MASTER'S THESIS

University of The Gambia

TOPIC

COMBINING INDIGENOUS AND SCIENTIFIC KNOWLEDGE OF WEATHER FORECASTING AS POSSIBLE SOLUTION TO INCREASE RURAL FARMERS ADAPTIVE CAPACITY AGAINST CLIMATE CHANGE IN BAMBEY, SENEGAL

by

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This thesis is being submitted in partial fulfillment of requirements
for award of Master of Science Degree in Climate Change and Education at
the School of Education of the University of The Gambia.

Thesis Advisors'
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UNIVERSITY OF THE GAMBIA

MASTER'S RESEARCH PROGRAM ON CLIMATE CHANGE AND EDUCATION

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Thesis Reviewers and Defense Panel:

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Date of the thesis Defense: 9th July, 2018. **Place:** UTG School of Law, Kanifing

Declaration

I, Fatoumata Haidara declare that “COMBINING INDIGENOUS AND SCIENTIFIC KNOWLEDGE OF WEATHER FORECASTING AS POSSIBLE SOLUTION TO INCREASE RURAL FARMERS ADAPTIVE CAPACITY AGAINST CLIMATE CHANGE IN BAMBEY, SENEGAL” is my personal work and I have not used any sources and others than those have been indicated in the references. This thesis has not previously been submitted for any degree or examination. No part of this thesis may be reproduced without prior permission from the author and or the University of The Gambia.

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Abstract

This study investigates on the possible combining of indigenous and scientific knowledge of weather forecasting. Combining the two methods of weather forecasting would help to fill the current gap in the dissemination of weather forecast information among farmers in remote rural area. The study was based on a multi-stage sampling technique of six communities and after calculation process we have arrived at 335 households to be surveyed. Data were also collected through focus group discussions (12) and key informant interviews (12). Analysis of data from household survey was done using Microsoft Excel statistical packages. Qualitative data was analyzed using the thematic approach. The study reveals that (74%) of respondents have noticed changes in rainfall and temperature patterns during last 30 years. However, (33%) of respondents were not aware about causes of climate change and (15%) considered climate change to be God punishment to mankind. Farmers reported to use Plant, Animal behavior, Atmospheric and Astronomical indicators for weather forecasting. For 2017 rainy season (61%) of respondents have forecasted rains to be normal using indigenous. The Senegalese meteorological service also has forecasted normal/above normal rains for the 2017 rainy season. Both scientific and indigenous forecast were true. According to (72%) of respondents both two methods of forecast can be combining and they suggested to create platforms where scientist and indigenous people can exchange information's. Some respondents responded to employ strategies to face the change climate such as: reforestation, sowing native variety and short cycle millet and groundnut, use of compost and use of adapted cooking soft. The study suggest to build capacity of farmers' leader, women leader, chief, religious leaders and "djeliba" (Traditional speaker) of the villages on causes of climate change and how to adapt from it. Also, research team from elderly famers' should be putting in place in view to gather information's on the observations made for the upcoming season in view to organize seasonal outlook with scientific forecaster and decision makers.

Keywords: Indigenous Knowledge, Seasonal Climate forecast, Weather forecast, Climate Change, Adaptation.

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Dedication

This thesis is dedicated to my Dear Mothers late Sadio Sow and late Zeinabou Haidara , my Father Mohamed Aboubacrine for their continuous prayers, love and assistance. I would like also to dedicate it to my Husband Dr Tidiani Siby and to all my family member for their invaluable assistance and advice.

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List of Abbreviations and Acronyms

ANACIM	Agence Nationale de l'Aviation civile et de la météorologie
ANSD	Agence Nationale de Statistique et de la Démographie
CCAFS	Climate Change Agriculture and Food Security
CILSS	Comité Inter-Etats de Lutte contre la Sècheresse au Sahel
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GDP	Growth Domestic Product
ICRAF	International Centre in Research Agroforestry
IKS	Indigenous Knowledge System
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
NGOs	Non-Government Organizations
SCFs	Seasonal Climate Forecasts
SSA	Sub-Saharan African
SST	Sea Surface temperature
UNEP	United Nations Environmental Programme
UNFCC	United Nations Framework Convention for Climate Change
URAPD	Union Régionale des Associations Paysannes de Diourbel

CHAPTER 1: INTRODUCTION

1.1. Background to the problem

One of the biggest challenges of the 21st century is climate change. "Climate change" means a slow change on climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere which is additional to natural climate variability observed over comparable time periods (UNFCC, 1992). According to the Intergovernmental Panel on Climate Change (IPCC, 2013), there is 95% scientific certainty that human activities in sectors such as energy, transportation, agriculture, industry, waste management, etc., are the main cause of the increase of greenhouse gas concentrations in the atmosphere.

There is no doubt about climate change because its impacts are already being felt by the ecosystems, biodiversity and human systems throughout the world and Africa is one of the most vulnerable regions to climate change in the world. This vulnerability is due to the fact that economically, many Africans depend for food, fibre and income on primary rainfall dependent sectors such as agriculture and fisheries (IPCC, 2014).

According to IPCC (2014), food availability could be threatened through direct or indirect impacts of climate change. Direct impacts include impacts on crops and livestock from increased flooding, drought, variation in the timing and amount of rainfall, and high temperatures. Indirect impacts can be felt through increased soil erosion from more frequent heavy storms or through increased pest and disease pressure on crops and livestock caused by warmer temperatures and other changes in climatic conditions.

Like many African countries, in the Sahel region agriculture employs more than 60% of the active population and contributes 40% of the Gross Domestic Product (GDP) (CILSS, 2004). Despite this high dependency, the sector remains highly under-developed due to factors such as (1) an almost total dependency on rainfall; (2) low use of inputs such as improved seeds and fertilisers; (3) absence of mechanisation; and (4) poor linkage to markets (ICRAF and UNEP, 2006).

These factors which are also linked to climate change will drastically impact the livelihood of people in this region and some of the impacts are already felt with socio-economic conflict due to scare resources in many part of Africa.

There is a likelihood of further conflict in the future with climate change expected to reduce total agricultural production by up to 50% in the next few decades in sub-Saharan Africa (Hoffmann, 2011).

Rainfall is highly variable in the Sahel, and to this variability is added the shortness of the rainy season from about July to September which makes these months critical for society, and given the distinct single peak (unimodal) climatology, the onset is also crucial (Ndiaye, 2010). Therefore, the ability of small scale farmers to accurately forecast and use impending weather information is imperative for ensuring sustainability of livelihoods under increasingly variable weather, and a changing climate (Chengula and Nyambo, 2016**).**

According to Ndiaye et al. (2012), a proper utilization of climate and weather forecasts information is known to guide farmers to make major decision such as borrowing money from the bank to invest more in their farm, or hiring workers.

Efforts have been made in the elaboration and dissemination of climate information to farmers in many part of the Sahel. However this has not yet benefitted user community, particularly the most vulnerable to climate variability and change (Ndiaye et al., 2012).

Apart from the problem of access to climate and weather forecast information, we have the probabilistic character of the seasonal forecast which predicts the seasonal rainfall total as chance of being ‘above normal’, ‘below normal’ or ‘near normal’. Furthermore, a seasonal forecast gives only an idea of the total amount of rain, but not its distribution in time (Ndiaye et al., 2012). Therefore, it is imperative that efforts to improve access, accuracy, and reliability of seasonal forecast will need to be enhanced for better agricultural outcomes in Africa.

Studies show that indigenous knowledge could contribute to fill gaps in formal seasonal forecasts, which are largely at broader spatial and temporal scales and focus on rainfall amounts rather than on the timing of the rains (Luseno et al., 2003).

Moreover, local communities and farmers have developed a rich knowledge based on predicting climatic and weather events by observing behaviour of animals, plants, and celestial bodies, among others (Gyampoh and Asante, 2011; Chang’a et al., 2010; Mhita, 2006; Kihupi et al., 2002). According to Roncoli et al. (2001) indigenous knowledge on rainfall forecasting can form an important part of the scientific forecasts in Burkina Faso with the fact that currently, scientific forecasting is unable to predict duration, amount or distribution of rainfall (Mafongoya et al., 2017).

Therefore, integrating indigenous forecasting method in scientific forecasting will provide insights into knowledge gaps at local level and increased farmers trust in scientific forecasting (CCAFS, 2015). A survey conducted in Kaffrine (Senegalese region) revealed that farmers did not use seasonal forecasts instead they relied on their indigenous knowledge (Ndiaye et al., 2012).

In Senegal (West Africa), the national meteorological agency (Agence Nationale de l'Aviation Civile et de la Météorologie, ANACIM) is the Agency responsible for monitoring and predicting weather and climate including seasonal rainfall forecasting. CCAFS scientists collaborated with ANACIM to downscale climate information services in five (5) Senegalese regions: Kaffrine, Diourbel, Thiés, Fatick and Louga and the great success of the project was possible due to consideration given to local knowledge of local communities. However, the extent on which indigenous knowledge is used in weather forecasting in Senegal is quite limited in the literature.

A systematic documentation of local indicators used in weather and climate forecast is therefore urgent for the sustainability of indigenous knowledge and for a better combination in scientific knowledge.

1.2. Statement of the problem

The District of Bambey in Diourbel Administrative Region of Senegal is among the most affected zones by climate variability and change due to its high dependency on rain-fed agriculture which remains as the primary source of income. Rainfall is highly variable in Bambey with recurrent floods (most recent occurred in 2012) and drought series that occurred in 1968, 1973, 1977, 1980-83, 1986, 1991, 1996 and 1998 (Faye et al., 2000). This variability combines with the absence of sources of water other than those obtained from rain water with a short availability of one to two months after rainy season, leaves the District more vulnerable to the adverse impacts of climate variability and change (Yanon and Ndiaye, 2013).

Accessible, accurate, and reliable forecasts therefore, become a key solution for farmers to adapt by basing their farming decisions and activities on predictions of the short and variable rainy season in the District. To date, ANACIM is responsible for elaboration and dissemination of seasonal forecast in Bambey which is known to present some utilization constraints.

According to Adejuwon et al. (2007) (as cited in Joshua et al., 2011) some of those constraints include the course spatial and temporal resolutions of weather forecast which are found to be not ideal for farm level decisions in the short term, like a day, and at lower spatial scales like a village. However, the fact that indigenous knowledge of weather and climate prediction is still used among farmers at local level in the study area but unfortunately, its documentation is quite limited and it is within the custody of the elderly people.

Thus, the knowledge is not only at risk of disappearance but its integration with the scientific methods of weather and climate forecast is not clear. In view of this, the study sought: i) to identify indigenous weather indicators and ii) investigate on the possible combination of these indicators into the scientific methods of weather and climate forecast.

1.3. Significance of the study

Information generated from this study could enrich the knowledge of weather forecaster on how the information they are provided is used by farmers in their day to day farming activities. This is after gaining a better understanding of how farmers in the study area perceive climate change and information generated by weather forecaster. Since they rely mainly on rain-fed agriculture, identifying the Indigenous Knowledge (IK) of weather forecasting used and assessing their perception on the combination of indigenous weather forecasting in scientific weather forecasting method could be very helpful in reducing their vulnerability because they will be more inclined to use it since their knowledge is taken into account.

The findings of this study could be also used to help local authorities and NGOs in the planning and elaboration of their adaptation strategies as they seek to engage with communities to increase understanding and preparedness in relation to the improvement of their resilience from adverse effects of climate change by increasing agricultural production.

1.4. Objectives

1.4.1. Main objective

The main objective of this study is to investigate the combination of scientific and indigenous method of weather and climate forecast in the farming system within Bambey district.

1.4.2. Specific objectives

We will specifically try to:

1. To assess the perception of household on climate change;
2. To identify indigenous knowledge indicators used for weather and climate forecasting in Bambey district;

3. To use and compare traditional and scientific seasonal forecasting methods for 2017 season;
4. To assess the perception of household on the combination of scientific method of weather and climate forecast with indigenous method.

1.5. Research questions

1. What is the perception of household on climate change in Bambey district?
2. What are the indicators used by farmers in Bambey district to forecast different weather and climate?
3. How does scientific seasonal forecast method compare with indigenous forecast method?
4. What is the perception of household on the combination of scientific method with indigenous method of weather forecast?

1.6. Scope and limitation of the study

This study seeks to establish the role that plays the combination of scientific method with indigenous method of weather forecast can plays to help farmers to cope with the effects of climate variability and change in Bambey district. It identifies the various biotic, astronomical and meteorological indigenous knowledge indicators for weather and climate forecast. It compares scientific seasonal forecast with indigenous seasonal forecast for the 2017 season. Validation of indicators is not covered in this study. For validation of indigenous knowledge of weather forecasting to be conclusive, a number of seasons are supposed to be studied to capture indicators for the normal, drought and above normal seasons, which was not possible in this study due to unavailability of data.

In this study, language barrier was a challenge because the researcher cannot speak the main local language. Another limitation was the delay in the starting of the field work which was supposed to start in May for researcher to get farmers forecast before the upcoming rainy season.

1.7. Outline of the thesis

This thesis report is presented in five chapters. Chapter 1 introduces the report and looks at the background of the study, statement of the problem, significance of the study, objectives, research questions, scope and limitation of the research. Chapter 2 reviews the related literature on scientific weather forecasting, indigenous knowledge systems of weather forecasting, various indicators used in weather prediction and impacts of climate change around the world. Related researches elsewhere in Africa on possible integration of seasonal climate forecasts and indigenous knowledge are also presented. Chapter 3 describes the general characteristics of the study area such as climate, vegetation; demographics, location as well as the various methods used to collect and analyse the data. Chapter 4 presents data analysis, results of the study and discussions. The final chapter of this report is conclusions that can be drawn out of this research and recommendations.

1.8. Definition of terms

Climate is the long-term average weather conditions (usually taken over a period of more than 30 years) of a region (IPCC, 2012).

Weather is the current atmospheric condition in a given place. This includes variables such as temperature, rainfall, wind or humidity.

Climate change is a change in the state of the climate that can be identified by changes in the mean and/ or the variability of its properties that persists for an extended period, typically decades or longer (IPCC, 2007). According to the United Nation Framework on Climate Change (UNFCC, 1992) this changes is attributed directly or indirectly to human activities that alter the composition of the global atmosphere which is additional to natural climate variability observed over comparable time period.

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2001).

Indigenous knowledge is a cumulative body of knowledge practice and belief, evolving by adaptation processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with their environment (Berkes , 2012).

Weather forecasting is a scientific estimation of the weather conditions at some future time which are expressed in terms of variables such as temperature, precipitation and wind (Lutgens and Tarbuck, 2010).

CHAPTER 2: LITERATURE REVIEW

2.1. Overview

The Intergovernmental Panel on Climate Change (IPCC, 2014) proclaims with high confidence that changes in climate, together with non-climate drivers and stresses, will exacerbate the vulnerability of African agricultural systems, particularly in semi-arid areas. The Fifth Assessment Report (IPCC, 2014) of the IPCC projects that temperatures in West Africa will rise by between 3°C and 6°C by the end of the 21st century while changes in rainfall are uncertain. Agriculture sector is projected to loss of between 2-7% of GDP by 2100 in parts of the Sahara, 2-4% & 0.4-1.3% in Western and Central Africa and Northern and Southern Africa respectively (FAO, 2009).

Climate models predict for Senegal an increase by the 2060s of 1.1 to 3.1°C in mean annual temperatures and a decrease in precipitation (USAID, 2012). Senegal vulnerability will therefore increase due to its large rural population living from rain-fed agriculture. Therefore, timely forecast information will be very crucial to farmers in view to make plans under a very shorter rainy season (from July to September).

2.2. Weather forecasting

2.2.1. Seasonal forecasting

Seasonal forecasting can be described as the total amount of rainfall expected during the season or over a given time period (Ziervogel and Calder, 2003). According to Ndiaye (2010), the rationale behind seasonal forecasting lies in the fact that the atmosphere could be constrained by external forcing and some of those external forcing are the variability of sea surface temperature, variability of incoming solar radiation, and variability of surface vegetation. Among these forcing agents, the variability of the Sea Surface Temperature (SST) is most used to successfully predict the inter-annual climate variability (Ndiaye, 2010). Sahel rainfall is found to be influenced by the following SST regions: the tropical Atlantic (Lamb, 1978a; Ward, 1998), and the Pacific Ocean El Niño Southern Oscillation (ENSO) (Ward, 1998).

Tropical Pacific warm events (El Niño) are related to reduce rainfall in the Sahel, and cold events (La Niña) are associated with above normal rainfall in Sahel West Africa (Ndiaye, 2010). These boundary conditions generally evolve slowly, and so can be used to provide a forecast of different weather regime probabilities (Mason et al., 1996). Currently the seasonal climate forecasts are being expressed in tercile with the probability of rainfall being in each of the following categories: above-normal, normal, and below-normal (Masinde and Bagula, 2012). These probabilities are obtained from 30 years historical data. Over the 30-year period, the data is ranked from the highest value to the lowest and then divided into 3 groups called terciles (WMO, 2007). Thus, the top 1/3 indicates the above-normal years (top number), the middle 1/3 indicates the near-normal years (middle number), and the bottom 1/3 indicates the below normal years (bottom number) (WMO, 2007).

2.2.2. Interpreting a weather forecast

The seasonal forecast is always expressed as percentages of occurrence of any of the categories (Below Normal, Normal and Above Normal). The most favourable forecast is usually presented by the category with the highest percentage. Also, other categories should not be neglected though less likely they may occur (Ndiaye et al., 2013).

In West Africa seasonal rainfall relates to the 3 months of July, August, and September, during which 90% of total annual rainfall occurs (Ingram et al., 2002). The rains typically start in early May (at least for the southern parts of the Sahel), reach a maximum in August and fall off in October following the migration of the ITCZ from the Equator to the North and returning back southward toward the Equator (Ndiaye, 2010). In the Sudano-Sahelian region, the forecast research community has been most interested in seasonal prediction of the total rainfall during the wet season, often defined as the July-August-September total.

2.2.3. Importance of weather forecasting

Climate information has never been so crucial for humanity has today. The information appears to be particularly important and in many cases a prerequisite for coping and adapting to the negative impacts of climate variability and change (Goddard et al., 2010), particularly in Senegal where most rural livelihoods depend on climate related sectors such as agriculture, livestock and fisheries. According to Kijazi et al., (2012), climate change impacts can be significantly reduced by having sound adaptation strategies based on increased accuracy in weather and climate predictions. Seasonal climate forecasts (SCFs) had been used by farmers to make appropriate crop management decisions related to crop choice, planting time, fertiliser use, area planted to a given crop, timing and tillage type (Patt and Gwata, 2002; Ziervogel, 2004; Patt et al., 2007). There is an increasing realization that agro-climatological information, particularly that which provides details on climate extremes and recommendations for actions to be taken, is crucial to improve on agricultural production and responsible use of agricultural resources and managing agricultural risk ((Friesland & Lo¨pmeier, 2006; Moeletsi et al., 2013) cited in Jiri et al., 2016).

Finding from a study conducted in Burkina Faso indicates that the most salient rainfall parameters farmers want in forecast are: (1) timing of the onset and end of the rainy season; (2) likelihood of water deficits, that is, rainfall distribution; and (3) total amount of rainfall (Ingram et al., 2002). In addition, study conducted in Kaffrine region (Senegal) revealed that farmers found the onset date to be the most relevant piece of information in their decision system (Ndiaye et al., 2013). The study further revealed that the forecast of onset of rainy season helped farmers to be better prepared and saved their harvest from the first rain. According to Siyakumar (2006) introduction of seasonal climate forecast into management decisions can reduce the vulnerability of rain fed agriculture to droughts and reduce its negative impacts.

Studies in West Africa have also demonstrated how the use of seasonal rainfall forecast information can reduce loss of lives, property and infrastructure caused by floods (Tall et al., (2008) and Braman et al., (2013)).

2.2.4. Limitations of scientific seasonal climate forecasts

As noted above, seasonal forecast is for great value in agriculture system. However, constraints related to legitimacy, salience, access, understanding, capacity to respond and data scarcity have so far limited the widespread use and benefit from seasonal prediction among smallholder farmers (Hansen et al., 2011).

A study conducted by Nganzi et al., (2015), revealed that 93% of farmers in the study area reported facing some challenges using scientific weather forecast information however the most outstanding challenges are the unreliability and inaccuracy of the forecast which have been reported by 91% of all the interviewed respondents.

Likewise, Mafongaya et al., (2017) identified the poor interpretation and communication of forecast to be challenges which lead to misunderstanding and low dissemination rates. However this misunderstanding some time is due to the lack of literacy among rural farmers in the Sahel.

The forecast is usually issued for a period of one, three or six months and suggests the total amount of rainfall expected over that period, but not the distribution of rainfall within that period. If the amount of rainfall forecast were to fall over a few days, the seasonal forecast would still be correct but the impact could be catastrophic (Agrawala et al., 2001 cited in Soropa et al., 2013).

Further challenge is the lack of specific information about timing of rainfall and season onset or length (Hansen et al., 2011; Kolawole et al., 2014 cited in Jiri et al., 2016). Therefore farmers in Burkina Faso considered a less accurate forecast with sufficient lead-time to be more valuable than a highly accurate forecast that arrives after they have made irrevocable decisions (Ingram et al., 2002). It is therefore imperative that efforts to improve accuracy and reliability of seasonal forecast will need to be enhanced. Systematic documentation and subsequently integration of Indigenous Knowledge (IK) in seasonal rainfall forecasting is one of the promising initiatives that need to be explored. (Chang'a et al., 2010)

Constraints to the capacity to respond to climate forecasts lie in economic and social structures, rather than uniquely in a lack of information (CICERO Report, 2000). According to Mafongoya et al., (2017), access to seed, implements, fertiliser, labour and credit would allow farmers to make adjustments in relation to the expected seasonal climate forecast. Research (Ziervogel and Opere 2010) has shown that SCFs are too supply-driven and are too ‘coarse’ to have relevance at a local community level. The terminologies (e.g. below and normal level) and formats used do not make much sense to most farmers.

