Food and Agriculture Organization of the United Nations

Water Productivity Analysis using WaPOR

The case of Sugarcane

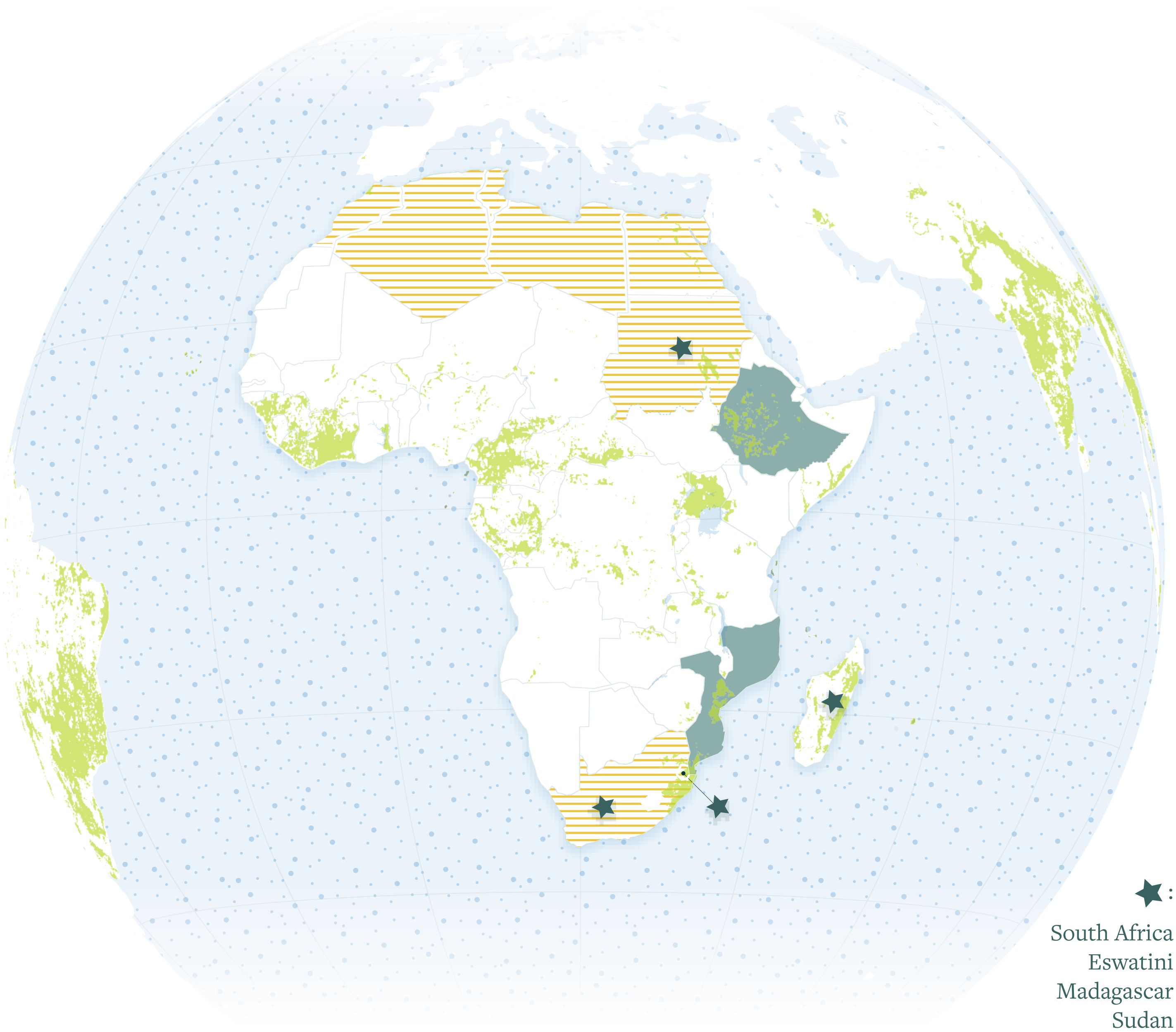
WaterPIP
Water Productivity Improvement in Practice

This analysis was produced under the **Water Productivity Improvement in Practice (WaterPIP) project**.

This document synthesises findings from two projects executed by two WaterPIP partners: IHE Deflt and MetaMeta. IHE Delft worked on the Xinavane case study while MetaMeta partners focused on Wonji.

