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Benue State Farmers-Herders Conflicts Wicked Problem - 2 : Sustainable Livelihoods and Food System Outcomes, North-Central, Nigeria

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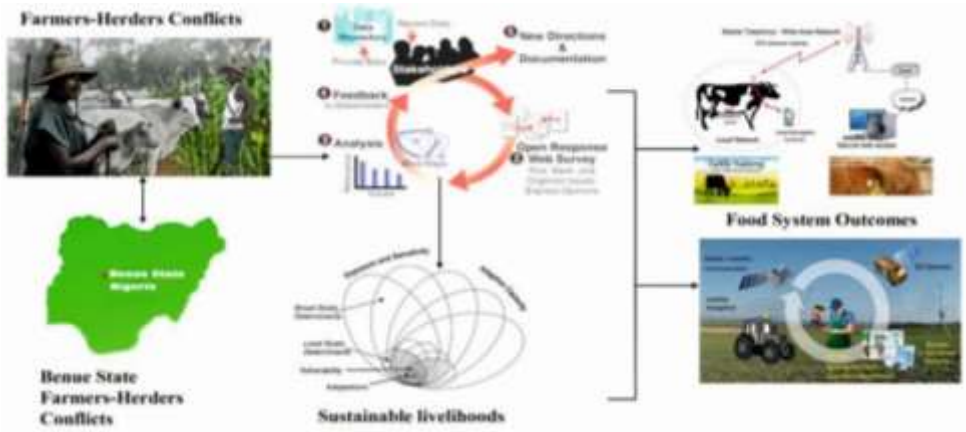
Graphic Abstract



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Abstract: *The crux of sustainable livelihoods and food system outcomes in Benue state, Nigeria and Sahel of Africa region for decades was driven by farmers-herders' conflicts resulting into poverty, security trajectories and underdevelopment. In 2022 qualitative and exploratory research was deployed in the 744 questionnaires survey at Guma and Gwer-West local government areas, Benue state, Nigeria. Data analyzed using the mean, frequency, percentage and Likert 5 scale. Likert 5 scale consensus inference are: as strongly agreed scores are: fear of losing livelihoods (457); competition for grazing (414); theft and destruction of farm land (374); internally displaced persons (415); Stability of the system (368); food security (413); peace and security (523); rapid development (376) and innovation (387) affirmed the farmers-herders' conflicts (Type III wicked problem) and the essence. In Nigeria 2026, 3.7 million internally displaced persons including the study area are the consequence of the farmers-herders' conflicts and the Boko Haram insurgency. Electronic warfare can be deployed to managed the security trajectories in Benue state and Africa Sahel region with 8000km transhumance epicentre of farmers-herders' conflicts. The framework solutions are: policy and economic drivers, saline soil biodegradation and restoration, climate mitigation and carbon sequestration using biowaste recycled into biofertilizer from anaerobic digester technology https://www.academia.edu/video/jyonKl . The impacts are soil health, food systems resilience, one health and pasture development that ensues partnership, collaboration, adaptation, climate mitigation and soil restoration for Benue state and Africa Sahel region 100 million hectares degraded land for food sovereignty. Integrated natural resource management can transform sustainable livelihoods by the development of agriculture corridor development to facilitate meeting sustainable development goals targets by the United Nations 2030.*

Keywords: Sustainable livelihoods, Framework, Regenerative agriculture, Farmers-herder's conflict, Agriculture security, Food systems resilience, UNDP, DFID, Wicked problem.

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1 | INTRODUCTION

The incessant occurrence of conflicts between crop farmers and herders has become one of Nigeria's popular and difficult-to-address security challenges (Awotokun *et al*., 2020). Livelihood comprises the capabilities, assets, both material and social resources, and activities required for means of living (Figure 1). The Sahelian draught of the 1970s and 1980s, and the accompanying migration of a huge number of pastoralists (Figure 3) into fringes of the humid forest zone of West Africa with the consequence of farmers-herder's crisis (Tonah,2006) with overgrazing fields account for the highest percentage of the conflict (Abbas,2012). In the study area (Benue state, Nigeria) pre-harvest period, cattle frequently destroy farmland and conflicts often leads to disunity or distrust, violence, disagreement, and bloodshed among the parties (Adebayo and Olaniyi, 2008).The Sub-Saharan Africa (SSA) being the most vulnerable to the adverse effects of farmers-herders' conflicts: failure of natural resource management (Okunlola and Okafor, 2022). Households' vulnerability to livelihoods sustainability and challenge to poverty reduction (Scoones *et al.*, 2019; Bukari, 2022) associated with rampant crop destruction and cattle killing, but little adaptation strategies by the actors to avert the effects of the losses (Krätli and Toulmin, 2020; Kugbega and Aboagye, 2021). The causes of farmers-herders' conflicts and their effects on livelihoods (Nnaji *et al.*, 2022), households' adaptation strategies now required asserted by scholars (Brottem 2021; Twumasi *et al.*, 2022) because of its negative impacts (Yakubu *et al*.,2021). Nformi *et al*., (2014) asserted that environmental issues like desertification, land degradation and climate change are becoming major factors in conflicts.

Persistent antagonism over scarce resources is the fundamental cause of conflicts between economic agents since all conflicts share common qualities (Ofuoku and Isife, 2009), requires problem re-framing (Chaya, 2024) for the development of bespoke solution to farmers-herders' conflicts in the study area. Farmers-herders crisis in Nigeria is not only seen as resource conflicts but it also takes ethno-religious and political dimension. Whenever crisis erupted between Fulani herdsmen and farmers in Nigeria, those from Niger Republic, Chad, Mali, Senegal, Gambia, Guinea and other West African countries including those living in Cameroon will migrate to Nigeria to fight the host communities to protect their interest, thus taking ethnic dimensions (Figure 3). Nigerian military who argues that the violent herdsmen that attack and kill rural farmers, burnt their houses, rape and destroy properties are not from Nigeria (Ojo, 2017). Herder and farmer groups have different values, customs, physical and cultural features, differences between them are often tagged as ethnic conflicts (Tonah, 2006). Destruction of crops by the cattle during grazing and cattle theft is one of the major causes of conflicts between Fulani herders and crop farmers in Nigeria. Farmers-herders' crisis reduces the capacities of people to live the kind of life they value and well-being (Musa *et al*., 2014). This is likely to be due to high inflation, poor governance, insecurity via the activities of Islamic State of West African Province (ISWAP), Boko-Haram, killer herdsmen among others (Adebo and Olotu, 2018; Solomon, 2021), Figure 3.

Hence, there is tendency that most farmers that characterized the majority of rural dwellers would be subjected to live in 'abject poverty' (Awotokun *et al*., 2020) because no agriculture security. Any farmers' livelihood is directly related to number of assets owned. This is evident from different researcher's opinions on how farmers' livelihood is influenced by the available assets to each farmer etc., Figure 1 asserted by Odebode, 2019. Assets in this context are social capital,

natural capital, human capital and financial capital, with natural capital as conflicts spot, most farmers are highly vulnerable if for any reason they lack access to their farm which is the main and only capital asset from which they derive their livelihood (Figure 1). The crisis between farmers and herders in the study area has resulted in displacement of most farmers which has led to inability to access their farms from which they derive their livelihood affirmed by Agyemang (2021). Therefore, conflicts between crop farmers and herders a major challenge to economic development and sustainable livelihood of the agrarian communities in Nigeria (Ukamaka *et al*.,2017). The resultant impact of poverty created by farmers-herders' conflicts is crux of this paper to find sustainable livelihoods for the actors and stakeholders. Why extremist militias are on the rise in the West African Sahel? https://www.youtube.com/watch?v=4L9VxCg_-VQ.

In the SSA, herdsmen's extremists are often in possession of illegal arms, as crop farmers become the vulnerable group with a high tendency for negative effects on their livelihoods (George *et al.,* 2020). Violence linked to farmer-herder conflicts has spiked high and triggered huge damage in West and Central African countries (Figure 3), including injuries, human fatalities, and displacement of large rural populations (Tanyi *et al.,* 2021). In Botswana (Kalabamu, 2021), Cameroon (Feldt *et al.,* 2020), Cote d-Ivoire (Cabot, 2017), Burkina Faso and Mali (Olumba *et al.,* 2022), Ghana (Issifu *et al*., 2022) and Nigeria (George *et al*., 2021; Komolafe *et al.,* 2022). Not only in Africa but also in South Asia countries where extremely large diversity of pastoral communities where the pastoralists contend for limited natural resources (Singh and Kerven, 2023; Ashraf *et al.,* 2022). Consequence's farmer- herder conflicts on agriculture have been reported to include loss of farm productivity (Amao *et al.,* 2018), food insecurity, hunger and loss of lives (Tanyi *et al.,* 2021), destruction of rural infrastructure (Effiong and Owolabi, 2020), displacement of crop farmers from their inherited farmlands (Yikwab and Tade, 2021) and low farm outputs (George *et al.,* 2021).

Shah and Wu (2019) and Arora (2018) asserted that addressing the socioeconomic impacts on livelihoods and agricultural sustainability is critical for achieving United Nation sustainable developmental 2030 goals targets related to poverty reduction, food security, gender equality, and environmental conservation. Additionally, sustainable livelihoods and agriculture are closely linked to overall economic development, contributing to employment generation, income growth, and rural development (Nyamekye *et al*., 2021). Sustainable agricultural practices, such as soil conservation, efficient water management, and proper biodiversity conservation, are fundamental for maintaining land productivity and ensuring future resource availability (Shah and Wu,2019). Gumplowicz (1885) viewed conflicts as a process where people fight for survival and personal growth. The solution to the impacts of conflicts on livelihoods and socioeconomic challenges is significance for 'building food resilience' to external shocks (farmers-herders' conflicts), such as climate change, economic downturns, and global pandemics (stressors). Sustainable livelihoods and agriculture can help communities adapt to and mitigate these challenges, ultimately contributing to more stable and secure societies (Wijerathna-Yapa and Pathirana, 2022). Udemezue and Kanu (2019) asserted that the activities of the nomad in Nigeria since the 1960s have fundamentally undermined the stability and development of the State and economy. Today, what seemed like pockets of violence in some parts of the country, especially the southern region of Nigeria, has degenerated into a major national security crisis in the country, defying several solutions (Mbaeze and Nnaji, 2018).

The farmers-herders conflicts appear quite natural; however, the context of its manifestation suggests that it is a by-product of a failed interaction process and a clash of interests of the involved parties (Stern, 1998; Akorede, 2005) with complexity and uncertainty (wicked problem) when herders attack on farmers look like hybrid warfare in Sahel of Africa (Otaiku,2018). Poverty and conflict are widely understood to be closely inter-connected; with poverty making countries (Figure 3) to be more prone to civil war, and armed conflict weakening governance and economic performance (Marks, 2016). Conflict impacts on physical capital example, destruction of and lack of investment in infrastructure and services (Goodhand, 2001). Ahmed-Gamgum (2018) affirmed that the major effects of the violent are food and livestock shortages, food price increase, loss of revenue and income. Farmer/herder clashes have led to lost in production by for both parties that results to increase in transportation cost, increased poverty index and food insecurity (Crisis Group, 2016).

1.1 Complexity gives rise to Wicked Problem

Ecosystems are inherently dynamic and largely unpredictable complex systems, ecosystem management is a 'wicked problem' (Ludwig, 2001; Rittel and Webber,1973) emerged 53 years ago. Wicked problems are inherently resistant to clear definitions and easily identifiable, predefined solution. Wicked problems have been described in many disciplines, including public health, political science, business management, urban and regional planning, and natural resource management where Rittel and Webber (1973) have defined 10 primary characteristics of wicked problems. Heifetz (1994) classified problems as: Type I problems are technical in nature and have clearly defined questions and mechanical, straightforward solutions (i.e., they are tame). Type II problems are clearly definable but have no clear-cut solution. Solutions to type II problems are only proposals that must be tested and refined on the basis of outcomes. Type III problems have neither clear-cut definitions nor technical solutions. Type III problems are the most wicked and require continual learning to understand the definition of the problem and adaptively work toward solutions, usually in framework (Otaiku,2018).

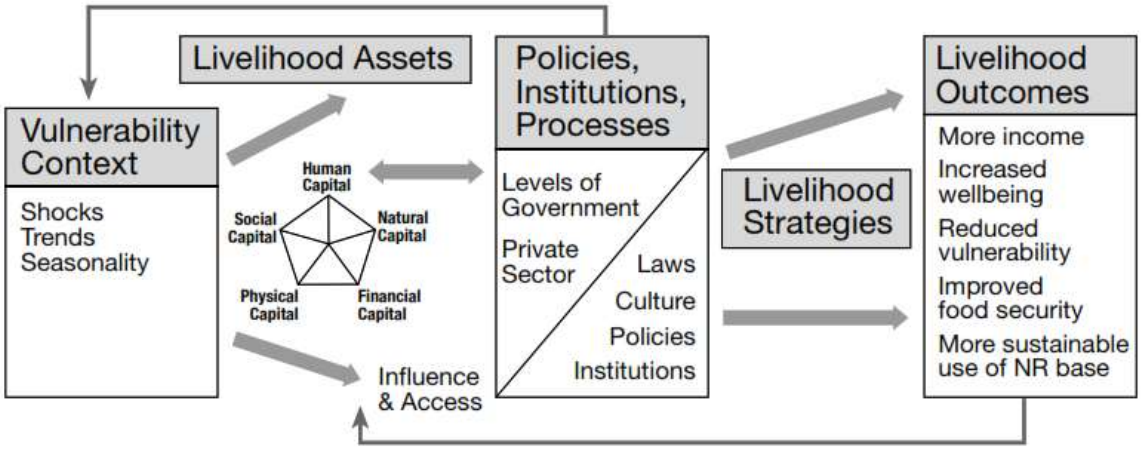

Figure 1. The sustainable livelihood framework (DFID,1999).

Resource Pressures and Risks

The food system is on the front line of environmental change and anticipated resource constraints. Modern food production now a wicked problem, increasingly homogenous, inter-connected, concentrated and input dependent with uncertainty (Rotz and Fraser, 2015; Bleischwitz *et al.,* 2014) with the potential to increase exposure, emerging risks, such as plant and animal diseases, resistant to current control mechanisms with complexity. Cropland and livestock farming is the leading cause of ecosystem degradation and biodiversity loss and contributes 11% of greenhouse gas emissions (WRI,2013). Balancing these competing demands for landscape for agriculture in a sustainable way is a fundamental challenge facing the food system in the 21st century. Today, crop requirements needed for livestock have caused major livestock-producing countries to become net importers of grain (Chatham House,2016). Precision agriculture techniques which use specific maps of soil and plant data to calibrate precise spraying and seeding applications, and controlled traffic farming, which uses global position system (GPS) and machine guidance to drive tractors and major farm appliances. Both techniques increase efficiency and can lead to reductions in chemical use and minimize soil degradation and pollution.[1,2]

Livestock feeds (pasture) alternatives research and development for replacement either the energy crop or the protein crop now urgent for sustainable livestock development globally. Bacteria assimilate high levels of protein or methane, without other feed inputs or sunlight, resulting in significant implications for land and resource use in agriculture production as an alternative (Overland *et al.*,2010). The use of 'big data', mapping and web-connected technology such as the Internet of Things (IoT) has the potential to revolutionize agriculture food supply chain (McKinsey,2016). Areas of innovation with the food system outcomes includes:

i. Optimizing agricultural and manufacturing systems - including improved demand and supply management using real-time data;
ii. Increasing supply chain traceability (Figure 16) and risk management - including the identification of current and future risks to supply risks from disruptions such as climate change;
iii. Enabling faster products development and innovation; and
iv. Development of agriculture corridors ((Paper 1 Figures 8A and 8B respectively).

Many researchers have called for systemic approaches to ecosystem management to replace previous, equilibrium-based methods for extracting maximum yields (Grumbine,1994; Sayer, 2013): The proposed solutions are:

i. Multisector decision-making, management decisions can lead to trade-offs or synergies among ecosystem, Figure 2 (DeFries *et al.*,2004);
ii. Multifunctional ecosystem management also requires multilevel governance systems that recognize the importance of state, community, and private ownership (Nagendra and Ostrom, 2012); and
iii. Institutions that enable management to span across administrative boundaries and adaptive management. Visit weblink: https://www.youtube.com/watch?v=dA2Is6qmeks.

1. Joint Research Centre of the European Commission (2014) Precision agriculture – An opportunity for EU farmers - Potential support with the CAP 2014 -2020.
2. http://cema-agri.org/page/precision-farming-key-technologies-concepts

The essence of adaptive management is learning by doing and recognition of uncertain outcomes (Figure 2). Key features of adaptive management are monitoring, re-assessing initial plans, redefining goals on the basis of new evidence, social learning, and collaborations (Armitage *et al.*, 2009; Holling,1978). Planning needs to be geared toward flexible decision-making, with nimble management structures that are capable of swift changes markets that incorporate natural capital, economic systems reward short-term production and consumption of natural resources. Changes in nonmarketed ecosystem services (such as watershed protection) and natural capital (such as stocks of minerals, energy sources, and forests) are externalities that are not factored into traditional economic accounting systems. Nearly a billion people will be affected by a scarcity of water by 2100 (Das and Ganguly, 2025, Appendix 2). Consequently, markets do not provide incentives to value ecosystem services and natural capital (Guerry *et al.*,2015). Many corporations have incorporated the value of nature into their supply chains-for example, with no-deforestation pledges (Kareiva *et al.*, 2015).

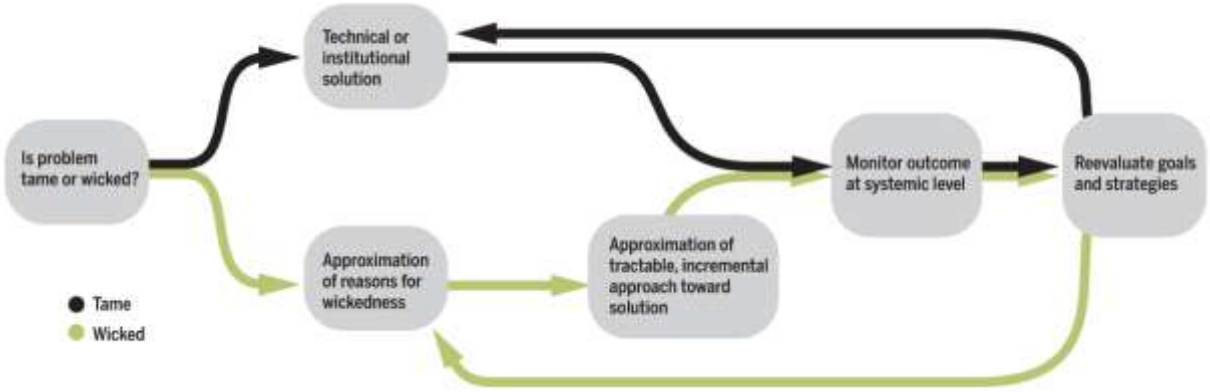

Figure 2. Decision flowchart for wicked problems in ecosystem management. Such an approach can help to avoid trap A (falsely applying a technical, tame solution to a wicked problem) or trap B (inaction from overwhelming complexity) by DeFries and Nagendra (2017).

Balancing Ideological Differences Among Stakeholders

Collaborative processes to engage diverse stakeholders and address inequalities (Figure 3, Table 1) for continual engagement among policy-makers, communities, and researchers within Sahel Africa aimed to balance pastoral livelihoods with wildlife conservation (Reid *et al.*,2015). Protected areas to conserve nature in the Sahel of Africa is fraught with differences in ideologies and values among diverse stakeholders, including conservationists, extractive industries, and local communities affirmed by DeFries (2017). Ecosystem management overwhelming complexity (wicked problem) requires an incremental approach using the principles of adaptive management (Figure 2). To deploy adaptive approach, analysis of a problem in ecosystem management, whether it is tame or wicked, and the primary reasons for the wickedness (if applicable) can help identify an initial, tractable institutional or technical intervention, whose outcome can be readily tracked (Chaya,2024). Analyses that consider divergent stakeholders and possible unintended consequences from the outset can help to avoid trap (Figure 2).

1.2 Research Justification

The agricultural sector's contribution to the growth and development of Nigeria's economy cannot be overemphasized (Olaoye, 2014). The consequence led to worries, unrest, dearth of food security, and adverse effects on the national economy and security; vibrant health, stable mental and physical development of the citizens, and national productivity (Kigelman, 2012). Sub-Saharan Africa farmers-herders' conflicts research gap (Figure 3) are :

1. Sustainable agricultural development policies and adoption of adaptation measures in farmers–herders conflicts hotspot areas (Benue state, Nigeria and Africa Sahel region) reported by Lipper and Zilberman (2018) are limited, leading to a high incidence of poverty and poor wellbeing and affirmed by Amadi and Anokwuru (2017);
2.The non-herding adaptation strategies include herding households' measures undertaken outside their herding activities to reduce or avert vulnerability to farmers-herders' conflicts and its potential livelihood impact (security, vulnerability and agricultural resilience);
3.No livelihood improvement strategies such as integrated scheme designed to improve the livelihood of rural dwellers to thrive in an environment plagued with insecurity, most scholars reports on the conflicts scenario. This is because livelihood improvement strategies are : designed to enhance the effectiveness of existing livelihood activities, which is only possible in a secured environment; and
4. No coping strategies of farming communities to displacement effect of farmers-herders' conflicts in north-central Nigeria affirmed by (Yikwab and Tade, 2021) and Great Green Wall in the Sahara and Sahel 8,000 km. herders source of transhumance (Appendix 1).Visit weblink: https://www.thegef.org/what-we-do/topics/great-green-wall-initiative.

