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INSTITUTIONALIZATION OF THE WATER-ENERGY- FOOD-ENVIRONMENT NEXUS IN THE NIGER BASIN

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Abbreviations and acronyms

BMZ	German Federal Ministry for Economic Cooperation and Development
CFA	Communauté Financière Africaine (African Financial Community) franc
DG DEVCO	Directorate-General for International Cooperation and Development C2
EU DG INTPA	European Commission Directorate-General for International Partnerships
EUR	Euro
FCFA	Franc de la Communauté Financière Africaine (African Financial Community)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWh	Gigawatt hours
ha	Hectares
ICSU	International Council for Science
km	kilometer
m^3	cubic meters
m^3/s	cubic meters per second
MW	Megawatts
NBA	Niger Basin Authority
NRDP	Nexus Regional Dialogues Programme
OP	Operational Plan
SP	Strategic Plan
WEAP	Water Evaluation and Planning
WEFE	Water-Energy-Food-Environment

Part One: Nexus Dialogues in the Niger Basin

Why this report?

In less than one year the Niger Basin Authority, an intergovernmental body tasked with the sustainable development of the Niger waters and associated resources, passed the first ever nexus policy in a transboundary river basin, contributing to a true acceleration of change for improved water and associated development in the Niger River Basin. The guidelines were developed in close collaboration with the nine basin countries and complemented by a large capacity building program.

Using the guidelines can reduce the threat of adverse impacts on the Basin's shared water and land resources and save millions of dollars of investment funds, while meeting various Shared Vision objectives. Doing so can also help strengthen positive impacts, reduce cross-sectoral constraints of single-sector solutions, and identify multisector solutions. Application of the nexus guidelines will increase the efficiency of natural resources use and support implementation and monitoring of (multipurpose) investments. If this can be achieved, the River of Rivers—thought to be the original meaning of the name Niger—will continue to enhance water, food and energy security, and environmental sustainability for generations to come.

To support the application of the guidelines, the study team developed an online, simplified nexus assessment tool that is summarized in Appendix 4.

The Niger Basin

Background

The Niger River Basin in West and Central Africa covers an area of 2.13 million kilometers (km) and is home to about 160 million people in nine countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, and Nigeria. Seven of the nine countries in the Basin are among the 20 poorest countries in the world, and significant income disparities exist within and across the Basin countries.

Many Basin countries are experiencing rapid population growth in a highly fragile environment characterized by security threats from international terrorism, environmental degradation, and already difficult climatic conditions exacerbated by climate change. Climate variability has long been an obstacle to development in the Basin. Over 70 percent of the population lives in areas where food security depends on unreliable rainfall and highly variable intra- and interannual river flows. High levels of poverty and heavy dependence on smallholder agricultural production persist in the region.

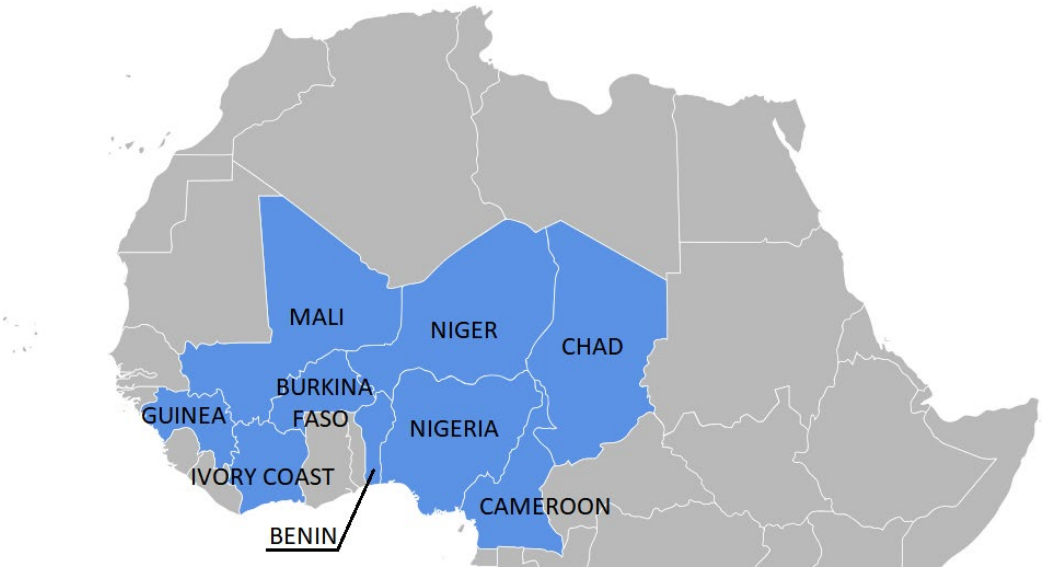

Figure 1. Member states of the Niger Basin Authority

The Niger Basin Authority

The River Niger Commission was created on November 25, 1964, by the nine Basin countries to promote navigation and economic cooperation between member countries. In November 1980, the Commission was renamed the Niger Basin Authority (NBA) and became an intergovernmental agency tasked with promoting the coordinated development of resources in a broad range of sectors: water, energy, agriculture, livestock, fisheries, forestry, mining, transport, and communication.

This is reflected in the Niger Basin Shared Vision, adopted in 2005 and reflected in the basin's Water Charter, which aims to make the Niger Basin a common area of sustainable development through the integrated management of water resources and associated ecosystems to improve living conditions and the population's prosperity (Niger Basin Authority, 2008). As such, the NBA is responsible for both horizontal (that is, across countries) and vertical (that is, between different levels of stakeholders) linkages and is increasingly tasked to link these concerns beyond the Basin region with regional and global processes such as the G5 Sahel, which focuses on development and regional security in West Africa.

Infrastructure Planning at the NBA

The "8th Summit of the Niger Basin Authority Heads of State and Government" in 2008 agreed on an investment program for 2008–2027, the Water Charter, and the creation of a donors' meeting for implementation of the 2008–2012 five-year plan. In November 2012, the NBA adopted its first Strategic Plan (SP) for the period 2013–2022 through which the Authority confirmed its mission, defined its vision and its values, and five strategic results areas to guide its overall actions.

Based on the SP, member state priorities, and input from the Executive Secretariat of the NBA, an Operational Plan (OP) was developed during 2013–2015 for the period 2016–2024 (NBA 2016). The OP includes 351 investment projects aggregated into 37 project types and 13 subprograms along the five strategic results areas that relate to both the performance of

the organization and investments across the Basin (Table 1). The current OP is more a compilation of projects put forward by member countries based on economic and political considerations than a coherent set of interventions developed to maximize benefits across the Basin. Potential tradeoffs across investment projects were not considered, nor were potential synergies.

Table 1. Summary of programmatic areas in the NBA Strategic Plan

STRATEGIC DIRECTION	STRATEGIC OUTCOMES	INTERMEDIATE OUTCOMES
Direction 1: Water as a Lever for Economic Development	The basin populations have higher income from agriculture, forestry, fishing and fish farming activities and increased access to affordable electricity	R1.1. Hydro-energy production is increased
		R1.2. Agriculture, forestry, fishing and fish farming productions are increased
		R1.3. The navigability of the river is facilitated
Direction 2: Basin Ecosystem Conservation	Ecosystems are sustainably preserved	R2.1. The basin's ecosystems are better managed
		R2.2. Threatened target ecosystems are protected
		R2.3. Natural risks and impacts of climate change are better managed
Direction 3: Innovative and Sustainable Funding	The sustainability of NBA and community infrastructure is ensured	R3.1. Selected funding mechanisms are functional
Direction 4: Cooperation with Member States and Partners	The commitment and participation of the populations, Member States and technical partners are maximized	R4.1. The people and the other stakeholders are committed and empowered in the sustainable management of the basin
		R4.2. Effective cooperation and coordination mechanisms between NBA and stakeholders for the integrated development of the basin are operational
Direction 5: Organizational Performance	NBA organizational capabilities are increased	R5.1. Management capacities are strengthened
		R5.2. Work environment and conditions are motivating
		R5.3. Staff commitment and stakeholders' mobilization are increased

The Water-Energy-Environment-Food Nexus as a Tool for Better Infrastructure Planning

With growing natural resource scarcity and climate change, OP investments in the Niger River Basin in one sector will likely affect outcomes in various other sectors. For example, an investment in surface water storage for irrigation would not only affect food production and nutrition in the Basin country where the investment takes place, but could also affect ecosystem health in that country and in downstream countries, as well as river navigation, hydro-electric production, and domestic water access. These potential impacts can be assessed and addressed using a nexus or systems approach, with a particular focus on the water-energy-food-environment (WEFE) nexus.

The WEFE nexus focuses on the interlinkages across the water, energy, and food sectors and their interlinkages with environmental sustainability (Figure 2). This integrated approach (1) takes into consideration the identification of linkages between several sectors and their objectives, and (2) focuses on reducing negative tradeoffs and strengthening positive synergies to reconcile the various human and environmental development needs that depend on or compete for the same resources. The nexus approach can help to:

- Improve the design and impact of development programs and projects;
- Achieve multiple objectives through a single intervention;
- Prevent negative cross-sectoral impacts;
- Strengthen intersectoral synergies between several interventions; and
- Facilitate the financing of development programs and projects.

Using a nexus approach can help the NBA ensure that projects in the next version of the OP are coherent and lead to more sustainable development across the Basin. With this understanding, the NBA requested support from the Nexus Regional Dialogues Programmes Phase I (2016–2020) and Phase II (2020–2023) for the development of capacity on the nexus and nexus tools, and a guideline on the integration of the nexus into NBA investment plans and programmes, respectively.

The Nexus Regional Dialogues Programme (NRDP) support in the Niger Basin focuses on mainstreaming a nexus approach in the NBA and Niger Basin activities, with the objective of a holistic assessment of the Basin's resources and capacities and a focus on crafting cross-sectoral policies and projects.

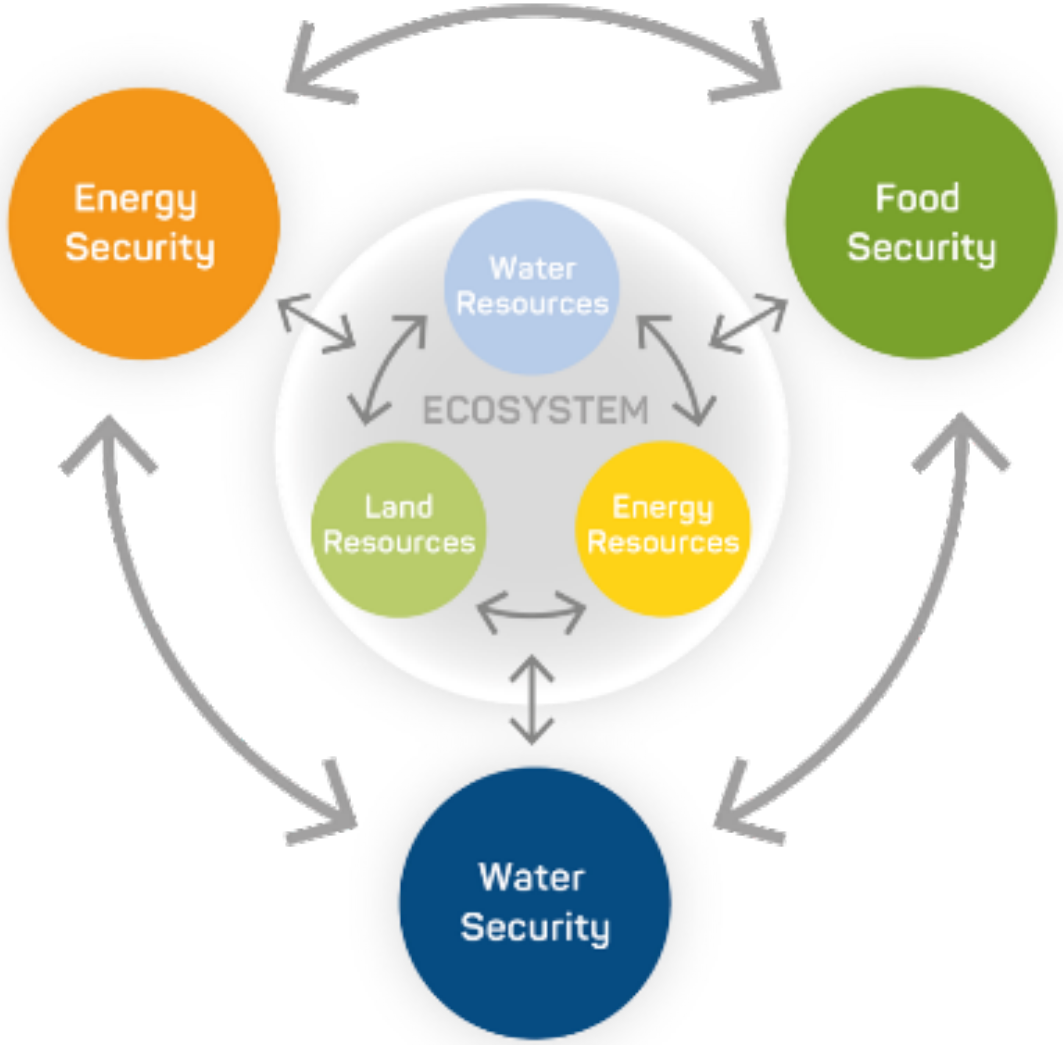

Figure 2. WEF nexus diagram

The Nexus Regional Dialogues Programme (NRDP)

The WEFE nexus approach represents a paradigm shift in the international development agenda from sectoral development interventions to an integrated approach to resource use in the context of a "green economy" and basic supply security. The approach involves the design of contextual and cross-sectoral solutions based on horizontally and vertically integrated interventions. Consequently, the WEFE nexus approach challenges existing global, regional, and national structures, policies, and procedures. To operationalize the approach, current limitations in national sectoral policy frameworks, institutional arrangements, and markets must be overcome.

The nexus approach has been promoted globally since 2010 through several large-scale international events and forums. The Nexus Regional Dialogues Programme (NRDP) Phase I (2016–2020) is the culmination of a global effort to institutionalize the nexus approach. The second phase, implemented during 2020–2023, aims to operationalize the approach with pilot and demonstration projects. The NRDP is jointly funded by the European Commission's Directorate-General for International Partnerships (DG INTPA) and the German Federal Ministry for Economic Cooperation and Development (BMZ), and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The NRDP aims to stimulate five regional nexus dialogues involving various stakeholders, including national and regional policymakers, the private sector, academia, and civil society. Five regions are covered: Africa (the Niger Basin and the Southern Africa Development Community [SADC]), Latin America (Andean region), Central Asia (Aral Sea region), and the Middle East and North Africa (MENA) (Figure 3).

This rest of this report focuses only on developments in the Niger Basin.

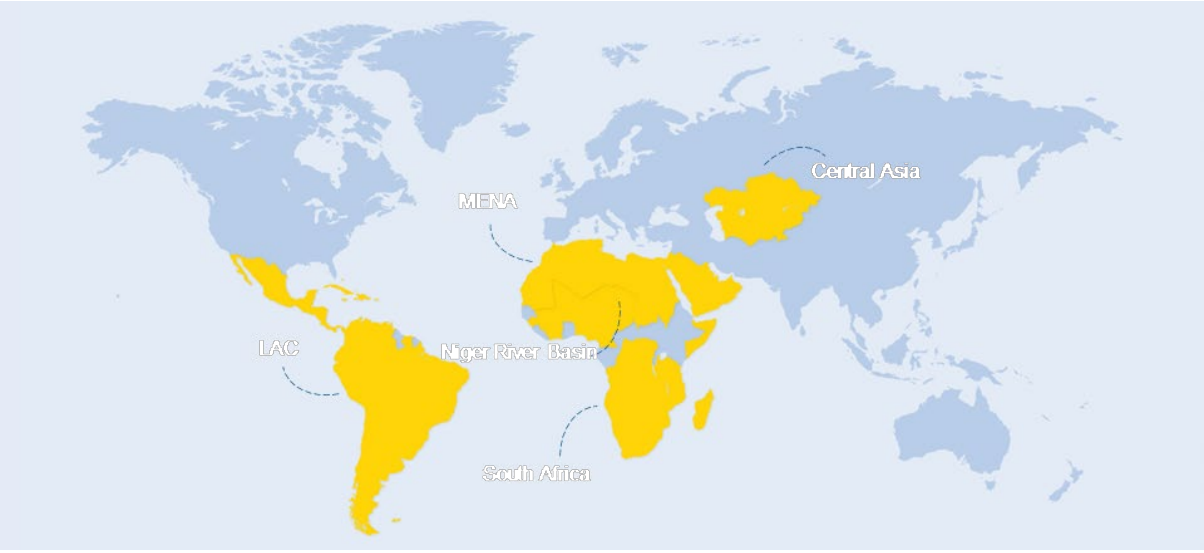

Figure 3. Regions covered by the NRDP

Outcomes of NRDP Phase I in the Niger Basin

In 2018, the Niger Basin Nexus project under the NRDP, supported by a team of consultants, developed nexus tools to strengthen the multisectoral approach of the NBA OP and implemented capacity-building workshops with the NBA and relevant government agencies

of the nine Basin countries. Specifically, the Risks and Options Assessment for Decision-Making (ROAD) process developed by the FE^{2}W network (Food, Energy, Environment, and Water) enabled NBA decision makers at different levels to identify and assess the complex risks associated with food, energy, water, and environmental systems. Representatives of ministries of agriculture, energy, environment and water from all Basin countries then qualitatively scored all of their national projects from the OP using the International Council for Science's (ICSU) 7-point scale (ICSU 2016).

Figure 4 presents the ICSU 7-point scale that allows for a simplified assessment of tradeoffs and synergies across the various nexus projects and actions reflected in the NBA OP. For each of the 351 activities or projects of the NBA OP, national representatives decided if the activity was indivisible (+3) with water, energy and food security and environmental sustainability objectives, i.e. if the project was essential to achieve one of these sectoral objectives; if the interaction was positively associated weakly or strongly (+1 or +2), neutral (0) or if the activity constrained achievement of a specific nexus objective weakly or strongly (i.e. -1 or -2), or if the OP activity would make it impossible to achieve one of the sectoral objectives, in which case a ranking of -3 was given.

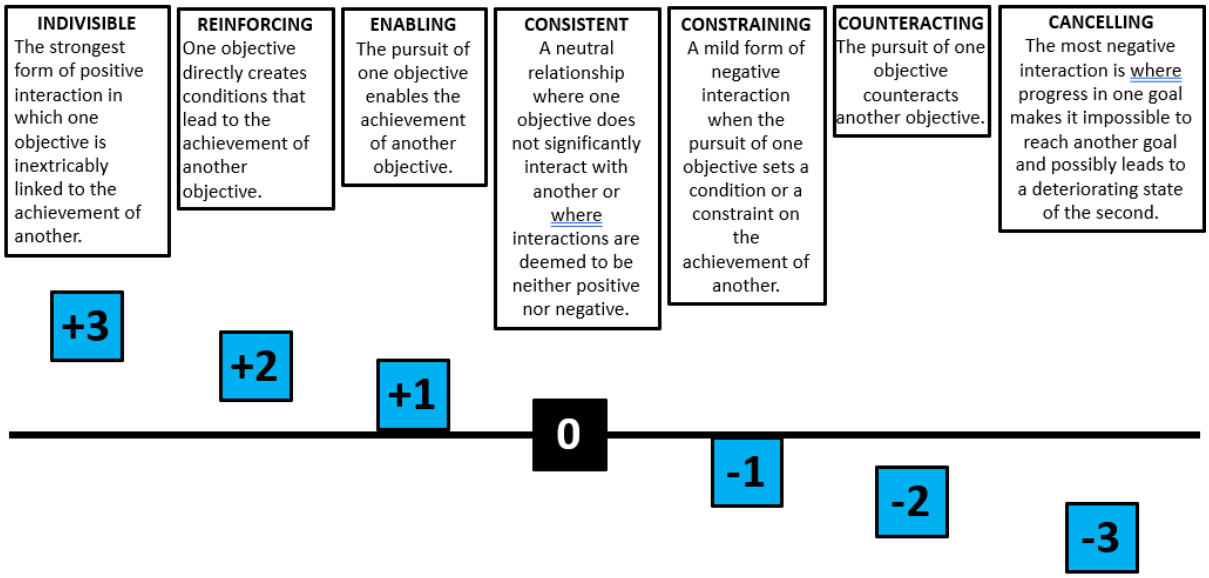

Figure 4. Seven-point scoring system

A sub-set of the results of the application of the seven-point scale to the 351 NBA OP activities by activity type by Niger Basin stakeholder are shown in Table 2. As the results suggest, there was a wide variation in the assessment of participants of some types of investments for specific sectors, whereas for other types of investments, variations in rankings were more limited. A case in point is environmental sustainability related to the construction of multipurpose dams. Here, the rankings of stakeholders range from -2 (counteracting environmental sustainability to +3 (indivisible for environmental sustainability), suggesting strong support for this kind of investment despite recognition that it can affect environmental sustainability objectives. Agroforestry and terrestrial ecosystem projects received a similarly wide range of rankings, not only for environmental sustainability but also for water security, energy security and food security objectives, suggesting limited familiarity of participants with this particular type of project.

Table 2. Ranking of a sub-set of project types by NBA country representatives and NBA Secretariat based on ICSU scale

Activity or project type	FOOD SECURITY			ENERGY SECURITY			WATER SECURITY			ENVIRONMENTAL SUSTAINABILITY		
	Min score	Most freq score	Max score	Min score	Most freq score	Max score	Min score	Most freq score	Max score	Min score	Most freq score	Max score
Agroforestry; protection or regeneration of terrestrial ecosystems	-2	1	3	-2	0	3	-2	2	3	-2	2	3
Improvement of energy efficiency	-1	-1	1	2	3	3	-2	-2	1	2	2	2
Improvement of agro-sylvo-pastoral productivity	-2	2	3	-2	0	1	-2	-1	2	-2	-1	2
Aquaculture	1	1	3	-2	0	1	-1	0	2	-2	1	2
Construction of an irrigated area	2	3	3	-2	0	2	-2	-1	2	-2	-1	2
Multipurpose dam construction	2	2	3	-2	0	3	-1	2	2	-2	-1	3
Agricultural dam construction	0	2	3	-1	0	2	-1	-1	3	-2	0	2

Note: Min score = minimum score; Max score = maximum score; Most freq score = most frequent score.

Source: Niger Basin Workshop, 2018.

This qualitative scoring identified the following issues: (1) not all countries scored projects equally; (2) scoring was challenging for complex projects such as dams, which can have both positive and negative impacts; (3) identifying the impacts of OP investments on water security and the environment based on a single score was particularly challenging; (4) some participants were reluctant to recognize the negative effects of flagship projects in their countries; and (5) while the scores generally worked well for individual investments assessed on their own, they did not allow for an assessment of the cumulative upstream to downstream effects of individual projects. Thus relying solely on the scores provided by participants based on the ICSU scale could muddy interpretation of the results.

To address these challenges, the qualitative scoring method was supplemented for the objectives of water security and environmental sustainability with a large-scale hydrological model, an already-available Soil and Water Assessment Tool (SWAT) tool, well suited for the simulation of water and environmental variables. For this semiquantitative analysis, classes of NBA OP projects were grouped into subclasses (representing a generic type of project, such as a multipurpose dam) associated with a certain size/scale. For example, a multipurpose dam with a capacity of more than 5,000 million cubic meters (m^3) is in the same class as one with a capacity of 3,750–5,000 million m^3, but the two investments are in different subclasses. Based on this additional classification, a total of 85 subclasses were identified for the 351 investments of the NBA OP. Given the complex nature of water security and environmental impacts, four subcriteria were developed to score each of these two sectors. These included, for example, effects of the project on dry- and peak-season downstream flows and potential impacts on downstream wetlands. Finally, given the importance of upstream-downstream linkages in a transboundary setting, a criterion for sensitivity to upstream disturbance was introduced, with three subcriteria to quantify the sensitivity of the investment to upstream changes in mean, minimum, and peak flow. Given the overall consistency of scores for energy and food security, these were retained in the semiquantitative modeling.

To implement the semiquantitative scoring, supported by modeling, the proposed NBA OP investments were mapped to ensure that upstream-downstream linkages were adequately represented, using The following steps: (1) participative mapping of the NBA OP projects (Figure 5); (2) quantitative assessment of potential downstream impacts using the SWAT model; and (3) calculation of the ICSU scores based on project type and size.

Figure 5 . Participatory mapping of NBA OP projects

After the NBA project locations were entered into a database, the SWAT model was used to examine the potential downstream impact of each project by calculating how a perturbation of the average flow, monthly peak flow, or monthly low flow would propagate along the river network. A model was used because propagation of a perturbation downstream in such a complex river cannot be ascertained easily qualitatively (Table 3). The results were used to update the OP project scores using the ICSU framework (ICSU 2016).

Table 3 . Subcriteria for improved water security and environmental sustainability assessment

CRITERIA	SUBCRITERIA	RANGE
Food Security		-3 to 3
Energy Security		-3 to 3
Water security	Effect on local water availability	-3 to 3
	Effect on average flow downstream	-3 to 3
	Effect on dry season flow downstream	-3 to 3
	Effect on peak flow downstream	-3 to 3
Environmental sustainability	Effect on local environmental conditions	-3 to 3
	Downstream environmental effect of an eventual change in low flows (0 if no impact on low flows)	-3 to 3
	Downstream environmental effect of an eventual change in peak flow (0 if no impact on peak flow)	-3 to 3
	Potential impact on wetlands downstream (0 if no impact on wetlands downstream)	-3 to 3
Sensitivity to upstream disturbance	Change in performance if the average flow changes	-1 to 1
	Change in performance if flow in dry periods changes	-1 to 1
	Change in performance if the peak flow changes	-1 to 1

Note that the modelled results only account for the location of each activity but not the size or type of investment. The highest and lowest potential impacts are presented in Table 4. Based on location, the rehabilitation and diversification of five small dams in Benin has the lowest potential downstream impact; and the construction of the multipurpose Taoussa dam has the largest potential impact (Fomi dam is only listed as a study and not as a construction project).

Table 4. Highest and lowest potential total downstream impacts

Country	Project	$PTDI_{high,i}$ Potential total impact on peak flows downstream	$PTDI_{average,i}$ Potential total impact on average flows downstream	$PTDI_{low,i}$ Potential total impact on low flows downstream
Benin	Rehabilitation and diversification of 5 small dams in Gamagou, Gah Guessou, Sombi Kérékou, Wara and Zougou Pantrossi in Upper Alibori	0.097654	0.028133	0.028133
Mali	Construction of the Taoussa multi-purpose dam in Mali	0.94817	1.037	1.037

The impacts on wetlands were also calculated as the average downstream impact in the Inner Niger Delta and the Niger Delta. The impacts ranged from 0 (several projects on low-flow tributaries) to 0.5 (irrigation project in Nigeria right before the Inner Niger Delta). Given the location of proposed projects, irrigation development in Nigeria is considered to potentially adversely affect the Niger Delta and various construction projects in Mali have potentially large adverse impacts on the Inner Niger Delta based on the calculation method.

The size and nature of the activities were incorporated into the final score, where simulated scores were matched with subclasses of investments and subcriteria. The score for a particular investment was obtained by multiplying the class score by the calculated environmental effect.

Alternative formulas were then proposed to calculate an overall score for the proposed investments. These alternative formulas included: (1) giving priority to those investments with the highest net benefits; (2) prioritizing projects with positive impacts independent of project size; and (3) prioritizing projects where the positive benefits outweigh the negative impacts, without giving too much weight to small investments. Such formulas would lead to different rankings of NBA OP projects. These are only examples (among many) of potential methods for ranking NBA investments using a nexus approach – the final formulation should be selected by the NBA following discussions with key actor groups. For additional information, see Seidou et al. (2021).

Moreover, based on the interactions with key actor groups and analyses of the NBA OP, a set of principles was identified for evaluation of NBA activities and investments, as follows:

- The size of the activity or project matters;
- The location of the activity or project matters;
- The strength of interactions (that is, tradeoffs or synergies) needs to be considered;
- Preference should be given to multisectoral projects;
- The importance of the socioeconomic environment should be considered;

- Resource efficiency and cost savings should be a focus;
- Policy coherence and projects that support multiple sectors are important;
- Mitigation measures for projects that constrain achievement of some NBA objectives need to be identified; and
- Environmental and social equity impacts of all NBA OP activities should be considered.

For additional details and descriptions, see the final report of the Niger Nexus Phase I Activity (Ringler, Seidou, and Kalcic 2018).

In addition to these principles, a supplemental series of principles were identified with the aim to integrate the nexus approach into the current NBA OP selection process. The additional principles include:

- Improve the effectiveness of OP activities;
- Identify and achieve multiple objectives through a single-sector intervention;
- Avoid harm for some Niger Basin Shared Vision goals by considering potential trade-offs of OP activities with other OP objectives; and
- Enlarge the impact of OP activities by strengthening positive cross-sectoral linkages.

To support integration of the nexus approach into the NBA OP, the checklist in use by the NBA for OP projects was updated to include data needed for the qualitative and semi-quantitative nexus assessment and to reflect the principles of nexus integration. As an example, the updated checklist asks for information on the location of the proposed investments, as well as on project contributions to various nexus objectives (that is, water, energy and food security, and environmental sustainability) in line with NBA goals.

Importantly, the checklist makes it clear that investments are not discouraged if objectives are scored negatively — that is, if progress in some sectoral objectives, such as environmental sustainability, cannot be achieved. Instead, proponents are asked to identify mitigation actions or additional activities that would need to be advanced for potential negative impacts to be reduced or eliminated. In addition, given that each investment is associated with potentially large positive, neutral, or negative impacts for different groups of the Basin population, proponents of NBA investment projects are also asked to describe the beneficiaries and to differentiate impacts for female and male beneficiaries. Appendix 1 provides the proposed expanded criteria for NBA OP projects.

As a final activity, a series of potential investment activities with nexus potential were identified following discussions with NBA staff, exchanges with key informants, and a review of project documents. These include:

- Basin-wide Water-Energy-Environment-Food Nexus analysis of the Fomi/Moussako project
- Enhanced Kandadji Program Resettlement Action Plan 1 (PAR 1)
- Siltation/sedimentation of the Niger River: Basin-wide study to identify hotspots and pilot rehabilitation in one hotspot
- Multiple Use Small-Scale Irrigation Projects in 5 Niger Basin Countries

- Assessment of the potential of navigation on the Niger River in relation to other infrastructure development plans
- Climate Change Resilient Fish Farming: Pilot implementation in Mali
- Improvement of livestock management through solar-animal watering points
- Identification of management options to enhance the roles of wetlands for water, energy and food security and the livelihoods of poor rural women and men with a pilot intervention
- Development of the NBA as a knowledge generation and diffusion center
- Expansion of the existing NBA Observatory monitoring system from a singular water focus to monitor developments of key food, energy and environmental indicators in line with the Niger Basin Shared Vision

The study concluded that adopting a nexus perspective can: (1) improve the effectiveness of OP activities; (2) achieve multiple objectives with a single intervention; (3) avoid undermining some of the objectives of the Shared Vision by considering potential trade-offs of OP activities; and (4) broaden the impact of OP activities by strengthening positive cross-sectoral linkages. Representatives of the nine Basin countries were involved in developing the methodology, principles and preliminary results through participation in regional nexus consultation workshop and key informant interviews. However, achieving full national ownership of the nexus approach takes time.

Outcomes of NRDP Phase II in the Niger Basin

The objectives of Phase II of the NRDP in the Niger Basin included: (1) integration of the WEFE nexus approach in governance and investment; (2) development of concrete policy recommendations and governance frameworks for integrated resource management; (3) identification of investment opportunities for multisector projects; and (4) provision of innovative training, tools, guidelines, and best practices to take the WEFE nexus approach from theory to practice.

The NRDP Phase II led to adoption of the first-ever nexus guidelines by an intergovernmental body (the Niger Basin Authority). This laudable global as well as regional milestone should lead to dramatic beneficial impacts on the sustainability of water and related resources for the 160 million people sharing the Niger River Basin

The next subsections describe the steps taken to integrate the WEFE nexus approach in NBA governance and investment programs through the development of nexus guidelines; and the application of innovative tools for multisector or nexus projects identified by the riparian governments. The activities undertaken were:

- Development of draft nexus guidelines;
- Identification of a flagship WEFE nexus project by each riparian country;
- Development of a quantitative nexus analysis for each national project;
- Three-day national workshops to a) build capacity on the nexus approach; b) consult on the draft guidelines; and c) present the quantitative nexus analysis of selected national nexus projects;

- Preparation of a second draft of nexus guidelines based on feedback at the nine workshops;
- Presentation of the second draft at a regional workshop attended by representatives from all countries; and
- Preparation of final nexus guidelines, presented to the NBA Technical Committee of Experts, which recommended their adoption by the NBA Council of Ministers.

Figure 6 presents the timeline of the phase II process. The following sections describe the development of the nexus guidelines. Appendix 3 details the WEFE nexus assessments of the national multisectoral flagship projects.

