

Report on the main activities undertaken and preliminary findings emerging from research on the CGIAR Targeting Agricultural Innovations and Ecosystem Services in the northern Volta basin (TAI) project

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A collaboration between:



and 18 communities across Centre-Est Burkina Faso and Upper-East Ghana

MAIN REPORT

Overview

The CGIAR Water, Land and Ecosystems research project on Targeting Agricultural Innovations and Ecosystem Services in the northern Volta basin (TAI) is a two year project (2014-2016) led by **Bioversity International** in collaboration with 11 institutes: **CIAT, CIRAD, International Water Management Institute (IWMI), King's College London (KCL), SNV World Burkina Faso (SNV), Stanford University, Stockholm Resilience Centre (SRC), University of Development Studies Ghana (UDS), University of Minnesota, University of Washington,** and the **World Agroforestry Institute**. We are working with communities across Centre-Est Burkina Faso and Upper-East Ghana to gather empirical data, test research methodologies and co-develop knowledge on solutions to ecosystem service management challenges.

Results from the project are still emerging and will continue to do so into 2017 as the team finish analysing the data and writing up their findings. This report presents the **main activities accomplished** and **preliminary headline messages** from the first 18 months of the project. Final results from the project will be made available in 2017 on the WLE website: <https://wle.cgiar.org/project/targeting-agricultural-innovation-and-ecosystem-service-management-northern-volta-basin>.

Project Aims and Structure

This project aims to improve NGO and extension services capacity in the northern Volta River to target irrigated and rainfed technologies to increase adaptability and transformability of local livelihoods and to close yield (Foley et al. 2011), nutrition (Remans et al. 2011), and ecosystem service gaps (Milder et al. 2012). Increasing rainfed crop water productivity by improved water-use efficiency in precipitation-limited regions has the potential to increase annual production. In the rainfed croplands of Burkina Faso and Ghana water efficiency improvement could increase production to feed an estimated one million people (Brauman et al. 2013). Improving water productivity of irrigated rice, in particular, would sufficiently reduce water consumption to meet annual domestic water demands of nearly 100,000 people (Brauman et al. 2013). Interventions need appropriate socio-ecological targeting to meet food security needs, capitalize on missing efficiencies and ensure equitable resource distribution and sharing (Bennett et al. in press).

We are working to identify suitable interventions to improve agricultural and landscape productivity and that are matched to socio-ecological contexts. This work will help meet three development outcomes that an increase in Volta River basin productive capacity has the potential to deliver: (1) **increased food security** by closing resource - notably water - efficiency gaps and promoting equitable and sustainable sharing of resources at the regional level; (2) **enhanced system-level resilience, landscape multi-functionality and equitable sharing of benefits** through collective management of ecosystem services in two target landscapes; and (3) **improved water-use efficiency** for increased productivity through informing specific intervention decisions currently under consideration.

Project activities are organized and presented in this report as five work packages:

Work Package 1: Socio-ecological characterization of the Volta basin

Work Package 2: Modelling food securities under foreseeable futures

Work Package 3: Ecosystem service mapping and modelling

Work Package 4: Multi-level and cross-level interactions

Work Package 5: Valuation to inform decision-making

Work Package 1: Socio-ecological characterisation (SRC, University of Minnesota)

Major activities accomplished:

1. Sourcing and integrating a range of national social and biophysical data from all provinces in Burkina Faso and all districts in Ghana
2. Producing maps and tables of potential crop yield by district for Burkina Faso and Ghana for 11 crops
3. Analysing patterns in these data to identify areas with similar socio-ecological characteristics
4. Comparing socio-ecological characteristics with food security outcomes indicators

Headline messages:

- We identified six different types of social-ecological systems in the Volta basin. They are **characterized mainly by the productive system**: the food they grow (the energy they obtain from crops in kilocalories and the labor required in cropped area), as well as the type of cattle, their access to market and landscape features such as abundance of trees. Variables related to users and biophysical variables play a role at differentiating SES but less important than the type of production in the agroecosystem.
- For the period of the study (2002:2009), and using data aggregated over large spatial extents, most of the provinces in Burkina Faso and few districts in Ghana have been **positively impacted by the presence of water reservoirs**. This observation does not imply causation, but supports the need for further research on disentangling this relationship at finer scales in time and space.

