IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
May 2018 Vol.:9, Issue:3

Rainfall Variability and its Impacts on Economic Activities: Case Study of Sylvo-Pastoral Zone of Linguère's Department, Senegal

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

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Submission: 19 April 2018
Accepted: 25 April 2018
Published: 31 May 2018

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Rainfall Variability, Agriculture, Livestock, Impacts, Linguère

ABSTRACT

This study aims to analyze the impacts of rainfall variability on economic activities in the sylvo-pastoral zone of Linguère's department. The economy in this area is mainly based on livestock and agriculture. However, in recent decades, it is subject to high rainfall instability. It is in this context that the current study is located, which attempts to analyze the recent trends in rainfall evolution in the Linguère rain gauge and their impact on economic activities, is located. It is based on rainfall data over the period 1951-2013. Standardized Precipitation Index (SPI) and the Gap index to normal were first calculated. Then, field surveys associated with the literature review were conducted to apprehend the impacts of rainfall variability. Results obtained are consistent and very telling. The analysis of the results related to the indices shows two distinct periods: a very humid period from 1951 to 1969 and a period with a dry tendency from 1970 to 2013. Economic activities have undergone profound upheavals related to recent rainfall trends. Agriculture is strongly affected by the frequency of rainfall breaks and the shortening of the rainy season, which leads to a decline in agricultural yields. Pastoral activity is also mortgaged by recent climatic changes. In fact, the early drying up of natural water points and the reduction of fodder resources jeopardize the development of livestock farming.

1. INTRODUCTION

Issues related to the persistence or otherwise of drought are of primary importance for countries and inhabitants of the Sahelian and sub-Sahelian regions (Faye *et al.,* 2015). This drought, which began in West Africa around 1969-1970, is reflected in the shortening of the rainy season (Sow 2007; Faye, 2013). In the Sahelian zone, for example, the work of Sarr (2009), on the Ferlo basin in Senegal, reached the same conclusion. According to (Le Barbé and Lebel, 1997; Hulme *et al.*, 2001; Le Barbé *et al.*, 2002), Senegal experienced between the end of the 1960s and the beginning of the 1980s situations and catastrophic events marked by a sharp decrease rainfall. According to (Sultan and Janicot, 2004), this period of climatic deterioration was accompanied by episodes of extreme droughts such as the 1972-1973 season or the 1983-1984 season. This is manifested by a decrease in rainfall, a narrowing of the duration of the rainy season and a reduction of rainy days and the frequency of dry sequences. Declining rainfall has severely affected the natural resources of the Sahelian countries, which form the basis of agropastoral production systems (Diagne, 2000). Thus, the development of the economic sector of the department of Linguère is constantly vulnerable to the vagaries of the climate since the area is made up of a population mainly agropastoral (Servat *et al.,* 1998; NEPAD, 2007). Currently, even if the climatic impacts on economic activities are no longer to be demonstrated, the anthropic action was also significant. Thus, a strong anthropization of the environment is noted since the beginning of the 1960s. The demographic explosion has generated a saturation of the land capital as a result of the colonization of new lands and this has the effect, the reduction or even the disappearance of pastoral areas and classified forests. Indeed, some methods, such as following, are less and less practiced due to the high demand for arable land (CSE, 2005). The depletion of natural resources is also a source of economic and social disruption and degradation of people's living conditions. Indeed, the current state of the environment seriously compromises certain rural activities, especially those related to agriculture or livestock farming. As a result, the decline in the productivity of arable land and pastoral resources is visible in all localities of the department. The predominant activities of the primary sector remain heavily dependent on rainfall and the condition of certain natural resources such as soil or vegetation. Therefore, any disruption of rainfall has repercussions on agropastoral activities. The sector's performances are, however, very sensitive to climatic hazards. Indeed, the droughts of the 1970s and 1980s led to significant losses for cattle herds estimated at 68.2 and 37.8% respectively for the events of the 1970s and 1980s (Corniaux et al., 2010). At the agricultural level, a decrease in the contribution of the agricultural sector to the country's Gross Domestic Product (GDP) is noted. Agriculture, which accounted for 30% in 1960, this contribution, rose to 20% in the late 1970s and 11.5% in 1990 and represented only 9.6% in 1999 (CSE, 2005). This situation is one of the fundamental reasons of this study whose objective is to analyze the impacts of climate variability in a specific way, in the Department of Linguère.

2. MATERIALS AND METHODS

2. 1. Study area

Linguère's Department is located in the North of Senegal and in the East of the Administrative Region of Louga. It is between latitude 15 ° 24 'to 14 ° 00' North and longitude 15 ° 07 to 14 ° 04 'West (Map 1). It covers an area of 15375 km^2; it is the largest department in the region is 61.80% of the regional territory. Its population is estimated at 232441 inhabitants in 2013, ie an average density of 15.11 inhabitants per square kilometer (ANSD, 2014). Linguère presents a rather homogeneous relief marked by a vast plateau very monotonous with sandy undulations and low altitudes. The climate is of Sahelian type marked by a unimodal rainfall regime, that is to say, a single rainy season centered in the boreal summer characterized by its irregularity in space and time as well as its weakness since being between 200 mm and 400 mm. Temperatures are generally high for most of the year, especially during the dry season with winds from the continental trade winds (Harmattan). The area is dominated by sandy soils where sparse vegetation with shrubby and treed steppe vegetation develops. Like the whole sylvo-pastoral area, the department of Linguère is a space exclusively for agropastoral purposes. The economy is mainly based on livestock and agriculture, which are the main sources of economic activity in the department. Agropastoral production provides the essential needs of the population and occupies a preponderant place in the functioning of the environment. However, these different activities have suffered for over five decades the strong rainfall pejoration. Thus, to study the impacts of rainfall variability on economic activities, we have referred to analyzing the evolution of rainfall.