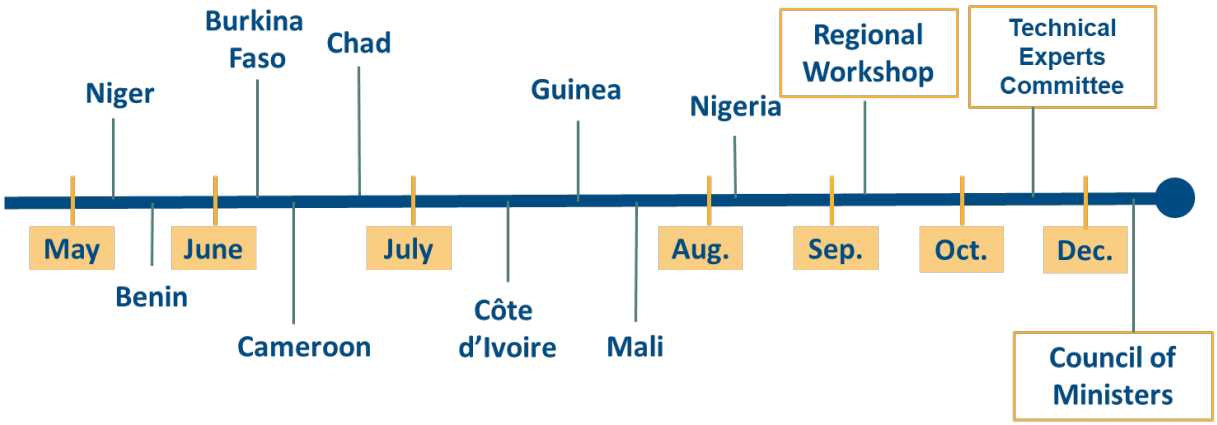

Figure 6. Timeline of NRDP Phase II in the Niger Basin

Development of the Nexus Guidelines

The NRDP with support from the NBA technical secretariat and legal counsel developed the first draft of the nexus guidelines, in the spirit of the Niger Basin Water Charter and its annexes. It also drew on insights from the NRDP Phase I activity, particularly the 2018 regional stakeholder workshop, which identified key principles for a nexus approach in the Niger Basin.

The nexus guidelines drew on and further developed the main legal and supporting documents of the NBA. These include: the Niger Basin Shared Vision, which advocates for the sustainable development of the Niger Basin through integrated management of water resources and associated ecosystems for the improvement of living conditions and the prosperity of the population; and the Water Charter, which refers in Article 14 to the various water uses supported by the NBA.[1] Article 15, furthermore, underpins the need to assess various water uses when competition exists.[2] Finally, the draft guidelines relate directly to

[1] Article 14 states that "the Niger Basin water uses shall aim at the satisfaction in a just and equitable manner of: - the water requirements of the populations; - the needs of agriculture, livestock rearing, fishing, industry, navigation, mining, energy, tourism, fish farming, transport and communications, forestry and the environment in general; and any other need that the Authority deems necessary."

[2] Article 15 states that "no use of the Niger Basin water resources shall have priority over the others, but in the event of a competition between several uses, particular attention shall be paid to essential human needs. The State Parties can jointly agree to establish a priority order in the use of the said Basin's water resources."

the Water Charter's Article 25, which focuses on the need for public information on water allocation to different sectors.

The nexus guidelines were first drafted as an additional Annex to the Water Charter, providing operational details for Articles 14, 15, and 25, similar to Annex 1 on the protection of the environment and Annex 2 on coordinated reservoir management, but were then restated as a separate Directive.

The draft guidelines included references to foundational legal documents that it further interpreted and an explanation of key terms, followed by the guidelines' purpose, goal, objectives, and applicable principles. The original, general objective, which was adjusted later on, was formulated as:

> "This Directive, adopted pursuant to Articles 14, 15 and 25 of the Charter, determines how the intersectoral links between sectors and objectives (nexus approach) must be taken into account in the design, implementation and operation of projects and Niger Basin Authority investments."

Moreover, the scope of the first draft, which was later amended, was exhaustive (Article 4):

> "This Directive is applicable to all applicable measures at the national and regional levels that could affect the use of natural resources for water security, energy security, food security and the health of ecosystems in the Niger Basin, in accordance with the Shared Vision."

The draft guidelines suggested two methodologies (a simplified and a detailed one) for nexus analysis with the type of analysis linked to the complexity of the proposed project (Article 9):

> "The level of detail required for identification depends on the level of maturity of the project. When the member country only wishes to have the project included in the NBA's Operational Plan, or when the project only has national impacts, a simplified assessment is sufficient to justify the Nexus nature of the project. A detailed analysis with a methodology that complies with international standards is required before the actual implementation of the project."

The two methodologies were retained in later versions in amended forms.

The simplified methodology referred to the ICSU's seven-point scale for scoring investment projects according to WEFE objectives that was used in NRDP Phase I activities. The complex methodology was not specified *a priori* in the draft, but key data that would be needed for such analyses were detailed. Table 5 shows the section headings of the nexus guidelines.

Table 5. Outline of nexus guidelines

CHAPTER I. GENERAL PROVISIONS
Article 1: Definitions
Article 2: Purpose
Article 3: Specific objectives
Article 4: Scope
Article 5: General principles
CHAPTER II. NEXUS FRAMEWORK FOR NIGER BASIN PROJECTS AND PROGRAMS
Article 6: Specific principles
CHAPTER III. NBA STAKEHOLDERS AND BODIES INVOLVED IN THE ASSESSMENT OF INTERSECTORAL LINKAGES (NEXUS)
Article 7: NBA actors and bodies involved in the evaluation of intersectoral links (Nexus)
CHAPTER IV. METHODOLOGY USED FOR THE EVALUATION OF NEXUS PROJECTS
Article 8: Characterization of the proposed project
Article 9: Identification of nexus linkages
Article 9.1: Simplified identification of nexus linkages
Article 9.2: Detailed identification of nexus linkages
CHAPTER V. ARBITRATION OF DISCREPANCIES RELATING TO NEXUS ANALYZES
Article 10: Inclusion of a Nexus analysis in the notification of the planned measures
Article 11: Settlement of disputes
ANNEX I: Non-exhaustive list of data required by type of project for the detailed analysis of Nexus
ANNEX II: Methodology for Simplified Nexus Linkage Analysis

National Nexus Dialogues

To validate the draft nexus guidelines, to share the results of national nexus analysis and to build capacity on the nexus approach, nine national stakeholder workshops took place between May and August 2022 in the nine riparian countries of the Niger River Basin (The workshops brought together representatives of government agencies in charge of the water, energy, food security, and environment sectors, the private sector, national and international nongovernmental organizations, national focal structures, and the NBA Executive Secretariat. Each national workshop followed the same format:

- Overview of the nexus approach and key principles
- Country experiences on integrating cross-sector projects into the NBA OP
- Participation in a nexus game
- Simplified and complex nexus assessment of an intersectoral project identified by the country [as described in the draft nexus guidelines]
- Insights on the potential bankability of the identified national project using a nexus approach

- Presentation of a nexus analysis using the selected national project
- Detailed, line-by-line review of draft nexus guidelines for incorporation of comments from the national focal structures

The workshops brought together representatives of government agencies in charge of the water, energy, food security, and environment sectors, the private sector, national and international nongovernmental organizations, national focal structures, and the NBA Executive Secretariat. Each national workshop followed the same format:

- Overview of the nexus approach and key principles
- Country experiences on integrating cross-sector projects into the NBA OP
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- Insights on the potential bankability of the identified national project using a nexus approach
- Presentation of a nexus analysis using the selected national project
- Detailed, line-by-line review of draft nexus guidelines for incorporation of comments from the national focal structures

Table 6. Dates of the nine national nexus dialogues

Country	National dialogue dates
Niger	10–12/05/2022
Benin	17–19/05/2022
Burkina Faso	07–09/06/2022
Cameroon	14–16/06/2022
Chad	21–23/06/2022
Côte d'Ivoire	12–14/07/2022
Guinea	19–21/07/2022
Mali	26–28/07/2022
Nigeria	02–04/08/2022

Figures 7-9 showcase elements of the national workshops. Figure 7 presents participants at the national workshop in Côte d'Ivoire, Figure 8 presents the nexus game played in Cameroon and Figure 9 presents the simplified nexus scoring methodology at the national workshop in Niger.

Figure 7. Participants at the national workshop in Côte d'Ivoire

Figure 8. Participants in the nexus game in Cameroon

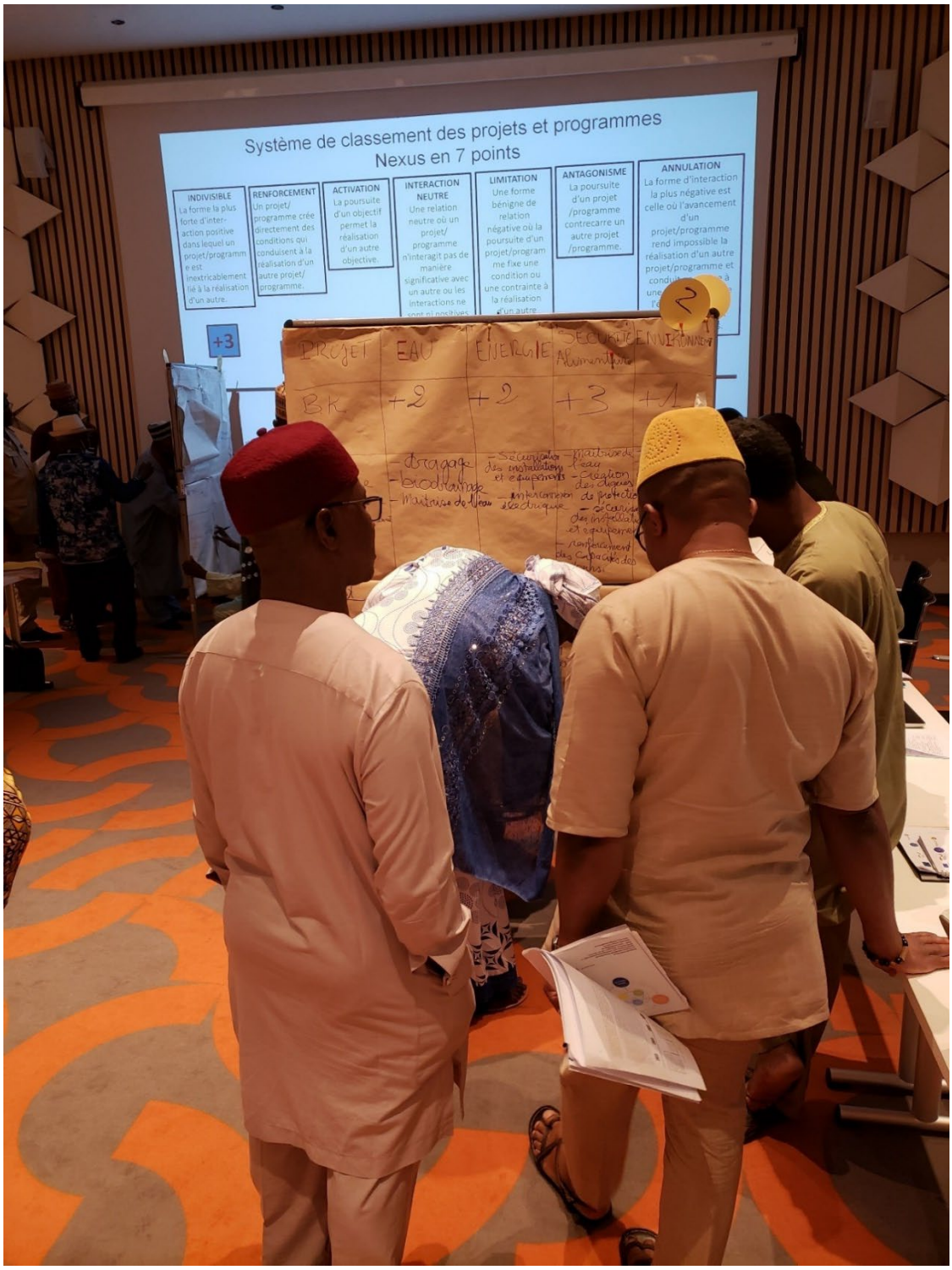

Figure 9. Participants in the simplified nexus scoring in the national workshop in Niger

Finalization of the Nexus Guidelines

To ensure that the legal terminology used in the guidelines reflected the best practices in nonconventional instruments developed for the management and governance of transboundary river basins, a jurist with extensive experience with the Water Charter (Dr.

Mohammed Garane) was invited to review and adjust the legal terms and provide other guidance to reflect the spirit of the Water Charter and related documents. Rather than an annex, the second draft considered the nexus guidelines as a separate, but complementary, document to the Water Charter. The guidelines would still be adopted by the Council of Ministers to the NBA but would not be a legal document emanating from or further interpreting the Water Charter.

Moreover, the second draft incorporated to the extent possible an extensive set of comments collected at workshops held in the nine Basin countries during detailed, line-by-line read-throughs of the draft guidelines (see below). The workshops also included: capacity building on nexus approaches (for example, Figure 8); a presentation on nexus activities under the United Nations Water Convention; a case study on the potential to obtain project funding by demonstrating nexus or linked sets of benefits; exercises using the simplified nexus scoring methodology (the ICSU 7-point scale, Figure 9); and the presentation of results of a more complex nexus analysis for a specific project pre-identified by each country.

The second draft of the nexus guidelines was finalized on August 9, 2022. Most countries provided 15 to 20 comments on the draft guidelines. Nigeria, which featured a larger group of attendees, provided more than 40 comments.

Key suggestions included from the national workshops included:

- Addition of relevant definitions to the document in relation to its purpose;
- Refinement of the specific nexus approach principles; in particular, further clarification of the WEFE definition and approach;
- Review and alignment of the specific objective of the guidelines;
- Enlargement of the group of actors who would participate in the nexus assessment to include local authorities and the national coordination groups of natural resource users;
- Clarification on the nexus methodology and additional suggestions on data to be used;
- Review of the guidelines' links to existing legal documents of the NBA;
- Use of the guidelines for the OP and investments being implemented;
- Inclusion of a timeline linked to the nexus approach and process;
- Suggestions on dispute resolution; and
- The need for additional capacity building for operationalization of the nexus approach in NBA projects and programs;

The scope of the second draft was written as (Article 4):

> "These guidelines apply to all investment programs and projects with transboundary impact being implemented or planned in the Niger Basin to ensure water security, energy security, food security, and environmental sustainability, in line with the mission and

objectives of the Authority. They cover the different development phases of investment programs and projects, including design, financing, construction, and operation."

Moreover, an earlier dispute settlement clause was removed and a chapter on operationalization of the nexus approach was added that includes capacity building of actors (Article 18) as well as a Regional Nexus Dialogue Network (Article 19) to "foster the exchange of information and good practices in integrating the nexus into investment programs and projects. It can rely on national networks of nexus dialogues."

The second draft was discussed at a regional workshop held on September 2, 2022, in Cotonou, Benin, during the NBA Regional Steering Committee (*Comité Régional de Pilotage*) meeting. At that event, exhaustive applicability of the nexus approach was identified as a key sticking point that might prevent the Council of Ministers' adoption of the guidelines. Specifically, the Basin countries were interested in the nexus approach, but worried that its adoption could lead to costly and time-consuming additional analyses that might make it more difficult to implement investment projects. There were possibly also perceived concerns that nexus analyses might prevent some flagship projects with high positive impacts but tradeoffs with other sectoral objectives (for example, environmental sustainability) from going forward. Finally, it was questioned if a nexus approach should be the only type of deeper analysis undertaken for projects to be considered worthy of financing and if adopting the guidelines might preclude adoption of other approaches in the future. Moreover, regional workshop participants largely differed from those in the national workshops, who had actively participated in various capacity-building activities on the nexus approach and thus had a better understanding of the concept and methodologies and had approved the more stringent guidelines language.

As a result of these deliberations, the scope of the final draft (and adopted guidelines) was toned down to (Article 3--Scope):

> "These Guidelines can relate to development programs and projects with significant transboundary and intersectoral impact being implemented or planned in the Niger Basin to ensure water security, energy security, food security, and environmental sustainability, in line with the mission and objectives of the Authority. They cover the different development phases of development programs and projects, including design, financing, construction, and operation."

Adoption of the Nexus Guidelines

The amended nexus guidelines were presented to the NBA Technical Experts Committee (TCE) on October 10, 2022, in N'Djamena, Chad. The TCE recommended adoption of the guidelines by the NBA Council of Ministers. The guidelines were adopted on December 8, 2022, during the 41st ordinary session of the NBA Council of Ministers in N'Djamena, Chad and came into force immediately (Annex 2 provides the final guidelines).

This is the first-ever Basin-wide adoption of nexus guidelines to support cross-sectoral collaboration and analysis and can support development of similar policies in other river basins with competing water-energy-food-environmental goals. They are publicly available on the website of the NBA.

Conclusions and Lessons Learned

The following lessons were learned during development of the nexus guidelines:

- The guidelines were developed as part of a highly consultative process during nine national three-day meetings of key Basin stakeholders, followed by a regional workshop and preceded by several meetings with the NBA Executive Secretariat. The deep consultations and capacity building activities were essential for ensuring full ownership of the nexus guidelines and their future use.

- The guidelines call for a capacity-building program on the nexus approach as well as for development and implementation of a regional WEFE nexus capacity-building program. The guidelines are thus a stepping stone for more in-depth development and application of nexus analytical capacity.

- The NBA still views itself as a water resources management organization rather than a resource management organization. Most NBA representatives in the member countries are from the water sector; as such the nexus approach is highly appreciated but the focus remains largely on water with limited consideration for other sectors, such as food and energy. This limited understanding of energy or food security as entry points into basin management.

- The two main concerns expressed by some workshop participants regarding adoption of the nexus guidelines were: (1) the perception that they do not have the resources to carry out the additional analyses entailed; and (2) the new guidelines may exclude "non-nexus" projects viewed as critical for Basin countries' economic development.

- Many countries had difficulty identifying a project with real nexus potential; the choice naturally fell on dam projects with significant electricity and/or agricultural production potential. The primary data for the project analysis were difficult to find or nonexistent. When data were available, they were not always shared due to various institutional and other barriers. Cross-sectoral WEFE analysis of priority projects in the Basin countries was welcomed and supported capacity development.

- Countries have minimal modelling capacity and leave the analysis of significant projects to foreign firms, which limits their ability to carry out more detailed nexus analyses. Member countries need to strengthen their systems for collecting and archiving data relevant to the nexus approach, accompanied by capacity building on its associated quantitative methodology.

- The NBA and its member countries must give more space to scientific research, given the highly evolving nature of concepts such as the nexus approach. This need is expressed in the sixth principle of the nexus guidelines – the continual updating of knowledge. Efforts should be made to better understand nexus interrelationships to make optimal decisions, including through comprehensive data collection and scientific research.

Part Two:

Analysis of Countries' Priority Projects

WEFE Capacity-Building Analyses Using Country Priority Projects

Background

As most projects in the NBA OP are too complex to be evaluated using stakeholder interviews and expert knowledge, some quantitative analysis is required. Given the study team's modelling background, it developed a (relatively) simple conceptual model of significant investments with transboundary effects using the Water Evaluation and Planning (WEAP) model, a water resources management model developed by the Stockholm Environment Institute.[3] The WEAP model simulates water demand, supply, runoff, streamflow, storage, pollution generation, treatment and discharge, instream water quality, food production, and hydropower generation, among other WEFE indicators.

While the duration of NRDP phase II activities was not sufficient to model all OP investments, a basic model describing one priority project selected by each country served to demonstrate how a complex WEFE nexus approach would look like. Exemplary priority projects were selected by a representative of the national focal structure of each member country in consultation with stakeholders in his/her country. The associated WEAP models were used to generate infographics and visual aids that improved stakeholders' understanding of the benefits of nexus analyses during the national and regional dialogues.

Criteria for Project Selection

Projects could be identified by countries directly or selected from a list of projects in the NBA OP or the Niger Basin Nexus Action Plan (Table 7), which contains a list of projects with nexus potential, most of which were identified by Ringler, Seidou, and Kalcic (2018). The Plan includes: (1) projects with clear intersectoral potential (that is, they relate to at least two sectors) and that feature prominently in the NBA OP; (2) projects that are positively linked to multiple objectives or, if linkages are negative, mitigation measures were identified or positive impacts are very strong; (3) projects that together reflect the geographic diversity of the Basin; (4) projects with potential for intra- and inter-Basin learning; and (5) projects that are not in the OP but were identified as foundational to the incorporation of a nexus angle into the NBA OP.

Countries could propose projects that were neither in the OP nor in the Niger Basin Nexus Action Plan, but had significant nexus potential (that is, they impact at least two sectors among water security, energy security, food security, and environmental sustainability, without negatively affecting other sectors). Due to the educational nature of the dialogues, well-defined projects for which data were readily available were preferred. However, government representatives had little knowledge of the NBA OP because of the high turnover in government positions, and only those who had participated in the Phase I workshop knew about the Niger Basin Nexus Action Plan. Furthermore, countries were more inclined to propose flagship projects (mostly dam construction) even when smaller projects with better nexus potential were available.

[3] See https://www.sei.org/.

Table 7. List of projects in the Niger Basin Nexus Action Plan

Project title	Project type	Region
Construction of the Fomi Dam and ancillary works	Nexus project	Guinea
Fomi Dam Operation Nexus	Support activity	Regional
Consolidation of water security, food security, energy security and environmental sustainability in the resettlement areas of the Kandadji Dam project	Nexus project	Niger
Soil and Water Conservation to Reduce Erosion and Sedimentation in the Niger Basin for Water and Land Security	Nexus project	Mali
Increase water security, food security, energy security and environmental sustainability in agriculture using a nexus approach in small-scale irrigation projects	Nexus project	Mali
Increase water security, food security, energy security and environmental sustainability in agriculture using a nexus approach in small-scale irrigation projects	Nexus project	Niger
Improving the navigability of the Niger and its main tributaries to increase trade and food security	Nexus project	Regional
Climate-resilient fish farming and processing for increased food security	Nexus project	Mali
Increasing food security and water efficiency through better livestock management	Nexus project	Chad
Protection of ecosystem services to increase water security, food security, energy security and environmental sustainability in wetlands	Nexus project	Mali
Coordinated Dam Operation in the Niger Basin for Water, Energy and Food Security	Nexus project	Regional
Securing water resources, energy resources and food security through forestry interventions	Nexus project	Côte d'Ivoire
Protection of water, energy and food resources through anaerobic digestion of fecal sludge	Nexus project	Burkina Faso
Establishment of a project preparation facility for water energy and food security projects in the basin/region	Nexus project	Regional

Table 8 lists the exemplary projects proposed by member countries.

Table 8. Exemplary projects selected by NBA member countries

Country	Selected project	Approximate budget (assumed exchange rate: 1 EUR=1 USD)	Status
Niger	Kandadji Program for the Regeneration of Ecosystems and Development of the Niger Valley (P_KRESMIN)	EUR 113 million	Financed; under construction, with commissioning planned for 2026
Benin	Socio-economic Infrastructure Development Project for Food Security (*Projet de Développement des Infrastructures Socio-économique pour la Sécurité Alimentaire* = PDISSA)	EUR 23 million	Funded and running
Burkina Faso	Dredging, Remediation, and Development of the Dori Watershed (Dragage, Assainissement et Développement du Bassin Hydrographique de Dori =DRABHyD) (Development of the Dori Pond)	EUR 4.5 million	Funded; work started but stopped New technical studies carried out in 2018
Cameroon	Project for the Development and Valorization of Investments in the Benue Valley (VIVA-BENUE)	EUR 200 million	Funded; in the process of being implemented
Chad	Surface water mobilization project for livestock feed and agriculture in the upper Benue basin in Chad	EUR 1.8 million	Looking for funding
Côte d'Ivoire	Koudan Dam Construction and Hydro-Agricultural Development Project	EUR 156.8 million	Partly funded (PIDACC)
Guinea	FOMI Dam Development Project	EUR 220 million	Looking for funding
Mali	Bagoé II Hydroelectric Power Plant Project	EUR 4.5 million	Looking for funding
Nigeria	Dadin-Kowa multi-purpose barrage	EUR 32 million	Funded; in the process of being implemented

Quantitative Analysis Methodology

When the required data were available, a simulation model of the project and the affected areas was developed with WEAP using the methodology outlined in Figure 10.

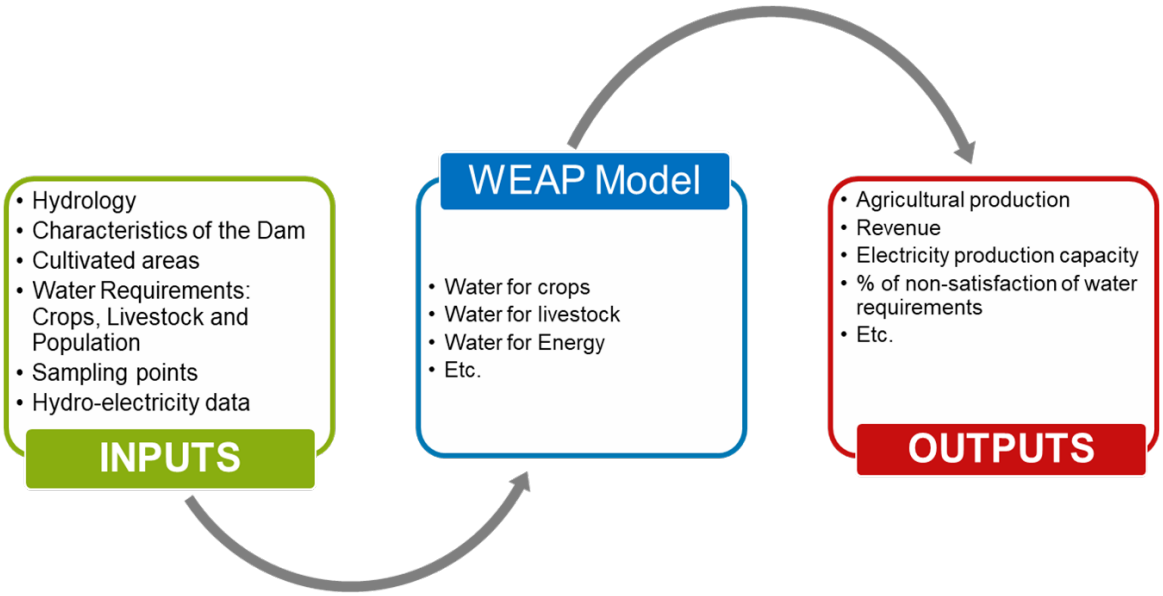

Figure 10. WEAP quantitative analysis methodology

When a country provided enough data, a simplified simulation model was developed with Excel and used to stimulate the discussions. For each selected project, indicators were defined for each nexus objective (water security, energy security, food security, and environmental sustainability). A WEAP model was then used to highlight how pursuing a specific nexus objective (for example, food security) would likely affect the other objectives. The implications for the selected project and how to apply a similar analysis to other projects of interest to the country were discussed. Each case study was organized as follows:

Description of the project: Geographic location, objectives, and main characteristics

Nexus analysis of the project: Type of analysis performed and presented at the national dialogues

- **Model development:** Type of modeling approach used, data sources, and main assumptions
- **Nexus indicators:** List of quantitative WEFE indicators evaluated
- **Development scenarios:** Variants of the project that were evaluated; climate and operation rules considered in the analysis
- **Main findings:** Conclusions of the analysis

Note that these simplified models were based on limited data and development resources, so the findings should not be used for decision making. Moreover, WEAP models could not be developed for Chad and Nigeria due to data limitations.

Appendix 3 presents the analysis of the exemplary projects selected by each of the nine Basin countries.

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Appendices

Appendix 1: Nexus Criteria for the Next Round of the NBA Operational Plan

Table 9. Nexus criteria for the next round of the NBA Operational Plan

Area	Details	Unit
1 PROJECT OVERVIEW	Project Number	No.
	Project Title	text
	Who is the main contact and institution for the project?	*text*
	Budget	*CFA*
	Project code (drop-down menu)	*P111-P351*
	Project category (drop-down menu)	*1-85*
2 BENEFITS	*Who benefits from the project?*	*No people / ha*
	How do women and men benefit from the project?	*text*
3 CONTRIBUTION TO THE STRATEGIC PLAN	No contribution of the project to the Intermediate Outcomes (IO) of the SP: score 0; contribution to one IO: score 1; two IO: score 2; more than 2 IO: score 3	score (0-3)
4 TRANSBOUNDARY CHARACTER	Local projects without transboundary impact: score 0; Local projects with transboundary impact: score 2: Projects including two countries: score 4: projects including more than 2 countries: Score 6	score 0-6
5 LEVEL OF MATURITY	Project idea: score 0; Identification completed: score 2; project preparation completed: score 3; preliminary studies completed: 4: Environmental and social impact assessment completed: score 5: evaluation completed: 6; negotiation stage: 7; agreement signed: 8	score 0-8
6 AVAILABILITY OF FINANCING	Donors NOT identified: score 0; in process of identifying doors: 3; donors identified: 5	score 0-5
7	Simple SCORE— (will be done by NBA)	(Sum of Q 3-6)
8 LOCATION	*Location I*	*District*
	Location II	*GIS Coordinates*
9 FOOD SECURITY	*Contribution to Food Security*	*from -3 to +3*
	WHY? (How is the project contributing to food security?)	*text*
	If the score is positive, please identify synergistic measures; if the score is negative, please identify mitigation measures	*text*
10 ENERGY SECURITY	*Contribution to Energy Security*	*from -3 to +3*
	WHY? (How is the project contributing to energy security?)	*text*
	If the score is positive, please identify synergistic measures; if the score is negative, please identify mitigation measures	*text*
11 WATER SECURITY	*Contribution to Water Security*	*from -3 to +3*
	WHY? (How is the project contributing to water security?)	*text*
	If the score is positive, please identify synergistic measures; if the score is negative, please identify mitigation measures	*text*
12 ENVIRONMENTAL SUSTAINABILITY	*Contribution to Environmental Sustainability*	*from -3 to +3*
	WHY? (How is the project contributing to environmental sustainability?)	*text*
	If the score is positive, please identify synergistic measures; if the score is negative, please identify mitigation measures	*text*
13 STRENGTH OF NEXUS LINKAGE	*If there is a strong linkage with a Nexus sector other than that reflected in the project lead, explain who was consulted from the other sector. (obligatory)*	*text*
14 POTENTIAL RISKS AND ACTIONS TO ADDRESS THE RISKS	*Programmatic risks*	*text*
	Measures to address the risks (if possible)	*text*
	Contextual Risks	*text*
	Measures to address the risks (if possible)	*text*
15 TOTAL SCORE	Weighted score—Contribution to SP: 40%	No
	Weighted score—Transboundary character: 30%	No
	Weighted score—Level of maturity of the project: 10%	No
	Weighted score—Availability of financing: 20%	No

Note: Existing Strategic Plan criteria are shown in black; new criteria are shown in red.

Appendix 2: Nexus Guidelines

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Guidelines for the integration of the Water, Energy, Food Security, and Environmental Sustainability Nexus approach in the development of sustainable development programs and projects in the Niger Basin

SUMMARY

These Guidelines for the integration of the water, energy, food, and environmental sustainability nexus (WEFE) in the development of sustainable development programs and projects in the Niger Basin, have been developed to support the sustainable development of the Niger River Basin in accordance with the shared vision and the Basin Water Charter. The Nexus is defined as an integrated approach that takes into consideration the identification of linkages between several sectors and their objectives**,** as well as the reduction of negative tradeoffs and the strengthening of positive synergies to reconcile the various human and environmental development needs that depend on or compete for the same resources.

The Guidelines propose an integrated approach that considers the links between water, energy, food security, and the environmental sustainability of development programs and projects to maximize the benefits for the Basin's population and to ensure that investments in one sector do not significantly harm other sectors. As such, they will strengthen the feasibility and bankability of the programs and projects of the operational plan and other projected development projects and programs in the Niger Basin.

CHAPTER I. GENERAL PROVISIONS

Article 1. Definitions and uses of terms

For the purposes of these Guidelines the following definitions apply:

Authority: Niger Basin Authority;

Council of Ministers: Council of Ministers of the Niger Basin Authority;

Data and technical characteristics of a program or project: technical data describing the relevant technical characteristics of the project, together with the hydrological, hydrogeological, climatic, environmental, socio-economic, and financial data required for its WEFE Nexus evaluation;

Detailed assessment of the Water, Energy, Food Security, and Environmental Sustainability Nexus: estimation of project effects on food security, water security, energy security, and environmental sustainability based on an in-depth study of the project that uses the best available data, methodology and state-of-the-art analysis tools in line with international standards in the field;

Development of development programs and projects: design, financing, implementation, and operation of development projects;

Energy security: uninterrupted availability of energy sources at an affordable price;

Environmental sustainability: responsible exploitation of natural resources, associated with adequate protection of ecosystems that can be maintained indefinitely;

Executive Secretariat: Executive Secretariat of the Niger Basin Authority;

Food security: access for everyone and at all times to enough food to lead an active and healthy life;

Impact: any change in the environment, economy, or social behaviour resulting in part or in whole from the investments made or services provided under the project;

Member State: Member State of the Niger Basin Authority;

National Coordination of Users of Natural Resources in the Niger Basin: national frameworks for consultation and social mobilization bringing together all the users of the natural resources of the Basin organized into associations as well as national and international NGOs whose aim is to organize the participation of users of the natural resources of the Niger basin in the implementation of related public policies, and ensure their representation before the bodies responsible for designing and implementing said policies;

National Focal Structure: structure responsible for ensuring the coordination of the activities of the Niger Basin Authority at the level of each Member State, through the involvement of all the actors on the one hand, and between the Member States, on the other;

Nexus: an integrated approach that takes into consideration the identification of linkages between several sectors and their objectives as well as the reduction of negative tradeoffs and the strengthening of positive synergies to reconcile the various human and environmental development needs that depend on or compete for the same resources. The Nexus approach helps to i) improve the design and impact of development programs and projects; (ii) achieving multiple objectives through a single intervention; (iii) prevent negative cross-sectoral impacts; (iv) strengthen intersectoral synergies between several interventions; (v) facilitate the financing of development programs and projects;

Niger Basin Observatory: management of the Executive Secretariat of the Authority, responsible for monitoring the hydrological, environmental, and socio-economic evolution of the Basin and producing regular information on the development of the Basin.