2.3. Indigenous knowledge of weather forecasting

2.3.1. Definition and characteristics

In recent years, there has been an increasing amount of literature on the importance of Indigenous knowledge (IK), which has been defined as institutionalized local knowledge that has been built upon and passed on from one generation to the other by word of mouth (Osunade, 1994; Warren, 1992). For a very long time, people in rural areas have observed the behaviour of plants, animals and insects, the condition of physical features such as mountains, and atmospheric states to predict impending weather patterns (Risiro et al., 2012). Indigenous knowledge has a strong practical emphasis that is oriented towards planning, and exhibits dynamism that allows for incorporation of new elements (Kolawole et al., 2014 cited in Jiri et al., 2016). Ellen and Harris (1996) cited in Mafongoya et al., 2017 provided characteristic of Indigenous knowledge (IK) as follows:

• IK is a consequence of practical engagement in everyday life, and is constantly refined by experience, trial and error. This experience is a product of many generations of intelligent reasoning and its failure has undesirable consequences for the lives of its practitioners. Its success is very often a good measure of a combination of factors. It is tested in the rigorous laboratory of survival.

• IK is empirical rather than theoretical knowledge. To some extent, its oral character hinders the kind of agonisation necessary for the development of theoretical knowledge.

• Repetition is an essential characteristic of tradition, even when new knowledge is added. Repetition aids retention and reinforces ideas.

• IK is constantly changing, being produced as well as reproduced, discovered and lost, though it is often portrayed as being static.

• IK is characteristically much further ahead than other forms of knowledge. Therefore, it is called the people's science. However, its distribution is still segregate and socially clustered. It is usually asymmetrically distributed within a population by gender and age and is preserved through the memories of individuals. IK may be focused on particular individuals and may achieve a degree of coherence in rituals and other symbolic occurrences; however its distribution is always fragmented. It does not exist in totality at any one point or within any one individual.

• IK is characteristically solicited within oral cultural traditions and therefore, separation of the technical from the non-technical and the rational from the non-rational, is problematic.

2.3.2. Importance of IK

Since time immemorial farmers in rural communities have been used indigenous knowledge of weather and climate forecasting to plan their faming activities. According to Chang'a et al., (2010), local communities in different parts of the world have continued to rely on IK to conserve the environment and deal with natural disaster. Moreover, in Tanzania local communities have been coping and adapting to increased climate variability normally manifested in the form of increased frequency and magnitude of various exigencies including droughts and floods, and outbreak of pests and diseases by using IK of weather and climate prediction (Chang'a et al., 2010). Additionally, the different farming operations that are being adopted by farmers in Zimbabwe basing on IK forecasts include changing varieties, staggering planting dates, dry planting and use of hoes for land preparation (Soropa et al., 2015). Integrating indigenous knowledge into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable (Hunn, 1993; Robinson and Herbert, 2001 cited in Ajani and et al., 2013). Such strategies will include the adoption of efficient environmental resources management practices such as the planting of early maturing crops, adoption of hardy varieties of crops and selective keeping of livestock in areas where rainfall declined.

2.3.3. Indigenous weather forecasting prediction indicators

Farmers in rural communities combined different indicators to predict weather pattern. Several literature shows that a number of African farmers have been using various local weather indicators such as plants, animals, insects, solar/moon/ star and wind/clouds in predicting the seasonal climate (Roncoli and al.,2002; Risiro et al., 2012; Kijazi et al., 2012; Joshua et al., 2011; Muguti and Maposa, 2012). It should be known here that these forecast indicators are not deployed haphazardly, but as a result of experimentation, a close understanding of nature, and the development of logical reasoning from daily life experiences and verified in an institutional setting, of what Odora-Hoppers (2002) cited in Mafongoya et al.,(2017) refers to as an 'indigenous academy' of survival.

2.3.4. Biotic indicators

i. Plants indicators

A study conducted in Zimbabwe revealed that in the eastern part of the study area plants such as msasa (Brachystegia spiciforms), mnondo (Julbernardia globiflora) bloom into green and release tender leaves indicating the onset of the rain season (Risiro et al., 2012). According to Zuma-Netshiukhwi et al., (2013), above normal blossoming of fruit trees like peach (Prunus persica) and apricot (Prunus armeniaca) in the farm surroundings, development of young leaves, grass emerging and sprouting of Aloe ferox in the mountains are indications of good rains. While the development stages of those fruit trees are associated with the onset of spring and summer seasons. In katsina state (Nigeria) the presence of an abundant fruit and leaves at certain time in trees like Adansona digitata (June-August), Tamarindus Indica (May-June), Vitex doniana (May-June), Zimenia Americana (May-June) and Magnifera (April-May) indicate abundant rain (Abdulrashid, 2013). Joshua et al., (2011) in a study conducted in Mulanje District, Southern Malawi found that the high production of mango fruits in a season is normally associated with low rainfall in the coming season and hence low agricultural yield. Dropping of fruits or drying of flowers before maturity is considered to indicate forthcoming very dry season.

ii. Birds, Insects and Animals indicators

Certain behaviour of birds can also be a helpful barometer in predicting the arrival and intensity of a particular rainy season (Muguti and Maposa, 2012). The singing, nesting and chirping of certain birds appears to be a useful indicator for the onset of the rains in southern Africa (UNEP, 2008). According to Mapara (2009), in

Tangwena, Zimbabwe people can foretell whether rains are going to fall in the next hour or two if they hear the sound of "dzvotsvotsvo" (rain bird).

According to Makwara (2013), when a black crow builds a nest in an area, swallows and water fowls lay eggs on raised patches in river valley, water fowls breed on the ground under cover of grasses and reeds it is an indication of below normal rainy season because the birds would not risk its eggs going bad so drought conditions will be expected.

The presence of various types of insects such as spittle bugs (Machaerotidae spp) on trees, the movement of safari ants (Shifameso) (Dorylus wilverthi), the occurrence of large numbers of big black ants (Nondo) that prey on brown ants and white termites (Msora or Mkokye) (Pogonomyrmex spp.), emerging from their nests to forage (spreading over on the surface looking for food and shelter) are indicative of impending rains (Chengula and Nyambo, 2016). According to Muguti and Maposa (2012), Shona people used continuously movement around and collection of grass for storage of insects like "*zviteza*" to predict the imminence beginning of rainy season.

When mbira (rock rabbit) squeaks for a long time in the morning and early evening this could indicate that the hot season has begun (Risiro et al., 2012).

Studies conducted in Tanzania and Burkina Faso has revealed that the perception of black or dark scorpions in the month of October is an indication of a possible good rainy season (Kijazi et al., 2013; Elia et al., 2014).

2.3.5. Atmospheric weather forecasting indicators

On meteorological indicators, wind patterns, direction and variation were also found to be used in monitoring rainfall (Kijazi et al., 2012). Winds blowing from the west to the east were the most common sign indicating the starting of rainy season in five districts out of six in Uganda (Okonya & Kroschel, 2013). While in Tanzania occurrence of strong wind was associated to poor rainfall season in this particular year (chang'a et al., 2010). As part of their indigenous knowledge, the Shona normally assert that if there is a lot of whirlwind in August to mid-September, it is a sign that there would be good rains. On the contrary, if there were little whirlwind, then rainfall would be erratic. People panic because it is an indicator of a looming drought and famine in the area (Muguti and Maposa, 2012).

According to Chang'a et al., (2010), people in Kilolo district foretell anomalously warming during the months of August to November has an indicator of high rainfall in the upcoming season. Additionally, high moisture producing emission of water vapours from the soil announces imminent rainfall within hours. In India, the moisture on dried chillies or tobacco leaves is considered to indicate high humidity and imminent rain (Rautela & Karki, 2015).

A study conducted by Rautela and Karki (2015) in Uttarakhand (India) associated Dark clouds to heavy rainfall within a few hours. Further, from a study conducted by Soropa et al., (2015) in Zimbabwe, heavy dark clouds before a rainy season are interpreted to mean a wet season.

Most of the respondents in a study conducted in Nigeria, believed that the rainy season starts during the darker phase of the moon and considered the visible phase of the moon to be likely dry than the darker phase (Abdulrashid, 2013). Furthermore, some seven to ten days dry spell (ban iska) is expected during the visible phase of the moon, particularly in July, to allow the weeding of the planted crops and the wilting of weeded grass. A halo around the moon is sign of a coming rain; most of the respondents believed that the halo is formed due to high moisture content in the atmosphere.

Farmers are always observing the sky to see the type of cloud, the direction and speed at which the cloud is moving to determine whether the cloud will bring rain or not or will move to another area to drop rain. When different clouds are seen, such as cumulus (bakin hadari) and stratus (farin hadari) are observed, it is an indication that clouds are gathering momentum, forming rain (Abdulrashid, 2013).

2.3.6. Challenges of using IKS

In spite of all these benefits, IK in weather and climate prediction is under threat of disappearance due to: lack of systematic documentation of the knowledge; lack of coordinated research to investigate the accuracy and reliability of IK (Chang'a et al., 2010). In addition those people with valuable information (elders) are passing away and living organisms such as plants and animals are quickly disappearing or extinct due to climate change and overpopulation (Risiro et al., 2012). Policymakers on the continent tend to view reliance on indigenous knowledge for climate forecasting with scepticism (Briggs and Moyo, 2012; Saitabau, 2014 cited in Jiri et al., 2016). According to Williams and Muchena (1991) cited in Makwara (2013), the skills to identify, collect, and develop indigenous knowledge into contemporary usable formats are needed so as to ensure the sustainability of the knowledge. Without that, our focus on the promotion of marrying local knowledge and modern science for sustainable agriculture will be futile.

2.3.7. Integration of IKS and SCFs

Several studies (Risiro et al., 2012; Chang'a et al., 2010 and Makwara, 2013) have concluded that both modern and traditional methods have some strengths and weaknesses, and should be used in a complementary fashion to produce more comprehensive information on weather forecasts for community-based end users.

In Western Kenya Rainmakers from the Nganyi family has got sacred shrines with indigenous trees they use to predict weather. Their weather forecast in combined with that from the Kenyan Meteorological Department to produce more accurate weather reports (Thomson Reuters Foundation, 2012 cited in Risiro et al., 2012). Roncoli et al., (2002) have demonstrated that indigenous knowledge on rainfall forecasting can form an important part of the scientific forecasts in Burkina Faso. Scientific and indigenous climate forecast present some complementarity according to Moller et al., 2004 cited in (Mafongoya et al., 2017). And some of that complementarity is presented in Table 1.

Table 1: Complementarity between science and traditional seasonal climate forecasts (adapted from Moller et al., 2004 cited in Mafongoya et al., 2017).

Principle	Explanation
Diachronic vs systematic complementarity	Science collects dynamic data in a time series over a large area e.g. the use of COFs in Africa. IKS focus on diachronic data and long term series' in small areas e.g. the use of indigenous indicators of forecasting in African villages or districts.
Focus on averages vs extremes	Science is based on the numerical data analysis of averages. IKS observe extreme weather events and unusual patterns, which is critical in climate change adaptation.
Quantitative vs qualitative information	Science demands quantitative data. IKS demand qualitative understanding of the system. Understanding complex systems like climate change requires both. Qualitative measures are rapid and inexpensive but they lack precision.
Hypothesis vs mechanisms	IKS rely on hypotheses for problem solving. Science has powerful tools to explain the reasons for mechanisms. The use of both IKS and science takes advantage of their relative strengths.
Objectivity vs subjectivity	Science is objective and excludes people's feelings. IKS include people's feelings, relationships and sacredness. The combination of both methods produces science with a heart.

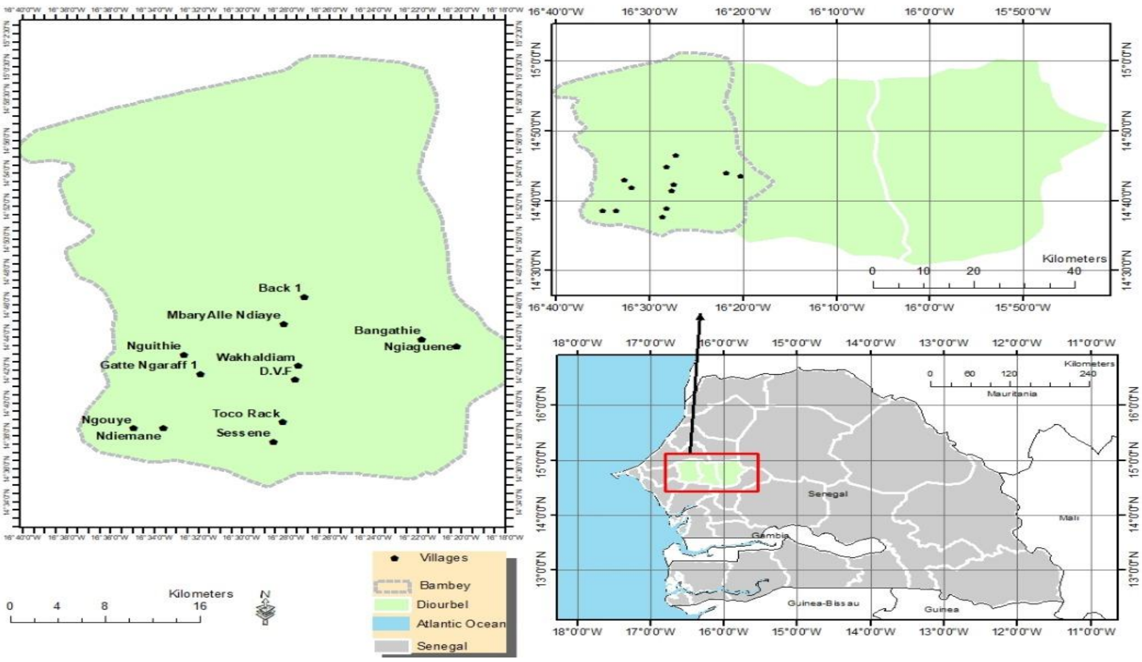
CHAPTER 3: METHODOLOGY

3.1. Description of study area

3.1.1. Physical location

The study was carried out in Bambey district in Diourbel Region, Senegal.

Bambey district belongs to the old groundnut basin of Senegal and covers an area of 1357 Km². The district is bordering by Tivaouane district in the North, Diourbel district in the East, Thiès district in the West, Fatick district in the South and Mbour district in the South-West.



Soure: Author of study

Figure 1: Map of Bambey District

3.1.2. Climate and vegetation

The climate of Bambey District is sahelien, with a variable annual rainfalls averaging 484, 92 mm from 1968 to 2010 (Yanon and Ndiaye, 2013). Two seasons are clearly defined: a rainy season from June to October and a dry season from November to May. Mean annual temperature is 35 °c and the mean annual evaporation is approximately 874 mm (ANSD, 2009). Trade wind blowing from North and North-East is hotter and dryer which result to high temperature. Harmattan wind blowing from May-June carries dust. Monsoon wind carrying moisture blows in July.

The vegetation is mainly dominated by the presence of Acacia albida.

3.1.3. Demographics and livelihoods

The population of Bambey District was estimated at 299476 persons from the 2013 census (ANSD, 2015). Bambey District has a population made up of Sérére, followed by Wolof, Fullas, Manding, Diolas and Toucouleur. Majority of the population are Muslim but we have also Christian and Animist in the district.

Agriculture is the main source of livelihoods in the district but yields are usually low due to rainfall variability, soil degradation, and rapid population growth (ANSD, 2009). Groundnut, millet, maize, sorghum and maize farming are the dominant activity (ANSD, 2015). Livestock farming, trade and craft industry are sources of income used in conjunction with agriculture in Bambey District.

3.2. Data collection procedure

3.2.1. Research Design

The proposed study was both qualitative and quantitative research (mixed method) for in-depth investigation into the subject under study. The approach was used so as to serve as a vehicle for cross checking the authenticity and validity of the various generated data sets. This was achieved by using and cross checking information across both primary and secondary data sources. Primary data was obtained through a survey (household survey, key informant interviews and Focus Group Discussions (FGDs)). Secondary data was obtained by reviewing relevant literature. These included among others; journals, text books, annual and periodicals reports.

3.2.2. Sample and sampling Technique

A multi-stage sampling technique was used in this study. Six communities in Bambey (Bambey, Ndangalma, Ngogom, Ndondol, Ngoye and Thiakhar) were purposely selected based on the fact that they are located next to each other (share the same boundaries) therefore they have similar environmental characteristic and indigenous knowledge systems are known to be localized knowledge domains. Two villages were randomly selected in each of the six communities: Bambey (Wakhaldiam and D.V.F), Ndangalma (Gatte Ngaraff I and Nguithie), Ngogom (Keur Aliou Diouf 1 and Keur Aliou Diouf 2), Ndondol (Ngouye and Ndiemane), Ngoye (Sessene and Toco Rack) and Thiakhar (Ndiagne Toufa and Ndiaguene). Finally with a population of 2576 households (ANSD, 2013) we have obtained a sample size of 335 households. The calculation of the sample size was done by using online software on sample size calculation (available on https://www.surveymonkey.com/mp/sample-size-calculator/#/). The Formula used by the software is given as:

$$S = \frac{\frac{z^2 * p(1-p)}{e^2}}{1 + (\frac{z^2 * p(1-p)}{e^2 * N})}$$

Where:

S = required sample size

e = margin of error, here e= 0.05

N= population size

z = 1.96

p = the population proportion (assumed to be 0.50 since this would provide the maximum Sample size).

A list of household practicing agriculture was obtained from village head and

a sample random sampling technique was adopted in administering the copies of questionnaire in all the villages. A key informant interview session was held with the individuals' elderly. Further purposive sampling was used to select 2 farmers based on age factors (Above 60 years) and experiences in forecasting weather using indigenous knowledge in each selected community of the district.

Table 2: Distribution of respondents in the study area

Community	Village	Total household	Sample
Bambey	*Wakhaldiam*	**730**	**95**
	D.V.F	**1234**	**160**
Ndangalma	Gatte Ngaraff I	**105**	**14**
	Nguithie	**71**	**9**
Ngogom	Keur Aliou Diouf 1	**56**	**7**
	Keur Aliou Diouf 2	**18**	**2**
Ndondol	Ngouye	**65**	**8**
	Ndiemane	**52**	**7**
Ngoye	Sessene	**127**	**17**
	Toco Rack	**82**	**11**
Thiakhar	Ndiagne Toufa	**16**	**2**
	Ndiaguene	**20**	**3**
Total		**2576**	**335**

Source: Field Survey Data, 2017

3.2.3. Data collection procedure

The first step of the data collection started with a workshop at the Headquarters of Union Régionale des Associations Paysannes de Diourbel (URAPD) with a view to explain the purpose of the research and to recruit individuals with the best profile for the field data collection.The reason behind approaching URAPD was due to their recognition by Senegalese Ministry of Interior since 1993 as a reliable agricultural organization for issues concerning their communities. Further, they have gained a huge experience in collaborating with farmers over several years. Thus, we proceeded to the recruitment of two individuals for the survey. The criteria of selection were based in the years of experience for survey, knowledge of French and the local languages and finally the knowledge of the area of data collection. We have finally, recruited one male and female after assessing them based on the criteria. Thus, a training session was organized with selected people on the questionnaire and data collection procedure. The training was mainly based firstly on the introduction of the purpose of the study, secondly the explanation of each section of the questionnaire in French, Serere and Wolof and finally a scenario of a pre-test in view to assess their understanding and reliability of the questionnaire.

The second step was based on the collection of data in different villages. Semi-structured interview, survey questionnaires and focus group discussions were used to obtain the desired information.

(a) The semi-structured interview of elderly farmers was used to collect in deep information on indigenous weather and climate indicators. The purpose of the interview was divulged to the participant one week before in view to enable him to prepare for the interview.

(b) Two focus group discussions (separate groups: men and women) in the each of the communities were used to collect deeper information related to their perception on indigenous weather forecast, source from which they heard weather information and how they perceived the combining of indigenous and scientific knowledge of weather forecast. Each focus group was constituted by a total participant of 10 people. Discussants were both women and men who are living in the communities for more than 20 years.

(c) The survey questionnaire was administered on the respondents. Information was collected on:

- Household demographic and socioeconomic character;
- Weather and climate perception;
- Indigenous weather and climate forecasting;
- Scientific weather forecasting.

The survey questionnaire had both qualitative and quantitative information

(d) Temperature and Rainfall data

Rainfall and temperature data from 1980 to 2017 were collected from ANACIM (Agence Nationale de l'Aviation Civile et de la Météorologie). Seasonal forecast information from 2017 season as well as the updated data for the 2017 rainfall season were also collected from ANACIM.

3.3. Data analysis procedure

The analysis was done in line with the four (4) specific objectives. Quantitative data from questionnaires was analysed in MS Excel 2010.Trends of rainfall and temperature data from ANACIM (1980 to 2017) were processed using MS Excel to show variation over time.

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter presents the findings of the study. We will first of all present the demographic characteristic of respondents.

The rest of the results are presented per objective and follow the order of objectives as presented in Chapter 1. Findings on perception of farmers on climate change are presented first. Identification of indigenous weather indicators are presented second. Integration of indigenous knowledge indicators into the scientific methods of weather and climate forecasting are presented third followed by comparison between traditional and scientific seasonal forecasting methods for 2017 season and finally the perception of farmers on the integration of indigenous knowledge of weather and climate forecasting with scientific method.

4.1. Demographic characteristic of respondents

The study revealed that totality of respondents in Bambey district were male except in Bambey and Ngoye communities where we had 17% and 4% females respondents respectively. This low rate of female respondent could be explained by facts that in rural area men are usually the major decisions makers thus the chief of the family. Women are not allowed to talk before the men because they may have an opinion which is not in line with their husbands' ones. We have faced cases where husbands were not present in the household but instead of their wife responding another male (son, brother, cousin, etc.) have responded. The percentage of female respondents in Bambey community was the highest among the six communities and this could be explained by the fact that people in that community have more access to the media thus there are more informed.

