THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

The Vulnerability of Irish Potato Production to the Observed Effects of Temperature Variation in Santa area, Cameroon

Dr. Clement Anguh Nkwemoh
Lecturer, Department of Geography,
Faculty of Arts, Letters and Social Sciences, University of Yaounde 1, Cameroon

Abstract:
The present climate change has greatly impacted global agriculture and this situation has aggravated the present burning issue of world food crisis. The Santa Sub-Division epitomizes areas over the globe, that are facing this problem. This study therefore stood out to research on the specific magnitude of the influence of temperature variations on Irish potato and the adaptation strategies of farmers.
Using a research methodology that entailed the administration of questionnaires and field observation complemented with topographical maps, aerial photos, satellite images and data from other secondary sources, the vulnerability of Irish production to the observed effects of temperature variation in Santa sub-division was investigated. Findings reveal that, there has been a rather generally gradual increasing trend with 9 anomalies, an increase in average dry season and rainy season temperatures, a fairly decreasing mean monthly minimum temperature with a gradient of -0.092, a considerable decreasing mean monthly maximum temperature with a gradient of -0.2575. A strong relationship has been observed between inter-annual temperatures; 5-year mean temperature trend, the mean monthly maximum temperature for March, April and June for the first growing season; the mean monthly maximum temperature of November and December for the second growing season; CV and Irish potato production. A high level of significance of correlation of 0.05 was observed between inter-annual average temperature and Irish potato production indicating a 95% probability that vagaries in temperature greatly impact Irish potato production.
The adaptation strategies that have been adopted were viewed at different levels. They include farm level, plant level and farmer level adaptation strategies. The test of performance, food security and the need to increase yields were the main factors that fostered farmer adoption of innovations. The recommendations entail the reinforcement of extension workers, improvement of small credit schemes, farm to market roads, rehabilitation of Meteorological Centers and the promotion of agro-forestry.

Keywords: *Temperature variation, Irish potato, vulnerability, adaptation strategy, adoption of innovation*

1. Introduction

Climate Change encompasses a gamut of phenomena including changes in long term trends in temperature as well as increasing year to year variability and a greater prevalence of extreme events. These inter monthly and annual variability has become a major concern worldwide. Due to increases in temperature, rainfall has already become variable and unpredictable and the strength of climate related extreme events such as droughts, floods, heat waves and cyclones are anticipated to increase in the future (FAO 2006, IPCC 2007, 2014). This has affected and is still affecting agriculture. This is a burning issue especially during an era when world food crisis is becoming more pronounced not only as a result of the inequitable distribution of food over the globe but also due to natural hazards as drought and dry spells. The condition is even precarious for some of the world's most staple food crops such as Irish Potato that are highly needed to feed the rapidly increasing global population.

Temperature variation is a terminology that is encapsulated in climatic variation since it is just a parameter. Climatic variation refers to the climatic parameters of a region varying from its long-term mean, with some years having low average Rainfall and temperature and others having average or are above average rainfall and Temperature (IPCC, 2007), Hare (1985) also describes climatic variability as the observed year-to-year differences in values of specific climatic variables within an averaging period (typically 30yrs). All of these definitions equally entail temperature variations. To the IPCC (2002), climatic variations include variation of the average state and other statistics of climate at all temporal and spatial scales above individual climatic phenomena. Rognon (1983) shows that the upsets in the seasonal rhythm during one or many years constitutes a climatic anomaly that the evolution curves clearly show from a static base. They presented two forms of anomalies; meteorology anomalies (effects for few hours or few days' atmospheric mechanisms known to be carried by its height and provokes catastrophic effects) and the climatic anomalies (known to bring about prolonged irregularities over one or many years in the usual seasonal progression).

One of the most important requirements for the growth of Irish potato is temperature. The major species of Irish potato grown worldwide is *Solanum tuberosum* (a tetrapod with 48 chromosomes), and modern varieties of this species are the most widely cultivated. Potato varieties can be grouped into early (90 to 120 days), medium (120 to 150 days) and late varieties (150 to 180 days) (FAO, 2012). There are more than 100 varieties of potatoes and only four basic potato categories: long whites, round whites, russets, and round reds. With this huge diversity of potato varieties worldwide, only the CIPIRA and a few other imported varieties thrive well in Santa

Weather and climate have a direct influence on cropping systems and plant yield. Thus, weather fluctuations and climate variability play a significant role in crop growth and yield. Occurrence of abnormal weather episodes during the growing season or during critical development stages may hamper growth processes resulting in yield reduction. This makes climate variability a threat to food production leading to serious social and economic implications (Geng and Cady, 1991; Hossain, 1997). However, a clear understanding of the vulnerability of food crops as well as the agronomic impacts of climate variability enable one to implement adaptive strategies to mitigate its negative effects.

An array of studies has already been carried out on the general overview of Climate Change Impacts by Tani (1978); Ayonge (2000): Tsalefac and Amougou (2008); Molua (2009) and Odjugo (2010). Others like Ekpoh (2004) looks at Climate change and tropical agriculture, meanwhile Rosenzweig and Parry1994 view the Potential impact of Climate Change on world food supply. De Datta (1981), Parry et al. (1999), Peng et al (2004), Sarker (2012), IPCC (2007, 2014) observed that high temperature (heat) stress and cold injury induces many biochemical, molecular and physiological changes and responses in turn influence many cellular and whole plant processes that affect crop yield and quality especially in the tropics. The impact of climate on specific crops has been viewed variously by Satake and Yoshida (1978) Shimshe (1986): Collier et al.(1991), Adams (2000), *Levy and Veilleux, (2007)*Sarker et al., 2012Nkiene (2015). A range of related studies are on the adaptation strategies to cope with the vagaries in climatic parameters. These include the works of (Bushesha, Lee-Throp and Hopkinson, (2009); Deressa et al. (2009); Molua (2000) and Aristide Justin (2012).The main research problem of our study centers on the vulnerability of Irish potato production to the vagaries of temperature. The guiding hypothesis thus states that;"there exists a significant relationship between temperature variation and Irish potatoes production in Santa".

2. Agro-Ecological Background

The Santa Area is situated between;longitudes $09^{o}58^{'}$ and $10^{o}18^{'}$ East of the Greenwich Meridian and latitudes $5^{o}42^{'}$ and $5^{o}53^{'}$North of the Equator (Figure 1). It is one of the sub-divisions of the Mezam division in the North-West Region of Cameroon. Santa is bounded to the North by Bamenda Central Sub-Division, to the West by Bali and Batibo sub-division, to the South by the Lebialem and the Bamboutos division and to the East by the Ngoketunjia division.

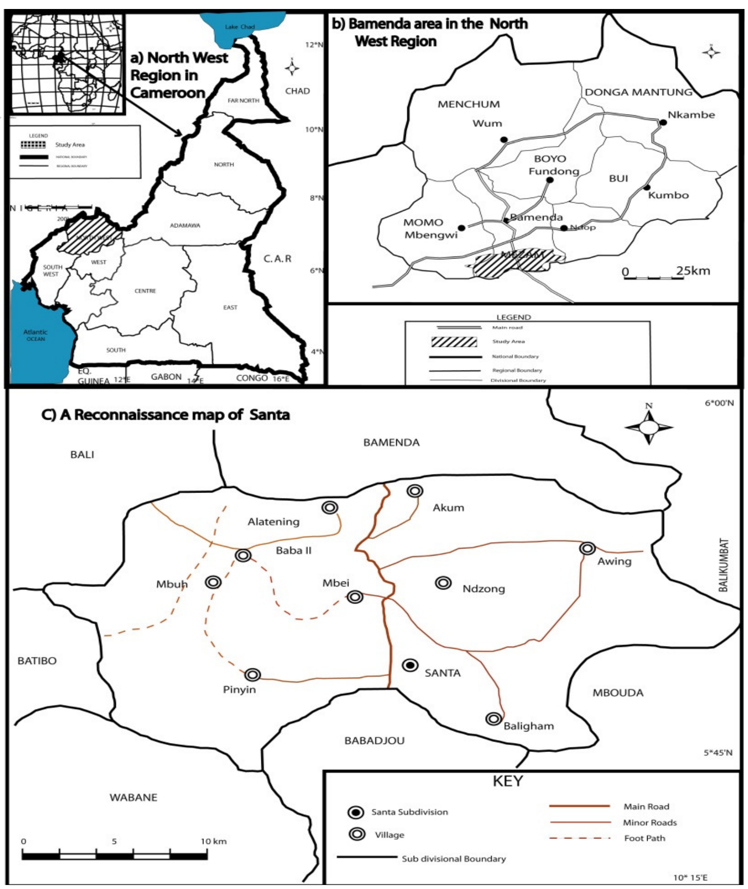

Figure 1: Location of the study area

Covering a surface area of about 532.67 km^2, and a population of about 99,832 inhabitants (BUCREP, 2010), her population density is about 108 persons per squared km, with a growth rate of about 2.8%. Santa is considered as a melting pot of ethnic groups that make up its different villages. These ethnic groups include; the Ngembas (Alatening, Akum, Awing, Njong and Pinyin), the Moghamos (Mbei, Mbuh and Baba II) and the Chambas (Baligham).

