CLIMATE CHANGE IMPACTS ON TRANSPORT INFRASTRUCTURE IN AGRARIAN COMMUNITIES AND POLICY IMPLICATIONS FOR AGRICULTURAL TRADE AND FOOD SECURITY IN NIGERIA

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Abstract

Climate change, a global environmental challenge driving natural hazards is a threat to sustainable agricultural development. Changes in average weather conditions, alongside extreme weather events are altering the climate system resulting in not only unpredictable rainfall and temperature patterns but also increasing occurrences of climate related events such as floods and droughts. Transport infrastructure which plays critical roles in agricultural production and trade by facilitating food availability and accessibility is progressively affected by climate change and its impacts. Future climate change may pose higher infrastructure risk. Therefore a need to manage climate change impacts on transport infrastructure for sustainable agricultural production and trade as well as food security. This paper critically assesses climate change impacts on transport infrastructure by focusing on how infrastructure disruption due to climate change led to a sequence of negative events. Using case study strategy and three (3) agrarian communities in Nigeria as case studies, climate related risks and their impacts on transport infrastructure were identified. Findings reveal that first heavy rainfall and floods have a higher correlation with road damages and bridge collapse. Secondly, infrastructure disruption/ failure have significant impacts on accessibility, food waste and market demand and supply. Finally the paper considers the need for the inclusion of current and future climate change into infrastructure planning, design construction and maintenance.

Keywords: Agricultural trade, Climate change, Food security, Policy and Transport Infrastructure.

1 INTRODUCTION

The Nigerian agricultural sector contributes about 39% of the country's GDP and supports the livelihoods of more than 70% of the economically active population (Adegoke, Ibe, & Araba, 2014; NBS, 2017). The sector plays a strategic role in the economic growth of the country by providing food for the population and support for livelihoods of not only rural areas but many of the world's economy (Ozor, Enete, & Amaechina, 2016). Increase in population and consequent increased demand for food and raw materials requires the sector doubling its production to meet the rising demand. However due to climate sensitive nature of agricultural production climate change sets great risks on the ability of the sector to meet the increasing demand by challenging sustainable agricultural development.

Climate change occurring either as slow or rapid onset events is a threat to global economic development affecting various sectors of the economy. The agricultural sector is one sector most affected by climate change in a range of negative ways (Rosenzweig et al., 2014). Current climate changes pose challenges to the sector as climate change risk on infrastructure, a vital pillar supporting the agricultural sector, is an added threat to the already risk on agricultural production. Transport infrastructure particularly road systems are unfortunately in deficit in agrarian communities, host to agricultural production and often located in rural areas, and the few available are in poor conditions (Goyol & Pathirage, 2017). These conditions make them vulnerable to existing climate risk, future uncertainties and much more.

Future climate change suggests increasing occurrences of climate related events with adverse impacts on almost all sectors of the economy. Record also suggests the likelihood of these impacts on agricultural production (WorldBank, 2010) and road infrastructure systems (Boehlert, Strzepek, Groves, Hewitson, & Jack, 2015) which will in turn affect both the availability and accessibility of agricultural produce. This can have significant policy implications for agricultural trade and food security as road infrastructure is the major form of agricultural freight in Nigeria. Schweikert, Chinowsky, Kwiatkowski, and Espinet (2014) opined that even though climate change possess challenges to the agricultural sector, it can provide opportunities for governments expansion particularly in planning infrastructure considerations, particularly in developing countries where it is projected to be worst hit by climate change. It is against this back drop that this paper aims to critically assess climate change impacts on transport infrastructure by focusing on how road infrastructure disruption/ failure due to climate related events lead to a sequence of negative events in order to suggest

policy measures to manage climate change impacts on road infrastructure for sustainable agricultural production, trade, and food security.