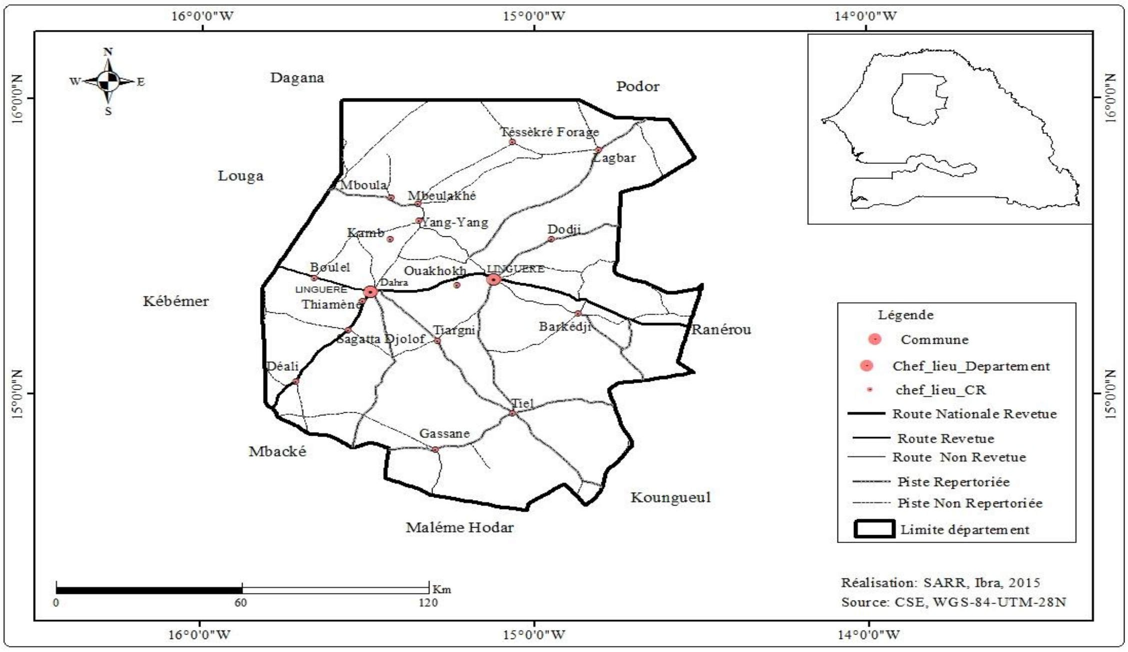

Figure 1. Location of Linguère Department

2. 2. Analysis of rainfall variability

The meteorological data collection and analysis concerned the Linguère station (15 ° 23'N-15 ° 07'W). These data stretching from 1951 to 2013 were made available to us by the National Meteorological Agency of Senegal (ANAMS). We will focus on these data to analyze the rainfall variability. The statistical procedures used in the rainfall series study concern: the deviation from the series average and the Standardized Rainfall Index (SPI).

2. 3. Gap index to normal

It is used to characterize and situate the evolution of rainfall heights through the interannual evolution of rainfall. This index is calculated by equation (1) (Jouilil *et al.*, 2013):

$$E_N = \frac{P_i - \overline{P}}{\overline{P}} * 100 \qquad (1)$$

With E_N is the standard deviation (%); P_i is the cumulative rainfall of the considered year; $\overline{P}$ is the average of the time series studied. This index is used to identify surplus and deficit years and their succession. The result obtained is divided into two classes: a surplus class and another deficit. The year is called wet when the variable is greater than zero; it is dry if the variable is less than zero. There is also a subdivision of the class into several subclasses with: surplus years, moderately surpluses and high surpluses and deficit years, moderately deficit and high deficit.

2. 4. Standardized index of rainfall

This index is of paramount importance because it captures the degree of deficit or excess rainfall. The Standardized Rainfall Index (SPI) is a simple and easy to use statistical tool for the characterization of rainfall irregularity. It is obtained by the expression (2) (Diouf *et al.*, 2018):

$$IPS = \frac{P_i - \overline{P}}{\sigma} \qquad (2)$$

Where Pi is the total of the rain of the year i studied; is the series average studied; is the standard deviation of the series. The calculation of the standardized index gives a classification that ranges from extreme humidity to high humidity, moderate humidity, extreme drought and severe to moderate drought (Table 1).

Table1. Categorization of Drought

SPI values	Classification of drought
SPI>2	Extreme humidity
1< SPI <2	High humidity
0< SPI <1	Moderate humidity
-1< SPI < 0	moderate drought
-2< SPI <-1	Heavy drough
SPI <-2	Extreme drought

