International Journal of Environment and Climate Change

Volume 14, Issue 7, Page 425-434, 2024; Article no.IJECC.118964
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Participatory Approach to Irrigated Landscape Ecosystems Boundary Determination: Use of Transect Walk and Focus Group Discussion

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/ijecc/2024/v14i74282

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/118964

Original Research Article

Received: 02/05/2024
Accepted: 04/07/2024
Published: 11/07/2024

ABSTRACT

Agricultural landscapes are continuously changing under the influence of humans and nature, resulting in a variety of local impacts. Agricultural landscapes are the visual result of land uses that represent the cultural landscape group with origin, structure and ecological relations that differ from the natural landscapes. In the White Volta Basin (WVB), ecosystem boundaries are dynamic in both space and time, periodic evaluation is required to determine the boundaries and ecosystem services on which community livelihood depends on. The objective is to identify and evaluate the characteristics of the ecosystem's boundaries and services in Irrigation Projects. Transect walk and focus group discussions are Participatory Rural Appraisal tools used. These participatory methods enabled the active participation of community members in research. Transact walk provided information on visual and physical characteristics in the ecosystems and focus group discussions with a checklist on thematic areas provided in-depth information on the ecosystem services'

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Cite as: *ZB, Gandaa. 2024. "Participatory Approach to Irrigated Landscape Ecosystems Boundary Determination: Use of Transect Walk and Focus Group Discussion". International Journal of Environment and Climate Change 14 (7):425-34. https://doi.org/10.9734/ijecc/2024/v14i74282.*

availability and uses. Transect walk not only identifies ecosystem boundaries in a landscape but also aids in the evaluation of the type of provisioning services available between boundaries. From the study, it was established that irrigate ecosystems can be partitioned into catchment, upstream, midstream, and downstream with very distinct boundaries and specific ecosystem provisioning services accessible in the demarcations.

Keywords: Landscape; ecosystem boundaries; ecosystem services; rural livelihood; provisioning ecosystem services.

1. INTRODUCTION

Agricultural landscapes are continuously changing under the influence of humans and nature, resulting in a variety of local impacts [1,2]. Agricultural intensification and short fallow periods are frequently observed but do not necessarily result in land degradation and a decrease in ecosystem services.

Kizos and Koulouri, [3] defined agricultural landscapes as the visual result of land uses that represent a cultural landscape group with the origin, structure and ecological relations differing from natural landscapes considerably. Sustainable ecosystem services in rural communities need the maintenance of equilibrium between the productive, economic and social function of the agricultural landscape and its ecological function, including maintaining biodiversity. Agricultural landscapes contain numerous plant and animal organisms not connected directly with agricultural production, but play important ecosystem functions (Fig. 1). Agricultural landscapes consist of different ecosystems such as grasslands, croplands, home gardens, woodlots, etc. which show clear boundaries between ecosystems in some cases and provide specific ecosystem services [4]. Knowledge of ecosystem boundaries and the types of ecosystem services in the ecosystems are best known by the people in the communities and can be established through transect walks and focus group discussions [5].

Ecological boundaries are classified in several ways. A classification system may be simple and practical defined by most boundary characteristics that ecologists consider [6-9]. These include (1) origin and maintenance, (2) spatial structure, (3) function, and (4) temporal dynamics. These characteristics cover a range of boundary attributes that ecologists have considered which attributes are related to one another and may interact with ecological boundaries. Ecosystem boundaries may change over time as a result of changes in structural or functional properties, mobility (stationary, directional, oscillating, or random) or age and history.

Ecosystem service in an agricultural landscape depends on components of the natural environment, land use system, and the intensity of farming [10]. For instance, in an irrigated landscape, biodiversity exists because of the multi-element structure and heterogeneity resulting in many ecosystem services. Irrigated landscapes are essential elements of the agricultural landscape and are therefore mutually ecologically related to agricultural ecosystems and other ecosystems (Fig. 1).

1.1 Irrigated and Non-irrigated Ecosystems

Irrigated landscapes may be divided into observable and definable ecosystems; these are based on locational convenience, availability of ecosystem services, economic need, management, or land use compatibility [11].

