Trade-off assessment in the Senegal River Basin

ICID

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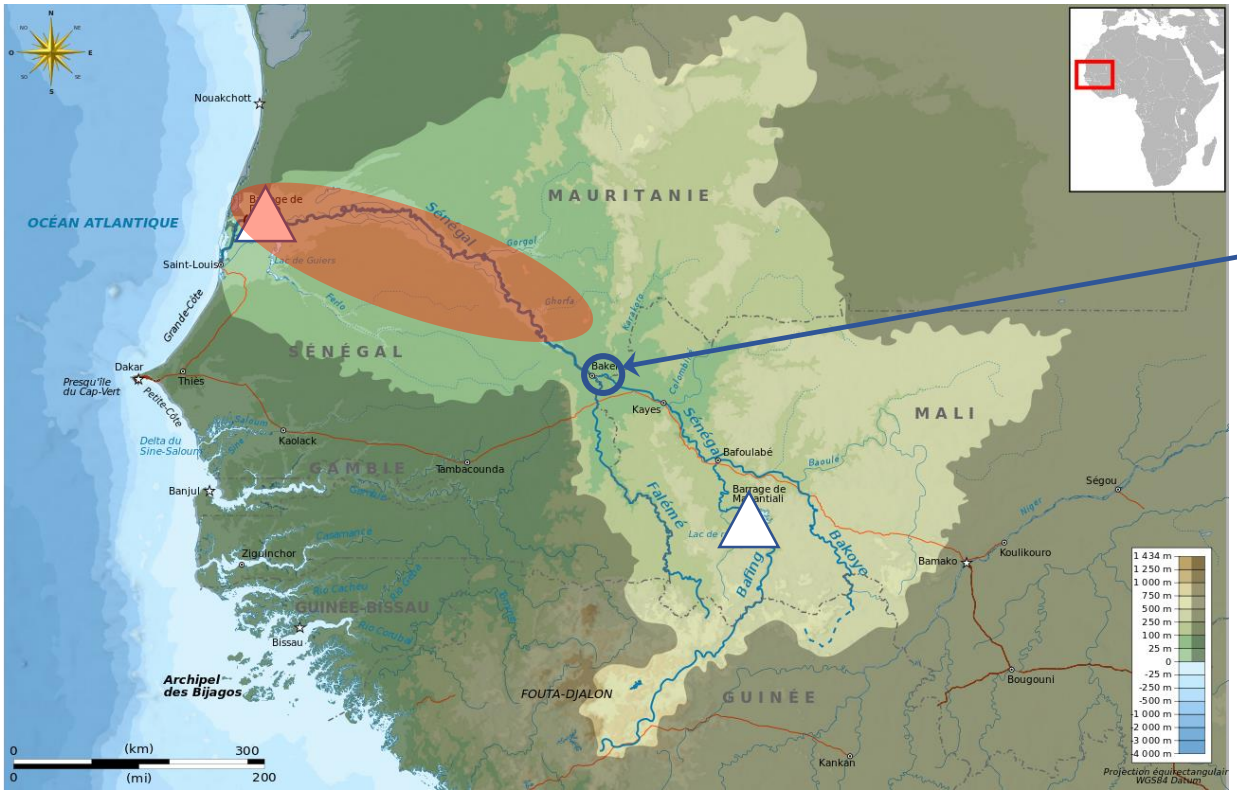
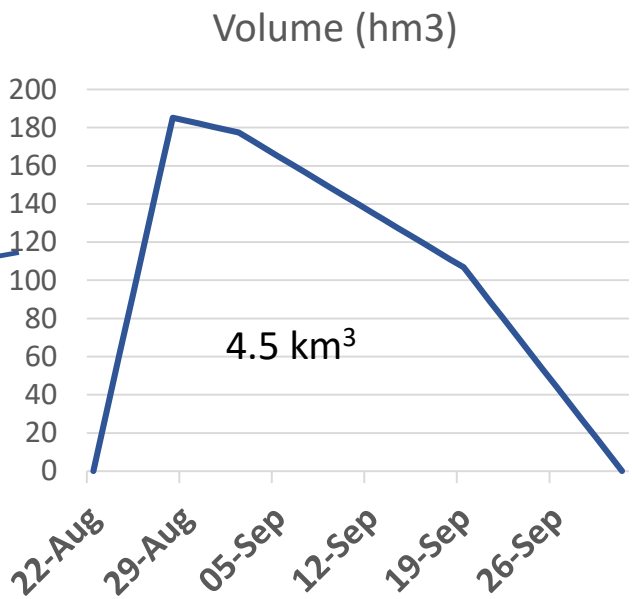
The Senegal River basin

- Located in western Africa
- Drainage area = 337000 km2
- Shared by four countries: Guinea, Mali, Mauritania and Senegal
- Traditional uses:
  - **transportation (navigation)**
  - **food production: fisheries + flood recession agriculture**
- More recently: hydroelectricity
- Significant year-to-year variability of river discharges:
  - **exposes water users to a high hydrological risk**
- Significant development potential in the basin. Coordination through the river basin authority: OMVS

The Senegal River basin

Artificial flood (AF)