2. 5. Analysis of economic impacts

Most of the data were collected, on the one hand, during surveys of agro-pastoral populations and on the other hand, by collecting and analyzing climatic, agricultural and pastoral data. Thus, to acquire information on the impacts of recent climate change on economic activities, we conducted a field survey of local populations. This is an important phase as they allow us to come into contact with the environment studied. In addition, we will have an overview on the climatic dynamics, its relations with the economic activities as well as on the ecological evolution of the environment. It is conducted in several phases: the first step is to make a prospecting visit; this phase made it possible to get in touch with some local resource persons. Maintenance guides are administered to the administrative authorities of the area. In the same vein, the village heads, as well as the department heads such as Linguère's Rural Development Department (SDDR), the heads of the Rural Development Support Centers (CADL) of the various districts, Forest brigades and veterinary posts supported the collection of data and information. The surveys were conducted through group focus and personalized surveys or personal interviews. Group surveys are conducted during weekly markets and at public places in order to apprehend the point of view of some breeders and growers on the objectives of the study. The simple personalized surveys were aimed, through a fact sheet, obtaining information on the history of climate variability, particularly that of rainfall in the department, as well as their effects on economic activities. The questionnaires particularly targeted heads of households, women and young farmers or breeders who wanted to be well suited to our questionnaire. Indeed, priority has been given to heads of households made up of farmers, pastoralists and foresters. According to (ANSD ,2014), a household is a "group of people, related or not, living together under the same roof and pooling all or part of their resources to meet their basic needs, including housing and the food. These people called household members usually eat together and recognize the authority of one and the same person, the head of household. In addition, the choice of the head of household is dictated by some consideration. It has a very important decision-making level, particularly in rural areas and especially among farmers and pastoralists. In addition, he is responsible for the management of land (the allocation of arable land), certain goods such as livestock. At the level of heads of households, it is mainly the elderly who have been most favored (aged at least 55). Given our theme, which focuses on rainfall variability and its impacts, elderly witnesses from the past can give us a history of the state of play. From there, we can make a comparison with the current state and a global appreciation of evolution.

3. RESULTS

The results concern the temporal variability of the gap index to normal and the standardized rainfall index first, then the impacts on economic activities.

3. 1. Gap index to normal

The graphical representation of the gap index to normal from 1951 to 2013 for the Linguère station is illustrated in Figure 2. Indeed, the observation of this figure highlights two phases in the chronicle. There is a first sequence that extends from 1951 to 1969. The latter is called wet and is marked by a domination of the rainy years. The wettest periods occur between 1951 and 1955. From 1956 to the end of this period the rains are relatively acceptable. However, it is during this sequence that deficit years begin to appear. It is essentially: 1956, 1962, 1963, 1965 and 1968. The second sequence is longer and extends from 1970 until the end of the series. Unlike the first, this stage is marked by the domination of the dry years. However, some seasons were particularly wet during this episode. This is the case for the years 1975, 1982, 1987, 1989, 1996, 1998 and from 2008 to 2012. The rainfall variability is also characterized by surplus years, even very high surpluses and years that are deficient or even very much in deficit. Thus among the years of good rainfall we find there surplus where their differences are between 40 and 50%. These are: 1952 and 1960. There are also very surplus years with values above 50%. This class concerns 1951, 1953, 1969 2009 and 2010. As regards the deficit years, we have two trends: years that are deficient and sometimes even very deficient. These two trends are mainly concentrated during the 1968-1992 sequence. It is during this interval that the rainy seasons described as very deficient are recorded: 1973 and 1983, 1984 and 1992. They recorded respective deficits of 41, 2 and 58.5%. The years 1968, 1972, 1978, 1994, 1997, 2002 and 2003 are called deficit. Their index is also important and is beyond -30 and -40%. The gap study is marked by high interannual variability. Indeed, Figure 1 shows an alternation of dry and wet years. The situation of rainfall deviations from the average in the Linguère station is marked by a dominance of deficit years. In fact, the locality has 36 years of negative rainfall compared to the average of 57.1%. Within this group, it is the years: 1983, 1973 and 1972 which are the most deficient with respectively 58.5; 41.2 and 39.2%. The most deficit year is 1983. In this interval station, from 4 to 5 or even 8 deficit seasons follow one another without interruption. These are the 1970-1974, 1976-1981, 1883-1986, 1990-1995 and 2000-2007 sequences. A total of 27 years with above average rainfall, 42.9% are enumerated. The rainiest seasons are: 1951, 1953, 1969, 2009 and 2010. The important rainfall phases are visible especially at the beginning of the series: 1951-1953, 1957-1961. Therefore, with 80.2% of surplus 2010 is the rainiest of the series.