In the White Volta Basin, there are many irrigated and unirrigated landscapes but the irrigated landscapes are perceived to be important because of extensive alteration of ecosystems during the development of irrigation projects which has resulted in the improvement of some ecosystem services (Food) and reduction of some, especially in cultural ecosystem services. The Tono (TIP), Bontanga (BIP), and Sisili-Kulpawn Irrigation (SKIP) projects are considered for this study; because of the large potential irrigation area (over 500,000 ha) that they cover.

Ecosystems in the White Volta Basin are demarcated with fences/hedges, and natural barriers (streams, hills, etc.) and often separated by different plant or animal groups for management convenience rather than as a productive unit. A field may thus compose of a single ecosystem or collection of agroecosystems that serve a common objective within the limits of the demarcated area.

An ecosystem in this paper is regarded as an interacting system of biota and its associated physical environment, which is identifiable at many different scales with boundaries that define their internal and external interactions [5]. Ecosystems' functions and services cannot, therefore, be clearly delineated by spatial boundaries within a landscape.

It is observed that in the White Volta Basin, the ecosystem boundaries are dynamic in both space and time and therefore need periodic evaluation to determine the availability of ecosystem services that rural communities depend on for their livelihood. This is believed to be as a result of climate variation in the sub-region.

The objective of the study is to identify and evaluate the different ecosystems in irrigation landscapes based on physical characteristics (land use, soil type, vegetation, crops cultivated, etc.), ecosystem services, and the location of key resources in order to determine the boundaries of the ecosystem in irrigated landscapes in the White Volta Basin.

2. METHODOLOGY

2.1 Study Area

The study was conducted in 2015 - 2016 in the White Volta Basin. The basin is bound to the east by the Oti River Basin, to the west by the Black Volta River Basin, and to the south by the Main/Lower Volta sub-basins. Burkina Faso forms its northern boundary. The White Volta Basin in northern Ghana is characterized by fairly low relief, with few areas of moderate elevation in the north and east. The drainage area of the basin is about 20% of Ghana's total land area and constitutes about 44% of the total area of the White Volta River Basin, also called Nakanbé River in Burkina Faso [12]. The White Volta Basin consist of non-irrigated and irrigated, with several small, medium, and large-scale irrigation schemes. Tono, Bontanga, and Sisili-Kulpawn Irrigation Projects are located in the White Volta Basin in northern Ghana.

Desk top studies were conducted and participatory tools used included, community entry, ground-truthing, transect walks focus group discussion (FGD), household questionnaires, and key informant interviews. A total of 180 questionnaires (60 in each landscape) were administered with a checklist for FGD in the communities. Four landscapes, Tono, Bontanse, Sissili/Kulpawn rivers, tributaries of the White Volta.

The transect walks in the landscapes were conducted starting from catchment to downstream through the communities. Land use, soil type and level of erosion, vegetation, crops cultivated and communities within a landscape were identified. The transect walks were led by community elders (between 3 - 5 members, Tindana[1] inclusive). Transect walks were along river Bontase in BIP, Tono River in TIP and Sisili-Kulpawn River in SKIP. Checklists on the thematic areas of the study were discussed. Expect interviews were also carried out with chiefs, opinion leaders, and Tindanas in some communities.

3. RESULTS AND DISCUSSION

3.1 Community Entry

In entering a community, the linguist and town crier was identified, who then informed the chief. Following a successful outcome of the meeting, permission was given for the start of the research. The community members were thereafter informed of the outcome of the meeting. The process offered establishment of the relationship with community members, because of community members.

Focus group discussions enabled the assessment of the types of the ecosystem (provisional and cultural) services available and ranking gave an indication of the most needed and available service and location to a household. Food, water, cash, energy, spiritual enrichment, and fiber were identified as important ecosystem services necessary for the sustenance of livelihood in rural communities (Table 1). However, the quantity and type depend on the demography and distance of a household in the ecosystem.

The ranking results showed the demand for ecosystem services in the landscapes. In SKIP and BIP landscapes food was ranked first however in TIP, food was ranked second. Cash was ranked first in TIP and second in the other three landscapes. Water, spiritual enrichment, craft/roofing materials, fodder, fuelwood, and fiber were ranking were different depending on the need and availability of the ecosystem service in a landscape (Table 1).

[1] *Custodian of land in a community*

Women on the other hand, in all the landscapes, ranked food as the most important, and with water, women in SKIP, BIP, and Soo ranked it second while in TIP it was ranked fourth. The other ecosystem services by women followed the same pattern (Table 1).

