Analysing the Impact of Precipitation and Temperature on Cassava and Cocoa Crop Yields in Ondo State

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ABSTRACT

The impact of rainfall and temperature on agricultural crop production, especially cocoa and cassava in Nigeria, has significant implications for yield, poverty, access to food, and the sustainability of farming as a livelihood. This study investigates the influence of temperature and rainfall on cocoa and cassava yield in Ondo State, Nigeria, from 1991 to 2020. The annual crop yield data for cocoa and cassava for the entire 30-year period were sourced from the Ministry of Agriculture, Ondo State. Data for the key climate variables, temperature (maximum and minimum), and rainfall, were obtained from the Nigeria Meteorological Agency (NIMET). Initially, a line graph was employed to visualize trends in rainfall, temperature, cocoa, and cassava. Subsequently, the data was subjected to K-Means clustering analysis, to partition rainfall, maximum and minimum temperature into distinct and meaningful groups, or cluster, based on the similarities between the years – identifying patterns and structures to reveal hidden relationships and groupings among the years. The collected yield datasets were further grouped by the cluster, an analysis of variance (ANOVA) was further performed to test the influence of each weather variables has on cocoa and cassava yield. The trend analysis revealed that Ondo State experienced minimal temperature fluctuations between 1991 and 2020, while rainfall and cassava exhibited distinctive fluctuations. The results confirmed the significant impact of temperature and rainfall on cocoa and cassava yield.

Keywords: Unsupervised Machine Learning, Cocoa yield, Cassava yield, Precipitation, Temperature.

INTRODUCTION

Background of the study

Weather and climate have become a recurrent subject of global deliberation in recent times. The intensity of the deliberation is on the increase due to the enormity of the challenge posed by the phenomenon, especially in the third world. Though the threat of climate change and weather is universal, agricultural production activities are more vulnerable than other sectors. The impact of climate change and weather on the Nigerian agricultural sector is of particular interest to policymakers, because agriculture is a key sector in the economy accounting for between 60-70% of the labor force and contributing about 40% to the GDP. A prevailing viewpoint within the scientific community suggests that in the forthcoming years, our planet is set to experience elevated temperatures and shifts in precipitation patterns. These changes are anticipated to result in diminished agricultural yields and subpar crop production. Substantial evidence indicates that climate change and weather patterns have already begun to exert a notable influence on crop yields across numerous nations (IPCC, 2007; Deressa et al., 2008). This holds especially true for less economically developed nations, where climatic conditions serve as the chief determinant of agricultural productivity, and the ability to adapt to these changes remains limited (SPORE, 2008; Apata et al., 2009). Numerous African nations, such as Nigeria, heavily reliant on weather-dependent agricultural production systems, are notably susceptible to the impacts of climate change and shifting weather patterns (Anselm and Taofeeq, 2010). The susceptibility of these regions has been starkly illustrated by the severe consequences of recent floods in

Nigeria's Niger Delta area and the persistent droughts afflicting parts of the Northern region. Consequently, in many economically challenged countries like Nigeria, which are exceptionally sensitive to the impacts of climate change and weather, gaining insights into farmers' reactions to climatic variations is of paramount importance. This understanding is essential for devising effective coping strategies. Extensive research has already been undertaken to explore the potential ramifications of climate change and weather on agricultural productivity (Lobell and Burke, 2008 and Deressa and Hassan, 2010). These studies endeavor to bridge the gap by integrating cutting-edge models from various academic disciplines, such as climatology, agronomy, economics and computer science. This interdisciplinary approach aims to forecast and predicting the forthcoming effects of climate change and weather on agriculture, and the resulting consequences for population growth. Several notable studies, including those by Kane et al. (1992), Rosenzweig et al. (1993), Rosenzweig & Parry (1994), Reilly et al. (1996), and Ayinde et al. (2010), have harnessed climate-induced alterations in crop yields to gauge potential global economic consequences. Other studies have explored the indirect ramifications on economic variables, such as farm revenue and income, as seen in works by Mendelsohn et al. (1994) and Adams et al. (1998). Given Nigeria's geographical location predominantly within the lowland humid tropics, the nation generally experiences a consistently high temperature regime throughout the year. Maximum temperatures in the southern regions typically range from 30°C to 32°C, while in the northern areas, they tend to be between 36°C and 38°C. Furthermore, Nigeria's diverse climate has given rise to six distinct vegetation zones: the Mangrove swamps, saltwater and freshwater swamps, tropical lowland rainforests, Guinea savanna, Sudan savanna, and Sahel savanna. From a water balance perspective, Nigeria encounters substantial spatial and temporal variations in rainfall, with relatively less fluctuation in evaporation and over-transpiration. As a result, rainfall stands as the most pivotal element of Nigeria's climate, serving as a critical gauge for assessing the country's agricultural and water resources, as noted by Ben et al. (2021). According to the projections of the Intergovernmental Panel on Climate Change (IPCC) in 2007, the humid tropical zone in southern Nigeria, already characterized by high heat and abundant rainfall, is expected to witness increases in both precipitation, especially during the peak of the rainy season, and temperature. In fact, temperature increases of approximately 0.2°C to 0.3°C per decade have already been observed in various ecological zones across the nation, while persistent drought has plagued the Sudan-Sahel regions, particularly since the late 1960s. For the tropical humid zones of Nigeria, an anticipated increase of about 2% to 3% in precipitation for each degree of global warming may be expected. Consequently, precipitation is likely to rise by approximately 5% to 20% in the very humid areas of the forest regions and the Southern Savanna regions. The temperature rise in these areas may also elevate evaporation rates, potentially offsetting the gains from increased precipitation. All these changes significantly impact food crop cultivation and, subsequently, influence the availability of agricultural produce. Given that agriculture is highly dependent on climate conditions, any shifts in the climate are bound to affect the sector and other socio-economic activities. These impacts could be either positive or negative. As outlined by the National Bureau of Statistics (NBS) in 2006, the major crops in the Southeast rainforest zone of Nigeria are Cassava, Yam, and Maize, with Cassava being the most crucial staple food. Despite Nigeria's substantial Cassava production, it primarily takes place on small farms, often in fields designated for fallow periods or even on marginal soils, replacing crops that demand greater soil fertility, as indicated by FAO and IFAD in 2005. In fact, Africa accounts for 62% of the total global Cassava production, and Nigeria stands out as the largest producer in the world, contributing roughly 19% to the global market share, according to FAO. In 2002, the southeast region emerged as the second-highest producer of Cassava per capita, with 0.56 tons per person, following the North Central region with 0.72 tons per person. Notably, significant progress has been made in Cassava farming, processing, and marketing, both at domestic and commercial scales. These achievements have been facilitated by the introduction of improved varieties and increased crop areas, supported by various programs from organizations such as the International Institute of Tropical Agriculture (IITA), National Root Crops Research Institute (NRCRI), Root and Tuber Expansion Program (RTEP), Agricultural Development Program (ADP), Federal Ministry of Agriculture, and the launch of the presidential initiative on Cassava in 2003, among others, as highlighted by Sanni et al. (2009). Cassava and cocoa are two agricultural products that have felt the impact of the ongoing climate changes in Nigeria. Therefore, it is imperative that we continue to scrutinize the effects of these climate variations on these essential food crops, cocoa and cassava, despite the wealth of existing research in this area.

Statement of the problem

The dynamics of climate change and weather variability are issues that deeply resonate with humanity (Haider and Hama, 2019). The recurring specters of droughts and floods cast ominous shadows over the livelihoods of billions, particularly those heavily reliant on the land for their sustenance. The global economic landscape finds itself persistently marred by the capricious disruptions caused by extreme events like droughts, floods, cold and heat waves, forest fires, and landslides. Even nature's tempestuous acts, such as earthquakes, tsunamis, and volcanic eruptions, though not directly tied to weather anomalies, hold the power to alter the very composition of our atmosphere. Amid these multifaceted challenges, agriculture stands as one of the primary recipients of the capricious and transformative forces of climate. The intricate dance between climate change and weather patterns has long been a defining factor in agricultural production, with a pronounced impact on essential crops like cassava and maize. The persistent metamorphosis of climatic patterns has sparked a burgeoning array of research endeavors and has spurred international concern, resulting in a growing body of knowledge dedicated to unraveling the intricate relationship between climate change, weather, and their far-reaching impacts. Within the unique tapestry of Nigeria's climate landscape, an unceasing need for continuous research arises to grapple with the diverse influences and predicaments confronting the country's agriculture and food production. This study, therefore, assumes the mantle of investigating the profound influence of climate change and weather on vital food crops, with a particular focus on the resilience of cocoa and cassava in the face of these formidable challenges (Thornton, et al., 2014).

Justification and significance of the study

Nigeria presently holds the distinction of being the foremost producer of cassava and ranks highly in cocoa production. Consequently, understanding the deterministic influence of climatic conditions on the production of these two crops assumes immense significance. Such insights have the potential to not only bolster their production but also safeguard them against the capricious variations in climate. The outcomes of this study, therefore, promise to furnish farmers and relevant authorities with invaluable data and adaptive strategies to counter the challenges precipitated by climate change and weather, furthering the pursuit of Sustainable Development Goals. This study delves into a profoundly critical facet of agricultural production, examining the profound ramifications of climate change and weather. In the current global landscape, the Sustainable Development Goals (SDGs) aim at the pivotal task of reducing poverty and insecurity, and it's imperative to acknowledge that climate change and weather phenomena are significant contributors to these challenges. The cultivation of food crops has been, and will continue to be, subject to the capricious influence of climate change and weather. Therefore, it remains of paramount importance that we engage in a continuous series of studies to unravel the intricate web of impacts that climate change and weather patterns weave upon agricultural food production, particularly concerning vital staples like cocoa and cassava (Christopher, et al., 2020).

Aim and objectives.

The major aim of this study is to determine the impact of rainfall and temperature, and to identify weather patterns on cocoa and cassava yield in Ondo state.

Objectives

The specific objectives are to;

1. To investigate the trend of rainfall and temperature over Akure.
2. Cluster the years or regions based on weather variables to identify distinct weather patterns.
3. Analyse the relationship between cassava yield and the identified weather patterns.
4. Provide recommendations for cassava farming practices based on the analysis.
5. Identify which weather patterns are associated with higher cassava yield.
6. Create clear and informative visualizations and reports to communicate the results to stakeholders.

Scope of the study.

The Earth's climate has varied considerably in the past, as shown by the geological evidence of ice ages and sea level changes, and by the records of human history over many hundreds of years. The causes of past changes are not always clear but are generally known to be related to changes in ocean currents, solar activity, volcanic eruptions and other natural factors. The difference now is that global temperatures have risen unusually rapidly over the last few decades. There is strong evidence of an increase in average global air and ocean temperatures, widespread melting of snow and ice, and rising of average global sea levels. The IPCC Fourth Assessment Report concludes that the global warming is unequivocal.

Atmosphere and ocean temperatures are higher than they have been at any other time during at least the past five centuries, and probably for more than a millennium. Scientists have long known that the atmosphere's greenhouse gases act as a blanket, which traps incoming solar energy and keeps the Earth's surface warmer than it otherwise would be, and that an increase in atmospheric greenhouse gases would lead to additional warming.

Considering the world population and the rate of food production, it must be stated that the agricultural and food-distribution systems may be further stressed by shifting of temperature and precipitation belts, especially if changes are rapid and not planned for see, for example, Adams et al. (1990). Therefore, it is necessary that a study such as this that will proffer a solution to a major threat like climate change and weather to food production.

LITERATURE REVIEW

Theoretical framework

Climate change and weather with agriculture are inextricably linked. Agriculture still depends fundamentally on the weather. Climate change and weather has already caused a negative impact on agriculture in many parts of the world because of increasingly severe weather patterns. Climate change and weather is expected to continue to cause floods, worsen desertification and disrupt growing seasons. The Food and Agriculture Organization (FAO) warns that an increase in average global temperatures of just two to four degrees Celsius above pre-industrial levels could reduce crop yields by 15-35 percent in Africa and western Asia, and by 25-35 percent in the Middle East. An increase of two degrees alone could potentially cause the extinction of millions of species.

Agricultural practices also exacerbate climate change and weather. The Intergovernmental Panel on Climate change and weather (IPCC) says that agriculture contributes 13.5 percent of global greenhouse gas emissions (2004). According to Greenpeace, if calculating both direct and indirect emissions from the food system, agriculture's contribution could be as high as 32 percent. (Greenpeace includes all related activities; in addition to agricultural production, they add land use, transportation, packaging and processing.) The future of agricultural production relies on both designing new ways to adapt to the likely consequences of climate change and weather, as well as changing agricultural practices to mitigate the climate damage that current practices cause, all without undermining food security, rural development and livelihoods. This is a huge undertaking. Climate change and weather and food security are related because climate change and weather can directly affect a country's ability to feed its people.

Agricultural production remains the main source of livelihood for most rural communities in developing countries. In sub-Saharan Africa in particular, agriculture provides a source of employment for more than 60% of the population and contributes about 30% of the Gross Domestic Product (GDP) (Ayinde, et al., 2011). In addition, agriculture provides an important source of export earnings, accounting for 16% of the total exports in sub-Saharan Africa (47% of total exports in East Africa, 14% in southern Africa and 10% in West Africa) (IAC, 2004; Dixon et al., 2001). Agricultural production in Africa is vulnerable to climatic conditions due to a number of reasons:

1. Most parts of the continent are already experiencing very high temperatures;
2. Most farmers depend on the quality of rain and production is mainly subsistence; and
3. Most parts of the continent are already water stressed (IPCC, 2001).