1.3 Statement of the problem

Scoones (1998) affirmed that: 'livelihoods' denotes the means, activities, entitlements, and assets by which people make a living. Assets are defined as: natural/biological (land, water, common-property resources, flora, fauna), social (community, family, social networks), political (participation, empowerment - sometimes included in the 'social' category); human (education, labour, health, nutrition); physical (roads, clinics, markets, schools, bridges); and economic (jobs, savings, credit) and encapsulated in Figure 1.This approach rejects the standard procedure of specific sector [such as agriculture (Paper 1), water, or health called livelihood resources]. The research paper focuses on three elements: the livelihood strategies; institutional processes and organizational structures; and livelihoods sustainability.

Our methodology combined the coherence analysis framework development with the gap policies analyses (formulation, coherence, context, outcomes and its impacts on sustainable livelihood outcomes such stresses (climate change) and shocks (farmers-herders' conflicts). It is insufficient just to analyses the three elements; one must also analyze the institutional processes and organizational structures that link these various elements together involving the local people (Benue state, Nigeria, case study) and conflicts sources. Intervention international donor agencies: Department for International Development (DFID) and the United Nations Development Programme (UNDP) role and programme was evaluated in terms of poverty reduction and methodologies either at the local level or at the policy level at the study area. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living (Figure 19 below).

A livelihood is sustainable when it can cope with and recover from stresses and shocks (farmers-herders' conflicts), maintain or enhance its capabilities and assets, while not undermining the natural resource base (Scoones,1998). The research paper broad and systematic view of the factors that cause poverty (impacts from the farmers-herders' conflicts) whether these shocks (conflicts) and adverse trends (climate changes etc.), poorly functioning institutions and policies, or a basic lack of assets and to investigate the relations between them and develop a bespoke solution. Farmers-herders conflicts impacts can easily be selected and tailored to justify particular actions or interventions for the shocks (conflicts) and stresses (climate changes) such as:

i. Climate-induced scarcity and related migration as well as crop destruction and encroachment on transhumance corridors (Figure 3), using language such as 'climate wars and transhumance bringing pastoralists into 'collision' with farming communities (Chime, 2021);
ii. Passing grazing bans to restrict the 'indiscriminate grazing' of pastoralists like in Benue state, Nigeria (Olufemi, 2021);
iii. Using degradation narratives to legitimize and pave the way for agricultural investments and environmental conservation under a 'green economy' (Bergius *et al*., 2020) and introduction of regenerative agriculture practice and renewable energy;
iv. Using scarcity narratives and the different interpretations of this narrative to justify decisions taken in terms of using 'underutilized' resources (Mehta *et al*., 2019; Scoones *et al.*, 2019);
v. Securitizing' and politicizing climate change by linking climate-change-driven migration with violence and insecurity (Benjaminsen and Ba, 2021; Wiederkehr *et al*., 2022); and bespoke solution for climate change, livestock pasture development; and
vi. Most dangerously, extremist groups and politicians using and manipulating farmers-herders' grievances to further specific ends (Cline, 2020; Ugwueze *et al.*, 2022).

1.4 Research Questions?

1.What 'policies and actions that promote sustainable livelihoods' eradicating poverty impacts of the farmers-herders' conflicts, Benue state, Nigeria and Africa Sahel region ?
2.Develop an integrated support activities to improve the sustainability of livelihoods among poor and vulnerable groups by strengthening the resilience of their coping, security and adaptive strategies, Benue state, Nigeria and Africa Sahel region.
3.What is the impacts of the intervention (by international donor agencies/institutions like UNDP/DFID) agencies in Benue state farmers-herders conflicts areas and the role of Nigeria government to improve the livelihood resources for sustainable development.

1.5 Research Objectives

1.To develop the framework, an analytical structure to facilitate a broad and systematic understanding of the various factors that constrain or enhance livelihood opportunities, development and they are connected;
2.To employ a holistic perspective in the analyses of livelihoods to identify those issues or subject areas, impacts of intervention (UNDP/DFID sustainable livelihood approach) on farmers-herders' conflicts and how modern technologies can improves activities, security, and agriculture infrastructure and livelihoods in the study area and Sahel Africa region?
3. What institutional processes and organizational structures that links to the three elements of sustainable livelihoods: livelihood resources, livelihood strategies, institutional processes, and organizational structures can help solve the herder's transhumance challenges; and

4. Solution to mitigating fodder (pasture) availability and to develop crop agriculture and food system resilience in Benue state, Nigeria and Africa Sahel region (Figure 3).

Objectives of livelihoods development in rural areas

The objectives of rural livelihood's include the following:

1. Develop 'one unified approach' for sustainable livelihood construct (Figure 19) that could be strategically important for effective poverty reduction (farmers-herders conflicts impact), either at the local level or at the policy level (Figure 3);
2. Analyze intervention by international development agencies (UNDP and DFID) for institutional processes and organizational structures impacts on sustainable livelihood outcomes; UNDP Visit weblink: https://www.youtube.com/watch?v=3DOcQRl9ASc
3. An assessment and determination of the potential contributions of modern science and technology impacts on sustainable livelihoods;
4. How farmers-herders' access to different types of assets (physical, human, financial, natural, and social) and their ability to put these to productive use; and
5. How to cope with and recover from stresses (climate change) and shocks (conflicts) and maintain or enhance its capabilities, assets both now and in the future, while not undermining the natural resource base within Benue state and Sahel Africa region transhumance.

2 | LITERATURE REVIEW

Food Systems

Food systems (FS) today intrinsically complex: they comprise many different processes, value chains, actors and interactions; their outcomes affect multiple stakeholders and sectors in diverse (wicked problem). The Food and Agriculture Organization (FAO) of the United Nations has recently advocated building resilient food systems in various contexts (FAO, 2013; Choptiany *et al*., 2014). Food systems as it exists today is not sustainable due to the multitude of negative externalities it generates from green revolution. Today, FS activities are largely responsible for detrimental environmental impacts land change, loss of habitat and biodiversity, water, soil, and air pollution (UNEP, 2016). It has been increasingly recognized that the FS needs to undergo a process of transformation to optimize its outcomes (Caron *et al.*, 2018). For food systems transformation, it is crucial to apply the FSs approach taking into account the complexity of existing interactions and feedback mechanisms elaborated in Paper 1 (Figure 9) affirmed by scholars (Niles *et al*., 2017; Bortoletti and Lomax, 2019).

The food systems literature addresses the food outcomes linking to FS activities referring to "what we get" (the outcomes) from "what we do" (FS activities) reported by (Ingram, 2011; UNEP, 2016). The Food systems outcomes are four broad groups: food and nutrition security (or health pillar); three pillars of sustainability: environmental, social and economic (Niles *et al*.,2017). The definition addresses four pillars of food security-physical availability of food, access to food (physical and economic), food utilization and stability of the food supply (FAO, 2008). National or regional food systems, which comprise multiple value chains contributing to food security and other outcomes of importance in the region (Figure 3). Individual food value chains ranging from local to global levels, national and regional food systems (together lead to the diverse outcomes of food systems). Individual's perspective in the value chain with specific outcomes (smallholder livelihoods, household food security, consumers' health etc.).

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Farmers-Herders Conflicts in Africa

The phrase 'farmers-herders' conflicts' is typically used to refer to conflict between herding and farming groups (Turner *et al.*,2004) and the enduring feature of social life in the Sudano-Sahelian zone in Africa (Figure 3) as the consequence of the stress of changes in climate, deteriorating security situation in the Africa Sahel are compounded with the effects of increasing population growth. The new pastoralist trends increased herd sizes were hired cowboys to manage herds), and the use of private security personnel and arms for self-defense and herd protection (Krätli and Toulmin, 2020). This new pastoralist trends have added to the existing factor to spawn conflict between herders' and farmers in Niger (Turner *et al.*,2004) and Mali. Kwaja and Smith (2020) reported that from Mali to South-Sudan, series of attacks between farming and herding communities resulted to thousands of lives and displaced tens of thousands within Africa Sahel region where conflicts intertwining and overlapping like hybrid warfare (Otaiku, 2018) the epicentre of transhumance leaving death and destruction across the Africa continent as emerged as a wicked problem in Agriculture livelihoods within the Sahel Africa region (Figure 3).Visit weblink https://www.youtube.com/watch?v=Cu-AXj6LqJQ.

Nnoko-Mewanu (2018) reported that, several hundred million people practice pastoralism, the use of extensive grazing on rangeland for livestock production, in over 100 countries worldwide. And that from the estimates given by the Africa Union, Africa has up to 268 million pastoralists-over a quarter of the total population-living on about 43 percent of the continent's total land mass, yet weak government regulation of pastoralism, poor land management and inadequate policies on climate change adaptation have worsen land-related tensions. Consequently, the violent clashes between farmers-herders' groups are becoming more frequent due to two main causes: competition for access to increasingly scarce productive resources and the failure of the local adjudicative mechanisms (traditional institutions) to resolve the tensions created by this competition.

Source: Data sources: ACLED, ESRI Map courtesy of Matthew Luizza /USFWS.

Figure 3. A West African vision of livestock mobility within the Sahel and the coastal countries.

Nwankwo (2021) asserted that the conflicts have intensified in recent years and has led to the destruction of property, deaths, and displacement of people in countries such as Ghana, Nigeria, Cote d'Ivoire, Burkina Faso, Cameroon, among others (Figure 3). In Cote d'Ivoire, clashes between pastoralists and farmers had been recorded with the case of Bouna in 2016 in the North-East region of the country resulting in the deaths of not less than 27 people and thousands wounded (Nnoko-Mewanu, 2018). Bukari (2021) reported that Ghana has witnessed an increase in the number of violent clashes between herders and farmers in the country, citing particularly, violent clashes between Fulani herders and farmers in Brekum, in the Brong-Ahafo region on 19th September, 2017, which left 17 people dead, several others wounded and many cattle killed. In Sudan Sahel region farmers-herders crisis has been largely recognized, that the initiation of collective action in natural resource management is mainly dependent on a common understanding of the problem and how it can be solved (Ostrom, 2005) where specific contexts of social complexity and uncertainty. Conflicts are also driven by the attitudes and power of the involved actors (farmers-headers) reported by Raik *et al*., 2008 and Mason *et al*., 2018. The choice of a desirable pathway solution will ultimately require consideration of the trade-offs among different priorities between different stakeholders. Transformations occur in dynamic open systems, influenced by a myriad of different factors and their transformative actions. Transformational change often involves, inter alia, shifts in perceptions, beliefs, values, and meanings that define the lifestyle of actors (Westley and Antadze, 2010). The combination of (1) high complexity, (2) uncertainty, (3) deep conflicts, and (4) scale mismatches exacerbate wickedness in terms of social-ecological transformability within the Africa Sudan-Sahel region (Figure 3).

Nigeria Farmers-Herders Conflicts: Causes of the Conflict

In West Africa (Figure 3) conflicts on the increase in 2025 (Benue state, Nigeria) has attracted the attention of researchers and policymakers by farmer-herder conflict: shooting of innocent citizens by herdsman, destruction of food crops, raping of women on their farms, herdsmen causing bushfires, pollution of water bodies by herdsmen and cattle rustling.[3,4] Breusers *et al* (1998) reported, competition over natural resources caused by human population growth, growth in the population of herds and extension of cultivated areas are the causes of the farmer-herder conflicts. Nchi (2013) asserted that competitive resources for pastures and farmlands for livelihood. Opoku (2014), affirmed the causes of the farmer-herder conflicts are: shooting of innocent citizens by herdsman, destruction of food crops, raping of women on their farms, herdsmen causing bushfires, pollution of water bodies by herdsmen and cattle rustling.

Consequences of the Farmers-Herders Conflicts

The consequences of the conflicts can be linked to humanitarian, social, economic, and security effects. Okoli and Atelhe (2014), reported that natives-nomads conflict results in loss of life, 'population displacements, human injury and livelihood crises. The conflicts impacts do not only lead to the killing of people, but also people become homeless, displaced and destitute. Elaborating further on the humanitarian effects, Ofem and Inyang (2014) asserted that apart from

3.Let's Get Those Criminals, Tinubu Tells Service Chiefs, IGP | Guma https://www.youtube.com/watch?v=k9u55pDz1X0
4.Killings: Give Us Peace in Benue State, Tor Tiv Tells President Tinubu https://www.youtube.com/watch?v=WwIyuhm3pUI

the killings by nomads and reprisal attacks by the indigenes, some people become widows, widowers and orphans during the conflicts, while other victims of the conflict are maimed or injured. The social effects of farmers-pastoralists conflicts threaten peace and tranquility among various groups. The economic effects of pastoralists and farmers conflict leads to dire productivity and agricultural consequences. Okoli and Atelhe (2014) contends that economic implications relate to losses associated with the destruction of homes, low agricultural productivity, community assets, and household properties. Hence, many farmlands and large volumes of farm crops and produce are destroyed while hundreds of cattle are killed. Civil wars in Chad and Niger started as a result of competition between Tubu, Arab and Fulbe herders over a well, while the tension between the Tuaregs and the state of Mali, Chad and Niger has been linked to resource conflict (Shettima and Tar, 2008). Therefore, the government should adopt a more targeted engagement with these communities to seek peaceful resolution of the conflicts.

3 | THEORETICAL REVIEW

Wicked Problem Theory

Today era of Anthropocene impacts on climate change and its vulnerabilities (Crutzen, 2002) change driven by social-ecological systems (Berkes *et al.,* 1998) seems unavoidable as livelihoods stressors on the planet. The sustainability of the state of social-ecological systems (SESs), continuously changing, is the crux of modernity and development (Herrfahrdt-Pahle *et al.,* 2012; Levin *et al.,* 2013). Resilience defines as the capacity of a system to persist and reorganize in the face of change (Folke *et al.,* 2002; Gunderson *et al.,* 2005; Walker *et al.,* 2004) emerged last 20 years. Today, resilience theory requires 'construct validity' by scholars due to the lack of analytical power available to study the shifts and fundamental changes in the structure and functioning of SESs transformations (Gelcich *et al.,* 2010; Pelling *et al.,* 2011; Jerneck and Olsson, 2008) globally. The increase in uncertainties and the interconnectedness of crises, observed through global climate change, transformations are necessary to prevent SESs from collapsing (Folke *et al*., 2010; Westley *et al*., 2011). Achieved outcomes are sometimes very different to what is expected or desired of change when managing SESs-associated complexity and uncertainty (wicked problems). Biodiversity conservation, policies and incentives are known to generate unintended pervasive impacts (Steffen,2009).

The concept of wicked problems was developed by Rittel and Webber (1973). Proposed wicked problem lens (Xiang, 2013; Termeer *et al*., 2019) to draw attention to particular features of intractable social and ecological issues, which may represent barriers to transformation initiatives such as indeterminacy in problem formulation, non-definitiveness in problem solutions, irreversible consequentiality, individual uniqueness, among others. Transformability initiatives like regenerative agriculture practice (climate mitigation solutions, policies etc.) are candidates for solving the climate change wicked problem that intrinsically pervaded by social complexity. The product of framing narratives and stakeholders' perceptions of the problems, processes of change, and the desirability of the alternative trajectories of the system (Görg *et al.,* 2017; O'Brien and Wolf, 2010) in Figure 2. Social-ecological transformations involve a plethora of stakeholders with varying levels of power, whose values, interests, and goals are heterogeneous and often conflicting (Figure 2). These may result to 'policy myopia' or 'the inability to clearly see the horizon of the future policy environment in which impacts of the policy will develop' can lead to policy failure (Nair and Howlett, 2017). The consequence of ambiguity and human limitations in information processing related to the formulation of both

the problems and their solutions. The mechanisms at the root of development, social-ecological transformations are not clearly identified and understood (Walker *et al.*, 2006).

Context Specific

The problem of food insecurity is context specific as there are different combinations of the intertwined and interdependent causal factors impacting on different individuals, households, communities and countries (Figure 3). For example, the causal factor of climate variability within the stability pillar of food security would impact more on important agricultural areas. Farmers-herders' conflicts have multiple causes (Figure 3). Both food security and insecurity have multiple causes can also coexist at the individual, household, community, and national levels (Barrett and Lentz, 2010). The multiple causes of food insecurity also have many interdependencies (Figure 14). Due to its multi-causality and interdependency, attempts to address food insecurity often leads to unforeseen consequences.

Seddon and Sumberg (1997) have argued that 'the current levels of conflict that occur in some locations' are clearly intolerable for farmers and herders within the environment. The solution can be community driven and location specific with the role of national government mediation for herders and farmers conflict (Nnoko-Mewanu, 2018). In Nigeria, Bill for the establishment of Grazing Reserves and cattle Routes Commission in 2008 to address the lingering conflict between the herders and farmers and establishment of ministry of livestock development (2024). Pragmatist scholars have offered their particular opinion based on reality based on environment and can only be encountered through human experience (Goles and Hirschheim, 2000; Tashakkori and Teddlie, 2008). Today requires the urgency for agriculture security architecture (Figure 18) and the development of Nigeria farmers-herders conflicts livestock agro-corridor for sustainable livelihoods (Appendix 3).

Agrivoltaics: Integrating Energy and Regenerative Agriculture

54.9 % of the Nigeria population is urban (130,312,056 people in 2025) and 450 million by World Bank [5] where food system outcome driven by chemical agriculture cultivation and 60% rise in methane emissions from agriculture over the past four decades (Fróna *et al.*, 2019) with the consequence of soil degradation, nutrient depletion, pollution (Hamuda *et al*.,2010) threatening ecological stability that impacts of the climate variability in Benue state and Sahel of Africa (Green Wall, Appendix 1). Regenerative agriculture has emerged as an alternative approach to food production, potential to achieve positive environmental and social outcomes (Rhodes,2017) and sustainable food production (Schreefel *et al.*, 2020). Nigeria is projected to lose approximately $460 USD billion by 2050 due to the impacts of climate change, equating about 20% of the nation's Gross Domestic Product (GDP).[6] Nigeria produced 129 metric tons of CO_2 in 2023, the 4th highest emissions in Africa (emissions are from oil and gas production, and the practice of "gas venting") and ethane is a greenhouse gas 28 times more potent that carbon dioxide.[7]

5. U.N. Dept. of Economic and Social Affairs - Population Division. World Population Prospects: The 2024 Revision. (Medium-fertility variant). Source: https://www.worldometers.info/world-population/nigeria-population/
6 Nigeria faces $460bn climate change loss by 2050 – Report.
https://www.vanguardngr.com/2024/11/nigeria-faces-460bn-climate-change-loss-by-2050-report/.
7. Population and the Environment in Nigeria – Too big to go green?
https://populationmatters.org/news/2024/02/population-and-the-environment-in-nigeria-too-big-to-go-green/

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Nigeria produced 129 metric tons of CO_2 in 2023, the 4th highest emissions in Africa (emissions are from oil and gas production, and the practice of "gas venting") and ethane is a greenhouse gas 28 times more potent that carbon dioxide.[7]Agrivoltaics,[8,9] a dual-use system combining solar energy generation with agricultural production, driven by solar technologies to achieving global sustainability goals (Østergaard *et al.*, 2023) and Figure 4 illuminate its significance.

Figure 4. A comparison of conventional farming and regenerative agrivoltaics and adapted from adapted from O'Callaghan *et al.*, 2022.

Agrivoltaics multiple impacts multiplier are: lower greenhouse gas emissions (GHGs) (Fthenakis,2008), increased economic and environmental advantages (Wade and Jennings, 2015) enhanced water-use efficiency (Elamri,2018), soil resilience for crop yields, environmental stressors such as wind (Willockx *et al.*, 2022), improved land use efficiency (Trommsdorff *et al.*, 2021); mitigation of soil erosion (Xiao *et al.*, 2022), and reversal of desertification (Williams, 2022). Also, localizes food production (Brain,2012), improves health due to reduced pollution (Prehoda,2017), acts as a hedge against inflation (Sommerfeldt *et al.*, 2023), provides energy for human capital development (McDonald *et al.*,2022) and integrating renewable fuel production, such as hydrogen (Tributsch *et al.*, 2008; Fereidooni *et al.*,2018). Agrivoltaics (Figure 5) will improve the sustainable livelihood of farmers-herders by generates dual revenue streams through agricultural outputs and energy sales, enhancing farmers'

8.Regenerative Farming and Agrivoltaics.
https://www.google.com/search?q=Regenerative+Farming+and+Agrivoltaics&oq.
9. Agrivoltaics in Africa.
https://www.youtube.com/watch?app=desktop&v=JToQ0O7tcrM

financial stability (Jamil and Pearce,2023), agriculture livelihoods and ultimately reduce farmers-herders' conflicts in Benue state and Sahel of Africa (Appendix 1). Managed grazing within agrivoltaic systems offers a scalable solution contributing to dual-use land management. Rotational grazing under solar modules presents a viable strategy for pasture regeneration and carbon storage (Díaz de Otálora,2021). By controlling grazing patterns, farmers can ensure even vegetation coverage and reducing overgrazing risks (Lytle, 2021). The shade from modules (Figure 4) creates microclimate that promote diverse forage growth (Adeh *et al.,* 2018), supporting livestock nutrition, soil ecosystem health and sustainable development, visit: weblink https://www.youtube.com/watch?v=Vz11Xt-TxP4.

