What dams for Sahelian Africa?
Quels barrages pour l'Afrique sahélienne?

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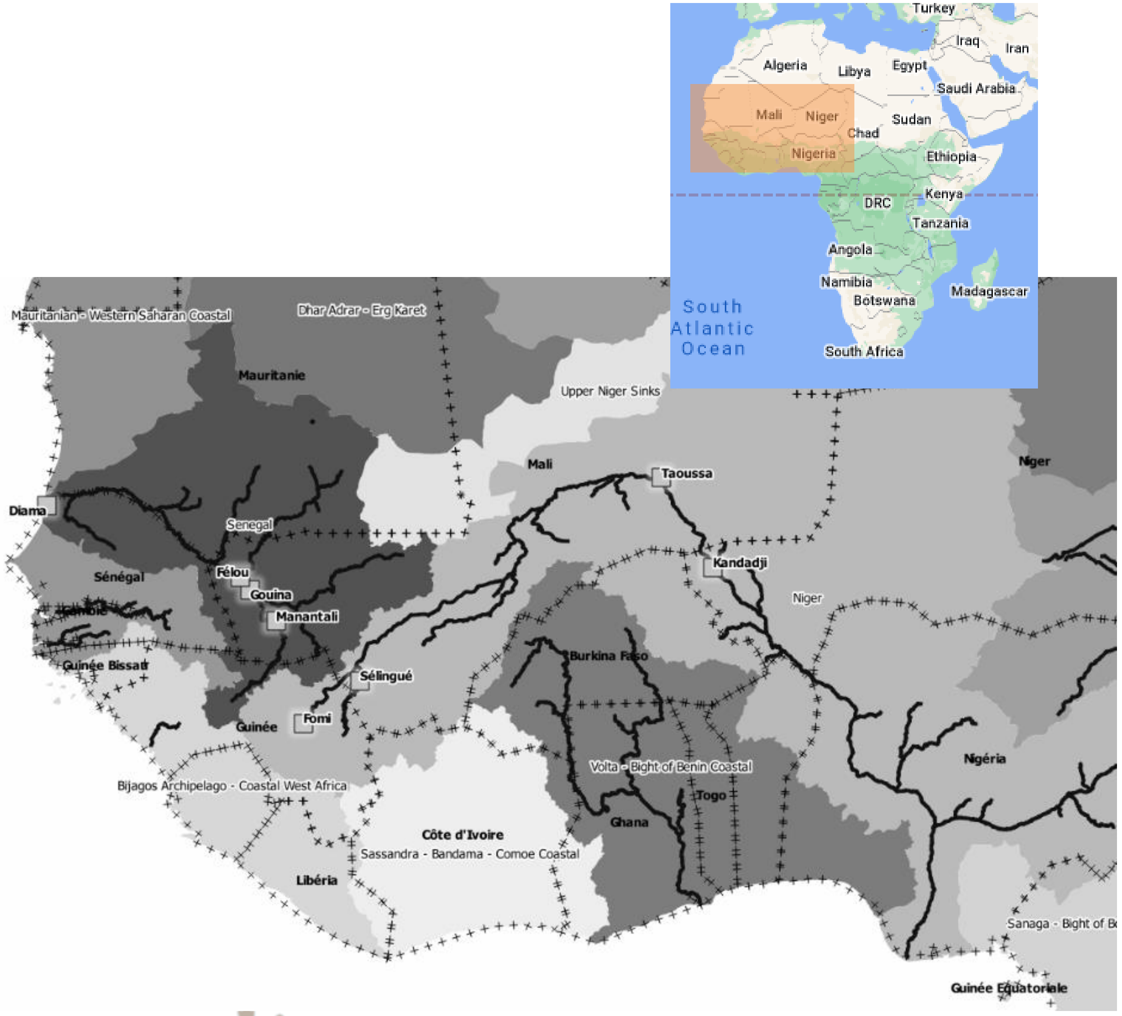
Specificity of dams in the Sahelian zone

