extension research and liaison services (NAERLS) Zaria; Analytical hierarchy process (AHP) criteria were developed from (2014) household survey of farmers' perception on climate change with 400 respondents, using cluster sampling technique. Stochastic frontier analysis model (SFAM) was used to estimate risk, inefficiency and technical efficiency of respondents, other statistical tool were used to compare variables. DSSAT – CSM forecasting, indicate average yields reduction by 8.5% until 2039. The AHP results indicate mitigation as best criteria. SFAM mean estimation shows the presence of both risk and inefficiency in the production, Lambda_λ is largely caused by inefficiency, estimated Gamma_γ = 54.5%. The production technical efficiency score = 87.5%. There exist significant difference between different vegetation zones and rainfall regimes technical efficiency. The independent-sample t-test for extension services and farmers' association, perception and farming status shows significant difference, cross tabulation and chi square of perception and gender indicate significant level. Policy makers were recommended to proper funding of research institution for staff training and modern facilities, peasant farmers' should have access to credit schemes, extension services, and timely information's on climate change. Crop production provides employment to rural populations and raw-materials to urban industries in Nigeria. Findings are significant to both farmers and government to prepare for future climate impact on maize yield and would serve as frame work to policy makers on self-sufficiency maize production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PERUBAHAN IKLIM KESAN KEPADA HASIL JAGUNG DAN ANGGARAN TINGKAH LAKU PENGELUARAN JAGUNG DI UTARA BELT, NIGERIA

Oleh

ADAMU BUBA NDAWAYO

Mac 2017

Pengerusi : Profesor Mad Nasir Shamsudin, PhD
Fakulti : Pengajian Alam Sekitar

Perubahan iklim global membawa perubahan yang mencabar terutamanya pada pertanian yang bergantung kepada air hujan sebagai sumber pengairan. Beberapa kajian telah menunjukkan bahawa jumlah keseluruhan produktivti pertanian di kawasan sub - Saharan Afrika, mungkin akan mengalami penyusutan disebabkan oleh kesan perubahan cuaca. Hal ini mengakibatkan keselamatan makanan sedunia turut terkesan di negara membangun seperti Nigeria di mana kesannya dapat dilihat pada pengurangan pada pengeluaran hasil tanaman, penyusutan daripada segi pendapatan ladang dan ketidakcekapan dalam penghasilan jagung. Seperti kebanyakkan negara membangun, pengeluaran jagung di Nigeria adalah sangat terdedah pada perubahan keadaan cuaca (suhu, karbon dioksida dan hujan). Masalah ini mengakibatkan isu kelaparan dan kemiskinan di kalangan petani dan golongan berpendapatan rendah. Objektif utama kajian ini adalah untuk menganggarkan kesan perubahan cuaca terhadap hasil pengeluaran jagung dan tingkah laku pengeluaran petani di jaluran tanaman jagung di utara Nigeria. Untuk mencapai matlamat utama tersebut, beberapa sub-objektif akan dilalui seperti, menganalisis dan meramal hasil jagung, menilai dan menganalisis persepsi petani terhadap perubahan iklim dengan langkah-langkah pelarasan yang sesuai dan menentukan tingkah laku pengeluaran. Kajian yang dijalankan menggunakan pendekatan multi-disiplin dengan menggunakan sistem sokongan keputusan untuk pemindahan agroteknologi model simulasi tanaman (DSSAT - CSM) dalam hasil jagung ramalan sehingga (2039) dengan data sekunder (suhu, hujan dan sinaran solar) yang direkodkan di antara tempoh (1992 - 2015) dari Institut Data Penyelidikan Pertanian Zaria (IAR) dan pengurusan dari pengembangan pertanian kebangsaan penyelidikan dan perhubungan (NAERLS) Zaria; proses hierarki analisis kriteria (AHP) juga telah dibangunkan daripada kajian (2014) rumah persepsi petani terhadap perubahan iklim dengan 400 responden, menggunakan teknik persampelan kelompok. Model analisis sempadan stokastik (SFAM) telah digunakan untuk menganggar risiko, ketidakcekapan dan kecekapan teknikal daripada responden disamping analisa statistik yang lain telah digunakan untuk membandingkan pembolehubah yang terdapat. Hasil ramalan daripada DSSAT – CSM menunjukkan bahawa kesan daripada perubahan iklim menunjukkan purata pengurangan hasil sebanyak 8.5% sehingga 2039. Hasil daripada AHP pula menunjukkan pilihan mitigasi adalah kaedah yang terbaik untuk mengatasi masalah ini. Nilai purata SFAM menunjukkan kehadiran kedua-dua risiko iaitu ketidakcekapan dalam pengeluaran, Lambda_λ adalah sebahagian besarnya disebabkan oleh ketidakcekapan, dibuktikan oleh nilai anggaran Gamma_γ = 54.5%. Pengeluaran skor kecekapan teknikal = 87.5%. Terdapat perbezaan yang signifikan di antara zon tumbuh-tumbuhan yang berbeza dan kecekapan teknikal di kawasan hujan. Analisa ujian bebas t-test bagi perkhidmatan pengembangan dan petani persatuan, persepsi dan status pertanian menunjukkan perbezaan yang ketara di mana jadual silang dan persegi chi persepsi dan jantina menunjukkan tahap yang ketara. Hasil daripada kajian ini boleh digunkan oleh pembuat dasar dan agensi yang terlibat. Antara cadangan tersebut adalah, pembuat dasar mengeluarkan dana bagi institusi penyelidikan bagi latihan kepada staf dan permodenan kemudahan infrastruktur, para petani perlu mempunyai akses kepada skim kredit, khidmat pengembangan, dan maklumat yang tepat pada masanya mengenai perubahan iklim. Penghasilan tanaman menyediakan pelang pekerjaan bagi populasi luar bandar dan menyediakan bekalan bahan mentah untuk kerpulan industri di Nigeria. Dapatan daripada kajian ini adalah sangat penting bagi kedua-dua para petani dan agensi kerajaan untuk menyediakan persedian bagi mengahadapi kesan perubahan iklim di masa depan ke atas hasil pengeuaran jagung dan akan menjadi dasar kepada rangka kerja untuk pembuat keputusan tentang pengeluaran sara diri individu dan organisasi yang terlibat dalam penghasilan jagung.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AE	Allocative Efficiency
ANOVA	Analysis of variance
AOGCM	Atmospheric Ocean Coupled GCM
APSIM	Analyse the Performance of Point-scale Crop Model
CGE	Computer General Equilibrium
CIMMYT	International Maize and Wheat Improvement Centre
CMIP	Couple Model Inter-comparison Project
CMIP5	Coupled Model Inter-comparison Project Phase 5
CO2	Carbon Dioxide
CO_2	Carbon Dioxide
CORDEX	Coordinated Regional Downscaling Experiment
COS	Corrected Ordinary Least Squares
CR	Corn Ratio
CRM	Coefficient of Residual Mass
CSM	Crop System Model
CV	Coefficient of Variation
DMU^s	Decision Making Units
DSSAT	Decision Support System for Agrotechnology Transfer
ECHAM	Global Climate Change Model
ECOWAS	Economic Community for West African States
EE	Economic Efficiency
EPIC	Model Erosion Productivity Impact Calculator
ETCCDI	Expert Team on Climate Change Detection and Indices
FACE	Free Air Carbon dioxide Enrichment

