

Mapping Irrigation Potential from Renewable Groundwater in Africa

A Development Perspective

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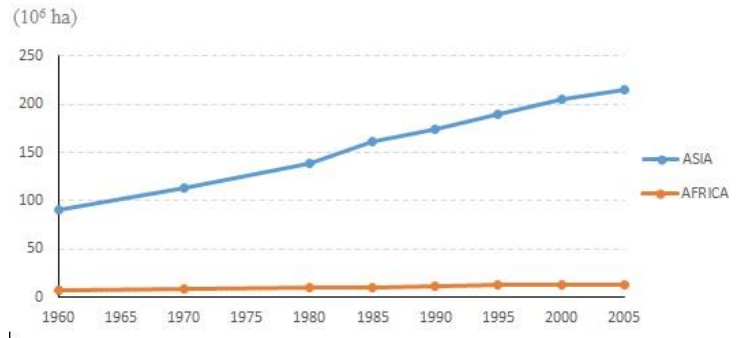


Presentation outline

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

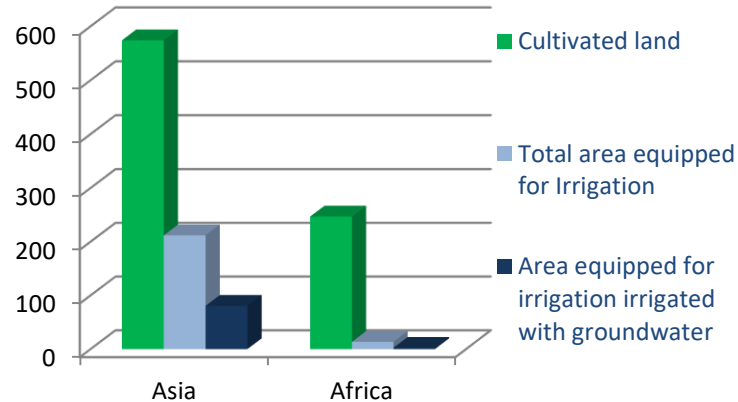
- Need to increase crop production in Africa to meet future food demand:
 - Population is projected to reach at 1,634 million by 2030 (+500 million)
 - Undernourished population increase by 35 million over the last 20 years
 - Crops represent 89% of the diet in Sub-Sahara Africa (SSA)
- Crop production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

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

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

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

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

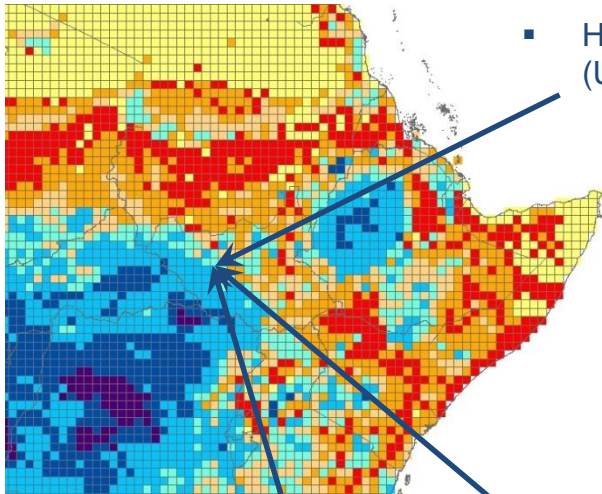
$$Irrig. \text{ Water Demand} = \frac{Net \text{ Irrg. Water Demand}}{Irrig. \text{ Efficiency}} \quad (n = \text{crop})$$

(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

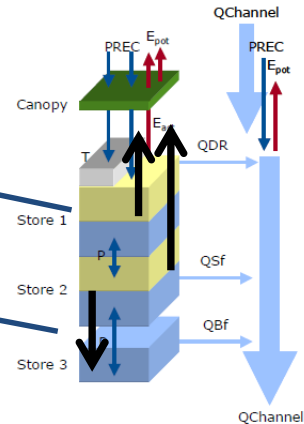


Resolution:
0.5 degree
($\approx 50 \text{ km} \times 50 \text{ km}$ cell)

- Crop data
 - Crop distribution
 - Crop water demand
 - Irrigation efficiency
- ➡ monthly calendar for crop group water demand