Operational Plan: Niger Basin Operational Plan;

Panel of independent experts: group of independent experts responsible for issuing specific technical opinions on issues relating to developments in the Basin;

Permanent Technical Committee: Permanent Technical Committee of the Niger Basin Authority;

Private sector: sector, run by individuals and businesses, usually with the aim of making

a profit;

Regional Coordination of Users of Natural Resources in the Niger Basin: space for dialogue and permanent consultation of users of natural resources in the Basin and a framework for mobilizing them with a view to their participation in decision-making relating to the process of sustainable development of the Basin;

Simplified assessment of the Water, Energy, Food Security, and Environmental Sustainability Nexus: qualitative assessment of project effects on food security, water security, energy security, and environmental sustainability based on the International Council of Science's seven (07)-point scale, described in the appendix to this document;

Sustainable Development Action Plan: Niger River Basin Sustainable Development Action Plan;

Transboundary impact: any significant effects such as changes in the characteristics of transboundary waters caused by human activity;

Water Charter: Niger Basin Water Charter;

Water security: reliable availability of an acceptable quantity and quality of water for health, livelihoods, and production, associated with an acceptable level of water-related risks;

Water, Energy, Food Security, and Environmental Sustainability Nexus, in short, WEFE: version of the Nexus that considers the water, energy, and food sectors and the objectives of water, energy, and food security. Environmental sustainability is a key additional objective and often directly included in sectoral analyses.

<u>Article 2</u>. Objetive

These Guidelines aim to integrate the WEFE Nexus approach in the development of development programs and projects in order to ensure water security, energy security, food security, and environmental sustainability in the Niger Basin.

These Guidelines specifically aim to:

i) define the principles for assessing the WEFE Nexus criteria in development

programs and projects;

ii) determine the role and responsibilities of actors for better governance in the development of WEFE Nexus programs and projects;

iii) determine the methodology for integrating the WEFE Nexus approach into development programs and projects;

iv) determine the modalities for monitoring the integration of the WEFE Nexus approach into development programs and projects;

v) determine the promotional measures contributing to reinforcing the integration of the WEFE Nexus approach in development programs and projects.

Article 3. Scope

These Guidelines can relate to development programs and projects with significant transboundary and intersectoral impact being implemented or planned in the Niger Basin to ensure water security, energy security, food security, and environmental sustainability, in line with the mission and objectives of the Authority.

They cover the different development phases of development programs and projects, including design, financing, construction, and operation.

Article 4. General principles

The Authority and the Member States, in the context of the integration of the WEFE Nexus approach in development programs and projects, comply with the following fundamental principles enshrined in the Niger Basin Water Charter:

i) **Principle of complementarity,** by virtue of which it is necessary, with a view to regional integration, to make the best use of the complementarities of the economies of the Member States based on the current or potential comparative advantages within the Member States;

ii) **Principle of cooperation**, by virtue of which the Member States lend themselves to permanent consultation and negotiation to achieve the objectives of the Authority;

iii) **Principle of social equity**, whereby the interests and concerns of women, men, and vulnerable segments of society are taken into account in the formulation of capacity development policies and planning of programs and projects;

iv) **Principle of sustainable development**, by virtue of which the management of the Basin must make it possible to meet the needs of current generations without compromising those of future generations by reconciling, in a balanced manner, economic development, environmental protection, and social development;

v) **Principle of non-transfer of risk**, under which Member States take appropriate measures to prevent the movement and transfer within the Basin of any activity or substance which causes serious deterioration of the environment or which is harmful to human health;

vi) **Principle of prevention**, by which the Member States must take into account the principle of preventive action and correction, by priority at the source of the damage to the environment, using the best techniques available at an economically acceptable cost;

vii) **Polluter-pays principle**, by virtue of which the costs of pollution prevention, control, and reduction measures are borne by the polluter;

viii) **Principle of responsibility**, by virtue of which Member States strive to implement in good faith the orientations and procedures resulting from these Guidelines;

ix) **Principle of transparency**, by virtue of which the initiatives of the Member States must be based on the free flow of adequate information between the Member StatesB;

x) **Principle of non-harmful use of the national territory** under which Member States have a duty to ensure that activities carried out within their jurisdiction or under their control do not cause significant damage to the environment of other Member States or areas beyond national jurisdiction;

xi) **Principle of solidarity**, by virtue of which cooperation between the Member States for the sustainable management of the Basin, must be based on the idea

that the Niger Basin constitutes a common good that, on one hand, the Member States strive to preserve to promote peace and development in the Basin, and, on the other hand, they support the most disadvantaged populations and areas, to eliminate the disparities between the Member States gradually;

xii) **Principle of substitution** according to which an action that is likely to have a detrimental impact on transboundary waters can be substituted for another which presents lesser risk or danger;

xiii) **Principle of subsidiarity,** by virtue of which it is convenient to seek the most appropriate level of Powers.

Article 5. Specific principles of the Water, Energy, Food Security, and Environmental Sustainability Nexus governance framework

The Authority and the Member States, in the context of the integration of the WEFE Nexus in development programs and projects, comply with the following specific principles of the governance framework of the WEFE Nexus approach in the Niger Basin:

i) **Principle of the systematic multisector effects,** according to which, a priori, any intervention in the BBasin affects all four WEFE Nexus sectors (water, energy, food security, and environmental sustainability) to different degrees. It is up to the Member State promoting the project to demonstrate that the negative effect is negligible on some of the sectors and to assess the effect on the other sectors;

ii) **Principle of the cumulative effect,** in virtue of which the effect of any intervention must always be estimated by considering the extent of its interactions with existing and planned interventions in the Basin. These effects depend, among other things, on its size in terms of surface area, the volume of water stored or impacted but also its location relative to said interventions;

iii) **Principle of promoting intersectoral efficiency,** according to which programs and projects that increase intersectoral efficiency in the use of resources and adequately address social and environmental issues and improve equity should be prioritized;

iv) **Principle of impact mitigation** according to which mitigation measures must

be systematically identified and, as far as possible, implemented for an intervention for which negative interactions in one of the WEFE Nexus sectors: water, energy, food security, and environmental sustainability are identified.

v) **The continual updating of knowledge** is the principle that all efforts should be made for a better understanding of Nexus interrelationships in order to make optimal decisions, in particular through exhaustive data collection and scientific research.

CHAPTER II. ROLE AND RESPONSIBILITIES OF ACTORS IN INTEGRATING THE WATER, ENERGY, FOOD SECURITY, AND ENVIRONMENTAL SUSTAINABILITY NEXUS APPROACH INTO DEVELOPMENT PROGRAMS AND PROJECTS

Section I. Role and responsibilities of the organs of the Authority

Article 6. Permanent Technical Committee

The Permanent Technical Committee provides informed advice on all questions relating to the integration of the WEFE Nexus approach into development programs and projects.

It facilitates dialogue, consultation, negotiation, and mediation in the event of divergences of appreciation that may arise while integrating the WEFE Nexus approach into development programs and projects.

Article 7. Executive Secretariat

The Executive Secretariat examines and evaluates the projects in preparation, according to the WEFE Nexus criteria through its technical services using WEFE Nexus methodologies, having recourse, if necessary, to WEFE Nexus evaluation tools.

Article 8. National Focal Structures

The National Focal Structures guarantee the coordination of interventions and the consideration of several sectors as well as different users in the design of new projects to

achieve multiple objectives from one project and to avoid negative impacts on one or several sectors.

They apply the WEFE Nexus approach to development programs and projects, using available WEFE Nexus assessment instruments or tools as needed.

Article 9. Independent Expert Panel

The Panel of Independent Experts issues, at the request of the Permanent Technical Committee, technical opinions on all issues related to the integration of the WEFE Nexus approach in development programs and projects in the Basin.

Section II. Role and responsibilities of the Authority's partners

Article 10. Local authorities

Local authorities support central and decentralized State structures in integrating the WEFE Nexus into development programs and projects in the Basin.

Article 11. Coordination of users of natural resources

The regional coordination and the national coordination of users of the natural resources of the Niger Basin ensure the monitoring of the integration of the WEFE Nexus in development programs and projects.

They contribute to building the capacities of national actors in integrating the WEFE Nexus approach into development programs and projects.

Article 12. Private sector

The private sector collaborates with the Authority and States in promoting the integration of WEFE Nexus.

Article 13. The media

The media contribute to informing and raising public awareness on the integration of the WEFE Nexus into development programs and projects in the Niger Basin.

Article 14. Development Partners

Development partners provide financial and technical support for implementing regional strategies promoting the integration of the WEFE Nexus approach in development programs and projects.

CHAPTER III. METHODOLOGY FOR INTEGRATING THE THE WATER, ENERGY, FOOD SECURITY, AND ENVIRONMENTAL SUSTAINABILITY NEXUS INTO DEVELOPMENT PROGRAMS AND PROJECTS

Article 15: Characterization of the proposed project

The Member States of the Authority identify, for all development programs and projects with transboundary impacts, the data and technical characteristics necessary for the WEFE Nexus assessment of the said programs and projects.

The nature of the data and technical characteristics required for the characterization will depend on the nature of the development program or project. It must allow the application of NBA reference methodologies, as indicated in Appendix I, which lists the data required for certain types of structures.

The Executive Secretariat may, as part of the WEFE Nexus review and analysis, request from the Member States any additional technical data that it deems relevant.

The proposed program or development project submission will be considered complete when the Executive Secretariat has received all relevant data. Once complete, the submission is examined and analysed by the Executive Secretariat.

The results of the WEFE Nexus review and analysis carried out by the Executive Secretariat are communicated to the Member States concerned for consideration.

Article 16. Simplified evaluation of the Water, Energy, Food Security, and Environmental Sustainability Nexus

All projects will be subject to a simplified assessment either when they are included in the NBA's Operational Plan or at any time deemed appropriate by the States and the

Authority.

The simplified assessment of the relative contribution of the program or project to water security, energy security, food security, and environmental sustainability will be based on a seven (07)-point scale described in Annex II of these guidelines.

To this end, the Executive Secretariat makes a specifically developed software or an online tool available to Member States to facilitate the implementation of this methodology.

The methodology for a simplified evaluation of WEFE Nexus links is set out in Appendix II of the Guidelines.

Article 17. Detailed evaluation of the Water, Energy, Food Security, and Environmental Sustainability Nexus

A detailed assessment is strongly encouraged when development programs and projects are likely to have significant adverse effects, based on the simplified methodology.

The technical studies related to the latter must contain an appendix in which the project's impacts on the water, energy and food security, and environmental sustainability in the affected Member States are analyzed.

The evaluation must be carried out based on objective data and analysis tools corresponding to the state-of-the-art in the field considered.

The analysis tools will be validated beforehand by the Executive Secretariat. The Executive Secretariat sends a WEFE Nexus endorsement note to the country after a positive review of the program or project documentation.

The non-exhaustive list of data required for each type of project for the detailed WEFE Nexus analysis appears in Appendix I of this Guidance.

CHAPTER IV. REVIEW OF THE WATER, ENERGY, FOOD SECURITY, AND ENVIRONMENTAL SUSTAINABILITY NEXUS

INTEGRATION IN DEVELOPMENT PROGRAMS AND PROJECTS

Article 18. Inclusion of a Water, Energy, Food Security, and Environmental Sustainability Nexus analysis

For development programs and projects in the Basin, the control of the Nexus SEEAE evaluation will be done by the Executive Secretariat internally or by resorting to national or international service providers competent in this field.

Article 19. Results of the evaluation of the integration of the Water, Energy, Food Security, and Environmental Sustainability Nexus in programs and projects.

The Executive Secretariat's assessment of the inclusion of the WEFE Nexus approach is justified.

When the Executive Secretariat concludes that the SEEAE Nexus has been successfully integrated, the program or project concerned continues the process of its development.

When the evaluation of the integration of the WEFE Nexus reveals that the integration of the WEFE Nexus is insufficient, the Executive Secretariat indicates to the Member States concerned the considerations which motivated its decision and makes recommendations in order to better integrate the WEFE Nexus in the planned program or project.

The State concerned may request the support and guidance of the Executive Secretariat for better integration of the WEFE Nexus into the program or project concerned.

CHAPTER V. PROMOTING THE WATER, ENERGY, FOOD SECURITY, AND ENVIRONMENTAL SUSTAINABILITY NEXUS INTEGRATION IN DEVELOPMENT PROGRAMS AND PROJECTS

Article 20. Capacity building of actors

The Authority supports Member States in building the capacities of national actors to promote the integration of the WEFE Nexus approach in development programs and projects.

It develops and implements a regional WEFE Nexus capacity-building program.

Article 21. Regional Dialogue Network on the Water, Energy, Food Security, and Environmental Sustainability Nexus

The Authority, in cooperation with the Member States, could foster the promotion of Nexus regional dialogues on Water, Energy, Food Security and Environmental sustainability. .

CHAPTER VI. FINAL PROVISIONS

Article 22. Monitoring of implementation

The Executive Secretariat monitors the implementation of these Guidelines for integrating the WEFE Nexus approach into development programs and projects.

It regularly evaluates the guidelines for integrating the WEFE Nexus approach into development programs and projects at the regional level.

The evaluation reports of the guidelines for the integration of the WEFE Nexus approach in development programs and projects are widely published among basin stakeholders.

Article 23. Application

These Guidelines on the integration of the WEFE Nexus approach in development programs and projects are in force as soon as the Council of Ministers adopts them.

Annex I. Non-exhaustive list of data required by type of project for the detailed analysis of Nexus

1. Hydro-Agricultural development

1. Geographic location of the site (longitude/latitude or polygon)
2. Area to be irrigated in ha (existing/planned/potential)
3. Monthly water needs per Ha, or type of crops planned with their cropping calendar and the local climatology
4. Annual water consumption (m^3/year/ha)
5. Percentage of monthly consumption (%)
6. Characteristics of the weather station closest to the site (name, latitude, longitude, elevation)
7. Expected crop yields (Tonne/ha or Kg/ha)
8. Water source (surface water, groundwater)
    1. Flows into the watercourse (if applicable)
    2. Aquifer depth and annual recharge (if applicable)
    3. Water quality
1. Energy needed to pump water (KWH/m^3) or technical data to calculate it
2. Monetary values of all costs incurred during the implementation of the projects (land purchase, irrigation infrastructure, seeds purchase, fertilizer purchase, water abstraction costs, energy costs, labor cost work, cost of pesticides, etc.)
3. Institutional costs (personnel involved, transport and data monitoring)
4. Market price of the different crops grown on the site (XOF/Kg)
5. Demographic data (affected populations, beneficiaries, water users' association)

2. Dam

1. Geographic location (longitude/latitude or polygon)
2. Reservoir objectives (hydroelectric production/agricultural production/low water support/water supply)
3. Reservoir characteristics
    i. Maximum volume
    ii. Dead storage

iii. Live storage
iv. Volume-height-area curve
v. Conservation zone volume
vi. Buffer zone volume
vii. Inundated area

4. Hydropower (if applicable)
    i. Installed capacity
    ii. Average fall height (if applicable)
    iii. Turbine efficiency
5. Characteristics of associated projects (see the previous list)
6. Other withdrawals at a monthly time scale
7. Hydrological information

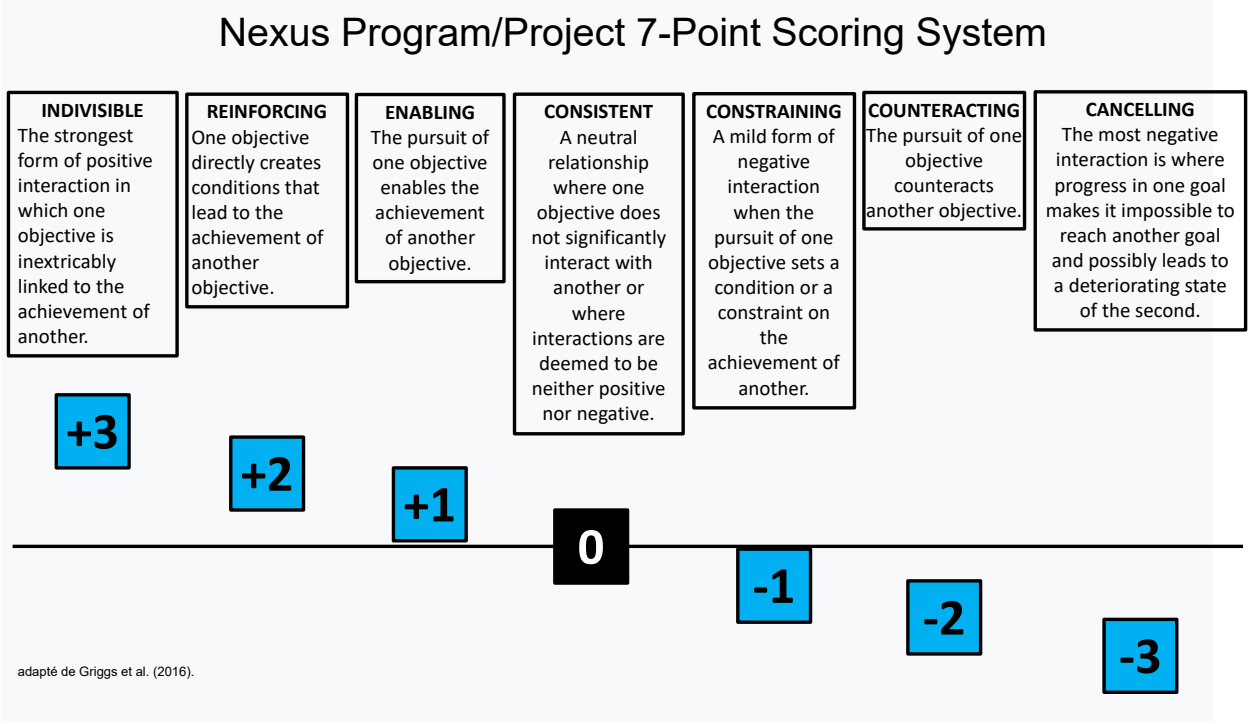
3. Protection of the environment

1. Description of the project
    i. Objective of the project
    ii. Size of the area that needs to be protected
    iii. Initial use of the area
2. Food production in the zone
    i. Volume of water withdrawn from the reservoir for agriculture and livestock development
    ii. Source of freshwater supply
    iii. Cropland areas and crop types
    iv. Agricultural production that could be lost if converted to a protected area
    v. Number of agricultural producers or sedentary livestock producers to be relocated/displaced
3. Energy production
    i. Volume of firewood extracted and deforestation
    ii. Energy needs of riparian populations
4. Environment
    i. Current biomass
    ii. Biomass lost in the last 10 years due to climate change

iii. Expected biomass in 10 years
iv. Loss of biodiversity through flooding and other disasters for example
v. Frequency of Bushfires
vi. Minimum flow requirement

Annex II. Methodology for Simplified Nexus Linkage Analysis

This approach makes it possible to assess in a simplified way the contribution of a project or program to water, energy, food security and environmental sustainability. To do this, we use the 7-point scoring framework developed by Griggs et al. (2016) and adopted by the International Science Council - formerly the International Council of Science Universities, to analyze the links between the SDGs. Figure 1 presents the framework for a simplified cross-sector assessment of the tradeoffs and synergies of a proposed project or investment in water, energy, food security, and environmental sustainability.



A score of 3 indicates that the project is essential to achieve a certain sector goal; a score of 2 indicates that the project is important for achieving a certain sector objective; a score of 1 means that the project enables a certain sector goal. For each positive rating, a brief explanation is given of how the synergies between the positive interactions can be enhanced. A score of 0 indicates that there is no significant link between two sectoral objectives; a score of negative 3 suggests severe negative damage to another sector goal in that pursuing one goal would negate the other sector goal; a score of minus 2 means substantial negative impacts on another sector goal; a score of minus 1 indicates that the opposing project or intervention limits to some extent the realization of another project or intervention. For each negative score, an explanation is added on how the negative impacts can be reduced. This analysis will be done, at a minimum, for water, energy, and food security and for environmental sustainability. Other sectors could be considered if they are related to the current project, for example, mining, transport, and navigation, as indicated in the Water Charter.

During project implementation, representatives of sectors identified with positive and negative linkages will be consulted to ensure that identified positive linkages (synergies) will actually be strengthened and identified negative linkages (tradeoffs) will be effectively reduced. The assessment will be reviewed and updated during implementation as other unexpected NEXUS links may be identified during implementation. These steps will be made available to the actors referred to in Article 14 in an online tool.

Appendix 3: Basin Country Exemplary Projects

Niger: Kandadji Program for the Regeneration of Ecosystems and Development of the Niger Valley

Description of the project

The Kandadji Program for the Regeneration of Ecosystems and Development of the Niger Valley (P_KRESMIN), originally called the ”Kandadji Dam Project," is considered a major development milestone for Niger. The country therefore chose it as an exemplary project. The Dam is under construction on the Niger River 189 km upstream from Niamey (Figure 11), and its commissioning is scheduled for 2025.

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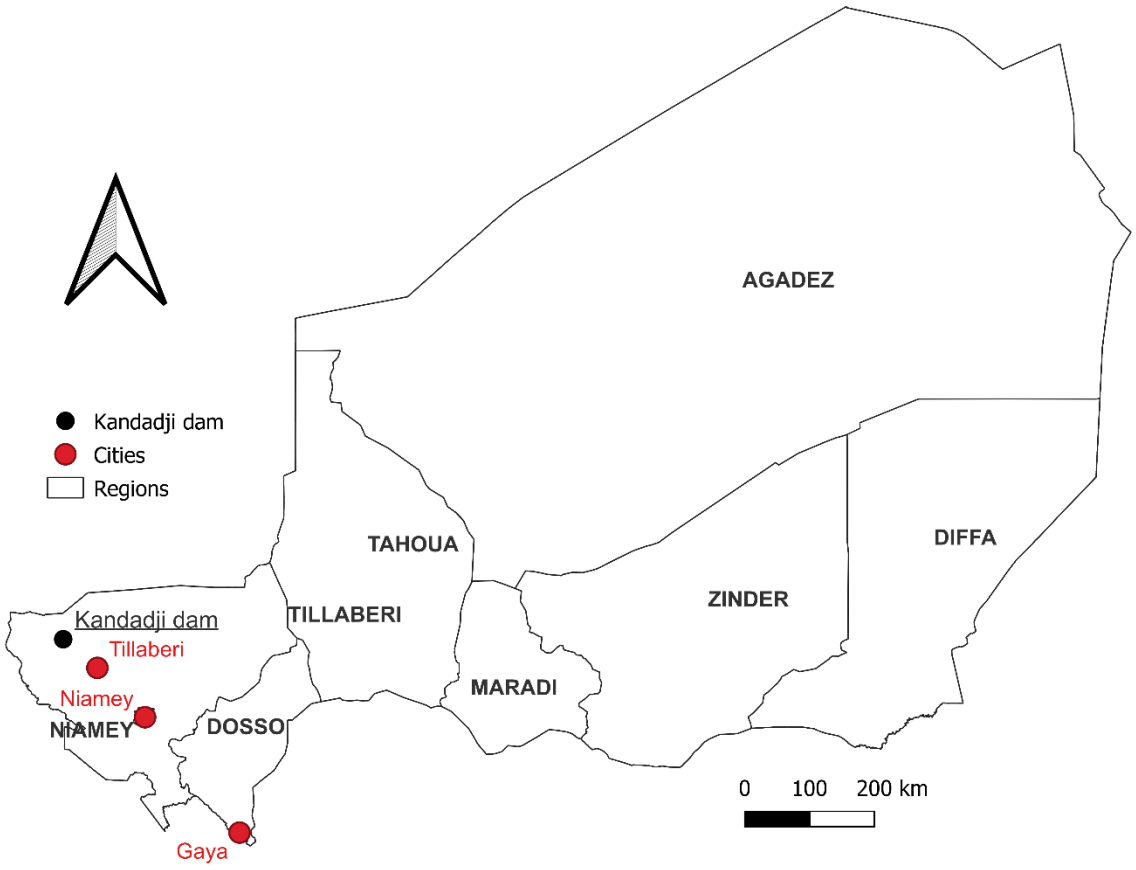

Figure 11. Geographical location of the Kandadji Dam

Nexus analysis of the project

Model development

The study team prepared and presented a quantitative analysis of the Kandadji project during the Niger nexus dialogue. The aim was to demonstrate the use of modeling tools for identifying and estimating the strength of intersectoral links. For this, the team developed a WEAP model of the Niger River from the border of Mali to the border of Nigeria (Figure 12)

that takes into account water storage in the Kandadji Dam and water withdrawals for irrigation, pastoralism, and domestic needs in the cities of Tillabéry, Niamey, and Gaya.

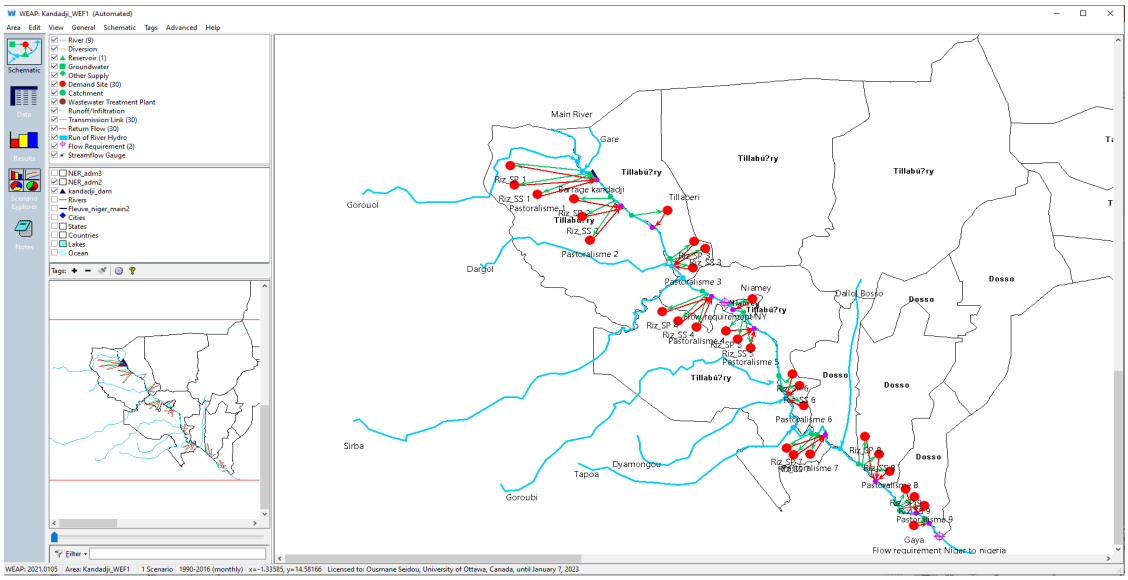

Figure 12. Intervention area and WEAP model of the P_KRESMIN project

The model considers the minimum flows required in Niamey (140 m^3/s) and at the border with Nigeria (80 m^3/s). The model is coupled with a "dashboard" developed in Excel that allows decision makers without a background in modeling to simulate their own scenario with one click (Figure 13).

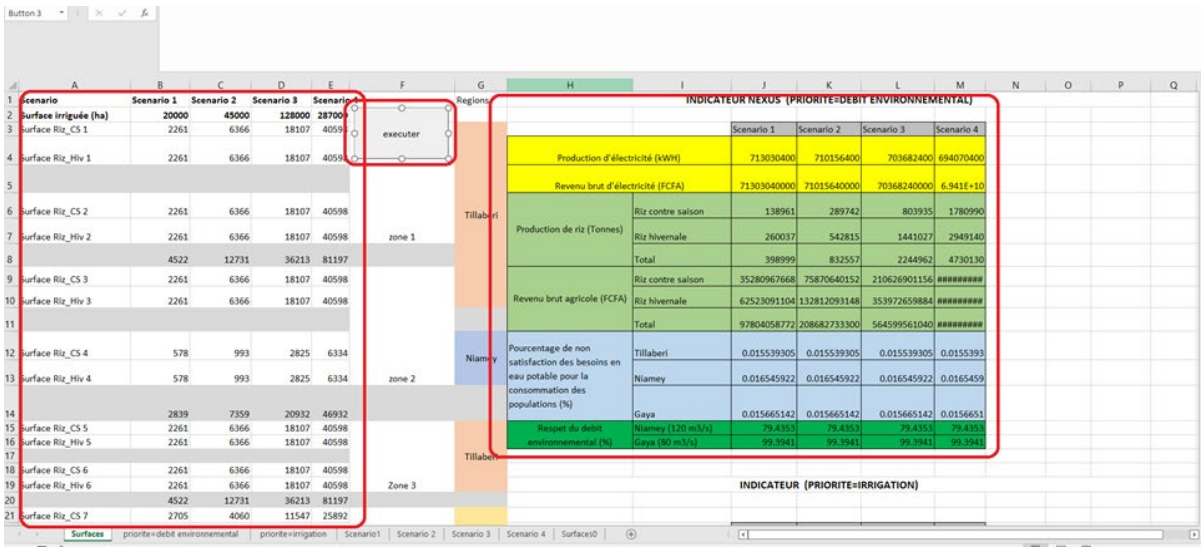

Figure 13. Excel dashboard for the WEAP model of Kandadji Dam

Nexus indicators

Nine indicators were selected to represent the four nexus sectors:

- **Energy security (two indicators):** Annual hydroelectric production gigawatt hours (GWh) and revenue generated from electricity (CFA) assuming a revenue of 100 CFA per kilowatt hour (KWh).
- **Food security (two indicators):** Annual rice production (tons) and associated income (CFA) assuming a revenue of 13000 CFA/ton of rice.
- **Water security (three indicators):** Percentage (%) of municipal water supply requirements not met in Tillabéry, Niamey, and Gaya.
- **Environmental sustainability (two indicators):** Percentage (%) of times minimum flow in Niamey and Gaya is not met.

Additional indicators could have been developed using model outputs but the analysis was restricted to the above nine for simplicity.

Development scenarios

Nine scenarios were developed based on the extent of irrigated areas and the usage that will be given priority when the Dam is in operation:

1. Irrigated areas:

   Scenario 1: 20000 ha (current project objective)
   Scenario 2: 45000 ha
   Scenario 3: 128000 ha
   Scenario 4: 287000 ha

2. Priority of usages:

   Usage priority option 1: Prioritize environmental flow, followed by irrigation then hydropower
   Usage priority option 2: Prioritize irrigation, followed by environmental flow then hydroelectricity

Main findings

Analysis of the indicators showed that while increasing irrigated area will lead to a proportional increase in food production, it may or may not affect drinking water requirements in Niamey and Dosso, or environmental flow requirements at the Niger-Nigeria border depending on the usage priorities. For instance, when the usage priority favors environmental flows at the Niger-Nigeria border (80 m^3/s), the requirement is satisfied 100 percent of the time independent of the irrigated area (Figure 14, lower left panel). The environmental flow requirement at Niamey (120 m^3/s) is satisfied around 80 percent of the time regardless of the irrigated area (Figure 14, lower left panel). The percentages of nonsatisfaction of drinking water requirements in Tillabéri, Niamey, and Gaya are virtually zero (Figure 14, upper left panel). Naturally, crop production and irrigation revenue grow proportionally with irrigated area (Figure 10, center panel). Electricity production and electricity revenues marginally decrease as irrigated area increases (Figure 10, left panel).

The relationship between electricity production, electricity revenue, crop production, and revenue from crops is almost unchanged under usage priority 2 (irrigation), followed by environmental flow then hydroelectricity (Figure 11, left and center panels). However, in this

scenario the percentage of nonsatisfaction of drinking water requirements increases to 1 percent for scenario 3 (128000 ha) and 8 percent for scenario 4 (287000 ha).

Figure 16, Figure 17, Figure 18, and Figure 19 show for each of the scenarios the impacts of usage priority on the selected nexus objectives. The conclusions are that: (1) a negative but weak interaction exists between agricultural production and energy production (Figure 14 and Figure 15, left panels); (2) environmental flow and water security are sensitive to the priority of uses of the reservoir (Figure 16–Figure 19); (3) Niger's capacity to maintain the environmental flow at the border of Nigeria is close to 100 percent if it is given priority of use (Figure 14, left panels), but not if irrigation is pushed to the extreme and given priority (Figure 15, left panels).