FAO	Food and Agriculture Organization
FARM	Future Agriculture Farm Model
FDAR	Federal Department of Agriculture Research Ibadan
GCE	Computer General Model
GCM	Global Circulation Model
GCM	Global Circulation Model
GDD	Growing Degree Days
GDP	Gross Domestic Product
GDP	Gross Domestic Product
GDP	Gross Domestic Products
GHG	Green House Gases
ha	Hectare
HadCM3	Hadley Centre
HBV	Hydrological Model
IADP	Integrated Agriculture Development Project Malaysia
IADP	Integrated Agriculture Development Project
IAR	Institute for Agriculture Research
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
IRDP 2	Jamaican Integrated Rural Development Project II
IRDP	Integrated Rural Development Project
ITCZ	Inter-Tropical Converging Zone
kg	Kilogram
LAI	Leaf Area Index

LGP	Length of Growing Period
mm	Millimetre
NAERLS	National Agriculture Extension Research and Liaison Services
NCBRbu	Nigeria Composite B
NGO	Non-Governmental Organization
NIME	Nigeria Metrological Agency
nRMSE	Normalize Root Mean Square Error
ppm	parts per million
PRECIS	Providing Regional Climates for Impacts Studies
RCP	Representative Concentration Pathway
RMSE	Root Mean Square Error
SEM	Spatial Equilibrium Model
SOC	Soil Organic Carbon
SON	Soil Organic Nitrogen
SPSS	Statistical Package for the Social Science
SSA	Sub-Saharan Africa
SSL	Self Sufficient Level
TC	Tropical Continental
TE	Technical Efficiency
TM	Tropical Maritime
VHLSS	Vietnam Household Living Standard Survey

CHAPTER 1

INTRODUCTION

The scientific evidence has indicated that world climate has been dynamic for several millions of years. However, climate change during the last two centuries was unprecedented, contemporary situation of changes in weather elements with low agricultural output particularly in developing countries were defined as the major impediments to agriculture in northern Nigeria. This study was conducted to understand the impact of climate change on yield and farmers production behaviour in northern maize belt, Nigeria. Findings were intended to improve on the climate change existing literature, with regards to issues in contemporary context of northern Nigeria. Climate change is already recognized globally as the most serious important environmental problem affecting the entire humanity. The exacerbating effects are serious and continuous in weather pattern due mostly by anthropogenic caused due to development in transport, farming and development of infrastructure.

1.1 Background of the Study

Africa continent has been identified as one of the parts of the world most vulnerable to the impacts of climate change (Niang et al., 2014). The researchers have essentially believed that the earth weather conditions have continuously changed for millions of years. Though, many evidence specified that humans' activities from industrial revolution in the past two centuries were mainly responsible for the recent rise in the level of greenhouse gases above usual limits. According to Intergovernmental Panel on Climate Change, fourth assessment report (Parry et al., 2007), indicated that anthropogenic factors led to changes in the frequency and intensity of climate with consequent results in extreme and violent weather events. The extreme weather prevalence is evidence as rising temperatures and carbon dioxide, heavy rainfall, drought, floods and cyclones. The aggregate shift in weather pattern is known as climate change; the impact of which together with rising world population poses a serious threat to vital sectors of world economy. The economic sectors most vulnerable to climate change are mainly water supply, ecosystems, coastal habitats, industries, health and agriculture. Climate change is our major challenge of this era, is one of the major issues of the time; enhances a considerable stress to our existing society and to the entire environment. An effect of the changes arises on the fluctuation of weather conditions and patterns, causing threats to production of food, sea level raising that caused risk of catastrophic flooding. The impact of climate change is universal in scope and is unprecedented in scale, without taking any drastic action today; it will be difficult in future time to adapting these impacts of the changes and costly (UNEP) (Hertwich et al., 2010). However, climate change has over time ceased to be a scientific inquisitiveness and is contempt to be no longer as one of the many environmental and regulatory concerns, but contemporary studies shown that climate change is the major intervening environmental problems of our time and is the most single challenging issue that is facing environmental regulators. The impact is a growing crisis within sector of economics, health and safety, food production sectors, security, and other dimensions. The impact aroused for instances in a slight shift of weather patterns will result to a serious threat on crop production through increased instability of precipitation, raising sea levels, pollution of coastal freshwater reserves and increased the risk of disastrous flooding. Increasing warming of the atmosphere has aids the pole ward spreading of pests and diseases that is once limited only to the tropics.