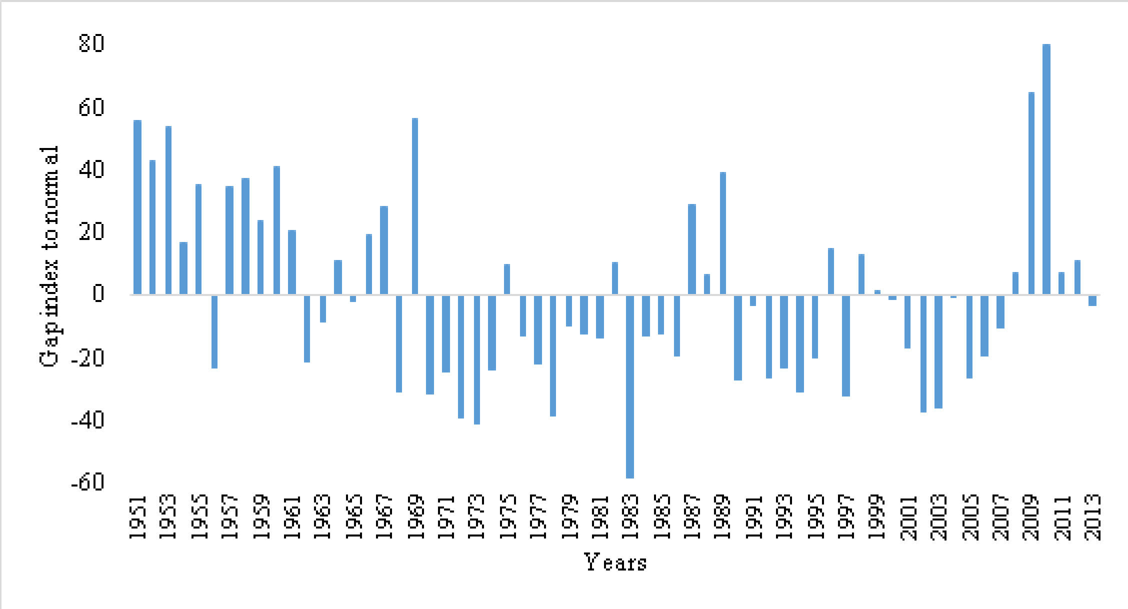

Figure 2. Evolution of gap index to normal at Linguère from 1951 to 2013

3. 2. Standardized index of rainfall

This index makes it possible to make an analysis of the evolution of the rain over the period of study. It expresses the rainfall surplus or deficit for the year under study compared to the average of the chronic. A classification of the years following the degree of humidity and / or drought is thus made according to the values of the index. Thus (Figure 3) illustrates the evolution of the IPS over the study period. At first sight, there are strong fluctuations; dry sequences remain everywhere in the majority. According to the different classes of IPS, the class of moderate drought is more representative than the others, followed closely by moderate humidity. The number of years of moderate drought is more significant (Table 2). Its frequency is estimated at 40%. Only one year observed an extreme drought, it is 1983 with an IPS of -2. This situation shows that cases of extreme drought are rare. On the other hand, extreme humidity occurs twice in the Linguère stations. These are the years 2009 and 2010 with IPS 2.2 and 2.7 respectively. Thus, we find that years of extreme humidity are more important than those of extreme drought. However, the Ferlo has been hit since the 1970s by an intense rainfall pejoration. This situation is indeed the consequence of years of moderate drought and severe drought, but is not related to extreme drought. The years with moderate humidity and drought are the classes with the largest frequencies and a slight importance of the moderate drought group. The moderate humidity class, like moderate drought, has a relatively high coefficient of 25% or more. Years with high humidity and drought have an average percentage with, however, a small advantage of severe drought. No year, in these 2 groups, recorded a rate greater than or equal to 20%. For the strong drought, the station recorded a rate of 14% whereas for the strong humidity it is evaluated at 16%. The graphical representation of the Index shows the alternation of wet and dry years. Given the size of the variations from one year to another, we have doubled the curves by the moving average calculated over 5 years (Figure 3). It allows us to appreciate and clarify trends in rainfall abundance or insufficiency. In addition, the moving average has the effect of "damping abrupt variations, of completely eliminating the extreme values and of rolling out all the values to reveal long trends or cycles" (Chuzeville, 1990 quoted by Ndione, 1998). The dry sequences are longer than the wet ones in our field of study. Evolution is characterized by a concentration of wet years at the beginning and end of measurements and dry years in the middle of the chronicle. The curves of the SPI of the series make it possible to discover the very variable nature of the rainfall, but also to grasp the nature of the deficit or the surplus of the rains from one year to another. The general conclusion is that the 1951-1960 and 1961-1970 decades are wetter than those of 1971-1980 and 1981-1990 which remain very dry in the sylvo-pastoral zone. Then, we observe an alternation of wet and dry years for the decades 1990 and 2000. Finally, a wet episode characterizes the 2000 decade in Linguère station. The last decade characterized by a return to wet conditions is in sync with Ali's studies of (Ali et al., 2008; Sarr,2009 ;Ali and Lebel, 2009). In summary, we can say that the analysis of the Standardized Rainfall Index in the Ferlo allowed us to highlight a decreasing evolution of the pluviometry. This downward trend that began in the 1970s was exacerbated over the previous two decades, 1981-1990 and 1991-2000.

Table 2 : Fréquences de l'IPS dans à la station de Linguère de 1951 à 2013

		Humidité			Sécheresse			Total	
Station	Number of years	HE	HF	HM	SE	SF	SM	wet year	dry year
Linguère	63	2	16	25	2	14	40	44	56

HE: extreme humidity, HF: high humidity, HM: moderate humidity, SE: extreme drought,