Nigeria Surface Water Resources

Agriculture (44 percent), municipal/domestic (40 percent), and industry (16 percent) are the principal sources of demand for freshwater and approximately 41 percent of all freshwater abstractions are from surface water (Figure 6). Nigeria's surface waters primarily drain through the Niger and Lake Chad Basin, in addition to several smaller coastal river basins. Nigeria organizes its basins into eight Hydrological Areas (HA). The Niger North, Niger Central, Niger South, Upper Benue, and Lower Benue Hydrological Areas (HAs) form the lower reaches of the Niger Basin.[10] Collectively, they drain almost two-thirds of the country and account for about 60 percent of total runoff.[11-13] The Niger River originates in Guinea (Figure 3) and outlets to the Gulf of Guinea through the Niger Delta, which is the third largest delta in the world covering 70,000 km^2 and containing seven percent of the world's mangroves.
The Benue River is the largest and most important tributary of the Niger River in Nigeria.[14]

Nigeria has over 300 dams of varying sizes and purposes located across the country. Some provide electricity, some help with irrigation, and others help control flooding (Figure 6). The types of dams: hydroelectric dams, water supply dams, flood control dams, multipurpose dams.[15a] The study revealed that there are 323 large, medium and small dams, which have been constructed and are being operational in Nigeria (Figure 6). They have a total storage capacity of more than 30×109 m^3. Eighty-five percent of the larger dams are located in the Sudano-Sahelian zone of the country (Oke *et al.,* 2013). Seventy-nine percent have domestic and industrial water supply components, while 33% have irrigation as a major use to which the stored water is put; 29% are for fisheries, 16% for recreation and 4% are also for hydro-electric power generation (HEP) asserted by Oke *et al.*, 2013.

10.Adelodun, B.; Choi, K.-S. (2018). A Review of the Evaluation of Irrigation Practice in Nigeria: Past, Present and Future Prospects. *Afr. J. Agric. Res*., 13 (40), 2087–2097.
11.Federal Ministry of Water Resources. *National Water Resources Policy*; 2016.
12.FAO. (2016). AQUASTAT Country Profile - Nigeria; Rome, Italy.
13.Idu, A. J. Threats to Water Resources Development in Nigeria. *J. Geol. Geophys*. 2015, 4 (3). https://doi.org/10.4172/2329-6755.1000205.
14.Government of Nigeria. Nigeria. Post-Disaster Needs Assessment 2012 Floods,2013.
15a. Nigeria has over 300 dams of varying sizes and purposes located across the country. https://www.withinnigeria.com/piece/2024/08/26/full-list-of-dams-in-nigeria-and-their-locations-2024/#google_vignette.

Figure 5. A comparison of conventional farming and regenerative agrivoltaics from adapted from O'Callaghan *et al.,* 2022.

Theoretical Explanations

1. Tragedy of the Commons Theory

Garrett Hardin (1968) improved the William Forster Lloyd theory of the tragedy of the commons (1833) asserted that within a shared resource system (common resources collectively owned), each individual users act independently to their own self-interest and behave contrary to the common good of all users by depleting or spoiling that resource through their collective action. In relation to open grazing, herdsmen allow their cattle to graze and each herdsman continue to add cattle to the pasture so as to expand the amount of proceeds coming from their herds (Figure 3). The consequence, damage done to the atmosphere that causes global warming, climate change and scarcity of resources shared by all and as the resources become scarcer competition over the resources increases leading to conflict (Audu,2013).

2. The Eco-Violence Theory

The theory of Eco-violence examines the inter-linkage between environmental changes and possible conflict situation. Soysa (2002), the proponents of this framework maintain that conflicts are generated by the scarcity of natural resources in at least two primary ways. First, resource scarcity has direct effects on conflict when scarcity drives elites to 'capture' resources, marginalizing powerless groups in the process. This is hinged on the argument of Homer-Dixon that 'resource capture occurs when the degradation and depletion of renewable resources interact with population growth to encourage powerful groups within a society to shift resource distribution in their favour' (Soysa, 2002). The second primary way, according to Soysa (2002), is that, the indirect effect of scarcity is also very vital in the larger picture. Accordingly, Homer-Dixon cited Soysa (2002) noted:

. . . many developing countries face increasingly complex, fast-moving, and interacting environmental scarcities. These scarcities can overwhelm efforts to produce constructive change and can actually reduce a country's ability to deliver reform. Consequently, environmental scarcity sometimes helps to drive society into a self-reinforcing spiral of violence, institutional dysfunction, and social fragmentation. . .A persistent and serious ingenuity gap raises grievances and erodes the moral and coercive authority of government, which boosts the probability of serious turmoil and violence . . . if these processes continue unchecked, countries with a critical ingenuity gap therefore risk becoming trapped in a vicious cycle . . .

The theory has continued to influence studies associated with environmentally induced conflicts as scholars have adopted in paper inference of analysis, the *expose*/gap captured by Figure 11 (Paper 1): inter-relationships, perspectives and boundaries for a scenario. Rehabilitating degraded lands: Investing in soil conservation, reforestation, and sustainable water management (e.g., along the Sahel and Lake Chad Basin) to reduce land degradation (Amoah *et al.*, 2025).

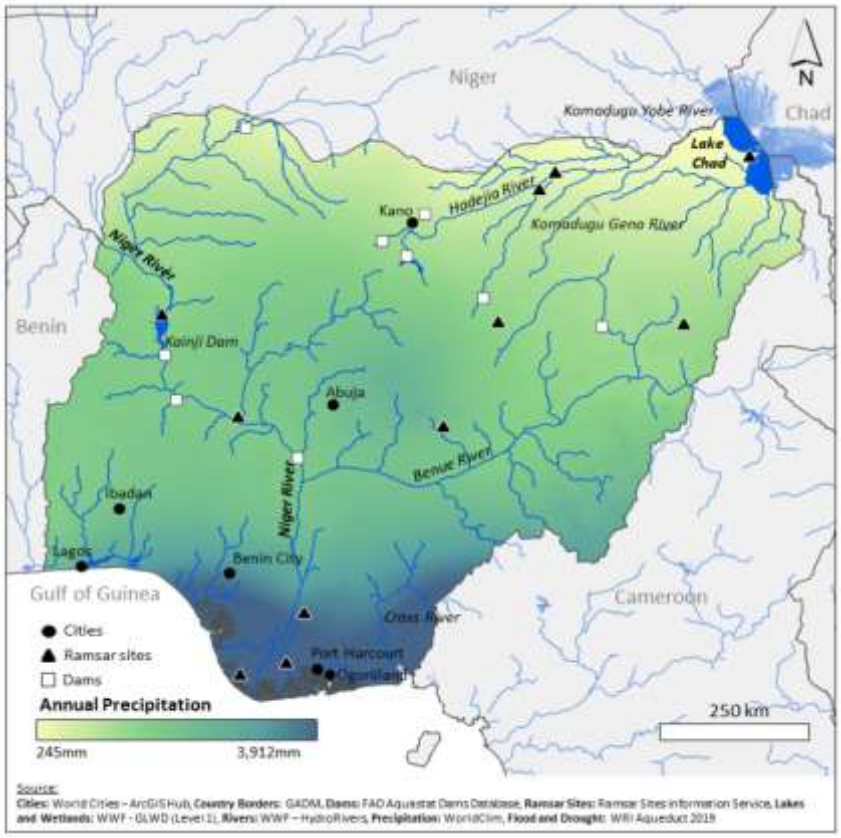

Figure 6. Nigeria's hydrological surface waters primarily drain through the Niger and Lake Chad Basin, showing hydrological areas.

3. Green Theory

Humankind has caused serious damage to nature. In this context, Green Theory should be considered as one of the critical theories. (Dyer, 2017) affirmed that the green theory, the structure, actors, and functioning of the current international order harm nature (Figure 3). Green theory, which aims to prevent the destruction of nature, offers a normative approach to the international system where, environmental issues can be prevented by establishing new concepts, institutions, and systems. Green Theory has arisen to explain all these political developments in the discipline of International Relations. (Dyer, 2017). Dyer (2018) gave a vivid historical background to the emergence of the framework, thus:

In the 1960s there was public recognition of the global environmental crisis arising from the 'tragedy of the commons', which is the idea that as self-interested individuals, humans will overuse shared resources such as land, fresh water and fish. In the 1970s the first United Nations conference on the subject was held and by the 1980s green political parties and public policies

had emerged. This coincided with a demand for a green theory to help explain and understand these political issues. By the 1990s, International Relations had come to recognize the natural environment as an increasingly significant source of questions for the discipline, requiring theoretical as well as practical attention (Dyer, 2018:1).

Green theory analysts look at 'real world environmental problems' differently as compared to Realism or Neoliberalism or critical theorist. For instance, the realists assume constant struggle between the various member states of the global world and don't think environmental problems have any role in national security. Neo-liberals do acknowledge environmental challenges and want to tweak the incentive structures in order to bring about cooperation amongst various countries (The Green Wall, Appendix 1). Dauda (2013), affirmed that, green theory is rested on three main features of eco-centricism, the limits of growth and decentralization. The Green Wall initiative's ambition is to restore 100 million hectares of currently degraded land; sequester 250 million tons of carbon and create 10 million green jobs by 2030. This will help communities living along the Wall to grow. Visit weblink: https://www.unccd.int/our-work/ggwi.

4. Wicked Problems

Wicked problems, opposite to 'tame problems', are complex, intractable, open-ended and unpredictable (Alford and Head,2017) illuminated by the agriculture livelihood construct (Paper 1, Figure 9). Most complex social problems (Farmers-herders conflict, Type III wicked problem) difficult to be solved by the rational-technical approaches confounded by complexity, uncertainties, and different values of stakeholders (Head,2022) like climate change (Levin *et al*., 2012) associated with multiple stakeholders having different facts and values, there is possibly a distinction of explanations to the problems (Bannink and Trommel, 2019). Reframing is one among recommended solutions in dealing with wicked problems (Brower, 2022). The concept of frame reflection is defined as the way policy actors reviewing the existing policy frames and calling for frame shifts or reframing (Schon and Rein,1994) for solution resolution like climate change (Figure 2), the crux of agriculture wicked problem. Visit weblink: https://www.youtube.com/watch?v=LxgMdjyw8uw.

4 | MATERIALS AND METHODS

4.1 Research Methodology

Gap analyses and systemic review of policy reframing; problem sense-making, problem exploration and categorization was applied for the research study. Framework development integrates concepts and methods for policy gap, eco-solution, coherence analysis for reframing and similar (van Hulst and Yanow, 2016; Nilsson *et al.*, 2012). Understanding the wicked problem through perceptions and experience for policy gap and coherence analyses, for implementation practice requires a bottom-up approach and engagement of stakeholders (Nilsson *et al*.,2012; Chaya *et al*.,2019). The qualitative aspect of this study involved fieldwork conducted (Benue state, Nigeria 2022). The areas were sampled purposively based on the frequency and the scale of the conflicts (Guma and Gwer-West local government areas). Secondary data were utilized through existing literature such as; books, journal articles, policy reports, and information from based-line data. The data obtained from these areas were subjected to content analysis.

Ethical issues like consent of local authorities, ensuring the anonymity of the respondents, as well as the confidentiality of the responses, were respected at all stages of the research. During interviews, participants were reminded that participation was voluntary; they did not have to respond to every question, and they may choose to stop the interview at any time. The procedural framework used (Remenyi *et al*., 1998) and it involves the use of specific methods to:

i. Gather adequate and representative evidence of phenomena (Buckley *et al.,* 1976);
ii. Develop appropriate ways to analyse collected data: content and face validity;
iii. Criterion-related validity [15b] and plausibility and theoretical significance (Amaratunga *et al.*, 2002);
iv. Triangulation - established through the correct design and use of data collection tools for the specific concepts being studied; and
v. Developed framework which provides a researcher with the tools to name the research constructs (research objects) and the context (s) of those constructs.

Systematic Reviews Interventions Programme
Sustainable livelihoods approach of United Nations Development Programme (UNDP) and British Department for International Development (DFID) to poverty reduction as an 'Examplar' interventions was systematic reviewed: value, impacts, programme duality and outcomes of activities. Aim to identify, evaluate and summarize the findings of all relevant UNDP/DFID individual/communities' studies under similar scenario of farmers-herders' conflicts. Systematic reviews adhere to a strict scientific design based on explicit, pre-specified and reproducible methods. Systematic reviews can also demonstrate where knowledge is lacking as guide future research (Higgins *et al*., 2022; Aromataris and Riitano,2014). Systematic scoping reviews to summarise and disseminate research findings, to identify research gaps, and make recommendations for future research (Peters *et al*., 2015).

UNDP | The United Nations Development Programme (UNDP)
UNDP Target | Use sustainable livelihoods (SL) to facilitate the planning of concrete projects and programmes. UNDP mandate includes: poverty eradication, employment and sustainable livelihoods, gender, protection and 'regeneration of the environment'[5], and governance. The sustainable livelihoods (SL) deliverables are:
1.UNDP the SL approach serves primarily as a programming framework to devise a set of integrated support activities to improve the sustainability of livelihoods among poor and vulnerable groups by strengthening the resilience of their coping and adaptive strategies.
2. In principle an open-ended process, certain emphasis is given to the introduction of improved technologies as well as social and economic investments. Policy and governance issues as they impinge on people's livelihoods are addressed (similar to Pape 1, Figure 9).
3. The various support activities are organized as specific SL programmes, usually implemented at a district level with ramifications at the community and household level.

15b. Creswell, J. W., and Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

UNDP employs an asset-based approach, emphasizing the promotion of people's access to and sustainable use of the assets upon which they rely as central to poverty reduction. To that end it stresses the need to understand the coping and adaptive strategies pursued by men and women. Coping strategies are short-term responses to a specific shock such as drought,[5] while adaptive strategies entail long-term change in behaviour patterns as a result of a shock or stress. UNDP specifically focuses on the importance of technological improvements as a means to help people rise out of poverty.[5] UNDP has developed a methodology (or rather procedure) for the design, implementation, and evaluation of sustainable livelihood programmes consisting of five steps: principle an open-ended process.
1.A participatory assessment is carried out of the risks, assets, and indigenous knowledge base found in a particular community[16] as reflected in the coping and adaptive strategies pursued by men and women, since poverty reduction is at its core.
2. An analysis of the micro, macro, and sectoral policies that influence people's livelihood strategies. That is, rejects the usual sectoral entry point [e.g. agriculture (Paper 1), water, or health] and instead begins with an analysis of people's current livelihood systems to identify an appropriate intervention. Visit weblink: https://www.youtube.com/watch?v=LxgMdjyw8uw.
3.An assessment and determination of the potential contributions of modern science and technology that complement indigenous knowledge systems in order to improve livelihoods.[16]
4.An identification of the social and economic investment mechanisms (i.e., microfinance, expenditures on health and education) that help or hinder existing livelihood strategies.
5.An assurance that the first four stages are integrated in real time, so that this process is part of overall programme of development, rather than a series of isolated events.

DFID | British Department for International Development (DFID)
DFID Target | DFID the SL approach is more of a basic framework for analysis. Livelihoods are constructed (Scoones,1998). DFID is the elimination of poverty in poorer countries.
1. Aim is a commitment to 'policies and actions that promote sustainable livelihoods'(Carney *et al*., 1999).
2. DFID's approach is the SL framework, an analytical structure to facilitate a broad and systematic understanding of the various factors that constrain or enhance livelihood opportunities, and to show how they relate to each other.
3. DFID SL framework elaborated three of the elements the framework: livelihood resources, livelihood strategies, and institutional processes and organizational studies.
4.Four types of capital are identified in the framework (natural capital, economic or financial capital, human capital and social capital) which are often used in combination, that people rely on for making a living (Paper 1, Figure 7).

Poverty-focused development activity (Ashley and Carney,1999) are:
1. People-centred: sustainable poverty elimination will be achieved only if external support focuses on what matters to people, understands the difference between groups of people, and works with them in a way that is congruent with their current livelihood strategies, social environment, and ability to adapt.

16. UNDP Anaerobic Digester | Biofertilizer Production by Ayodele Otaiku.
Regenerative agriculture and climate mitigation biotechnology. https://www.academia.edu/video/jyonKl.

2. Responsive and participatory: poor people themselves must be key actors in identifying and addressing livelihood priorities. Outsiders need processes that enable them to listen and respond to the poor.
3.Multi-level: poverty elimination is an enormous challenge that will only be overcome by working at multiple levels (Paper 1, Figure 9), ensuring that micro-level activity informs the development of policy and an effective enabling environment, and that macro-level structures and processes support people to build upon their own strengths.
4.Conducted in partnership: with both the public and the private sector.
5.Sustainable: there are four key dimensions to sustainability- economic, institutional, social and environmental sustainability. All are important -a balance must be found between them.
6. Dynamic: external support must recognize the dynamic nature of livelihood strategies, respond flexibly to changes in people's situation, and develop longer term commitments.

The fact that livelihoods depend on a combination of assets of various kinds and not just from one category. DFID framework (Paper 1, Figure 12) offers a way of assessing how policies, institutions, organizations, cultural norms shape livelihoods, both by determining who gains access to which type of asset, and defining what range of livelihood strategies are open and attractive to people. (Carney,1998). The value of using a DFIF framework, it does not take a sectoral view of poverty but holist perspective, that includes:
1. Direct support to assets (i.e., providing poor people with better access to the assets that act as a foundation for their livelihoods); and
2. Support to the more effective functioning of the structures and processes (policies, public and private sector organizations, markets, social relations, etc.) that influence not only access to assets but also which livelihood strategies are open to people.

4.2 The Study Area
Study was conducted in two local government areas out of the 23 local governments in Benue state, Nigeria which are Guma and Gwer-West local government areas. The choice of the locations was based on the following:
1. Producing large tons of agricultural products and agricultural products;
2. The locations are the commercial agriculture of Benue state, Nigeria ; and
3. Agriculture commodities prices in the locations are now very high, consequence of the dangerous effect of the farmers herders' conflict in the area.

The research study questionnaire was the major instrument used in field survey between the farmers and herdsmen and stakeholders in area (Gwer-West and Guma) Benue state, Nigeria with 23 local government areas (LGAs) with its headquarters in Makurdi. As an *ex post* facto research, cross sectional survey research design was employed in the study with aid of structured questionnaires administered to farmers and herders in the affected farming two communities. Based on the prevalence of farmer-herder conflicts in the localities. Qualitative data was generated through key informant interviews (KIIs) and personal observation (Figure 4).

Gwer-West | Gwer-West local government area is located in Benue state, Nigeria with headquarters in Naka town. The 2006 population census estimated the population of the local government to be 122,313, and it was projected to reach 165,100 by 2016. Gwer-West occupies a total area of 1, 207 km^2 and a population density of 136.8/km^2. Gwer-West and Guma LGAs are in the Benue valley - the epicentre of the farmers-herders' conflicts in Benue state. It is majorly a farming area inhabited by the Tivs (Figure 7).

Guma | Local government area in Benue state, Nigeria and it was created out of the former Makurdi local government area (LGA). The LGA is purely tropical in terms of temperature. Guma occupies a total land area of 240,000 square km and 191,599 population, according to 2006 census. The local government shared boundaries with Gwer-West, Makurdi and Tarka and Doma (Nasarawa state, Nigeria) LGAs on the East, South and West respectively. Its headquarters is located at Gbajimba Beside the Tivs who are the dominant ethnic group in the area, Jukun, Hausa and Kabuwa also live in the area (Figure 7). Guma local government area is made up of 10 council wards (Figure 7).

Method of Data Analysis

The data from the survey were presented quantitatively using simple percentage and descriptive statistical analysis tools tables, the mean, frequency, percentage, while data sourced through in-depth interviews were presented qualitatively and secondary data were analyzed using content analysis by application of Likert 5 scale (first introduced by Rensis Likert in the 1930s). Likert (1932) suggested that response options to several statements on Likert summative attitude scales can be written as 1 = strongly disapprove to 5 = strongly approve.

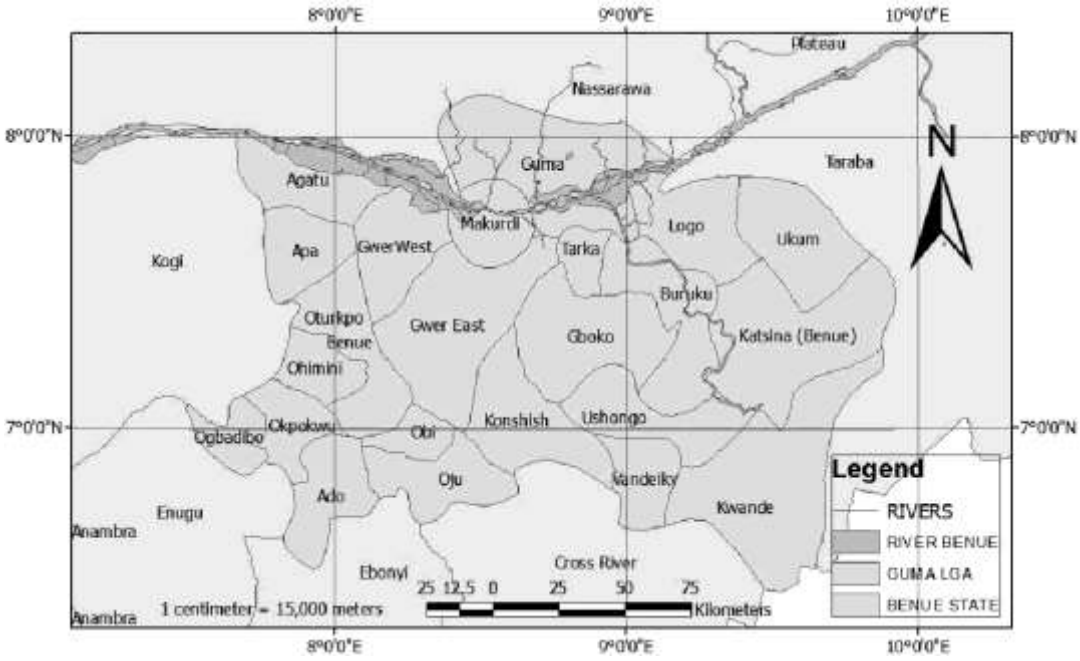

Figure 7. Map of the study area adapted from Ilevbare and Yusufu (2020).