African farmers and systems have adapted in many ways to climate change and weather through, for example, growing multiple crops, mixing crops and livestock, and using irrigation (Kurukulasuriya & Rosenthal, 2003). With respect to the main goals of the study, this chapter presents an overview assessment of the African climate and how it influences agricultural production in major farming systems.

African climate and agricultural potential

According to the IPCC (2001), most parts of Africa are mainly tropical and experience hot and dry conditions. Temperate climatic conditions are found in the extreme south and north, and at high altitudes in between. Humid conditions are experienced in parts of West Africa, including the western part of Central Africa, throughout the year. The sub humid region covers a large area north and south of the humid central region, and experiences substantial rainfall during the wet season and almost no rain during the dry season. Semi-arid climates are located from the sub-humid region further to the poles and are characterized by extreme unreliability of rainfall. Most of the human population is located in the sub-humid and semi- arid zones (IPCC, 2001).

Scientific evidence on global warming shows that further increases in average temperatures of 1.4-5.8°C are expected in the 21st century (Berry, 1975). These increases are expected to be more harmful in tropical areas such as Africa that are already experiencing very high temperatures. Most climate models predict more frequent and severe extreme weather events in the tropics generally, including both localized drought and flooding. Agricultural productivity in Africa is considered being vulnerable to such extreme weather events.

An important example is the increased frequency of drought episodes over the last several decades, particularly in southeast Africa, that are associated with the El Niño Southern Oscillation (ENSO3) phenomenon. In addition, arid and semi-arid sub-regions and the grassland areas of eastern and southern Africa, as well as areas currently under threat from land degradation and desertification, are particularly vulnerable to global warming, indicating a reduced potential for agricultural activities in these regions. A reduction in rainfall projected by some climate models for the Sahel and southern Africa, if accompanied by high inter-annual variability, could be detrimental to the hydrological balance of the continent and disrupt various water-dependent socio-economic activities that include agricultural production systems (IAC, 2004).

Trends in precipitation and temperature for the African region indicate that the region is warming and getting drier. Trends in variability of temperature in Africa over the 20th century show a rising trend in observational records at a rate of about 0.05°C per decade. Much of the warming has been recorded in the June November seasons compared to the December-May seasons (Daniels et al., 2011). According to the

IPCC (2001), temperatures are expected to increase most in southern and northwest Africa at a rate of about 0.6°C to 1°C per decade and around 0.4°C in East Africa. Precipitation trends show that Africa is going to experience drier conditions, with precipitation decreasing at a rate of between 10 and 20% in southern Africa and 10 to 50% in eastern and northern parts of Africa (IPCC, 2001). These trends are expected to negatively affect agricultural productivity and food security in the region, unless precautionary adaptive measures are taken. These adaptive measures, both at the local farm level and national levels, are necessary to help reduce the potential negative effects associated with these changes in temperature and precipitation. It is difficult to establish causality between climate variability and rain- fed crop and livestock production. It is, however, true that for some countries and certain years, food production has been declining in the face of increasing temperature and decreasing precipitation regimes. The impact of these changes, in addition to other factors, is that food production in most of sub-Saharan Africa (SSA) has not kept pace with population growth over the past three decades. For example, in Africa as a whole, food consumption exceeded domestic production by 50% in drought-prone areas in the mid-1980s and by more than 30% in the mid-1990s (WRI, 1998). This has left many countries in Africa being net food importers, with food aid constituting a major proportion of net food trade in the region. For instance, food aid constituted two-thirds of food imports during the 1990s in Kenya and Tanzania (IPCC, 2001). In addition, per capita dietary needs supply (DES) remains relatively low (Hulme, 1996).

About one-third of the countries in Africa had per capita DES of less than 2000 kcal per day in the 1990s, which is lower than the minimum recommended intake of 2100 (Todd, 2004; Naiken, 2002). The results from the three graphs suggest a direct correlation between increasing temperatures, decreasing precipitation and declining food production. The implication of predicted further warming in Africa is that food production is going to be adversely affected, unless farmers use adaptation strategies, such as irrigation. It is therefore important to find ways and strategies of reducing the vulnerability and improving the adaptive capacity of African agriculture in the face of the adversities of predicted climate change and weathers.

Practical framework

In the global context, externalities are specified in terms of the distinction between polluting and victim countries. However, Mendelsohn and Dinar have examined the impacts of climate change and weather on agriculture in India and Brazil. They employed three different methods for the analysis namely; the Ricardian method, Agro-economic model and agro-ecological zone analysis. Environmental factors such as farm performance, land value or net income and traditional economic inputs which are land and labour, and support system such as infrastructure were used as explanatory variables in the model. Unlike most studies, this analysis pointed out the significance of adaptation. They argue that farmers will adapt to new conditions due to climate change and weather by making production decisions which are in their own best interest. Crop choice is one of the examples of farmers' adaptation to warmer weather in the study. Wheat, corn and rice are three crops, for example, used since the regions in which they grow depend on the temperature. As temperature gets warmer wheat farmers switch from production of wheat to corn for enhanced profit making. Later, if the temperature gets warmer again enough to lose profits, farmers adapt to warmer weather, thus switch to rice from corn. The results of the Ricardian method agro-economic model and agro-ecological zone analysis showed that an increase in temperature will decrease crop production, especially the crops grown in cool areas such as wheat. However, the authors argued that the result of the Ricardian method suggest that farmers' ability to adapt to new conditions will mitigate the impact of climate change and weather in the long run while the agro-economic model and agro-ecological zone analysis would be more suitable for short run analysis since the adaptations is not included in the models. Mathauda, Mavi, Bhangoo, and Daliwal investigated the effects of temperature change on rice yield in the Punjab region in India by using the Ceres Rice simulation model between 1970-1990. They stratified the weather scenarios by 5 different conditions which are normal weather, slight warm (0.5 increase), and extreme warm condition (2°C increase) in the simulation model. The model predicted that temperature increase decreases rice yield

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by 3.2% in slight warm, 8.2% in greater warm, and 8.4% in extreme warm condition compared to normal condition scenario. The result also showed that an increase in temperature negatively affects not only rice production but also other rice attributions such as biomass, crop duration and straw yield. Torvanger, Twena, and Romstad analyzed climate change and weather in Norway for the period 1958-2001. The study employed time series data with a biophysical statistical model to examine the dynamic linkages between yields of potatoes, barley, oats, wheat and climate change and weather variables, such as temperature and precipitation. The study found that there is a positive impact on yields from temperature in 18% of the crops. The effect is found to be strongest for potatoes. Regionally, the study revealed that temperature is likely to be a more important limiting factor for crop growth in Northern Norway than in other regions. The effect of precipitation is found to be negative in about 20% of the cases.

Basak, Ali, Islamand Rashid analysed climate change and weather impacts on rice production in Bangladash by using a simulation model. The model specifically focused on Boro rice production which amounts to 58% of the total rice production during 2008 in Bangladesh to estimate to estimate the effects of future climate change and weather, soil and hydrologic characteristics of the locations, typical crop management practices, and traditional controlled in the simulation model called DASAT (Decision Support System for Agrotechnology Transfer). The simulation results show that rice production varies in different locations for different climatic conditions and hydrological properties of soil, although same Boro rice was used in all areas. The model also indicates that rice production decreased drastically from 2.6% to 13.6% and from 0.11% to 28.7% when the maximum temperature was increased by 2°C and 4°C. Although the simulation model shows that a drop in minimum temperature also reduces the rice yield. It suggests that increases in temperature causes more damage in production. The model also found some positive effects of CO2 concentration on rice yield, but the impact was little compared to that of temperature change.

In Nigeria, Agboola and Ojeleye, examined the impact of climate change and weather in Ibadan Nigeria. The study adopted both primary and secondary sources of data. For the secondary source of data, time series data covering 30 years were collected on climatic variables and the analysis was done with bivariate Chi-square and ANOVA, supported by graphical illustrations. The study revealed that farmers have experienced reduced crop yield on food crop production due to reduction in rainfall and relative humidity, as well as increase temperature. Terfa studied “climate change and weather and food supply in Nigeria” the study adopted the use of generalized error correction model using time series data sourced from CBN statistical bulletin and world bank country data from 1970 to 2009 on variables like food output, temperature and rainfall. The study found that both temperature and rainfall had an insignificant influence on food supply and the increase in temperature leads to a decrease in food supply while an increase in rainfall leads to an increase in food supply. Eregha, Babatolu, and Akinnubi did a study titled “Climate change and weather and Crop Production in Nigeria: An Error Correction Modeling Approach” the work used time series data sourcedfrom Food and Agricultural organization Database, 2012 Central Bank Statistical Bulletin 2011 and data from World Development indicator Database 2012. The technique of analysis was done with the Error Correction technique. The data coverage was 1970-2009. The study used variables like crop output, temperature and rainfall as well as carbon emission. The study found that temperature and had a significant negative influence on crop production, while rain was found to have a significantly positive effect, while carbon emission was found to have a significant negative impact on crop production in Nigeria.

Cassava production and the environment

Cassava (Manihot esculenta) production is vital to the economy of Nigeria as the country is the world’s largest producer of the commodity. The crop is produced in 24 of the country’s 36 states. In 1999, Nigeria produced 33 million tonnes, while a decade later, it produced approximately 45 million tonnes, which is almost 19% of production in the world. The average yield per hectare is 10.6 tonnes.

In Nigeria, cassava production is well-developed as an organized agricultural crop. It has well-established

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multiplication and processing techniques for food products and cattle feed. There are more than 40 cassava varieties in use. Cassava is processed in many processing centres and fabricating enterprises set up in different parts of the country.

Originally a crop of South America, it was introduced in to Nigeria's southern part during the period of slave trade proliferated by Portuguese explorers and colonizers in the sixteenth century. However, its importance to the country got a boost in the late nineteenth century when more formerly enslaved Nigerians returned to their homeland and introduced processing techniques. Over the years, it has become a major economic sustenance crop and it has attained the status of the largest producer in the world with a recorded production of 34 million tonnes and is a cash crop of great importance to the people of Nigeria.

Historically, many scholars have asserted that cassava depletes the soil. For example, Hendershott et al., reported that cassava is well known not only for producing large quantities of carbohydrate but also for exhausting the soil (1972, p.60). Similar assertions have been made by Davesne (1950), Irvine (1953) and Grace (1977). Soil fertility is a subject of major importance in a discussion of expanding food production in Africa (IITA, 1998). Human-induced land degradation is severe in Africa. Numerous researchers claim that a lack of replenishment of nutrients is leading to rapid deterioration in soil fertility. Fertilizer use is low because of high transport costs, late delivery and the risks associated with food production in marginal areas (Pinstrup-Anderson et al., 2000). To test the hypothesis that cassava depletes the soil, COSCA researchers collected soil samples from 1 501 fields planted with staple crops in 281 villages in the cassava growing areas of the Congo, Côte d'lvoire, Ghana, Nigeria, Tanzania and Uganda. The soil samples collected over the 1991 to 1992 period revealed that the amount of clay, silt and sand did not differ between cassava fields and the levels found in the fields of other crops20. In fact, soils of cassava fields were higher in total N, organic matter, Ca, Na, TEB, ECEC and pH21.

A twenty-year cassava yield-experiment conducted by S. K. Hahn at IITA's high rainfall station at Ibadan in the transition zone from the early 1970s until the early 1990s found that the yield dropped significantly from an average of 40 tons per ha during the first four years and then stabilized at around 20 tons per ha from the fifth to the twentieth year. Cassava was grown every other year in a two-year rotation without chemical fertilizer. Hahn concluded that cassava produces a large amount of foliage which is recycled as manure to the soil. Hahn's landmark twenty-year study shows that cassava yields are sustainable under continuous cultivation. The COSCA soil survey and Hahn's twenty-year yield experiment provide evidence that the assertion that cassava depletes the soil is a half-truth. The myth of cassava being a soil depleting crop may be attributed to the fact that cassava is widely grown in the forest zone where high rainfall and sandy soil accelerate organic matter decomposition, leaching and soil erosion at a faster rate than in the transition and the savannah zones22. For example, an eight-year experiment in the forest zone of Ghana revealed that cassava yields declined under a continuous rotation of cassava and maize with fertilizer. In the transition zone, a similar experiment was carried out without the application of fertilizer and cassava yields declined but at a slower rate than in the forest zone (Nye and Greenland, 1960 cited in Odurukwe and Oji, 1981).

The myth of cassava as a soil degrader has been used to downgrade cassava's role as an environmentally friendly crop. Cassava cultivation entails minimal soil disturbance, especially in light soils which are susceptible to wind or water erosion. Cassava is normally grown on flat land in sandy soils and on ridges and mounds on heavy lateritic soils (Hahn, 1984). The plant provides soil cover so long as it grows; as a semi-perennial, it does not shed all its leaves with senescence. As a semi-perennial, cassava plants serve as a planted fallow. Although there are places, especially high population density and market centre areas, where cassava is harvested from six to 12 months after planting, the normal time of harvest is 12 months or more. The cassava plant protects the soil by providing cover and recycles nutrients by shedding old leaves as it grows.

