INITIATIVE ON
West and Central African Food Systems Transformation

CGIAR

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International Water Management Institute

SITUATIONAL ANALYSIS OF THE DOMA-RUTU SOCIO-ECOLOGICAL LANDSCAPE IN NASARAWA STATE, NIGERIA

October 2023

Citation

Igbadun, H. E.; Ojeleye, O. A.; Oke, A.; Atampugre, G.; Tilahun, S.; Ismail, H.; Cofie, O.; Mabhaudhi, T. 2023. *Situational analysis of the Doma-Rutu socio-ecological landscape in Nasarawa State, Nigeria.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on West and Central African Food Systems Transformation. 49p.

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Acknowledgement: We would like to thank all the funders who support this research through their contributions to the CGIAR Trust Fund. To learn more about TAFS-WCA and other initiatives in the CGIAR research portfolio, please visit https://www.cgiar.org/research/cgiar-portfolio/. The authors also acknowledge the invaluable contributions of all officials of Nasarawa State Ministries and organizations who provided information used for this report.

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SUMMARY

Several challenges constrain the food systems in West and Central Africa causing low productivity and increasing food insecurity. These include weak institutional arrangement, low capacity for integrated production practices, dwindling resources, and the absence of innovative solutions for food system transformation, among others. The CGIAR Initiative on West and Central African Food Systems Transformation (TAFS-WCA), aims to address some of these challenges through the development and implementation of a landscape management strategy in selected countries. This involves the inclusive engagement of communities in resource inventory, evaluation of challenges, co-design of possible interventions, and implementation of innovation bundles to address the identified challenges.

In this context, the Doma-Rutu socio-ecological landscape in Nasarawa State of Nigeria was selected to support previous intervention by the CGIAR in promoting innovations within the rice-based value chain in Nigeria. A comprehensive situation analysis of landscape was carried out to determine the state and trends of the landscape's functionality in terms of agricultural production resources and ecosystem services while considering potential consequences for human well-being and institutional arrangements. The main source of information was the primary data collected during the field survey in January-February 2023, as well as secondary data provided by key informants operating within the landscape.

The landscape boasts abundant water resources and agriculturally viable uplands and floodplains that favor flood-recession agricultural crop production and artisanal fishing. The climate is also conducive for forestry and livestock production. However, issues like constraining land tenure systems, tenancy insecurity, low production capacity development, uncontrolled tree-cutting for charcoal production and firewood trading, land degradation due to erosion, and vast uncultivated land within the Doma Irrigation Scheme during the dry season represent persistent risks to the socio-ecological landscape's well-being and function.

Unsustainable practices, such as the indiscriminate destruction of aquatic life and bio-resources through deforestation of floodplains for paddy rice production, use of pesticides for fishing, and livestock encroachment into irrigated fields, endanger biodiversity, livelihoods, and ecological health. The floodplains are also shrinking due to erosion, sediment deposition, and the effects of climate change on water resources.

Using the DPSIR-SEL Framework which details the Driving force -Pressure -State -Impact -Response (DPSIR) as a model for analyzing the socio-ecology with the indicators required to give feedback to policymakers on environmental quality and the ensuing impact of the political decisions taken, or to be made in the future, the following were established.

DPSIR-SEL dimension	Findings
Drivers	Food need Energy need Access to farmland Farmer-header conflicts Unsustainable fishing Weak governance structures
Pressures	Expansive/intensive use of floodplains in the dry season for food production Increasing indiscriminate cutting of trees Frequent Floods Increased (unwholesome) exploitation of fish and aqua diversity Increased complexity of LULC transitions

State	Constrained agricultural production. Land access challenges created by irrigation schemes. Increased urban encroachment into floodplains. Contaminated water and the accumulation of pesticide residues in aquatic organisms Decreasing soil fertility Inadequate socio-economic infrastructure Limited access to markets
Impacts	Constrained sufficiency in food production Harmful effects of fishing with Gamalin 20 on the ecosystem, including the death of non-targeted aquatic species, the disruption of natural food webs, and water quality degradation. Post-harvest losses Economic poverty Land use conflicts (e.g., between farmers and herders) Increased poverty and food insecurity, fewer options for a livelihood, entrenched inequities in access to production resources for a living, soil and water damage, degradation of the vegetation, Biodiversity loss, removal of vegetation exposes the soil to surface runoff, resulting in erosion and soil fertility loss Drying up and contaminated rivers
Institutional Responses	Nasarawa State Forestry Law of 2007 Nasarawa State Environmental Protection Agency (NASEPA) Community-Based Natural Resources Management Program (Forest Trust Fund) Agricultural Policy for Nasarawa State (2019-2027).

To address these challenges, increased government presence in the landscape is needed to enhance stakeholder inclusiveness, prevent conflicts, and halt landscape degradation. Farmers should be organized and trained in effective water management to sustain the use of floodplains for dry-season farming. Innovative water management techniques and technologies should be considered, such as alternate wetting and drying technology for paddy production and pipe irrigation systems. The vast land under the Doma and Rutu irrigation schemes must be put to productive use during the dry season to minimize degradation caused by leaving it bare. Attention should also be given to raising native tree seedlings to reforest marginal lands exposed to degradation, and technology transfer on floodplain management should be actively pursued. After the harvest of rain-fed crops, open grazing takes place, and the government is recommended to create an enabling environment for controlled open grazing practices in the landscape.

1. INTRODUCTION

1.1 Background of Study

A socio-ecological landscape is an environment where various entities interact and respond to their surroundings. These interactions have a profound impact on both society and the environment. It represents a complex, interconnected system comprising natural and human components, where changes in one element can significantly affect the others. Managing such a landscape involves stewardship of the land, natural resources, and biodiversity. The goal is to ensure that the landscape can effectively and sustainably meet the needs and aspirations of present and future user communities. The scope of influence in a socio-ecological landscape extends beyond its physical resources. It is also shaped by broader socio-economic and political factors that significantly impact the entire area. This includes factors like population growth, infrastructure development, and climate change, which can have far-reaching effects on the landscape's ecological and social systems. Understanding this intricate landscape is crucial for developing effective strategies to sustainably manage and conserve natural resources. Simultaneously, it plays a pivotal role in promoting the well-being and livelihoods of the communities that rely on these resources.

The West and Central African Food Systems Transformation (TAFS-WCA) is a part of the CGIAR initiatives, aiming to tackle the growing challenges in the agricultural food production environment. One of its key components, Work Package 3 (WP3), focuses on Inclusive Landscape Management (ILP). WP3 is built on the premise that ensuring equal access to and proper utilization of land and water resources is essential for creating a healthy, productive, and One-Health sensitive environment that can support resilient agri-food systems and livelihoods. WP3 utilizes a combination of participatory tools and citizen science to collaboratively develop and implement inclusive landscapes owned by the communities. These landscapes facilitate the sustainable scaling of integrated land, water, aquaculture, and climate-smart agronomic and digital innovations.

Many challenges plague the agricultural production systems across West and Central Africa. WP3 posits that a landscape management strategy will provide a comprehensive perspective of the production ecosystem. This approach encourages the inclusive involvement of stakeholders in various activities, such as resource assessment, evaluation of existing challenges, co-designing potential interventions, and implementing innovative solutions tailored to the identified challenges. The growth in the use of “social-ecological systems thinking” for the achievement of sustainable development (particularly SDGs 2, 6, 13, and 15 etc.) sets the stage for this present study and the entire TAFS-WCA initiative, particularly Work Package 3 (WP3).

A good take-off point for inclusive and sustainable landscape management is the co-establishment of the present situation of the landscape through comprehensive studies and pre-intervention stakeholders’ engagement and establishing partnerships with relevant government agencies, development partners, non-governmental organizations, community-based organizations, and other production agencies operating in the landscape. It is also important to identify and align with government strategic plans and key developmental agendas about agriculture, land, and water resources management for the increased economic productivity of the landscape. Such a study will provide relevant information that will assist in developing Sustainable Landscape Functions (SLF) for the area and formulating strategic interventions using Citizen Science strategy to Co-design and develop Landscape Management Plans and Interventions (LMPI) for the transformation of food systems the landscapes.

This report provides a comprehensive situation analysis of the Doma-Rutu socio-ecological landscape in Nasarawa State, Nigeria, one of the selected study areas under the West and Central African Food Systems Transformation (TAFS-WCA) initiative.

1.2 Study Objective

The objectives of the study were to:

- Conduct a comprehensive assessment of the state, status, opportunities, and constraints to production systems of the Doma-Rutu landscape, and document the enabling environment, hydroclimatic, land cover, land- use, and functions, and socio-economic issues.
- Identify constraints to productivity, technology dissemination, capacity development limitations, and related issues in the landscape.
- Validate findings in a multi-stakeholder dialogue (MSD) setting.

1.3 Scope

The documentation of the study area is largely based on primary data collected at the time of the field survey of the landscape (January-February 2023) and secondary data made available by government functionaries who have jurisdiction over the study location and other stakeholders whose operations are within the landscape. Emphasis is on the functionality of the landscape concerning agricultural production, and the analysis is limited to the state and trends of the agricultural production resources and ecosystem services while considering the potential consequences on human well-being and institutional responses.

1.4 Site Selection

In the build up to the selection of site for a situational analysis involving experts from IWMI and the consultant team in Nigeria, several themes were outlined throughout the discussions for the initiative's case including:

- Case landscape location: Nigeria requires the site to be in the zone of natural vegetation transition.
- Considerable degradation associated with competing land uses, such as forestry, agriculture, and the growth of settlements.
- Considerably fishing and aquaculture practice
- Watersheds and associated concerns: water quantity and quality, as well as efficient water usage.
- Current landscape management programs and low-hanging fruit (ideally from the CGIAR)
- Organizations and associated initiatives, such as TAAT, and AfricaRice,
- Current multi-stakeholder forums and platforms.

Consequently, the Doma-Rutu Landscape (DRL) was selected. DRL is located within latitude 8^0 17’ 32” to 8^0 26’ 48” N and longitude 8^0 12’ 34” to 8^0 23’ 16” E, with altitude ranging from 73 m above sea level around the Mada River to 217 m above sea level southwest of the Doma Dam as shown in Figure 1.1. The population of Doma Local Government Area as of 2022 is estimated at 214,600 people at a growth rate of 2.8% per annum[1]. The Doma-Rutu landscape

[1] https://citypopulation.de/en/nigeria/admin/nasarawa/NGA026003__doma/

boasts diverse ecosystems, including grasslands and wetlands, which support agricultural activities throughout both wet and dry seasons. This landscape was chosen due to its vital role in agriculture for Doma Local Government Area and Nasarawa State. It serves as a hub for subsistence and commercial farming, focusing on crops such as rice, maize, sugarcane, vegetable production, artisanal fishing, and free-range livestock production. However, the landscape faces increasing competition for land and water resources among the farmers engaged in these agricultural production systems. Doma Local Government Area benefits from various projects, including the Rice Compact and the Water Enabler Compact of Technologies for Africa Transformation (TAAT), managed by AfricaRice and the International Water Management Institute (IWMI), respectively. Additionally, National Research Institutions such as the National Cereal Research Institute (NCRI) in Badegi and the Institute for Agricultural Research (IAR) in Zaria are involved in research activities within the Local Government Area.

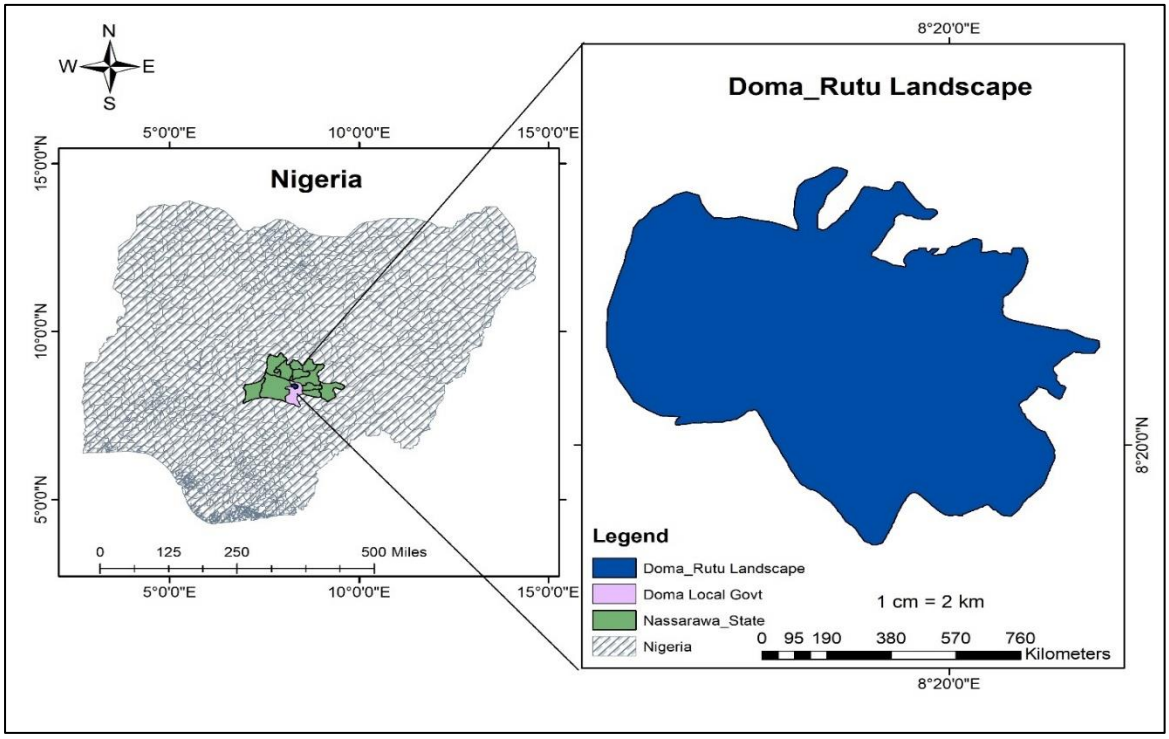


Figure 1.1: Map of the Dome-Rutu Landscape

2. METHODOLOGY

2.1 Materials and Methods

This chapter details the methodology to conduct the Doma-Rutu situational analysis. Figure 2.1 shows the schematic schedules of activities.

