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nexus

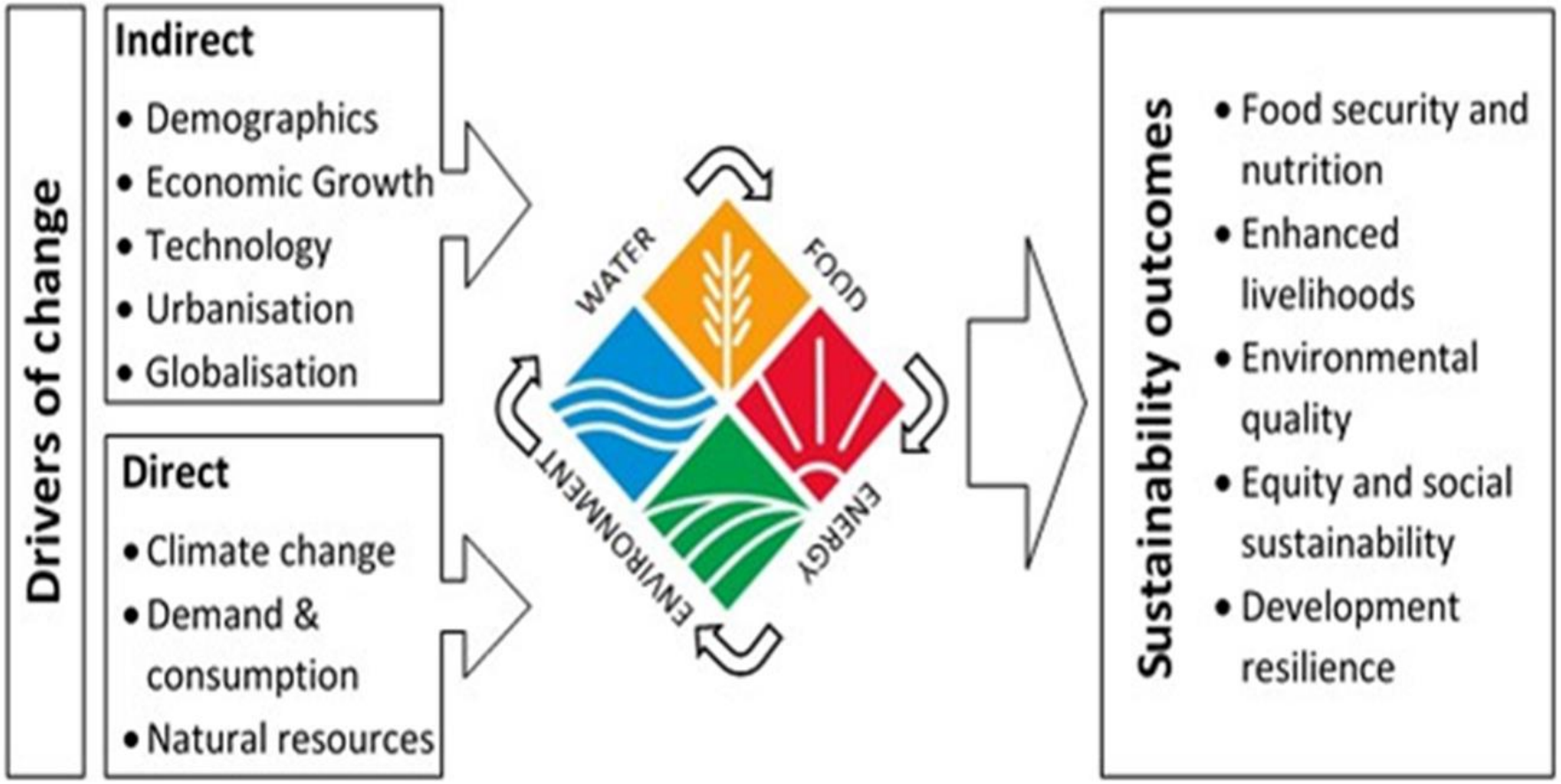
Water-Energy-Food-Environment Nexus with Case Study Niger Basin

16 December 2021 (*based on Seidou et al. 2021*)

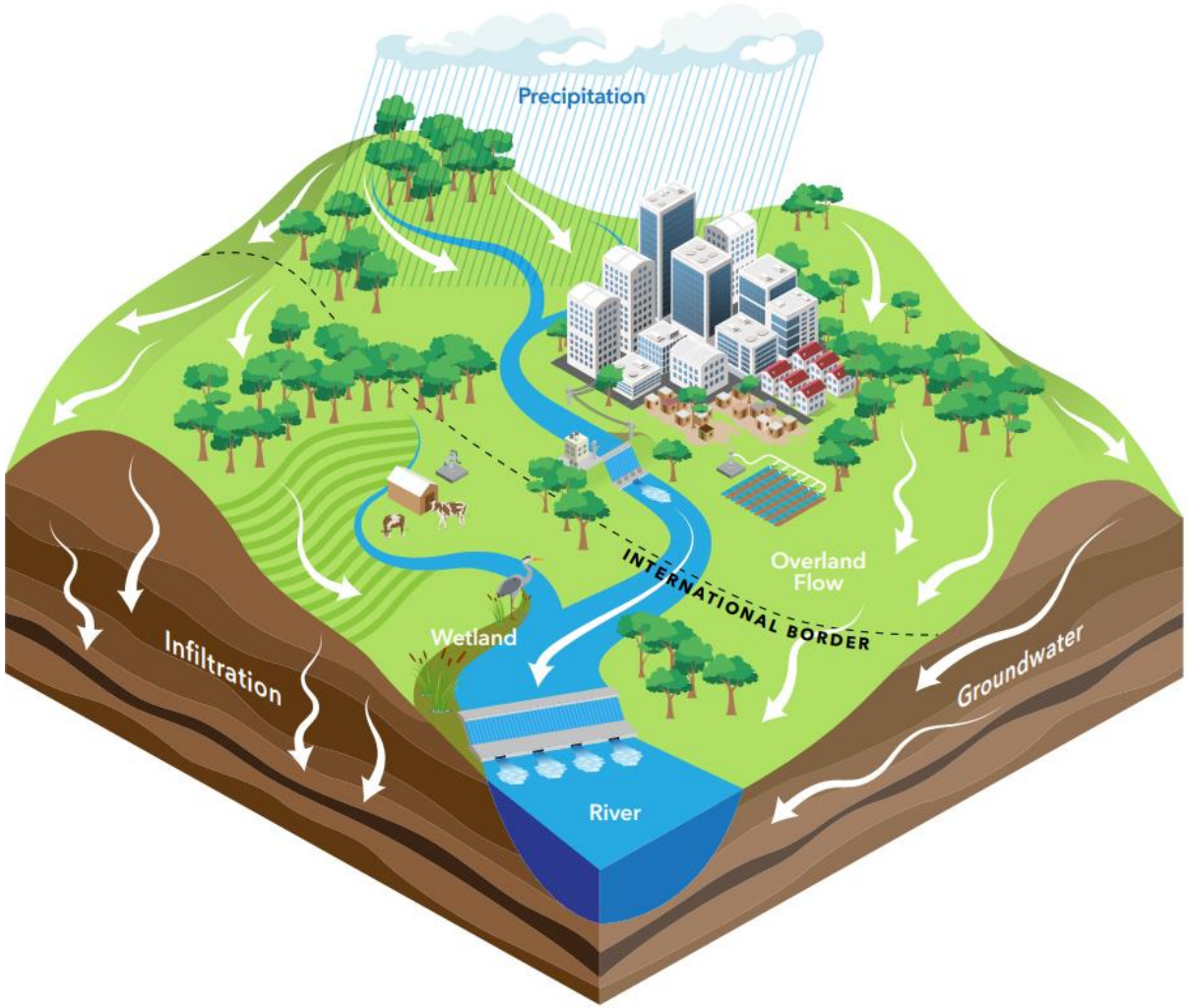
The Water-Energy-Food-Environment Nexus

- Climate change intensifies the Water-Energy-Food-Environment Nexus
  - Energy investment will likely affect water and food security and environmental sustainability, or
  - Food security investment will affect all other sectors