Image source: Wikimedia Commons

A large part of the African continent boasts the right climatic conditions to grow sugarcane, a crop with potential for economic development and employment generation. Oxfam documented the doubling of employment figures in the Sofala province in Mozambique since the rehabilitation of two sugar estates that dated from the colonial period (Oxfam). However, any increase in production should be done sustainably, that is, taking into consideration the available land and water resources.
In fact, sugarcane is known to have a high year-round water demand to support optimal growth (typically 1,500-2,500 mm/year). The crop can therefore compete with other water users in the same basin, as all rely on finite water resources.



Most of the countries South of the Sahara Desert experience seasonal rainfall patterns with long periods with no rainfall, which constitute ideal conditions for growing sugarcane. Particularly during the dry season, competition for the scarce water resources can be fierce, even though at an annual and national scale it may seem that there is no water scarcity.

This case study demonstrates the use of remote sensing data to measure the water productivity and other indicators that give us a pulse of the sugarcane irrigation schemes and to help with decision-making regarding production and water use.

Map source: Natural Earth data modified to comply with UN, 2020.

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Final boundary between the Sudan and South Sudan has not yet been determined.

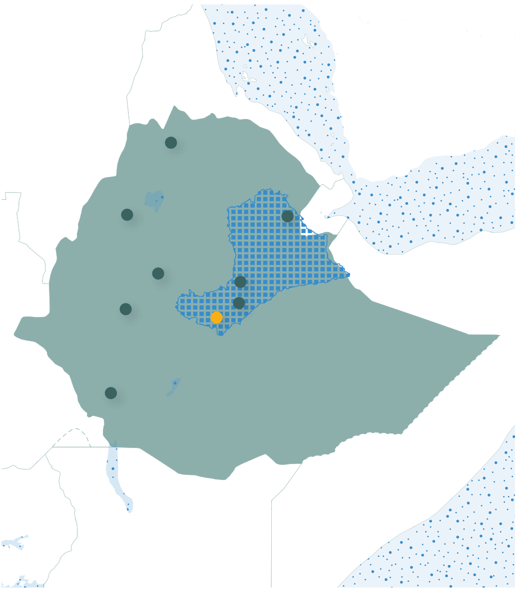
sugarcane production areas based on modelled data (HarvestChoice, 2015)

top sugarcane producers

case study countries of focus

countries suffering from water stress freshwater withdrawals as proportion of available freshwater resources above 50%, in 2018 (source: AQUASTAT)

Ethiopia

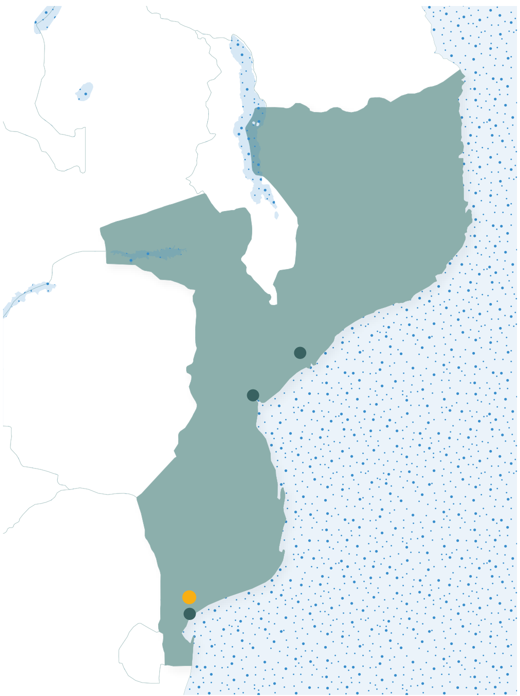


Ethiopia is one of the larger sugarcane producers in Africa with a total of 9 operational factories (● + ●).
Though Ethiopia itself does not suffer from water scarcity as seen in the world map on page 2, particular areas where sugarcane is grown, such as the Awash River Basin (▦) where there is a total of 4 factories, face high water stress during peak irrigation in the dry season.

Commercial production of sugarcane at the Wonji Estate (●) started in the 1950s, requiring large quantities of water from the Awash River, the main stream in the most utilized basin in Ethiopia. After decades of mono-culture farming, nutrients in the soils are being depleted and water logging (too much water in the root zone) is a common problem in Wonji.

This highlights the need for better water management informed by data. Through the Wonji case study, we will explore how remote sensing data can be used to evaluate the performance of different areas with different irrigation methods and to investigate what improvements can be made.

Mozambique



Map sources: Natural Earth data modified to comply with UN, 2020.