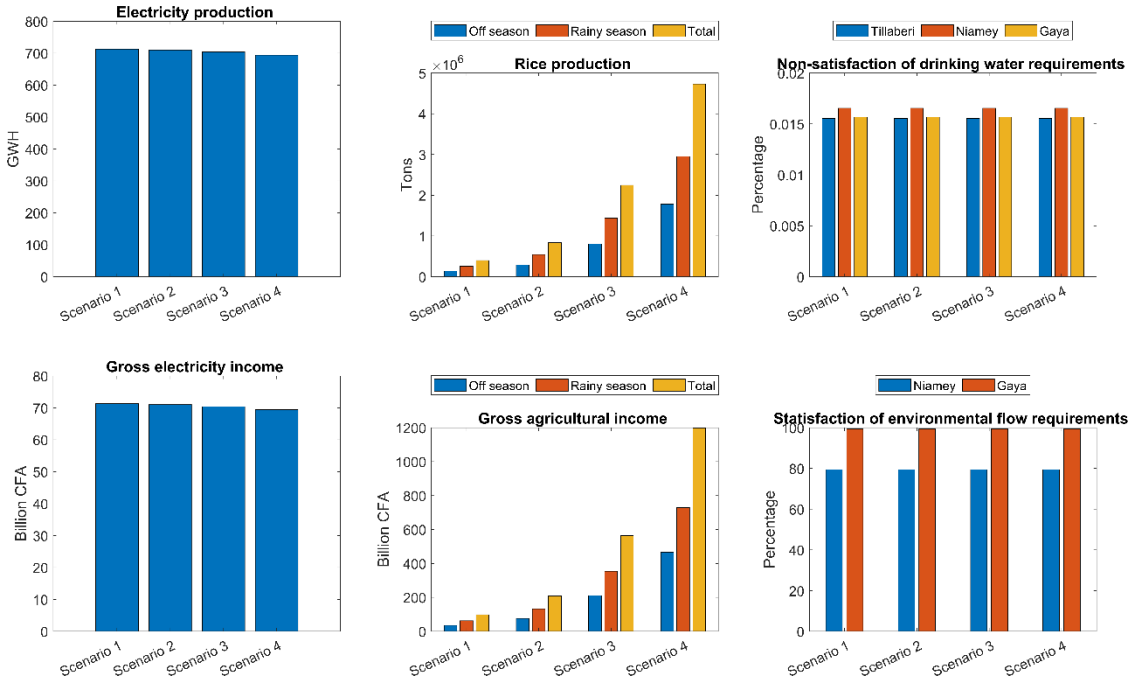

Figure 14. Variation in nexus indicators by irrigated area: Usage priority 1

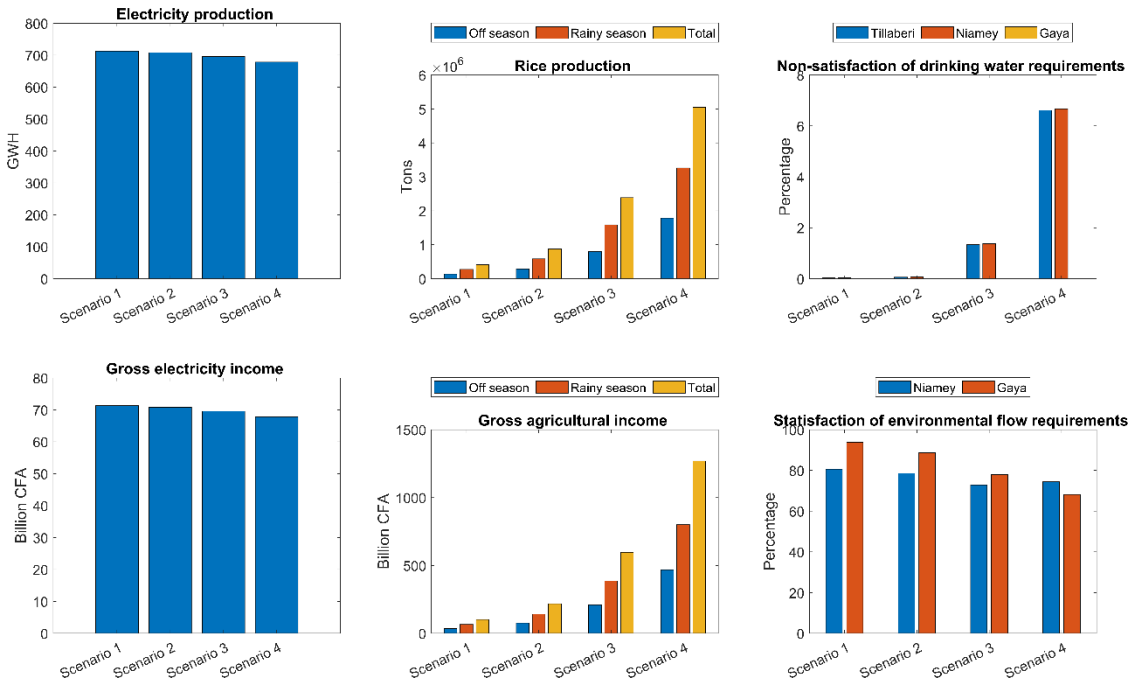

Figure 15. Variation in nexus indicators by irrigated area: Usage priority 2

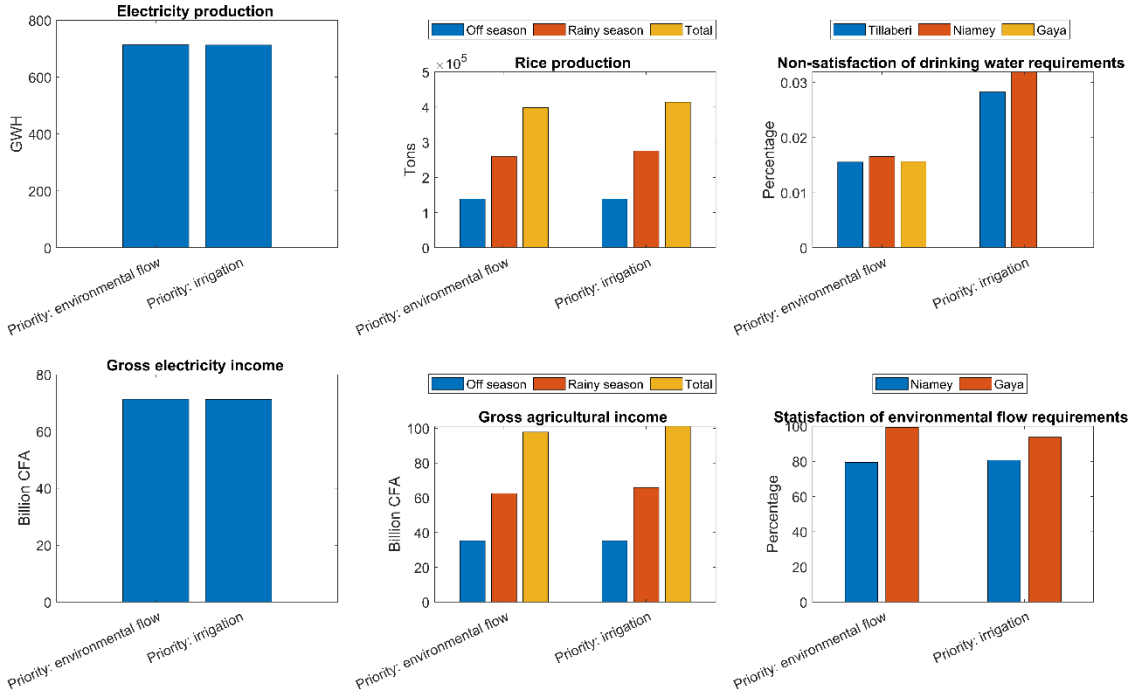

Figure 16. Impact of usage priority on nexus indicators: Scenario 1

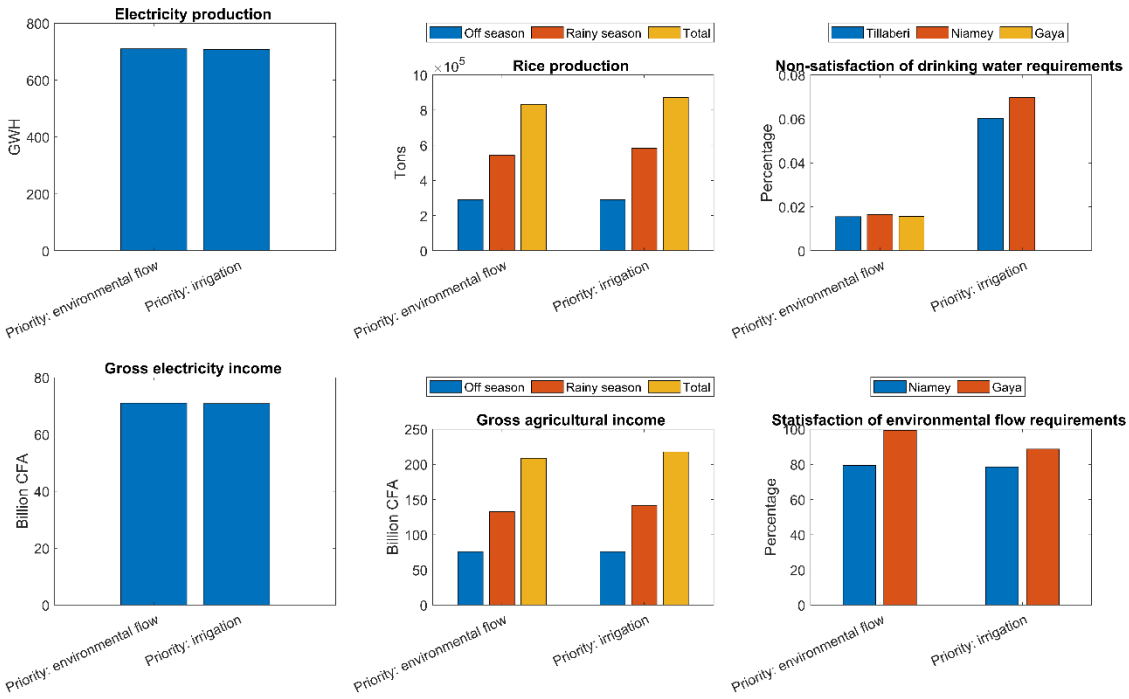

Figure 17. Impact of usage priority on nexus indicators: Scenario 2

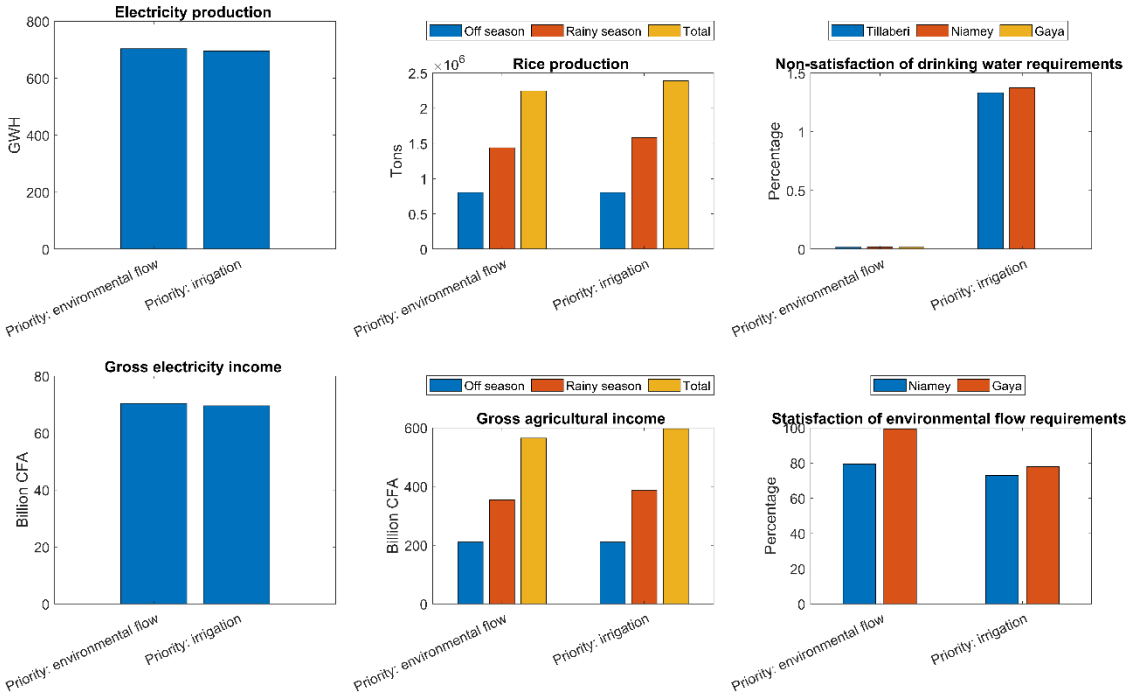

Figure 18. Impact of usage priority on nexus indicators: Scenario 3

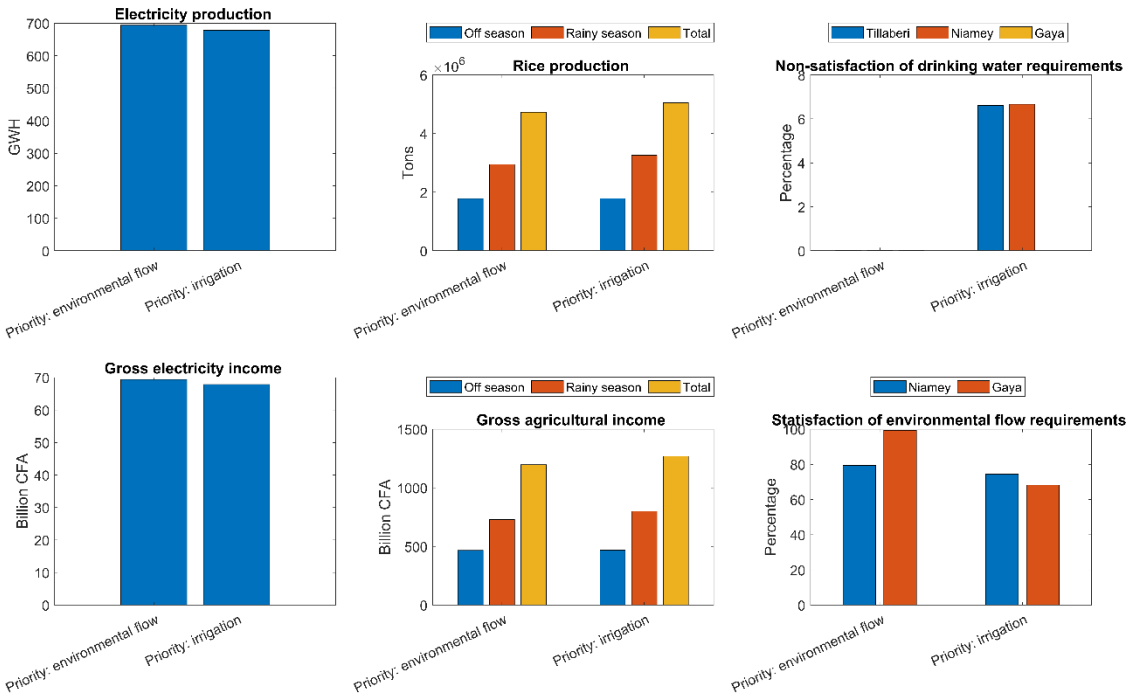

Figure 19. Impact of usage priority on nexus indicators: Scenario 4

Benin: Socio-economic Infrastructure Development Project for Food Security

Description of the project

Benin chose the Socio-economic Infrastructure Development Project for Food Security (PDISSA) as an exemplary project. The PDISSA is financed by the West African Development Bank and the Government of Benin for a total cost of 11,850,000,000 FCFA and operates in four communes of the country: Kèrou, Péhunco, Kandi, and Nikki (Figure 20). PDISSA is expected to contribute to sustained growth in the Beninese part of the Niger Basin by fighting poverty, strengthening food security, and promoting sustainable development. Its specific objectives are:

- Intensification of and increase in agricultural, pastoral, and fishery production;
- Improvement of the living environment of the populations benefiting from the project;
- Contribution to job creation;
- Fight against poverty and creation of additional wealth.

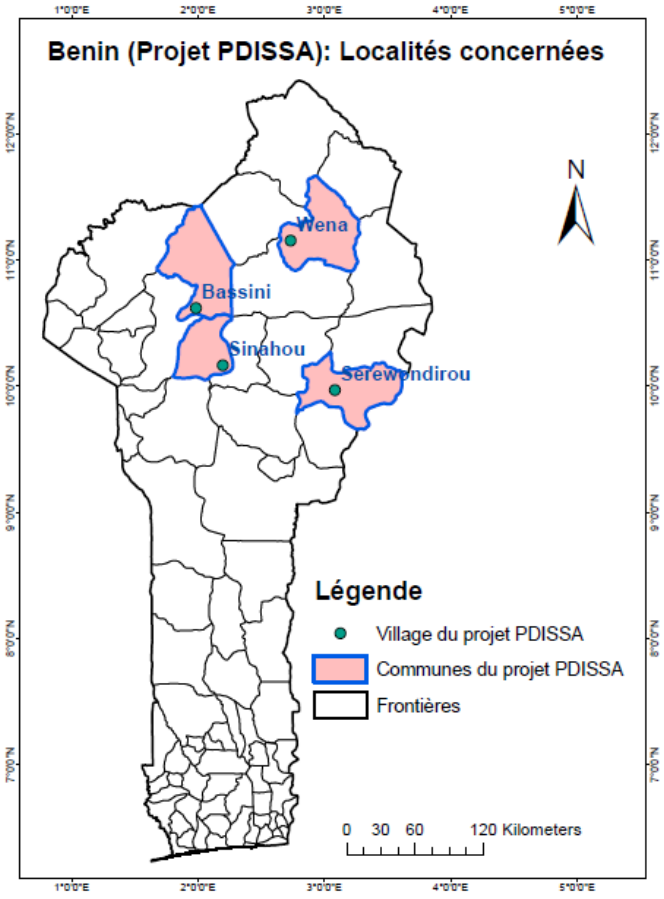

Figure 20. PDISSA intervention area

Nexus analysis of the project

Model development

A simulation model of the study area was developed with WEAP. Three planned dams (Bassim, Wena, and Sindu) as well as three points of water withdrawal for irrigation and cattle breeding were included in the model (Figure 21). Irrigation in the model is represented by two cycles of rice production (one cycle in the dry season and one in the wet season).

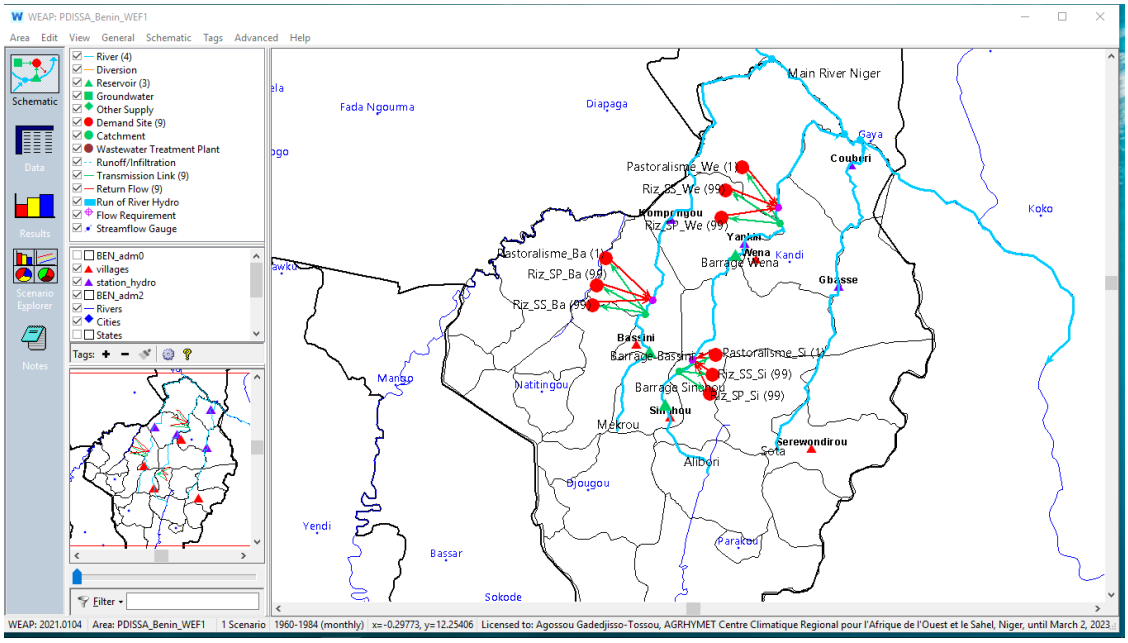

Figure 21. WEAP model of the PDISSA

Nexus indicators

Two indicators were selected to represent the nexus sectors:

- **Food security:** Annual rice production (tons) and associated income (CFA) assuming a revenue of 13,000 CFA/ton of rice.
- **Water security:** Percentage (%) of cattle breeding water requirements not met in Bassini, Sinahou, and Wena.

Note that energy security and environmental sustainability were not taken into account because of insufficient data.

Development scenarios

The scenarios analyzed are combinations of four levels of hectares of land (125 ha; 250 ha; 375 ha; 500 ha) irrigated for rice developed under the project and two water management strategies (priority to irrigation; priority to pastoralism).

Main findings

Results show that rice production in both the rainy and dry seasons will increase as irrigated area increases regardless of the usage priority (Figure 22 and Figure 23). When priority is given to agriculture, up to a 20 percent deficit in water available to livestock occurs (Figure 22), versus less than 3.5 percent when priority is given to pastoralism (Figure 23). Figure 24, Figure 25, Figure 26, and Figure 27 show the impacts of usage priority on the selected nexus objectives for each scenario. Giving priority to irrigation has a little impact on irrigation revenue but can dramatically increase the probability of nonsatisfaction of irrigation water requirement for pastoralism, suggesting that the system should prioritize that usage first. The main limitation to agricultural production is the amount of surface water available in the dry season. Water storage or a combination of surface water and groundwater use is required to maximize agricultural production, but care must be taken with the pressure on surface water supplies (required for other human uses and the maintenance of ecosystems) and groundwater (limited by recharge).

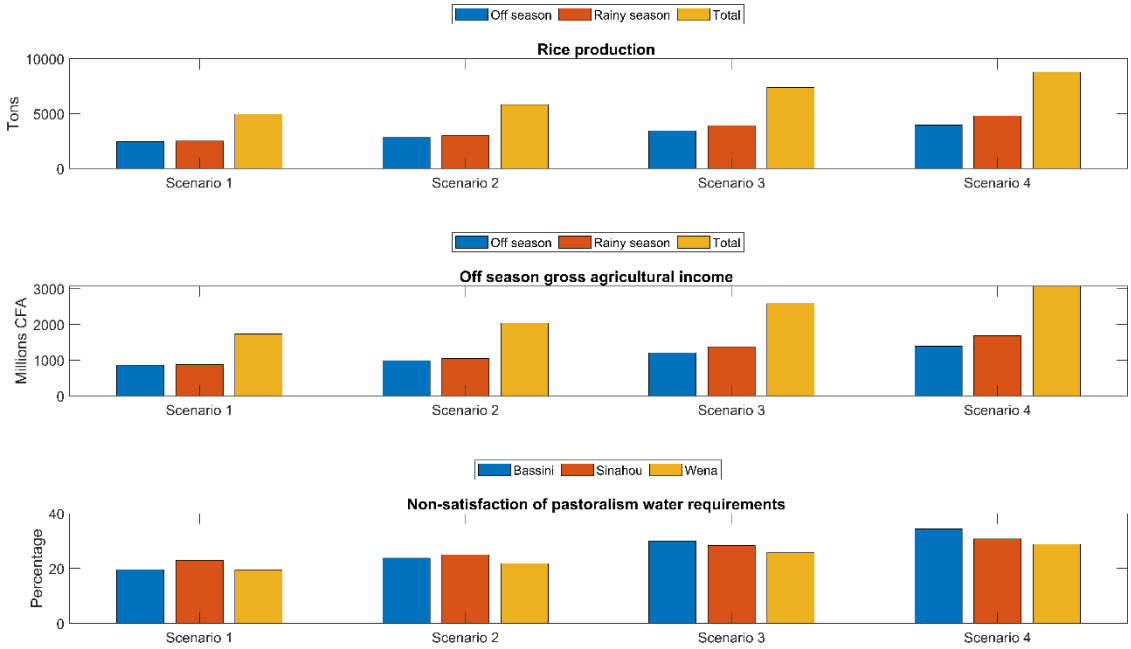

Figure 22. Variation in nexus indicators by irrigated area: Priority is irrigation

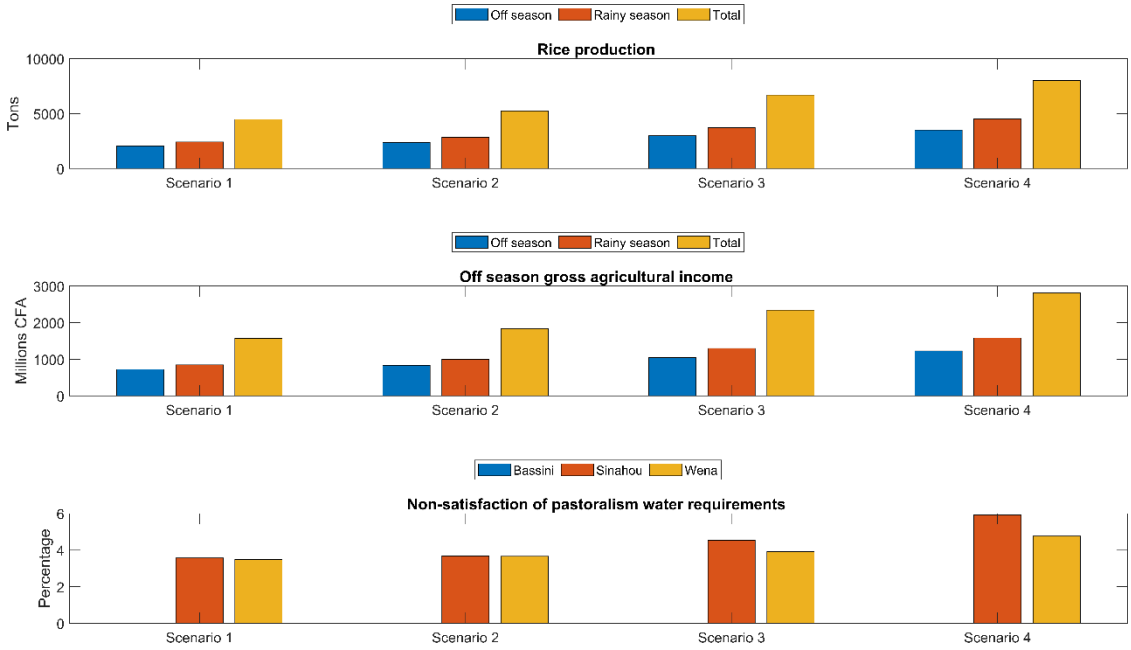

Figure 23. Variation in nexus indicators by irrigated area: Priority is pastoralism

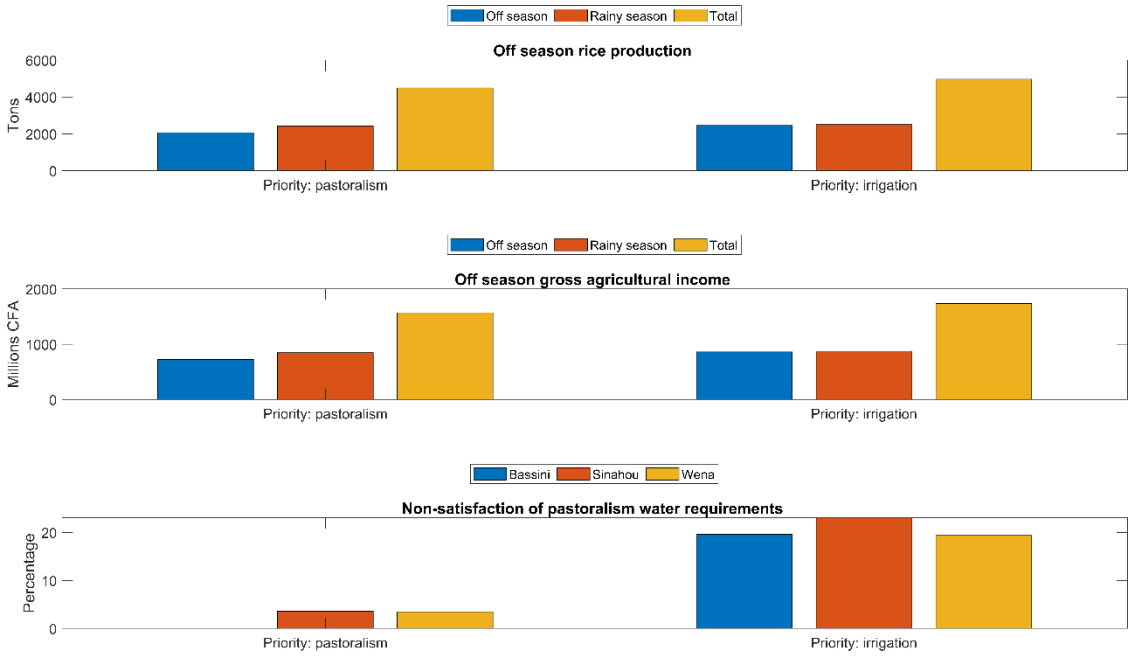

Figure 24. Impact of usage priority on nexus indicators: Scenario 1

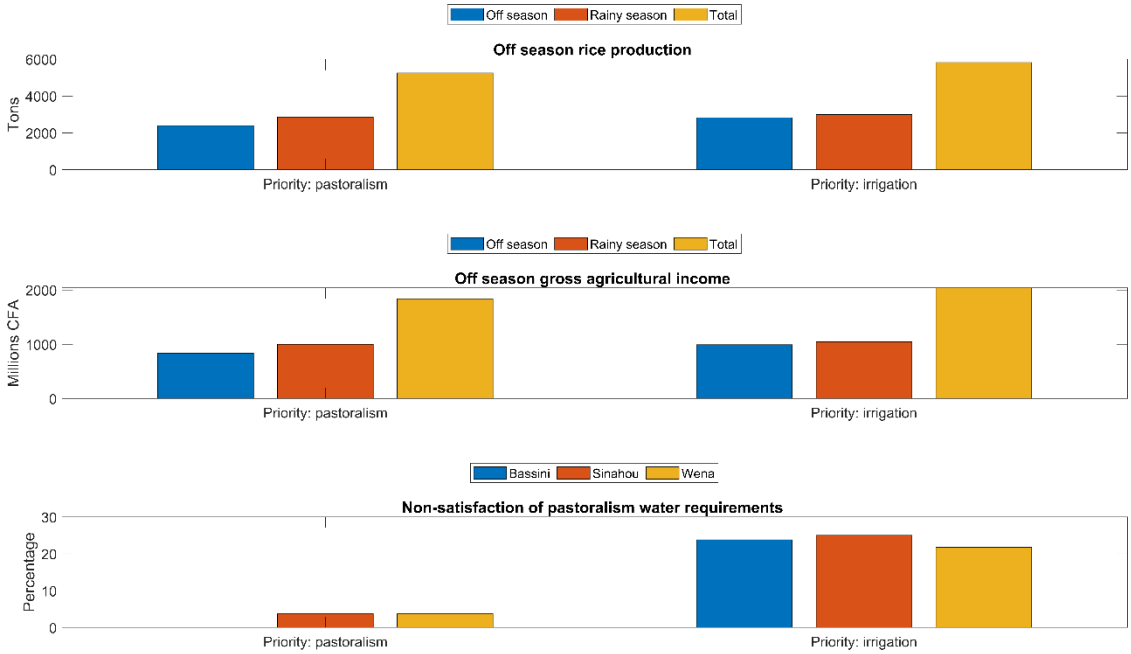

Figure 25. Impact of usage priority on nexus indicators: Scenario 2

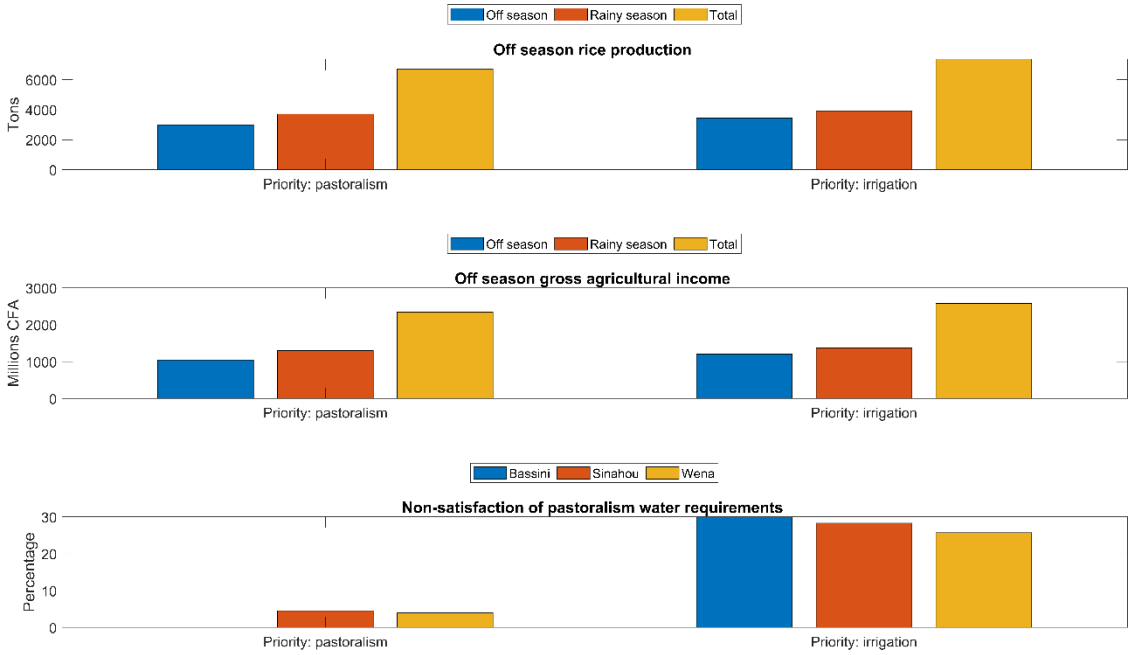

Figure 26. Impact of usage priority on nexus indicators: Scenario 3

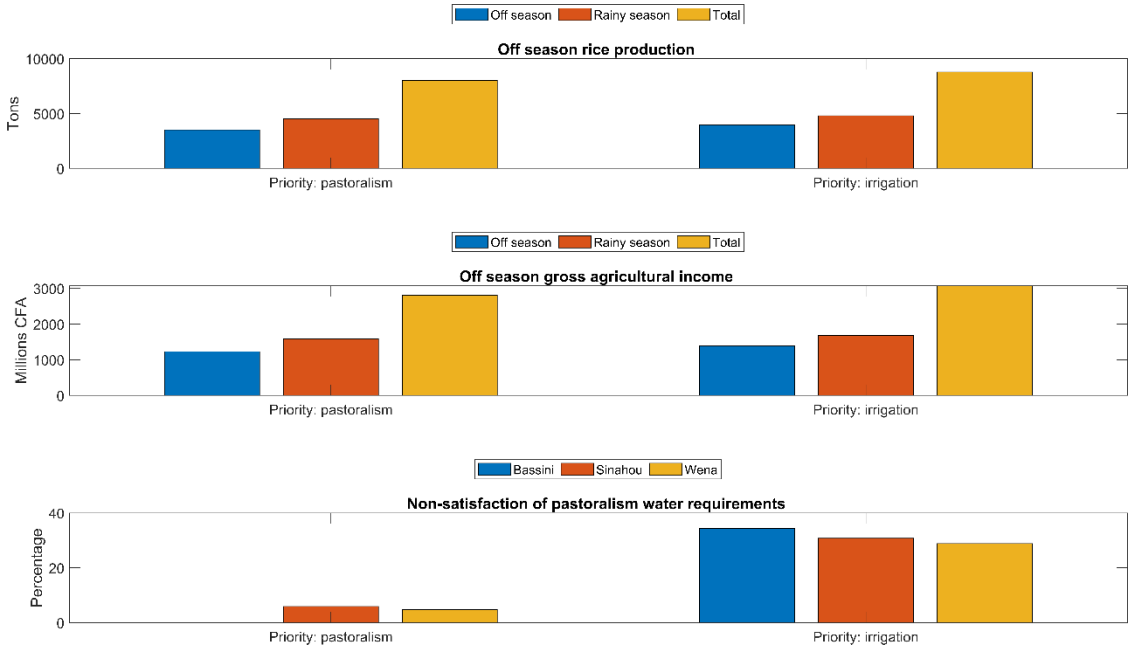

Figure 27. Impact of usage priority on nexus indicators: Scenario 4

Burkina Faso: Development of the Dori Pond (DRABHyD)

Description of the project

The city of Dori (270 km north of Ouagadougou) has several natural depressions, the most important of which is the large pond that surrounds it (Figure 28). This pond is the primary natural resource for diverse and multifaceted usages (human consumption through sumps, brick making, market gardening, animal watering, grazing area, transit area for migratory birds, etc.). It is also the natural receptacle for the overflow of the stormwater drainage system of Dori. Unfortunately, over several years the pond has gradually experienced siltation, resulting in a reduction of the pond volume, increased risk of flooding of surrounding neighborhoods, shorter water retention time as well as the decline or even disappearance of some animal and/or plant species. The DRABHyD Project contributes to implementation of the large pond development project in the municipality of Dori and aims to recover the Dori Pond watershed. Development of this primary water supply source for the whole city using hydraulic interventions is expected to solve the city's flooding and early drying problems.