Drivers and Outcomes

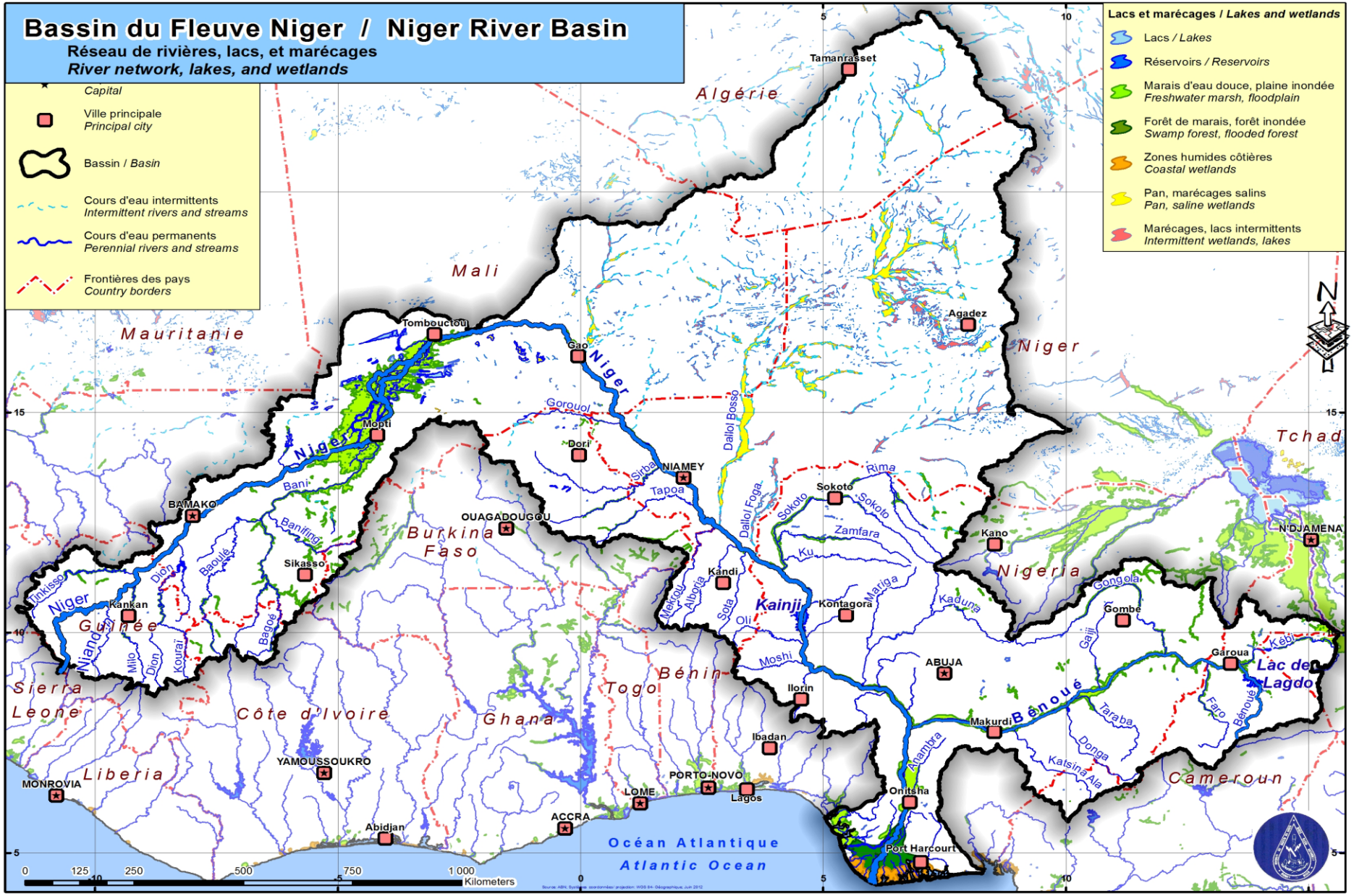


River Basin Context



- Water and related topics are best analyzed in a river basin context---all precipitation drains into a watershed, drainage basin or river basin
- However, administrative boundaries almost always differ from hydrological boundaries
- Many different types of water: precipitation, surface runoff, groundwater, good and bad quality water

Niger River Basin: 9 countries and 100 million people



The Shared Vision of the Niger Basin Authority

Make the Niger basin a common space for sustainable development through integrated management of water resources and associated ecosystems, for the improvement of living conditions and the prosperity of populations by 2025

Nexus Analysis of Investment Plan

351 projects

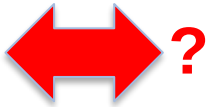
250 climate actions

Multi-sectoral planning

Standards and indicators

Attracting finance

- SP11 Increase in hydroelectric production
- SP12 Increase in agricultural production
- SP13 Navigation development



- SP21 Management of basin ecosystems
- SP22 Protection of targeted threatened ecosystems
- SP23 Management of natural risks and impacts of climate change

- SP31 Implementation of the funding mechanisms selected
- SP32 Monitoring of financial resource management
- SP41 Empowerment of populations and other stakeholders in the sustainable management of the basin
- SP42 Operationalization of collaboration and coordination mechanisms for integrated basin development
- SP51 Management capacity building
- SP52 Improvement of the working environment and conditions
- SP53 Improved staff engagement and stakeholder mobilization

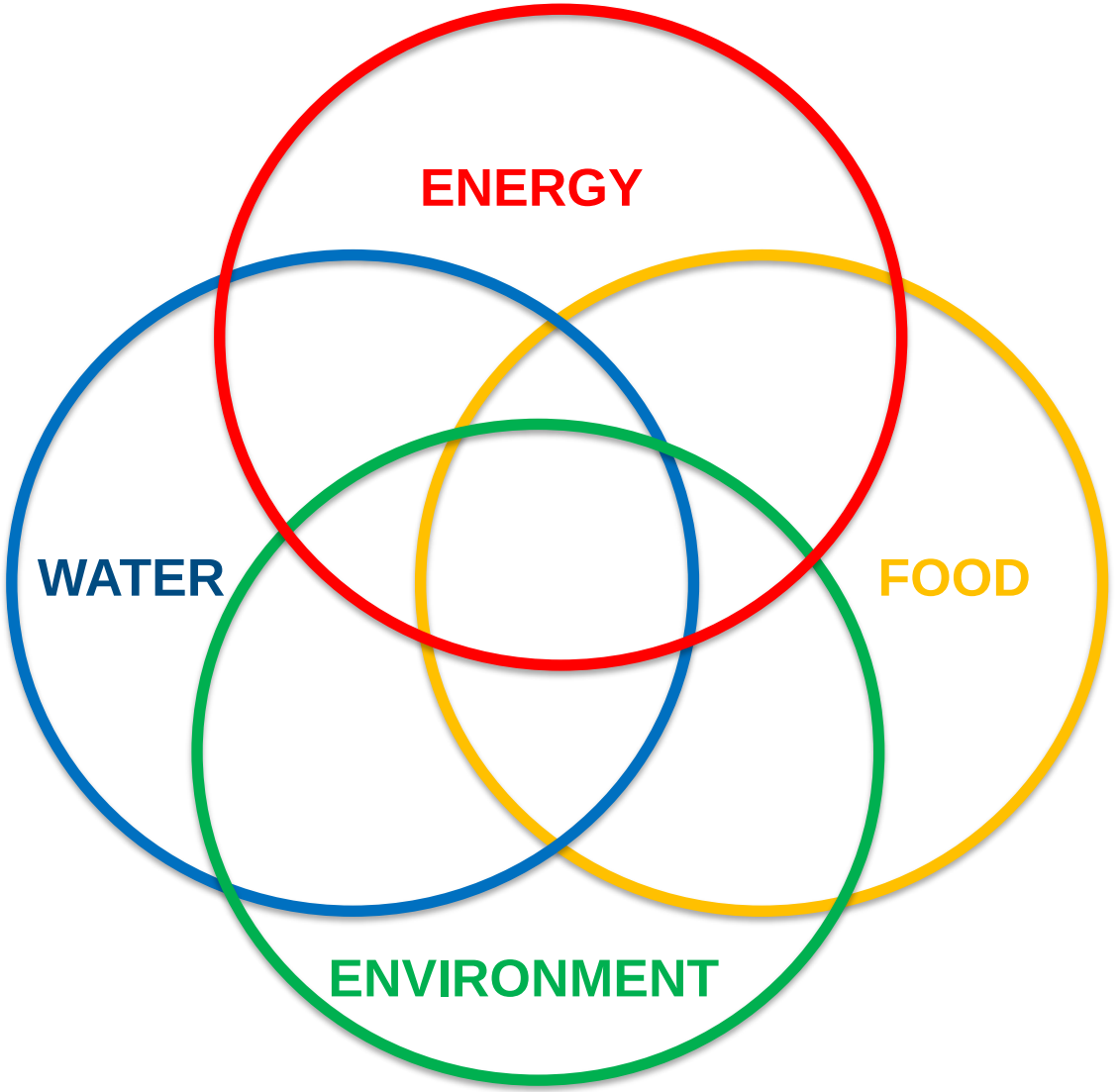
Why a Nexus Angle?