The original Likert scale used a series of questions with five response alternatives: strongly approve, approve, undecided, disapprove, and strongly disapprove. It can be combined the responses from the series of questions to create an attitudinal measurement scale (Boone and Boone, 2012). Likert type data is taken as the discrete instead of continuous values, tied numbers, and restricted range (De Winter and Dodou, 2010). Such kinds of challenges occur while using Likert type data. It is necessary to plow out the entire problem while using Likert type data and also necessary to search the common solution. A Likert-type data assumes that the strength/ intensity of experience is linear, i.e. on a continuum from strongly agree to strongly disagree, and makes the assumption that attitudes can be measured (McLeod, 2008).

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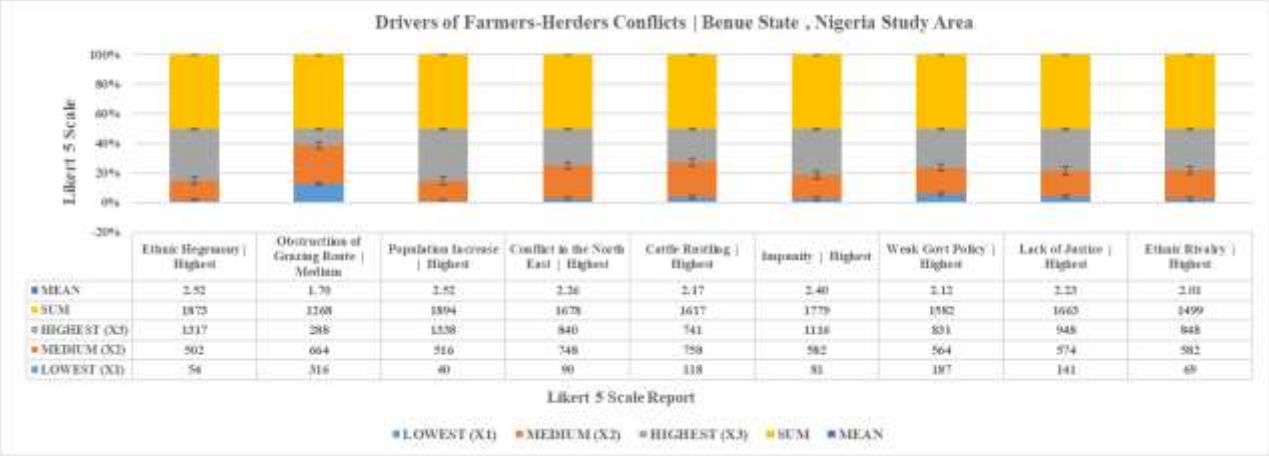
Respondents may be offered a choice of five pre-coded responses with the neutral point being neither agree nor disagree. So, data obtained from such kind of responses have not merely categories, there is ordered categories. Considering this fact, Likert type data has been treated as ordinal level of measurement (Jaminssion, 2004). Ordinal scales arrange or rank things (Brown, 2011) with the interval scales that show the order of things, but equal intervals between the points on the scale is also essential for the interval scale. Likert items that are combined into a single composite score/variable during the data analysis process (Boone and Boone, 2012; Joshi *et al,* 2015). We developed Likert 5 scale construct for the Benue state study data as an interval data. The attitude and behavior of the participants were captured through mutually exclusive items which are generally known as Likert items. Through Likert scale, we collect the opinions or perceptions of the participants in a specific construct (Figure 19). Numbers of items related to particular construct are prepared as statements or questions and during the analysis the score of the entire items of a construct is combined to generate composite score.

5 | RESULTS AND DISCUSSION

Farmers-Herders Quest for Solution: What causes conflicts?

Farmers-herders' conflicts are a complexity and uncertainty look like promising candidates for specifying wickedness in any issues (Termeer *et al*.,2019). Complexity gives rise to wicked problems because ecosystems are inherently dynamic and largely unpredictable complex systems. Conflicts is a wicked problem (Berkes and Fish, 2012). Data collected in the study area analyzed using the Likert 5 scale and using the mean, frequency, percentage reveal the networks of patterns and processes for decision relevant to delineating an effective bespoke solution for agriculture livelihood (resources land and water) for an holistic solution with Figure 8 survey reports : obstruction of grazing route (288) ; population increase (1338); conflicts in North-east, Nigeria (840); cattle rustling (741); weak government policy (831); ethnic hegemony (1317) and lack of justice (948).



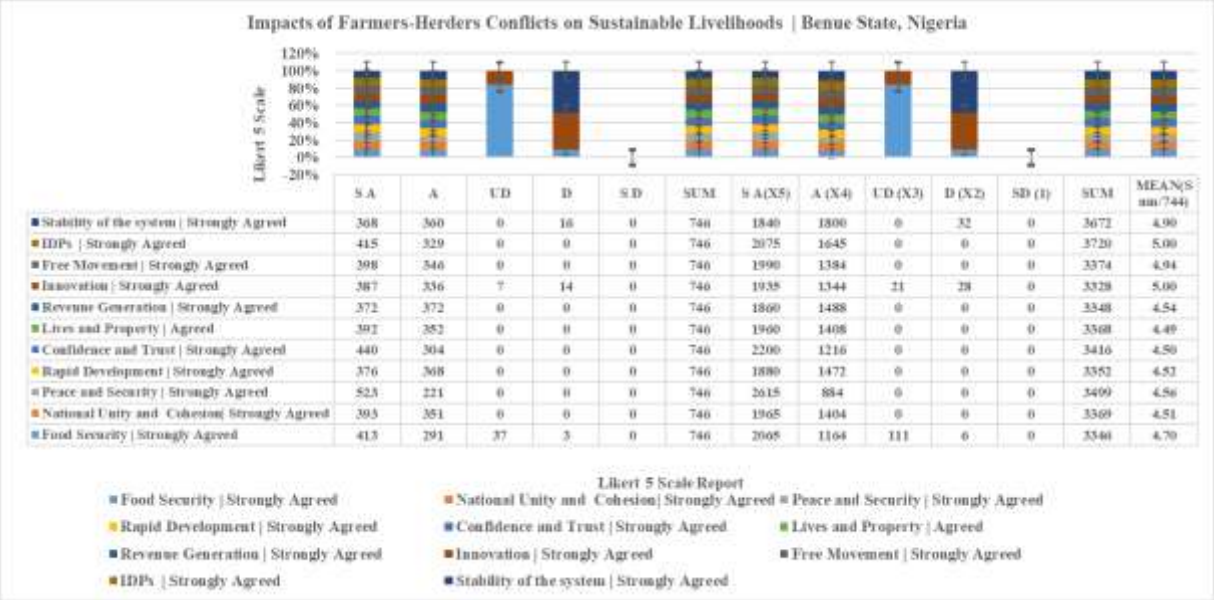
Source: Study field survey, 2021: Gwer-West and Guma, Benue state, Nigeria

Figure 8. Drivers of farmers-herders' conflicts (Likert 5 scale) analyses on study area.

Farmers-herders conflicts actions are linked to consequences in ways that are open to change and the situations of the action change, their consequences would also change (Figure 14). Like Farmers-herder's conflict, creating new trajectories for a system with any level of consensus and reliability remains difficult because of the inherent complexity of the social-ecological systems (SESs) and the uncertainties that they entail (Bai *et al.,* 2016) within the Sudan-Sahel region of Africa (Figure 3). Like climate change in SESs may also emerge without apparent warning (Preiser *et al.,* 2018; Pace *et al.,* 2015) where the drivers and consequences of social actions may be intensified with retroaction and recursive loops, propelling the system outside of sustainable domains, even with a cross-scale effects (Liu *et al*., 2016; Folke *et al*., 2011) as encapsulate in Paper 1 (Figure 9).

Conflicts Impacts on Sustainable livelihoods | Mechanism and Solution
How has the conflicts affected the cost of living and sustainable livelihoods in the Benue state, North-central region of Nigeria?

Likert 5 scale consensus report (Figure 9) scores from the respondent's study area. Schramm-Nielsen (2002) defines organizational conflicts as a breakdown in the standard mechanism of decision making which leads an individual or group to experience difficulty in selecting a mutually acceptable alternative. The survey results from Figure 9 shows the following indicators impacts on the sustainable livelihoods scores: National unity and cohesion: strongly agreed (393); peace and security: strongly agreed (523) as affirmed by Schramm-Nielsen (2002). Umana and Okafor (2019) asserts that group decision-making requires careful deliberation and is most advantageous when participants generate answers from a list of choices without prejudice respectively. Farmers-herders' conflicts exhibit 'wicked problem', lacking clear solution due to divergent values of stakeholders, and being embedded within wickedly complex environments within Benue state and similar to the Sudan-Sahel regions of Africa for centuries (Figure 3).



	S A	A	UD	D	S D	SUM	S A(X5)	A (X4)	UD (X3)	D (X2)	SD (1)	SUM	MEAN(Sum/744)
Stability of the system | Strongly Agreed	368	360	0	16	0	744	1840	1800	0	32	0	3672	4.90
IDPs | Strongly Agreed	415	329	0	0	0	744	2075	1645	0	0	0	3720	5.00
Free Movement | Strongly Agreed	398	346	0	0	0	744	1990	1384	0	0	0	3374	4.94
Innovation | Strongly Agreed	387	336	7	14	0	744	1935	1344	21	28	0	3328	5.00
Revenue Generation | Strongly Agreed	372	372	0	0	0	744	1860	1488	0	0	0	3348	4.54
Lives and Property | Agreed	392	352	0	0	0	744	1960	1408	0	0	0	3368	4.49
Confidence and Trust | Strongly Agreed	440	304	0	0	0	744	2200	1216	0	0	0	3416	4.50
Rapid Development | Strongly Agreed	376	368	0	0	0	744	1880	1472	0	0	0	3352	4.52
Peace and Security | Strongly Agreed	523	221	0	0	0	744	2615	884	0	0	0	3499	4.56
National Unity and Cohesion| Strongly Agreed	393	351	0	0	0	744	1965	1404	0	0	0	3369	4.51
Food Security | Strongly Agreed	413	291	37	3	0	744	2065	1164	111	6	0	3346	4.70

Source: Study field survey, 2021: Gwer-West and Guma, Benue state, Nigeria

Figure 9. Impacts of Farmers-herders' conflicts on sustainable livelihoods in Benue state, Nigeria.

The survey results from Figure 9 scores shows stability of the system: strongly agreed (368); internally displaced persons (IDPs): strongly agreed (415); food security: strongly agreed (413); lives and property: agreed (392); revenue generation: strongly agreed (372) and innovation: strongly agreed (387). Conflicts over natural resources and conservation are widespread globally (Redpath *et al*.,2015) and highly damaging to UN Sustainable Development Goals (SDG) such as biodiversity and food security (D'Harcourt *et al.,* 2017).

Scenario | Farmers and Herders Conflicts - Symbiotic Relationship

Farmers and pastoral people are increasingly trying to make use of the same land (ecology). The demand of cities for crops and meat induces many producers to maintain large herds and to expand farmland. The availability of road transportation enables delivery of even fragile resources to remote markets and locations that are difficult to reach (Blench, 1996). Livestock are increasingly owned by either farmers or urban-based investors, with both groups having little knowledge or cultural pride in livestock husbandry. Sahelian grasslands are very sensitive to persistently high grazing pressure (Figure 3). The reduced herd mobility associated with the reduction in the quantity and quality of the labour used for herding is likely to have environmental repercussions (Turner,1999) encapsulated as agriculture livelihoods value framework (Paper1, Figure 9) called farmers and herders conflicts scenario. The quest for greener pastures by herdsmen usually brings them in contact with the sedentary population who are involved in crop production. The consequence of this contact results in an invasion of the farmland worked by the sedentary group, and the ensuing conflicts are often violent and long lasting (Obioha, 2008). The Fulani-Hausa people farm pearl millet and cowpeas during the rainy season and raise cattle, horses, goats, sheep, and donkeys as supplementary subsistence activities (Figure 10). The bespoke solution illustrated in Appendix 3 below.

When they face food shortages, they sell their livestock at the market, which is 7 km from the village. Hausa villagers engage in various economic activities, serving as butchers, barbers, blacksmiths, shop owners etc.[17] During long dry seasons, most Hausa men emigrate to domestic urban areas or to cities in neighboring Nigeria, Benin, Cote d'Ivoire, Mali, and Gabon to work in small businesses or private mines for cash income (Figure 3). Fulani-Hausa farmers sow pearl millet and cowpea seeds in the middle of June, and they weed from July to the middle of September (Figure 10). Hausa people talk about their relationships symbolically and harvest millet between (mid-September and October). The survey report in Figure 9 based on the Likert 5 scale strongly agreed validate impacts on sustainable livelihoods and the scenario causing the conflicts in the study area. Fulbe are good friends (*abok*i) during the dry season, but become our enemies (*makiyi*) during the rainy season. Access to farmland is strictly restricted to land owners during the rainy season, it is open for public use during the dry season. Post-harvest by farmers finish, including cowpea leaves and millet stems for fodder, the herdsmen can use the farmland for grazing livestock during the dry season. The sedentary farmers (Figure 10) have established socioeconomic relationships with the nomads in the Africa Sahel region for purposes of subsistence (Adamu, 1978; Baier, 1980). There are two main ethnic groups of herders, the *Fulbe* and the *Tuareg*. The *Fulbe* usually graze cattle, goats, and sheep and live throughout the Sahel region, in Senegal, Mali, Niger, Chad, and Cameroon. (Figure 3).

The *Tuareg* are also herders, but they graze camels as well as goats and sheep. The farmers obtain milk and livestock products in exchange for crops, woven clothes, wooden and iron products, and weapons. Hausa farmers and *Fulbe* herders have established a contract governing livestock grazing. After *Fulbe* herders lost their livestock during the severe droughts of 1972-73 and 1984-85, they began to live in Hausa villages to maintain their livelihood. Fulbe living in Hausa villages are known as Fulani gari in the Hausa language and *Fulbe shile* in the *Fulbe* language. Both *gari* and *shile* mean 'village'.

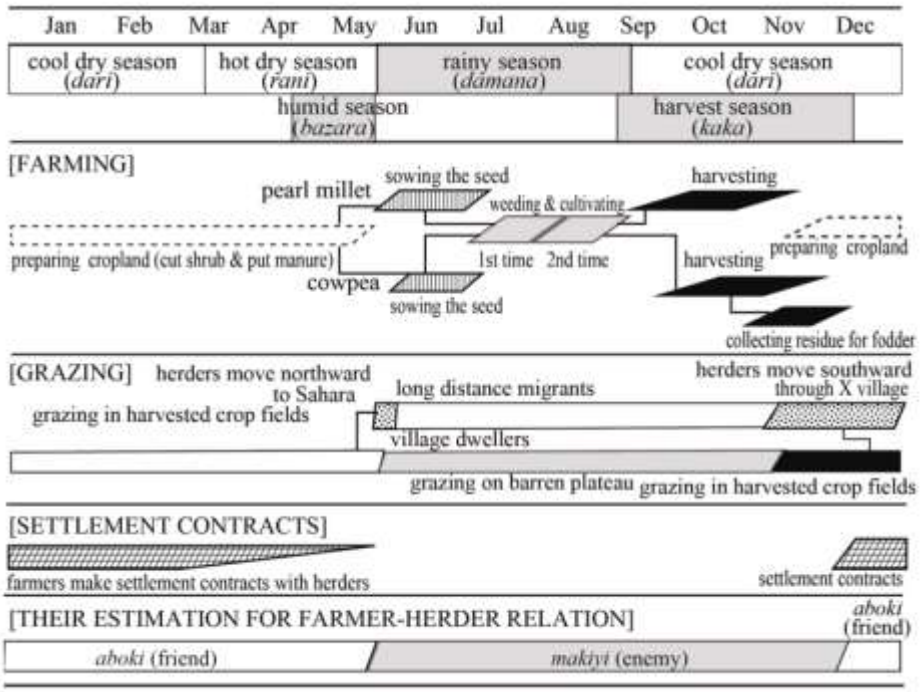
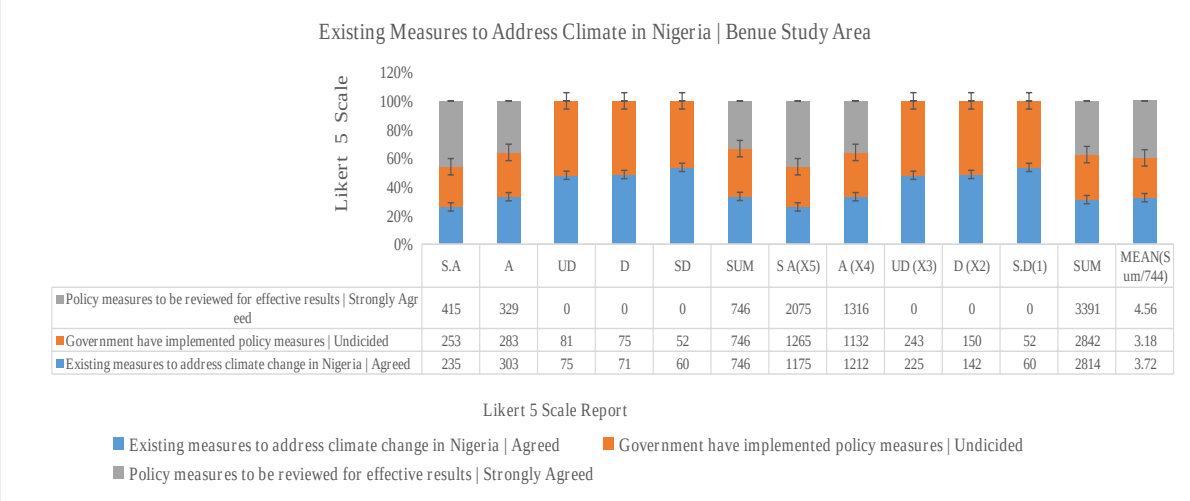


Figure 10. Farmers-herders conflicts scenario (crop and livestock calendar).[17]

The Hausa have entrusted their livestock to some pastoral Fulbe, who graze the farmers' livestock on a daily basis (Figure 10). When rainy season end, the pastoralists move southward from the Sahara Desert, passing through X village from November to January. Pastoralists are nomads who move their settlements throughout the year. These individuals are known as Fulani *daji* in the Hausa language and *Fulbe ra'de* in the *Fulbe* language. Both *daji* and ra'de mean 'bush' and remaining pastoralists live in and graze livestock near the village (Figure 10). The village fertile for crop farmland is very difficult for herders to find suitable grassland. Hausa farmers postharvest crops, both types of herders, i.e., village *Fulbe* and bush *Fulbe*, seek to establish contracts with farmers to camp on their farmland for a few weeks to several months. Ayantunde (2000) reported, herders camps during the night and graze their livestock around the camp during the day. The farmers provide substantial meals and pay bonuses after the contracts end.

17.Shuichi Oyama African study *monographs, suppl*. 50: 103–122, October 2014, 103 farmers-herders' conflicts, land rehabilitation, and conflict prevention in the Sahel region of West Africa, page 106.

Consequently, domestic animals provide *excreta*, which improve the fertility of the soil. Hence, the popular custom followed by the farmers and herders in Africa Sahel region (Figure 3), herders receive millet and money from the farmers according to the number of livestock and the duration of the settlement (domestic animals provide *excreta).*The survey report, Figure 8 based validate that: government policy reviewed is effective to fix climate change challenges (415) score: strongly agreed; and existing measures will address climate change problems (235) score: agreed (Figure 11).