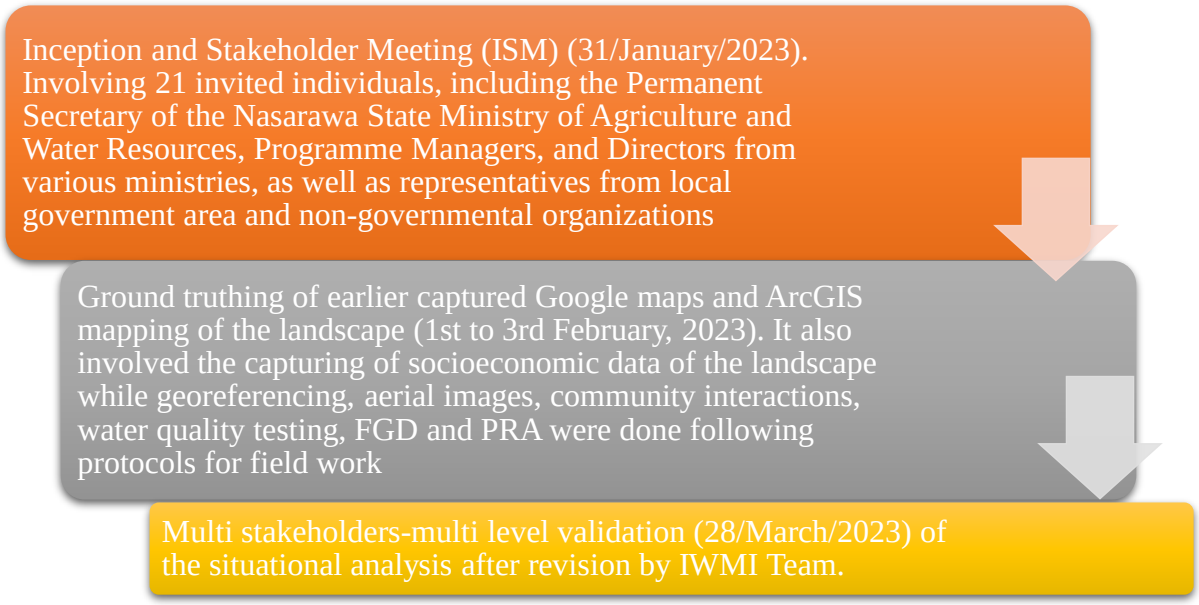


Figure 2.1 Schematic schedules of Situational Analysis Study activities

2.1.1 Geospatial Data Collection

The research team, accompanied by the Doma Irrigation Scheme Project Manager and an Agricultural Extension Agent whose operations covers the landscape, visited floodplains, dams, rivers, rice and sugarcane fields in Odorogya-Doma, Rutu, Iwashi and Alagye. A DJI Mini 2 drone was used to capture aerial images.

2.1.2 Water Quality Testing

In-situ rapid water quality testing was conducted for various streams using the C-600 7 in 1 digital water quality tester. The parameters measured included Water pH, Electrical Conductivity, Total Dissolved Solid, Salinity, Oxidation-reduction potential (ORP), Specific Gravity (SG), and water temperature. Water samples were collected and tested on-site, each repeated three times to ensure accuracy and consistency. The geographical coordinates of the water sampling points were also carefully documented. (Photo 2.1 displays the water quality testing exercise).


Photo 1.1: In-situ rapid water quality testing on the field (Pictures taken on 1st February 2023)

2.1.3 Social-economic and Rural Appraisal Data Collection

The study analyzed data from four Nasarawa State communities using primary and secondary data. The methodology prioritizes gender inclusion, a fundamental human right, to ensure the success and sustainability of interventions. This comprehensive approach helps understand the landscape, challenges, and potential solutions, resulting in a more equitable and effective outcome for all community members.


Photo 2.2: Various FGD sessions in the communities

The study utilized Focus Group Discussions and Participatory Rural Appraisal sessions to gather insights from community members resident for over ten years in the landscape, covering topics like food production, land use systems, socio-economics, livelihood options, biodiversity restoration, and ecosystem services. Nineteen Key Informant Interviews were conducted with influential community figures, and an Online Data Kit was used to capture responses.

2.2 Data Analyses

2.2.1 Geospatial, land cover and land use analyses

The Doma-Rutu landscape was analyzed using geospatial techniques, including obtaining and processing the target catchment's digital elevation model (DEM) using ArcGIS version 8.0. Flow characteristics were generated based on the conditioned DEM, and pour points at the Ohina and Mada rivers were identified for watershed delineation. Land use/cover classification was done using Google Earth Pro, Google Earth Engine, and ArcGIS version 8.0 software. Historical images were collected from the watershed, and 450 training points representing all nine land use/land cover classes were collected. These images were georeferenced within ArcGIS software, and Google Earth Engine was used to process historical images for specific years, including 2000, 2010, and 2022. Land cover and land use types were identified using a modified version of the Food and Agricultural Organization's Land Cover classification system (FAO

2023). Community members and local leaders were also involved in mapping the various land cover/land use categories in the study area.

2.2.2 DPSIR-SEL Framework

The Driving Force-Pressure-State-Impact-Response (DPSIR) framework is a structured approach used to analyze socio-ecology and situational analysis of landscapes. It provides a model for presenting indicators needed to inform policymakers about environmental quality and the impact of political decisions. The framework assumes causal connections between driving forces (economic sectors and human activities), pressures (reactions to these forces), states (physical, chemical, and biological conditions of the environment), and impacts on ecosystems, human health, and various functions. These impacts lead to responses from the political system, including prioritization, target setting, and specific indicators. The DPSIR framework is an extension of the Patient Safety Incident Response (PSIR) framework, which improves understanding of the impact of human activities on the environment throughout the causal chain (Eurostat, 1999). It is based on systems science and has been widely used in integrated environmental assessment, including coastal zones, water management, transportation, and pollution management. Figure 2.2 provides a schematic representation of the DPSIR framework applied to analyze the Doma-Rutu landscape, as presented in the findings section.

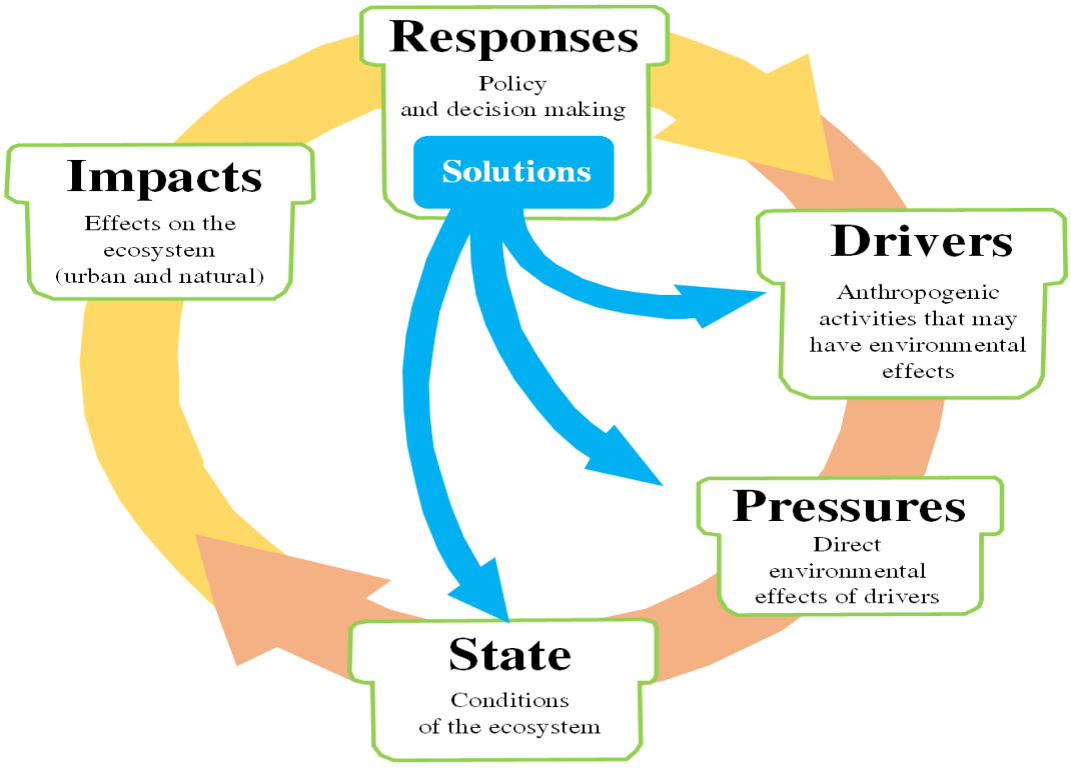


Figure 2.1: The DPSIR Framework

In the DPSIR framework:

Drivers: These are the fundamental elements that motivate human behavior and fulfill essential needs associated with a good quality of life, well-being, positive social interactions, security, and freedom. The social, demographic, and economic dynamics of societies are referred to as driving

forces. Additionally, socio-cultural, and political factors are recognized as driving factors in this framework, as they significantly influence the dynamics of social-ecological landscapes.

Pressures: "Pressures" refer to human activities resulting from the operation of social and economic driving forces that lead to environmental or human systems modifications. The factors of the environment that change due to these pressures are known as stressors. For instance, land development is a pressure, increasing sediment (a stressor) in urban watersheds, which may stress a reef's ecological components.

State: The "state" represents the condition of both the built and natural environments. It provides information about the quantity and quality of the physical, chemical, biological, and human systems that constitute the landscape.

Impacts: Impacts encompass the effects on ecosystems and human well-being. Changes in the structure, function, and composition of ecosystems can affect the production of ecosystem products and services, ultimately influencing human well-being. Environmental impacts often include ecological processes or the outcomes of those processes that directly or indirectly benefit humans. These impacts are related to services provisioning and regulation, culture-related services and supporting processes. Human well-being measures a healthy physical, mental, and social state, including indicators of satisfying fundamental needs such as social connections, good health, security, and freedom. Economic success, safety and health, and societal and cultural well-being are also part of human well-being.

Responses: Responses encompass actions taken by individuals or groups in society and government to address various aspects, such as preventing, compensating for, ameliorating, adapting to changes in the environment, modifying behaviors contributing to health risks, and directly influencing health through medical treatments or addressing the social and economic impacts on human well-being.

Responses can be directed towards driving factors, pressures, the state of the landscape, or impacts. For instance, responses to driving factors may involve changes in agriculture, education reforms, technological advancements, and equality policies. Responding to pressures may include techniques like land use planning and management, behavior modification, discharge restrictions, resource use management, outreach, and education. Responses at the state level may encompass revitalization, cleanup, landscape and community design, restoration, and assessment. Impact-based responses may involve measures related to adaptation, livelihood diversification, mitigation, welfare indexing, ecosystem service evaluation, and monitoring, among other approaches.

3. FINDINGS AND IMPLICATIONS

3.1 The Doma Rutu Landscape

The Doma-Rutu Landscape (DRL) covering 192.26 km^2 and ranging from 73 m above sea level around the Mada River to 217 m southwest of the Doma Dam. It is part of the Doma Local Government Area and borders the Mada River to the west and Doma Dam to the south. The landscape includes communities such as Odorogya in Doma town, Iwashi (also known as Dogon Kurmi) village, Rutu village, and Alagye village. As of 2022, the population of the Doma local

government area is estimated at 214,600 people, with a growth rate of 2.8% per annum[2]. Records of the human population of the DRL are not available.

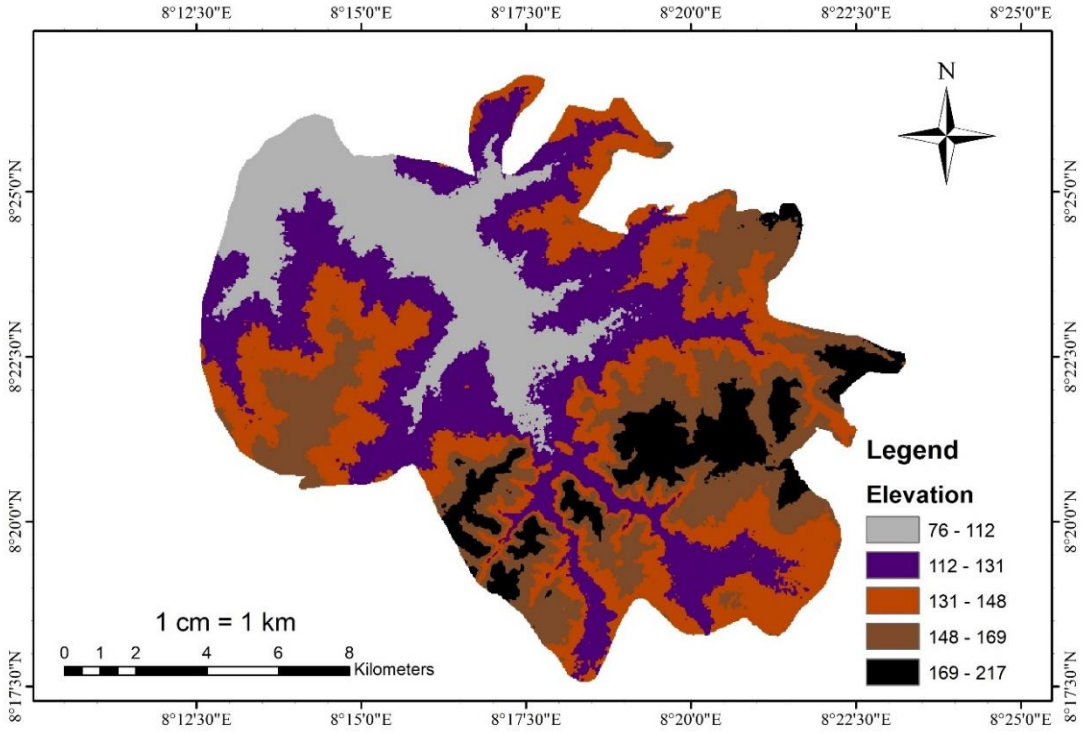


Figure 3.1: Elevation (m) classification of Doma-Rutu landscape

[2] https://citypopulation.de/en/nigeria/admin/nasarawa/NGA026003__doma/

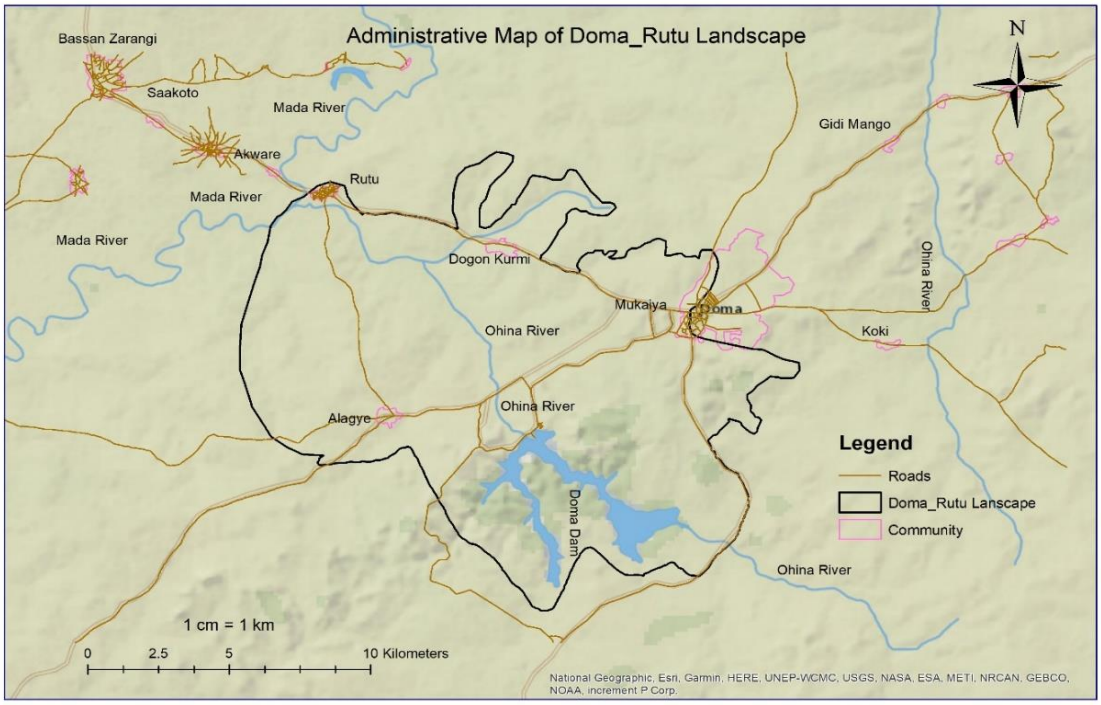


Figure 3.2: Communities and major features of Doma-Rutu Landscape

The Doma-Rutu landscape, a hub for subsistence and commercial farming in Nasarawa State, is characterized by diverse ecosystems like grasslands and wetlands. It supports agricultural activities during wet and dry seasons, artisanal fishing, and free-range livestock production. However, the landscape faces challenges due to competing land and water use among farmers. Despite the presence of a major river, the competition for water resources is increasing. The area is situated in the derived Savannah, a transition zone between the southern forest belt and the northern Guinea-Sudan Savannah. Deforestation, environmental degradation issues, and uncontrolled bushfires pose significant challenges to the landscape, including uncultivated lands and uncontrolled grazing.