1. Improve effectiveness of OP activities
2. Achieve multiple objectives through a single intervention
3. Avoid harm for some Shared Vision goals by considering potential tradeoffs/ negative cross-sectoral impacts of some OP activities
4. Enlarge impact of OP activities by strengthening positive, intersectoral linkages

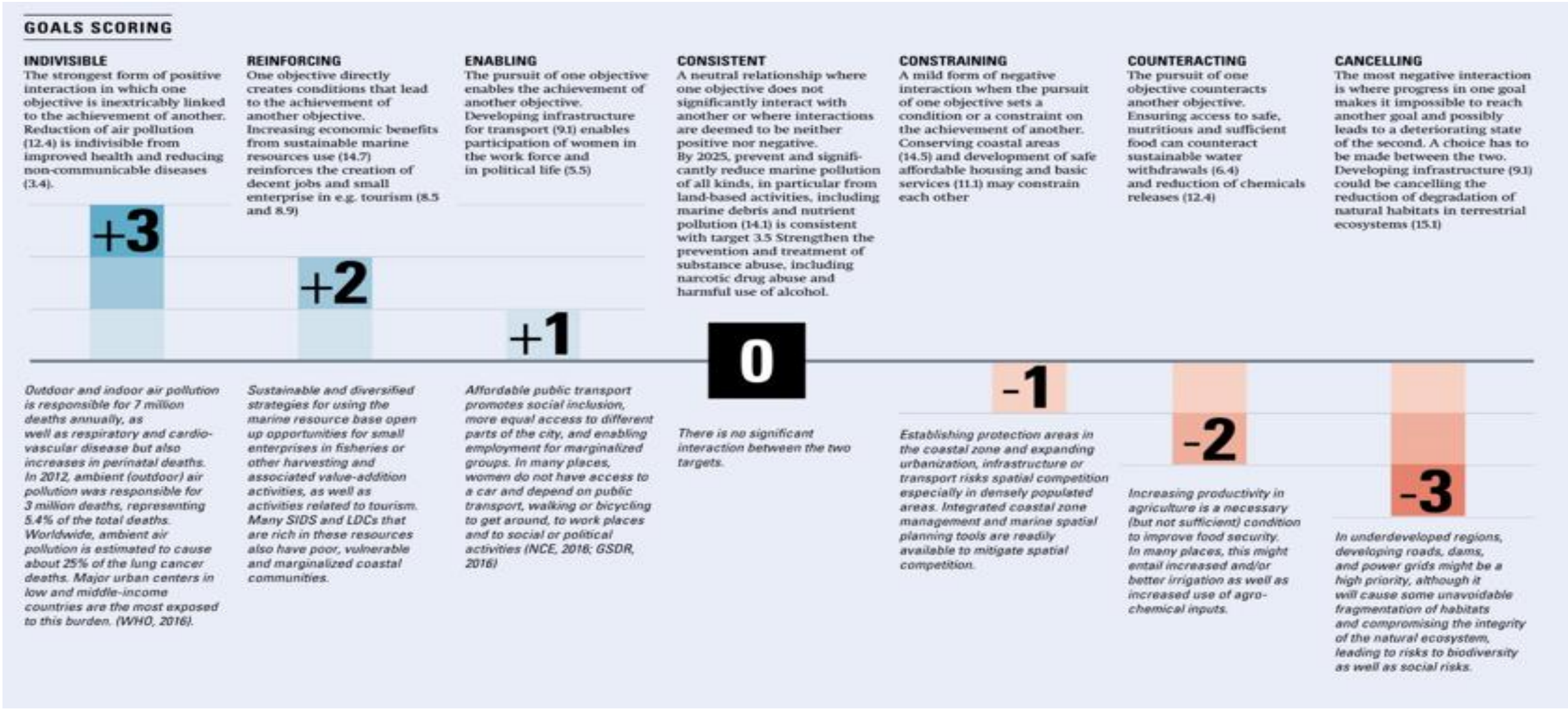
Challenges

- Modeling tools are challenged to consider more than 2 sectors
- Mix of monetary and non-monetary values
- Mismatch between nexus systems boundaries and traditional management units
- Involvement of multiple spatial and temporal dimensions, as well as heterogeneous procedures for various Nexus dimensions
- Different national priorities for Nexus dimensions
- Overly focus on water dimensions at river basin orgs

Nexus



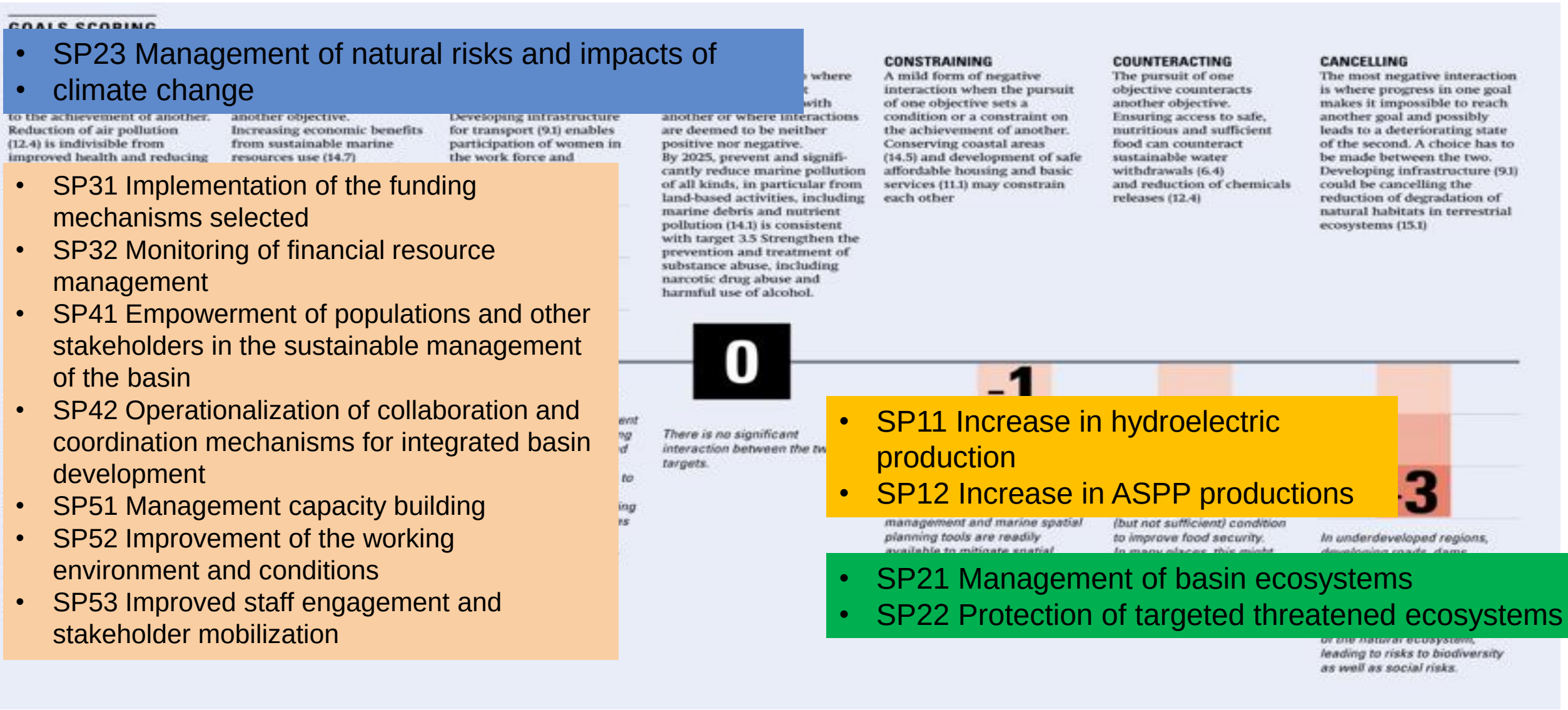
7-point scale of interactions



Griggs et al. (2017).

SP11 Increase in hydroelectric production SP12 Increase in ASPP productions

- SP23 Management of natural risks and impacts of
- climate change



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- SP11 Increase in hydroelectric production
- SP12 Increase in ASPP productions

- SP21 Management of basin ecosystems
- SP22 Protection of targeted threatened ecosystems

Griggs et al. (2017).

Suggestion to update the criteria for the selection of OP activities using a Nexus angle

Nexus concepts in a river basin context

- Size of activity or project: It is clear that one large irrigation dam is likely to have greater negative effects than several small irrigation dams which are more widely distributed across the basin. It is important to note here that size should be evaluated cumulatively; while a series of small projects is often less sensitive than a megaproject, the sum of a series of small projects may well be more constraining for the achievement of certain Nexus objectives.

Nexus concepts in a river basin context

- Geographic location of activity or project :projects located near environmentally sensitive areas (e.g. the Inner Niger Delta and the Niger Delta) or those with significant downstream impacts or close to environmentally sensitive areas require additional examination or, in any case, a further consideration that projects upstream of abundant flow.

Nexus concepts in a river basin context

- Magnitude of the interaction: (limiting or strengthening) with nexus objectives other than those of the project: while some projects slightly limit the achievement of other Nexus objectives, others have significant negative impacts on one or more Nexus objectives ; the force or severity of the impact must therefore be taken into account.

Nexus concepts in a river basin context

- Cross-sectoral focus: Projects that support improvements in more than one sector should be given priority. Projects should specify the extent to which they improve water, energy, food security and environmental sustainability. Projects, which can be led by institutions that support several sectors, should be prioritized

- Social criteria: Projects that address or fit into the enabling environment for successful implementation should be given priority. For example, a water and / or energy project, which does not take into account land conflicts, is less likely to be successful and therefore should not be prioritized.

Nexus concepts in a river basin context

- Resource efficiency and cost savings: Projects that increase cross-sector efficiency in the use of resources should be given priority. For example, projects that use less water for energy production or those that use less water and less energy for food production should be prioritized. Likewise, projects that achieve certain levels of production of water, energy and food at lower cost should be given priority.

