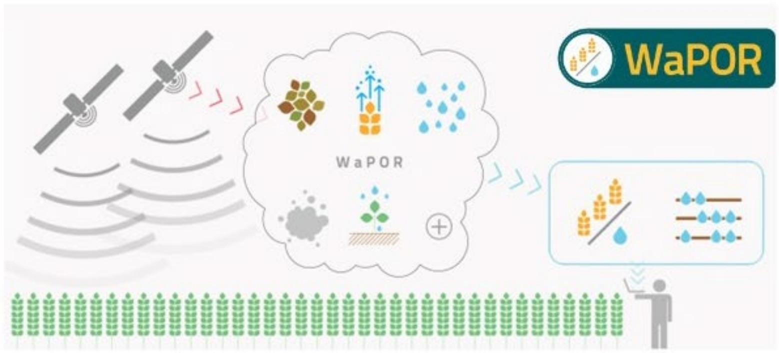
WaPOR4Awp

A dashboard for estimating agricultural water productivity to support monitoring SDG indicator 6.4.1 using WaPOR data



Objective

To develop an interactive dashboard to support monitoring Sustainable Development Goal (SDG) indicator 6.4.1 - Change in Water Use Efficiency (CWUE) using remote sensing data (RS). The focus will be on an alternative approach to estimate agricultural water use efficiency (water productivity) using the FAO WaPOR database (Safi, 2022; Gillet and Biancalani, 2022).

SDG indicator 6.4.1 – Change in Water Use Efficiency

SDG indicator 6.4.1 tracks the value added in US dollars per volume of water withdrawn. It considers water use by all economic activities aggregated into the three major sectors of agriculture, industry and the service sector. The indicator allows countries to assess to what extent their economic growth depends on the use of their water resources. SDG indicator 6.4.1 is calculated using the following equation (FAO, 2017).

$$WUE = A_{we} * P_A + M_{we} * P_M + S_{we} * P_S \qquad (1)$$

Where:

A_{we}, M_{we}, S_{we} = water use efficiency of agriculture, industry, and services sector [USD/m^3]

P_A, P_m, P_s = proportion of total water withdrawn per sector [%]

The data for computing this indicator is usually compiled by National Statistical Offices (NSO) of countries. To obtain a comprehensive data set annually requires a lot of human and financial resources, the data is therefore often incomplete and is filled through interpolation or using estimations. The data is reported at a national level, although regional differences in climate and water availability within countries can affect the interpretation of this indicator, in particular for agriculture. RS offers spatially disaggregated data which creates the opportunity to monitor land and water use at various scales, which can assist in monitoring the agricultural component of SDG 6.4.1.

Agricultural water use efficiency

The equation to calculate water use efficiency in irrigated agriculture (Awe) is as follows (FAO, 2017):

$$A_{we} = \frac{GVA_a * (1-C_r)}{V_a} \quad (2)$$

With:

GVA_a = Gross Value Added by agriculture (river and marine fisheries and forestry excluded) (USD)

V_a = Volume of water used by the agricultural sector (including irrigation, livestock, and aquaculture) (m^3)

$1\text{-}C_r$ = Proportion of agricultural *GVA* produced by irrigated agriculture obtained from AQUASTAT

FAO's WaPOR database

RS data for hydrological and agricultural applications has improved significantly over the past decade. More and more products are also available for open access. One such comprehensive database is WaPOR (FAO's data portal to monitor Water Productivity through Open access of Remotely sensed derived data) which provides information on biomass production and evapotranspiration for Africa and the Near East in near real-time, covering the period 1 January 2009 to date1. In addition to that, it provides annual Land Cover Classification (LCC) maps, based on Copernicus land use data from 2015 with an additional annually varying split of the croplands into irrigated and rainfed agriculture. Table 1 shows the WaPOR data used for the analyses. As the tool will support the annual reporting of the SDG at the country level, we will use WaPOR Level 1 – 250m resolution which covers the entire continent of Africa and parts of the Middle East.

Table 1. WaPOR data used for computing A_{we}

Data	WaPOR level	Spatial resolution	Temporal resolution
Actual evapotranspiration & interception (*ET*)	Level 1	250m	Monthly
Precipitation (*P*)	Level 1	5km	Monthly
Land cover classification (LCC)	Level 1	250m	Annual

An alternative approach for estimating A_{we} using remote sensing

Whereas RS provides a lot of opportunities, it is not able to monitor the denominator of the Awe (equation 2) on agricultural water withdrawals (V_a). However, RS can monitor the water consumption in irrigated agriculture (V_{ETb}) by monitoring the actual evapotranspiration. While the two are not the same, they are connected as can be seen in Figure 1. Actual evapotranspiration (ET) can come from two sources, rainfall and water withdrawal for irrigation, also called green and blue ET respectively (ET_g and ET_b) (Chukalla et al., 2015). Especially in large irrigation systems where irrigation water is reused many times, ET_b and water withdrawals can approximate each other (Hellegers and van Halsema, 2020), in other cases the difference can be approximated using an irrigation efficiency coefficient. Using V_{ETb}, instead of V_a, we decided to rename the indicator agricultural water productivity (A_{wp} in USD/m^3) to clearly distinguish between the two.

