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RESEARCH PAPER

Agricultural productivity in developing countries and influence of climate change on agriculture

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Key Message: There was unstable agricultural productivity in developing countries due to policy summersault, low level of technology and climate change. In this study, some of the effects of climate change on agricultural productivity were presented using the rubber tree as an example.

Abstract

Agricultural productivity is critical to the supply of food and fiber required to support good quality life, more so with increasing World population. In this regard, developing countries are at the risk of food scarcity. The primary objective of this paper was to evaluate the trend of agricultural productivity in Low Income (LI) and Lower Middle Income (LMI) countries in comparison with High Income (HI) countries. A secondary objective was the evaluation of the effect of climate change on agriculture in Nigeria. Metadata was collated on agricultural total factor productivity and per capita income from 1960 to 2000. The data was regrouped into class data of five years interval. The class data was analyzed using means, correlation and regression analysis. The High Income countries had a regular sigmoid curve for agricultural productivity. LMI countries had an undulating regression curve though with a short stable period. The curve for LI countries was unstable. In multiple regression, HI countries recorded a high regression coefficient of 0.97 compared with 0.06 and 0.35 in LMI and LI respectively. The intersection point, i.e. the constant was -0.83. This negative constant supports previous reports on World food crises. The options of cross sectorial policy formulation/implementation, North-South and South-South Cooperation were suggested to ensure that the entire World system works in unison to respond positively to the challenges of food and nutrition security. This is moreso as agriculture in developing countries is mainly nature dependent, hence vulnerable to the effect of climate change. In this regard, the effect of climate change on agriculture in Nigeria was studied, with a situation report and recommendations.

Keywords: Agricultural productivity, Climate change, Total factor productivity

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Introduction

Agricultural productivity in Sub-Sahara Africa has pre-colonial, colonial and post-colonial phases. In spite of these time demarcations, one common factor is the high proportion of the population involved in agriculture (Allen et al., 2018). The pre-colonial period was characterized by food adequacy as more than 90% of the population was involved in agriculture (Cordell & Gregory, 2021). It may have the limitation of low intake of animal protein, especially in the Rain Forest areas which could not support extensive cattle rearing due to tse-tse fly infestation (Green, 2016). On a general note, food, including plants, animals and fishery, were in abundance. There was fibre for local fabrics in assorted forms (Adamu & Bello, 2015). Agriculture in the colonial period shifted gradually with emphasis on export crops to production of raw materials for industries, especially in Europe. This was a gradual compromise against production of basic food items, loss of diversity of food crop species, malnutrition, loss of soil fertility, etc. Notwithstanding, cultivation of export crops was financially rewarding as a means of acquiring western education for children, some electronics and electrical items, and other household goods (Roessler et al., 2022). White collar jobs and artisan work also led to reduction in farm household labour.

The impact of decline in food production in quantity and quality was obvious in the post-colonial period. In Nigeria, the National Accelerated Food Production Programme was launched in 1972 (Iwuchukwu & Igbokwe, 2012). This was the beginning of the policy intervention in agriculture in the Nigerian post-independence era. Nigeria attained independence in 1960. The agricultural policy thrusts in Nigeria can be in three groups viz colonial, post-colonial but military era, and postcolonial but democracy period (Abubakar et al., 2022). Agricultural productivity is technically defined as input/output ratio, return on investment or production efficiency (Awoyemi et al., 2017). The other perspective of agricultural productivity is the proportion of gross domestic product due to agriculture (Zepeda, 2001). In the new millennium, i.e. since the year 2000, Total Factor Productivity (TFP) became popular. The TFP sums up into an index of inputs and a separate index for outputs. The ratio of the index of input to index of output gives the TFP (Seibert & Doll, 2010; Fuglie, 2015).

The main objective of this study was to present an overview of the trend of agricultural productivity, implications and the way forward in six developing countries with emphasis on post-independence agricultural productivity in comparison with three advanced countries. In addition, an overview of the impact of climate change on agricultural productivity in Nigeria will be presented.