Majority of farmers in all the six community interviewed where married.

The main ethnic groups in Bambey district was "Serere" followed by "Wolof" and others ethnic group like "Maur" was the least funded. Among all six communities it was only in Bambey district that we have recorded various ethnic groups: Serere (54%), Wolof (33%), Peulh (4%), others_Manding (2%), others_Diolas (1%), others_Toucouleur (3%) and others_Maur (2%), this could be due to fact that Bambey community was the most populated community among the six communities.

Majority of famers in the six communities have never attended school (40%, 82%, 52%, 60%, 43%, and 80%) in Bambey, Ngogom, Dangalma, Ndondol, Ngoye and Thiakhar respectively. Low literacy is very common in rural area especially among farmers. However, high numbers of farmers have attended Koranic school (23%, 9%, 28%, 13%, 39%, and 20%) in Bambey, Ngogom, Dangalma, Ndondol, Ngoye and Thiakhar respectively.

Bambey community has the lowest number of uneducated farmers because they have schools and university.

Table 3: Demographic characteristic of respondents

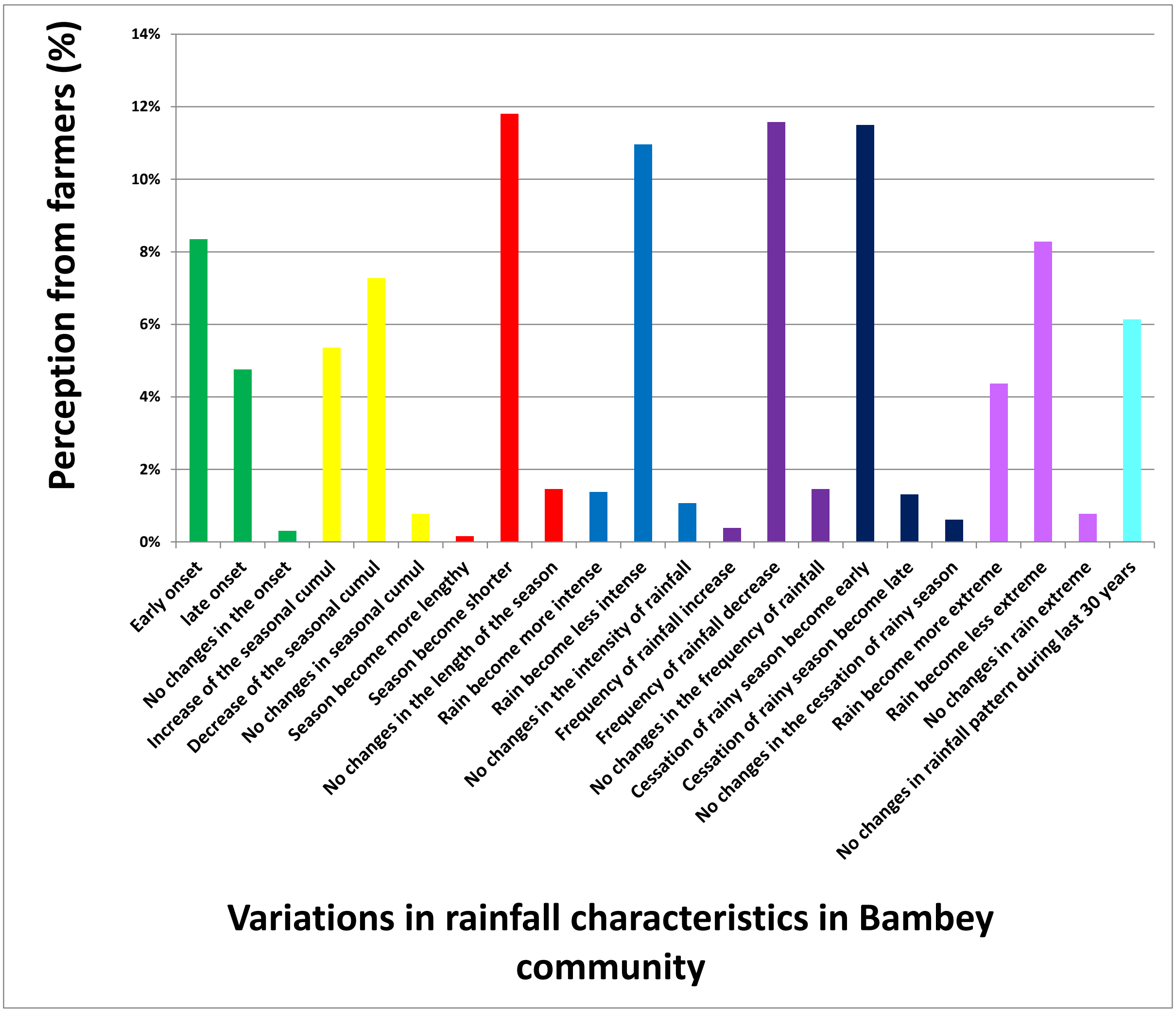
Variables	Bambey		Ngogom		Dangalma		Ndondol		Ngoye		Thiakhar	
Gender	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Female	45	17%	0	0%	0	0%	0	0%	1	4%	0	0%
Male	215	83%	9	82%	25	100%	15	100%	27	96%	5	100%
Age				0%								
Less than 24 years	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Between 25 and 34 years	31	12%	0	0%	0	0%	3	20%	2	7%	1	20%
Between 35 and 44 years	34	13%	0	0%	1	4%	0	0%	9	32%	0	0%
Between 45 and 54 years	56	22%	0	0%	3	12%	2	13%	7	25%	0	0%
Between 55 and 64 years	72	28%	2	18%	11	44%	6	40%	4	14%	0	0%
Between 65 and 74 years	37	14%	3	27%	6	24%	1	7%	3	11%	4	80%
Above 75	23	9%	5	45%	4	16%	3	20%	3	11%	0	0%
Marital situation of HH												
Single	5	2%	0	0%	0	0%	0	0%	1	4%	0	0%
Married	217	83%	11	100%	25	100%	15	100%	27	96%	5	100%
Divorced	4	2%	0	0%	0	0%	0	0%	0	0%	0	0%
widower	30	12%	0	0%	0	0%	0	0%	0	0%	0	0%
Ethenic group of HH												
Wolof	87	33%	0	0%	9	36%	1	7%	2	7%	3	60%
Serere	140	54%	11	100%	16	64%	14	93%	26	93%	2	40%
Peulh	11	4%	0	0%	0	0%	0	0%	0	0%	0	0%
others_Manding	4	2%	0	0%	0	0%	0	0%	0	0%	0	0%
others_Diolas	2	1%	0	0%	0	0%	0	0%	0	0%	0	0%
others_Toucouleur	9	3%	0	0%	0	0%	0	0%	0	0%	0	0%
others_Maur	5	2%	0	0%	0	0%	0	0%	0	0%	0	0%
Length of residence in the locality												
Less than 10years	24	9%	0	0%	0	0%	0	0%	0	0%	0	0%
Between 11 and 20 years	47	18%	0	0%	0	0%	0	0%	1	4%	0	0%
Between 21 and 30 years	19	7%	0	0%	2	8%	1	7%	4	14%	0	0%
More than 30 years	76	29%	4	36%	7	28%	4	27%	18	64%	2	40%
Always	79	30%	7	64%	16	64%	10	67%	4	14%	3	60%
Education level												
Never attended school	103	40%	9	82%	13	52%	9	60%	12	43%	4	80%
Primary	41	16%	0	0%	4	16%	2	13%	4	14%	0	0%
Secondary	44	17%	1	9%	0	0%	0	0%	0	0%	0	0%
Tertiary	6	2%	0	0%	1	4%	2	13%	1	4%	0	0%
Koranic school	61	23%	1	9%	7	28%	2	13%	11	39%	1	20%

4.2. Farmers' perception on climate change

4.2.1. Perception on rainfall

Results from household survey on farmers' perceptions of rainfall variation in the six communities of the study area showed that all the interviewed farmers noticed variations in rainfall patterns over the past 30 years.

Therefore, 69% of respondents have noticed changes in rainfall pattern in Bambey, 67% in Ngogom, 87% in Dangalma, 80% in Ndondol, 61% in Ngoye and finally 80% in Thiakhar (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7).



**Percentage is the proportion of response on total responses.*

Figure 2: Variations in rainfall characteristics as perceived by farmers over the past 30 years in Bambey Community.

Onset

The largest number of respondents in Bambey community has perceived an early onset (8%) of respondents while the lowest number of respondents (4%) has perceived a late onset.

Seasonal cumuli

The largest number of respondents in Bambey community has perceived a decrease in the seasonal cumuli (8%) of respondents while the lowest number of respondents (1%) has perceived no changes in seasonal cumuli. Further (5%) of respondents have perceived an increase in seasonal cumuli.

Length of the season

The largest number of respondents in Bambey community has perceived season length to become shorter (8%) of respondents while the lowest number of respondents (1%) has perceived no changes in season length.

Intensity of rainfall

The largest number of respondents in Bambey community has perceived rain to become less intense (11%) of respondents while the lowest number of respondents (1%) has perceived rain to become more intense and also (1%) of respondents has perceived no changes in rain intensity.

Frequency of rainfall

The largest number of respondents in Bambey community has perceived a decrease in rainfall frequency (12%) of respondents while the lowest number of respondents (1%) has perceived no changes in rainfall frequency.

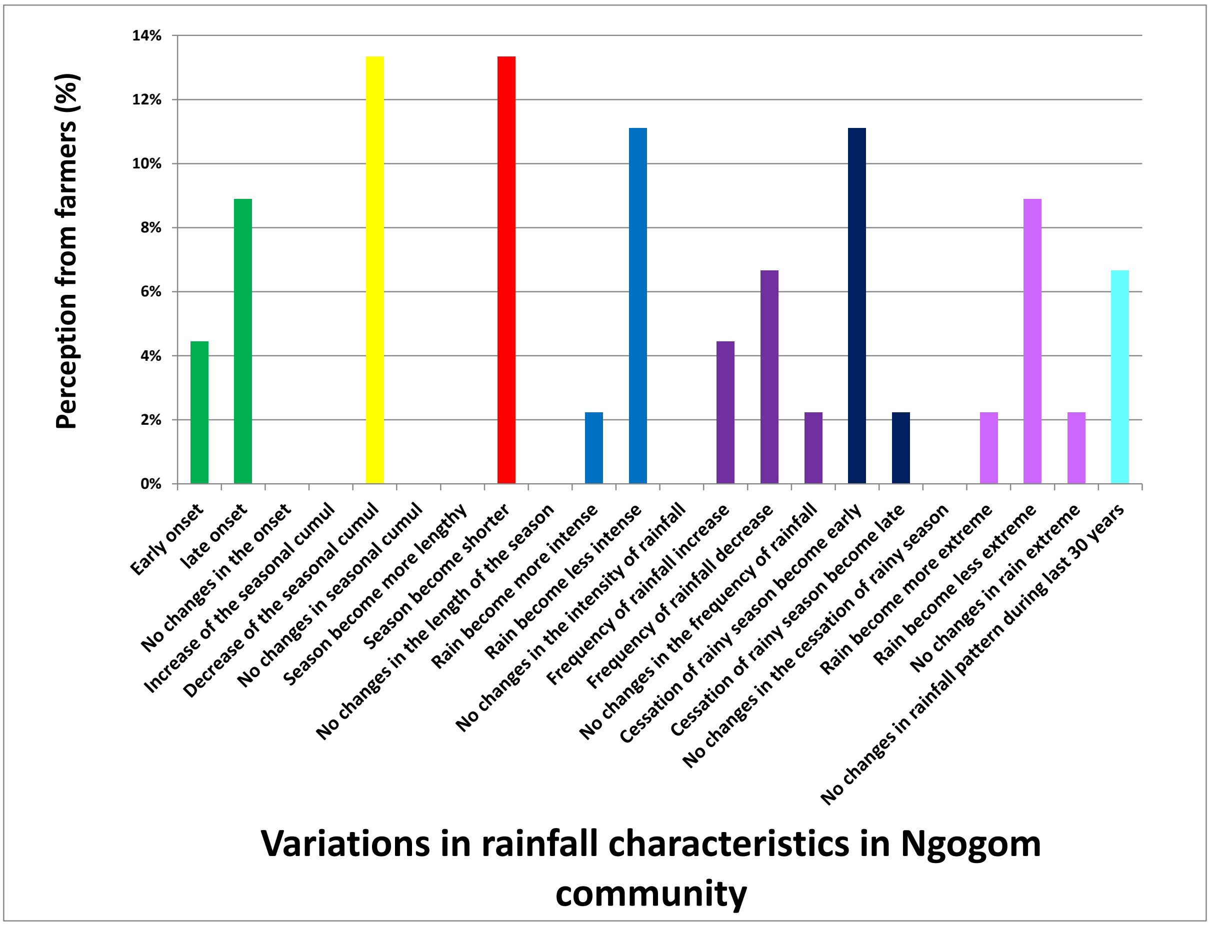
Cessation of rainy season

The largest number of respondents in Bambey community has perceived an early cessation of the season (11%) of respondents while the lowest number of respondents

(1%) has perceived a late cessation and also (1%) of respondents has perceived no changes in cessation of rainy season.

Rain extreme

The largest number of respondents in Bambey community has perceived rain to become less extreme (8%) of respondents while the lowest number of respondents (1%) has perceived no changes in rain extreme and also (4%) of respondents has perceived rain to become more extreme.



*Percentage is the proportion of response on total responses.

Figure 3: Variations in rainfall characteristics as perceived by farmers over the past 30 years in Ngogom community.

Onset

The largest number of respondents in Ngogom community has perceived a late onset (9%) of respondents while the lowest number of respondents (4%) has perceived an early onset.

Seasonal cumuli

Almost all respondents in Ngogom community have perceived a decrease in the seasonal cumuli (13%) of respondents.

Length of the season

Almost all respondents in Ngogom community have perceived season length to become shorter (13%) of respondents.

Intensity of rainfall

The largest number of respondents in Ngogom community has perceived rain to become less intense (11%) of respondents while the lowest number of respondents (2%) has perceived rain to become more intense.

Frequency of rainfall

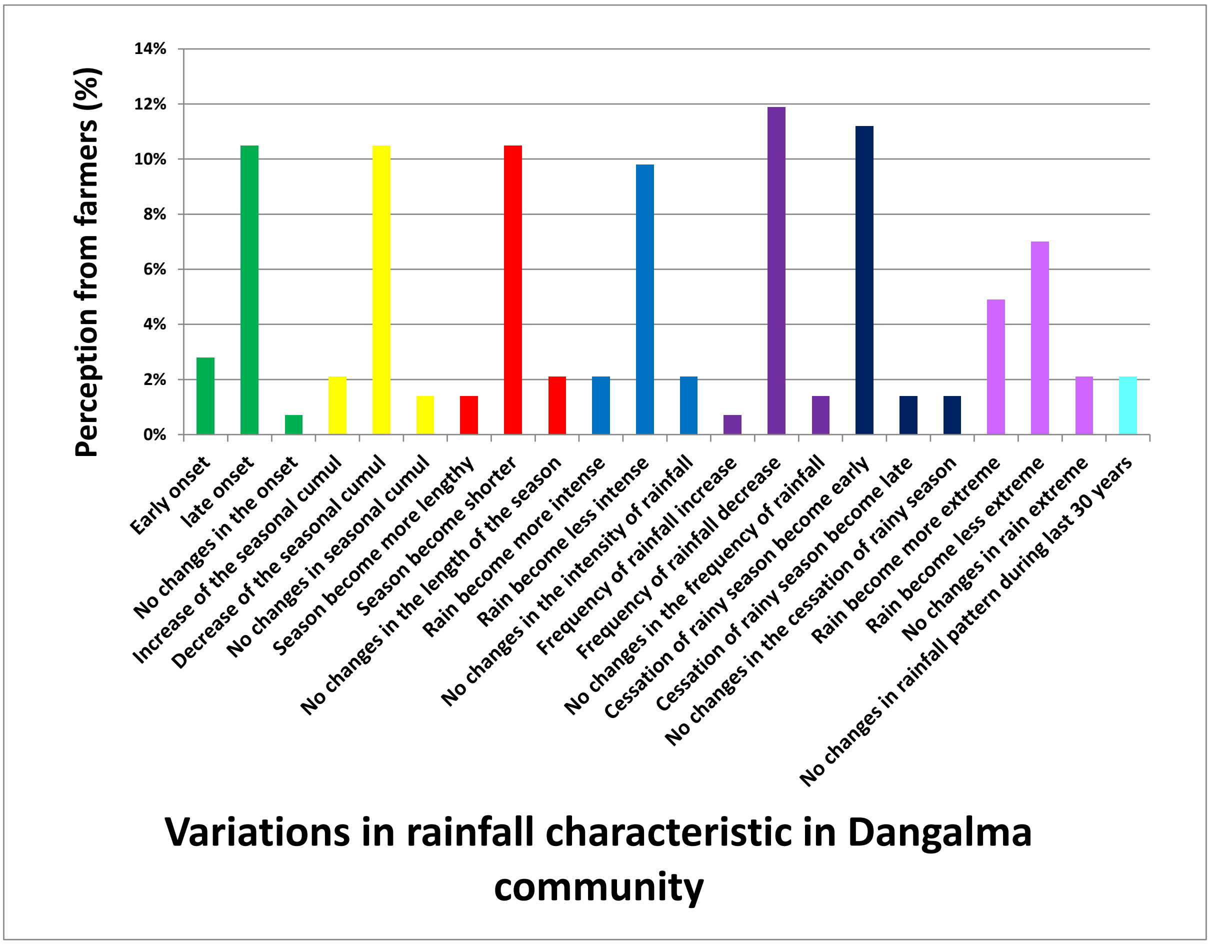
The largest number of respondents in Bambey community has perceived a decrease in rainfall frequency (7%) of respondents while the lowest number of respondents (2%) has perceived no changes in rainfall frequency and also (4%) has perceived an increase in rainfall frequency.

Cessation of rainy season

The largest number of respondents in Ngogom community has perceived an early cessation of the season (11%) of respondents while the lowest number of respondents (2%) has perceived a late cessation.

Rain extreme

The largest number of respondents in Bambey community has perceived rain to become less extreme (9%) of respondents while the lowest number of respondents (2%) has perceived rain to become more extreme and also (2%) of respondents has perceived no changes in rain extreme.



**Percentage is the proportion of response on total responses.*

Figure 4: Variations in rainfall characteristics as perceived by farmers over the past 30 years in Dangalma community.

Onset

The largest number of respondents in Dangalma community has perceived an early onset (10%) of respondents while the lowest number of respondents (1%) has perceived a late onset and also (3%) has perceived no changes in season onset.

Seasonal cumuli

The largest number of respondents in Dangalma community has perceived a decrease in the seasonal cumuli (10%) of respondents while the lowest number of respondents (1%) has perceived no changes in seasonal cumuli. Further (2%) of respondents have perceived an increase in seasonal cumuli.

Length of the season

The largest number of respondents in Dangalma community has perceived season length to become shorter (10%) of respondents while the lowest number of respondents (2%) has perceived season to be lengthier and (1%) perceived no changes in season length.

Intensity of rainfall

The largest number of respondents in Dangalma community has perceived rain to become less intense (10%) of respondents while the lowest number of respondents (2%) has perceived rain to become more intense and also no changes in rain intensity.

Frequency of rainfall

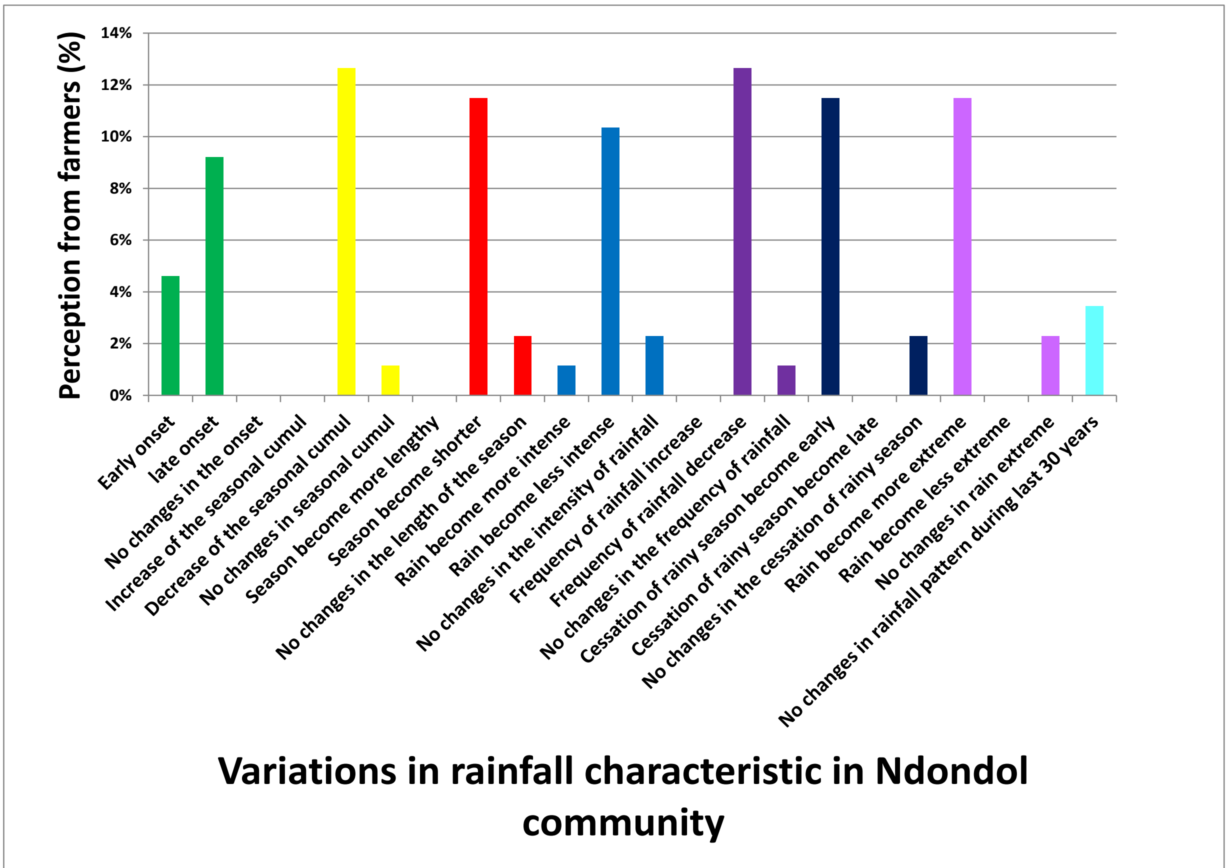
The largest number of respondents in Dangalma community has perceived a decrease in rainfall frequency (12%) of respondents while the lowest number of respondents (1%) has perceived an increase in rainfall frequency and no changes in rainfall frequency.