Possible blockbusting for greenhouse gas warming is real, and it has never been more as present, the materials at our disposal must be used, applied immediately and aggressively. In different system of agricultural practices that were applied by farmers in practice to adopting and repatriating climate change variability either due to nature force or human activities, for vulnerability of agriculture may be viewed as a highly sensitive for agriculture to changes in climate, adaptive capacity of the farming system and degree of exposure to the hazards (McCarthy, 2001). Agricultural crop production in different geographical locations is being determined by sensitive to variability on climate. Farmers all over the world have the potentials in terms of physical, economic, agricultural and social resources to be able to moderate or implementing the sensitivity impact of climate on agriculture crop production systems. Though, that is not the case in many African countries, rather agriculture activities system is branded so vulnerable in particular (Haile, 2005). The major uncertainties on the larger fraction of African crop productions is the directly dependents on rainfall, (Cooper, 2004), cited an example that eighty nine percentages of cereals in sub-Saharan African countries depends on rainfall, the key driver of food security on the continent of Africa is climate (Gregory et al., 2005; Verdin et al., 2005). The GIS Surface Temperature Analysis (Schmidt et al., 2016) team on temperature annual anomalies for land metrological station indicate the global temperature trends continued to rise with uncertainty over century (Figure 1.1 below). Recalling that climate change phenomenon is global in nature and should agree that agricultural production in all countries of the world is exceptionally vulnerable due to their dependence on weather conditions. Agriculture is the world's oldest activity that provides food and raw materials to the entire world population. World Bank source (World Bank, 2012) indicated that the agriculture sector serves as the major source of employment to over 70% of the active world rural populace and accounts for 30% of World GDP. Similarly, agriculture provides food security and a source of foreign exchange, industrial raw materials and savings in many countries.

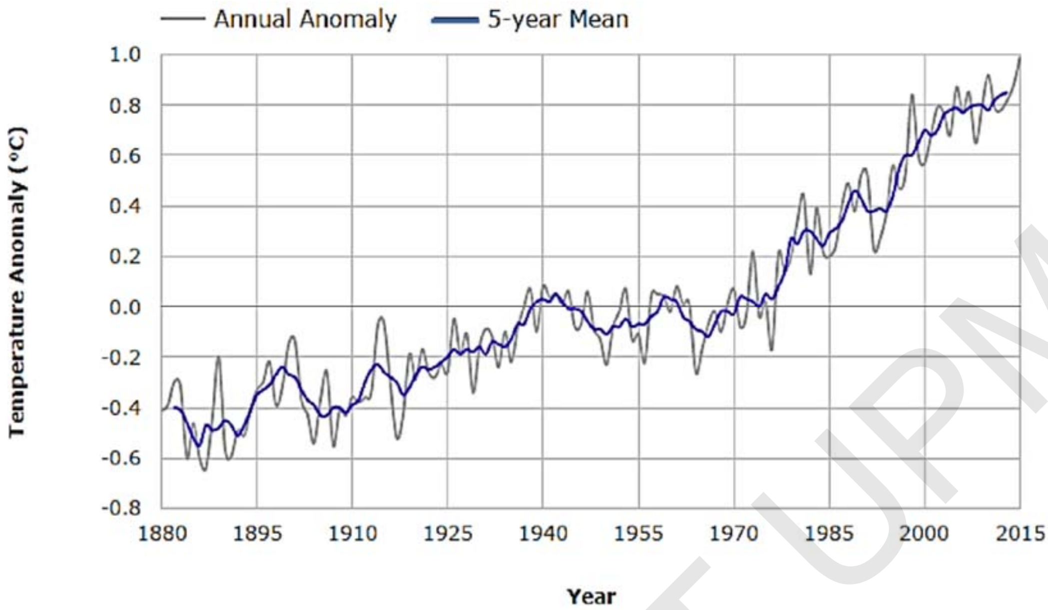

Figure 1.1 : Global Annual Temperature Anomalies from Land Meteorological Station, 1880 – 2015 (Source: Schmidt et al., 2016)

Additional rainfall projected changes of +5 to -15% (Sillmann et al., 2013) in total rainy-days precipitation for tropical western Africa with great uncertainties, particularly at the Guinea coast, "very rainy days that is the top (5%)" indicated even stronger escalations by 50–100% in eastern tropical Africa, and by 30–70% in western tropical Africa (Serdeczny et al., 2015). In southern Africa, total rainy-days precipitation is projected to decrease by 15–45% and very rainy-days precipitation to increase by around 20 – 30% over parts of the region. However, some localized areas along the west coast of southern Africa are expected to see decreases in very rainy days (up to 30%). Here, increases in consecutive dry days coincide with decreases in heavy precipitation days and maximum consecutive five-day precipitation, indicating an intensification of dry conditions. The percentile changes in total rainy days precipitation, as well as in very wet days, are much less pronounced in the low-emission scenario RCP2.6 (Sillmann et al., 2013).

One estimate put losses in agricultural production from developed countries at 24% and developing countries will lose an estimated -10% - 24% of their total production (Table 1.1); In addition, more evidence of the impacts of climate change on world agriculture is emerging from growing body of literature. It was predicted that a (2.5ºC) rise in temperature will hamper crop yields (Amiraslany, 2010), this coupled with growing human population will result in higher food prices. In the same way, historical temperature increases have had considerable negative effects on agricultural value added in developing countries. A 1ºC increase in temperature in developing countries has been found to be associated with 2.66 % lower growth in agricultural output, leading to estimates of economic growth reductions by an average of 1.3 percentage points for each degree of warming (Dell et al., 2012) and reductions in export growth by 2.0 – 5.6 percentage points (Jones & Olken, 2010). Although agriculture sector employs 65% of Africa's labour force and the sector's output has increased since (2000), mainly due to an expansion of agricultural area (World Bank, 2013).

