Mapping Irrigation Potential from Renewable Groundwater in Africa

A Development Perspective

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Presentation outline

1. Introduction

2. Mapping sustainable physical groundwater irrigation potential (PGWIP)

3. Mapping the groundwater irrigation development potential (GWIDP)

4. The combined groundwater irrigation potential (CGWIP)

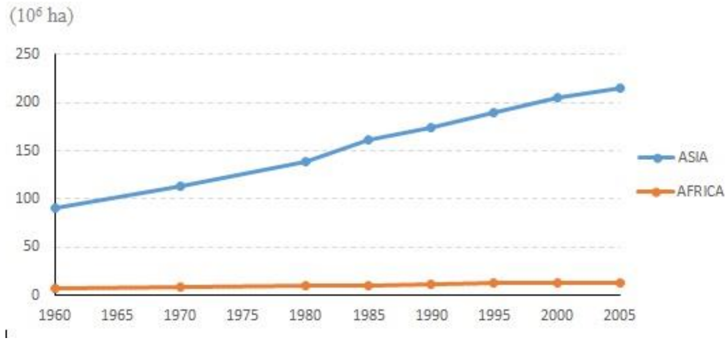
5. Conclusions

Introduction

- Need to increase crop production in Africa to meet future food demand:
  - Population is projected to reach at 1,634 million by 2030 (+500 million)
  - Undernourished population increase by 35 million over the last 20 years
  - Crops represent 89% of the diet in Sub-Sahara Africa (SSA)

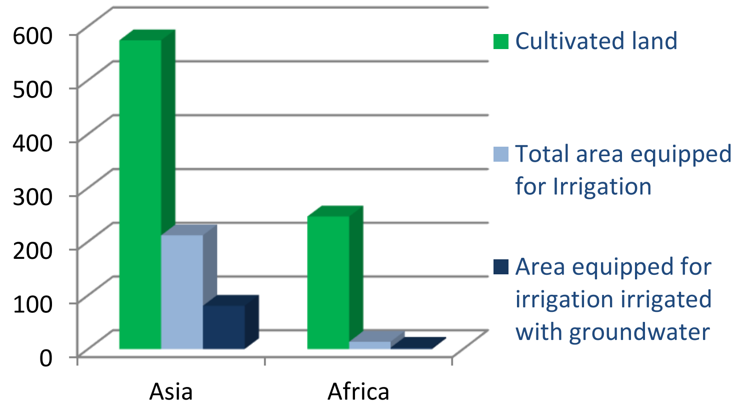
- Crop production growth in SAA is mainly due to extension of cultivated area and cropping intensities while crop yield improvement is low

- Irrigation can play a significant role in increasing crop yield. However, development of area equipped for irrigation is slow in Africa (only +6.2 million hectares over last 45 years)



Introduction

- Groundwater: under-utilized water source for irrigation



- 1% of cultivated land is equipped for irrigation with GW in Africa, 14% in Asia (Siebert et al., 2010)
- Huge groundwater storage in Africa (MacDonald et al., 2012) but not all available for abstraction, and unevenly distributed
- Groundwater provides an important buffer to climate variability and change. It is relatively affordable, safe and reliable
- Yields of groundwater irrigated areas are typically much higher than areas under surface water irrigation

→ Where and how much of an area can renewable groundwater physically irrigate over Africa? (PGWIP)

→ Where should groundwater irrigation be developed in Africa? (GWIDP)

→ What is the combined potential? (CGWIP)

PGWIP - Methodology

- Based on water balance calculation done annually over a 41 year period (1960 – 2000) at a resolution of 50 km x 50 km

$$\boldsymbol{PGWIP}\ (m^2) = \frac{GW\ Available\ (m^3\ year^{-1})}{Irrig.Water\ Demand\ (m\ year^{-1})}$$ (calculated annually)

$$\boldsymbol{GW\ Available} = GW\ Recharge - Human\ GW\ Demand - Environ.\ GW\ Req$$

(calculated annually then averaged over 41 years to consider buffer effect of GW)