Cessation of rainy season

The largest number of respondents in Dangalma community has perceived an early cessation of the season (11%) of respondents while the lowest number of respondents (1%) has perceived a late cessation and also (1%) of respondents has perceived no changes in cessation of rainy season.

Rain extreme

The largest number of respondents in Dangalma community has perceived rain to become less extreme (7%) of respondents while the lowest number of respondents (2%) has perceived no changes in rain extreme and also (5%) of respondents has perceived rain to become more extreme.



*****Percentage is the proportion of response on total responses.*

Figure 5: Variations in rainfall characteristics as perceived by farmers over the past 30 years in Ndondol community.

Onset

The largest number of respondents in Ngogom community has perceived a late onset (9%) of respondents while the lowest number of respondents (5%) has perceived an early onset.

Seasonal cumuli

The largest number of respondents in Ngogom community has perceived a decrease in the seasonal cumuli (13%) of respondents while the lowest number of respondents (1%) has perceived no changes in seasonal cumuli.

Length of the season

The largest number of respondents in Dangalma community has perceived season length to become shorter (11%) of respondents while the lowest number of respondents (2%) has perceived no changes in season length.

Intensity of rainfall

The largest number of respondents in Ngogom community has perceived rain to become less intense (10%) of respondents while the lowest number of respondents (1%) has perceived rain to become more intense and (1%) has perceived no changes in rainfall intensity.

Frequency of rainfall

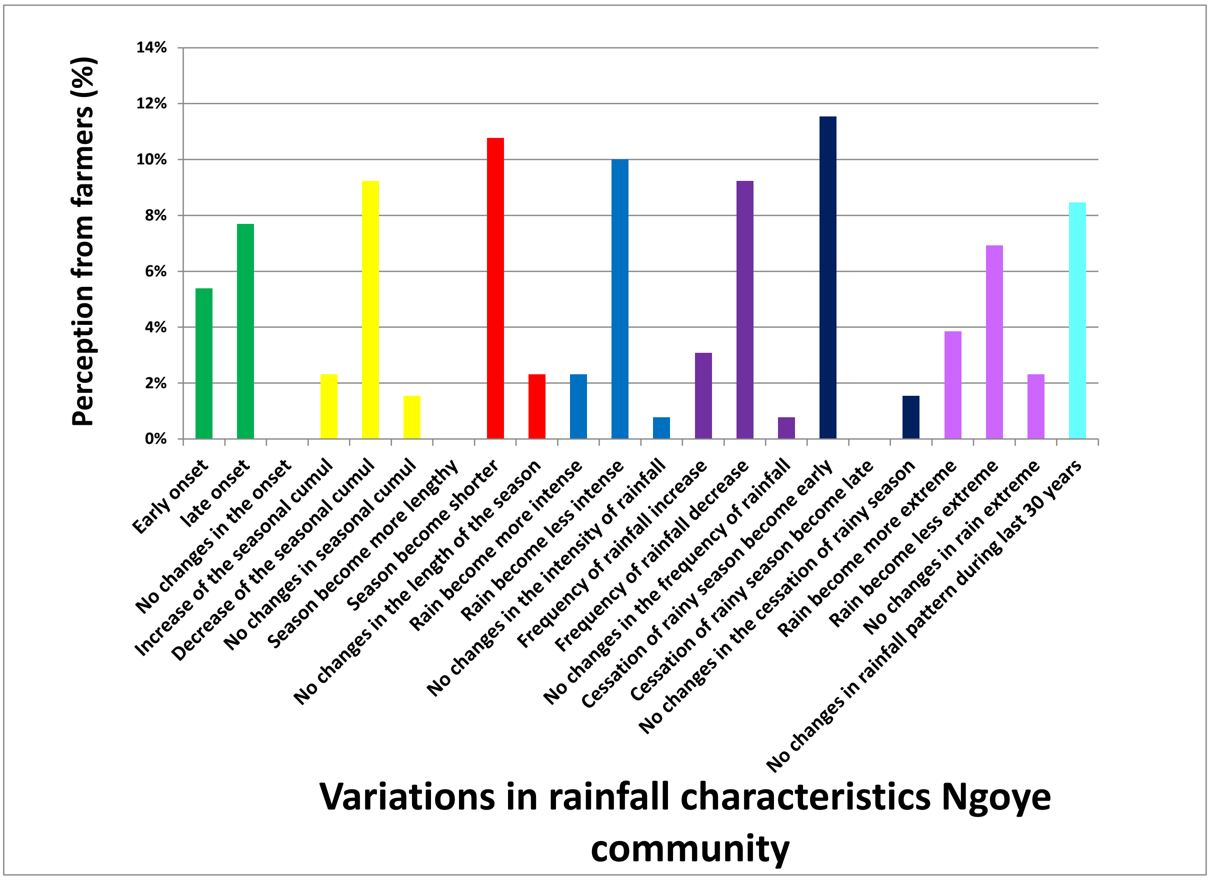
The largest number of respondents in Bambey community has perceived a decrease in rainfall frequency (13%) of respondents while the lowest number of respondents (1%) has perceived no changes in rainfall frequency.

Cessation of rainy season

The largest number of respondents in Ngogom community has perceived an early cessation of the season (11%) of respondents while the lowest number of respondents (2%) has perceived no changes in season cessation.

Rain extreme

The largest number of respondents in Bambey community has perceived rain to become more extreme (11%) of respondents while the lowest number of respondents (2%) has perceived no changes in rain extreme.



**Percentage is the proportion of response on total responses.*

Figure 6: Variations in rainfall characteristics as perceived by farmers over the past 30 years in Ngoye community.

Onset

The largest number of respondents in Ngoye community has perceived a late onset (8%) of respondents while the lowest number of respondents (5%) has perceived an early onset.

Seasonal cumuli

The largest number of respondents in Ngoye community has perceived a decrease in the seasonal cumuli (9%) of respondents while the lowest number of respondents (2%) has perceived no changes in seasonal cumuli and an increase in seasonal cumuli.

Length of the season

The largest number of respondents in Ngoye community has perceived season length to become shorter (11%) of respondents while the lowest number of respondents (2%) has perceived no changes in season length.

Intensity of rainfall

The largest number of respondents in Ngoye community has perceived rain to become less intense (10%) of respondents while the lowest number of respondents (1%) has perceived no changes in rainfall intensity and (2%) has perceived rain to become more intense.

Frequency of rainfall

The largest number of respondents in Ngoye community has perceived a decrease in rainfall frequency (9%) of respondents while the lowest number of respondents (1%) has perceived no changes in rainfall frequency and (3%) has perceived rain frequency to increase.

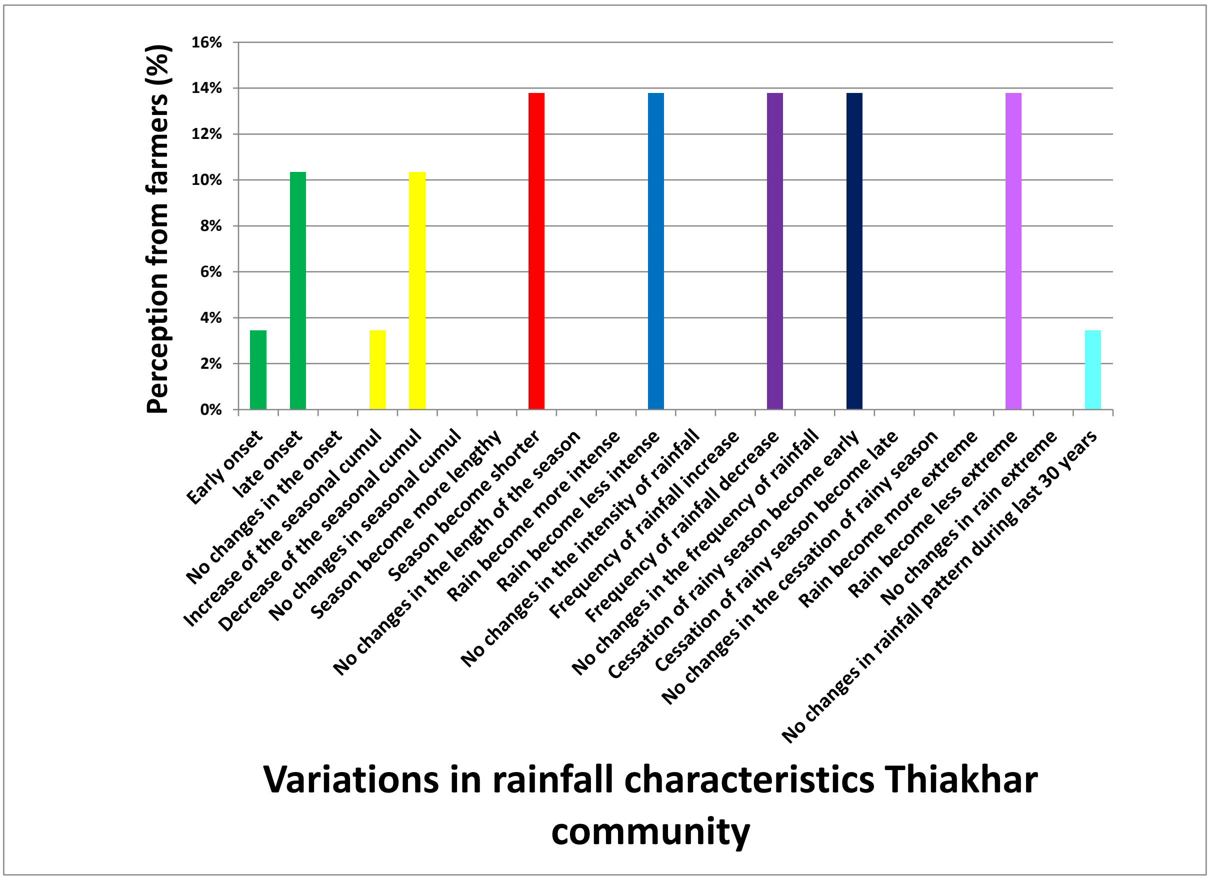
Cessation of rainy season

The largest number of respondents in Ngoye community has perceived an early cessation of the season (12%) of respondents while the lowest number of respondents (2%) has perceived no changes in season cessation.

Rain extreme

The largest number of respondents in Ngoye community has perceived rain to become less extreme (7%) of respondents while the lowest number of respondents

(2%) has perceived no changes in rain extreme and (4%) has perceived rain to become more extreme.



**Percentage is the proportion of response on total responses.*

Figure 7: Variations in rainfall pattern as perceived by farmers over the past 30 years in the community of Thiakhar.

Onset

The largest number of respondents in Thiakhar community has perceived a late onset (10%) of respondents while the lowest number of respondents (3%) has perceived an early onset.

Seasonal cumuli

The largest number of respondents in Thiakhar community has perceived a decrease in the seasonal cumuli (10%) of respondents while the lowest number of respondents (3%) has perceived an increase in seasonal cumuli.

Length of the season

Almost all respondents in Thiakhar community have perceived season length to become shorter (14%) of respondents.

Intensity of rainfall

Almost all respondents in Thiakhar community have perceived rain to become less intense (14%) of respondents.

Frequency of rainfall

Almost all respondents in Thiakhar community have perceived a decrease in rainfall frequency (14%) of respondents.

Cessation of rainy season

Almost all respondents in Thiakhar community have perceived an early cessation of the season (14%) of respondents.

Rain extreme

Almost all respondents in Thiakhar community have perceived rain to become less extreme (14%) of respondents.

Table 4: Variations in rainfall characteristics as perceived by farmers over the past 30 years in the six communities of Bambey District

Variable	Community					
	Bambey	Ngogom	Dangalma	Ndondol	Ngoye	Thiakhar
Onset						
Early onset	8%	4%	3%	5%	5%	3%
No changes in the onset	0%	0%	1%	0%	0%	0%
Late onset	5%	9%	10%	9%	8%	10%
Seasonal cumul						
Increase of the seasonal cumuli	5%	0%	2%	0%	2%	3%
No changes in the seasonal cumuli	1%	0%	1%	1%	2%	0%
Decrease of the seasonal cumuli	7%	13%	10%	13%	9%	10%
Length of rainy season						
Season become more lengthy	0%	0%	1%	0%	0%	0%
No changes in the length of rainy season	1%	0%	2%	2%	2%	0%
Season become shorter	12%	13%	10%	11%	11%	14%
Rainfall intensity						
Rain become more intense	1%	2%	2%	1%	2%	0%
No changes in the intensity of rainfall	1%	0%	2%	2%	1%	0%
Rain become less intense	11%	11%	10%	10%	10%	14%
Frequency of rainfall						
Frequency of rainfall increase	0%	4%	1%	0%	3%	0%
No changes in the frequency of rainfall	1%	2%	1%	1%	1%	0%
Frequency of rainfall decrease	12%	7%	12%	13%	9%	14%
Cessation of rainy season						
Cessation of rainy season become early	11%	11%	11%	11%	12%	14%
No changes in the frequency of rainfall	1%	0%	1%	2%	2%	0%
Cessation of rainy season become late	1%	2%	1%	0%	0%	0%
Extremety of rainfall						
Rain become more extreme	4%	2%	5%	11%	4%	0%
No changes in rain extreme	1%	2%	2%	2%	2%	0%
Rain become less extreme	8%	9%	7%	0%	7%	14%
No changes in rainfall pattern during last 30 years	6%	7%	2%	3%	8%	3%

Onset

Farmers in all communities have reported to perceive changes in the onset. The highest number of respondents was recorded in Dangalma and Thiakhar communities (10%) respectively. Late onset was highest percentage perceived in all community.

Seasonal cumuli

The highest change perceived by farmers was in the decrease of rainfall total particularly in Ngogom and Ndondol communities (13%) respectively.

Length of the season

Season become less lengthy was the highest change perceived by farmers particularly in Thiakhar (14%).

Intensity of rainfall

Rainfall intensity was reported by farmers to diminish and this was mostly perceived by farmers in Thiakhar community (14%).

Frequency of rainfall

The highest change perceived by farmers was also in the decrease of rainfall frequency particularly in Thiakhar community (14%).

Cessation of rainy season

The Cessation of rainy season was perceived by farmers to become early particularly in Thiakhar community (14%).

Rain extreme

Rainfall extreme was perceived by farmers to diminish particularly in Thiakhar community (14%).

4.2.2. Perception on temperature

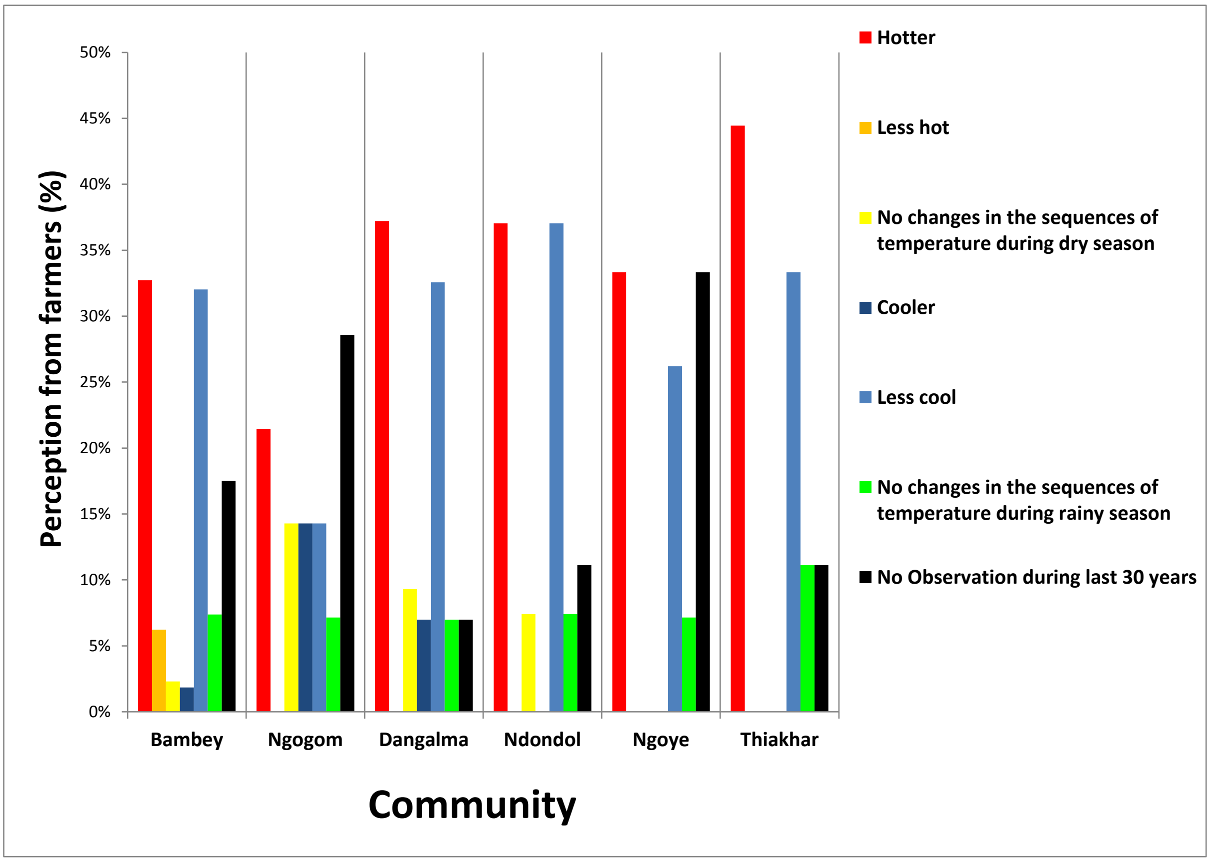


Figure 8: Variations in temperature pattern as perceived by farmers in six communities in Bambey District.

The overall perception is Temperature is getting hotter with always the highest score. This is in line with studies of Kalanda-Jousha et al., (2013); Yanon and Ndiaye (2013) and Soropa et al., (2015). In Thiakhar community (45%) of the respondents have reported it. The next highest score is the perception of less cool where Ndondol community recorded highest score (37%) of respondents. It is only in Bambey community that (6%) of farmers asked said it is less hot everywhere else the score is "0".

4.2.3. Perception on the causes of climate change

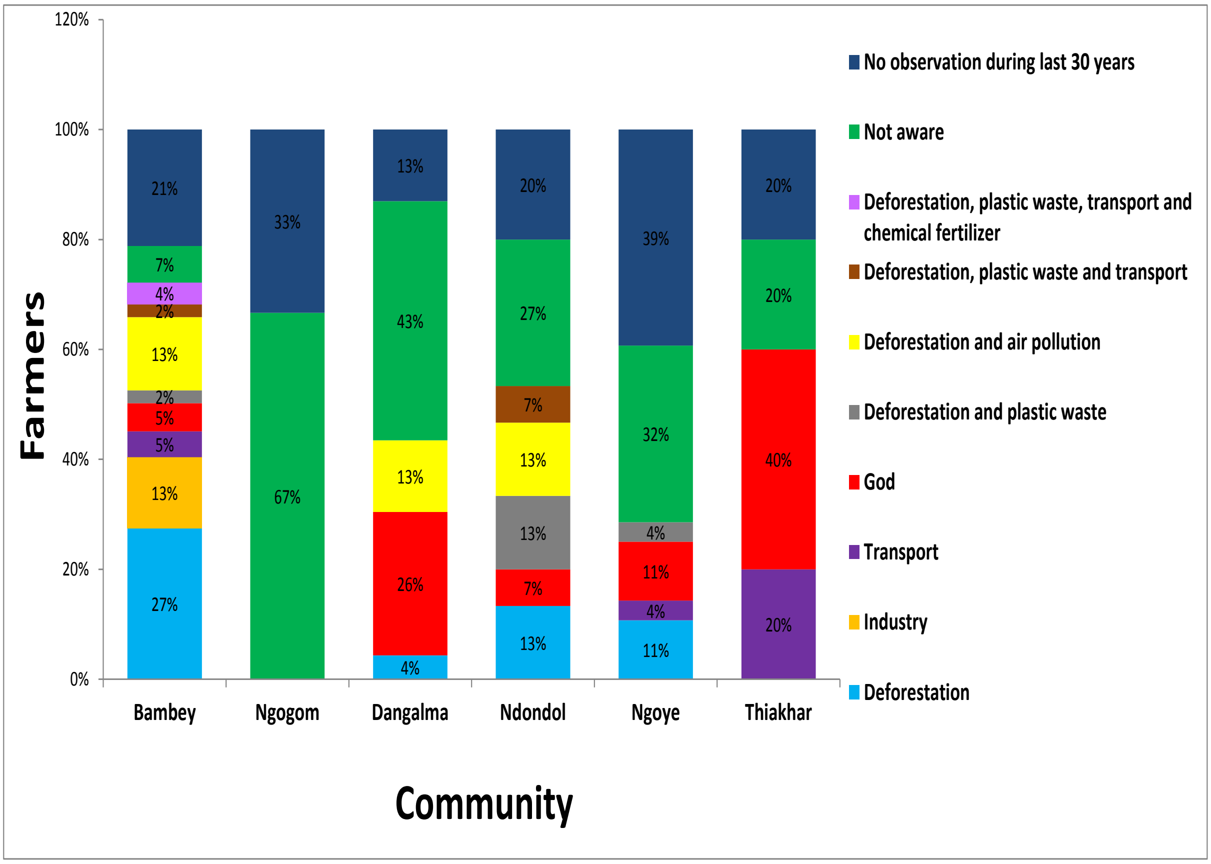


Figure 9: Causes of climate change as perceived by farmers in six communities of Bambey District.