Materials and Methods

The Agricultural TFP (A-TFP) and per capita income (PCI) from three countries in each of three PCI groups were obtained as metadata. The sources of metadata are presented as Annexure 1. The three PCI groups were High Income (HI) consisting of the Netherlands, New Zealand and the United Kingdom and the Lower Middle Income group with Cote d'Ivoire, Ghana and Nigeria. The third group was Low Income (LI) having Guinea Bissau, Senegal and Zambia as sample countries. The data covered A-TFP from 1960 to 2020 and the same period for PCI. In each data set, class data of five years interval were obtained. The mean A-TFP for each of HI, LMI and LI countries for each class was calculated. The mean values were plotted to obtain a line graph of the trend of A-TFP for each of HI, LMI and LI groups. This was accompanied with multiple regression of Year Group against A-TFP. In addition, the PCI data was reorganized into class data of five years interval synonymous with the A-TFP classes. There was correlation between PCI and A-TFP for each of HI, LMI and LI country groups. A review of the effect of climate change on natural rubber tree, *Hevea brasiliensis*, and possible solutions was carried out.

Results and Discussion

Agricultural productivity index

The data collated and mean values of productivity index for each of the nine countries, from 1961 – 2020 are presented in Table 1 and 2. The trend of agricultural productivity index over the study period was presented in Fig. 1. There was the typical sigmoid curve for the HI countries rising steadily from 53% in 1960 – 1965 to 92% with a plateau from 2001 – 2010, and followed by another steady rise to 98% in 2015 – 2020 (Fig. 1). This suggests a healthy growth of the agricultural sector (EU, 2016). It is also a reflection of political and economic stability. The input of technology such as improved mechanization, automation and digitalization are factors supporting agricultural productivity in the High Income countries (Pawlak et al., 2002). It was however observed that the agricultural productivity index was higher in Low Income and Lower Middle Income countries from 1961 to 1980. This is a reflection of low input agriculture which would have given the impression of a higher productivity index. This is typical of peasant agriculture well stated by Pleog (2014). This phase of higher productivity index has limitation of scale (Gogoi, 2018).

In the case of the LMI countries, the curve was undulating from 75.7% in 1960 – 1965 dropped to 65.9% from 1981 – 1985 from which it assumed the sigmoid trend to 2011 – 2015 at 96%. There was further inflection to 95% from 2015 – 2020. The relatively high A-TFP was encouraging in the immediate post-independence era for many African countries. The second phase showing a decline represents the early stage of military intervention or short lived civilian regime. The sigmoid trend represents the later era of military regime leading to steady growth sustained by the succeeding civilian era till 2015. The downward trend to 2020 is a reflection of policy summersault (Manyong et al., 2003; Igudia, 2017). The Low Income countries recorded A-TFP of 87% from 1960 – 1961 and declined to 84% from 1981 – 1985. The range of A-TFP was 83% - 87% in 1960 - 2000. The difference of only 4% is evidence of low inputs including poor technology. Agriculture is mainly nature dependent with vulnerable agrarian population. Low technology input and poor extension support in the overall economy is typical of this group (Mayer, 2000).

Correlation and regression

The high and positive correlation at 0.93, between per capita income (PCI) and A-TFP in develped countries showing that there was increasing A-TFP along with increasing PCI (Table 3). The economy of the HI group therefore had balanced growth of both the industrial and agricultural sectors. The LMI had 0.79 correlation between A-TFP and PCI, compared with HI countries, it is an indication of some disconnect between the agricultural sector and other aspects of the economy (Raheem et al., 2014; Soininen, 2014). Many of the LMI countries have drive towards industrialization without commensurate attention to the food and fibre needs of the economy, especially with high rural urban migration, white collar, artisan and factory jobs. This was accentuated by hazards of climate change (Omokhafe, 2017).

The correlation of 0.91 between A-TFP and PCI for LI countries, though apparently good, is within the scope of low technology and low agricultural productivity with none without the capacity to provide the impetus for the other. There was an upward leap from 2001 – 2005 to a peak of 105% in 2006 – 2010 but declined to 98% in 2016 – 2020. Agricultural development in LI countries needs a lot of supports to enable it assume some shape from its current state.