Table 1.1 : Projected Impact for Maize Crop in global Regions and Sub-Regions

Region	Sub-region	Yield Impact (%)	Scenario	Reference
World		Maize up to -4 to -12	CSIRO (MIROC) 2050	Nelson et al, 2010
East Asia	China	-22	-CO_2	*CH 14
South Asia	South Asia	-16	2050	Knox et al, 2012
Africa	All region	-24	2090 +5ºC	Thornton et al, 2009
	East Africa	-3 to +15	2030;2050	Thornton et al, 2010
Central & South America	Brazil (NE)	0 to -10	2030	*CH 27
	Brazil (south)	-15	2080 +CO_2	*CH 27
	Central America	0/-10/-30	2030/2050/2070	*CH 27
	panama	-0.5/+2.4/+4.5	2020/2050/2080	*CH 27
	Chile	-5 to -10	2050 +CO_2	*CH 27
North America	US Midwest	-2.5	+0.8ºC	Hatfield et al, 2011
	US SE	-2.5	+0.8ºC	Hatfield et al, 2011
Europe	Boreal /Alpine/AtlN	+34 to +54	2080	Iglesias et al, 2012
	Alt C/Atl S/Cont N	+5 to 19	2080	Iglesias et al, 2012
	Cont S/Med N/Meds	+11 to +33	2080	Iglesias et al, 2012

*CH = Means IPCC WGII AR5 Chapter.
Source: Porter et al., (2014)

The anthropogenic contribution of climate change coupled with economics development, urban expansion and fast growing populations are most likely to reduce per capita surface water availability in the country and the region entirely, and climate change is expected to worsen this situation especially in the seasonally dry areas (Niang et al., 2014; Cooper, 2004).

1.1.1 Crop Production in Northern Maize Belt, Nigeria

Agriculture in Nigeria depends on rainfall for crop production to a very large extent that the activities in rainy season are more affected by the uncertainty of the onset of rainfall, since the 1970s drought disaster crop production has been under uncertainty in Nigeria and other countries of the continent Table 1.2 (FAO, 2013). Crop production in the countries especially maize has been facing the negative impact of extreme event which continuous to worsen over a long period of weather changes. Nigeria has in the past decades experience some of its worst flood and drought conditions which destroyed farms and property worth millions, the effects varies with region in the country. The dwindling seasonal variation results to rising temperature, rainfall shortage and its cessation at critical growth stages of crop, consequently the growth has repeatedly results to a serious deficit in crop production especially maize. According to the united nation food and agriculture organization special report on assessment mission to Nigeria, indicates that 20% decline in sorghum production, 10% for maize due to irregular rains for production (Murtadha et al., 2008). Nigeria has experiences below average and reduction in cereals production as a result of unpredictable temperature and rainfall patterns, which are exacerbating the impact of rising unemployment, rural urban migration and increasing the poverty amongst youths (Oseni & Masarirambi, 2011). This study is to analyse the impact of climate change on yield in northern maize belt, Nigeria and to examine the production behaviour of farm input on the production and its implication on peasant farmers and household food security in the region and Nigeria.

Table 1.2 : Cereal Production (kg/ha) for Nigeria and other African countries

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Benin	1136.4	1125.2	1013.6	1248.0	1271.2	1200.6	1517.8	1373.2	1399.3	1460.3
Ethiopian	1361.4	1563.3	1439.0	1449.7	1682.5	1832.8	1961.6	2046.8	2193.1	2325.4
Ghana	1432.3	1334.5	1317.0	1598.1	1659.8	1814.3	1594.2	1768.1	1688.8	1703.4
Kenya	1646.3	1646.7	1773.4	1417.7	1242.7	1710.1	1514.6	1744.8	1661.5	1627.7
Malawi	777.8	1444.7	2467.0	1598.7	2124.3	1906.9	2094.3	2087.1	2068.8	2187.8
Nigeria	1421.7	1507.5	1399.8	1598.4	1531.1	1528.4	1337.9	1401.2	1236.4	1593.7
South Africa	3314.5	3159.1	2792.6	4061.5	4412.6	4143.0	4024.0	3689.4	3724.9	4320.4
Swaziland	1307.0	1413.9	555.6	988.8	1076.9	1196.2	1334.8	1329.5	1364.6	937.8
Zimbabwe	587.8	851.0	653.1	309.4	424.4	742.8	793.6	806.0	724.2	788.7

Source: FAO data (2013)

Rainfall is one of the most variable climatic parameters. It is this variability that has resulted in the uncertainties associated with rainfall, both spatially and temporally. This has further been exacerbated by the onset of localized climatic variability which has resulted in anomalous behaviour in rainfall amounts and distribution. Hence, rainfall is important and cannot be over emphasized (Obot & Onyeukwu, 2010). Rainfall is one of the most important indicators of climate change (Novotny & Sfefan, 2007; Adger et al., 2003 & Frich et al., 2002). Human activities have tended to exacerbate. World Bank, (2004) established that an approximately 75% of total gas production in Nigeria is flared. It has been estimated that Nigeria accounts for about 17.2% of global gas flaring. Aside the beneficial aspect of rainfall, it can also be destructive in nature: extreme rainfall events are the major caused of flooding (Ratnayake & Herath, 2005; Ologunorisa, 2004; Folland et al., 1986).

Available meteorological data on surface air temperature for all regions in Nigeria show evidence of increasing surface air temperatures since 1920 (Federal Ministry of Environment, Nigeria, 2003). Also, there are indications that those other climate variables especially rainfall have been affected both in magnitude and temporal distributions. Analysis of monthly rainfall data from 1911 to 1980 reveals a changing pattern in annual precipitation, with rainfall decline between 1941 and 1980 (Federal Ministry of Environment, Nigeria, 2003). In fact, (Odjugo, 2010) established that total rainfall in Nigeria has decreased by 81mm in a period of 105years. Some localities are experiencing extreme weather conditions as a result of rainfall variations and an associated climate change (Odjugo, 2005; Olaniran, 2002). Nnaji and Mama, (2014) have observed rainwater harvesting, that rainfall coefficient of variation (CV) is an important feature of rainfall distribution; the 30-year average coefficients of variation for all locations were presented on (Table 1.3) (Nnaji, 2016).