The cause of climate change remain unknown in farmers community except in Bambey community where the score is the lowest (7%), in the other rural communities farmers were not aware of the cause of climate change (67%, 43%, 27%, 32%, and 20% in Ngogom, Dangalma, Ndondol, Ngoye and Thiakhar respectively). The lack of observation and lack of awareness are the most answered particularly in Ngogom community where they were the only answered reported.

It is also clear that in most rural community they attributed the cause to God which is quite true in most rural population.

It is interesting to note that in city (Bambey community) the answers were diverse and all actual causes were noted with high score for deforestation and air pollution and industry.

4.3. Climate data analyses

The meteorological data for Bambey community was used in this study because it is the only place having meteorological station.

4.3.1. Rainfall

1. Mean onset, cessation, length, frequency, cumuli and intensity in Bambey District

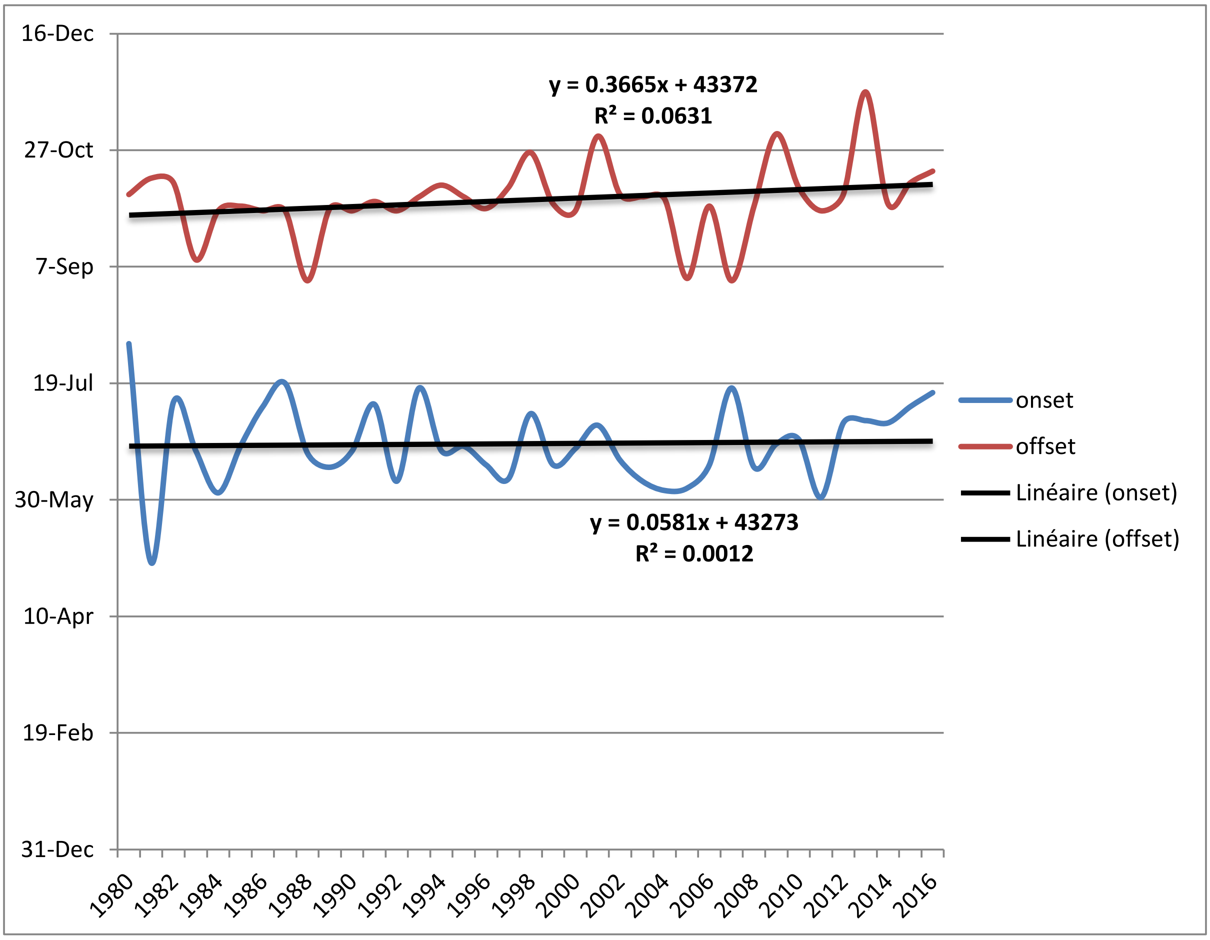


Figure 10: Trend of the onset and offset of rainy season during last 30 years in Bambey District.

The findings of figure 10 show that, the onset of rainy season has increase at a non-significant rate of R^2= 0, 0012. Rain onset has become late especially during the years 2010, 2012, 2014 and 2016. This is in line with farmers' perception. Farmers perceived rainy season onset to be late. The offset of rainy season has also increase at a non-significant rate of R^2= 0, 0631 which is similar to the onset. However, farmers perceived rainy season offset to be late this can be explained by the fact that for farmers only sufficient rain matter while for meteorologist it is the number of rains. And also they may also not pay attention to the little change which occurs because the offset has decrease with only 3 days. These findings are in line with a study conducted by Mkonda (2017) and (Yanon and Ndiaye, 2013).

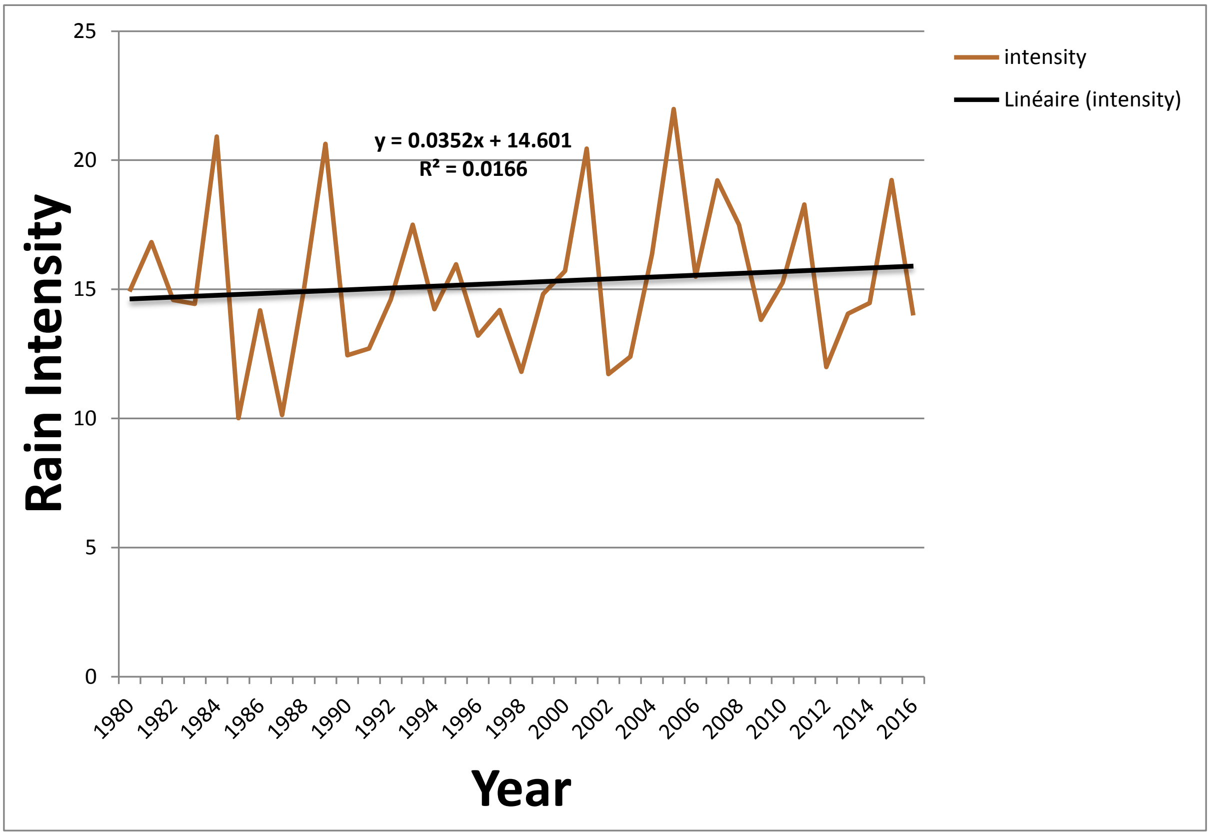


Figure 11: Trend of rain intensity in Bambey District

The findings of figure 11 show that, the intensity of rainfall has increase at a non-significant rate of R^2= 0, 0166. This is in constraint with farmers which reported the rain to become less intense. Farmers may not know how to quantify rain falling within an hour. This observation is supported by IPCC (2014) which highlight the uncertainty of rainfall.

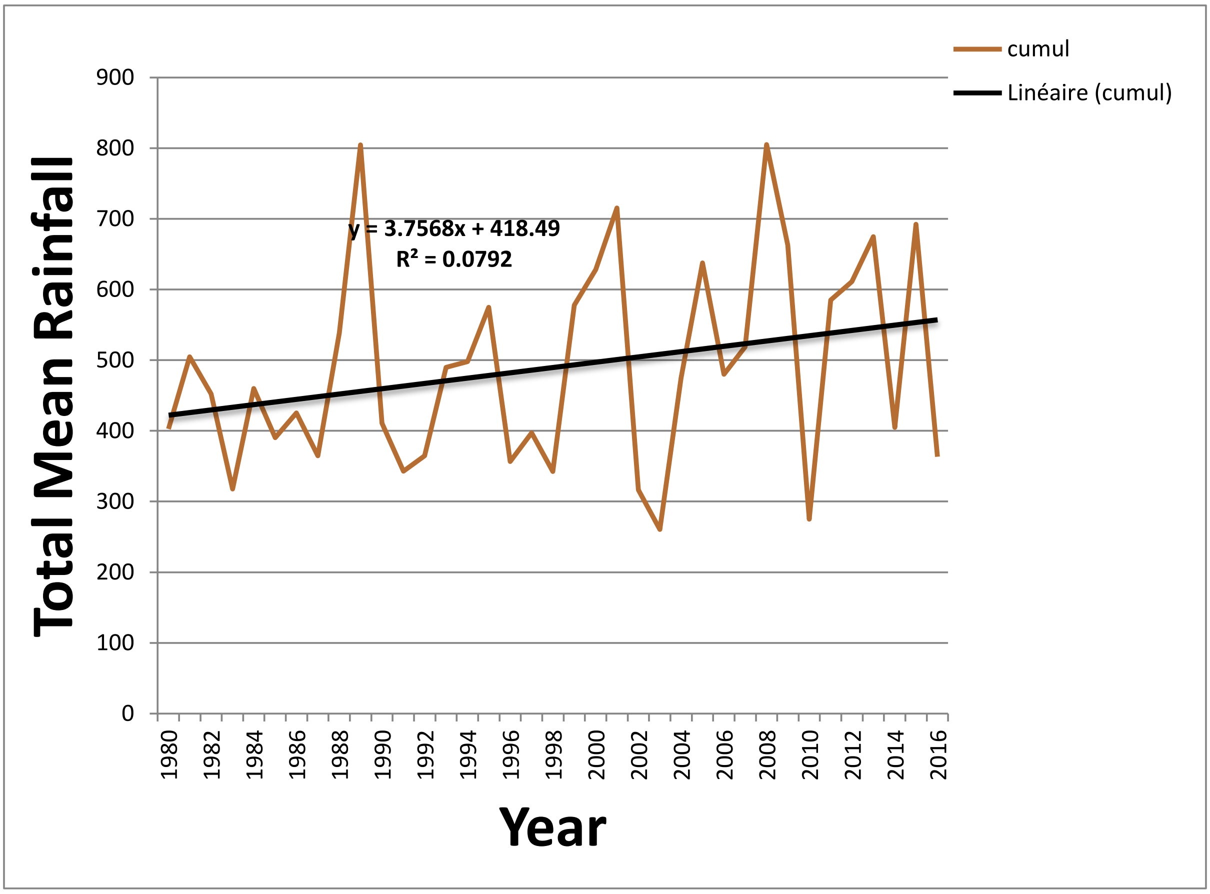


Figure 12: Trend of rainfall cumulative

The findings of figure 12 show that, the cumulative of rainfall has increase at a non-significant rate of R^2= 0, 0792. Farmers' perception is not in line with climate data since farmers have perceived a decrease in rainfall cumulative. However the findings of this study are similar to the findings of Moyo *et al*. (2012) in which farmers' perceptions about rainfall pattern contrast the meteorological data over a long period of time. In addition, in terms of farmers' perceptions about onset and interruption of the rainfall, the results of this study are in line with the results of Dhanya and Ramachandran (2015) and Mulenga and Wineman (2014).

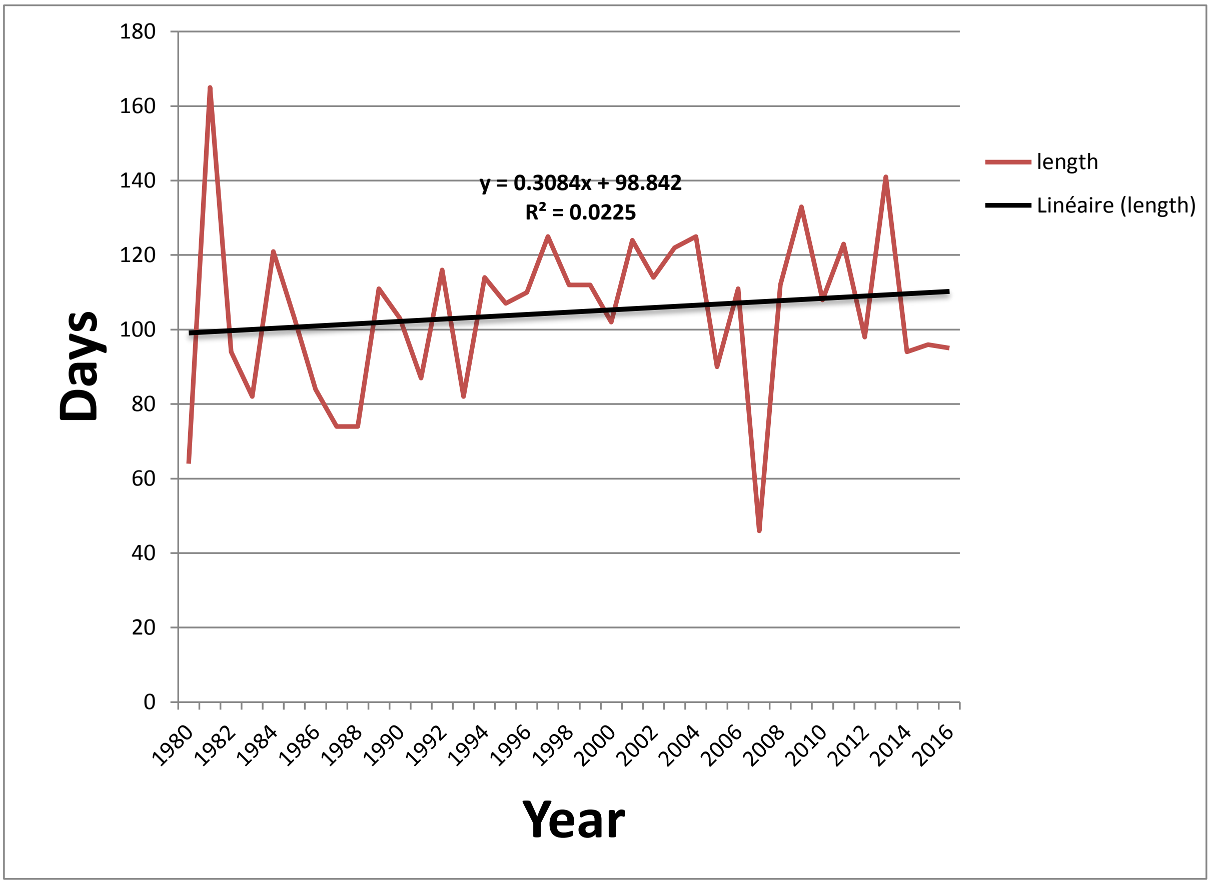


Figure 13: Trend of rainfall length

The findings of figure 13 show that, the length of rainfall has increase at a non-significant rate of R^2= 0, 0225. Farmers' perception is not in line with climate data since farmers have perceived a decrease in the length of rainy season. According to IPCC (2014) there is lot of uncertainty on rainfall.

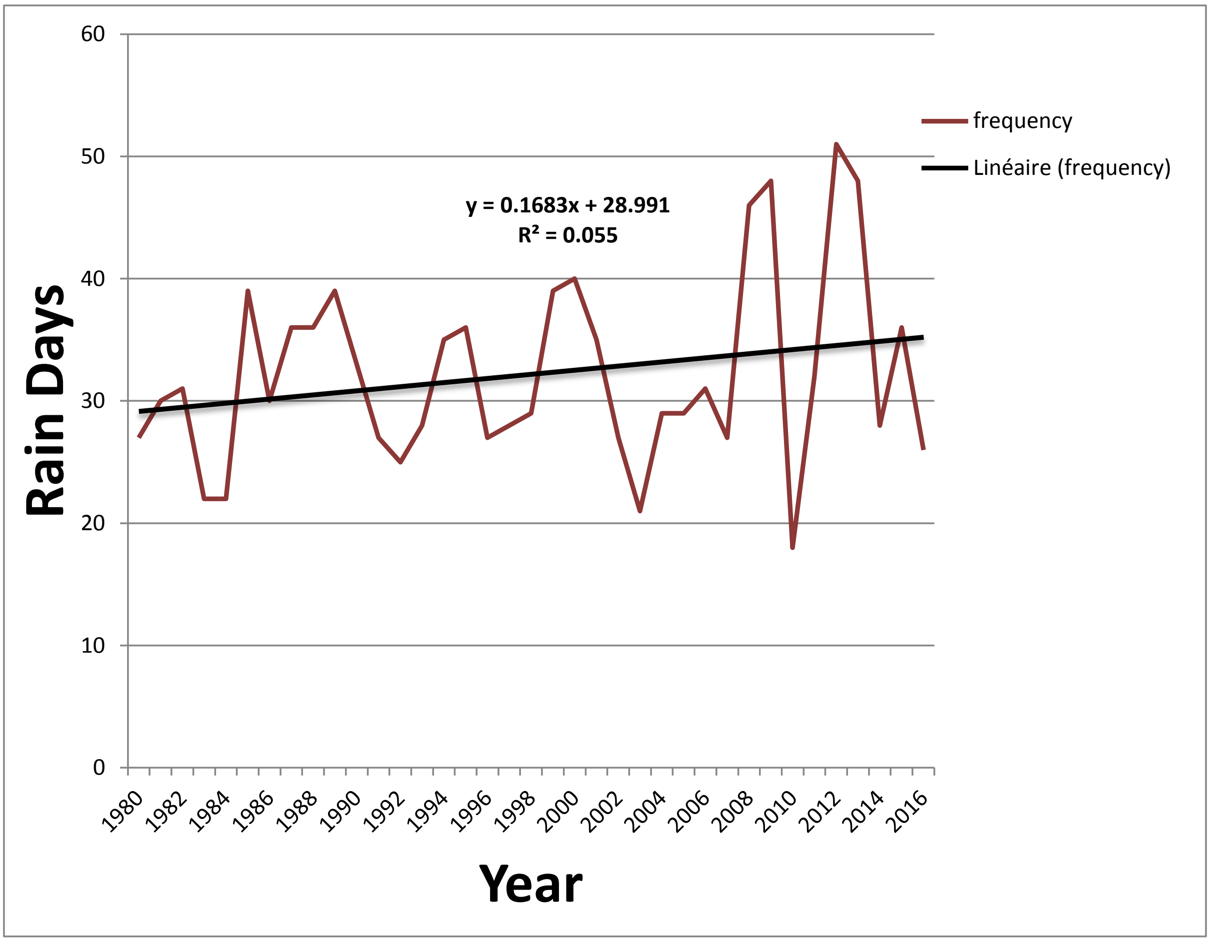


Figure 14: Trend of rainfall frequency

The findings of figure 14 show that, the frequency of rainfall has increase at a non-significant rate of R^2= 0. Farmers' perception is not in line with climate data since farmers have perceived a decrease in the frequency of rainfall. According to IPCC (2014) there is lot of uncertainty on rainfall.

