

A scaled-up approach

Dr Heriberto Teixeira explains how characterisation, modelling and mapping of water use and productivity in Brazil is informing the development of innovative strategies that combat water scarcity



What is your academic and professional background? How did you come to join Embrapa Satellite Monitoring?

I graduated in Agronomy from the Pernambuco Federal Rural University (UFRPE), Brazil, in 1988. I then completed a Master's degree in Meteorology at the Federal University of Paraíba (UFPB), also in Brazil, and a PhD in Environmental Sciences from Wageningen University, The Netherlands, which I completed in 2008. Following my PhD, I moved to Embrapa Satellite Monitoring in São Paulo, where I began work on new upscaling tools with water variables.

Today, I am still at Embrapa Satellite Monitoring and my expertise lies in agronomy and meteorology. Specifically, I am involved in agricultural meteorology and am currently focusing on radiation and energy balance, evapotranspiration, biomass production and water productivity. The goal of my research is to develop techniques for upscaling these parameters from point measurements to large-scale landscapes, as this Embrapa's unit is focused on geotechnologies, agricultural monitoring, land use and climate changes, and their implications on environmental and economic sustainability of agribusiness.

You are developing tools for the large-scale quantification of water productivity. On what remote sensing technologies do most water productivity models rely? Are there any novel technologies currently under development that may be used in the future to improve modelling?

Most water productivity models rely on acquiring radiation and energy balance data from large-scale and vegetation parameters. Additionally, most current technologies need a thermal band for retrieving evapotranspiration measurements.

On one hand, some satellites with the thermal band have a good spatial resolution but poor temporal resolution, which can cause cloud contamination. On the other hand, some satellites have good temporal resolution but poor spatial resolution. Excitingly, one of the new technologies under development relies on obtaining surface temperature by residual in the radiation balance equation. This increases the spatial resolution of the water productivity parameters and opens opportunities for using high-resolution satellite images from sensors without thermal bands.

What challenges are associated with retrieving water productivity at different spatial and temporal scales?

Considering the different spatial and temporal resolutions of the satellite images, the main challenge is to develop realistic physical models with sufficient accuracy, which are also simple enough for implementation. In addition, the availability of weather data is important, as the models combine these data with remote sensing parameters.

In which areas of Brazil do you conduct the most work? Does your research have applications further afield?

The models were initially implemented in the semi-arid regions of Brazil. Following this, some applications were made in these regions and later extrapolated to the southeast, central west and south regions. The models' equations can be used in other agro-ecosystems outside Brazil, provided the coefficients are calibrated through the combined use of satellite and field measurements. Modelling is important for supporting public policies highlighting the priorities of the National Ministry of Agriculture in the sense of criteria for subsidising actions related to the agricultural climatic risk.

Which aspects of your work do you enjoy the most? Conversely, what are the greatest challenges?

I enjoy developing techniques that facilitate the upscaling of several biophysical parameters

by using remote sensing and weather data together. Indeed, using field measurements alone renders the characterisation of different mixed ecosystems impossible.

Related to this, the greatest challenge involves making these techniques more operational, allowing analyses of the data to occur in real-time and with good spatial and temporal resolution.

You have presented your findings at a number of international symposia; in fact, this year will be your third consecutive year presenting papers at SPIE Remote Sensing. Could you provide an insight into your favourite events?

My favourite events this year were INOVAGRI, SWAT 2014 and, of course, SPIE Remote Sensing. Indeed, the SPIE International Symposium on Remote Sensing delivers excellent technical programmes, which largely focus on advances in sensor technology, next-generation satellites, remote sensing of the Earth and its environment, atmospheric propagation and signal and image processing.

This year's event was held in Amsterdam, The Netherlands, and was SPIE's 21st Remote Sensing Europe meeting. Previous symposia have been held in various locations throughout Europe, with the most recent locations including Prague, Berlin, Edinburgh and Dresden. The event is widely recognised as an important forum for science, industry and governments to access and share information about remote sensing. It focuses particularly on the research aspects of remote sensing, concentrating on European and international science and technology.