2 THE SIGNIFICANCE OF TRANSPORT INFRASTRUCTURE IN AGRICULTURAL DEVELOPMENT AND FOOD SECURITY

Transport Infrastructure to include road system is generally associated to global economic growth as it improves agricultural productivity, reduces poverty levels and advances the non-agricultural sector. In considering agricultural productivity, Gollin, Lagakos, and Waugh (2013) in a research on rural economy buttressed that road development has a strong link to farm output, production levels, poverty levels, and the development of non-farm sectors. Patel (2014), Storeygard (2016), Fungo and Krygsman (2017) asserts that roads in good conditions reduces travel time and cost, enhances business, commercial and economic activities along routes, as well as increase traffic flow and profitability.

On the other hand, lack of good road infrastructure compounds the challenge of accessibility. First, access to input services resulting to low use of inputs and modern agricultural technologies resulting to low agricultural productivity. Second, access to market and market services by hindering the movement of produce to points of demand thereby hindering economic development (Gbadebo & Olalusi, 2015; Starkey & Hine, 2014). Also, poor road network in rural area can be a barrier to the integration of labour markets across space. Shamdasani (2016) in assessing the relationship between road infrastructure and economic growth, explained how due to improved rural road infrastructure households are able to diversify cropping for higher returns, access input services, hire more labour and access markets. Through this process, producers were able to market farm produce to improve household income.

Likewise, several researches conducted in Nigeria (Adeoti, Oluwatayo, & Soliu, 2014; Afolabi, Ademiluyi, & Oyetub, 2016; Akinwale, 2010; Okoye, Onyenweaku, & Ukoha, 2010; Olubomehin, 2012; Tunde & Adeniyi, 2012) identified the importance of road transportation to agriculture to include access to farm inputs and agricultural services, ease in movement and marketing of farm produce, reduced level of food wastage, reduced prices of food and transport cost, as well as the access to other non-farm services. On the whole, poor road conditions hikes production costs leading to low returns on investments, affects income levels accompanied by increase in poverty levels all of which challenges sustainable agricultural development.

Considering the agricultural sector as a part of a wider interconnected system, a disruption in one part can lead to a chain of negative events in other parts of the system. The concept of food security is tailored around the four dimensions of food availability, food accessibility, utilization and stability (Jones, Ngure, Pelto, & Young, 2013). Advances in crop production improves food availability (Ewert et al., 2015; Palazzo et al., 2017; Rutten et al., 2016; Webber, Gaiser, & Ewert, 2014) nevertheless, food can be far from reach due to issues of accessibility both in terms of the distance and cost. Food accessibility which is the link between food availability and utilization is closely related to the availability of good transport systems as it ensures the physical and economic access to food to meet required dietary conditions. The means of making food available to points of need, often by road transport, can be dependent on the availability and the nature of the roads. Hendriks (2015) suggested that addressing the challenge of the four dimensions of food insecurity can be overcome by ensuring long term development measures to address insecurity. This can be a challenge to developing countries like Nigeria where short and medium term development plans are the norm for the provision of infrastructures such as roads.

3 OVERVIEW OF CLIMATE CHANGE AND ROAD INFRASTRUCTURE BURDEN IN NIGERIA

Nigeria, a developing African country located in the tropical region, is bounded by the Saharan desert to the North and the Atlantic Ocean to the south. It falls within the Inter-Tropical Convergent zone (ITCZ) which has 2 seasons (dry and wet season). The country like others in the region have experiences changes in average weather conditions over the years.

Table 1: Current and Future Climate Change (Extracted from World Bank, 2016)

Parameters	**Recorded Change**	**Future Change**
Mean annual temperature	0.8^{o}C	1.1-2.5^{o}C
Mean annual precipitation	3.5mm /m	Extreme rainfall
Annual no. of hot days	73 days	18-49%
Annual no. of cold nights	45 nights	Hot nights 32-60%
Sea level rise	2-5mm: coast	0.4 -0.7m

Mean annual temperature has increased by 0.8mm btw 1960-1960, Mean annual precipitation has decreased by 3.5mm per month. Future projections suggests mean annual temperature will

increase by 1.1-2.5oc by 2060 and a decline in the amount of rain as supported by Abiodun, Salami, Matthew, and Odedokun (2013). Climate change records in Nigeria reveal more drier conditions are experienced towards the north (Abaje, Ati, & Iguisi, 2012; Ogungbenro & Morakinyo, 2014), over 20% of the country experiences significant reductions in the amount of annual rainfalls (Lawal et al., 2016; Oguntunde, Abiodun, & Lischeid, 2011).