Major crops cultivated by small-scale and large-scale farmers in the landscape include maize, rice, sorghum, benniseed, yam, cassava, and melon. Table 3.1 shows the crop production output for Doma Local Government in 2020 and 2021 cropping seasons. Livestock rearing, including poultry and artisanal fishing, is also practiced. The area has an estimated 600 heads[3] of cattle owned by herders, including those who migrate across the landscape. Communities are connected by untarred feeder roads, facilitating the movement of agricultural produce and livestock for sale at the main market in Doma town. There are also livestock and fish farm settlements within the landscape.

[3]Sum obtained from list of cattle owners provided by the Livestock Department of the State Ministry of Agriculture and Water Resources

Table 3.1: Crop production output for Doma LGA in 2020 and 2021

		2020			2021		
S/no	Crop	Prod('000mt)	Area('000ha)	Yield(mt/ha)	Prod('000mt)	Area('000ha)	Yield(mt/ha)
1	Maize	82.16	26.69	3.08	111.44	26.95	4.13
2	Rice (paddy)	74.09	20.80	3.56	104.30	24.35	4.28
3	Yam	693.42	29.63	23.40	859.35	30.59	28.09
4	Cassava	533.41	21.33	24.99	810.83	26.30	30.83
5	Benniseed	19.37	19.19	1.01	36.65	24.01	1.53
6	Melon	12.08	14.307	0.85	22.61	20.26	1.12
7	Okro	6.47	0.56	11.62	8.09	0.70	11.49
8	Pepper	5.21	0.84	6.18	8.08	1.30	6.22
9	Spinach	6.02	0.40	14.94	7.87	0.56	14.13

Source: NSADP PME Department Nasarawa State.

3.1.1 Climate of the Landscape

The Doma area experiences unimodal rainfall from March/April to October/November, with an average annual rainfall of 1,140 to 1,935 mm and 55 to 114 rainy days. The rainfall pattern is typical of derived savanna belts, with heavy rainfall in July and August with an average monthly downpour of 278 mm (Figure 3.3). The rainfall depths consistently exceeded average values from 2013 (except for 2015), indicating extreme rainfall events, which may be responsible for the heavy runoffs and flash and fluvial floods experienced by the communities.

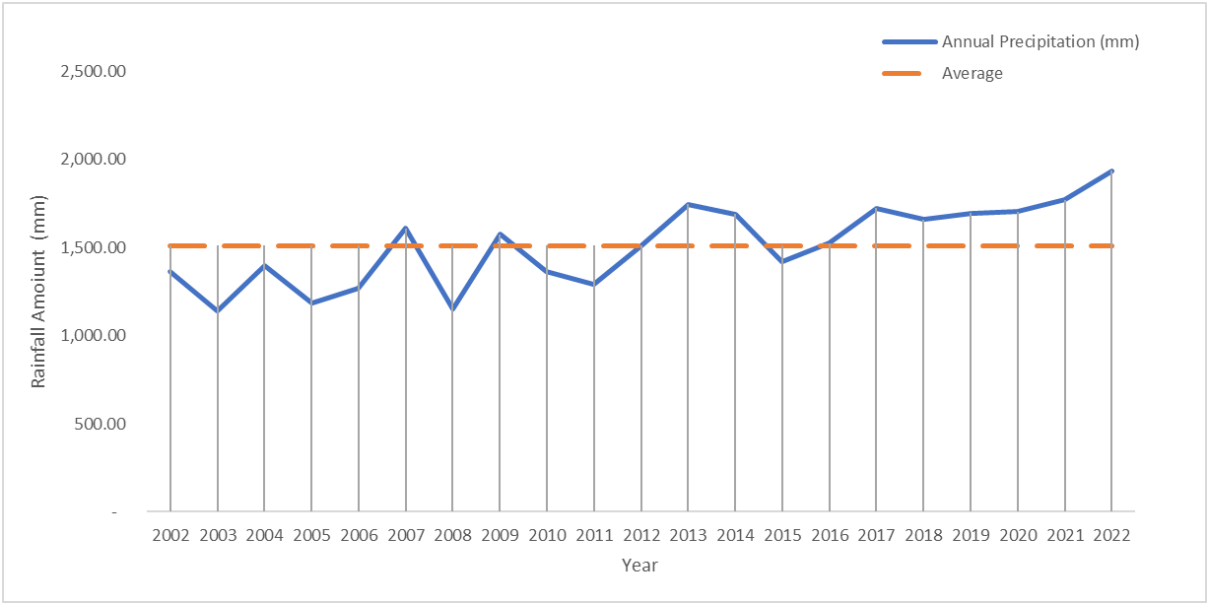


Figure 3.3: Annual rainfall trend of Doma Local Government Area (2002-2022)

The mean air maximum and minimum temperatures range from 25.6°C to 31.4°C and 24.9°C to 30.4°C, respectively. Temperatures are lowest in August (which also witness the heaviest rainfall) and highest in March (which is the onset of rains). The maximum relative humidity is between 34 % in January and 92 % in August. The winds are highest in January, the peak month of the harmattan winds and haze coming from the northern part of the country. The solar radiations are peak in November and April. The climate is typical of the country's middle belt, which is usually hot and humid in the wet season and hot and dry in the dry season. Table 3.2 presents the mean monthly weather data for Lafia town, which is about 25 km away from the

study location. (Since there are no Meteorological Stations in the landscape, the data for the Lafia area obtained from an Automatic Weather Station managed by the Nasarawa State Agricultural Development Programme (NSADP) were adopted for the landscape under study).

Table3.1: Climatic Data for the Doma-Rutu landscape (Average data record 2013 to 2021)

Month	Max Temp (°C)	Min Temp (°C)	Max Rel. Humidity %	Min. Rel. Humidity (%)	Wind Speed m/s	Solar Radiation Ws^{-2}
January	27.4	26.0	34.8	29.8	1.3	179.8
February	30.3	28.9	42.4	37.1	1.0	187.7
March	31.4	30.4	59.0	54.6	1.2	186.0
April	31.1	30.1	62.1	57.5	1.2	212.6
May	29.1	28.3	79.3	75.0	1.1	179.2
June	27.4	26.7	85.6	81.1	0.9	176.9
July	26.2	25.5	90.9	86.9	0.8	158.1
August	25.6	24.9	91.9	88.1	0.8	138.0
September	25.9	25.2	84.6	79.7	0.8	170.6
October	27.7	26.8	78.9	73.2	0.8	202.8
November	28.1	26.9	64.3	57.3	0.8	216.2
December	26.9	25.5	43.6	37.7	1.1	190.0

3.2 Hydroclimatic Dynamics of the Landscape

3.2.1 River and Streams Network of the Landscape

The Ohina River, originating from the Shandam-Plateau hills, is the primary river in the Doma-Rutu Landscape. It flows from the southeastern side and drains into the Mada River in the northwest. The river flow within the landscape is regulated by the Doma Dam which is built on the river course. After the dam, the river flows for approximately 15.4 kilometers before merging with the Mada River. The Mada River, a larger river from the Plateau hills, flows along the northeastern border of the landscape, passing by Rutu village, and joining the Benue River. Although the flows in Ohina River in the landscape is significantly affected by the dam's retention, the river is sustained by tributaries and perennial streams. There are no river discharge monitoring equipment or secondary records of river flow data, making it challenging to analyze the river's characteristics. Figure 3.4 shows a map of the Doma-Rutu Landscape water resources.

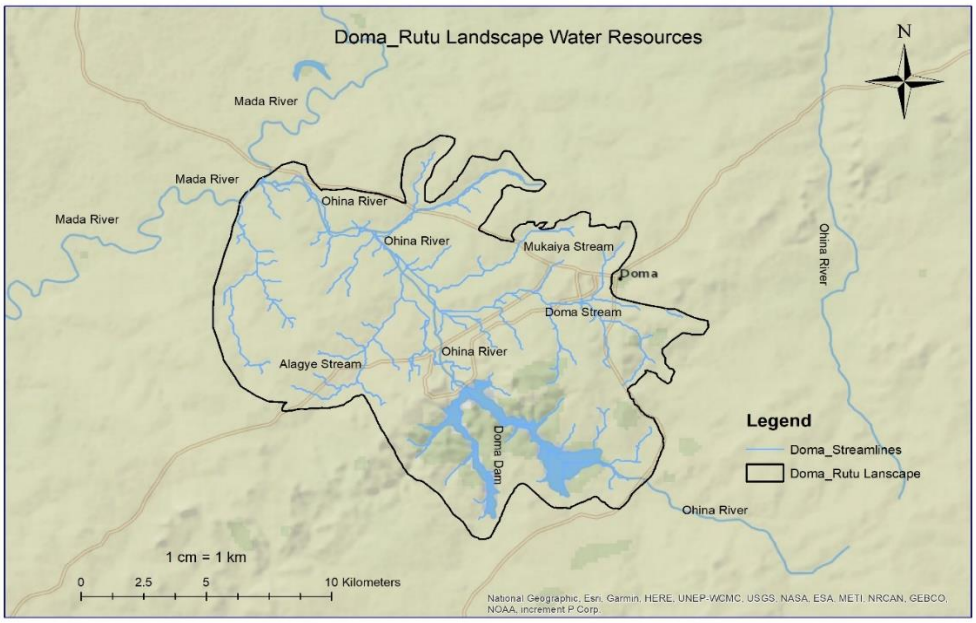


Figure 3.4: Doma-Rutu Landscape Water Resources

3.2.2 Floodplains

The Doma-Rutu landscape features floodplains where flood-recession agricultural activities occur during the dry season. Major floodplains include those of Doma-Odorogya, Iwashi, Alagye, and Rutu (Figure 3.5 to 3.10). Some floodplains are not accessible during the rainy season, especially from June to October, but after the rains, the fields are cultivated with crops like rice and sugarcane. The floodplains serve as water sources and agricultural production nerves for community dwellers. Table 3.3 presents the estimated cultivable area of some of the floodplains.

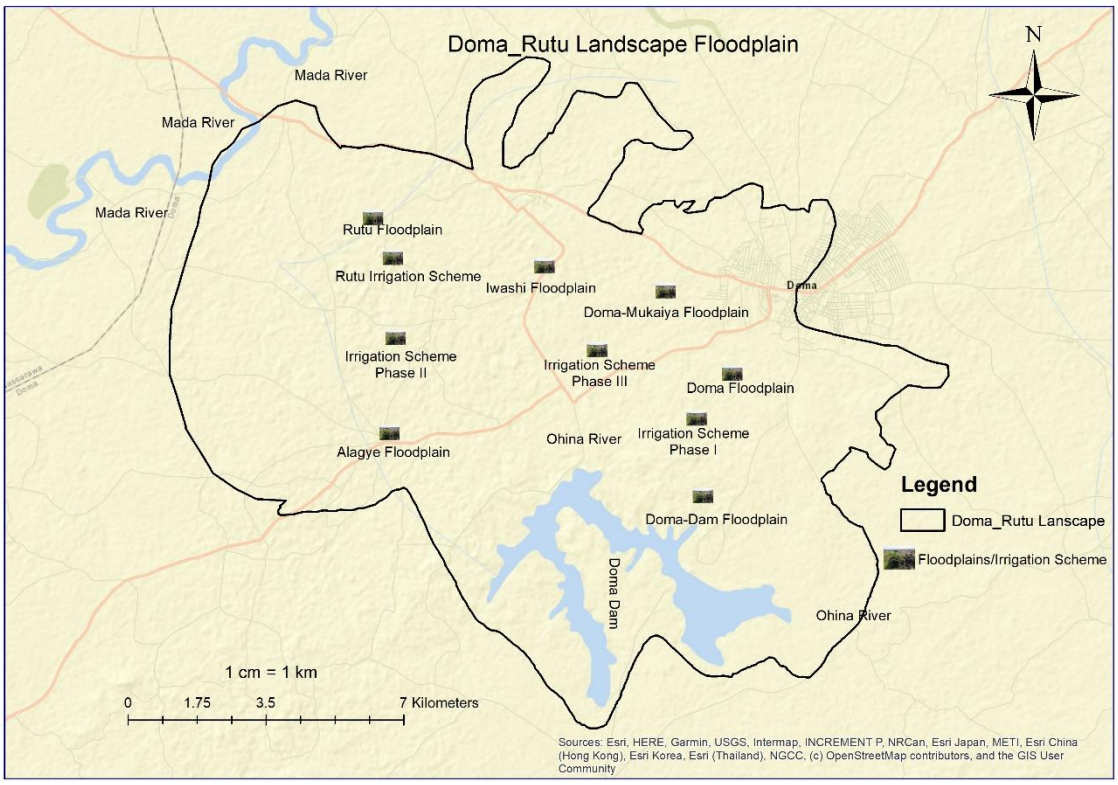


Figure 3.5: Doma-Rutu Landscape floodplains locations

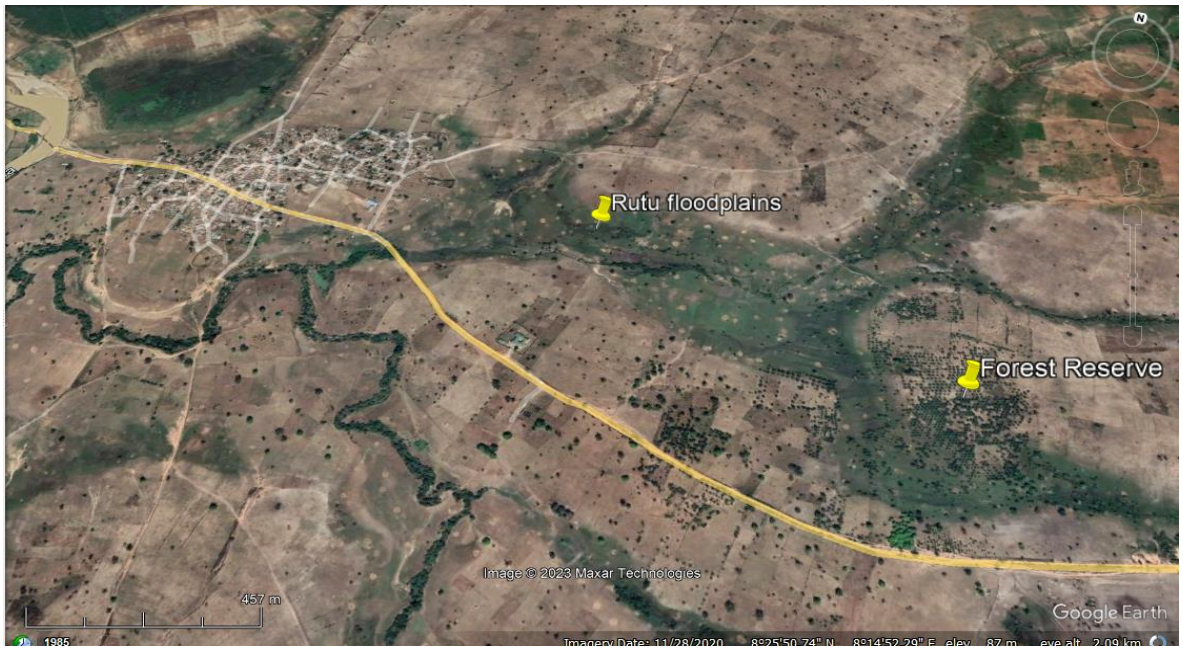


Figure 3.6: Google Map of the Rutu community and the floodplain used for vegetation production in the dry season