The multiple regression equation for relationship between Years (Y) and A-TFP is presented as follows:

$$Y = -81.99 + 0.97X_1 + 0.06X_2 + 0.35X_3$$

Where X_1 is High Income Countries, X_2 is Lower Middle Income Countries and X_3 for Low Income Countries.

The intercept is on the negative side which suggests an overall world crisis in the agricultural sector, even as often reported as global food crises (Global Report on Food Crises [GRFC], 2022). This is further deepened by climate crisis, desertification, desert encroachment, degradation of Rain Forest, loss of Mangrove Forest, loss of agricultural labour without commensurate increase in application of technology, etc (Omokhafe et al., 2019; Omokhafe et al., 2020). South-

South cooperation especially between the LMI and LI countries is suggested (United Nations Framework Convention on Climate Change [UNFCC], 2017). This will be facilitated by HI countries in addition to North-South Cooperation (Stamm, 2023). This is more so as the HI countries have high a coefficient of 0.97, an indication of the positive influence of HI countries on World Agricultural Production. The positive though low coefficient for LMI and LI countries is an indication of a system that will have positive and immediate response to interventions.

Table 3 Correlation between Agricultural Total Factor Productivity (A-TFP) and Per Capita Income (PCI)

Country Group	Correlation
High Income	0.93**
Lower Middle Income	0.79*
Low Income	0.91**

*, **: Significant at $p \leq 0.05$ and $p \leq 0.01$ respectively

Effect of climate change on rubber cultivation

Climate change has impacted negatively on rubber cultivation worldwide (Jacob et al., 2022). Some of the effects of climate change are as follows:

i. Rain Forest degradation

The natural rubber tree, *Hevea brasiliensis*, is adapted to the Tropical Rain Forest and cultivated extensively in Indonesia, Thailand, China, Malaysia, Cambodia and Vietnam in Asia, Nigeria, Ghana, Cote d'Ivoire and Liberia in West Africa and Brazil in South America. The Rain Forest as the natural habitat of the rubber tree is threatened by degradation of the Rain Forest, such that several terms are used to describe the degraded Rain Forest. Among such terms are ecotone, derived savannah, forest-grassland mosaic etc (Freedman et al., 2023; Razafimanantsoa & Razanatsoa, 2024). The derived savannah in West Africa is estimated at 63.7 million hectares (Omokhafe et al., 2019).

ii. Production of planting materials

Rubber tree is propagated by budding. Three weather factors which affect budding are temperature, relative humidity and evaporation leading to reduced production of budded stumps for planting (Omokhafe et al., 2016). The major effect is desiccation as described by Jacob et al. (2022). Increasing temperature leads to reduced budding success, whereas high humidity is a requirement for high budding success. The reality of climate change is reduced relative humidity, hence a negative effect on budding success. High evaporation suggests loss of ambient moisture, which is required for good growth of rootstock as well as budding success. The amelioration methods result in increased cost of production. Among these factors are increased irrigation, increased labour, increased soil amendments, etc.

iii. Latex yield

Natural rubber latex is the major source of elastomers that require high tensile strength and heat resistance and *H. brasiliensis* is the major source of natural rubber world-wide. It is a major component of tyre, pneumatic tube, shoe sole, conveyor belt, condom, carpet underlay, etc. Latex is a colloidal solution of mainly water and rubber particles. Any distortion of the water cycle, therefore affects latex production. Interstitial water is obtained mainly through soil absorption meanwhile soil moisture depends mainly on rainfall (Mesike & Esekhade, 2014). In a study conducted by Omokhafe (2004), the lowest latex yield was in January to May, in Nigeria, synonymous with the period of dry weather in Nigeria. Yield depression is imminent following increasing aridity associated with climate change.