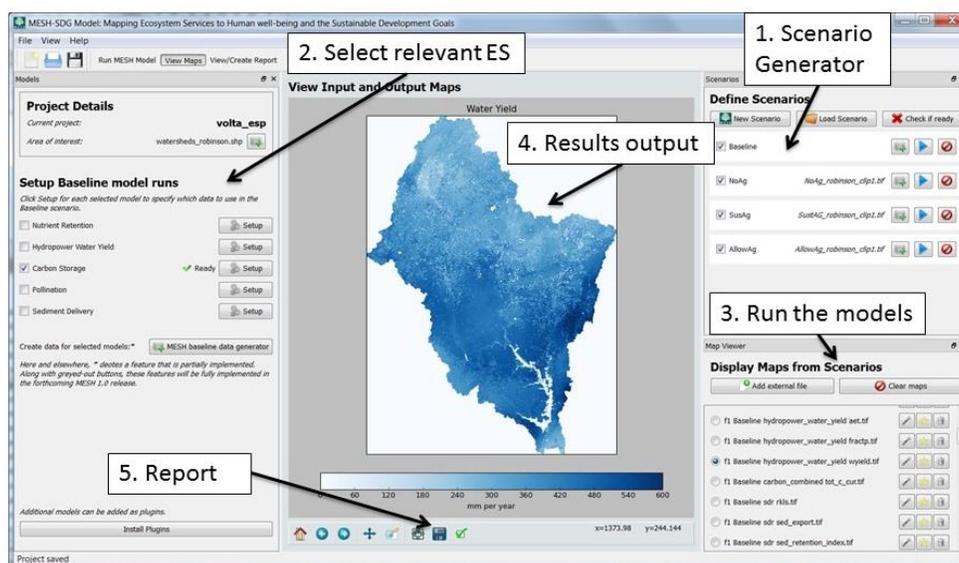
Work Package 2: Food security under foreseeable futures (University of Minnesota, UDS)

Major activities accomplished:

1. Sourcing data to enable modelling of future population, climate and land use scenarios
2. Further developed the MESH modeling tool) to enable the scenario generation.
3. Statistically analysed land use and cover changes over time using satellite imagery data and used this to establish probable future scenarios for land use and land cover change at the regional level

Headline messages:

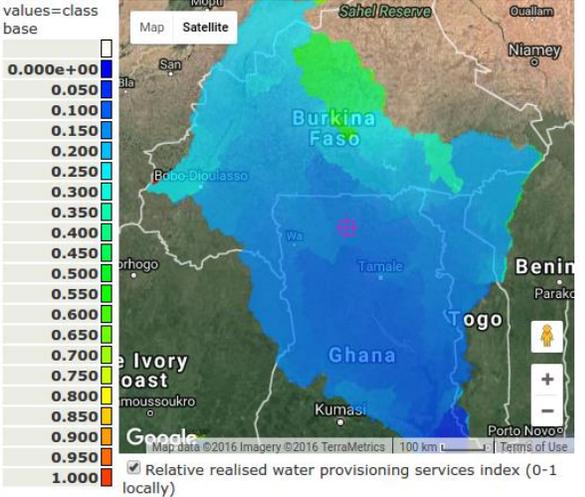
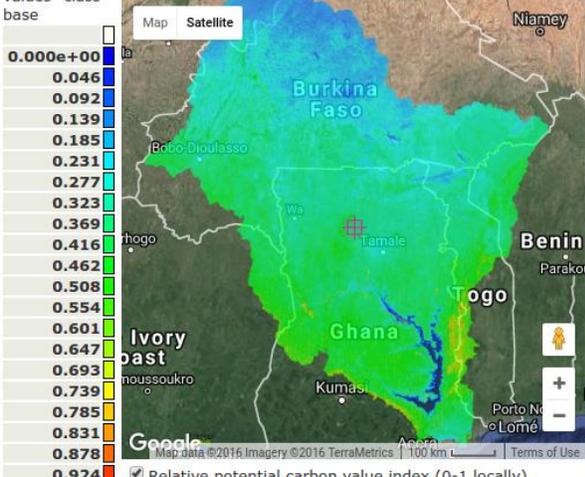
- The Mapping Ecosystem Services for Human wellbeing (MESH) ecosystem service modelling tool is now hosted online and available for download at www.naturalcapitalproject.org/mesh

