Mapping and Comparison of Maize Products Value Chains in Nigeria and Rwanda


ABSTRACT

Maize products are very significant for domestic consumption as well as industrial uses both locally and globally. For there to truly appreciate the spread of maize production in Africa, the geospatial mapping and subsequent comparison of the value chain for Nigeria and Rwanda were necessitated hence the purpose of this study. Farm mapping geospatial techniques and remotely sensed data were used for both Nigeria and Rwanda in this study. GIMMS Global Agricultural Monitoring data from United States Department of Agriculture (USDA) were adopted for Nigeria and Rwanda. The crop calendars of both countries were examined which thereafter reviewed a marked distinction among them. The results of the agroecological zones for the two countries showed a significant variation in their distribution and types, which in turn affect both the planting and harvesting of maize; storage, marketing, processing, and policy framework for maize products value chain in Nigeria and Rwanda. Mapping of the two countries was carried out and the normalized differential vegetation index (NDVI) and the policy associated with maize value chains were checked and reported.

Keywords: Maize, NDVI, Nigeria, Rwanda, Value chain.

Submitted: April 26, 2022
Published: June 13, 2022
ISSN: 2684-1827
DOI: 10.24018/ejfood.2022.4.3.501
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I. INTRODUCTION

Maize is considered a high value cereal crop all over the globe [1]. Maize serves as food for humans and animals alike, as well as raw material for the industrial production of starch, bioethanol, alcoholic beverages, hemicellulose, and so on [2]. The demand for maize has been on the increase throughout the entire African countries [3] and [4]. In Nigeria, small and large maize farms are distributed randomly with poor networking between farmers [5], though, the production and supply networks are not well understood [6]. However, maize in Rwanda by comparison is equally a high value crop and is often considered the major staple food [7]. Over a thousand families in Rwanda (engaging both sexes) are involved in the production of maize [8].

Food supply chains also known as value chains represent the lifeline for human existence on the planet earth, and a food supply chain or food system refers to the process that describes how food from a farm ends up on our tables [9]. Supply chain of any good or commodity shows a link between the production, processing, and distribution of such commodity. Every step of the supply chain requires human
and/or natural resources. The food value chain is domino-like in nature hence, when one part is affected, the entire chain is affected, which often manifests through changes in price thereby leading to food shortage [10]–[12].

The objective of the study was to compare the maize value chain of Nigeria and that of Rwanda using geospatial techniques and statistical tools carried out at the Strategic Space Applications Department of National Space Research and Development Agency of Nigeria. The role of geographic information systems (GIS) application in the management of the food supply chain to enhance food security in Africa cannot be over emphasized. Khan et al. (2018) [11] acknowledged that the application of GIS helps in the evaluation of Agricultural Supply Chain Risk Management (ASCRM) due to its ability to carry out optical investigations, which allows scientists and policymakers to take action toward mitigating dangers in the supply chain processes.

II. LITERATURE REVIEW

A. Study Areas

1) Nigeria

Nigeria is located in the tropical zone of West Africa with a latitude 9.07°N and longitude 8.67°E and has a total area of 923,770 km² [13]. The average air temperature is 26.6 °C. The climate is semi-arid in the north and gradually changes toward the south into savanna and finally tropical rainforest with humid conditions. Rainfall averages over 2000 mm/year. Nigeria is by far the most populous country in Africa. With its over 182 million people, it accounts for over one-seventh of the total population of Africa’s 54 countries [14]. The country is divided into three broad ecological zones which are: the northern Sudan Savannah, the Guinea Savannah zone or Middle Belt, and the southern rainforest zone. Agriculture contributes 20% to the country’s economy and provides occupation to 31% of the economically active population in 2007 [15] and is thus the largest employer in the country, especially considering the fact that 45% of the economically active population is unemployed [16]. Farming systems are mainly smallholder-based and agricultural landholdings are scattered. Simple, low input technology is employed, resulting in low-output labour productivity. Total agricultural land is estimated at almost 71 million hectares, which is 77% of the total area of the country. In 2013, the cultivated area was 40.5 million hectares of which arable land covered 34.0 million ha and permanent crops 6.5 million hectares. Internal water bodies cover around 1 million hectares [15].