Days with extreme rainfall are projected to increase, to span within the fewer number of rainy days as a result of either late on-set of rains, extended periods of "august breaks", or early cessation of rains (Tyokumbur, 2014). So also the annual number of hot days have increased by 73 between 1960- 2006 and annual number of cold nights have decreased by 45 nights. Future projections suggests that annual number of hot days per year is expected to increase by 18-49% by the 2060s and annual number of hot nights by 32-60%. On the other end, cold days and nights is expected to substantially decrease (Tyokumbur, 2014).

Along the coast, sea level rise of 2-5mm has significantly increased the incidences of coastal floods. Nkeki, Henah, and Ojeh (2013) went further to observe that not only along the coastline; floods are becoming more frequent throughout the country particularly along major rivers and water bodies. Desertification often accompanied by drought commonly experienced in the northern part of the country is intensifying, shifting the deserts towards the central parts.

Table 2: Climate Related Events in Nigeria 1900-2016 (EM-DAT IDD, 2017)

Event type	Events count	Total deaths	Total affected
Flood	44	1493	10,478,919
Drought*	1	-	3,000,000
Epidemic	42	23,978	304,436
Storm	6	254	17,012
Extreme Temperature	2	78	-

Five (5) major climate related events experienced in Nigeria are flood, drought, Epidemics (often triggered by temperature and rainfall variability), storms and extreme temperature (refer to Table 2). Floods and drought have greater impacts negatively affecting socio-economic development; however floods have consequential effects on road infrastructure.

Nigeria currently has the largest road network in West Africa and the second largest in SSA yet falls short of the international benchmarks (WEF, 2013). The government is solely

responsible for the provision of over 80% of road infrastructure (Goyol, Pathirage, & Kulatunga, 2017) and each tiers takes responsibility of roads under its administration.

Table 3: Road Infrastructure in Nigeria Extracted from Gbadebo and Olalusi (2015)

NIGERIA	Statistics
Landmass	**9,110,000km2**
Road network	**193,200km**
• Federal • State • Local	34,123km 30,500km 128,577km
***Road density of 21km/km^2**	

More than 65% of Nigerian roads are classified as local government roads, 16% state roads, and 17% federal roads (refer to **Table 3**) out of which 70% are in a deplorable state making them vulnerable to threats such as floods**.** Emmanuel and Olamigoke (2013) point to poor investment in road infrastructure as the major cause of the poor road conditions in the country. It is worth taking note that 95% of passenger and freight movement particularly agricultural freight in Nigeria is by road, moving food crops from agrarian communities to markets, processing points and urban centers.

A typical agrarian community is characterized by poor road infrastructure among others (Yunusa, 2008), which are more often unpaved feeder roads with laterite surfaces and poor drainages. Similarly, Porter (2014) observed that only about 30% of rural roads are all season roads thereby affecting agricultural production and rural livelihoods. On the other hand, other production sectors such as the industries tend to benefit from transport investment more than the agricultural sector because a greater number of good roads are located in the urban areas where most of these industries are sited (Melo, Graham, & Brage-Ardao, 2013).

Policies over the years expressed intentions by developing programs geared towards rural infrastructure provision one of such is DFRRI (Directorate for Foods, Roads and Rural Infrastructure) which was established to develop the rural areas, however about 80% of the roads constructed under the program were cited in urban areas thereby defeating the aim of rural road development (Olayiwola & Adeleye, 2005). As such rural roads still remained in

their deplorable states and continuously affecting agriculture, the major occupation of the rural populace and contributor for the Nigeria's GDP.