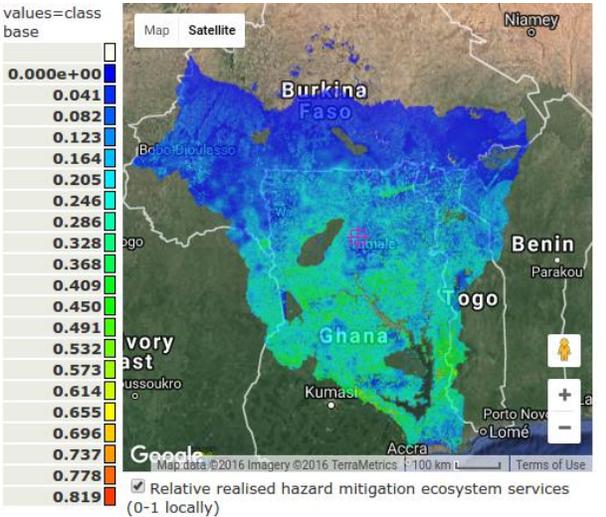
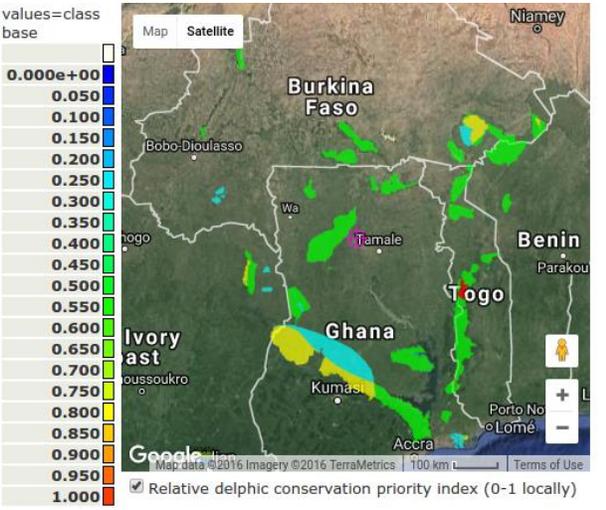
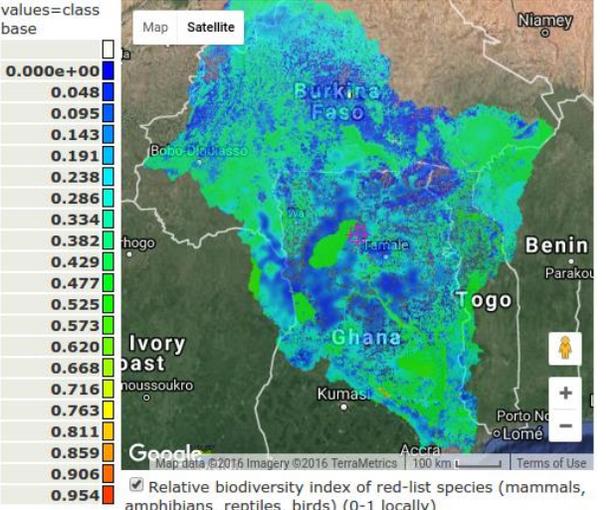


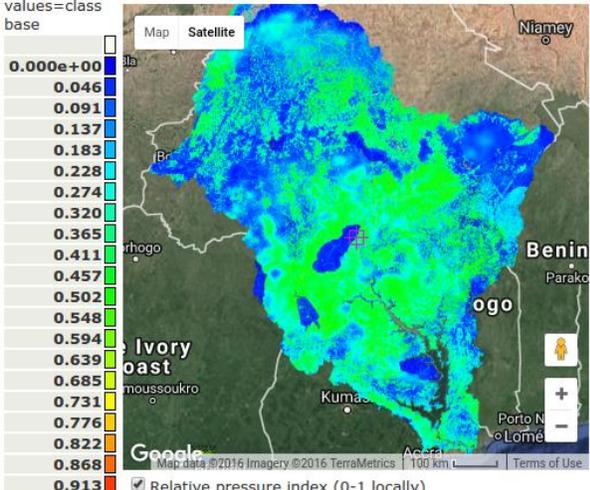
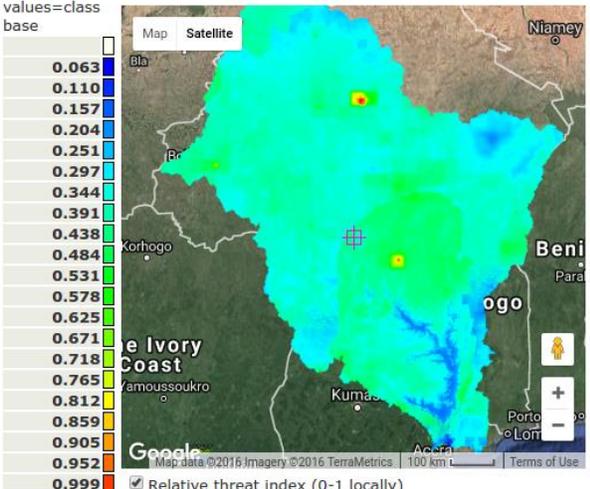
Work Package 3: Ecosystem service mapping and modelling (Bioversity International, CIAT, KCL, Stanford University, University of Washington)