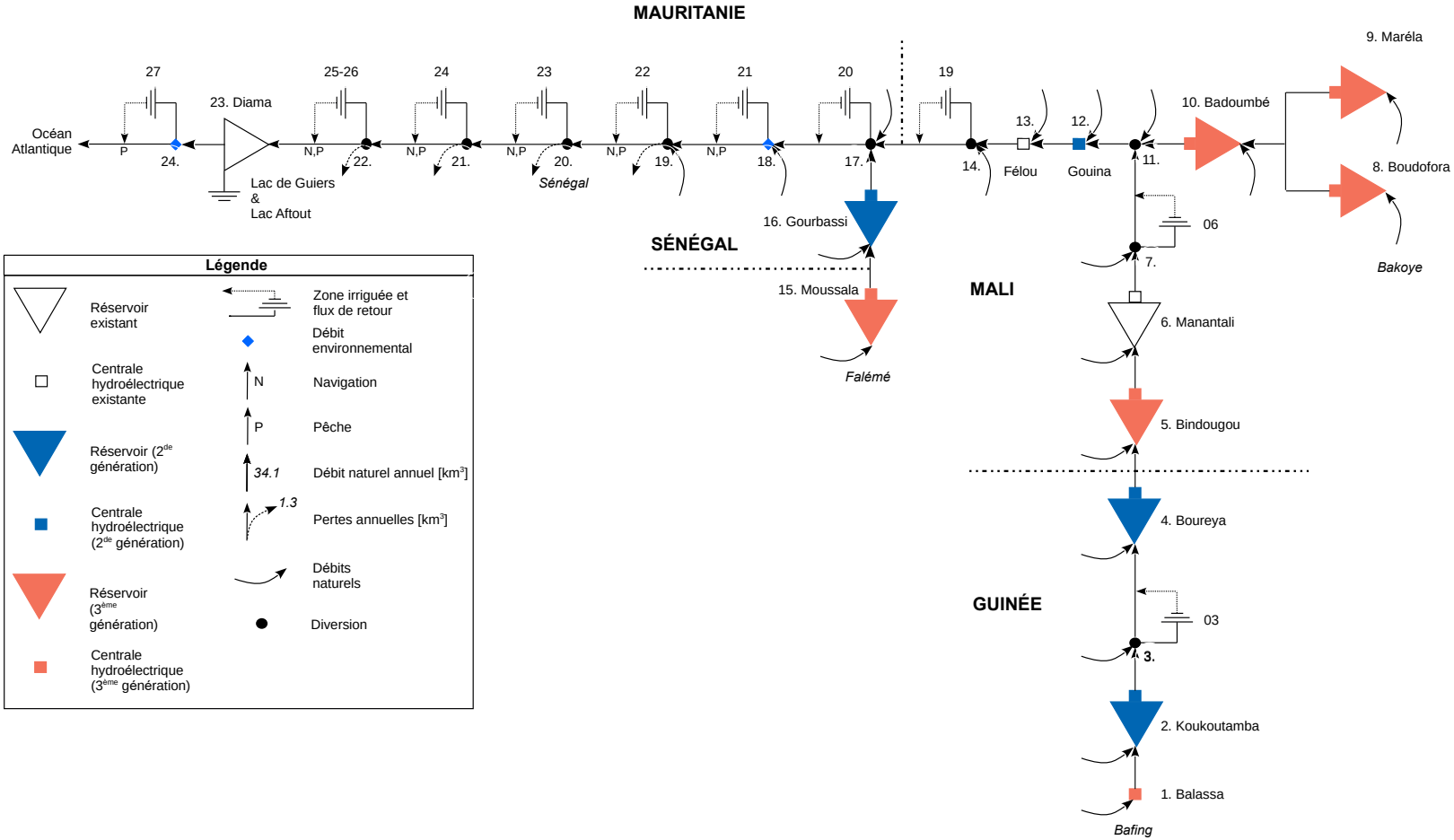




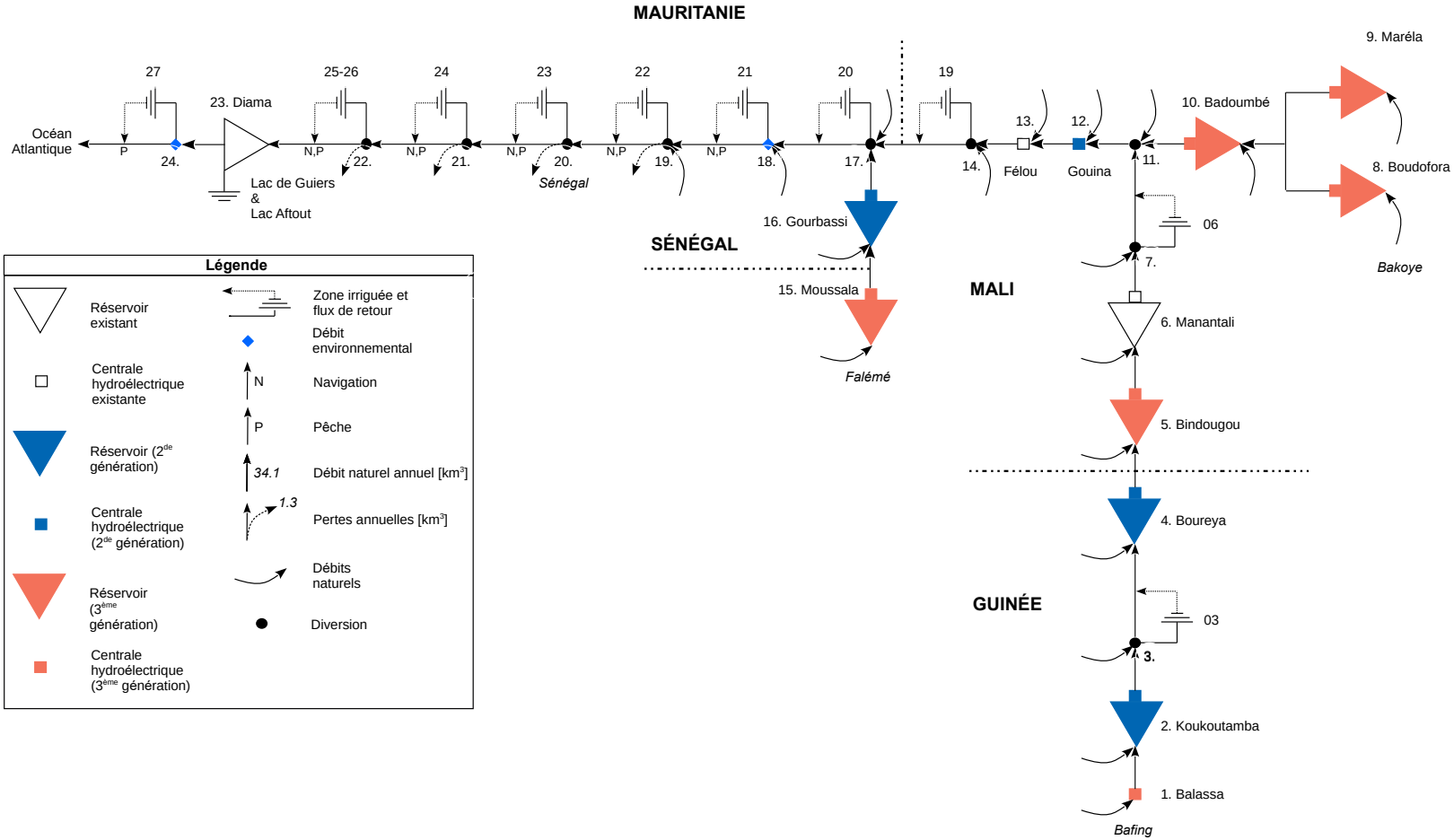
HEM for the Senegal River basin

- As river basins develop it becomes more and more relevant
  - **To seek efficient allocation policies**
  - **To understand the linkages between**
    - Economic sectors
    - Water users
    - Water users and their biophysical and social environment
- In the Senegal River basin, the following hydro-economic principles apply:
  - **Water should be used where and when its user value is the greatest**
  - **Water should be stored in reservoirs upstream**
  - **Water for consumptive uses should be withdrawn downstream**
- How to find the balance between these principles?