4 METHODOLOGY

Nigeria, a developing country located in the tropical region is bounded by the Saharan desert to the North and the Atlantic Ocean to the south. It falls within the Inter-Tropical Convergent zone (ITCZ) which has 2 seasons (dry and wet season). As such, same country experiences both Droughts (prevalent in the northern part) and floods (at the coastal south). Two major rivers (Niger and Benue rivers) pass through the country leading to floods along these water bodies. Climate change is changing patterns as areas experiencing occasional floods are now experiencing annual occurrences. So also desertification and deforestation is shifting the desert towards the central part of the country. Researches show that the nature of drought in Nigeria currently has very little or no impact on transport infrastructure However, this study assesses the impacts of both.

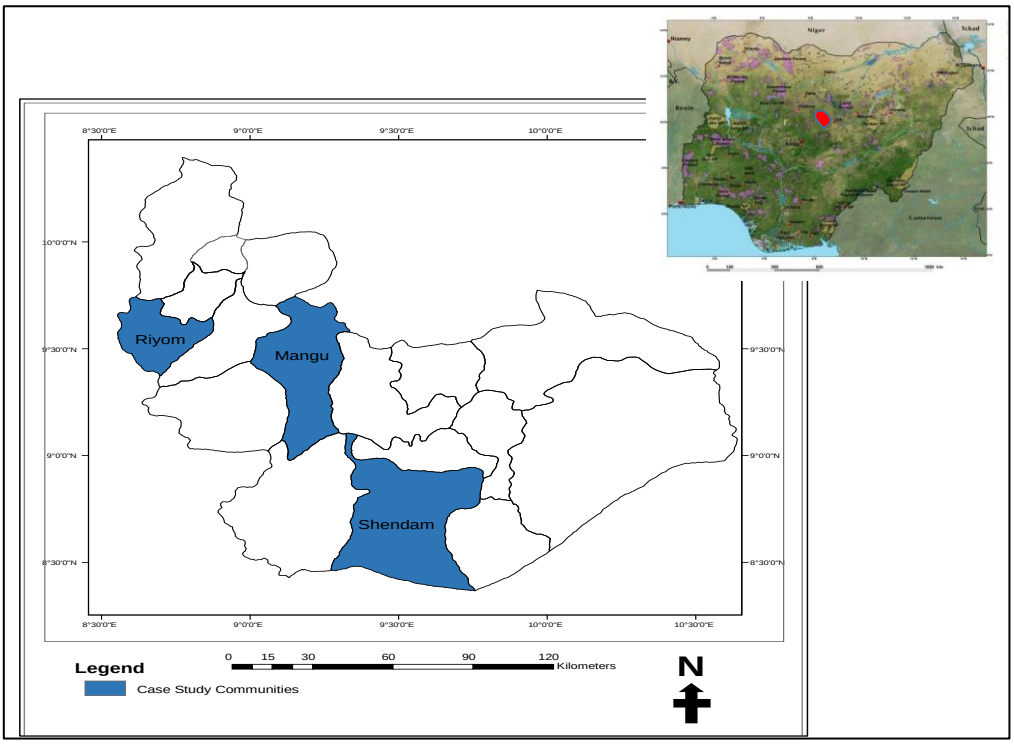

Figure 1: Case Study Communities

Plateau state is located in the central part of Nigeria. As the name, the area comprises of the highland, where most rivers in northern Nigerian get their source and so referred to as a hydrological centre, and the surrounding lowland. The state has the tropical intercontinental climate type conducive for agricultural production of various, grains and roots, and exotic fruits

and vegetables peculiar only to this part of the country. More than 50% of the population engage in at least one form of agricultural activity and therefore the area is endowed with a number of small scale farmers thereby making them vulnerable to threats such as Climate change. Just like other parts of Nigeria, the area has in recent years experienced changes in average weather conditions by marking new records of climate related events such as floods and its impacts on various sectors of the economy to include the agricultural sector.