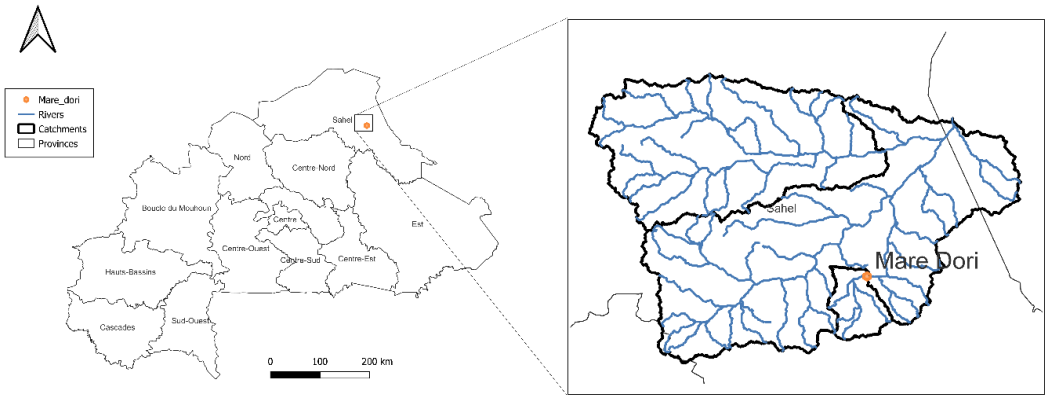

Figure 28. Location of Dori Pond and its watershed

Nexus analysis of the project

Model development

Given the lack of data, the pond's capacity before and after the project could not be assessed. Hence, the question examined in this study was limited to whether the pond can sustain tomato irrigation using surface water alone, groundwater alone, or a combination of both. The WEAP analysis (Figure 29) used data obtained by the National Focal Structure from various agencies, and with NBA support. The model consisted of one watershed, one reservoir representing the pond, one groundwater element, and one irrigation scheme with one crop (tomato).

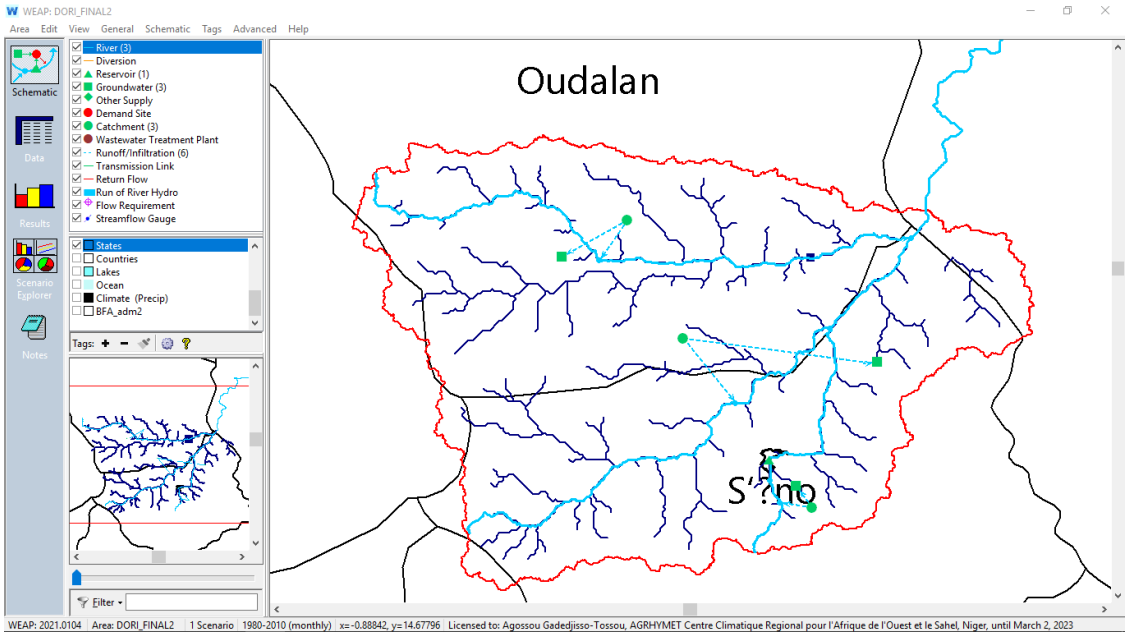

Figure 29. WEAP model of Dori Pond

Nexus indicators

Two indicators were selected to represent the nexus sectors:

- **Food security:** Annual tomato production (tons) and associated income (CFA).
- **Water security:** Percentage (%) of satisfaction of water requirements for tomato production.

Note that energy security and environmental sustainability were not taken into account because of insufficient data.

Development scenarios

Nine scenarios were considered, using combinations of three water sources (surface/pond water alone; groundwater alone; both groundwater and surface water) and three surface areas to be irrigated (20 ha – scenario 1; 40 ha – scenario 2; 80 ha –scenario 3).

Main findings

Results show that using surface water alone leads to severe water deficits during the dry season (Figure 30), and a deficit of around 25 percent during the rainy season, suggesting that Dori Pond alone cannot satisfy the water requirements of any of these irrigated areas (Figure 30). The reason may be that the pond's outlet is uncontrolled, and water flows out at the end of the rainy season before crop growth is complete. Using groundwater or surface and groundwater together (groundwater in the dry season and surface water in the rainy season) leads to zero deficit in the dry season (Figure 31 and Figure 32), but a deficit in the rainy season alone. This suggests that groundwater pumping may be needed even during the rainy season. Alternatively, a structure to store the water could be built at the pond's outlet. Figure 33, Figure 34, and Figure 35 show the impacts of each source of water on nexus indicators. All suggest that groundwater pumping is required. However, a lot of uncertainty arises about the sustainability of such intensive use of groundwater in an arid region, so more studies are

required. The best and safest scenario (that is, the one that leads to moderate stress on surface and groundwater resources) was found to be an 80-ha development using both surface and groundwater.

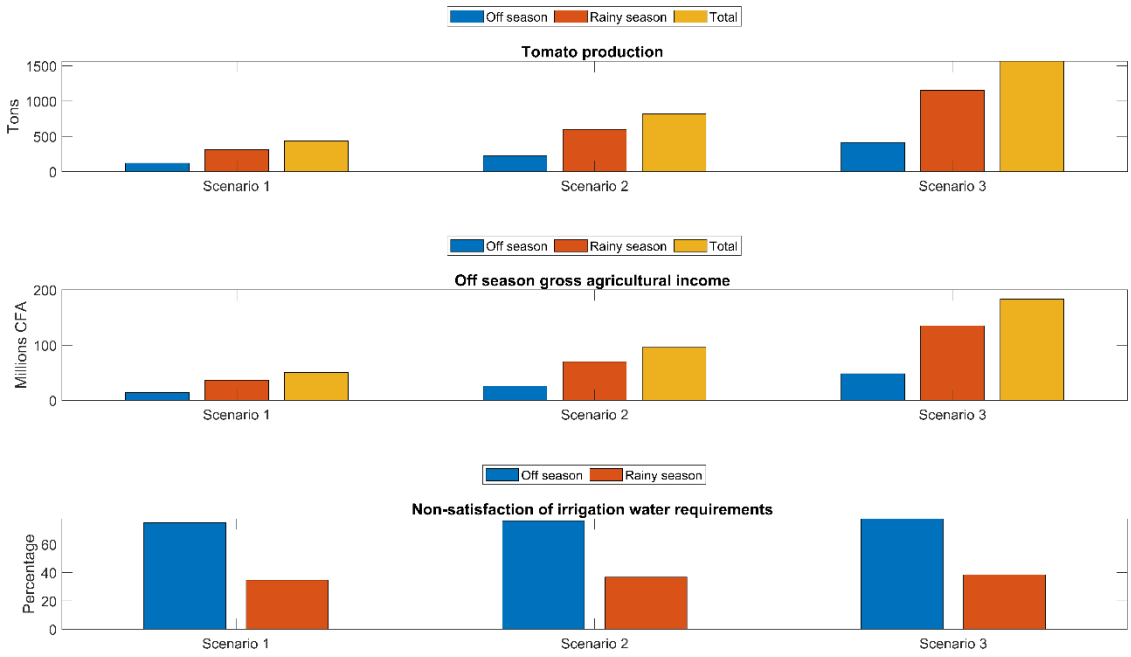

Figure 30. Variation in nexus indicators by irrigated area: Surface (pond) water alone

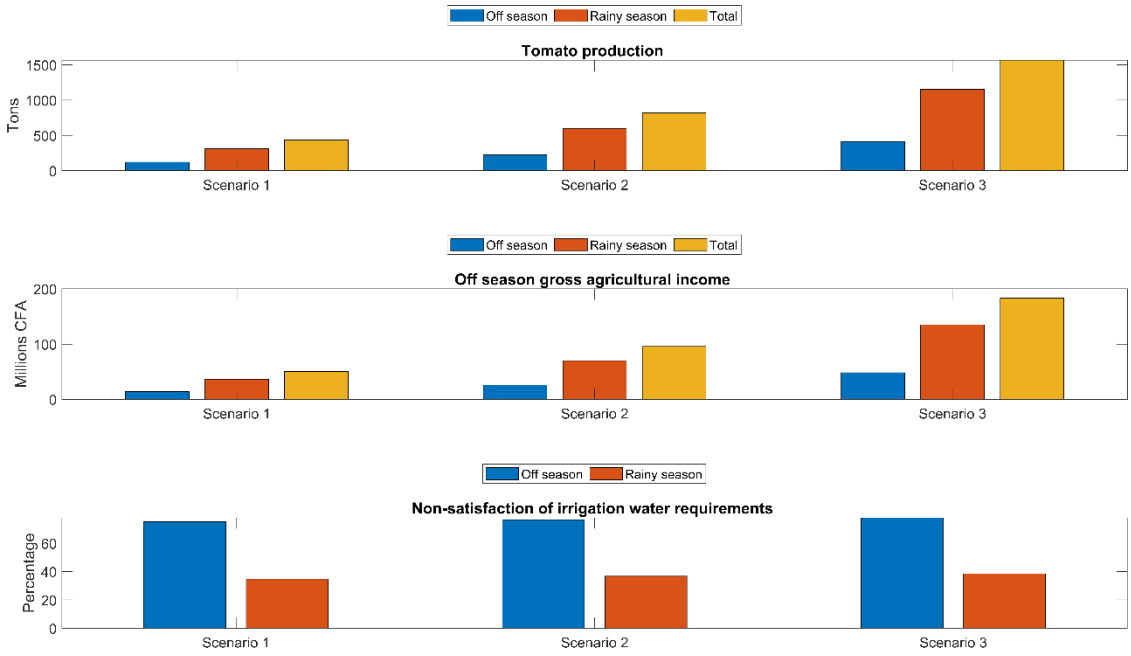

Figure 31. Variation in nexus indicators by irrigated area: Groundwater alone

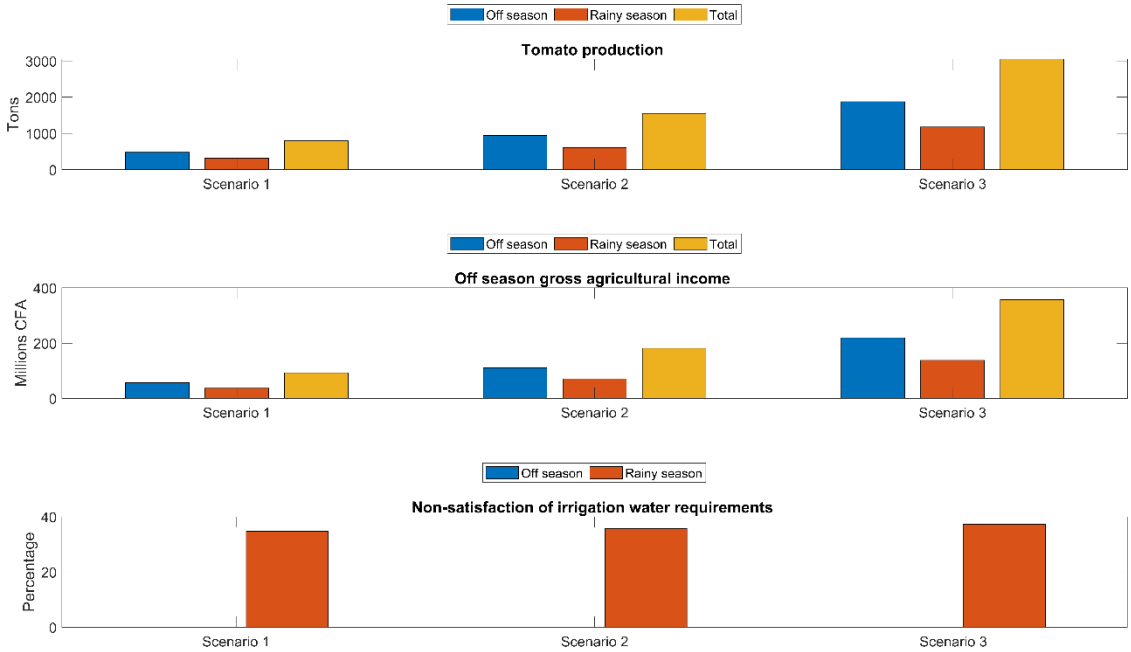

Figure 32. Variation in nexus indicators by irrigated area: Both surface and groundwater (groundwater in the dry season and surface water in the rainy season)

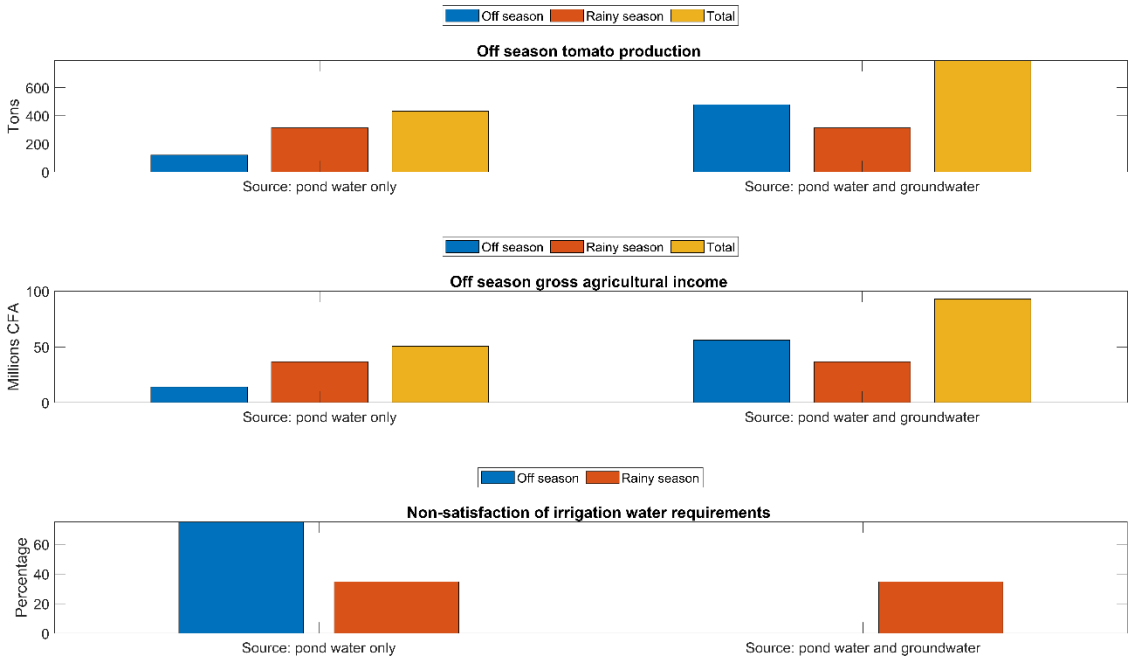

Figure 33. Variation in nexus indicators by water source: Scenario 1

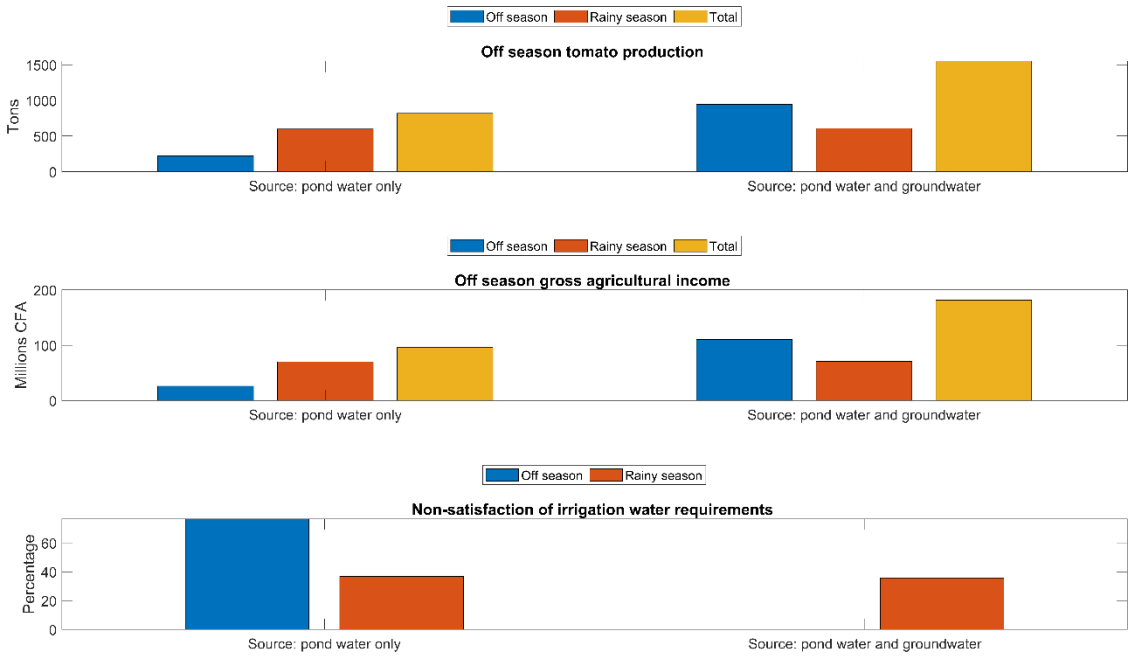

Figure 34. Variation in nexus indicators by water source: Scenario 2

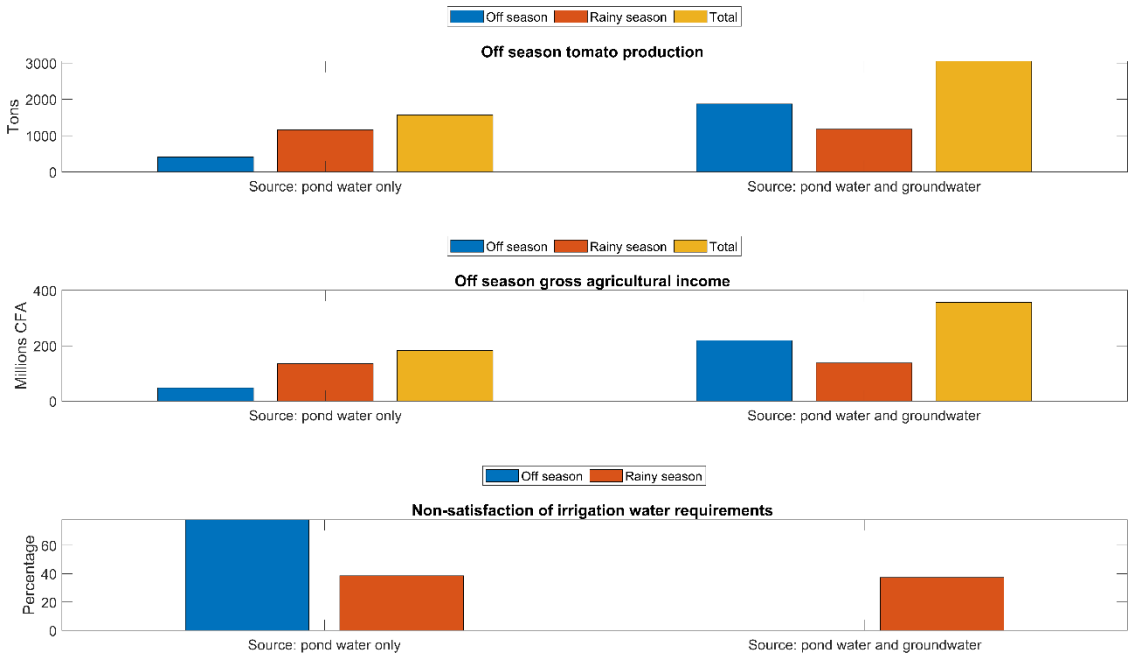

Figure 35. Variation in nexus indicators by water source: Scenario 3

Cameroon: Project for the Development and Valorisation of Investments in the Benue Valley (VIVA-BENUE)

Description of the project

The Lagdo multi-purpose barrage (Figure 36) was built on the Benue River between 1978 and 1982. A 72-megawatt (MW) hydroelectric plant was built, and plans have been drawn for development of irrigation downstream of the reservoir. The hydroelectric plant has been in operation since 1982, but irrigation development has not occurred as initially planned: the current irrigated area has barely 600 ha of functional irrigation.

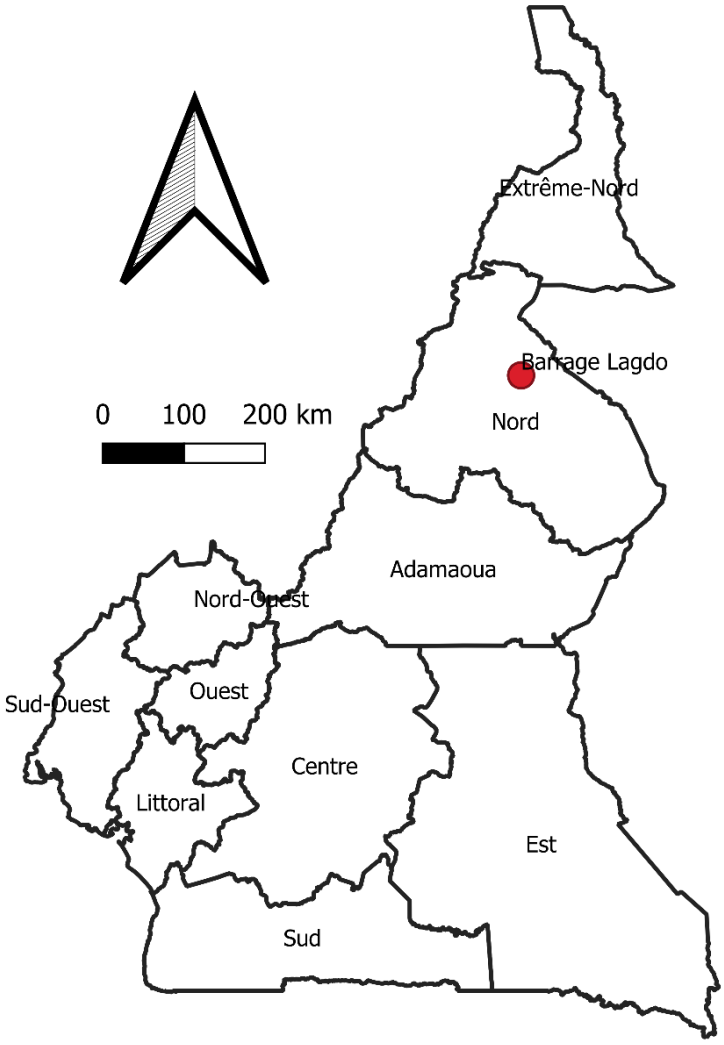

Figure 36. Geographical location of the Lagdo Dam

The VIVA-BENUE project, developed in 2020, aims to develop agricultural land downstream of the Lagdo Dam. It was presented at the Cameroon national dialogue to show the added value of the nexus approach based on a quantitative analysis of the impacts of investment choices on water, energy, food security, and environmental sustainability.

Nexus analysis of the project

Model development

A model of the study area was developed using WEAP. The model contains a representation of the Lago Dam, the power plant, its upstream catchments, and irrigation schemes downstream of the Dam that could potentially be developed by the VIVA-BENUE project (Figure 37).

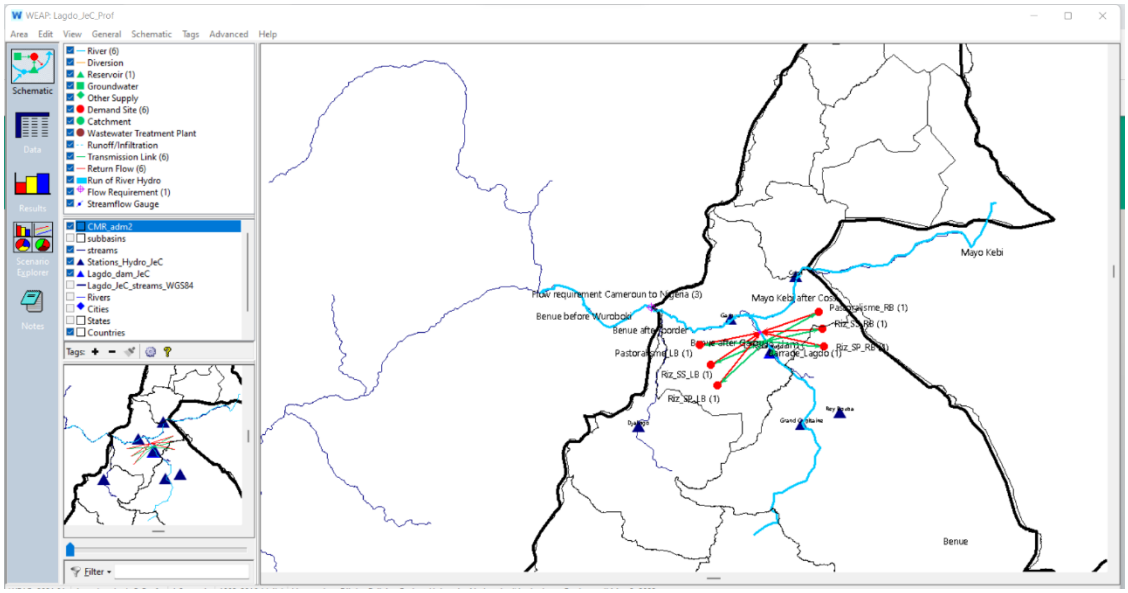

Figure 37. WEAP model of the Lagdo Dam and upstream catchment area

Nexus indicators

Three indicators were selected to represent the four nexus sectors:

Energy security: Annual hydroelectric production (GWh).
Food security: Annual rice production (tons) and associated income (CFA).
Environmental sustainability: Percentage (%) of times minimum flow at the Cameroon-Nigeria border is not met.

Water security was not taken into account because of lack of data availability.

Development scenarios

Scenarios were developed based on combinations of four irrigated area scenarios (11000 ha – scenario 1; 22000 ha – scenario 2; 33000 ha – scenario 3; 44000 ha – scenario 4) and two usage priorities (hydropower; irrigation).

Some of the scenarios were flagged as unrealistic by nexus dialogue participants, as only 17000 ha of land can be irrigated downstream of the Dam, of which 11000 ha must use water from the reservoir and 6000 ha from downstream tributaries. These scenarios were nevertheless presented in the results.

Main findings

Results showed that there is enough water to easily sustain the planned 11000 ha of irrigated land. The required water is only 5% of the dam capacity. There is however a challenge or tradeoff between electricity production and water storage, and between reservoir management for hydropower production and flood risk reduction in Nigeria. The model was able to capture massive water releases when the reservoir is full, following intense precipitation events.

It was found that the dam storage is too small to sustain the continuous operation of all four turbines. Since very little information was available to quantify flood damages, a quantitative analysis of the linkage between electricity production and downstream floods could not be performed. The study team strongly recommends that such a study is performed to develop a reservoir management rule that minimizes emergency water releases while maximizing energy outputs.

Chad: Surface Water Mobilization Project for Livestock Feed and Agriculture in the Upper Benue Basin in Chad

Description of the project

The overall objective of the surface water mobilization project for livestock feed and agriculture in the Upper Benue Basin in Chad is to contribute to the mobilization of surface water resources for agro-sylvo-pastoral purposes in the Chadian part of the Niger Basin (Figure 38). Specifically, the project aims to: (1) build hydro-agro-pastoral structures; (2) develop the catchment area to protect the structures; and (3) build the capacities of actors in the management of hydro-agro-pastoral structures.

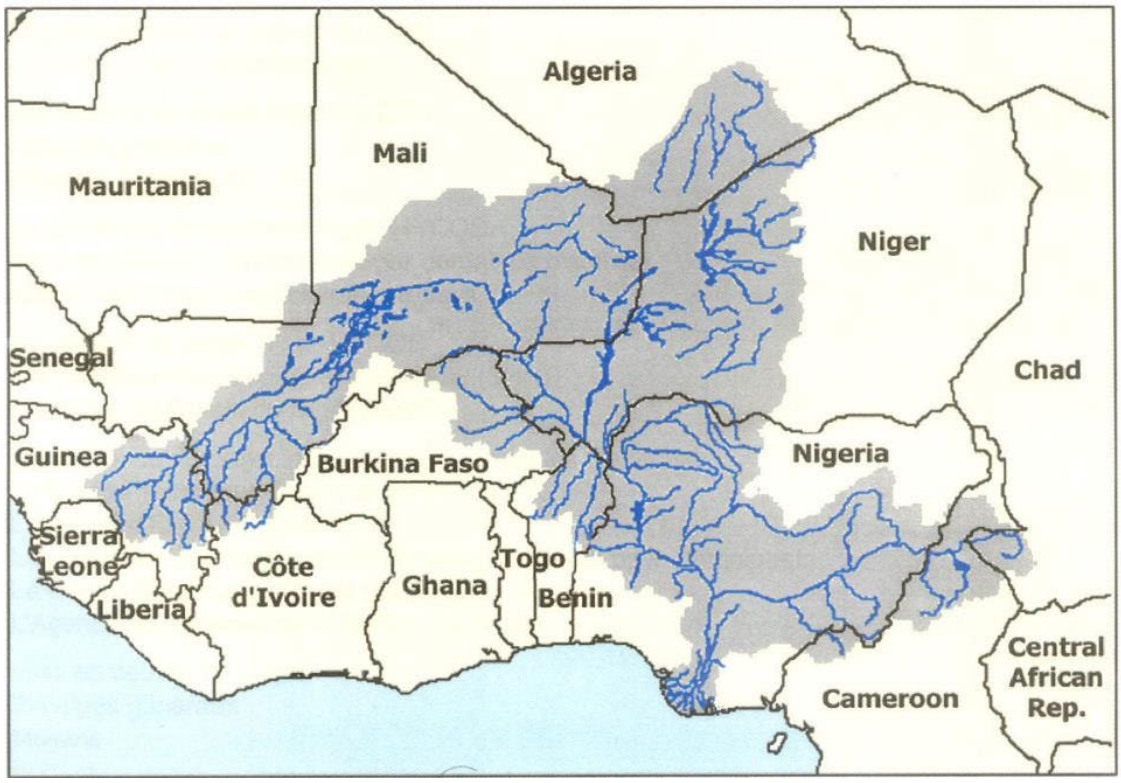

Figure 38. Chadian part of the Niger Basin

Nexus analysis of the project

The study team struggled to obtain data related to the project and could not develop a WEAP model of the study area. Dialogue participants came with data about water requirements for livestock and irrigation, and rough estimates of these requirements were compared to available surface water in the current climate and under hypothetical climate change scenarios.