Table 1.3 : Characteristics of Northern Nigeria Locations With Respect to Rainfall Coefficient of Variation

Location	Geo Zone	Eco Zone	CV Behaviour	Mean CV
Adamawa	Northeast	MFG	Just > 1	1.1
Bauchi	Northeast	NGS	General > 1	1.36
Benue	North central	DGS	Just > 1	1.05
Borno	Northeast	A/SA	General > 1	1.59
Kaduna	Northwest	NGS	Just > 1	1.14
Kano	Northwest	NGS	General, clearly > 1	1.43
Katsina	Northwest	NGS	General, clearly > 1	1.62
Kebbi	Northwest	NGS	Just > 1	1.2
Kwara	North central	DGS	≈ 1	0.94
Niger	North central	SGS	Just > 1	1.14
Plateau	North central	MFG	Mostly > 1	1.3
Sokoto	Northwest	A/SA	General, clearly > 1	1.53
Taraba	Northeast	MFG	Just > 1	1.09
Zamfara	Northwest	A/SA	General, clearly > 1	1.31

GeoZone geopolitical zone, ***EcoZone*** ecological zone, ***A/SA*** arid/semi-arid zone, ***DGS*** derived guinea savannah, ***MFG*** montane forest/grassland, ***SGS*** southern guinea savannah, ***NGS*** northern guinea savannah, ***RF*** rainforest.

Source: Nnaji et al., (2016).

1.1.2 Climate Change Impact on Agriculture

Agriculture crop production in Nigeria and most rural community in developing countries remain the main sources of livelihood. Maize production and the entire agricultural produce in Nigeria has provides employments opportunity for over 60% of mostly rural population and contributed to about 30% of the country gross domestic products (Kandlinkar & Risbey, 2000). Climate changes were mostly the determinant on the performance of agricultural production in the regions, different parts of the world experience different climate change effect, the effects depend on the climate factors such as soil condition, rainfall received and daily atmospheric conditions, also the trend of changes and the available means and infrastructure to help in facing the change.

Nigeria is one of the fast developing regions in the world with over one hundred and eighty (180m) million people, having a great agro-ecological and cultural diversity. The regional population is projected to approach 1.5 billion people by 2050 with profound need to agriculture production which has implication in meeting their food demand due to climate change. The current undernourished persons in the region of sub-Saharan Africa which Nigeria is included were about 223million, but climate change effect could increase that number by about 132 million until 2050. Estimates indicate that, there is higher importation of staple crop in the region; there will be additional requirement of 360% as much food production in the year 2050 as witness in the years (2006) to feed its fast growing population (Searchinger et al., 2014). Peasant farmer are the major producers of maize in northern maize belt, Nigeria and all other agricultural outputs in the other regions. There population account for about 80%, of all the farms and cultivated small percentage of the land which are regularly ruined and there is no access to reliable irrigation. They do not have access to sufficient labour and are sometimes classified as ‘resource poor’ and most of them do not have access to monetary and other financial credit. They normally don’t participate in marketing of their farm produce. Most peasant farmers practices highly subsistence farming characterised by low input and low production which leads to their average yields fall well short of global averages. Productivity in labour and income from agriculture are also very low related to global average of between two united state dollars ($2.0) per day or less, typically they mostly spend an average of about 60% of their hard earning on food for the family (Vanlauwe et al., 2014).

Climate change impacts coupled with challenges facing peasant farmer in trying to produce enough food for regional growing population. Climate change is worsening the situation of already tight resource constraint that is facing the peasant farmers and weather pattern is extreme and more erratic, thereby decreasing the average yields. Nigeria is confronted with a range of climate risks that could have far-reaching consequences for its agriculture systems in the future. Rainfall is fast changing and temperature patterns are evidently posing effects to crop production that leads to price shocks, increasing the vulnerability and accentuate rural poverty. Under 2^{o}C warning that can caused the existence variation in water availability across the region could become more pronounced (Waha et al., 2013). On the other hand, the length of growing period (LGP), which is enable to display as indicator on the adequacy or level of moisture availability, temperature level and soil condition for crop growth, were projected to decrease by up to 20% for most parts of the region by 2050 (Sarr, 2012; Thornton et al., 2011).

Projected shifts in Africa’s ecosystem could lead to extension of savannah grasslands, thereby reduces the availability of forage for grazing animals. Impact of high temperatures interrupt the food intake of animals and can also impair their reproductive system. Most livestock survives comfortably in temperature zones of 10-30ºC. If the temperature exceeds this level the animals reduced their feed intake by 3-5% for each degree Celsius rise in temperature (Thornton & Cramer, 2012). climate change impact can caused the surfacing of pests and diseases that were once a minor problem becoming major livestock and crop production constraints, the intensity and pervasiveness of pests and disease may increase and move to area where they don't exist before, consequently the overall ecosystem will be severely impacted (Waha et al., 2013). Generally plants growth and development depends on its surrounding temperature with each of the plant species has its own required temperature range of minimum to maximum and optimum range. Hatfield at al., (2011) summarizes the different species ranges of crop and fruits. The feature changes expected on temperature over the next 30 – 50 years are predicted to be between 2 – 3ºC (Parry et al., 2007). Extreme temperature or heat waves are projected to become more severe than what is known in past years (Meehl et al., 2007). The forecasted extreme temperature will last for a period of short term in few days with temperature increase by over (5ºC) higher than the normal temperature. However extreme event occurring during summer period would have high impact on plant productivity; though few researches have been conducted on these effects as found by (Kumudini et al., 2014). Also in a recent related study by (Barlow et al., 2015) on the temperature extreme effect, heat and frost, in wheat (Triticum aestivum L) confirm that frost is causing abortion and unproductiveness of formed grains, while extreme heat is causing reduction in number of grains and reduced duration of the grain filling period. An analysis by Meehl et al., (2007) find out that daily minimum temperature, can increase faster than the increased daily maximum temperature which caused increase in daily mean temperature and would resulted to extreme heat and these changes could have detrimental effects on grain yield. If these changes in temperature are expected to occur over the next coming 30 years then understanding the prospective impacts on plant growth and development will help improve adjustments policies to offset these impacts (Hatfield & Prueger., 2015).