→ **Hydro-economic modelling (HEM)**



- Maximizes expected net benefits from hydropower generation and irrigated agriculture
  - **Constraints: M&I uses, artificial flood (eflows), navigation**
- Up to 10 reservoirs / 12 hydropower plants
- 11 irrigation demand nodes / 52 crops



- Maximizes expected net benefits from hydropower generation and irrigated agriculture
  - **Constraints: M&I uses, artificial flood (eflows), navigation**
- Solved using Stochastic Dual Dynamic Programming (SDDP)
- Generic HEM coded in MATLAB + efficient Gurobi solver

Scenarios - Senegal River basin

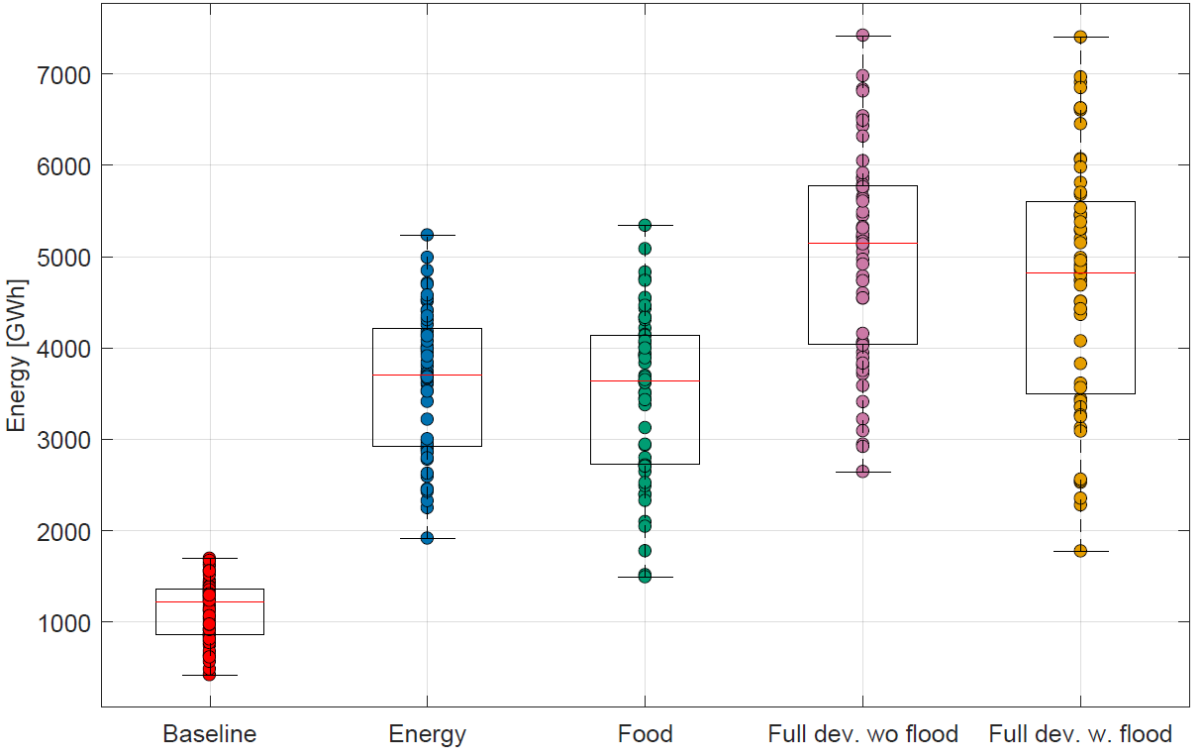
- Development scenarios represent alternative levels of water resources' commitment in the basin