A review of existing literature focusing on the climate related events experienced in Nigeria identified five (5) major events (Table 2). Using case study strategy the study explored how these events driven by climate change has impacts on transport infrastructure in three (3) selected agrarian communities across Plateau state (refer to Figure 1 and Figure 2).

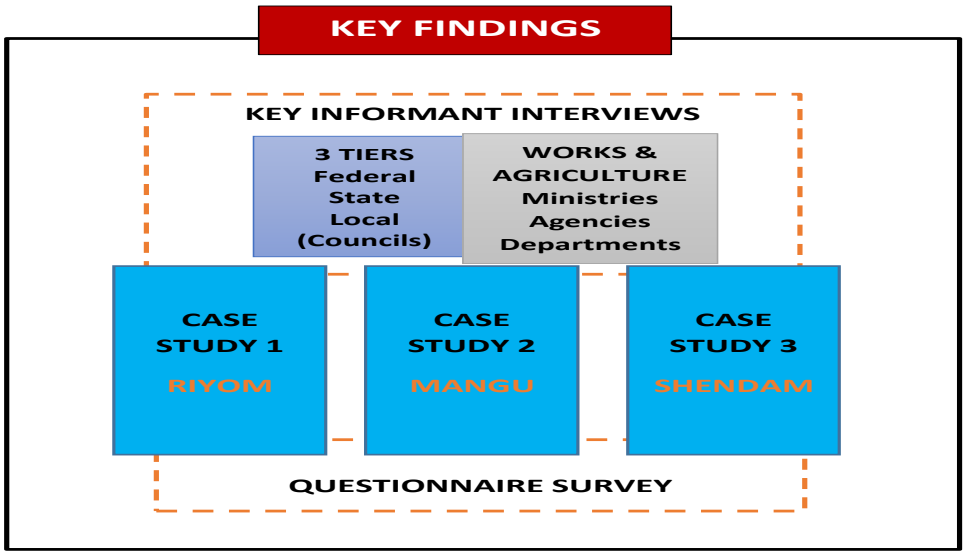

Figure 2: Methodology Design

A total of 21 key informant interviews were conducted across federal, states and local governments' level to ascertain the impacts of climate change on transport infrastructure and assess the institutional capacity to prepare against, and recover from infrastructure damage/disruption from climate change. 229 copies of questionnaire were administered to farmers across the 3 case study communities (Riyom, Mangu and Shendam represents case studies 1, 2, and 3 respectively) to obtain information on how the impacts of climate change on transport infrastructure affects crop production, returns on investment, and livelihoods. Content analysis was employed using NVivo software to systematically quantify responses of transcribed qualitative based on coded themes while SPSS was utilized to statistical analyse

the quantitative data obtained from the questionnaire survey. Key findings are here discussed in the following section.

5 FINDINGS AND DISCUSSIONS

First considered is the average temperature and rainfall condition of the three (3) case study communities in order to gain understanding of the average weather conditions in the study area as these are the two major climatic parameters driving climate related events.