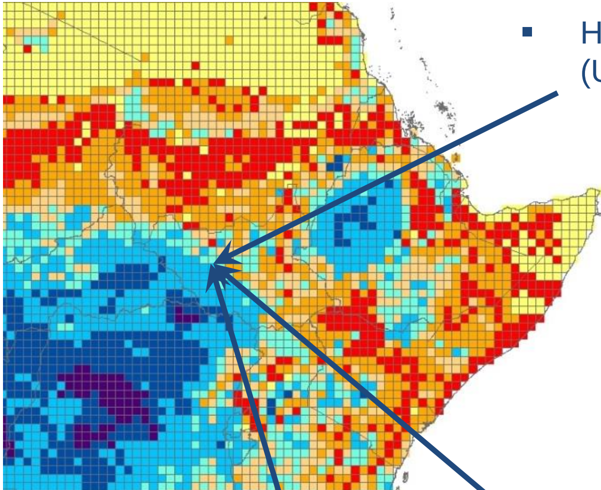
$$\boldsymbol{Irrig.\ Water\ Demand} = \frac{\{\sum_{i=1}^{n}\left(\left[\sum_{j=1}^{m}(Crop\ Water\ Demand - Green\ Water)_j\right] \times [\%\ of\ Area]_i\right)\}}{Irrig.\ Efficiency}$$

$$\boldsymbol{Irrig.\ Water\ Demand} = \frac{Net\ Irrg.Water\ Demand}{Irrig.Efficiency}$$ (n= crop)

(Calculated monthly then summed for annual value)

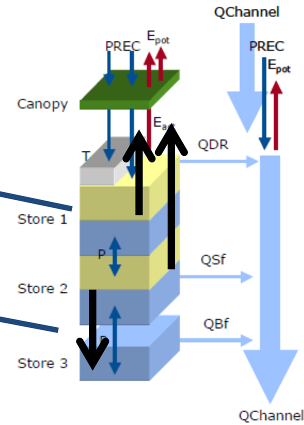
- Some assumptions in computations
  - GW is the only water source for irrigation (no conjunctive use with SW)
  - GW is usable and accessible (no quality, yield, or socio-economic constraints)
  - GW is locally available
  - Population and climate stable

PGWIP - Methodology



Resolution:
0.5 degree
(≈ 50 km x 50 km cell)

- Hydrological data from the PCR-GLOBWB model (Utrecht University, the Netherlands, Wada et al., 2011)
  - Reference Evapotranspiration
  - Water available for crop from rain (green water = transpiration soil 1 and 2)
  - Recharge



- Other GW uses
  - human activities (domestic, livestock, industrial) based on ''present'' human water demand derived from density of population and livestock, and unit requirement (FAO, geonetwork)
  - environment based on according to three different scenarios:
    - Scenario 1 : 70 % of the recharge goes to environment
    - Scenario 2 : 50 % of the recharge goes to environment
    - Scenario 3 : 30 % of the recharge goes to environment

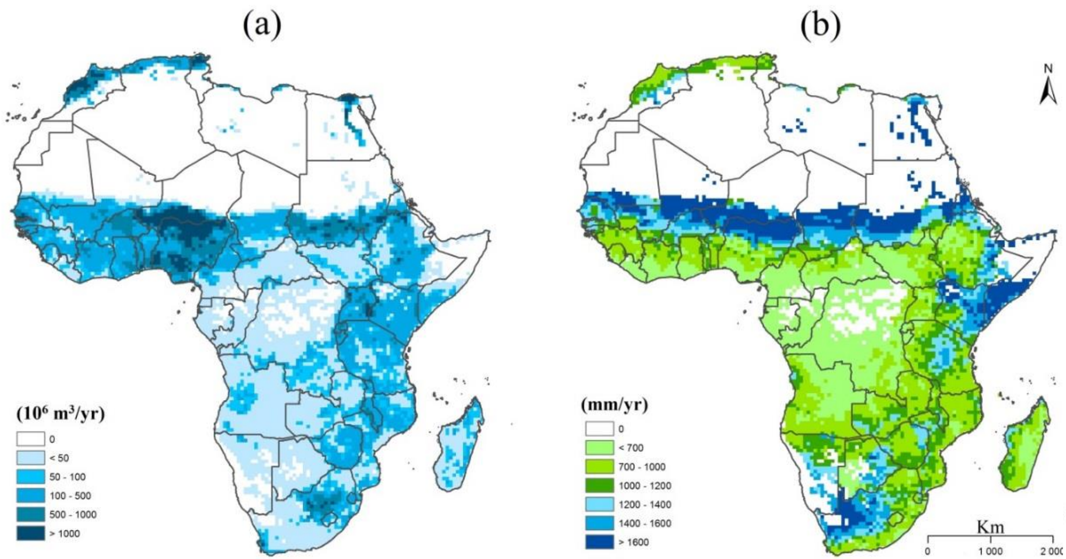
- Crop data
  - Crop distribution
  - Crop water demand
  - Irrigation efficiency

