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Irish Potato Production In Relation To Climate Change and Variability In Ndaragwa Agro-Ecological Zone In Nyandarua County. Kenya

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Abstract: *Irish potato production and food security are intertwined. This is true because globally potato is ranked the fourth most important food crop after rice, wheat and maize while in Kenya, it is the second most important food crop after maize. It is cultivated by over 70% small scale farmers and apart from being source of food at household level, Irish potato is a source of income for farmers in Ndaragwa Agro-ecological Zone of Kenya. Despite such importance, Irish potato production is highly declining which has been associated to climate change and variability. The study found that Irish potato is highly sensitive to extreme weather patterns and in a scenario of climate change and variability, the production of Irish potato will be at risk especially in developing countries. Based on the above backdrop, there was an urgent need to understand the nature of climate change and the relationship to potato production for such information is vital in designing an effective resilient strategies to counteract the effect of climate change The study adopted a cross-sectional research design which is an observational design that enables analysis of data collected on given points at a specific time across a sampled population. The study established that climate change and variability is indeed taking place in Ndaragwa with cases of increased temperatures and erratic rainfall being observed from the analysis. Data subjected to inferential statistics using correlation analysis establish a strong positive relationship(r= 0.979) between long rains and r=0.896 in short rains and production while in temperatures, a weak positive relationship r=0.237 was established between minimum temperature and production while a negative relationship r= -0.381 between maximum temperatures and production was established.*

Key words*: climate change, climate variability, production, Irish potato.*

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I. Introduction

The Intergovernmental Panel on Climate Change Fourth Assessment Report confirms that climate change is here to stay and is anticipated to worsen mainly in developing countries where vulnerable people will be the worst affected. The report further argue that Africa and especially those countries lying south of the Sahara are the most vulnerable to climate change because of their geographical position which lies within the tropics (IPCC, 2007). The report further shows that during the 20th century the continent of Africa has been warming at a rate of about 0.05°C per decade with slightly larger warming in the June–November seasons than in the December–May one (Hulme *et al*. 2001; IPCC, 2007). By 2000, the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is similar to that experienced globally (IPCC 2001). These would however cause a serious effect on the production of many crops with cereals doing well while horticulture would be destroyed.

Kenya has also realized the changes brought by Climate change and variability that have impacted on the country's economic development and threatens the realization of Vision 2030. In the scenario that GHG emissions will continue to grow over the next decades, there is strong evidence that the effect has result not only in changes in the mean weather conditions, but also in increase of the variability of climate (IPCC, 2012; IPCC, 2007). Large parts of Kenya have experienced more than 100mm decrease in long rain seasonal as at 2009, and recent La Nina years tend to be drier whereas El Nino years tend more towards average rather than above average rainfall (FEWSNET, 2010)

According to The National Climate Change Action Plan (NCCAP , 2013),excessive floods in Kenya occurs relatively frequently (on average every three to four years) and is linked to El Niño or La Niña episodes that can lead to extreme weather in the country and region. Annual rainy seasons in Kenya are becoming progressively wetter, with sudden and/or late onsets bringing with them floods and inundation.

In Nyandarua region, rare extremes such as frequent frosts events have been experienced in the recent past, which are as a result of abrupt, sharp temperature gradients that attain the threshold temperature values for frost formation. The area also frequently experience cases of drought associated with less moisture, heat stress and high temperatures while sometime intense rain occur, impacting on the Irish potato value chain since the

hazard increases both production and marketing risks. On the other hand dry spells result in remarkably reduced yields arising from water scarcity and damage by frost (MoALF, 2016)

According to the Government of Kenya, (GOK, 2013). The county did not have distinct rainfall seasons as it is the case now, it experienced rainfall throughout the year and was categorized under regions that experience trio- modal rainfall seasons. However, the report indicates that nowadays there are two rainfall seasons with the long rains in March to May and short rains from September to December which are still unpredictable, these changes have also changed the farming patterns in the county as some areas such as Ndaragwa agro-ecological zone experience some periods of famine, floods , frost and most cases of crop failure have also been common due to extremely low temperatures at night leading to frost bite (ROK, 2013).