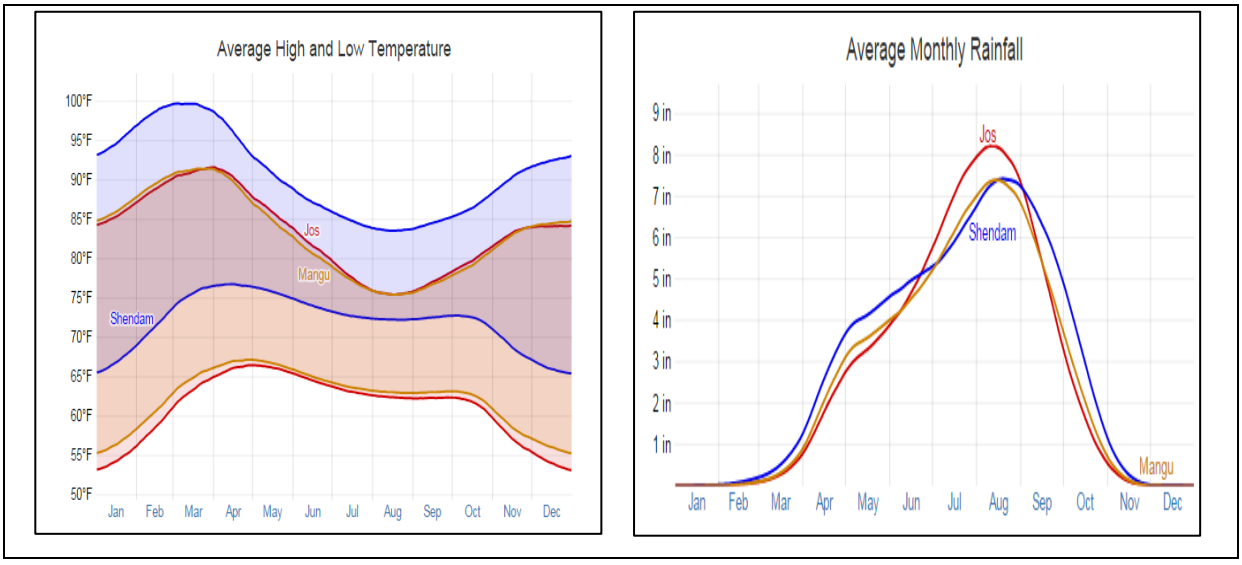

Figure 3: Average Temperature and Rainfall Patterns of Case study Communities

Figure 3 presents temperature and rainfall patterns of the 3 case study communities. Riyom (case study 2) experiences a cooler temperature of less than 55^{o}F in the month of January and higher amount of rainfall with the peak in the month of August. Mangu (case study 2) has similar temperature patterns with Riyom but different rainfall patterns. Shendam (case study 3) records high temperatures of up to 100^{o}F in the month of March and has the most variation in rainfall.

Secondly, having identified the five (5) major climate related events experienced in the area (refer to Table 2), responses on the impacts of these events on road infrastructure is presented in Figure 4.