Main findings

The limited analysis suggests that Chad's current mobilization capacity is insufficient to meet its water needs. A reasonable allocation of water resources to achieve the project objectives

would require efforts to reverse the declining trend of meeting water needs. In addition, construction of the structures planned under the PIDACC (Programme intégré de développement et d'adaptation aux changements climatiques dans le bassin du Niger - Integrated Programme for Development and Adaptation to Climate Change in the Basin of Niger) will not cover the needs by 2050. The master plan to be drawn up will have to consider this.

Côte d'Ivoire: Koudan Dam Construction and Hydro-Agricultural Development Project

Description of the project

Côte d'Ivoire proposed the Kouban Dam Construction and Hydro-Agricultural Development project as exemplary project to be quantitatively analyzed. The Dam is to be built in the Folon region at Kouban (a subprefecture of Tienko) (Figure 39). The Dam is part of a larger ensemble of infrastructures to be developed by the Integrated Programme for Development and Adaptation to Climate Change in the Basin of Niger (PIDACC/BN).

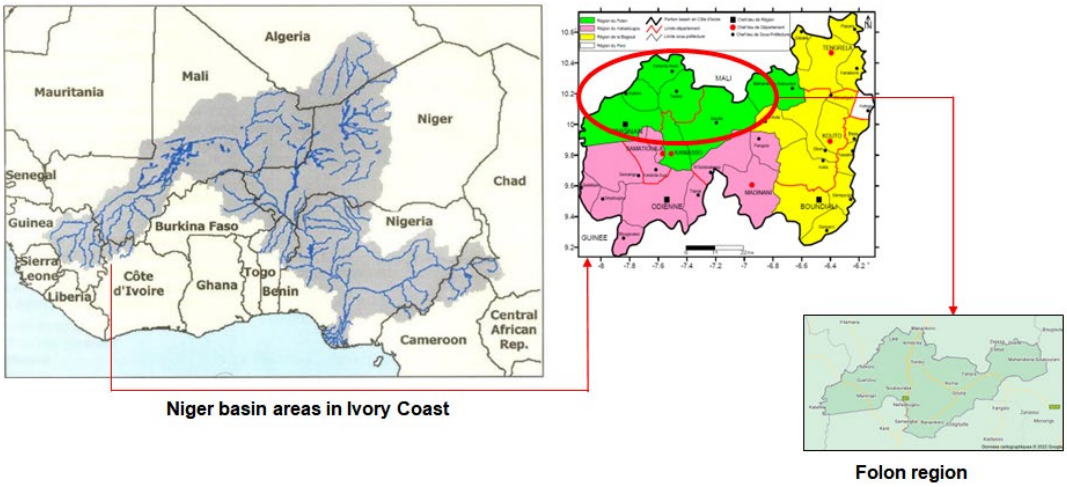

Figure 39. Geographical location of the Folon region

Nexus analysis of the project

Model development

Figure 40 shows the simulation model of the study area developed using WEAP. The model consists of one dam, one river network, a groundwater node and nine consumption nodes representing dry season and wet season rice cultivation and market gardening, as well as transhumant and sedentary livestock water consumption.

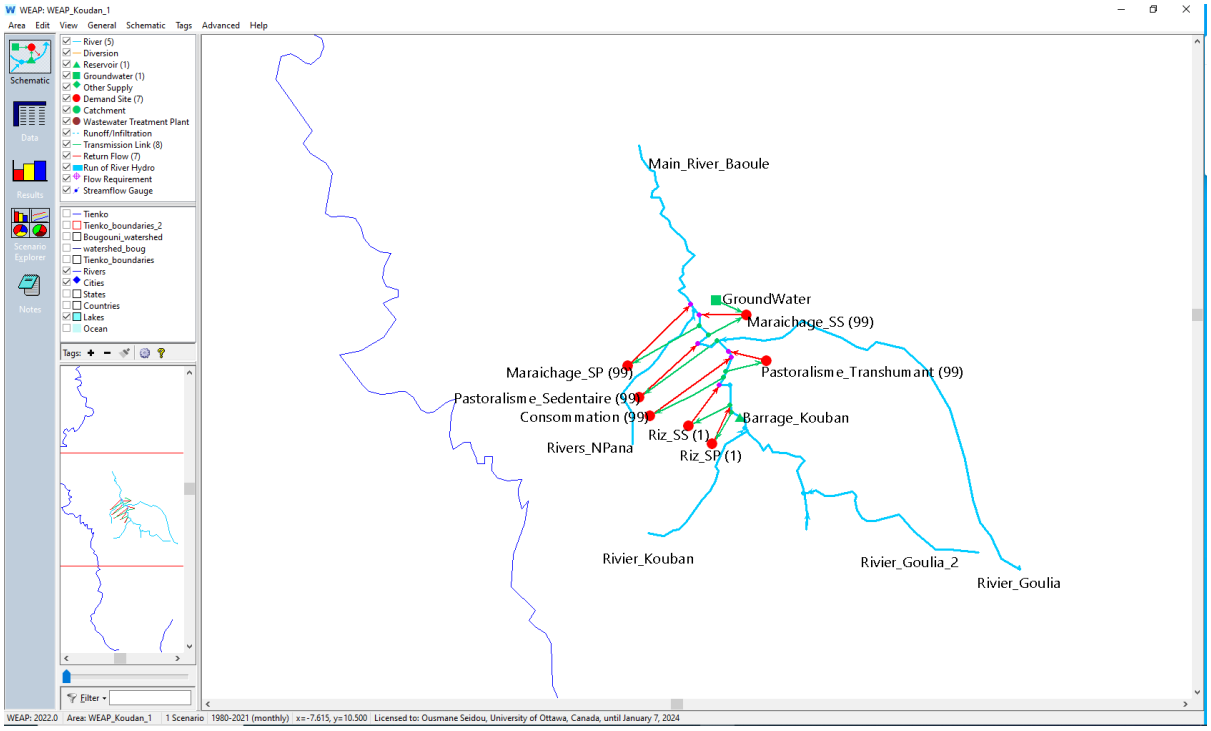

Figure 40. WEAP model of the Koudan Dam Construction and Hydro-Agricultural Development Project area

Nexus indicators

Two indicators were selected to represent the four nexus sectors:

Food security: Annual rice and vegetable production (tons) and associated income (CFA)
Environmental sustainability: Percentage (%) of times minimum flow at the Côte d'Ivoire-Mali border is not met

Energy security and water security were not taken into account because of data unavailability.

Development scenarios

Combinations of four land resource use scenarios (sown areas):

- Scenario 1 (reference project): 330 ha of cultivated land (300 ha of rice and 30 ha of market gardening)
- Scenario 2: 660 ha of cultivated land (600 ha of rice and 60 ha of market gardening)
- Scenario 3: 990 ha of cultivated land (900 ha of rice and 90 ha of market gardening)
- Scenario 4: 1320 ha of cultivated land (1200 ha of rice and 120 ha of market gardening)

Three water use prioritization scenarios (priority 1 = rice irrigation; priority 2 = market garden irrigation; priority 3 = watering of sedentary and transhumant livestock) were

simulated. Each scenario quantitatively highlights the levels or percentage of the project's contribution to the different nexus objectives (food security, energy security, water security). The study team demonstrated the ease of use of this decision-making tool, although most manager-planners rarely use it.

Main findings

Naturally, an increase in cultivated area leads to an increase in production and income for both rice and vegetable, regardless of whether priority is given to rice production, vegetable production, or pastoralism (Figure 41, 38, and Figure 43). However, the total amount produced for each crop varies significantly depending on which crop is prioritized (up to a 2000-ton decrease in rice production and a 3500-ton increase in vegetable production under scenario 3 if priority is switched from rice to vegetable production). By prioritizing vegetable irrigation or pastoralism during the dry season under scenario 1, rice production decreases by 12 tons, while vegetable production increases by only 6 tons (Figure 41 and Figure 42). The percentages of nonsatisfaction of the water requirements of livestock slightly increase with an increase in cultivated area. The same patterns (with different amplitudes of changes) were observed for all four scenarios (Figure 44, Figure 45, Figure 43, and Figure 47).

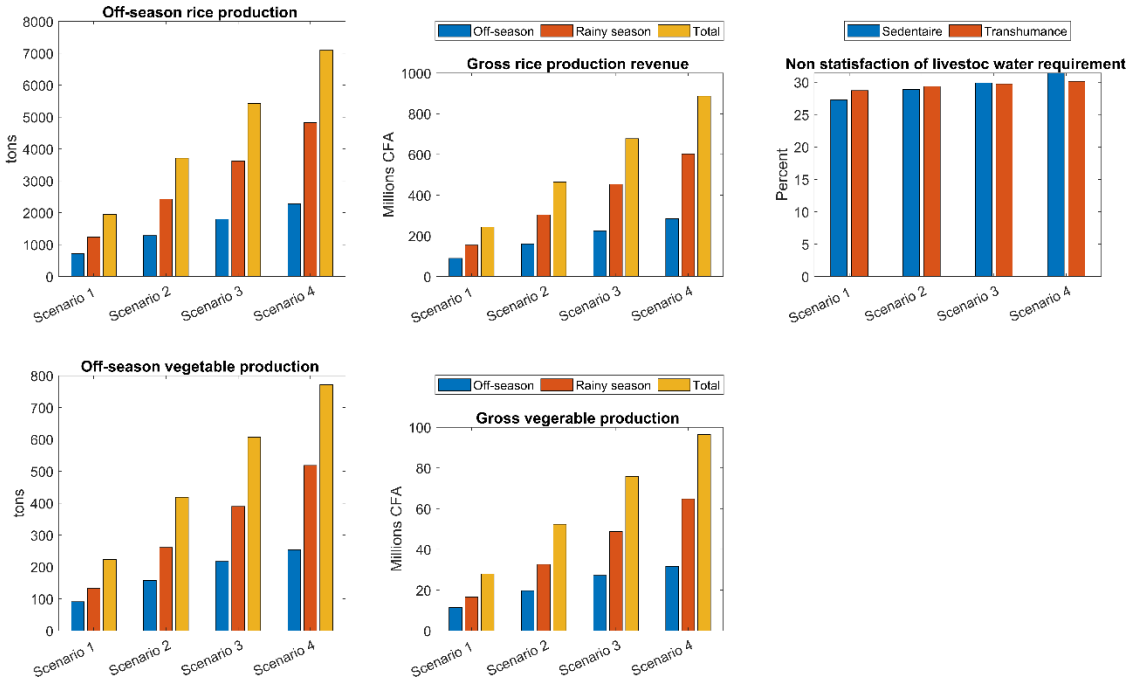

Figure 41. Variation in nexus indicators by scenario: Priority is rice cultivation

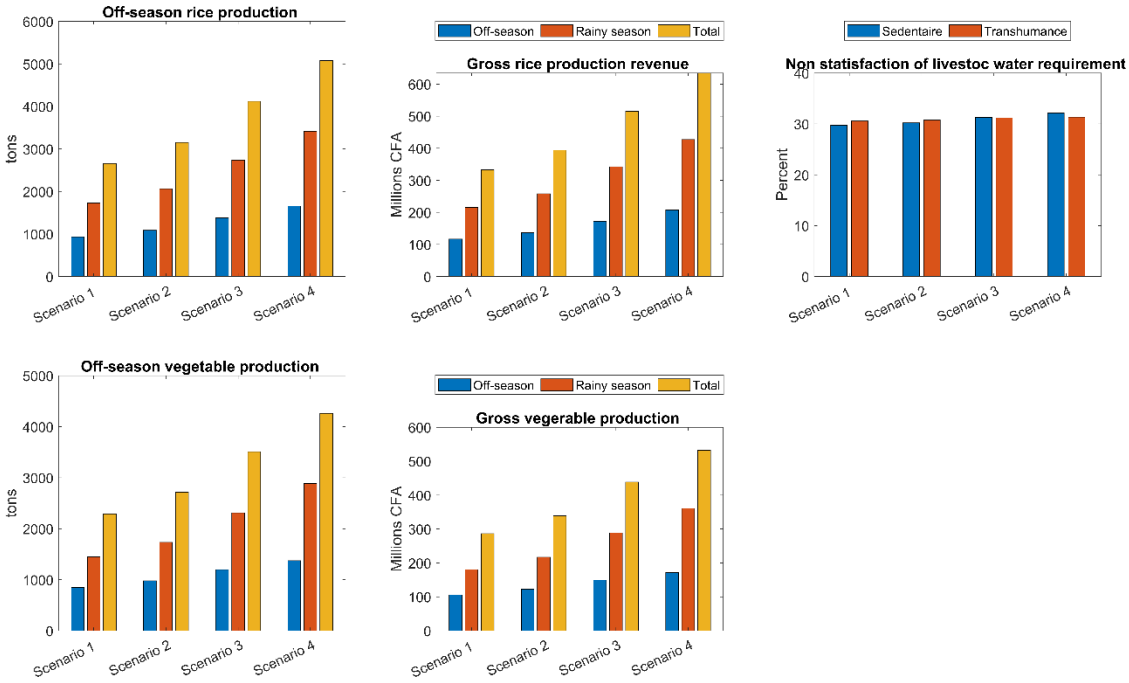

Figure 42. Variation in nexus indicators by scenario: Priority is vegetable cultivation

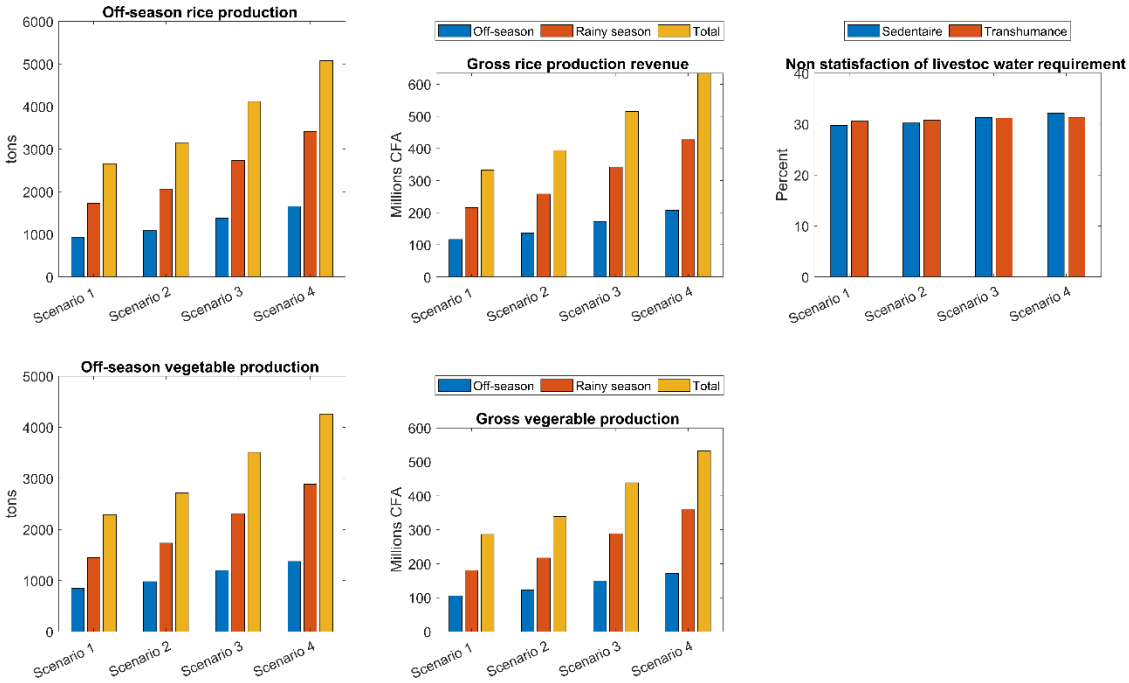

Figure 43. Variation in nexus indicators by scenario: Priority is pastoralism

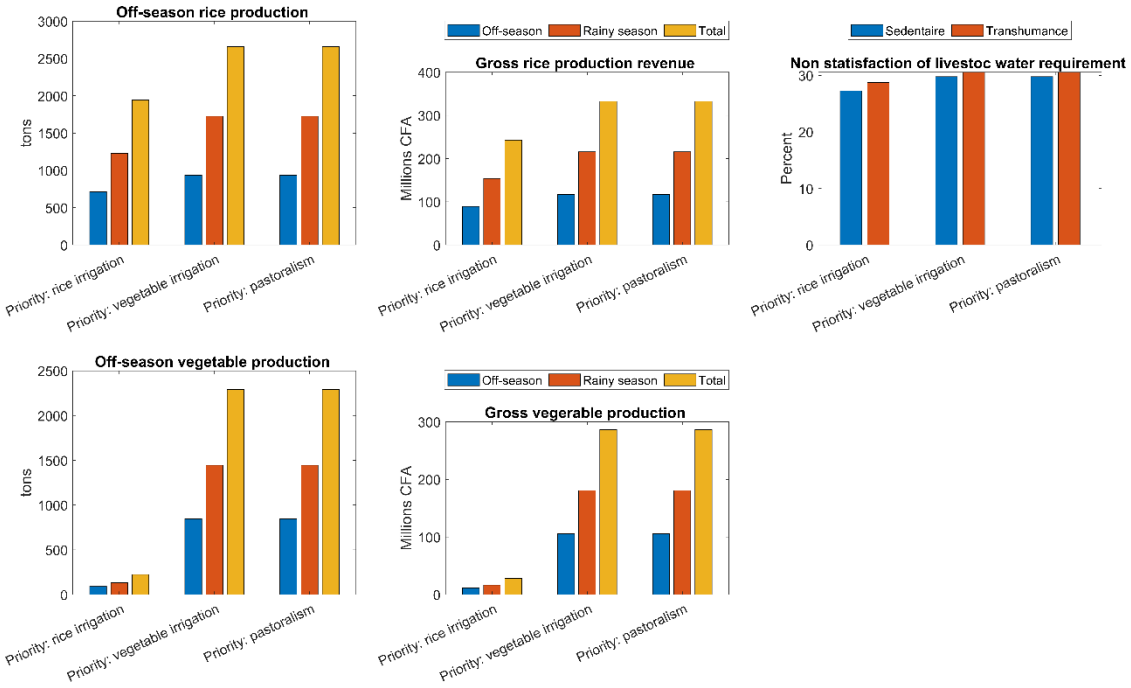

Figure 44. Impact of usage priority on nexus indicators: Scenario 1

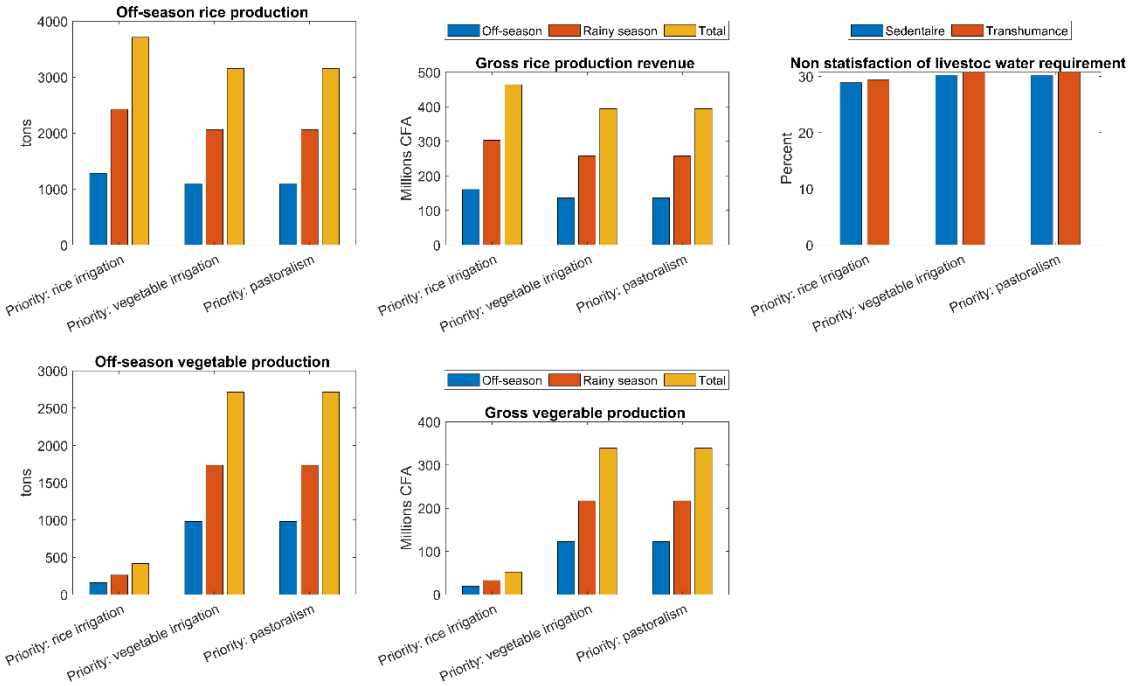

Figure 45. Impact of usage priority on nexus indicators: Scenario 2

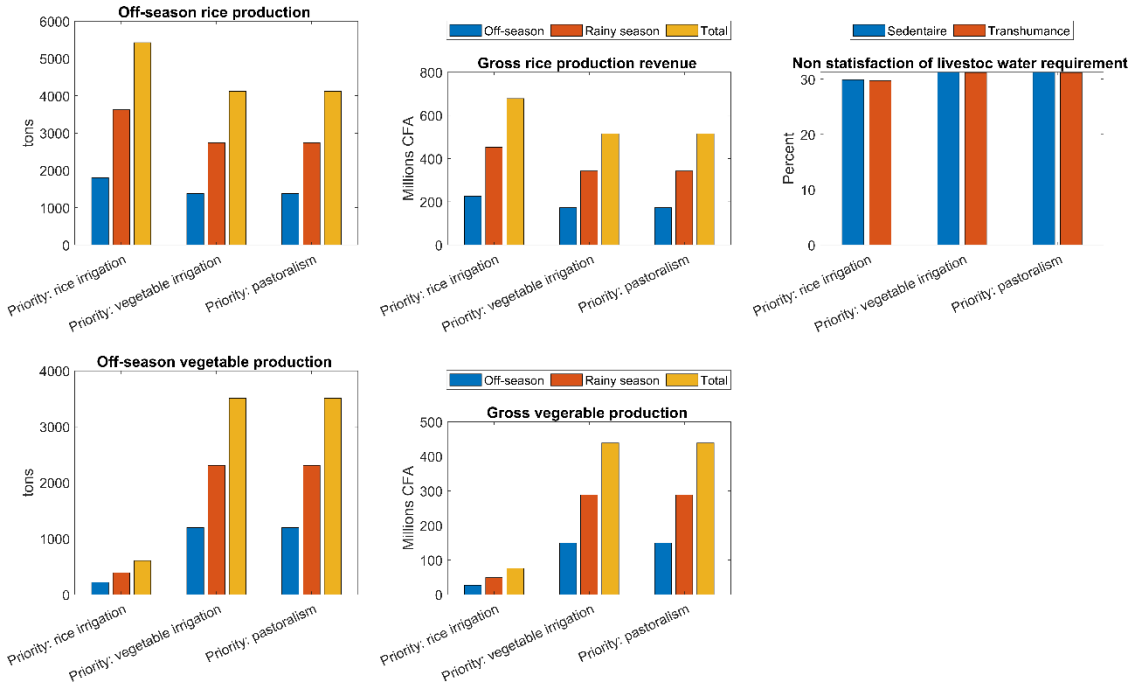

Figure 46. Impact of usage priority on nexus indicators: Scenario 3

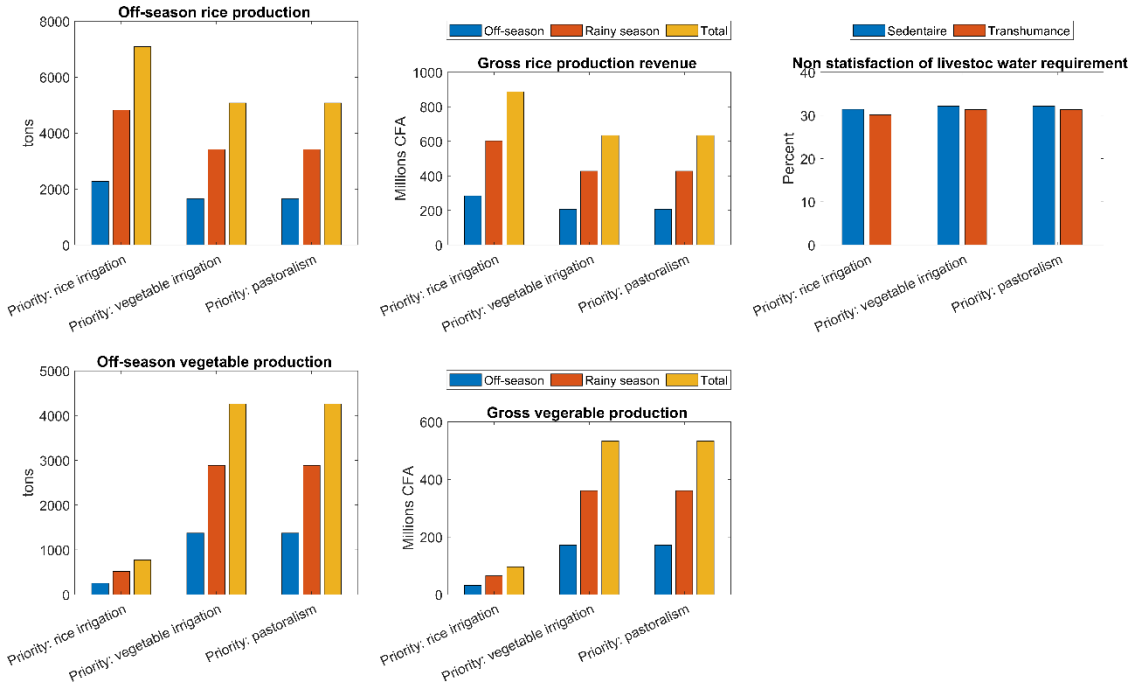

Figure 47. Impact of usage priority on nexus indicators: Scenario 4

Guinea: FOMI Dam Development Project

Description of the project

The Fomi Dam site is in Upper Guinea (Figure 48), 30 km upstream from its confluence with the Niger River. Given its size and location close to the headwaters of the Niger river, the Fomi Dam is a key project of the NBA, and is part of a vast program aimed at developing shared infrastructure among NBA member countries. The Fomi Dam would constitute the head reservoir of a linear complex of natural environments, developed environments, and other dams downstream.

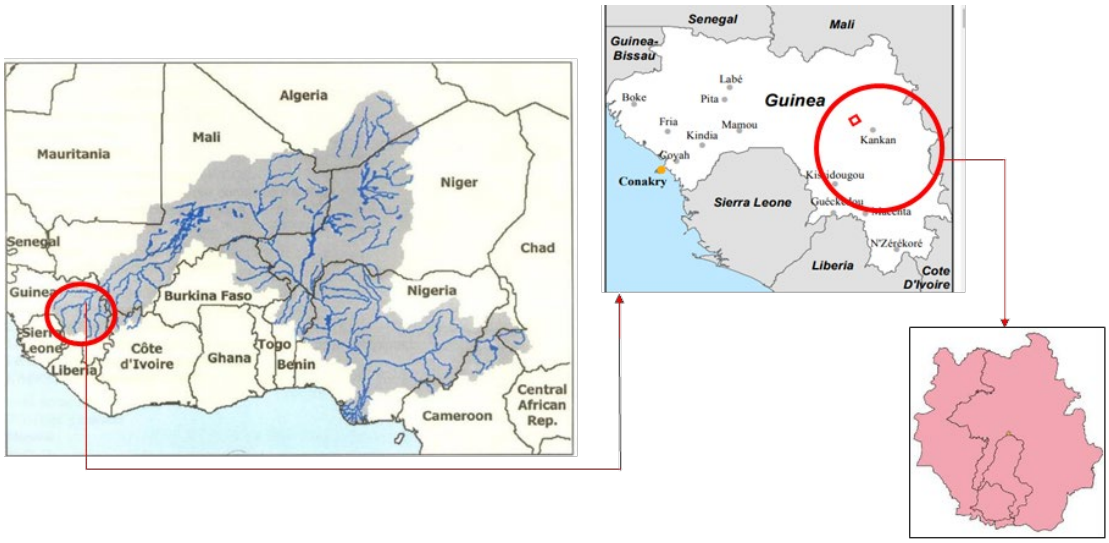

Figure 48. Geographical location of the FOMI Dam project

The objectives of the FOMI Dam project are to: (1) satisfy the environmental flow requirements and thus ensure regularization of the regime of the Niger River watercourse; (2) create a water reservoir of about 3 billion cubic meters of capacity; (3) produce 90 MW of electricity annually; and (4) develop land for agricultural production.

Guinea and Mali, the two countries directly impacted by the Fomi Dam, signed a protocol establishing an Interministerial Consultation Committee for the monitoring and implementation of this important project.

Nexus analysis of the project

Model development

A WEAP model of the study area (Figure 49) analyzed the relationships between water, food, energy, and the environment and the impacts of prioritizing production in one sector over the others. The model contains the Dam, its power plant, and water withdrawal for irrigation and livestock, as well as minimum flow requirements at the Guinea-Mali border.

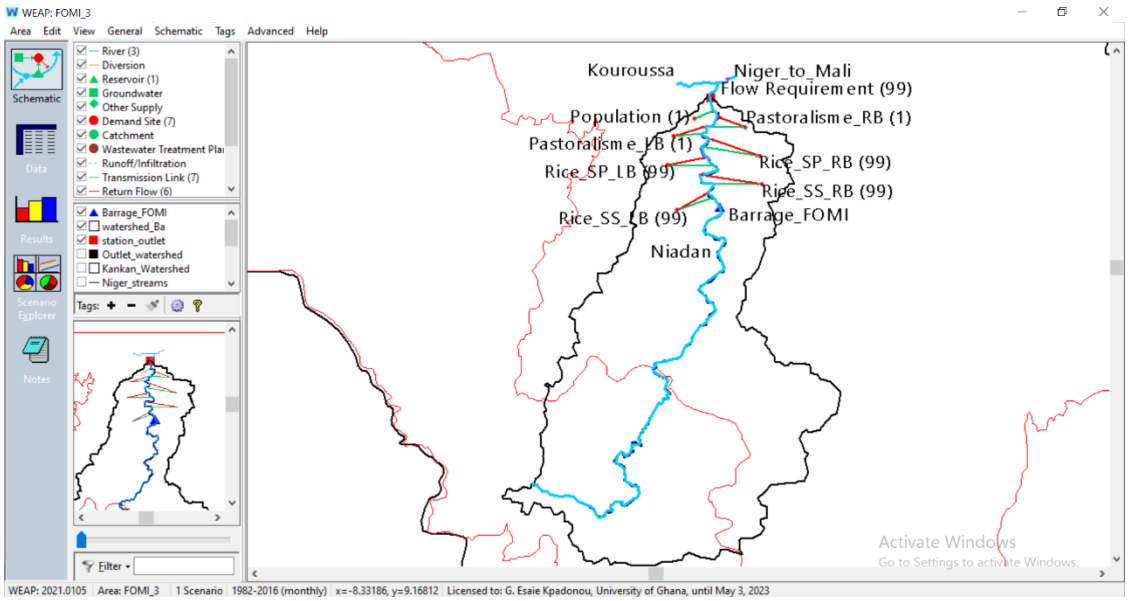

Figure 49. WEAP model of the FOMI Dam project

Nexus indicators

Four indicators were selected to represent the four nexus sectors:

- **Energy security (two indicators):** Hydroelectricity production (GWh) and associated revenues.
- **Food security (two indicators):** Annual rice and vegetable production (tons) and associated income (CFA).
- **Water security (two indicators)**: Percentage (%) of satisfaction of livestock and agricultural water requirements.
- **Environmental sustainability (one indicator):** Percentage (%) of times the environmental flow is not met.