Some of the ecosystem services were observed to be more important to men than women. For instance, spiritual enrichment was observed to be very ranked high in some landscapes TIP. Fuelwood and water were considered important to women and thus ranked high. During the Focus group discussions (FGDs), participants also indicated areas in landscapes where these ecosystem services are available and can easily be accessed. This is clear evidence in northern Ghana that men are not very much interested in available ecosystem services that affect women. Services such as water provision, fuelwood, picking shea fruits, etc. do not interest men and are not the priority of men as can be observed in Table 1. Men claimed that traditionally, harvesting fuelwood and fetching water are part of the domestic roles assigned to women.

Generally, in the landscapes, household interviews indicated quite similar findings to that of FGD, except that some services which were not considered at FGD were in the view of households very necessary. For example, herbal medicine was one of the services not considered at the FGD, which was considered very necessary for households, because of the lack of formal health care.

Food, in the household questionnaire ranking in the study area, was ranked first ecosystem service (22.2%), followed by cash with 17.9%. Traditional religion is one of the was highly respected in the study area. Traditional beliefs were ranked third in households (10.9%). An interesting observation was the low ranking of water and fodder by men, with water being the least. At the landscape level, there was no difference between Soo and SKIP in the household ranking of food each had 15 households, and no significant difference between BIP and TIP, 13 and 12 households, respectively. TIP landscape had the highest household number for cash but surprisingly, the Soo landscape had a higher number than the BIP landscape. This may be due to higher business opportunities in terms of ecosystem services. Water and traditional spiritual beliefs ranking showed the same trend as that observed in FGD.

3.2 Identification, Categorisation, and Management of Ecosystems

The ecosystem boundaries in the White Volta basin are complex and therefore triangulation of indigenous and scientific knowledge was used to understand the processes in an ecosystem helps in defining ecosystem boundaries. For instance,

Table 1. Community FGD Ranking Ecosystem Services

Ecosystem Services Ranking – Men			
Ecosystem service	**TIP**	**SKIP**	**BIP**
Food	2	1	1
Cash	1	2	2
Water	6	4	3
Spiritual enrichment	3	5	5
Fodder	5	3	4
Craft	7	6	8
Fibre	4	8	7
Fuelwood	8	7	6
Ecosystem Services Ranking – Women			
Ecosystem service	**TIP**	**SKIP**	**BIP**
Food	1	1	1
Water	4	2	2
Cash	2	4	3
Fuelwood	3	3	4
Fodder	6	5	6
Fibre	5	7	5
Craft	7	6	8
Spiritual enrichment	8	8	7

Source: Field Survey. (2018)

the ecosystem boundaries of Bontanga Irrigation Project boundaries the development irrigation was a forest ecosystem of Northern Region with no distinct boundaries, the Tono Irrigation landscape used to serve as a wildlife corridor between Burkina Faso and Mole Game Reserve in Ghana, while the SKIP landscape has luxuriant pastures and serves as a passage for nomadic herdsmen from Burkina Faso and Mali to Southern Ghana for several decades [3].