The Santa area possesses a diversified relief with generally entrenched valleys adjoining interfluves or hilly chains and steep slopes.The Santa sub-division falls within the tropical latitude and it is classified under the Guinean climate. This indicates that the area has humid domain characteristics with great ecological variation at the local scale and marked by 2 seasonal rhythms. They include the dry season that lasts for 4 months and the rainy season that lasts for 8 months.The heterogeneous topography portrays a diversified soil in the area. The main soils are classified under volcanic, granitic and depositional soils. Santa is an area with an altitudinal range of about 1200 – 2600m. The main climax communities include the Bamboo Forest (at $2200m^+$), the Moist Montane Forest (at 1600-2200m) and the sub-climax zone- the Savanna Woodland (1200m – 1600m)

Irish potato is a starchy tuber crop from the perennial *Solanum tuberosum* of the *Solanaceae* family. The physical conditions it requires for its growth entail amongst others rainfall/water, temperature and the soil conditions. Most of the varieties of Irish Potato cultivated in Santa are new varieties grown from seed and are propagated vegetative by tuber planting. The seed multiplication of improved varieties is assured by the state in the existing firms in the region. The species cultivated in the region are both imported varieties and national or the Cameroonian type. The national specie cultivated in the region is CIPIRA. Meanwhile those imported from the Netherlands include; MONDIAL, SPUNTA, DOSA, CAESER and those originated from Peru include; CHALLENNGER and PANAMERA.

3. Materials and Methods

The research methodology that has been adapted entailed classical and empirical approaches. Data was collected from secondary sources via main Libraries of the University of Yaounde 1, the World Bank, Ministries of Agriculture and Rural Development. Numerical data on Temperature, number of Irish Potato farmers, surface areas, Irish Potato production in tons were collected from the Bamenda Up Station office for Statistic/Climatic data and the Santa Sub-Divisional Delegation of Agriculture.Topographic sheets of Bafoussam 3c (Foumban Dchang) at the scales 1:50 000 1:200 000), Aerial photos and LANDSAT image of 2010) have been utilized for location and mapping of specifics sites. A total of 250 questionnaires were intended for Irish potatoes farmers but those who actually responded were 214. This questionnaire was made up of 60 questions; both open ended and guided which permitted the better comprehension of the farmer's perception. Questions were stratified or regrouped under nine sub groups which include; identification of farmer, socio-economic information, farm structure, institutional accessibility, sales and expenditure, farmers' perception about temperature change and innovation and farmers' response

Statistical Analysis System (SAS) was used for Analysis of Variance (ANOVA) of the average seasonal temperature of the whole area and the station located in the study area. This process was employed to validate the use of divisional climatic data at a sub-divisional level. 5-year running averages were used to normalize the erratic nature of inter-annual averages. Coefficient of Variation (CV) was employed so as to determine the reliability nature of the weather variables under study. The Coefficient of Variation being a statistical tool which determines the reliability index of a parameter.

$$SD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Coefficient of Variation $(CV) = \frac{\text{standard deviation}}{\text{Mean}} \times 100$

The Student's T-Test was used to establish any difference or similarities in the two data sets of temperature and Irish Potato production. Simple regression analysis for divisional Temperature data was performed by MS Excel using the model below:

$Y(j) = ak + c$ ……………..…. (1) Where: Y (j) = Physical factor (temperature)

a = Gradients (slopes) of the regression equation k = Number of growing seasons (years) from 1985-2015 due to data availability; c = Regression constant

To determine if Santa sub division had been affected by present trend of temperature changes, the aridity index has been calculated. The De Martonne (1923) formula has been used to calculate the aridity index. The formulae are;

$I = P/T+10$

where; I= Aridity index P= Average annual Rainfall T=Average annual Temperature.

As I values increase, the tendency is towards hyper arid or absolutely desert areas and vice versa. The results were then compared with inter-annual production to determine vulnerability. The *XY* scatter plot was produced with both regression line and regression equations established. The R–square (R^2) values were recorded for each analysis for the purpose of determining the significance of the trends.The cartographic part of this work was realized by the use of Computer Assisted Drawing and GIS programs such as QGIS 2.0 and ArcGIS 10.0. Data analyses were then realized by the use of the S.P.S.S (Statistical Package for Social Science) 21 and EXCEL. Data on the Findings of the research has been presented in the form of tables, figures, Graphs and synoptic Charts

4. Findings and Discussions

4.1. Analysis of Temperature Variations

The presentation of temperature data has been done with the use of tables. Graphs, regressive lines, mean, Standard Deviations and Coefficient of Variation have been used for analysis. Inter-annual and 5 year running temperature average were analyzed to observe their patterns. Mean maximum and minimum temperature for the entire period and mean anomalies average have been analyzed to determine their trends. The coefficient of variations for temperature was used to analyze 5 year average values in order to determine their reliability.

4.1.1. Observed Inter-Annual and 5-Years Running Mean Temperature Pattern

The chronological time series data of inter-annual mean temperature shows a generally gradual and a negligible increase in inter-annual mean temperature from the periods 1985-2015 (Figure 2).

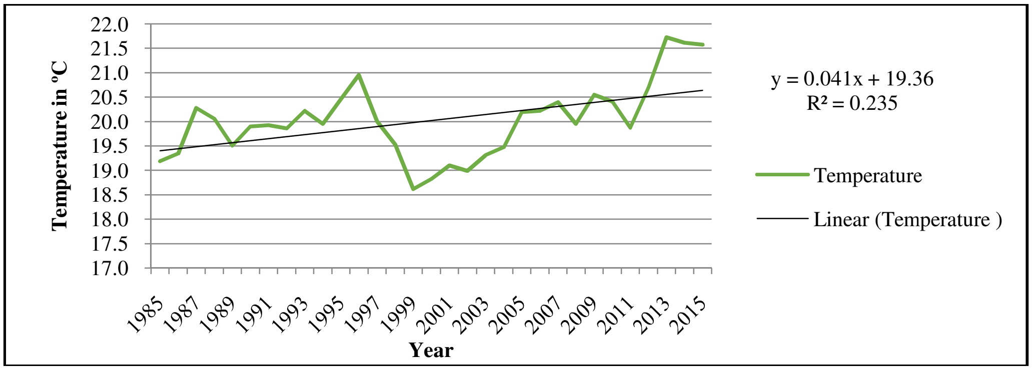

Figure 2: Inter Annual Mean Temperature from 1985-2015
Source: field work 2015

This is observed from the positive gradient of 0.0413 of the linear regression line and a coefficient of determination between the years and temperature of 0.2354. We can therefore conclude that there is a gradual increase in mean temperature in terms of the pattern.
Due to the erratic nature of the inter-annual mean curve, the trends could not be easily observed. The 5-year moving average was then used to normalize the erratic nature of this data (Figure 3).

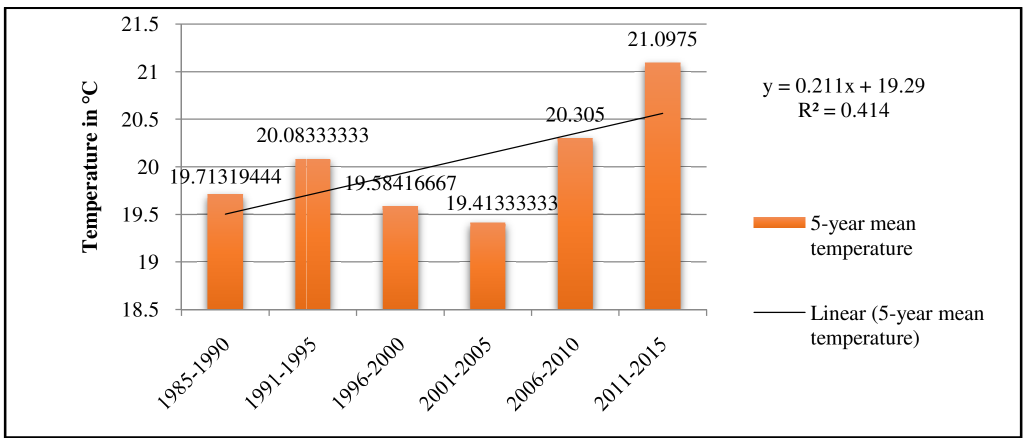

Figure 3: 5-Year Running Temperature in Santa from 1985-2015
Source: Field work 2015

As observed on the graph, the 5-year moving average shows periods of high, moderate and low temperatures relative to the period under study. As observed on the graph, the first, third and fourth sub-decades stand out as sub-decades with low temperature while the last sub-decade stands out as a decade with relatively high temperature.
Despite these fluctuations, a generally observed 5-years moving temperature pattern with a gradient of 0.2119 and a coefficient of determination of 0.414 indicates a more rapid increase in temperature as compared to the inter-annual pattern.