1.1.3 Climate Change Effect on Potential Production of Maize

As global emissions of anthropogenic greenhouse gases (GHGs) continue relatively unabated, their impact on climate is already being felt (temperature change, rainfall fluctuation and rise in carbon level) Furthermore, the acceleration of climate change in coming years is virtually assured, due at least in part to the long half-lives of most GHGs. While many of the impacts on people are projected to be modest in the short run (with the exception rate of increased and intensity of weather extreme events), the adverse consequences remain projected to accelerate as climate change accelerates. The projection of climate change is likely to affect agriculture production more than any other sector, which means that populations that depend most on agriculture could be the ones most adversely affected. This is especially true in most African countries and Nigeria in particular. Most of these countries have limited resources that will enable them prepare for climate change adjustment, or to recover from adverse climate shocks to crop yield in the extreme weather condition, (Willenbockel, 2012) summarize in Table 1.3 the assumed yield shocks for each of the crop along with the historical year in which yield deviations have been observed. In each case, adverse weather events are the only plausible explanation for the huge drop in average yields over the whole geographical region.

Table 1.4 : Shocks to Staple Crop Yields in the Extreme Weather Event Scenarios (Percentage Deviation from 2030 Baseline Yields)

Regions	*Years	Maize	Wheat	Rice
North America	1988	-24.8	18.2	-0.8
South America	1990	-17.3	-8.0	-9.0
Oceania	2002	-4.2	-44.3	-4.3
Indian	1979	-7.4	-4.9	-16.9
Other East Asia	1980	-9.1	-18.3	-13.5
West Africa	1983	-19.1	-11.5	-4.2
Central Africa	2004	-6.2	-19.3	-5.2
East Africa	1992	-25.9	-13.1	-3.8
Southern Africa	1995	-42.4	-23.9	-10.0

*Historical year in which negative deviations of annual yields from long-run trends over the period 1979 to 2009 of this size have been observed.
Source: Willenbockel., (2012)

In order to help African peasant farmers, policy makers, researchers, non-governmental organizations and the donors, to have a better plan in preparing for the impact of climate change. The national level research study on these field were recently undertaken, it provide spatially refined analyses on the impacts of climate change on some key crops. These national level studies were published by (IFPRI) on climate change agricultural alteration in West Africa (Jalloh et al., 2013).

Climate change impact on agriculture and its basic understanding depends more on biophysical and phenological maize features. The processes of maize biophysical and phenological are highly climatic dependent, climatic variables including solar radiation, temperature, and regional variation of moisture. Given an example with photosynthesis rate in plants, it depends on the photosynthetically active amount of radiation and carbon dioxide rates in atmosphere. The determinant of plants progressive growth rate is temperature, the phenological stages up to maturity in plant progress is determined by the temperature level. The biomass accumulation is constrained by the availability of surface moisture and soil nutrient to a growing plant (Rosenzweig & Liverman, 1992).

A new challenge poses by climate change on agriculture and entire society in general, especially regarding food supply and land use. This has been out of agenda for food policy, including policy makers and peasant farmers. However the United Nations deliberation on the climate change effect in Copenhagen has been promulgated after the (2009) climate change framework convention conference. Where the data publication is showing the role of both agriculture in climate change effect and climate change effect on agricultural production, in this case the interest of climate change were developed due to its effects on the food system. Including other factors such as increasing food demand in many parts of the world, market speculator for agriculture produce and land clutches. Agriculture has been pushed by climate change into new era of uncertainty surrounded by shocks. The unpredictability on wanting resilience on the agricultural food system globally is a new radically and apparent improved straightaway needed solutions (Garnett et al., 2013). Globally, people have converted virtually 3.8 billion hectares of land, which is a third of the entire landmass on Earth, mainly to agriculture and urban areas. Roughly 85 percent of the land dedicated to agriculture contains areas of soil degraded by rising salt in groundwater, excessive compaction, and erosion. In the past three centuries, 300 million tons of topsoil have been lost each year, in just the last fifty years period, that rate has additional doubled to 760 million tons per year, and some estimates say that this soil degradation has decreased global agricultural productivity by about 15 percent (Fitzgerald, 2016).

The world population may be seeing the start of the global food revolutions with impact of climate change as the main factor that increases to uncertain of the global food system. In the past years of the 2006 to 2008 the prices of food upsurge, food and agriculture organisation factual price index on food rose to about 184.7 points which is greater than 2002 to 2004 average value of one hundred (Conforti, 2011). The consequence of these effect shows that, more than forty countries around the world experienced food rebellions include were Africa, Europe, Asia and Middle East. Food price peak has been exceeded in 2008, presently the real food price export index of fifty five commodities which maize is include has increased to about 205.7 (Conforti, 2011) an all-time high. Verily the impact of climate change is an element that increases more uncertainty to an already food system that is not certain. It increases challenge to peasant farmers and policy makers whom will have to address the problem of food under this current changing socioeconomic condition and climate change.