SF: strong drought, SM: moderate drought

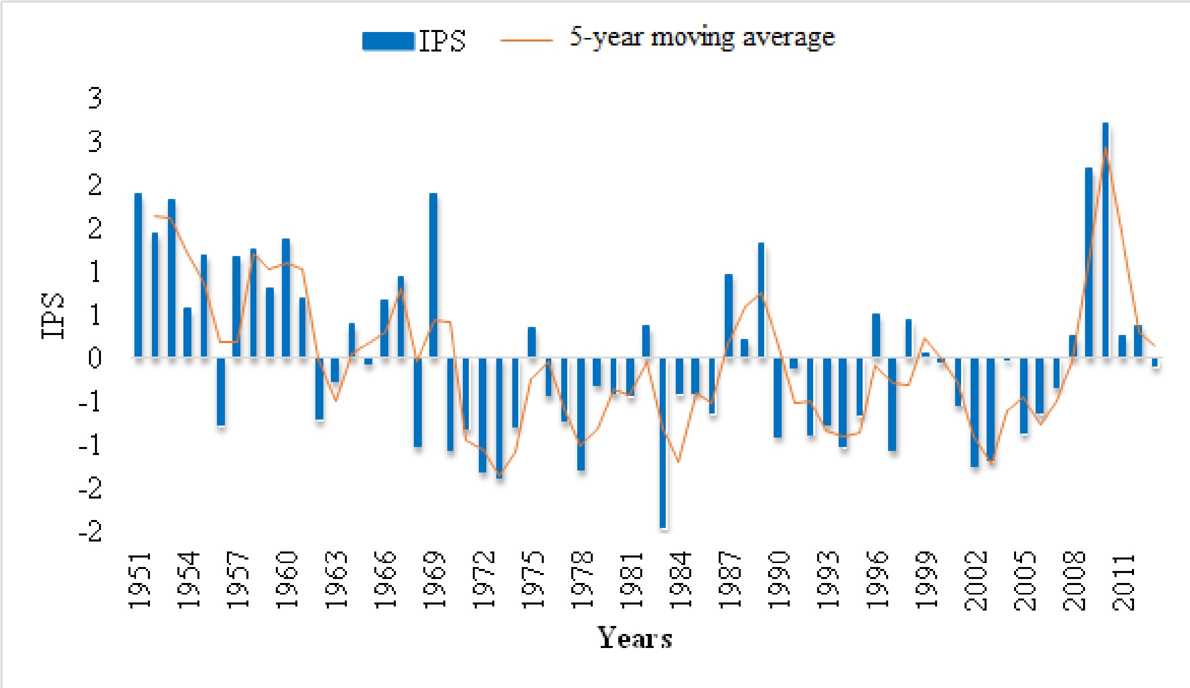

Figure 3: Interannual evolution of the IPS at Linguère station from 1951 to 2013

3. 3. Rainfall variability on the economy of the department

Climate variability impacts on economic activities in the silvo-pastoral zone are unequivocal. Indeed, the phenomenon is well apprehended by pastoralists and farmers who fear them very much and have seriously damaged the agro-pastoral activities and the social life of the local population.

3. 3. 1. Rainfall variability on livestock farming

Livestock development depends largely on good rainfall well distributed in space. Rainfall has a direct influence on the filling of ponds and the productivity of pastures. Rainfall determines water availability, quantity and quality of plant biomass. As a result, the environment is decreasing, with precipitous annual totals affecting the pools that are sources of livestock watering. Indeed, the rainy season is currently characterized by late beginnings and early endings. This situation of shortening the wintering does not allow a good filling of the ponds. This results in a decrease in surface water. Their water retention period is 2 to 3 months (August to October). However, they dry up immediately after wintering. This is due to the thermal conditions of the medium. It is marked by very high temperatures (above 35 °

C) that result from extremely high evaporation. The consequence is a rapid drying up of the pools during the dry season. The impacts of climate variability can also be measured from the results of field surveys. The local populations told us about the decrease or drying up of surface water, linked to rainfall events. This makes (Sagna, 1988) say that "the interannual rainfall variability in West Africa is of concern to the populations. Rainfall deficit that began in 1968 is accompanied by drying up of the Sahelian zone. This translates into a depletion of the superficial waters ". In the department, the effects of climate change are also manifested by the scarcity of today's ponds, which tend to disappear. The majority of respondents, especially the oldest, say that most of the pools have disappeared. More than 80% of the villagers surveyed say that 70% of the ponds have disappeared or are endangered with a reduction in their quantity, their depth, but especially their area. The decrease of the volumes of precipitated water and consequently of the pools in our sector of study makes recognize to Mr. TOP, 75 years old and resident of Ouarkhokh: "once, the rains were abundant, there were in our village several ponds, I counted a dozen. Today, with the decrease of the rains all the ponds are almost dry. In addition, I noticed that the ponds, which exist so far, dry up immediately after the rains stopped while the water stagnated until March or April. Others have found that some pools are shrinking from year to year. So, according to Mr. KA, an inhabitant of Wellou mbel a Fulani village in the commune of Déali "the surface of our pond has considerably diminished. It was estimated at about 500 km2 before 1973, but today it is less than 150 km2. This is especially noticeable in the villages of Mbacke Djolof Thiare and Sine which are located in the Municipality of Sagatta Djolof. Indeed, in these localities, there are currently puddles and the pools have lost about 90% of their area. Pastoralists also experience enormous difficulties in feeding livestock. According to the testimonies of some of them, a great reduction of the natural course is observed. It results in a decline in the production of woody plants (leaves and fruits) and herbaceous biomass. Most pastoralists say that many forage plants, which were the most palatable species, have disappeared. The food deficit forces cattle to consume plant species previously neglected by animals: ndiandame (Boscia senegalensis), neem (Azadiracta indica), cram (Cenchrus biflorus), Cassia obtusifolia ex. tora. The stubble of boxes and cartons are frequently used. Increasingly, foreign bodies such as plastic bags, pieces of wood, bone and other debris are also ingested by ruminants (Diop A.T *et al.*, 2011). The lack of feed for livestock pushes breeders to make daily trips longer and longer. These displacements to which the animals exert a lot of efforts to feed have indeed adverse consequences on these "with the decrease in quantity and the quality of the pastures, the animals provide more efforts to eat well. It follows changes with an increase in age at first calving (two and a half years ago, the age of the first calving has passed for some cows at 4 years). An increase in gaps between calvings was also noted. Changes have occurred in milk production (quantity and quality).Diseases of concern are also reported (botulism indicated by all breeders in the ZSP, parasitism, pasteurellosis, pneumopathies, etc.) "(Diop *et al.*, 2011). After our interviews with the breeders, it appears that the animals most vulnerable to this situation are cattle and sheep which sometimes even die of inanity. Breeders say goats are less affected because of their ability to exploit woody plants. This lack of fodder also explains weight loss in many animals. Livestock development in the sylvo-pastoral zone is compromised to a chronic shortage of natural grazing. For more information on the impacts of rainfall variability on livestock, the analysis of the different climatic hazards seems to us fundamental.