Farming in Ndaragwa agro-ecological Zone is mainly rain-fed and farmers mostly practice small scale mixed farming, combining crop production and livestock keeping. Population is largely concentrated in rural areas (about 97%) with estimated equal distribution across the genders. There is a high dependency on Irish potato in the area for both consumption and commercial purposes. Despite the fact that the region has high potential for potato production there is low production and in terms of economic, Ndaragwa is ranked the poorest region in the county (Adbi, 2004).

II. Methodology

The study adopted a cross-sectional survey of respondents from the four ward of Ndaragwa constituency. Using semi-structured questionnaires and an interview guide the study conducted a household survey among 398 Irish potato farmers. The study also used data from the Kenya Meteorological station headquarters for a period 30-33 years from 1985 for precipitation and 1988 for monthly maximum and minimum temperatures which was sought to establish the nature of variability and change in temperature and rainfall and was analyzed using excel spread sheet to compute the mean, standard deviation and coefficient of variance and then presented in form of tables and graphs. To establish the relationship between climate elements and potato productions, data on Irish potato production was obtained from the Ministry of Agriculture in Nyandarua County and was analyzed using excel spread sheet to calculate the annual Irish potato production and then used simple correlation analysis to determine the relationship between the two variables.

III. Results

3.1 The Nature of change and variability And Change in Temperature and Rainfall In Ndaragwa Agro-Ecological Zone

Climate is rapidly changing all over the world with extreme cases of drought, floods, frost, heat wave and cold waves being reported regularly. Ndaragwa agro-ecological zone has also witnessed a change in Climate since 1981, Previously the region did not have distinct rainfall seasons as it is the case now, it experienced rainfall throughout the year but nowadays there are two rainfall seasons with the long rains in March to May and short rains from September to December which are still unpredictable, this changes has also changed the farming patterns in the area as it is experience some periods of famine, floods , frost and most cases of crop failure have also been common due to extremely low temperatures at night leading to frost bite (MoALF,2016). According to Karanja *et al* (2017), Ndaragwa has been experiencing drought with cases reported in 1987, 1999, 2000, 2009 and 2014. This was in line with IPCC (2007) report that, countries in East Africa has been experiencing large variability in rainfall patterns with extreme cases experienced in 1983/84,1991/92, 1995/96, 1999/2001, 2004/2005 leading to famine while EL-Nino related to floods in 1997/98 and La-Nina in 1999/2000 respectively. The many indicators including: rapid increase in temperatures, frequent and longer dry seasons, delay in onset of rains, increasing number of days without rains and intensity of rains with flood potentials shows a rapid change in climate in the future as compared to the past(Micev ,2014).

In analyzing the nature of climate change data on rainfall and temperature parameters obtained from the meteorological department was used. Figure 1, 2 and 3 clearly indicate that climate of Ndaragwa is changing, with the trend showing high variability while both maximum and minimum temperatures shows a rapid increase throughout the period.

Figure 1:1 **Comparison between the monthly mean rainfall over the whole period and over the two sub-periods.**

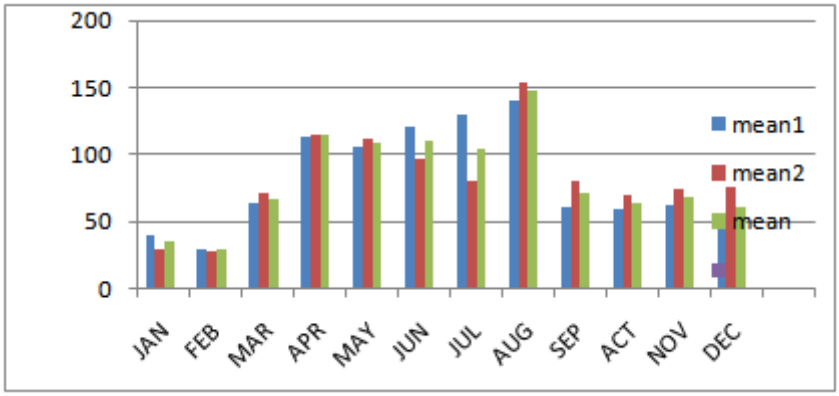


Figure 1.2Annual Average Rainfall data Trend for the years 1985 -2018.