- Policies, institutional level and governance: Projects involving institutions from different sectors should be given priority, as they are more likely to improve policy coherence and reduce the likelihood of conflicts between different policies. Purely sectoral projects are more likely to ignore or harm other sectors. For example, some hydroelectric projects may affect the timing and quality of water availability, while some projects focusing on water security may require a lot of energy.

Nexus concepts in a river basin context

- Mitigation of negative impacts: Tradeoffs and negative linkages does not mean that projects cannot be implemented. There is a need for the identification of the capabilities/mitigation measures to address the constraints.

Aggregated project types (25/82)

No.	Activity Category
1	Indefinite
2	agroforestry; regeneration or protection of terrestrial ecosystems / Agroforestry; protection or regeneration of terrestrial ecosystems
3	Improvement of agro-forestry-pastoral productivity / Improvement of agro-forestry-pastoral productivity
4	Improving energy efficiency / Improvement of energy efficiency
5	fish farming
6	Increased income populations / Income Increase for people
7	Improving access to water and sanitation / Improved access to water and sanitation
8	Construction of an irrigation scheme (less than 100ha) / Construction of an irrigated area (Less than 100ha)
9	Construction of an irrigated area (100ha to 500ha) / Construction of an irrigated area (100ha to 500ha)
10	Construction of an irrigated area (500ha to 1000ha) / Construction of an irrigated area (500ha to 1000ha)
11	Construction of an irrigated area (1000ha to 5000ha) / Construction of an irrigated area (1000ha to 5000ha)
12	Construction of an irrigated area (5000ha to 10000ha) / Construction of an irrigated area (5000ha to 10000ha)
13	Construction of an irrigation scheme (10000ha to 25000ha) / Construction of an irrigated area (10000ha to 25000ha)
14	Construction of an irrigation scheme (25000ha to 50000ha) / Construction of an irrigated area (25000ha to 50000ha)
15	Construction of an irrigation scheme (over 50000ha) / Construction of an irrigated area (more than 50000ha)
16	Dam construction hydroagricultural (less than 2.5 million m3) / Agricultural dam building (Less than 2.5 million m3)
17	Dam construction hydroagricultural (between 2.5 and 75 million m3) / Agricultural dam building (Between 2.5 and 75 million m3)
18	Dam construction hydroagricultural (Between 75 and 300 million m3) / Agricultural dam building (Between 75 and 300 million m3)
19	Dam construction hydroagricultural (Between 300 and 750 million m3) / Agricultural dam building (Between 300 and 750 million m3)
20	Dam construction hydroagricultural (Between 750 and 1750 in million m3) / Agricultural dam building (Between 750 and 1750 in million m3)
21	Dam construction hydroagricultural (Between 1750 and 3750 in million m3) / Agricultural dam building (Between 1750 and 3750 in million m3)
22	Dam construction hydroagricultural (Between 3750 and 5000 in million m3) / Agricultural dam building (Between 3750 and 5000 in million m3)
23	Dam construction hydroagricultural (More than 5 billion m3) / Agricultural dam building (More than 5000 million m3)
24	Construction of hydroelectric dam (less than 2.5 million m3) / Hydroelectic dam building (Less than 2.5 million m3)
25	Construction of hydroelectric dam (between 2.5 and 75 million m3) / Hydroelectic dam structure (Between 2.5 and 75 million m3)

Project Scoring by Category (Niger stakeholders)

CATEGORY	FOOD SECURITY			ENERGY			WATER			ENVIRONMENTAL DURABILITY		
	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score
Agroforestry; protection or regeneration of terrestrial ecosystems / 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
Income increase for populations	1	1	1	1	1	1	0	0	0	-1	-1	-1
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
Hydroelectic dam construction	2	2	2	1	2	3	2	2	3	-1	2	2

Project Scoring by Category (Niger stakeholders)

CATEGORY	FOOD SECURITY			ENERGY			WATER			ENVIRONMENTAL DURABILITY		
	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score
Capacity building or knowledge generation for climate change adaptation	0	2	3	0	0	2	0	0	2	1	2	2
Capacity building or knowledge generation for food production	0	2	2	-2	0	1	0	0	2	0	2	2
Capacity building or knowledge generation for water management	-2	2	3	-2	1	3	-3	2	3	-3	2	3
Capacity building or knowledge generation for energy production	0	0	0	0	0	0	0	0	0	0	0	0
Capacity building or knowledge generation for environmental protection	0	0	2	0	0	2	0	0	3	0	0	3

Project Scoring by Category (Niger stakeholders)

CATEGORY	FOOD SECURITY			ENERGY			WATER			ENVIRONMENTAL DURABILITY		
	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score
Energy transport infrastructure	1	1	1	3	3	3	0	0	0	1	1	1
Goods transport / infrastructure	1	1	2	0	0	0	0	0	0	0	0	0
Erosion control intervention	-1	2	2	-2	-2	2	-2	2	2	1	2	3
Flood protection	1	1	2	0	0	1	-1	-1	2	-1	-1	2
Protection or regeneration of aquatic ecosystems	-2	1	2	-2	0	2	-3	2	3	-3	2	3
Land reclamation or reforestation	0	2	2	-2	-2	0	-1	-1	2	1	2	2
Rehabilitation of an irrigated area	2	2	2	0	0	0	-1	-1	-1	0	0	0
Multipurpose dam rehabilitation	1	1	3	3	3	3	0	1	3	0	1	2
Agricultural dam rehabilitation	1	2	3	-2	-1	1	1	2	3	-2	1	2

Project Scoring by Category (Niger stakeholders)

CATEGORY	FOOD SECURITY			ENERGY			WATER			ENVIRONMENTAL DURABILITY		
	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score	Min score	Most common score	Max score
Use of alternative or renewable energy / Use of alternative gold renewable energy sources	0	0	0	1	1	1	0	0	0	1	1	1
Use of alternative or renewable energy / Use of alternative or renewable energy sources	0	0	0	1	1	1	1	1	1	0	0	0

Qualitative scoring observations

- Most scored NBA OP projects as supporting food security objectives positively
- Investments were considered to be largely neutral for energy security
- More diverse results for water and environmental security, with wider ranges of values based on geographic location of basin stakeholders as well as sectoral origin.

Qualitative scoring observations

1. Scores were not consistent from country to country
2. Participants had trouble identifying the effects of 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 or number was particularly challenging
4. Some participants were reluctant to recognize the negative effects of flagship projects in their countries
5. Scores generally worked well for individual investments assessed on their own, they did not allow for an assessment of the cumulative effects from upstream to downstream of individual projects.

Semi-quantitative scoring

- A semi-automated scoring method that allows a more objective consideration of the impact of actions on water security and environmental sustainability. The individual projects were grouped into 85 sub-classes under the 25 classes.
- Dams were disaggregated into various sizes (based on storage capacity), f.ex.
- Use of a SWAT model (distributed hydrological model that considers impacts of changes in land use / physical/other structures on runoff) to calculate environmental and water security indicators

Semi-quantitative scoring

CRITERIA	SUB-CRITERIA	Symbol	RANGE
Water security	Effect on local water availability	S_{WS1}	-3 to 3
	Effect on average flow downstream	S_{WS2}	-3 to 3
	Effect on dry season flow downstream	S_{WS3}	-3 to 3
	Effect on peak flow downstream	S_{WS4}	-3 to 3
Environmental sustainability	Effect on local environmental conditions	S_{E1}	-3 to 3
	Downstream environmental effect due to changes in low flows (0 if no impact on low flows)	S_{E2}	-3 to 3
	Downstream environmental effect due to change in peak flow (0 if no impact on peak flow)	S_{E3}	-3 to 3
	Potential impact on wetlands downstream (0 if no impact on wetlands downstream)	S_{E4}	-3 to 3
Sensitivity to upstream disturbance	Change in performance if the average flow increase	S_{U1}	-1 to 1
	Change in performance if flow in dry periods increases	S_{U2}	-1 to 1
	Change in performance if the peak flow increases	S_{U3}	-1 to 1

