SUSTAINABLE FOOD SUPPLY: THE INTERPLAY BETWEEN POPULATION GROWTH AND LAND PRODUCTIVITY CHANGESAS A PATHWAY TO 2030 AND BEYOND FOR NIGERIA

ABSTRACT

Context and background

Sustainable food supply is a critical global challenge, particularly in developing countries like Nigeria, where rapid population growth and limited land resources create a complex interplay with far-reaching implications. Thus, there will be a need to increase food production to keep pace with the population increase.

Goal and Objectives:

This study seeks to analyse the interplay between population growth and land productivity changes in Nigeria as a pathway towards achieving sustainable food supply by 2030 and beyond, in line with Goal 2 of the 2030 Sustainable Development Goals (SDGs) which is aimed at “ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture.

Methodology:

Data on land productivity and Nigeria's population and Population growth for 1961-2022 was sourced from the Economic Research Service of the United States Department of Agriculture (ERS-USDA, 2023). The data was analysed using descriptive statistics such as mean; standard errors and graphs; the Autoregressive Integrated Moving Average (ARIMA) was used to explain the interplay between population growth and land productivity changes in Nigeria.

Results:

The results of the population estimates revealed that the model successfully converged and significantly ($p<0$) explained 98.3% of the variance of the endogenous variable that is, the population at an intercept of -2500.7. Of the hypothesized variables, year (1.212), cropland (9.14E-4), irrigated (0.283), and pasture (0.003). These findings imply that the future population would increase in each period until the series becomes explosive because, the coefficient of the lagged variable of population is positive and greater than 1, which is in contrast with the assumptions of the ARIMA model which should be less than 1. Thus, the study recommends the adoption of precision agriculture and digital technologies to transform farming practices in Nigeria.

Keywords:

1. INTRODUCTION

Sustainable food supply is a critical global challenge, particularly in developing countries like Nigeria, where rapid population growth and limited land resources create a complex interplay with far-reaching implications.The nexus between population growth and land productivity has attracted considerable interest globally, particularly in the context of developing countries facing rapid demographic changes and agricultural challenges. One such nation grappling with this intricate relationship is Nigeria, a West African country with a population of about 218 million people an annual growth rate of 2.4%, and a high dependence on agriculture. However, the average productivity of major crops in Nigeria is less than 1000kg/ha on over 60% of the farmland[1], which is insufficient to meet the increasing demand of the growing population. The rapid population growth in Nigeria has emerged as a pressing concern, significantly exerting immense pressure on its land resources, and posing critical implications for food supply, sustainable development, and environmental conservation [2].

Population growth also drives urbanization, with more people migrating to cities in search of better economic opportunities and living conditions. This migration exerts additional pressure on agricultural land as urban areas expand, leading to the conversion of productive farmlands into non-agricultural uses.The demographic dynamics in Nigeria will continue to exacerbate these challenges, with the population expected to grow from 206 million people in 2020 to 400 million people in 2050 [3].Consequently, achieving a balance between population growth and land productivity has become a critical issue that necessitates comprehensive analysis and strategic interventions to ensure the well-being and prosperity of the nation. Agricultural efficiency and productivity are central to the farming sector's debates, policies, and measures. Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use. At its most basic level, productivity measures the output of a target group based on the resources and inputs used.

The world population has been on the increase, and according to Food and Agriculture Organization (FAO) estimates, there will be a need to increase food production by 60% by 2050 to keep pace with the population increase [4]. He also noted that agricultural land has been on the decline especially in the 21st century, which implies that land previously used for food production is being used for other purposes [4].

Nigeria is one of the African countries that produce agricultural commodities in large quantities especially in the 60s and early 70s when it was the world's largest producer of some commodities which include palm oil, and cocoa. Groundnut, rubber among others [5]. This trend of high production has been reducing over the years due to the country's high population growth rate, which revolves around 2.5% per annum [6] and competes with the available productive land. Thus, unguided processes of urbanization and increased population density have exerted unprecedented pressure on available agricultural land in Nigeria [5].