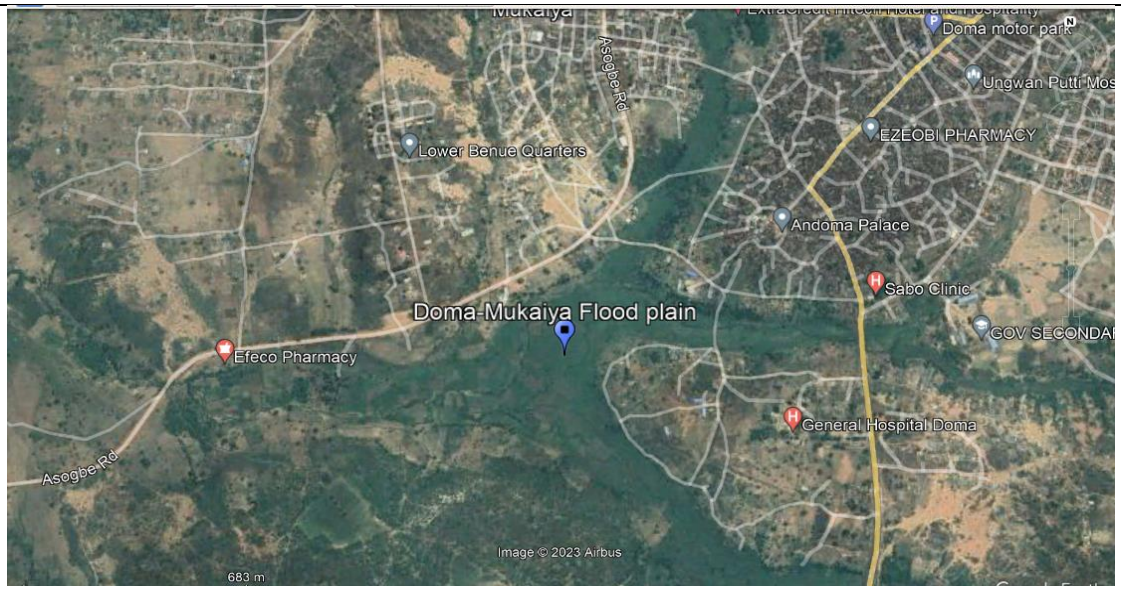


Figure 3.7: Google Map and aerial images of Doma-Mukaiya floodplains cultivated for sugar cane, rice and vegetable crops in the dry season

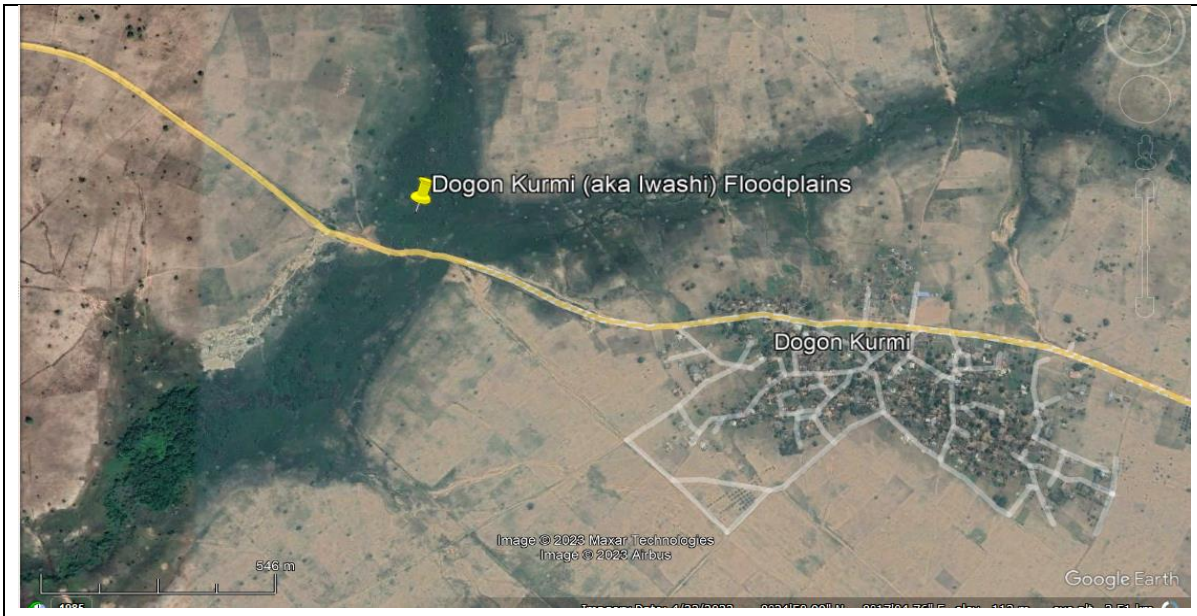


Figure 3.8: Google Map of the Dogon Kurmi (aka Iwashi) community and the floodplains used for rice production in the dry season

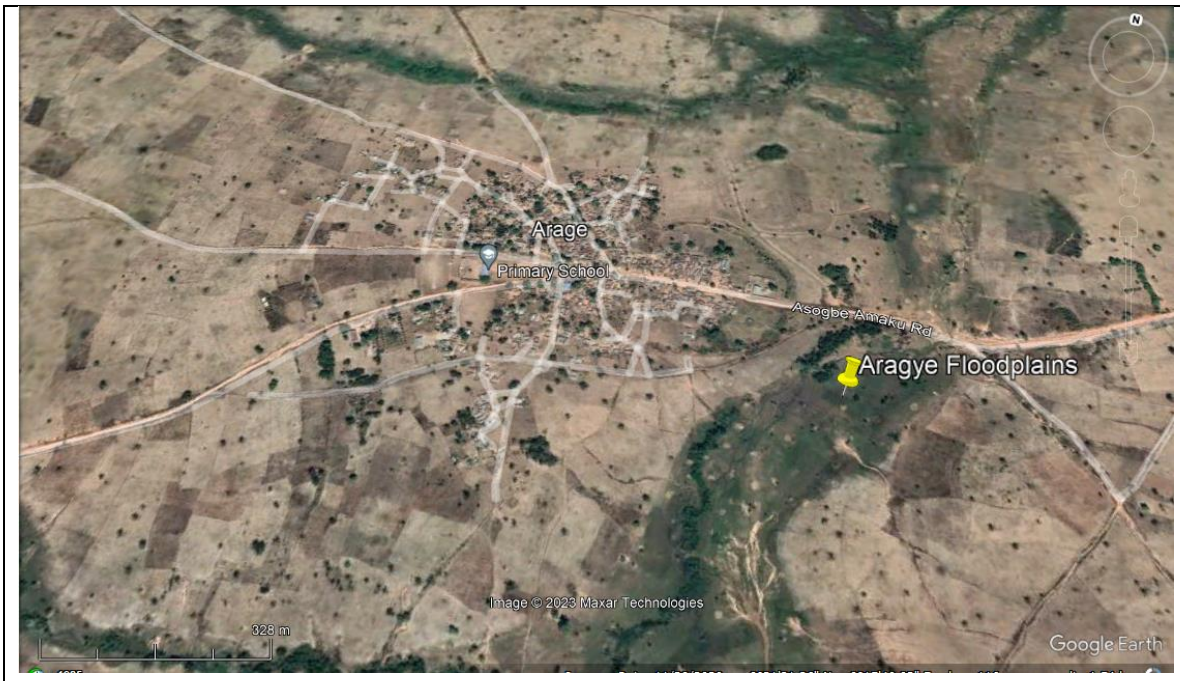


Figure 3.9: Alagye Community and the floodplain used for rice production in the dry season


Figure 3.10: The Doma Irrigation Scheme with patches of floodplains cultivated to rice in the dry season

Table 2.3: Major Floodplains in Doma-Rutu Landscape

S/ No	Name of floodplain/communities	Latitude (°)	Longitude (°)	Altitude (m)	Area (ha)	Major Crops
1	Doma-Mukaiya (Odurogya)	8.3819	8.3834	187.683	345	Rice, maize, benniseed, sugarcane, vegetables
2	Iwashi (Dogo Kurmi)	8.4176	8.2833	112.769	422	Rice, maize, benniseed, vegetables
3	Alagye	8.3571	8.2625	183.646	209	Rice, sugarcane, vegetables
4	Rutu	8.4321	8.2399	120.344	283	Rice, maize, vegetables, cassava
5	Doma-Aseogbe Road	8.3513	8.3004	196.676	103	Rice, sugarcane, maize,
6	Floodplain within the Rutu Irrigation Scheme	8.4321	8.2399	120.344	262	Rice, maize, benniseed, sugarcane, vegetables
6	Floodplain within the Doma Irrigation Scheme Phase I & II	8.3834	8.3239	184.085	109	Rice, maize, vegetables, cassava
7	Floodplain in Irrigation Scheme Phase III & IV	8.3834	8.2404	180.385	85	Rice, maize, vegetables, cassava
8	Floodplain within the Irrigation Scheme Phase V	8.3758	8.2956	159.496	290	Rice, maize, vegetables, cassava
	Total (ha)				2,108	

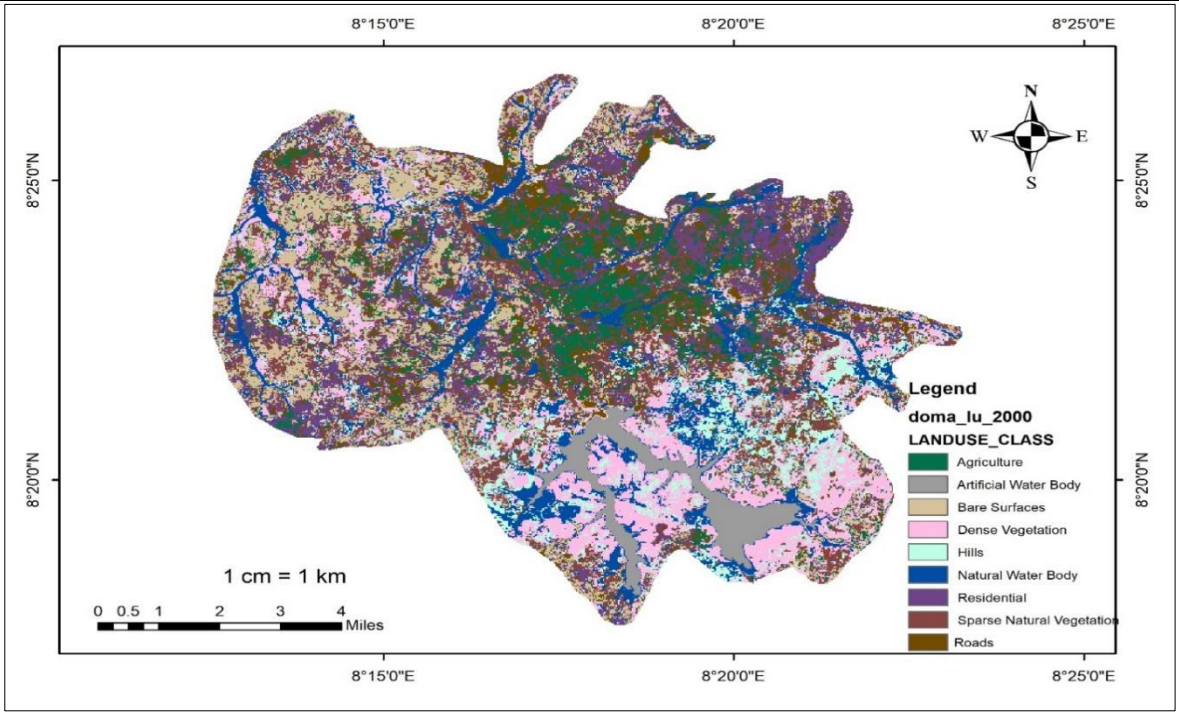
3.2.3 The Doma Dam and the Irrigation Schemes

The Doma Dam, located in the southeast of the Doma-Rutu landscape, has a surface area of 12 km^2 and three arms. It has 30 million cubic meters live storage capacity and receives an average annual inflow of 114 million cubic meters. The dam was constructed to serve multiple purposes, including irrigation, municipal water supply, and electricity generation. However, these intended purposes have not been fully realized due to unbuilt hydro-power plants, and abandoned irrigation facilities. Irrigation activities in both schemes and the entire landscape are predominantly conducted in the floodplains scattered across the area.

3.2.4 Changes in land cover and land use

The area's major competing land uses/cover include agriculture, urbanization, forestry, irrigation, fishery, hills, bare surfaces, and roads. Figure 11 (a – c) shows the maps of the land cover/use and the classification for 2000, 2010 and 2022, and Table 3.3. presents the statistical data of the classification. As of 2000, approximately 15.0 % of the landscape was dominated by dense natural vegetation. Other dominant land cover types were sparsely vegetated areas (12.8 %) and artificial water bodies, particularly the Doma Dam which occupied 3.9 % of the land area. The natural water body, including the floodplains,' streams and river flow, occupied 11.8 % of the land area. The area under cultivation (irrigated agriculture) was 9.4 %. The hilly areas covered about 8.9 %. The bare surfaces make up a large part of about 14.8 %. The analysed satellite images were obtained for the dry season, when only areas with access to water were cultivated. Likely, the areas that appear bare surface were not cultivated because of lack of water, and the vegetation in such areas may have been grazed by livestock.

It may also be noticed from Table 3.4 that as of the year 2010, 9.6 % of the landscape was covered by dense natural vegetation; the sparsely vegetated areas were 9.7 %; the artificial water body was 4.0 %; and the natural water body was 14.5 %. The cultivated area was about 16.7 %, and the bare surface took a large part of about 17. 8 %. In 2022, the land cover/use analysis shows that 16.7 % (3200 ha) of the landscape was under cultivation in the dry season. The artificial water body occupied 3.7 %; the natural water body (streams, floodplains and rivers) occupied about 9.7%; the dense vegetation covered 8.8%; sparse natural vegetation occupied 7.5 %., while the hills occupied 11.2 %. About 3590 ha of the landscape, constituting 18.7 %, is bare surface.



