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179

Dependence of Riparian Communities on Ecosystem Services in Northern Ghana

Marloes Mul, Laetitia Pettinotti, Naana Adwoa Amonoo, Emmanuel Bekoe-Obeng and Emmanuel Obuobie

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Project

This work was undertaken as part of the Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes (WISE-UP to Climate) project. This project aims to demonstrate how natural infrastructure as a 'nature-based solution' contributes to climate change adaptation and sustainable development. The project has developed knowledge and options on the use of portfolios of built water infrastructure (e.g., dams, levees, irrigation channels) and natural infrastructure (e.g., wetlands, floodplains, watersheds) for poverty reduction, water-energy-food security, biodiversity conservation, and climate resilience. The project is working in the Volta River Basin (Ghana, principally, and also Burkina Faso) as well as the Tana River Basin in Kenya.

The project is led by the International Union for Conservation of Nature (IUCN) and involves the Council for Scientific and Industrial Research - Water Research Institute (CSIR-WRI); African Collaboration Centre for Earth System Science (ACCESS), University of Nairobi; International Water Management Institute (IWMI); Overseas Development Institute (ODI); University of Manchester; and the Basque Centre for Climate Change (BC3). The project is part of the International Climate Initiative. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety), Germany, support this initiative on the basis of a decision adopted by the German Bundestag.

For further details about the project, visit: www.waterandnature.org or www.iucn.org/water_wiseup

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Contents

Acronyms

BI	Built Infrastructure
CBO	Community-based Organization
CREMA	Community Resource Management Area
CSO	Civil Society Organization
ES	Ecosystem Services
FGD	Focus Group Discussion
FSD	Forestry Services Department
GSP	Global Positioning System
ITCZ	Intertropical Convergence Zone
NI	Natural Infrastructure
NTFP	Non-timber Forest Product
PGIS	Participatory Geographic Information System
PMD	Pwalugu Multipurpose Dam
PRA	Participatory Rural Appraisal
SADA	Savannah Accelerated Development Authority
VRA	Volta River Authority

Summary

Natural infrastructure supports large parts of the rural communities in northern Ghana through the generation of ecosystem services that it provides. The provisioning of ecosystem services is a function of the seasonal nature of the climate in northern Ghana. Natural infrastructure enables food provision, which translates into food security and generates income through the year while providing an important safety net during the dry season. Rainfall is concentrated in the period from May to September followed by a long dry season. The river, responding to the climate, shows similar seasonality, flooding large parts of land during the rainy season and drying up during the dry season. Natural water infrastructure supporting riparian communities, such as headwater catchments, wetlands and seasonal floodplains, is affected by water resource development decisions. This study investigated the dependence of three riparian communities on ecosystem services in northern Ghana. In particular, the role of natural water infrastructure in supporting these ecosystem services. Participatory mapping and ranking exercises in gender-segregated groups were used to elicit information on the communities' livelihoods.

The riparian communities are dependent on five types of natural infrastructure: forest reserves, shrubs and woodlands, riparian ponds, the White Volta River and floodplains. Different ecosystem services are derived from natural infrastructure and these enable livelihood activities. The most important activities are farming, fishing, livestock watering and grazing, and collection of wild fruits and vegetables, as well as provision of water for domestic use. The major ecosystem service-based activities (agriculture - 95% participation, fishing - 70% and livestock keeping - 87%) are dependent on the seasonal flows of the White Volta River. Floods occur annually between July and September depositing fertile soils on the riverbanks and increasing soil moisture content that supports flood-recession agriculture. The flooding also fills riparian ponds, restocking them with water and fish. Residual moisture in the soils around the ponds enables grass and reed growth, which supports livestock grazing on the floodplains during the dry season and provides raw materials for weaving.

During the lean season, at the end of the dry season, when limited income is generated from agriculture, other food and income sources support the communities. The protected forest and the woodlands that are not directly dependent on the river flow provide biomass for energy (firewood or charcoal for direct consumption or selling) as well as wild foods (shea nuts and dawadawa fruit) that contribute to the communities' coping strategy during the lean season. The traditional fishing regime of the ponds is managed in a way that ensures maximum income is generated from fishing at a crucial time of the year. Fishing is restricted until the end of the dry season, ensuring that fish grow to a reasonable size. The fish are then caught by both male and female members of the communities.

Provision of ecosystem services is under pressure due to climatic and other anthropogenic changes. For example, delays in the start of the rainy season are affecting rainfed agricultural activities on the floodplains. Delayed planting on the floodplains results in damage to, or loss of, crops as floods arrive before the harvest. Unsustainable natural resource management, related to over-abstraction of resources from the forests, shrubs and woodlands, reduces ecosystem service provision in the long run.

Moreover, the Bagré Dam in Burkina Faso, built upstream of the communities, has impacted the natural river flow both positively and negatively for the communities. It currently provides dry-season flow, which is used by the communities for dry-season irrigation and for domestic purposes when other sources of water (boreholes) have dried up. However, in the past, the Bagré Dam has been forced to release emergency spills for dam safety reasons at the end of the wet season. This

has washed out crops and caused loss of human lives in downstream Ghana. The planned Pwalugu Dam (with a larger storage capacity than the Bagré Dam) may, depending on the final operations, increase baseflow and also affect the flooding regime of the White Volta River, potentially reducing flood-dependent ecosystem services. We, therefore, recommend that operations of the Pwalugu Dam should take into consideration releasing sufficiently large flood flows that support ecosystem services while minimizing the release of large damaging floods.

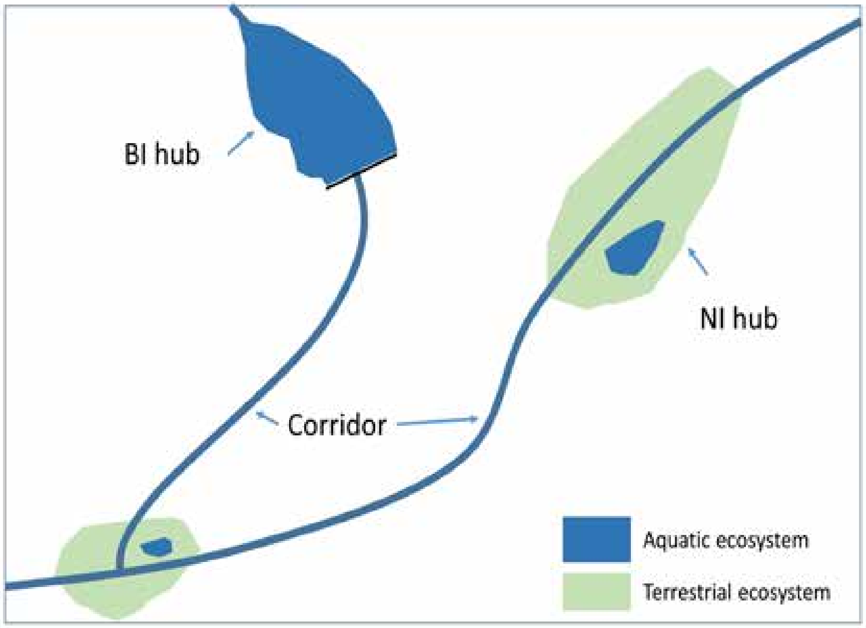
INTRODUCTION

Water is a key factor in human lives, not only in sustaining lives but also in contributing to food production and income generation. In sub-Saharan Africa, water availability is highly dependent on the seasonality of rainfall through the movement of the Intertropical Convergence Zone (ITCZ). Long seasonal periods without rainfall are not uncommon in the region. During these periods, rural communities are dependent on water sources stored during the wet season. Many communities have, therefore, settled down close to water sources such as rivers and wetlands to bridge the lack of water during such periods. However, living close to these water sources also comes with challenges, as the communities are at risk of damaging floods. In the past century, water resources development has attempted to store water to overcome seasonal and inter-annual variability in rainfall through the construction of dams, thereby contributing to economic development via hydropower production and irrigation development. However, this development also comes at a cost to riparian communities (WCD 2000), whose dependence on the natural system or infrastructure and its variability is affected by the construction and operation of these dams. This impact is rarely quantified and hence there are only a few cases where natural infrastructure is taken into consideration in the same way as built infrastructure.

The 'WISE-UP to Climate' project was established to demonstrate the value of natural infrastructure for climate change adaptation and sustainable development in river basin management. Natural infrastructure comprises networks of ecosystem hubs on the landscape interconnected by corridors (Figure 1). In river networks, aquatic hubs are natural lakes and wetlands as well as reservoirs. Corridors are the rivers connecting the hubs, which also include connecting terrestrial ecosystems such as forests, grassland and agroecosystems. Natural infrastructure (NI) provides benefits such as provisioning services, flood control, sediment trapping, water purification and generally higher levels of biodiversity, leading to greater system resilience compared to built infrastructure (BI) (Balvanera et al. 2006). BI such as dams provides benefits including energy production via hydropower generation and increased food production through irrigation. In addition, it provides a range of benefits similar to the benefits provided by NI, although less diverse in many cases and with fewer co-benefits (McCully 1996). Often, BI is seen as creating benefits at the cost of ecosystem services (ES) (Richter and Thomas 2007; WCD 2000; Postel and Richter 2003; MA 2005). However, controlled releases from the dams can support important natural ecosystem functions, when released in a timely manner with sufficient magnitude and frequency, although this may create a trade-off with hydropower and irrigation, as it will leave less water in the dam.

To understand and properly manage the benefits derived from NI (i.e., ES), the benefits need to be identified and quantified. ES are people focused, in the sense that the services are *to* human beings. ES are defined across landscapes at multiple scales and contribute to human well-being. Commonly understood ES definitions can be found in the literature (see Box 1) and often serve as the basis for research for development.

FIGURE 1. Conceptualization of hubs and corridors in a river network.



Note: BI – Built infrastructure; NI – Natural infrastructure

ES are commonly divided into four categories (TEEB 2010):

- Provisioning services – products obtained directly from ecosystems, such as food, freshwater, fuel, firewood, fiber and medicine.
- Regulating services – benefits obtained by regulating ecosystem processes, such as climate, floods, disease and water quality.
- Cultural services – material and non-material benefits derived from ecosystems, such as aesthetic, spiritual, educational and recreational benefits.
- Habitat services – species life cycle maintenance and genetic diversity.

Box 1. Commonly used definitions of ecosystem services.

"the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (**Daily 1997)**

"the combined actions of the species in an ecosystem that perform functions of value to society" (**Walker and Salt 2006)**

"the benefits that people obtain from ecosystems" (**MA 2005)**

The focus of the WISE-UP to Climate project is on ES that are related to water flows, either due to their flow regulating function or because they are modified by changes in water flows (WLE 2017). In this study, the focus is on the latter. NI, such as wetlands, floodplains and riparian vegetation, generates its benefits from the natural flow regime, and changes due to, for example, construction and operation of an upstream dam may have consequences for the provision of ES. Earlier studies have shown qualitatively (MA 2005; TEEB 2010) and quantitatively (see Barbier et al. 1991; Loth 2004; Hamerlynck et al. 2016; Turpie et al. 2006) the reliance of NI on river flows.

We selected riparian communities and assessed the different types of NI they depend on and the type of ES they obtain from each NI. The relative contribution of these ES and NI towards local livelihoods was assessed through qualitative and quantitative approaches. In this study, it was important to identify the role of the White Volta River in supporting the NI and its benefits, as these are potentially at risk from changes in flows.