To summarize, in Africa, increased production of cassava will not lead to environmental degradation because, contrary to conventional wisdom, cassava does not deplete the soil more than any other crop. Cassava is often grown on flat seedbed with minimum tillage. It produces a large amount of foliage which is recycled as soil nutrient. As a semi-perennial crop, cassava provides year-round soil cover (Deosthali and Chandrahekkar, 2004).

Cassava has been described as a women's crop by some scholars (El-Sharkawy, 2003; Fakayode et al., 2008). For example, Fakayode et al., (2008) found in the Abakaliki area of southeast Nigeria that women owned more cassava fields than men and concluded that cassava is a women's crop. COSCA researchers collected data from six countries and found that the categorization of cassava as a women's crop is a misleading half-truth that is based on anecdotal evidence and isolated village studies. The COSCA studies show that the proportion of the household cassava field area (hereafter field) owned by women ranged from 4 percent in the Congo to 24 percent in Côte d'Ivoire23. By contrast, the proportion of cassava fields owned by men ranged from 15 percent in Côte d'Ivoire to 72 percent in Uganda and 81 percent in Nigeria. Joint ownership by both men and women account for the balance of the percentages in each country. There is an important exception in tree crop-dominated rural economies. Among the six COSCA countries, women in Côte d'Ivoire owned a higher proportion of the cassava fields than men. In Côte d'Ivoire and in most other tree crop dominant-farming systems, the men concentrate on producing tree crops such as cocoa and coffee. Hence, although there are specific locations in certain countries where women owned more cassava fields than men (Deji et al., 2017; Eke-Okoro and Njoku, 2012), these locations are exceptions and not the norm. Cassava production in the country has been increasing for the past 20 or more years. A recent survey of the cassava-growing areas shows that in more than 90 percent of the 65 representative villages, the farmer group respondents reported an increasing trend in cassava production over the 20 years prior to the interview in 1989 (Gilbert and Morgan, 2010). Further analysis of the available production data shows that, on the average annual basis, the harvested land area was over 80 percent higher in 1990-1993 than in 1974-1977. Both the yield and of course, the overall production showed a similar trend. Total production at present is estimated at over 34 million tons. With this production level, Nigeria is the largest producer of cassava in the world.

Cassava production was reported to be increasing among villages where cassava, yam, rice, beans or peas were the most important crops (based on farmers' ranking) in the cropping system (Ugwu, 1996). This implies that cassava was replacing these major crops, including fallow and pasture land in those villages.

Cassava production was reported to be declining in less than 10 percent of the representative villages for reasons connected with losses from livestock (mainly from cattle), pests and diseases, and/or declining soil fertility. Unless fenced round, which is prohibitive considering the relatively low value of the crop, cassava fields could be destroyed by cattle, especially during the dry season when pasture is scarce. The villages with declining production trend were mostly located in the non-humid climate zone. Where soil fertility is low in this zone with short rainfall duration, farmers with a limited supply of fertilizer would prefer to grow short duration crops such as millet or sorghum. Reasons adduced for the increasing trend by the farmer group respondents were rapid population growth and market demand. These two factors are related, since rapid population growth tends to increase market demand. The proportion of villages where cassava was increasing was significantly higher in the high population density zone (95 percent) than in the low population density zone (65 percent) (Ugwu, 1996). This agrees with the "contention that comparison between cassava growing environments and actual cassava distribution in Ghana and Nigeria demonstrates that the distribution of cassava could be primarily a function of population density rather than of agro-ecological considerations" (*William, 2010*).

In Nigeria, cassava production is well-developed as an organized agricultural crop. It has well-established multiplication and processing techniques for food products and cattle feed. There are more than 40 cassava varieties in use. Though the crop is produced in 24 of the country's 36 states, cassava production dominates the southern part of the country, both in terms of area covered and a number of farmers growing the crop.

Planting occurs during four planting seasons in the various geo-ecological zones. The major states of Nigeria which produce cassava are Anambra, Delta, Edo, Benue, Cross River, Imo, Oyo, and Rivers, and to a lesser extent, Kwara and Ondo. In 1999, Nigeria produced 33 million tonnes. As of 2000, the average yield per hectare was 10.6 tonnes. Cassava is grown throughout the year, making it preferable to the seasonal crops of yam, beans, or peas. It displays an exceptional ability to adapt to climate change, with tolerance to low soil fertility, resistance to drought conditions, pests, and diseases, and suitability to store its roots for long periods underground even after they mature. Use of fertilizers is limited, and it is also grown on fallow lands. Harvesting of the roots after planting varies from 6 months to 3 years. The land holding for farming in Nigeria is between 0.5–2.5 hectares (1.2–6.2 acres), with about 90% of producers being small-scale farms. In order to increase production, several varieties of cassava have been developed which are pest resistant; production in the country is hampered by problems with green mite, the cassava mealybug, and the variegated grasshopper. Diseases affecting cassava crop are mosaic disease, bacterial blight, anthracnose, and root rot (*Verter and Bečvářová, 2014).*

Cocoa production and the environment

Cocoa production is important to the economy of Nigeria. Cocoa is the leading agricultural export of the country and Nigeria is currently the world's fourth largest producer of cocoa, after Ivory Coast, Indonesia and Ghana, and the third largest exporter, after Ivory Coast and Ghana. The crop was a major foreign exchange earner for Nigeria in the 1950s and 1960s and in 1970 the country was the second largest producer in the world but following investments in the oil sector in the 1970s and 1980s, Nigeria's share of world output declined. In 2010, cocoa production accounted for only 0.3% of agricultural GDP. Average cocoa beans production in Nigeria between 2000 and 2010 was 389,272 tonnes per year rising from 170,000 tonnes produced in 1999 (Hauser, 2014).

The earliest cocoa farms in Nigeria were in Bonny and Calabar in the 1870s but the area proved not suitable for cultivation. In 1880, a cocoa farm was established in Lagos and later, a few more farms were established in Agege and Ota. From the farms in Agege and Ota information disseminated to the Yoruba hinterland about cocoa farming, thereafter, planting of the tree expanded in Western Nigeria. Farmers in Ibadan and Egba land began experimenting with planting cocoa in uncultivated forests in 1890 and those in Ilesha started around 1896. The planting of cocoa later spread to Okeigbo and Ondo Town both in Ondo State, Ife and Gbongan in Osun State and also in Ekiti land. Before 1950, there were two main varieties of cocoa planted in Nigeria. The major one was Amelonado cacao, which was imported from the upper Amazon river Basin in Brazil. The second was a heterogeneous strain from Trinidad. The Amelonado pods are green but turning yellow when ripe but the Trinidad variety is red. Cocoa flourishes in areas that are not more than 20 degrees north or south of the equator. The trees respond well in regions with high temperature and distributed rainfall. In Nigeria, the cocoa tree is grown from seedlings which are raised in nurseries, when the seedlings reach a height of 3 cm, they are transplanted at a distance of 3 to 4 meters. The cultivation of cocoa is done by many smallscale farmers on farmlands of around 2 hectares, while export is dominated by a few firms. Historically, Nigeria's cocoa production was marketed through a monopsony by marketing boards created by the government. In the 1980s the World Bank and the International Monetary Fund advised Nigeria to liberalize the sector because the marketing boards were ineffective. In 1986, Nigeria dissolved the marketing boards and liberalized cocoa marketing and trade. However, trade has not yielded the anticipated results, in addition, aging trees and farms, low yields, inconsistent production patterns, disease incidence, pest attack and little agricultural mechanization has contributed to a stagnant cocoa industry. Currently, farmers sell their products indirectly through a cooperative or a licensed buying agent who in turn sell it to exporting firms. The major states that produce cocoa are Ondo, Cross River, Ogun, Akwa Ibom, Ekiti, Delta, Osun and Oyo.

Cocoa crop thrives in tropical climate and production is therefore dominated by countries in those regions, while consumption is mostly by countries in temperate regions of the world. West Africa is a major producer accounting for approximately 70% of global production which fluctuates annually with climatic variations. This is often cyclical with periods of rapid expansion followed by periods of stasis. However, overall production continues to expand with cultivation becoming more widespread. In West Africa, Nigeria is the third largest producer of Cocoa. While the crop is sometimes farmed on a large scale in Nigeria, the sector is dominated by small-scale farmers and remains a critical source of livelihood for rural populations in states where the crop is produced. In the South-west, cocoa-producing states include Ondo, Oyo, Osun Ogun and Ekiti where farmers either operate on inherited field or operate a sharecropping system in which two-thirds of the produce accrues to the land owner who also contributes to purchase of farming input.

The country is currently reported to be experiencing low and declining yields due to inconsistent production patterns, disease and pest attack. Low levels of mechanization with dependence on cutlass and hoe agriculture and ageing of cocoa fields play a role in decreased productivity, especially in southwest states that contribute nearly 80% of national cocoa yields. Although reports are conflicting, annual cocoa yields for Nigeria are generally estimated at an average of between 300 to 350,000. Reports also set production per hectare at 0.38 tonnes, but these are reported to have declined to less than 0.3 hectares, mostly due to reduced rainfall.

Problems with production according to available literature include high cost attendant to the establishment of nurseries and plantations, a dearth of market information, high levels of spoilage, low quality of beans and extremely weak linkage between producers and processor/exporters. Even with this, reports indicate that there is a positive relationship between area harvested or farm size and cocoa production in Nigeria (Fadipe et al., 2012). It is widely acknowledged that there is under-investment in agriculture, while studies have highlighted a strong relationship between cocoa out and farm size and access to finance (Fadipe et al., 2012).

Nigeria's cocoa is cultivated on (estimated) 800,000 hectares of land and makes up 5% of global cocoa production, which is contributed by an estimated 300,000 cocoa farmers, two-thirds of which live in southwest Nigeria. Majority of them inherited farms with trees that are more than 25 years old with declined production.

Prone to disease, maintenance of cocoa farms is labour intensive and requires the use of expensive chemicals to keep black pod disease at bay. Cultivation is a delicate process and trees are sensitive to changing weather conditions such as excessive rain or drought, which negatively affects yield per hectare. Osun, Ondo and Cross River states are reported to contribute approximately 68% of Nigeria's yearly cocoa output, which reached a high of 350,000 MT in 2014 when the Ministry of Trade and Industry also reported that Nigeria made $1.3 billion from cocoa export. There is however, poor price transmission between export markets and producers (Denton et al., 2004).

Yield

The Cocoa Transformation Plan of the Federal Ministry of Agriculture and Rural Development set a national target for production at 500,000 MT by 2015 and 1 million MT by 2018. This is to build on the target of 600,000 MT by 2015 set by the National Cocoa Development Committee. Between 2002 and 2007, NCDC distributed inputs for cocoa farming to farmers at 50% subsidy. The Committee also raised 62 million high yielding early maturing hybrid seedlings–enough to plant 56,000 hectares of new cocoa fields (Ofori-Boateng and Insah, 2014).

Farmers are responding to rising international market prices for cocoa and reports indicate a potential increase in production, resulting from adoption of improved production practices to meet the UTZ certification requirements. There are indications that farmers are willing to rehabilitate abandoned farms and to increase area under production. Production has however, been hampered by the inability of the Cocoa Research Institute of Nigeria to meet demand for seedlings, and utilize adequate mechanisms for distributing

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improved varieties of cocoa to farmers. Production has therefore fallen short of 2015 targets of 500,000 MT (Denning et al., 2009).

RESEARCH METHODOLOGY

Area And Population of The Study.

Ondo state was created on the 3rd of February, 1976 and it is made up of 18 Local Government Areas. The state lies between Longitude 4˚30″ and 6˚ East of the GMT, and Latitude 5˚45N and 8˚15″N of the Equator. It has land area of 15,500 km2. It is located in the Southwestern part of Nigeria (Omosuyi, et al., 2021). The climate of the state is of the tropical rainforest type, characterized by distinctive wet and dry seasons, mean annual temperature of 27˚C and mean annual rainfall of 2000 mm associated with relative humidity of not less than 70%. The natural vegetation is typical of the high forest composed of many varieties of hard timber such as Miliciaexcels (iroko), Terminaliaivorensis (black afra), Heveabrasiliensis (rubber), etc (Opeyemi, et al., 2016). Over most part of the state, the natural vegetation has been very much degraded due to human activites. Tree crops cultivated in the study area include cocoa, kola, coffee, rubber, oil palm and citrus while food crops include cassava, yam, maize, plantain, cocoyam, okro and vegetables. Large proportion of the population of the study area engages mainly in agriculture with few in the public service employment.

Agriculture is the mainstay of the economy, and the chief products are cotton and tobacco from the north, cocoa from the central part, and rubber and timber (teak and hardwoods) from the south and east; palm oil and kernels are cultivated for export throughout the state. Ondo is Nigeria's chief cocoa-producing state. Other crops include rice, yams, corn (maize), coffee, taro, cassava (manioc), vegetables, and fruits. Traditional industries include pottery making, cloth weaving, tailoring, carpentry, and blacksmithing. Mineral deposits include kaolin, pyrites, iron ore, petroleum, and coal. There is a textile mill located at Ado-Ekiti and a palm-oil processing plant at Okitipupa.

The state, primarily inhabited by the Yoruba, a people with a tradition of living in towns, has a high proportion of urban dwellers. Akure, the state capital, is rapidly developing into a commercial and industrial Centre and is the site of a federal university of technology. The Ikogosi hot spring and the historic Idanre Hills are places of interest (Omosuyi, et al., 2021).