1.2 Problem Statement

Climate change issue is global as Nigeria faced predictable environmental disaster from climate change impact on agriculture due to changes in temperature, rainfall and carbon dioxide. Nigeria's broad reach of its rapidly increasing population hastens the changes in land use and over dependents of its teaming growing population on farming as the main source of living. With new evidence of climate change using improved climate models that replicate observed continental-scale surface temperature patterns and trends over many periods, including the more rapid warming since the mid-20th century. Greenhouse gases emitted from human activities contributed a global mean surface warming in the range of 0.5°C to 1.3°C over the period 1951 – 2010. The rise in greenhouse gas (GHG) concentrations from 270ppm in the 19th century to over 350ppm as the 20th century came to a close brought to the fore realization that the planet was heating up to a degree that would threaten life on earth, food production and the human's very existence, if such trends continue. Climate change is likely to affect the agricultural sector more than any other sector, which means that populations that depend most on agriculture could be the ones most adversely affected. This is especially true with Nigeria and most African countries. In order to help maize peasant farmers' in northern region, policy-makers and researchers in Nigeria to better plan and prepare for climate change impacts, regional level studies has to be conducted. The study would provide spatially-refined analyses of the impacts of climate on maize yield, along with additional analysis that examines other factors that are changing with the climate, including production behaviours.

Nigeria is generally having three climatic zones which cover the north, middle and southern areas of the country: the Sahel (11º – 14º N), Savannah (8º – 11º N) and the Guinea (4º – 8º N) zones. Climate plays a significant role in the distribution of vegetation and agriculture in Nigeria. About two-thirds of the agricultural area of Nigeria occurs in the northern region, with the remaining one-third of the agricultural area distributed between the middle and southern regions. Nigeria is the most populous country in Africa with over 140 million people and a population density of 138 people per square km and growth rate of 1.7% per annum, according to the 2006 census, Nigeria's population represents more than half of the population of West Africa, and it has a large influence on all of the regional statistics presented for West Africa. Over seventy percent of Nigerians are classified as poor and thirty-five percent live in absolute poverty. As the increasing population puts more pressure on diminishing resources, escalating environmental problems further threaten food production, land degradation as a result of deforestation and overgrazing is already severe in many parts of the country. Drought is a common problem in the northern region, while heavy rains and floods are major problems in the southern and southeast regions; climate change is likely to further aggravate these environmental problems in the future.

Historical rainfall trends and variation is unavoidable to Nigeria's future development especially in agriculture sectors. Nigeria's rainfall trends has been examine over the years (1911 – 2002) from several metrological stations including Global gridded climatology of climate research unit time series (GRU TS.2.1), it shows that Nigerians' annual rainfall has been reduced significantly over 20% of the landscape and the amount of annual rainfall reduced by 50 – 350mm in 64% portion of Nigeria, these would have significant effect on maize growth and development in the study region. In view of the above a comprehensive use of decision making tools would be required to determine which option is best for farmers to apply when in climate change distress, therefore, we need to seek farmers perception on climate changes and developed criteria's from several alternative of their perception to come up with precisely design effective coping strategies, this knowledge will enable maize farmers, authorities at local, national and regional levels to accurately design effective coping strategies.

The current low level of maize production which at present stood at 8 million tons is a source of concern for policy makers and farmers. Under this situation, the demand for the commodity is always short of supply, resulting into shortages and price escalation. The situation is more worrisome because of the fact that Nigeria's average yield which stood at 1.4 tons/ha is far lower than world average yield of 4.3 tons/ha. It is even lower than some African countries such as South Africa. Several efforts made by the government in Nigeria to tackle the problem of low yield, such as the use of enhanced production technology like the use of fertilizer, improved seeds, chemicals and improved farm production practices failed to yield the desirable results. Findings from several studies began to point towards production behaviour (risk, inefficiency and technical inefficiency). Low input use and knowledge about the efficient application was identified as one of the major constraint to maize production in Nigeria. Without this empirical evidence based knowledge, many farmers' current practices and policies in coping strategies are based on potentially assumptions, inaccurate data and predictions.

1.3 Research Question

The question that guided this study is how the impact of climate changes affects yields and the factors that contribute to farmers' production behaviour in northern maize belt, Nigeria?

1.4 Objectives

The general objective of this study is to analyse the effect of climate change on yield and farmers' production behaviour in northern maize belt, Nigeria.

The specific objectives are:

i. To analyse and forecast maize yield grown under rainfed condition and determine the sensitivity of weather elements on yield;
ii. To evaluate and analyse farmers' perceptions towards climate change and appropriate adjustment measures; and
iii. To determine the farmers' production risk, inefficiency and technical efficiency in the region;

1.5 Significance of the Study

Northern savannah region of Nigeria is considered as maize belt of Nigeria. The farmers in this region tend to prefer maize cultivation than any other cereal crop. This trend is brought about by several reasons: included were the accessibility of streak resistant varieties for all the ecological zones, obtainability of high-yielding and hybrid varieties, growing demand for maize which coupled with recent federal government policy prohibition on importation of rice, maize and wheat mainly to boost farmers moral and gear up the local production to encounter the domestic demand for food and industries (breweries, pharmaceutical companies, baby cereals, livestock feeds) and all agro-allied industries for their raw materials. Maize is amongst the most important grains in Nigeria, not only on the basis of the great number of peasant farmers that engaged in its cultivation, but equally at grass root level it has higher economic value. Maize crop is generally cultivated as substantial amongst the cereal crop in derived savannah zones of Nigeria. Over the centuries maize has been in the diet of Nigerians, this begins by using it as a subsistence crop produce by peasant farmer which gradually become more important crop. Currently maize production is engaged by many peasant farmers and its value has risen to a commercial crop that provides raw materials to many agro-based industries. The government implementation of mono-economic on switching from oil base to agriculture economy commence from their inception into power, and continue its effort with a higher determination as reflected in their first budget of the year (2016) where agriculture sector received (N76,753,672,273) when compare with policies of the past government. Last year 2015, the authority resolved in banning all rival crops into the country since northern maize belt, can produced cereals requirement of the country if properly enhance and addresses the problem of climate change in the production. Currently Nigerian farmers are accounting of 10% lost from maize and the predicted lost will be more in future (NBS, 2014), maize price has been stagnant at (N2, 800:00) around the year 2010 until the recent policy pronouncement on the banned of maize import by agro-based industries has put hope for small farmer and begins to see patronage, currently the price is appreciating to (N15, 000:00) per 100kg bag in the market. The (2016) budget of Nigerian government has clearly translated a way forward for self-sufficiency in maize production; the effort is more on provision of farm input. In line with this policy Nigerian government has no power over climate change and is one of the detrimental factor to maize production in the country, climate change impacts has been felt already by many small farmers in recent time. The loses could have been averted if these farmers have knowledge on mitigation and adaptation strategies, currently the situation is worsening as there is heightening of the corn price and uncertainty of the rainfall.