This paper presents the results of a qualitative participatory rural appraisal in the White Volta River Basin in Ghana to identify – according to the benefiting communities - the key NI that provides the services that support riparian livelihoods in a gender-disaggregated way. The NI dependent on the river flows was then identified. Key drivers of change influencing the provision of ES were identified and their qualitative potential impact on NI and ES was determined.

STUDY AREA

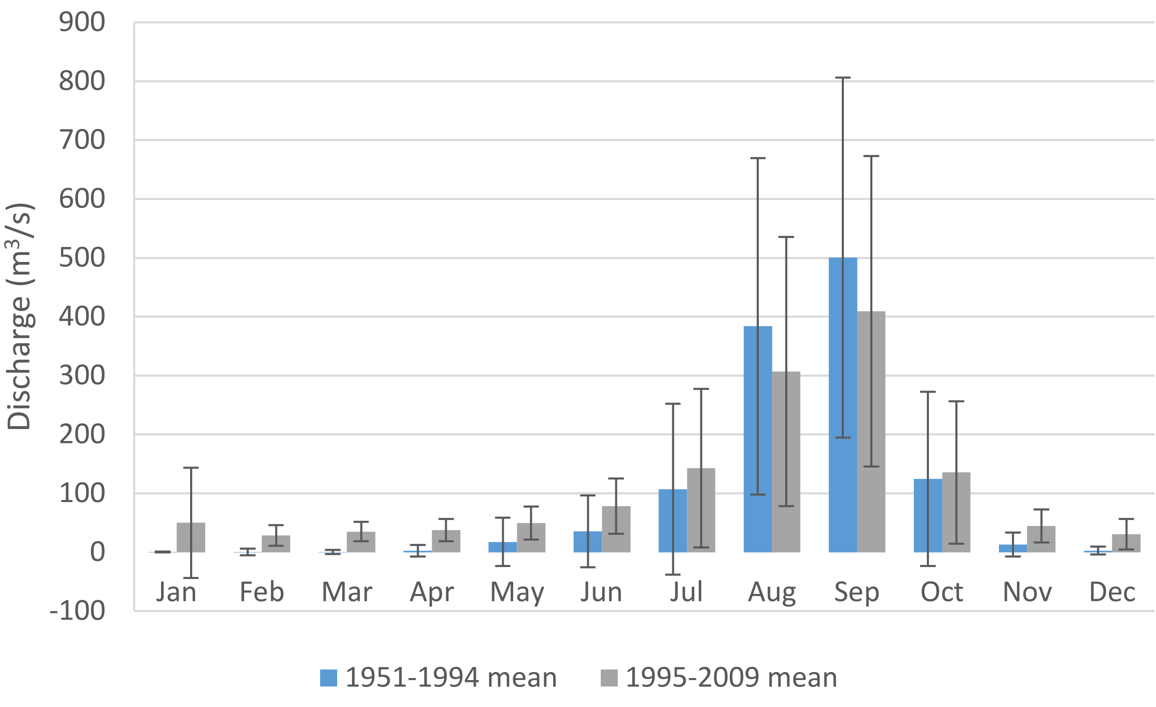
Biophysical Background

The White Volta River flows from Burkina Faso into the three northern regions of Ghana: the Upper East, Upper West and Northern regions. The area has a strong seasonality in both the climate and surface water availability. The climate in the three northern regions is characterized by a single rainy season between the months of May and October, with the dry season occurring from November to April. The mean annual rainfall in the area is 991±195 mmy^{-1} and the mean annual potential evaporation is 1,977±34 mmy^{-1} (Navrongo station, Upper East region, 1960-2012; Kadyampakeni et al. 2017). Maximum daily temperature reaches 45 °C in March/April while minimum daily temperature drops to 12.8 ºC in August. The streamflow in the river follows this seasonal pattern, with the peak flows occurring on an annual basis in August and September, overtopping the banks annually (Mul and Gao 2016). The flood can reach up to 1 km inland (Balana et al. 2016). Key land uses in the floodplains are irrigated crops, wetland vegetation, and uncultivated woodlands and rangelands (Balana et al. 2016). Outside the floodplain, major land uses comprise cultivated savanna woodlands, rangelands and settlements/bareland. Generally, the top soils overlay granites and sandstones. Soils are suitable for cereal cultivation and moderately suitable for grazing. On the floodplains, alluvial deposits provide excellent soils for agricultural activities (WCD 2000).

The White Volta River in Ghana is located downstream of the Bagré Dam in Burkina Faso. The Bagré Dam started operations in 1994, with an installed hydropower capacity of 16 megawatts (MW), and a potential irrigated area (Bagrépole irrigation scheme) of 30,000 ha, of which around 3,300 ha are developed at present (Mul and Gao 2016). Electrification in Burkina Faso is very low, and with only one other hydropower dam (Kompienga) (Moner-Girona et al. 2016), hydropower generation at Bagré is of national importance. The dam is operated to maximize hydropower production. During seven out of the 10 most recent years, water spilled from Bagré Dam with the peak flow occurring in the month of September. On an annual basis, 22% of the inflow into Bagré Dam is spilled. However, during peak flow periods, more than 80% of the inflow into the dam is sometimes spilled during the same month (data source: Sonabel, Burkina Faso).

Due to the construction and operation of the Bagré Dam, the flow at Pwalugu has changed (Figure 2). Seasonal drying up of the river between December and April has been replaced by a steady flow regime of 30-40 m^3s^{-1} (Mul and Gao 2016). However, it is expected that, once/if the total potential irrigated area at Bagrépole is developed, the baseflow at Pwalugu would reduce significantly. During the wet season, the peak flows have reduced, although the inter-seasonal variability remains very high. The data show that, although there is a widespread belief that the Bagré Dam has increased the occurrence of floods in Ghana, this is not the case. However, due to the management of the Bagré Dam, in its early years, spilling occurred in an ad-hoc manner when the dam operators felt the safety of the dam was at stake. After the construction of the Bagré Dam, there have been incidences of flooding in Ghana, causing significant damage. It has been reported that the floods in 2007 displaced 200,000-300,000 people and affected agriculture, livestock and infrastructure (Obrecht and Mead 2014). These floods, however, cannot be attributed solely to releases from the Bagré Dam, as the source of floods is a combination of localized rainfall concentrating in tributaries joining the White Volta River in Ghana and river flows coming from Burkina Faso. However, after the 2007 flooding event, Ghana and Burkina Faso have increased their collaboration, resulting in Burkina Faso giving two weeks' notice before the Bagré Dam starts spilling, thereby reducing damage and casualties (Obrecht and Mead 2014).

FIGURE 2. Changes in the flow hydrograph at Pwalugu after construction of the Bagré Dam (mean monthly flows with standard deviations).



Data source: Hydrological Services Department, Ghana.

The regional development plan for the northern regions of Ghana by the Savannah Accelerated Development Authority (SADA) focusses on agriculture-led economic transformation for the SADA zone (SADA 2016). One priority public infrastructure project is the Pwalugu Multipurpose Dam (PMD), which is intended to support agribusiness development in the north by supplying energy and expanding the irrigated area. The planned PMD will be located in Ghana, downstream of the Bagré Dam and upstream of the Pwalugu communities. The confluence of the Red and White Volta rivers is immediately upstream of the planned PMD. Downstream of the PMD, the Tankwiddi tributary joins the main White Volta River. The reservoir will flood the Gambaga Forest Reserve on the border of the Talensi and Mamprusi districts (VRA 2014).

The Pwalugu Dam project has been abandoned and taken up again several times. At the time of writing, the Volta River Authority (VRA) is the lead institution coordinating the feasibility studies and it is expected that they will manage the dam when it is in operation (Mosello et al. 2017). The nationally driven project is perceived as a contribution to addressing the development deficit of northern Ghana, with the objective of reducing flood-related damages, producing hydropower and providing water to an irrigation scheme downstream of the Pwalugu communities. The PMD will have a hydropower capacity of 48 MW, contributing 3% of hydropower capacity to the country (VRA 2014) and supporting the electrification of the northern regions of Ghana. As such, it will support the rural population of Ghana, much of which still lives below the poverty line (Diao 2010). A large part of the investment cost of the dam is envisaged to come from the benefits generated from the irrigation scheme downstream of the Pwalugu communities, with different options for areas between 20,000 and 95,000 ha (VRA 2014). Even an area of 20,000 ha would mean more than doubling the area under formal large-scale irrigation in the whole of Ghana (MoFA 2011). In addition, flood mitigation is a key component in the feasibility of the PMD. Although large areas are inundated annually and provide local benefits (Sidibé et al. 2016), large floods have caused significant damage and resulted in casualties in Ghana (VRA 2014). The Bagré Dam located in Burkina Faso has not reduced the flooding situation in Ghana significantly because flood mitigation is not a key objective of the dam, partly due to the limited area of Burkina Faso being affected by flooding downstream of the dam.

Livelihoods and Socioeconomic Background[1]

The Pwalugu study communities, immediately downstream of the planned dam, are settled in the Talensi and West Mamprusi districts in the Upper East and Northern regions, respectively. An estimated 81,000 persons, representing about 7% of the population of the Upper East region, live in Talensi District. It is the lowest populated district in the region with a majority of individuals being below the age of 30 (GSS 2014a). West Mamprusi District in the Northern region accounts for 121,000 inhabitants, which amounts to 5% of the region's population. The majority (46%) of the population is aged 15 and below (GSS 2014b). About 80% of the population is rural and farming is a widespread activity, with about 97% of households in Talensi District engaging in some form of agricultural practice, while about 79% of the population works in agriculture. Livestock rearing is also a key activity for most of those engaged in crop farming (86% of agricultural households) (GSS 2014a).

In West Mamprusi District, the rural population share is lower and amounts to 60%. Crop farming is common with about 85% of households engaging in it and 70% of households engaging in livestock rearing. About 80% of the active population works in agriculture (GSS 2014b). This is in line with the rest of Ghana, where farming remains the main economic activity, with the exception of the Greater Accra Region. According to the Ghana Living Standard Survey, the poverty level is highest in the Upper East region; 44% of the population lives below the poverty line at USD 1.8 per day and 21% lives below USD 1.1 per day (the extreme poverty line). In the Northern region, 50% of the population lives below the poverty line and 22% below the extreme poverty line. The two regions are the second poorest in Ghana behind the Upper West region. There is a poverty gap

[1] Unless otherwise stated, all figures are for the year 2010, corresponding to the last year of the census.

between the northern part of Ghana and the rest of the country, as these three savannah regions account for half of the people living under the poverty line (GSS 2014c).

In both rural and urban areas of Talensi, boreholes and pumps are the primary sources of water for drinking and domestic use, followed by protected wells and unprotected streams and rivers. Protected and unprotected wells, boreholes and pumps are the first, second and third most used sources of water, respectively, for drinking and domestic use in West Mamprusi (GSS 2014a, 2014b). Only 7% and 25% of the population of Talensi and West Mamprusi districts, respectively, has access to toilet facilities. Waste disposal is limited. Solid waste is burned or left on public grounds, while liquid waste is disposed onto the streets (GSS 2014a, 2014b). In the rural areas of both districts, connection to the electricity grid is low (10% and 16% in Talensi and West Mamprusi districts, respectively; these figures provide an indication of connectivity but not of actual use, which is constrained by the availability of funds for payment) and the main source of lighting is kerosene lamps, while firewood is the most used source of fuel for cooking followed by crop residues in Talensi and charcoal in West Mamprusi (GSS 2014a, 2014b).