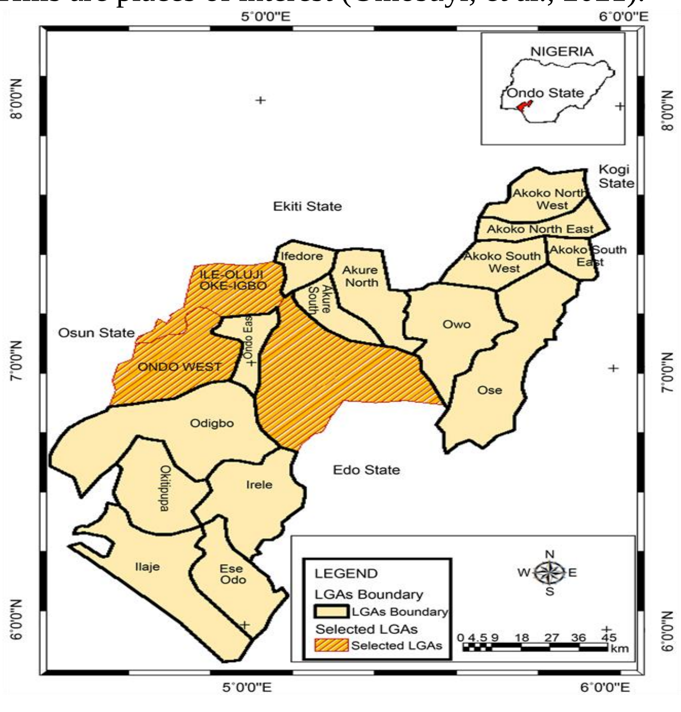

Figure 3.1: Map of the Study Area

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Data

The data used for this research was gotten from the archive of the ministry of agriculture Akure, Ondo state. Monthly rainfall data over a period of 30 years, monthly minimum and maximum temperature data over a period of 30 years, annual average data for cocoa and cassava over a period of 30 years.

Methodology.

A line chart was adopted to view the trend of rainfall and temperature over the Ondo state. Relevant weather variables were selected for clustering. At first, these variables were standardized to ensure that they are on the same scale, which involves transforming the variables such that they have mean zero and standard deviation of one.

$$\frac{X_i - Center(X)}{Scale(X)}$$

Where center(x) = mean of X, and scale(X) is a standard deviation of X

After this, the variables' distance was measured by Pearson correlation to detect the dis–similarities between each pair of observations

D (x, y) = 1 – Correlation Coefficient (Pearson)

$$= 1 - \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

$$x_i = values\ of\ the\ x - variable\ in\ a\ sample$$
$$\bar{x} = mean\ of\ the\ x - variable\ in\ a\ sample$$
$$y_i = values\ of\ the\ y - variable\ in\ a\ sample$$
$$\bar{y} = mean\ of\ the\ y - variable\ in\ a\ sample$$

A K-means clustering was applied to the standardized weather data, and the optimal number of clusters (K) was determined using the elbow method.

A bar chart was used to visualize both cassava and cocoa yield across different clusters and analysis of variance (ANOVA) was conducted to determine if there are significant differences in cassava yield between the clusters this was done to understand how different weather patterns impact cassava yield. However, the within-cluster sum of squares (WCSS) was calculated for each cluster C, which is the sum of squared Pearson correlation distances between data points X_i within cluster C and the cluster centroid C_k. This is typically done for all n data points in d dimensions. The total within-cluster variation (TWSS) was estimated by summing up the WCSS for all C_k clusters.

WCSS for Cluster:

$$W(C_K) = \sum_{X_i \in C_k}^{N} \left(1 - \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}\right)^2$$

For i = 1 to *N* in cluster C_k

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Total Within-Cluster Variation (TWSS):

$$\sum_{K=1}^{N} W(C_K) = \sum_{K=1}^{N} \sum_{X_i \in C_K}^{N} \left(1 - \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}}\right)^2$$

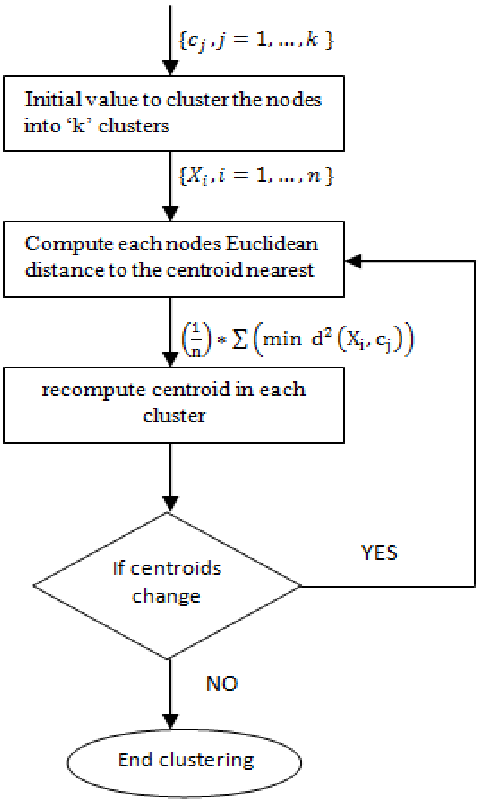

Figure 3.2: Flow Chart of K-means Algorithm

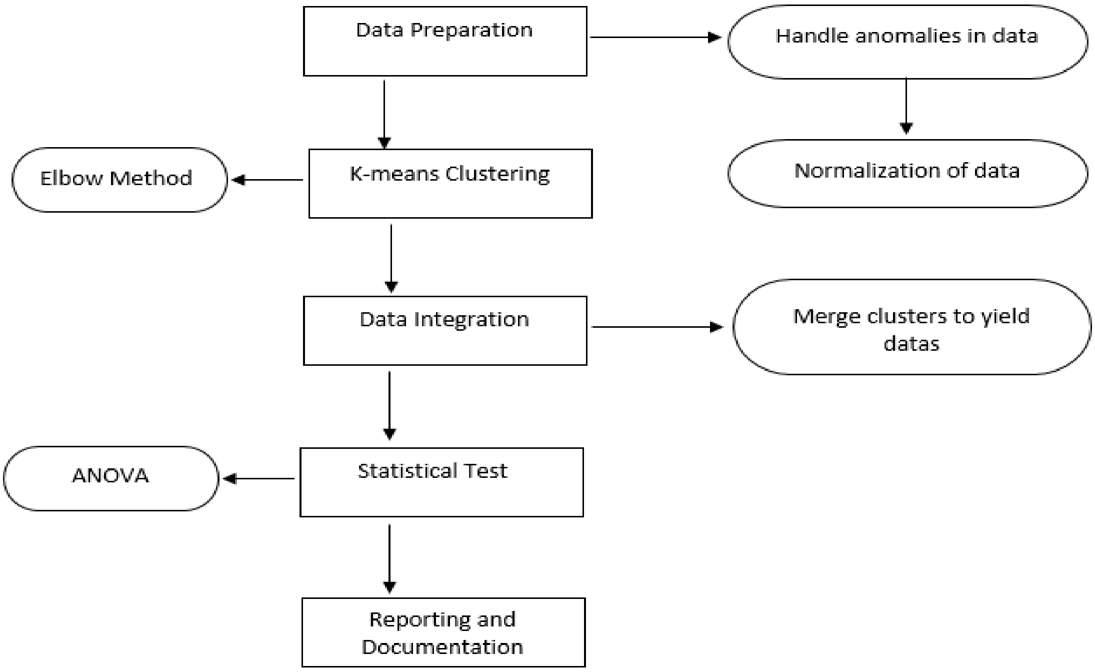

Figure 3.3: General analysis flowchart

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RESULT AND DISCUSSION

Introduction

This chapter presents the result from the statistical analysis carried out using R and also the interpretation and discussion based on the analysis.

Results

Plotting of the depending variable (Cassava, Cocoa) to determine their trend since 30yrs back.

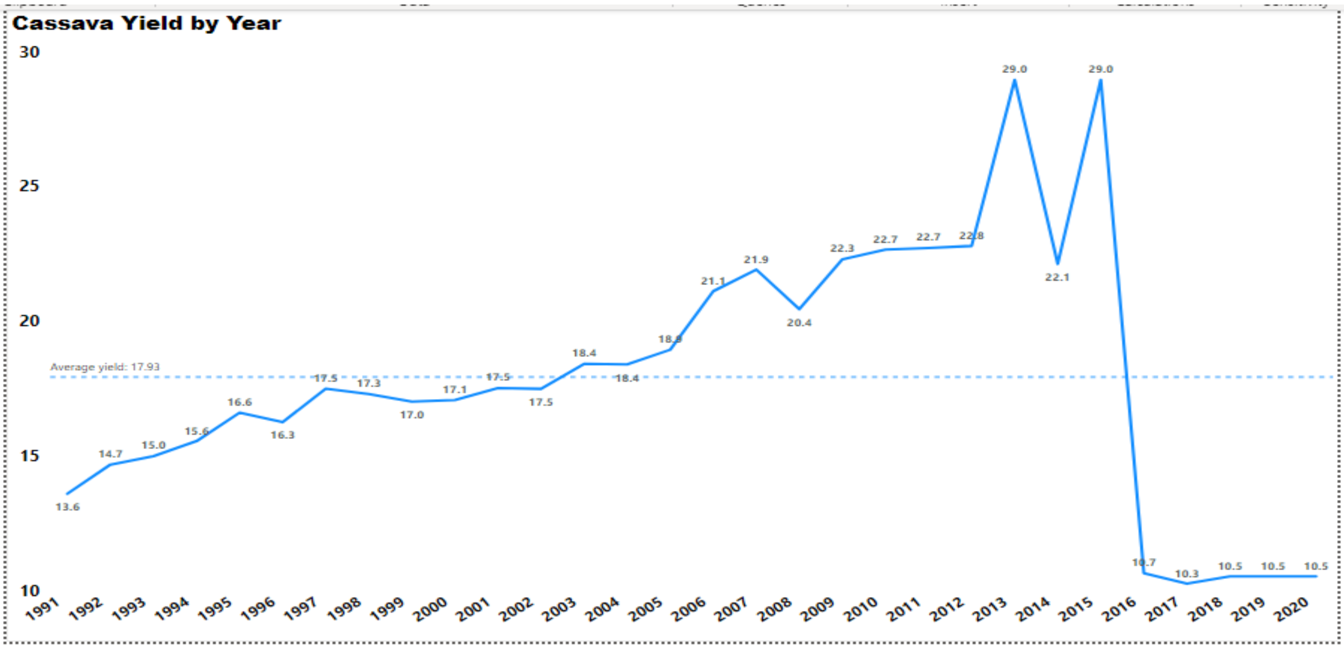

Figure 4.1: Cassava Yield by Year

Figure 4.2: Cocoa Yield by Year

Identifying weather pattern

Cluster means

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	-0.21	-0.37	-0.28	-0.39	-0.30	0.49	0.27	0.16	-0.34	0.38	0.58	-0.10	-0.34
Cluster 2	0.41	0.31	0.52	0.21	0.23	-0.36	-0.76	-0.56	0.03	-0.64	-0.60	-0.32	0.44
Cluster 3	-0.20	0.06	-0.24	0.18	0.08	-0.13	0.49	0.40	0.31	0.26	0.02	0.41	-0.10

Table 1: Cluster means (centroids) of Maximum Temperature by Months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	0.28	0.67	0.08	-0.05	0.18	-0.01	0.70	0.14	0.01	0.53	-0.23	-0.32	0.10
Cluster 2	-0.08	-0.19	0.45	-0.25	0.17	0.01	0.11	0.17	0.76	0.10	0.36	0.05	-0.04
Cluster 3	0.02	-0.24	-0.03	0.80	0.22	-0.01	-0.01	-0.28	-0.37	0.11	0.34	0.30	0.02
Cluster 4	-0.21	-0.19	-0.55	-0.58	-0.62	0.01	-0.80	-0.02	-0.45	-0.76	-0.56	-0.07	-0.08

Table 2: Cluster means (centroids) of Minimum Temperature by Months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	0.08	-0.03	0.45	-0.58	-0.04	0.31	0.11	0.18	0.65	0.31	0.52	-0.06	0.46
Cluster 2	-0.01	0.35	-0.50	-0.43	0.10	-0.28	-0.01	0.49	0.36	-0.03	0.57	0.63	0.16
Cluster 3	0.02	-0.05	0.92	0.57	0.51	0.48	0.40	0.11	-0.32	-0.27	-0.62	-0.01	0.39
Cluster 4	-0.08	-0.28	-0.70	0.43	-0.51	-0.42	-0.43	-0.74	-0.65	-0.01	-0.49	-0.57	-0.90

Table 3: Cluster means (centroids) of Rainfall by Months

Average Values for each clusters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	31.983	32.631	32.393	31.415	30.402	29.992	29.339	29.179	29.597	30.353	31.152	31.181	32.855
Cluster 2	32.574	33.315	33.462	31.987	30.875	29.633	28.765	28.899	29.736	29.802	30.565	31.055	33.778
Cluster 3	31.993	33.056	32.443	31.961	30.741	29.728	29.461	29.276	29.837	30.287	30.875	31.479	33.145