Baseline 2015	Mid-development 2030	Full-development 2050
2 reservoirs 2 hpp 74 kha 5.9 million inhabitants	5 reservoirs 6 hpp 255 kha 9.7 million	10 reservoirs 12 hpp 402 kha 16.8 million

- Management scenarios reflect alternative allocation policies between competing uses
  - **Food security: flood recession agriculture, fisheries and irrigation**
  - **…**
  - **Energy security: hydropower generation**

Hydropower generation

- Annual energy generation



Baseline 2015	Mid-development 2030	Full-development 2050
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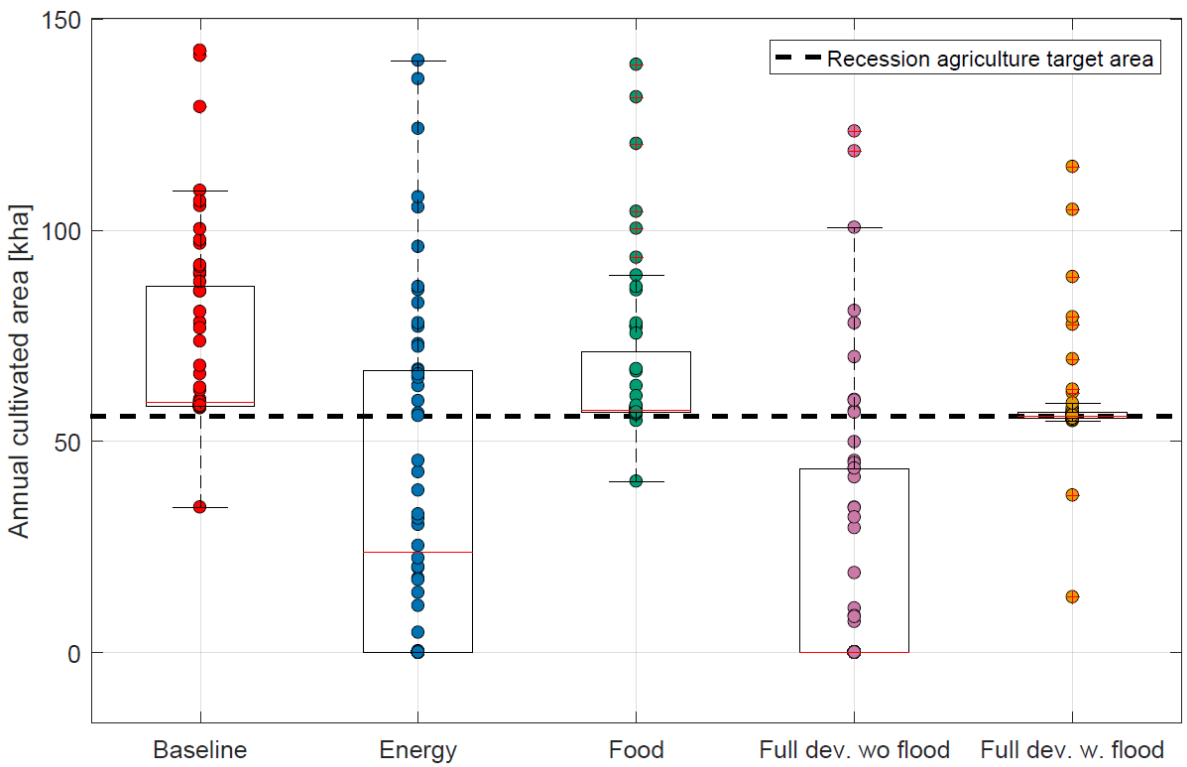
2 hpp	6 hpp	12 hpp
74 kha	255 kha	402 kha