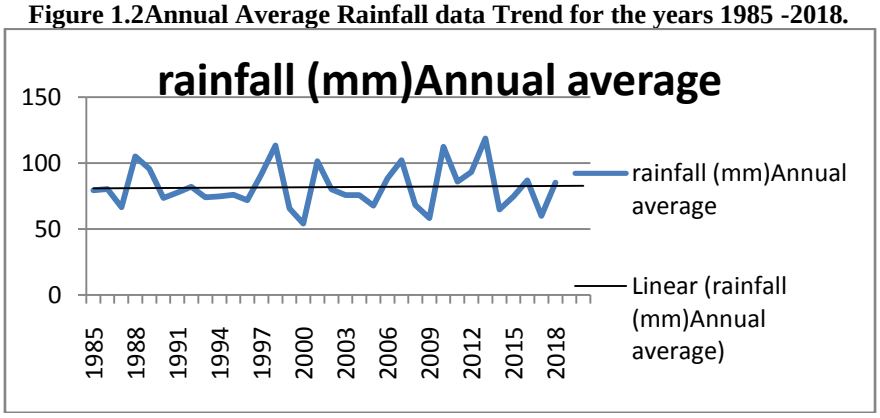


Figure 2: Comparison of the monthly mean maximum temperature over the whole period and over the two sub-sets.