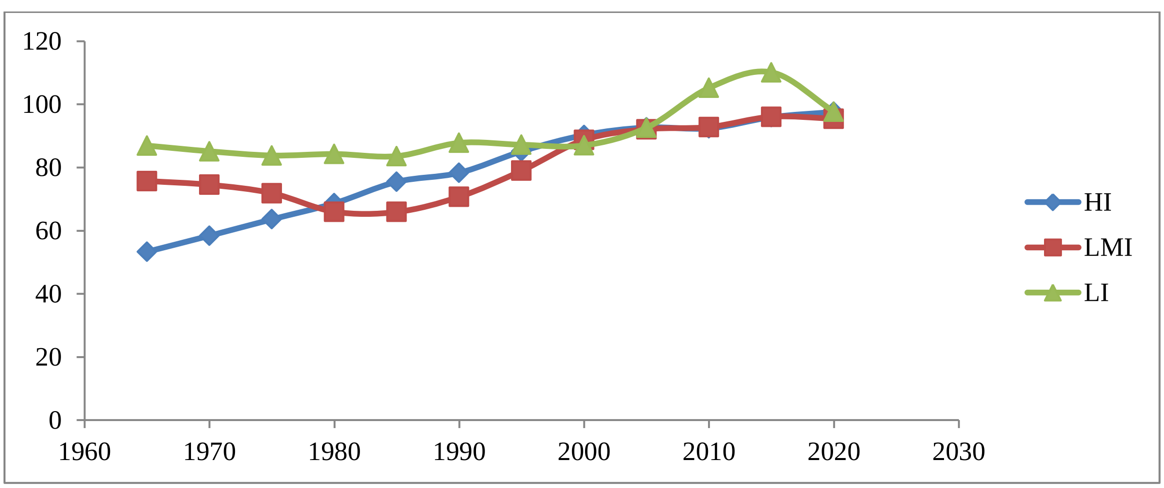

Fig. 1 Trend of Agricultural Total Factor Productivity (A-TFP) from 1960 to 2020 in high income, lower middle income and low-income countries

Table 1 Agricultural total factor productivity (TFP) index: High income countries

Country	1961	‘62	‘63	‘64	‘65	1966	‘67	‘68	‘69	‘70	‘71	‘72	‘73	‘74	‘75	‘76	‘77	‘78	‘79	‘80
Netherlands	59	61	60	61	59	59	66	70	68	71	75	71	74	75	81	79	78	82	80	83
Class mean	**60**					**66.8**					**75.2**					**80.4**				
United Kingdom	57	58	58	60	62	62	64	64	64	69	70	70	70	76	73	70	77	79	79	84
Class mean	**59**					**64.6**					**71.8**					**77.8**				
New Zealand	40	42	41	41	41	42	43	44	45	45	45	45	44	41	44	49	47	46	47	50
Class mean	**41**					**43.8**					**43.8**					**47.8**				

Country	‘81	‘82	‘83	‘84	‘85	1986	‘87	‘88	‘89	‘90	1991	‘92	’93	‘94	‘95	1996	‘97	‘98	‘99	2000
Netherlands	88	89	91	90	87	91	91	88	99	93	92	99	101	94	98	100	98	99	103	100
Class mean	**89**					**92.4**					**96.8**					**100**				
United Kingdom	82	82	83	88	86	85	85	84	87	91	93	97	97	95	96	95	94	96	100	99
Class mean	**84.2**					**86.4**					**95.6**					**96.8**				
New Zealand	51	51	53	53	58	56	56	59	57	53	56	61	60	68	70	72	75	77	70	76
	53.2					**56.2**					**63**					**74**				

Country	2001	‘02	‘03	‘04	‘05	2006	‘07	‘08	‘09	‘10	2011	‘12	‘13	‘14	‘15	2016	’17	‘18	‘19	2020
Netherlands	92	96	89	93	92	86	88	87	89	90	97	94	100	99	100	102	102	97	101	102
Class mean	**92.4**					**88**					**98**					**100.8**				
United Kingdom	91	97	95	96	95	93	90	98	95	96	98	91	93	98	100	95	97	94	100	93
Class mean	**94.8**					**94.4**					**96**					**95.8**				
New Zealand	73	91	96	97	97	102	96	93	93	90	89	92	92	96	100	97	94	97	96	97
Class mean	**90.8**					**94.8**					**93.8**					**96.2**				

Table 2 Agricultural total factor productivity (TFP) index: Lower Middle Income countries and Low Income (LI) countries