4.1.2. Observed Decadal Mean Seasonal Variations

Data collected from field indicates that rainy season 10 year observed monthly averages is generally increasing as indicated by its slope gradient of 0.427 (Figure 37).

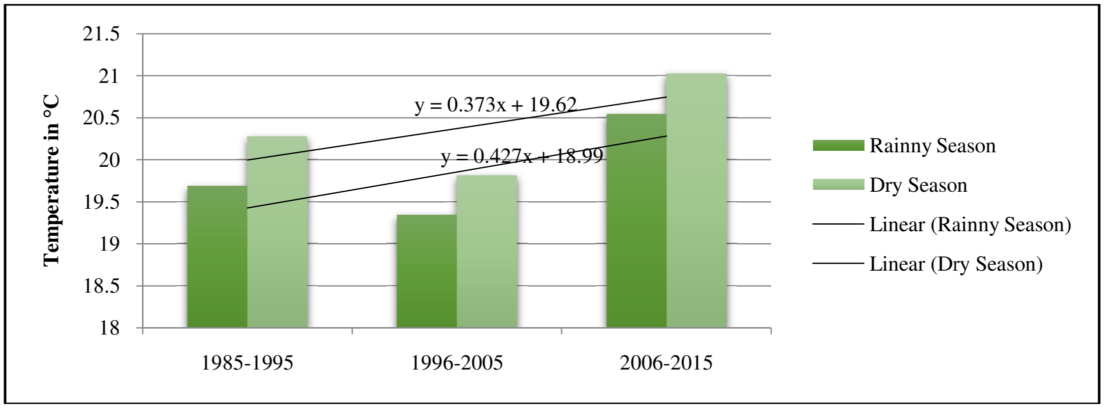

Figure 4: Variations in Decadal Mean Seasonal Temperature
Source: Field work 2015

While dry season monthly averages are increasing at a slower rate relatively speaking indicated by its slope gradient of 0.373. This situation is not favorable for agricultural activities as many plants grown in the rainy and dry season will have to grow more towards their upper tolerance limits. An example is the Irish potatoes tuber plants which are grown in both seasons. During the rainy season the plant may suffer from low temperature stress and in the dry season, the plants might suffer from high temperature stress.

4.1.3. Observed Temperature Anomalies

Temperature anomalies for the 31 years' period under study have been obtained relative to its average (20.03ºC) (Figure 5).

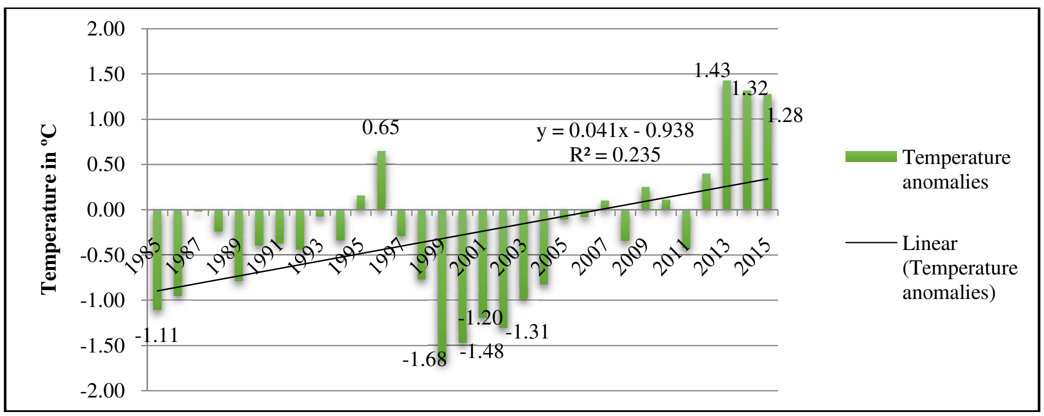

Figure 5: Temperature Anomalies from 1985-2015
Source: Field work 2015

It indicated both negative and positive anomalies with positive increasing tendency of the gradient at 0.0413. The years 1996, 2013, 2014 and 2015 are presented to be very hot with extreme positive anomalies of 0.65, 1.43, 1.32 and 1.28 ºC respectively from the 31 years' average. Meanwhile, the years 1985, 1999, 2000, 2001and 2002 are presented to be very cold years with extreme negative anomalies of -1.11, -1.68, -1.48, -1.20 and -1.31 ºC from the 31 years' average. These years of positive and negative anomalies can be considered as years of extreme climatic conditions.

4.1.4. Observed Mean Monthly Maximum and Minimum Temperature

The results from data collected from the field permitted us to show the tendencies in mean temperatures over the years. This is clearly shown in regression curves and trend lines of maximum and minimum temperatures in Figure 6.

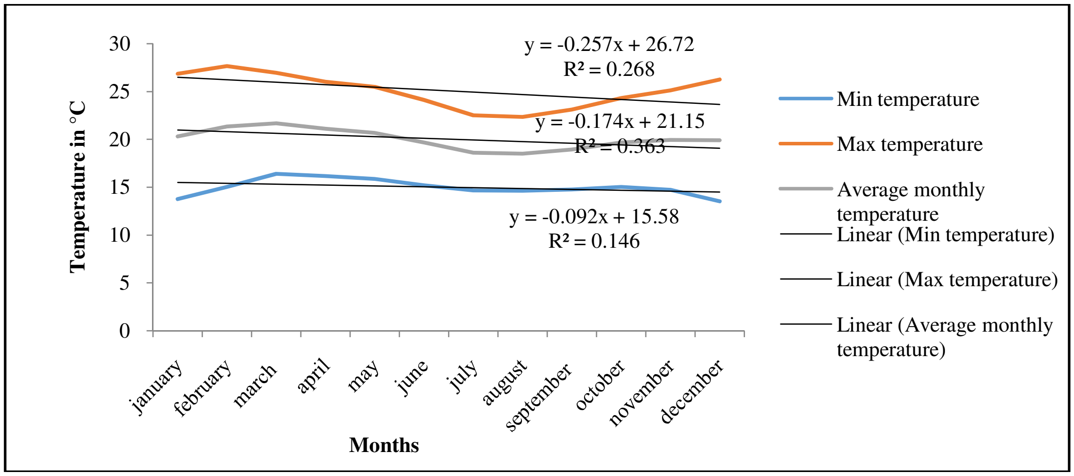

Figure 6: Regressive Curves of Mean Monthly Minimum and Maximum Temperature from 1985-2015
Source: Field work 2015

From the above figure, it indicates that the minimum temperature is fairly decreasing at a negligible rate especially during the months of the rainy season. The rate of decrease is indicated by the negative gradient value of -0.092 with a negatively sloping trend line at an angle of 0.1464. On the other part, maximum temperature is generally decreasing at a considerable rate with a gradient of -0.2575 and at a sloping angle of 0.2683. The rate of decrease in terms of maximum temperature is greatest in the heart of the rainy season during the months of July, August and September while minimum temperature is fairly constant. This indicates an extension of cold period through-out the night and the day. This period is therefore characterized by cold spells. Away from these months the disparity between max and min temperature especially in the dry season months become highest indicating possibly heat stress during the day and cold injury at night. We can therefore conclude by saying that monthly maximum temperatures are rapidly decreasing while minimum temperatures are fairly decreasing.

4.1.5. Observed Mean Monthly Maximum and Minimum Temperature Trends for 2014 and 2015

Analysis on mean monthly max and min temperature trends for these two years showed a generally more fluctuating maximum temperature trends and an almost stable minimum trend. The months of January, August, September, November and December demonstrated an increasing mean maximum temperature as indicated by the positive gradient of their curves. The increase was more rapid for November in 2014 and the same scenario for November 2015. This indicates hotter days for this particular month with mean maximum temperatures above 30°C for most days of the month.

