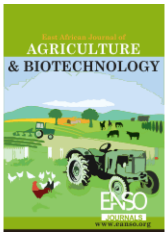

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Original Article

Analysis of Climate Change and Variability on Irish Potato Production among Small-Scale Farmers Using GIS in Narok County, Kenya

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Geographical Information Systems (GIS), Climate Change and Variability, Inter-cropping, Sustainable Development Goals (SDGs), National Aeronautics and Space Administration (NASA).

ABSTRACT

This study explored the analysis of climate change and variability on Irish potato production among small-scale farmers using GIS in Narok County, Kenya. Data collection methods in this study involved: small-scale farmers' respondents' descriptive survey, in-depth key informant interviews, and GIS website downloads. A sample of 393 small-scale farmers was randomly sampled to gather data on Irish potato production factors. Key informants from the Narok South Agriculture Department provided Irish potato production data from 1991 to 2020, and temperature and rainfall data were downloaded from Google NASA Power. Data from the field was screened and evaluated using the Statistical Package for Social Sciences version 22.0 program to give frequencies and percentages. Chi-square was calculated and inference made at a confidence level of α=0.05. The results indicated that, Pearson correlation coefficient of variation (CV) of rainfall and temperature against Irish potato production for period in 1991 to 2020 revealed high positive correlations for rainfall ($r = 0.826$) and high negative correlations for maximum temperature ($r = -0.741$) and very low negative correlations for minimum temperature ($r = -0.2152$). The study further outlined that, majority of the respondents, comprising about 90.2 % of the households in the study area, observed highly dry conditions, and only 48.9 % of the household respondents were able to observe low temperature occurrence in their area. From these findings, climate change and variability have an effect on Irish potato production and therefore affect food availability in Narok County. The study recommends that the agricultural extension agents, together with the Kenya Meteorological Department, should endeavour to inform and train farmers on the use of modern geographical information technologies. Moreover, farmers should be encouraged to intercrop Irish potatoes with other food crops to cushion them against climate change and variability. This will not only increase food security within their households but will also equip them with up-to-date information and therefore help them make informed decisions on Irish potato production. This will improve food security amid climate change and variability in Narok County.

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INTRODUCTION

The second Sustainable Development Goal (SDG) aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030 (United Nations, 2021). Though this sounds convincing in eradicating the yoke of food unsustainability in the world, it may not be fully achieved due to climate change and variability, poor food crop production methods, changes in soil fertility status, among other production factors (United Nations, 2020).

Climate change and variability affect agricultural production through altering climatic conditions of crops, limiting optimum growth and development (Benson, 2013). This effect is greatly observed within small-scale farmers across sub-Saharan Africa due to their sole reliance on rain-fed agriculture, unlike their counterparts in developed countries who alter the climate by introducing technologies like greenhouses (Benson, 2013). The most affected food crop production is short-season crops like Irish potato, which requires close monitoring (Mbugua, 2016; Benson, 2014; Justus *et al.,* 2016; Wang'ombe & Van, 2013). It's from this production challenge that this study was undertaken with the main objective of analysing the impact of climate change and variability among small-scale Irish potato farmers using Geographical Information Systems (GIS).

Climate Variability and Geographical Information Systems

A geographical information system (GIS) is a system that works toward processing topographical data (Sayed & Fadl, 2021). It is an application installed in a computer device that captures data, stores it, assimilates, manipulates, evaluates, and presents (displays) the synthesised outcomes information in the form of maps and reports. This synthesised outcome information is a milestone in human technological innovations, especially in the area of geospatial technology in generating a vibrant and competitive economy, especially in the agricultural sector (Nouf Abdulaziz *et al*., 2021).

This technology not only increases the agricultural economic status of the people but also enhances the protection of the environment while at the same time providing utmost food security to the people. Current trend shows that there are no technological innovations that can be developed by humans without incorporating the use of GIS (Amos, 2020). Haggquist & Nilsson (2017) outline that GIS tools in combination with online website resources have become popular in the agricultural sector by helping

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farmers to farm and manage their farms effectively. At farm levels, the technology uses multispectral imagery collected by satellites and then transmitted to the computer for analysis. This capability of GIS to investigate and visualise agricultural productivity in the farm has been very beneficial to the farming activities by counteracting climate change and variability (Amos, 2020; Canillo & Hernandez, 2021; Alkobaisi *et al*., 2012).

GIS innovation tool in the current world assists in mapping the present and upcoming variations in the weather, crop yield output, as well as soil adjustment analyses, such as temperatures. The mapping of the present features within the farm allows GIS experts and farmers to effectively work together towards achieving the same objective, forming more varied, operative, and efficient agricultural techniques (Henrico *et al*., 2021). Moreover, Tagliabue *et al*. (2020) further outline that GIS aids in increasing food production at the farm level as well as eliminating problems of food scarcity in a country. In addition, natural inputs in farming, though very hard to be controlled but they, can be better understood and managed with GIS applications (Louhichi *et al.,* 2020; Goodchild *et al*., 2007).

Kheder (2014) advocates that the use of GIS at the farm level has several advantages, like extreme ability to analyse soil data and determine the appropriate type of crop to be farmed, and the generation of soil nutrition information status, therefore equipping farmers with the needed nutrients. This finally leads to an increase in yield within the household (Wang'ombe & Van, 2013; FAO, 2013). Zeng *et al*. (2021), when soil is equipped with appropriate nutrition, then the sole goal of GIS at the farm level will be achieved, as there will be a reduction of farming costs while at the same time maintaining the environment. Adu & Ngulube (2017) attribute that when GIS technology is embraced by farmers at the grassroots levels, then there will be a reduction of household marginalisation and vulnerability. The result will increase food security and resolve world hunger (Alkobaisi *et al*., 2012; El-Hames *et al*., 2011; Kheder, 2014).

Further to this, according to Sayed & Fadl (2021), GIS technology can also be used in agricultural farming by mapping variations of temperature, rainfall, crop productivity, pest and disease proliferation, and weed infestations. In line with this, GIS data systems can determine and solve problems that arise from crop damage or failure (Haggquist & Nilsson, 2017). This is breakthrough information since it can be used by the farmer and insurance company in compensation claims. This is an added advantage to the farmers and insurance companies having access to their crop information throughout the season (Henrico *et al*., 2021).

GIS technology can also be used in an increasing food scarcity awareness. This is done by identifying the affected area. Once the area has been identified, necessary assistance is then determined, and the GIS data can be used to safeguard that area (Khatri-Chhetri *et al.,* 2017; Henrico *et al*., 2021; Amos, 2020). Using these data, researchers can be able to use this geographical data to study the reasons behind food scarcity. This data can then be transmitted to the farmers within that area and help the researcher in helping them in determining fertiliser use and the extent to which natural resources in the area have been depleted, as well as the extent of pollution (Tagliabue *et al*., 2020; Khatri-Chhetri *et al.,* 2017).