This study enhance the ability of those in production of maize, authority in planning and policy making, through evaluating the effects of climate change on food security and its future consequences on yield and production. This study provided an in-deep research in observing the yield and its future change due to temperature and rise in carbon level, farmers lack knowledge about feature climate change and its effects on crops, this study provide focus on future crop production venture on when to invest more and how to avert catastrophic situation. Most common problem faced by small scale farmers is their inability to know what input is needed more or less, thereby causing waste in the production which leads to losses. Stochastic frontier analysis determines production behaviour. The adjustment to rickety climate change condition has been a challenge to most farmers but this study analyses the climate effects, determines the future trends and proffer adjustment measures to climate change condition to achieved successes in production, this is significant to both peasant farmer and the government agencies. The findings of this study will be a reference to both the farmers, researchers and government in attaining her transformation agenda on the banned of cereals import and improve domestic production for self-sufficiency.

In figure 1.2 presentation of the work flow chart indicate the steps taken is top to bottom process, the step by step presentation give guide for the thesis work and clarity on how interdisciplinary models work to come up with climate change solutions.

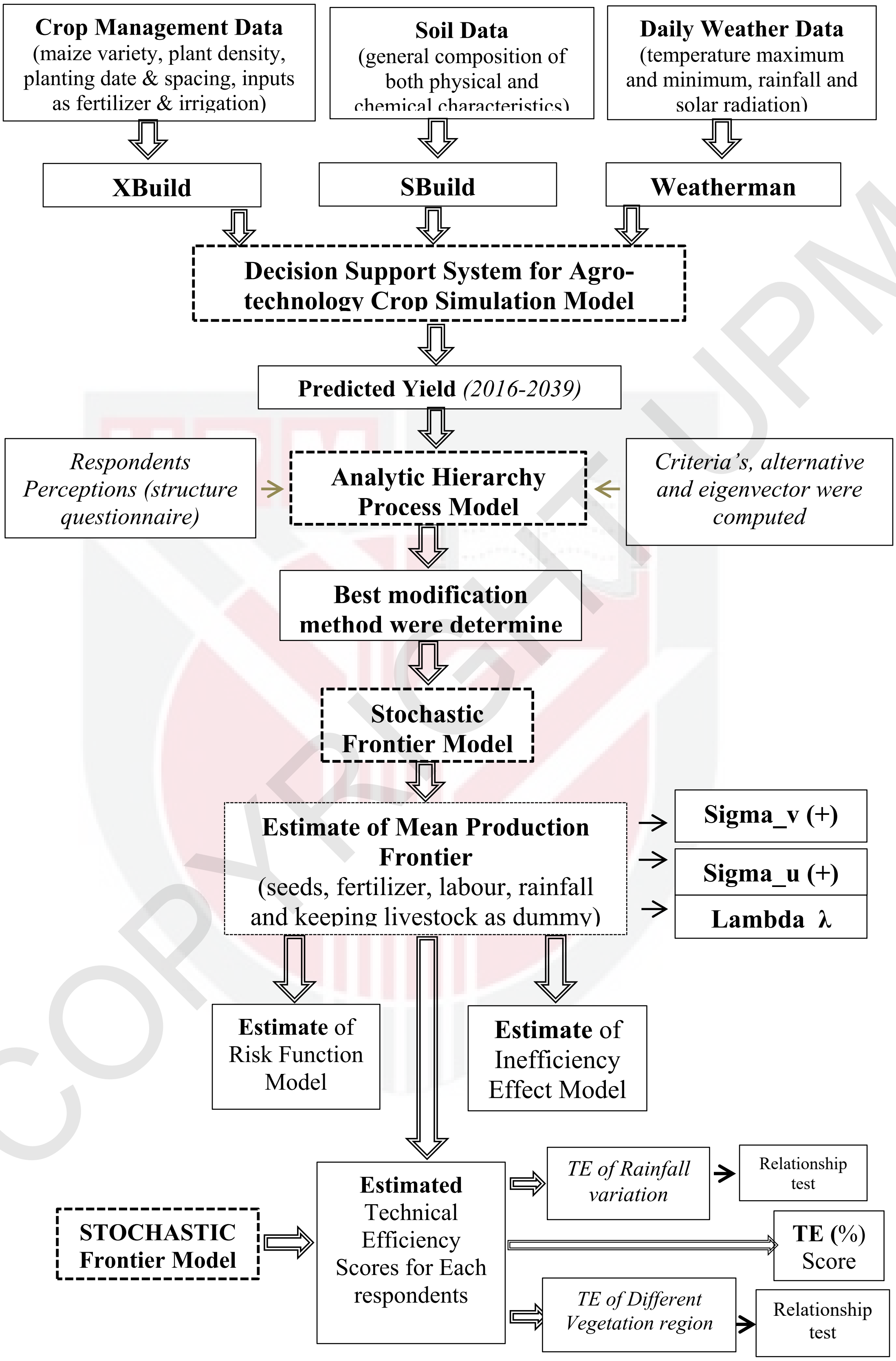

Figure 1.2 : Flow Chart of the Study

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