2) Rwanda

Rwanda, on the other hand, is a landlocked country situated in the Great Lakes region of East Africa. It is bordered by Uganda, Tanzania, Burundi and the Democratic Republic of Congo (DRC). It is a small country with an area of 26,338 km² and a population of about 12 million people; Rwanda’s population density is considered amongst the highest in Africa. Rwanda lies between latitude 1.9°S and longitude 29.9°E. Has an average temperature of 27 °C and its vegetation ranges from the dense equatorial forest in the north-west of the country to tropical savannah in the east. The rainy seasons are from March to May and from October to November with an average of 110–200 mm per month. The soil pH is at least 5 or more. The salts can, after water evaporation, accumulate on the surface in the dry season. In general, the agricultural potential of these soils is very high. An estimated 75% of the working population in Rwanda farms as agriculture constitutes an estimated 32.5% of the GDP and also makes about 63% of Rwanda’s exports, [17].

B. Maize Supply Chain in Nigeria

In Nigeria, maize production has been steadily increasing by 11.96% from 10,813,980 tonnes in 2016 to 12,107,580 tonnes in 2017, according to the National Agricultural Extension and Research Liaison Services [18]. Only about 6,5% of the world's maize is produced in Africa, with Nigeria contributing the most [19]. Although maize output has increased in Nigeria, its contribution to GDP remains modest, as highlighted by the World Bank [19]. This is because only a small percentage of the food is technically exported, while the majority are consumed locally with little added value [14]. Maize is a significant cereal grain in Nigeria, and it is widely grown by practically all farmers because of its great economic value and adaptability in the rainforest and derived Savannah zones of the country [20]. It began as a subsistence
crop, grew in importance over time, and has now evolved into a major commercial crop on which many agro-based companies rely for basic materials [20]. Maize in Nigeria has 28 culinary items or dishes, as well as six medical values [18]. Hot and cold pap, "tuwo," "massa," "couscous," "gwate," "nakia," "dambu," "dakuwa," "popcorn," and boiled and roasted maize are a few examples [21].

Every portion of the plant has economic worth; maize is a versatile crop. The seeds, stems, and leaves are used for food, livestock feed, and medications, while the seeds are utilized for food, livestock feed, and pharmaceuticals [22]. Maize supply chain in Nigeria requires certain key factors to give a proper link between each stage of the chain. Nigeria is the second highest producer of Maize in Africa, which she has consistently maintained since 2004, after South Africa with a production quantity of 8.4 million tons as of 2013 [13]. Maize value chain analysis includes all factors of production, such as land, labour, capital, technology, and inputs, as well as all economic activities, such as input supply, production, transformation, handling, transport, marketing, and distribution, that are required to create, sell, and deliver a product to a specific destination. The supply of inputs used for maize production is typically provided by private sector firms in response to demand from producers in most countries around the world. However, this demand can be weakened by poor access to credit and information as well as substandard infrastructure, consequently, it is not uncommon for the public sector also to offer inputs through a variety of free or subsidized programs, albeit with varying degrees of success [23] and [24]. The Nigeria maize value chain is quite similar to the global supply chain. Geographic, environmental, social and political characteristics are important factors that cause competitiveness in production. Nigeria has different soil types as well as variability in the quantity of rainfall or access to water, temperature variations, as well as land ownership structures, which significantly affect maize cultivation [25] and [26]. Practices involved in the production of maize range from land preparation or clearing, ploughing, weeding, and irrigation to the use of fertilizers for increased sustainable maize production and the majority of farms in Nigeria are practicing a mix crop farming [27]. Aggregation in the supply chain is more prominent in markets that do not rely on large-scale modern production. In many developing countries, the major aggregators are producer cooperatives, small- and medium-sized traders, or processors that have vertically integrated into this stage of the chain [28] and [29]. In informal maize supply chains, aggregation occurs through multiple layers of small traders, who sell to small-scale processors or exporters. In both formal and informal chains, some degree of aggregation occurs in order to achieve economies of scale. Village agents are the traders who generally work most closely with farmers [30]. Two primary milling techniques follow for maize: dry milling and wet milling; both processes involve the breakdown of maize into a range of outputs; however, there are also costs and benefits for each. Dry milling, which describes the grinding of the entire kernel in hammer or rolling mills, is less capital intensive and yields a greater array of inexpensive food outputs, which include flour. While the maize in wet milling is separated from its nutritional content and therefore not used for direct human consumption, the process produces an increased range of chemical by-products [31], [2] and [32]. If there are no demands the actors’ components of the MVC (maize value chain) would remain unprogressive input supply, moving onto production, harvesting, postharvest handling, storage, marketing, processing and consumption. Different actors, using different technologies and interacting with various participants in the value chain, carry each of these functions out [33].