The finding of [7] in the study on agricultural land use and population growth in Nigeria revealed that while population growth was growing at 2.57%, agricultural land utilization was growing at 0.62%. In a related study on agricultural production indicators and the dynamic macroeconomic variables, [8] observed that land density is one of the determinants of crop production gross index and agricultural gross production index in the long run. [9] reported that population growth reduces the quality and quantity of natural resources through over-exploitation, intensive farming, and land fragmentation thus, intensifying pressure on food production. [10] in their study of the impact of population pressure on agricultural land, discovered that a large number of populations in an area indirectly puts pressure on land through the activities that are done which include massive conversion of agricultural land into building land thus reducing land for agricultural purposes. furthermore, [11] in their study on constraints to increasing agricultural productivity in Nigeria, opined that the low productivity of agricultural land is due to continuous cropping resulting from excessive land fragmentation and shortages of arable lands induced by an increase in population.

Against this backdrop, this study seeks to analyse the interplay between population growth and land productivity changes in Nigeria as a pathway towards achieving sustainable food supply by 2030 and beyond, in line with Goal 2 of the 2030 Sustainable Development Goals (SDGs) which is aimed at “ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture” [21-23].

ARIMA is a widely used time series forecasting method in statistics and econometrics. It is a powerful technique for modelling and forecasting time series data, which are sequences of observations collected at equally spaced time intervals. ARIMA models are particularly useful for capturing and predicting trends, patterns, and seasonality in time series data.

ARIMA models consist of three main components:

i. **Autoregressive (AR) Component (p)**: The autoregressive part of an ARIMA model represents the relationship between the current value of the time series and its past values. The "p" in ARIMA(p,d,q) indicates the order of the autoregressive component. It specifies the number of lagged observations to include in the model.

ii. **Integrated (I) Component (d)**: The integrated part of an ARIMA model accounts for differencing the time series data to make it stationary. The "d" in ARIMA(p,d,q) denotes the differencing order. It indicates how many times the data needs to be differenced to achieve stationarity (i.e., constant mean and variance).

iii. **Moving Average (MA) Component (q)**: The moving average component of an ARIMA model represents the relationship between the current value of the time series and its past forecast errors (residuals). The "q" in ARIMA(p,d,q) specifies the order of the moving average component, indicating how many past forecast errors are considered in the model.

The ARIMA model is often denoted as ARIMA(p,d,q). The choice of the values for "p," "d," and "q" depends on the specific characteristics of the time series data and is determined through a combination of data exploration, statistical tests, and model selection techniques.

2. METHODOLOGY

2.1.Study area

The study was based on land productivity and population growth in Nigeria. Nigeria is estimated to be the largest country in sub-Saharan Africa in terms of the size of both the economy and the population. Nigeria’s population at the end of 2020 is estimated to range from 200.96 million to 206 million.Nigeria is a geographically diversified country with a variety of landscapes, from coastal districts along the Gulf of Guinea in the south to savannahs, plateaus, and mountainous regions in the centre and northern parts. Nigeria is home to one of Africa's major rivers, the Niger, which greatly impacts the country's landscape and agriculture.

2.2.Data Source

Data for Nigeria's population and Population growth for 1961-2022 was sourced from the National Population Commission [12] as projected to 2022 while the data on land productivity is from theEconomic Research Service of the United States Department of Agriculture [13].

2.3.Data Analysis

To understand the inherent time series characteristics of the data, they were analysed using the Autoregressive Integrated Moving Average (ARIMA) methodology. The methodology reveals the properties and which further analytical tools are to be applied. The interplay between population growth and land productivity changes in Nigeria was determined using the Autoregressive Distributed Lag (ARDL) methodology since the data exhibited differing orders of integration and differencing.With ARDL, we can determine the nature of the interplay between land productivity and population dynamics in a situation where the individual series are not of the same order. To understand how the two series will interplay into the future, their forecasts were established using dynamicforecast methods. The forecast automatically uses the length of the data and forecasts equal length to the future. The data covers 1961-2022, hence the forecast is from 2023-2084. All the estimations were carried out with functions provided in R ([14] [15] [16] [17).

3. RESULTS AND DISCUSSIONS

Table 1 shows the summary statistics of the variable included in the model. The mean cropland value was 35645 while the population was 110million. Cropland, irrigated, pasture and arable land had a skewness value of 0. This is an indication that the data distribution was approximately symmetric. Implying that the mean, median, and mode were generally close to each other and located at the centre of the distribution. This is further confirmed by the negative kurtosis value which was also negative suggesting that the distribution has a flatter peak or less pronounced central peak compared to a normal distribution because the data is relatively more spread out around the mean. However, the population data was skewed to the right meaning the mean (average) wasgreater than the median which, in turn, wasgreater than the mode.