Natural resource management is largely carried out through the so-called Community Resource Management Area (CREMA) approach (Forestry Commission 2004). However, with limited resources to implement the policies, traditional management structures are also important. A typical rural community social hierarchy in northern Ghana consists of several key figures, including the Chief, who holds the land in trust for the community and answers to the regional (paramount) chief (FAO 2017). Another prominent community member involved in natural resource management is the *Tindana*, the land priest, who is symbolically in charge of the lands in the customary land tenure system (Imam 2015). The Chief and *Tindana* form a crucial part in the allocation of lands for various activities as well as monitoring and regulating the use of the natural resources.

Study Communities

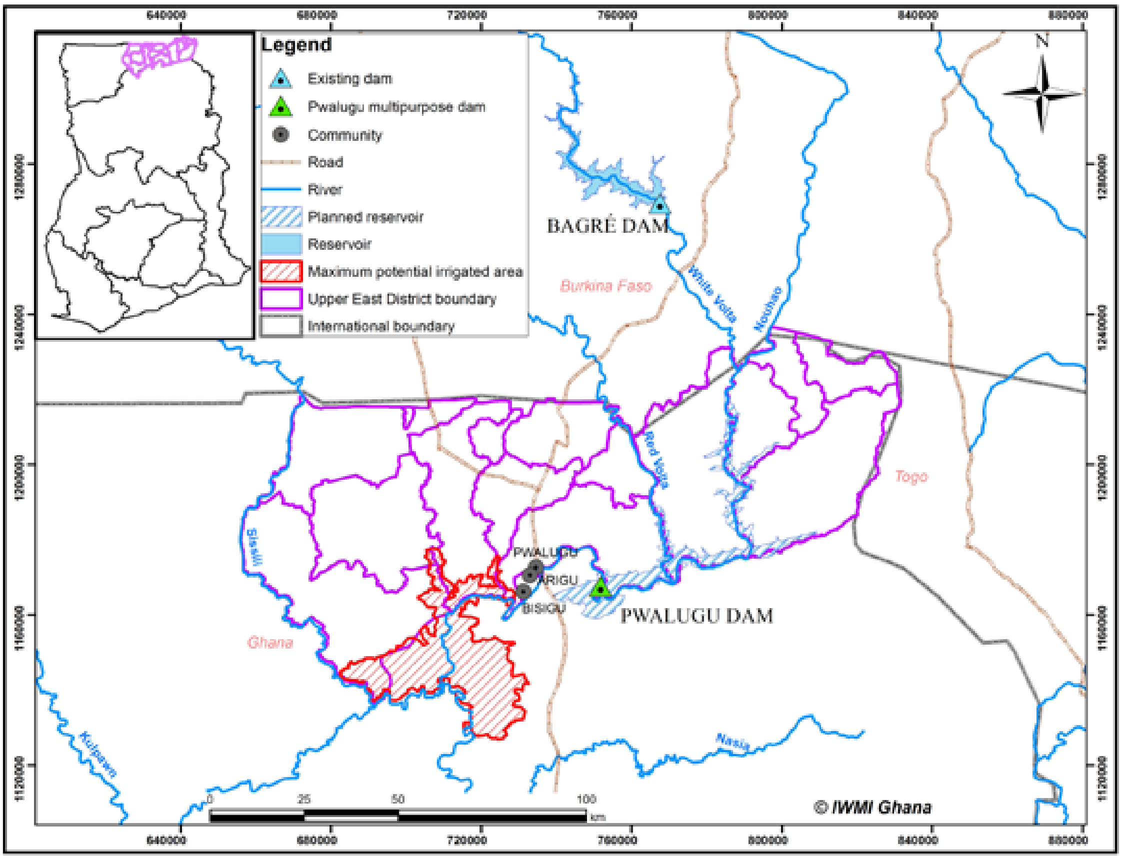
This study focused on three communities located on the border of the Upper East and Northern regions of Ghana (Figure 2). The communities are settled along the White Volta River. The Pwalugu village is located in Talensi District, Upper East region, while the Arigu and Bisigu communities are situated in West Mamprusi District, Northern region. Pwalugu, the village closest to the road with a market, is the most populated. Bisigu, the village furthest away from the main road, is the least populated (Figure 3; Table 1). The typical riparian communities are engaged in activities linked to the seasonality of the White Volta River (Balana et al. 2015).

TABLE 1. Communities considered in the study.

Community	District	Region	Population	Households
Pwalugu	Talensi	Upper East	2,943	577
Arigu	West Mamprusi	Northern	1,580	309
Bisigu	West Mamprusi	Northern	600	120

Source: Interviews with chiefs are cross-checked with the assemblyman (locally elected representative).

FIGURE 3. Locations of the three study communities in relation to the location of the Pwalugu Multipurpose Dam and Bagré Dam.



METHODOLOGY

Theoretical Framework

Ecosystem Services Mapping

ES are spatially explicit. To be able to get the best overview of the ES relevant for the riparian communities, a community-based mapping approach was used. Community-based mapping is a type of participatory mapping carried out with members of a community and used to represent the views of some or all members (Forrester and Cinderby 2014). It is, therefore, an ideal tool to identify key ES that are beneficial to the communities and their location in the landscape.

The mapping exercise helps gather information on a number of points. First, it aims to identify key ecosystems and features in the landscape, which are of importance – for whatever reason - to the riparian communities. Second, it elicits information on ES and key users, as well as the contribution towards livelihoods. Participatory maps provide a valuable visual representation of what a community perceives as its place and the significant features within it. These include depictions of natural physical features and resources, and sociocultural features known by the community (Corbett 2009).

Community-based mapping was carried out using a Participatory Geographic Information System (PGIS) approach. This method employs two-dimensional (flat, printed) maps of the area surrounding the communities, and where community members live and carry out activities. Participants were guided through a series of focused questions and asked to identify locations of resources on the maps which correspond to places on the landscape that pertain to their lives and activities they undertake.

Women utilize landscapes differently to men due to their engagement in separate types of livelihood activities and they may have a different set of ES priorities (Perez et al. 2015). Consequently, we implemented a gender-differentiated approach to the PGIS survey. As part of the participant selection process, efforts were undertaken to ensure gender-differentiated participation opportunities, allowing females and males within the same household or community to carry out the surveys separately. This provided insights into how men and women rely on and perceive ES differently.

Ecosystem Services-related Preference Ranking

The economic dependency of the communities on ES can be rapidly assessed using qualitative methods. Various participatory exercises focus on eliciting information from stakeholders in a limited period of time (World Bank 1996). In this study, we selected the preference ranking exercise to inform the design of the household survey (see section *Socioeconomic Household Survey*).

Preference ranking is a widely used technique in Participatory Rural Appraisal (PRA) (World Bank 1996). It has also been developed as a tool to assist in the economic assessment and valuation of ES (see, for example, Emerton 1996; Emerton and Mogaka 1996; Campbell and Scoones 1997; Ngugi et al. 2011). Applied in this study, this exercise corresponded to a non-monetary implicit valuation of ES relative to each other. The ranking elicited reflects individuals´ preferences based on their livelihoods. As the ranking is non-monetary, the difficulty of assigning monetary values for communities with limited availability of funds can be overcome. The objective of the method is to give a qualitative overview of the relative importance of ES to the individuals. The main sources of livelihood and economic dependencies per gender are made clear. Carrying out the exercise in gender-segregated groups provided insights into preferences and discrepancies due to gender-based activities. The ranking exercise can be carried out in groups or on an individual basis. In this study, public voting was used[2], although it may create some bias in the answers due to peer conformity. Additional information was collected by asking follow-up questions right after the voting and during conversation.

Seasonal Calendar

A seasonal calendar is a visual method showing the distribution of seasonally varying phenomena (such as economic activities) over time (World Bank 2007). This approach was used to map the seasonality of the availability of different ES. This was then compared to key times when funds are required, e.g., for school fees. This was translated into a seasonal calendar indicating key periods of provision of ES.

[2] This was due to time constraints. In each focus group discussion (FGD), about 70 votes were recorded.

Data Collection

Data were collected using a number of approaches to triangulate information. A literature review was undertaken to gather a general understanding of the various features of the ecosystems present in the study area. This was followed by a reconnaissance visit during which semi-structured questionnaires were administered to key stakeholders, such as the chief of each community and other stakeholders involved in natural resource management. Data were collected through:

1. semi-structured interviews and informal interviews with key stakeholders;
2. focus group discussions (FGDs), using the community-based mapping approach;
3. transect walks; and
4. a socioeconomic household survey.

Semi-structured Interviews

Semi-structured interviews were held with key stakeholders that are involved in the management of natural resources. Chiefs are the custodians of the land and therefore the main managers of natural resources in the area. Each community has its own chiefs and they were all interviewed. The Forestry Services Department (FSD) plays a major role in the management and conservation of the area's forest reserves. For these communities, there were no Civil Society Organizations (CSOs)/Community-based Organizations (CBOs) involved in the management of natural resources in the study area.

Chiefs

The semi-structured interviews with the chiefs focused on the history of the community, ownership and management of the resources, and the benefits the communities derive from the resources. We also discussed whether there were changes over time in relation to the natural resources and its benefits. Finally, we discussed the PMD project, and whether the community was aware of it and how they anticipated the dam would impact the local resources and ecosystem services. The information gathered helped shape the mapping exercise.

Forestry Services Department (FSD)

The semi-structured interview with the rangers of FSD was held in Bolgatanga where their district office is located. FSD manages forest reserves in Ghana. There is one forest reserve in the study area - the Tankwiddi Forest Reserve, which is managed from Bolgatanga. FSD was approached to provide additional information on the forest reserves in the district, including the management practices as well as issues they have with managing these reserves.

Focus Group Discussions

Focus group discussions (FGDs) were held in all three communities (Figure 4). The groups were gender-segregated to (i) foster women's participation in discussion in a women-only setting, and (ii) better identify the gendered use of the different ES. There were six groups in total (i.e., two in each village), with each group comprising 15-20 members.

FIGURE 4. Focus group discussions in Pwalugu and Bisigu communities.

Photos: Marloes Mul (IWMI).

The discussions first centered around the livelihoods and main seasonal activities of the participants. The participants were then asked to create a map with the key features in the community, which was discussed in the FGD to identify the location of their livelihood activities and the NI that supported these activities. Following the mapping exercise, ES for each ecosystem identified were discussed. This was followed by a detailed discussion on when activities to extract the ES take place during the year to inform the creation of a seasonal calendar. It was also identified as to whether or not there were formal and informal rules in the management of the resource. Finally, a ranking exercise was conducted to identify the order of importance of the different ES-based activities.

Outputs of these FGDs were (separate for women and men) as follows:

- Overview of income-generating activities.
- Maps of the NI and key landscape features in the vicinity of the communities.
- ES in the area.
- Results of the preference ranking exercise.
- Seasonal calendar of NI use.

Transect Walks

Transect walks with a local villager were carried out to validate information elicited during the discussions and to provide complementary cross-checks (Figure 5). During these walks, global positioning system (GPS) coordinates of the ponds in each village, the dry woodland and the floodplain in Pwalugu were obtained.