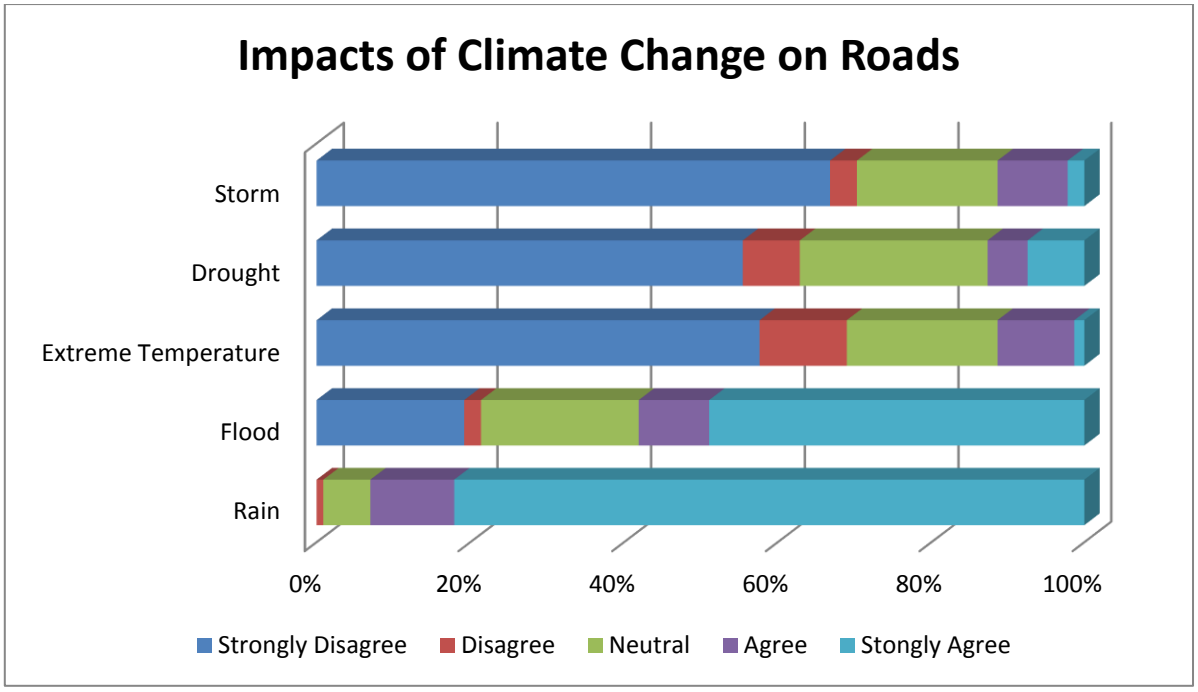

Figure 4: Impact of Climate Related Events on Road Infrastructure

In ranking findings of respondent's perception on which climate related event has impacts on transport infrastructure, Rainfall, floods, droughts, storms, and extreme temperature rank from the highest to the least respectively. Across the 3 case study communities, respondents strongly agree that rainfall variability (85%) and flood (53%) are indicated to have higher impacts on transport infrastructure.

Thirdly, the distribution of infrastructure particularly road system to include (carriage way, bridges and culverts and drains) across the 3 case studies varies. In a related study, Adefila and Bulus (2014) identified categories of road infrastructure distribution in Plateau state to have Mangu as advantaged, Riyom less advantaged and Shendam least advantaged. Findings from this study reveal that Rainfall and floods have impacts on all categories of road infrastructure distribution as most of them were found to be vulnerable due to their conditions. More than 80% of the road infrastructure damage, disruption or failure was found to have issues with the condition of the infrastructure at the time of the event (Table 4). The nature of the road system (poor surfaces, unpaved laterite roads), age of infrastructure, design and construction methods, and lack of maintenance were found to exacerbate the impact on the event on such infrastructures.

Table 4: Impacts of Climate Change on Transport Infrastructure

A) Type of Transport Infrastructure Road system to include Carriage way, Bridges/culverts and Drains	**Total number of Participants: 21**		
a) Availability	Number of Responses	Response Percentage (%)	
• Not available	5	24%	
• Available but Insufficient	13	62%	
• Available but in Poor Condition	6	29%	
Available and in Good Condition	1	5%	
b) Condition			
• Laterite	3	14%	
• Poorly constructed	7	33%	
• Uncompleted	2	10%	
• Abandoned	3	14%	
• Ageing	2	10%	
• No maintenance	4	19%	
B) Case Study Communities	**Number of Interview Participants: 21 Number of Questionnaire Respondents: 229**		
	Case Study 1 (RIYOM)	Case Study 2 (MANGU)	Case Study 3 (SHENDAM)
Location	Upland 1200m amsl	Midland 1000m amsl	Lowland 200m amsl
Road Infrastructure Distribution	Less advantaged	Advantaged	Lest Advantaged
Flood			
Impact on Road Infrastructure	X -Washout of road surfaces and drains	X X -Rivers overflow banks and shallow submerge bridges	X X X X X X X -Destruction of Bridges, Pillars, Retaining walls, embankments and washout of culverts. -Damage to roads
Rainfall Variability			
Impacts on Road Infrastructure	X X X X X -Washes off Laterite surfaces -Erodes and cuts off parts of the roads -Water logging causing roads to be unmotorable	X X X X -Erodes laterite roads -Water logging causing laterite roads to be un-motorable (common at the peak of the rains)	X X X -High deposits of sand on unpaved roads and in drain lines blocking flowing water. -Weakens paved roads, expands cracks to potholes, erodes drain lines

