MANAGING CLIMATE CHANGE FOR AGRICULTURAL SUSTAINABILITY

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Abstract

Agricultural production and advancement is significantly affected by climate change, especially in drought-prone regions where farmers depend primarily on rainfall for their livelihoods. One of the main threats to the agricultural sector for decades has been global warming, and the sector is particularly susceptible to climatic circumstances. Climate change has become a crucial concern impeding sustainable development due to rapid changes in urbanization, industry, and agricultural systems. Food security, which is a worldwide concern, is an essential component connected to a country's economy and people's livelihoods. In view of these, this study set out to examine the impact of climate change on food security and sustainable agricultural development. The study was based on the school farm of the Federal Polytechnic Ilaro, Nigeria. A slack-based approach was introduced to quantify inefficiencies in overall agricultural production. This study further scrutinized the decomposition of specific variables. The study will help policymakers to make appropriate decisions to minimize the impact of climate change on sustainable agricultural practices and improve human living standards through food security.

Keywords: *Agriculture, Atmosphere, Climate change, Food security, Sustainability*

1.0 Introduction

Climate change is one of the most challenges of our day, which has profound effects on the economy, human health, and ecology. The effect is more easily felt in the field of agriculture, which incidentally, is the primary source of food for mankind. Thus, any adverse effect of climate change on agriculture poses a threat to global food security and the livelihoods of millions. This would result due to the delicate balance of our ecosystems being altered by rising temperatures, shifting precipitation patterns, and an increase in the frequency of extreme weather events (Intergovernmental Panel on Climate Change, IPCC, 2019).

Sustainable farming methods that can adjust to the difficulties posed by climate change are more important than ever as the world's population continues to rise. For food production to remain adequate in spite the effects of climate change, and with the farming activities not accelerating the change, agricultural sustainability is essential to emissions of greenhouse gases, food and agriculture organization (FAO 2017; Garnett et al. 2013). A potential remedy in this regard is climate-resilient agriculture, which places an emphasis on methods that improve soil condition, preserve water, encourage biodiversity, and strengthen farmers' resilience. These are practices that can lower agricultural emissions, increase crop yields, and protect farming communities' well-being by implementing climate-smart agriculture. The necessity is obvious in order to combat the existential threat posed by climate change. There is need to build a future that is more resilient, sustainable and food secure for future generations. According to the former UNFCCC Executive Secretary, climate change is the single biggest threat to global food security (Figueres, 2019). Climate change has severe effects on agriculture. Global food security and the livelihoods of millions of farmers worldwide are under danger as a result of the delicate balance of our ecosystems being altered by rising temperatures, shifting precipitation patterns, and an increase in the frequency of extreme weather events. Africa's agriculture is facing an unprecedented threat from climate change, as observed by Agnes Kalibata, President of the Alliance for a Green Revolution in Africa (AGRA). The Food and Agriculture Organization's (FAO) Deputy Director-General, Dr. Maria Helena Semedo, also posited that sustainable agriculture is essential for achieving food security and addressing climate change (Semedo, 2019). According to Vincent et al (2017), climate change has a significant impact on livelihoods, especially those that are primarily focused on natural resources. For instance, the destruction of physical capital (like infrastructure) as a result of say, frequent rainstorms, may limit the opportunity for agro-ecological tourism, which could serve as an additional sustainable livelihood opportunity for the impoverished rural population (Singh et al., 2017). In other words, vulnerable-smart agriculture that not only addresses food security and mitigates climate change, but also puts small-scale farmers and their lives at the centre of all agricultural activities, requires that the climate-smart agriculture assumptions and goals be modified. Consequently, the system can be intelligent enough to withstand climate change and provide the farmers with stable income.

Options for managing climate risk that impact the shift from agricultural to non-agricultural livelihoods would require coordinated cross-disciplinary research and development across a wider range of disciplines than has been done thus far in the climate-smart agriculture to vulnerable-smart agriculture framework (Thornton, et al. 2018).