	S.A	A	UD	D	SD	SUM	S A(X5)	A (X4)	UD (X3)	D (X2)	S.D(1)	SUM	MEAN(Sum/744)
Policy measures to be reviewed for effective results | Strongly Agreed	415	329	0	0	0	746	2075	1316	0	0	0	3391	4.56
Government have implemented policy measures | Undicided	253	283	81	75	52	746	1265	1132	243	150	52	2842	3.18
Existing measures to address climate change in Nigeria | Agreed	235	303	75	71	60	746	1175	1212	225	142	60	2814	3.72

Source: Study field survey, 2021: Gwer-West and Guma, Benue state, Nigeria

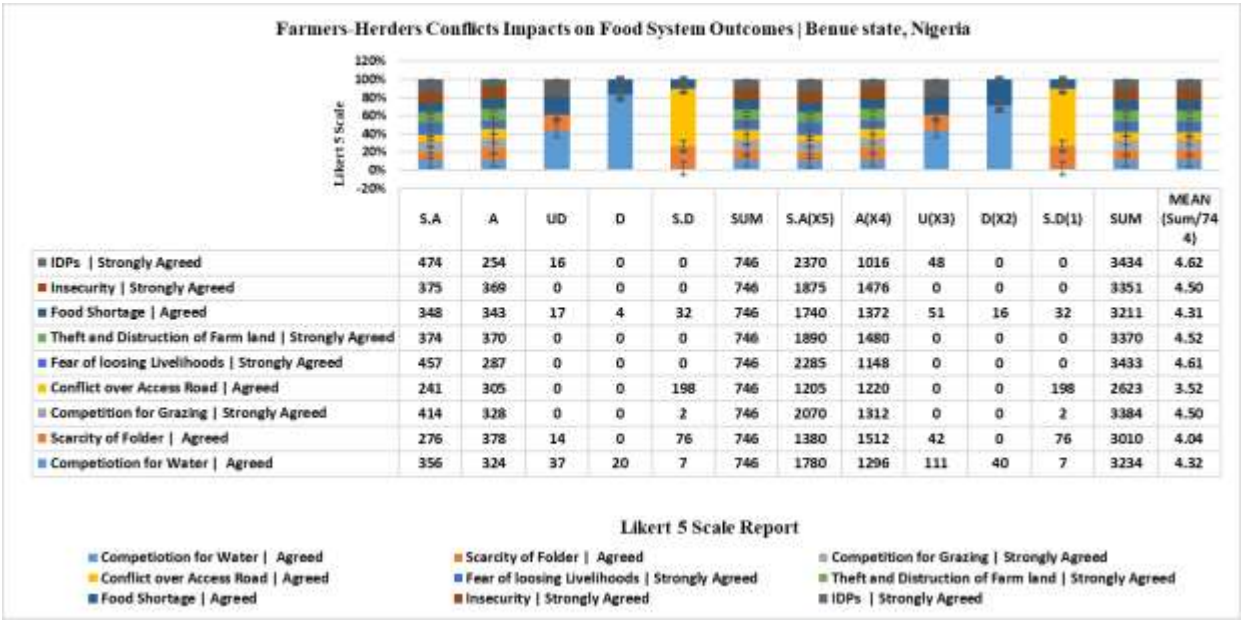
Figure 11. Existing measures to address climate change in Nigeria.

Farmers-Herders Conflict Impacts on Sustainable Livelihoods

The study area (Benue state, North-central region, Nigeria) agropastoral systems value chain development provides the supply of high protein foods (milk, meat), manure for soil fertilization, and energy (transport, water extraction, animal traction), skin, wool and leather that resulted to agriculture job and wealth creation, Figure 13. Farmers-herders conflicts destroys livelihoods and leads to displacement; conversely, livelihood insecurity induces migration, which in some cases create disputes over land and leads to violent conflicts.
The Figure 12 study area Likert 5 scale consensus report scores: competition for water: agreed (356); scarcity of folder: agreed (276); competition for grazing: strongly agreed (414); conflict over access road: agreed (241); fear of losing livelihoods: strongly agreed (457); theft and destruction of farm land: strongly agreed (374); food shortage: agreed (348); insecurity strongly: agreed (375) and IDPs: strongly agreed (474).

The inference : livestock breeding probably represents the most regionally integrated activity in West Africa and Sahel food industry trade and commerce (Figure 13).Herders' livelihood strategies change in response to shifts in a household's access to assets, their effectiveness depends on many external factors-transhumance within the Sahel region of Africa (Figure 3), policies, institutions, systems of governance, gender roles, ownership systems, religious doctrine, and culture[17] (Figure 10). Farmers-Herders conflicts framework developed (Paper 1, Figure 9) is for execution of 'practical application' of adaptive capacity and adaptive needs in Sahel-Africa region or community (Gwer-West and Guma, Benue state, Nigeria) in order to identify means of identification (Table 1).

The development and implementing adaptation initiatives or enhancing adaptive capacity within Sahel-Africa that may accommodate adaptations or provide means of improving adaptive capacity (Sutherland *et al.*, 2005). Mohamed Habibou Assouma (2016) reported 24 kg of methane emission for year in Senegal (Figure 13) which contribute the climate change in the Sahel of Africa (climate mitigation now necessary).



	S.A	A	UD	D	S.D	SUM	S.A(X5)	A(X4)	U(X3)	D(X2)	S.D(1)	SUM	MEAN (Sum/744)
IDPs | Strongly Agreed	474	254	16	0	0	746	2370	1016	48	0	0	3434	4.62
Insecurity | Strongly Agreed	375	369	0	0	0	746	1875	1476	0	0	0	3351	4.50
Food Shortage | Agreed	348	343	17	4	32	746	1740	1372	51	16	32	3211	4.31
Theft and Distruction of Farm land | Strongly Agreed	374	370	0	0	0	746	1890	1480	0	0	0	3370	4.52
Fear of loosing Livelihoods | Strongly Agreed	457	287	0	0	0	746	2285	1148	0	0	0	3433	4.61
Conflict over Access Road | Agreed	241	305	0	0	198	746	1205	1220	0	0	198	2623	3.52
Competition for Grazing | Strongly Agreed	414	328	0	0	2	746	2070	1312	0	0	2	3384	4.50
Scarcity of Folder | Agreed	276	378	14	0	76	746	1380	1512	42	0	76	3010	4.04
Competiotion for Water | Agreed	356	324	37	20	7	746	1780	1296	111	40	7	3234	4.32

Source: Study field survey, 2021: Gwer-West and Guma, Benue state, Nigeria

Figure 12. Impacts of farmers-herders' conflicts on food system outcomes, Benue state, Nigeria.

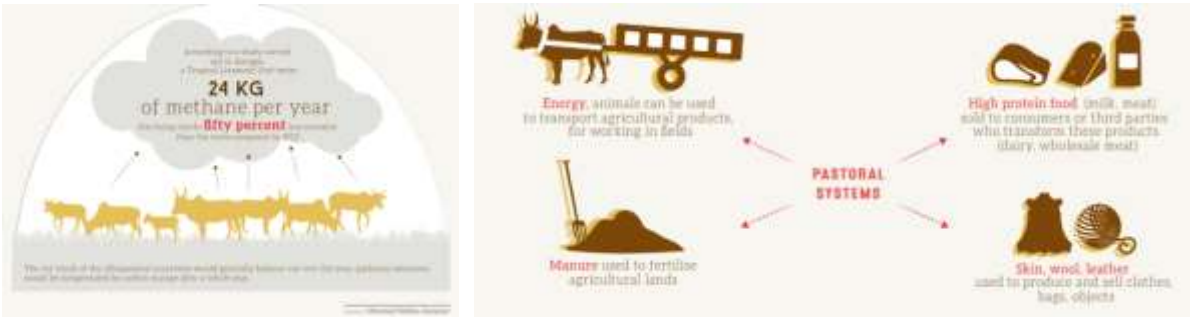


Figure 13. Mohamed Habibou Assouma (2016) adapted pastoralism creates value chain and economy. Visit weblink: https://www.youtube.com/watch?v=dA2Is6qmeks.

Land Use Planning

Given the ongoing encroachment of farming, settlement, urban expansion, and other large scale development activity on both pastoralist rangelands and migration routes, states should implement prior recommendations around land use planning (Figure 10).The conflicts resolution of the Farmers-herders conflicts should include revisiting land tenure and land use

policy nationally (and addressing disparities between groups considered 'indigenes' and 'settlers' in their ability to access to political office and land ownership); ensuring availability of pasture and water through expanding grazing routes and reserves; and compensating current landowners of reserves. These policy changes will be critical to reducing farmer-pastoralist conflict in the long-term (Plate 1) with Nigeria Agriculture Water Resources (Table 3).

Cause-Effects of Conflicts and Mitigating Measures

Factor Responsible | Other factors that have been identified for persistence of farmer-herder conflicts (Figure 12) includes: pollution of water sources, destruction of crops/farmlands by stray cattle, land tenure system, cattle rustling, killing of stray cattle by crop farmers, encroachment of cattle routes by crop farmers and indiscriminate bush burning and affirmed by scholars (Aliyu, 2015; Musa *et al*., 2014; Shimawua, 2018; Akuva and Yusufu, 2018). In Guma, poor security in communities has been singled out as one of the causes of clashes between the two groups under study. Alubo (2006) submitted that a community that can no longer produce for itself will starve. Best (2006), conflict especially during planting season has serious economic implication for the food security of Benue state and indeed the entire nation.

Plate 1. The scenario that triggers farmers-herders conflicts the Benue state, Nigeria.

Impacts of Conflicts on Economy

The results of the study area survey Figure 14A 79.5% conflicts frequency and Figure 14B farming occupation 53.4%.The farmers-herders conflicts frequency 79.5% intensity of the farming occupation 53.4% results of the study area survey (Paper 1, Figures 14A and 14B) heightened the fragile relations in Benue state, North-central, Nigeria with unleashed devastating humanitarian challenges.[3,4] Socio-economic development crisis with estimated death toll of approximately 2,500 people in 2016 (International Crisis Group, 2017). May 13, 2017: 20 people were killed in a conflict between Tiv farmers and herdsmen at Nzorov in Guma local government area. The incessant and intensification of the farmers-herders' conflict has become one the Nigeria's greatest security threat, particularly when juxtaposing with the Boko-Haram insurgency (Bada, 2018). Benue state emergency management agency (SEMA) statistics show series of attacks registering over 80,000 Internally Displaced Persons (IDP) across four camps located in Guma and Logo local government areas of the Benue state (Ugbudu, 2020) and confirmed the survey report and the lost assets and property worth over N95 billion and over 2000 lives to herdsmen crisis with particular references to Guma, Gwer-West, Gwer-East reported by Daga (2018). Over 390 persons have been attacked and killed in a repeated armed Fulani herdsmen attacks on communities in Gwer-West local government area (LGA) of Benue state reported by Duru (2022). Guma local government has a network of roads and water routs through River Benue and River Katsina-Ala (Figure 7).

The Government's Strategic Response to the Herdsmen-Farmer Conflicts

1.Creation of Grazing Reserves in 1965.

In 1965 the northern regional government initiated one of the first attempts to respond to the herdsmen-farmer conflict in the country. The grazing reserves allocated large portions of land to be exclusively used by herders to rear their livestock.[18] However, the grazing reserve system was not supported adequately. The government was still in the process of initiating legislations to legitimize the grazing reserves before natural factors such as population growth, urbanization, and migration encroached on these designated areas reducing the herders' chances of accessing the reserves and the solution is livestock agro-corridor (Appendix 3).

Establishment of the National Commission for Nomadic Education (NCNE),1989

The federal government in 1989 established the NCNE and it is supported by the Nigerian legal system. The main goal of the programme was to integrate nomadic pastoralists into national life through mobile basic education and skill acquisition. The programme intended to integrate them into society through education goal of the programme was to integrate nomadic pastoralists into national life through mobile basic education and skill acquisition (like Tree Planting in Nigeria, Plate 2).

Source: Federal government established the Great Green Wall Agency to tackle desertification. (UN Photo/Nektarios Markogiannis). Details in Appendix 1 below.

Plate 2. Tree Planting in Nigeria for climate mitigation within the Africa Sahel and Benue state, Nigeria.

The Use of the Armed Forces to Curb Internal Security

One of the Federal government's immediate measures to address the herdsmen-farmer conflicts is the engagement of the Armed Forces of Nigeria as enshrined in the Constitution.[19] Presently, many are calling for a total declaration of a state of emergency in Benue and Plateau states as a result of the gruesome killing and displacement of thousands of people in those states. Nigerians also expect the government to activate all the necessary sections of the constitution regarding the use of the military in internal security.

Establishment of the National Grazing Reserve Bill 2016

A National Grazing Reserve bill was sponsored in 2016 at the parliament to address the herdsmen-farmer conflicts. The Bill did not survive due to opposition from different stakeholders. Those that opposed the Bill hinged their rejection on the provisions of the Land Use Act of 1978 which vests all powers related to the regulation of ownership, acquisition, administration, and management of Nigerian land with the state governors.

18. Peace and Security Forum (2017). Resolving the Farmers-herders Conflicts in Nigeria, Policy Brief.
19. Federal Government of Nigeria (1999) Constitution of the Federal Republic of Nigeria.

The Land Use Act

The Act of the National Assembly, and by implication, a binding legislation, unless it is amended. State governments in Nigeria and their representatives at the parliament have always opposed any attempt to establish grazing reserves in their domain. They consider it to be usurping the constitutional powers vested in them (Kwaja *et al*., 2018).

Proposed Cattle Ranching System, 2018

Figure 12 study area Likert 5 scale consensus report scarcity of folder score (378, Agreed). Farmers-herders conflicts consequence nationwide resulted to the government in 2018, approval of 10-year National Livestock Plan at a cost of about N179 billion naira for the establishment of 94 ranches in 10 pilot states of the federation (Alli,2018). Again, state governments, especially in the South and North-Central States rejected the proposal on the grounds of not having enough space for such projects.

Legislation Prohibiting Open Grazing

The states governments in Nigeria began enacting legislations prohibiting open grazing in their states as mitigation measures for the farmers-herders' conflicts (Benue, Ekiti and Taraba states) outlaws open grazing. On 22nd May 2017 Benue state enacted the Open Grazing Prohibition and Ranches Establishment Law (2017) and its implementation began on 1 November 2017 (Kwaja *et al.*, 2017). Ekiti and Taraba states have also signed Bills prohibiting open grazing in their states. This makes open grazing under any guise, an illegal activity punishable by law.[20]

Plate 3 | Africa Great Green Wall

The "Great Green Wall" is an initiative to increase the amount of arable land in the Sahel, the region bordering Africa's Sahara Desert. Eleven nations are investing in projects as varied as agroforestry to sustainable development. Execution model illustrated in Appendix 3.

Source | https://education.nationalgeographic.org/resource/great-green-wall/

In 2013, the Nigeria Federal government established the Great Green Wall Agency to tackle desertification (Plate 3). This was in response to the 2007 African Union Great Green Wall Initiative that aimed at encouraging member states to plant 8000km of trees along the Southern Sahel to counter the effects of desertification along that area (source of the herder's migration). Continued desert encroachment along the Sahel region of Africa as a result of climate change is a major factor responsible for seasonal migration of herdsmen from one region to the other in search of water and vegetation for cattle grazing (Figure 3) and see Appendix 1 below.

20. Land Use Decree (1978) No.6, Cap,202. Laws of the Federation of Nigeria.

6 | FINDINGS

6.1Transformability and Resilience

Farmers-Herders Conflicts Impacts

Pastoralism in the Sahel of Africa plays a crucial role in the exploitation contribution to the carbon balance of the landscapes? Estimating this balance is complex: it requires attention to all the elements of the ecosystem and their interactions, including animals, their movements and their access to water, plants and soils in ecosystems in Benue state, north-central, Nigeria (see Future work of the study area). The three techniques are suited to pastoralism: developing watering points, making use of animal waste through anaerobic digestion [16] and storing fodder when it is abundant and high quality (Figure15). Major trends that can impact the livestock food supply chain are increases in atmospheric carbon dioxide (eCO_2) and tropospheric ozone (O_3) concentrations; changes in both mean and variability of temperature and precipitation; sea level rise and storm surges; and increased risk and frequency of extreme weather events (Myers *et al*., 2017). Hence, livestock provides a range of other services, including as a source of draught power, a means of transportation (Figure13), a source of nutrients for poor soils, a source of income generation and diversification, and a form of financial capital, all of which contribute to the overall well-being and resilience of many communities (CIRAD, 2016).

Intergovernmental Panel on Climate Change Working Group II (IPCC, 2014a). Risk of climate-related impacts results from the interaction of climate-related hazards with the exposure and vulnerability of human and natural systems from the activities of Pastoralism in the study area (Benue state) north-central, Nigeria (Figure 7). We use the term hazard to refer to climate-related physical events or trends that impact livestock systems (IPCC, 2014). Exposure refers to the parts of the livestock supply chain that could be adversely affected, while vulnerability encompasses humans' capacity to cope and adapt to changes that impacts on food system outcomes (Figure 14). The ecosystems solution, livestock agriculture corridor development (Appendix 3), biofertilizer production[16] biotechnologies and practices that enhance adaptation, reduce greenhouse gas emissions, and contribute to food security; the so-called triple win and also affirmed by (Lipper *et al.*, 2014).

The consequence is that agriculture (shocks by farmers-herders' conflicts) will be transformative and contribute to sustainable development goals (SGDs) of sustainable production, improve poverty, a greater emphasis is needed on issues of farmer heterogeneity (Table 1). Resilience encompasses both agriculture and socio-ecological dimensions. Practitioners (Farmers-herder's conflict) need to be more cognizant of the dangers of (i) benefiting groups of already better off farmers at the expense of the most vulnerable and/or (ii) focusing on farmers for whom agriculture is not a pathway out of poverty. Climate adaptation projects can reinforce existing vulnerabilities either by promoting adaptation interventions that benefit powerful elites or by transferring risks and exposures between groups rather than alleviating them (Blythe *et al*., 2018; Schipper, 2020). It will be impossible to create transformative change without bringing social equity issues (Plates 4 and 5) to the fore and tackling the issues of power relationships and decision-making within agriculture resources between the farmers-herders within the ecosystem-the needs for resilience can be transformative ('transformability'). This paradigm shift means that socio-ecological resilience not only requires the ecological characteristics of persistence and recovery but also the conditions for households to move from one asset threshold and livelihood pathway to another (Figure 14) and human capital development (Table 4 and Figure 21).

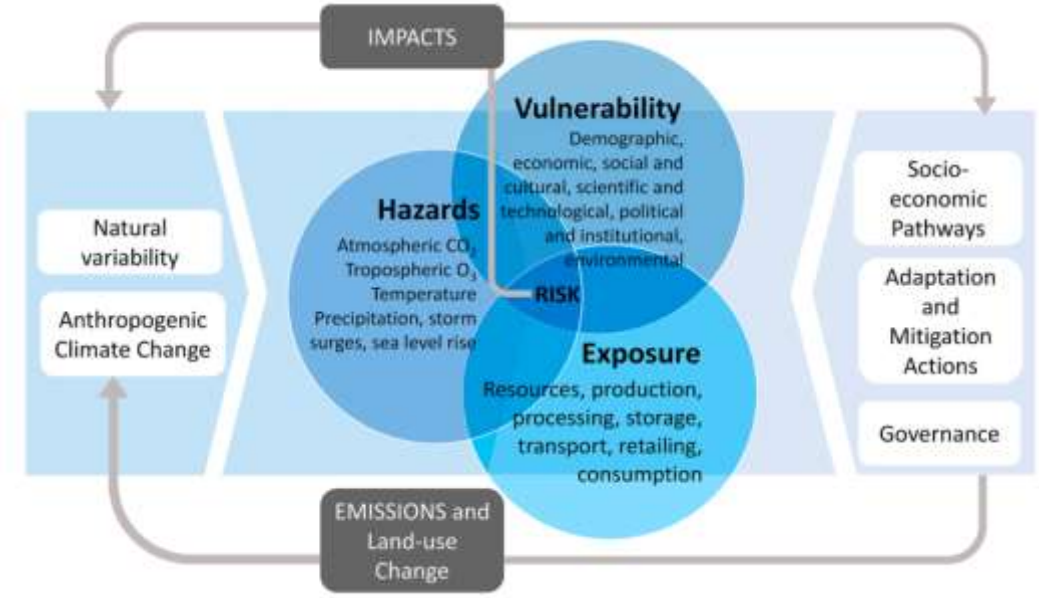
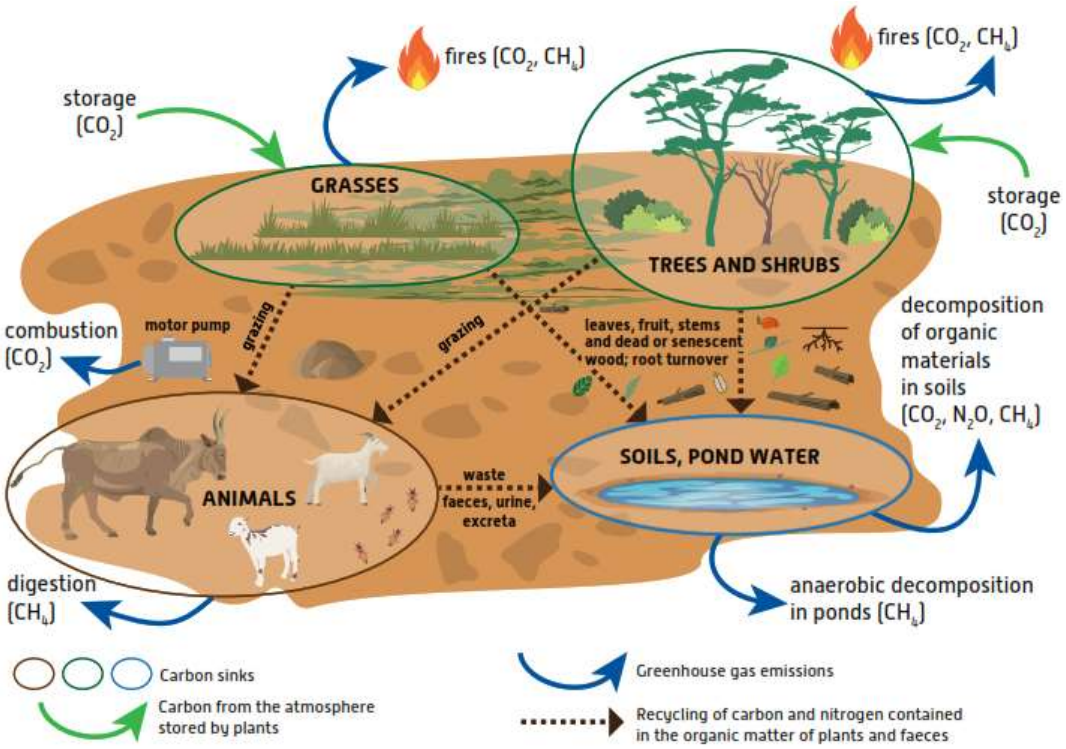


Figure 14. Schematic of the interaction among the physical climate system, exposure, and vulnerability producing risk in the livestock supply chain. Risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (adapted from IPCC,2014).