- 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

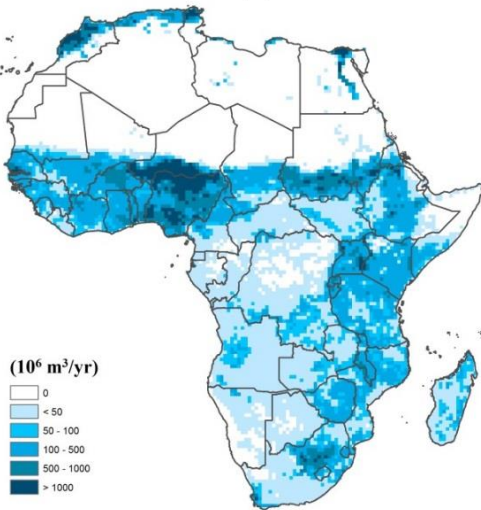


Different geographical data compiled in GIS

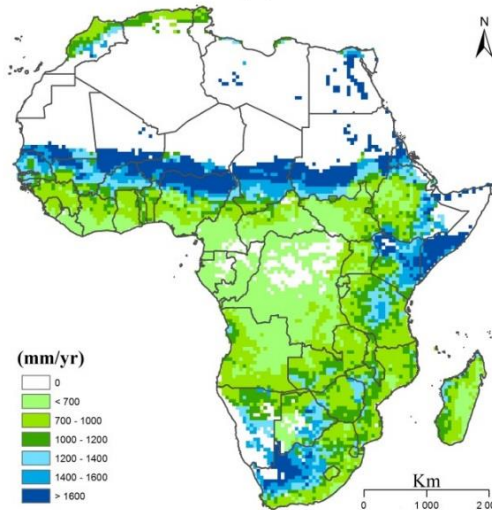
PGWIP - Results

■ Average Net Irrigation Water Demand (1960-2000)

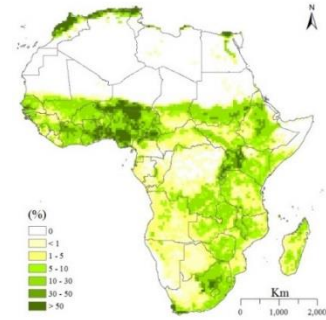
(a)



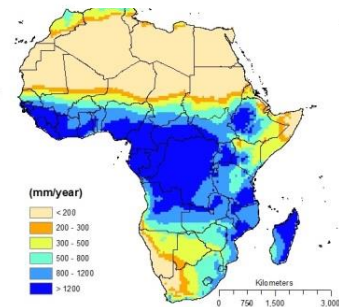
(b)



Cropland



Rainfall



PGWIP - Results

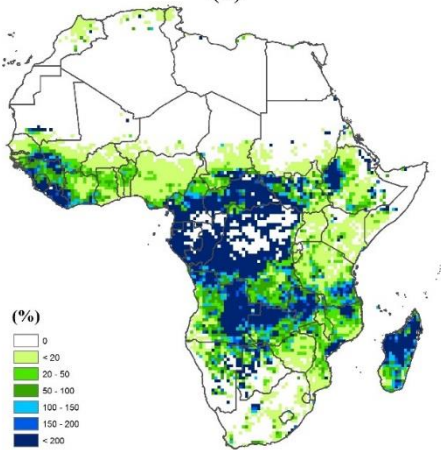
- Proportion of cropland irrigable with groundwater:

when environmental requirements represent :

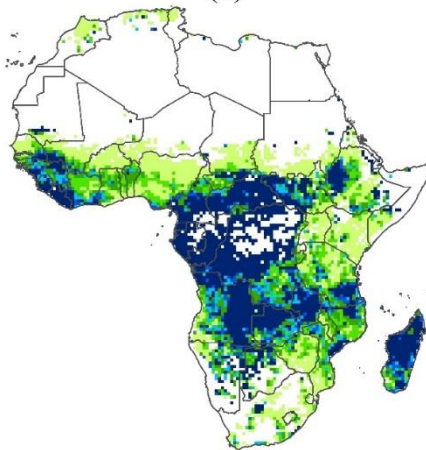
	(a) 70% of recharge	(b) 50% of recharge	(c) 30% of recharge
Area (10 ⁶ ha)	44.6	74.9	105.3
% of cropland	20.5%	34.5%	48.5%

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

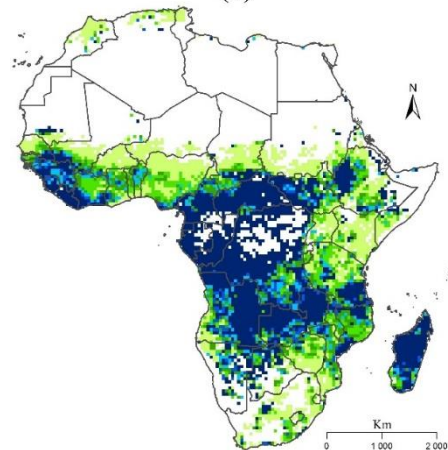
(a)



(b)