Major activities accomplished:

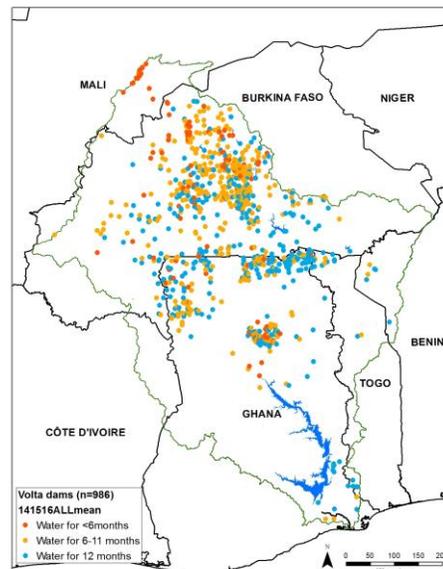
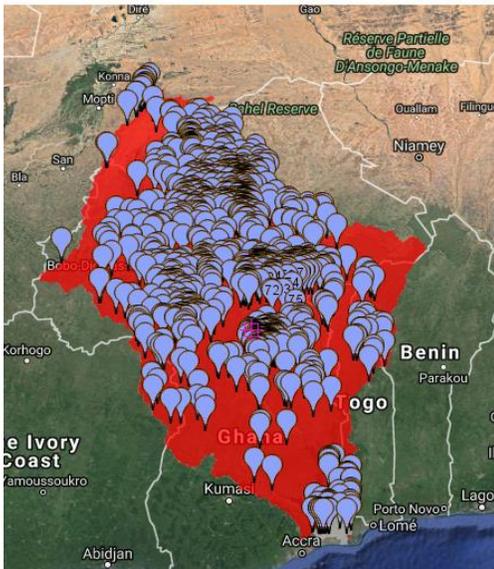
1. Modelling supply of water-related ecosystem services across the Volta basin. The following table provides maps for a range of ecosystem services and conservation priority metrics for the Volta, using outputs from Co\$ting Nature. The results indicate very different geographical distributions of key ecosystem services and thus the clear tradeoffs between protection of services, biodiversity and delphic conservation priority and pressures and threats to those services, including agriculture. These data can be generated using Co\$tingNature (<http://www.policysupport.org/costingnature>).

Name	Whole Volta map	Explanation
Relative realised water provisioning services index	 <p>values=class base</p> <p>0.000e+00</p> <p>0.050</p> <p>0.100</p> <p>0.150</p> <p>0.200</p> <p>0.250</p> <p>0.300</p> <p>0.350</p> <p>0.400</p> <p>0.450</p> <p>0.500</p> <p>0.550</p> <p>0.600</p> <p>0.650</p> <p>0.700</p> <p>0.750</p> <p>0.800</p> <p>0.850</p> <p>0.900</p> <p>0.950</p> <p>1.000</p> <p>Relative realised water provisioning services index (0-1 locally)</p>	Relative volume of clean (not human impacted) water available to downstream people and dams
Relative potential and realised carbon services index	 <p>values=class base</p> <p>0.000e+00</p> <p>0.046</p> <p>0.092</p> <p>0.139</p> <p>0.185</p> <p>0.231</p> <p>0.277</p> <p>0.323</p> <p>0.369</p> <p>0.416</p> <p>0.462</p> <p>0.508</p> <p>0.554</p> <p>0.601</p> <p>0.647</p> <p>0.693</p> <p>0.739</p> <p>0.785</p> <p>0.831</p> <p>0.878</p> <p>0.924</p> <p>Relative potential carbon value index (0-1 locally)</p>	Relative carbon sequestration and relative carbon stock (from living plant biomass and soil) services (all potential is realised)