Resilience can be seen variously, in terms of persistence, adaptability and transformability (Folke *et al.*,2010). Persistence is the capacity of a socio-ecological system to change and adapt while remaining within critical thresholds. Adaptability, the system adjusts responses to changing internal processes and external drivers in ways that allow for development along the current trajectory (Agriculture livelihood framework, Figure 9, Paper 1). Transformability is the capacity to transcend thresholds and move into novel development trajectories (Figure 14). In the context of climate change, a resilience approach is one that transforms undesirable socioeconomic states, such as inequalities in power and income, into more desirable ones without undermining the integrity of ecological systems (agriculture resources) that humans depend on (Fisher *et al*., 2022).Fostering climate-resilient agriculture, hence, requires inter-and trans-disciplinary responses that bring together networks of researchers, practitioners, and policy-makers (Cundill *et al*., 2019). This is accompanied by shift from output-directed to process-oriented research during which these diverse actors co-produce knowledge (Miller *et al.*, 2010). Inter-and transdisciplinary approaches allow for a greater understanding of farmers-herders diverse needs and aspirations by encouraging practitioner's stakeholder engagement, and social learning (Table 1). The success of these approaches rests on genuine transdisciplinary partnerships and systems approaches that ensure adaptation and mitigation goals along with more equitable incomes, food security and pasture development (Appendix 3, Tables 5 and 6).

6.2 Ecosystem Solution - Climate Change Mitigation

Modern agriculture and climate points the finger at pastoralism in the Sahel: the low productivity of herds and the ingestion of roughage, which makes up most of their diet, produce high levels of methane emissions per unit of animal product (milk or meat).



Source: Assouma *et al.*, (2019) CIRAD (dP PPZS, https://www.ppzs.org/en).

Figure 15. Herbaceous plants, as annual plants, are not considered as a carbon sink. Wildfires, characteristic of grazed ecosystems in the Africa Sahel region, are a source of greenhouse gases.[16] Termites, like ruminants, emit methane through their digestion ('enteric methane'), the landscapes?

Estimating this balance is complex: it requires attention to all the elements of the ecosystem and their interactions, including animals, their movements and their access to water, plants and soils are complex and uncertainty (wicked problem). Livestock impact on the estimation of enteric methane emissions (Sahelian cattle methane emissions from their digestion, known as 'enteric methane') affirmed by (Assouma,2016). In the Sahel of Africa, storage in trees, shrubs and soils offsets the greenhouse gas emissions herds produce through their feeding and their cow dung (Plates 4 and 5 respectively). The annual carbon balance varies from the study area and Sahel of Africa and this variation is linked to livestock practices (Figure 3).

The grasslands, shrublands and wooded areas in which herds graze are places where sequestration is predominant (Figure 15). Whereas, the resting spots close to camps and watering points, which receive large amounts of cow dung, are high-emitting places-whole pastoral ecosystem requires adaptation measures because in rainy season, the ecosystem emits far more greenhouse gases than the carbon it stores-animals and watering points are the main sources of emissions (Plate 4). Conversely, in the dry season, the ecosystem stores carbon – cow dung and grasses are worked into the soil through trampling by herds. The equilibrium of the carbon balance in Sahelian pastoral landscapes is not called into question (Figure 3), since herd mobility enables pastoralists to adapt to grass production (Appendix 3, Tables 5 to reduce pressure on grazing areas (Assouma *et al.*,2019).

In addition to the recognized option of tree planting, such as the Great Green Wall in Africa (Plate 3), three techniques are suited to pastoralism: developing watering points, making use of animal waste through anaerobic digestion[16] and storing fodder when it is abundant and high quality. Areas around watering points emit one fifth of greenhouse gases. Harvesting a proportion of the ungrazed grass and storing it as hay would meet the requirements of herds and enable transhumance to begin later (Figure 14 and Plate 5). The grass could be harvested before the end of the rainy season to guarantee optimal quality and to ensure regrowth. Fodder banks could be created by stakeholders, with a whole sector to be organized - the management of harvesting, storage sites and structures, the redistribution of stock and its remuneration for impactful food system outcomes. This would imply a change for pastoralists, who are not accustomed to collecting fodder, although the recent recurrent droughts have led some of them to begin doing so (resilience). This innovation has a threefold positive mitigation effect: lower risk of fire, less enteric methane due to better fodder, and higher animal performances (meat and milk) – transformative (Figure 15). These practices also foster adaptation to climate change by partially offsetting the variability in plant production linked to the climate, reducing the vulnerability of pastoral systems and improving pastoralists' income (Assouma *et al*., 2017).

Plate 4. Livestock: Mitigation co-benefits of adaptation. Depicting ecosystem solution from the challenge of pastoralism in the Sahel of Africa.

Plate 5. The field work survey (2021) with Fulani herders were not allowed for 'open grazing' in Guma and Gwer-West local government area of Benue state due to the strict enforcement of the anti-open grazing policy by the government in Benue state, Nigeria.

Outlook:
In Africa, 1.3 million hectares for agriculture, representing significant potential for sequestration. Green funds and carbon credits could also be mobilized in support of pastoralism in sub-Saharan countries are (Figure 3). The carbon balance per hectare (Figure 14) could become an additional indicator to assess the performance of an extensive grassland pastoral system in tropical regions Simplified model of greenhouse gas emissions and carbon storage in a Sahelian pastoral landscape: the carbon balance ecosystem approach is based on this model (IPCC,2014). Boko-Haram insurgency. Visit weblink : https://www.youtube.com/watch?v=WL7GJu6pEGM.

6.3 Sustainable Livelihoods Solution for Farmers-Herders Conflicts

Food System Approaches

The design and implementation of effective policy and management interventions for farmers-herders conflicts require an understanding of these complex interactions and their implications for sustainable livelihood (Figure 16) impacts of global interventions (by UNDP, DFID etc.,) for sufficient food system outcomes (Pinstrup-Andersen and Watson, 2011). By sufficient, we understand sufficient quantity and nutritional quality of food; by appropriate, we include the notions of culturally, technically and nutritionally appropriate food; by accessible, we mean physically and economically accessible. These components represent the four dimensions of food security: availability, access and utilization (FAO, 2008b) functional goal during times of disturbance (shock) from farmers-herders' conflicts within the study area and Sahel of Africa. We introduce food stability with the Sustainable livelihoods framework (stakeholders, diplomacy and development) for study area and Sahel region of Africa (Figure 19).

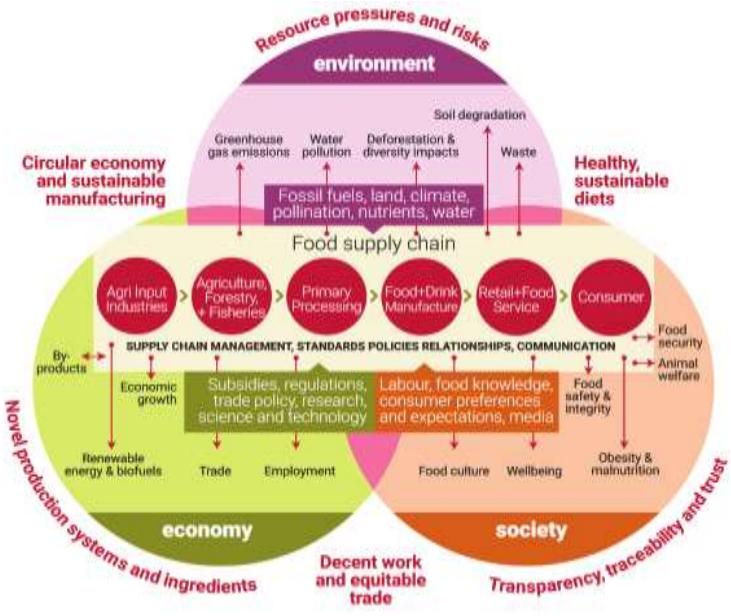


Figure 16. The key components of the global food systems.[21]

21. Food System Framework | a focus on food sustainability. Institute of Food science and Technology (www.ifst.org) 5 Cambridge Court 210 Shepherds Bush Road, London W6 7NJ.

Food system activities and outcomes eventually result in processes that feed back to environmental and socioeconomic drivers (Ericksen, 2008; FAO, 2008a): this may lead to unintended consequences (Ingram *et al.,* 2010) as capture in Table 1. These complex interactions and their implications need to be accounted for in the design and implementation of effective policy and management interventions for the impacts of the farmers-herders' conflicts in Benue State, Nigeria for food system and its internal interactions between components affirmed by (Pinstrup-Andersen and Watson, 2011) and see Figure 15.

Building Food System Resilience

National or regional food systems development (Figure 14), which comprise multiple value chains contributing to food security and other outcomes from local to global levels that lead to the diverse outcomes of food systems (Figure 16). Individual's perspective in the value chain, and the specific outcomes that concern them: this includes smallholder livelihoods, household food security, consumers' health etc. Any approach seeking to assess and build resilience in food systems needs to include a wide range of stakeholders and interest groups in some form of participatory and collaborative process (Table 1): who is initiating, leading and supporting the process; who is involved; what are the goals of the process; what are the major issues in the food system of interest. by using the concepts of continuous learning, flexibility and "back-up" capacity. Resilience stands for 'the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner by ensuring the preservation, restoration, or improvement of its essential basic structures and functions' (Allen and Prosperi, 2016). These properties are vital for ensuring the sustainability of food system outcomes linked to agroecology with a distinct community-based approach (King, 2008).

Sustainability is the measure of system performance, whereas resilience can be seen as a means to achieve it (Brand and Jax, 2007) during times of disturbance (farmers-herders' conflicts). The sustainable livelihoods framework (Figure 19) offers the prospects of a more coherent and integrated approach to poverty [22] (impacts of the farmers-herders conflicts outcomes) with a broad and open-ended analysis (Paper 1, Figure 9), but this requires a highly flexible planning situation which rarely exists.[23] A food system's resilience can be broken down into various components affecting the behavior of the food system over time (Simonovic and Peck, 2013) and transdisciplinary research[22] :

i. Robustness, or the capacity to withstand the disturbance in the first place before any food security is lost (Anderies *et al*., 2013);
ii. Redundancy, or the extent to which elements of the system are replaceable, affecting the capacity to absorb the perturbing effect of the disturbance and avoid as much food insecurity as possible;

22. Transdisciplinary research Ecological Grazing Management, Food Security and Surveillance in Nigeria: Innovation Ecosystem Approach.
https://www.academia.edu/42701518/Transdisciplinary_research_Ecological_Grazing_Management_Food_Security_and_Surveillance_in_Nigeria_Innovation_Ecosystem_Approach
23. Agriculture growth corridor development | Nigeria regenerative agriculture.
https://www.academia.edu/94332246/Agriculture_Growth_Corridor_Development_Nigeria_Regenerative_Agriculture.

iii. The development of agriculture corridor in Nigeria [23] with flexibility and thus rapidity (food system reactivity); and
iv. Resourcefulness and adaptability, which determines just how much of the lost food security is recovered. Together, these capacities form the basis of the food system resilience action cycle.

Future Outlooks | Benue state, Nigeria and Sahel Africa region

The sustainable livelihoods in Benue state farmers-herders conflicts requires the development of measures of food system resilience (FSIN, 2014) in the form of indicators, Table 1 (Hoddinott, 2014). Systems resilience (Figure 14) is assumed to be enhanced by system attributes such as diversity, redundancy, buffering capacity, modularity, capital (economic, financial, environmental, social, physical), exposure to disturbances, profitability, self-organization capacity, governance capacity, transformability, transparency, learning capacity (Engle *et al.,* 2013) appropriate institutional framework (Figure 9, Paper 1) for decision-making processes (Tyler and Moench, 2012) security and climate change (IISD, 2013); freshwater distribution systems (Milman and Short, 2008); smallholder farmers (Choptiany *et al*., 2014); community and natural disasters (Cutter *et al.,* 2010); landscapes (Oudenhoven *et al*., 2010); urban communities and climate disasters (Joerin *et al*., 2014); adaptive capacity of institutions (Gupta *et al.,* 2010); agroecosystems (Cabell and Oelofse, 2012) and regenerative agriculture crop production. Nigeria will be 5th large population by 2050 (Table 2 below).

6.4 Regenerative Agriculture and Farm Security

Regenerative agriculture is a holistic approach to farming that focuses on creating a healthy and resilient ecosystem that produces food and fiber while also benefiting the planet: soil health,[25] biodiversity and carbon sequestration.[26] Regenerative agriculture holistic farming approach that focuses on improving soil health and the overall ecosystem while producing food and fiber.[27] Agroecology is instrumental for realizing 12 of the 17 Sustainable development goals, including the reduction of poverty and hunger; agroecology empowers farmers and local communities. Anaerobic digester for holistic response to some of the greatest challenges to planetary health-helping to cut waste, reduce emissions and stop the pollution of natural environments.[26] It enhances soil health, improves water cycles, and increases carbon sequestration by promoting diverse and resilient grazing systems.[16] Nigeria agriculture farm security (Figure18) infrastructure framework requires information communication and technology for the management of the farmers-herders' conflicts within the north-central Nigeria (Benue state) using adaptive security infrastructure framework by Yazdinejad *et al.,* 2021. Sustainable livelihoods framework (Figure 19) is driven by spatial polysingularity construct (Otaiku,2022) where, 'everything matters, connected and related within the biosphere' for value co-creation (Paper 1, Figure 9) and competitiveness (Table 1).

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24. Maize and Vegetable cultivation | Regenerative Agriculture. Field Application and Evaluation of Biofertilizer and Organo-Mineral Fertilizer (OMF), Niger State, Nigeria. https://www.academia.edu/video/kALBdl.
25. Ayodele Otaiku Biofertilizer Production and Bioeconomy. https://www.youtube.com/watch?v=58sK1q0prwc&t=26s.
26. Ayodele Otaiku Climate-smart fertilizer. https://www.youtube.com/watch?v=zIIuiMT2u20&t=99s.

Regenerative agriculture builds soil organic matter, which contains roughly 58% soil organic carbon (SOC), serves as the primary engine for biological, chemical, and physical processes in agricultural soils. Regenerative practices like cover cropping, crop diversification, biodigester biofertilizer [25] and rotational livestock grazing increase SOM through specific mechanisms (Patil *et al.*, 2025). Aggregational protection occurs when intact root systems and fungal networks, particularly *arbuscular mycorrhizal* fungi (AMF) bind microaggregates and organic residues into stable macroaggregates while fungal-derived compounds like glomalin act as biological glue. This physical occlusion encapsulates soil organic carbon within pore spaces, shielding it from microbial decomposers and limiting atmospheric oxygen exposure, which slows microbial respiration and stabilizes stored carbon over long timescales (Barbosa *et al*., 2019).

In regenerative agriculture practice, plant growth-promoting bacteria (PGPB) or root-colonizing rhizobacteria (PGPR) and their fungal equivalents promote plant growth providing plants with specific compounds, water or nutrients (biofertilizers)[25] or by providing protection against pests and diseases (biopesticides)and bioherbicide (biological weed killer). Also, improved abiotic stress tolerance of crops, stresses include drought, salinity, heavy metal toxicity and temperature extremes using microbial inoculation (Goswami and Deka, 2020; Grover *et al.*, 2011; Rubin *et al.*, 2017).The ongoing goal of the project is to restore 100 million hectares (250 million acres) of degraded land, capture 250 million tons of carbon dioxide, and create 10 million jobs in the process, all by 2030 (Appendix 1). Great Green Wall (Africa) https://en.wikipedia.org/wiki/Great_Green_Wall_(Africa). The ongoing goal of the project is to restore 100 million hectares (250 million acres) of degraded land, capture 250 million tons of carbon dioxide, and create 10 million jobs in the process, all by 2030 (see Appendix 1).

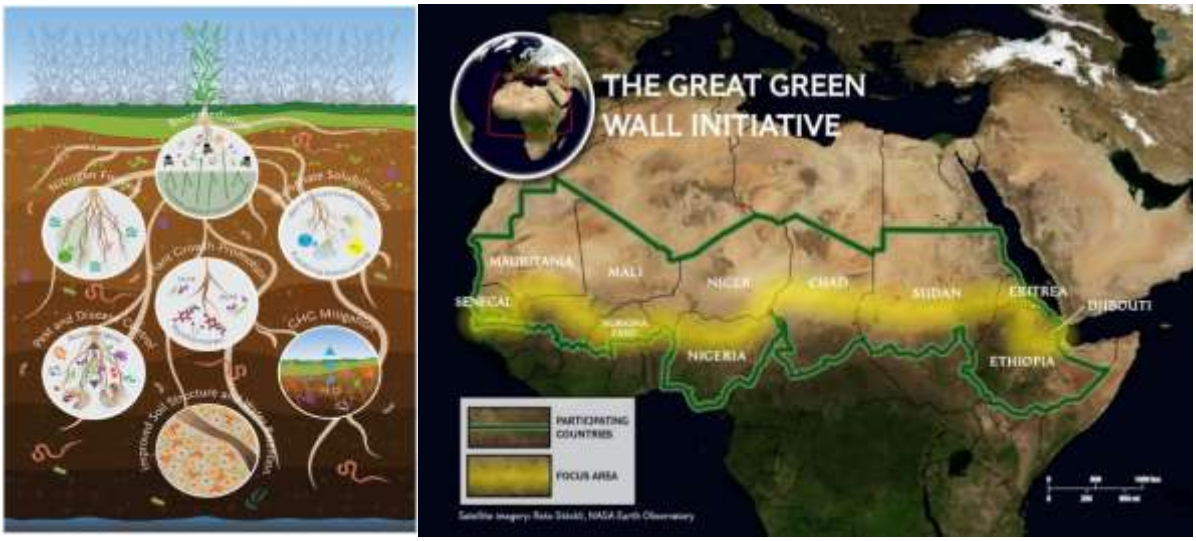

Figure 17. Great Green Wall (Africa) bespoke solution for farmers-herder' conflicts. https://en.wikipedia.org/wiki/Great_Green_Wall_(Africa).

27. Regenerative Agriculture - Integrating Livestock. https://www.youtube.com/watch?v=1uu7kGFfkTY .

6.5 UNDP and DFID Sustainable Livelihoods Impacts

Challenge | Benue state, Nigeria

1.The idea of sustainable livelihoods (SL) approach is broad and open-ended analysis, but this requires a highly flexible planning situation which rarely exists (Paper 1, Figure 7).

2. The planning of development co-operation projects or programmes seldom start from a 'blank sheet', more often building upon earlier support to a sector (Figure 19). Alternatively, it is shaped by strategic priorities and detailed sector plans developed by the counterpart ministry of the recipient country, which might set narrow limits to the kind of issues or areas of activity that the donor might support (Paper 1, Figure 12). Besides, donor agencies as well as government ministries are usually organized by sector, and the planning process is biased by whichever donor or ministry is responsible for administering the project (Paper 1, Figure 6). Generally speaking, the idea is that if people have better access to assets (Benue state), they will have more ability to influence structures and processes so that these become more responsive to their needs (Carney *et al.*, 1999). DFID's SL approach puts great emphasis on transforming the structures and processes that have the capacity to 'transform' livelihoods, in ways which provide better opportunities for the poor (DFID, 1999). The focus of DFID tends to be on the more easily detectable and formal aspects of such transforming processes, i.e., organizations, policies, and legislation, as these impinge upon the livelihood opportunities of the poor, presumably because they are easier to influence through external donor support (Paper 1, Figure 12).

Food System Outcomes | UNDP and DFID work at community level, but also emphasize that tackling enabling policy environments, macro-economic reforms, and legislation is equally important for effective poverty reduction. Policies and actions that promote sustainable livelihoods. Multiplicity of assets that people make use of when constructing their livelihoods by focusing on the variety of factors, at different levels, that directly or indirectly.