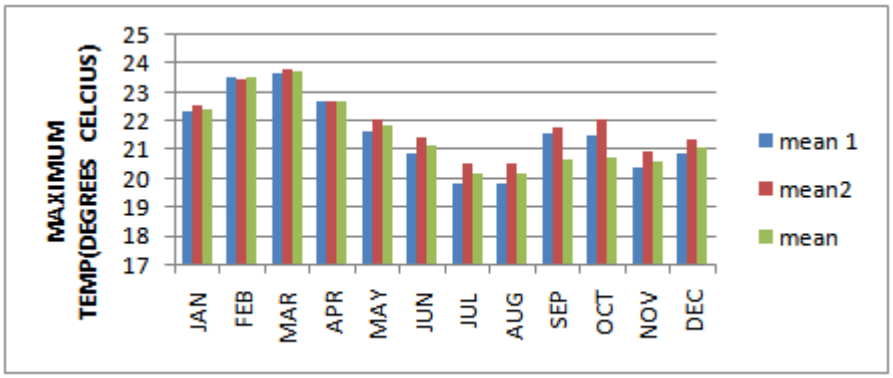


Figure 2.2 Annual maximum mean temperatures

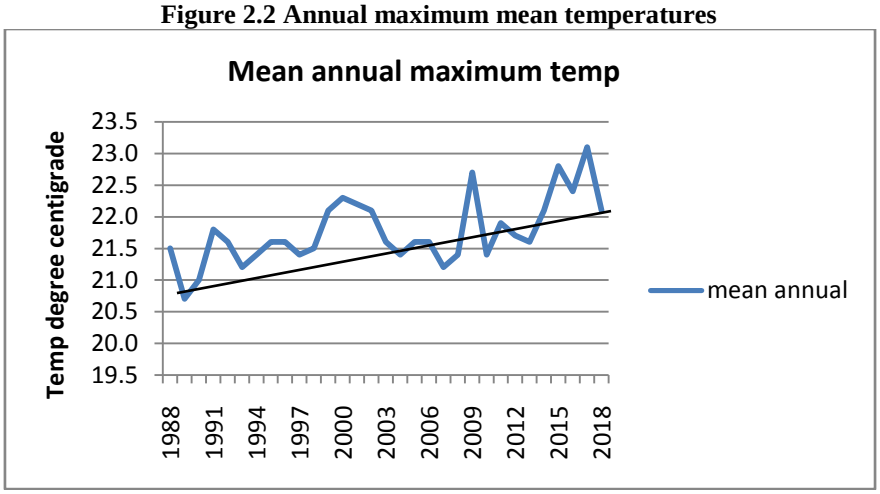


Figure 3.0 Monthly minimum mean temperatures

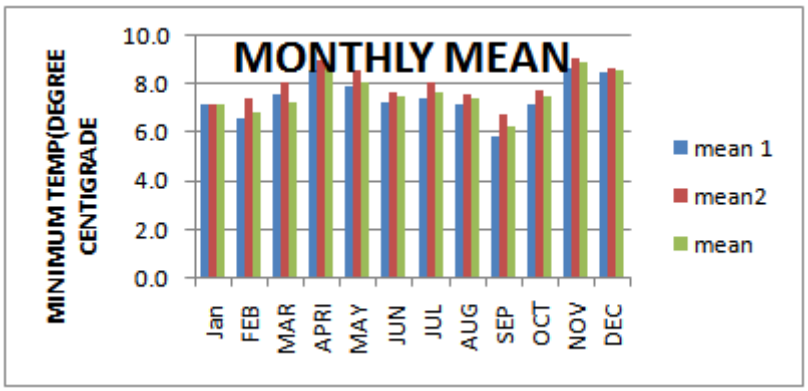
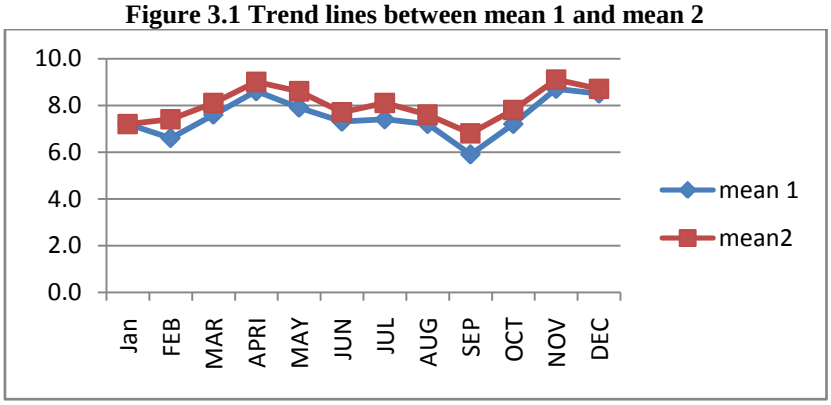


Figure 3.1 Trend lines between mean 1 and mean 2



This analysis of the climate data clearly reveal that there is high variability in rainfall and temperatures soaring over the study area during the period under consideration and such like in other previous studies the two parameters are the most significant weather elements affecting Irish potatoes and agriculture at large. According to Mwangi (2017), temperatures and rainfall are the most significant climatic parameters affecting agriculture, because it in rainfall and temperatures that climatic anomalies like floods, droughts, water shortage and cold waves are most pronounced. This compares favorably with the information obtained from the agricultural extension officer who reported that extreme temperature and precipitation which result to cases of drought and floods in the region have major effects on Irish potato growth and development reducing the overall production. The officers also said that yields increases with increasing rainfall but start decreasing when rainfall goes extremes.

3.2 The relationship between Irish potato production and climate elements

From the study survey, the respondents observation an overall reduction of Irish potato production in their locality. The majority 64.1% reported decrease in potato production while 35.9% reported increase in potato production. The decrease in Irish Potato production in Ndaragwa Agro-ecological Zones was associated with low rainfall, drought and frost bite. These findings compares favorably with those of Karanja *et al,* (2017) in a study of analyzing rainfall variability on potato production in Oljororok which reported that 45% of the respondent agrees that rainfall variation is the main course of decreased Irish potato yield in the region.

The information was also captured through an interview with a meteorological officer who reported that the area receives rainfall below the mean average of 875mm per year with extreme cases experienced in 1999, 2000, 2009, 2014 and 2017 affecting Irish potato farms in the region. Karanja *et al* (2017) furthers indicated that Ndaragwa receives rainfall below the mean average, where the lowest average rainfall was experienced in 1984, 1999, 2000, and 2009 with 1999 and 2000 coinciding with la-Nina phenomena that followed the El-Niño rains of 1997 and 1998. According to Blom-zandstra *et al* (2015) Irish potato shows a high sensitivity to drought and water stress especially during tuber bulking which inhibit future bulking of those Irish potatoes and it does not only decrease potato grade but also lower yield.