Additionally, it's critical to spread climate-smart agriculture and vulnerable-smart agriculture techniques at the field level in order to apply them in university curricula, conferences, symposiums, and analyses in order to build a better future. The effects on the economy, ecology, and society of not understanding and utilizing these tactics will also be evaluated. Definitions from the literature and variations across the frameworks of sustainable livelihood, climate-smart agriculture and vulnerable-smart agriculture have been examined for this purpose, (Lipper, et al. 2014).

Therefore, the primary goal of this study is to present vulnerable-smart agriculture as a comprehensive form of climate-smart agriculture and enhance climate-smart agriculture by including the underutilized but crucial component of small-scale farming. By developing a conceptual framework at the farmer's level, this study suggests significant adjustments that must be made to the climate-smart agriculture set-up in recognition of small-scale farmers as the backbone of a sustainable agricultural system, (Sayer, et al. 2013).

1.1 Climate Change and Agriculture

Agriculture is a major industry that both significantly contributes to and is negatively impacted by climate change, as it is ultimately held responsible for 20% of all greenhouse gas emissions. Agribusiness output and other agro-environmental and climatic parameters are significantly impacted by precipitation extremes, such as floods, droughts, and forest fires (Chivangulula et al., 2023). Furthermore, the excessive dependence on limited resources, which leaves agriculture vulnerable to devastation globally, is what fuels the fire. Systems of agriculture are essential to both national economies and individual households' financial stability, particularly in developing countries (Chikafa et al., 2023). GHG concentrations in the atmosphere have risen to previously unheard-of levels during the past few millennia, according to the IPCC (2022). GHGs consist of N_2O, CO_2, and CH_4. Additionally, it has been projected that the average global temperature may increase by 1.1 to 3.7 degrees Celsius by the end of the twenty-first century (Urban et al., 2023). Increased temperatures will have significant detrimental effects on agricultural growth, making global crop output extremely vulnerable to these patterns of temperature change (Ratnayake et al., 2023). Due to rising temperatures, shifting precipitation patterns, and an increase in the frequency of extreme weather events, climate change is seriously endangering food security, agricultural sustainability, and the livelihoods of millions of farmers globally. Crop yields, quality, and appropriateness are affected; growing seasons and agricultural productivity are altered; pest and disease pressure is increased; farming communities' resilience and adaptability are threatened; agricultural productivity and food security are compromised. The aim of this project is to analyse the consequences of climate change on agricultural farmland in federal polytechnic Ilaro. It evaluate how susceptible agricultural systems are to climate change, measures how climate change affects crop yields, and agricultural output, looked into how agricultural practices might mitigate the effects of climate change. Global food security is seriously threatened by climate change, and it is essential to comprehend how it affects agriculture in order to ensure sustainable food production. Climate change also has an impact on agricultural systems, which has an impact on human well-being, especially in communities that are already at risk. Additionally, policy decisions are influenced by climate change, which aids in the creation of successful mitigation and adaptation plans. Global agricultural systems are impacted by climate change, which makes research on this topic pertinent and crucial for sustainable development. It also reduces agricultural productivity, which costs farmers and communities' money.

The Yewa South Local Government in Ogun State, Nigeria, serves as the study area. In Ogun State, the Yewa South Local Government is located between the longitudes 2°47′24″E and 3°6′48″E and the latitudes 6°37′46″N and 6°55′42″N. Ifo and Ado – Odo/Ota Local Governments are to the east, Ipokia Local Government is to the west, and Yewa North is to the north. It has a population of about 150,850.

2.0 Review of Literature

Climate change is a pressing global issue that significantly impacts agricultural sustainability. Agricultural systems are highly sensitive to climatic variations, which can lead to decreased productivity, food insecurity, and economic instability. This explores the multifaceted relationship between climate change and agriculture, emphasizing farmers' perceptions, adaptation strategies, economic implications, and the necessary policy frameworks. (FAO 2016), (Wheeler, and von Braun 2013). Climate change has been greatly impacted in cane productivity in Uttar Pradesh and Uttarahand, which has also changed and decreased crop duration in main crops including rice and sugarcane (Vinesh et al., 2009). Rainfall has little effect on Andhra Pradesh's sugarcane production (Ramulu, 1996).