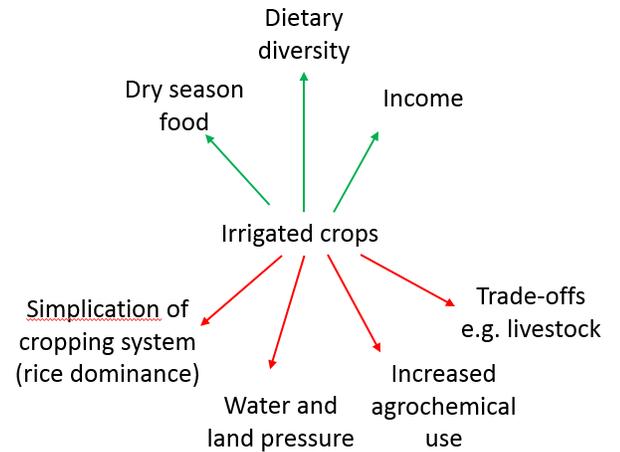
Name	Whole Volta map	Explanation
<p>Relative realised natural hazard mitigation index</p>	 <p>values=class base</p> <ul style="list-style-type: none"> 0.000e+00 0.041 0.082 0.123 0.164 0.205 0.246 0.286 0.328 0.368 0.409 0.450 0.491 0.532 0.573 0.614 0.655 0.696 0.737 0.778 0.819 <p>Relative realised hazard mitigation ecosystem services (0-1 locally)</p>	<p>Relative hazard mitigation services for flood/drought, landslide/erosion, inundation/tsunami/cyclone according to relative risk protected against</p>
<p>Relative delphic conservation priority index</p>	 <p>values=class base</p> <ul style="list-style-type: none"> 0.000e+00 0.050 0.100 0.150 0.200 0.250 0.300 0.350 0.400 0.450 0.500 0.550 0.600 0.650 0.700 0.750 0.800 0.850 0.900 0.950 1.000 <p>Relative delphic conservation priority index (0-1 locally)</p>	<p>Conservation priority by overlap of EBAs (Birdlife), Global200 Ecoregions (WWF), Hotspots (CI), Last of the Wild (WCS,CIESIN), Important Bird Areas (Birdlife) and Key Biodiversity areas (IUCN, BI, PI,CI)</p>
<p>Relative biodiversity priority index</p>	 <p>values=class base</p> <ul style="list-style-type: none"> 0.000e+00 0.048 0.095 0.143 0.191 0.238 0.286 0.334 0.382 0.429 0.477 0.525 0.573 0.620 0.668 0.716 0.763 0.811 0.859 0.906 0.954 <p>Relative biodiversity index of red-list species (mammals, amphibians, reptiles, birds) (0-1 locally)</p>	<p>Relative richness and endemism for redlisted mammals, reptiles, amphibians, birds</p>

Name	Whole Volta map	Explanation
Relative pressure index		<p>Current pressure according to population, wildfire frequency, grazing intensity, agricultural intensity, dam density, infrastructure (dams, mines, oil and gas, urban) density</p>
Relative threat index		<p>Future threat according to accessibility, proximity to recent deforestation (MODIS), projected change in population and GDP, projected climate change, current distribution of nighttime lights</p>

2. Mapping 1184 small dams in the Volta basin and remote sensing (using satellite and drone imagery) analysis of the spatio-temporal dynamics of reservoir water levels, and conducting an analysis of the properties of the dam watersheds.



3. Mapping land uses types through focus groups and land use surveys in selected communities (e.g. Ladwenda, Binaba) to enable ecosystem service characterisation by land use type and assessment of ecosystem service values.