Though the use of GIS sounds very good and pleasant, noble technology, it also comes with its glitches. The most serious obstacles are the apparent complexity of GIS and the lack of qualified staff (Tanser & Le, 2002; Sipe & Dale, 2003; Yeh, 1991). Since GIS is a new technology, there are very few staff with this technology and therefore their demand is very high, which is beyond the reach of researchers (Sipe & Dale, 2003). Moreover, there is a limitation of data; this is the problem that has faced the globe in finding money to collect paper map data all over the world and convert it into a

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digital format (Edralin, 1991). Yeh (1991), in connection with this, there have also been financial complications in the use of hardware and software; the majority of the farmers across sub-Saharan Africa have limited sources of funds to purchase computers and software for their use in their farms (Sipe & Dale, 2003; Yeh, 1991).

Bretas (1996) also notes that most decision makers do not understand the application of GIS. The GIS experts use technical jargon that cannot be understood easily by decision makers; therefore, they reject it, and hence, funding becomes a difficult phenomenon. Edralin (1991) and Yeh (1991) state that, in line with this, there is relatively low training on GIS use, and when they are there, the cost is beyond the reach of the majority of farmers and students who are eager to learn. Sipe & Dale (2003) and Bretas (1996) also outline that another problem of GIS is the lack of software which can be used to perform spatial analysis. This is because spatial statistics analysis is not yet fully developed and due to this, it's not well understood by most users in solving global problems.

Yeh (1991) as well as Sipe & Dale (2003) further elaborate that most of GIS originates from developed countries and therefore getting copies of software in sub-Saharan Africa proves to be a futile challenge. Last but not least, most GIS tools are developed by professionals in computer science and cartography disciplines and as a result, since they are not professionals in other practical fields they end up being interested in GIS improvement research rather than GIS practical improvement research (Yeh, 1991; Sipe & Dale, 2003; Canillo & Hernandez, 2021).

Google Data Access Viewer- NASA Power Data Sets

Currently, the use of Google data, especially in key fields, has received a lot of applause from researchers and scholars. Google data, especially on climate change and variability, has been uploaded and updated by NASA regularly. For this remarkable reason, several scholars have been using these data sets in their studies, and others have tested these data sets and found them reliable to be used in research. Just to mention a few, Alfred *et al.* (2022) on an assessment of solar radiation using NASA power data sets and ground-based data to analyse clean energy in Ghana. The study found that there were low root mean square error (RMSE) values between the two datasets. Similarly, Puteri *et al.* (2023) on an assessment of climate change using NASA power data sets and the De Martonne Climate Index in Northern Peninsular Malaysia. The findings showed that NASA power data sets performed satisfactorily in estimating both mean temperature and rainfall over the northern Peninsular Malaysia.

Furthermore, Silvina *et al.* (2020), on the other hand, in assessing daily solar radiation using NASA power data sets while considering atmospheric transparency, the research was able to show that NASA power data was purely potential to estimate solar radiation and therefore an important information resource for different applications. In addition, Monteiro *et al.* (2018), in an assessment of NASA power satellite-based weather data to simulate sugar cane yield in Brazil, found that NASA power data sets as a useful source of climatic data for agricultural activities with a reasonable confidence for regional and national spatial scales. Moreover, Marzouk (2021) on a study assessing global warming over 39 years using NASA power data sets and local meteorological measurements in Al Buraimi, Sultanate of Oman. The study concluded that NASA power data are reliable for the 2-meter air temperature. In general, many scholars have used NASA power data sets in their study, and therefore, this research also found that NASA power data sets as reliable to be used in this study.

Irish Potato Production Trend in Kenya Amid Climate Change and Variability

In Kenya, Irish potatoes are preferred and cultivated intensively by small-scale agricultural farmers (GIZ, 2016). This, therefore, makes this crop

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important to agricultural policy decisions as food security and overall development of the agricultural sector (Beatrice *et al.,* 2020). The greatest challenge of producing this crop is that many farmers do not understand the nutritional value and many benefits of producing and consuming it, especially in curbing poverty, famine, and malnutrition (Kariuki, 2010; Muthoni & Nyamongo, 2009).

According to FAOSTAT (2019), in Kenya, Irish potato production has been fluctuating over the years. In the year 1990, the average production per hectare was 8.87, with a total production of 779,190 harvested on 87,890 hectares. Ten years later, in the year 2000, with technological advancement, the average production of Irish potatoes per hectare dropped to 6.18, with total production of 670,303 harvested on 108,516 hectares. Twenty years later 2010, the average Irish potato production per hectare increased from 6.18 to 19.17, with total production of 2,725,940 harvested on 121,542 hectares. This may be attributed to government interest in the promotion of Irish potato production through the Ministry of Agriculture (Beatrice *et al.,* 2020; FAOSTAT, 2020; KARI, 2005).

MATERIALS AND METHODS

Study Area

This study was conducted in Narok County-Kenya with the main focus in Narok South Sub-County. The sub-county has six (6) administrative Wards, mainly Sagamian, Sogoo, Melelo, Ololulunga, Loita, and Maji-Moto / Naroosura. The six wards have a population of 238,301 with 46,723 households (KNBS, 2019). The sub-county covers an area of approximately 4,959.20 km^2 and is found in the southwestern side of Kenya (KNBS, 2019).

The sub-county borders Tanzania to the South, Narok to the West, Bomet to the North, and Narok North to the East. The agriculturally upper zone of the sub-county practices crop production, while the lower zone practices pastoralism. Wards practising Irish potato production activities are namely Sagamian, Sogoo, Melelo, and Ololulunga, which are mainly produced by small-scale farmers (GoK, 2013; MoA, 2006).

The sub-county has a bimodal rainfall dispersal pattern. The long showers occur from March to May (MAM), and short rains occur from mid-October to December (OND). During this period, Irish potato is planted by farmers and especially during long rains. The average annual rainfall ranges between 500-1800 mm. Temperature ranges between 7ºC in July and 28 °C in January and March. The average temperature is 18 °C. These average rainfall and temperature are usually optimum for Irish potato production (GoK, 2009; Anderson, 2008).