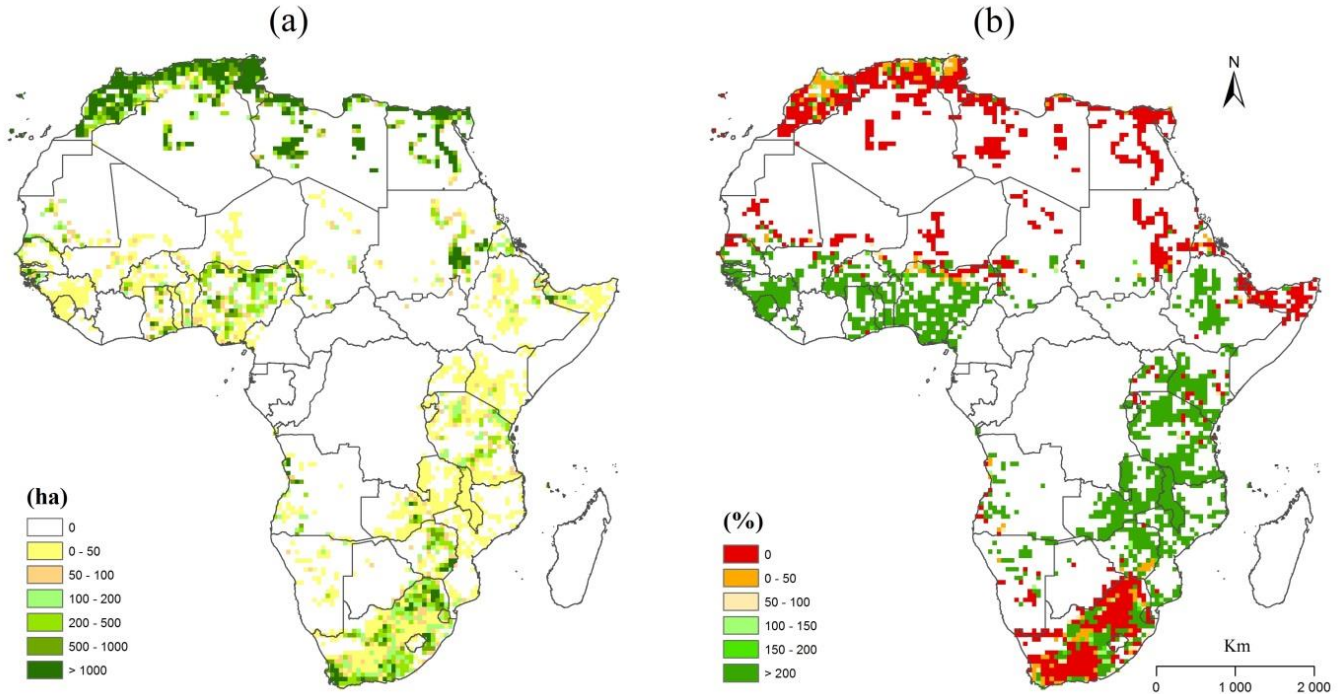


(c)



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:

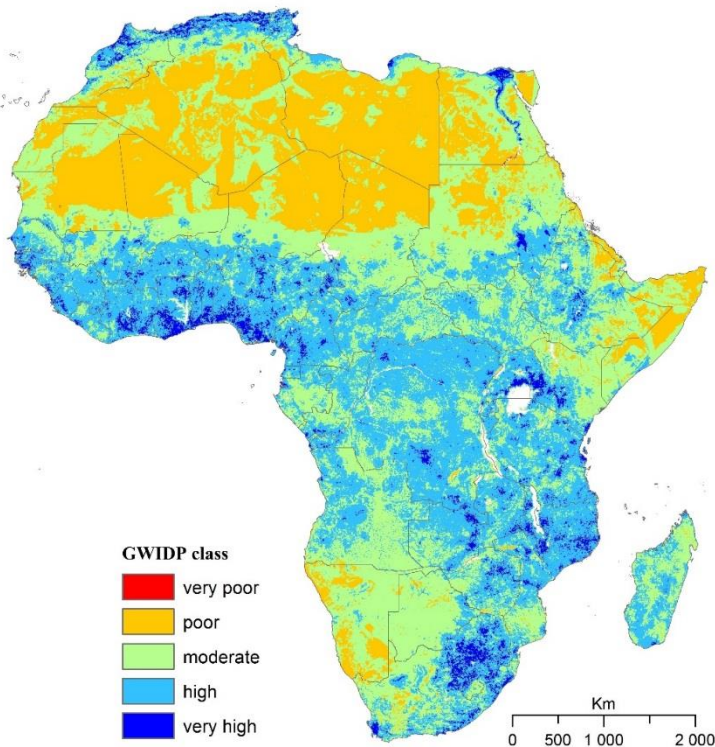
Irrigation is more suitable for specific soil characteristics.