Fourthly, the impacts on Road Systems: Plateau state in recent years has experienced increasing variability in rainfall patterns with various magnitudes of floods recorded however the year 2012 is one not quickly forgotten as it had devastating impact. Heavier rains with consequent floods are becoming more frequent experience almost annually in the southern part of the state (area includes case study 3: Shendam). Case studies 1 and 2 (Riyom and Mangu) have experienced a few cases of floods mostly along water bodies however their impacts in relation to Case study 3 will be considered minimal. The impacts of floods on road infrastructure across the 3 case study communities include:

- Damage to road surface
- Destruction of Bridges, Pillars, Retaining walls, embankments
- Washout of culverts and drains
- Rivers overflow banks and submerge shallow bridges

So also, impacts of Heavy Rainfall in road infrastructure include:

- Washout of laterite surfaces and Erosion of road parts
- Water logging causing laterite roads to be un-motorable (common at the peak of the rains)
- High deposits of sand on roads and in drain lines blocking flowing water
- Weakens paved roads, expands cracks to potholes, erodes drain lines

Table 5: Effects of Infrastructure Disruption/ Failure

Effects of Infrastructure Disruption/ Failure	Mean Score	Rank
Access to Farm & Community	1.35	11
Cost of Inputs	1.41	10
Cost of Transportation	1.44	9
Low yield	1.47	8
Damage to Crops & Farmlands	1.52	7
Low Returns on Investment	1.62	6
Access to Market & Market Services	1.69	5
Waste of Inputs	1.86	4
Spread of Plant Epidemics	1.88	3
Inability to meet Demand	2.05	2
Loss of Production & Farm Operations	2.28	1

Apart from the physical destruction of roads, accessibility is a problem. The loss of transport services for agricultural freight movement led to large amounts of food waste due to farmer's inability to transport food crops from interior villages to market. Most road infrastructure disruption and failure was at the peak of the rainy season when farmers have suitable price periods to make profit on investments. Inability to move produce to markets affected their income levels as they had low returns on investment.

Participants noted a general increase in the prices of good. Farm inputs and agricultural services available were at a higher cost. Costs of both food crops and none food items were higher. Commercial activities at local markets were said to decline as a result of low patronage which in turn affected revenue generated from traders and motorists on market days. Also, farming seasons preceding a major road infrastructure disruption were affected because they lack the capacity for intense cultivation due to losses recorded in the previous season.

In summary, list of the effect of infrastructure disruption/ failure on agricultural production, economy and livelihoods include:

Agriculture Impact

- Waste of food crops
- High cost of transportation
- High cost of inputs such as fertilizer
- Loss of production due to infrastructure damage

Economic Impacts

- Market instability and Price hike of goods
- Low patronage of small scale industries e.g rice mills
- Less profit
- Disruption of commercial activities due to supply chain disruption
- Constraints economic development

Human Impacts

- Loss of human lives
- Loss of livelihoods
- Human displacement
- Diseases/ Epidemics

- Increased poverty levels
- Food Insecurity
- Disruption of social activities

Policy Implications of the study

The findings of this study reveal that there are policy implications for agrarian road infrastructure development in order to ensure sustainable agricultural production and trade. These include:

- Consider the inclusion of climate change into the planning and designs of road systems to guard against the collapse of the economy.
- Agrarian road development should be given priority in budgetary allocations in order to sustain the supply of inputs for improved productivity and supply chain agricultural products.
- Policies should be directed towards agrarian road investments to ease agricultural freight and policies to ensure that projects are implemented to the later end.
- Policies should consider agrarian road development as a means of reducing food waste and not only on improving outputs to end as waste.
- Provision of resilient road infrastructures to enhance community's capacity for adaptation to current climate variability and future climate change.

9 CONCLUSION

Climate change impact on transport infrastructure is affecting agricultural production both directly and indirectly with consequences on livelihoods and economic development. Road infrastructure disruption/ failure as a result of climate change leads to a sequence of negative events with significant effects on agricultural production and trade as well as food security. Managing current and future climate change impacts on road transport infrastructure will safeguards efforts towards sustainable economic development.

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