By the middle of the twenty-first century, surface warming and changes in rainfall are predicted to reduce crop yields in India by thirty percent. As a result, there may be less arable land available, which would put pressure on agricultural output (Kapur et al., 2012). According to Lai (2010), climate change puts long-term agricultural sustainability at risk by exacerbating nutrient depletion, salinization, and soil erosion.

Climate change has a detrimental impact on India's food grain productivity. The majority of studies examine the influence of climatic change on agricultural output limited to a single state or region and based on one crop, two crops, or three crops. However, as food security is not solely dependent on food grain crops, evaluation of the total impact of climate change on major food grain crops is an important empirical subject, (Birthal, Khan, Negi, and Agarwal 2014).

According to Kaul and Ram (2009), Karnataka (India) farming communities' incomes and food security have been impacted by the Jowar crop's decreased yield due to excessive rainfall and drastic temperature fluctuations. Geethalakshmi et al. (2006) found that a 40C increase in temperature in Tamil Nadu caused a 41% decrease in rice crop productivity. Also, Saseendran et al. (1996), examined the predicted outcomes for the years 1984–2038, a temperature increases of up to 50°C can cause a constant drop in rice yield, with each degree increase in temperature resulting in a 6% decrease in yield in Kerala, India.

Moreover, Srivastava et al. (2013), monsoon sorghum productivity in central India would decline by up to 13% due to climate change zone (CZ) and as much as 2% in the south central zone (SCZ) by 2018; this model also indicated that yields would probably be even more impacted in 2040 and 2070 scenarios; in India, the effects of climate change on winter crops are predicted to lower yields by 6%, 12%, and 22% by 2020, 2050, and 2080, respectively.

Schmidhuber and Tubiello (2009) discovered that water scarcity results from altered precipitation patterns and greater evaporation brought on by warming temperatures.

Vermeulen et al. (2012) discuss how adopting climate-resilient farming methods, like conservation agriculture and agroforestry, can improve agricultural sustainability in terms of adaptation and mitigation tactics. All economic sectors are impacted by the climate and its variability in a number of ways, such as abnormal rainfall that increases the frequency and severity of floods. Large populations in peninsular and coastal regions would be impacted by any increase in the maximum temperature, which could raise mean sea levels. There could be a 15–40% increase in rainfall and a 3-6-degree increase in the average yearly temperature. Through agricultural productivity, climate change has a negative impact on food security in every nation. Four factors influence food security: food system stability, food availability, food accessibility, and food use. Human health, livelihood resources, and the production and distribution of food will all be impacted (FAO, 2007).

As the world's population grows, climate change will put pressure on agricultural production and food security (production location, supply, volume, and quality). By 2082, agricultural output in LDCs may drop by 20% as a result of climate change, with yields potentially declining by 15% on average, while output in industrialized nations is predicted to drop by 6% (Masters et al., 2012). Approximately 200 million people who depend on fishing and aquaculture for their livelihoods and their families around the world would be impacted (Greg et al., 2013). By 2080, climate change may cause India's GDP to drop by up to 6.2% and agricultural output to drop by up to 24% (Zhai and Zhuang, 2010; and Zhai et al., 2009).

FAO (2017), tackling the effects of climate change on agriculture and advancing sustainable agricultural development need bolstering policy frameworks and international cooperation.

3.0 Farmers' Views on Climate Change

Farmers' views on climate change play a crucial role i n their readiness to adopt adaptive measures. Research shows that individuals who have faced sever e weather incidents are more inclined to perceive clim ate change as a risk (Barnes & Toma, 2012). Confidence in information s ources, such as agricultu-ral extension agencies and environmental groups, is al so vital in shaping these perspectives (Weber, 2010

Climate smart farming encompasses methods aimed a t boosting productivity while lowering greenhouse ga s emissions. Climate smart practices entail better fertil izer management and agroforestry, which can promo te carbon sequestration and biodiversity (Howden et a l., 2007).

Climate change brings considerable economic conseq uences for agriculture. Studies predict that diminished crop yields resulting from climate change could incur losses amounting to billions of dollars ann ually (Tol, 2013). Smallholder farmers, who typically lack resources, are particularly susceptible to these e conomic repercussions.