Semi-quantitative scoring

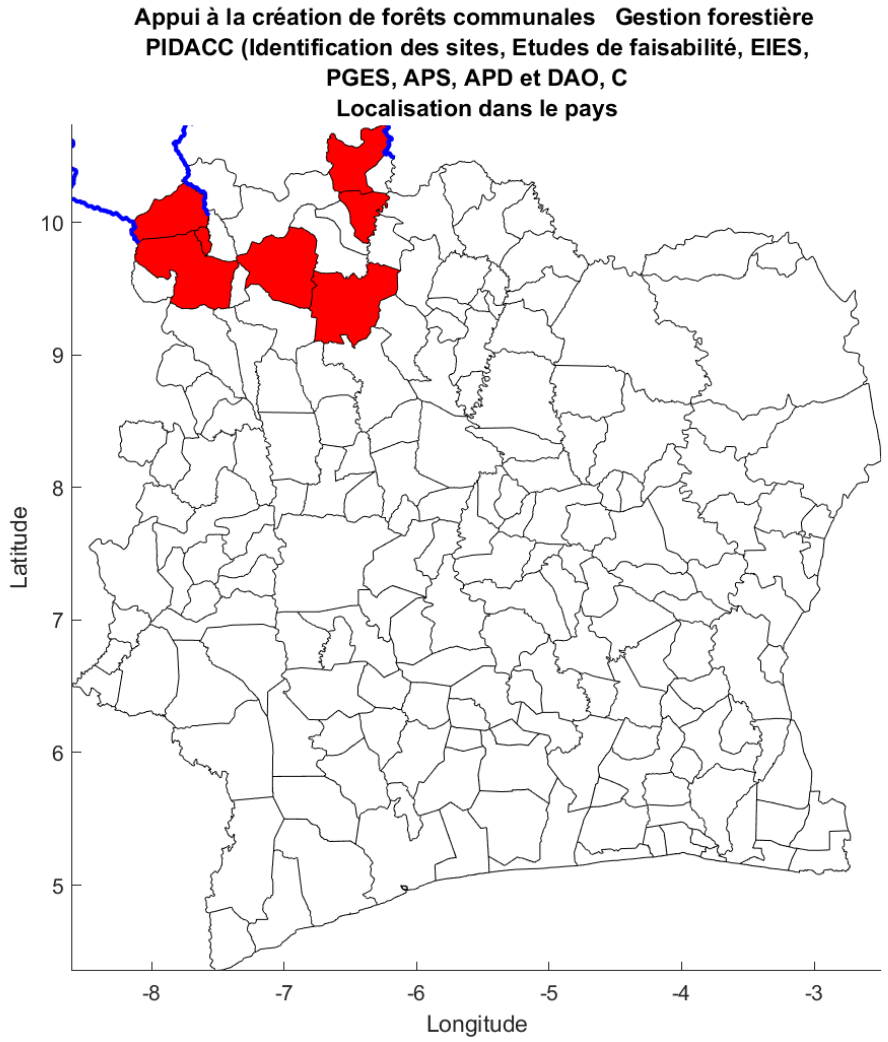
1. As an example, decrease the average flow in subwatershed i by 20% in the hydrological model

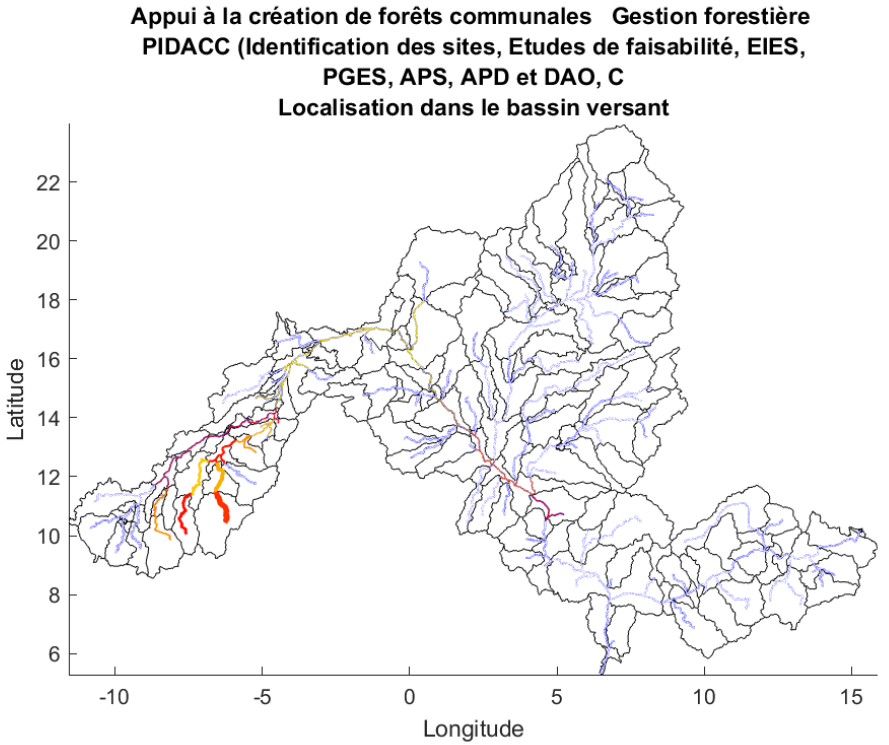
2. The Potential Downstream Impact PDI of subwatershed i on subawatershed j is then calculated as: $PDI_{average,i,j} = \frac{\text{relative change in average flow in subwatershed j}}{\text{relative change in average flow in subwatershed i}}$.

   $PDI_{average,i,j}$ will vary from zero (no impact) to 1 (severe impact).

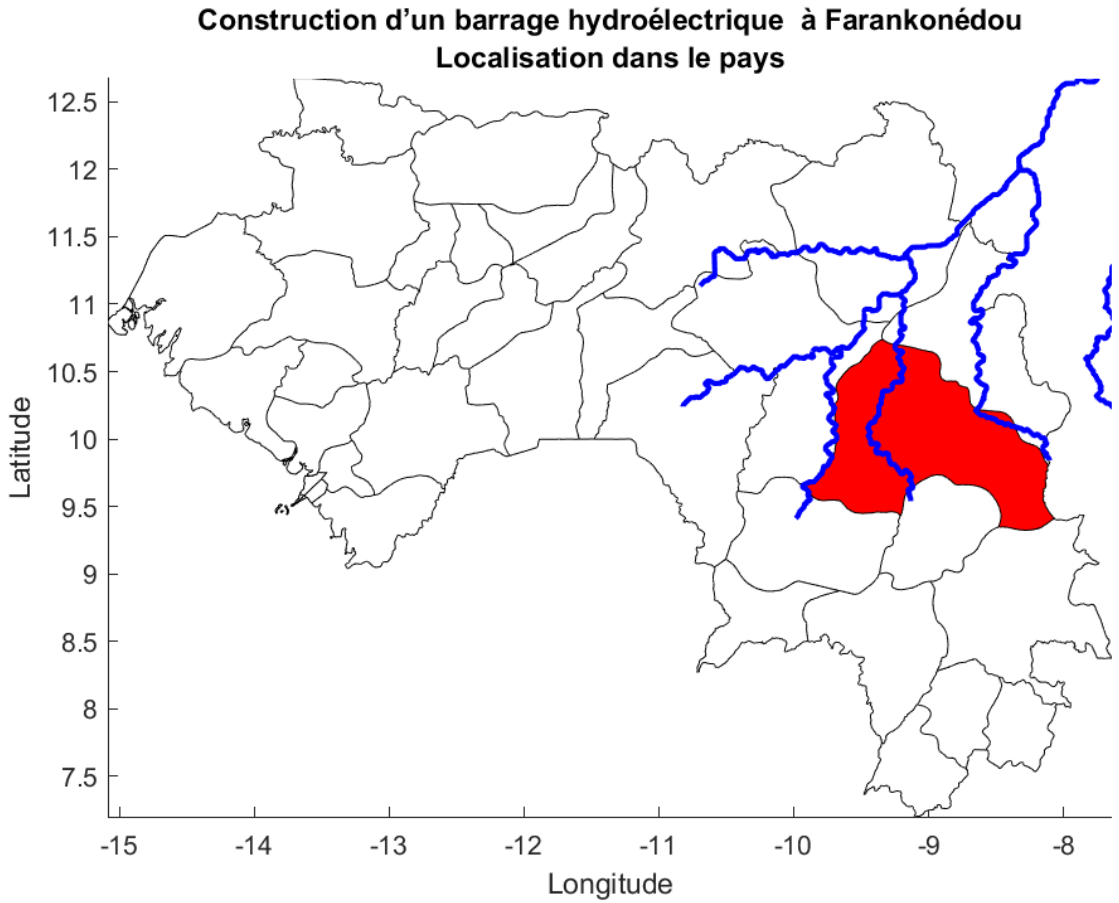
3. The Potential Total Downstream Impact of subwatershd j is $PTDI_{average,i} = \sum_{j} PDI_{average,i,j} * L_j$ where L_j is the length of the channel in subwatershed j.