Table 1: Summary Statistics of Variables

Statistics	Year	Cropland	Irrigated	Pasture	Arable land	Population ‘000,000	Population growth
Mean	1992	35645	250	27033	62927	110	0
SD	18	14170	56	1445	14289	51	0
SE Mean	2	1800	7	184	1815	6	0
Min	1961	15958	200	23927	43711	46	0
Median	1992	34069	233	27044	64140	99	0
Max	2022	64441	341	30141	93495	219	0
Q1	1976	24228	200	26000	50473	66	0
Q3	2007	44842	311	27979	71408	145	0
Skewness	-0	0	0	0	0	1	3
Kurtosis	-1	-1	-2	-1	-1	-1	13
Nobs	62	62	62	62	62	62	62

Table 2 indicates that the current cropland conditions or acreage are not influenced by its condition in previous periods and likewise arable land. The current cropland and arable values are determined by factors other than their historical values. These factors might include factors like weather conditions, agricultural practices, land-use policies, and more.However, the data points for pasture and irrigated land were assumed to depend linearly on the previous values. This implies that the current values of pasture and irrigated land are influenced by their respective values in the immediately preceding period.Again, the moving average lag for cropland, pasture, irrigated, population, and population growth were zero suggesting that, current observations or outcomes such as crop yield, or land use related to these variables are not influenced by past values in a moving average sense. In other words, changes in crop management, environmental factors, agricultural practices, or population are assumed to have an immediate impact.That is to say, there are no systematic patterns or trends that repeat regularly at fixed intervals throughout the time series. The absence of a Seasonal Autoregression (SAR) term simplifies the seasonal time series model. SAR terms are used to capture the seasonal patterns or dependencies in data, so when SAR is zero, the model becomes simpler and may have fewer parameters.

Table 2: Results of Autoregressive lag

Variable	Autoregressive lag (p)	Differencing order (d)	Moving average lag (q)	Seasonal autoregressive lag (P)	Seasonal Differencing order (D)	Seasonal Moving average lag (Q)	Order of seasonality (m)
Cropland	0	0	0	0	1	1	0
Pasture	1	1	0	0	1	0	0
Irrigated	1	1	0	0	1	2	0
Arable	0	0	0	0	1	1	0
Population	0	1	0	0	1	2	0
Population growth	0	1	0	0	1	1	0

The results of the population estimates revealed that the model successfully converged and significantly ($p<0$) explained 98.3% of the variance of the endogenous variable that is, the population at an intercept of -2500.7. Of the hypothesized variables, year (1.212), cropland (9.14E-4), irrigated (0.283) and pasture (0.003) variables significantly and positively affected the population at a 1% level (Table 3). These findings imply that the future population would increase in each period until the series becomes explosive because, the coefficient of the lagged variable of population is positive and greater than 1, which is in contrast with the assumptions of the ARIMA model which should be less than 1. The impact of increasing cropland on population dynamics, environmental sustainability, and food security is a complex issue. Expanding cropland has a significant impact on providing enough food to support the increasing global population. As cropland acreage increases, the potential for higher agricultural productivity also increases, which is crucial to ensure that the world's inhabitants have enough to eat. However, the conversion of natural habitats into agricultural land can result in a decline in biodiversity due to the loss and fragmentation of habitats [18]. This can pose a threat especially when coupled with deforestation, and can exacerbate climate change by releasing stored carbon and disrupting ecosystems.In addition, the expansion can result in soil erosion, water pollution, and the depletion of vital natural resources such as water and fertile soil.

In the same vein, involvement in irrigation and pasture had a positive effect on the population. This could be because irrigation systems have significantly increased agricultural output by providing reliable water supply to crops. Thus, enhanced agricultural productivity can contribute to food security, reduce hunger, and support growing populations [19]. More so, improved crop yields due to irrigation can attract people to agricultural regions, contributing to population growthand thus rural areas may experience demographic changes as a result of this migrationsincea more secure food supply can support larger communities.Pasture is vital for livestock production, which provides food, income, and livelihoods for many rural populations. Well-managed pastures can support livestock and, in turn, support the populations that rely on them.