  ➡ monthly calendar for crop group water demand

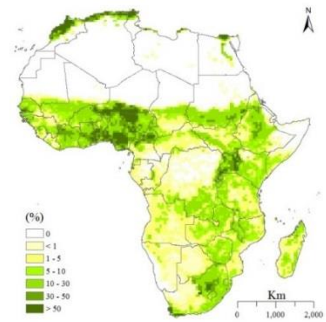
➡ **Different geographical data compiled in GIS**

PGWIP - Results

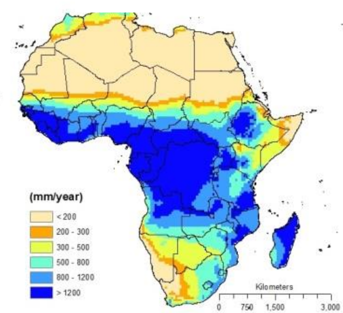
- Average Net Irrigation Water Demand (1960-2000)



Cropland



Rainfall

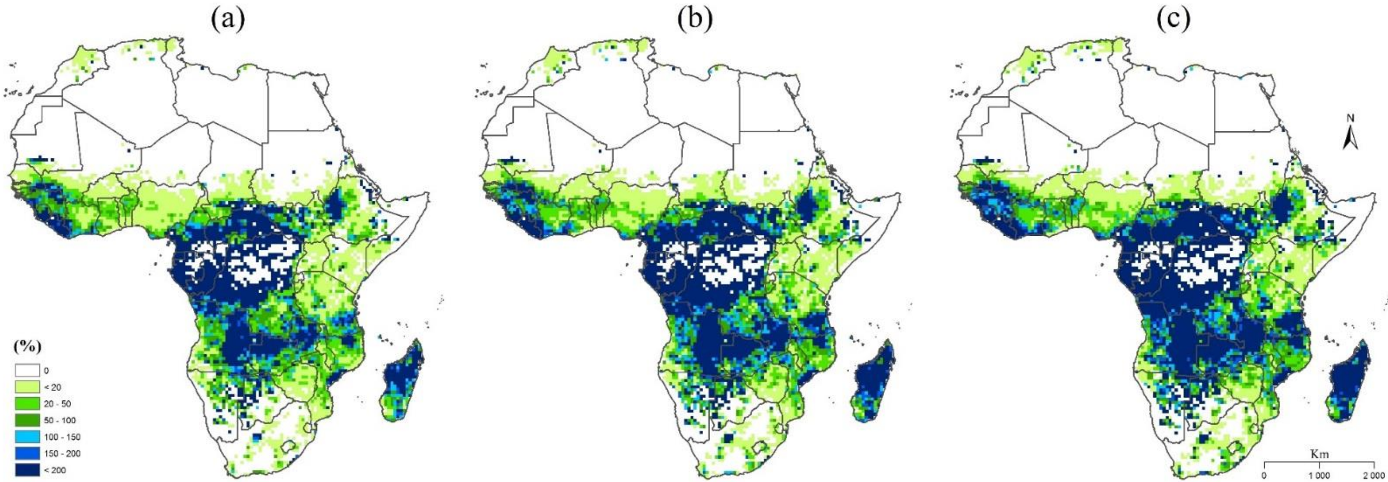


PGWIP - Results

- Proportion of cropland irrigable with groundwater:

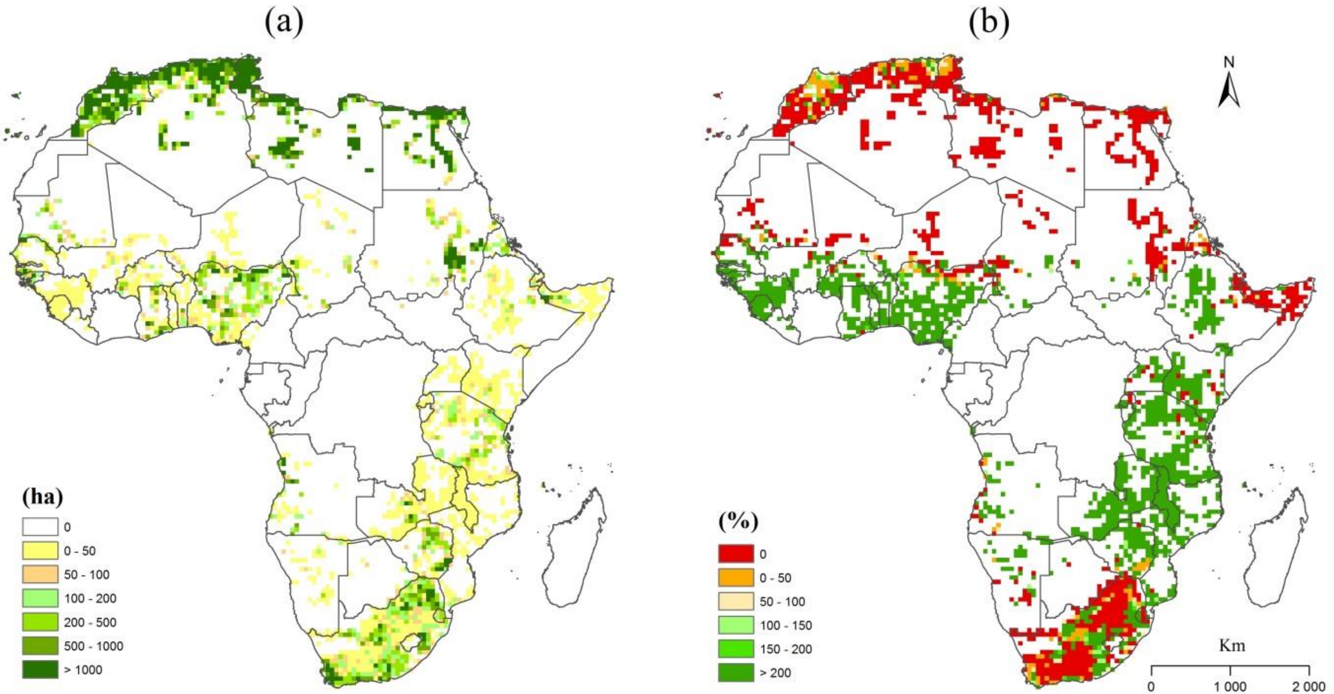
	when environmental requirements represent :		
	(a) 70% of recharge	(b) 50% of recharge	(c) 30% of recharge
Area (10^6 ha)	44.6	74.9	105.3
% of cropland	20.5%	34.5%	48.5%

A factor of **20** increase in overall GWI area possible (from 2 to ≈ 40 mill ha.)