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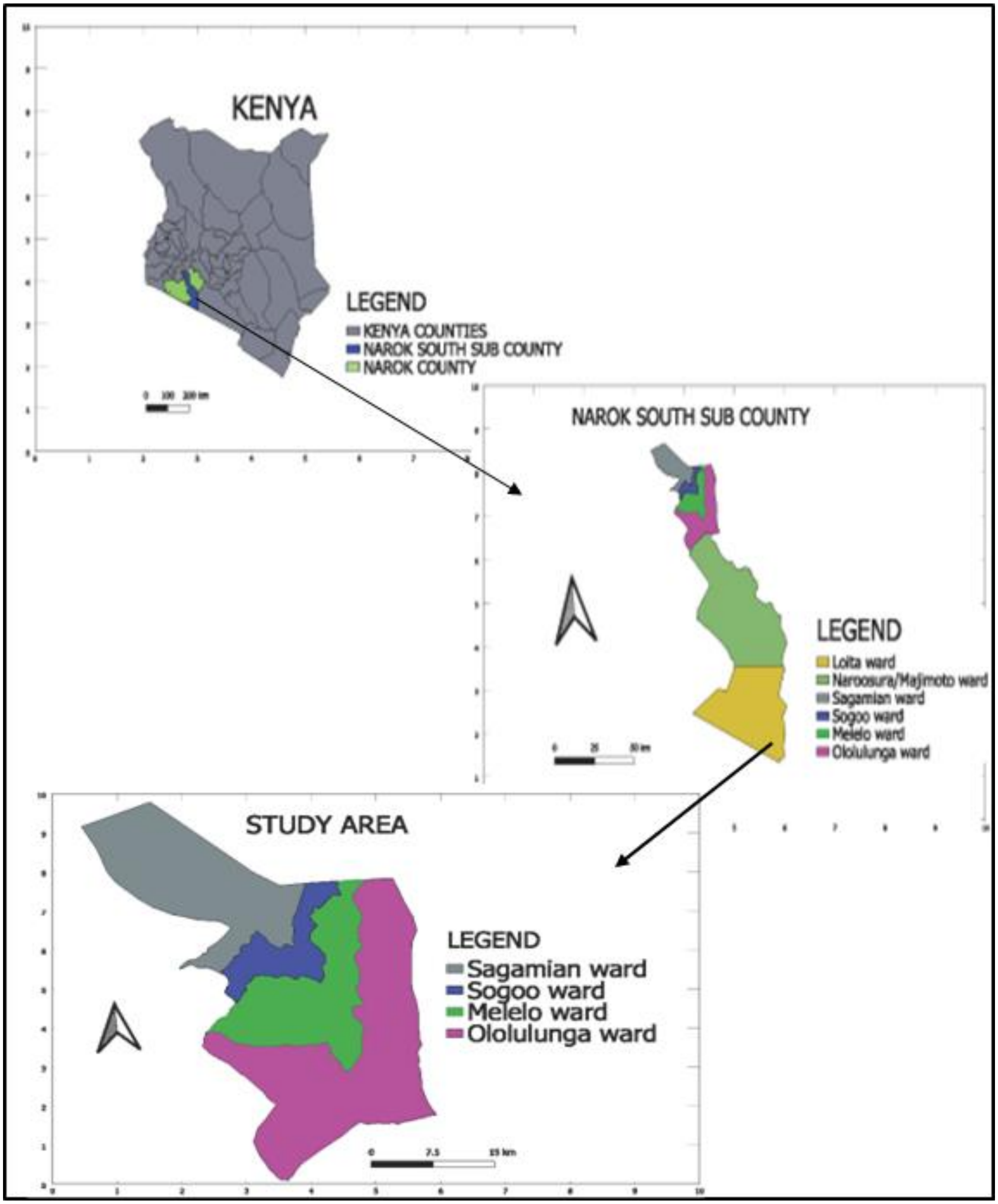
Figure 1: Study Area-Narok South Sub-county



Source: *Google Slippy Map and Drawn Using QGIS 3.28.11.*

Research Design

The target population for this study was small-scale Irish potato farmers in Narok South Sub-County, Kenya. This study embraced a mixed research design due to various data-gathering sources. The designs include a cross-sectional survey research design, an explanatory research design, and a correlational research design. These research designs allowed the study to derive insights into the opinions, attitudes, perceptions, and knowledge regarding climate change and variability, as well as

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coping and adaptation mechanisms. A cross-sectional descriptive survey design was used to understand Irish potato production at small-scale farms. An explanatory research design was employed during focus group discussions and in-depth interviews with key informants to understand Irish potato production trends across villages. Lastly correlational research design was used to understand the relationship between Irish potato production against climate (Rainfall and temperature) and variability.

Sample Size and Sampling Procedure

The study embraced a multi-stage sampling procedure involving three stages within the study area. The first stage was purposively eliminating two wards from the study. These are Loita and Naroosura/Majimoto wards, since across these two wards, Irish potato production occurs. The second stage involved selecting villages within the remaining four wards that had a high concentration of Irish potato production. The third and final stage involved random sampling of respondents within villages based on the Kenya population survey of 2019 and using the household as a data collection point (KPHC, 2019). As indicated in Table 1

Table 1: Number of Households and Percentage Sample Size Per Ward

	Wards	No of households	Percentage per Ward	Villages practising potato production	household sample
1.	Ololulung'a	6,161	28.8	66	113
2.	Melelo	6,280	29.4	54	116
3.	Sogoo	5,102	23.9	52	94
4.	Sagamian	3,837	17.9	43	70
	Total	**21,380**	**100%**	**215**	**393**

The sample size of respondent households was then calculated using the Yamane (1967) formula.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

The research used a 95% confidence level with an error of 5% and therefore, after calculation, 393 respondents' households were interviewed.

In focus group sampling, the quota sampling procedure was used to select groups for discussions. The study used a controlled sampling procedure where each focus group had 10-12 members in size and considered gender, age, and village of stay. Twelve (12) focus group discussions (three from each ward; Ololulunga, Melelo, Sogoo, and Sagamian) were formed, and the meetings were held at central points (basically at churches, the assistant chiefs' boardroom, or on selected farmer residences). Similarly, key informant in-depth interview samples were carried out at the Sub-county agricultural officer and the ward agricultural officers.

Data Collection Procedure

The household data collection procedure used questionnaires. The questionnaire was first subjected to a validity test by agricultural and academic experts. The questionnaires used a combination of both quantitative and qualitative data collection methods, and therefore, both open-ended and closed-ended questions were used. These questionnaires were used by five (5) trained research assistants to gather data based on proportionate stratified random sampling interviews for small-scale Irish potato farmers' households. Household interviews were conducted through a transect walk within the villages. The first interviewee within each village was sampled randomly, and the next respondent depended on the sample size within each village.

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During the focus group discussions data collection procedure, a moderator was used during the data collection procedure to gather data. The moderator was guided by an interview guide which was set to guide the group discussions so that deviation from the area of research area was avoided. Key informant in-depth interviews at the Sub-county agricultural office and ward agricultural office were used to provide Irish potato production data for the past 30 years.

Rainfall and temperature data were downloaded from Geographical Information Systems (GIS) through Google data access viewer- NASA power website (NASA, 2020). The researcher, together with Ward Agricultural Officer (s) (WAOs), first identified four central GPS points from each ward (Sagamian -0.7818, 35.5974; Sogoo -0.8367, 35.5776; Melelo -0.8741, 35.6210 and Ololulunga -0.7930, 35.6752). The average GPS Point was then calculated as follows (-0.7818 + -0.8367 + -0.8741 + -0.7930 = -3.2856/4= -0.8214 and 35.5974 + 35.5776 + 35.6210 + 35.6752= 142.4712/4=35.6178 which gave (-0.8214, 35.6178). This GPS point (-0.8214, 35.6178) was then adopted in this study. It was then followed by downloading temperature (Minimum, maximum, and Earth skin) and rainfall data sets for a period of thirty years (1991-2020) from Google data access viewer- NASA power (NASA, 2020)

Data Analysis

Data from the field were grouped according to category (cross-sectional and focus groups). For cross-sectional quantitative data, it was checked for correct entry, coded, and then entered into the computer through the Statistical Package for Social Sciences version 22.0 (SPSS 22.0) software program. Using this software program, data were evaluated in order to indicate statistical differences or relationships among variables. Chi-square was then calculated and inference made at a confidence level α=0.05. The multiple linear regression analysis was calculated to test the hypothesis. The research adopted multiple linear regression analysis.