Table 4: Average Maximum Temperature for each clusters by months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	32.14	32.55	32.18	31.94	30.38	29.83	29.30	29.03	29.64	29.96	30.65	31.09	32.84
Cluster 2	31.94	32.89	32.46	31.52	30.52	29.95	29.47	29.26	29.65	30.56	31.29	31.34	33.03
Cluster 3	32.63	33.55	33.56	32.14	31.40	29.78	29.27	29.40	29.91	30.23	31.04	31.64	33.91
Cluster 4	31.99	32.94	32.80	31.54	30.30	29.56	28.67	28.72	29.68	29.76	30.40	30.81	33.21

Table 5: Average Minimum Temperature for each clusters by months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cluster 1	0.61	1.00	3.30	3.42	5.60	9.31	8.94	7.58	11.63	7.63	2.49	0.53	5.18
Cluster 2	0.56	1.32	1.61	3.73	5.84	7.61	8.56	8.67	10.64	6.63	2.54	1.00	4.90
Cluster 3	0.58	0.98	4.13	5.91	6.54	9.80	9.89	7.34	8.26	5.93	1.30	0.57	5.12
Cluster 4	0.52	0.79	1.26	5.61	4.80	7.21	7.20	4.33	7.13	6.67	1.44	0.18	3.94

Table 6: Average Rainfall for each clusters by months

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Visualizing Distance Measures between Months

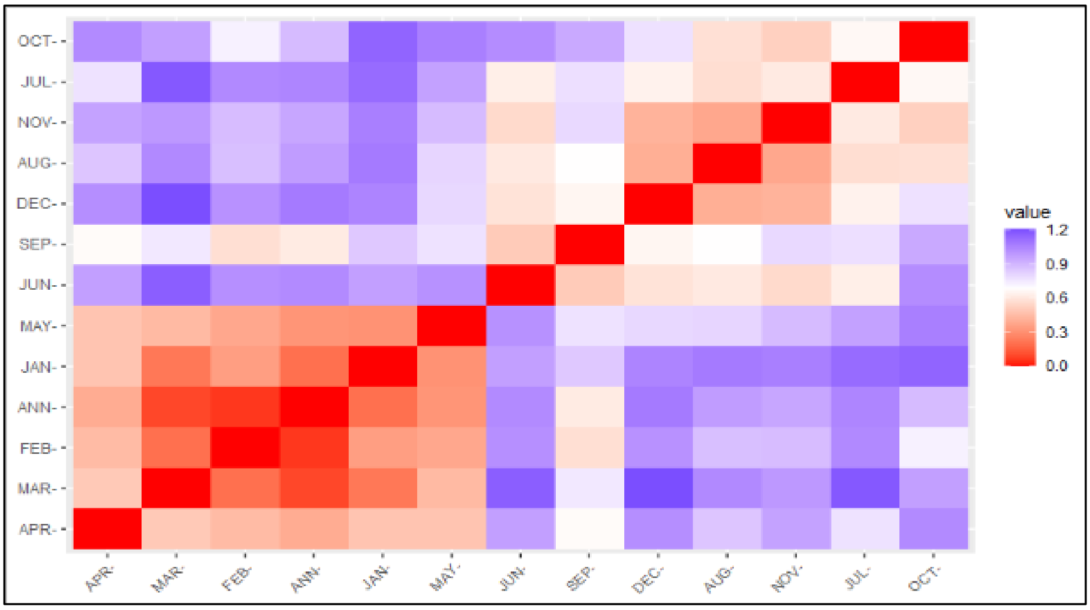

Figure 7: Maximum temperature

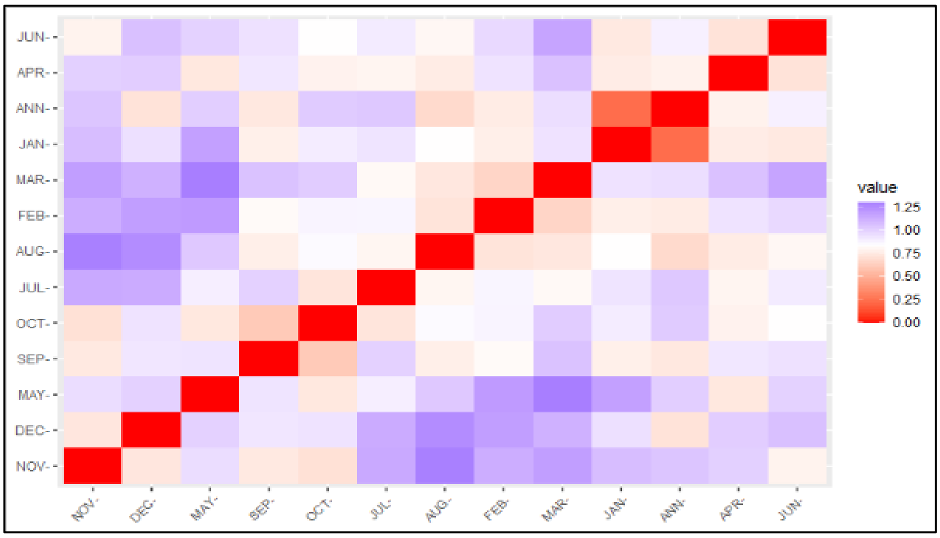

Figure 8: Minimum Temperature

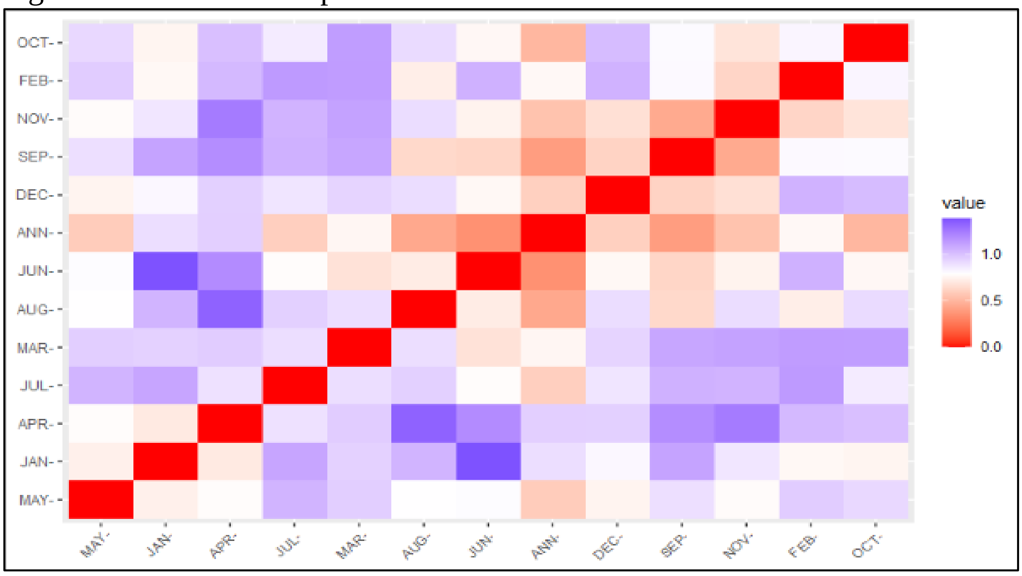

Figure 8: Rain

Optimum Number of Cluster

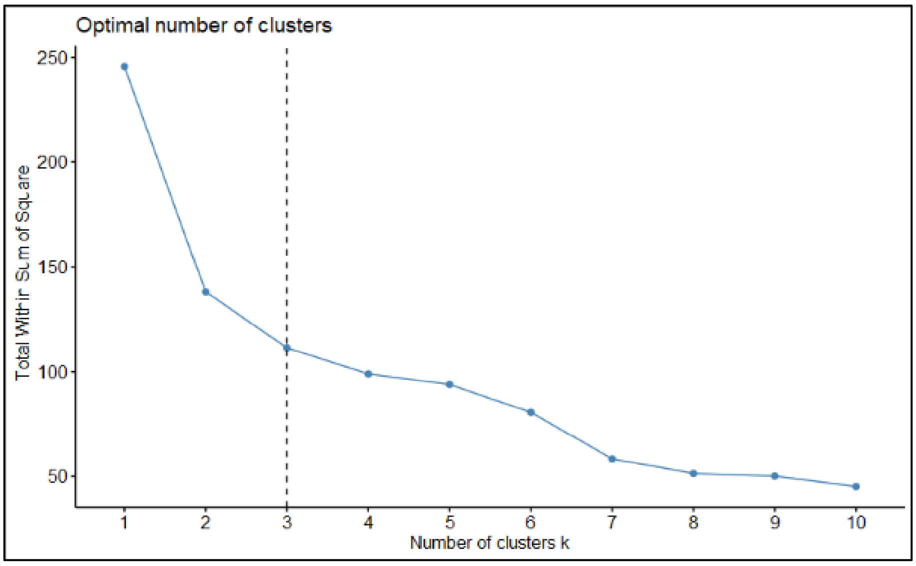

Figure 9: Maximum Temperature

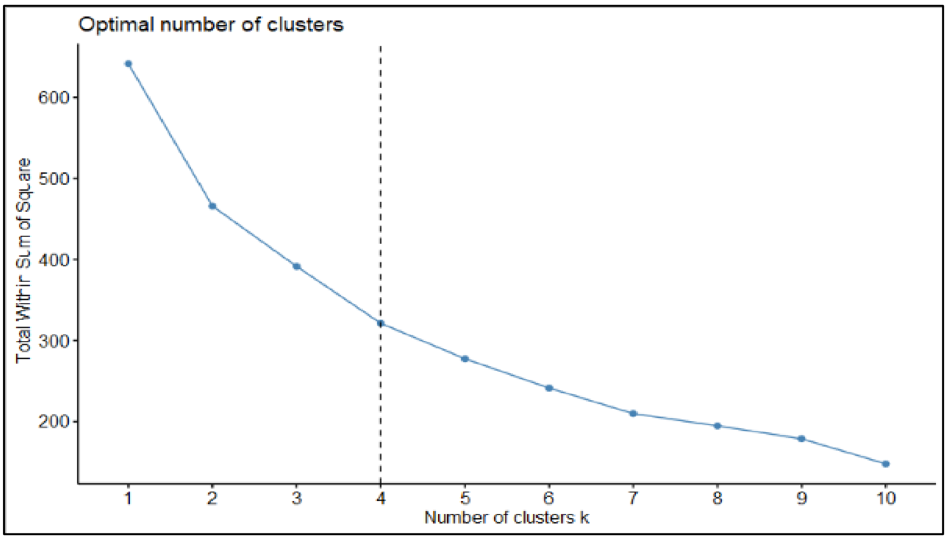

Table 10: Minimum Temperature

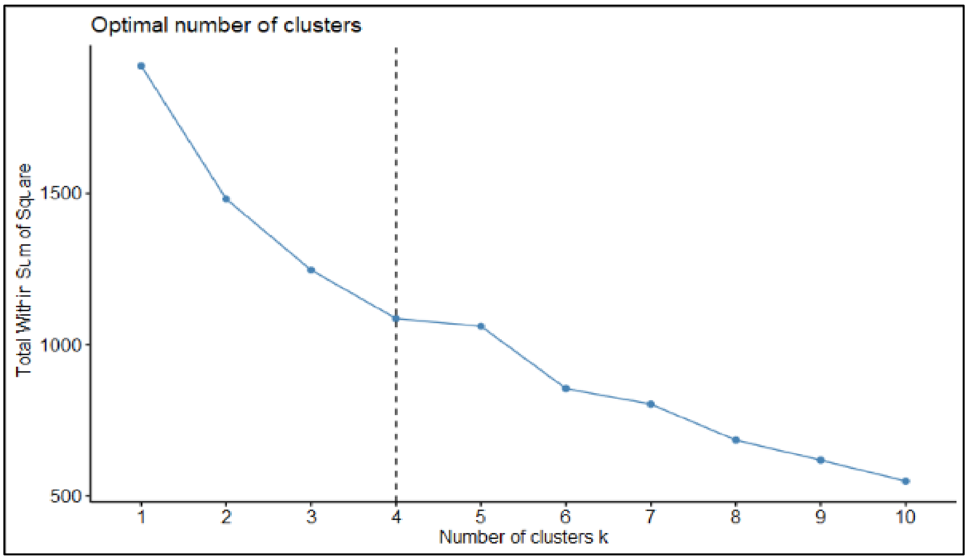

Figure 11: Rain

Visualizing K-means Clusters

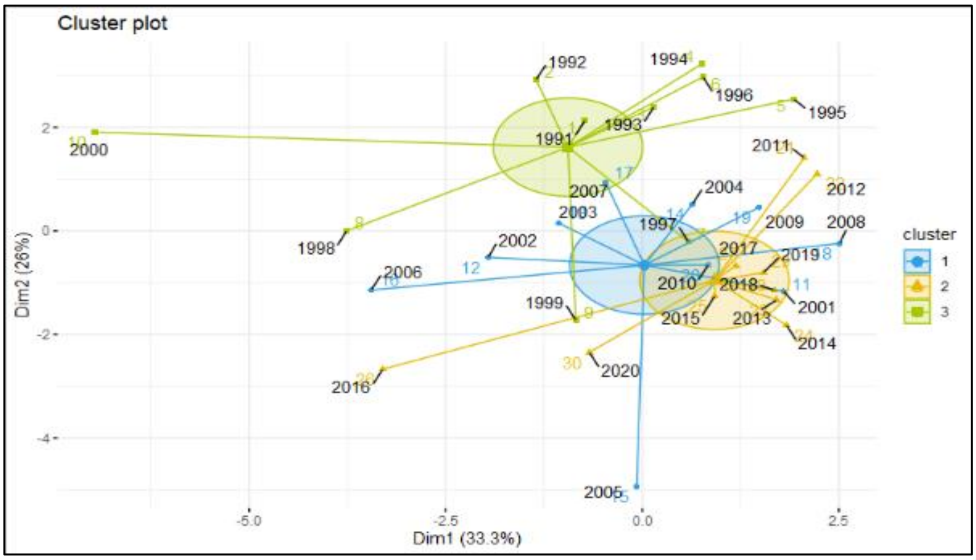

Figure 12: Maximum Temperature

K-means clustering with 3 clusters of sizes 10, 10, and 10. The within cluster sum of squares by cluster(withiness): 187.7091, 163.4330, and 221.7057. Betweenss = 2051.652. tot.withinss = 572.8478, totss = 2624.5

tot.withinss = $\sum withinss$= 187.7091+163.4330+221.7057 = 572.8478

Total_ss = $\sum(X_i - \mu)^2 = 2624.5$,

Betweenss_ss = Total_SS - TOT. withniss = 2624.5 – 572.8478 = 2051.652.;

$$\frac{between\_SS}{total\_SS} \times 100 = \frac{2051.652}{2624.5} \times 100 = 78.2\ \%$$