PGWIP - Results

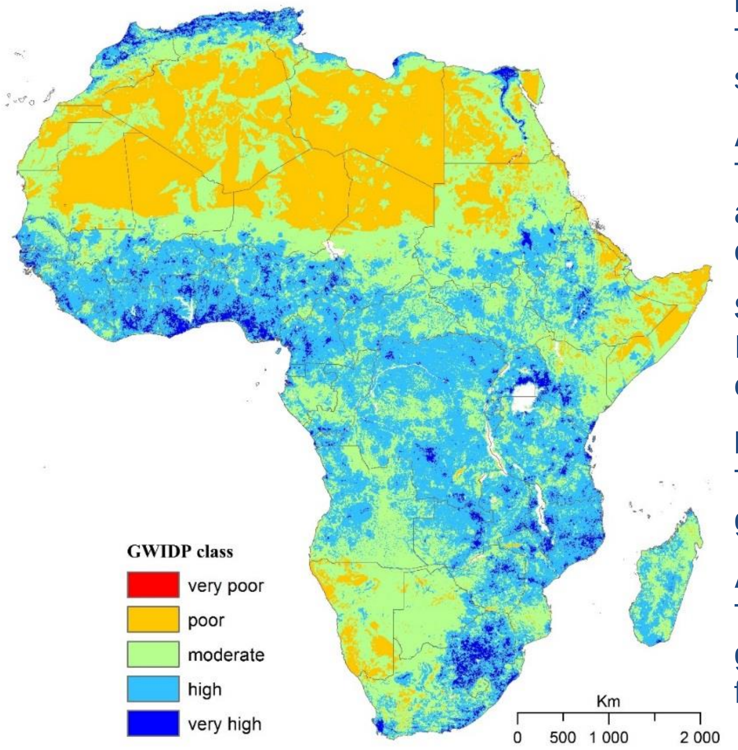
- Comparison with GW irrigated cropland in 2005 (Siebert et al., 2010)



(**a) Actual** area irrigated with groundwater in 2005 expressed in ha. per cell adapted from Siebert et al. (2010) and **(b)** physical groundwater irrigation potential for scenario b for the year 2000 expressed as the percentage of the area irrigated with groundwater in 2005

GWIDP – Methodology and Results

The GWIDP is determined by combining the factors influencing the groundwater irrigation development in Africa through a composite mapping analysis. These factors are:



Lack of access to surface water:
The GWIDP decreases closer to perennial surface water resources

Access to market:
The GWIDP increases closer to towns and roads as groundwater irrigation is often associated with cash crops

Soil suitability for agriculture:
Irrigation is more suitable for specific soil characteristics.

Borehole investment:
The GWIDP decreases with the depth of the groundwater table

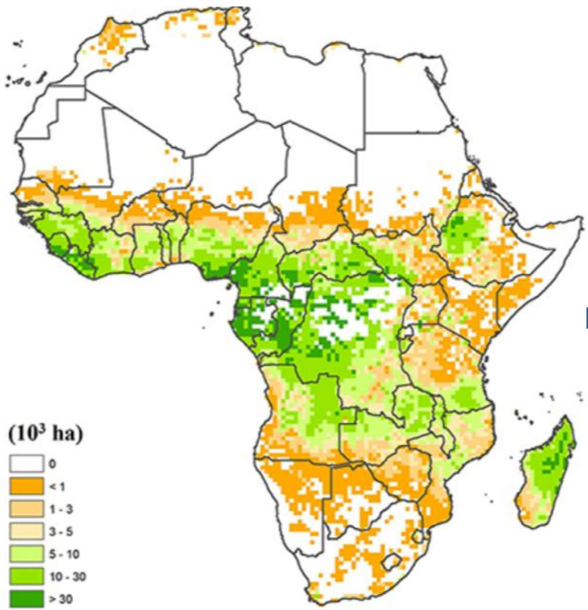
Access to energy:
The GWIDP increases closer to the electrical grid as electricity is the cheapest energy source for pumping.