Production of sugarcane started during colonisation and was severely disrupted by the civil war that ended in 1992. In 1998, the government undertook the rehabilitation of the industry as the country benefits from ideal conditions for growing sugarcane. Xinavane (●), the estate that is object of this case study, is one of those rehabilitated estates.

Mozambique does not suffer from water scarcity at the national-level either, but at the local level too there can be periods of water shortage. The country is also particularly prone to acute weather events in both extremes, with increasingly frequent and severe occurences. In 2016 it was hit by a drought that deeply affected the country's food production. Conversely, in 2019, hurricane Ida caused innundation and widespread destruction in the most hardly hit parts of the country.

Through the example of Xinavane, we will examine how remote sensing data can help understand the implications of increasing agricultural production on the water consumption of the estate. Such information can be very important for planning and water allocation purposes as water management entities seek to make basins and agricultural systems more resilient.

WaPOR is FAO's portal to monitor Water Productivity through Open access of Remotely sensed derived data. Users have open access to the water productivity database and its thousands of underlying map layers.

To find out more about WaPOR, explore the portal and the website.

WaPOR data comes in raster format in a range of spatial and temporal resolutions and can provide information about an area in near real time in a way that is unparalleled by on-the-ground data collection. Some of the data layers offered are: evapotranspiration (as well as its individual components: evaporation, transpiration, interception), gross biomass water productivity, precipitation, net biomass production, land cover classification, etc.
Find out more about the data and its uses in the WaPOR catalogue.

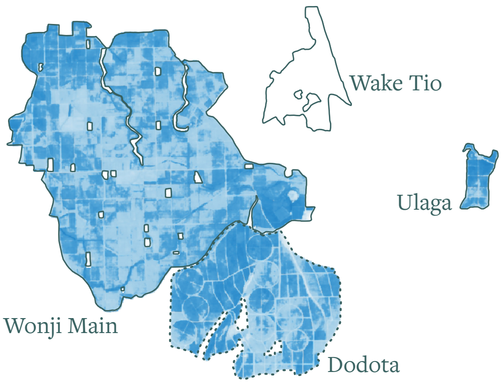
Wonji, Ethiopia

The Wonji-Shoa sugar estate is the oldest in Ethiopia. Sugarcane production started in 1954 and from 2009 the scheme has been expanding and irrigation methods diversifying. In this case study we are focusing on the schemes in the estate that are covered by high resolution 30m data.

WaPOR data provides information on the **spatial variation of water consumption, plant biomass production and water productivity.** Analysis can identify the better performing areas and, with the help of field-based knowledge, aid in deriving insights on how to improve the lesser-performing areas. Each map below displays a 6-year average for the indicated variable between 2014 and 2019:

Actual evapotranspiration (**ET**) tells us about the water consumption of crops:

low high



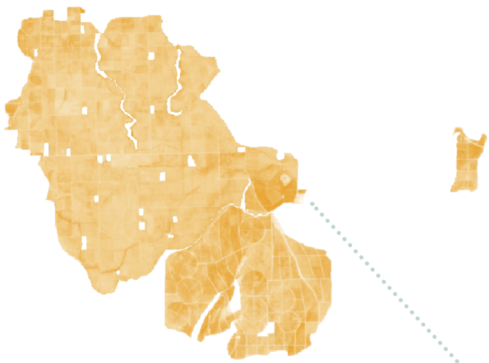
This case study focuses on Wonji Main, Dodota and Ulaga.

Wake Tio is left out of the computations for the 6-year average as it had a large uncultivated area in 2017. Consult the full report to view computations for this subscheme.

The **net primary production** (**NPP**) layer gives us information about the **productivity of the land**: how much plant matter is being produced.

low high

With sugarcane-specific coefficients it can be converted into yield.



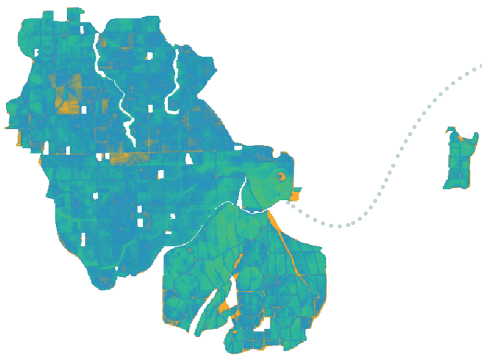
Water productivity relates to the quantity of biomass produced per unit of water. Increasing water productivity can be done by producing more using the same quantity of water, using less water or both.

low high

This area at the easternmost tip of Wonji Main displays high biomass production and water productivity, deviating from the trend in the other parts of the subscheme caracterised by low land and water productivity.