The late on- set of rain was another factors associated to decline of Irish production in that due to delays in rains, planting seasons of Irish potatoes from three seasons which were: March to June, August to October and November to February have reduced to two seasons which are now: May to September and October to January and has actually led to low yield because crop density is not optimum. The information corresponds that of Mbaisi, (2014) who found that the erratic pattern of rainfall causes increased cost of production to some of the farmers who normally plant their crops during dry season just before the onset of the rains. The author indicate that the practice of early planting is only beneficial if the rains are consistent but in the event that the rains are not consistent and timely there is usually poor germination and poor emergency that may lead to re-roughing and replanting which increases the cost of production and lowers the gross margin for farmers.

Beside rainfall and drought, the respondent also associated reduction of Irish potatoes with frost bite, pest and diseases. The information share by the Agricultural Extension Officers revealed that the area is regularly experiencing cases of adhesive frost bite that occur in January and mid-June to July. He further reported that Frost bite occur when there is no much moisture and the minimum temperatures at night are too low that freezes the moisture cell sap in the plant cell, rupturing the cell wall, killing the entire crop and turning them black. He continued that, in the past cases of frost was still reported but in the month of June and September and its effects on Irish potato was not highly felt because farmers were already in harvesting stage

Further, during the FGDs, it was revealed that the spread and increase of pest and diseases was due high rainfall and drought. The respondent (male participant) reported that extreme rainfall causing flood lead to higher spread of potato pest and diseases in farms while in other years the rainfall decreases causing accessional periods of drought that lead to water stress and increase pest that do well in warm and hot climate. This finding was supported by the information received from the Agricultural officer who reported that, reduction of rains and increased temperatures improve the environment for pest and diseases which is among the main challenge facing Irish potato farmers in Ndaragwa region. Giving examples, the officer reported that diseases like late blight, thrives well during cool and humid climate and that it spread out by infected tubers causing a lot of damage especially during long rain seasons.

The study however reveals that moderate rainfall and moderate temperatures leads to increase in Irish potato production. Some of the respondents reveal that in some years when rainfall is reliable they have pamper harvest but their main challenge in such season is lack of ready market and poor road networks to transport their produce to the market.

To examine the nature of relationship between production and rainfall, data on Table 3.1 was computed and used for analysis using Pearson's product-moment correlations and the result are presented in Table 3.2

Table 3.1: Irish potato production and rainfall

Years	Total yield	P.LR season	P.SR season	LR. MAM	SR. SON	Annual rain
1999	**1834.00**	1332	502	236.10	115.00	788.2
2000	**900.00**	546.00	345	80.70	170.50	650.3
2001	**8111.00**	6719.71	1391.29	455.80	172.80	1217.4
2002	**7590.00**	5888.19	1701.81	333.60	105.00	961.5
2003	**6742.00**	4324.00	2418.00	263.40	119.70	907.8
2004	**7903.00**	5222.90	2680.10	266.40	185.90	908.8
2005	**4654.00**	3637.68	1016.32	329.20	175.30	811.9

2006	**5664.00**	4000.00	1664.00	271.00	260.20	1059.1
2007	**17094.0**	12760.0	4334.00	209.50	368.60	1224.8
2008	**14220.0**	8974.00	5246.00	178.40	385.70	818.1
2009	**1103.00**	653.00	450.00	181.60	190.00	698.4
2010	**13546.0**	7581.00	5965.00	509.50	157.50	1346.1
2011	**3010.18**	645.10	2365.08	189.40	333.20	1030.9
2012	**9182.50**	5507.50	3675.00	466.40	236.80	1117.4
2013	**8432.50**	5007.50	3425.00	520.00	284.20	1422.7
2014	**1111.50**	657.30	454.20	186.80	147.70	777.3
2015	**6399.00**	4510.00	1889.00	214.70	287.10	897.8
2016	**8632.00**	6375.00	2257.00	371.10	175.20	1043.7
2017	**1048.05**	626.05	423.00	125.40	318.40	719.1
2018	**3456.00**	3024.00	432.00	457.50	95.10	1022.2