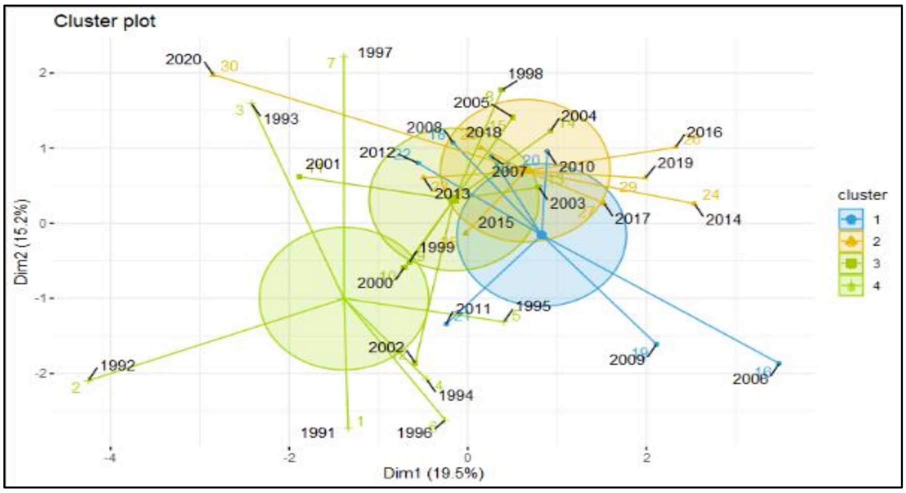

Figure 13: Minimum Temperature

K-means clustering with 4 clusters of sizes 7, 8, 8, and 7. The within cluster sum of squares by cluster (withinss): 98.05686, 125.27918, 124.38566, and 120.54158.

tot.withinss = $\sum withinss$= 98.05686+125.27918+124.38566+120.54158 = 468.2633

Total_ss = $\sum(X_i - \mu)^2 = 2624.5$,

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Betweenss_ss = Total_SS - TOT. withniss = 2624.5 – 468.2633 = 2156.237;

$$\frac{between\_SS}{total\_SS} \times 100 = \frac{2156.237}{2624.5} \times 100 = 82.2\ \%$$

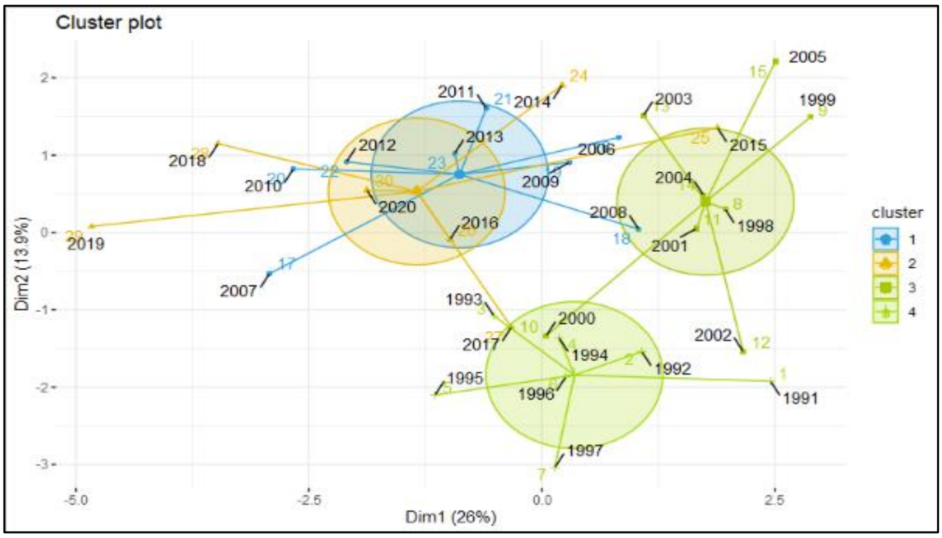

Figure 13: Rain

K-means clustering with 4 clusters of sizes 8, 7, 8, and 7, the within cluster sum of squares by cluster(withinss): 118.9109, 115.2425, 124.2534 and 85.2895. Total_ss = 2624.5, Tot.withinss = 443.6962, between_ss = 2180.804

tot.withinss = $\sum withinss$= 118.9109+115.2425+124.2534+ 85.2895 =

Total_ss = $\sum(X_i - \mu)^2 = 2624.5$,

Betweenss_ss = Total_SS - TOT. withniss = 2624.5 – 468.2633 = 2180.804

$$\frac{between\_SS}{total\_SS} \times 100 = \frac{2180.804}{2624.5} \times 100 = 83.1\ \%$$

4.2.2.6 Years in each cluster for the weather variables

	Cluster 1	Cluster 2	Cluster 3
1	2011	1991	2001
2	2012	1992	2002
3	2013	1993	2003
4	2014	1994	2004
5	2015	1995	2005
6	2016	1996	2006
7	2017	1997	2007
8	2018	1998	2008
9	2019	1999	2009
10	2020	2000	2010

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Table 7: Maximum Temperature

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
1	2006	2013	1998	1991
2	2007	2014	1999	1992
3	2008	2015	2000	1993
4	2009	2016	2001	1994
5	2010	2017	2002	1995
6	2011	2018	2003	1996
7	2012	2019	2004	1997
8		2020	2005	

Table 8: Minimum Temperature

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
1	2014	2006	1991	1998
2	2015	2007	1992	1999
3	2016	2008	1993	2000
4	2017	2009	1994	2001
5	2018	2010	1995	2002
6	2019	2011	1996	2003
7	2020	2012	1997	2004
8		2013		2005

Table 7: Rain

Relationship between cassava yield and the identified weather patterns.

Comparing the mean of cocoa and cassava yield between clusters

Relationship between Cassava yield and weather pattern

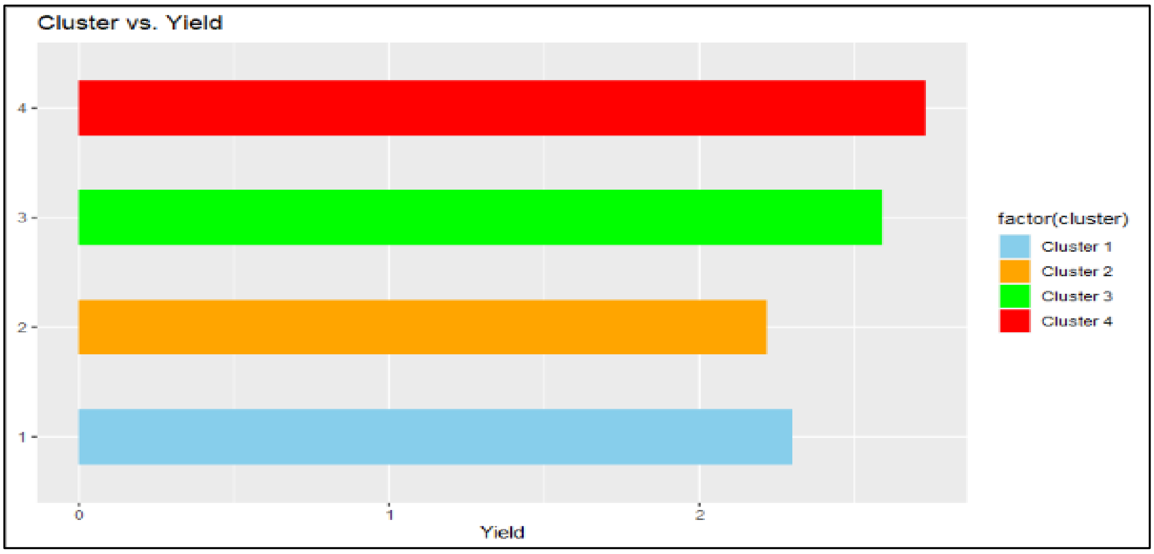

Figure 14: Maximum temperature clusters on cassava yield

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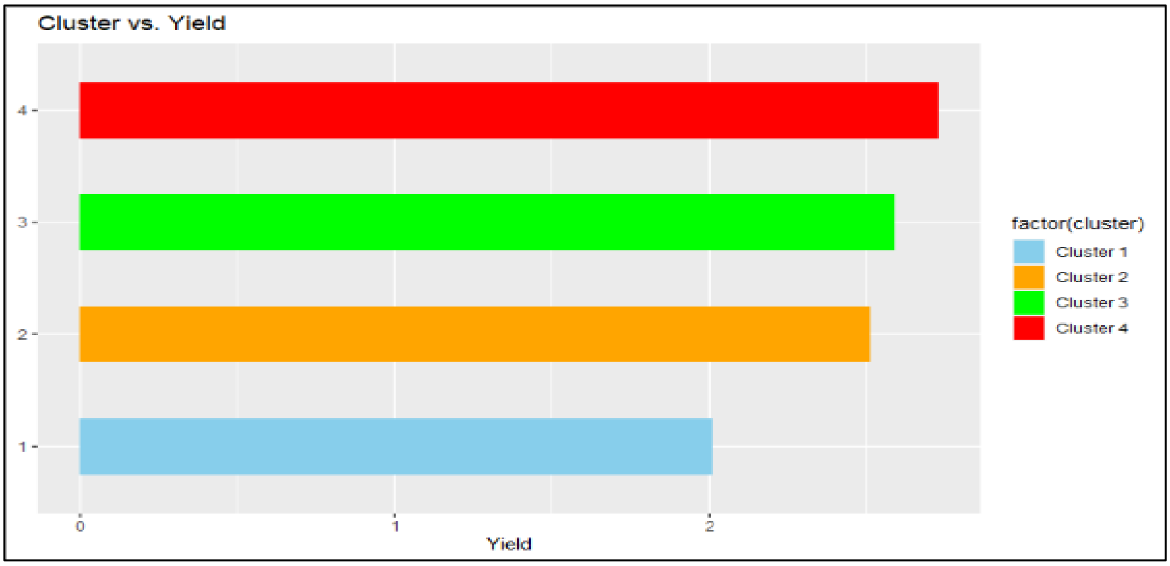