Adequacy measures to what extent the irrigated water delivered meets the required water consumption by the crops:

low high

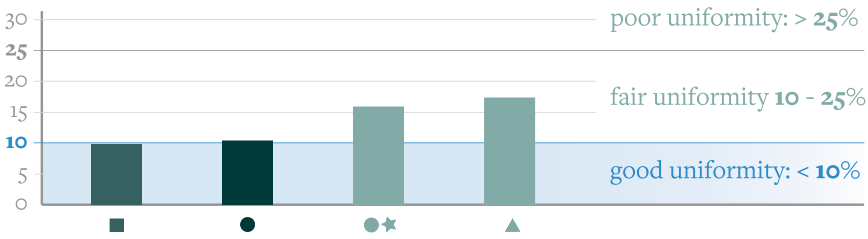


the same area displays mostly a high level of adequacy , meaning that the water delivered to the sugarcane plants meets their needs.

Map source: shapefiles provided by MetaMeta

Uniformity is a measure of the evenness of the water supply in an irrigation scheme. This graph shows uniformity calculated by irrigation type:

- ■ Wonji Main (surface: furrow)
- ● Dodota (centre pivot)
- ●★ Dodota and Ulaga (sprinkler)
- ▲ Wake Tio (sprinkler)



Wake Tio has the lowest uniformity of all the subschemes, yet, still well within the range of fair uniformity.

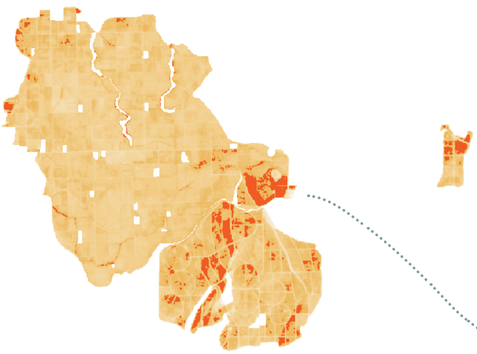
Best performing areas in both water and land productivity (bright spots):

note that Wake Tiowas left out of computation of best performing areas

Best performing areas are defined here as the areas that are in the 95th percentile of the distribution of the productivities in the estate. Their productivities are high and attainable and can constitute local targets. Once these very productive areas are identified, the analytical work must be combined with additional statistical analysis and with field investigations to understand which practices are leading to the high productivities, in an effort to emulate them in other areas of the scheme. In fact, there are several factors to take into consideration: irrigation methods, irrigation frequency, agronomic performance of the crop, fertilizer application, soil conditions, etc.

The study found that furrow irrigation (surface), in Wonji Main, had the lowest productivity. Yet, it also identified that the lower levels of productivity were not connected to the irrigation application methods, but likely caused by water logging due to shallow groundwater and limiting nutrient condition as Wonji Main is the oldest subscheme of the estate that has been subjected to decades of monoculture.

Land productivity best performing areas



area of high concentration of bright spots, contrasting with other parts of the subscheme (Wonji Main) which have some of the lowest productivities in the estate

Water productivity best performing areas

The report goes into far greater detail and uses statistical tools on the data to explore the potential explanations for high and low productivities in the schemes.

Xinavane, Mozambique

The Xinavane sugar estate is located in Maputo province on the banks of the Incomati river from where it gets its water, released by the Corumana dam. In terms of climate, soils and water availablity, the area presents optimal conditions for sugarcane production. Yet, the estate is still vulnerable to drought as was the case in 2016 where low water levels at the dam translated to a drop in production that year at the same time as the high reference evapotranspiration translated to high water consumption by crops.

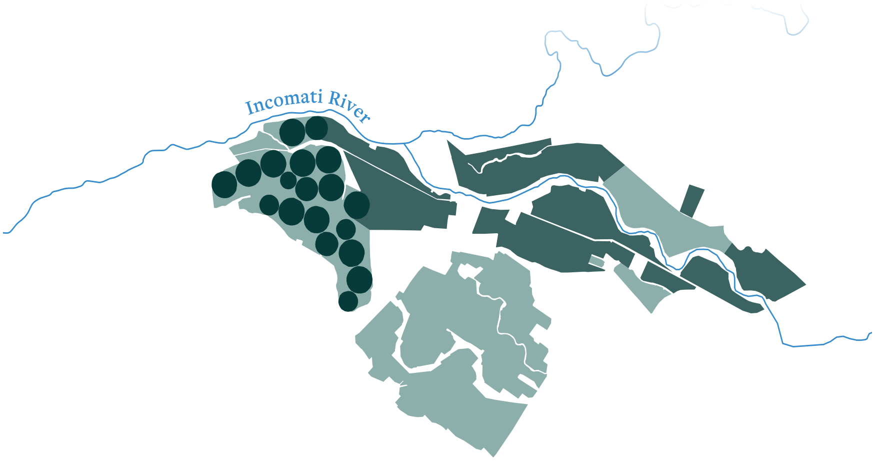
The estate has undergone several expansions since its inception in the 50s. Any future increase in production will require careful consideration of the available land and water resources.