FIGURE 5. Transect walks by the research team.

Photos: Marloes Mul (IWMI).

Socioeconomic Household Survey

A detailed socioeconomic household survey focusing on the economic value of ES-based activities was administered in the three communities (Pettinotti 2017). A total of 150 households were sampled (50 in each community), representing 15% of the total number of households. A stratified random sampling strategy was followed to select the households. A detailed description of the methods and analyses of the data are presented in Pettinotti (2017). Basic information on the different types of household (female- versus male-headed households and for different socioeconomic status) engagement rate in the various livelihood activities, as well as their use of outputs (consumed at home or sold) are presented in the section *Results*.

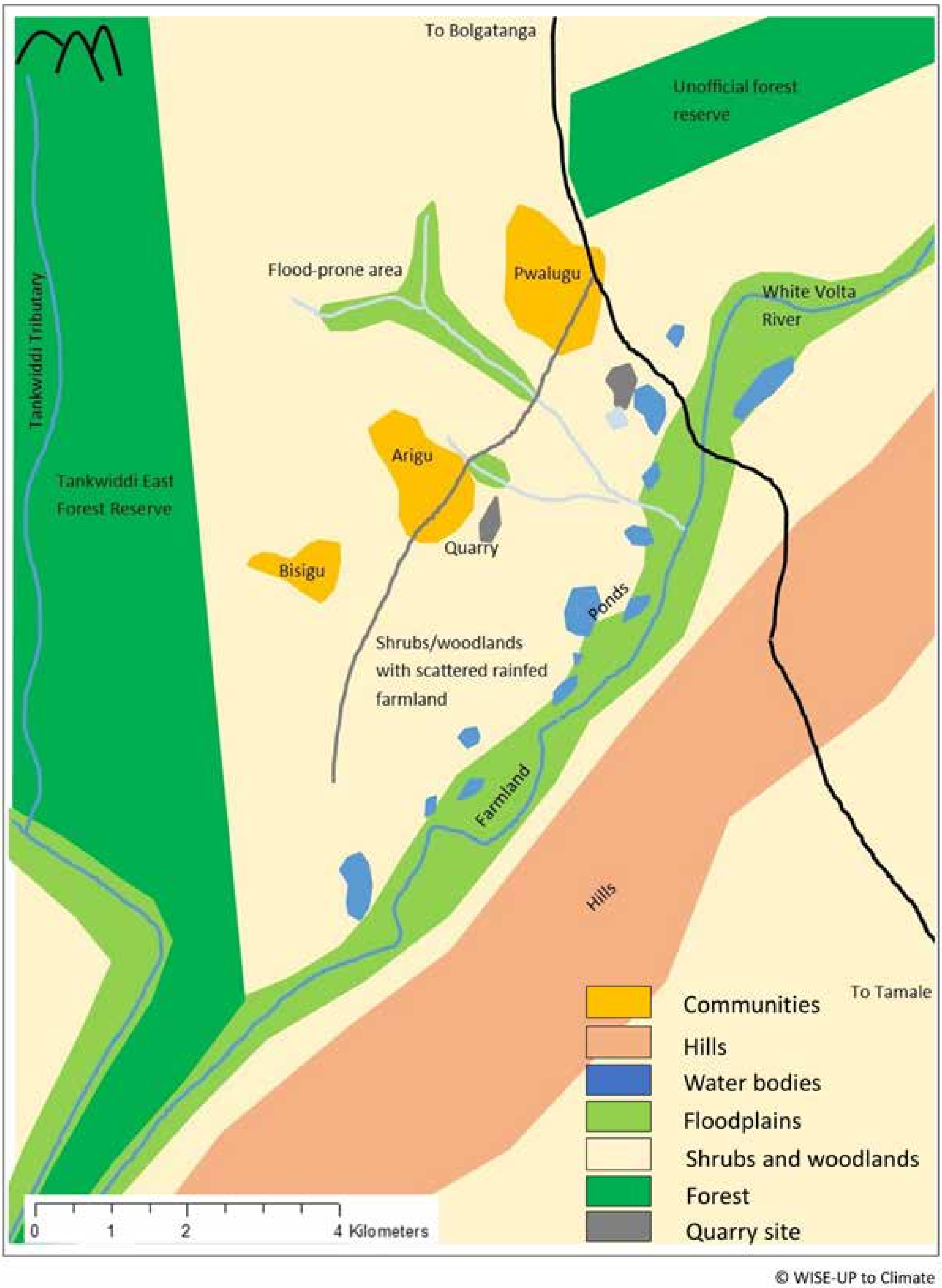
RESULTS

This section first describes the types of NI and the related services based on the information compiled during the FGDs. It is followed by the results of the analysis to determine the economic dependence of communities on ES (derived from the household survey), and finally the seasonal calendar is presented based on the information provided by the FGD participants.

Natural Infrastructure and Ecosystem Services in the Study Area

Five types of NI were identified by all three communities: (1) forest reserves, (2) shrubs and woodlands, (3) natural ponds, (4) White Volta River, and (5) floodplains. Figure 6 shows the map of the area with the locations of the types of NI. This map was compiled from the community maps (see Annex A), which were superimposed on the available GIS maps (land use, river network and Google maps).

FIGURE 6. Location and types of NI in and around the study communities.



The Tankwiddi Forest Reserve (Figure 6) is the main forest reserve in the area and is located to the west of the communities. According to the communities, the Tankwiddi River source was located in a hilly area with wildlife, north of this forest reserve. Most of the area comprises shrubs and woodlands, which are basically degraded forest areas. Similar vegetation is found in both types of NI, albeit the shrubs and woodlands have lower densities. Some scattered farm plots, used during the rainy season, are located closer to the three communities. Floodplains are located along the White Volta River, where seasonal flooding deposits fertile sediment. Thirteen natural ponds were identified on the northern bank of the White Volta River - four in Bisigu, five in Arigu and four in Pwalugu. The ponds differ in size and some of the larger ones hold water all year round while the smaller ones dry up over the year. Some other features highlighted during the discussions included quarry sites and some flood-prone areas (around Pwalugu and Arigu) where water accumulates from local ephemeral streams during the wet season enabling rice production. The benefits derived from the ponds, floodplains and the river are dependent on the river flows, while the forest, and shrubs and woodlands are not directly impacted by changes in flow in the White Volta River.

Forest Reserves

Three forest reserves (Figure 7) are located in the Bolgatanga District, of which only the Tankwiddi East Forest Reserve (area 193.21 km^3) is accessed by the three communities. The Tankwiddi River flows through the forest reserve and joins the White Volta River downstream of the three communities. Arigu and Bisigu are so-called fringe communities, bordering the Tankwiddi East Forest Reserve, which "have the right to have access to the forest reserves to maintain a basic standard of living while ensuring sustainable use of the forest resources" (Edusah 2011).

FIGURE 7. Protected forest found near Bisigu community.

Photo: Marloes Mul (IWMI).

Fringe communities have communal rights to collect dead or fallen wood and harvest non-timber forest products (NTFPs), although not in commercial quantities as per the Forestry Act 624 which stipulates fines for infringement (Edusah 2011). However, effective monitoring and law enforcement are limited by the staff and budget resources available to FSD. Moreover, the forest reserve is unfenced and the villagers alleged confusion over the exact delimitation between protected and unprotected forest. As a result, illegal activities such as hunting and felling of live trees take place. Part of the firewood is processed into charcoal during the wet season, when the type of grass required to make charcoal is available and when water can be collected in a rain barrel (and is hence more readily available). Charcoal making is an intensive process that requires a hand dug hole where firewood and grass are accumulated, and set alight but kept moist for as long as a week. Charcoal making is not illegal in itself, but the felling of trees to make charcoal is. In particular, FSD has been trying to tackle the illegal felling of rosewood timber, a high-value tree. Because most activities are illegal, it was not possible to obtain the full extent of ES derived from the protected forest. We, therefore, focused on the legally derived ES in the form of NTFPs which the communities can harvest in non-commercial quantities. These NTFPs include shea fruit (*Vitellaria paradoxa*) - the nuts of which are processed to produce butter, honey, mushrooms (*Agaricus*), dyes (the envelopes of the dawadawa fruit produce dye when soaked in water overnight, *Parkia biglobosa)*, medicinal plants, wild fruits such as sibisibi (*Lannea acida*), baobab fruit (*Adansonia*) and gaa (*Diospyros mespiliformis*). The seeds of the dawadawa and baobab fruits are also consumed after being processed to a paste. Apart from honey, which is exclusively collected by men, the other products are collected by both men and women.

Shrubs and Woodlands (Mixed with Sparse Agricultural Lands)

Shrubs and woodlands (Figure 8) generally have the same species as the forest reserves. Similar NTFPs are, therefore, collected in the forest reserves, and shrubs and woodlands. However, in the shrubs and woodlands, the NTFPs can be collected in unregulated quantities (contrary to the forest reserve) (Forestry Act 624). Similar to the forest reserve, tree felling is not allowed, but the collection of branches and dead wood is allowed. Poles can be used as beams for building of houses. Smaller trees and shrubs are often cleared for firewood, of which some is processed into charcoal (Figure 9). Grasses, ropes and sticks are mostly collected by women for roof thatching, basket weaving and making fishing gear (Figure 10). These areas are not protected and patrolled by FSD, but the chiefs enforce some protection with penalties for illegal activities (confiscation of the abstracted resource and sometimes reporting to the police). However, enforcement is difficult and the villagers do fell trees at times. Some scattered rainfed agriculture is also practiced in these areas. As a result, the shrubs and woodlands are highly degraded compared to the forest reserves.

FIGURE 8. Shrubs and woodlands found in the Pwalugu area.

Photo: Marloes Mul (IWMI).

FIGURE 9. (a) Firewood collected, and (b) charcoal produced from the firewood.

(a)

(b)

Photos: Marloes Mul (IWMI).

FIGURE 10. Material collected in woodlands and used for roof thatching, basket weaving and making fishing gear.

Photos: Marloes Mul (IWMI).

In the northern parts of Ghana, livestock is a key asset that is exchanged for cash to buy farm inputs such as seeds, pesticides and fertilizers. During the dry season, livestock grazing is mainly dependent on the shrubs and woodlands. Animal farming includes the rearing of cattle, donkeys, dogs, sheep and guinea fowl. In the village of Bisigu, there have been incidents with people from outside the community (*Fulani*) taking animals through the shrubs and woodlands to graze, leaving the community's livestock with a reduced grazing area.

During periods when other food sources are limited, community members also engage in hunting. Men hunt with bows and arrows, spears, dogs and occasionally with rifles, while women and children hunt with traps. Examples of wild animals hunted for their meat include monkeys (*Macaca fascicularis*), rabbits (*Oryctolagus cuniculus*), grass cutter or cane rats (*Thryonomys swinderianus)* and antelopes. The bush meat is consumed or smoked at home and sold by the women on the roadside from Pwalugu to Bolgatanga.

Rainfed plots are scattered near the homesteads in the degraded woodlands. Crops that are grown during the wet season are cereals (millet, sorghum, rice and maize) and legumes (groundnuts, Bambara beans and cowpea). Only one crop is grown per year under rainfed agriculture, with planting at the onset of the rains in April/May and harvesting in September.