<u>C</u>GWIP - Results

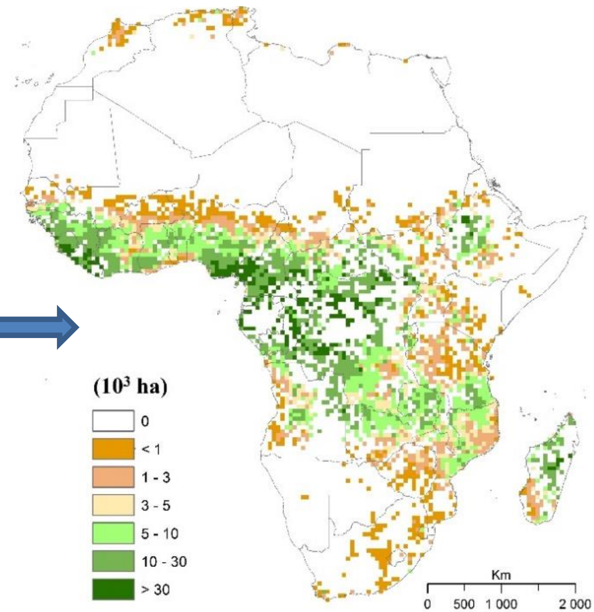
What is the Groundwater Irrigation Potential (GWIP) of Africa?

The combined GWIP (<u>C</u>GWIP) is determined by overlaying the <u>P</u>GWIP for the most constraining case (70% of the recharge goes to the environment) with GWI<u>D</u>P map. Only those areas where GWI<u>D</u>P is high and very high are included.

<u>P</u>GWIP

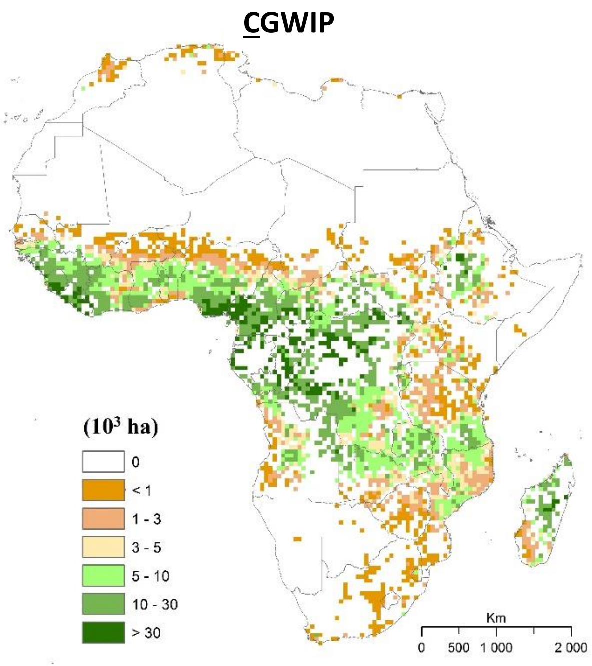


<u>C</u>GWIP



CGWIP - Results

What is the Groundwater Irrigation Potential (CGWIP) in Africa?



In these areas, the annual renewable groundwater availability for irrigation is **442 km^3 a^{-1}** which represent about 64% of the total annual renewable groundwater availability for irrigation in Africa.

Over the continent, CGWIP amounts to an accumulated total area of cropland irrigable with groundwater of **28.5 ×10^6 ha,** which is close to **15 times** more than the current groundwater irrigated cultivated lands.

In conclusion, groundwater irrigation can enhance smallholder livelihoods significantly by increasing crop production and productivity, particularly in the semi-arid regions like Sahel and parts of East Africa where CGWIP is notable.

Groundwater Irrigation Potential in Africa - Conclusions

- A pan-Africa distributed map of GWIP from renewable resources has been produced for the first time
- Map shows spatial variability across Africa, and even within countries. In some areas (e.g. Northern Africa and South Africa), the potential has already been exhausted
- The potential (29 mill ha, up from presently 2 mill ha) is particularly significant and relevant in the semi-arid Sahel and East African corridor, especially for small-scale and smallholder irrigation, with huge poverty alleviation potential
- Actual potential will be greatly influenced by irrigation efficiency and crop choices
- Uncertainties relate to groundwater pumping yields
- Climate change might affect potential through change in groundwater recharge and crop water demand

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