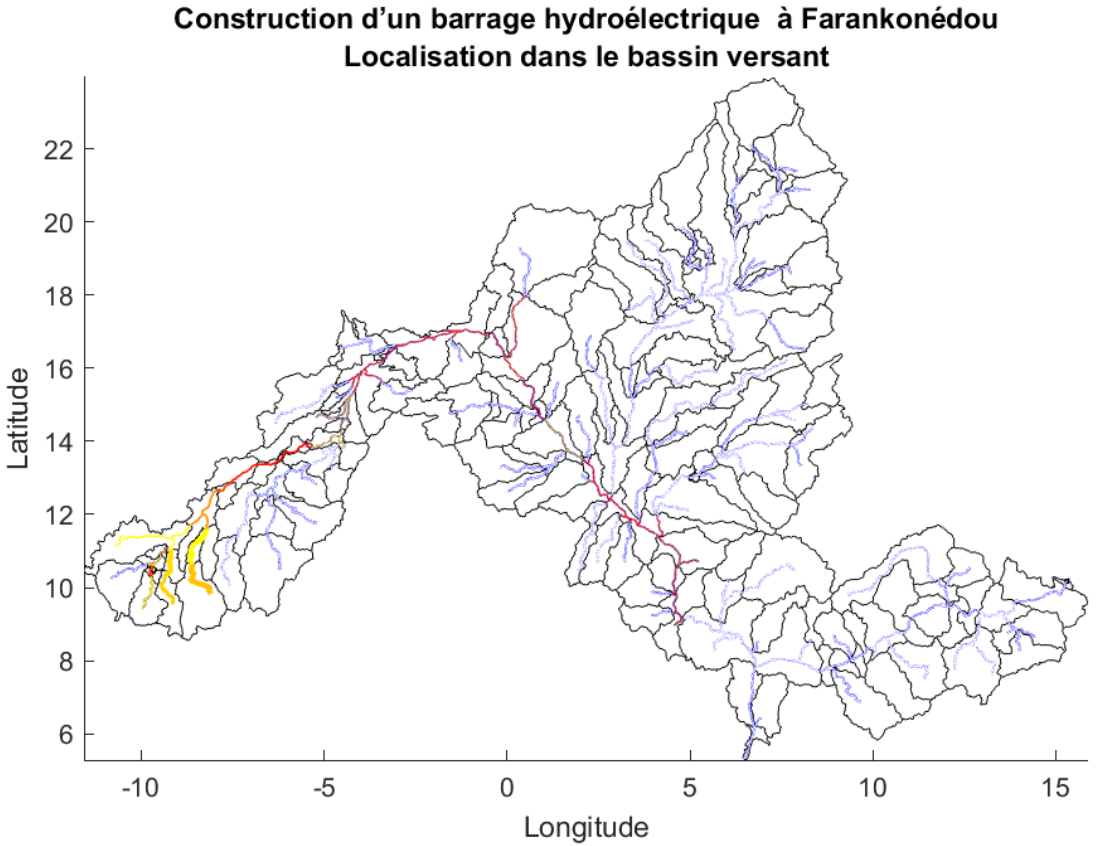
Mapping of project locations to evaluate potential downstream impacts: Development of communal forests