In Pwalugu, the community believes that some trees are abodes for their ancestors and therefore cannot be felled. Many households have at least one tree on their property, which represents the ancestors' spirits. Some trees are also used as the site for traditional sacrifices.

Ponds

Riparian ponds (Figure 11) are seasonally replenished during the flooding season and are connected to the main river channel. Fish move from the river to the floodplains and ponds. When the water subsides in September, some fish are trapped in the ponds. The same indigenous fish species are, therefore, found in both the river and ponds. These are tilapia (of the *Tilapia* genus), mudfish (from the *Protopterus* genus) and so-called 'herrings', which are actually sardinella (from the *Clupeidae* family). The 13 riparian ponds play an important seasonal role for the communities. Fishing in these ponds is strictly regulated by the traditional rulers (*Tindana*). Fishing is not allowed until the *Tindana* announces the opening of the fishing season (Box 2). This is generally towards the time the ponds are drying up, allowing fish to grow and hence maximizing the fish yield. Any fisherfolk caught fishing before the fishing season face a fine set by the chief. The fine varies depending on the regularity, extent of the violation of the rule and at the discretion of the chief. The pond fishing season generally takes place in March and April. These two months correspond to the end of the dry season when other food is scarce and wet-season farming is yet to start. Besides fish, snakes, aquatic tortoises and crabs are also caught and consumed at home or sold.

FIGURE 11. Pond found at Pwalugu community.

Photo: Marloes Mul (IWMI).

Box 2. Communal pond fishing.

The start of the fishing season is announced by the chiefs (Figure 12). The chief of each village sets the order in which the ponds are used for fishing (i.e., usually from the pond with the lowest water level and is most likely to dry up first to the one with the highest water level). Inhabitants from all three communities gather at the designated pond. Before the fishing starts, a ritual is performed by the chief to appeal to the gods to provide the community with a good catch as well as to appease the gods to protect the fisherfolk. In Bisigu, shrines are set up specifically for this ritual.

Fishing takes a full day, starting at dawn, peaking at noon and finishing at sunset. The fishing technique is labor intensive and uses low-technology inputs (basic fishnets and reed traps). Both women and men fish in the ponds, except for one pond in Pwalugu which is exclusively used by women. To ensure that most fish are caught, a large number of villagers enter the pond and walk in circles closing in on the fish. Fish tend to come to the surface to escape, but the villagers catch them with small fishnets or women catch them using fish traps made out of reeds (Figure 13). Most of the fish in the pond are caught within one day. After the communal fishing event, community members are allowed to continue fishing in the pond until the rains start.

FIGURE 12. Schematic representation of the pond fishing cycle.

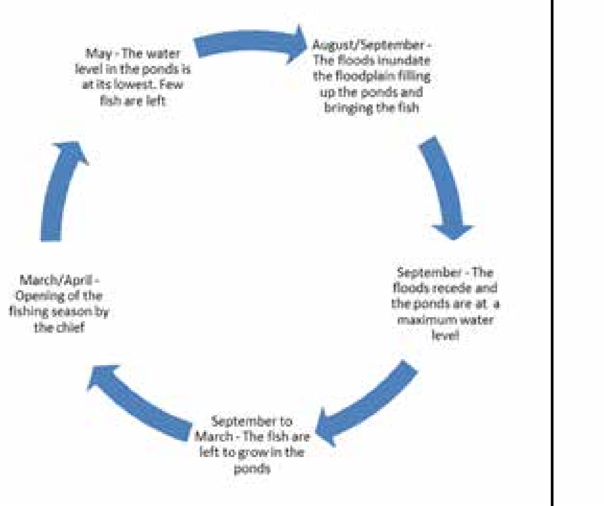


FIGURE 13. Fishing day in the Pwalugu pond.

Photo: Laetitia Pettinotti (BC3).

The ponds are also the main source of water for livestock. During the grazing period, livestock access the ponds directly. However, during the wet season, when livestock are tethered near the house, water is collected from the ponds and brought to the house. During the dry season, when domestic water use is scarce due to the drying up of the boreholes, pond water is generally not used as its quality is affected by the roaming livestock. A few crops such as calabash (*Lagenaria siceraria*), canary melon (*Cucumis melo L.*), watermelon (*Citrullus lanatus var. lanatus*) and cowpea (*Vigna unguiculata*) are grown in and around the ponds after the flood season ends in September.

A strong spiritual value is associated with the ponds and their surrounding trees. For instance, in Arigu, one pond called 'the grandmother crocodile pond' holds a particular spiritual value. It is believed that one of the community's female ancestors transformed into a crocodile after her death, a typical belief in the tribe she originated from. Since that time, crocodiles in this pond are referred to as ancestors, and buried like human beings. Crocodiles and humans live peacefully side by side with no fear[3].

In Pwalugu, one of the ponds is used as the site for rain dances during extended dry periods. Rain dances are performed by the *Tindana* at the edge of the pond. The dance allegedly triggers rain to fall in the vicinity of the ponds to fill them up. Interestingly, on certain occasions, the *Tindana* mentions the name of the place they prefer the rain to fall. Anecdotal evidence was provided of an event occurring 5 years earlier when a rain dance was performed and a downpour was observed not long after the ritual was conducted. However, at the time of the field visit, an extended dry period was being experienced and rain dances had not been performed, as the communities were discussing issues related to land tenure and could not agree to organize the rain dance.

The ponds are initially filled at the beginning of the rainy season. During the flood season, the ponds located in the floodplains are completely submerged and are hydraulically connected to the river, thereby replenishing the fish stock in the ponds.

The White Volta River

The White Volta River (Figure 14) and its seasonal flooding provide a lifeline for the riparian communities. However, the river itself also provides benefits to these communities. For example, river fishing is an activity carried out by men using canoes and fishing nets. Since the construction of the Bagré Dam in Burkina Faso, the White Volta River at Pwalugu has become perennial, and river fishing with canoes and nets is carried out by men year round. Only men can fish in the river as they have access to funds needed to buy canoes, while culturally women are deemed unable to row against the current and swimming is perceived as inappropriate. However, women buy the fish from the men and smoke it before selling it at the markets.

FIGURE 14. The White Volta River at Bisigu.

Photo: Marloes Mul (IWMI).

[3] Note that crocodiles in the river, on the contrary, are regarded as being highly dangerous. While being of the same species, the river crocodiles are larger than those in the ponds.

During the dry season, when many of the boreholes in the communities have dried up, people collect water from the White Volta River for domestic purposes. Despite it being 3-5 km away from the communities, the river is the most reliable water source during this period, both in the amount available and the quality of the water. Before the river became perennial, the communities would fetch water from the ponds despite the health risks associated with its water.

Floodplains

The floodplains (Figure 15) are located on both sides of the White Volta River, where there are good soils. It supports three different types of farming practices: rainfed (also practiced in the uplands), flood-recession and irrigated farming.

FIGURE 15. Submerged maize field at Pwalugu.

Photo: Marloes Mul (IWMI).

Rainfed agriculture within the floodplains is practiced during the rainy season. It starts at the beginning of the rainy season around April or May and crops are harvested in late July. This is a risky practice as seasonal flooding can wash away the entire crop, if the floods arrive before the crops are harvested. Delayed start of the rainy season, as observed in northern Ghana (Lacombe et al. 2012), makes this practice increasingly unreliable.

Annual flooding, as a result of the natural dynamics of the White Volta River, supports flood-recession agriculture during the dry season starting in early September. Crops grown under flood-recession farming include cowpea, maize and rice. Planting generally starts around September/ October after the flood recedes and harvesting takes place around December/January. These crops are often sold at nearby markets or to middlemen to supplement the family income.

Other crops require irrigation during the dry season. Supplementary irrigation is applied to crops such as tomato, onion, water/sweet melon, okra, pepper, cabbages and carrots, which are planted using residual soil moisture from the floods (Balana et al. 2015). Full-scale irrigation practiced on a limited scale during the dry season enables several harvests, if the farmer can afford the inputs (diesel, seeds, pesticides and fertilizers). Crops are irrigated using rented diesel pumps to pump water from the river onto the farm. Sometimes the men pool their resources to rent a pump together.

Typology of Ecosystem Services

The NI in the study area provides different types of ES. Provisioning services include NTFPs obtained from the forest reserves, and shrubs and woodlands. The White Volta River and natural ponds in the floodplains are the sources of fish. More dominant are the supporting services that provide the right environment for livestock grazing and watering. According to the communities, soil moisture and fertile soils are provided by the seasonal flooding of the floodplains, thereby supporting farming activities. An overview of the natural infrastructure, its ES and the subsequent activities it supports is presented in Table 2.

TABLE 2. NI and ES found near the riparian communities in the White Volta River Basin.

NI	Forest reserves	Shrubs and woodlands	Natural ponds	White Volta River	Floodplains
Provisioning Services	NTFPs	NTFPs Construction materials (poles and grasses)	Fish	Fish Water for people during the dry season	
Supporting services	Hunting	Livestock rearing	Livestock watering		Farming (rainfed and flood recession)
Cultural services		Ritual practices	Rain dances, ritual practices		

Dependence and Reliance on ES

The communities mainly identified provisioning services as contributing towards their livelihoods, because these tend to be more easily identified than supporting services or cultural services. The FGDs identified that agriculture is the main livelihood activity for the majority (95%) of the people living in the three communities[4]. These agricultural activities are highly dependent on the seasonality of the climate as well as the White Volta River. About 95% of households in all the communities are also engaged in livestock rearing, fishing, and collection of firewood and NTFPs. The following sections describe, in more detail, the dependence of these communities on the different income-generating activities.

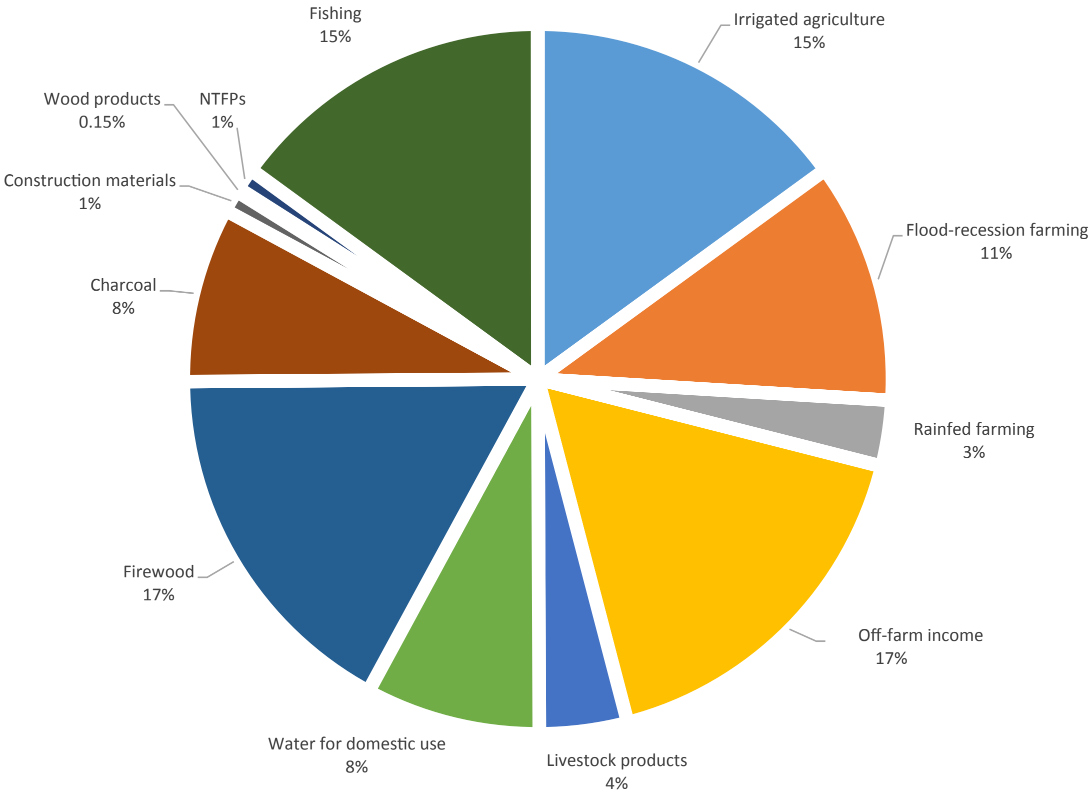
Activities Underpinning the Households' Livelihoods

The income-generating activities contribute in different proportions to the communities' livelihoods and is dependent on the household. Figure 16 shows the relative proportion that each ES-based activity contributes to overall revenue for an average household in the area (Pettinotti 2017). The highest-value activities include crop production, fishing, fuelwood collection and off-farm income, because these are the predominant livelihood activities (GSS 2014b).