Y = a + b0 + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 + b6x6 + …+ bnxn, (2)

Where:

Y = Irish potato production in tonnes/hectare/year

a =Constants (i.e. land)

b = Rise or fall as X increases

b0 = The y-intercept, which represents the Y value when all independent variables are zero

X1 = Rainfall (mm)

X2 = Maximum temperature (°c)

X3 = Minimum temperature (°c)

X4 = Earth skin temperature (°c)

X5 = Farmers' endowment (Kenya shillings)

X6 = Agronomic practices (days)

N = Infinity of variables

Rainfall and temperature variation trend data for the last 30 years (1991 – 2020), on the other hand, were analysed and computed using the Mann-Kendall Statistical method using XLSTAT version 2020

(Mondal1 *et al.,* 2012)

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \quad (3)$$

RESULTS AND DISCUSSIONS

Knowledge of Climate Change and Variability among the Respondents

The majority of the respondents, comprising about 90.2 % of the households in the study area, observed highly dry conditions (Table 1). Only 48.9 % of the household respondents were able to observe low temperature occurrences in their area. Significantly, only an average of 7.5 % of the respondents were

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unable to observe any climate change and variability, while an average of above 71% of respondents had observed climate change and variability. This is a good indicator in regards to Irish potato production, as farmers can be able to come up with adaptation strategies for Irish potato production.

Table 2: Views on Climate Change and Variability among Households

Climate characteristics	High observed		Minimal observed		No observation	
	freq	**%**	freq	%	freq	%
Dry conditions	332	90.2	28	7.6	8	2.2
Unreliable rainfall patterns	338	91.8	16	4.3	14	3.8
Drying of water sources	252	68.5	81	22.0	35	9.5
Occasional flooding	219	59.5	107	29.1	42	11.4
Alternate weather changes	303	82.3	37	10.1	28	7.6
High temperatures	223	60.3	109	29.6	36	9.8
Low temperatures	180	48.9	159	43.2	29	7.9

Source: *Field data 2022*

Across age groups (Table 2), those who were below 25 years of age, only 9.5% were able to see any climate change and variability. Those aged above 25 years, an average of 81.6 % of respondents, witnessed climate change and variability. It's further observed that knowledge of climate variability and change cuts across the age groups, with older people attesting to climate change and variability, while younger people hardly see any change in climate.

Table 3: Views of Climate Change and Variability across Different Age Groups

Age (years)	Observation of climate change and variability			
	Yes		No.	
	frequency	**%**	**Frequency**	**%**
Below 25 years	35	9.5	13	3.5
26-35	47	12.8	7	1.9
36-45	73	19.9	9	2.4
46-55	116	31.5	2	0.5
56-65	41	11.1	2	0.5
Over 65	23	6.3	0	0.0
Total	**335**	**91.0%**	**33**	**9.0 %**

Source: *Field data 2022*

Chi-square test indicated that knowledge of climate change and variability was found to be significantly influenced by education level (χ^2 =7.684, df=3, p=0.053) and age (χ^2 =31.651, df=5, p=0.00). The correlation coefficient between educational level and climate change indicated a very low positive correlation (r = 0.114) and also a very low negative correlation between age and climate change knowledge (r = - 0.262). During focus group discussions, it was indicated that initially, farmers knew the exact days of rainfall onset and cessation. However, with climate change and variability, they can hardly predict weather patterns.

Rainfall and Temperature Analysis Amid Climate Change and Variability

The yearly data downloaded considered long rain (March, April and May) and decadal rainfall and temperature distributions from 1991 to 2020 According to figure 2, across March from 1991 to 2020 the highest rainfall achieved was 274.22 mm in the year of 2008 with the year 2019 receiving

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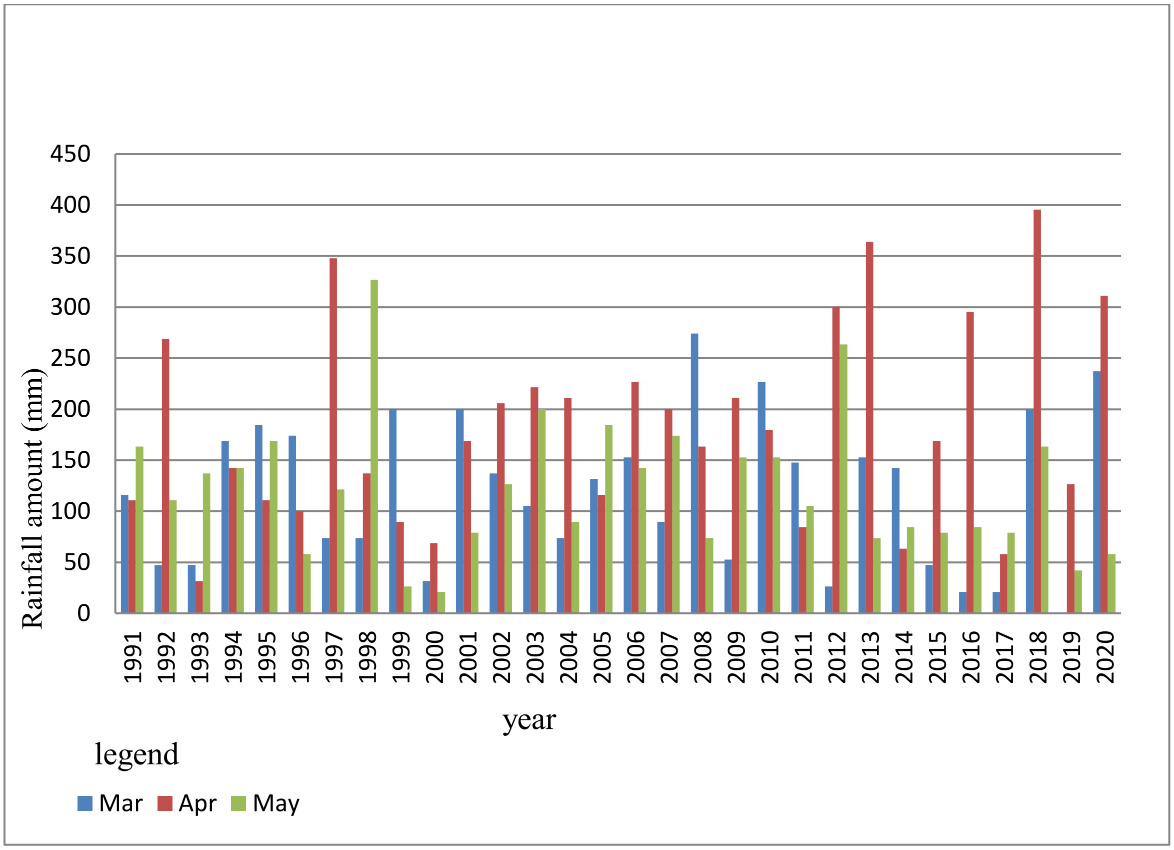
none (0 mm) though this may be registered as out array (range). Similarly, in the month of April from 1991 to 2020, the highest rainfall achieved was 395.51 mm in the year of 2018, with the year 1993 receiving the lowest 31.64 mm. Furthermore, in the month of May from 1991 to 2020, the highest rainfall achieved was 326.95 mm in the year 1998, with the year 2019 receiving the lowest 42.19 mm.