For the mean monthly minimum temperature trend, the months of June, July, August, November and December for 2014 and 2015 experienced a decreasing mean minimum temperature trend as indicated by their high negative gradient of their regression lines. The months of increasing mean maximum temperature corresponds to the same months with decreasing mean minimum temperature. This indicates a wide disparity between maximum and minimum temperature. The disparity was greatest in the months of November, especially from the second half of the month with minimum temperature as low as 11°C for the same days and maximum temperature as high as 31°C. This indicates possible heat stress during the day and cold injuries during the night.

With data collected from the field, we could conveniently compute the Coefficient of Variation for temperature for the duration of 5years in each sub-period. From field data (Table 1), it can be observed that temperature is reliable for each sub-period from 1985-2015 since the calculated amount for each of each sub-period is less than 30% which is the limit for reliability (under rainfall). However, in relative terms, the sub-period 1996-2000 and 2011-2015 have a greater unreliability in temperature than the other four sub-periods. This is indicated by their high values of Coefficient of Variation with the great values of 4.29% and 3.36% respectively. This also indicates that temperature has varied considerably within these 2 sub-periods relatively.

Year (sub-period)	Mean	Standard Deviation	Coefficient of Variation
1985-1990	19.71	0.39	1.98%
1991-1995	20.08	0.22	1.10%
1996-2000	19.58	0.84	4.29%
2001-2005	19.41	0.42	2.16%
2006-2010	20.31	0.21	1.03%
2011-2015	21.10	0.71	3.36%

Table 1: Coefficient of Variation for Temperature from 1985-2015
Source: Field work 2015

4.2. Farmers' Perception on Temperature Variations in Santa

An analysis of questionnaire to respondents permits us to realize that farmers in the Santa area are not unaware of the effects of temperature on their crops. Framer' perceptions on temperature variations have been presented since they are very instrumental for the

integration of local perception into scientific knowledge. With regards to the perception of farmers on the Observed Inter-Annual Temperature Trend, 47.2% of those interviewed observed an increasing trend in the inter-annual mean temperature. Meanwhile 26.6% observed no change, 19.6% observed a decrease and 5.6% were indifferent. As for Farmers perception on the observed seasonal variations in temperature, results from the analysis of questionnaires show that 39.3 % of the farmers held that temperature had decreased during the rainy season. 27% of them held that they had not witnessed any change during the same season. Following other trends, 22.4% of those interviewed observed an increase while 11.2% of the respondents are indifferent Only the village of Pinyin stood as a majority of those interviewed indicating an increasing trend in temperature during the rainy season.
As regards the trend of temperature during the dry season, a majority (63.6%) of farmers interviewed held that it has increased over the past years. This was specific in all of the villages in the area. Nevertheless, some (19.6% and 11.2%) farmers stood up for a decrease, and a no change. Meanwhile, 5.6% of the farmers interviewed had unresponsive opinion about temperature during this season.
Concerning Farmers' Perception on the observed Severity of Heat Waves, 40% of the farmers interviewed said that there has been an increase; affirming an increase in this event. A majority of those who are in affirmative comes from the Pinyin village.However, 28% said they felt no change on the heat waves with a majority coming from Baforchu and Baligham villages. Meanwhile, 23% others confirmed a decreasing trend in the occurrence of extreme temperature events with a majority from Alatening village. About 9 % of the farmers stayed unresponsive on this event. Judging from the perception of respondents, it is worthwhile remarking that farmers' perceptions are not very different from scientific analysis under section 4.1.

4.3. Temperature and Potato Production
A correlation of temperature variation and Irish potato production in the area gives impressive results. Figure 7 presents a vivid picture of observations.From the regression curve above, it can be observed that there is a direct relationship between the average annual temperature and Irish potatoes production. This is indicated by the fact that variations in annual temperature from high, moderate to low causes variations in potatoes productivity. It can be observed in general that years of high temperatures correspond to years of low yields. From the graph, years such as 2013, 2014 and 2015 with high annual temperature >21ºC directly corresponds to the years of low yields as indicated above with annual productions <4500 tons. The year 2013 with a high temperature of 21.7ºC and low production of 3812 tons stands out as a visible example.
Contrarily to the years of high temperatures, the years of moderate annual temperature that range between 20 and 21 ºC corresponds to years with relatively high production with yields >4000 tons. The year 2006 with 20.2ºC and production of 5928.75 tons is a clear-cut example. Also, years with low annual temperatures (18.5-20ºC) correspond to years with very high production. This is observable with the year 1998 whose annual temperature was 19.5ºC and had the highest production of the entire 20 years' period with 7000 tons.

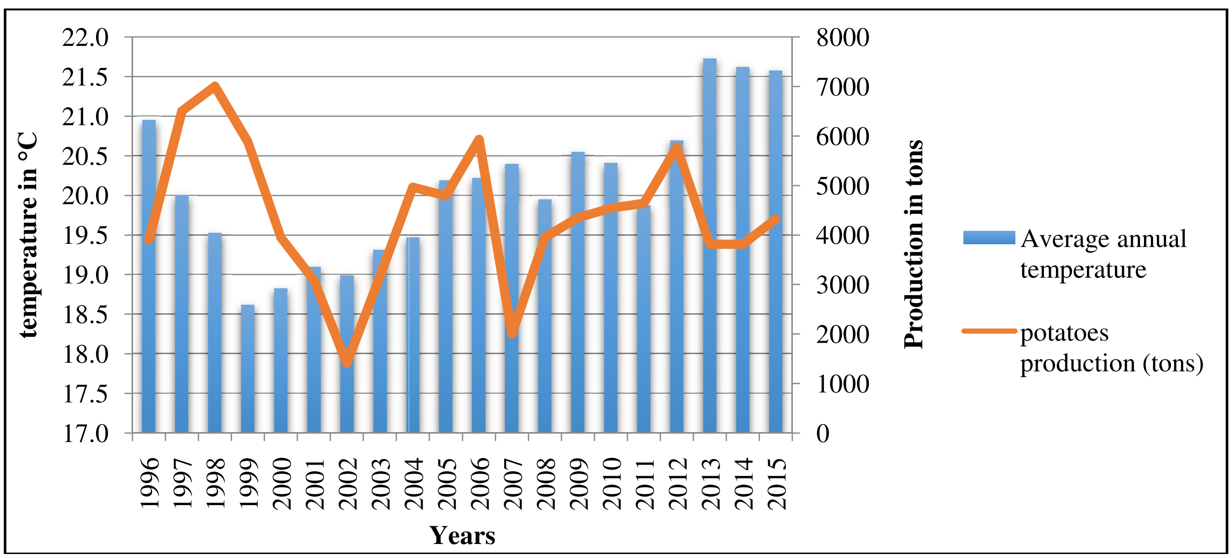

Figure 7: Graph and Regressive Curve of Temperature and Irish Potatoes Production from 1985-2015
Source: Field work 2015

This could be indicative of the fact that production is determined more by temperature than by other factors as they corresponded directly to the temperature range needed by the potatoes plants. Exceptions observed from these two variables (moderate and low temperature) are the years 2007 with 20.4ºC and 2002 with 19ºC, where production was relatively low with 2000 and 1411 tons respectively. Thereby, indicating that potato was greatly vulnerable to other factors than to temperature since these years had the required range.

4.3.1. Observed Moving Averages between Temperature and Potato Production
Data from field investigation permits to establish the observed moving averages between temperature and Irish potato and the variability of 3 – 5 year running averages in potato production.

4.3.1.1. 25-Years Projection of Temperature and Potato Production

Data also collected from the statistical station in Bamenda and the Santa area council has permitted us to carry out a projection of temperature and potato production. On figure 8, Inter-annual temperatures have been regressed against production and it shows a complete contrast relation. Temperature trend is increasing at a fast rate as indicated by a positive gradient of 0.1049; while the trend of production is rapidly decreasing at a negative rate of -37.167.

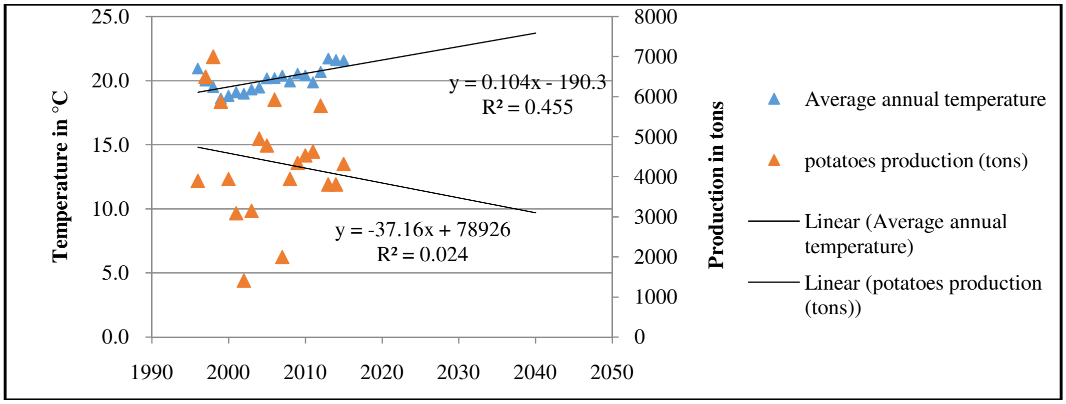

Figure 8: Inter-annual 25 Years Projection in Temperature and Production
Source: Field work 2015

The data was projected for 25 years which showed that under such circumstances, the trends will continue to be at far extremes of a continuous speed increasing temperature and a continuous fast decrease in production.