[4] The percentages of community members engaged in a particular activity were estimated by the participants themselves. For activities with a high engagement rate, the participants would indicate a rate of 95%, meaning that they estimated that almost all community members would engage in that activity.

Off-farm activities, which correspond to casual and formal employment (including business and trade) as well as home remittance, are not ES-based activities. However, they are included to assess their relative contribution (17% of overall revenue) to the villagers' livelihoods. It is not possible to make a comparison with the literature as reports on the rural non-farm economy compare off-farm revenues to farm outputs sold exclusively, not taking into account farm outputs that are consumed at home. This translates into a high relative contribution of non-farm revenues (Davis et al. 2002; Haggblade et al. 2010). Here, farm outputs and outputs from ES-based activities that are consumed at home are included in the overall revenue.

FIGURE 16. Contribution of different revenue sources to the livelihood of an average household in the three communities.



Source: Pettinotti 2017.

Note: NTFP – Non-timber Forest Product

Engagement Rate in the Different Livelihood Activities

The socioeconomic household survey shows that all households engage in water collection and agriculture, and a large majority engage in livestock rearing, fishing, collection of firewood and at least one NTFP (Table 3). An important proportion of households collect firewood across all groups except for rich households (57% of this group collect firewood), which would rather buy firewood than dedicate time to collecting it[5]. The engagement rate for charcoal making, collection of wood products and construction material is 17%, 10% and 59%, respectively.

[5] *Note:* At the time of the survey, the communities did not have access to electricity.

TABLE 3. Percentages of households engaging in each activity for different household groups in 2015.

Household*	Irrigated agriculture	Flood-recession agriculture	Rainfed agriculture	Livestock	Domestic water	Fishing	Firewood	Charcoal	Construction material	Wood products	NTFPs	Off-farm activities
All	23%	57%	47%	87%	100%	92%	75%	17%	59%	10%	99%	64%
Female headed	25%	63%	63%	88%	100%	88%	88%	25%	75%	13%	88%	50%
Male headed	23%	56%	46%	87%	100%	92%	75%	16%	58%	10%	99%	65%
Poor	4%	84%	66%	70%	100%	86%	100%	6%	78%	14%	98%	44%
Middle	24%	43%	41%	93%	100%	96%	70%	26%	61%	13%	98%	61%
Rich	41%	43%	33%	98%	100%	94%	57%	19%	52%	7%	100%	85%

Note: * For the methodology on the disaggregation between rich/middle and poor households, see Pettinotti 2017.

Two-thirds of the sample earns income from off-farm activities. Despite a majority of households being employed in off-farm work, the income it brings is quite disparate. It is possible that better paid work and more lucrative businesses are carried out by households with higher socioeconomic status, since they have access to information to find work, possibly have more skills and can potentially pay for transport.

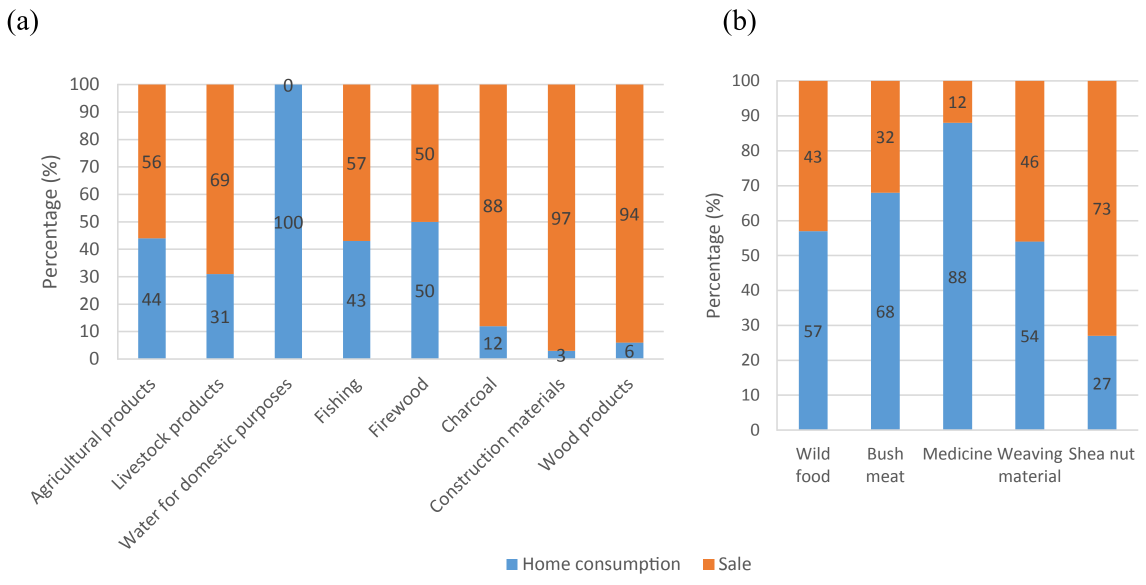
While all households engage in crop cultivation, the type of agricultural practice varies per household group (Table 3). With 57% of the sample practicing flood-recession agriculture and 47% practicing rainfed agriculture (both in the uplands and floodplains), only 23% is engaged in irrigated agriculture.

Contribution of the ES-based Outputs for Home Consumption and for Sale

Part of the production retrieved from the ES-based activities is for home consumption while some is sold in the Pwalugu and Bolgatanga markets (livestock products, construction materials and wood products). The share of production used at home or sold differs between products as shown in Figure 17. For example, just under half of the agricultural output is consumed at home, while some outputs are specifically produced to be sold, e.g., charcoal, construction materials and wood products. For an average individual, about 57% of the output produced is consumed at home, while 43% is destined for sale.

Interestingly, while the collection of NTFPs only contributes to 1% of overall revenue, on average (Pettinotti 2017), almost the entire sample carries out this activity (Table 3). Even the better-off household group still engage in the collection of NTFPs. The NTFPs are mostly consumed at home (see Figure 17[b]), apart from shea nuts, the cash “crop” for which women have prerogative (Boffa 2015). This gives quantitative evidence to the FGDs where the communities highlighted how important NTFPs are towards the end of the dry season.

FIGURE 17. Percentage contribution of (a) each ES-based activity, and (b) each NTFP to the total value used for home consumption and for sale in 2015.



The forest reserves, and shrubs and woodlands provided the most diverse provisioning ES, which a large part of the community is engaged in abstracting. However, 54% of the average household income is derived from the floodplains and the White Volta River, with 27% derived from forest reserves, and shrubs and woodlands, and the remainder from off-farm income and rainfed farming (Pettinotti 2017).

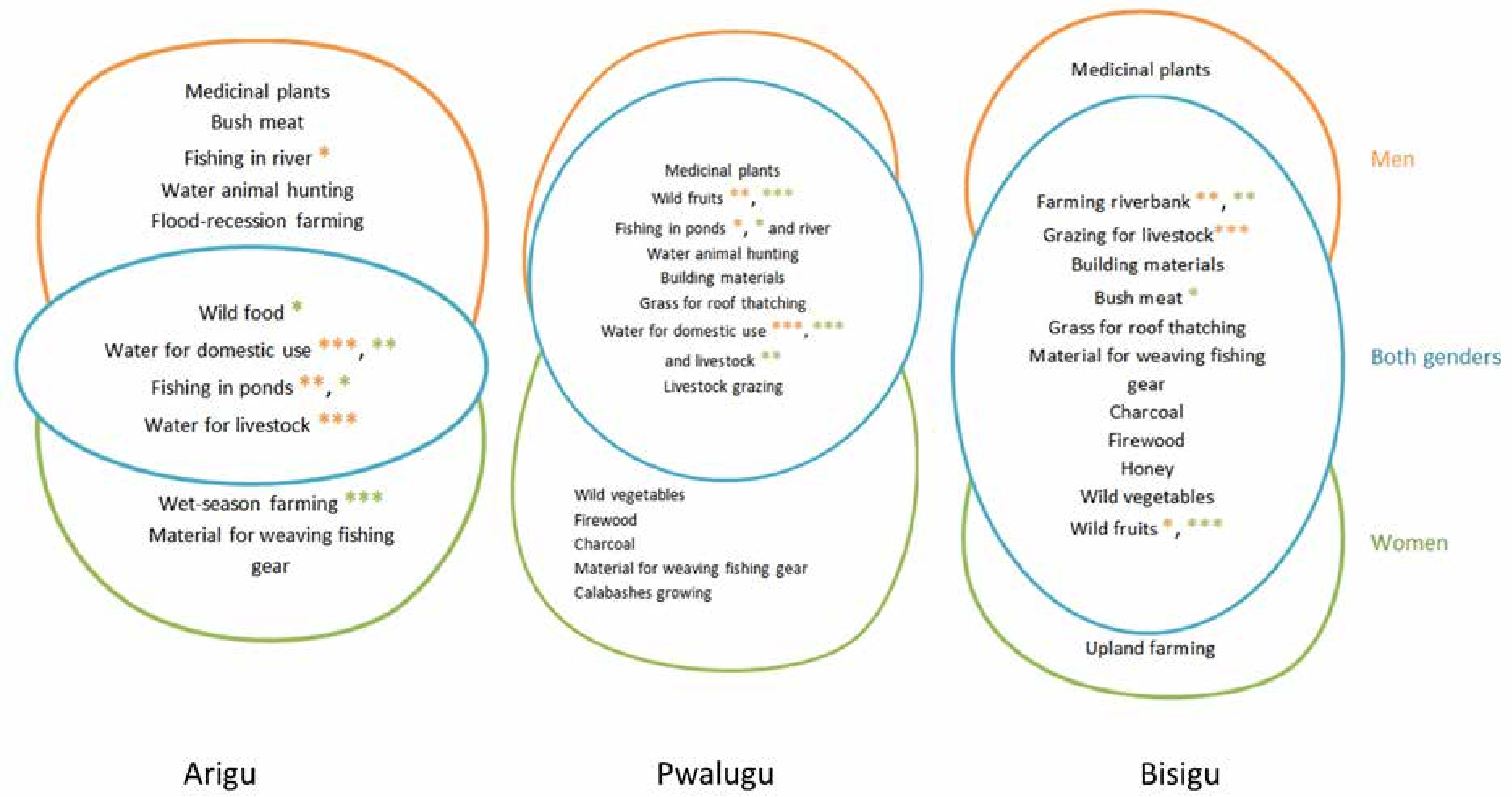
Gendered ES-based Activities

The communities studied presented a gender divide in terms of responsibility for everyday activities, similar to observations made by Perez et al. (2015). Some of the ES-based activities were carried out by both men and women, but others were prioritized differently between the male and female groups (Figure 18). For example, firewood was an item very rarely voted for in the male groups and conversely it was river fishing in the female groups. Figure 18 shows the ES-based activities ranked most important by gender. It does not mean that activities not voted for are not carried out, but simply that they were not perceived as being the most important.