In summary, the key inputs for efficient maize production in Nigeria are land and land cultivator facilities, good seeds, fertilizers, crop protection products and water [34]. Most maize harvests in Nigeria is done manually because the predominant producers are smallholder farmers with limited or no capacity to afford the application of mechanical support [35]. The harvesting can be done either when the maize is fresh or dry depending on the need [36].

![Fig. 3 Stages of maize value-chain in Nigeria [13].](image-url)
Maize in Rwanda like in other nations is also considered to be a very important food crop [37]. It plays an important role in the livelihoods of millions of poor farmers. About 900 million both farmers and consumers have considered it a preferred crop from low- to middle-income countries of whom over 90% live in tropical and sub-tropical areas of Africa, Asia, and Latin America [38]. By 2025, maize has the tendency of becoming the crop with the greatest value and high demand in Rwanda, while by 2050, the demand and production is projected to double [39]. Maize has different production and trading patterns, as well as end-users, depending on geographic regions within Africa. In Rwanda, agriculture production employs about 75% of the labour force, crop production contributes about 69% of total national agricultural output with maize accounting for more than 50% [40]. Maize is grown on both hills and marshlands where it is usually associated with other food crops which are especially legumes such as beans. It is especially cultivated in monoculture (pure) on large farms generally held by farm cooperatives. As all marshes belong to the state, their operation is done under its permission through the local authority [41].

For the utilization of wetlands, priority is given by the district to the farmers’ cooperatives and associations that can occur over large areas particularly to crops recommended by MINAGRI, including maize crops. These cooperatives basically work with agricultural support and supervision of various specialized organizations. Maize cultivation in swamps is developed mainly in areas of medium and low altitudes [42] and [43]. The use of agricultural inputs such as chemical fertilizer in these areas is very low and according to the National Institute of Statistics of Rwanda [17] only 11% of farm households use improved seeds, 32% of sheep manure, 16% pesticides, 31% compost and 16% mineral fertilizers [44].

Despite the fact that maize has not traditionally been a basic crop in Rwanda, ranking far below plantains, potatoes, cassava, and sweet potatoes in terms of daily consumption, it was included in the government’s International Potato Center (CIP) in 2007 due to its potential to improve food security [45]. Over the last decade, this project, which includes efforts to improve the quality and access to critical inputs, has contributed to a significant increase in yields and production volumes. In 2013, the country produced 667,000 metric tons of maize, up to more than 650% from 2004. There are around 300,000 maize-growing households in the country, with an average farm size of 0.6 hectares [46].

In terms of trade patterns, Rwanda imports maize from Uganda and is becoming a more important market for local aggregators and processors [28]. Maize flour is the country’s most important export, and its value has risen dramatically in recent years. In 2013, Rwanda was one of Africa’s main exporters of the product, and maize flour has also become one of the country’s top ten export items, accounting for 1.6% of total exports in 2014 [47]. Although much of Rwanda’s flour is of lower quality, it finds a market in countries like the Democratic Republic of Congo and Burundi, where processing facilities are scarce and consumers are price conscious [48]. The maize value chain is divided into various segments: inputs, production, aggregation, processing, transportation, marketing, and distribution.

Minimex sources maize from 10–15 cooperatives around the country, with warehousing and drying facilities provided by its sibling firm (ProDev Rwanda Ltd). It also owns a minority stake in the RGCC LTD (Rwanda Grains and Cereals Corporation Limited) and sources the rest of its maize from the import market [28]. These are the first link in the supply chain comprising both producers and consumers. Planting maize in Rwanda is done between June and August with 12 weeks production circle [49] and [50].
Over 52% of the production has been consumed on farms. They sell during harvest rarely storing due to cash needs. Later they buy back maize for use as seed and food. Transactions take place either on the farms (households) or at the market. At the market, farmers transact with consumers, as they take on the added function of transporting produce to market. Farmers generally have limited market power. They usually sell smaller quantities and enjoy little bargaining power, as they need cash. They lack credit; they typically sell as individuals and are essentially price takers, farmers, who live near the main road, have better market information [28]. Poor transportation structure has been known as a major setback in Rwanda’s transportation sector which has hindered the effectiveness of agricultural production and enticed local and external investment opportunities in the agricultural sector. Local farmers have no accessible road networks to storage facilities and markets, and the available ones are either within the state or the central areas [52].