Borehole investment:

The GWIDP decreases with the depth of the groundwater table

Access to energy:

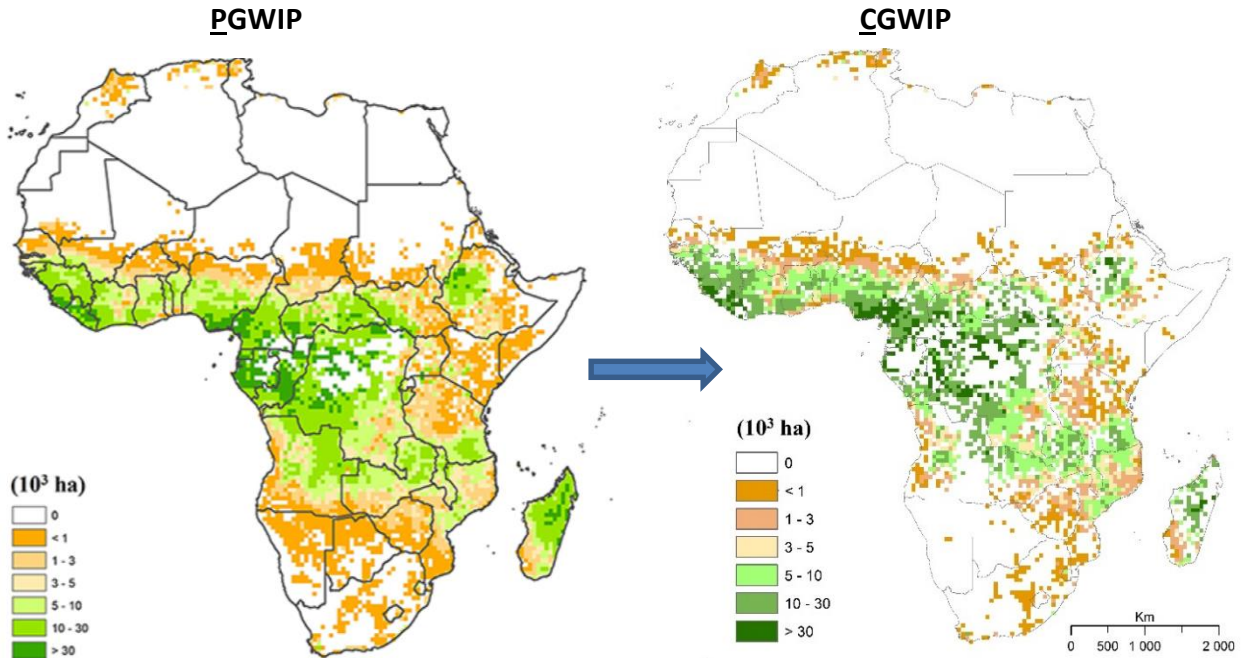
The GWIDP increases closer to the electrical grid as electricity is the cheapest energy source for pumping.



CGWIP - Results

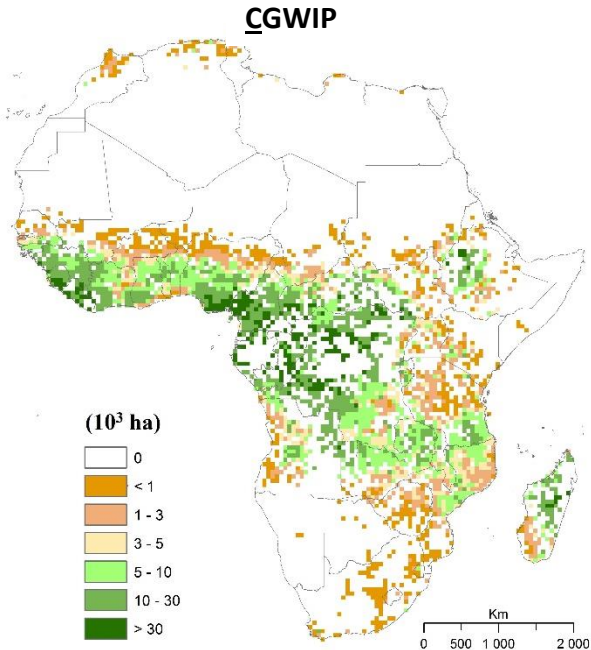
What is the Groundwater Irrigation Potential (GWIP) of Africa?

The combined GWIP (CGWIP) is determined by overlaying the PGWIP for the most constraining case (70% of the recharge goes to the environment) with GWIDP map. Only those areas where GWIDP is high and very high are included.



CGWIP - Results

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



In these areas, the annual renewable groundwater availability for irrigation is **442 km³ 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 ×10⁶ 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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Photo by: A. Lichanko

Photo by K. Villhøth

Thank You



Photo by X. Cai