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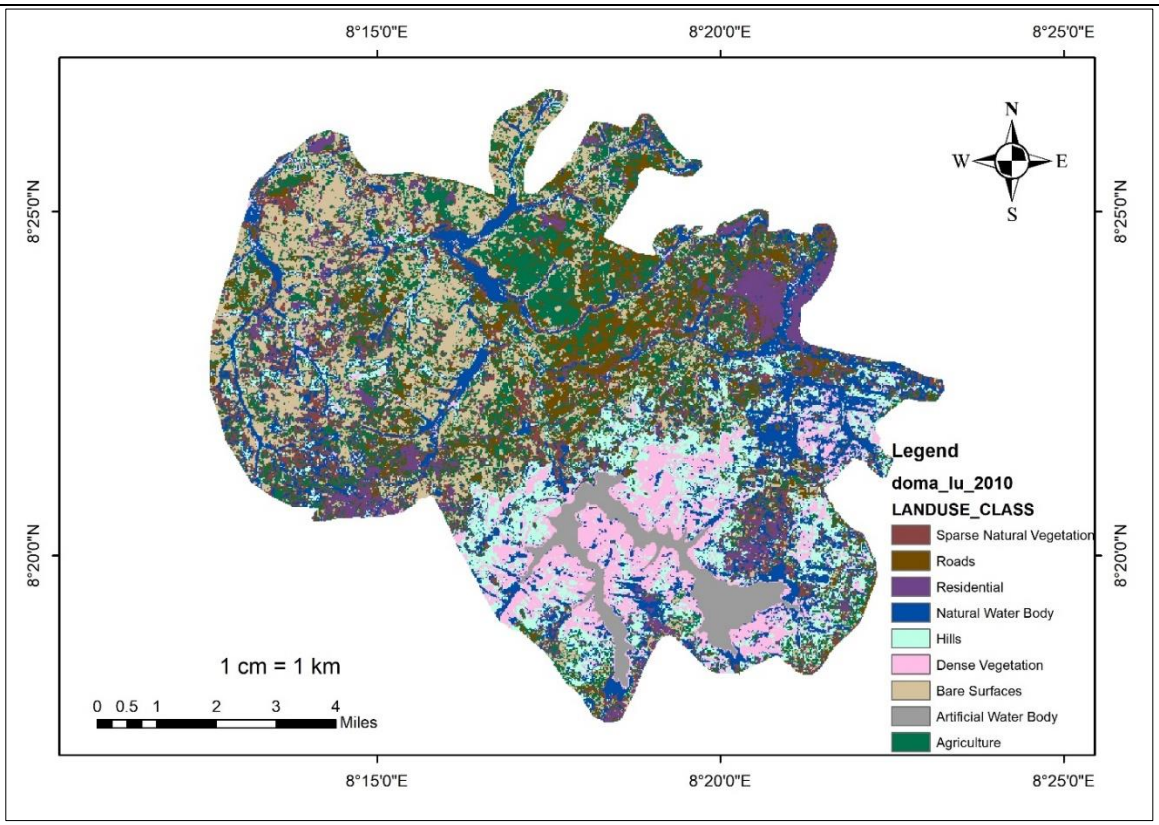

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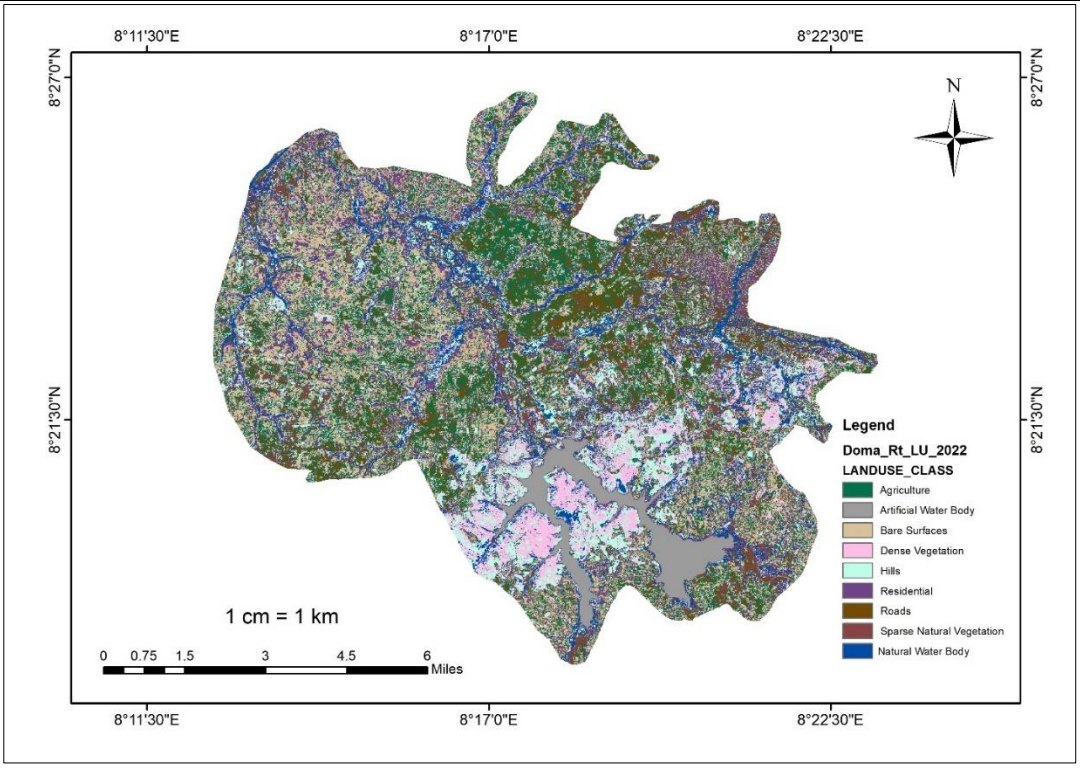

c.

Figure 31(a-c): Land cover/land use map of the Dome-Rutu landscape 2000, 2010 and 2022 respectively.

Table 3.3: Doma-Rutu Landscape Landcover-Land use classification and Statistics 2000-2022

Classification	2000		2010		2022	
	Area covered (ha)	%	Area covered (ha)	%	Area covered (ha)	%
Artificial Water Body (Doma Dam and other artificial pools)	747.9	3.9	767.1	4.0	703.7	3. 7
Residential	2770.5	14.4	1459.3	7.6	2374.4	12.4
Natural Water Body (Streams and river flows)	2261.0	11.8	2791.6	14.5	1866.9	9.7
Roads	1747.6	9.1	1738.0	9.0	2178.3	11.3
Agriculture (cultivated area including the floodplains)	1805.3	9.4	3245.4	16.9	3208.8	16.7
Dense Vegetation	2874.3	15.0	1847.6	9.6	1697.7	8.8
Sparse Natural Vegetation	2464.8	12.8	1857.2	9.7	1445.8	7.5
Bare Surfaces	2853.1	14.8	3416.5	17.8	3589.5	18.7
Hills*	1701.5	8.9	2103.3	10.9	2161.0	11.2
Total	**19226.0**	**100.0**	**19226.0**	**100.0**	**19226.0**	**100.0**

*** Description of the classification**

a) Artificial Water boy = The n Doma Dam and other artificial pools
b) Natural water body= Streams and river
c) Roads = vehicular roads network
d) Agriculture = Cultivated area including the floodplains
e) Dense vegetation= large densely wood area
f) Spare natural vegetation=Scattered shrubs and grasses
g) Bare surfaces = Flat land that has been left bare (without vegetation) either not cultivated or overgrazed.
f) Hills= Widespread rocks and stone packs in high altitude, (not high enough to be called mountain), and cannot be cultivated.

Further, analyses of the land cover/use indicate that between 2000 and 2022, agriculture has increased from 9 to 17 %, with land area cultivated increasing from about 1800 ha to 3200 ha. This implies that the area cultivated under dry season farming has doubled within twenty years. The farmers in the landscape have cultivated the wetland/flood plains. Crops cultivated include rice and vegetables. The increase in the land area used for dry-season farming is not without implications. The land cover/use analysis indicates that the dense vegetation in the area has also reduced from 15% to 8.8 % and the sparse vegetation has also reduced from 12.8 % to 7.5%. This suggests that the landscape is increasingly deforested to expand the area used for farming. This fact was identified during the field visit to the Iwashi floodplain, where stumps of trees cut from the wetland are still very visible, and the land has been cultivated to paddy rice (Photo 3.1). The other reason for the rapid decrease in vegetation may be attributed to felling of trees for charcoal. Charcoal is used as a source of energy in many homes and roadside roasting of fish and green maize which is also a lucrative business among the low-class urban dwellers in Doma and Lafia towns.

The landcover/use analysis also revealed that between 2010 and 2022, the area covered by natural water bodies decreased from 14.5% to 9.7%, possibly due to climate change effects or increased water use for dry-season farming. This trend suggests that the floodplains are under threat of potential water stress, and practical steps need to be taken to mitigate drift. Open grazing by livestock, which occurs after harvesting of rain-fed crops also increases the bareness of the fields, making the area susceptible to erosion by wind and from early rainfalls.

Photo 3.1: Deforested floodplain now cultivated to rice in Iwashi

The Doma and Rutu Irrigation Schemes cover 2500 hectares of farmland. The development of the schemes has been abandoned; thus, it is not cultivated during the dry season. They constitute the most visible bare surfaces in the landscape during the dry season. Agricultural activities are limited to floodplains and around perennial streams, and along the Ohina River, where farmers use petrol-powered pumps to irrigate their crops. Although there is a good number of dry season farmers operating in the scheme, they are not formally organized. There is and no regulation for sustainable use of the water resources of the floodplains. During the field survey, some farmlands were found to have been abandoned because the wetted front of the floodplains have retracted, and the farmers were not prepared/lack the means to lift water from streams or rivers directly to continue to irrigate the fields. It shows lack of preparedness or experience. Interaction with some of the farmers revealed lack technical know-how, particularly in field-layout techniques and water management at the field level.

3.2.5 Water Quality of the Landscape

The water quality data in the Doma-Rutu landscape showed pH values ranging from 6.03 to 7.94 (Table 3.4), with the highest value obtained from the Doma dam. Figure 3.12 shows the spatial map of the water sampling points. Based on classification of irrigation water quality (Bouaroudj et al., 2019), most samples are in the normal pH range (6.5-8.4), except for two samples in a Rice Farm (6.03) and a floodplain (6.38) both in Alagye community that are slightly acidic. Water temperature varied slightly between locations. The electrical conductivity (EC) of water in the landscape ranges from 26 to 115 µS/cm (0.026 to 0.115 dS/m). The values are within the acceptable range for irrigation water. Electrical conductivity values of 0 to 2 dS/m have negligible salinity effect, and most crops will grow well if such water is used to irrigate crops (Balachandar *et al*., 2010). The highest EC values were obtained at the rice fields within the Doma-Rutu landscape. These values were notably found at higher temperatures (33.5- 34.4 °C) compared to other EC values, which indicate increased EC values with an increase in temperature. On the other hand, the total dissolved solids (TDS) range between 13 to 54 ppm, indicating that the water is within the acceptable standard limit of 1000 ppm by the world health

organization (Mohsin *et al*., 2013). The oxidation-reduction potential (ORP) values obtained at various places within the landscape ranged between 194 and 325 mV. These values are below the recommended ORP of 650 mV for sanitized, safe drinking water. Although the water, based on its pH and EC values, is not harmful, there may be a need for treatment to improve the water's oxygen level, bromine and chlorine to enhance its quality for drinking by the residents.

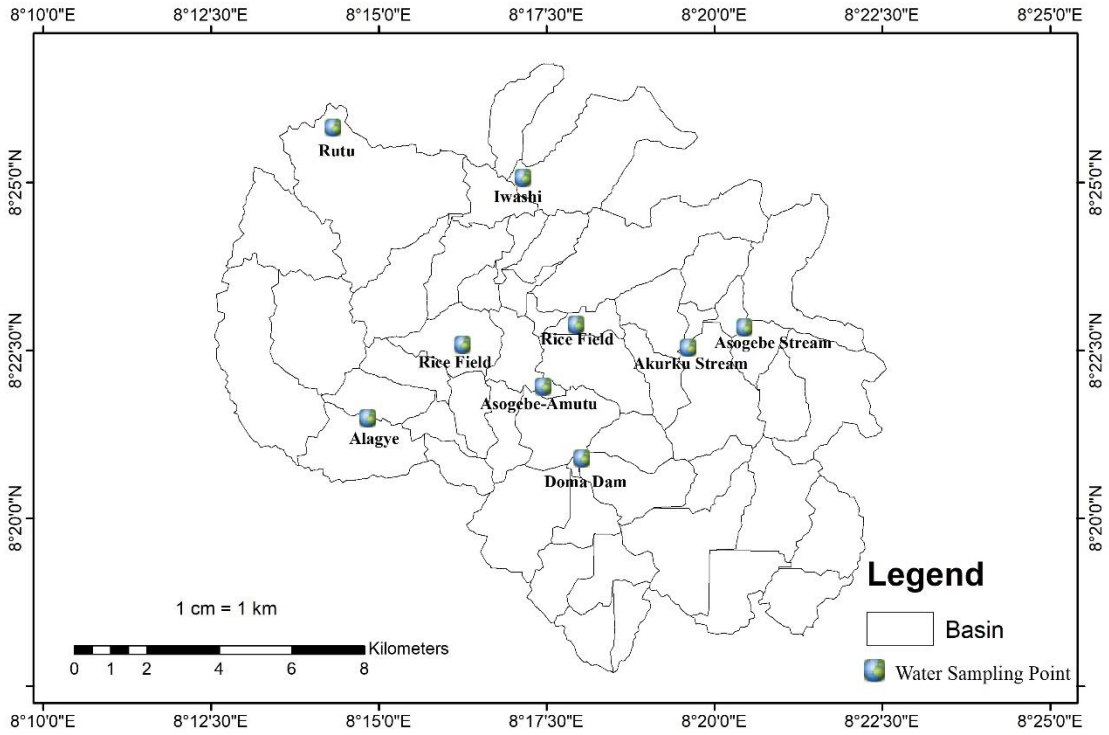

Figure 3.12: Spatial Map of Water Sampling Points

Table 3.4: Water Quality Parameters at Doma-Rutu Landscape

S/ No	Geographical coordinates		Location of Flood plains	Water Quality Parameters						
				Temp	pH	Electrical Conductivity	Total Dissolved Solids	Salinity	Oxidation Reduction Potential	Specific Gravity
	Lat	Long		(°C)		(µS/cm)	(ppm)	(ppm)	(mV)	g/cm^3
1	8.4181	8.2871	Iwashi	31.4	6.59	72	33	126	288	1.002
2	8.4127	8.2824	Iwashi	30.5	6.67	97	48	143	284	1.002
3	8.4172	8.2820	Iwashi	29.8	6.62	65	33	112	268	1.002
4	8.4315	8.2391	Rutu	33.5	7.32	77	40	128	250	1.003
5	8.4332	8.2138	Rutu	32.4	7.51	75	39	122	244	1.003
6	8.4348	8.2298	Rutu	33.5	7.05	82	41	132	268	1.003
7	8.3818	8.3333	Akurku stream	34.8	6.76	115	63	288	274	1.004
8	8.3514	8.3003	Doma Dam	35.2	7.94	42	21	111	228	1.003
9	8.3654	8.2916	Asogebe-Amutu	32.4	6.51	41	20	108	325	1.003

10	8.3581	8.2635	Alagye	34.4	6.38	46	23	102	317	1.003
11	8.3779	8.2946	Rice Field in Alagye I	33.0	6.81	106	53	123	292	1.003
12	8.3767	8.2938	Rice Field in Alagye II	35.2	7.55	26	13	98	270	1.003
13	8.3747	8.2936	Rice Farm, Alagye I	32.9	6.85	108	54	108	271	1.003
14	8.3817	8.3369	Asogebe stream	29.8	6.71	94	47	101	270	1.002
15	8.3669	8.2862	Rice Field in Alagye II	30.8	6.03	45	22	98	194	1.002

3.3 Socio-economic Dynamics of the Landscape

3.3.1 Drivers of Change

Food production

The landscape in the region is primarily agrarian, with tropical savanna woodlands, scattered trees, and grasses. Agriculture is crucial for the local economy, providing income, employment, and food. Rice, yam, cassava, maize, millet, and sesame are cultivated under rainfed. Dry-season farming is practiced in floodplains, but only a small percentage of the community have access to this type of farming. The upper fringes of floodplains dry quickly, leaving only areas near watercourses suitable for cultivation during the full dry season.