3. 3. 2. Droughts of 1972-1973 and 1983-1984

Like the rest of the country, two episodes of drought occurred in the sylvo-pastoral zone in 1972-1973 named ("band hitande", or "the bad year") and 1983-1984 ("Velingara hitande" or "Year of Vélingara", destination of the majority of breeders during this year). They are characterized by a lack of rain (1973) or quantities are very low. These situations of rainfall deficit during these periods led to a decrease in the number of livestock. The droughts of 1972-1973 and 1983-1984 have deeply shaken the lives of pastoralists. Many breeders have lost a large part of their livestock. The aftermath of these droughts boils down to the reduction of the herd marked by a high mortality in a period of time, "I lost nearly 60% of my herd all species confused between the two droughts", testifies a breeder during our surveys. According to (Corniaux *et al.*, 1980) the drought of the 1970s and 1980s led to significant losses for the cattle herd in Tessékré Forage Commune, a reduction of 68.2 and 37.8% respectively for 1970s and 1980s. According to the breeders, the first crisis was the most severe than the second. In 1983, pastoralists used their experience from the drought of 1973 to set up more efficient mobility systems. They left earlier to the regions (Peanut Basin, River Valley or Casamance) less affected by the rainfall deficit, at the first signs of drought. Thus, even if the drought of 1983-1984 was, in terms of rainfall, lower than that of 1973, it was less destructive in terms of mortality rate thanks to a better mobility strategy partly based on the memory of the previous shock. According to a farmer in Kamb commune "the drought of 1973 decimated 70% of my livestock, there is a total collapse of herds, but in 1983 I did not suffer as much as the previous episode. I started transhumance very early and that's why we had fewer losses. "Along with livestock rearing, recent rainfall trends have also affected the agricultural sector.

3. 3. 3. Rainfall variability on agriculture

As in the rest of the country, agriculture in the Department of Linguère is highly dependent on rainfall. The bulk of agricultural production is in the hands of rainfed crops. However, recent studies have shown that during the last 4 decades the rains have decreased by 35% in quantity, also characterized by an inter and intra-annual irregularity, a short duration of the rainy season and a decrease of the frequency rainy days (Diagne, M, 2000, Sultan B, 2002, CSE, 2005). Thus, with the deterioration of rainfall conditions, the environment is experiencing a significant decline in agricultural yields. This reduction in agricultural productivity, observed since the 1970s, is correlated with that of rainfall, ie about 35 to 40% in the northern regions. To better understand the influence of rainfall variability on agriculture, the study of dry sequences during the rainy season is fundamental.

3. 4. Dry sequences during the rainy season

3. 4.1. Duration of the rain breaks

The analysis relating to the rainfall patterns of the area is shown in Figure 4. Note in advance that the rainy season is marked in the Sahelian zone by its high irregularity. This characteristic is at the origin of the existence of dry frequencies during wintering. A rainfall pause is defined in this study as a period of at least 7 days during which the rainfall received is less than 1 mm. In estimating that the rainfall breaks of less than 7 days do not affect too much the harvests, we considered as dry sequence the one whose duration is greater than or equal to 7 days. The study deals with the interannual evolution of the dry sequences then their intra-seasonal evolution to be able to determine the most affected months. The analysis of dry events in our study environment is marked by its great instability from one year to another. Indeed, the observation of the figure shows us that during the period prior to 1970, it is the dry sequences of 7 to 9 days and 10 to 14 days that are most noticeable. However, only 5 years have experienced dry episodes greater than 15 days. These are 1956, 1963, 1966, 1967 and 1968. The longest rainy truces occurred in 1956 and 1966 with 26 dry days. In contrast, with only 7 days of breaks 1951 and 1954 are the least affected. Between the early 1970s and the late 1980s, breaks of up to 15 days are more frequent. We notice them in 1971, 1972, 1976, 1980, 1983, 1987 and 1988. They recorded respectively: 19, 28, 18, 17 and 18 days.

The longest break of the series is noted in this interval, that is to say, the year 1972 with 28 days. On the other hand, short breaks are recorded in 1975 and 1985 with less than 10 days. From the early 1990s to the end of the series the longest rainfall troughs do not exceed 15 days. Only two years have experienced rainfall stops greater than or equal to 15 days. These are 2002 and 2007 respectively 16 and 15 days. The dry sequences recorded in 1991, 1992, 1993, 1997 and 2003 are relatively large and are between 12 and 13 days old. The years 1995, 1998 and 1999 have the shortest dry sequences with 8 days. In summary, we can say that dry episodes of a week or more are more visible in the beginning of the series while the longer days are noticed after the drought of the 1970s. The most frequent rainfall breaks occurred during the period 1970-2008, thus inadequacy with the rainfall dynamics. Thus, the number and length of dry sequences have evolved in correlation with rainfall trends (Manetsa, 2011). With an agriculture whose yield emanates from the good rainfall behavior, the appearance of dry sequences during wintering can have harmful consequences to the development of cultivated plants.