4.3.1.2. Variability of 3 And 5 Years Running Averages in Temperature and potato Production

In order to demonstrate the variability of 3 and 5 year running averages, data has been presented diagrammatically (Figure 9 and 10).

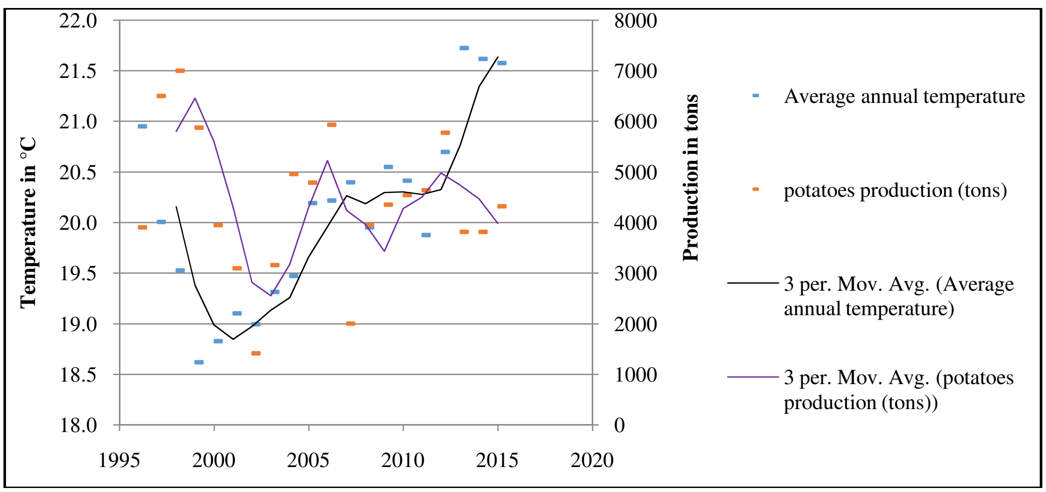

Figure 9: 3-Years Running Mean for Temperature and Irish Potato Production from 1985-2015
Source: Field work 2015

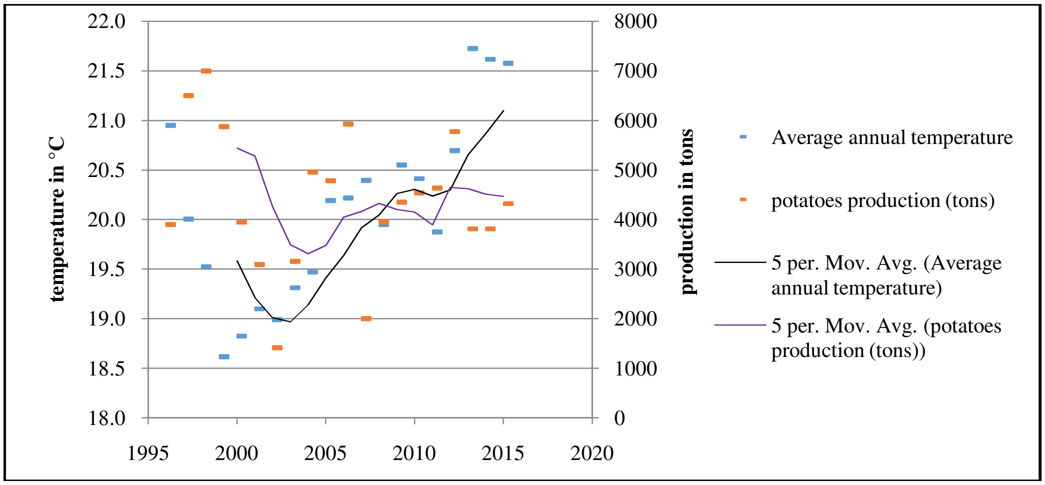

Figure 10: 5-Year Running Mean for Temperature and Irish Potatoes Production from 1985-2015
Source: Field work 2015

The graphs based on 3 and 5 years running averages have been used to normalize the irregular nature of inter-annual data. This graph shows differences between the mobile averages of the two curves in most cases. The mobile average curve of temperature shows two moments of fluctuation during 20 years' period. The first is characterized by a gradual decrease in average temperature that goes from the year 1996 to 2000. The second is rather a fast-increasing average temperature that goes from 2011-2015 except for 2008 and 2010 where their temperatures observed a decrease compared to this growing trend.

The same scenario of increase and deficit during the same years as above is observed in the trend curve under production. This therefore indicates that temperature directly impact potatoes production in Santa as any variation in temperature causes fluctuation in yields.

4.3.1.3. Effects of Observed Fairly Unreliable Temperature on Potato Production

Figure 11 permits a comparison of curves to determine the level of significance of relationship.

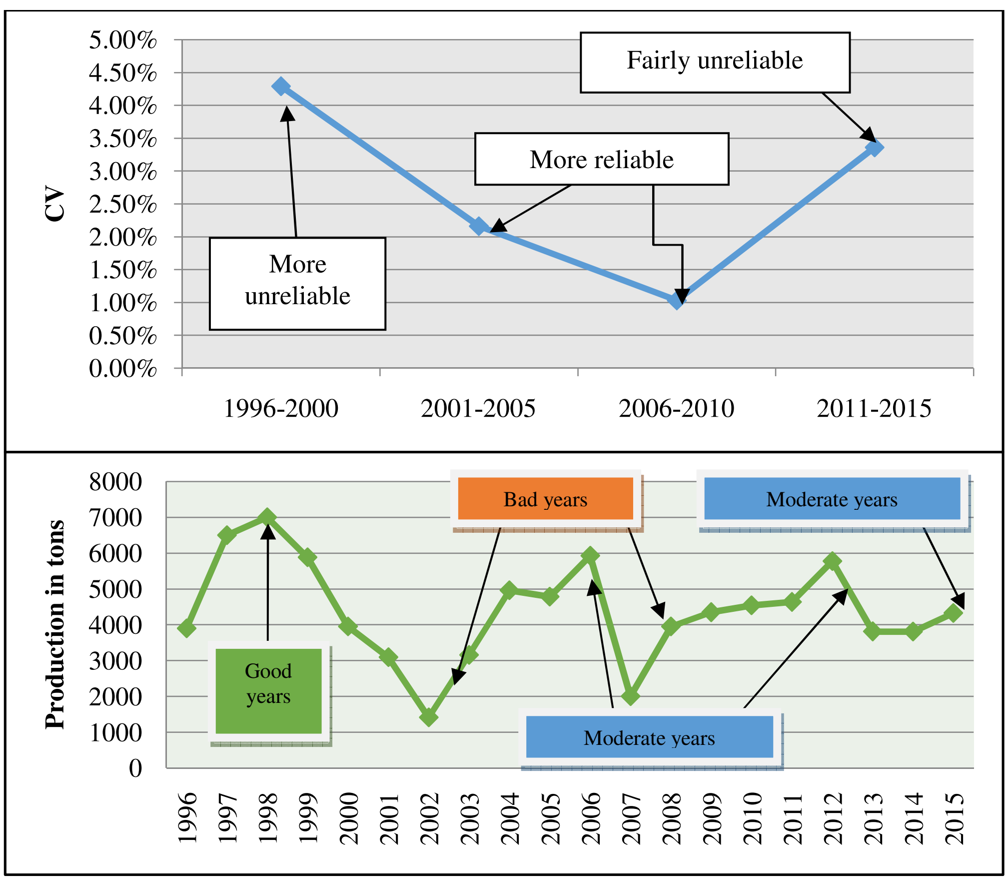

Figure 11: Secular Changes in Coefficient of Variation and Annual Potato Production.
Source: Field work 2015

The high CV values of more than 4% indicate less unreliable temperature within that sub-decade which influenced bad potatoes production which is unreliable as well. This is the situation of the first sub-decade. On the other hand, the second decade with low CV values of below 2.5% led to reliable production at a moderate level.Production was therefore vulnerable to a fairly reliable temperature. The last sub-decade with CV value less than 4% and greater than 2.5% indicating a fairly unreliable temperature, as well led to a fairly moderate inter-annual production.