Figure 2: Rainfall Amount in March, April, and May in Narok South Sub-County



Source: *Google data access viewer- NASA power website 2022*

According to FAO (2008), for a three-month Irish potato production cycle, rainfall requirement should be well distributed, ranging between 500 – 700 mm (millimetre) during the growing period. From the Narok South sub-county agriculture office, farmers plant three three-month growing cycle potatoes. They are planted in late February or early March and harvested in June. According to Figure 2 in the year 2000, the rainfall distribution within the three months (MAM-March, April, and May) was very low, with a rainfall amount of 121.8 mm. This amount of rainfall was so little that it could not sustain Irish potato growth. During focus group discussions, members were able to recall that during this time (year 2000), they harvested Irish potatoes, which were small in size. A similar harvest was also observed on year 2017.

For decadal rainfall distribution, the year from 1991 to 2020 (Figure 3) shows that the amount of rainfall in Narok South sub-county has been fluctuating between a high of 1708.59 mm on year 2020 and a low of 569.53 mm on year 2000. For Irish potato production, they do well in areas that receive annual rainfall ranging from 850 mm – 1200 mm per year (NPCK, 2021). It's only 2000, 2005, and 2017 that the area received less than 800mm per year. This, therefore, is an indicator that Narok South sub-county is an ideal place for Irish potato production as it receives relatively high rainfall. Linear regression analysis shows a gentle decline of the

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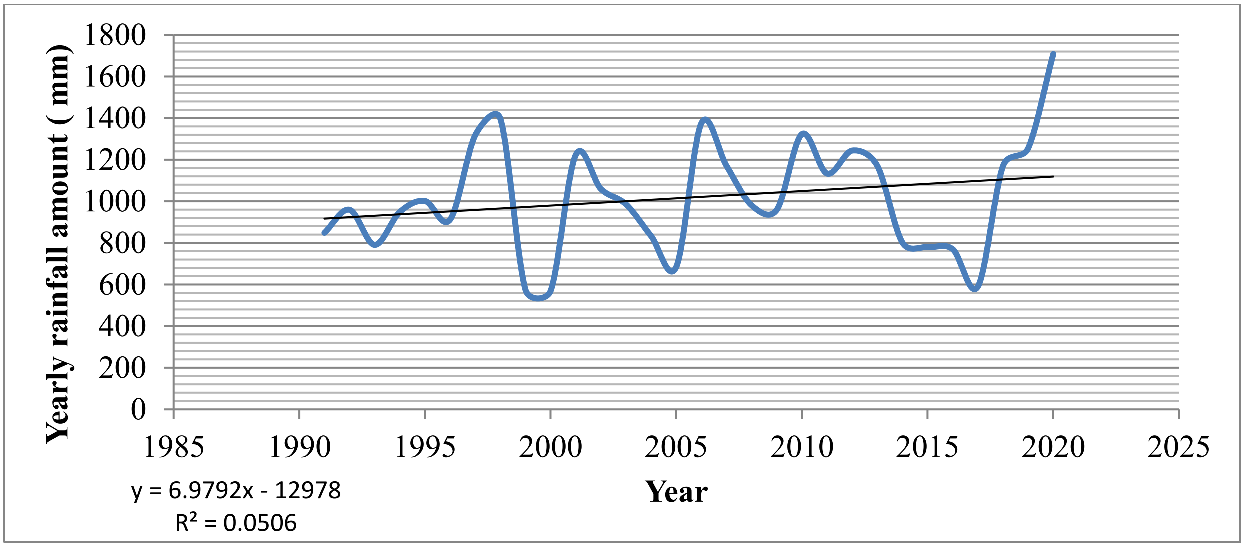
total amount of rainfall over the years (y=6.9792x-12978, R^2 = 0.0506).

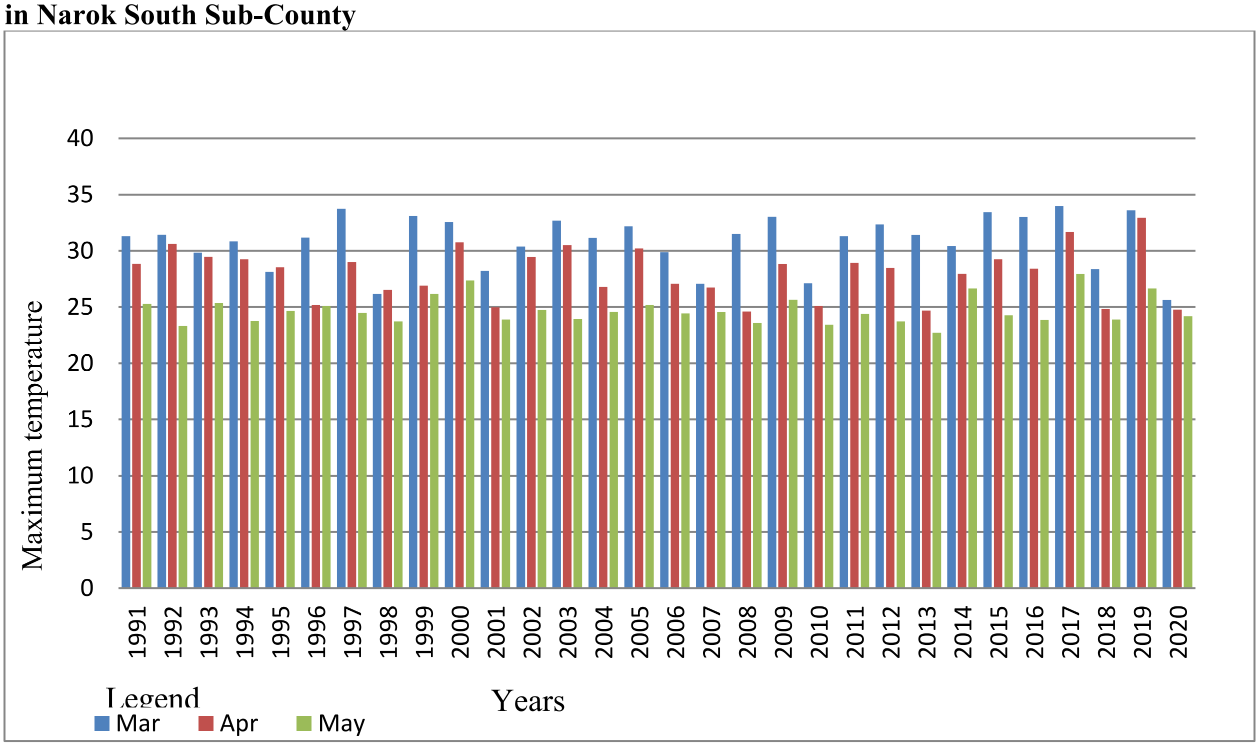
Figure 3: Total Annual Rainfall from 1991-2020 in Narok South Sub-County



Source: *Google data access viewer- NASA power website 2022*

On temperature analyses, across March from 1991 to 2020, the highest temperature achieved was 33.9ºC in the year of 2017. This temperature was quite high for the ecological requirements of Irish potato growth. The year 2020 received the lowest maximum temperature of 25.64ºC (Figure 4).