Country	1961	1962	1963	1964	1965	1966	‘67	‘68	‘69	‘70	‘71	‘72	‘73	‘74	‘75	‘76	‘77	‘78	‘79	1980
Nigeria (LMI)	87	88	87	87	86	83	83	83	85	90	81	76	74	82	76	70	72	72	72	72
Class mean			**87**					**84.8**					**77.8**					**71.6**		
Côte d'Ivoire (LMI)	86	79	84	92	82	90	78	90	83	86	86	83	86	83	90	87	83	80	84	85
Class mean			**84.6**					**85.4**					**85.6**					**83.8**		
Ghana (LMI)	57	55	55	58	53	53	55	53	54	52	53	52	52	54	50	46	41	42	42	42
Class mean			**55.6**					**53.4**					**52.2**					**42.6**		
Guinea-Bissau (LI)	104	103	98	93	86	83	84	84	82	81	76	77	76	75	78	83	78	76	76	75
Class mean			**96.8**					**82.8**					**76.4**					**77.6**		
Liberia (LI)	147	144	136	131	134	157	154	136	131	142	157	144	148	148	150	152	148	140	137	139
Class mean			**97**					**103.4**					**103**					**98**		
Zambia (LI)	66	65	65	69	70	73	71	70	68	64	69	75	68	68	80	83	80	75	72	76
Class mean			**67**					**69.2**					**72**					**77.2**		

Country	1981	'82	'83	'84	'85	1986	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000
Nigeria (LMI)	73	74	74	73	76	74	74	80	84	85	89	93	95	97	99	101	103	104	107	105
Class mean			**74**					**79.4**					**94.6**					**104**		
Côte d'Ivoire (LMI)	91	82	81	80	87	86	88	86	86	89	86	88	83	82	86	89	91	95	96	103
Class mean			**84.2**					**87**					**85**					**94.8**		
Ghana (LMI)	39	37	38	42	42	46	45	46	49	43	55	55	59	57	61	65	63	67	71	71
Class mean			**39.6**					**45.8**					**57.4**					**67.4**		
Guinea-Bissau (LI)	76	81	74	82	86	89	86	86	87	88	87	87	87	87	88	91	90	89	93	92
Class mean			**79.8**					**87.2**					**87.2**					**91**		
Sierra Leone (LI)	134	139	133	137	140	100	96	96	98	84	87	84	82	82	79	82	83	78	72	69
Class mean			**95**					**94.8**					**82.8**					**76.8**		
Zambia (LI)	73	75	78	78	76	79	75	89	83	81	94	80	103	92	89	97	90	89	96	94
Class mean			**76**					**81.4**					**91.6**					**93.2**		

Country	2001	'02	'03	'04	'05	'06	'07	'08	'09	2010	'11	'12	'13	'14	'15	'16	'17	'18	'19	2020
Nigeria (LMI)	104	103	103	106	108	110	100	102	94	100	91	96	90	100	100	99	95	94	96	92
Class mean	**104.8**							**101.2**			**95.4**					**95.2**				
Côte d'Ivoire (LMI)	100	96	95	94	97	97	93	99	93	92	96	98	97	98	100	96	100	97	92	94
Class mean	**96.4**					**94.8**					**97.8**					**95.8**				
Ghana (LMI)	70	76	76	75	79	76	76	82	88	90	92	90	93	100	100	97	95	98	93	94
Class mean	**75.2**					**82.4**					**95**					**95.4**				
Guinea-Bissau (LI)	92	90	91	93	98	100	99	108	107	105	101	100	99	100	100	96	93	87	85	85
Class mean	**92.8**					**103.8**					**100**					**89.2**				
Sierra Leone (LI)	73	83	101	100	99	111	101	103	122	123	126	130	129	114	100	95	91	83	84	110
Class mean	**91.2**					**112**					**119.8**					**92.6**				
Zambia (LI)	91	93	95	93	97	90	91	99	109	110	115	114	110	114	100	103	118	111	113	111
Class mean	**93.8**					**99.8**					**110.6**					**111.2**				