Mapping land use through participatory mapping at Ladwenda (17/04/2016, Bioversity / KCL / SNV), and example of ecosystem service characterization by land use (irrigated land)

4. Constructing and installing a series of low-cost, robust, easy to use FreeStation (weather stations) across the White Volta basin in collaboration with local communities (especially schools) to provide those communities with meteorological data and improve the datasets available for WaterWorld parameterisation, especially with respect to current and high temporal resolution data. These stations will remain with the communities (as shown below) and we will continue to support them post project. Datasets are to be made open source and available online very soon. In the meantime if you would like access, contact mark.mulligan@kcl.ac.uk or s.jones@cgiar.org. For more information see: <http://www.policysupport.org/freestation>



Garango, Burkina Faso



Zebilla Senior High School, Ghana



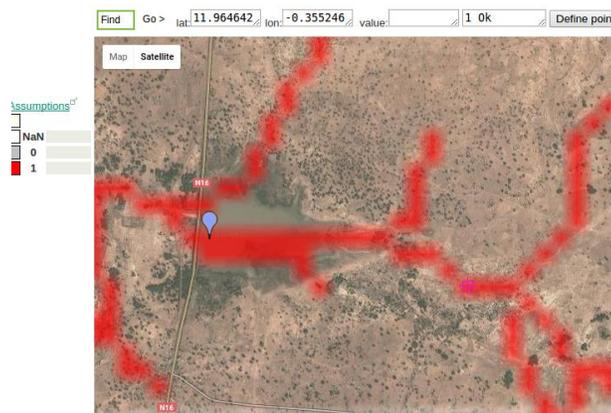
Lagdwenda, Burkina Faso



Sandema Senior High Technical School, Ghana

5. Assessed **future supplies of ecosystem services** based on potential interventions identified by stakeholders at Ladwenda and other communities. Some of the **results from four of these intervention scenarios** are explained below.

Intervention 1: building 36 check dams that are each 2m tall, upstream of 31 dams in the Centre-Est area, with placement shown as below



Results indicate:

- At nominal cost of 2000 USD/each, totals 62000 USD:
- Landscape scale sediment retention *capacity*: +0.00013mm (2150 tonnes or 59 tonnes per dam)
- Causes reduction in deposition at all reservoirs by only a fraction of a tonne (because of complex sediment reworking, runoff changes and scouring below check dam due to changed detention and transport capacities).
- More focused so cheaper than NBS (but maintenance and dredging costs). Many current dams act as effective check dams for dams downstream anyway. Does not help with water quality

Main message: This intervention is unlikely to result in much change in sedimentation rates.

Intervention 2: No agriculture allowed within a 90m of any rivers or streams that are within any dam watersheds in the Volta basin, and planting grass in these buffer strips until grass cover 100% of the buffer.

Results indicate:

- At nominal cost of 100 USD/ha, totals 703 MUSD
- Volta herb cover: 82.0936 -> 82.108%
- Volta croplands: 22.344 -> 21.965%
- Volta Quantity: 0.0018% (-0.005 mm/yr) 159729, 167530 people **benefitting, dis-benefitting**
- Volta HFWQuality: -0.036% 491037, 4545 people
- Volta Gross Erosion: -0.05 % (-0.00028 mm/yr) 320944, 172331
- Volta Net Erosion: -0.052% (2.5e-08 mm/yr) 310197, 57711
- Volta Sediment transport: -0.034% (-5.7e-05 mm/yr)
- Volta Sediment deposition: -0.019% (-0.00014 mm/yr)

Main message: This intervention is expensive and as many people lose water as gain it. Many people have higher water quality, and twice as many people benefit from reduced erosion compared to the number of people that find erosion increases. Overall this intervention appears to have a very small effect on sediment transport and deposition at dams or elsewhere in the Volta basin.

Intervention 3: No agriculture allowed within a 100m of any rivers or streams that are near a dam in the Volta basin, and planting trees in these buffer strips until trees cover 50% of the buffer.

Results indicate:

- At nominal cost of 100 USD/ha, totals 1.64 million USD
- Volta tree cover: 5.925 -> 5.927%
- Volta croplands: 22.344 -> 22.343%
- Volta Quantity: -0.0029% (-0.0044 mm/yr) 0, 2100 people **benefitting, dis-benefitting**
- Volta HFWQuality: -0.00076% 45000, 8800 people
- Volta Gross Erosion: -0.0075 % (-0.000052 mm/yr) 38000, 6000
- Volta Net Erosion: -0.0045% (-0.000000024mm/yr) 33300, 6200
- Volta Sediment transport: -0.03% (-0.00002 mm/yr)
- Volta Sediment deposition: -0.0057% (-0.000026 mm/yr)

Main message: Even an expensive intervention leads to very small changes for the population served by reservoirs, but those changes affect significant numbers of people. Cost per beneficiary is ~43 USD.