The effects of irrigation and pasture on population depend on various factors, including the sustainability of these practices, local socio-economic conditions, and environmental considerations. When managed sustainably, they can contribute to food security, livelihoods, and population well-being.

The arable land estimates revealed that the model successfully converged and significantly (p<0) explained 100% of the variance of the endogenous variable, that is arable land at an intercept of 2.6E-9. The lagged value of arable land is negative and less than 1, and as such, arable land would tend to decrease in the future. More so, of the hypothesized variables, year (-1.3E-12) significantly and negatively affected arable land at a 1% level. Whereas, cropland (1.0), irrigated (1.0) and pasture (1.0) significantly and positively affected arable land at 1% level.Cropland, irrigated land, and pasture can have numerous positive impacts on arable land, such as increased productivity, improved soil health, carbon sequestration, biodiversity conservation, and rural community support. Irrigation, for instance, plays a strategic role in improving productivity.These practices are essential for sustainable agriculture and addressing the challenges of feeding a growing global population while preserving the environment. However, their positive effects depend on responsible and sustainable management practices. This is in line with [20] who reported that an increase in the area of arable land was mostly associated with the expansion of the cultivated area for main food crops.

Table 3: Autoregressive Moving Average Model

	Population with intercept only	Population	Land with intercept only	Land
(Intercept)	109.667*** (6.414)	-2500.734*** (349.564)	62927.234*** (1814.668)	0.000*** (0.000)
Year		1.213*** (0.190)		0.000*** (0.000)
Cropland		0.001*** (0.000)		1.000*** (0.000)
Irrigated		0.284*** (0.060)		1.000*** (0.000)
Pasture		0.003*** (0.001)		1.000*** (0.000)
Popgrowth		346.954 (358.916)		0.000 (0.000)
Population				0.000 (0.000)
Num.Obs.	62	62	62	62

	Population with intercept only	Population	Land with intercept only	Land
R2	0.000	0.983	0.000	1.000
R2 Adj.	0.000	0.982	0.000	1.000
AIC	665.3	421.7	1365.3	-2961.3
BIC	669.5	436.6	1369.5	-2944.3
Log.Lik.	-330.639	-203.852	-680.638	1488.659
F				22541537578890649408008284240066.000
RMSE	50.10	6.48	14173.01	0.00

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1 indicates that arable land availability will rise to only about 300,000ha by the year 2084

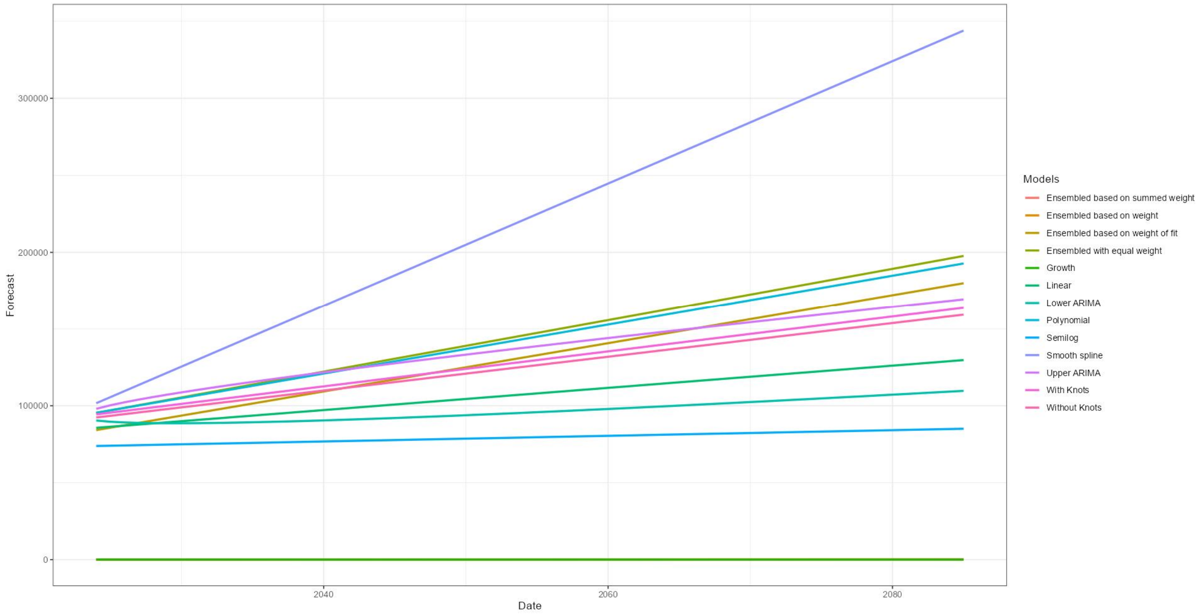

Figure 1: Forecast of arable land availability (2023-2084)