iv. Gene changes

The rubber tree has experienced a change in flower structure due to climate change. This is however a mutant and evolution is such that if a mutant enjoys an advantage, it may become a variant among the species. Species variant has its consequences, especially in agriculture where acceptance is a major factor. There were twenty loculi ovary arranged in linear rows of ten loculi each (Fig. 2), in contrast with the radial arrangement of three, four or five loculi ovary Omokhafe et al. (2023). Flower phenology is such that the rubber tree flowers once in West Africa, from February to April each year, but twice in Asia, from February to June and August to October, each year (Yeang, 2007; Omokhafe et al., 2023). In 2017, there was unusual incidence of flowering in Nigeria in October – November. It was a single instance observation. There is continuous observation for a possible second occurrence. Distortion in flowering pattern may lead to reduced seed production valued in development of seedling nurseries, breeding programmes and industrial utilization of rubber seed.

v. Pests and diseases

Corynespora leaf fall disease was first described in India in 1955 and till the 1980s, but it remained a nursery disease treatable with the readily available fungicides. Since the 1980s it has assumed a devastating effect on plantations (Jacob, 2006).

Fig. 2 Twenty loculi ovary of *Hevea brasiliensis*

Conclusions and Recommendations

The World Agricultural System needs added impetus if it will meet the needs of the growing population of the World. This is more so in the face of environmental challenges working against nature dependent agricultural communities. The abundance of land and labour in LMI and LI countries needs to be harnessed towards enhancing the green potential aspect of nature based solutions to climate change. Climate Smart Agriculture, Tree Farming, Agroforestry are recommended for support as these are compatible with the farm practice of the vulnerable communities (Facciotto et al., 2014; Omokhafe et al., 2019). The Director General, World Trade Organization has counselled countries against policy summersault, even when governance changes between political interests (Onanuga & Ogundele, 2024). Social and economic policy consistency is hereby advised. Recommendations on response to impact of climate change on rubber cultivation

i. Intercropping: This is cultivation of two or more crop plants on the same plot of land. It will promote biodiversity and check the spread of crop specific diseases. Gyro et al. (2012) gave a report on intercropping with *Hevea brasiliensis*.

ii. Mixed farming: This is a combination of crops and minilivestock. It will enhance intake of animal protein, provide farm yard manure for organic farming, promote biodiversity and diversify sources of income of farmers, as reported by Omokhafe (2020).

iii. Agroforestry: This is cultivation of crops of various storey, i.e. herbaceous, shrubs and trees crops in combination with livestock. A workshop on rubber tree agroforestry was organised in Nigeria in 2024 (Omokhafe et al., 2014).

iv. Recycling of waste: Rubber processing has effluent which can be treated to produce organic fertilizer and biogas (Abhanzioya, 2018; Maliki & Adedokun, 2019).

Annexure 1

https://www.worldometers.info/gdp/cote-d-ivoire-gdp/
https://www.macrotrends.net/countries/SLE/sierra-leone/gdp-per-capita#:~:text=Sierra%20Leone%20gdp%20per%20capita%20for%202022%20was%20%24461%2C%20a,a%202.6%25%20decline%20from%202019
https://www.macrotrends.net/countries/GNB/guinea-bissau/gdp-gross-domestic-product

https://www.macrotrends.net/countries/ZMB/zambia/gdp-per-capita#:~:text=Data%20are%20in%20current%20U.S.
https://www.macrotrends.net/countries/GHA/ghana/gdp-per-capita#:~:text=Ghana%20gdp%20per%20capita%20for,a%200.4%25%20increase%20from%202019
https://www.macrotrends.net/countries/NGA/nigeria/gdp-per-capita#:~:text=Nigeria%20gdp%20per%20capita%20for,a%2011.11%25%20decline%20from%202019
https://www.macrotrends.net/countries/NZL/new-zealand/gdp-per-capita#:~:text=New%20Zealand%20gdp%20per%20capita%20for%202022%20was%20%2448%2C249%2C%20a,a%202.42%25%20decline%20from%202019
https://www.macrotrends.net/countries/NLD/netherlands/gdp-per-capita
https://www.macrotrends.net/countries/GBR/united-kingdom/gdp-gross-domestic-product
https://worldpopulationreview.com/country-rankings/low-income-countries
https://www.ers.usda.gov/data-products/international%20agricultural-productivity
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