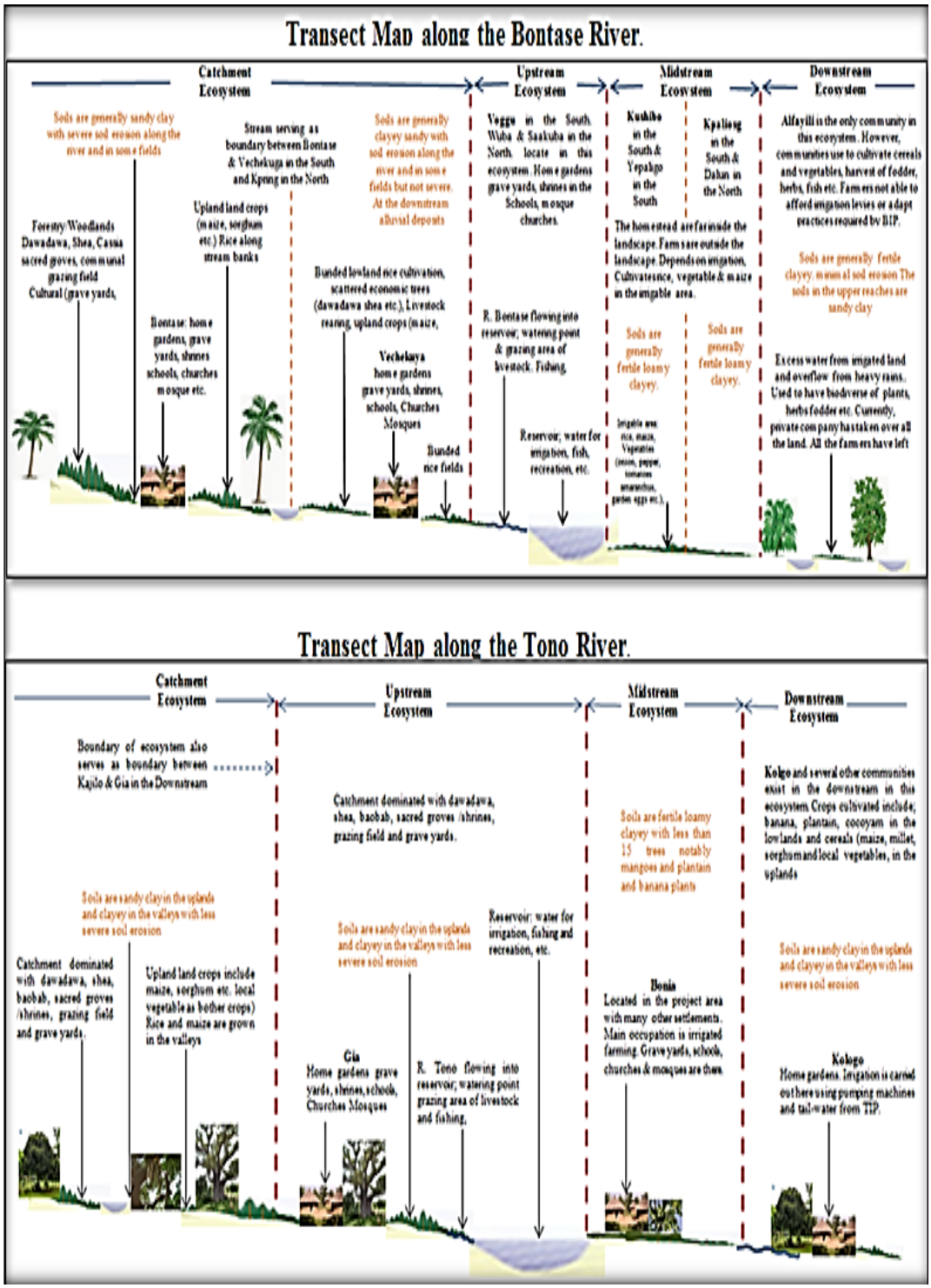

Fig. 1. Transect maps along the Bontase and Tono Rivers

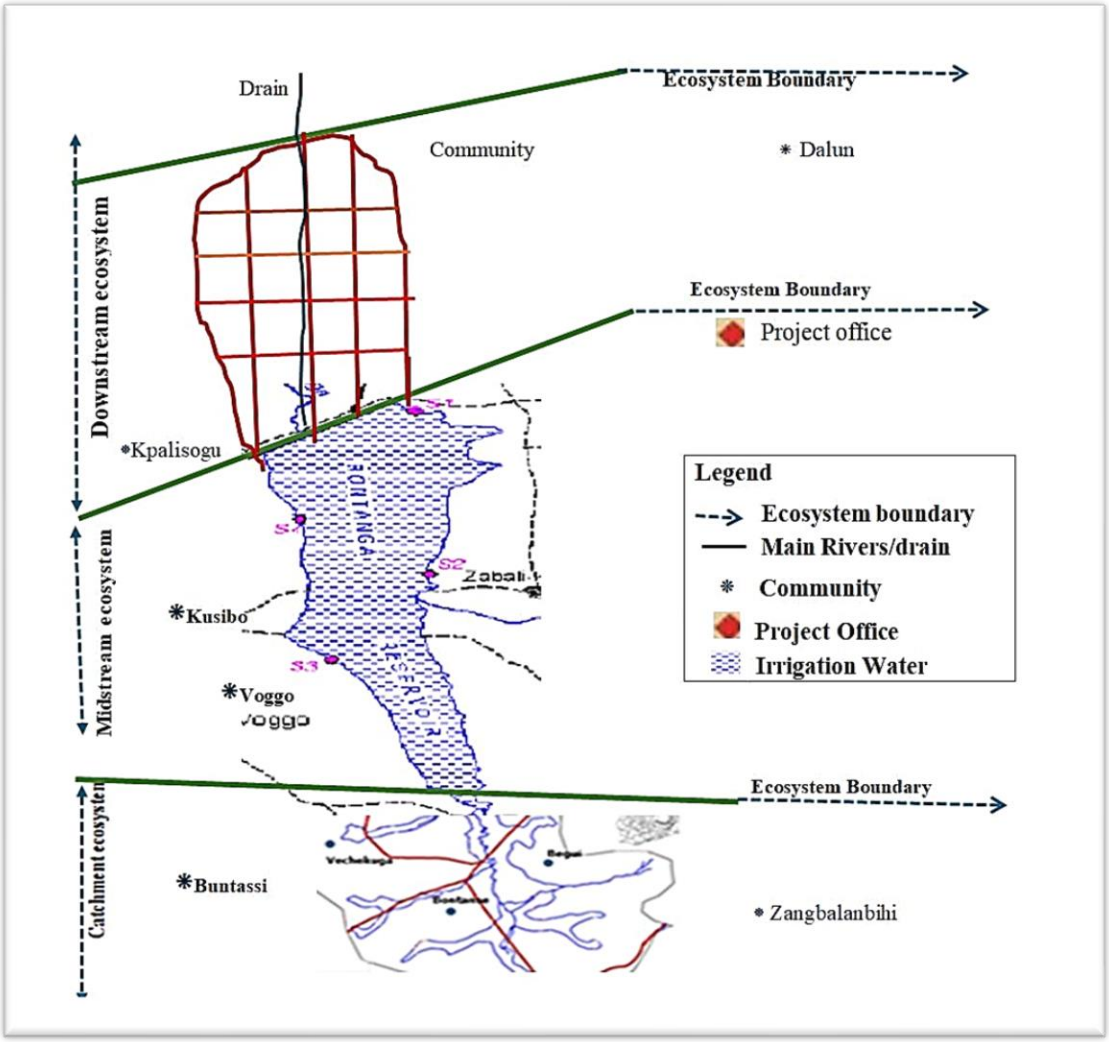

Fig. 2. Ecosystem Boundaries in BIP Landscape
Source: Field Survey, 2016

The Soo landscape has a high potential for crop production e.g., rice maize, etc., and other crops. Before the development of irrigation infrastructure, it was difficult to detect boundaries between ecosystems, but with irrigation development, the emergence of climate change, wild bush fires, and human interference several ecosystems have emerged. Identification and categorization of ecosystems in the landscapes for this study was done with the use of biophysical features, availability and access of ecosystem service, and observations during participatory transect walks.

3.3 Boundaries of Ecosystems in Irrigated and Rain-Fed Landscapes

Transect maps (Fig. 1) developed from the walks and other data mentioned above gave clear distinctive marks between boundaries in the landscapes. Physical characteristics such as land use, soil type and level of erosion, vegetation, crops cultivated, etc., and ecosystem services such as food, spiritual enrichment, fodder, fuelwood, etc. were clear indicators for categorization during the investigation [13]. Ecosystem services in the different ecosystems identified by community members were also an indicator used in defining an ecosystem boundary. The trend of the above indicators, from less dense in the catchment area to denser downstream of rivers and streams also serve as the boundaries between ecosystems.

Ecosystems in the landscapes were categorized into catchment ecosystems, which consist of ephemeral streams, trees, shrubs, upland crops farmlands, home gardens, and grazing fields:

Upstream ecosystem contains the reservoir and vegetation: the Midstream ecosystem is the irrigable area with cultivated crops and very few trees; Downstream ecosystem, the area where drainage water collects, fodder, herbs, food etc. The boundaries between the ecosystems are indicated by thick green lines (in Fig. 2 – Fig. 4).