4.3.2. The Effects and manifestations of Variations in Temperature on Potatoes Production

The mean monthly and inter-annual variability in temperatures influence not only the growth duration but the growth pattern of the potato plant. Potatoes like every other crop have a temperature tolerance range in which the plant can survive. When this temperature tolerance is at optimum at every developmental stage, the plant achieves maximum physiological and morphological growth thus producing high yields. When these critical threshold temperatures are closer to their lower tolerance or upper tolerance, the plant might grow under stress thereby negatively affecting yields (Table 2).

Stage	Minimum	Optimal	Maximum	Symptoms
Early	12 -17°C	18-20°C	24°C	Sprout delayance and a reduced expansion rate
Mid	12-15°C	15-20°C	21-25°C	Delayance in tuber initiation and highly promotes haulm growth

Table 2: Temperature Tolerance Range at Different Growth Stages
Source: Adapted from Pandey N.K et al (2008)

4.3.2.1. Effects of High Temperatures on Potatoes

Potato is characterized by specific temperature requirements and high temperatures during the growing season cause an array of changes in potato plants, that affect its development and may lead to a drastic reduction in yield. High temperature induces development of plants with thin stems, small leaves, longstolon’s, increase in the number of inter-nodes, inhibition of tuber development and a decrease in the ratio of tuber fresh weight to total fresh weight. High temperatures also cause the partitioning of assimilated carbon between leaves and tubers hence more carbohydrates are used up as respiratory substrate and less are available for translocation to the tubers. The observed effects of high temperatures and potato production varied with the two cropping seasons. Most farmers of the first cropping season observed a high effect of high temperatures on potatoes than those of the second cropping season. Their main observations were in terms of agricultural droughts and drying of crops.

Agricultural drought is a situation in which high temperature leads to a high rate of Actual Evapotranspiration, thereby leading to an insufficiency in soil moisture that can support plant growth. This situation is observed in the months of the onset of rain; especially that of March as observed by the farmers. Besides agricultural droughts, farmers observed that the crops dry up at the early stages of plant growth. This is due to the high temperatures at the onset of the rainy season.

According to results from the analysis of questionnaires, 24% of farmers interviewed affirm that the effect of drying of crop is a major problem. Meanwhile, 76% of them do not consider this effect as a major problem probably because they adequately irrigate their farms.The effects of agricultural drought and drying up of crops often in the early growing stages of planting and emergence possibly lead to the following; Prevents the healing of cut seed piece surfaces which lead to decay, Delayed and uneven emergence, Less haulm per plant. Thereby cause the plant to grow under stress, hence fewer yields are obtained. The farmers explained that it was difficult to connect water from downstream up to the farm as they usually do because there was a great reduction in the level stream water, hence a reduction in stream velocity and speed which reduced water force.

Concerning the observed effects of temperature on potatoes in the first cropping season, there were some major observations. A keen study of the data permits to note the mean monthly maximum temperatures for the months of March, April and May that mark the beginning of the first farming season of the area. At this period, he crops are in their early stage of growth and so these mean monthly maximum temperatures are compared with the temperature range required by Irish potato plants at this stage of growth. It was realized that, the month of March has temperatures that are above this required range, indicated by the domination of temperatures between 25-27°C (10) and those > 27°C (8). Only two years had temperatures that corresponded to the required range. On the other hand, April and May are less dominated by the range >27°C (4 and 2 respectively) but more dominated by the range 25-27°C. However, we can note 6 years in April and 7 years in May that did not go above 24°C.

From these observations, we can therefore conclude that the months of April and May are more reliable in terms of maximum temperatures than March and therefore present more suitable conditions for the plants than March. Also from the data it is clear that Santa is largely vulnerable to the effects of maximum temperature on potato yields in the first farming season. We denote 8 years in the area in which the three months observed temperatures above 24°C. The effects were mostly felt in the years 2001, 2002, 2013 and 2014 when production was relatively low with yields <4000 tons.

4.3.2.2. Effects of Low Temperature on Potatoes at the Second Cropping Season

Farmers’ perception on the effects of the observed effects of low temperatures and potatoes in Santa equally vary with the two farming seasons. Most farmers of the second cropping season observed a high effect of low temperatures than those of the first growing season. Their main observations were in terms of blight infections. To the blight effects caused by the combined factors of excessive humid conditions and low temperatures, low temperatures brings an additional effect on the plants. This is basically through the stimulation of seed production prematurely, loose germination ability and reduction in tuberization.

We also viewed the results by comparing monthly minimum temperatures to the tolerant minimum temperature range of potatoes growth of the months of August, September and October. It was observed that; during these three months, the crops are less vulnerable to induced effects of low temperature as the temperatures in most years lie within the range of 12 - 17°C. Nevertheless, we observe 3 years in August, 2 years in September and 1 year in October whose minimum temperatures went below the range.

This result indicates that during the second cropping season at the early stage of plant growth, production was mostly influenced by other factors than minimum temperatures. It can be observable with the year 1998 and 1999 where minimum temperatures for the month of a month in 1998 and over the three months in 1999 went below the range, yet production was relatively high with more than 5000 tons. However, the year 2000 observed low temperatures that went below 12ºC in the months of August and September. The effects of these very low temperatures on potatoes were felt in the relatively low production (<4000 tons) obtained that year.

During our field trip, we computed the effects of minimum and maximum temperature at the Mid Growth Stage of Potatoes in the First Cropping Season. The results are presented in table 3.

Year	**June**		**July**		**Observation**
	Max	Min	Max	Min	
1996	26**x**	16.3 ✓	24.8 ✓	15.8 ✓	Less vulnerable
1997	26.5 **x**	15.8 ✓	24.3 ✓	14.9 ✓	Less vulnerable
1998	25.4 ✓	12.8 ✓	23 ✓	12.3 ✓	Not vulnerable
1999	24.5 ✓	12.8 ✓	22.6 ✓	11.9 **x**	Less vulnerable
2000	25.4 ✓	12.1 ✓	24.1 ✓	11.8**x**	Less vulnerable
2001	24.3 ✓	12.7 ✓	22.9 ✓	12.5 ✓	Less vulnerable
2002	24.6 ✓	13 ✓	23.9 ✓	12.8 ✓	Not vulnerable
2003	23.8 ✓	13.5 ✓	22.4 ✓	12.5 ✓	Not vulnerable
2004	23.7 ✓	13.7 ✓	22.4 ✓	12.8 ✓	Not vulnerable
2005	22.9 ✓	16.2 ✓	21.7 ✓	15.8 ✓	Not vulnerable
2006	23.6 ✓	15.6 ✓	21.4 ✓	15.9 ✓	Not vulnerable
2007	21.9 ✓	17.4 ✓	20.7 ✓	16.3 ✓	Not vulnerable
2008	22.2 ✓	15.9 ✓	21.5 ✓	15.1 ✓	Not vulnerable
2009	23.5 ✓	12.4 ✓	21 ✓	16.6 ✓	Not vulnerable
2010	22 ✓	18.5 ✓	21.2 ✓	16.3 ✓	Not vulnerable
2011	22.8 ✓	16 ✓	22.5 ✓	15.7 ✓	Not vulnerable
2012	26.4 **x**	16.5 ✓	25.8 ✓	16.4 ✓	Less vulnerable
2013	26.4 **x**	16.9 ✓	25.3 ✓	16.4 ✓	Less vulnerable
2014	27.1 **x**	15.1 ✓	23.5 ✓	14.5 ✓	Less vulnerable
2015	25.4 ✓	16.1 ✓	24.7 ✓	16 ✓	Not vulnerable

Table 3: Effects of Maximum and Minimum Temperatures at the Mid Growth Stage in the First Cropping Season

Key

x✓ Less vulnerable to temperature
xx More vulnerable to dominating max or min
✓✓✓✓ Not vulnerable

Source: Field work 2015

As can be seen in table 3, there are the monthly maximum and minimum temperatures of June - July for the first cropping season. These monthly temperatures have been compared to the temperature range required for potato growth (12 - 25°C, table 3 above) in order to observe their degree of vulnerability to variations in maximum and minimum temperature. In absolute terms, it is indicated that June and July are not vulnerable to variations in temperature by the domination of non-vulnerability with 13 years over less vulnerability with 7 years. However, in relative terms the month of June on one hand is more vulnerable to variations in temperatures. This is observable in the years 1996, 1997, 2012, 2013 and 2014 where they were vulnerable to maximum temperatures variations. The effects of this vulnerability were felt in their relatively low production observed especially in the years 2013 and 2014 with 3811 and 3812 tons respectively. The month of July on the other hand had two years (1999 and 2000) in which they were more vulnerable to minimum temperature, which equally was translated in their relatively moderate production values of 5877 and 3948 tons respectively. From this observation, we can conclude that the mid growth stage of the first growing is more vulnerable to variations of maximum temperatures.