Figure 15: Minimum temperature clusters on cassava yield

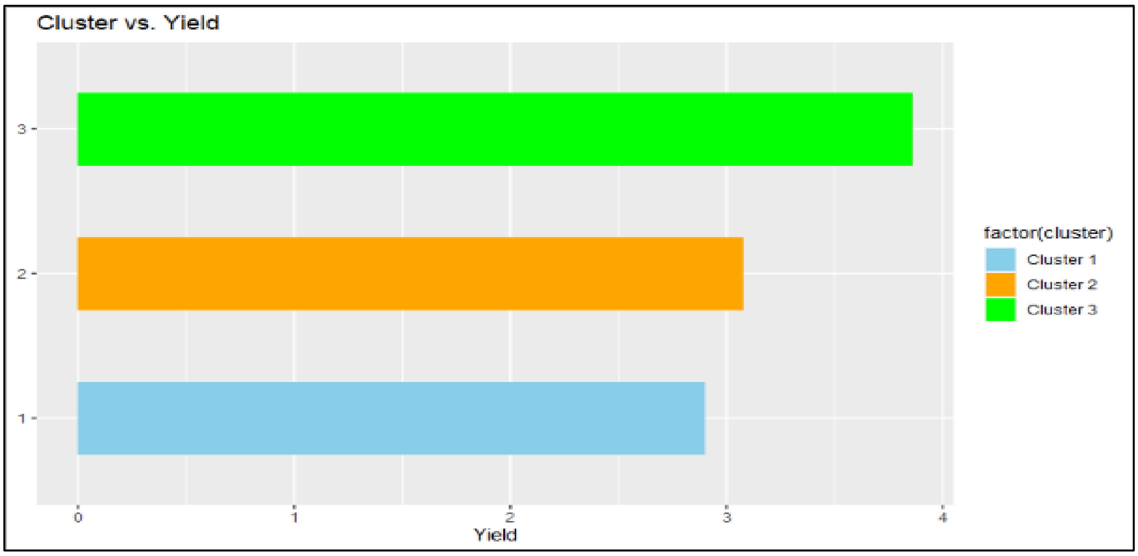

Figure 16: Rain clusters on cassava yield

4.2.3.1.1. Relationship between Cocoa yield and weather pattern

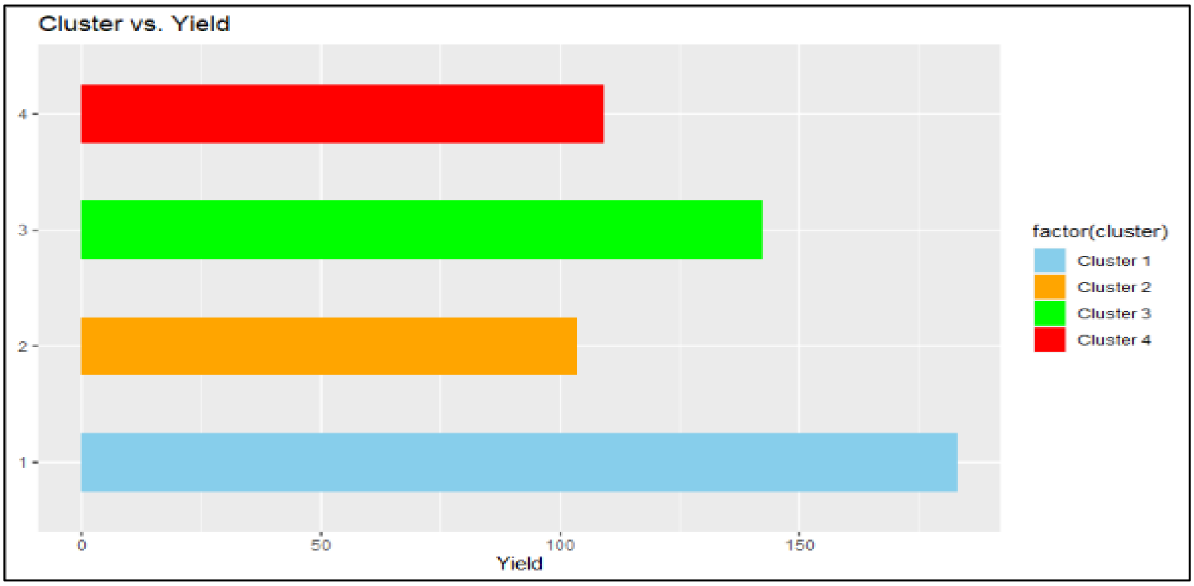

Figure 17: Maximum temperature clusters on cocoa yield

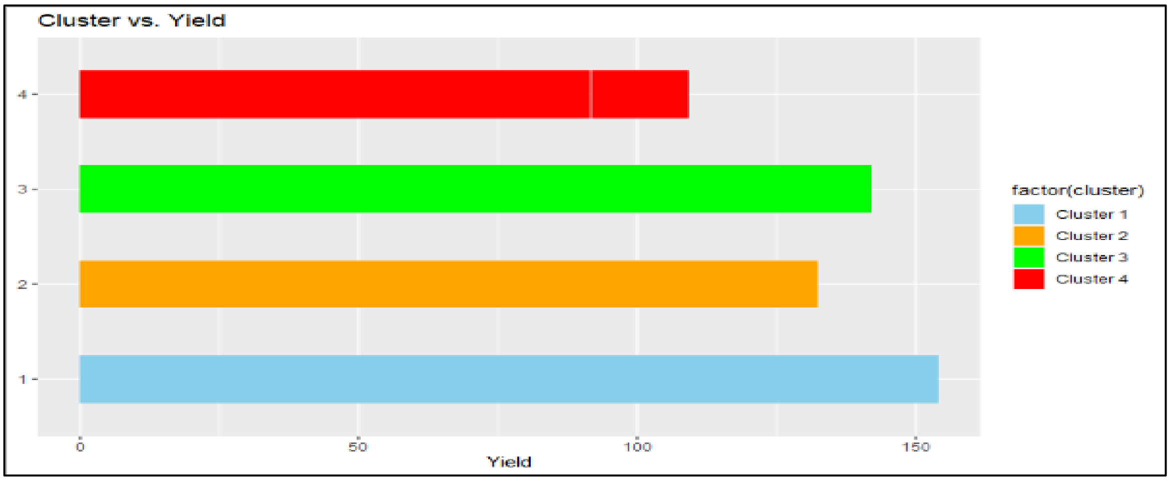

Figure 18: Minimum temperature clusters on cocoa yield

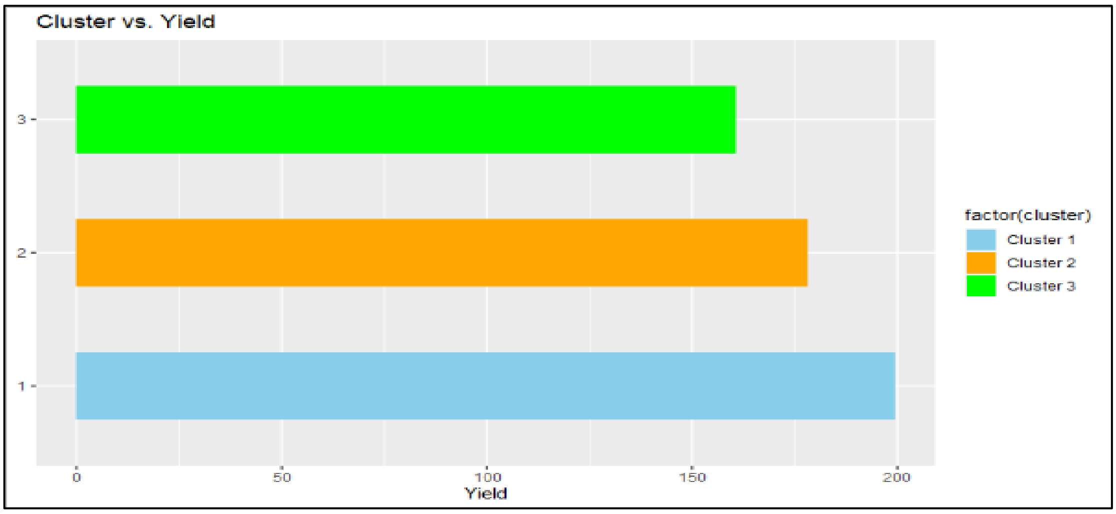

Figure 19: Rainfall clusters on cocoa yield

Analysis of Variance to statistically compare the mean of cassava and cocoa yield between different clusters

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	3	0.04060	0.013533	13.21	1.97e-05 ***
Residual	26	0.02664	0.001025		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 8: Effect of each cluster of rain on Cassava

	Diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	-0.02936250	-0.074811390	0.01608639	0.3088774
Cluster 3 – Cluster 1	0.07262857	0.025689160	0.11956798	0.0013265
Cluster 4 – Cluster 1	0.00695000	-0.038498890	0.05239889	0.9746420
Cluster 3 – Cluster 2	0.10199107	0.056542182	0.14743996	0.0000094
Cluster 4 – Cluster 2	0.03631250	-0.007595299	0.08022030	0.1316687
Cluster 4 – Cluster 3	-0.06567857	-0.111127461	-0.02022968	0.0027148

Table 9: Tukey test of rain on Cassava

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	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	2	0.05194	0.025971	45.84	2.09e-09 ***
Residual	27	0.01530	0.000567		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 10: Effect of each cluster of maximum temperature on Cassava

	Diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	0.07794	0.05154673	0.104333268	0.0000002
Cluster 3 – Cluster 1	-0.01791	-0.04430327	0.008483268	0.2301317
Cluster 3 – Cluster 2	-0.09585	-0.12224327	-0.069456732	0.0000000

Table 11: Tukey test of maximum temperature on Cassava

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	3	0.04008	0.013361	12.79	2.52e-05 ***
Residual	26	0.02716	0.001044		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 12: Effect of each cluster of minimum temperature on Cassava

	diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	0.02691429	-0.018971244	0.07279982	0.3912091
Cluster 3 – Cluster 1	0.03696429	-0.008921244	0.08284982	0.1470523
Cluster 4 – Cluster 1	0.10264286	0.055252486	0.15003323	0.0000163
Cluster 3 – Cluster 2	0.01005000	-0.034279633	0.05437963	0.9241130
Cluster 4 – Cluster 2	0.07572857	0.029843042	0.12161410	0.0006388
Cluster 4 – Cluster 3	0.06567857	0.019793042	0.11156410	0.0029871

Table 13: Tukey test of minimum temperature on Cassava

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	3	0.04060	0.013533	13.21	1.97e-05 ***
Residual	26	0.02664	0.001025		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 14: Effect of each cluster of rainfall on Cocoa

	diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	-0.02936250	-0.074811390	0.01608639	0.3088774
Cluster 3 – Cluster 1	0.07262857	0.025689160	0.11956798	0.0013265
Cluster 4 – Cluster 1	0.00695000	-0.038498890	0.05239889	0.9746420
Cluster 3 – Cluster 2	0.10199107	0.056542182	0.14743996	0.0000094

Cluster 4 – Cluster 2	0.03631250	-0.007595299	0.08022030	0.1316687
Cluster 4 – Cluster 3	-0.06567857	-0.111127461	-0.02022968	0.0027148

Table 15: Tukey test of rainfall on Cocoa

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	2	0.05194	0.025971	45.84	2.09e-09 ***
Residual	27	0.01530	0.000567		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 16: Effect of each cluster of maximum temperature on Cocoa

	Diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	0.07794	0.05154673	0.104333268	0.0000002
Cluster 3 – Cluster 1	-0.01791	-0.04430327	0.008483268	0.2301317
Cluster 3 – Cluster 2	-0.09585	-0.12224327	-0.069456732	0.0000000

Table 17: Tukey test of maximum temperature on Cocoa

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Cluster	3	0.04008	0.013361	12.79	2.52e-05 ***
Residual	26	0.02716	0.001044		
Signif. Codes	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 18: Effect of each cluster of minimum temperature on Cocoa

	diff	lwr	Upr	p adj
Cluster 2 – Cluster 1	0.02691429	-0.018971244	0.07279982	0.3912091
Cluster 3 – Cluster 1	0.03696429	-0.008921244	0.08284982	0.1470523
Cluster 4 – Cluster 1	0.10264286	0.055252486	0.15003323	0.0000163
Cluster 3 – Cluster 2	0.01005000	-0.034279633	0.05437963	0.9241130
Cluster 4 – Cluster 2	0.07572857	0.029843042	0.12161410	0.0006388
Cluster 4 – Cluster 3	0.06567857	0.019793042	0.11156410	0.0029871

Table 19: Tukey test of minimum temperature on Cocoa

DISCUSSION

Maximum Temperature have been divided into three clusters by months for each year, each year in the same cluster possess similar maximum temperature, whereas year in difference clusters has different characteristics. The cluster mean (also known as centroid) are the average maximum temperature values of the months (January to December) within each cluster. 1^{st} has a negative average maximum temperature for most months, except for June (0.49), July (0.27), August (0.16), October (0.38) and November (0.58) which are positive with a peak in November. On the other hand, the 2^{nd} cluster has a positive average maximum temperature for most months, with the highest average maximum temperature in March (0.52). Also, cluster

3 has mixed average maximum temperature, with some month's value being negative and some positive. It has the highest positive average value in July (0.49).

The Within Cluster Sum of Squares (WCSS) by Cluster represents the sum of squared distances of data points within each cluster to their respective cluster centres. And the three clusters (1^{st} cluster, 2^{nd} cluster and 3^{rd} cluster) have an approximate WCSS of 163.4330, 221.7057 and 187.7091 respectively. These values indicate the tightness of each clusters in which a lower or smaller WCSS means that the maximum temperature points within a cluster are closer to each other. In this case, the 1st cluster has the lowest WCSS, suggesting that it is the most internally consistent cluster. Furthermore, the 78.2% ration between the between_ss and total_ss represent the proportion of variance between clusters compared to the total variance, a higher ratio of 78.2% indicates that the clusters are well-separated.

The minimum temperature was also described by the mean(centroid) values across different months; 1^{st} cluster has a positive mean value for January(0.28), February(0.67), March(0.08), May(0.18), July(0.70), August(0.14),September(0.01) and October(0.53) which suggested that these months has higher minimum temperature within 1^{st} cluster. However, it has highest mean values in February and July among all clusters, this cluster has a relative higher values compared to other clusters for several months. 2^{nd} cluster has mixed centroid across the months. But it has a strong positive centroid for March (0.45), and the highest mean for September (0.76) among all clusters. The 3^{rd} has a strong positive mean April (0.80), May (0.22), November (0.34) and December (0.30). Although, it has the highest mean values for April (0.80) among all clusters. This indicate that this cluster has a higher minimum temperature during the later months of the year. However, the 4^{th} cluster generally has a negative mean values across the months for the years and it is characterized by lower values across compared to other clusters. The 1^{st} cluster for minimum temperature has 98.057 variability, 2^{nd} cluster with 125.279 variability, 3^{rd} cluster with 124.386 variability, and 4^{th} cluster with 120.542 variability which indicates how close the minimum temperature within each cluster was grouped together. And this shows that, among the clusters, minimum temperature for the months in the years for the 1^{th} cluster are relatively similar to each other – having the lower variability. Additionally, 82.2% of the total variance in the minimum temperature is explained by the differences between the clusters. This proved that the clusters are effective in capturing a significant portion of the variability minimum temperature.