III. MATERIALS AND METHODS

A. Reconnaissance Surveys

Farm mapping geospatial techniques (GPS for Nigeria) and remotely sensed data for Rwanda [53]. GIMMS Global Agricultural Monitoring data from USDA were adopted for both Nigeria and Rwanda [54]. Reconnaissance survey was carried out to locate the various farm settlements where maize is being cultivated in Nigeria. Information about the cultivation of maize was acquired from the study area through discussion with the local inhabitants and all relevant stakeholders in the study area during the reconnaissance survey. Data for the research were retrieved from satellite imageries of Nigeria through National Space Research and Development Agency (NASRDA), GRID3 portal, Office of Surveyor General of Federation (OSGOF), Global Land Cover Facility (GLCF) and United States Geological Survey (USGS). These data include Landsat Imageries/sentinel data and they were analyzed using ArcGIS 10.8.

IV. RESULTS AND DISCUSSION

From the International Production Assessment Division of USDA data, the result (Fig. 5) shows that maize planting and harvest periods in Nigeria vary according to region. In northern Nigeria, the planting period is from May to June while the harvest is from August to September. This is a result of the late commencement of rain within the region. But in southern Nigeria, planting and harvest periods are March–April, and June–September respectively. However, in Rwanda (Fig. 6), planting of maize could commence in September–October, or February–March while the harvest period could be January–February, or June–July respectively. Planting and harvesting of maize in Rwanda like all other crops are basically affected by the period for cultivation which can be divided into the first cultivable season (from September to January) and the second cultivable season (from February to June).
While the calibrated (NDVI) was observed from 0–16 for the months of May to December. The cumulative NDVI of Nigeria increased proportionately from the months of May to December. It was observed that the mean NDVI of 2018 was slightly higher than that of 2021. While the minimum cumulative NDVI for 2018 was 12.5, the maximum was 16. The highest cumulative NDVI was observed for 2019 while the least was seen for 2021. However, the cumulative NDVI for Rwanda showed a marked difference. The cumulative NDVI was calibrated from 0–20 for the months of November to May. There was an almost proportional increase as well for the two countries, although the one for 2020 was the highest while the least was for 2019.

The NDVI and NDVI anomaly showed a similar pattern, with a maximum of 0.7 within the year 2019 and a minimum of 0.28 for the NDVI throughout the years. However, the NDVI anomaly had a maximum of 0.14 for the year 2010 and a minimum of -0.22 for the year 2001 in Nigeria.

Conversely, the maximum NDVI for Rwanda was 0.75 while the minimum was 0.4. The NDVI anomaly, however, was approximately 0.1 whereas the minimum was -0.15.

Table 1 below shows the summary of the comparison of the maize products value chain of Nigeria and Rwanda. From the table, the climate condition of Nigeria shows a tropical region whereas temperate tropical highland is for Rwanda.

The cumulative normalized differential vegetation indices (NDVI) of both countries are shown in figures 9 and 10 above. For Nigeria (Fig. 9), the cumulative NDVI was calibrated from 0–16 for the months of May to December. The cumulative NDVI of Nigeria increased proportionately from the months of May to December. It was observed that the mean NDVI of 2018 was slightly higher than that of 2021. While the minimum cumulative NDVI for 2018 was 12.5, the maximum was 16. The highest cumulative NDVI was observed for 2019 while the least was seen for 2021. However, the cumulative NDVI for Rwanda showed a marked difference. The cumulative NDVI was calibrated from 0–20 for the months of November to May. There was an almost proportional increase as well for the two countries, although the one for 2020 was the highest while the least was for 2019.