4.3.2. Temperature

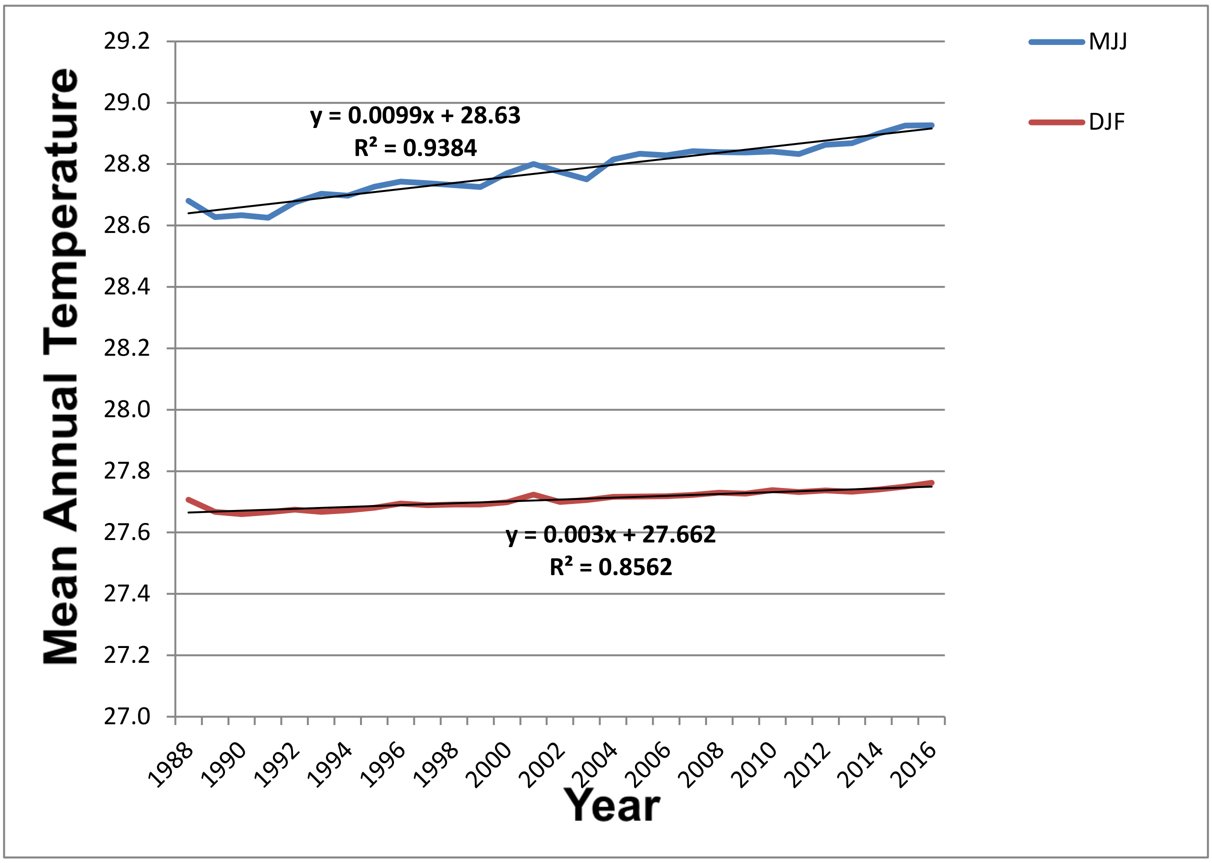


Figure 15: Trend of temperature during last 30 years

The findings of figure 15 show that, temperature during December-January-February has increase at a significant rate of R^2= 0.8562 which. This finding is supported by IPCC (2014) observation which revealed that minimum temperature has increased. The finding is also in line with farmers' perception which reported to perceive an increase of the minimum temperature in Bambey District. In addition the figure 15 show also that temperature during May-June-July has increase at a very significant rate R^2= 0.9384. This finding revealed therefore that farmers have well perceived changes on temperature during rainy season.

4.4. Indigenous weather indicators

Different indicators are observed by farmers in weather and climate prediction. The knowledge of indicators is gained after years of experiences. Some of the indicators include plant, animal, cloud and moon.

4.4.1. Plant indicators

From the interview carried out in all communities of Bambey district, the sprouting of all trees was cited to be an indicator of rainy season approaching while trees flourishing indicate the end of the rainy season. This correspond with findings from Kijazi et al., (2012) in Mahenge and Ismani wards (Tanzania) where spout of new leaves in trees like "Minusi" and "Mikwee" indicate that rainy season is approaching.

Timing of trees sprouting was also used in Bambey District as an indicator; early growing of new leaves indicate that the rainy season will start early while late sprouting indicates late starting of the rainy season.

The way of sprouting of baobab was found to be a good indicator in the prediction of the timing of rainy season, thus if the sprout of new leaves start on the bottom than the rainy season will start early while if the sprouting start at the top than starting of rainy season will be late.

Trees like "Ngeer" (*guiro senegalensis*) and "Vén" (Pterocarpus erinacerus) when their leaves are falling means the first onset of rains is about to fall. Ripening of fruit of "Beer" (Sclerocarya birrea) is an indication of imminent rain usually within a week. The abundance of fruit in trees is an indicator of drought for the coming season.

Joshua et al., (2011) in a study conducted in Mulanje District, Southern Malawi also found that the high production of mango fruits in a season is normally associated with low rainfall in the coming season and hence low agricultural yield.

Table 5: Plant indicators and their predictions (IKS) as applied in Bambey District

Tree type	Behavioural sign	Forecast
Sumpu (*Balanites aegyptiaca)* At least seven (7) Tamarinds (*Tamarindus indica)* Nguediane (*Anogeissus leocarpus*) Jujube (*Ziziphus*) Fromager *(Ceiba pentandra)* Baobab Flamboyan (*Delonix regia*) Mango tree	Trees sprouting	Indicates that the rainy season is approaching. Generally, when tree start growing new leaves it means the rain are near. Early sprouting of new leaves means the rains will come early that particular year and late sprouting indicates late rain.
All trees above	Trees Flourishing	Indicates that the rainy season is about to end.
Beer (*Sclerocarya birrea*)	Ripening of the fruit	Indicate an imminent rain within a week
Baobab	Sprouting	If the sprouting of new leaves start at the bottom that means the rainy season will start early while when it start at the top rainy season will start late.
Ngeer tree (*guiera senegalensis*) Vén tree (*Pterocarpus erinacerus*)	Losing their leaves	First onset of rain season is about to fall.
All trees	An abundance of fruit	Indicate drought for the coming season.

4.4.2. Animal indicators

Behaviour of animals and appearance and movement of birds and insects are frequently used by farmers to predict weather and climate in Bambey district.

a) Insect

Ant securing their habitat is an indication that rainy season is closer and the first rain will fall within days. The presence of termites, in large number, on roads during May indicates that the upcoming rainy season will be good which results on high yield. Similarly to studies of Zuma-Netshiukhwi et al., (2013) and Mugabe et al., (2010) where appearance of red ants indicate good rains are coming.

An increase of "*Xorondom*" (Big ant) activities was an indication of near rainfall in Bambey district due to the fact that they are collecting food for storage during days and get into their habitat up to the occurrence of dry spell. The presence in large number of insects like *Cicada* was reported by majority of farmers in Bambey district to indicate good rainy season with abundant rains.

Table 6: Insect indicators and their predictions (IKS) as applied in Bambey District

Indicator	Behavioural sign	Forecast
Ant	Secure their habitat by forming circle. Presence of whiter substance in their body Leave their habitat	Indicates that rainy season is closer and the first rain will fall within one to two days. Good rainy season with lot of sorghum Near dry spell
"ngarageen" insect	Appear when the millet is ready	Near ending of rainy season
"ngouyoum tane"	Fly at night by emitting light	Near ending of rainy season
Termites	If funded frequently on the road in May	Expectation of good rainy season with high yield this particular year.
"Xorondom" (wild ant)	Increased their activity by collecting food and get into their habitat. Get out from their habitat	Near rain is expected Announce the end of rainy season.
Cicada	Presence in large number	Good rainy season with an abundant rains

b) Birds and certain animals

Behaviour of birds was also used in predicting the timing and the quality of the season. Therefore, the presence of birds like *"njalax", "dethe ngaan", "roogo diw diw a dip"* announce the near beginning of rainy season.

Further, *"yaaayayaaw"* coming from the north flying to the south indicates the approaching of rainy season and rain are expected within days.

This correspond with a study done by Abdulrashid (2013) in Katsina state, Nigeria where the Hausa also use the arrival of migratory birds from the north to the south to indicates the approaching of rainy season.

"Naaw-naaw" flying in swarm indicates that the upcoming rainy season will be normal/good while "*Naaw-naaw"* flying alone is an indication of below normal rains for the upcoming season. The singing of "*wild Duck"* by going toward west is an indication of near rainfall while Crow building is nest indicates late starting of the rainy season. Some respondents reported the singing of *"naak-naawou"* to indicate upcoming rainfall in hours because the *"naak-naawou"* calls water in their singing. Though there are not the same birds Mapara, (2009) also found that Tangwena, Zimbabwe people can foretell whether rains are going to fall in the next hour or two if they hear the sound of "*dzvotsvotsvo"* (rain bird).

The croaking of frog is telling that rainy season has started while they stop croaking at the end of the season. The same behaviour was observed by Shona people (Muguti and Maposa, 2012).

Respondent associated the appearance of a specific earthworm with dark hair with upcoming drought.

Table 7: Animal and Bird indicators and their predictions (IKS) as applied in Bambey District

Indicator	Behavioural sign	Forecast
“guuttuut” “paapaan” “njalax” “dethe ngaan” “roogo diw diw a dep” “xaax”	Singing Leave Caour to Fatick Presence Presence Presence Appear and cut tree leaves	Indication of a near starting of rainy season.
“naak-naawaou”	Singing	Rain will fall in few hours. They called water in their song.
“yaayayaaw”	Come back from the north where they have spent months to the south.	Rain will fall in few days
“naaw-naaw”	Flying together	Normal rains are expected.
“naaw-naaw	Flying alone	Expectation of below normal rains with insufficient yield.
Wild Duck	Singing and go toward west	Near rain within days
Crow	Building their nest	Late starting of the rainy season
Birds	In movement toward the north-east	Expectation of normal rains
“thiarokh” “a qule” (dark bird with long queue) Pigeon	Leave Fatick to Caour Singing to night Securing their nest	Near ending of rainy season
Frog	Croaking	Rainy season has begun. They stop croaking at the end of the season.
Big gecko	Break their eggs	Indicates the end of rainy season.
Earthworm	Appear with their dark hair	Indicate drought condition

4.4.3. Atmospheric indicators

Cloud, Wind, Temperature and thunder were also observed in weather and climate prediction in the district of Bambey. These indicators are commonly used in both scientific and indigenous method of weather forecast. Respondents have indicated the movement of clouds as indicators of onset and quality of rainy season. Therefore, if dark clouds move from East to West imminent rain are expected, according to farmers the Dark colour of cloud is due to the fact that the cloud contains lot of water. This is in line with the findings of study conducted by Rautela and Karki (2015) in Uttarakhand (India) where Dark clouds are also considered to indicate heavy rainfall within few hours. Appearance of Red clouds were also said to indicate strong wind within hours. Increase movement of clouds indicates a near onset of the rainy season, the presence of clouds at low altitude announce normal rains for the season. Further, the appearance of *"A Karin"* (three clouds) in the west and south indicate that upcoming rain will fall everywhere within the area if clouds from west are bigger than cloud in the south while when the southern clouds are bigger than northern clouds the rain will not fall everywhere in the area.

A wind blowing from the West to East was reported to announce the beginning of rainy season while wind blowing from the East to West indicates upcoming of the first rain within hours or days. Similar observation was made in five districts out of six in Uganda where winds blowing from the west to the east were the most common sign indicating the starting of rainy season (Okonya and Kroschel, 2013).

The rumbling pattern of thunder like *"Ngooratuul"* was also used in weather prediction. Therefore, *"Ngooratuul"* rumbling from East is an indication that rainy season has started while it rumbling from West indicates near ending of the season.

Temperature was reported to be a crucial parameter in weather and climate prediction. Thus, continuously heat in May was reported to indicate normal rains with high yield in the upcoming rainy season.

Respondents reported the falling of first rain around July, 15^{th} to be an indicator of below normal/ bad rains for upcoming season resulting to a low yield.

Table 8: Atmospheric indicators and their predictions (IKS) as applied in Bambey District

Indicator	Behavioural sign	Forecast
Cloud	Dark colour leave the east for west	Imminent rain
	Red colour Appear	Indications of near strong wind within hours
	Increase movement	Near onset of the rainy season
	At low altitude	Normal rains are expected
"A Karin" (three clouds)	Appear in west and south	1) When the cloud from the west is bigger than cloud in the south than rain will fall everywhere 2) When the bigger cloud is the one from south then rain will not fall everywhere
Wind	Blowing from the east to the west	Indicates that first rain will fall within hours or 1 to 2 days.
	Blowing from west to east	Announce the beginning of the rainy season
"Diaz"	Blowing	Near starting of dry season
"Thioror"	Blowing	Beginning of rainy season
Thunder "Ngooratuul"	Rumbling from east	Indicates that rainy season has started
	Rumbling from west	Announce near ending of rainy season
Temperature	Continuously hotness in may	Indication of normal rains with high yield.
	High moisture causing an emission of water vapour from the soil	Imminent rain within hours.
	Very high temperatures, causing body pain and sweating even at night.	Expectation of rains within hours or days.
Rainbow	Appearance during rain event	Indicate that rain will stop immediately
First Rain	If first rain fall in July, 15th	Indications of below normal rains with low yield. Therefore the season is considered to be bad.

4.4.4. Astronomical indicators

Shape of stars was reported by elderly to tell the timing and type of season, hence when four stars are observed from the "Niay" shaping like a laying elephant paw up is an indication of the beginning of rainy season while when the shape is an elephant standing properly drought condition are expected. The appearance of *"Dulun"* in the west and the pattern of *"Faniigane"* moving from the East to north indicate that rainy season has began. A related study in Mahenge and Ismani Wards, Tanzania by Kijazi et al. (2012) documented a similar belief related to the appearance of strars. The study found that appearance of five stars *"vilimila"* indicates that rainy season is approaching.

Table 9: Astronomical indicators and their predictions (IKS) as applied in Bambey District

Indicator	Behavioural sign	Forecast
Stars (Group of four (4) stars)	From the "Niay" having the feature of elephant laying and having it paw up From the "Niay"having the feature of elephant standing properly	Announce the beginning of rainy season Announce drought condition
"Dulun"	Appear in west	Rainy season has began
"Faniigane" (Group of five (5) stars)	Leaving east for the north	Rainy season has began
Moon	Change direction	Indicates that rainy season is approaching

4.4.5. Indigenous knowledge indicators used when planning for farming activities

Farmers were found to be knowledgeable of indigenous weather and climate knowledge in the study area but only few of them have declared to use the knowledge in their farming activities. The extent of use of indigenous knowledge in farming activities in Bambey District varied from community (see fig 16).

Thiakhar community had the largest number of respondents using indigenous knowledge (60%) in farming activities while Bambey community had the lowest number of respondents using indigenous knowledge (24%) in farming activities. The reason for which Bambey community had the lowest number of respondent could be due to the fact that the community is widely urbanised than the others communities.

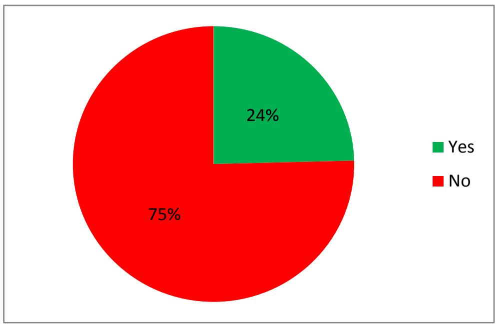


Figure 16a: Used of indigenous knowledge in farming activities in Bambey Community

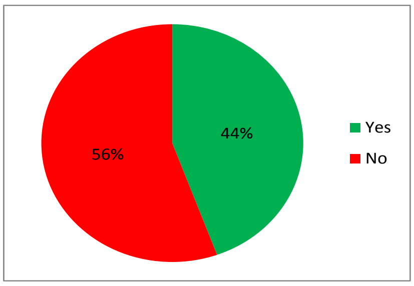


Figure 16b: Used of indigenous knowledge in farming activities in Ngogom Community

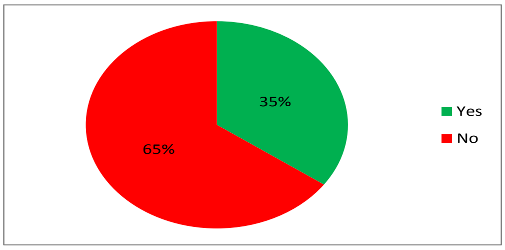


Figure 16c: Used of indigenous knowledge in farming activities in Dangalma Community

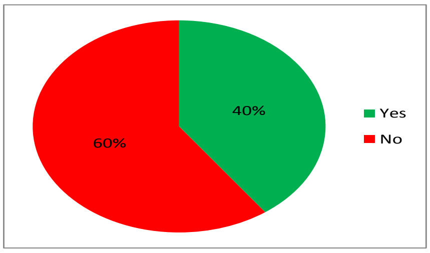


Figure 16d: Used of indigenous knowledge in farming activities in Ndondol Community

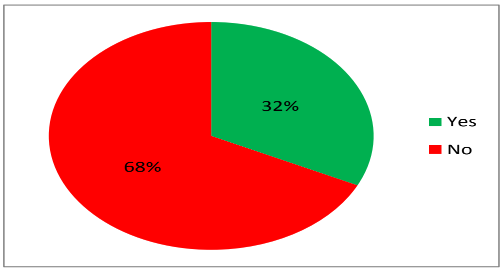


Figure 16e: Used of indigenous knowledge in farming activities in Ngoye Community

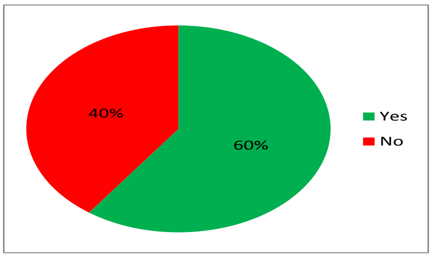


Figure 16f: Used of indigenous knowledge in farming activities in Thiakhar Community

Figure 17: Use of indigenous knowledge in farming activities in Bambey District

In planning for the various farming activities, farmers in Bambey community were found to make use of the IK differently. The main activities in which the IK indicators were used in farming activities were found to be land preparation and determination of planting time with over 12% of farmers using it when planning for the two activities. Only 8% of the farmers used the IK indicators to determine when to carry out weeding, harvesting and storage activities in farms (Table 9a).

Table 10a: The IK indicators and their level of use (%) in farming activities in Bambey community

Ik indicatoes	Farming activities				
	Land preparation	Planting	Weeding	Harvesting	Storage
Vegetation	3%	5%	4%	4%	0%
Animal bahaviour	3%	3%	1%	2%	3%
Atmospheric	3%	2%	0%	2%	4%
Astronomic	2%	2%	3%	1%	1%

**Percentage concerned only farmers who responded yes in Fig 16.*

Farmers in Ngogom community have reported to make use of the IK indicators in taking major decisions in farming. Thus, main activities in which the IK indicators were used in farming activities were found to be land preparation and harvesting with over 22% of farmers using it when planning for the two activities. Only 17% of the farmers used the IK indicators to determine when to carry out planting, weeding and storage activities (Table 9b).

Table 10b: The IK indicators and their level of use (%) in farming activities in Ngogom community

Ik indicators	Farming activities				
	Land preparation	Planting	Weeding	Harvesting	Storage
Vegetation	6%	11%	17%	11%	3%
Animal bahavi	6%	0%	0%	0%	0%
Atmospheric	11%	6%	0%	11%	14%
Astronomic	0%	0%	0%	0%	0%

**Percentage concerned only farmers who responded yes in Fig 16.*

In Dangalma community, main activities in which the IK indicators were used in farming activities were found to be land preparation, planting and harvesting with over 15% of farmers using it when planning for these activities. Only 11% of the farmers used the IK indicators to determine when to carry out weeding and storage activities (Table 9c).

Table 10c: The IK indicators and their level of use (%) in farming activities in Dangalma community

IK indicators	Farming activities				
	Land preparat	Planting	Weeding	Harvesting	Storage
Vegetation	3%	4%	9%	10%	1%
Animal bahaviour	2%	4%	0%	0%	1%
Atmospheric	8%	9%	2%	3%	9%
Astronomic	0%	0%	0%	1%	0%

In contrary of what have been reported by farmers in Bambey community, in Ndondol community the main activities in which the IK indicators were used in farming activities were found to be weeding, harvesting and storage with over 11% of farmers using it. Only 17% of the farmers used the IK indicators to determine when to carry out land preparation and planting activities (Table 9d).

Table 10d: The IK indicators and their level of use (%) in farming activities in Ndondol community

Ik indicators	Farming activities				
	Land preparat	Planting	Weeding	Harvesting	Storage
Vegetation	0%	2%	10%	8%	2%
Animal bahaviour	0%	0%	0%	5%	0%
Atmospheric	5%	3%	0%	0%	8%
Astronomic	2%	0%	0%	0%	0%

Similarly to what have been reported by farmers in Ngogom community, the main activities in which the IK indicators were used in farming activities by farmers in Ngoye community were found to be land preparation and harvesting with over 6% of farmers using it when planning for the two activities. While only 3% of the farmers used the IK indicators to determine when to carry out planting, weeding and storage activities (Table 9e).

Table 10e: The IK indicators and their level of use (%) in farming activities in Ngoye community

IK Indicators	Farming activities				
	Land preparation	Planting	Weeding	Harvesting	Storage
Vegetation	3%	2%	4%	5%	0%
Animal bahaviour	1%	0%	0%	2%	0%
Atmospheric	1%	3%	0%	0%	2%
Astronomic	1%	0%	0%	0%	0%

The main activities in which the IK indicators were used in farming activities by farmers in Thiakhar community were similar to have been found in Ngogom and Ngoye community which are land preparation and harvesting with over 6% of farmers using it when planning for the two activities. While only 3% of the farmers used the IK indicators to determine when to carry out planting, weeding and storage activities (Table 9f).

Table 10f: The IK indicators and their level of use (%) in farming activities in Thiakhar community

IK indicators	Farming activities				
	Land preparation	Planting	Weeding	Harvesting	Storage
Vegetation	5%	15%	5%	5%	0%
Animal bahaviour	0%	5%	0%	0%	0%
Atmospheric	5%	10%	0%	0%	5%
Astronomic	0%	5%	0%	0%	0%

4.5. Comparison of SCFs and IKS

4.5.1. Forecast for the 2017 season using IKS

For the 2017 season, of all the respondents who participated in the interviews, 28% in Bambey, 52% in Dangalma, 33% in Ndondol, 25% in Ngoye, and 45% in Thiakhar of the respondents did not observe or did not make any prediction. From Figure 16, majority of farmers in all communities (58% in Bambey, 78% in Ngogom, 43% in Dangalma, 60% in Ndondol, 68% in Ngoye and 60% in Thiakhar) responded that they had observed that this was going to be a normal rainfall season because the temperature was very high in May. A continuous heat on that month was considered to be an indicator of a good/normal rainy season. About, 5% in Bambey, 11% in Ngogom, 4% in Dangalma, 7% in Ndondol, and 7% in Ngoye of respondents made an observation of below normal rainfall season. Finally, only respondents from Bambey and Thiakhar (8%, 11%) had predicted an above normal rainfall season.