Rainfall was classified into four clusters, the 1^{st} cluster have a higher mean(centroid) during the middle to later months of the years and a positive centre for January(0.08), March(0.45), June(0.31), July(0.11), August(0.18), September(0.65), October(0.31) and November(0.52) having the highest value in September among all clusters. In 2^{nd} cluster there is a mixed mean values across months in the years. Although, it has a positive mean for February (0.35), May (0.10), August (0.49), September (0.36), November (0.57) and December (0.63), and a consistency high mean value across in later months in years. The 3^{rd} cluster were strongly positive mean values for March (0.92), April (0.57), May (0.51) and July (0.40), with the highest for March – indicating that it has higher means during the earlier months of the year. Finally, the 4^{th} cluster has a lower rainfall during the earlier months of the year and it generally has a negative centroid across most months with 1^{st} cluster having 115.2424 variability, 2^{nd} cluster, 118.9109, 3^{rd} cluster, 85.2895 and 4^{th} cluster, 124.2534. Among all, 3^{rd} cluster has the lowest WCSS, indicating that rainfall in this cluster are relatively similar. And 83.1% of the total variance in rainfall for each year is explained by the differences between these clusters.

There are significant differences in yield of cassava in terms of rainfall among the clusters at $p < 0.05$ for [$F(3,26) = 13.21$, $p = 1.97e-05$]. And the Tukey test shows specific difference in the yield of cassava, the 3^{rd} cluster has a significantly higher ($p < 0.05$) cassava yield compared to 1^{st} and 2^{nd} , but 4^{th} does not significantly ($p > 0.05$) differ from 1^{st} and 2^{nd} , 3^{rd} cluster has a significantly higher ($p < 0.05$) cassava yield compared to Cluster 4. Also, there are significant differences in yield of cassava in terms of maximum temperature among the clusters at $p < 0.05$ for [F(2,27) = 45.84, p = 2.09e-09]. The results show that there are significant differences ($p < 0.05$) in cassava yield between 2nd and 1st, as well as between 3rd and 2nd. However, there is no statistically significant ($p > 0.05$) difference in cassava yield between 3rd and 1st. There are significant differences in yield of cassava in terms of minimum temperature among the clusters at $p < 0.05$ for [F(3,26) = 12.79, p = 2.52e-05]. Specifically, 4th appears to have significantly higher ($p < 0.05$) cassava yield compared to 1st, 2nd, and 3rd, while there are no significant differences ($p > 0.05$) between 1st, 2nd, and 3rd in terms of cassava yield.

Also, there are significant differences in yield of cocoa in terms of rainfall among the clusters at $p < 0.05$ for [F(3,26) = 13.21, p = 1.97e-05]. Specifically, 3rd cluster has a significantly higher ($p < 0.05$) cocoa yield compared to 1st and 2nd, while the 4th cluster does not significantly differ ($p > 0.05$) from 1st cluster, 2nd cluster, or 3rd cluster in terms of cocoa yield. Additionally, 4th cluster has a lower cocoa yield compared to 3 rd cluster ($p < 0.05$). There are also significant differences in yield of cocoa in terms of maximum temperature among the clusters at $p < 0.05$ for [F(2,27) = 45.48, p = 2.09e-09]. 2nd cluster has a significantly higher ($p < 0.05$) cocoa yield compared to 1st cluster, whereas, 3rd cluster does not significantly($p > 0.05$) differ from 1st cluster, and 3rd cluster has a significantly lower ($p < 0.05$) cocoa yield compared to 2nd cluster. Finally, there are significant differences in yield of cocoa in terms of minimum temperature among the clusters at $p < 0.05$ for [F(3,26) = 12.79, p = 2.52e-05]. Specifically, the 4 th cluster has a significantly higher ($p < 0.05$) cocoa yield compared to 1st and 2nd cluster, but the 3rd cluster does not significantly ($p < 0.05$) differ from 1st cluster and 2nd, and 4th cluster has a significantly higher (p
< 0.05) cocoa yield compared to 3rd cluster.

CONCLUSION AND RECOMMENDATION

Conclusion

The main objective of the study was to analyze the effects of weather variables (rainfall and temperature) on cassava and cocoa yield in Ondo State, Nigeria from 1991-2020. The study therefore concludes that weather variables (rainfall and temperature) have significant and varying effects on cassava and cocoa yield in Ondo state as can be seen from the graphs plotted in the study and the ANOVA analysis carried out using R.

Having examined the impact of climate change on Cassava and cocoa yield with productivity in Ondo state Nigeria, the need to adopt improved agricultural and environmentally sensitive technologies has become imperative. As shown by the results, rainfall and temperature impacts cassava and cocoa yield and production in Ondo state, therefore the need to adopt or make preparations for sophisticated technologies that will come in handy in times of extreme weather events such as prolonged drought.

Recommendation

Based on examination and analysis of the impact of climate change on Cassava and cocoa yield in Ondo state Nigeria, the need to adopt improved agricultural and environmentally sensitive technologies has become imperative. As shown by the results, rainfall and temperature impacts cassava and cocoa yield and production in Ondo state, therefore government and other agencies need to sensitize farms and concerned bodies as to adaptive measures to carry out. Also other measures in order to maintain this minimum changes in the rainfall and temperature of the area, the following recommendations are made:

1. a) The extension agents should advice the farmers in the area to adjust cassava and cocoa cropping calendar to synchronize planting and growing period with soil moisture availability based on rainfall forecast.
2. b) Adopting Climate-smart agriculture which promotes a number of water conservation practices, such as planting a buffer of trees and bushes along streams and rivers to prevent erosion and

contamination from crop runoff. Another climate-smart water technique is to treat wastewater caused by agricultural processing before it is released back into waterways.

3. c) Tending to the soil increases the amount of greenhouse gasses sequestered, and means healthier plants with higher yields. Healthy soil holds more moisture, keeping plant roots hydrated in dry periods. Soil conservation methods such as contour planting or no-till farming reduce erosion, keeping the soil in place during heavy rains or floods.
4. d) Government should also allocate more funds to the National Meteorological center to procure latest equipment for weather forecasting.

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APPENDIX

```
library(cluster)

library(factoextra)

library(tidyverse)

library(readxl)

library(ggrepel)

dat1 <-read_excel(file.choose())

dat2 <-read.csv(file.choose())

dat3 <-read.table(file.choose(), header = T)

dat4 <-read.table(file.choose(), header = T)

dat5 <-read.table(file.choose(), header = T)

#Clustering the weather datas

Max_Temp <-na.omit(dat3[,-c(1,2)])

Max_Temp_scaled <-scale(Max_Temp)

Max_Temp_dis <-get_dist(t(Max_Temp), method=”pearson”)

fviz_dist(Max_Temp_dis)

Max_Tempt_scaled_T <-cbind(Max_Temp_scaled, select(dat3,YEAR))

Kmeans_Max_Tem <-kmeans(Max_Tempt_scaled_T, 3, iter.max=40, nstart=40)

print(Kmeans_Max_Tem)

Kmeans_Max_Tem$betweenss

Kmeans_Max_Tem$withinss

Kmeans_Max_Tem$tot.withinss

Kmeans_Max_Tem$totss

fviz_nbclust(Max_Temp, kmeans, method =”wss”)+geom_vline(xintercept=3, linetype=2)

aggregate(Max_Temp, by = list(cluster = Kmeans_Max_Tem$cluster), mean)

dd <-cbind(CassavaMax, cluster = Kmeans_Max_Tem$cluster)

View(dd)

fviz_cluster(Kmeans_Max_Tem, data = as.data.frame(Max_Tempt_scaled_T), palette = c(“#2E9FDF”,
```

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```
 “#E7B800”, “#A7C800”),
          ellipse.type=”euclid”, star.plot=TRUE, repel=TRUE, ggtheme=theme_minimal()) +
geom_text_repel(
aes(label = Max_Tempt_scaled_T$YEAR ), # Use “YEAR” directly here
box.padding = 0.5
)
#CLUSTERING MINIMUM TEMPERATURE
Min_Temp <-na.omit(dat4[,-c(1,2)])
Min_Temp_scaled <-scale(Min_Temp)
Min_Temp_dis <-get_dist(t(Min_Temp), method=”pearson”)
fviz_dist(Min_Temp_dis)
Scaled <-cbind(Min_Temp_scaled, select(dat4,YEAR))
fviz_nbclust(Min_Temp, kmeans, method =”wss”)+geom_vline(xintercept=4, linetype=2)
Min_kmean <-kmeans(Scaled, 4, iter.max=40, nstart=40)
Min_kmean$totss
Min_kmean$withinss
Min_kmean$tot.withinss
Min_kmean$betweenss
aggregate(Max_Temp, by = list(cluster = Min_kmean$cluster), mean)
dd_min <-cbind(CassavaMax, cluster = Min_kmean$cluster)
View(dd_min)
fviz_cluster(Min_kmean, data = as.data.frame(Scaled), palette = c(“#2E9FDF”, “#E7B800”, “#A7C800”,
“#A0D900” ),
          ellipse.type=”euclid”, star.plot=TRUE, repel=TRUE, ggtheme=theme_minimal()) +
geom_text_repel(
aes(label = Scaled$YEAR ),
box.padding = 0.5
)
```

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```
####################################################

#RAIN CLUSTERING

rain_data <-na.omit(dat5[,-c(1,2)])

rain_scaled <-scale(rain_data)

rain_dis <-get_dist(t(rain_data), method=”pearson”)

fviz_dist(rain_dis)

rain <-cbind(rain_scaled, select(dat5,YEAR))

fviz_nbclust(rain_data, kmeans, method =”wss”)+geom_vline(xintercept=4, linetype=2)

rain_kmean <-kmeans(rain, 4, iter.max=40, nstart=40)

rain_kmean$totss

rain_kmean$withinss

rain_kmean$tot.withinss

rain_kmean$betweenss

aggregate(rain_data, by = list(cluster = rain_kmean$cluster), mean)

dd_rain <-cbind(rain_data, cluster = rain_kmean$cluster)

View(dd_rain)

fviz_cluster(rain_kmean, data = as.data.frame(rain), palette = c(“#2E9FDF”, “#E7B800”, “#A7C800”, “#A0D900” ),

            ellipse.type=”euclid”, star.plot=TRUE, repel=TRUE, ggtheme=theme_minimal()) +

  geom_text_repel(

    aes(label = rain$YEAR ), # Use “YEAR” directly here

    box.padding = 0.5

  )

#FRUITE AND MAXIMUM TEMPERATURE

Cassava_rain <- cbind(dat1, cluster = rain_kmean$cluster)

Cassava_Min <- cbind(dat1, cluster = Min_kmean$cluster)

Cassava_Max <- cbind(dat1, cluster = Kmeans_Max_Tem$cluster)
```

```
#FRUITE YIELD AND MINIMUM TEMPERATURE

Cocoa_rain <- cbind(dat2, cluster = rain_kmean$cluster)

Cocoa_Min <- cbind(dat2, cluster = Min_kmean$cluster)

Cocoa_Max <- cbind(dat2, cluster = Kmeans_Max_Tem$cluster)

#####################################################

ggplot(Cassava_rain, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtitle("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),
                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank())
ggplot(Cassava_Min, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtitle("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),
                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank())
ggplot(Cassava_Max, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtitle("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),

                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank())
```

```
ggplot(Cocoa_rain, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtitle("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),
                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank())

ggplot(Cocoa_Min, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtit(le("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),
                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank()))
ggplot(Cocoa_Max, aes(x = YIELD, y = factor(cluster), fill = factor(cluster))) +
  geom_bar(stat = "identity", width = 0.5) +
  labs(x = "Yield", y = "Cluster") +
  ggtitle("Cluster vs. Yield") +
  scale_fill_manual(values = c("skyblue", "orange", "green", "red", "purple"),
                    labels = c("Cluster 1", "Cluster 2", "Cluster 3", "Cluster 4", "Cluster 5"))+
  theme(axis.title.y = element_blank())
  #Cassava
  CasRain <-aov(YIELD ~ factor(cluster), Cassava_rain)
  summary(CasRain)
  tCasRain <-TukeyHSD(CasRain)
```

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```
print(tCasRain)

summary(tCasRain)

CasMax <-aov(YIELD ~ factor(cluster), Cassava_Max)

summary(CasMax)

tCasMax <-TukeyHSD(CasMax)

print(tCasMax)

summary(tCasMax)

CasMin <-aov(YIELD ~ factor(cluster), Cassava_Min)

summary(CasMin)

tCasMin <-TukeyHSD(CasMin)

print(tCasMin)

summary(tCasMin)

#Cocoa

CoRain <-aov(YIELD ~ factor(cluster), Cassava_rain)

summary(CoRain)

tCoRain <-TukeyHSD(CoRain)

print(tCoRain)

summary(tCoRain)

CoMax <-aov(YIELD ~ factor(cluster), Cassava_Max)

summary(CoMax)

tCoMax <-TukeyHSD(CoMax)

print(tCoMax)

summary(tCoMax)

CoMin <-aov(YIELD ~ factor(cluster), Cassava_Min)

summary(CoMin)

tCoMin <-TukeyHSD(CoMin)

print(tCoMin)

summary(tCoMin)
```