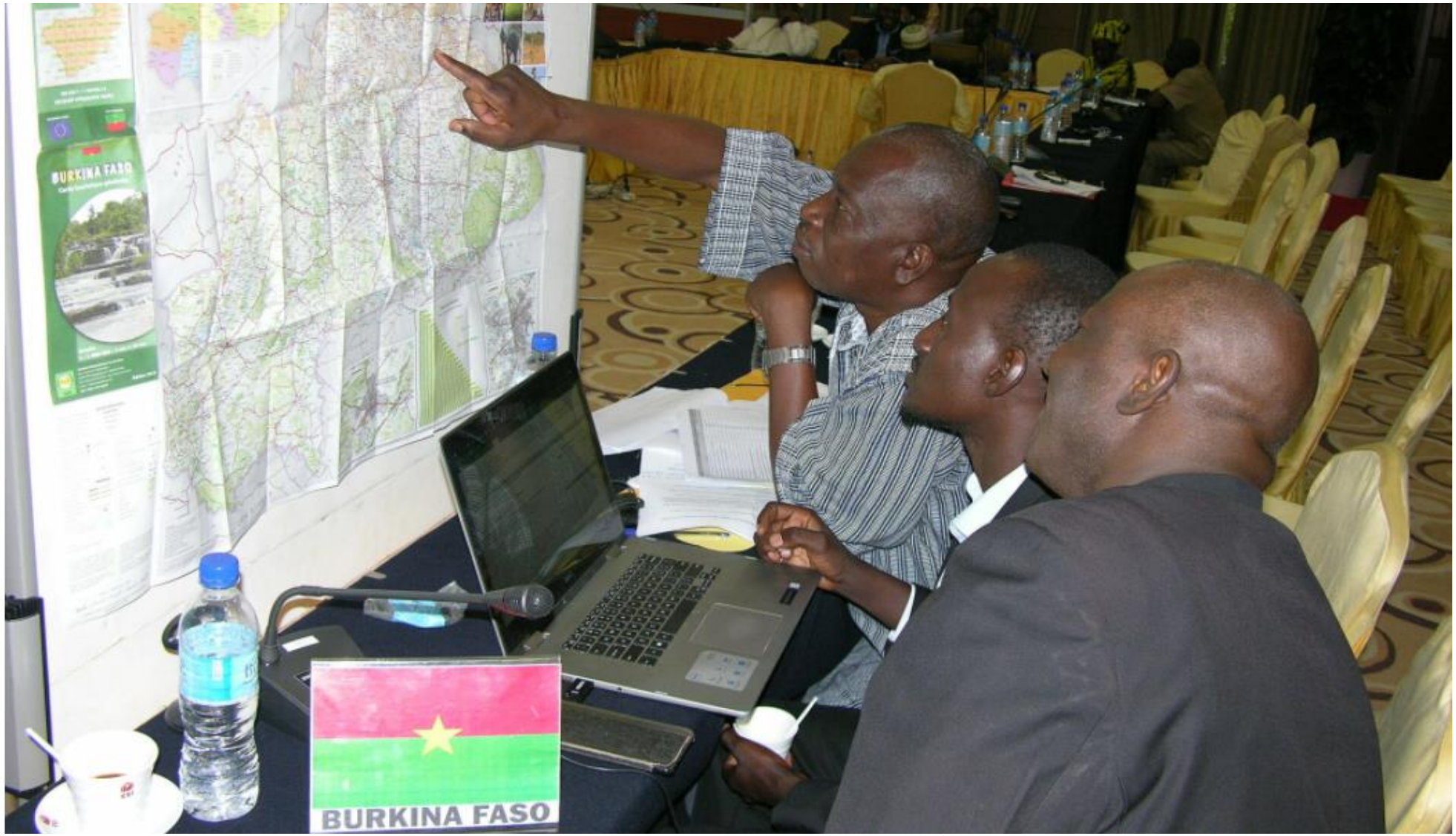


Mapping of project locations to evaluate potential downstream impacts

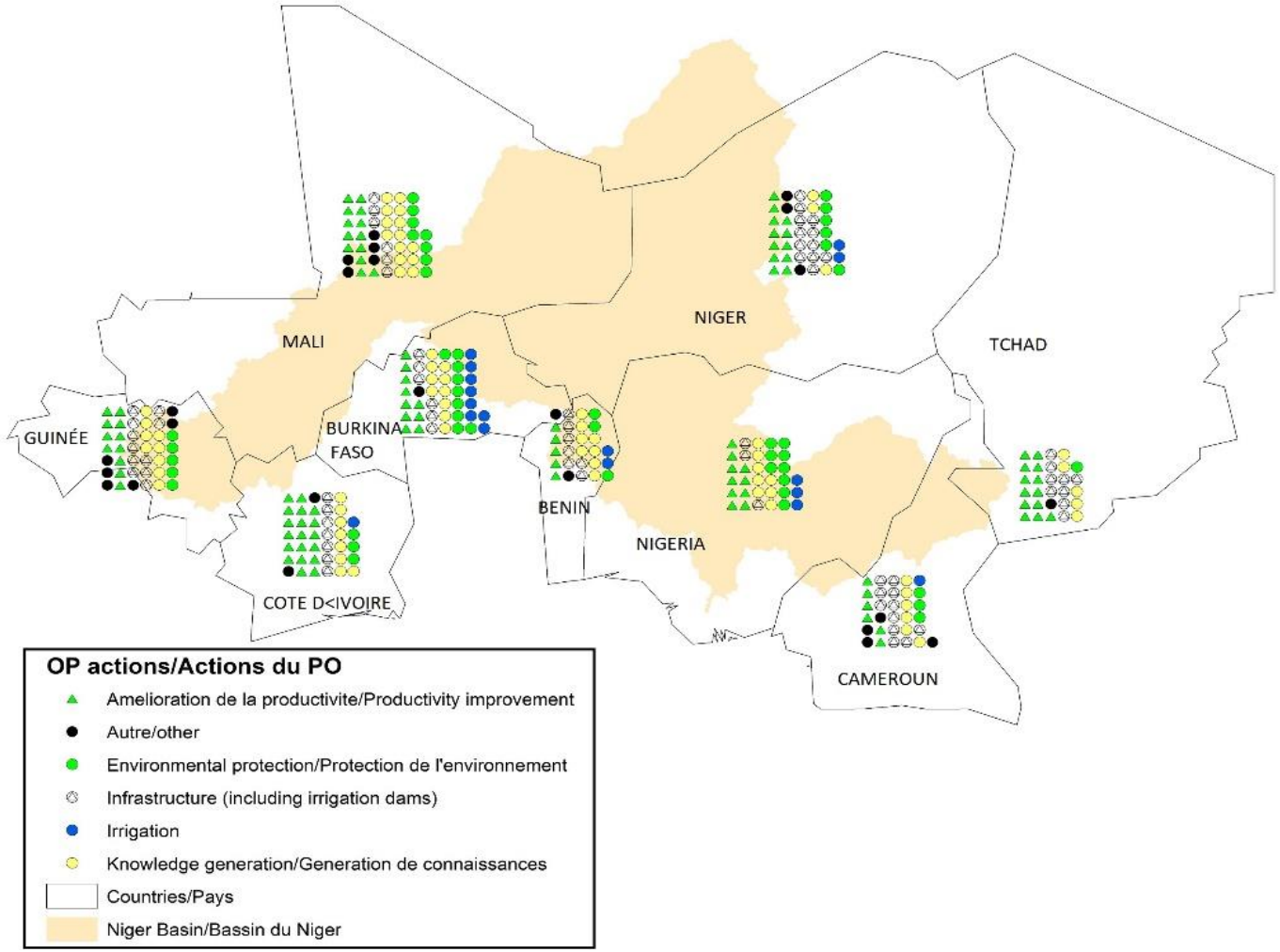




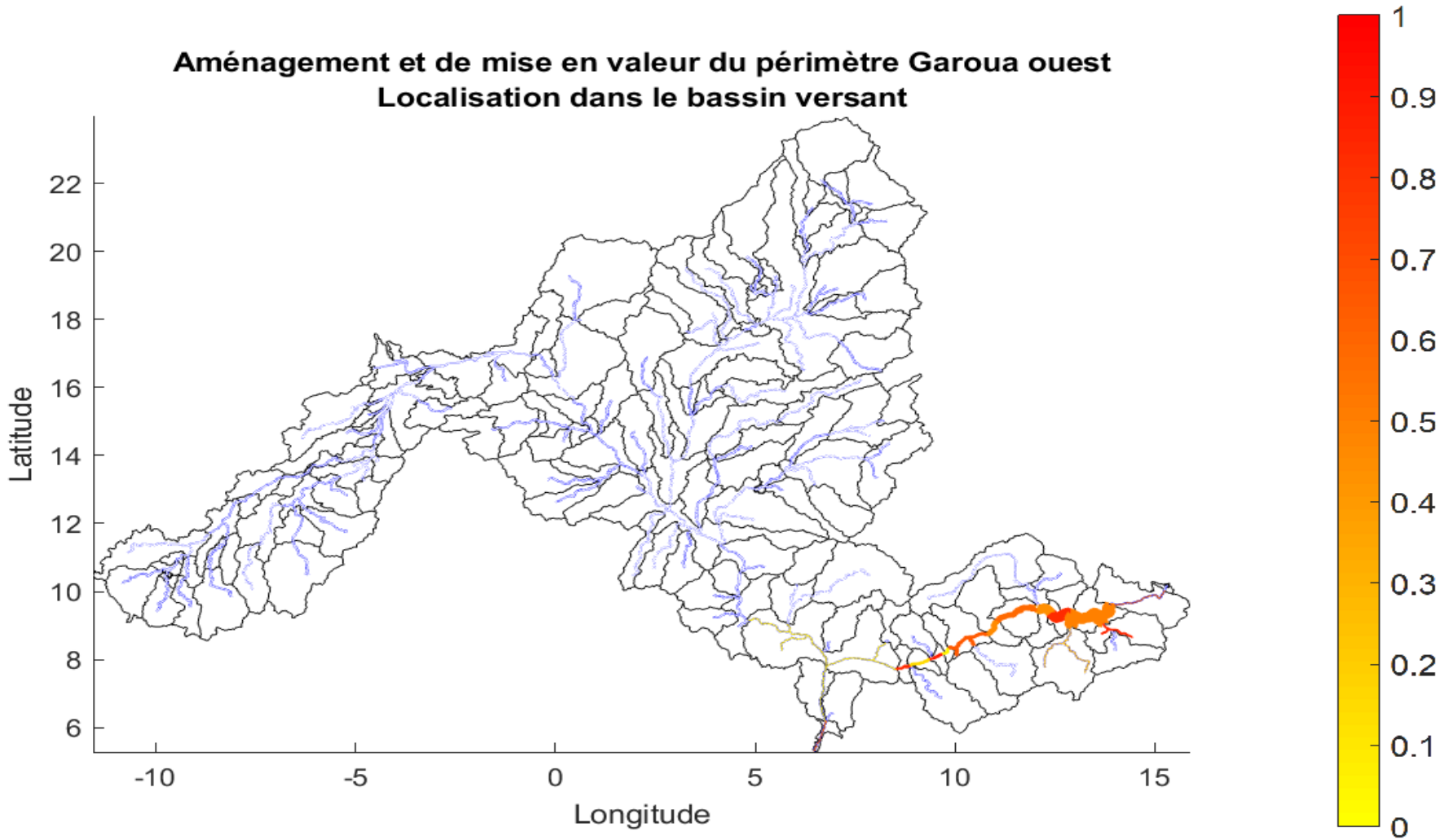
Location of projects in the river basin (Ex BFO)



Types of planned activities per the operational plan



Example of cumulative downstream impact of Garoua Ouest Irrigation system



Lowest and largest impacts of NBA OP projects on flows

Basin country	Investment 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 reservoirs (Gamagou, Gah Guessou, Sombi Kérékou, Wara and Zougou Pantrossi) in the Upper Alibori	0.097654	0.028133	0.028133
MALI	Construction of the multipurpose dam of Taoussa in Mali	0.94817	1.037	1.037

Largest impacts of NBA OP projects on wetlands

Country	Investment project	IMPACT ON WETLANDS
NIGERIA	Flood management Project	0.20308
MALI	Construction of the Markala hydroelectric plant, Mali	0.22283
NIGERIA	Contribution to the financing of the construction of a dam on the Bénoué	0.24942
MALI	The Economic and Environmental Rehabilitation Project for the Niger River	0.25502
MALI	Construction of the Kenié run-of-the river hydroelectric dam, Mali.	0.30581
NIGERIA	Irrigation development Tada Shonga (Kwara State)	0.50388

Combination of impact with size of project

CRITERIA	SUB-CRITERIA	Class score	RANGE	Subclass score	Investment i score
Food security		S_A	-3 to 3	$Size \times S_A$	$Size \times S_A$
Energy Security		S_E	-3 to 3	$Size \times S_E$	$Size \times S_E$
Water security	Effect on local water availability	S_{WS1}	-3 to 3	$Size \times S_{WS1}$	$Size \times S_{WS1}$
	Effect on average flow downstream	S_{WS2}	-3 to 3	$Size \times S_{WS2}$	$Size \times S_{WS2} \times PTDI_{aver}$
	Effect on dry season flow downstream	S_{WS3}	-3 to 3	$Size \times S_{WS3}$	$Size \times S_{WS3} \times PTDI_{low,i}$
	Effect on peak flow downstream	S_{WS4}	-3 to 3	$Size \times S_{WS4}$	$Size \times S_{WS4} \times PTDI_{high,i}$
Sensitivity to upstream disturbance	Change in performance if the average flow increase	S_{U1}	-1 to 1	$Size \times S_{U1}$	$Size \times S_{WS2} \times PTDI_{aver}$
	Change in performance if flow in dry periods increases	S_{U2}	-1 to 1	$Size \times S_{U2}$	$Size \times S_{U2} \times PTDI_{low,i}$
	Change in performance if the peak flow increases	S_{U3}	-1 to 1	$Size \times S_{U3}$	$Size \times S_{U3} \times PTDI_{high,i}$
Environmental Sustainability	Effect on local environmental conditions	S_{E1}	-3 to 3	$Size \times S_{E1}$	$Size \times S_{E1}$
	Downstream environmental effect due to changes in low flows (0 if no impact on low flows)	S_{E2}	-3 to 3	$Size \times S_{E2}$	$Size \times S_{E2} \times PTDI_{average}$
	Downstream environmental effect due to change in peak flow (0 if no impact on peak flow)	S_{E3}	-3 to 3	$Size \times S_{E3}$	$Size \times S_{E3} \times PTDI_{low,i}$
	Potential impact on wetlands downstream (0 if no impact on wetlands downstream)	S_{E4}	-3 to 3	$Size \times S_{E4}$	$Size \times S_{E4} \times PTDI_{high,i}$