- Geographic's area
  - Sahelian strip located in West Africa between the Sahara desert and the Gulf of Guinea
  - 2 large river basins :
    - Senegal, managed by OMVS (Guinea, Senegal, Mali, Mauritania)
    - Niger by NBA (Guinea, Mali, Niger, Nigeria, Cameroon, Ivory Coast, Benin, Burkina Faso, Chad).
- The 2 rivers sourced in the well-watered Fouta Djalon massif, the water tower of West Africa.
- Intense sunshine and high evaporation :
  - Solar potential : 2000-2500 kWh/m^2
  - evaporation at Taoussa dam in Mali : 2500 mm/year i.e. 3,6 km3/year i.e. 12,5% of annual inflow



Specificity of dams in the Sahelian zone

Existing and planned dams

- Niger basin
  - Sélingué on the Sankarani river : energy (175 GWh/year) and irrigated perimeters (1600 ha).
  - Two dams under construction : Taoussa (Mali) and Kandadji (Niger) for **environnemental purpose, irrigated perimeters** and energy
  - **Fomi/Moussako (Guinea)** under design **environnemental purpose, irrigated perimeters** and energy

- Senegal basin
  - **Manantali dam** on the Bafing **energy** (800 GWh/y) and **irrigated perimetersin Mali and Senegal** (100 000 ha), Félou (60 MW
  - The other projects are Gouina (140 MW), Koukoutamba (294 MW), Balassa (48 MW), Boureya (160 MW), Gourbassi (18 MW).

Specificity of dams in the Sahelian zone

Feedback from existing projects

- **Energy objectives generally achieved**
- Development of **irrigated perimeters** more uncertain : the **targeted yields per hectare rarely reached**
- **Fishing** in the dam reservoirs provides **important revenues**
- **Ecosystemic** objectives (low flow and floods) not clearly identified
- **Relocation of populations** living in the reservoir : a **very difficult issue**,
  - good land often only available in the river valley
  - replacement land difficult to maintain the standard of living of displaced populations

Specificity of dams in the Sahelian zone

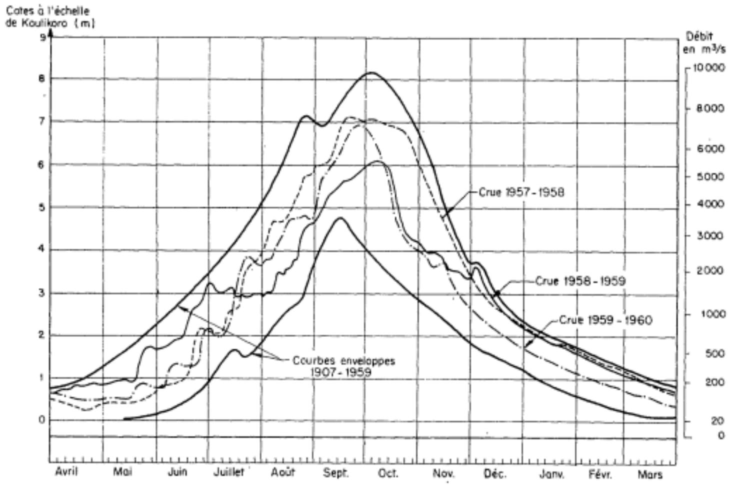
Difficult conditions

- Unfavorable natural conditions
  - hydroelectric fall created by the dam itself - no natural fall (except Guina and Felou)
  - low relief → large and shallow reservoir
  - river regime with long dry season → large reservoir to ensure a minimum of hydroelectric production in dry season
- Consequence for the project
  - large dam in a wide valley with high construction cost
  - shallow, very extensive reservoirs → huge water losses through evaporation
  - large population displacement (more than 50,000 people in Kandadji)
  - Dead storage (lost...): 14% of the surface of the reservoir in Kandadji