We equally computed the effects of maximum and minimum temperature at mid-growth stage in the cropping season. The results have been presented in details on table 3.

Year	November		December		Observations
	Max	Min	Max	Min	
1996	25.5 ✓	15.1 ✓	26.7 **x**	14.8 ✓	Less vulnerable
1997	25.7 ✓	11.8 **x**	25.3 ✓	11.1 **x**	More vulnerable to min temperature
1998	25.8 ✓	12.7 ✓	27.7 **x**	12.3 ✓	Less vulnerable
1999	25.1 ✓	12.5 ✓	26.6 **x**	11.4 **x**	Less vulnerable
2000	24.9 ✓	12.6 ✓	25.6 ✓	11.5 **x**	Less vulnerable
2001	25.8 ✓	12.8 ✓	27.4 **x**	12.6 ✓	Less vulnerable
2002	23.5 ✓	12.6 ✓	24.1 ✓	12.5 ✓	Not vulnerable
2003	25.7 ✓	12.9 ✓	26.6 **x**	12.8 ✓	Less vulnerable
2004	27.7 **x**	15 ✓	28 **x** ✓	10.2 **x**	More vulnerable to max temperature
2005	25 ✓	15.6 ✓	25.1 ✓	15.5 ✓	Not vulnerable
2006	25.9 ✓	15.3 ✓	25.5 ✓	15.6 ✓	Not vulnerable
2007	23.3 ✓	16.5 ✓	24.9 ✓	15.2 ✓	Not vulnerable
2008	24.1 ✓	15.6 ✓	24.6 ✓	15.9 ✓	Not vulnerable
2009	24.4 ✓	18.1 ✓	25.7 ✓	16.8 ✓	Not vulnerable
2010	25 ✓	15.8 ✓	25.2 ✓	14.8 ✓	Not vulnerable
2011	22.1 ✓	13.2 ✓	27.4 **x**	12.6 ✓	Less vulnerable
2012	27.1 **x**	16.2 ✓	28.4 **x**	10.8 **x**	More vulnerable to max temperature
2013	27.1 **x**	15.7 ✓	26.9 **x**	12 ✓	More vulnerable to max temperature
2014	27.2**x**	15.1 ✓	30**x**	13.7 ✓	More vulnerable to max temperature
2015	28.3 **x**	15.2 ✓	31.4 **x**	12.5 ✓	More vulnerable to max temperature

Table 4: Effects of Max and Min Temperatures at the Mid Growth Stage in the Second Cropping Season

Key

XLess vulnerable to temperature
XX More vulnerable to dominating max or min
✓✓✓✓ Not vulnerable

Source: Field work 2015

As can be seen in table 4, there are the monthly maximum and minimum temperatures of November and December characterizing the mid growth stage of the second cropping season for the 20 years under study. These monthly temperatures have also been compared to tolerant temperature ranges for an optimal potatoes growth (12-25°C, table 4 above) in order to observe the degree of crop vulnerability to variations in temperature at this stage. In a global view, it can be observed that the months of November and December are vulnerable to variations in temperatures. This is indicated by the domination of the number of vulnerable years (13 years) over the years of non-vulnerability (7 years). Out of these 13 years, we can notice 2 years vulnerable only to minimum temperatures, 8 years to maximum temperatures only and 3 years to both maximum and minimum temperatures. To all this vulnerability, we can perceive that variations in maximum temperatures are more impacting on potatoes production than variations in minimum temperatures. This is shown in the years 2001, 2003, 2013 and 2014 where production was relatively low with less than 4000 tons produced.

In comparative terms, the month of November is less vulnerable to temperatures variations as it presents only 6 years of vulnerability than the month of December which presents up to 13 years of vulnerability. Again, November turns to be more vulnerable to maximum than minimum temperatures with 5 and 1 year respectively. Meanwhile, December is vulnerable to both variations in maximum and minimum temperatures with 10 and 5 years respectively. We can therefore conclude that the mid stage of plant growth in the second cropping season is largely affected by variations in high temperatures in the area. Judging from the analysis of data on plant sensitivity to temperature at different growth stages, we could tabulate the basic tendencies. These have clearly been presented in table 5.

Cropping Season	Plant's Growth Stage	Years	Sensitivity To Temperature	Productions Respectively
First cropping season	Early	1996, 1997, 1998, 2012, 2013, 2014 and 2015	Sensitive to high and very high temperatures	3900, 6500, 7000, 5775.5, 3812, 3811 and4322.5
	Mid and late stage	1999 and 2000	Sensitive to minimum temperatures	5877 and 3948
		1996, 1997, 2012, 2013 and 2014	Sensitive to maximum temperature	3900, 6500, 5775.5, 3812 and3811
Second cropping season	Early	1998, 1999 and 2000	Sensitive to minimum temperatures	7000, 5877 and 3948
	Mid and late	1997 and 2000	Sensitive to min temperature only	6500 and 3948
		1996, 1998, 2001, 2008, 2011, 2013, 2014 and 2015	Sensitive to max temperature only	3900, 7000, 3092, 3154, 4635, 3812, 3811 and 4322.5
		1999, 2004 and 2012	Sensitive to max and min	5877, 4958 and 5775.5,

Table 5: Plant Sensitivity to Temperature at Different Growth Stages
Source: Field work 2015

From the observations made in the first and second cropping seasons on the first and second growing stages of the plants, we were able to show on the table above most sensitive years to temperature variations. From this table, can be picked out years that are regularly sensitive to temperatures in both cropping seasons. These years include; 1996, 1997, 1998, 1999, 2000, 2012, 2013,2014 and 2015. From these years, we can distinguish the years of bad production (<4500 tons) and years of good production (>4500 tons). The bad years due to low sensitivity were; 1996, with 3900 tons; 2000, with 3939, tons; 2013, with 3812 tons; 2014, with 3811 tons and 2015, with 43225.5 tons. The good years due to low sensitivity were; 1997, with 6500 tons; 2000, with 7000 tons; 1999, with 5877 tons and 2012, with 5775.5 tons. We were equally able to canvass farmers' perception on the observed effects of temperature on potato at the mid growth stages. We were thus able to deduce their perception based on tuber exposure to sunlight and the effects of insects and pests.

4.3.3. Correlation of Temperature and Potato Production

Following the interpretation of data from field investigation, there is a direct relationship between temperature and potato yields (Table 6). How significant is the relationship is the center of focus of the hypothesis to be verified.

Year	Av. Temp(y)	Irish Potato(x)	Y^2	X^2
1996	21	39	441	1521
1997	20	65	400	4225
1998	19.5	70	380.25	4900
1999	18.6	58.8	345.96	3457.44
2000	18.8	39.5	353.44	1560.25
2001	19.1	30.9	364.81	954.81
2002	19	14.1	361	198.81
2003	19.3	31.5	372.49	992.25
2004	19.5	49.6	380.25	2460.16
2005	20.2	47.9	408.04	2294.41
2006	20.2	59.3	408.04	3516.49
2007	20.4	20	416.16	400
2008	20	39.5	400	1560.25
2009	20.6	43.5	424.36	1892.25
2010	20.4	45.4	416.16	2061.16
2011	19.9	46.4	396.01	2152.96
2012	20.7	57.8	428.49	3340.84
2013	21.7	38.1	470.89	1451.61
2014	21.6	38.1	466.56	1451.61
2015	21.6	43.2	466.56	1866.24
Total	402.1	877.6	8100.47	42257.54

Table 6: Temperature and Irish Potatoes Tested
Source: Field work 2015

Correlation with the Student T-test:
Formulae

$$t = \frac{\dot{y} - \dot{x}}{\sqrt{\dfrac{\dfrac{\Sigma y^2 - (\dot{y})}{ny}}{n-1} + \dfrac{\dfrac{\Sigma x^2 - (\dot{x})^2}{ny}}{n-1}}}$$

Where;

- ẏ = mean of independent variable
- ẋ = mean of the dependent variable
- n= number of observations
- Σ= (big summa) sum
- Degree of freedom= nx +ny – 2

$$t = \frac{-23.76}{\sqrt{\dfrac{\dfrac{8100.47 - 404.41}{20}}{19} + \dfrac{\dfrac{42257.54 - 1925.45}{20}}{19}}}$$

$$\Rightarrow t = \frac{-23.76}{\sqrt{\dfrac{384.8}{19} + \dfrac{2016.6}{19}}}$$

$$\Rightarrow t = \frac{-23.76}{11.24}$$

$$t = 2.1$$

Degree of freedom= ny + nx – 2=20 +20 – 2 = 38
Level of significance=0.05

With the degree of freedom of 38, at 0.05 level of significant the t-table for two tail T-Test could be viewed. Since the calculated t-value is 2.1 which are far greater than the table value (2.04), the alternative hypothesis which states that "there exists a significant relationship between temperature variation and potato production in the Santa sub-division" is validated based on the data of temperature and potatoes cultivation. Hence as can be observed clearly from the vagaries in climatic indices and the impact on Irish potato crop, something was supposed to have been done. Reactive and planned adaptation strategies were therefore necessary so as to mitigate the observed effects of these temperature variations on Irish potato production in the area.