Development scenarios

Twelve scenarios were analyzed based on four different areas of cultivated land downstream of the Dam and three usages to be prioritized in its operation, as follows:

- Irrigated area:
  - Scenario 1 (current objective of the FOMI Dam Project): 4122 ha of cultivated land (in two planting seasons: 8244 ha)
  - Scenario 2: 15828 ha of cultivated land (in two cycles)
  - Scenario 3: 23743 ha of cultivated land (in two cycles)
  - Scenario 4: 31657 ha of cultivated land (in two cycles)

- Water management strategy:
  - Strategy 1: Respect of the environmental flow: Satisfaction of the environmental flow toward Mali is prioritized
  - Strategy 2: Hydro-electric production: Production of energy is prioritized

– Strategy 3: Agricultural production: Meeting the water needs of crops is prioritized

Main findings

The following conclusions can be drawn from Figure 49 to Figure 51:

- Increasing irrigated land steadily increases crop production and gross agricultural income regardless of the water management priority.
- The increase in arable land does not affect hydroelectric production, probably because the proposed irrigation areas are modest compared to the available water resources.
- Livestock flow requirements are only satisfied 35 percent of the time when hydropower is prioritized, and 80 percent of the time when environmental flow is prioritized. Change in irrigated area has little impact on these numbers.
- When hydropower is prioritized, the percentage of nonsatisfaction of environmental flow requirement goes from zero to 20 percent under all scenarios

Figure 52, Figure 53, Figure 54, and Figure 55 reveal that prioritizing electricity production versus environmental flow has a marginal effect on energy production, but a significant impact on the satisfaction of environmental flow requirements. Therefore, environmental flow requirements should be prioritized. Note that the model does not consider the positive and negative impacts in Mali, an important limitation.

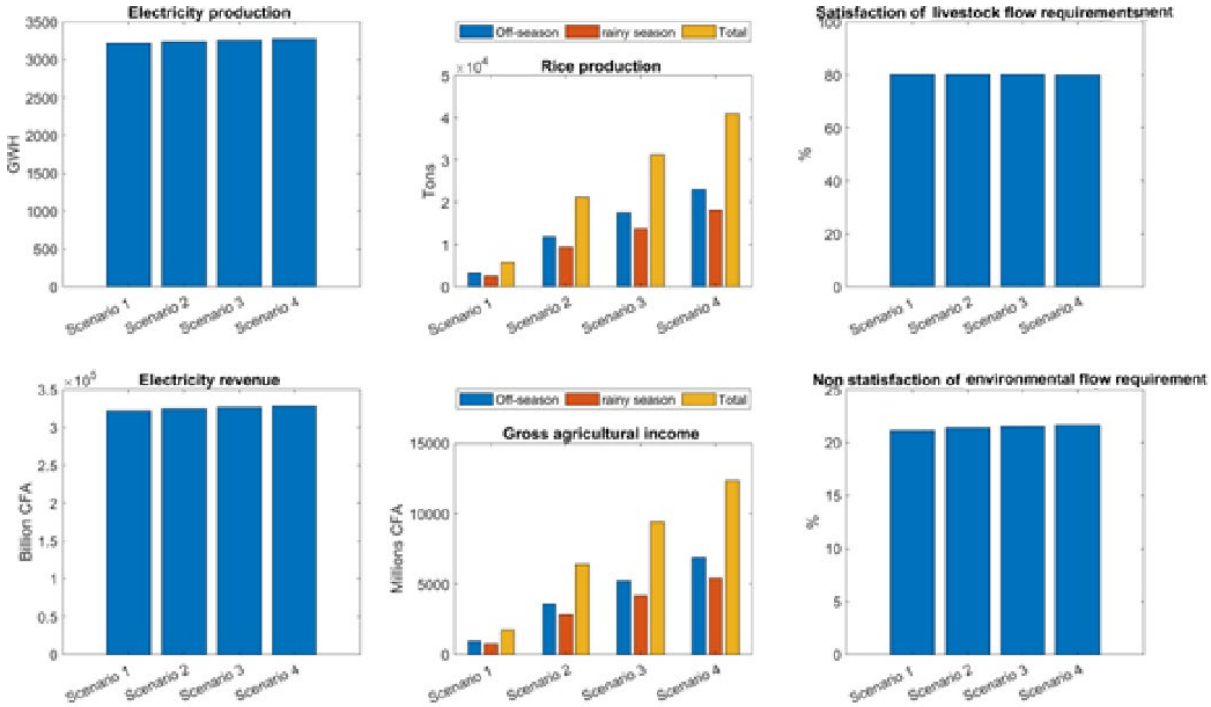

Figure 50. Variation in nexus indicators by irrigated area: Priority is hydropower

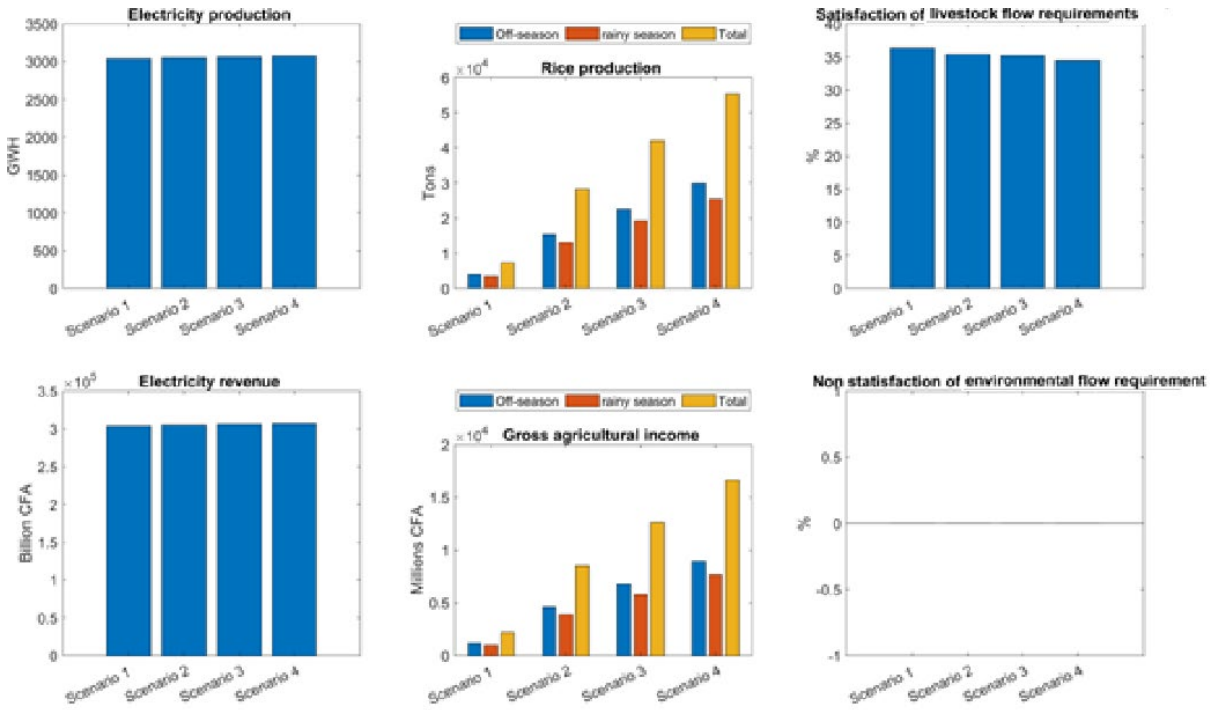

Figure 51. Variation in nexus indicators by irrigated area: Priority is environmental flow

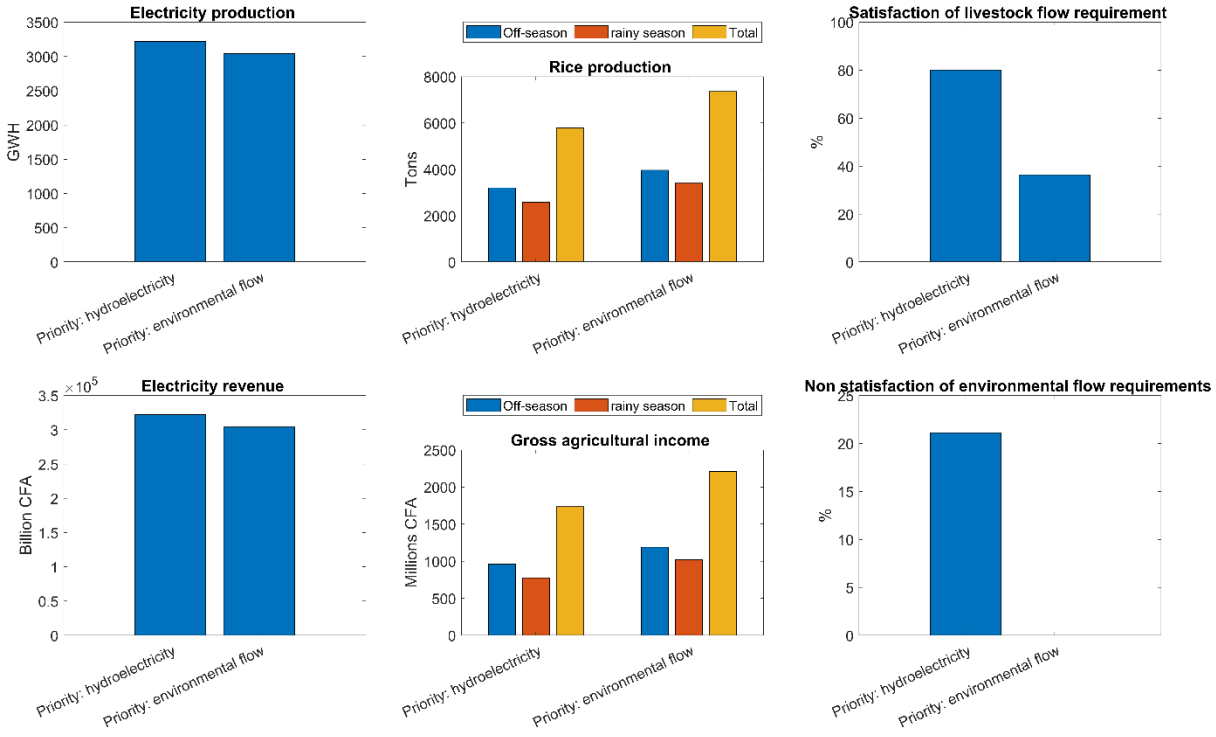

Figure 52. Impact of usage priority on nexus indicators: Scenario 1

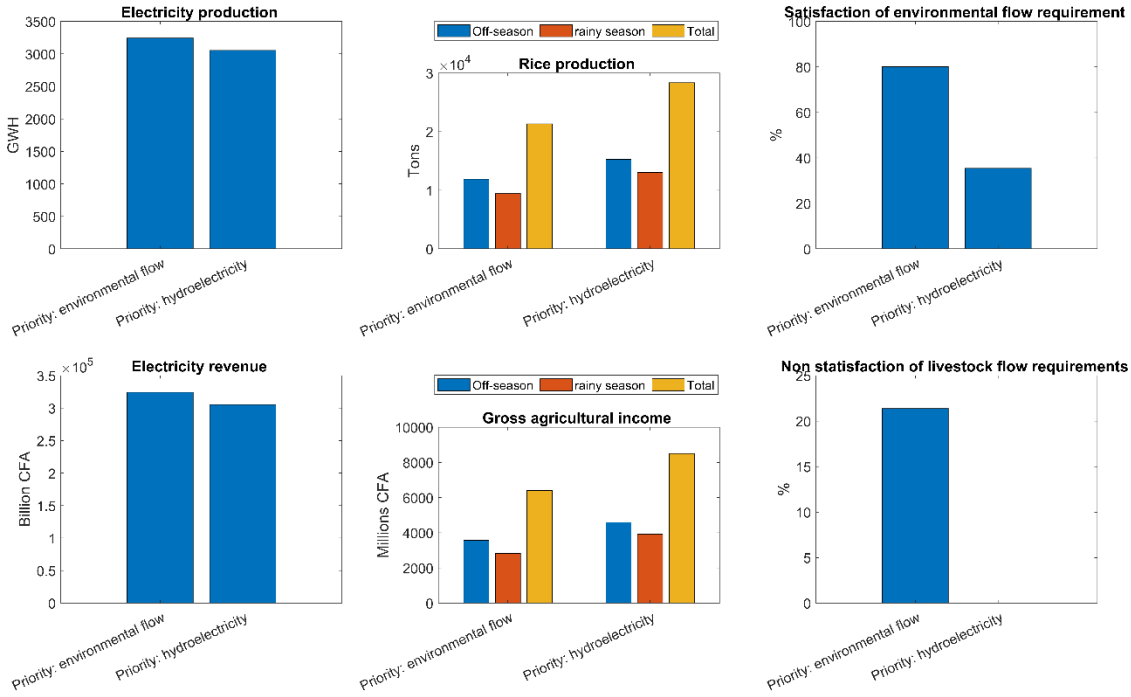

Figure 53. Impact of usage priority on nexus indicators: Scenario 2

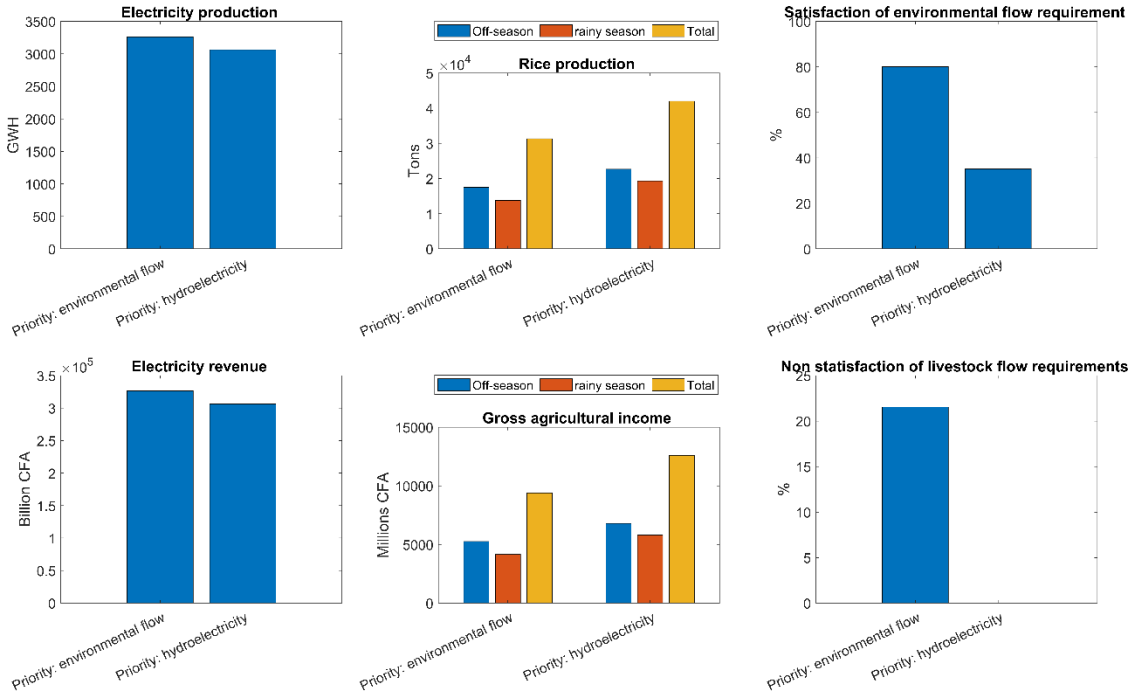

Figure 54. Impact of usage priority on nexus indicators: Scenario 3

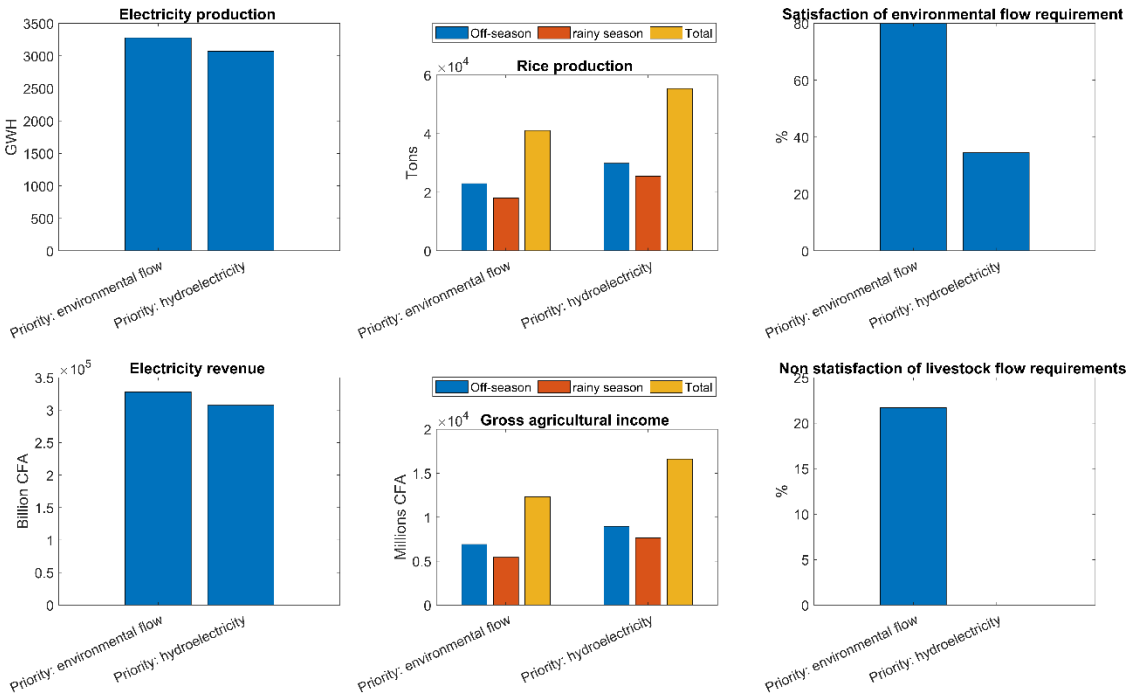

Figure 55. Impact of usage priority on nexus indicators: Scenario 4

Mali: Bagoé II Hydroelectric Power Plant Project

Description of the project

The Bagoé II hydroelectric plant is planned to be built on the Bagoé River, about 100 km from the city of Sikasso in Mali (Figure 56). With a reservoir capacity of 1340 million m^3, the new dam will control a large catchment area, estimated at 34637 km^2. In addition to electricity production, the dam is expected to support low water levels and contribute to regulating the regime of the Niger River watercourse. Mali selected the project to be quantitatively analyzed during the Mali nexus dialogue.

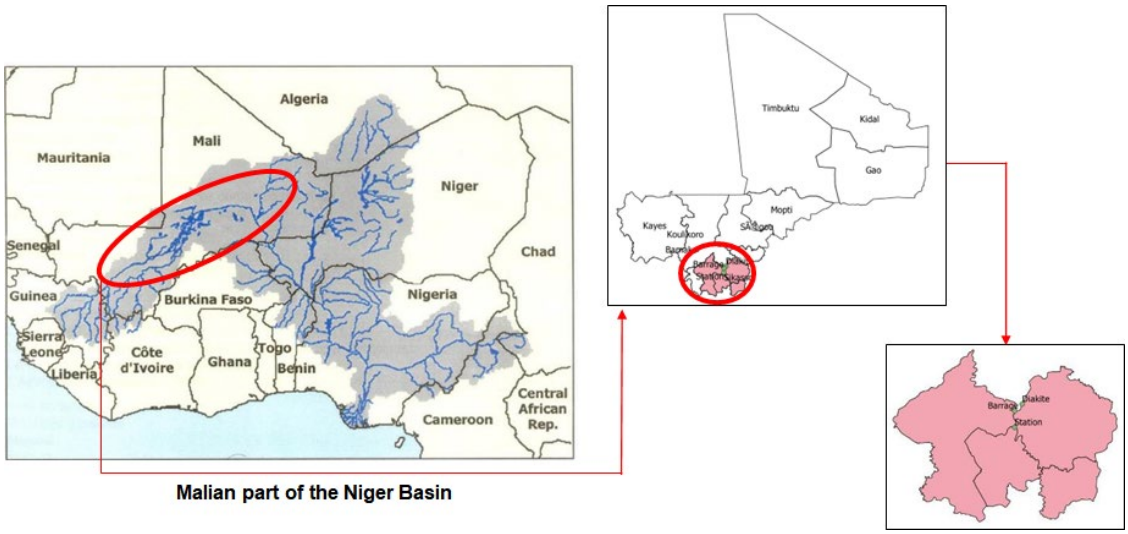

Figure 56. Geographical location of the Bagoé Dam project

Nexus analysis of the project

Model development

A WEAP model of the study area (Figure 57) analyzed the relationships between water, food, energy, and the environment and the impacts of a decision to prioritize production of one sector over the others. The model contains the Dam, water withdrawal for irrigation and livestock, as well as minimum flow requirements at the Guinea-Mali border.

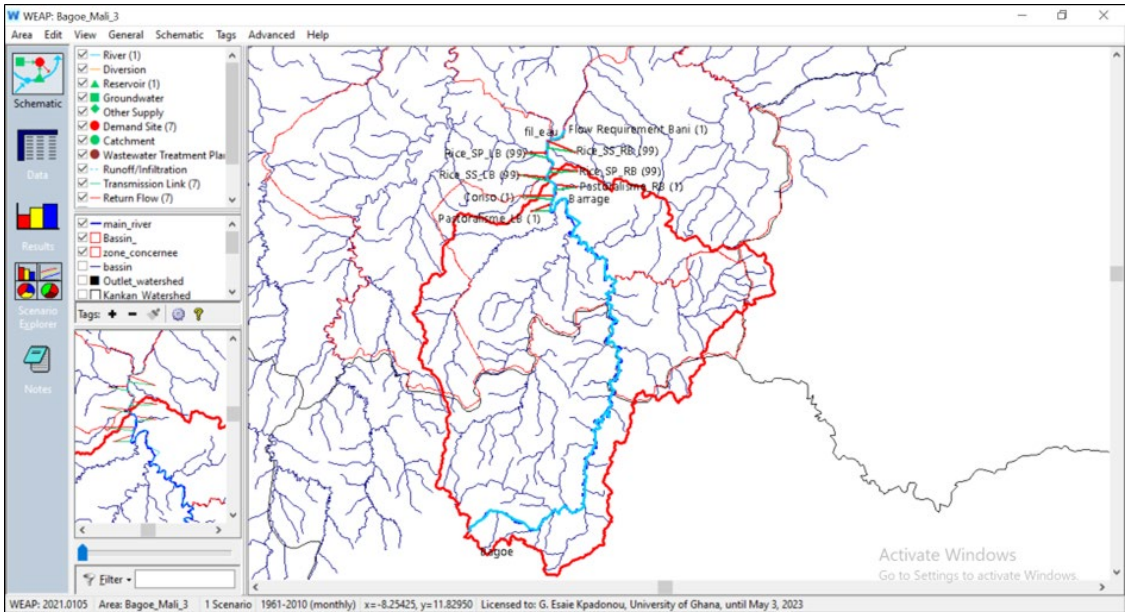

Figure 57. WEAP model of the Bagoé Dam project

Nexus indicators

Four indicators were selected to represent the four nexus sectors:

- **Energy security (two indicators):** Hydroelectricity production (GWh) and associated revenues.
- **Food security (two indicators):** Annual rice and vegetable production (tons) and associated income (CFA).
- **Water security (two indicators)**: Percentage (%) of satisfaction of livestock and agricultural water requirements.
- **Environmental sustainability (one indicator):** Percentage (%) of times the environmental flow is not met.

Development scenarios

Twelve scenarios were analyzed based on four sizes of cultivated land downstream of the Dam and three uses to be prioritized in its operation:

- Irrigated area:
  - Scenario 1 (baseline): 8200 ha of cultivated land (in two seasons)
  - Scenario 2: 16400 ha of cultivated land (in two cycles)
  - Scenario 3: 24600 ha of cultivated land (in two cycles)
  - Scenario 4: 32800 ha of cultivated land (in two cycles)
- Water management strategy:
  - Strategy 1: Respect of the environmental flow: Satisfaction of the environmental flow toward Mali is prioritized

- Strategy 2: Hydro-electric production: Production of energy is prioritized
- Strategy 3: Agricultural production: Meeting the water needs of crops is prioritized

Main findings

- Agricultural production and income increase with an increase in cultivated areas, independently of water management strategy (Figure 58 to Figure 64). It is however higher when priority is given to irrigation (Figure 59) compared to when priority is given to other uses.
- Giving priority to environmental flows and giving priority to hydropower production yield the same results (Figure 58 and Figure 59). In both cases, environmental flow if 100% fulfilled and annual hydropower production is around 1750 GWH independently of irrigated areas.
- Hydropower production is drastically reduced when priority is given to irrigation, and environmental flow requirements is no longer 100% satisfied when irrigated areas is above 600 ha (Figure 59 and Figure 60)
- Irrigation production and outcome is almost zero unless priority is given to irrigation, showing a strong antagonism between hydropower production and environmental flow requirement on one side, and agricultural production on the other side. The tradeoff is visible for all scenarios (Figure 60 to Figure 64)

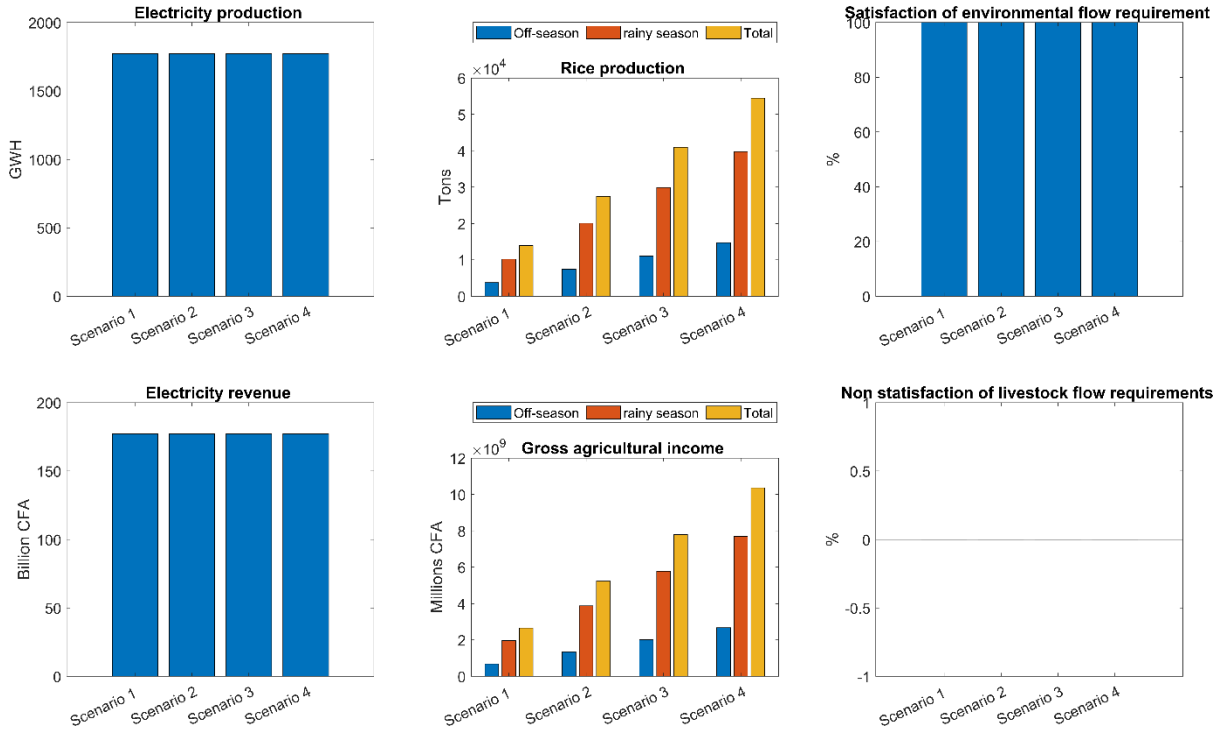

Figure 58. Variation of nexus indicators as function of irrigated areas when priority is given to environmental flow

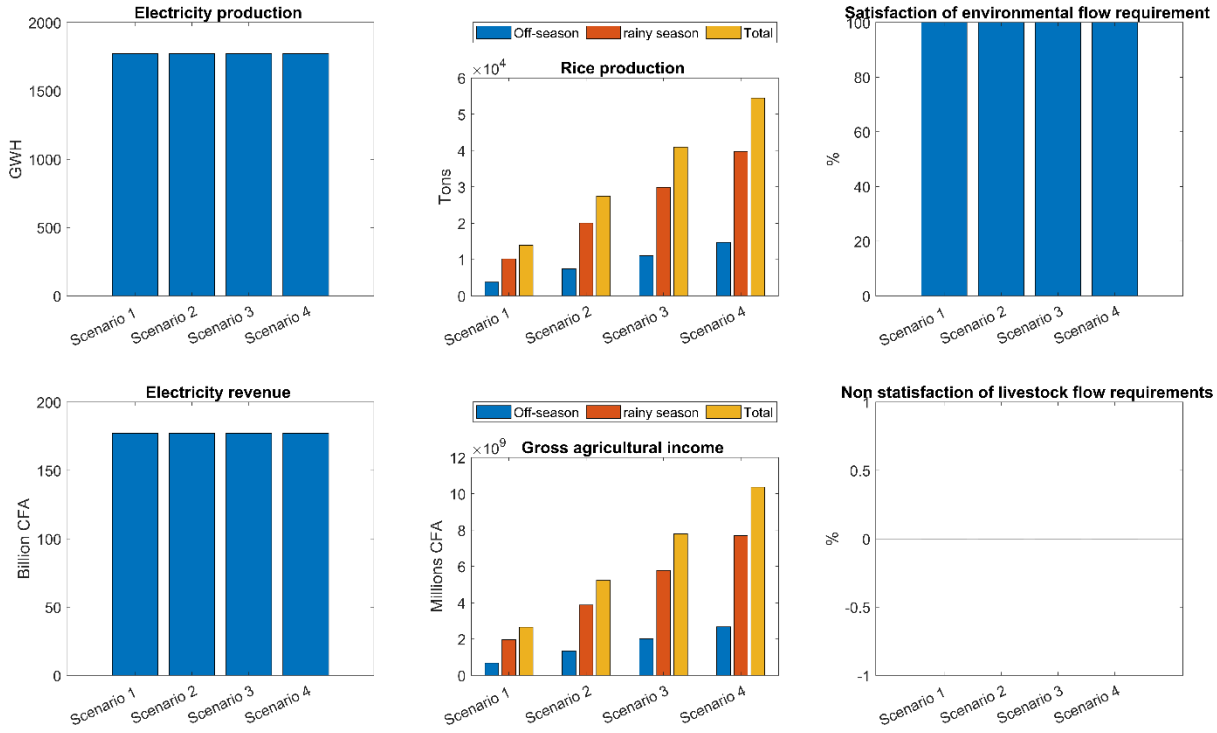

Figure 59. Variation of nexus indicators as function of irrigated areas when priority is given to hydropower production

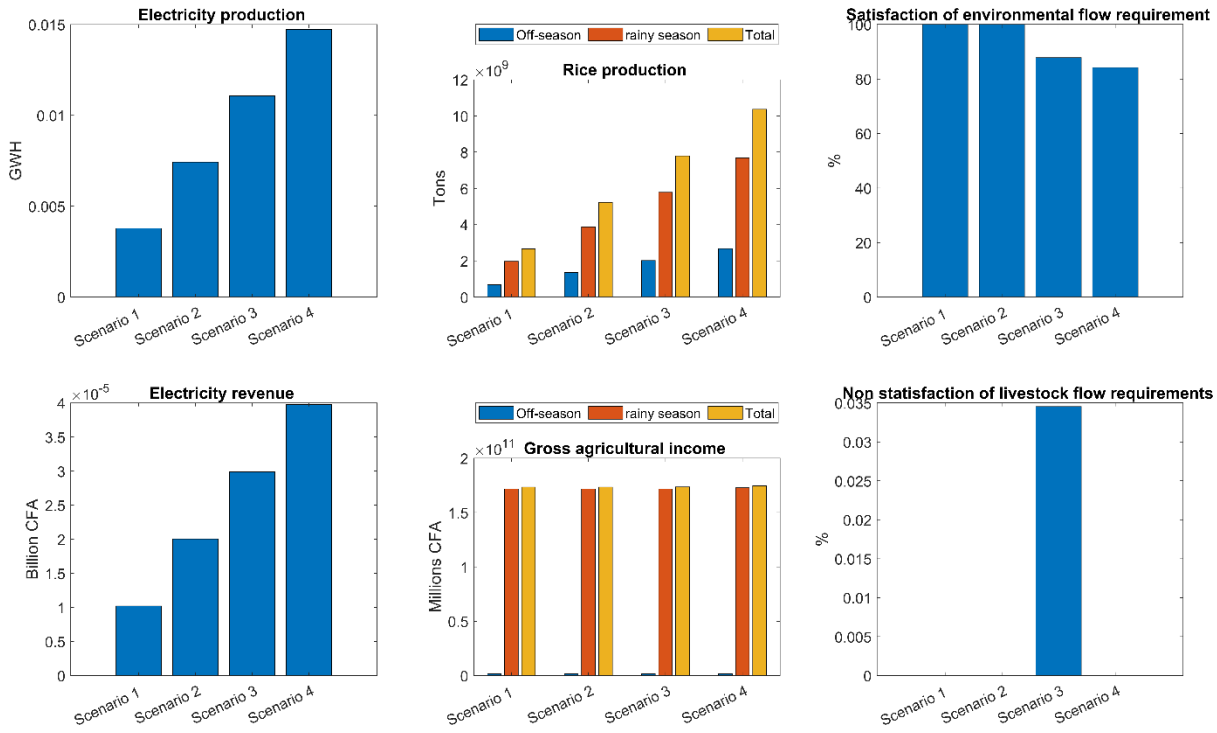

Figure 60. Variation of nexus indicators as function of irrigated areas when priority is given to irrigation.