WaPOR data can help answer the question: **what is the implication of increasing the production on land and water resources?** This can provide decision makers with important information regarding the implications of increasing production, either through agricultural land expansion or intensification of production in existing lands.

In Xinavane, 3 types of irrigation are practiced:

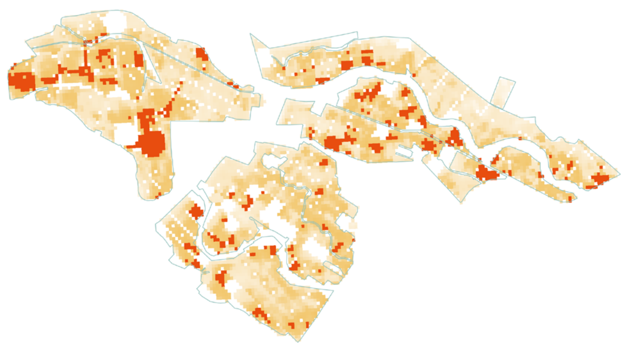
- sprinkler irrigation
- surface irrigation (furrow)
- center-pivot irrigation

the most prevalent one being sprinkler irrigation.



In **red** we can see the best performing areas in terms of land productivity, that is, with productivities in the 90th percentile of the range measured in the estate for 2016.
In Xinavane, **yield** was calculated using NPP data and other parameters from the litterature.

low high



Here too the areas with the highest water productivities in 2016 are shown in red:

low high

Map source: shapefiles provided by IHE Delft

The following scatterplot shows the water and land productivity of every pixel in Xinavane as well as its water consumption during the 2016 growing season (the full report presents analysis from four growing seasons from 2015 to 2018):

The **productivity gap** gives insight into the performance of a field in comparison to the target productivity of the area:
Improvements in agricultural practices can help close the gaps:

Increasing water productivity can be done at the **same water consumption level by producing more**, or by **using less water** (= lowering **ET**)

Increasing land productivity is often associated with an **increase in crop water consumption.**

1 quadrant containing areas meeting neither of the productivity targets

2 areas that only meet the water productivity target

3 areas that meet both productivity targets

4 areas that only meet the land productivity target

WaPOR data can help estimate how much improvements in agricultural practices could contribute in terms of extra biomass production (which can be converted into yield with local data) but it also allows to estimate how much extra water would be required to increase production.
This information can can be especially useful to water managers for the purpose of planning.

- if **land and water productivity** targets were met for all areas:

73,259 more tons in yield could be produced for each season,

about **739 ha** of additional land would have to be cultivated to obtain this same yield,

that is, **9.2%** of the existing cropland.

- closing the land productivity gap would lead to a net additional blue water demand (coming from surface water and groundwater sources through irrigation application) of:

4.4 Mm³ per season if production is intensified in the current extent of the scheme which would be less than the

6.4 Mm³ per season that would be necessary from land expansion. Further analysis and fieldwork is required to be able to identify which practices might lead to those increases in productivity.

Improving management of water resources requires reliable information at different scales. Data derived from remote sensing, can provide us with a perspective onto what is happening on the ground that is unparalleled in its ability to provide information with high spatial and temporal detail, compared to other data collection methods. Yet this perspective alone is not enough. It must be combined with field work, in-situ data collection for verification and calibration of the algorithms on the one hand and understanding of the agricultural practices on the other.

In tandem with these practices, this disaggregated view of the landscape allows for the elaboration of very targeted solutions at the field level that can have ripple effects in the estate and in the basin to increase overall resilience to water shortages. This, however, requires strong institutions to elaborate plans of action based on the insights provided.

The pressures on water resources will only continue to increase. Stakeholders at every level and in each sector of activity must take measures to make the best use of the water resources while still growing to meet increasing demands.

The main objective of WaterPIP is to guide water projects in partner countries to reach a 25% improvement in water productivity in the agricultural sector using WaPOR.

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