[1] https://wapor.apps.fao.org/home/WAPOR_2/1

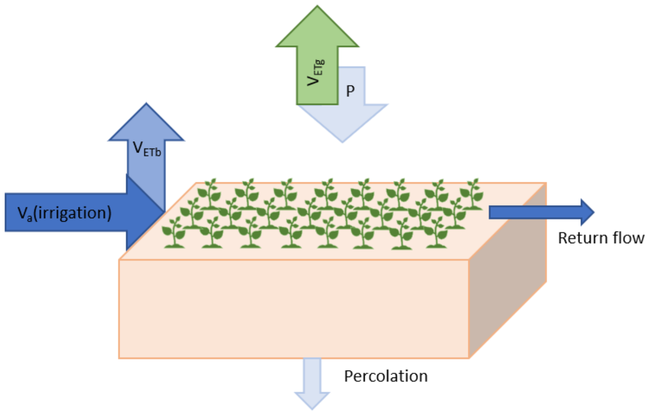


Figure 1 Differences between irrigation withdrawals in relation to ET_b (after Karimi et al., 2013)

There is another major distinction between A_{we} and A_{wp}, whereby the analyses of A_{wp} focus on irrigated agriculture, even though the definition of A_{we} includes livestock and aquaculture.

Methodology for estimating A_{wp}

An overview of the proposed workflow is presented in Figure 2. The numerator of equation 2 depicts the value derived from the water use (GVA_a * (1-C_r)), the information to calculate this is derived from global databases such as AQUASTAT and the World Bank. The denominator, depicting the water use by agriculture (V_{ETb}) is estimated using the FAO WaPOR database and described in the following section.

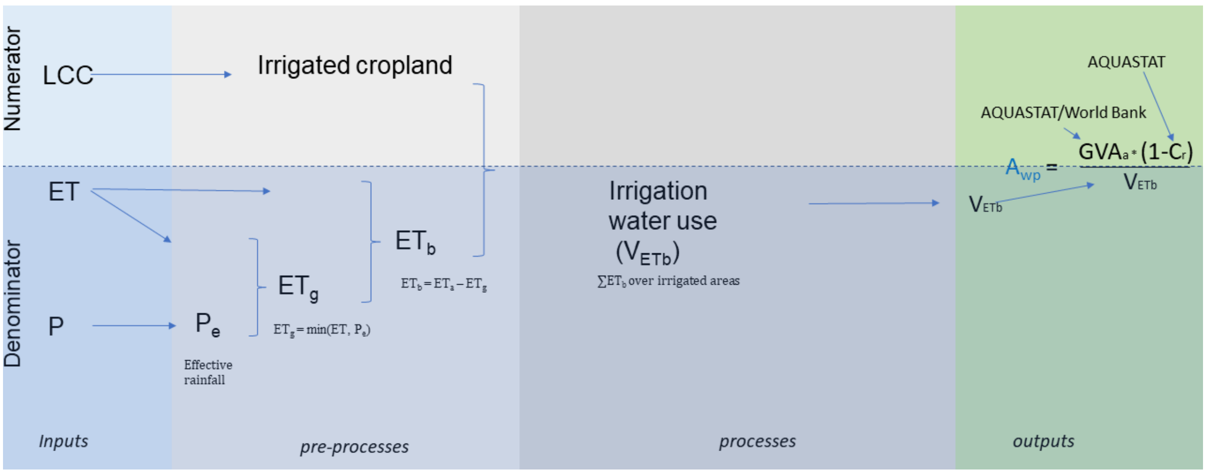


Figure 2. Computation workflow; further described in the following sections, based on Safi, 2022

Denominator of A_{wp} (V_{ETb})

While there are various ways to split ET_g and ET_b, the different approaches are not easy to validate as there are no direct measurements of ET_g and ET_b (Msigwa et al., 2021). We decided to use a simplified approach, approximating effective rainfall (P_e) to be ET_g. The effective monthly rainfall was calculated using Brouwer and Heibloem (1986)'s equations:

$$P_e = 0.8 * P - 25, \text{ if } P > 75 \text{ mm/month}$$
$$P_e = \max(0.6 * P - 10, 0), \text{ if } P < 75 \text{ mm/month} \quad (3)$$

ET_b or blue water use per annum (in mm/year) is then calculated at monthly timesteps and aggregated to annual values using the following formula:

$$ET_{b,y} = \sum_{n=1}^{12} max(ET - P_e, 0) \quad (4)$$

With ET being the actual evapotranspiration and interception from WaPOR. The final step is to aggregate $ET_{b,y}$ for the irrigated areas to compute the total water consumed (V_{ETb}) by irrigated agriculture:

$$V_{ETb} = \sum_{lcc=irr} ET_{b,y} \quad (5)$$

A_{wp} can then be calculated by adapting equation 2 (by replacing V_a with V_{ETb}):

$$A_{wp} = \frac{GVA_a * (1-C_r)}{V_{ETb}} \quad (6)$$

Change and trend in Awp

The final step is to calculate the change (c) and trend (t) in Awp using the following formulas, based on FAO (2017):

$$cA_{wp} = \frac{A_{wp,t}-A_{wp,t-1}}{A_{wp,t-1}} * 100 \text{ \#year to year} \quad (7)$$

$$tA_{wp} = \frac{A_{wp,t}-A_{wp,t-1}}{A_{wp,t-1}} * 100 \text{ \#start to base year (2015)} \quad (8)$$

Acknowledgements

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