Groundwater management and climate impacts: Analysis of the Niayes region of Senegal

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Context: Climate Change and irrigated agriculture in Senegal

- Irrigated agriculture
  - Senegal River Valley
  - Northern coastal region called Niayes

- Niayes
  - Main area of horticultural crops’ production and supplies 40% of horticultural products’ market (Senegal’s Direction of Horticulture, 2010)

- Horticulture, an important source of revenue to producers and contributes to the country’s economy (exports, raw material to food processing industry, food security, etc.)

- Producers use almost exclusively groundwater for irrigation
Context: Climate and irrigation water availability in Coastal North of Senegal Niayes

• Studies show average decrease of GW levels in 1958-1994 period (Aguiar, 2010)

• Aquifer recharge is also low or absent during dry season in the south of the area (Dasylva, 2005)

• Hydrologic studies showed variable recharge depending mostly on precipitation levels (Gaye, 1990; Eil Faid, 1999; Tine, 2004)

• Besides discharge related to climate conditions (precipitations and evaporation), the aquifer is subject to competing use: potable water needs for urban population, rural populations boreholes, horticultural producers

⇒⇒ Assess the impact of rainfall variability (normal and dry scenarios) on irrigation water availability and its implications for farmer welfare and policies
Sample and data

- **Area of study:** Niayes (Dakar, Thies, Louga, St-Louis)
- **ISRA-BAME Survey data** undertaken in 2014 on agricultural activities of 369 horticultural crop producers
- Data on crops, inputs, labor quantities and costs and associated revenues
- **Hydrologic and climate data** from national institutions

*Figure 1: Map Niayes area (adapted from PADEN)*
Methodology: integrated approach

- Stochastic model for precipitation scenarios
- 10 years precipitation scenarios: 2015-2025

Farm model calibrated with PMP approach (Howitt, 1995)

Hydro-economic model
Max (B(w)-C(w))
s.t. equation of motion

Water demand function for producers (D(W))
Per hectare irrigation water used at t0

Water extracted for irrigation

Stochastic model for precipitation scenarios
Results: simulated rainfalls

- Use of **Standardized Precipitation Index** (1993 par McKee, Doesken et Kleist) and rainfall data 1970-2011 to define year types and build probability transition matrix with a first order Markov chain

19% decrease in precipitations on average
Results: Depleting resource over time

G-S effect when just accounting for farmers benefits
Results: Difference in Ag withdrawals under base and dry scenarios

More withdrawals in base scenario.
Results: Difference in aquifer levels under base and dry scenarios

Positive difference: higher aquifer lift in dry case => less water availability in dry case

Graph showing the difference in aquifer levels in meters between base and dry scenarios over a 10-year period. The graph indicates that the difference increases over time, with positive values indicating higher aquifer levels in the dry scenario compared to the base scenario.
Policy implications: Including additional costs in objective function

• The “Gisser-Sanchez” effect, often mentioned in literature, refers to the relatively small gains to optimal resource management that some models show.

• Some authors have shown this could arise from the functional form or from the lack of accounting for the environmental externalities associated with the resource (e.g. ecosystem benefits, etc).

• We carried out an exercise to add a quadratic environmental cost and found that it leads to noticeable differences between myopic and optimal lift.
Policy implications: Changing GW lift with environmental cost

The magnitude of the environmental cost that would lead the social planner to stabilize the aquifer is equivalent to a user cost of between 0.2 and 0.3 fcfa per cubic meters.

On average, 11 million cubic meters are required annually to stabilize the resource over the next ten years (2015-2025).
Conclusions

• Regardless of the climate scenario GW resources are likely to decline over time under prevailing conditions in the Niayes area

• Results also highlight small differences between myopic and optimal situations when we just account for on-farm net benefits

• To stabilize the resource, policy makers should think of a range of options including:
  – increasing recharge into the aquifer
  – demand side measures (focusing on ag water use)

• Further work is needed to quantify the potential environmental cost (say saline intrusion) of depleting the aquifer

• Extend the hydro-economic model into a four cell aquifer model to account for spatial heterogeneity