The Symposium features 10 conferences that both include oral and poster presentations, as well as a plenary session. Events such as these add enormous value to the research landscape and I look forward to attending more in future.

A wealth of water

With water scarcity a growing issue throughout the world, researchers based at **Embrapa Satellite Monitoring** in São Paulo, Brazil, are forging important advances in the development of tools and methods that enable the large-scale quantification of water productivity

AS THE FOUNDATION of life on Earth, water is a fundamental resource that is often taken for granted by many in the developed world. Yet roughly 1 billion people in developing countries have no access to clean, safe drinking water – and, in places such as sub-Saharan Africa, the time lost as a result of searching for water or suffering from water-borne diseases is drastically limiting human development. Unfortunately, the problem of water scarcity is a growing one. As the rapidly increasing global population places further demands on limited supplies, creating and maintaining access to water will become more difficult, challenging political and social stability throughout the world.

Water scarcity is intensified by the deteriorating quality of water in a number of developing countries – a phenomenon that primarily occurs in river basins that have seen rapid changes in land usage in conjunction with climate change. All too often, the successful implementation of on-the-ground solutions is impeded by a range of complex factors including scant investment, a lack of commitment to tackling poverty, weak or unstable governance and inadequate human capacity.

Moreover, the availability of water and the development of sustainable water resources

can be further hampered by the competing demands of different user groups. Monitoring water productivity in different regions must therefore account for the activities of different water users in a river basin and for the water flows in terms of net consumption and production.

UNDERSTANDING WATER PRODUCTIVITY

Water productivity refers to the value of goods and services produced per unit of water consumed, with its two essential components being evapotranspiration and biomass production. As the sum of soil evaporation and plant transpiration from the Earth into the atmosphere, evapotranspiration is vital for agricultural production – yet its increase diminishes the amount of water for human and ecological use in river basins. Biomass production, which partly represents the energy captured by photosynthesis, is a key indicator of water productivity in any agro-ecosystem, but its values can vary greatly throughout space and time.

In water-scarce environments, the main challenge is to improve biomass production through the optimisation of water management practices. However,

it is very difficult to obtain data about evapotranspiration and biomass production on large scales through field measurements, necessitating the use of remote sensing by satellite images: “Large-scale water productivity components can be analysed by instantaneous satellite measurements in the visible and infrared bands, with or without the thermal band,” discloses Dr Heriberto Teixeira, a researcher based at Embrapa Satellite Monitoring in Brazil. “This is possible by modelling evapotranspiration and biomass production at satellite overpass time, in conjunction with the availability of daily weather variables.”

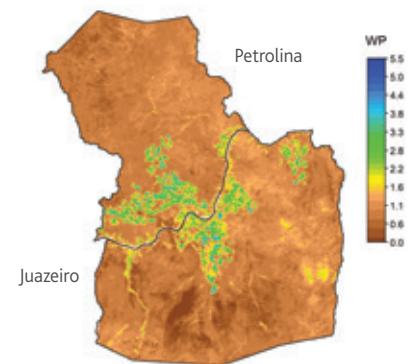
LARGE-SCALE ASSESSMENTS

Indeed, while many prominent researchers have devised site-specific and large-scale models of water productivity, there remains a need for further research that analyses and assesses combined evapotranspiration and biomass production models. Such research is especially important for informing the development of operational applications in different agro-ecosystems with notable temporal and spatial thermal-hydrological differences. In response to this challenge, Teixeira and his team have conducted water productivity assessments that used a combination of remote sensing methods with satellite images at varying temporal and spatial resolutions. A detailed description of his innovative study will be published in the *Remote Sensing Handbook*.

In their study, Teixeira and his colleagues combined the Simple Algorithm For Evapotranspiration Retrieving (SAFER) with the Monteith radiation model to show that satellite measurements coupled with weather data can be effectively used for large-



Crop irrigation using pivots, Brazil.