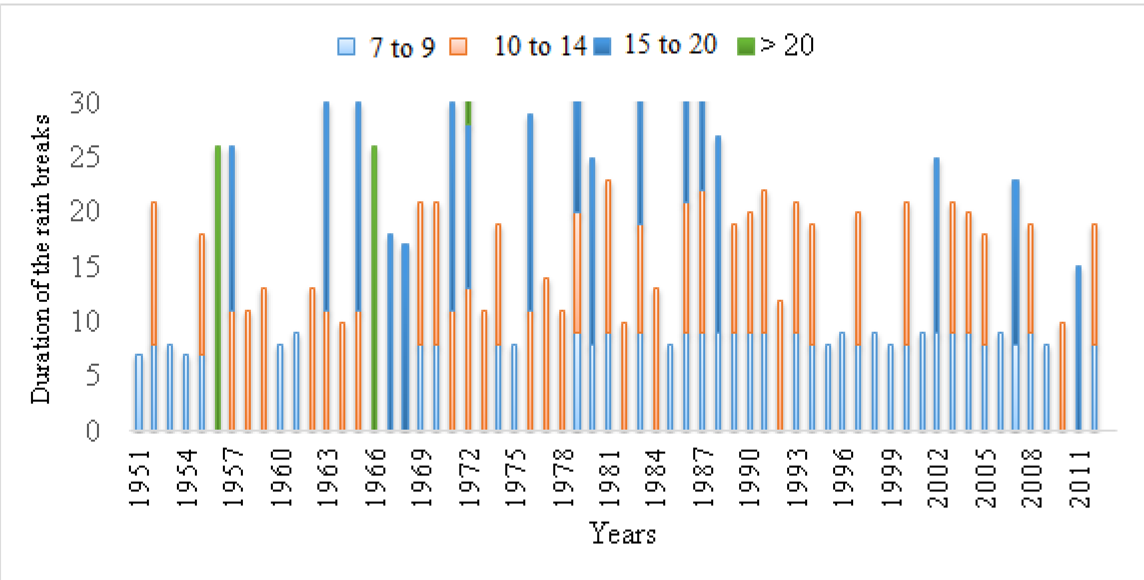

Figure 4. Duration of the rain breaks during wintering in Linguère

3. 4.2. Frequency of rainfall breaks

We present in Figure 5 the analysis of the frequency of rainfall breaks in the study area. Indeed, during the beginning of the rainy season (June-July) the non-rainy events of 10 to 14 days are the most representative (45%). Those from 7 to 9 days are also important with 37%.

The frequency of 15 to 19 days represents 14% while that of more than 20 days is the least important and totals 4%. In general, the beginning of the rainy season is marked by the relatively large share of dry sequences of duration 7 to 9 and 10 to 15 days. The August-September period is considered the wintering environment. During this phase, we have the same behavior on the frequency of the dry sequences. During the month of August, rainfall stops of 7 to 9 days are the most important. Their proportion is estimated at 63%. The frequency of the sequences of 10 to 14 is evaluated at 32% while that which is between 15 to 19 days is only 5%. During this month, no rainfall interruption is greater than 20 days. During the month of September, dry episodes of 7 to 9 days are the most representative with 48% followed by dry sequences of 10 to 14 days which make 39%. The frequency of the sequences of 15 to 19 days is equal to 13%. The dry sequences observed at the end of the rainy season and which correspond to October have characteristics similar to those at the beginning of the rainy season. We note that stops of 10 to 14 days remain dominant. It is at this moment that its frequency is greater with 56%. A fall in the sequences of duration of 7 to 9 days is observed (25%) while that of 15 to 19 days knows a progression (19%). Rainfall breaks of more than 20 days are non-existent during this period. The presence of dry sequences during the rainy season is a major constraint for agricultural activity. To be able to characterize these obstacles, Sultan (2002) has subdivided the plant cycle into four phenological stages each corresponding to a dry sequence whether it is the beginning, the middle or the end of the rainy season: (i) the juvenile phase which characterizes the vegetative period; (ii) the reproductive phase, which corresponds to the beginning of flowering; (iii) the end of flowering phase and the beginning of maturation with grain filling; (iv) the last stage of ripening corresponding to the desiccation of the grains. The impacts of rainfall breaks on agriculture vary according to the time from which they are triggered. Thus, according to (Sultan, 2002), the phases most vulnerable to water stress are the second and third phases, i.e the reproductive and grain filling periods. These stages, which coincide with the months of August and September "are characterized by a high value of the water satisfaction index with 92% for the second phase and 83% for the third phase" (Sultan, 2002). The dry episodes have a negative effect on the crops, because the water demand of the plant is by no means satisfied, "the persistence of the dry episodes and consequently the non-satisfaction of the water needs of the crops, in this decisive period of their development, will delay or disrupt the vegetative cycle of crops and play negatively on production or even on their quality "(Sané, 2003). On the other hand, the breaks noted at the beginning (the juvenile phase) and the end (last phase of maturation) of the season have a weak influence on the yield compared to those recorded during the second and the third sequence. This situation is explained by the fact that these stages have the lowest values of the water satisfaction index. The first phase has the smallest value (34%) while the last stage shows that only 44% of the water requirements for the plant are satisfied (Sultan, 2002). Even though their effects are less than the previous ones, these reported breaks can cause enormous damage to harvests. Thus, if they are observed during the months of sowing (June or July) they can cause the rotting of the seeds or the death of the young plants because of the lack of water. In this context, some farmers opt for new planting and if the crops are made late this can compromise the development of plants especially when the end of wintering is early. Water stress during the last phase can also affect performance. During this time, we are in the closing phase of the vegetative cycle and if the break occurs, we can witness a poor filling of the grains. This situation affects the quality and quantity of agricultural production.