As we progress through the 21st century, we face a si gnificant and potentially catastrophic environmental c hallenge: global warming and climate change. These phenomena threaten to cause irreversible damage to la nd and aquatic ecosystems and reduce agricultural effi ciency. We must remain alert, as the very foundation of human survival, the need for food, could be compromised due to the environmental risks posed by global changes affecting our natural ecosystems IPCC (2019).

4.0 Materials and Method

ArcGIS and satellite imagery are powerful tools widely used in geospatial analysis for diverse applications, ranging from environmental monitoring to urban planning. Satellite imagery provides high-quality, remotely sensed data captured by sensors onboard satellites, offering a detailed view of the Earth surface across various spatial, temporal, and spectral resolutions. This data is essential for analyzing land use patterns, detecting changes over time, and studying environmental dynamics on both local and global scales.

ArcGIS, a leading Geographic Information System (GIS) software, complements satellite imagery by offering robust tools for data visualization, analysis, and spatial modelling. By integrating satellite imagery into ArcGIS, researchers can process, analyze, and visualize geospatial data effectively. This combination enables precise mapping, change detection, and spatial decision- making through advanced methodologies such as classification, raster analysis, and spatial interpolation. Surveys, interviews, experiments, GPS observations, and data generated by the researcher themselves are some of the things that research journals are created for. Secondary data refers to data that is collected by someone else, the data is taken from a wider range of data files, such as government publications, websites with satellite imagery, books, academic papers, internal records, etc. The following criteria are used in this study: Slope, DEM, Topography, texture, precipitation, temperature, and used land cover are all components of the soil.

GPS visualizer was used to visualize geographic data by creating custom maps or profiles. It processed GPS data, including waypoints, tracks, and routes, and convert them into formats such as Google Maps, interactive maps, elevation profiles, or even KML/GPX files.

Table 1: Satellite Contributors to Google Earth

Satellite Name	Sensor	Spatial Resolution	Temporal Coverage	Applications
Landsat Series	OLI, TM, ETM+	15-30 m	1972 - Present	Land use, environmental monitoring
Sentinel-2	MSI	10-60 m	2015 - present	Vegetation, water monitoring
Worldview Series	WV-1 WV-2 WV-3	0.31-1.84 m	2007 - present	Urban planning, high-resolution mapping

Source: Authors' compilation, 2025

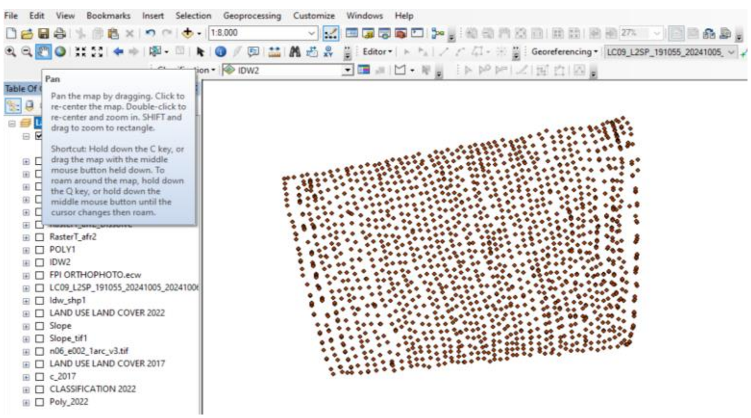


Figure 1: Satellite Images
Source: Google Earth[R], 2025

This is the collection, manipulation, and transformation of raw data into meaningful information. The Satellite images (containing different bands) were downloaded from Google Earth.

5.0 Results and Discussion

This part presents the status of land use, land cover, digital elevation model (DEM) (fig 2), Slope as they were in 2017 and 2022 for Google Earth imageries. It also shows the maps of the land use and land cover. The land use and land cover classification accuracy in shape area is also presented alongside land use and land cover changes.