while the population will rise above 600 million people (figure 2) an indication that the population is growing faster than the availability of arable land. This finding corroborates[7] who posited that the population growth rate for Nigeria was higher than the growth rate foragricultural and arable land utilization respectively. Access to arable land is crucial for food production. However, as the population increases, the availability of arable land becomes limited, which can result in reduced agricultural productivity. This, in turn, can lead to food shortages, price hikes, and greater susceptibility to famine or food crises. More so, increased competition for arable land may lead to conflicts over land rights and usage, as well as pressure on existing agricultural areas, resulting in overuse, and degradation of soil, water resources, and ecosystems. This can result in soil erosion, depletion of groundwater, and loss of biodiversity, which can have long-term ecological consequences. As the population continues to grow, the limited capacity of arable land to support its needs may force people to migrate internally or externally in search of better opportunities and access to resources. This migration can result in a brain drain, causing a loss of highly skilled professionals in their respective fields which may have some economicconsequences.

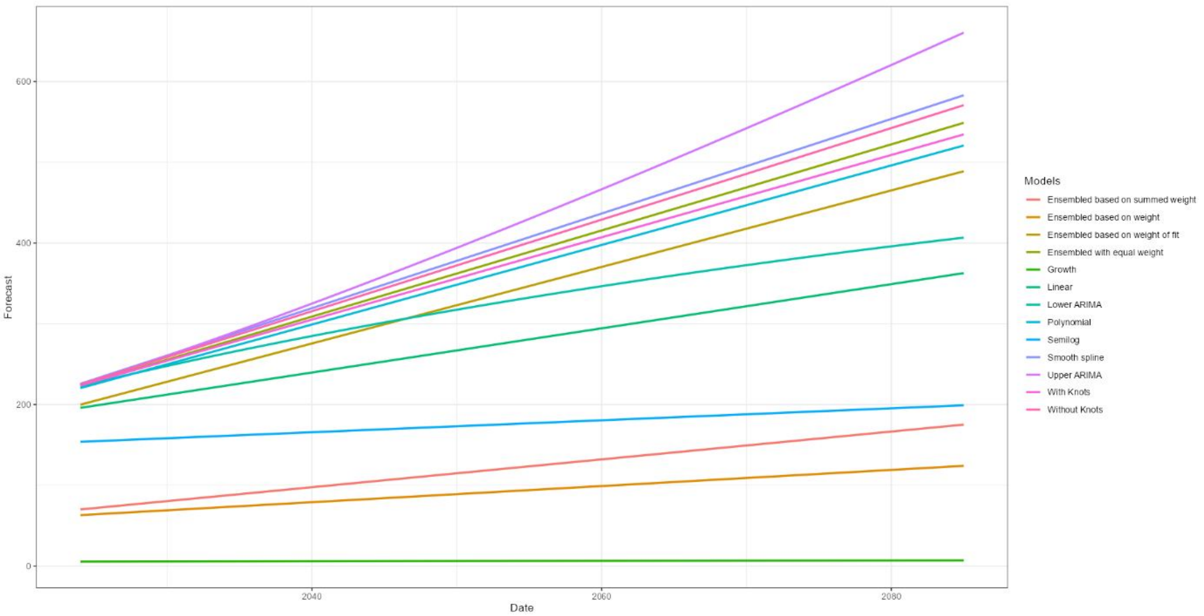

Figure 2: Forecast of population (2023-2084)

4. CONCLUSION AND RECOMMENDATIONS

Thus, the study recommends the adoption of precision agriculture and digital technologies to transform farming practices in Nigeria. By adopting these technologies, farmers can make informed decisions regarding crop selection, planting schedules, and irrigation, leading to improved land productivity and resource efficiency. In addition, the Nigerian government must prioritize investments in agricultural research and extension services, encouraging innovation and knowledge transfer to farmers.

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