Dual-gender ES – 95% of all villagers (male and female) in the three communities are smallholder farmers engaging in some livestock rearing and seasonal fishing in the communal ponds. Both genders are involved in rainfed agriculture in the floodplains. It must be noted that access to land by the river for flood-recession farming differs across the three communities: women have access to land in Bisigu and Arigu, but this was not the case in Pwalugu.

Fishing in ponds is undertaken by both genders, but with a higher prevalence of women (95% of women compared to 70% of men across all communities). Men use nets while the women use fishing traps made by a local male weaver utilizing sticks and reeds harvested from around the ponds. The women provide the raw material and pay for the skilled labor to make traps. The smoking and selling of fish is mainly done by women.

FIGURE 18. Gendered relative preference ranking of livelihood activities in Arigu, Pwalugu and Bisigu communities.



Note: ***, **, * - first, second and third preferences as prioritized ES by the men's group.
***, **, * - first, second and third preferences as prioritized ES by the women's group.

Male-dominated ES-based activities - Traditionally, activities requiring high inputs in terms of material are led by men. For example, all community members engaged in year-round river fishing using nets and boats are men, because fishing equipment is expensive to acquire. Similarly, hunting with bows and arrows is a skilled activity reserved for men, although it is only carried out by 20% of the men in Arigu, 10% in Bisigu and none in Pwalugu. As hunting is an illegal activity, the reported percentages are probably an underestimate. A few women set traps to catch game.

Some income-generating activities such as honey collection from wild or domesticated hives are an exclusively male task. Fifteen-percent (15%) and 20% of all men in Bisigu and Arigu, respectively, collect honey. In Pwalugu, this figure is higher at around 60%. Charcoal making has long been traditionally led by men (33% of men in Pwalugu and Bisigu and up to 70% of men in Arigu), but women were reported to be engaged in it as well (up to 40% in Bisigu). Again, the percentage stated for charcoal making may be an underestimate, as tree felling in the protected forest is illegal.

Female-dominated ES-based activities - All able women (95% of the female population) collect water for livestock during the wet season (when the livestock are tethered close to the homesteads) and also for domestic needs as well as firewood collection year round. They are also occasionally helped by men, who lend donkeys and carts during the peak dry season when available water sources (i.e., principally the river) are further away.

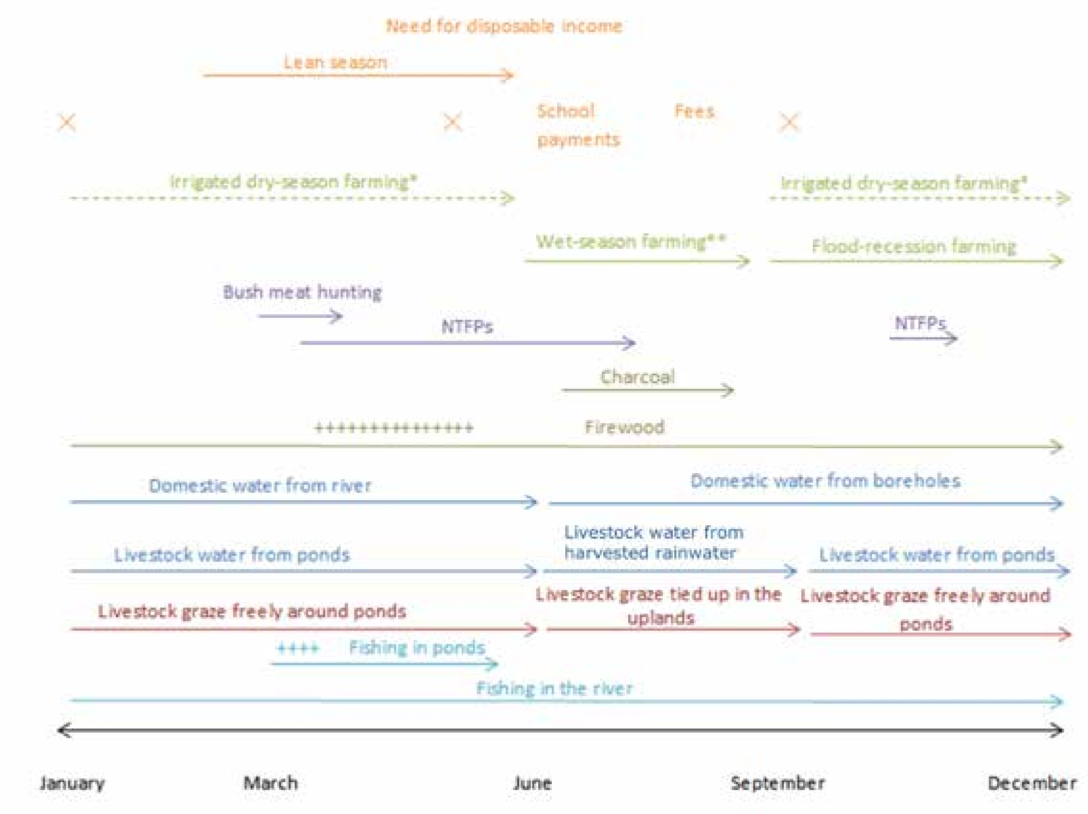
Across all communities, 95% of women and 20% of men stated that they collected medicinal plants such as neem tree leaves (*Azadirachta indica*), which are extracted and used to alleviate the symptoms of malaria, and moringa leaves (*Moringa oleifera*) and paw leaves (*Carica papaya*) which, when brewed together, soothe stomachaches. The bark of the sibi sibi tree (*Lannea acida*) is chewed to help childbirth.

Wild food harvesting is a complementary activity that becomes crucial at the end of the dry season (March to June) when food is scarce and there are few farming activities taking place. Only a few farmers with access to irrigation equipment continue farming to the end of the dry season. As described in the section *Forest Reserves*, berries, wild fruits and vegetables, and nuts are harvested by 95% of the women year round. In Bisigu and Pwalugu, men harvest wild vegetables during the lean season. Shea nuts are collected by 95% of the women and children, as it represents a substantial cash income supplement during the dry season for all three communities.

Seasonal Calendar

Figure 19 shows the seasonal calendar of the provisioning services obtained from NI. The provisioning services are seasonally available, and associated with the rainy and flooding seasons. In addition, the management of the ponds takes into consideration the availability of income sources, and maximizes the ES. For example, at the end of the dry season, there are few sources of income and food stocks are often running low. However, school fee payments are made during this period. Collection of shea nuts and other wild foods provides a lifeline (either because they are consumed at home and cash can be saved, or because they are sold in the Pwalugu market), enabling the payment of school fees and to also pay for unexpected expenses such as medical bills. The traditional management of the ponds also plays into this system, whereby pond fishing is taking place at the time of need and aimed at maximizing fish catch.

FIGURE 19. Seasonal calendar of ES collection by the three riparian communities.



Notes: * Irrigated dry-season farming is practiced by a few farmers.
** Wet-season farming takes place in the uplands and on the floodplains.

DISCUSSION

ES Underpinning Communities' Livelihoods

Pettinotti (2017) shows that an average household in the three communities derives most of its food and revenue from crop cultivation and livestock rearing, which are constrained by the availability of and access to farm technology and labor. Market access was not stated as an issue because it is possible to go to the Pwalugu and Bolgatanga markets and get back within a day. As off-farm employment opportunities are limited, livelihoods are, to a large extent, underpinned by ES.

Broadly, these ES-based activities can be divided into three categories (see Pettinotti 2017):

- Direct river flow-dependent ES-based activities. These are activities reliant on NI – floodplains, ponds and river – that exist due to the seasonality of the White Volta River, such as flood-recession and irrigated agriculture, fishing in ponds and the river, livestock watering from the ponds in the dry season, and water collection from the river.
- Forest-based ES activities such as collection of NTFPs, firewood and construction material, and charcoal making.
- Other ES-based activities such as rainfed agriculture, which, if practiced in the floodplain, is at risk of flooding.

Households' reliance and engagement in these ES-based activities are likely to differ with the size and economic status of the household as well as gender of the household head. Pettinotti (2017) further analyzes the quantitative data collected in the surveys.

Direct River Flow-dependent ES-based Activities

ES-based activities that are directly dependent on river flow can be grouped into two categories: (i) ES dependent on the seasonal flooding, and (ii) ES dependent on the dry-season flow. The majority of the prioritized ES are dependent directly on the river flow. These include the ES dependent on the dry-season flow, such as water for domestic use, and ES dependent on the seasonal flooding, such as fishing in the ponds, flood-recession farming, and livestock watering and grazing.

The availability of dry-season flow due to releases from the Bagré Dam provides water for domestic use during the dry season, when other sources of water have dried up (boreholes) or are of very low quality (pond water). Fishermen also continue fishing during the dry season and this was not possible before the Bagré Dam was constructed, as the river would dry up for several consecutive months. Of the farmers, 23% have access to diesel pumps for dry-season irrigation. This suggests that the Bagré Dam has provided an opportunity for farmers, but this is still on a very limited scale as many farmers are unable to make the initial cash investment due to the lack of funds. A few farmers also use buckets to irrigate small pieces of land.

The ES dependent on seasonal flooding are of high cultural importance to the communities. Crocodiles living in the ponds are allegedly a reincarnation of the queen mother (in the Arigu village). Rain dances are performed in ponds in Pwalugu, and there are a number of shrines that are used to appease the gods and crocodiles before the pond fishing season in Bisigu. In addition to the cultural importance, the seasonal pond fishing provides nutrition and income at crucial times of the year. After the seasonal pond fishing, the livestock is allowed to drink water from the ponds and graze around them.

It is clear that the White Volta River provides crucial ES that support the livelihoods of the riparian communities. Not only is the natural flow important, but the dry-season releases from the Bagré Dam provide additional services, which are crucial during critical times of the year. However, further development of the Bagrépole irrigation system to its design potential may severely affect dry-season flow provision at Pwalugu.

Seasonality of Use: A Coping Strategy

Long lean seasons are recurrent and result in the heightened dependence on natural resources and trigger a cyclical vulnerability, especially towards the end of the lean season when food reserves diminish and the rains are still weeks to months away.

An increased use of particular NI during the lean season signals the adoption of coping strategies to alleviate temporary unavailability or degradation of a resource. Observed coping strategies are the timing of access to an NI (the use of ponds for fishing) and the heightened dependence on specific NI (open and protected forests for the collection of NTFPs, and the river as a source of water for domestic purposes).