Figure 4: Specific Study Area Maximum Temperature in March, April, and May between 1991-2020 in Narok South Sub-County



Source: *Google data access viewer- NASA power website 2022*

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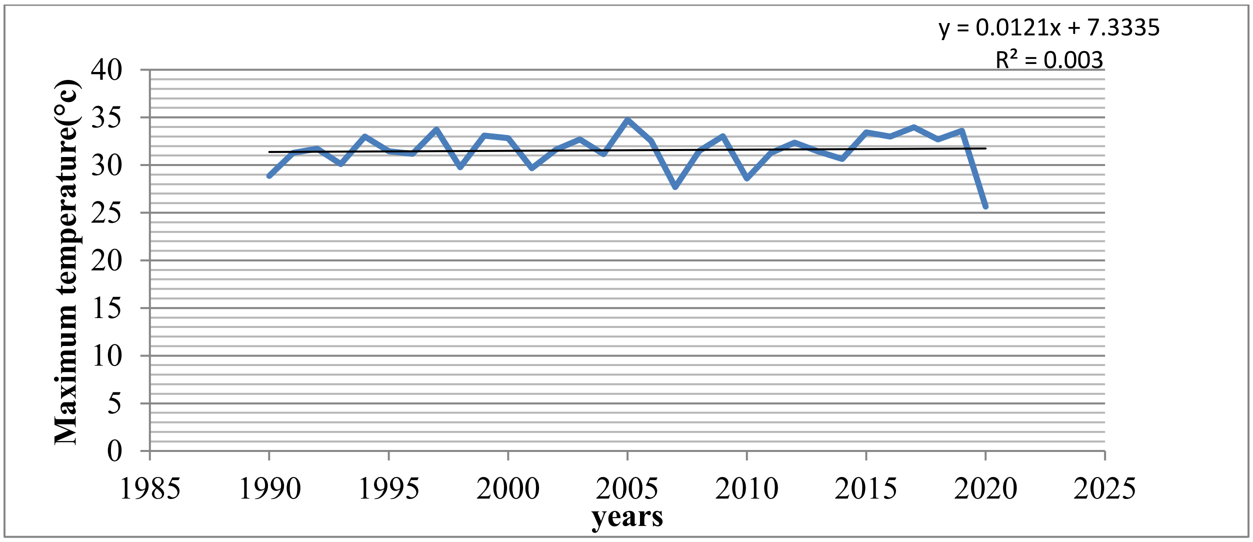
Annual maximum temperature, according to Figure 5, within Narok South sub-county has been experiencing fluctuation over the period from 1991-2020. The highest average annual maximum temperature was experienced in the year 2005 with a Maximum temperature of 29.3ºC. This average temperature was high and was not favourable for Irish potato growth and development. Similarly, the lowest average annual Maximum temperature was experienced on the year 2020 with the lowest Maximum temperature of 25.64ºC. This average temperature was favourable for Irish potato production. Linear regression analysis shows a gentle increase in the total maximum temperature over the years ($Y=0.0121x+7.3335$, $R^2=0.003$).

Figure 5: Maximum Temperature in Narok South Sub-County from 1991-2020



Source: *Google data access viewer- NASA power website 2022*

According to Figure 6, the lowest minimum temperature observed in the month of March was year 1993, pegged at 9.0ºC, while the highest monthly minimum temperature observed in March was in the year 2019, with 12.41ºC. During April, the highest minimum temperature was observed in the year 2019 with 12.69 ˚C, while the lowest minimum temperature was in the year 2001 with 9.64˚C. Similarly, in the month of May, the lowest minimum temperature observed was in the year 1997 with 8.25 ºC, while the highest minimum temperature was observed in the year 1991 with 11.81˚C. Minimum temperature below 9.0ºC is not favourable for Irish potato production (NPCK, 2021).

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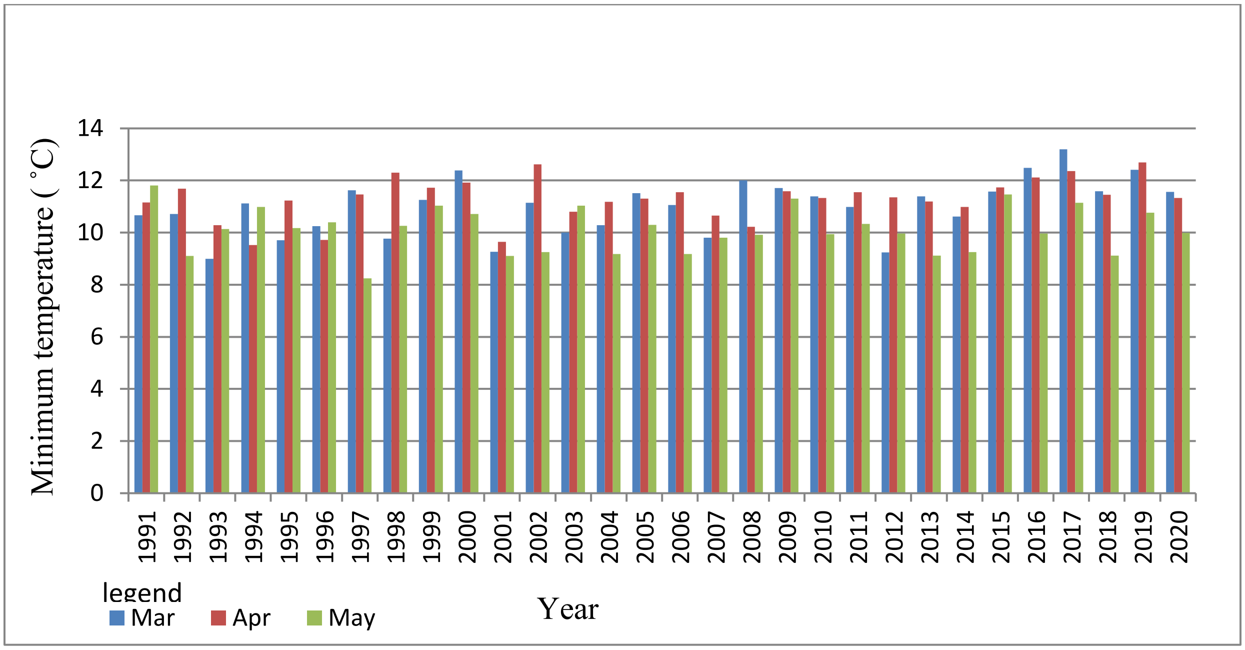
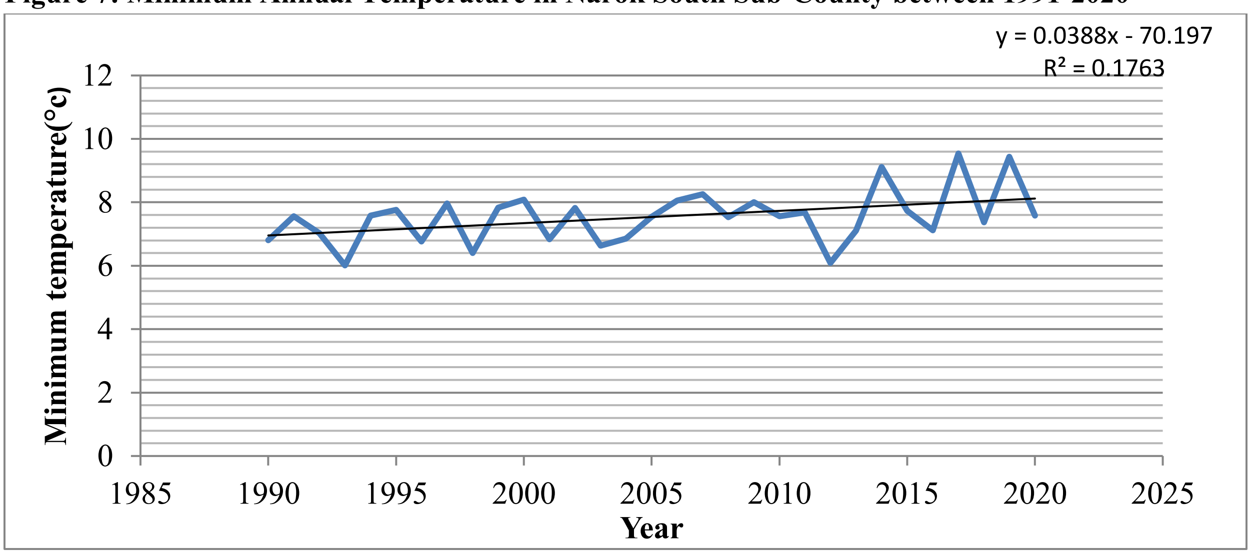
Figure 6: Minimum Temperature (March, April, and May) in Narok South Sub-County