Cultivated area – flood recession agriculture



Baseline 2015	Mid-development 2030	Full-development 2050
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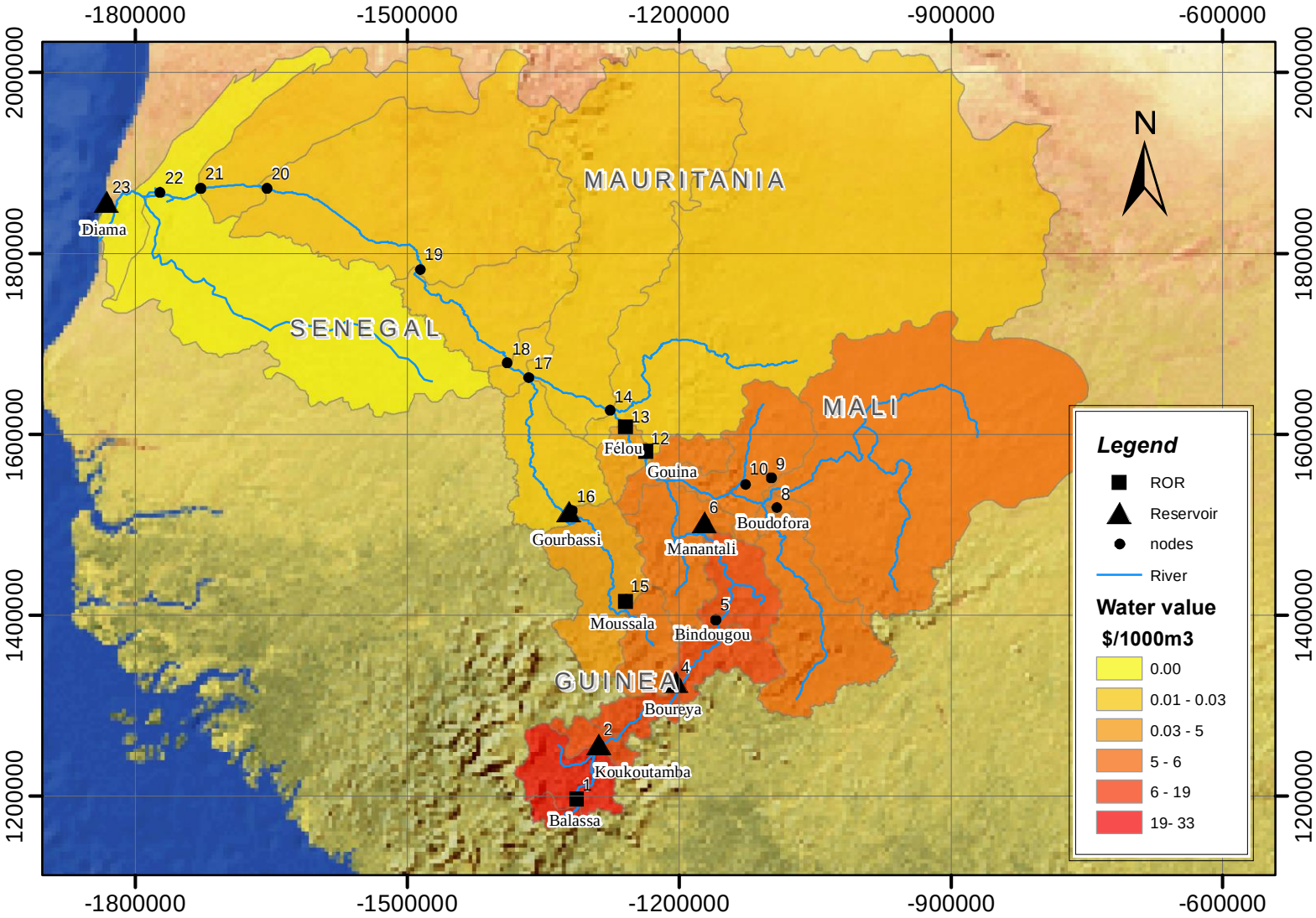
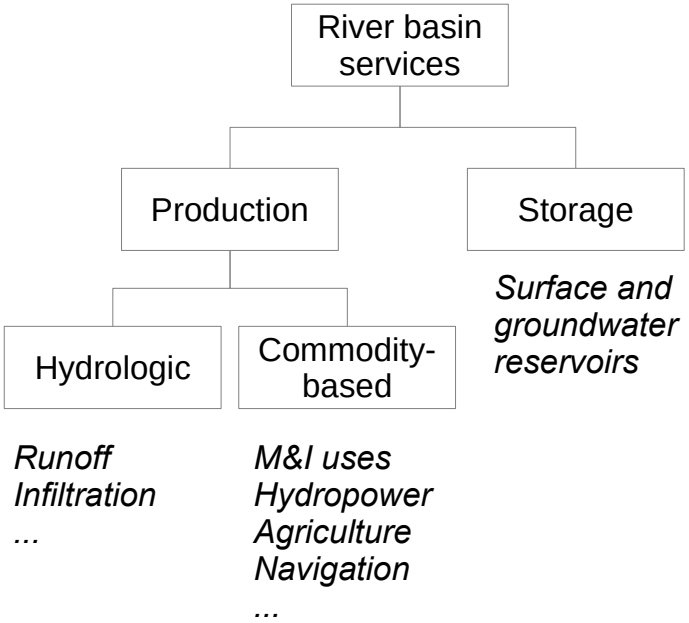
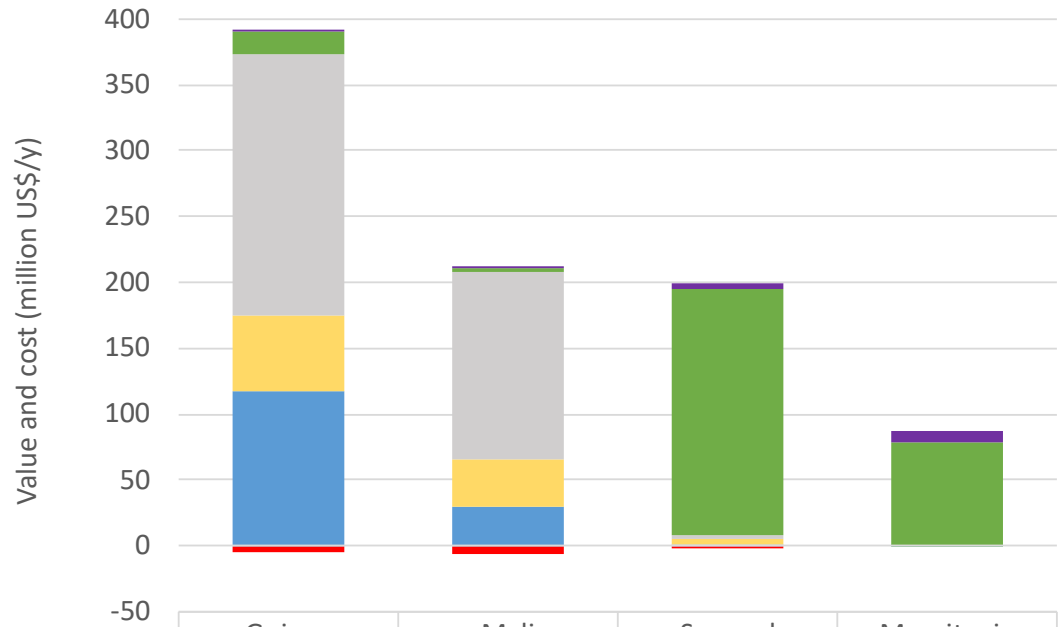
Marginal value of water