The timing set by the chief to start fishing in ponds is crucial as the interdiction to fish before the set date allows fish growth and provides food to the communities at the most critical time of the year. Surplus fish catch is smoked to be gradually consumed until the rains start and some is sold in the market for cash (59%) (Pettinotti 2017).

NTFPs are for home consumption (59%) and for sale to obtain a disposable income (41%). The cash is reinvested to buy food, pay children's school fees or buy diesel for a pump to practice irrigated farming. This dependence on NTFPs as "safety nets" contributing to food security is in line with other research findings (Angelsen and Wunder 2003; Chidumayo and Gumbo 2010; Dewees 2013; Djoudi et al. 2015).

Dependence on the river is heightened during the dry season, as it becomes the preferred drinking water source due to the low water quality of the ponds. However, this can come at a cost, since having to walk further to the river can threaten and delay the education of girls compared to boys (Perez et al. 2015). It is interesting to note that the availability of water in the river during the dry season is due to the releases from the Bagré Dam in Burkina Faso, whereas naturally the river would fall dry for 2-3 months in the year during the dry season (Mul and Gao 2016).

The observed delays in the onset of the rains by the farmers and confirmed by researchers (Laux et al. 2008; Lacombe et al. 2012) could deepen the current level of reliance on these NI, stretching the coping capacity of the communities. Delayed onset of rains would reduce the cropping season for rainfed farming on the floodplains, damaging the crops when floods arrive before the harvest. Operations of Bagré Dam could be tweaked to avoid these losses. This heightened reliance can also accelerate degradation rates of the NI as they are increasingly encroached upon and over-exploited.

Built Infrastructure Supporting ES

The study shows that the riparian communities are benefiting from the seasonality of flows in the White Volta River. Seasonal flooding and dry-season baseflows support specific agricultural and fishing activities that generate income during critical times of the year. These variations are the result of the natural seasonality of the climate and also due to the management of BI. Changes to this flow regime will affect the livelihoods of the riparian communities. For example, climate change could result in more extreme floods and prolonged droughts (Sylla et al. 2016).

BI is often considered detrimental to the natural flow regime and to downstream ES-based activities. However, this study shows that the Bagré Dam in Burkina Faso has had a positive impact in providing dry-season flows, which could be at risk when the Bagrepole irrigation scheme expands. The planned PMD in Ghana, together with the advance notice from the Bagré Dam, can significantly reduce the damage caused by flooding while maintaining dry-season flow for fishing, irrigation and domestic water needs. The PMD could affect downstream ES-based activities, such as pond fishing and flood-recession agriculture, if dam operations do not consider ES that are dependent on the flood regime. It is, therefore, important for dam operations to be designed to smooth out some of the extremes (damage caused by flooding and drying up of the river), while still providing controlled releases to support downstream ES-based activities. Investments in aquaculture and small-scale irrigation supporting the livelihoods of these riparian communities could offset the reduction in benefits.

CONCLUSION

The riparian communities studied are for a large part reliant on NI and the related ES for their livelihoods. The different NI, forest reserves, shrubs and woodlands, ponds, the White Volta River and floodplains, all contribute to an agroecological landscape underpinning the smallholder farmer communities through the delivery of mainly provisioning ES. Gender division of labor prevails:

men are more involved in dry-season farming, hunting and river fishing, while women engage more in fish product transformation, and in the collection of water, firewood and NTFPs.

Based on the FGDs, floodplain ES such as flood-recession farming, dry-season irrigation and fishing in the riparian ponds were the most important livelihood activities undertaken by the community members. There is a clear seasonality observed in the availability of different types of ES, which contribute to household income. During the period when income from the main activity, agriculture, is generally at its lowest, income from other ES activities dominate. In particular, the traditional management of the riparian ponds aims to ensure a large fish catch at a crucial period of the year.

These floodplain ES are underpinned by the seasonality of the White Volta River and in particular the seasonal flooding. The upstream BI - the Bagré Dam - supports ES by providing dry-season flows used for river fishing, dry-season irrigation and domestic water needs. However, while seasonal flooding provides benefits, uncontrolled floods can cause significant damage. While the Bagré Dam has limited capacity to control and release beneficial floods, PMD will be able to better manage floods. Coordination between the two dams is needed to maintain both the benefits derived at a national level, provided by the BI, while maintaining the NI, which supports local-level benefits. Since the two dams are located in different countries, this becomes a transboundary issue. The Volta River Authority should play a role in mitigating potential conflicts due to the construction and operation of these two dams, and their impacts on the riparian communities.

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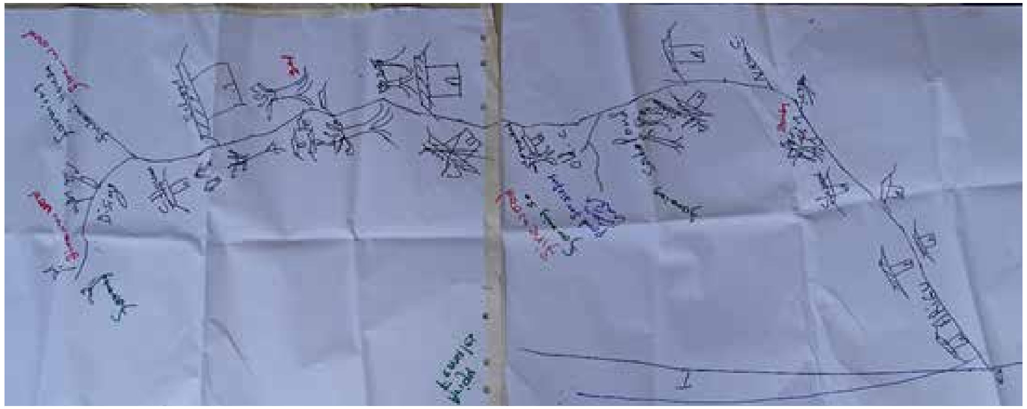
ANNEX 1. COMMUNITY MAPS.

FIGURE A1.1. (a) Men, and (b) women in Arigu village.

(a)

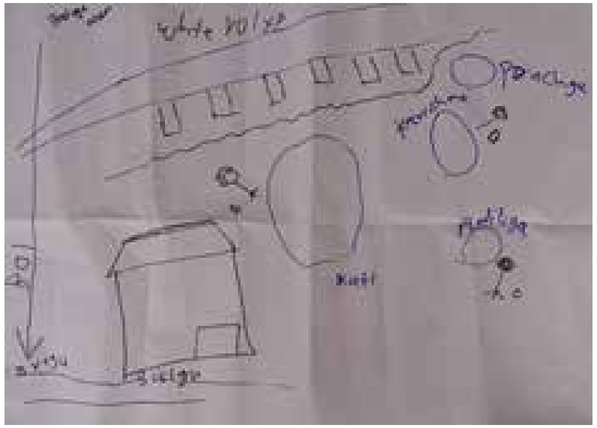
(b)



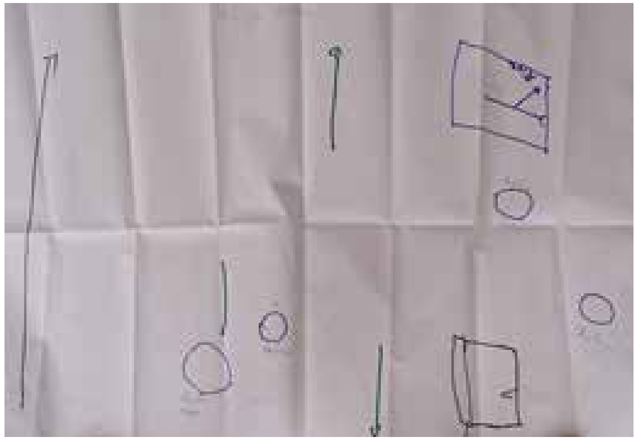
Photos: Marloes Mul (IWMI).

FIGURE A1.2. (a) Men, and (b) women in Bisigu village.

(a)



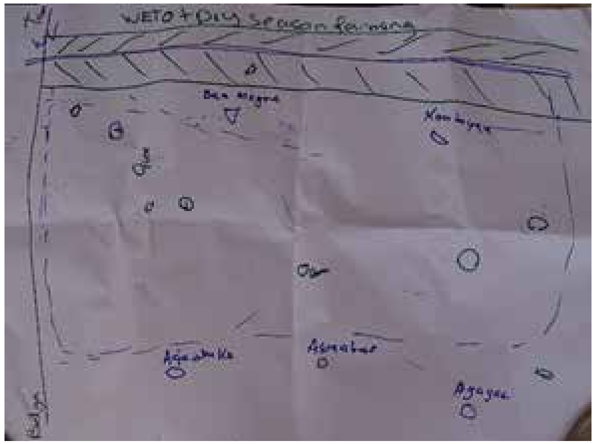
(b)



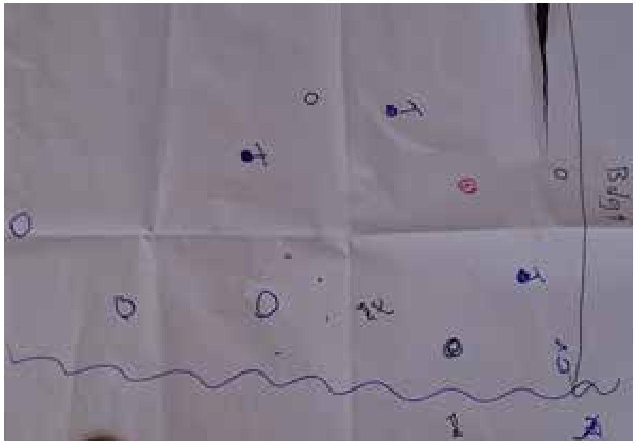
Photos: Marloes Mul (IWMI)

FIGURE A1.3. (a) Men, and (b) women in Pwalugu village.

(a)



(b)



Photos: Marloes Mul (IWMI)

ANNEX 2. DETAILED SEASONAL CALENDAR.

Activity	NI		Men	Women	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Farming	Shrubs and woodlands/ floodplains	Rainfed	X	X												
	Floodplains	Dry-season irrigation*	X	(X)***												
		Flood-recession farming	X													
Non-timber Forest Products (NTFPs)	Forest reserves/shrubs and woodlands	Shea nuts	(X)	X												
		Dawadawa		X												
		Edible wild forest fruits		X												
		Honey	X													
		Medicinal plants**	X													
		Mushrooms														
Construction materials	Forest reserves/ shrubs and woodlands	Poles (e.g., for huts, roofing)														
		Canes (e.g., for roof, fishing baskets, hats, rope)														
		Grasses (e.g., for roof)	X													

NTFPs - fuel	Forest reserves/ shrubs and woodlands	Firewood		X												
		Charcoal	X	X												
Domestic water		Boreholes		X												
	River		X	X												
	Ponds			X												
Livestock watering	Ponds	Livestock watering at the ponds	X	X												
		Water carried from the ponds	X	X												
Livestock grazing	Shrubs and woodlands	Free range grazing	X	X												
		Tethering at home	X	X												
Fishing	River	Fishing with canoes and nets	X													
	Ponds	Communal fishing	X	X												
Hunting	Forest reserves		X													
Water availability	Flooding/recharge of ponds															
	Rainfall															

Notes:
* Irrigation using motorized pumps.
** Collected by traditional healer.
*** Only women in Bisigu practice irrigation.

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