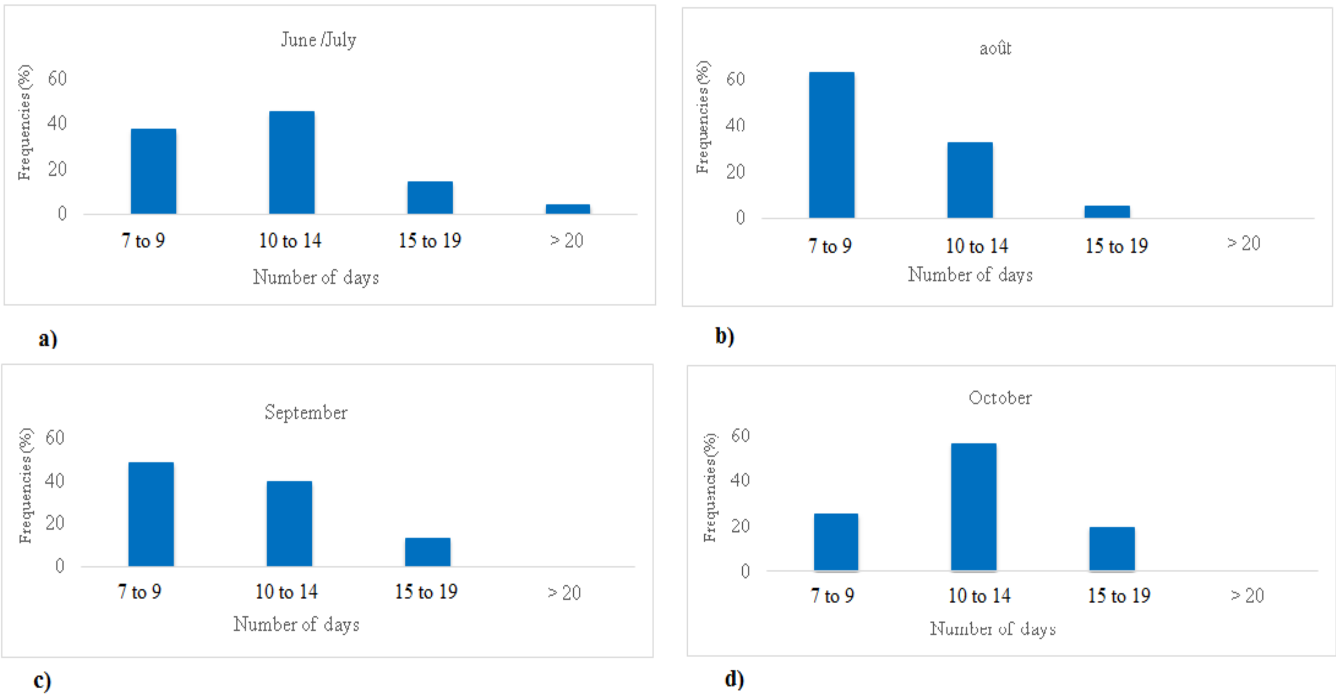

Figure 5: Frequency of rainfall breaks at Linguère during wintering

a)June/July, b)August, c)September, d)October

4. DISCUSSION OF RESULTS

The analysis of the rainfall evolution through the deviations from the mean and the standardized rainfall index showed us the persistence of the interannual rainfall variability in the Department of Linguère. These results are in line with work done previously (Ndong 1996; Bigot *et al.*, 1997; Lebel *et al.*, 1997; Lebel *et al.*, 2000; Sagna, 2005; Fall 2014). They identified two different periods: the wet sequence from 1951 to 1969, and the dry phase, which has been since 1970-1980. Since then, there has been a general decrease in rainfall (Le Barbé and Lebel, 1997; Le Barbé *et al.*, 2002; Sultan and Janicot; 2004). Some researchers such as Hulme et al, 2001 and Ali *et al.*, 2005) point out that these last 30 years have been marked by a decrease in rainfall totals. Meanwhile, some researchers (Sultan, 2002; NEPAD, 2007; FAO, 2008) discuss the impacts of climate variability visible in the agricultural sector with declining production, declining cropland and scarcity of water resources. In the field of livestock, the work of (Corniaux *et al.*, 2010; Gaye, 2010; Jorat 2011) showed that bioclimatic hazards such as droughts and off-season rains have profoundly changed the lives of pastoralists. Ferlo. According to the latter, it is mainly the extreme episodes of drought in 1972-1973 and 1983-1984 and the cold rains of January 2002. This situation contributes to limiting the performance of the herd characterized by a considerable reduction in numbers.

5. CONCLUSION

Recent climate change has consistently affected livestock and agriculture. Indeed, pastoral activity suffers from the harmful effects of climatic variability through the scarcity of fodder resources, water and the reduction of natural rangelands. The fall in rainfall affects the feeding of livestock, which leads to poor performance on pastoral production (butchery and dairy). The agricultural activity is also shaken by the climatic pejoration since very dependent on the pluviometry. The latter is characterized by the drop in annual totals, the poor spatial-temporal distribution, the narrowing of the duration of the rainy season and the frequency of dry sequences. All these phenomena have repercussions on agricultural yields, which are experiencing a considerable reduction in all speculations. This results in a drop in annual totals marked by their poor distribution in time and space. All these factors have a negative effect on agropastoral production and yields. The result is unprecedented food insecurity and impoverishment of pastoralists and farmers, resulting in the influx of urban labor by rural youth with all the social, economic and political consequences. In addition to climatic factors, other constraints hinder the development of these activities. Thus, we note in the livestock sector the recurrence of cases of theft and diseases such as rinderpest or sheep, the lack of health infrastructure and qualified animal health personnel, the lack of infrastructure with d enormous difficulties related to the processing and preservation of milk, the extension of crop fields contributing to the narrowing of grazing areas, the overly extensive nature of livestock farming. In the agricultural sector, the constraints are linked to the decline in soil fertility, the locust invasion especially, that observed in 2004, the poor quality of seeds, the lack of organization of agricultural campaigns and the bad agricultural policies implemented placed by the public authorities. All these difficulties noted at the level of livestock and agriculture certainly contributes to lower yields.

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