Water accounting (2030)

- Short-run values and costs (million US$/y)





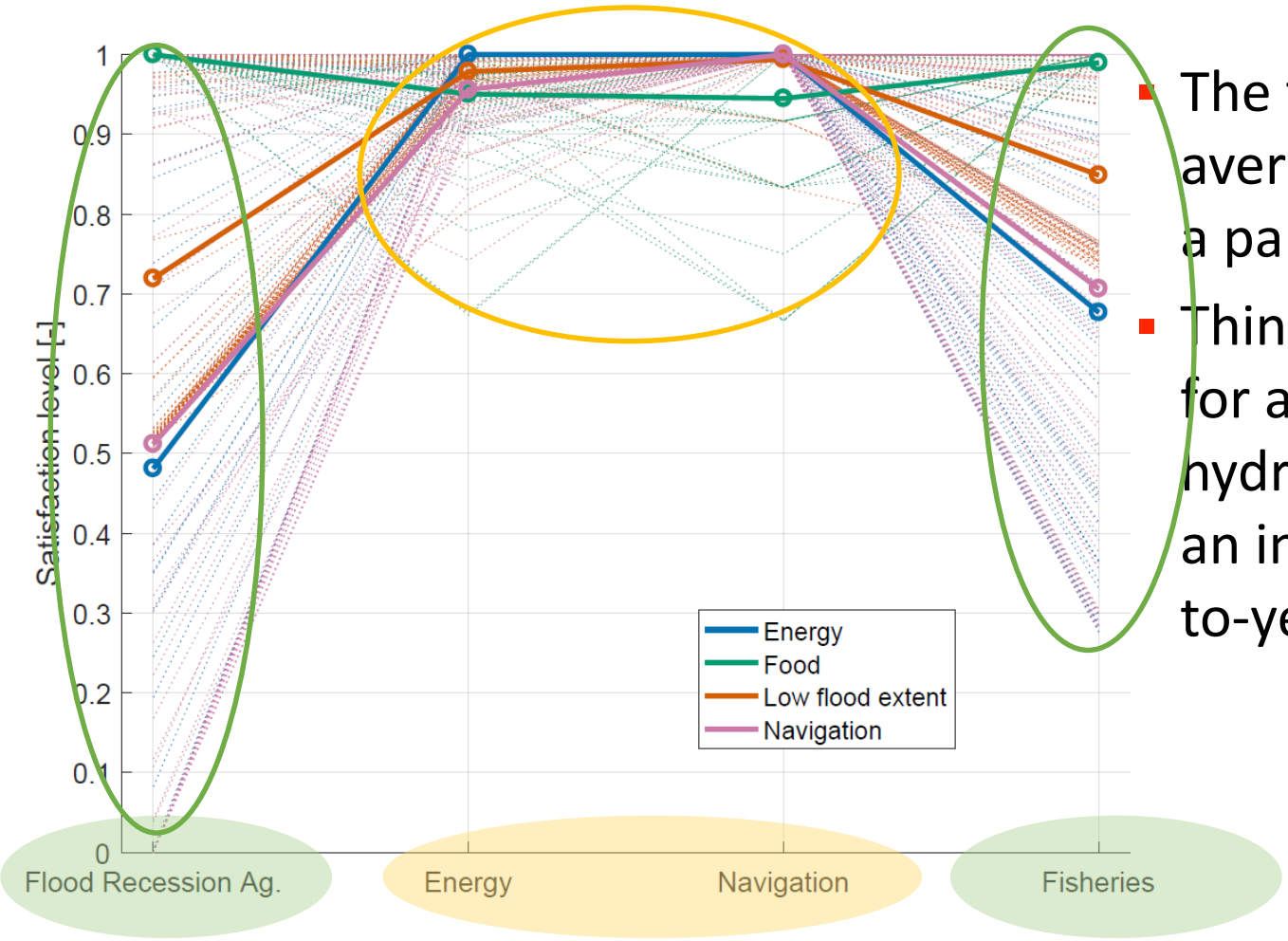
	Guinea	Mali	Senegal	Mauritania
Fisheries	0.4	0.6	3.6	8.4
Irrigation	17.4	3.0	187.7	78.2
Hydropower	199.3	142.9	2.8	0.0
Evaporation	-4.7	-5.8	-0.4	0.0
Storage services	57.4	35.6	3.6	0.0
Natural inflows	117.0	29.6	1.1	0.0