Intervention 4: No agriculture allowed within 100m of any rivers or streams within any dam watersheds in the Centre-Est region, and planting trees in these buffer strips until trees cover 50% of the buffer.

Results indicate:

- At nominal cost of 100 USD/ha, totals 14.03 million USD
- Tenkodogo tree cover: 1.6 -> 4.5%
- Tenkodogo croplands: 43 -> 39%
- Tenkodogo Quantity: -7.5% (-9.9 mm/yr) 0, 98000 people **benefitting, dis-benefitting**
- Tenkodogo HFWQuality: -0.23% 124000, 13000 people
- Tenkodogo Gross Erosion: -0.57 % (-0.0044 mm/yr) 136800, 6
- Tenkodogo Net Erosion: -1.3% (-3.2e-05 mm/yr) 102000, 1700
- Tenkodogo Sediment transport: -0.75% (-0.013 mm/yr)
- Tenkodogo Sediment deposition: -0.28% (-0.0044 mm/yr)

Main message: Maintenance of buffer strips along rivers throughout the dam catchments leads to much more significant erosion reduction, benefitting many more people, than if buffers are maintained only near the dams themselves. Though water quality also improved, water quantity declines, affecting many people and most reservoirs. Cost per beneficiary of ~107 USD

5. We estimated the **reservoir storage capacity** for six reservoirs in Ghana and Burkina Faso using a combination of drone imagery and terrestrial scanning LIDAR and compared these to the volume when the reservoirs were initially constructed to find the **volumetric reservoir storage loss**. This is a rapid method for estimating reservoir volume that could be applied to other dams to better estimate reservoir sedimentation rates. We use these data to estimate **fish production loss** due to sedimentation in each reservoir to quantify the loss of fish production, and will estimate the loss of key nutrients to be able to quantify the impact on people.

Reservoir storage capacity at eight case study sites:

RESERVOIR	YEAR	% FILL	CURRENT VOLUME (M ³)	INITIAL VOLUME (M ³)	VOL LOST PER YEAR (M ³ /YR)	DEPTH LOST PER YEAR (CM/YR)
BINABA	1962	28%	842,007	1,170,000	6,073	1.5
BOYA	2006	74%	76,479	292,414	21,594	19.3
SURUNGU	1961	61%	39,038	100,000	1,109	1.7
LAGDWENDA	2002	63%	166,371	449,750	20,241	9.2
TANGA 1			152,623		No construction data	
TANGA 2			54,997		No construction data	

Headline messages:

- We identified **1184 small reservoirs in the Volta basin**. Dam watersheds are generally between 1 and 5km²
- **Sedimentation rates** into four case study reservoirs were found to significantly impact storage capacity. We estimate storage loss due to sedimentation between 2 to 20cm per year. This has resulted in **28 to 74% loss in storage capacity**, with the highest rates coming from the newest dams.
- Active ecosystem service management (e.g. planting) to improve benefits to people (e.g. securing water in dams longer into the dry season) can be **very expensive to scale**. Scenarios have to be realistic to have policy-relevance.
- Passive ecosystem service management (e.g. back to nature by leaving land fallow or uncultivated) is **cheaper and more scalable** but still has opportunity costs and social impact (e.g. population displacement)
- We are exploring the potential for active **on-farm ecosystem service management** (e.g. cover crops, agroforestry)
- Huge data (and model) uncertainties exist, making accurate trade-off analyses difficult at scale and expensive
- **Recognising the limits to nature based solutions** in the face of significant human and natural pressures on sustainability is important so as not to oversell or mislead
- Different ecosystem services and conservation priority metrics show very **different geographical distributions in the basin** and thus trade-offs are necessary to protect multiple services, and maximise agricultural production
- The **impacts of current agricultural land use** on downstream hydrological ecosystem services are significant in some parts of the basin but not throughout the basin and are highly variable from one season to another. Both downstream people and small dams are affected
- The **impacts of existing small dams** on downstream hydrological ecosystem services affect fewer people (compared with the impact of agriculture) but affect more small dams since dams tend to occur in series along rivers leading to significant river fragmentation and downstream influence of one dam on the next
- For dams where the main target is managing sedimentation, **check dams** are not guaranteed to be effective and there are no obvious side-benefits of these check dams meaning it seems **a less sensible investment** than other strategies that do have side-benefits, like **buffer protection** when some fruit trees and agriculture are allowed, or **dredging** where the nutrient-rich sediment can be used to improve soil on farm plots