Table 3.2 Pearson moment correlation result between rainfall and production

		Annual Yield	production in long rains	production in short rains	long rains MAM	short rains SON	Annual rains
AnnualP. Yield	Correlation	1					
	sig-1tailed						
	N	20					
Production In Long rains	P.correlation	.976**	1				
	sig-1tailed	.000					
	N	20	20				
Production in Short rains	P. correlation	.896**	.777**	1			
	sig -1- tailed	.000	.000				
	N	20	20	20			
Long rains MAM	p. correlation	.201	.220	.131	1		
	sig-1- tailed	.198	.176	.290			
	N	20	20	20	20		
Short rains SON	p.correlation	.403*	.318	.514*	-306	1	
	sig-1 tailed	.039	.086	.010	.095		
	N	20	20	20	20	20	
Annual Rains	P.correlation	.400*	.418	.302	.789**	.147	1
	sig-1 tailed	.040	.033	.098	.000	.269	
	N	20	20	20	20	20	20

****Correlation is significant at the 0.01 level (1-tailed)**
*** Correlation is significant at the 0.05 level (1-tailed)**

The results reveal that there was a strong positive relationship which was statistically significant between production during long rains and annual total production. according to Taylor (1990), when Pearson's r is close to 1, it means that the relationship between the two variables is strong and that change in one variable are strongly correlated with change in the second variable and when it is close to 0, there is a weak relationship between the two variable and therefore change in one variable are not correlated to change in the second variable. The findings from Table 3.2 Pearson's r=0.979, n=20, p≤.01 showing a strong relationship between production during long rains and annual Irish potato production. This means the two are strongly positively related and as rainfall increases during long rain season, the annual production also increases by 0.979 as well.

This is also observed during the short rain seasons where r= 0.896 showing a strong relationship which is significant.

A positive relationship also exists between long rains, short rains and annual rainfall and Irish potato production. Long rains reveals (r=0.201, n=20, p≤ 0.05), which is not significant, short rains (r=0.403) and annual rains (r=0.400) which are statistically significant. This confirms that indeed the rainfall is strongly positively related to Irish potato production in all seasons and as rainfall amount increases, potato production also increases. In a similar study Karanja (2013) arrived at similar findings in which he noted that there is a strong positive relationship between rainfall amount and potato production and vice versa. The relationship between potato yield and rainfall was analyzed to test the null hypothesis H_{O1} (**There exist no significant relationship between**

Irish potato yields and rainfall variability in Ndaragwa A.E Zone.)Table 3.2 shows the value of r=0.400 indicating a positive relationship with a sig(1-tailed) value of 0.040 which is less that 0.05 confidence level thus implying that we reject the null hypothesis because there is sufficient evidence to conclude that there is a significant linear relationship between rainfall and production since the correlation coefficient is significantly different from zero (0). This indicated that indeed changes in rainfall in either way affect Irish potato production.

In order to establish the relationship between Irish potato production and temperatures both minimum and maximum, Table 3.3 was computed and analyze using Pearson's product-moment correlations and the result are presented in Table 3.4

Table 3.3: Irish potato production and Temperatures

Years	Total yield	P.LR season	P.SR season	Annual min temp	Annual max temp
1999	**1834.00**	1332	502	7.00	22.10
2000	**900.00**	546.00	345	7.20	22.30
2001	**8111.00**	6719.71	1391.29	7.40	22.20
2002	**7590.00**	5888.19	1701.81	7.50	22.10
2003	**6742.00**	4324.00	2418.00	7.60	21.60
2004	**7903.00**	5222.90	2680.10	7.70	21.40
2005	**4654.00**	3637.68	1016.32	7.60	21.60
2006	**5664.00**	4000.00	1664.00	8.00	21.60
2007	**17094.0**	12760.0	4334.00	8.30	21.20
2008	**14220.0**	8974.00	5246.00	7.70	21.40
2009	**1103.00**	653.00	450.00	7.70	22.70
2010	**13546.0**	7581.00	5965.00	8.80	21.40
2011	**3010.18**	645.10	2365.08	7.90	21.90
2012	**9182.50**	5507.50	3675.00	8.00	21.70
2013	**8432.50**	5007.50	3425.00	8.10	21.60
2014	**1111.50**	657.30	454.20	7.90	22.10
2015	**6399.00**	4510.00	1889.00	8.00	22.80
2016	**8632.00**	6375.00	2257.00	8.30	22.40
2017	**1048.05**	626.05	423.00	8.00	23.10
2018	**3456.00**	3024.00	432.00	8.10	22.10