4.4. Adaptation Strategies and Adoption of Innovations

It was realized that coping strategies to temperature variation are developed by Irish potato farmers in Santa. This finding has been buttressed by an array of factors. Different reactive and proactive adaptation strategies have been adopted in the area by both farmers and stakeholders (Government, NGOs and Research Institutions). The first was at farm level and this entails strategies like soil fertility improvement with fertilizers, increasing water canalization and irrigational facilities and increasing farm sizes. The second was at the plant level and it involves strategies like the use of more resistant plant species and the use of short cycle species. Farmers' level of adaptation was the last and entailed the use of methods like ameliorating planting technics, varying planting dates and the planting different species of the crop.

The study also revealed that the actors used different approaches that determined to a great extent the rate of farmer's adoption of the different innovations introduced. The identified innovations were either well introduced or not well introduced. The results show that 53.7% have once tried it out. Of this figure or percentage, only 79% are presently implementing new agricultural practices. It is also realized that biological and chemical innovations were generally more adopted than mechanical ones. This is because small land holdings and limited capital made it difficult to engage in large scale mechanized farming. The study showed that farmers that received adequate follow-up applied the innovation better than those who were not adequately followed-up. Generally, follow-up was more effective in farmer's groups and associations than with individuals. Once introduced to innovation, farmers watched and waited to see the results before applying them.

5. Conclusion

Drawing from the above study we can conclude that there is a significant relationship observed between inter-annuals as well as three and five year moving average trend and potato production. Potatoes are therefore more vulnerable to the present observed temperature pattern. Secular changes in the CV for temperature and potatoes production demonstrate a significant relationship in their curves.

Therefore, potato production is vulnerable to the variability of average temperature in the region. Farmers' perception corroborates highly with scientific knowledge on the variations in temperature in the sub-division. At its early stages of growth, Potato is vulnerable to mean monthly maximum temperature for the first cropping season and to the maximum temperature of June at the mid-stages for this season. For quantitative purposes, with the degree of freedom of 38, the t-table for two tail t-test indicates a level of significance of 0.05. Since the calculated t-value (2.1) is far greater than the table value (2.04), the alternative hypothesis which states that "there exists a significant relationship between temperature variation and potato production in the Santa sub-division" is validated which is 0.05 Thus the inter annual temperature variation strongly influences potato production at a 95% level of probability. This indicates that as the operational variable changes, the response variable changes in a like-manner.
Since the adaptation strategies have been viewed to be greatly insufficient or not a panacea, the study rounds up with some lucid recommendations that would salvage the situation. Firstly, the Ministry of agriculture should reinforce the training of Extension Workers to assist the farmers in the area. Secondly, the government should encourage projects and initiatives like the transformation of Irish potato into flour and chips. Thirdly, the government should encourage home consumption of locally produced items through the provision of subsidies and reduce the importation of substitutes as well as improve farm to market roads. Fourthly, micro credit schemes that are most appropriate to small scale farmers should be much embarked upon. The interest rates on loans as well as the debt repayment schedule should tie in with the farming realities. Micro financial institutions should make available and in good time both financial and technical support to farmers. Fifthly, there should be the promotion of agro-forestry because it is economically viable, socially just, ecologically sound, flexible and adaptable. Meteorological Centers should be rehabilitated and well equipped. Finally, the government should improve on aspects that will enhance the rate of adoption of innovative strategies of adaptation for instance through sensitization and training.

6. References

i. Ayonges N., (2000): "A quantitative evaluation of global warning and precipitation in Cameroon from 1930 to 1995 and projections to 2060, Effects on the environment and water resources", in readings in Geography, Unique printers, commercial avenue, Bamenda-Cameroon, p. 140-155.
ii. Bushesha M., Lee-Thorp J.,and Hopkinson P., 2009. "Subsistence farmers' responses to climate variability and change in Kyela, Tanzania", IOP Conference Series: Earth Environ. Sci.,6.
iii. Collier R.H., Finch S., Phelps K., Thompson A.R., (1991): "Possible impact of global warming on cabbage root fly (Delia Radium) activity in the UK", Annals of Applied Biology 118, p. 261-271.
iv. De Martonne, E., 1926. "Aréisme et indice aridité". Comptes Rendus de L'Acad Sci, Paris, 182, 1395-1398.
v. Deressa, T.T., and Hassan, R.M., 2009. "Economic impact of climate change on crop production in Ethiopia: evidence from cross-section measures". J. Afr. Econ. 18, 529–554.
vi. Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M.,(2009). "Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia", Global Environmental Change, vol. 19, no. 2, pp. 248–55
vii. Ekpoh, I.J**,** 2004. "Climate change and tropical agriculture in the 21st Century" In journal of applied and Social Sciences, Presbyterian Printing Press, Limbe, Cameroon Pp151-159.
viii. FAO (Food and Agriculture Organization), 2006. Livelihood adaptation to climate variability and changes in drought-prone areas of Bangladesh, Rome, Italy
ix. FAO (Food and Agriculture Organization), 2007. Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities, Rome
x. F.A.O. (2015):"Crop water information: potato, water depth and management unit", Retrieved 7 November 2012.
xi. IPCC, (1996): "Climate change; Impacts, Adaptations and Mitigations of the change, Cambridge", Cambridge University Press.
xii. IPCC (Inter-governmental Panel on Climate Change), 2007. Climate Change 2007: Synthesis Report Summary for Policymakers, Workgroup contribution to the fourth Assessment Report at IPCC Plenary Valencia, Spain 22: 12-17 International Institution for Environment and Development (IIED) (2009).
xiii. Katz, R.W. andBrownB.G**.,** 1992. "Extreme events in a changing climate: variability is more important than averages" In Climatic Change journal 21, pp 289-302
xiv. Levy, David; Veilleux, R. E. (2007):"Adaptation of Potato to High Temperatures and Salinity A Review", American Journal of Potato Research84: p. 487–506.
xv. Molua, E.L.,2000."Climate variability, vulnerability and effectiveness of farm-level adaptation options, the challenges and implications for food security in south western Cameroon". In Environment and Development Economics, vol. 7, pp 529-45
xvi. Molua, E.L.,2009. "An empirical assessment of the impact of climate change on small holder agriculture in Cameroon". Global and planetary change, vol. 67, no. 3-4, pp.205-208
xvii. Nkiene V. A., 2015. Vulnerability of swamp rice production to the effects of climate variability. Case of Ndop sub-division. University of Yaounde 1, geography department pp 179
xviii. Nkwemoh C. A., (1991): "Environmental degradation of the Pinyin-Awing area", Maîtrise Memoire, University of Yaoundé I, 105 p.
xix. Nkwemoh C A., (1999): "The impact of agro-pastoral activities on the physical environment of the Mezam-Ngoketunjia area", Doctorat de 3em Cycle in Geography, University of Yaounde 1, 306 p.
xx. Parry, M.L., et al., 1999. "Climate Change and world food security; a new assessment" Global Environmental Change, vol. 9 pp. 51-67
xxi. Rosenzweig C. and Parry M.L., 1994. "Potential impact of climate change on world food supply", Nature 367, pp133–138.
xxii. Shimshe D. (1986): "The effects of high temperature and water deficit on potato". Journal of the European association for potato research, Vol. 29, no.1, p. 95-107.
xxiii. Tani, N., 1978. "Agricultural crop damage by weather hazards and the counter measures in Japan" In Takahashi K. and Yoshino M.M. (eds) Climatic Change and Food Production, University of Tokyo Press, Tokyo, pp. 197-215.
xxiv. Tsalefac, M. and Amougou, J.A. (2008). "Changements Climatique et vecu quotidiennedes Camerounaise" In Annals of the Faculty of Arts, Letters and Social Sciences, Special edition June 2008. Pp 35-70.