The expansion of land cultivation has led to soil fertility degradation due to continuous cultivation. This soil degradation is a key driving force behind the increasing socio-ecological landscape pressures and changes in the area. Other factors contributing to these changes include using herbicides like Glycel, Gobara, Weedoff, Roundup, and others and slashing and burning practices. Additionally, agrochemicals such as Karat, Snipper, Sharp shooter, Perfect Killer, and some others, are used to manage crop insects and pests. Unfortunately, these agrochemicals sometimes have adverse effects, killing off beneficial bacteria and insects essential in natural soil regeneration.

Energy Needs

The landscape faces significant environmental challenges related to deforestation and the unsustainable energy demand. Energy demand, primarily for cooking and heating, has led to the extensive cutting of trees for charcoal production and firewood trading in the landscape. Urban areas like Doma and Lafia rely on the hinterlands to meet this source of energy demand. As a result, there is a gradual but notable depletion of economically valuable trees within the landscape since they are fell to make firewood or charcoal. This situation mirrors the challenges faced in many forested areas of Nigeria, where human activities contribute to deforestation. The country loses more than 350,000 to 400,000 hectares of natural forest cover annually (FAO, 2005). Charcoal production has played a significant role in this trend. The share of deforestation attributable to charcoal production increased from 6% to 14% between 1990 and 2015, and it is expected to rise further to 20% by 2030 (Lansu et al., 2020).

Wood remains the cheapest and primary energy source in the landscape, leading to an ever-increasing demand for wood resources (Photo 3.2). As the population grows, this vicious cycle of forest loss reduces the available wood for cooking and industrial uses, exacerbating ecological problems. The production of charcoal, driven by the high demand for energy, is a major environmental issue in the landscape. Although there are official regulations in Nigeria, including a law enacted to empower the National Environmental Standard Regulation and Enforcement Agency (NESREA) in 2014, aimed at controlling indiscriminate tree felling, commercial charcoal production without permits, and the export of charcoal, enforcement has been limited. This unsustainable practice of deforestation for charcoal production persists in the Doma-Rutu landscape, with inadequate efforts to control it or establish corresponding afforestation programs. The direct consequences of this practice include soil degradation and desertification, further threatening the region's ecosystems. Addressing these energy and deforestation challenges while promoting sustainable land use practices is crucial for the long-term health and resilience of the landscape.

Photo 3.2: Fire woods conveyed from the Alagye to the market in Doma

Access to farmland

The Doma and Rutu Irrigation Schemes, which control over 2,000 hectares of land suitable for irrigation agriculture, are criticized for their underutilization and politicization of land access. The schemes' legal structure imposes tenancy and tenure security, which creates uneven access to land and resources, favoring certain individuals or groups with political connections while disadvantaging others. Farmers are expected to make rent payments immediately after harvest to guarantee retainership of use of the same land the following year. If farmers default for two or more seasons, the land lease by the Scheme is revoked. The practice of rent payment and tenure insecurity also discourage locals from the schemes, putting pressure on scattered wetlands, which are not under the jurisdiction of the scheme, for dry season cultivation.

Land is a crucial production resource, but its productivity can be hindered by lack of sovereignty over its use. The land tenure system governs people's access to farmlands and security over its use. While some native rights are owned by individuals, most are held by the Doma Irrigation Scheme for their land, which dictates specific rights, duties, and responsibilities to land use. The tenure system does not guarantee transfer and access security, and land access is often small and fragmented, affecting mechanization potentials. The fragmented nature of land systems and users' tenure insecurity hinder efficient land management for optimal agricultural production.

Farmer-herder's conflicts

Herd invasions and conflicts between herders and farmers in the landscape have limited the production of certain crops, such as yam and cassava. Herders also claim that there age-long cattle routes are being invaded and obliterated by farmers, thus denying them access to land and water resources and opportunity to ply their trade. Disputes between herders and farmers in the Doma-Rutu landscape are a complex issue influenced by factors such as competition for scarce resources, seasonal herd movements, land use changes, resource scarcity due to environmental factors like climate change and land degradation, historical grievances, disputes, unresolved conflicts, inadequate regulations, and ethnic and socioeconomic differences. The increasing agrarian population and expansion of agricultural lands have made herders' transhumance routes less available, leading to contentious legal claims to land. Environmental decline, desertification, and soil degradation have also impacted herders' transhumance routes. Climate change is not always the cause of conflict, but it has only modified herders' movement patterns (Madu and Nwankwo, 2020). Resolving these conflicts requires a comprehensive approach involving local communities, government authorities, and all stakeholders.

Unwholesome fishing practices

Certain fisherfolks are using toxic pesticides like Gamalin 20 and Perfect Killer in artisanal fishing, killing the fish and make them to float on the water's surface for them to harvest. These illegal activities pose a significant threat to aqua biodiversity and food chains in surrounding water bodies. These toxic chemicals in fish can be harmful to human health. Heavy metals in these chemicals can predispose people to bioaccumulation in their bodies, leading to malignant illnesses and central nervous system abnormalities. The practice is unsustainable, making it difficult for fishermen to make a living and affecting the quality and quantity of fish catch. However, no fishermen disclosed any involvement in such activities.

Pesticides are well-documented in aquatic systems for reducing the quantity and variety of fish and aquatic invertebrates and causing changes in aqua-biodiversity and composition in water bodies receiving toxification (Fleeger et al., 2003; Schäfer, 2019). Besides, pesticide runoff from agricultural production can cause massive fish fatalities in severe circumstances (Polidoro and Morra, 2016). These consequences lower inland fisheries' potential (McCarthy et al., 2008), which can hamper people who rely on inland fisheries for food and a living (Lynch et al., 2020). However, only the landscape's weak structures and non-functioning control systems can adequately combat these sharp practices.

Failure of governance institutions and structures

Institution failures are common in many developing countries. These failures impacted the country's economic growth, political stability, and social development. The Doma Irrigation Scheme, established in the 1980s was never completed. It has long been abandoned, even those

different government keep making promises to complete the development. The scheme is under the control of the Lower Benue River Basin Development Authority. The Scheme's administrative offices and staff quarters are in the scheme area, and the workers have very little to do. The failure of institution to complete a laudable project after many years, the lack of institutional structure to put a vast land with sufficient water resources to use during the dry season have hindered the success of the Scheme to adequately promote irrigated agriculture in the landscape.

3.3.2 Pressures in the landscape

The pressures from anthropogenic and associated intensity in the Doma-Ruttu landscape, as induced by the above driving forces, can be categorized into four, namely, increased use of wetlands during the dry season to augment food production, indiscriminate felling of trees, firewood trading and charcoal making gradually changing the original vegetation characterization, increased depletion of natural fish resources and aqua-diversity in the water bodies around the landscape and complex land use land cover (LULC) transitions.

The Doma-Rutu landscape is complex regarding land use and land cover transitions, as depicted earlier in 3.2.4. Generally, land use and land cover changes are driven by various factors, including demographic changes, economic development, political policies, and environmental changes. One of the landscape's main land use and land cover transitions is converting forested land into agricultural land. This transition has been driven by the need for more agricultural land to support the growing demand for agricultural products. As a result, large forest areas have been cleared for farming, leading to a decline in forest cover and associated ecosystem services such as carbon sequestration, biodiversity conservation, and watershed protection. Changes in the vegetation cover and water resources were also observed.

Another major transition is expanding urban areas at the expense of agricultural land and natural ecosystems. Rapid urbanisation has driven this transition, especially around the Doma-Madakiya, which has led to the construction of new buildings as the development encroached into the farmlands. As a result, agricultural land and natural ecosystems have been converted into urban areas, leading to biodiversity loss, soil degradation, and other environmental problems. The complexity of land use and land cover transitions in the Doma-Rutu landscape has significant implications for the local environment, natural water bodies reduction, biodiversity loss, and climate change.

3.3.3 State of the Doma-Rutu SEL

Agricultural systems and land uses

Pressures created by the earlier enumerated drivers have brought about an agricultural system in the landscape fraught with constraints for self-sufficiency in food production and a prevalent distrust in the structure of the Doma irrigation scheme by the people in the communities. The Doma-Rutu landscape is predominantly an agricultural region, with agriculture being the mainstay of the local economy. The area supports a wide range of crops and livestock. There are several agricultural systems in the Doma landscape, including:

- ***Monocropping***

Monocropping is a farming system where a single crop is grown on an average farm size of 2 to 3 hectares, with crops like rice, maize, sorghum, millet, and sesame. This system is common in the Doma landscape, where fertile soils make it suitable for various crops. Monocropping allows

for specialization and specialized farming equipment, increasing efficiency and productivity. However, it can reduce biodiversity and increase vulnerability to pests and diseases. Farmers in the Doma-Ruttu landscape can mitigate these negative impacts by using crop rotation, fallowing, and agrochemicals.

- ***Mixed cropping system***

In the bid to reduces crop failure risk, improves soil health, and increases productivity, mixed cropping, a traditional agricultural system is well practiced in the Doma-Rutu landscape of Nasarawa State, Nigeria, where multiple crops are grown together to maximize water, nutrients, and sunlight. Common crops include cereals, legumes, and vegetables. Farmers can plant maize and cowpea together, as cowpea can fix nitrogen in the soil, benefiting maize. Mixed cropping also offers a diverse income source for farmers, as they can sell multiple crops instead of relying on a single crop.

- ***Relay cropping system***

An agricultural practice that involves planting a second crop in the same field after the first crop is harvested to maximize resources and improve productivity is referred to as relay cropping. Relay cropping is commonly practiced in the Doma-Rutu landscape. It involves planting the second crop shortly after the first crop to take advantage of residual nutrients and moisture in the soil. Common crops include melon, maize, cowpea, and sorghum. Relay cropping improves soil health, reduces pest and disease pressure, and increases land productivity. It also provides farmers with a diverse revenue source.

Livestock production system

This system involves raising livestock, mainly cattle, sheep, goats, and marginally pigs and poultry birds. Communities in the landscape raise sheep, goats, and birds (hens and cocks) in their backyards for extra revenue and as a source of protein. Livestock is an integral part of the agricultural system in the Doma-Rutu landscape, as it provides a source of income for many families in the area. The livestock production system in Doma-Rutu is predominantly based on traditional pastoralism, which involves the movement of livestock herds in search of grazing and water. The herds are usually managed by pastoralists, who may move from one area to another in search of grazing lands. The primary livestock breeds in the area are the White Fulani and Sokoto Gudali (see Photo 3.3). The livestock are often raised as a store of wealth, meat and milk. Livestock production in Doma-Rutu faces several challenges, including disease outbreaks, inadequate veterinary services, and conflicts between pastoralists and farmers over land use. Recently, increased emphasis has been on improving livestock production through improved breeding, better animal health care, and promoting sustainable grazing practices.

Photo 3.3: Livestock grazing in the Alagye floodplain also cultivated to paddy rice

Constraints to agricultural production and capacity development in the landscape

Major agriculture and farmers' capacity development-related challenges impacting food production and the livelihoods of the people include:

- ***Decreasing soil fertility***: Soil fertility is crucial in agriculture, and in Doma-Rutu, low fertility is due to continuous cultivation without proper management practices. This issue is exacerbated by limited fallow opportunities, the Doma Irrigation Scheme, and overused land. The soils in Doma are sandy clay loam and clay loam, well structured, and slightly acidic with pH ranging from 5.12 to 7.12. Sandy clay loam texture slakes and disperses, leading to poor air and water infiltration, waterlogging, and high surface runoff.
- ***Flooding:*** The floods in the landscape are mainly indicated for proximity to active river/stream flows around floodplains. These natural disasters can endanger human lives, impair community functioning, and cause a lot of damage because of crop losses that result. Flood hazards are predicted to grow globally due to climate change (Collins et al., 2014; Blöschl et al., 2015) and changing land uses and cover (Wheater and Evans, 2009; Pattison and Lane, 2012). These are frequent incidences around the floodplains in the landscape, especially in Rutu and Iwashi.
- ***Inadequate access to modern farming technology***: Many farmers in Doma-Rutu do not have access to modern farming technology, such as tractors, irrigation systems, farm inputs and improved seed varieties. Traditional production mode is still widespread, with only a few elite farmers able to undertake production using modern farming technologies limited to inputs like inorganic fertilizers and improved seed varieties. This also limits the productivity of farms and reduces crop yields.
- ***Inadequate infrastructure***: Inadequate infrastructure, principally poor road networks, makes it extremely difficult for farmers to transport their produce to markets, resulting in losses and reduced income. Transportation of inputs to and produce from the farm in wet seasons is particularly tough, as only motorcycles are usable for such undertakings in Rutu, Dogon Kurmi and Alagye. Certain communities beyond the Mada River can only

use canoes for people and produce movements. In the dry season, the situation is milder and better managed. Still, in the wet season, losses of goods, lives and animals are recorded around Mada river as the locals commute to and from Rutu.