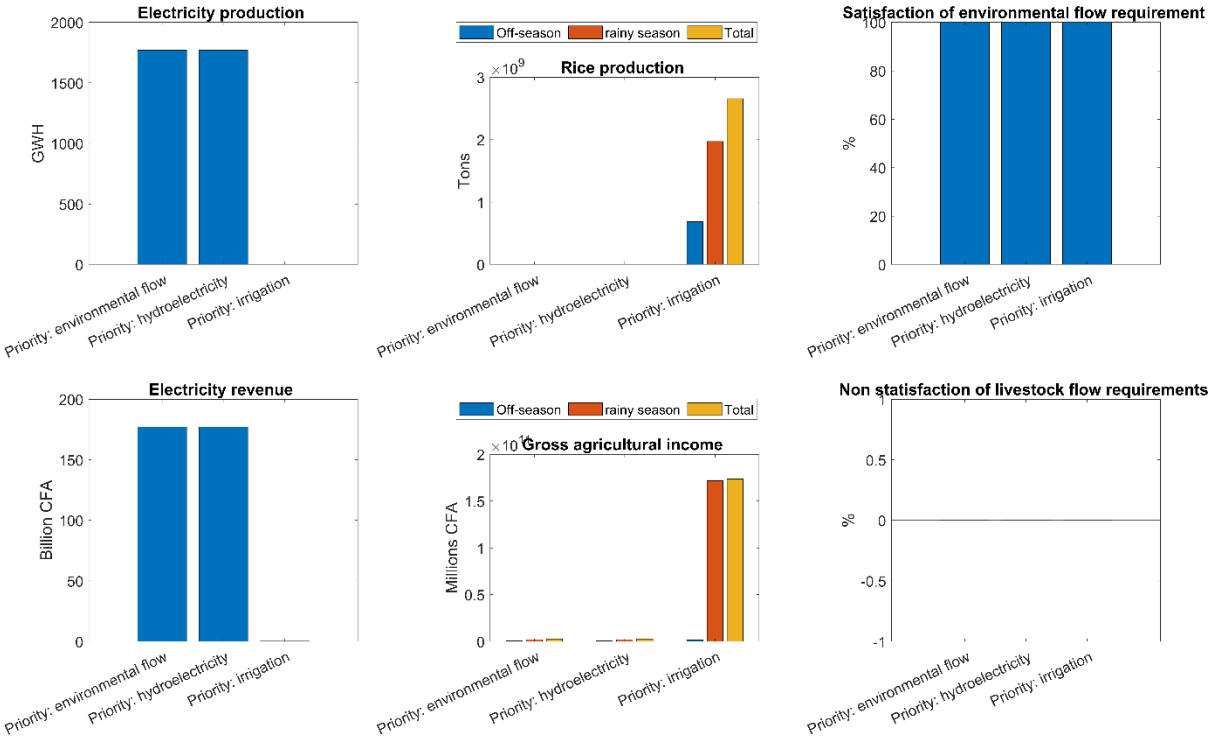

Figure 61. Impact of usage priority on nexus indicators, scenario 1

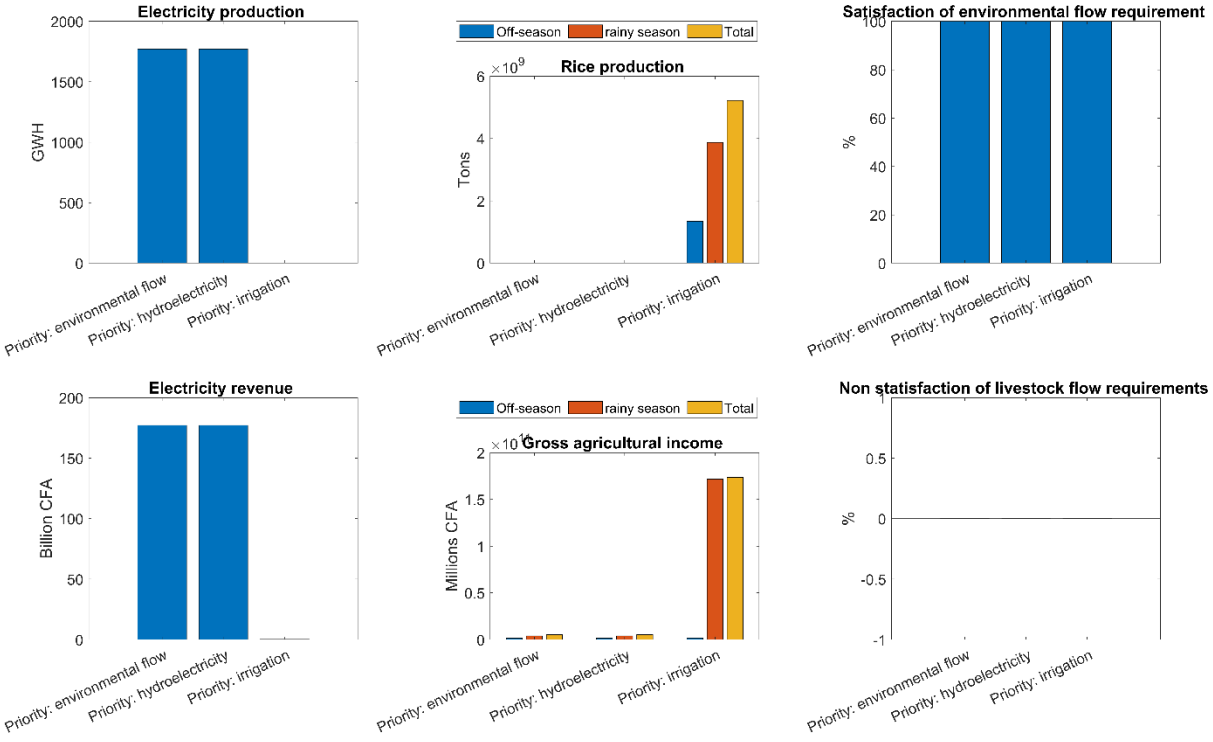

Figure 62. Impact of usage priority on nexus indicators, scenario 2

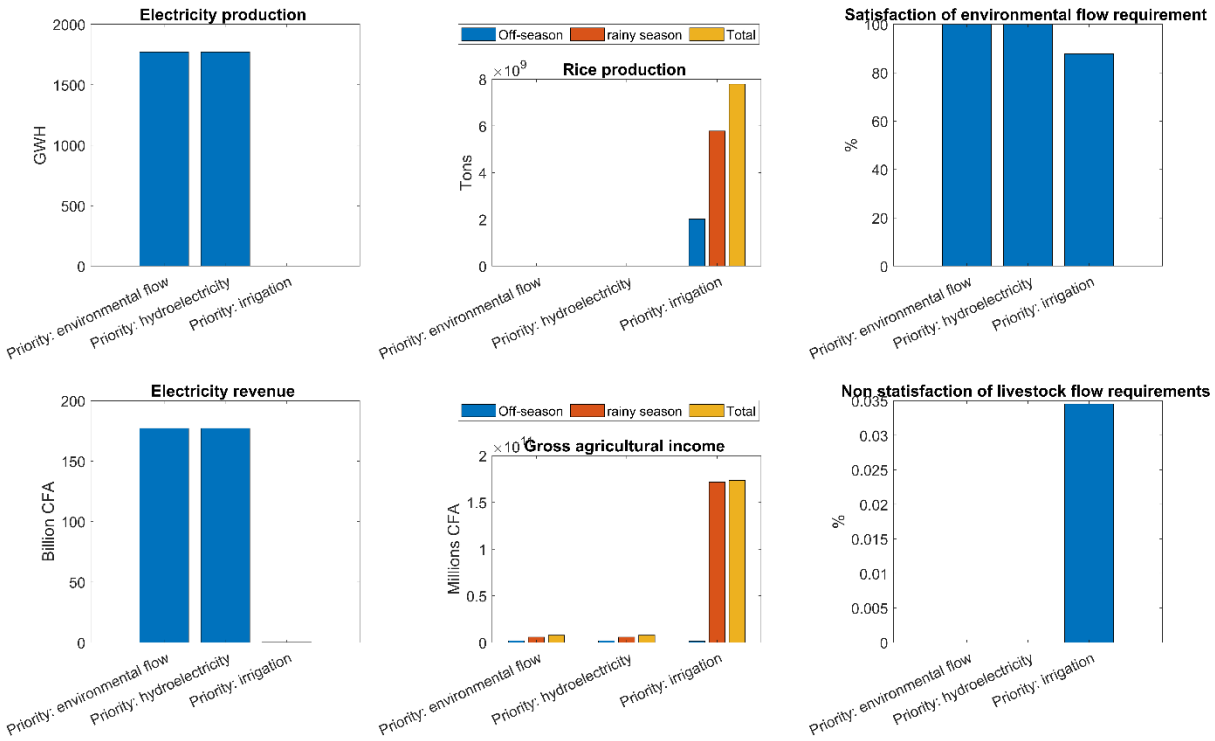

Figure 63. Impact of usage priority on nexus indicators, scenario 3

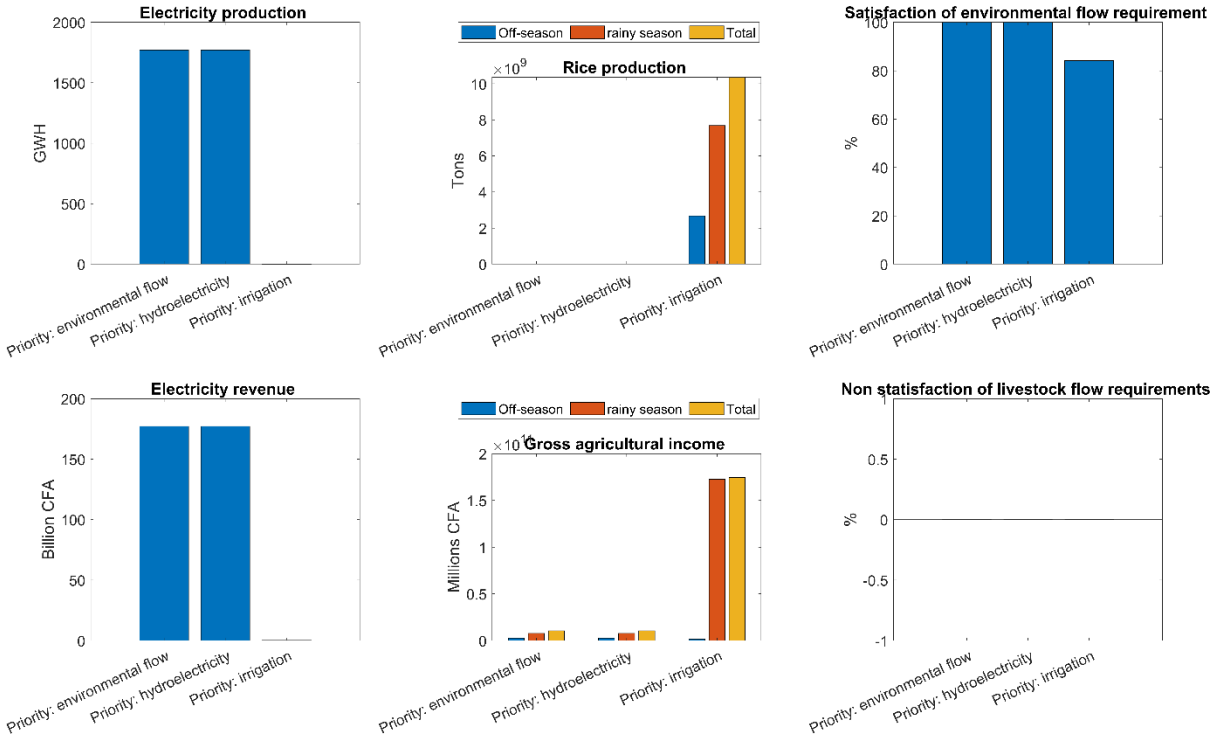

Figure 64. Impact of usage priority on nexus indicators, scenario 4

Nigeria: Dadin-Kowa Multi-Purpose Dam Project

Description of the project

Nigeria chose to focus on the Dadin-Kowa Multi-Purpose Dam (Figure 65), built in 1987. The Dam was designed to have a water storage capacity of 2.8 billion cubic meters, but the reservoir is only used for fishing and very marginal (less than 200 ha) irrigation. The Dam has the potential to produce 40 MW of electricity, irrigating 44000 hectares of agricultural land for food production and supplying drinking water to the town of Gombe and its surroundings.

Nexus analysis of the project

Model development

Given the short lead time and the lack of data it was not possible to develop a WEAP model of the study area. A quantitative analysis of nexus links in the project area was carried out with a simple simulation model developed in an Excel spreadsheet. The objective was to show the added value of the nexus approach based on a quantitative evaluation of the impacts of investment choices on water, energy, food security, and environmental sustainability.

Nexus indicators

The only indicator considered was the satisfaction of domestic and agriculture water requirements.

Development scenarios

Possible reductions of the current storage capacity by 10 percent and 25 percent were considered, along with six levels of irrigation expansion (1253 ha; 3000 ha; 11000 ha; 22000 ha; 33000 ha; 44000 ha). Climate change was also considered. In the 44000 ha scenario, water security could not be achieved, even during a typical year with a full reservoir.

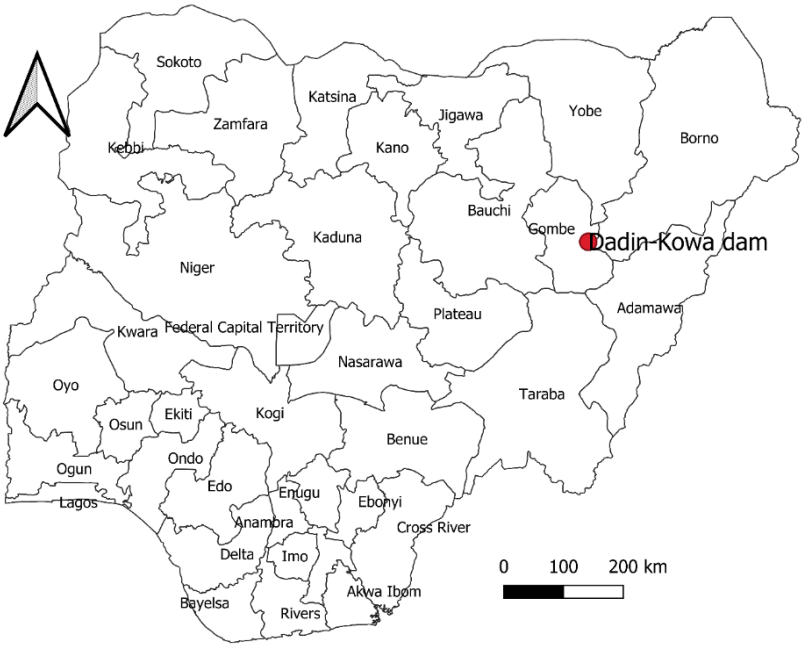

Figure 65. Geographical location of the Dadin-Kowa Dam

Main findings

Results show that when the dam water storage is reduced by 10%, municipal and agricultural water security were compromised if irrigated area is above 22000 (ha), meaning that the two last scenarios are not recommended. With a 25 percent decrease in reservoir storage capacity, WEFE securities cannot be achieved if irrigated area is equal to or above with 22000 ha, meaning that the two last scenarios are not feasible..

Appendix 4: Development of a Nexus Tool to Automate the Simplified Assessment

The developed nexus guidelines recommend that each investment project submitted by a member country undergoes either a simplified or a detailed nexus assessment before being put forward for approval by head states, and (co-)funding by development partners. However, several Basin countries, while recognizing the benefits of the approach, noted that nexuses analyses might become a bottleneck in the process of project development, slowing down projects that are urgent and beneficial for their populations. The concerns have some merit as during the national dialogues, most member countries struggled to provide basic data (e.g., streamflow, precipitation) to analyse the priority/exemplary project they had put forward.

Thus, for the nexus guidelines to be followed, a solution needed to be found to directly support countries with, at a minimum, the simplified nexus assessment of proposed projects in the face of challenges with data quality and access, as well as the lack of capacity on modelling both at the NBA and in member countries. The study team decided to initiate the development of a Nexus tool to automate the nexus assessment process and reduce the level of effort and data required to develop an actionable nexus assessment of planned interventions in the basin. The tool was developed as software that will be available either through the Web or as a standalone Windows application. It is prepopulated with global environmental data and automatically generates the best possible estimates of variables that were not available through primary data collection. These data complement user-provided data and assist the user in the generation of a simplified nexus analysis. A first version of the tool was developed and presented to the NBA during an online and an in-person training session in the Spring of 2023. A second version is under development to account for the comments and suggestions of NBA staff. A version of the tool is presented below.

Expected functionalities

The app will allow a user with minimum technical skills to:

- Download the official database of infrastructures available in the Niger Basin in his country and other countries and explore them via a GIS interface
- Query basic information about any of the existing infrastructure
- Create a new project by clicking on the map or entering geographical coordinates
- Enter basic information on the planned project:
    - Storage volume
    - Irrigated area
    - Expected monthly withdrawals
- Based on the location selected by the user, the app will calculate:
    - Monthly surface water availability
    - Monthly groundwater availability (assuming it is equal to recharge)
    - The ratio of availability to withdrawals
    - The list of infrastructure downstream of the location of the planned infrastructure
    - The expected percent change in flow at downstream infrastructure

The user will then be asked to score four nexus objectives (water security, energy security, food security and environmental sustainability) based on her knowledge and the information provided. The resulting scores represent the simplified assessment of the project.

The user can then

- Save the new project on a hard drive or in a database and open it later to continue working on it
- Modify the information on existing infrastructure and submit the modifications to the NBA
- Users with special privileges can add the submitted projects to the official list of infrastructures in the basin

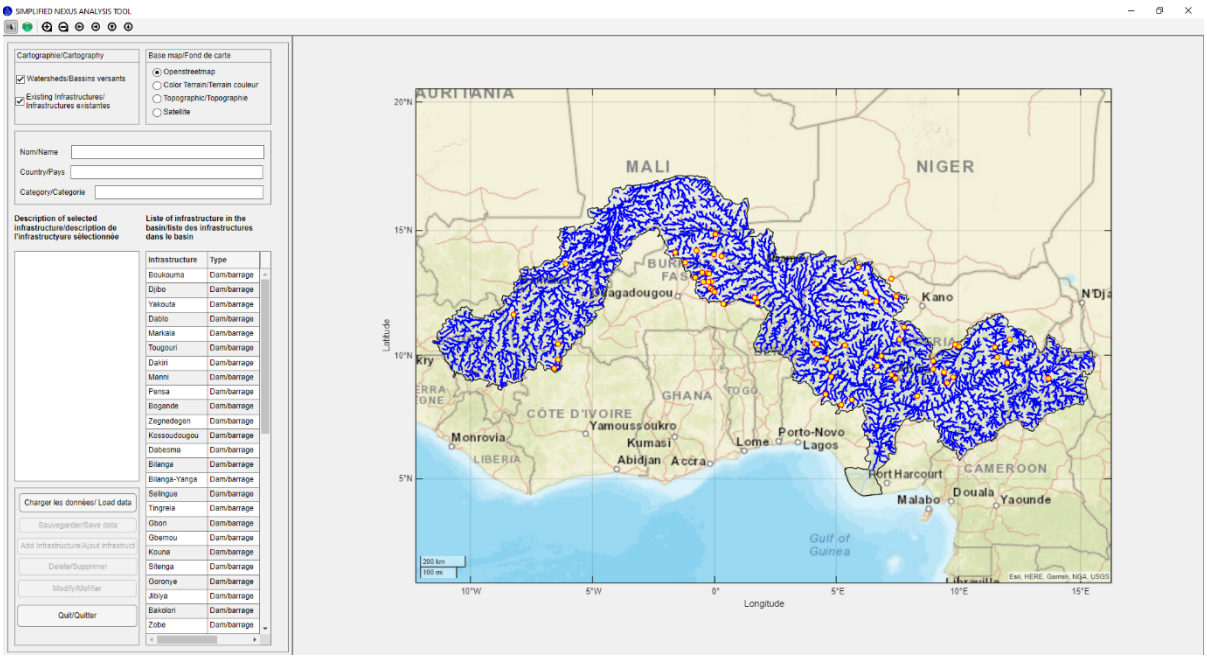

Figure 66: Main window of the Nexus tool

Progress in the development of the tool

The tool is being developed as a desktop application in MATLAB, that can be deployed on next users' computers. The application will be connected to a central database where new infrastructure as well as modifications to the information about existing infrastructure can be suggested. The main window of the application allows the user to explore NBA OP projects as well as monthly streamflow and infiltration (a proxy for the amount of groundwater that can be sustainably pumped) throughout the basin. The NBA OP infrastructure are presented as yellow circles in the app. The user can manipulate the data and maps. When the '***explore infrastructure'*** icon  is selected, the name and type of NBA OP infrastructure is displayed when the user hover the mouse over it.

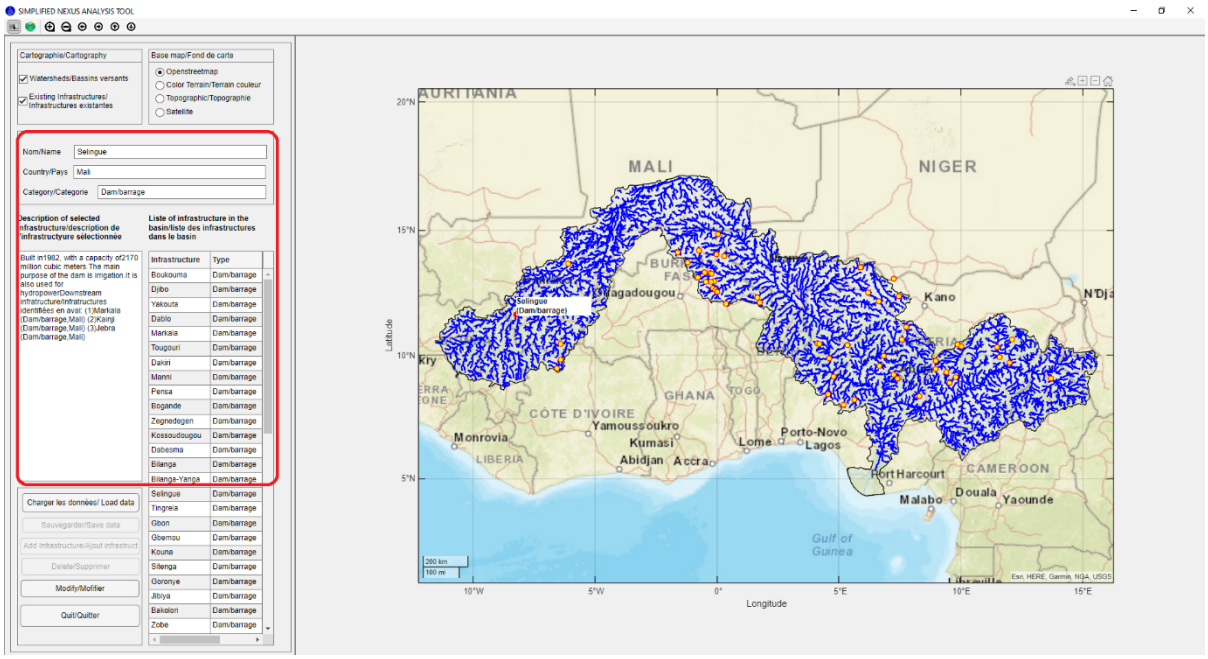

Figure 67: Display of basic information on NBA OP infrastructure

If she clicks on it, the colour of the selected item changes to red (selected) and summary information on the infrastructure is shown on the left panel (example shown in Figure 67). When the '***explore hydrology***' icon is selected, information about upstream watershed area, available surface water and groundwater resources are displayed for any point in the watershed when the user hovers the mouse over it (Figure 68). The information comes from a SWAT model of the Niger Basin previously developed at the University of Ottawa.

In order to analyse a planned infrastructure, the user has to click on the 'New/Nouveau' button and then on the expected location of the infrastructure, or manually enter the coordinates of the new infrastructure or project. The information on surface and groundwater availability will be displayed to guide the selection of the location (Figure 69). Once the user confirms the location, the nexus analysis windows appears (Figure 70). The user can input information about monthly water withdrawals, reservoir storage and average height, as well as up to three irrigated crops. The current version of the tool does not automatically estimate crop water requirements, but the functionality can (and should) be added in a future version.

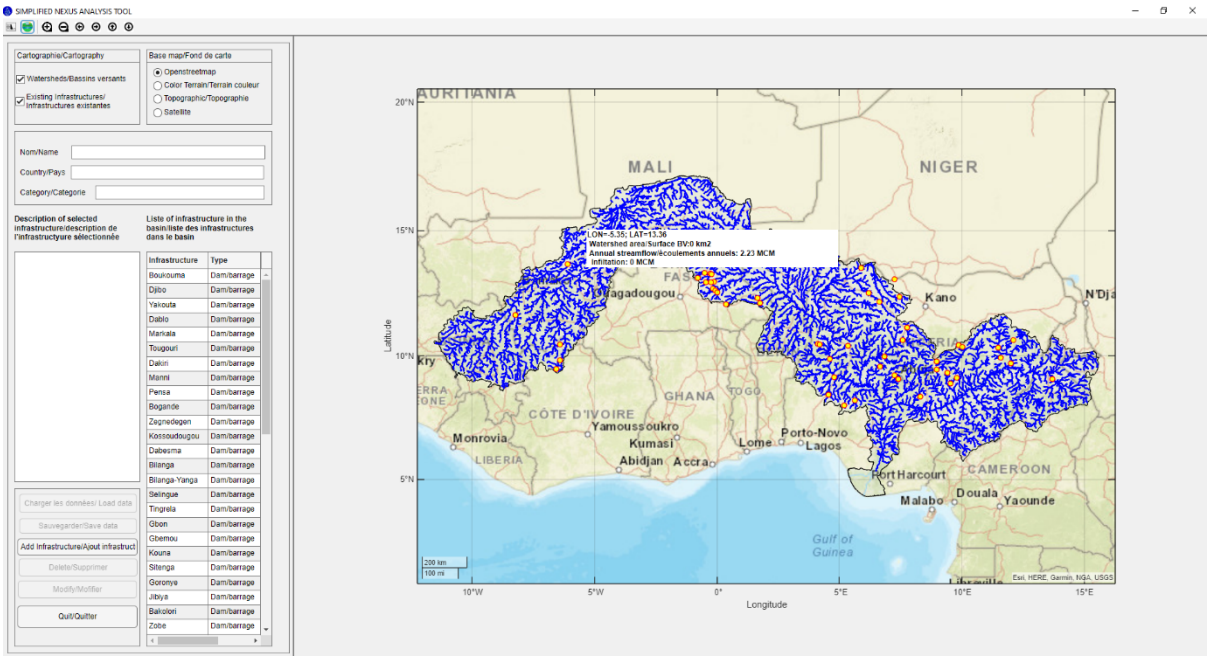

Figure 68: information about upstream watershed area as well as surface and groundwater availability on any point of the watershed

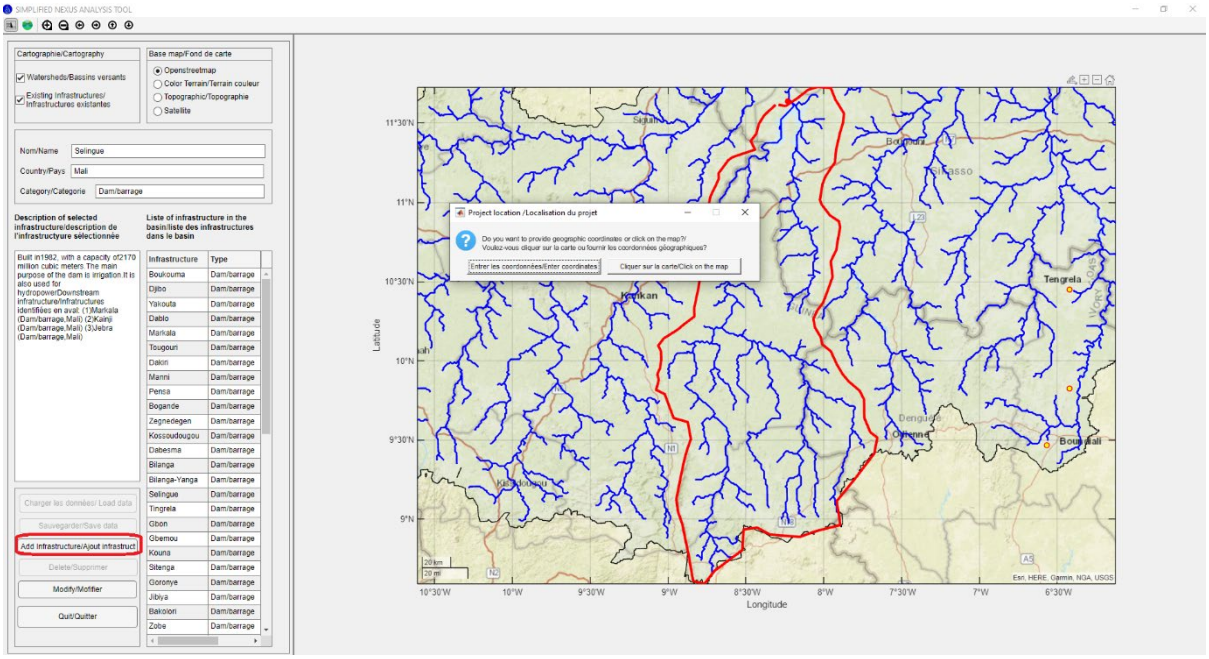

Figure 69: Selection of the location of a future infrastructure

The tool will compare water requirements with available surface and groundwater resources and display the results as a figure on the right. A future version of the tool will estimate expected energy generation and agricultural outputs based on information provided by the user. The last result presented to the user is the list of NBA OP infrastructures downstream, the distance to these infrastructures as well as the ratio of the planned water withdrawals to annual streamflow at these infrastructures.

At the very last step, the user is invited to use the provided information as well as any additional knowledge she or he has to input a score between -3 and 3 for water security, energy security, food security and environmental sustainability.

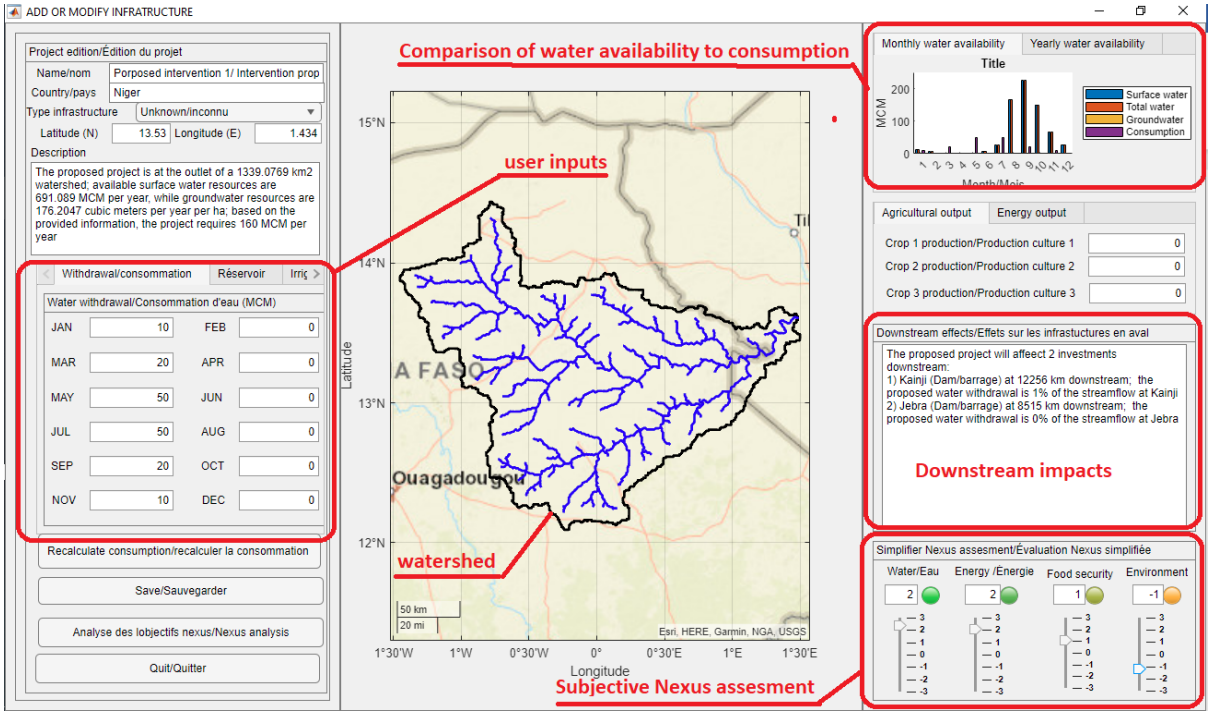

Figure 70: results and assessment window

To do list (as of June 1, 2022)

- Automate the exchange of information between the online database and the tool
- Add a report generation functionality
- Automate the estimate of agricultural production and energy output based on user inputs

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nexus

Implemented by

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