Source: *Google data access viewer- NASA power website 2022*

Minimum annual temperature analysis according to Figure 7 within Narok South sub-county has been experiencing fluctuation over the period from 1991-2020. The highest average annual minimum temperature was experienced on the year 2019 with a minimum temperature of 9.44ºC. Similarly, the lowest average minimum annual temperature was experienced on the year 2012 with the lowest minimum temperature of 6.09ºC. This temperature range is optimum for Irish potato production. Linear regression analysis shows a gentle decline of the total annual minimum temperature over the years ($Y=0.0388x-70.197$, $R^2=0.1763$).

Figure 7: Minimum Annual Temperature in Narok South Sub-County between 1991-2020



Source: *Google data access viewer- NASA power website 2022*

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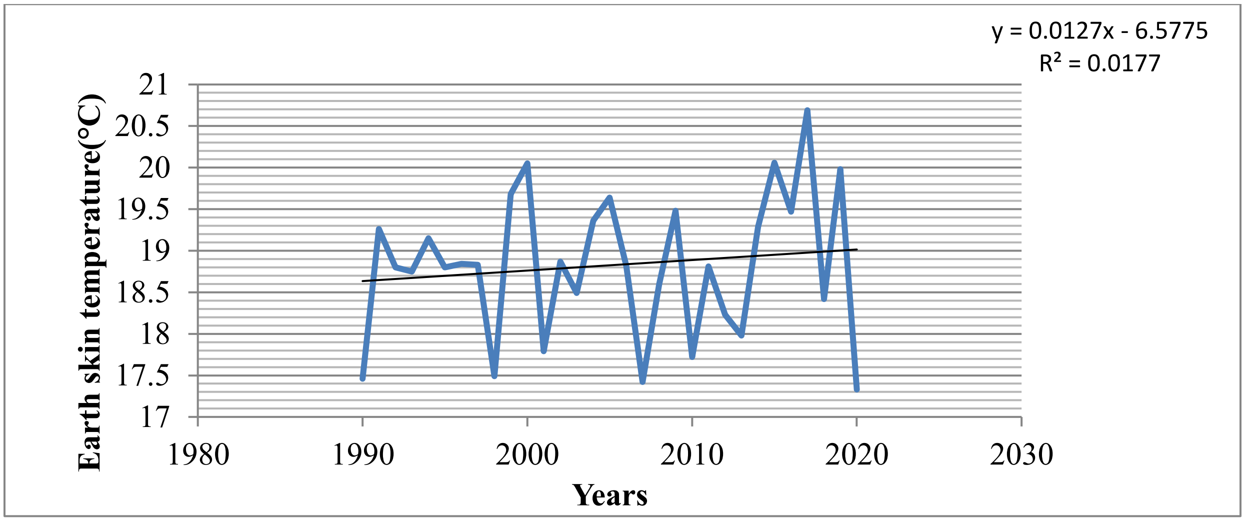
According to Figure 8, on analysis of Earth skin temperature within Narok South sub-county, the sub-county has been experiencing Earth Skin temperature variability over the period from 1991-2020. The highest average annual Earth Skin temperature was experienced on the year 2017 with an Earth Skin temperature of 20.69ºC. This high Earth skin temperature scotches Irish potatoes, leading to the greening effect and therefore compromising the quality (KALRO, 2021). Similarly, the lowest average annual Earth skin temperature was experienced on the year 2020 with an Earth skin temperature of 17.33ºC. The Earth's skin temperature is ideal for potato development. Linear regression analysis shows a gentle decline of the Earth's skin temperature over the years (Y=0.0127x-6.5775, R^2=0.0177).

Figure 8: Skin Earth Temperature in Narok South Sub-County from 1991-2020



Source: *Google data access viewer- NASA power website 2022*

Irish Potato Production against Rainfall in Narok South Sub-County

According to Figure 9 increase in rainfall increased Irish potato production per acre. Similarly, a reduction in rainfall also resulted in a decrease in Irish potato production per acre. In the year 1997, average rainfall was 109.6 mm, while Irish potato production per acre was 10.4 tonnes per acre. In the year 2000, when there was depressed rainfall, Irish potato production also dropped significantly to 6 tonnes per acre. In the year 2019, the rainfall amount started to increase than in other years. Likewise, Irish potato production rose steadily up to a certain level. By 2020, when rainfall continued to increase, Irish potato production per acre started to decrease. This may be attributed to an increase in late blight disease (*Phytophthora infestans*) as well as waterlogging in the soils. Late blight disease increases with an increase in humidity in the air, and this significantly reduces Irish potato yields (Karanja, 2013). Moreover, excessive rainfall, especially during the tuberization period, leads to tuber rotting due to excess soil moisture, causing poor soil aeration, leading to root damage and consequently limiting crop development and yield (Ambrose *et al.,* 2013; Karanja, 2013).