The NDVI and NDVI anomaly showed a similar pattern, with a maximum of 0.7 within the year 2019 and a minimum of 0.28 for the NDVI throughout the years. However, the

Table 1: Comparative Analysis of Maize in Nigeria and Rwanda

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>MAIZE IN NIGERIA</th>
<th>MAIZE IN RWANDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate region</td>
<td>Tropical region</td>
<td>Temperate tropical highland</td>
</tr>
<tr>
<td>Planting period</td>
<td>March – July</td>
<td>September – March</td>
</tr>
<tr>
<td>Harvest period</td>
<td>June – October</td>
<td>January – July</td>
</tr>
<tr>
<td>Harvest time</td>
<td>Any time of the day</td>
<td>Any time of the day</td>
</tr>
<tr>
<td>Drying methods</td>
<td>Grains extracted and dried in sun, shades or rooms</td>
<td>Drying under the shade or in the room.</td>
</tr>
<tr>
<td></td>
<td>while others use mechanized drying methods in</td>
<td>Cooperative-drying (semi-mechanized)</td>
</tr>
<tr>
<td></td>
<td>industrial farms</td>
<td>Large scale drying facilities</td>
</tr>
<tr>
<td></td>
<td>Moisture content</td>
<td>10-14%</td>
</tr>
<tr>
<td></td>
<td>11-15%</td>
<td></td>
</tr>
<tr>
<td>Materials used for</td>
<td>Grains packed in sacks, or polythene bags also called</td>
<td>Packaged in poly bags,</td>
</tr>
<tr>
<td>packaging</td>
<td>(bagco) bags</td>
<td>Grains Packaged in sack bags</td>
</tr>
<tr>
<td>Storage place</td>
<td>Crib storage, constructed from farm materials,</td>
<td>Custom made bags for finished products.</td>
</tr>
<tr>
<td></td>
<td>warehouse storage, stacked bags on a pallet, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>some stored grains in silo</td>
<td></td>
</tr>
<tr>
<td>Storage period</td>
<td>29 days</td>
<td></td>
</tr>
<tr>
<td>Processing methods</td>
<td>Traditionally; staple human food and feed for livestock,</td>
<td>Milling to produce: maize flour (human consumption),</td>
</tr>
<tr>
<td></td>
<td>Mechanically as raw material for industrial products</td>
<td>bran (for animal feed), and grit (beer production)</td>
</tr>
<tr>
<td>Marketing</td>
<td>Sold on the spot without record from the rural farmer,</td>
<td>Small markets and informal sales, institutional</td>
</tr>
<tr>
<td></td>
<td>sold as grains in markets</td>
<td>buyers, large wholesales.</td>
</tr>
</tbody>
</table>
The seasonal time series plot of Nigeria (Fig. 13) showed a minimum NDVI of 0.27 (2018) for the month of April and a maximum of 0.7 (2019) for the month of August. However, Rwanda shows a minimum NDVI of 0.52 (2020–2021) for the month of February, and a 0.74 (2019–2020) maximum for the month of August.

The importance of NDVI in this study was noticed as Rwanda had a higher NDVI than Nigeria. This is in line with the work of [54] that reiterated that NDVI was necessary as a degree of greenness which is equal to the chlorophyll concentration of vegetations and crop plants. Maize needs good vegetation health equivalent to high NDVI to thrive. Nigeria had an overall lower NDVI anomaly of -0.22 than Rwanda with -0.15. An NDVI anomaly is the difference between the average NDVI over a particular time step compared to the average NDVI for the same time step across a specific number of years, typically between 5 to twenty years. Anomalies are used to characterize the health of the vegetation for a particular time step compared to what is considered normal. In agricultural monitoring, negative values can be a good indicator of poor crop conditions or a slower growth rate of the crop due to a variety of environmental conditions such as drought or a significantly delayed season [54].

V. CONCLUSION

The study confirmed that maize is produced in both countries of Nigeria and Rwanda but, there exists a variation in the seasons of both countries. Although Nigeria has a higher production output for maize which perhaps is due to the large arable land mass and the prevalent agroecological zones, Rwanda on the other hand has a better maize value chain due to better agricultural policies prevalent in the country. The policy thereby leads to a better regulation of maize value chain products in Rwanda which affects the planting and harvesting, storage, marketing, and so on.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of the Acting Director of Strategic Space Applications Department (Dr Matthew O. Adepoju) of National Space Research and Development Agency of Nigeria; and the efforts made by the staff of the Department in provision of the relevant data for the project. The Director General (Dr Halilu A. Shaba) of National Space Research and Development Agency, Nigeria is well acknowledged.
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