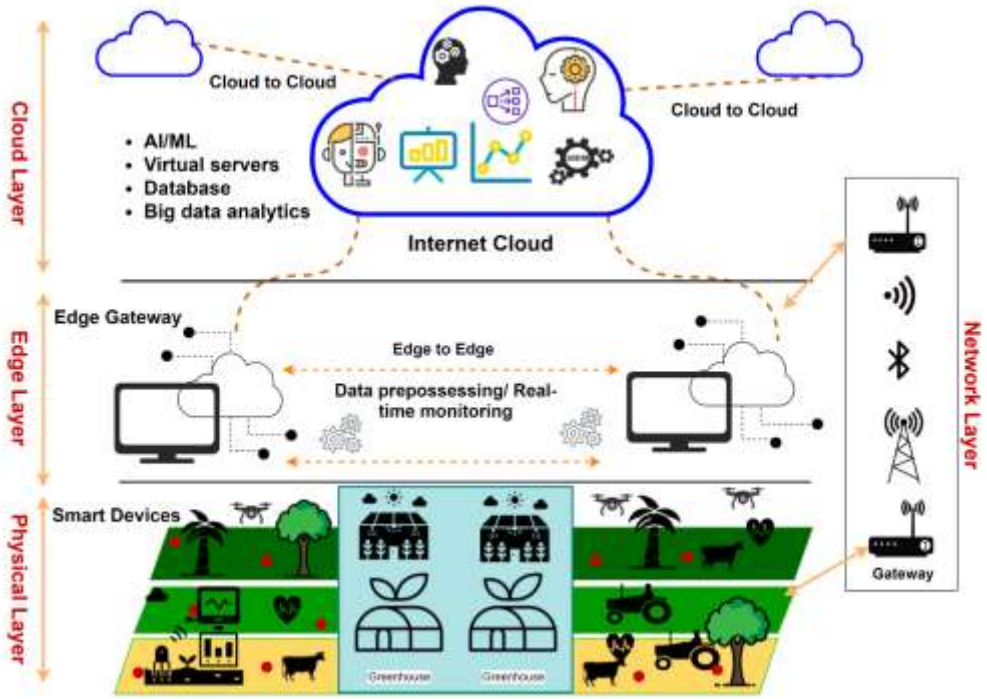

Figure 18. Nigeria agriculture farm security infrastructure framework adapted from Yazdinejad *et al.*, 2021. The invisible battlefield: electronic warfare, explained: https://www.youtube.com/watch?v=2L_2ITqvRQA.

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Publication of the European Centre for Research Training and Development-UK

Social Sustainability
Scenarios-Stakeholders **Diplomacy** (Participatory & Collaborative Scales). Sustainable livelihoods resilience and empowerment for Africa Sudan-Sahel Countries (Shock | Farmers-Herders Conflicts) : Nigeria (Benue state), Kenya, Uganda, and South Sudan; Chad, Central African Republic (CAR) Democratic Republic of the Congo (DRC), Mali, Niger, and Burkina Faso, Cameroon, Sudan, Mauritania, Senegal, Eritrea, Tanzania, Rwanda and Somalia.

Livelihoods' Assets:
Natural, Social, Political, Human, Physical and Economic

Trans-disciplines

Political and Economic factors

Transformability

Food Security Vulnerability

Environmental sustainability Capabilities:
Coping and Adaptive strategies
Desertification, Migration, Food insecurity, Resource use , Social fragmentation, Anthropometric measures, Livestock and crop collections. Climate change (natural disasters, sea-level rise, and increasing resource scarcity), Social violence and communal conflict Natural disasters Environmental Vulnerability, Social Unrest and Climate change and variability.

Development of Food System Outcomes

Food Systems Drivers :
ICT & IoT.
Precision Agriculture.
Pasture Development.
Collaborating.
Partnership.
Farmers-Herders Conflicts.
Great Green Wall (Africa's Sahara Desert).
Regenerative Agriculture.

Food System Outcomes:
Food and nutrition security, environmental, social and economic.

Building Africa food systems resilience

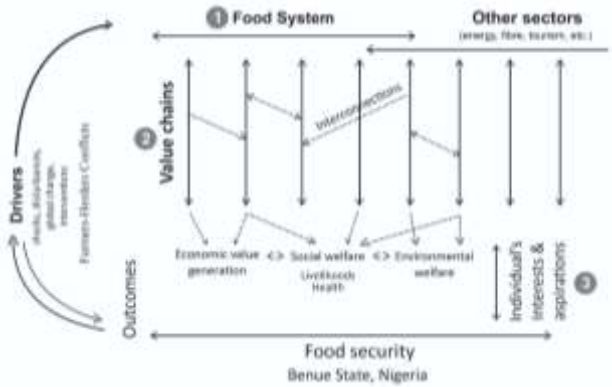
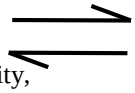


Figure 19. Sustainable livelihoods framework (stakeholders, diplomacy and development) solution for Africa Sahel region and Africa Great Green Wall (Appendix 1).

Table 1. Institutional processes and organizational structures of sustainable livelihoods linked Global Competitive Index (GCI)[28]

Symbolic Representation	12 Pillars of GCI | Drivers of Change	References
Value	Pillar 6: Goods market efficiency Pillar 8: Financial market development	Bist, 2018; Herciu and Ogrean, 2015.
Farmers- Herders Conflicts	Research Problems Context	Brinkman and Hendrix .2011;
	Adaptive cycle: Context, Conditions, Trends: history, politics, culture, demography, perceptions, values.	Adger and Kelly,1999; Berkes *et al.*,2003; Handmer et *al.*,1999; Holling, 1986; Folke, 1998.
 Food security, Food sovereignty	Pillar 12: Innovation Open innovation paradigm Pillar 9: Characterization; Vulnerability and Adaptability. Improving agrifood systems.	Allison and Hobbs,2004; Brooks *et al.*,2005; Wittman, 2011; Fairbairn, 2011.
H - Human Capital (livelihood Assets) I -Infrastructure	Scales : Spatial, Temporal and Institutional Pillar 4: Health and primary education Pillar 5: Higher education and training Pillar 7: Labour market efficiency Pillar 2: Infrastructure (Telecommunication, Agriculture corridor development etc.	Meijerink *et al*., 2021; Yang *et al.*, 2018; Stevens and Schieb,2007; Inderst, 2010; Brancheau *et al*, 1996; and Fan and Zhang, 2004.
S – Stakeholders Participatory Development Approaches (PDA)	Sahel of Africa Co-evolution livelihoods and food assets and outcomes	Bourne and Walker, 2006; Christenson and Walker, 2004; Reed, 2008; Akinrinde *et al*., 2021.
A – Scenarios	Pillar 1: Institutions Pillar 10: Market size development of business model for communities of practice using resilience innovation.	Schoemaker, 2002; Schwartz, 1991; van der Heijden,1996; Zimmerer *et al*, 2003.
@ Internet of Things	Pillar 11: Business sophistication Agriculture 4.0. Agro-security | Drones and Satellites.	Kiritsis, 2011; Vasconez *et al*., 2019; Pierpaoli *et al*., 2013; Altieri and Toledo, 2011.
HI + SA resilience, adaptability, and transformability	Pillar 3: Macroeconomic environment. Food Activities: Food Strategies; Food Outcomes and Food Assets.	Coppack *et al.*,1988; Scoones, 2009; Sen, 1984; Amekawa, 2011.

Food Systems Transformation | Benue state, Nigeria and Sub-Saharan Africa

By drawing attention to the multiplicity of assets that people make use of when constructing their livelihoods, the SL approach produces a more holistic view on what resources, or combination of resources, are important to the poor, including not only physical and natural resources, but also their social and human capital (Figure 19). Poverty is a much more complex phenomenon than just low incomes or insufficient food production (Blackburn Holland,1998). The SL approach shows the variety of activities that people carry out, often in combination, to make a living (Figure 19). Where it is not any activity but their combined effect for the household economy that matters (Chambers, 1995; Hussein and Nelson, 1998). Such conflicts affect agriculture production, destabilize food security and poverty levels enhancing the affected community's unfavorable conditions. Farmers–herders conflicts deepen the incidence of poverty and worsen the wellbeing of both farming and herding households in Sub-Saharan Africa (Appendix 1).

28. Global Competitive Index (GCI). 12 pillars www.weforum.org/gcr.ISBN-13: 978-92-95044-98-2.

Another crucial aspect of the SL approach is that it facilitates an understanding of the underlying causes of poverty by focusing on the variety of factors, at different levels, that directly or indirectly determine or constrain poor people's access to resources/assets of different kinds, and thus their livelihoods (Paper 1, Figure 12). Such constraints might spring from formal and informal institutional and social factors at the local level, or they may be the outcome of overriding policies, economic processes, and legislative frameworks at the macro level. A 'micro-macro' perspective is thus built into the approach and is more likely to lead to more strategic interventions (Table 1 and Figure 16). In Figure 19 sustainable livelihoods framework (stakeholders, diplomacy and development) solution for Africa Sahel region and Africa Great Green Wall (Appendix 1) encapsulate the bespoke solution proposed for farmers-herders' conflicts in Africa based on *ex post facto* research of the study areas.

6.6 Solution to Mitigating Fodder Availability | Benue state, Nigeria

Juncao (improved hybrid Napier grass) fodder can be used as feed for cattle, pigs, chickens, goats and even fish (Plate 6). JUNCAO herbaceous plant, the application of JUNCAO to cultivate edible and medicinal fungi is called JUNCAO technology (Rolim *et al*, 2014), livestock forage and serves as an economic nutrient source (Liu *et al.,* 2015) and *Pennisetumpurpureum Schumach* (Maleko *et al*., 2019). JUNCAO types (Plate 6) have several good properties including strong stress resistance, high yield, abundant crude protein and sugar content, and developed root system which can also show good performance in remediating the stony desertification or desertification (Ye *et al*., 2020). Juncao grass grows rapidly and produces massive biomass, yielding up to 180-450 metric tons of green fodder per hectare annually. This provides a year-round, reliable supply of feed, mitigating seasonal grazing deficits (Ye *et al*., 2020) and proposed for pasture development (Appendix 3). Therefore, development of the JUNCAO industry favors the nutrient management and safe production of a livestock–fungi–plant system (Appendix 3, Tables 5 and 6). In addition, the developed root system and strong stress resistance of JUNCAO benefits their function in ecological management (Ye *et al*., 2020).

Formulated by Lin Zhanxi of China's Fujian Agriculture and Forestry University back in 1986, and now part of the United Nation's 2030 Agenda for Sustainable Development, Juncao technology is employed in over 100 countries across the world from the Pacific, Asia and Africa. Nutritional features mainly depend on the drying conditions. Mainly suitable for following animals: cattle, sheep, goats, horses, rabbits, poultry (Plate 6). The food system is the biggest user of key natural resources, such as terrestrial and marine biodiversity, soils, freshwater, minerals and fossil fuels. For example, the United Nations Environment Programme (UNEP) estimates 60% of global terrestrial biodiversity loss is related to food production. Food system has significant influence over critical global and local biophysical processes such as the water cycle, climate, nitrogen cycle.[29] Water, in particular, has been identified as a critical food system resource that is under threat and has the potential to impact upon yields, quality and safety of food (Appendix 3, Figure 21 illustrate development of pasture within livestock agro-corridor).

29.Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., and Ludwig, C. (2015), Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223), 1259855. https://doi.org/10.1126/science.1259855.

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Processing of JUNCAO feed

Common processing methods of JUNCAO feed：

i. Green forage (direct feeding, chopping, or crushing)

ii. Silage (chopping and ensiling)

Plate 6. Juncao *Pennisetum sp.* (*Jun* meaning fungi, *Cao* meaning grass 46 species of plants).

7 | CONCLUSION

Sustainable livelihoods framework development as a tool (stakeholders, diplomacy and development using converged technologies) for transdisciplinary partnerships and food systems approaches that ensure adaptation and mitigation goals (Figure 19). It encapsulates the intersection of regenerative agriculture, renewable energy, and sustainability, regenerative agrivoltaics emphasizes the transformative potential of integrated systems in reshaping land use and resource management (Figure 1 and Table 1)), the crux of farmers-herders' conflicts in Benue state and Africa Sahel region that prioritizes resilience, productivity, and ecological health to attend the United Nations Sustainable Development Goals.[30] Partnerships for the goals. Regenerative agriculture has the potential to capture atmospheric carbon dioxide (CO_2) and sequester it in the form of soil organic matter (Poeplau,2015) major cause for the resource management conflicts in

Benue state and Sahel of Africa (Figure 3); sustainable agroecosystems and soil health (Fageria,2005) and mitigates soil erosion (Frye *et al.,* 1988).

Despite Kenya government efforts to boost hybrid maize production to meet national food demands, climate change is exposing the vulnerabilities of these commercial crops Farmers groups in Kenya are technically breaking the law by sharing local seeds, which they say are better adapted to local conditions than imported hybrid seeds.[31]Studies and media reports, pastoral communities (Fulani 'Fulani jihad' and Tuareg) are becoming increasingly synonymous with violence and insecurity, while governments frame them as nuisances, that disrupt state progress and industry (Benjaminsen and Ba, 2019) the solution is electronic warfare (EW).It refers to the use of electronic means in electromagnetic spectrum to disrupt, deny, degrade, or deceive an adversary's information or communications systems without causing physical damage (Figure 18). A assists air, ground, naval, and space forces at multiple levels of conflict by limiting the use of the radio frequency (RF) spectrum (Lazarov, 2019). Society can address pressing challenges in sustainable agriculture and renewable energy via Agrivoltaics clean energy generation and creates microclimatic conditions (Weselek *et al.,* 2021) that can bolster regenerative practices (Khangura *et al*.,2023) support regenerative agriculture principles increase biodiversity (Schulte *et al.,* 2022). The sustainable livelihoods framework developed accentuate the significance of 12 pillars.

Global Competitiveness Index (GCI) index for modern agriculture a country's level of productivity.[28] There is an urgent need for agriculture livelihoods infrastructure development for internally displaced persons (IDPs) characterized by conflicts nationwide.[32] Livestock agro-corridor development within the Nigeria six geopolitical zones (Appendix 3, Figure 21) with make foods system outcomes sustainable by creating jobs, empowerment and wealth creation (Figure 1 and Table 2).

Key Impacts of Juncao on the Livestock Sector:

i. High Feed Yield and Supply Security: Juncao grass (Plate 6) grows rapidly and produces massive biomass, yielding up to 180-450 metric tons of green fodder per hectare annually. This provides a year-round, reliable supply of feed, mitigating seasonal grazing deficits.
ii. Nutritional Quality and Productivity Gains: With a high crude protein content (around 16%–18%, nearly double that of conventional Napier grass), Juncao significantly improves animal growth rates and daily milk yields doubling milk output in some dairy herds.
iii. Drought Resilience and Climate Adaptation: Juncao is a deep-rooted, drought-tolerant crop that thrives in arid, semi-arid, and low-fertility soils, helping livestock farmers maintain feed security during severe dry spells and harsh weather conditions (Appendix 3).
iv. Reduced Feed Costs and "Food-vs-Feed" Mitigation: As a perennial forage, Juncao reduces reliance on expensive commercial feed supplements and grain crops like corn and soybeans, significantly lowering farm operating costs and reducing human-livestock grain competition (Figure 19 framework execution for agriculture livelihoods in Sahel region of Africa).

30. United Nations THE SDGs 17 GOALS | Sustainable Development Available online: https://sdgs.un.org/goals.
31. Kenyans fight for their right to seed sovereignty.
https://www.dw.com/en/kenyans-fight-for-their-right-to-seed-sovereignty/video-73231732
32. Nigeria 2025 Humanitarian Needs and Response Plan (January 2025).
https://www.unocha.org/publications/report/nigeria/nigeria-2025-humanitarian-needs-and-response-plan-january-2025

v. Silage Quality: Juncao ensiles well especially when harvested at optimal heights (around 2–2.5 meters) producing high levels of lactic acid and favorable protein preservation that livestock digest efficiently (Figure 21, Table 4 bespoke solution).
vi. Soil and Land Conservation: Integrating Juncao production into livestock systems reduces overgrazing, prevents soil erosion by up to 98%, and restores degraded rangeland.
vii. Reduced Feed Costs and "Food-vs-Feed" Mitigation: As a perennial forage, Juncao reduces reliance on expensive commercial feed supplements and grain crops like corn and soybeans, significantly lowering farm operating costs and reducing human-livestock grain competition (Figure 19 framework execution for agriculture livelihoods in Sahel region of Africa).
viii. Silage Quality: Juncao ensiles well especially when harvested at optimal heights (around 2–2.5 meters) producing high levels of lactic acid and favorable protein preservation that livestock digest efficiently (Figure 21, Table 4 bespoke solution).
ix. Soil and Land Conservation: Integrating Juncao production into livestock systems reduces overgrazing, prevents soil erosion by up to 98%, and restores degraded rangelands.

Supplementary Information | Visit weblinks

1.National Environmental Standards and Regulations (NESREA) Biofertilizer Plant, Port Harcourt Rivers State, Nigeria. https://www.youtube.com/watch?v=F0qTerWRo1Q&t=169s.
2.How the UN is Holding Back the Sahara Desert
https://www.youtube.com/watch?v=WCli0gyNwL0.
3.Traore shocks the World! Plants 5 million trees in 1 hour
https://www.youtube.com/watch?v=_Hlb3deiFwU.
4.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study.

DECLARATIONS | Conflict of interest

The authors declare no conflict of interest of any sort in publishing this manuscript.

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Appendix 1 |
The Great Green Wall (GGW) Sahel Africa Farmers-Herders Conflicts Solution

Supporting Resilient Livelihoods and Landscapes in the Africa Sahel

The Great Green Wall (GGW) is one of the most inspirational and urgent movements of our times. This African-led initiative aims to grow an 8000km new world wonder across the entire width of the Continent to transform the lives of millions living on the frontline of climate change. https://thegreatgreenwall.org/ .Over a decade ago, the Global Environment Facility, in close partnership with the World Bank, invested in what has become a landmark project for Africa and the world-the Great Green Wall Initiative (GGWI) in the Sahara and Sahel. Visit weblink: https://www.thegef.org/what-we-do/topics/great-green-wall-initiative.

Objectives:

The GGW initiative's ambition is to restore 100 million hectares of currently degraded land; sequester 250 million tons of carbon and create 10 million green jobs by 2030. This will help communities living along the Wall to grow. https://www.unccd.int/our-work/ggwi one of humanity's most precious natural assets: fertile land economic opportunities for the world's youngest population food security for the millions that go hungry every day climate resilience in a region where temperatures are rising faster than anywhere else on Earth a new world wonder spanning 8000km.

Source | https://education.nationalgeographic.org/resource/great-green-wall/

Plate 7. Great Green Wall Challenge
The "Great Green Wall" is an initiative to increase the amount of arable land in the Sahel, the region bordering Africa's Sahara Desert. Eleven nations are investing in projects as varied as agroforestry to sustainable development.

Bespoke Eco-Solution | Visit Weblink
1.Ayodele Otaiku Biofertilizer Production & Bioeconomy
https://www.youtube.com/watch?v=58sK1q0prwc&t=26s
2.Ayodele Otaiku Climate-smart fertilizer
https://www.youtube.com/watch?v=zIIuiMT2u20&t=99s
3.Regenerative Agriculture - Integrating Livestock
https://www.youtube.com/watch?v=1uu7kGFfkTY
4. Regenerative Agriculture Products
https://www.youtube.com/watch?v=xOZa_KkNIjY&t=32s

Source |
https://education.nationalgeographic.org/resource/great-green-wall/

Plate 8. Desertification Challenge
Overgrazing by livestock and poor farming practices can lead to a drought-prone region suffering from desertification. Desertification occurs as the soil becomes drier and vulnerable to erosion-resembling a desert.

Bespoke Eco-Solution | Visit Weblink
1. Regenerative Farming and Agrivoltaics,
https://www.google.com/search?q=Regenerative+Farming+and+Agrivoltaics&oq,
2. Africa Saline Agriculture,
https://www.aratiagro.org/products/pages/icons/saline-agriculture.html,
3.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study,
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study.
4.Agriculture - Integrating Livestock,
https://www.youtube.com/watch?v=1uu7kGFfkTY

Plate 9. Edge of the Sahel Challenge
Despite its name, the Great Green Wall project is much more comprehensive than a "wall" of trees across the continent. Establishing sustainable farming and livestock cultivation is an important consideration of the project. Here, a girl tends goats on the edge of the Sahel in Feris, Niger.

Bespoke Eco-Solution | Visit Weblink
1.Regenerative Agriculture 4.0 Tool Box
https://www.academia.edu/44877314/Regenerative_Agriculture_4_0_Tool_Box.
2.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study.
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study.

Source |
https://education.nationalgeographic.org/resource/great-green-wall/

Plate 10. Agroforestry | Challenge
"It's very possible to restore trees to a landscape and to restore agroforestry practices without planting any trees. This is also a sustainable way of regenerating agroforestry and parkland," says Jean-Marc Sinnassamy, a senior environmental specialist with the Global Environment Facility (GEF). The leaves of this acacia tree in Kano, Nigeria, fertilize crops, as do bacteria in nodules on the tree's roots.

Bespoke Eco-Solution | Visit Weblink
1.Gateway Organic Fertilizer | Biofertilizer Gateway Biofertilizer ® Organic 3.0
https://www.academia.edu/42632817/Gateway_Organic_Fertilizer_Biofertilizer_Gateway_Biofertilizer_Organic_3_0.

Source | https://education.nationalgeographic.org/resource/great-green-wall/

Plate 11. Tree of Ténéré | Challenge
The Great Green Wall Initiative unites the Sahel-Sahara region in a campaign to fight land degradation and desertification. This species of acacia, called a Tree of Tenere, exists in isolation on the Sahara-Sahel boundary.

Source |
https://education.nationalgeographic.org/resource/great-green-wall/

Bespoke Eco-Solution | Visit Weblink
1.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study
2.Regenerative Agriculture 4.0 Tool Box
https://www.academia.edu/44877314/Regenerative_Agriculture_4_0_Tool_Box.
3.Regenerative Agriculture - Integrating Livestock .
https://www.youtube.com/watch?v=1uu7kGFfkTY.
4.Africa Saline Agriculture.
https://www.aratiagro.org/products/pages/icons/saline-agriculture.html.
5.UNDP Anaerobic Digester | Biofertilizer Production by Ayodele Otaiku. Regenerative agriculture and climate mitigation biotechnology.
https://www.academia.edu/video/jyonKl
6.Regenerative Farming and Agrivoltaics.
https://www.google.com/search?q=Regenerative+Farming+and+Agrivoltaics&oq.