Difficult to make a "good" dam in this context

Water management issues of in large basins of West Africa

- **Seasonal and variable surface water resources, mainly supplied by the Fouta Djalon massif**
  - Unimodal monsoon regime with a dry season and an annual flood
  - High interannual variability
  - Impact of climate change
- **Traditional activities at the rhythm of the flood**
  - The flood plains are the site of fishing, livestock, cereal crops and fodder (sorghum, rice, cowpeas, bourgou ...).
  - Flooding allows for soil fertilization.
  - Agricultural activities in the plain complement those of the flooded lands and depend on local rainfall.
  - Importance of receding flood crops
  - Numerous fishing ponds when the flood recedes



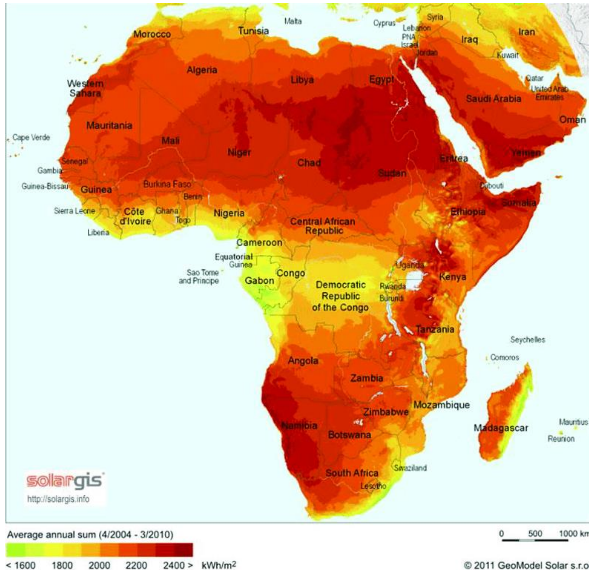

Baro pond

Water management issues of in large basins of West Africa

- **Sharing the benefits structuring project is difficult**
  - irrigated crops versus traditional crops : strong increase (up to x8) in the productivity
  - But the large projects aggravates the vulnerability of not direct beneficiaries
  - Migration and adaptation of practices: migration of fishermen to large artificial reservoirs, pressure of breeders on low plains, transformation of pastures into food crops
  - Relocation: always a challenge
- **Hydroelectricity and other uses may conflict**
  - Hydroelectricity, a source of renewable and low-cost energy
  - Other uses must be considered to guarantee a sharing of the benefits
    - flood support for traditional activities,
    - safeguarding of ecosystem resources,
    - safeguarding of a minimum flow for water supply needs and water quality.
  - ➡ constraining schedule of water availability

Hydroelectricity, the most profitable component of project, conflicts with other uses

Are hydrosolar projects the solution?



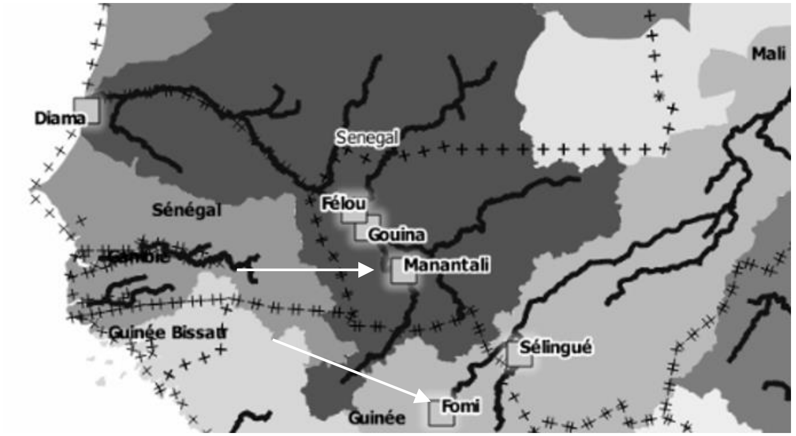
- **Africa is the sunniest continent**
  - Very good potential solar potential : Senegal, Mali, Niger, Burkina, Chad
  - Good potential : Guinea
  - Fairly good potential: Ivory Coast, Ghana, Togo, Benin, Nigeria, North Cameroon with a strong North-South gradient for all these countries
- **The Sahelian context is not optimal for hydropower** due to unfavorable natural conditions and conflicts of water use.