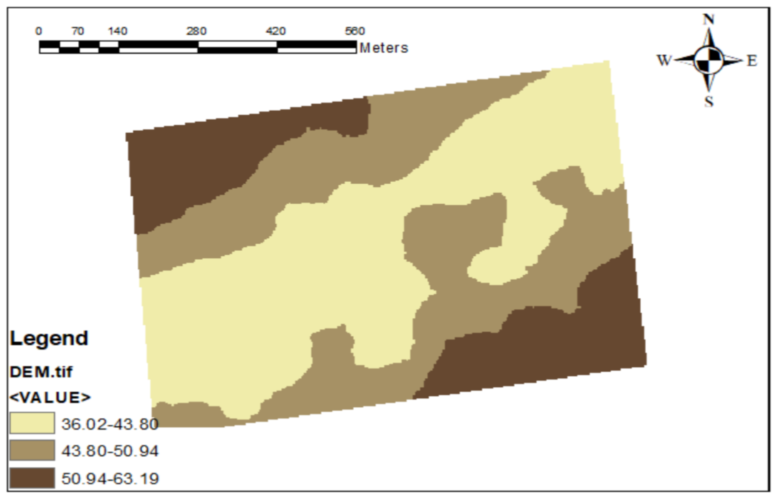


Figure 2: Digital Elevation Map
Source: Authors, 2025

This ability clarifies whether the study area's topography is suitable for agriculture. This capacity is based on the depth of the soil, which is a crucial factor for crop and vegetation production, as well as the likelihood of erosion. In this study, the terrain of the study region is classified as steep, moderate, or flat slopes to identify the most suitable for farming. The DEM of this study region was taken from Google Earth Pro.

Slope analysis was performed using the spatial Analyst tool in ArcGIS, which calculates the maximum rate of change in elevation between each cell and its neighbours. The area's topography is indicated by the slope. A DEM was used to build a slope map of the target region. A steeper topography is indicated by a higher slope, whereas a flatter terrain is indicated by a lower slope. The slope of the research region varied from less than 3% to over 30%.

Steep slopes frequently result in increased soil erosion and runoff, which lowers soil fertility and water-retention capacity. The study area's topography is provided via the DEM (see figure 2), which aids in identifying elevation differences. The research area's highest elevation (50.94–63.19m) and lowest elevation (36.02–43.80m) are two important findings from the DEM. The poor, less productive soil found at high elevations can restrict crop output, and the shorter growing seasons caused by lower temperatures at higher elevations might restrict the kinds of crops that can be grown.

Steep, moderate, and gentle slopes are highlighted on the slope map created from the DEM. Steep slopes are mostly found in the research region, while moderate slopes are transitional or foothills, and gentle slopes are best suited for communities and agricultural operations (See Figure 3). Low-lying locations are more vulnerable to flooding, particularly during periods of excessive rainfall or extreme weather, which can harm crops. Poor drainage in low-lying areas can result in soggy soils that impact crop growth and root health.

Climate-resilient crops that can withstand shorter growing seasons can be grown at high elevations. Minimizing erosion by contour farming and terracing. Using flood-resistant crop cultivars and constructing drainage systems to avoid waterlogging are important strategies at low elevation