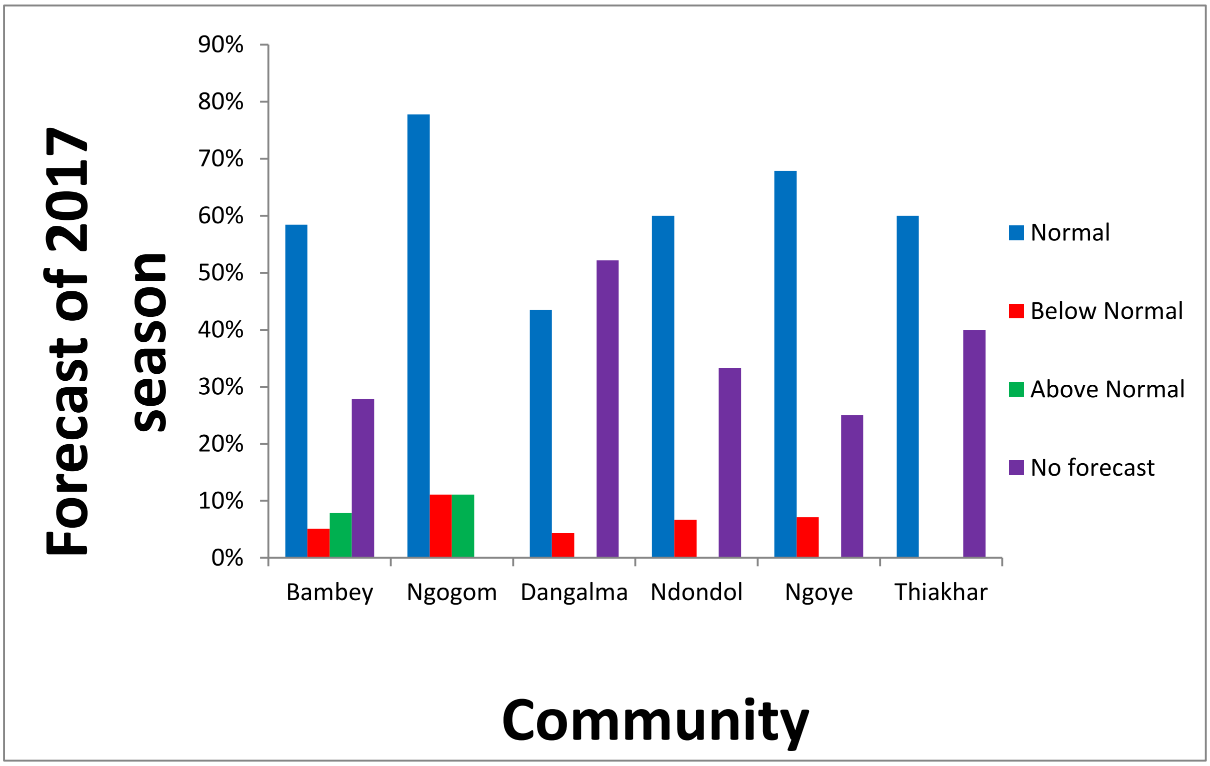


Figure 18: IKs forecast for 2017 season in Bambey district

Since farmers forecast was collected after the ex-ante beginning of rainy season, we found necessary to have their view on the accuracy on what have been forecasted.

Therefore, the highest percentage of respondents in Bambey district has responded that the forecast of normal rainfall season was correct (43%, 78%, 43%, 60%, 75%, and 60%, respectively in Bambey, Ngogom, Dangalma, Ndondol, Ngoye, and Thiakhar communities) (Figure 19).

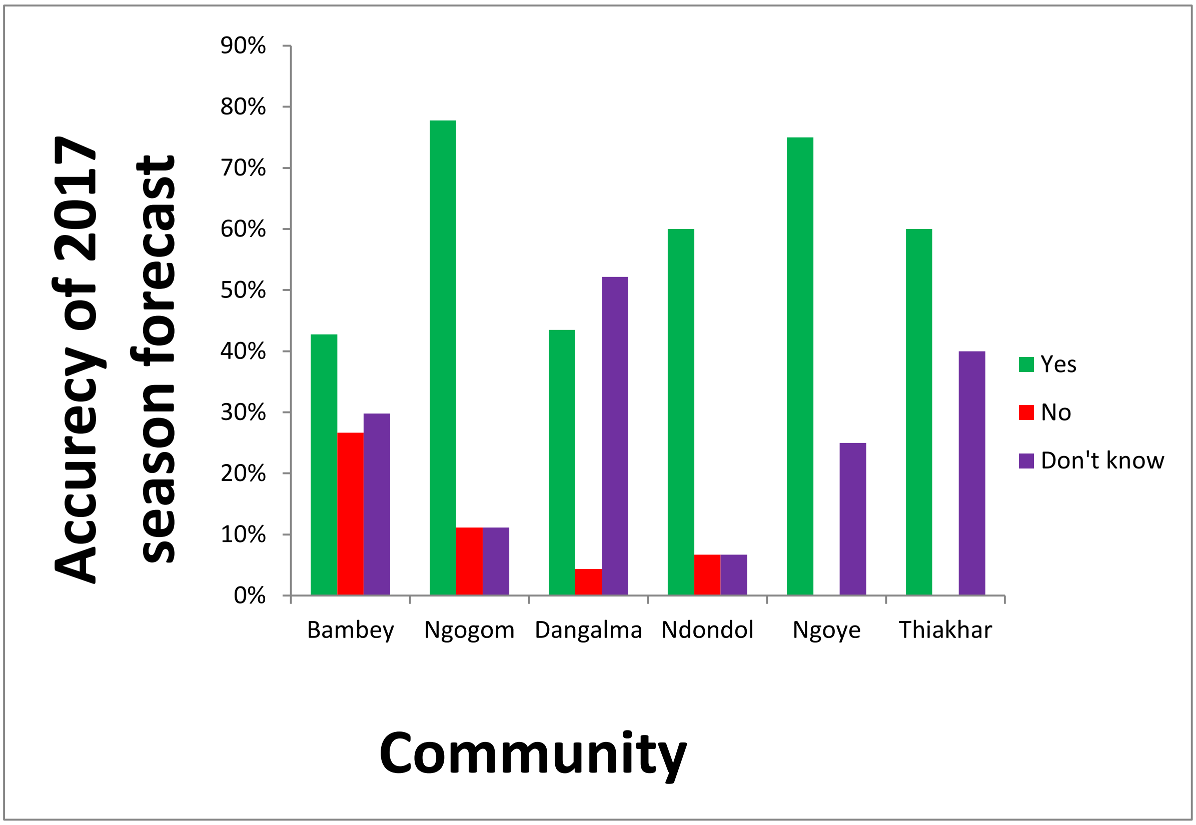
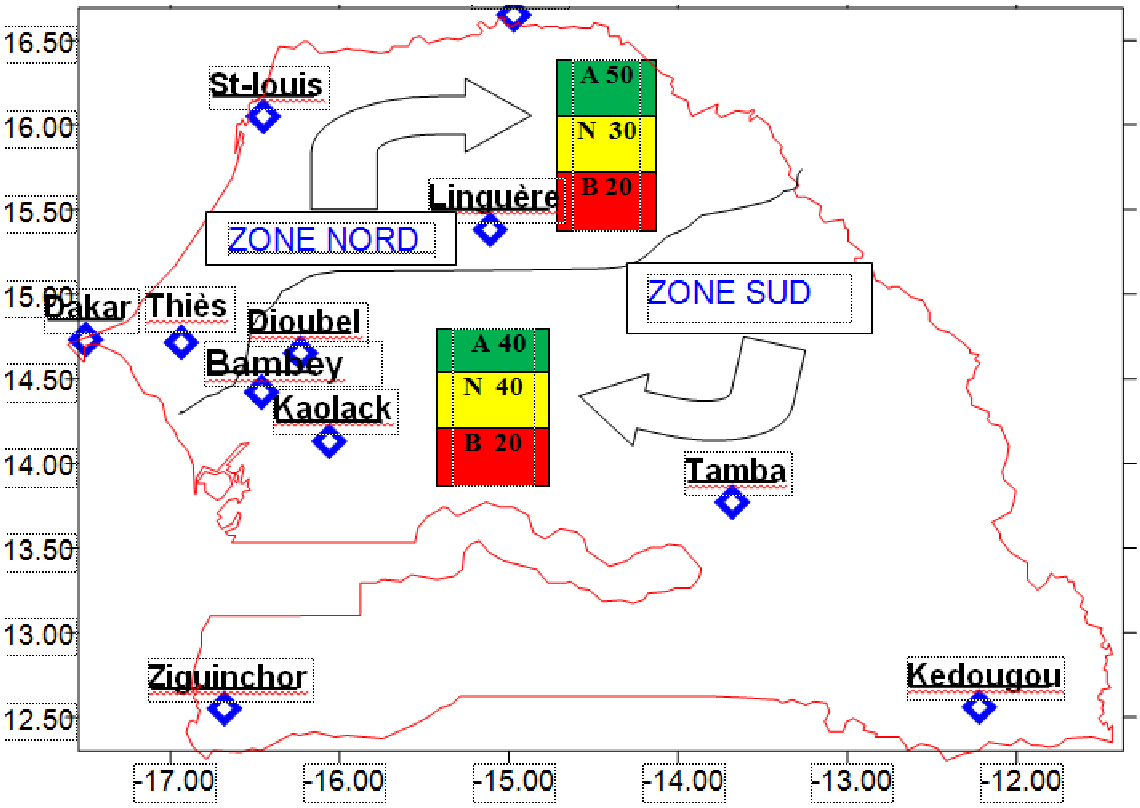


Figure 19: Accuracy of IKs forecast for 2017 season in Bambey district

4.5.2. The 2017 seasonal forecasting using metrological data

Senegal was divided into two meteorological zones (North and South) for the 2017 rainfall season, each zone having the same probabilities of rainfall occurrences. Zone north comprised the regions of St-Louis, Linguere, Dakar and Thies while Zone south comprised the regions of Diourbel, Kaolack, Tamba, Kedougou and Ziguinchor. Figure 19 shows the two zones and the amount of rains expected for the forecast issued in May 2017. For the 2017 rainfall season, both two zones were expected to have normal to above normal rainfall.



A: Probability of above normal rainfall
N: Probability of normal rainfall
B: Probability of below normal rainfall
NB: Probabilities of A, N, and B are expressed in percentages

Figure 20: Rainfall outlook for July-August-Sep 2017

4.5.3. Similarities and differences for SCFs and IKS

Seasonal climate forecast give precise dates as to when the season is expected to begin and end, whereas IKS cannot give precise times. In terms of dissemination, IKS information is disseminated through mouth to ear while SCFs used technology such TV, radio, internet, newspaper etc. (Figure 20 & Figure 21). The SCFs gives weekly and monthly updates, whereas for IKS, there is no regular update but observations from the environment are used as forecasts.

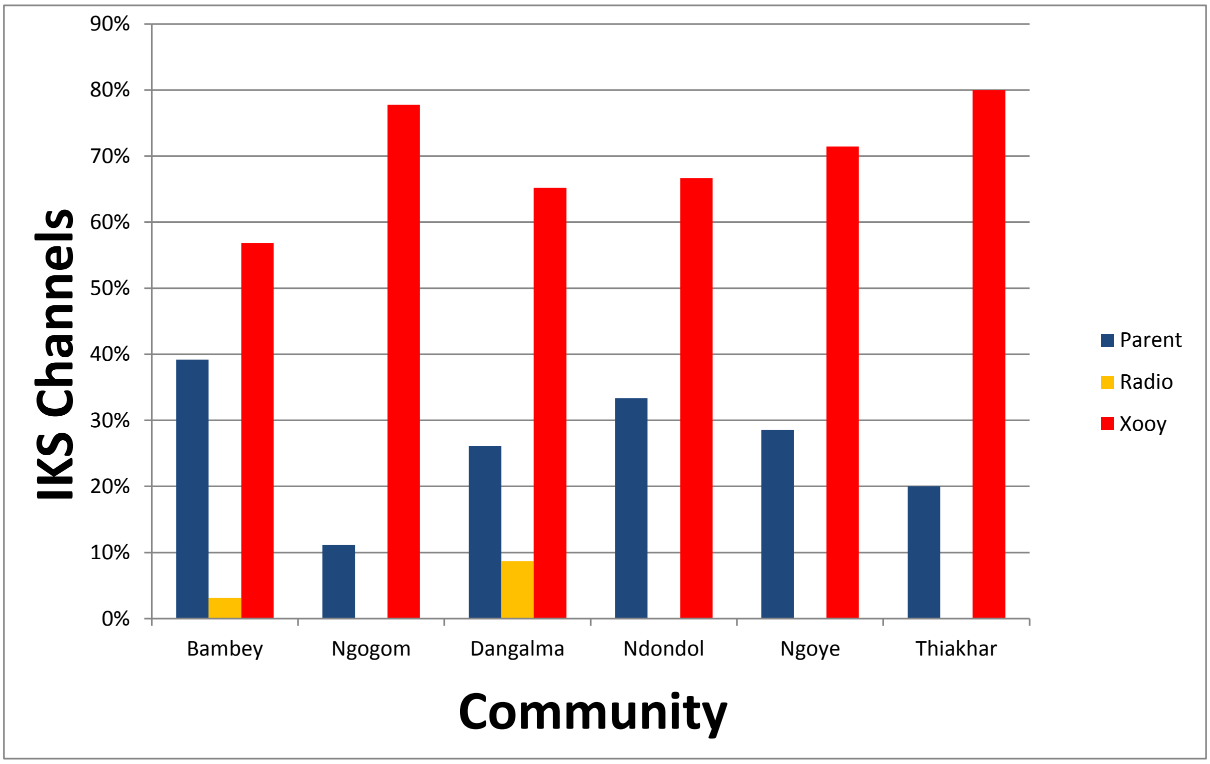


Figure 21: Channel used by IKS forecaster for information dissemination

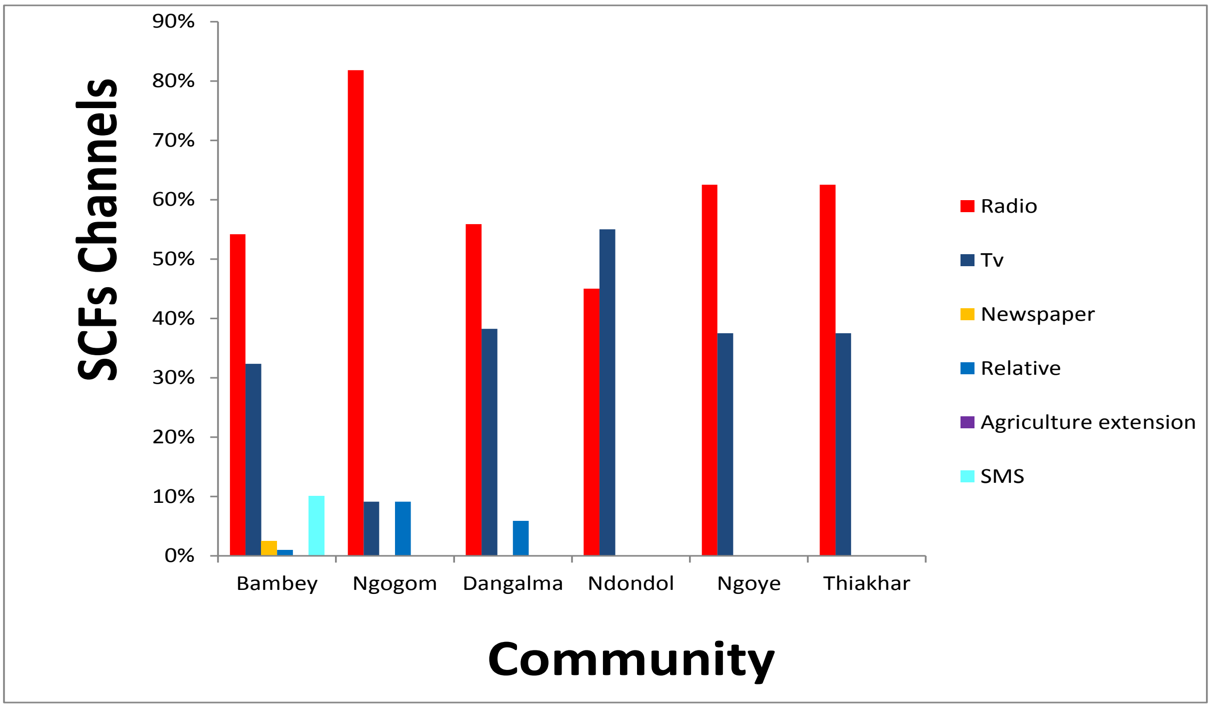


Figure 22: Channel used by SCFs forecaster for information dissemination

These two figures (Figure 19 & Figure 20) reveal that in the Bambey district the most means used for IKS information was Xooy (scored between 70% and 80% of respondents in all communities). The Xooy is an annual meeting where saltigues (knowledgeable on indigenous weather and climate forecast and had a celestial power) and farmers together make forecast for the upcoming season. From the FGD elder Saltigue reveal that: *"Years ago people was having strong faith on what saltigue's forecast because it becomes always true while now a day due to high dominance of religions and modernity lot of people lost faith on Saltigue's"*

Furthermore, another Saltigue also revealed: *"When we observed a particular season to be bad then we asked farmers to make sacrifices of black cow which will bring all goodness and destroy all evil from the season."*

While for SCFs it was radio (Scored between 50% and 80%). This is similar to findings from Kitchell (2016) in a study conducted in Kaffrine Region where 68% of farmers used radio for climate information.

4.6. Integration of in indigenous with scientific knowledge of weather and climate forecast.

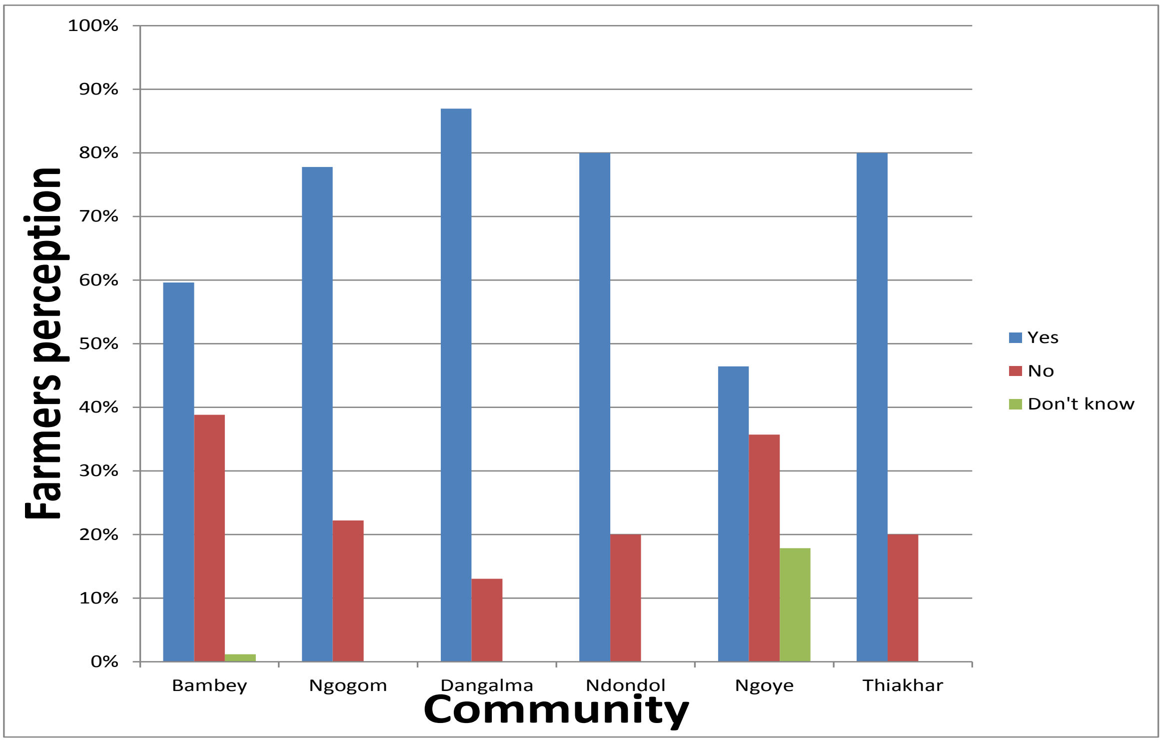


Figure 23: Farmers perception on integration of indigenous and scientific knowledge in Bambey District

The largest number (Between 60% and 80%) of farmers perceived that indigenous and scientific knowledge of weather and climate forecast can be combining. Furthermore they have reported some key strategies' in view to integrate the two methods (see figure 23).