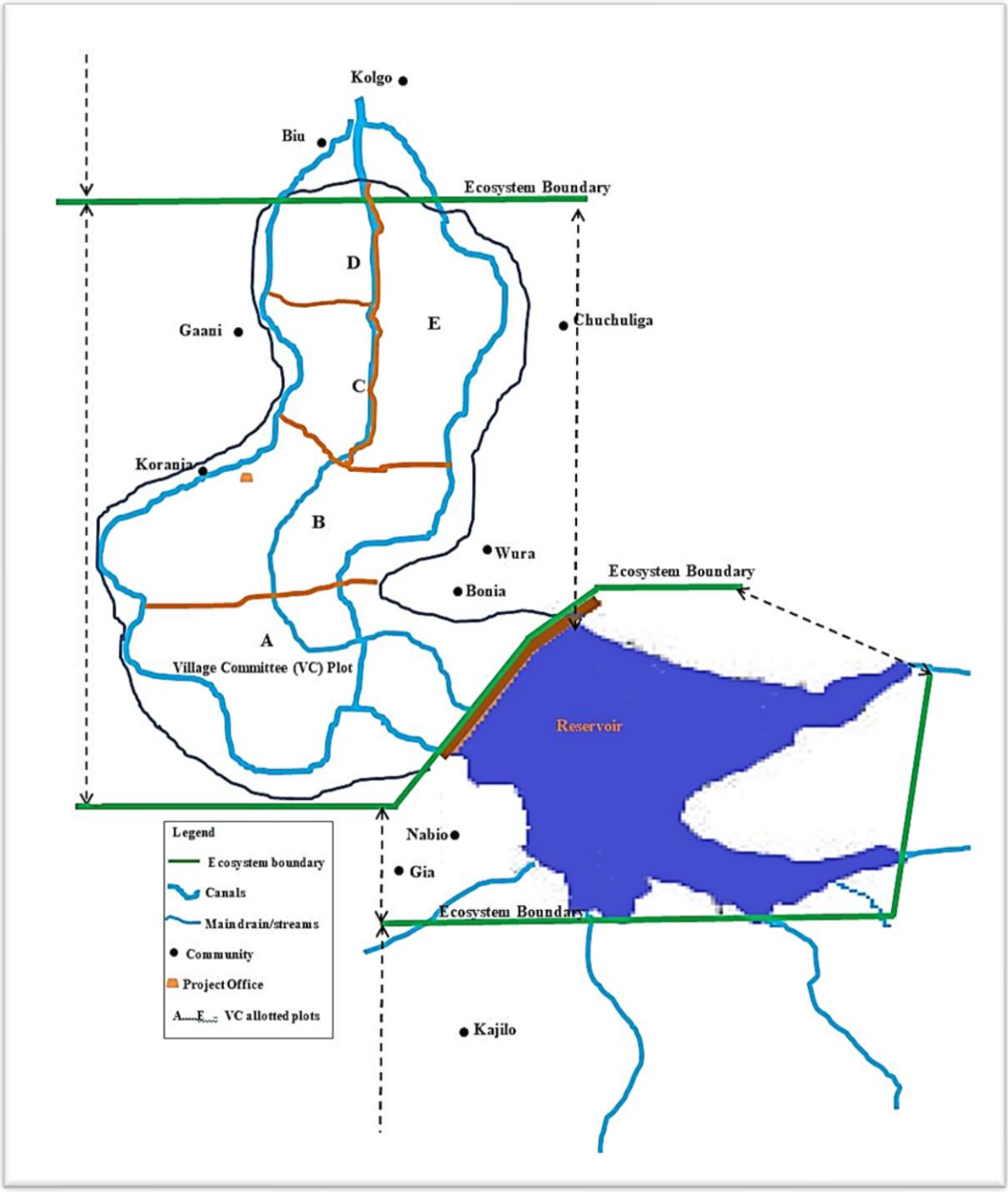

Fig. 3. Ecosystem boundaries in TIP landscape
Source: Field Survey, 2016

Catchment Ecosystem: This ecosystem (as indicated in the maps) is characterized by relatively poor gravelly soils, and mild and severe gully erosion (Table 2). Rainfed farming is widely practiced with upland crops and small ruminants reared on free-range during the dry season but tethered during the farming season. The vegetation consists of predominant economic tree species such as Dawadawa (*Parkia biglobosa*), shea (*Vitellaria paradoxa*), kapok (*Ceiba pentandra*), baobab (*Adansonia digitata*), and whitethorn (*Faidherbia albida*) with ground cover of perennial grasses, such as *Andropogon gayanus.* Strings of ponds exist in rainy season which dry up in the dry season thus making households and livestock congregate around dug-out and bore-holes (if any exist) of water. Communities in this ecosystem are of close proximity to reservoirs in the upstream ecosystem. Very few ecosystem services such as fruits and herbs for medicine are accessible in this ecosystem. During the dry season, ecosystem services are very scarce in this ecosystem.