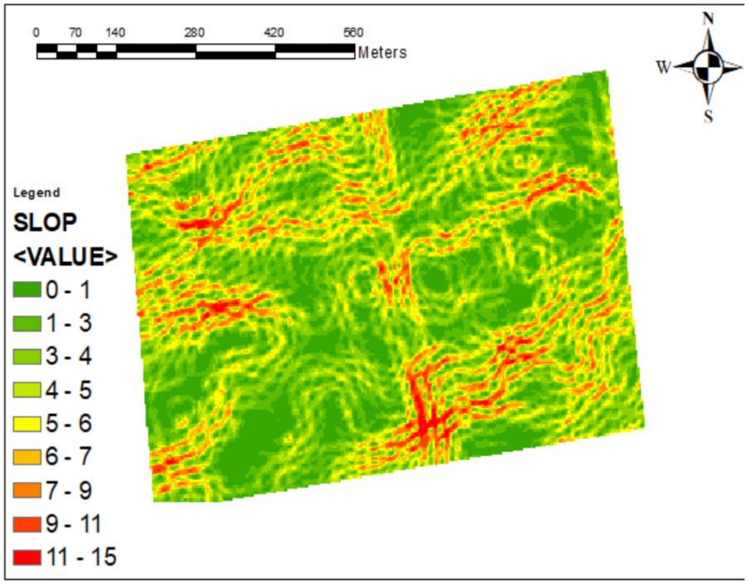


Figure 3: Slope Map
Source: Authors, 2025

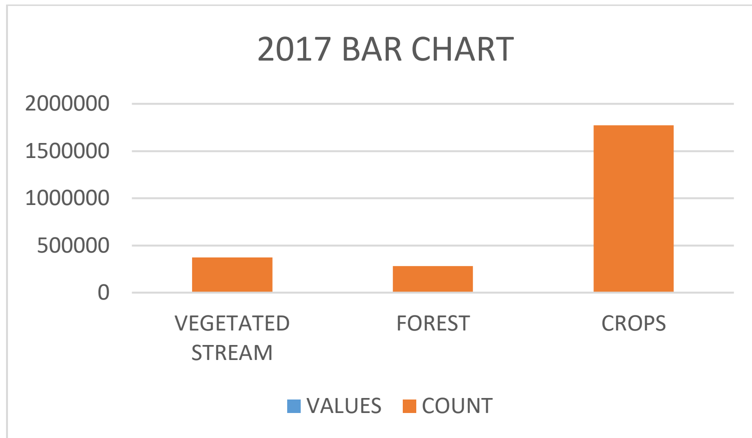
LULC data was derived from Google Earth satellite imagery, processed using supervised classification in ArcGIS. A supervised classification approach using the interactive classification was employed to categorize the satellite imagery into three LULC classes. The LULC categories identified in the study area include crops, vegetated stream and forest, agricultural land (crops) dominates the central portion of the study area.

Table 2: Land Use / Land Cover shape areas for 2017

OBJECTID *	Shape *	Class_name	Shape_Length	Shape_Area
1	Polygon	CROPS	64280.141614	413283.788584
2	Polygon	FOREST	10188.666474	2745.103961
3	Polygon	VEGETATED STREAM	61318.184963	109839.960588

Objects	Values	Count
Vegetated Stream	1	373053
Forest	30	280883
Crops	38	1772766

Source: Authors, 2025

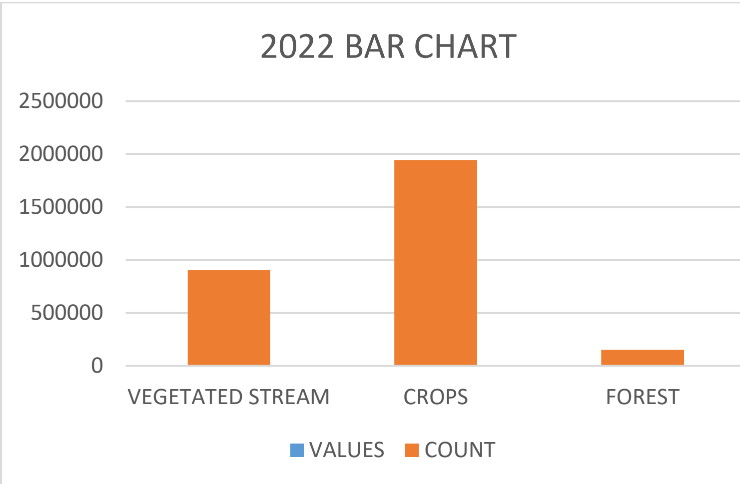


Source: Authors, 2025

Table 3: Present Land Use / Land Cover shape areas

OBJECTID *	Shape *	Class_name	Shape_Length	Shape_Area
1	Polygon	CROPS	77106.366597	427161.871887
2	Polygon	FOREST	3955.784025	1861.813758
3	Polygon	VEGETATED STREAM	77591.558687	96844.07574

Objects	Values	Count
Vegetated Stream	1	901815
Crops	8	1943799
Forest	9	151072



Source: Authors, 2025

Changes in land use, such as urbanization and deforestation, can upset regional climates, influencing temperature and rainfall patterns. Land use changes have the potential to uproot rural communities, which would affect the local economy and food security. types of land use, including forests, vegetated streams, and farms. The analysis shows how different land-use categories are distributed spatially, where crops grow in fertile, level regions with mild slopes, where the research area is heavily forested, and where streams line vegetated up with valleys or lower elevation regions (See figure 4 and 5).