Can hydrosolar coupling enhance projects?

- Two example of large regulating reservoir in the upstream catchment
  - **Fomi** dam in Guinea: environmental and hydroagricultural vocation

    Can HS optimize electricity production?
  - The Manantali dam in Mali: a hydroelectric project :

    Can HS optimize water resources for other uses?



Are hydrosolar projects the solution?

Fomi dam in Guinea (under design)

- Located in Upper Guinea on the Niandan River
- 1 of the 3 NBA structuring dams (with Kandadji and Taoussa)
- Large reservoir at the head of the basin: capacity 3 to 5 km^3
- The objectives of the Fomi dam
  - Low water support: target flow 50 m^3/s at the entrance to the IND, a wetland of worldwide importance
  - Supply the irrigated areas of the Office du Niger
  - Minimum flood to safeguard crops associated with flooding of the plains and to mitigate the impacts on wetlands (ponds and DIN)
  - Hydroelectric production corresponding to the turbining of the releases defined by the three previous uses.

⇒ Strong penalty of the hydroelectric potential

  - Annual production drop from 312 GWh to 264 GWh: 15% loss
  - Guaranteed power90% : 31 to 10 MW

Can the addition of a hybrid solar power plant improve the energy performance of the project?

Are hydrosolar projects the solution?

Fomi dam in Guinea (under design)

- An installed capacity of 50 MW of solar power allows to compensate the loss of energy production while adopting the optimized management of the water resource (support of low water level, hydroagriculture, artificial flood).
- The guaranteed power increases from 10 to 16 MW.

Is the operation profitable?

- The economic value of the services provided by the hydrosolar plant in terms of water resources is evaluated
  - development of the irrigated perimeters in total control: benefit 500 €/ha/year
  - controlled submersion crops safeguarded: net benefit 2400 €/ha/year
  - services rendered by low water support: willingness to pay 1 euro per person per year (PADD
- YES: a 50 MW solar power plant (capex of 35 M€ and Opex of 2%) financed by the gains on irrigation in total control, crops in controlled submersion and low water support over 25 years with an IRR close to 5%.
- But: guaranteed power down from 31 to 16 MW, disadvantage mitigated by interconnection to Guinean and Malian electrical systems.

The addition of a 50 MW solar power plant makes it possible to compensate for the energy penalty of a management driven by water resource objectives.

Are hydrosolar projects the solution?

Manantali dam (Mali)

- The Manantali reservoir is located on a tributary of the Senegal River
  - Primary objective : energy production
    - Large reservoir of 12 km3.
    - Installed capacity 205 MW for a flow rate of 475 m3/s and a head of 40 m
    - Productivity: about 850 GWh/y.
  - Secondary objective: low water support 200 m3/s at Bakel
  - Other objective: **support of the annual flood** (artificial flood) in conflict with the first 2

Addition of a solar plant allows artificial flood by saving water in the dry season.

- A 70 MW solar plant allows the same annual production **with flood support service**
- The cost of the solar plants is paid by
  - increased flood related revenues from agriculture
  - surplus energy obtained when hydrological conditions do not require artificial flooding

Are hydrosolar projects the solution?

Conclusion

- **Unfavorable conditions for dams:**
  - wide valley with little relief
  - monsoon hydrological regime requiring large reservoirs
  - large, shallow reservoir subject to intense evaporation and critical environmental and social impacts
  - low head for hydroelectric production
- **Multipurpose projects**, in a context of increasing water demand, scarcity of the resource and conflict of use
  - Energy production
  - Irrigation in total control and receding flood crops supporting the riparian populations
  - Support of low water levels
  - Support to the annual flood essential to the safeguard of wetlands and their ecosystem

Possible to improve the performance of HPP by adding a hybrid solar power plant to optimize the use of the water resource and energy production.