Work Package 4: Multi-level and cross-level interactions (Bioversity International, CIRAD, CIAT, IWMI, SNV World)

Major activities accomplished:

1. We held a series of multi-stakeholder workshops involving 18 communities: Ankpaliga, Azum Sapeliga, Binaba, Boya, Nafkuliga, Tanga, Widenaba, and Zongoyire in Ghana, and Bagré, Bané, Boakle, Boussouma, Garango (Bedega), Kanakoulé, Komtoéga, Lagdwenda (Ladwenda), Niaogho, and Zidré in Burkina Faso.
2. Participants in workshops indicated all small reservoirs in Burkina Faso are faced with high siltation rates whatever their nature and condition. Stakeholders identified conflict of use due to non-respect to regulations, lack of consultation and coordination between actors, pollution caused by illegal agrochemicals products use, and lack of dam maintenance as central problems in small reservoir management.
3. These workshops and focus groups were designed to enable knowledge transfer and shared learning between farmers, their communities, regional and national level stakeholders regarding ecosystem service management
4. Participants identified and discussed issues concerning fair use and management of water and other natural resources around small reservoirs
5. Three types of benefit-sharing mechanisms (BSMs) were designed for three communities in the Upper East Region and three in Tenkodogo. These can be categorized as knowledge sharing, institutional strengthening and incentive provision mechanisms.
6. The opportunities and limitations of applying the proposed BSMs were assessed by focus group discussions by:
 - (i) mapping out conflicts related to water;
 - (ii) mapping actors key for effective negotiation of the proposed BSMs;
 - (iii) discussing costs and benefits of proposed BSMs; and
 - (iv) assessing cooperation attitudes with a “Basin game” inspired by experimental economics tools.
7. Various scenarios for management ecosystem services will be modelled at the sub-catchment level according to the identified trade-offs and existing regulations / policy instruments that were discussed at district level.

Headline messages:

- Multi-stakeholder workshops and other platforms **facilitate policy development** in water and land management and contribute to developing **synergies across multi-sector and multi-level policies** through stakeholder dialogue.
- Stakeholders (Burkina Faso) proposed that the Local Water Committee in charge of larger small dam catchments, such as the Bagré dam catchment which covers a relatively large area, needs to be decentralized to enable an effective reservoir management system; **governance challenges vary with dam infrastructure and catchment size**.
- Communities in Burkina Faso voiced acceptance of the idea of **establishing a buffer strip** of 100 meters or more around reservoirs and alongside streams, comprising several successive strips such as i) a water-side strip with natural (grass) species ii) an adjacent strip comprising firewood or timber species, iii) an outer strip comprising fruit trees. However individual perspectives on this may vary among stakeholders.
- In all communities, farmers recognized the potential benefits of **incentive provision mechanisms** to: (i) reduce siltation and water shortages; (ii) increase incomes and reduce migration; (iii) foster unity among communities.
- In all communities, the “basin game” (game-theory based upstream-downstream cooperation game) indicated that in the long run farmers realize that **conserving soil and water** (upstream users) and **paying for conservation** (downstream users) **pays off both individually and for the common good**. However, introducing a fine mechanism to punish non-cooperative behavior at random brings on cooperative behavior much faster.
- The results from mapping with stakeholders at community and district level (Ghana) and locating the ecosystem services mediated by the presence of reservoirs shows that the **effects of small dams are highly and dependent on their size, functioning and maintenance, but also on the spatial configuration of other available ES** use by the various communities sharing the same sub-catchment area (effects of activity and vulnerability transfer).

Next steps

The TAI project is coming to a close, however we are seeking opportunities to continue working in the Volta region. We will share our final results and policy recommendations via email to the project stakeholder contact list (if you would like to be added, please contact s.jones@cgiar.org) and online through the CGIAR Water, Land and Ecosystems website and our institutional websites. If you would like any further information on TAI project activities or any of the findings reported here, please contact f.declerck@cgiar.org or one of the project team in the work package that interests you.

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