Indicators

- Satisfaction level = degree to which one objective is achieved in a particular scenario (compared to the max achievable performance in the corresponding “best” scenario)

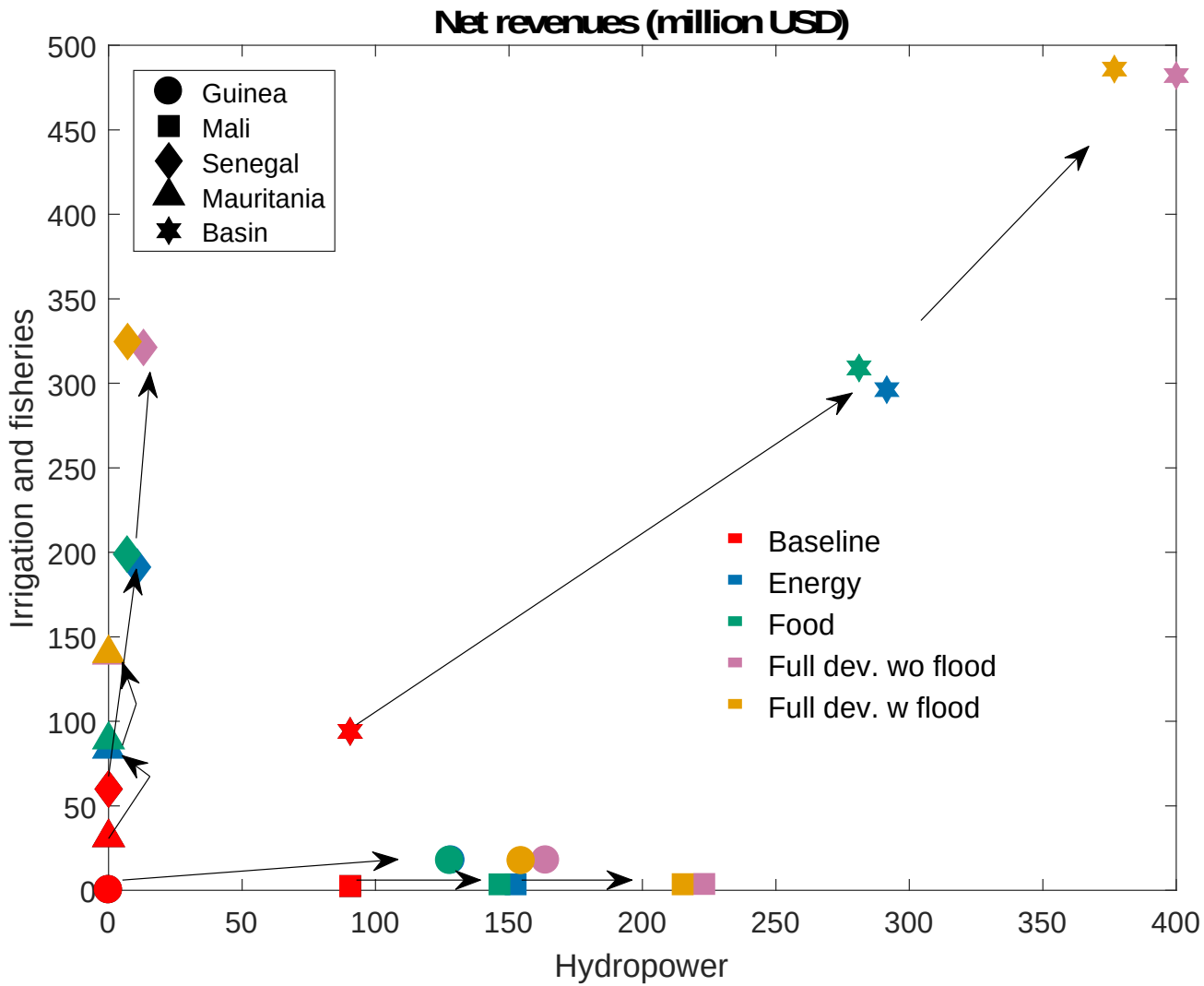
Indicator	Scale & units	« best » management scenario
Flood recession ag	Flooded area (ha)	Food security
Energy	Energy (MWh)	Energy security
Navigation	Probability of exceeding min flow (-)	Navigation
Fisheries	Fish catch (T)	Food security