Water productivity (biomass/BIO) per evapotranspiration (ET) in the municipalities of Petrolina (Pernambuco state) and Juazeiro (Bahia state) in kg/m³

INTELLIGENCE

WATER PRODUCTIVITY STUDIES FROM EARTH OBSERVATION DATA: CHARACTERISATION, MODELLING AND MAPPING WATER USE AND WATER PRODUCTIVITY

OBJECTIVE

To carry out water productivity assessments by using remote sensing methods with satellite images at different spatial and temporal resolutions, involving natural vegetation and agricultural crops, considering both irrigation and rainfed aspects, for some Brazilian agro-ecosystems.

KEY COLLABORATORS

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HERIBERTO TEIXEIRA holds a Bachelor's degree in Agronomy from the Pernambuco Federal Rural University, Brazil, a Master's in Meteorology from the Federal University of Paraíba, Brazil. He completed his PhD in Environmental Sciences in 2008 at the Wageningen University, The Netherlands. Currently, Teixeira is a researcher with the Embrapa Satellite Monitoring, Campinas, São Paulo, Brazil, with expertise in agronomy and meteorology, and emphasis in agricultural meteorology, highlighting the following themes: radiation and energy balance, evapotranspiration, biomass production and water productivity.



Image composition of Brazil - Landsat images processed by Embrapa Satellite Monitoring. Source: <http://landsat.usgs.gov>

scale water productivity assessments. They observed natural vegetation and agricultural crops in various agro-ecosystems in Brazil, taking into account both rainfed and irrigation aspects. Importantly, the dual use of remote sensing and weather data allowed them to obtain these large-scale water productivity assessments from different agro-ecosystems: "The analyses may contribute to a better understanding of the biophysical parameter dynamics, which are highly important for appraising the impact of climate and land use changes and for informing government plans to expand the irrigated areas," Teixeira points out.

In addition, Teixeira's study provides large-scale temporal information about crop growth rates and the responses of plants to dynamic weather conditions under both irrigation and rainfed conditions. This is particularly important in the Brazilian context, where

recent rainfall shortages in several regions have contributed to water scarcity. Essentially, Teixeira's analyses promote evidence-based decision making regarding the efficient use of water resources: "The available tools can be operationally implemented to monitor the intensification of agriculture and the adverse impact on downstream water users in changing environments," he elucidates.

DRIVING RESEARCH IMPACT

In their research, Teixeira and his team have demonstrated that Earth observation data can be used to make fresh insights into water use and productivity. The hope is that these insights will not only make waves in academic circles but that they will also contribute to influencing environmental policy at local, national and global levels. Indeed, while the researchers primarily focused on semi-arid areas of Brazil, their findings have important applications for the large-scale quantification of water productivity further afield. The quantification of this highly complex phenomenon is vital, helping to pave the way for the implementation of evidence-based water management strategies worldwide.

The dual use of remote sensing and weather data allowed the researchers to obtain large-scale water productivity assessments from different agro-ecosystems

Mapping the models

Dr Heriberto Teixeira and his colleagues used the following models to obtain information regarding water productivity in certain areas of Brazil:

The Simple Algorithm For Evapotranspiration Retrieving (SAFER) enables large-scale measurements of evapotranspiration. Compared to other models it has certain key advantages, including its simplicity to operate. Moreover, SAFER can incorporate daily weather data from both conventional and automatic meteorological stations: "This is an important characteristic because it allows the performance of a large-scale historical evaluation of the energy balance components," Teixeira explains. Based on

global solar radiation, the Monteith model is used to calculate biomass production, which presupposes a direct proportional relationship between biomass production and the absorption of solar radiation – something that can vary widely throughout the year and during crop growth periods.

The Surface Resistance Algorithm (SUREAL) is a biophysical model that is able to calculate surface resistance to water fluxes. It is extremely useful for classifying irrigated crops and natural vegetation, as well as for calculating the incremental values of evapotranspiration and biomass production when natural vegetation is replaced by irrigated crops.