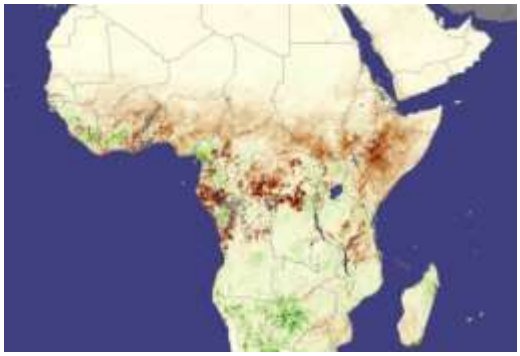

Plate 12. Drought in Africa Challenge
This map displaying six successive years of poor rain is also a rough map of areas of conflict in central Africa in the early 2000s. Drought augmented a brutal civil war in the Democratic Republic of Congo, for instance, the area in central Africa with the most dramatic losses of vegetation.

Bespoke Eco-Solution | Visit Weblink
1.UNDP Anaerobic Digester | Biofertilizer Production by Ayodele Otaiku Regenerative agriculture and climate mitigation biotechnology.
https://www.academia.edu/video/jyonKl .
2. Regenerative Farming and Agrivoltaics.
https://www.google.com/search?q=Regenerative+Farming+and+Agrivoltaics&oq.

Source |
https://education.nationalgeographic.org/resource/great-green-wall/.

Plate 13. Oasis Farming Challenge
Land degradation in the Sahel has its roots in both human activities and natural climate cycles. Over farming in the region can include irrigation practices that may drain aquifers or other freshwater resources. Lack of freshwater can leave seasonally arable land barren. This cotton farm thrives in an oasis (not desert) ecosystem in Marsa Gulbub, Eritrea.

Bespoke Eco-Solution | Visit Weblink
1.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study.

Source | https://education.nationalgeographic.org/resource/great-green-wall/

Plate 14. Cattle in the Omo |Challenge
Human behavior can also contribute to a drought's impact. Some regions are unable to support livestock ranching, which requires enormous amounts of water for fertilization, irrigation of crops, as well as watering the animals. Here, cattle have pulverized the drought-prone Omo region of Ethiopia.

Source |
https://education.nationalgeographic.org/resource/great-green-wall/

Bespoke Eco-Solution | Visit Weblink
1. Regenerative Agriculture Products.
https://www.youtube.com/watch?v=xOZa_KkNIjY&t=32s.
2.Africa Saline Agriculture Biotechnology Solution | Nigeria Case Study.
https://www.academia.edu/127646240/Africa_Saline_Agriculture_Biotechnology_Solution_Nigeria_Case_Study
3.Regenerative Agriculture 4.0 Tool Box.
https://www.academia.edu/44877314/Regenerative_Agriculture_4_0_Tool_Box.
4.Biofertilizer Field Application in Nigeria Agro-Ecology and Training.
https://www.academia.edu/video/BjYBo1
5.Regenerative Agriculture - Integrating Livestock .
https://www.youtube.com/watch?v=1uu7kGFfkTY.
6.Agrivoltaics in Africa.
https://www.youtube.com/watch?app=desktop&v=JToQ0O7tcrM.

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Appendix 2 |

Nearly a billion people will be affected by scarcity of water by 2100

The researchers also ran the models against five different carbon emission scenarios. We saw that if there is a greener world, the water availability will be higher and fewer people will be impacted because of the decrease in water availability. With lower carbon emissions, she says, "We found that 500 million people (would be affected) instead of 900 million people, but water availability will still decrease in certain parts of the world (Das and Ganguly ,2025)

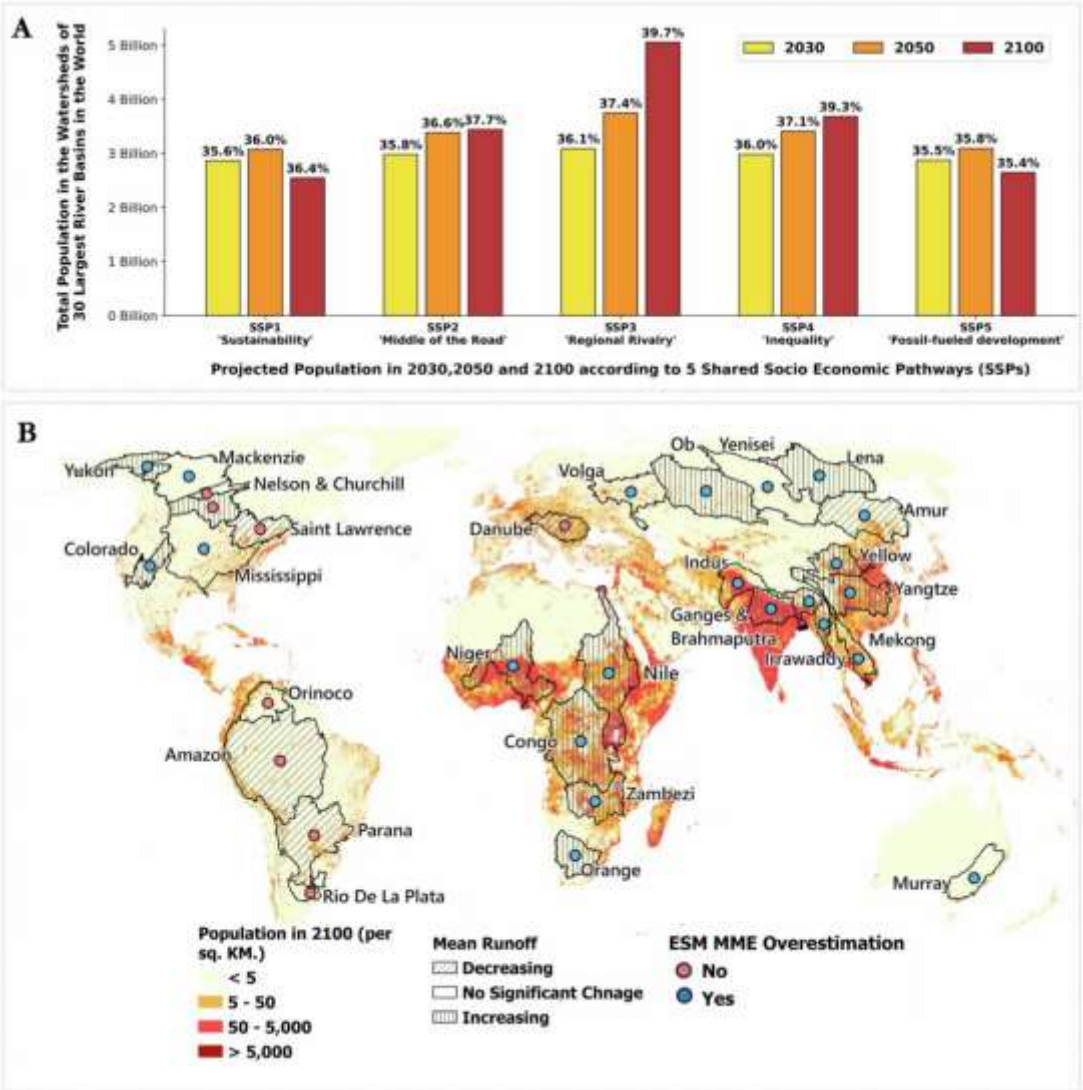

Figure 20. Nearly a billion people will be affected by a scarcity of water by 2100.[33]

33. Nearly a billion people will be affected by a scarcity of water by 2100 (2025, July 16) retrieved 19 July 2025 from https://phys.org/news/2025-07-billion-peopleaffected-scarcity.html

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Appendix 3 |
Nigeria Farmers-Herders Conflicts Livestock Agro-Corridor for Sustainable Livelihoods

Table 2. Nigeria Population Forecast 2050

Year	Population	Yearly % Change	Yearly Change	Migrants (net)	Median Age	Fertility Rate	Density (P/Km²)	Urban Pop %	Urban Population	Country's Share of World Pop	World Population	Nigeria Global Rank
2030	**262,380,970**	2.01%	4,970,638	24,085	19.3	3.82	288	59.60%	156,299,881	3.06%	8,569,124,911	6
2035	**287,685,763**	1.86%	5,060,959	35,506	20.5	3.41	316	64.30%	184,887,647	3.24%	8,885,210,181	6
2040	**312,710,416**	1.68%	5,004,931	41,202	21.7	3.1	343	69.10%	216,083,536	3.41%	9,177,190,203	5
2045	**336,662,502**	1.49%	4,790,417	44,157	22.7	2.85	370	74.30%	250,285,391	3.57%	9,439,639,668	5
2050	**359,185,556**	1.30%	4,504,611		23.9	2.66	394	79.90%	287,130,349	3.72%	9,664,378,587	5

Source: https://www.worldometers.info/world-population/nigeria-population/.

Nigeria Agriculture Water Resources

Nigeria has a large endowment of freshwater resources (286,200 MCM) and 23 percent of this supply originates outside the country. Renewable water supply (1,499 m^3/capita) is just below the Falkenmark Water Stress threshold of 1,500 m^3/capita due to Nigeria's large population (210 million) however, withdrawals are low relative to supply (9.67 percent) and well below the SDG 6.4.2 water stress threshold. Water stress is generally highest in the north whereas water is abundant in the south. Nigeria's federal system divides water management responsibilities between federal, state, and local institutions (Table 3).

Table 3. Nigeria Agriculture Water Resources

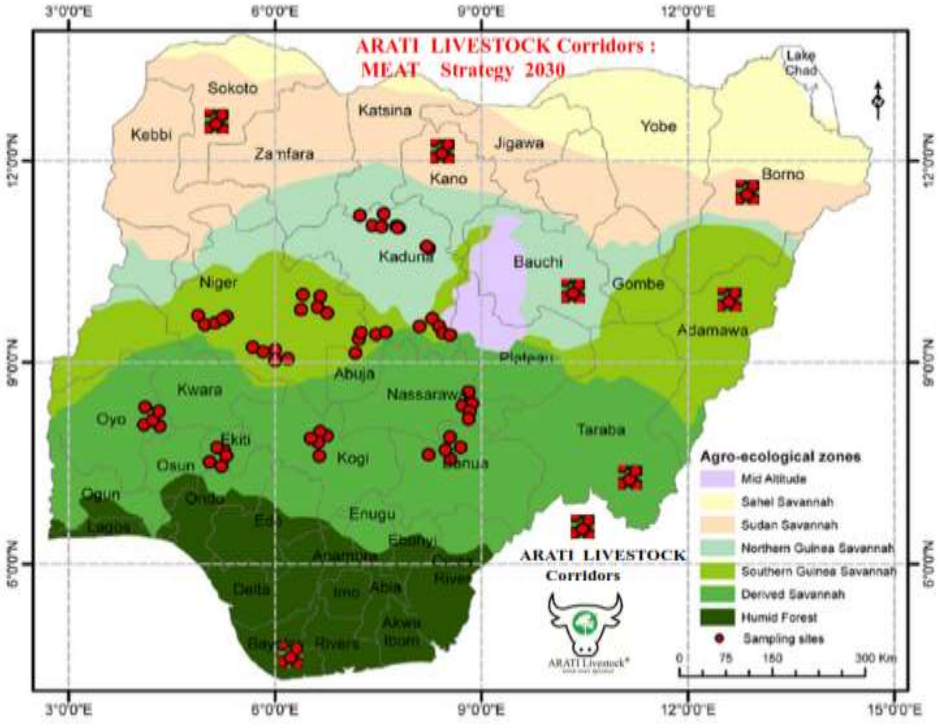
N/S	Colum 1	Colum 2	Column 3
	Name of Authority	**Area of Operation**	**Headquarters**
1	Anambra-Imo River Basin Development Authority	The whole of Anambra and Imo State	Owerri
2	Benin-Owena River Basin Development Authority	The whole Bendel and Ondo State excluding those parts of Bendel State	Benin
		drained by the Benin, Escravos, Forcados and Ramos Rivers creek Systems	
3	Chad Basin Development Authority	The whole of Borno State excluding those parts drained by the Jama'are and Misau Rivers	Maiduguri
		systems but including those parts of Gongola State drained by the	
		Yedseram and Goma Rivers system	
4	Cross River Basin Development Authority	The whole of Cross River State	Calabar
5	Hadejia-Jama'are River Basin Development Authority	The whole of Kano State and those parts of Bauchi and Borno States	Kano
		drained by the Jama'are and Misau rivers systems	
6	Lower Benue River Basin Development Authority	The whole of Benue and Plateau State	Makurdi
7	Niger Delta Basin Development Authority	The whole of Rivers State and those parts of Bendel State drained by Benin, Escravos,	Port Harcourt
		Forcados and Ramos Rivers Creek systems	
8	Niger River Basin Development Authority	The whole of Kwara and Niger State; the Federal capital Territory,	Minna
		the whole of Kaduna State excluding Katsina State	
9	Ogun-Oshun River Basin Development Authority	The whole of Oy, Ogun and Lagos States	Abeokuta
10	Upper Benue River Basin Development Authority	Those parts of Bauchi State drained by the Gongola River system, the whole of Gongola	Yola
		State excluding those parts drained by the Yedseram River System	
11	Sokoto-Rima River Basin Development Authority	The whole of Sokoto and Katsina State	

Grazing Pasture Technology

Factors that need to be considered before establishing a pasture are the following:

a. Soil conditions
b. Climatic conditions
c. Knowledge of pasture management
d. Specific needs from the farmer including preference to seasonal production, persistence of the specific pasture, stocking rates, infrastructure, current farming systems and animal type.

After considering Nigeria's conditions and doing some local trials over the past two years we have identified species that will fit into the Nigerian livestock farming model (Figure 2 below). Preference was given to perennial species due to infrastructure challenges and the inability to establish new pastures every season. The tropical and subtropical species proofed to be most adaptable in the different climatic regions and therefore our focus will be on singular species within these two groups.



Source: https://www.aratiagro.org/products/pages/icons/livestock.html.

Figure 21. Livestock agro-corridor (farms locations) Nigeria six geopolitical zones.

Livestock, Grazing Management and Technology Training
Nigeria Agriculture Grazing and Animal Management (NAGAMA ®) Solution.

Table 4. NAGAMA Course Modules

Course Code	Class room courses
NAGAMA 001	Organic Pasture Development, Livestock & Climatic Change
NAGAMA 002	Farmers-Herders Conflicts Solution: Technology & Peace Building
NAGAMA 003	Dry land Farming: Crops & Techniques for Arid Regions
NAGAMA 004	Development, Improvement of Animal feed supplement/Breeding
NAGAMA 005	Water Harvesting & Livestock Supply Chain Management
NAGAMA 006	Land Restoration, Small Farm Business Planning & Management
NAGAMA 007	Saline Agriculture and Sahel Green Wall Biotechnologies
NAGAMA 008	Animal Breeding and Genetics (Meat and Milk Production)
	Practical Courses
NAGAMA 009	Organic Farm In-puts Technologies & Farm Management
NAGAMA 010	Pasture Techniques & Management: Food Security & Agriculture 7.0
NAGAMA 011	ARATI Meat Security 2030 & Grazing Security Management

Carbohydrate Fractions in Nigerian Forage Grasses

Forage grasses in Nigeria serve as the primary source of dietary energy for ruminant livestock through both structural and non-structural carbohydrates. Tropical C4 forage species - such as Elephant Grass (*Pennisetum purpureum*) and Guinea Grass (*Panicum maximum*) are characteristically rich in structural cell-wall carbohydrates (Adegbola, 2002; McDonald *et al.*, 2010) and see Plate 6.

i. Structural Carbohydrates (Cell Wall): Constitute the largest fraction of dry matter in tropical grasses (Van Soest, 1994). They consist of Cellulose and Hemicellulose, measured as Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF), which rumen microbes' ferment into volatile fatty acids (VFAs) to generate metabolizable energy (Adegbola, 2002).
ii. Non-Structural Carbohydrates (NSC): Found within plant cell contents and composed mainly of soluble sugars (sucrose, glucose, fructose) and starch (McDonald *et al*., 2010). Tropical grasses generally exhibit lower NSC levels than temperate pastures, making ruminants heavily dependent on fiber fermentation (Feedipedia, 2021).
iii. Lignification Impact: As tropical grasses mature, lignin content increases and complexes with cellulose/hemicellulose, which reduces overall carbohydrate digestibility and voluntary feed intake (Van Soest, 1994).

Table 5. Carbohydrate Fractions in Nigerian Forage Grasses.

N/S	Forage Grass	Non-Structural Carbohydrates (NSC)	Neutral Detergent Fiber (NDF)	Primary Nutritional Role	Key Referencee
1	Elephant Grass	8% – 14% DM	55% – 75% DM	Basal energy source	Feedipedia (2021)
	(P. purpureum)			for rumen fermentation	
2	Elephant Grass /	7.8% to 11.1% of DM	64% DM	4% to 21% DM	de Leeuw and Agishi (1978)
	Napier Grass				
2	Guinea Grass	7% – 12% DM	60% – 72% DM	Sustained fiber digestion	Adegbola (2002)
	(P. maximum)			and energy supply	Ukanwoko and Igwe (2012)
3	Gamba Grass	6% – 10% DM	62% – 74% DM	Dry-season bulky	McDonald et al. ,(2010)
	(A. gayanus)			structural carbohydrate	de Leeuw and Agishi (1978)
	Note | Dry Matter (DM)				

Grass-legume Pasture

Grass-legume pasture mixtures are widely utilized in Nigerian livestock systems to optimize ruminant nutrition. Combining grasses (which provide structural carbohydrates and dry matter) with legumes (which fix biological nitrogen and supply crude protein) improves forage, Table 5, digestibility, overall feed intake, and soil fertility (Agishi, 1983; Ezenwa and Aken'Ova, 1998).

Key Forage Legumes in Nigeria

i. Stylo (*Stylosanthes hamata* / *Stylosanthes guianensis*): Highly adaptable legumes that thrive in infertile soil and provide nitrogen-rich dry season feed (Agishi, 1983).
ii. Lablab / Hyacinth Bean (*Lablab purpureus*): A fast-growing annual legume offering leafy biomass for hay, silage, or pasture mixtures (Oyewole *et al*., 2024).
iii. Centro (*Centrosema pubescens*): A trailing perennial legume ideal for intercropping with tall pasture grasses (Ezenwa and Aken'Ova, 1998).
iv. Leucaena (*Leucaena leucocephala*): A deep-rooted fodder tree whose high-protein leaves supplement livestock during dry months (Table 6).

Table 6. Tropical Grass-legume Pasture.

N/S	**Mixture Type**	**Common Grass Partner**	**Common Legume Partner**	**Primary Benefit**	**Key References**
1	Savannah Pasture	Gamba Grass *(A. gayanus)*	Verano Stylo *(S. hamata)*	Enhanced dry-season crude protein intake	de Leeuw and Agishi (1978)
2	High-Yield Ley	Guinea Grass *(P. maximum)*	Common Centro *(C. pubescens)*	Balanced protein energy forage	Ezenwa and Aken'Ova (1998)
3	Cut-and-Carry System	Elephant Grass *(P. purpureum)*	Lablab *(L. purpureus)*	Maximized dry matter and green foliage yield	Oyewole et al. (2024)

Significance within the One Health Framework to Agriculture

1. Animal Health and Welfare

i. Improved Nutrition: Legumes biological fixation of nitrogen enriches the pasture with higher crude protein content compared to pure grass stands, significantly increasing livestock feed quality, weight gain, and milk yield, and
ii. Enhanced Immunity: Better nutrition strengthens livestock immune systems, reducing susceptibility to infectious diseases and decreasing dependence on veterinary pharmaceuticals like antibiotics (Emikpe *et al*., 2024).

2. Human Health and Socioeconomic Wellbeing

i. Food and Nutritional Security: Higher livestock productivity directly improves the availability of animal-source proteins (meat and milk) for human populations.
ii. Antimicrobial Resistance (AMR) Mitigation: Healthy livestock require fewer antimicrobial interventions, lowering the risk of antibiotic resistance transferring from animals to humans through the food chain or environment , visit *https://www.academia.edu/video/jyonKl.*
iii. Livelihood Security: Sustainable pasture production enhances economic stability for smallholder farmers and pastoral communities in tropical regions (Rao *et al*., 2015).

3. Environmental and Ecosystem Health

i. Soil Enrichment: Legumes fix atmospheric nitrogen through biological nitrogen fixation, improving soil fertility, reducing reliance on synthetic chemical fertilizers, and preventing agricultural nutrient runoff.
ii. Carbon Sequestration and Reduced Emissions: Deep-rooted tropical pasture mixtures store carbon effectively in subsoil layers. Enhanced forage quality also improves enteric fermentation in ruminants, lowering methane (CH_4) emissions per unit of livestock output.
iii. Biodiversity and Land Preservation: Intercropping tropical grasses with legumes restores degraded rangelands, prevents soil erosion, and promotes healthier, more diverse soil microbiome ecosystems (Sollenberger *et al*., 2019). Visit weblink: *https://www.academia.edu/video/jyonKl.*