- ***Land access situation created by the scheme***: One of the key issues constraining agricultural production is access to land from the Scheme. The farmers complained of politics and tenure insecurity in land allocation. Besides these, the inadequacy of irrigation facilities in the Scheme's land has forced changes to traditional land use patterns and agricultural practices, with some communities being forced to abandon their traditional crops and adopt new ones more suitable for the scheme. Farmers are sometimes left to abandon the Scheme's land to search for wetlands for dry-season farming. The situation creates high demand and unsustainable use of wetlands around.
- ***Limited access to markets***: Farmers in the Doma-Rutu landscape face the challenge of accessing markets to sell their produce, which limits their income potential and discourages investment in agriculture. In the whole landscape, the only local market is in Doma, the administrative headquarters of the local government area. The market operates only weekly. Going by the earlier mentioned challenge of the poor road network, accessing the Doma market by Iwashi, Rutu and the communities of Rutu beyond is extremely tough.
- ***Climate change***: The consequent effect of variability in climate has caused extreme weather events, such as droughts and floods, which have negatively affected the livelihoods of the populace over the years and caused crop losses in the Doma-Rutu landscape. Changes in weather patterns and increasing temperatures have negatively impacted crop growth and production in the area.
- ***Land use conflicts***: Land use conflicts arise because of competing interests for land use, creating tensions and disputes among farmers and other land users in the area, particularly herders. These conflicts can arise due to several factors, such as competition for resources, encroachment on land, and cultural and religious differences, which tend to be from misunderstandings and mistrust between people groups.
- ***Lack of access to credit:*** Most farmers in the Doma-Rutu landscape do not have access to credit, making it difficult for them to invest in their farms and purchase essential inputs, such as fertilizer and improved seeds. In particular, no banks or credit institutions exist in any of the communities in the landscape safe in Doma, the LGA headquarters. The only forms of financial services available are informal savings and credit groups, also known as rotating savings and credit associations (ROSCAs), where groups come together to save and lend money among themselves. These groups provide a source of financing for small businesses and other needs but are very limited in capacity and capital base.
- ***Urban Encroachment into floodplains:*** Floodplains play an important role in regulating water flow and providing habitat for plants and animals and for irrigated dry season agriculture. Urban development can disrupt these functions, leading to ecological imbalances and biodiversity loss. In addition, urban encroachment into floodplains can create health hazards for residents as floodwaters can contain pollutants, sewage, and other hazardous materials that pose a risk to public health. This scenario is well observed in the Doma-Madakiya northeast end of the landscape, as seen in Photo 3.4. In this same location are sugar cane farms. This portends the risk of heavy metal contamination in soil, which can negatively impact the quality of sugar cane crops, leading to reduced

yields and quality. The plants can also take up heavy metals and accumulate in the sugar cane, posing health risks to consumers of the final product.

Photo3.4: Doma-Odorogya- floodplain under threat of human settlement encroachment

Doma-Rutu ecosystem services and structure

The landscape of Doma-Rutu is diverse, and the ecology provides various ecosystems, functions and services to the local community. Ecosystem services refer to the benefits humans derive from the natural environment, such as clean water, pollination, and soil fertility. FAO (2023) states that ecosystem services enable human life by providing nutritious food and clean water, regulating disease and climate, and assisting crop pollination and soil formation. The Millennium Ecosystem Assessment (MA), a major UN-sponsored effort to analyze the impact of human actions on ecosystems and human well-being, has identified four major categories of ecosystem services viz, provisioning, regulating, cultural and supporting services (UN Millennium Ecosystem Assessment n.d). Meanwhile, the physicochemical and biological processes within an ecosystem to sustain terrestrial life are called ecosystem functions. Ecosystem services are a collection of ecosystem functions that directly enhance human well-being (Kremen, 2005)

In the Doma-Rutu landscape, some of the key ecosystem services and structures include:

- ***Water resources***: The area is home to several rivers, including the Mada River and the Ohina River, which provide water for domestic and agricultural use. These rivers also support fisheries, an important food source and income for the local community.
- ***Savannah vegetation and woodlands***: The landscape is of savannah vegetation with woodlands, which provide various ecosystem services, such as carbon sequestration, soil conservation, and biodiversity conservation. These natural covers also provide wood and other non-timber forest products for fuel, construction, and medicinal purposes.

- ***Agricultural land:*** Agriculture is an important economic activity in Doma-Rutu, with crops such as sesame, maize, and sorghum grown in the area. The agricultural land and systems practised provide food and income for the local community and help maintain soil fertility and biodiversity.
- ***Grasslands and savannahs***: The landscape has several grasslands and savannahs, which provide grazing land for livestock and also support wildlife, such as antelopes, baboons, and monkeys, though this wildlife presence is being gradually eroded.
- ***Wetlands/Floodplains***: Doma-Rutu has several wetlands, which provide important ecosystem services, such as water filtration, flood control, groundwater recharge and irrigation farming. These wetlands also support wildlife, such as migratory birds.

It is important to note that the quality of ecosystem services and structures in Doma-Rutu is affected by various human activities, such as deforestation, overgrazing, and chemical water pollution. Besides, the ecosystem functions of water and climate regulations, nutrient cycling and biodiversity support are being eroded equally. Water regulation, as submitted at the various FGDs, is noted to be more of an excessive presence in the wet seasons, which recedes fast before it can be put to good use in the dry season. Prevalent flooding and nutrient erosion incidences, especially in Iwashi and Ruttu, are evidence of failed ecosystem water regulation function. The observed changing climate indicates failing ecosystem function and reported a gradual biodiversity loss. Monkeys and certain bird species are no longer easily sighted in the landscape. In addition, the FGD among women Iwashi reported that earthworms are also becoming uncommon, as was the case years before, indicating loss of soil fertility and biodiversity within the landscape.

Livelihoods status and options

The Doma-Ruttu landscape's people's livelihoods are primarily based on agriculture, with households relying on small-scale farming for income and food. The main crops grown include yam, rice, maize, sorghum, sesame, melon, and millet. Livestock rearing is common, but lack of access to modern farming techniques, credit facilities, and market access limits their potential to increase incomes and improve livelihoods.

Okada riding (motorcycle taxis) is a popular livelihood option for youths in the Doma-Rutu landscape due to poor road infrastructure and limited access to essential resources. Motorcycles are the most effective way to move and convey goods, especially during the wet season when flooding is prevalent around the landscape. This business provides an additional income source for farmers and individuals, diversifying their livelihoods. However, income from okada riding can be unpredictable and affected by factors like fuel prices, weather conditions, and competition from other riders.

Youth also hire out labor, as is a common practice in many other rural communities in Nigeria. This practice involves young people offering their labour services to other community members, who may require extra hands for various tasks such as farming, construction, or domestic work. In the Doma-Rutu landscape, where agriculture is the primary source of livelihood for many households, youth hiring out labour can be an important source of income for young people who may have limited access to land or resources to engage in farming for themselves. They work on other people's farms during the planting and harvesting seasons, earning wages for their labour.

Meanwhile, in the landscape, like many other rural communities in Nigeria, women face significant challenges in accessing economic opportunities and securing their livelihoods. The livelihood options available for women are principally in agriculture, where they play a significant role in farming activities involving the planting, weeding, harvesting, and processing of crops; in trading, such as buying and selling goods in local markets; and in microenterprises, such as small-scale food processing, catering, and tailoring. These activities often require low capital investment and can provide a means of income for women who may not have access to other economic opportunities.

Poverty

The Doma-Rutu landscape is plagued by poverty due to a lack of access to basic infrastructure like roads, electricity, and clean water, limiting economic opportunities and reducing quality of life. Healthcare services are also limited, contributing to high preventable diseases and mortality rates. Most households rely on subsistence agriculture and small-scale trading, resulting in low incomes and limited access to basic services. Factors contributing to poverty include limited access to resources, low levels of education, poor infrastructure, and climate change impact. These factors limit residents' access to formal employment opportunities, hinder economic development, and contribute to crop failures and income loss.

State of institutional and policy support

Institutional and policy support in the Doma-Rutu landscape is limited, and its development has several challenges. While there are some government agencies like the Doma Irrigation Scheme, the LGA, non-governmental organizations (only make visits), and community-based organizations (cooperatives) working in the area, the capacity of these institutions to provide effective support is often constrained by limited resources, inadequate infrastructure, and a lack of coordination and management. Explicitly, some of the key challenges to institutional and policy support in the Doma-Ruttu landscape include:

- ***Limited resources***: Many institutions working in the area, including government agencies and non-governmental organizations, are constrained by limited resources, which can limit their ability to implement effective programs and policies. For instance, for the whole landscape, only one extension agent is designated to the area, and he resides in the LGA headquarters, Doma. The extension agent is not mobile, and community visits are only occasional.
- ***Poor infrastructure***: The lack of basic infrastructure, such as roads, schools, markets, healthcare facilities, communication networks, and office spaces, can limit the effectiveness of institutions working there. For example, the communities in the landscape have primary and secondary schools, but most are deplorable. There is no piped water, and where there are boreholes, they either are bad, or the locals will have to pay for water. Many prefer not to pay but use rivers, streams and water bodies around.
- ***Weak coordination***: There is a lack of coordination and collaboration among institutions working in the area, which can result in duplication of efforts and limited impact.
- ***Limited capacity***: Many institutions working in the area, including government agencies and non-governmental organizations, have limited human resources, technical expertise, and financial resources.

Despite these challenges, there are some efforts to improve institutional and policy support in the Doma-Rutu landscape. For example, the government has established some programmes aimed at improving access to basic services, such as education and healthcare, and access to farm inputs like fertilizer. Non-governmental and community-based organizations are also working to support communities in the area, including promoting good agronomic practices and providing access to farm inputs. However, more is left to be desired to address the challenges facing institutional and policy support in the Doma-Ruttu landscape.

3.3.4 Impact: Ecosystem Services and Human Wellbeing

Natural resources in the landscape are under threat due to excessive use and exploitation. When combined with fast changing climate, the current scenario raises grave concerns if contemporary exploitations continue at the same rate as in prior decades. Depleting natural resources and related consequences for human health and wellbeing are the rising dangers to sustainability. Human wellness extends beyond cash, materials, or resources to include a society's fair, equitable, and ethical values for living sustainably and harmoniously with nature (Sen, 1989; Daly, 1996). To continue improving people's well-being, nature and its resources must be managed properly to maintain the supply and flow of ecosystem services (ES)—the benefits and products humans get from healthy ecosystems (Costanza et al., 1997). Nature's direct and indirect benefits to human well-being are included in these ES. The inclusion of ES in policy decision-making is critical at this time, especially for developing transformative sustainable economies (Costanza et al., 2014).

Assessing the significance of ES, their sources, limits, and levels of supply or flows at a sustainable level can assist in planning for "development" that operates within the bounds of a landscape, lowers the risks from climate change and natural hazards (floods, storms, bushfires, erratic rainfalls and temperature), and contributes to better management of biodiversity, soil, and water resources (Costanza *et al.,* 2017). The relationships between ES and human health are dynamic and intricate, necessitating a multifaceted approach to measuring and/or comprehending the interactions (Figure 3.13; Costanza *et al*., 2017). The provision of ecosystem services changes as a result of changes in biodiversity. The delicate ecosystem of the Doma-Ruttu landscape, once very rich in agricultural and fishing resources, now suffers because of the overuse of these resources to satisfy the socio-economic wants of the populace. The landscape's derived savannah vegetation has severely degraded due to direct and indirect human driving forces. These elements have accelerated the loss and depletion of ecosystem services and biodiversity.

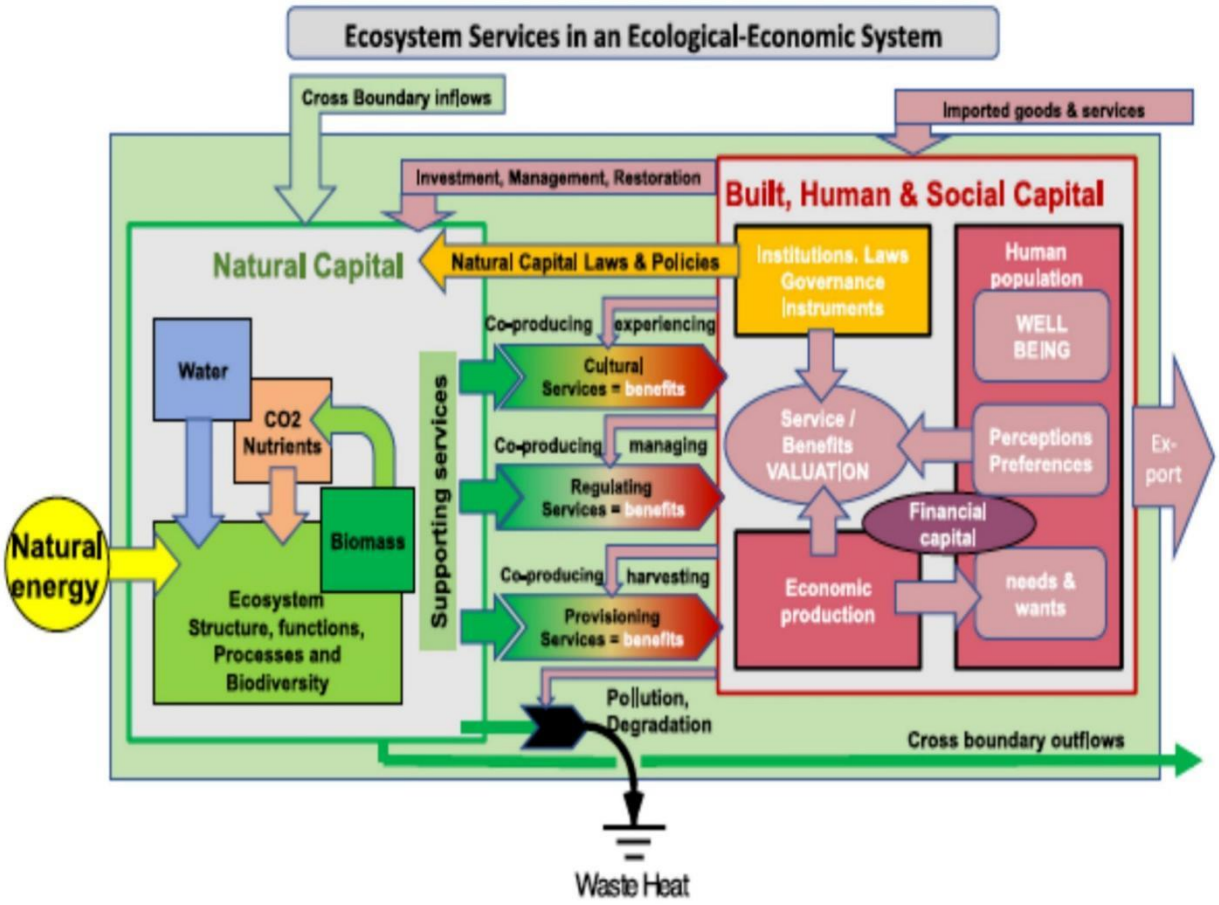

Figure 3.13: Illustrating the intricate and dynamic relationships between natural, built, human, and social capital that result in ES for promoting human welfare (Costanza *et al*., 2017)

Increased poverty and food insecurity, fewer options for a livelihood, entrenched inequities in access to production resources for a living, soil and water damage, vegetation degradation, etc., are all consequences of the constrained flow of ES. People rely on ecosystems for a range of services; thus, it is crucial to note that they assess an ecosystem's health according to its ability to meet those demands. Participants in the FGD across the landscape reported that their agricultural outputs barely suffice to meet their household food needs. They asserted that as a result, they now buy more food from surrounding communities, given that it is getting harder to meet 75% of their food needs. This is a sign that farm households are becoming more food insecure. The predicament of food security in the terrain was further exacerbated by flooding being more persistent. Wild foods are also progressively becoming rare in the area.