Trade-off (2030)



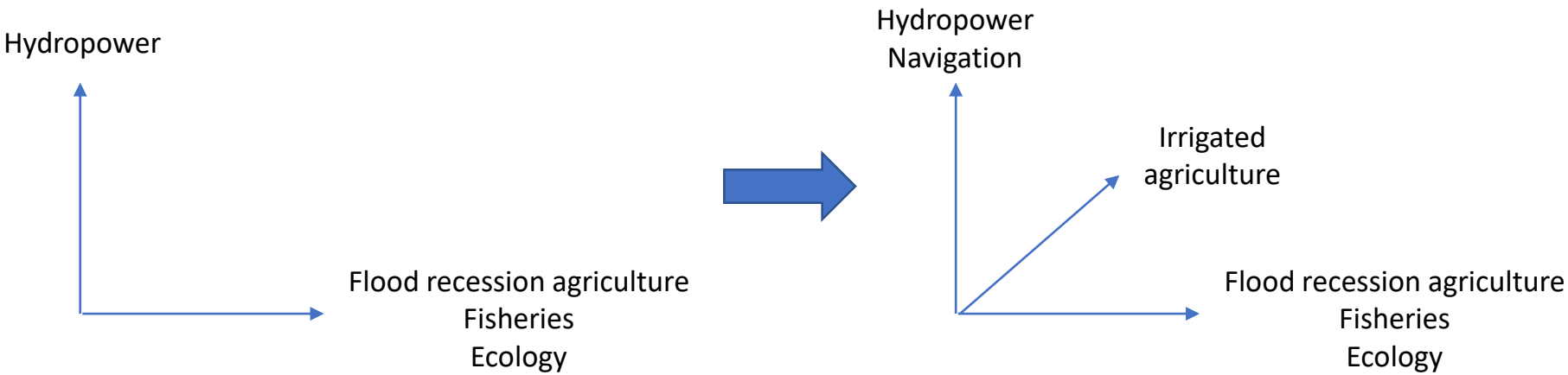
- The thick lines = the average performance of a particular scenario
- Thin lines = performance for a particular hydrological year → give an indication of the year-to-year variability

Basin-wide net revenues (2015, 2030, 2050)



Conclusions and recommendations

- Future developments of the basin will exacerbate the existing trade-offs between competing uses

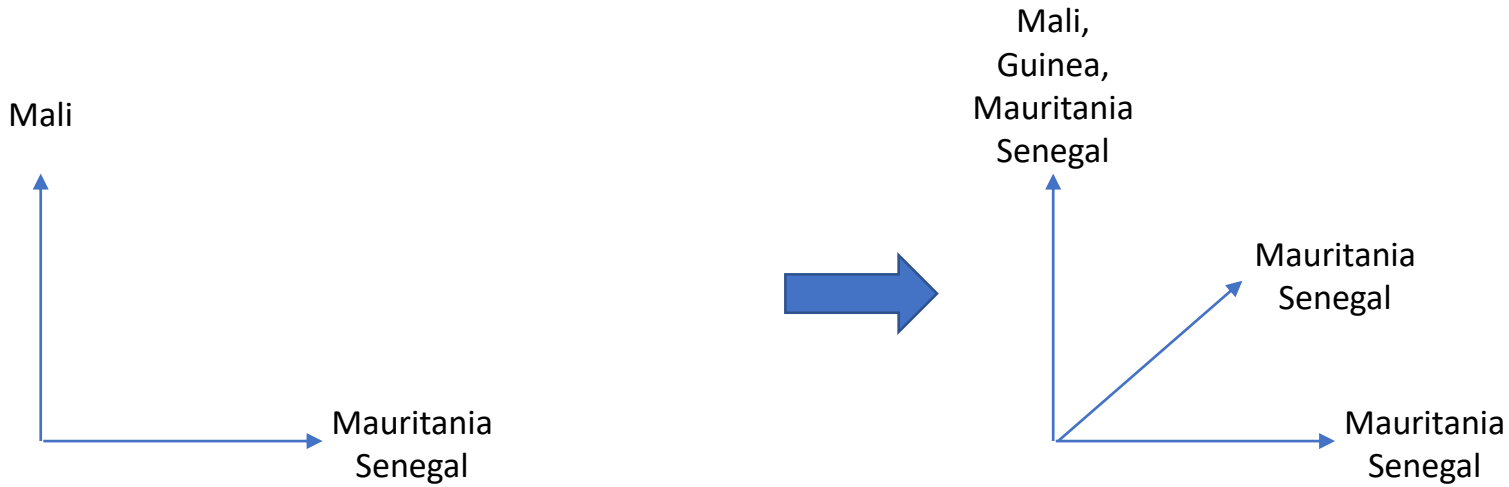


Baseline 2015

Full-development 2050

Conclusions and recommendations

- Future developments of the basin will exacerbate the existing trade-offs between competing uses
- Inter and intra-country trade-offs



Baseline 2015

Full-development 2050

Conclusions and recommendations

- Food production sector more vulnerable to hydro-climatic variability
- The performance of the Senegal river system can be significantly improved through the coordinated operation of the multireservoir system
- Impact of climate change on trade-offs has yet to be carried out