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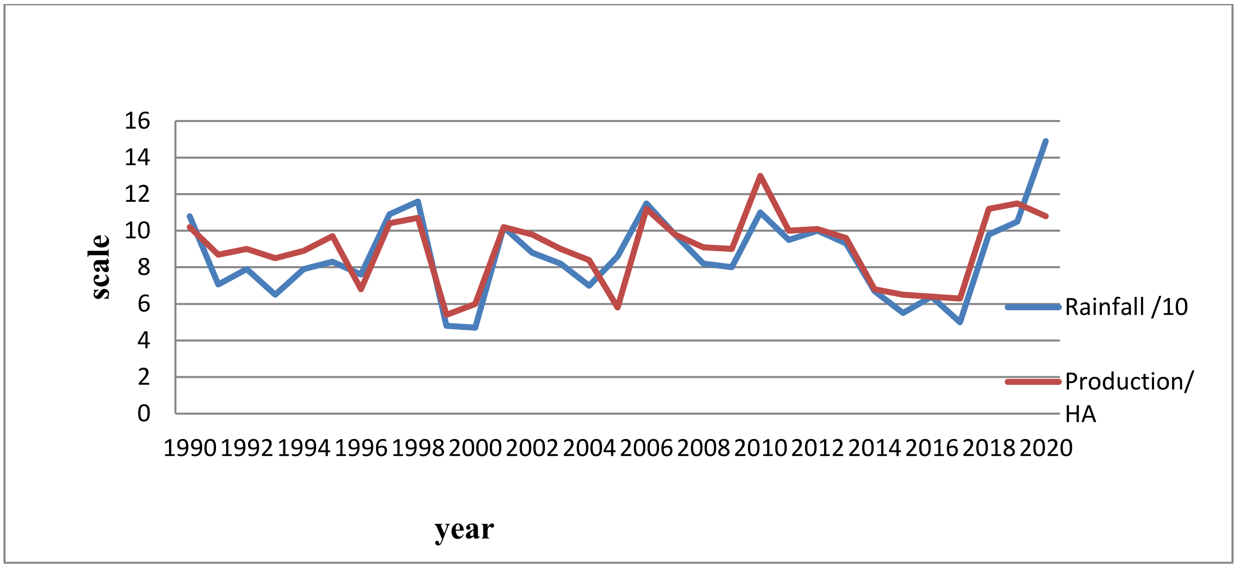
Figure 9: Rainfall and Irish Potato Production trend for Narok South Sub-County from 1991-2020



Source: *Narok South Sub-County Agricultural Office, Irish potato production database and Google data access viewer- NASA power website 2022*

Irish Potato Production against Temperature in Narok South Sub-County

Irish potato productions require cool climatic conditions with an optimum earth skin temperature range of 15°c – 20°C. During tuberization temperature requirement is pegged at 15°C. (JICA, 2022; Gildemacher, 2006; Daniel, 2009; CIP, 2021). According to Figure 10, Irish potato production in Narok South sub-county, the Earth's Skin temperature was within the range of 15°c – 20°C, and it's only in 2017 that the temperature exceeded 20.69°C. During this year, Irish potato production also decreased in production per acre.

According to the study, the maximum average temperature at 25°c, and Earth's Skin temperature at 17°c, and the minimum average temperature at 9°c. There is high Irish potato production in Narok South sub-county. Above or below these three temperature variations, the production is significantly affected. For example, on year 1990 maximum average temperature was 25.6°c, Earth skin temperature 17.5°c and minimum average temperature was 9.39°c the production of Irish potato per hectare was high 10.2 tonnes per hectare, similarly on 1998 when maximum temperature dropped to 25.1°c, minimum temperature was 9.75 °c and Earth skin temperature was 17.49°c, Irish potato production per acre was also high at 10.4 tonnes per hectare.

Likewise, when temperatures dropped below these points, as in the case of 2010, where the maximum average temperature dropped to 25.3°c, the minimum average temperature was at 9.74°c and the Earth's skin average temperature was 17.7°c. Irish potato production per hectare increased to 13 tonnes per hectare. Similarly, in the year 2005, when the maximum average temperature increased up to 29.3°c, the minimum average temperature at 9.71°c and Earth's skin average temperature at 19.64°C, average Irish potato production also dropped to 5.8 tonnes per hectare.

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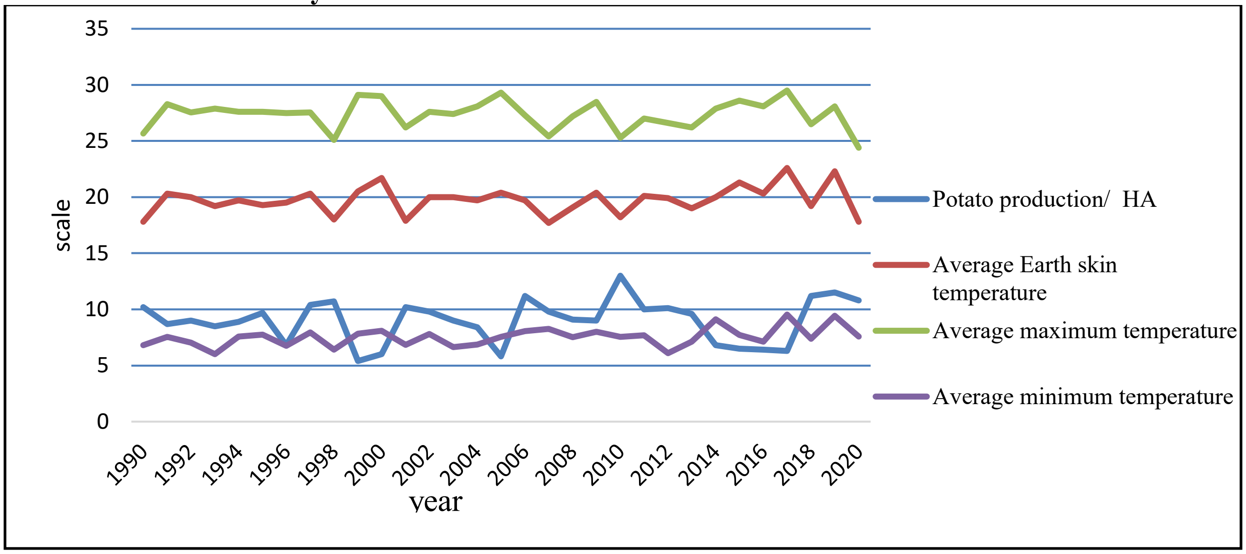
Figure 10: Maximum, Minimum, and Earth Skin Temperatures against Irish Potato Production in Narok South Sub-County from 1991-2020



Source: *Narok South Sub-County Agricultural Office, Irish Potato Production database, and Google data access viewer- NASA power website 2022*

CONCLUSION

From the study, the findings show variation in rainfall and temperature over the years. This variation also led to variation in Irish potato production. There is a high indication that Irish potato production is significantly affected by variation of rainfall, followed by maximum and skin Earth temperatures, while minimum temperature has a low effect. This production variation at farm levels leads to unpredictable weather patterns, and therefore, farmers are unable to make informed decisions on Irish potato production. However, there is an indication of both positive production trends as well as negative production trends, and therefore, farmers producing Irish potatoes should continue producing since there is a production balance.

Recommendations

There has been evidence of unreliable and irregular rainfall as well as temperatures, and these affect the Irish potato production cycle, including ploughing, sowing, weeding, pest and disease control, as well as harvesting dates. It is from this background information that this study recommends that the agricultural extension agents, together with the Kenya Meteorological Department, should endeavour to inform and train farmers on the use of modern geographical information technologies. Moreover, farmers should be encouraged to intercrop Irish potatoes with other food crops to cushion them against climate change and variability. This will not only increase food security within their households but will also equip them with up-to-date information and therefore help them make informed decisions on Irish potato production.

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