Prioritization options

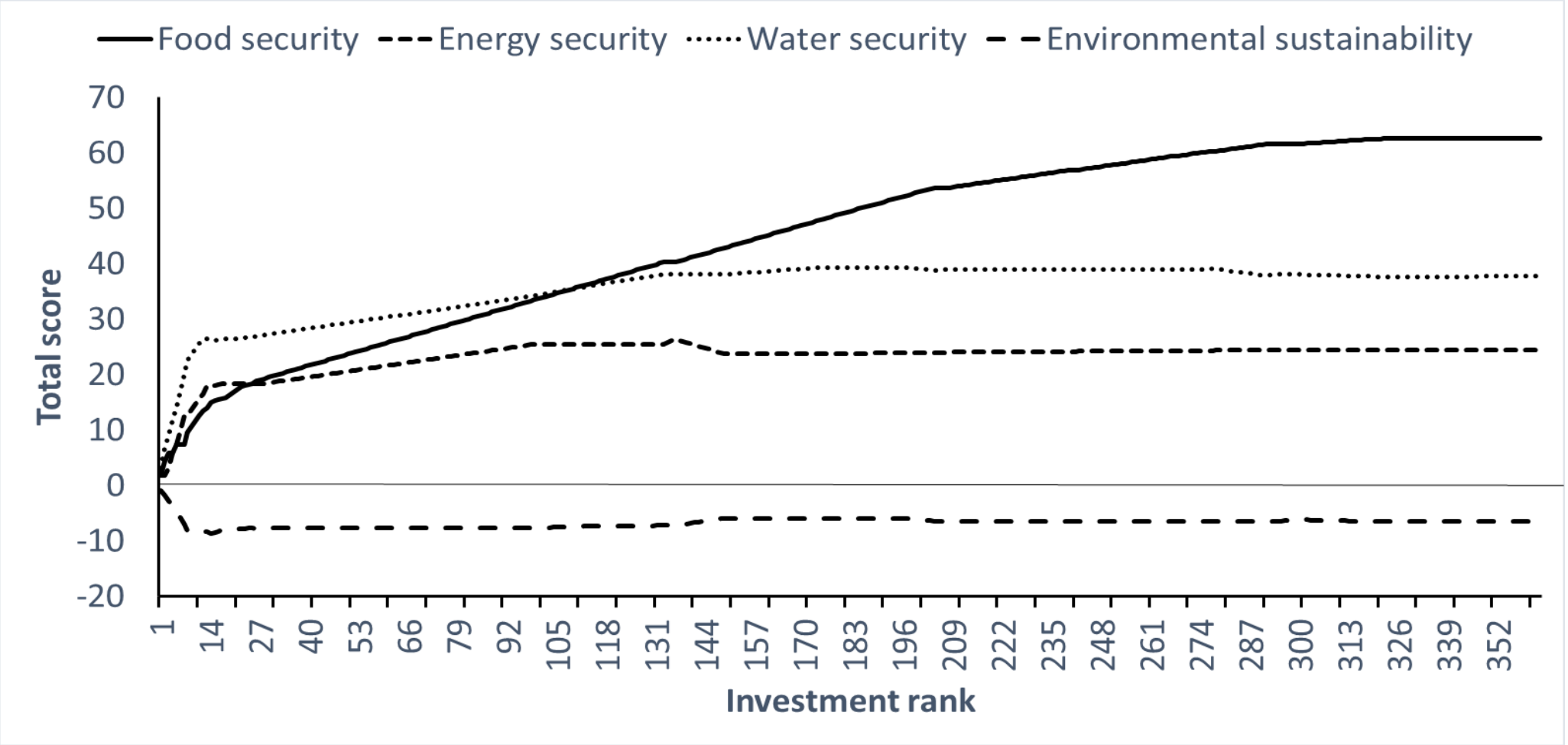
1 $$total\_score = sum(scores)$$

- Prioritizes those projects with largest positive impacts, potentially high negative impacts

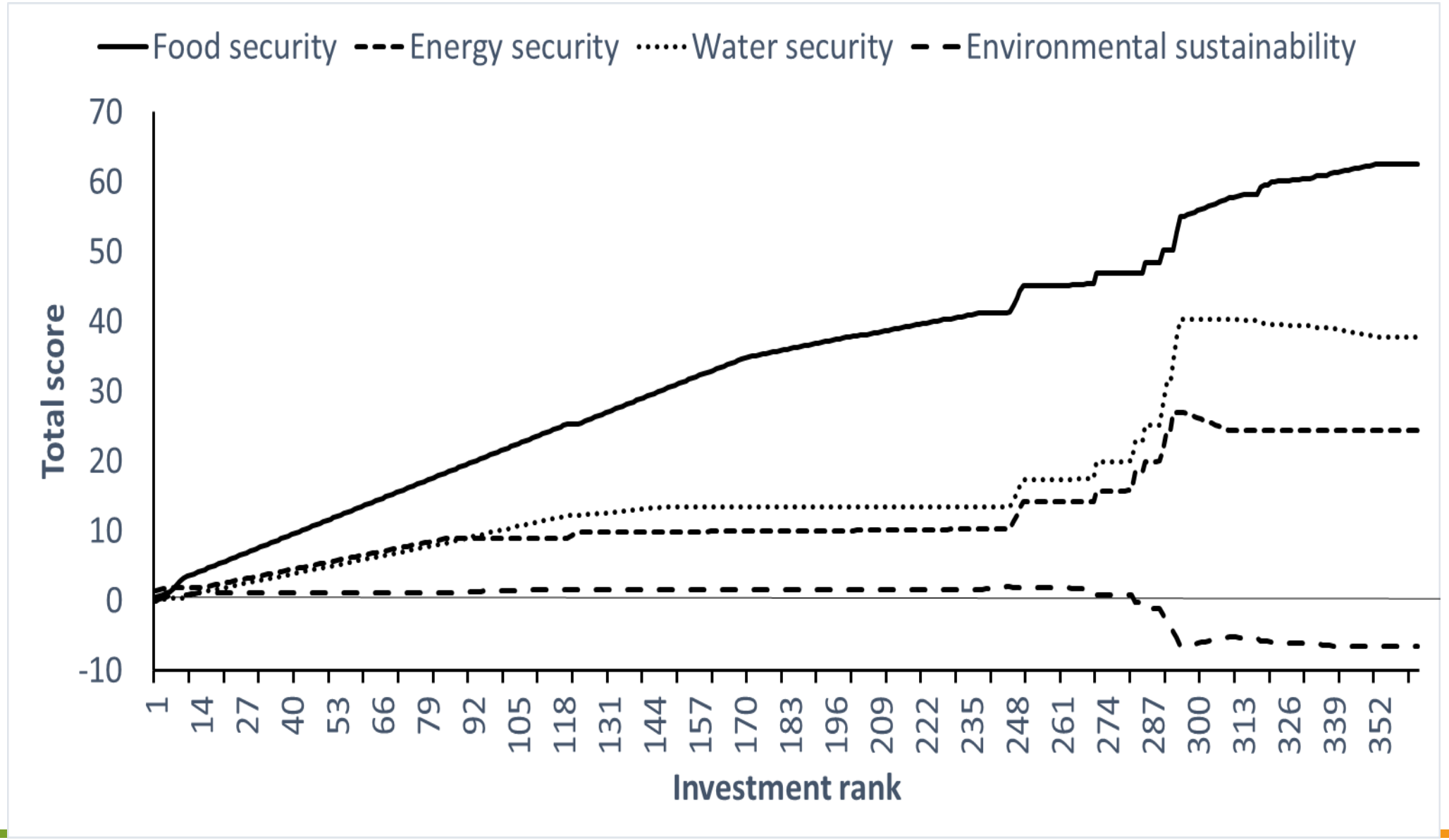
2 $$total\_score = \frac{\text{sum of positive scores}}{\max(0.0001, \text{sum of negative scores})}$$

  - Prioritizes those projects with lowest negative impacts, mostly studies

Prioritization options—Scen 1



Prioritization options—Scen 2



Prioritization results

Ranking (Top and lowest scores)		Equation 1	Equation 2
HIGH SCORES	1	Construction of the Kandadji dam	Chad-Cameroon Electric Interconnector
	2	Construction of the multipurpose dam of Taoussa in Mali	Reforestation of 300 ha of riverbanks
	3	Contribution to financing the construction of a dam on the Bénoué	Mayo Watershed Development -Louti (L Reclamation, Studies)
LOW SCORES	349	Construction of two extension stations	Food and Nutrition Security (Boundiali, T and Odienné) (PASAN-Nord)
	350	Rehabilitation of the irrigated area of Konni (PDREGDE 2B)	Strengthening and securing access to wa resources and sanitation services in a co climate change
	351	Galmi irrigated area rehabilitation (PIDACC) 250 ha	Accompanying measures and social prot

Nexus Indicator Framework I

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

Black color: former list; red color: proposed

Nexus Indicator Framework II

Area	Details	Unit
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*

Nexus Indicator Framework III

Area	Details	Unit
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

Nexus Indicator Framework III

Area	Details	Unit
16 ADDITIONAL ANALYSIS WATER SECURITY	*Effect on local water availability (increase = positive, decrease = negative)*	*modeled*
	Effect on the average downstream flow (increase = positive, decrease = negative)	*modeled*
	Effect on the average flow in the dry season downstream (increase = positive, decrease = negative)	*modeled*
	Effect on downstream peak flow (decrease = positive, increase = negative)	*modeled*
17 ADDITIONAL ANALYSIS ENVIRONMENTAL SUSTAINABILITY	*Locally improves the environment*	*modeled*
	Environmental effect of change on peak flow	*modeled*
	Environmental effect of the change in average flow in the dry season	*modeled*
	Effect on downstream wetlands (if any)	*modeled*
18 CUMULATIVE IMPACTS ACROSS ALL PROJECTS	*Increases if the average flow rate increases*	*modeled*
	Increases if the average flow in the dry season increases	*modeled*
	Increases if peak flow increases	*modeled*
19 GROUPING WITH OTHER PROJECTS TO AVOID NEGATIVE IMPACTS		*Project number*
		Why? (quan/qual)

Conclusions

1. Various complexities in NEXUS analysis at basin level
2. A combination of qualitative and quantitative measures needs to be considered
3. Final decision will depend on negotiations across key stakeholders that should consider modelled results for more complex NEXUS components