Upstream Ecosystem lies between the Catchment and Midstream ecosystems. The reservoir of large and scale dams lie in this ecosystem. Ecosystem services in this ecosystem include both from the vegetation (Fencing wood, food, herbs and materials to meet cultural and social services) and the reservoir (with aquatic life – such as fish, frogs etc and fodder for livestock). Livelihood of households in this ecosystem is better-off than in the catchment ecosystem.

Fig. 4. Ecosystem Boundaries in SKIP Landscape
Source: Field Survey, 2016

Table 2. Ecosystem Characteristics in Landscapes

Ecosystem	Description	
	Irrigated Landscape	**Rain-fed Landscape**
Catchment	Ephemeral streams, trees, shrubs, sacred groves/shrines, home gardens, grazing fields etc.	Sacred groves/shrines, trees, shrubs, farmlands, home gardens, grazing fields etc.
Upstream	Dam reservoir with aquatic life (fish, frogs etc.) and grass for livestock, with very few indigenous trees.	Farmlands, string of temporal ponds, tree of different type fertile soils, trees sacred groves/shrines
Midstream	Irrigable area (exotic crops) crops, few exotic trees (neem, cassia etc.) and very few indigenous trees (Dawadawa)	Dominated by rice and maize fields, trees, grass (fodder), permanent ponds very few trees
Downstream	Drainage water from irrigation schemes collects here. Grass, fodder, herbs etc. Most ecosystem provisional services not available in the other ecosystem are accessible here	Fertile soils, farmlands, grass (fodder), trees, sacred groves/shrines. Liable to flooding during rainy season. Traditional irrigation is practiced here using shallow wells and overhead watering.

Source: Field Survey, 2018

Midstream ecosystem lies between the Upstream and Downstream ecosystems and it comprises of the irrigable area and vegetation in the upper reaches where rain-farming is done [14]. Erosion in this ecosystem is minimal with cultivated crops and very few trees (Table 2). The limited tree population in this ecosystem is due to the mass land preparation during the development of the irrigable area and the slow rejuvenation of the vegetation that was left to natural regrowth and development.

Downstream ecosystem, the soils in this ecosystem are sand-clay are very fertile with less erosional features. According to farmers, the soils are very fertile and they seldomly use fertilizers because of their proximity to the main streams. The soils in this ecosystem are not prone to severe flooding in wet years due to the relatively thick vegetative cover and clayey nature of the soils. The vegetation is comparatively thicker than in the other ecosystems which also reduces rainfall impact on the soils and runoff. Traditional irrigation is practiced with drainage water through shallow wells and applied overhead. In this ecosystem, most of the ecosystem services not available in the other ecosystems are accessible [14,15].

4. CONCLUSION

Ecologists use the term boundary (or edge) to refer to a wide range of conceptual and tangible structures. Boundaries are important for ecological studies (precisely ecosystem management) to specify the type of boundary they are investigating this because different boundaries have different structural and functional characteristics. The intent of the study is to identify and demarcate ecosystem boundaries in large irrigation schemes which defines not only the type of ecosystem services available but also their accessibility.

Transect walks and focus group discussions were observed as necessary tools in identifying and categorizing ecosystem services available between ecosystem boundaries. Household interviews shows how accessible the ecosystem services are available within boundaries and their contribution to sustaining livelihood of community members.

In large-scale irrigated scheme landscapes in the White Volta Basin, clear boundary demarcations were identified as Catchment, Upstream, Midstream and Downstream Ecosystems. The boundaries between ecosystems have different characteristics of ecosystem services and uniqueness. Also, some common ecosystem services exist in landscapes in White Volta Basin but of varying quantities and ease of accessibility from the Catchment to the Downstream Ecosystems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image

generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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