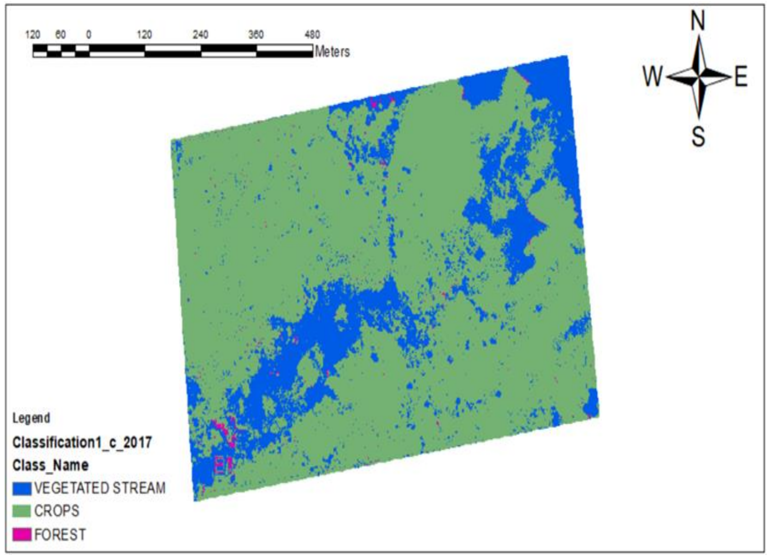


Figure 4: Land Use/Land Cover Map 2017
Source: Authors, 2025

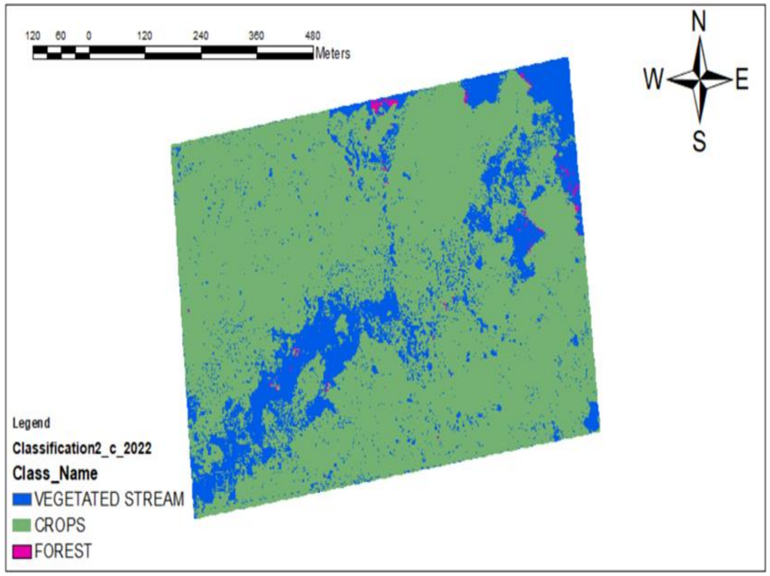


Figure 5: Land Use/Land Cover Map 2022
Source: Authors, 2025

Land use planning and sustainable farming methods, such as crop rotation, agro-forestry, and conservation agriculture, are crucial for addressing these issues and preserving the long-term sustainability of agricultural systems. According to Table 2 above, areas were computed using ArcGIS for the main land use categories for both 2017 and 2022. Crops occupy a larger area in the research region than other features like forests and vegetated streams. The area occupied by each land use class is shown graphically in the bar chart representation above.

6.0 Conclusion and Recommendations

Climate change presents significant challenges to agricultural sustainability, impacting crop yield through the effects on soil condition and water availability. As temperature rise and weather patterns become unpredictable, the resilience of agricultural system is tested. The resultant effects of climate change (including altered precipitation patterns, increased frequency of extreme weather events, and shifting pest and disease dynamics), on agricultural production constitutes a threat to food security and the livelihood of farmers worldwide.

By way of recommendations therefore, there is the need to develop climate-resilience crop varieties, educate the farmers on sustainable and crop rotation practices, and foster collaboration between the government and farmers to facilitate sharing of knowledge and resources.

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