The rivers and water bodies in and around the landscape are drying up and becoming contaminated due to unwholesome fishing practices. They may be agrochemical uses, especially since flooding is a common occurrence. Pollution affects rural residents who rely only on rivers, streams, and other bodies of water for drinking and other domestic purposes. For both people and animals in the communities, using contaminated streams and rivers for drinking water and domestic needs has serious health consequences. Additionally, as a result of degradation and competing land uses, land cover changes impact ecosystem health and functioning, biodiversity, and ecosystem services. Woodland carbon stores are decreasing through tree cutting and loss of vegetation cover, and certain birds, monkeys and some animal species are also being lost.

Aside from biodiversity loss, vegetation removal exposes the soil to surface runoff, resulting in erosion and soil fertility loss. Chemical fertilizer usage has diminished and depleted some ecosystem services and hardened the soil surface, decreasing agricultural output, as reported by FGD. Furthermore, the loss of vegetation may result in high land surface temperatures, which might impact other ecosystem components and their benefits. Regarding water resources, illicit fishing pollutes the water and renders it unfit for domestic and agricultural usage.

The dynamics of stakeholders' relationships

According to the "cascade" framework, ecosystem services flow from the ecosystem toward improving human well-being (Haines-Young and Potschin, 2010). As ecosystem service research continues to advance (De Groot et al., 2010; Martn-López et al., 2014; Kandziora et al., 2013), this paradigm has been gradually adjusted to reflect these changes, such as the addition of societal processes in the transition from "service" to "benefit" (Spangenberg et al., 2014). By identifying the interactions between stakeholders and ecosystem services that moderate and may hinder stakeholders' access to ecosystem services, Felipe-Lucia et al. (2015) proposed the framework in Figure 3.14.

The biophysical structure and operation of ecosystems, or ecosystem characteristics, have a role in the provision of welfare of humans. In contrast, ecosystem services depend on one another and interact, resulting in trade-offs and synergies (Villamagna et al., 2013). Some of these relationships may be influenced by how stakeholders consume and manage ecosystem services (Rodriguez et al., 2006; Felipe-Lucia et al., 2014; Haase et al., 2012). As a result, several sorts of complicated interactions among numerous stakeholders influence the flow of ecological services via the social system (i.e., stakeholders' interactions, roles, and preferences). First, different types of relationships between stakeholders are influenced by formal power imbalances (such as those resulting from access rights, property rights, or legal permissions) as well as informal power imbalances (such as those resulting from social leadership, gender inequity, or hidden power imbalances) (e.g., social pressure promoting self-censorship). Second, various stakeholders have varied responsibilities for managing and utilizing ecosystem services. According to Barnaud and Antona (2014), there are two basic roles that stakeholders may play: either they can manage ecosystem services (i.e., contribute to their production or degrade them), or they can be consumers of ecosystem services (i.e., benefit from them while being denied access). One stakeholder might play multiple roles (Hauck et al., 2014). Additionally, interactions among stakeholders have an impact on how each stakeholder functions within the system, which in turn sustains power dynamics (Hicks, 2013; Lamarque, 2011; Martin-López et al., 2012; Bryan et al., 2010). The social system directs environmental management, setting how ecosystem services are managed and used and influencing the characteristics of the ecosystems that support the supply of ecosystem services (Nagendra et al., 2013; Van Oudenhoven et al., 2012).

Consequently, by understanding and managing the power relationships among stakeholders, organizations can better navigate complex and dynamic environments, build trust and engagement, and achieve positive outcomes for all parties involved. Engagement with the stakeholders to understand their interests, concerns, and goals will help build relationships and trust and identify potential conflicts and areas of alignment.

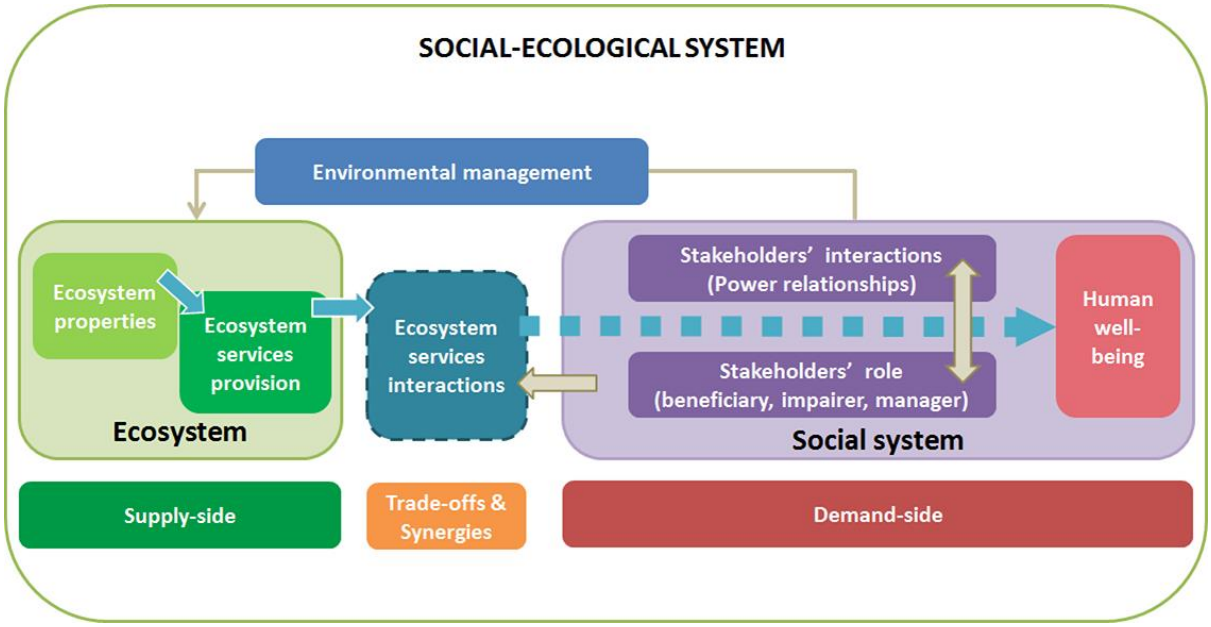

Figure 3.14: Ecosystem Services Flows: Why Stakeholders' Power Relationships Matter

Blue arrows reflect the flow of ecological services. Beige arrows show interactions inside or from the social system (Adapted from Felipe-Lucia et al. (2015).

3.3.5 Response to Drivers, Pressures, State and Impacts in the landscape

In Nasarawa State, Nigeria, the Doma-Ruttu landscape falls within the state government's jurisdiction. The state government has laws, policies, and institutions to promote conservation and sustainable natural resource management. One of the key policies supporting conservation in Nasarawa State is the Forestry Law of 2007, which seeks to regulate the state's exploitation, utilization, and management of forest resources. The law establishes the Nasarawa State Forestry Commission, which oversees the law's implementation and the sustainable management of forest resources in the state. Essentially, the law is to "make provision for the conservation, management and effective use of forest and the declaration of forest reserves, prevention of deforestation and control of forests, and for matters connected."

In addition to the forestry law, there is the Nasarawa State Environmental Protection Agency (NASEPA), which is responsible for ensuring compliance with environmental regulations in the state, including those related to natural resource management and conservation. Furthermore, the state government has also established various programs and initiatives to promote sustainable land use practices and protect biodiversity in the state, such as the Community-Based Natural Resources Management Program, which seeks to involve local communities in natural resource management and conservation.

The Agricultural Policy for Nasarawa State (2019-2027), as part of the quest to achieve sustainable access, availability and affordability of quality food for all the state's people and the country at large, was put together by the current administration. The policy goal is "to significantly improve productivity, expand and improve large scale production, improve storage and processing capacity as well as the required infrastructure to achieve food stability in the state eventually". The pursuant of this policy is, however, yet to be felt or seen to take effect on achieving the twelve stated objectives of the policy.

3.3.6 Summary of the DPSIR Framework for THE Doma-Rutu Landscape

The nexus of the driving forces. Pressure created, state, impact and responses in the landscape are summarized in Figure 3.15.

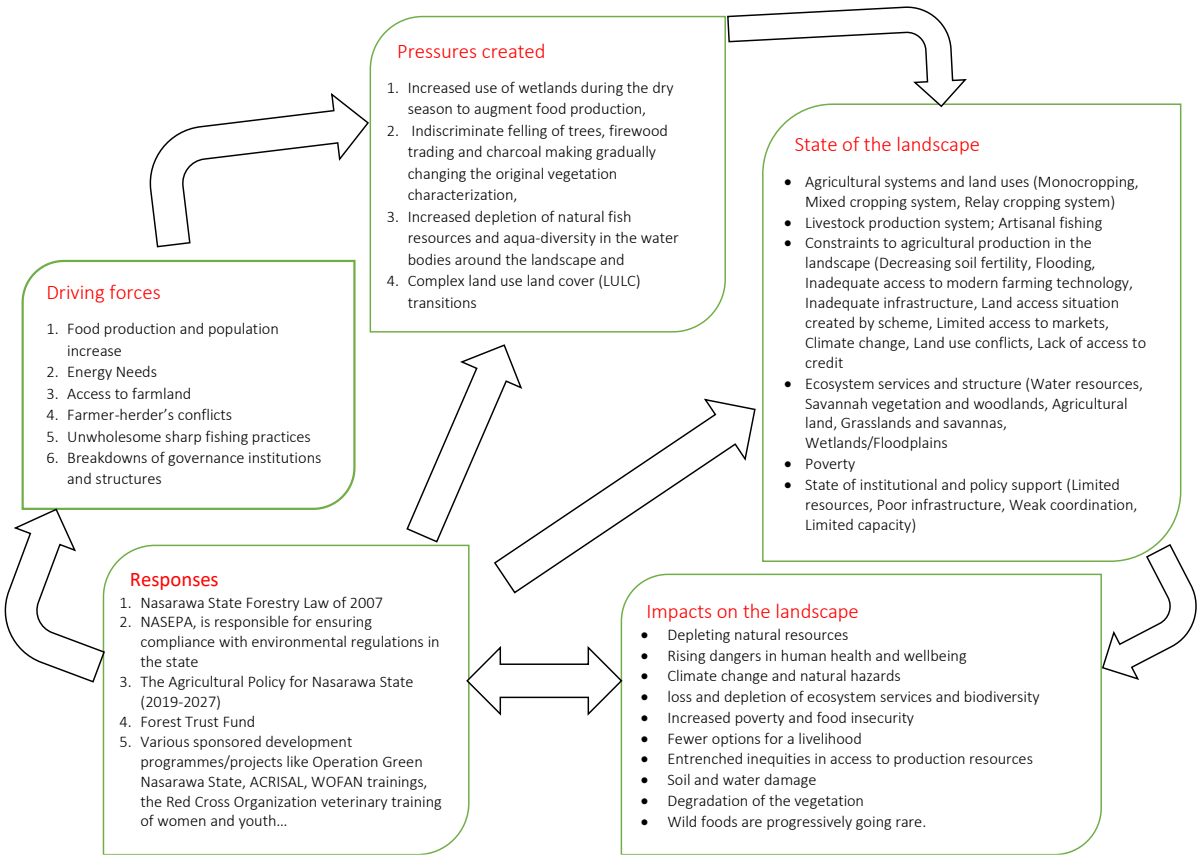

Figure 3.15: The DPSIR Framework for Doma-Rutu Landscape

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The Doma-Rutu Landscape is a lowland with several perennial and semi-perennial streams which flow from different directions into the Ohina River. The Ohina River flows through the landscape after its dammed section (Doma Dam) and discharges into the Mada River. Within the Doma-Rutu landscape are the Doma and Rutu Irrigation Schemes, which are not functional during the season. However, the landscape is dotted with floodplains/wetlands, which farmers in and outside the villages in the landscape cultivate to paddy rice and other vegetables during the dry season. These floodplains are usually inundated during the rainy season, but as soon as the water abates, privileged owners of farmlands around the plains use them for flood-recession agriculture. Deforestation of the trees along the floodplains is also happening. The farmers do so to increase the size of farmland used for flood-recession paddy rice production. This practice is unhealthy for the biodiversity and sustainability of the landscape's natural resources.

The Doma and Rutu Irrigation schemes that are not used during the dry season are a major driver of the pressure the landscape is exposed to. Since a larger part of the land held by the schemes is left uncultivated during the dry season, the area becomes an unofficial grazing hub for livestock belonging to roaming pastoralists. With the vegetation grazed, the land is left bare and susceptible to degradation by agents of erosion. The eroded sediments are eventually taken down

to the floodplain/wetland, increasing siltation and shrinking the water holdings. This effect decreases land mass for flood recession farming, and the farmers have deforested the floodplains.

A section of the massive floodplain in the landscape around the Mukaiya-Doma is under threat of extinction by urban settlement. The Doma town boards this floodplain, which is a hub for the cultivation of sugarcane and vegetables, and human settlements are encroaching rapidly in the floodplain. Besides the possible extinction of the floodplain, the buildings and the dwellers are exposed to flooding and its devastating consequences.

The major competing land uses/cover in the Doma-Rutu landscape include agriculture, urbanization, forestry, irrigation, fishing, hills, bare surfaces, and roads. Agriculture in the landscape has increased from 9 to 17 % over two decades, with land area cultivated increasing from about 1800 ha to 3200 ha. Thus, the area cultivated under dry season farming has doubled. Since the vast land occupied by two irrigation schemes in the landscape is not developed, pressure is mounting in the floodplains, which dotted the entire landscape and are now under threat of possible water stress soon.

4.2 Recommendations

- To sustain the wetlands/floodplains for dry season farming, the farmers must be organized and trained in effective water management to improve their practices and increase productivity.
- Prospect for groundwater within the fringes of the floodplains to support irrigation during the dry season and to expand irrigated areas. Tube wells and Aquifer Storage and Recovery technologies (also called Bhungroo) should be explored in this regard.
- Innovative water management techniques and technologies, such as alternate wetting and drying technology for paddy production using pipe irrigation systems to convey should be adopted to replace the open water conveyance method.
- The Doma and Rutu, irrigation scheme custodians, must put the vast land under their command to productive use during the dry season. This will minimize the rapid degradation caused by erosion and the pressure on the floodplain due to eroded sediment deposition.
- Alternative fuel sources for domestic/household use, especially converting and using the paddy rice husks and stubble briquettes, biogas and deployment of the AfricaRice Gasifier technology is strongly recommended. This may reduce the pace of deforestation in the landscape. Meanwhile, the relevant government ministries should be given to raising native tree seedlings to re-forest marginal lands that are exposed to degradation.
- Open grazing takes place in the vast landscape after harvesting rain-fed crops. Therefore, paying attention to the practice of open grazing by livestock in the landscape is recommended.
- Establishing laws that mandate the continuous gathering of reliable environmental data, land cover and changes to inform experts' decisions on agricultural systems and provide reliable environmental decision support tools is recommended. This will improve land use planning, enhance better management of natural resources, and improve resilience to climate change.
- There is a need for increased government presence in the landscape to create the enabling environment that will enhance stakeholders' inclusiveness in managing the landscape's natural resources, prevent existing and potential conflicts, and halt the degradation of the landscape.

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