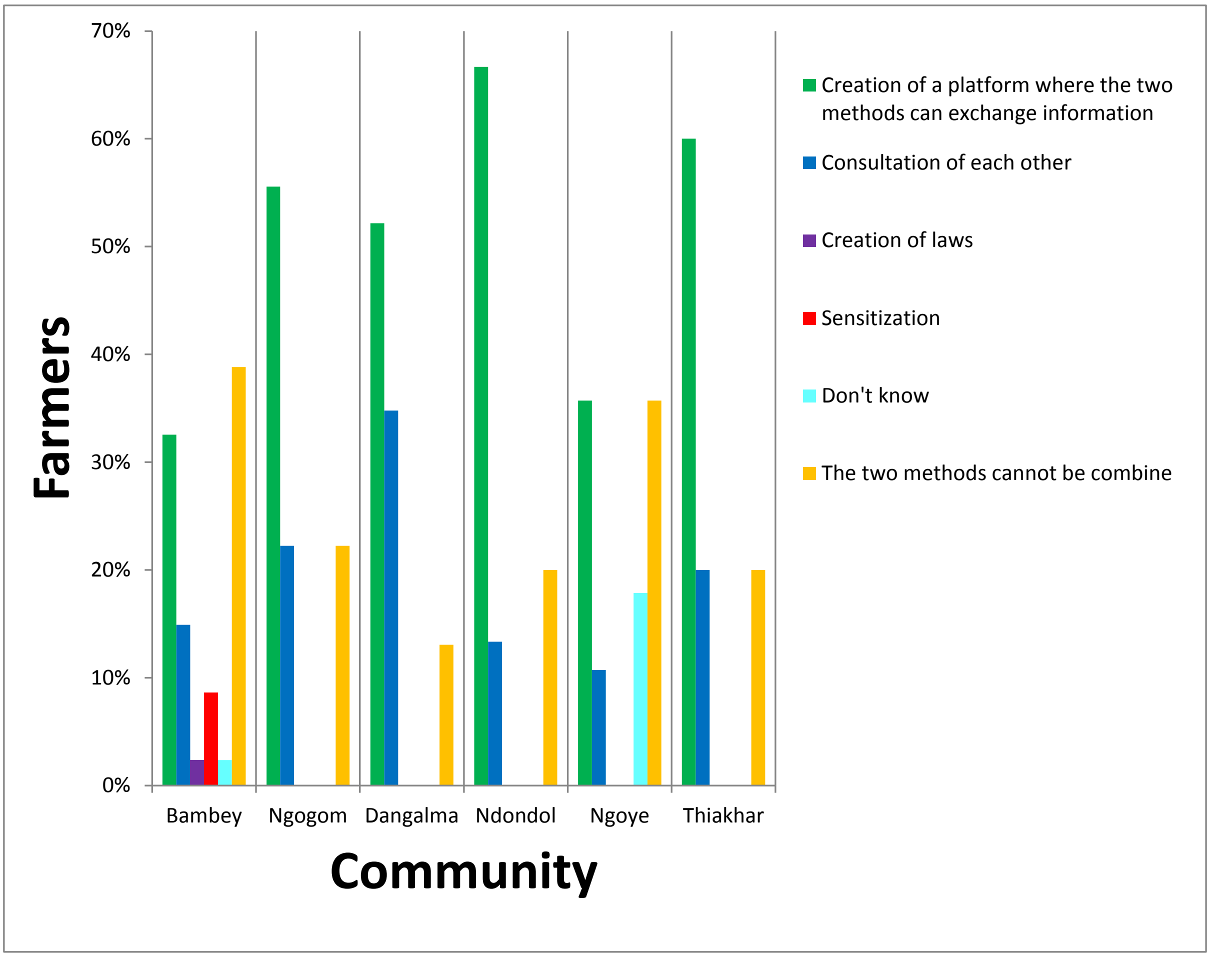


Figure 24: Integration of indigenous with scientific knowledge strategies from farmers in Bambey District

The highest percentage of farmers proposed the creation of a platform where farmers and Scientifics can exchange information scored of between 30% and 70% of respondents. While sensitization scored 8% of respondents were only reported by farmers in Bambey community. These findings could be explained by the fact that Bambey community is urbanized and has universities and schools.

This finding is similar to the study of Jiri et al., (2015) where it was also suggested to create a suitable platform.

4.7. Farmers adaptation strategies in Bambey district

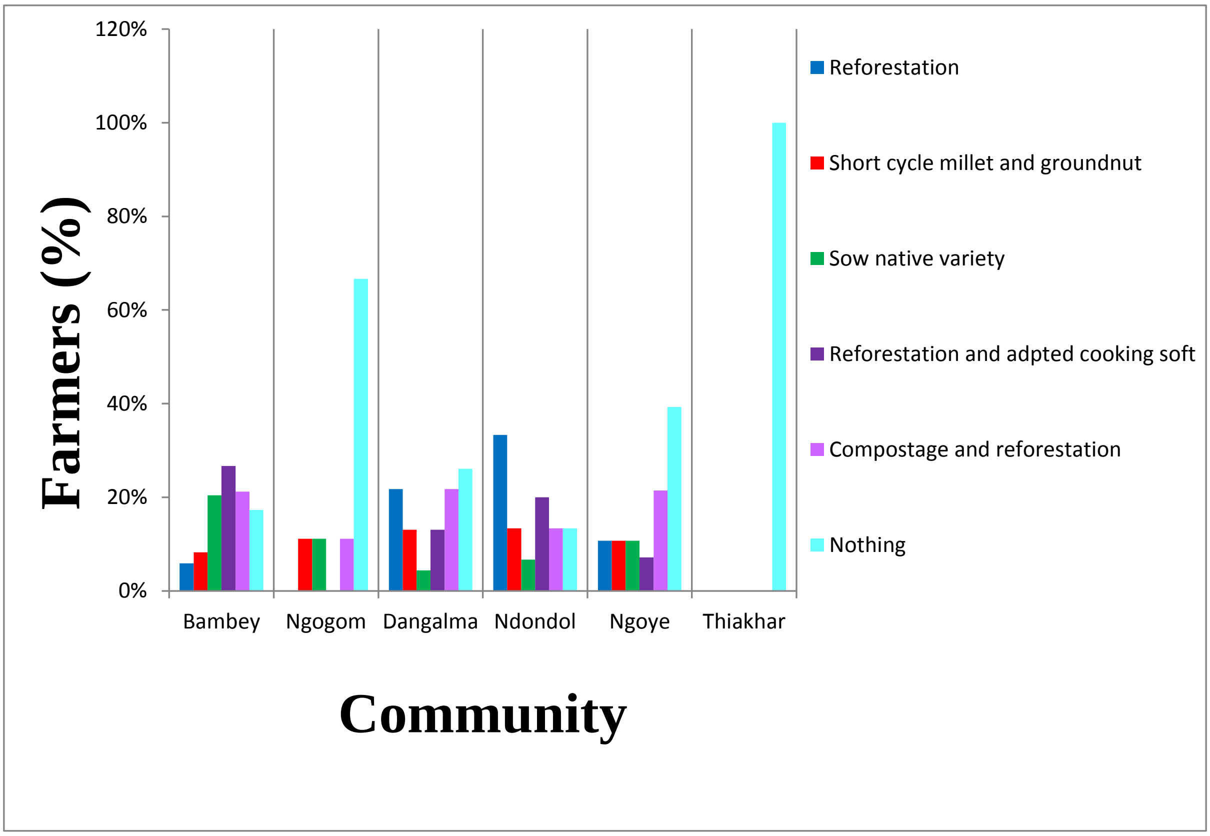


Figure 25: Farmers adaptations strategies in Bambey District

The largest number of farmers between (13% and 99%) did nothing to adapt to climate change especially in Thiakhar and Ngogom communities 99% and 65% of respondents respectively. This could be explained by the fact that most farmers in rural area are poor and illiterate therefore they tend to wait for finance and guidance in view to make adjustment.

Follow, reforestation and adapted cooking soft which have been reported by majority of farmers in Bambey and Ndondol community (27% and 33% respectively). The adopted cooking soft is used in view to reduce wood consumption which in long term will contribute to climate change mitigation. Farmers reported to apply animals waste in their farmers instead of chemical fertilizer which scored between 10% and 20% of respondents. According to Ajani et al., (2013), this helps to maintain soil microbial activities and promote absorption of nutrients by plants. Farmers have reported to show native variety and short cycle millet and groundnut. Similar to the finding of Kalanda-joshua et al., (2013).

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

From the results of this research, the following conclusions and recommendations were made.

Objective 1: To assess the perception of household on climate change

Majority of famers about 73% perceived changes in climate factors in their area for the past 30 years. Late onset, decrease of the seasonal cumuli, season becomes less lengthy, rain become less intense, frequency of rainfall decrease and cessation of rainy season becomes early were perceived by 51% , 63%, 72%, 66%, 66%, and 71% of farmers respectively. While 34% and 29% of the farmers' perceived temperature to increase during dry season and rainy season respectively. Farmers' perceptions were validated by rainfall and temperature data from the National Agency of Civil Aviation and Meteorology which showed non-significant increase of the onset, offset, length, intensity, frequency, and cumuli. The perceptions of farmers about temperature were not in line with the meteorological data. Furthermore, majority of farmers in Bambey District were not aware about the cause of climate change between 20% and 67%.

Most of them attributed the cause of climate change to God.

Recommendation

For farmers to adopt against climate change they need first of all to be aware about causes of climate changes. Though, this knowledge will allow them to don't continue to contribute to environmental degradation. Farmers' leader, women leader, chief, religious leaders and "djeliba" (Traditional speaker) of the villages should be train about causes of climate change and how to adapt from it. Therefore, those people would easily spread the information they received in their respective community. Furthermore, there is need for a policy framework which will address the problem of the ineffective dissemination of information related to climate change and variability among local farmers, particularly in the remote rural areas of Bambey district

Objective 2: To identify indigenous knowledge indicators used in Bambey District

Conclusion

In Bambey district, trees like "Ngeer" (*guiro senegalensis*) and "Vén" (Pterocarpus erinacerus) when their leaves are falling means the first onset of rains is about to fall. Ripening of fruit of "Beer" (Sclerocarya birrea), an increase of "*Xorondom*" (Big ant) activities, dark clouds move from East to west were all reported to indicate near rainfall. Presence in large number of insects like *Cicada* was reported by majority of farmers in Bambey district to indicate good rainy season with abundant rains.

Recommendation

Thorough documentation of all indigenous knowledge indicators is needed as well as educating the community about IKS is needed so as to encourage younger subsistence farmers to be aware of the environment and use forecasts to plan on which crops to plant and when to plant in order to increase farmers adaptive capacity.

Objective 3: To compare traditional and scientific forecasting methods for the 2017 season

Conclusion

Both the SCFs given by the Meteorological Services Department and indicators of IKS predicted that normal rains in terms of quantity were going to be received in the Bambey district. SCFs issues weekly and monthly forecasts via radios and TV and detailed forecasts can be obtained from meteorological stations. IKS indicators can tell the beginning or end of wet and dry spells but the time is not clearly outlined as the SCF forecasts.

Recommendation

Further studies are needed to validate indigenous knowledge indicators against seasonal climate forecasts for both good/normal rainfall seasons and drought seasons to determine their reliability taking climate change into consideration, and then the two forms of knowledge can be integrated for the benefit of the community.

Objective 4: To assess farmers' perception on possible integration of indigenous and scientific knowledge

Conclusion

Farmers reported to be very open on the integration of scientific knowledge to their indigenous knowledge of between 45% to 85% respondents. Farmers reported to use both indigenous and scientific knowledge when it comes to take majors decision in farming activities. Large number of farmers found the creation of a platform to be most available usable means of bringing local farmers with scientist. Sensitization and creation of laws were also reported by farmers to help in the integration of the two methods of forecast.

Recommendation

Research team from elderly famers' should be put in place in view to gather information's on the observations made in view to organize seasonal outlook with scientific forecaster and decision maker.

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Appendices

APPENDIX 1: Semi structured questionnaires

SECTION A: GEOGRAPHIC AREA

Name of interviewer: ________________________________

Date of interview: ____/____/____

Time when the interview started: ______:_____

Community: ________________________________

Village: ________________________________

Household number: __________

GPS coordinates:

S: ______o.______’._______”

E: ______o.______’._______”

SECTION B: HOUSEHOLD DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

No.	Variable label	Variables	Skip rules, information, remarks
1	Name of household head (**main decision maker**) ………………………………………………………………………		
2	Gender of household head ……………………….	1=male,2=female	
3	Name of the respondent ……………………………………………………		
4	Relationship of the respondent to household head ……………………………………………………….	1=household head,2=spouse to the household head,3=own children,4=relative,5=other (specify)………………………….	
5	Age of household head (year) …………………		
6	Marital status of household head ………………………	1=single,2=married, 3=divorced,4=widowed	
7	Group ethnic of household head ………………………………..		
8	Are you originally from this area? ……………	1=no, 2= yes	
9	How long have you resided in the area? ……………………………….	1=less than 10 years,3=11-20,3=21-30,4=more than 30	
10	Education level of household head ………………………………..	1=never been to school,2=primary,3=secondary,4=tertiary, 5= Koranic school	
11	Main occupation of the household head ………………………………………	1=full-time farmer,2= part-time farmer and other (to specify)	

12	How household do you have under the main household?		
13	Total number of man in the household		
14	Total number of woman in the household		
15	Total number of child in the household		
16	Size of household (total number of family members) ………………………………………	1=1-3,2=4-6,3=7-10,4=more than 10	
17	How many of the members mentioned above are involved in day to day farming? ………………………………….		
18	Total land size owned (in hectare or other land measurement unit) …………………..		
19	How many years the household has been involved in farming? ……………………………..		
20	Area under crops in the current season …………………………………		
21	Area under pasture in the current season ………………………………..		
22	Main source of labour in the household ……………………………..	1=family labour,2=hired labour, 3= mechanize, 4=other(specify)………….	

SECTION C: INFORMATION ON WEATHER PERCEPTION

23	Over the past 30 years, have you noticed any long-term change in the rainfall pattern? ………………..	1=no,2=yes	If no skip to question 34
24 a) b) c) d)	What changes have you noticed in the onset of rainy season? The onset of rainy season is early [ ] The onset of rainy season is late [ ] There is no changes in the onset of rainy season [ ] Other (Specify)……………..	a) b) c) d)	
25	What changes have you noticed in the onset of rainy season? The onset of rainy season is early [ ] The onset of rainy season is late [ ] There is no changes in the onset of rainy season [ ] Other (Specify)……………..		

26 a) b) c) d)	What changes have you noticed in the length of rainy season? The rainy season is more lengthy [ ] The rainy season is less lengthy [ ] There is no changes in the length of rainy season [ ] Other (Specify)……………..	 a) b) c) d)	
27 a) b) c) d)	What changes have you noticed in the intensity of rainfall? The rainfall is more and more intense [ ] The rainfall is less intense [ ] There is no changes in the intensity of the rainfall [ ] Other (Specify)……………..	 a) b) c) d)	
28 a) b) c) d)	What changes have you noticed in the frequency of rainfall? The frequency of rainfall is increasing [ ] The frequency of rainfall is decreasing [ ] There is no changes in the frequency of rainfall [ ] Other (Specify)……………..	 a) b) c) d)	
29 a) b) c) d)	What changes have you noticed in the frequency of break onset during the rainy season? The frequency of break onset during the rainy season is increasing [ ] The frequency of break onset during the rainy season is decreasing [ ] There is no changes in the frequency of break onset during the rainy season [ ] Other (Specify)……………..		
30 a)	What changes have you noticed in the frequency of break at midseason during the rainy season? The frequency of break at midseason during the	 a)	

	rainy season is increasing [ ]		
b)	The frequency of break at midseason during the rainy season is decreasing [ ]	b)	
c)	There is no changes in the frequency of break at midseason during the rainy season [ ]	c)	
d)	Other (Specify)……………..	d)	
31	What changes have you noticed in the frequency of break at the end of the rainy season?		
a)	The frequency of break at the end of rainy season is increasing [ ]	a)	
b)	The frequency of break at the end of rainy season is decreasing [ ]	b)	
c)	There is no changes in the frequency of break at the end of rainy season [ ]	c)	
d)	Other (Specify)……………..	d)	
32	What changes have you noticed in the cessation of the rainy season?		
a)	The cessation of rainy season is early [ ]	a)	
b)	The cessation of rainy season is late[ ]	b)	
c)	There is no changes in the cessation of rainy season [ ]	c)	
d)	Other (Specify)……………..	d)	
33	What changes have you noticed in the rainfall extreme?		
a)	The rainfall is more and more extreme[ ]	a)	
b)	The rainfall is less extreme [ ]	b)	
c)	There is no changes in the rain extreme [ ]	c)	
d)	Other (Specify)……………..	d)	
34	Over the past 30 years, have you noticed any long-term change in temperature? …………………………….	1=no,2=yes	If no, skip to question 37
35	What changes have you noticed in the sequence of temperature during the dry season?		
a)	It is more and more hot [ ]	a)	

b) c) d)	It is less hot [ ] There is no changes in the sequence of temperature during the dry season [ ] Other (Specify)……………..	b) c) d)	
36 a) b) c) d)	What changes have you noticed in the sequence of temperature during the rainy season? It is more and more cool [ ] It is less cool [ ] There is no changes in the sequence of temperature during the rainy season[ ] Other (Specify)……………..	 a) b) c) d)	
37	According to you what are the causes of those changes? ……………………………….		
38 a) b) c) d) e)	How have the weather changes affected farming activities? Decrease in crop yields/crop failures Increase in crop diseases Increase in crop pests Increase in weeds Death of livestock	 [1…..2…..3……4……5] [1…..2…..3……4……5] [1…..2…..3……4……5] [1…..2…..3……4……5] [1…..2…..3……4……5]	Circle the number according to the severity number 5 represent high level of severity and 1 the low level.
SECTION D: INFORMATION ON TRADITIONAL WEATHER FORECAST			
39	Do you know about traditional ways of weather and climate forecast?	1=no, 2=yes	If no skip to SECTION E
40	How do you get to hear about traditional weather forecasting? …………………………………………………....		
41	a) What traditional indicators do you know?, b) what do they do? and c) what they predict?		

Indicator	Behavior	Impact on the climate

42	Which indigenous indicators do you observe for		

	land preparation?		
43	Which indigenous indicators do you observe for planting?		
44	Which indigenous indicators do you observe for weeding?		
45	Which indigenous indicators do you observe for harvesting?		
46	Which indigenous indicators do you observe for storage?		
47	Which indigenous indicators do you observe before drought? ………………………………………………		
48	Which indigenous indicators do you observe before an imminent rain? ………………………………………………		
49	Which indigenous indicators do you observe before a strong wind? ………………………………………………		
50	What indigenous indicators do you use for seasonal forecast?		
51	Are you able to tell how the long the season will be from indigenous knowledge? If yes, what are the indicators?	1= no, 2=yes	
52	Are you able to determine the intensity of rain from indigenous knowledge? If yes, what are the indicators?	1=no, 2=yes	
53	What was the prediction for the 2017 season? Was it exact?	 1=no, 2=yes	
54	For the current season, which indicators did you observe? ………………………………………………..		
55	Among those indicators observed on which did you base your prediction?		
56	Are the changes in the rainfall pattern and temperature affecting the reliability of the indicators? If yes, how those changes affect your indicators?	1=no, 2=yes	

57	Since how many years did you start to use indigenous weather and climate forecasting?	1=less than one year, 2=1-5 years, 3=5-10 years, 4=more than 10 years, 5= always	
58	During the last 10 years how many times the prediction was exact?		
59	What are the indigenous techniques that you used to cope with the impact of climate change?		
60	How is doing the transmission of indigenous knowledge?		
SECTION E : INFORMATION ON SCIENTIFIC WEATHER FORECAST			
61	Have you heard about scientific way of weather and climate forecast?	1=no, 2=yes	
62	Did you use scientific weather forecast information?	1=no, 2=yes	
63	Why don't you use scientific weather forecast information?	1=lack of access to timely weather forecasts information, 2=lack of facilities, 3= lack of precision, 4=other (specify)……………………	
64	From which channels did you receive scientific weather forecast information?	1=radio, 2=television, 3=phone, 4=newspaper,5=relatives, 6=agriculture extension, 7= other (specify)	
65 a) b) c) d) e)	On which activities do you use the scientific weather and climate information? Land preparation[ ] Planting[ ] Weeding[ ] Harvesting[ ] Storage[ ]		
66	Since how many years did you start to use scientific weather and climate forecast information?	1=less than one year, 2=1-5 years, 3=5-10 years, 4=more than 10 years, 5= always	
67	During the last 10 years how many times the forecast was exact?		
68	Do indigenous ways of weather forecasting sometimes coincide with scientific forecast? ……… If yes, how often? ………..	1=no,2=yes 1=very often,2=less often,3=not at all	
69	Among the two methods of forecasting which one is the most reliable?		
70	Can we integrate those two methods of	1=no, 2=yes	

	forecasting?		
71	According to you how can we integrate those methods of forecasting?		

Time when the interview ended: ______:_____

APPENDIX 2: Focus group discussions

Focus group discussions

Date of discussion_________________

Village___________

1. Do you know about indigenous ways of seasonal weather forecasting?
2. How timely do you receive information about weather forecasts for the Meteorology department? If at all?
3. Which method of forecasting is more reliable?
4. Which indicators do you base your forecasting on?
5. Are the indicators (plants animals) still in abundance these days?
6. Does indigenous knowledge and science give the same forecast?
7. Do you use weather forecasts to plan agricultural activities?
8. Are you noticing any change in rainfall patterns and temperatures? How have they changed?
9. What did you notice prior to their coming?
10. What's the communities' perception on traditional knowledge?
11. How does indigenous and scientific ways of forecast can be combining?
12. From which sources did you receive traditional weather forecast information?

APPENDIX 3: Key informant interviews

Key informant interviews

Interviewer ……………………………………………………………………........................

Date of interview …………..

1. What are your social standing/ occupation?
2. What is your age?
3. How long have you resided / worked in this area?
4. Do you know about indigenous ways of seasonal weather forecasting?
5. How timely do you receive information about weather forecasts?
6. Which method of forecasting do you find more reliable?

7. Does indigenous knowledge and science give the same forecast?
8. Do you use weather forecasts to plan agricultural activities?
9. What are your most reliable indicators?
10. What's the communities' perception on traditional knowledge?
11. Do you think rainfall patterns and temperatures have changed? Yes/ No. If yes
12. How and when did you start noticing change?
13. How indigenous and scientific knowledge of weather forecast can be combining?