Table 3.4 correlation between production and temperatures

		Annual Yield	Annual min temp	Annual max temp
Annual Yield	P.Correlation	1		
	sig-1-tailed			
	N	20		
Annual Min Temp	P. correlation	.237	1	
	sig. (1-tailed)	.157		
	N	20	20	

Annual	P. correlation	-381*		-194	1
Max	sig.(1-tailed)	.049	.206		
Temp	N	20	20	20	

* Correlation is significant at the 0.05 level (1-tailed)

The correlation between Irish potato production and temperature as shown in table 3.4 reveals that there was a positive correlation (r=0.237, n=20, p≤ 0.05) between annual minimum temperature and production which is not statistically significant. This confirms that with increase in minimum temperatures, Irish potato production also increases. However Pearson's correlation reveals a negative relationship (r=-381, n=20, p≤ 0.05) which is statistically significant between maximum temperatures and annual Irish potato production this implying that when annual maximum temperature increases by one unit potato production reduces by 0.381 and on the other hand when annual minimum temperatures increases by one unit, the potato output increases by 0.237. The findings conceded with that of Mbugua (2016) findings who observed that mean maximum temperatures has a negative relationship and is significant while the coefficient of mean temperature has a positive relationship and is significant. In contrary, Naintoh et al (2018) discovered that correlation analysis between potato yield and temperature reveals a very weak positive relationship (r=0.02) and is not statistically significant. From Table 3.4 the calculated r-value for minimum temperature gave 0.237(a weak positive relationship) and sig. (1-tailed) value of 0.157 which is more that 0.05 confidence level implying that we retain the null hypothesis ($H_{O2)}$**that there exists no significant relationship between Irish potato yields and temperature (min temp) variability in Ndaragwa A.E Zone** because there is insufficient evidence to conclude that there is a significant linear relationship between min temperatures and production since the correlation coefficient is not significantly different from zero (0). More so, r value reveals a weak positive relationship meaning that changes in mean temperature has less impact on potato production. However, on maximum temperature r- value reveals a negative relationship (r=-381) and a sig.(1-tailed) value of 0.049 which is less than 0.05 confidence level thus implying that we reject the null hypothesis ($H_{O2)}$**that there exists no significant relationship between Irish potato yields and temperature (max temp) variability in Ndaragwa A.E Zone.** This indicates that there is a significant relationship which is negative revealing that when maximum temperatures increase the Irish potato production is negatively affected.

IV. Conclusion

From the study the findings shows a general slight increasing trend of the annual rainfall. The increase is highly contributed by the short rain seasons which shows an increasing trend throughout the years unlike during the long rains season where some years its shows a reducing trends or remain constant. An erratic rainfall pattern was observed showing that the region receive rainfall below the average most of the years with the peaks noticed in the month of April and August. This variation also bring about variations in Irish potato production for instance in 2000 and 2017 where low rainfall was recorded the total yield was 900 tons and 1,048.05 tons respectively while in 2001,2007,2008 and 2013 when rainfall was high and well distributed the total potato yields were 8,111tons, 17094 tons, 14,220 tons and 8,432.50 tons respectively. This variation leads to unpredictable weather pattern destabilizing farmers plan and decision, on when to prepare their farms and plant their seeds.

Further, the study clearly shows that temperature of the region in increasing in both minimum and maximum temperature, this come with both positive and negative impacts. The increasing trend in minimum temperature implies that cases of frost bite in the region will gradually reduce and therefore potatoes farmers will be relieved from this highly destructive event that have no cure. However, with the increasing trend of maximum temperature, the crop optimum temperatures of 18^0c will be surpassed influencing the production of Irish potatoes which adapt well in cool climates.

V. Recommendations

The study reveals that climate change and variability has occurred in Ndaragwa Agro-ecological zone as evidenced by unreliable rainfall, late onset and cessation, drought and floods that leads to changing planting dates, reploughing and replanting, increasing cases of pest and diseases hence increasing the cost of production and lowering production . It is for this reason that the study recommends that the meteorological department should strive to provide accurate and timely information, to help farmers make informed decision on when to prepare and plant the seed.

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