ORIGINAL ARTICLE

Evapotranspiration in Cuba with Satellite Images MODIS 16 and Google Earth Engine

Evapotranspiración en Cuba con imágenes satelitales MODIS 16 y Google Earth Engine

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ABSTRACT: The results of satellite images of evapotranspiration in Cuba are presented, grouped into series of 8-day averages of the dry period from November to April and the wet period from May to October from 2018 to 2022. MOD16A2 Version 6.1 of evapotranspiration (ET) is found within the catalog of public data and free use of the Google Earth Engine aimed at monitoring the progress of the 2030 Agenda for Sustainable Development and improving the limitations of the implementation of advisory services to the irrigator, while establishing mechanisms of permanent dialogue between the farmers so that they can make better decisions regarding the irrigation management of their crops.

Keywords: Remote Sensing, Irrigation Advisory Services, Irrigator, Wet and Dry Period.

RESUMEN: Se presentan los resultados de imágenes satelitales de evapotranspiración de Cuba, agrupadas en series promedios de 8 días del periodo seco de noviembre a abril y del periodo húmedo de mayo a octubre de los años 2018 al 2022. MOD16A2 versión 6.1 de evapotranspiración (ET) que se encuentra dentro del catálogo de datos públicos y de uso gratuito del Google Earth Engine orientado a monitorear los avances de los Objetivos de Desarrollo Sostenible de la Agenda 2030 y mejorar las limitaciones de la implementación servicios de asesoramiento al regante, estableciendo mecanismos de diálogo permanente entre los agricultores para que estos puedan tomar mejores decisiones respecto a la gestión de regadío de sus cultivos.

Palabras claves: teledetección espacial, servicios de asesoramiento, regante, período humedo y seco.

INTRODUCTION

In Cuba, new legal standards are being developed that regulate the ownership, possession and use of agricultural and forestry land by economic actors and aspects related to sustainability indicators on the use and management of water resources have also been introduced, hence a change in the concepts of the application of irrigation based on empirical knowledge is an imperative (Funes-Monzote, 2001; Pavó-Acosta & Hechavarría-Rivera, 2023; Sierra, 2023)..

Technical information needs to be provided to farmers to achieve more efficient water management and increased crop yields.

In this sense, quantifying evapotranspiration (ET) as the fundamental deficit variable in the water balance equation, is a complex process that links the global cycles of water, carbon and energy (Brust *et al.*, 2020; 2021).

Because ET depends on the characteristics of the earth surface, such as the type of vegetation and soil moisture, the available thermal energy from sunlight and atmospheric weather conditions, it cannot be measured directly.

Remotely sensed observations provide several of the terrestrial and atmospheric parameters useful in estimating ET. Methodologies using satellite observations to estimate ET have been developed over the past two decades. (Frąckiewicz, 2023). These ET products are used for a variety of applications, from the agricultural to the watershed scale.

On the other hand, relevant international experiences propose the use of satellites to monitor the progress of the Sustainable Development Goals of the 2030 Agenda (Banco Mundial, 2017).

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Target 6.4, focused on water use efficiency (6.4.1) and water scarcity (6.4.2), have used evapotranspiration for measurement of these indicators using a range of freely available remote sensing data such as MODIS, Landsat, Proba-V and Sentinel-2. (CEPAL, 2021). This constitutes an opportunity for developing countries to address the availability of geospatial information and processing possibilities for Irrigation Advisory Services (SAR).

Cisneros *et al.* (2004) pointed out that Cuba aspires to provide this service adapted to local conditions, concerning irrigation programming, design optimization, information dissemination and training of technicians and irrigators. Likewise, other services that are now interrogations, must be cleared by future research that enables their implementation.

After 18 years, the full implementation of this service has not yet been possible, because the SAR task is expensive and requires human and material resources due to the need for intensive monitoring in the field over large areas.

Earth observation technologies using sensors on board satellites provide images at regular intervals, which allow effective monitoring (Obasi, 2003; Akiyama *et al.*, 2022). On the other hand, information technologies make it possible, for the information generated by the SAR, to reach the user quickly, smoothly and in a personalized way. The introduction of these technologies, available on the Internet and mobile telephony, can generate added value by introducing high-value employment opportunities in rural settings (Cisneros *et al.*, 2007).

The objective of this paper is related to estimation of the ET and to introduce simplified innovative solutions to the SAR for monitoring the water condition of the crops and for answering two basic questions of irrigation programming (when and how much to irrigate), trough the processing of large volumes of data information from the cloud, free software, open data, bid data and application programming interface (API). The aims are to improve irrigation system implementation and establish permanent dialogue mechanisms between farmers so that they can make better decisions regarding the irrigation management of their crops.

MATERIALS AND METHODS

Satellite image data of evapotranspiration (ET) from MOD16A2 Version 6.1 were processed, grouped into series of 8-day averages of the dry period from November to April and the wet period from May to October, from 2018 to 2022. Geospatial information is found within the Google Earth Engine's free-to-use, public data catalogue.

MODIS 16. Evapotranspiration

MODIS is a moderate-resolution imaging spectroradiometer aboard NASA's TERRA, AQUA Satellite platform in the public domain available on the Internet for studies of global climate change, observation of environmental impacts and changes in biodiversity (Tavana *et al.*, 2023).

The MOD16A2 Version 6.1 algorithm for evapotranspiration/latent heat flux is used for collection of MOD16 satellite-derived data. It is based on the logic of the Penman-Monteith Equation, which includes daily meteorological reanalysis data inputs along with Moderate Resolution Imaging Spectroradiometer (MODIS) remote sensing data products, such as the dynamics of vegetation properties, albedo and ground cover (Modis, 2023a).

The validation process, carried out against 46 Eddy covariance flux towers and weather stations in 232 watersheds in the years 2000 to 2010, indicate average daily biases of -0.11 kg/m2/day and -0 .02 kg/m2/day against meteorological data.

Mean absolute errors (MAE) of 0.33 kg/m2/day (24.6%) and 0.31 kg/m2/day (24.1%), respectively, indicate that the precision of the observations is in the range from 10-30%. (Modis, 2023b).

Processing With Google Earth Engine

Google Earth Engine (GEE) is a cloud computing platform linked to an open-source computing engine, designed to store and process huge data sets (at petabyte scale) for change detection, analysis, trend mapping and quantification of differences on the Earth's surface for decision making (GEE, 2023).

GEE uses techniques to average ET and other spatial data at predefined boundaries like states, counties, watersheds, irrigation districts and farmland boundaries. Spatial averages are stored in a large geodatabase that is connected to an API and open source raster and vector tile software. This framework supports rapid response to data queries, as well as spatial and temporal visualizations of ET and associated variables (e.g., NDVI, reference ET and reference ET fraction) through a data visualization application and lightweight web mapping (GEE, 2023).

For processing, the web-based IDE Code Editor was used to write and execute scripts (Figure 1).

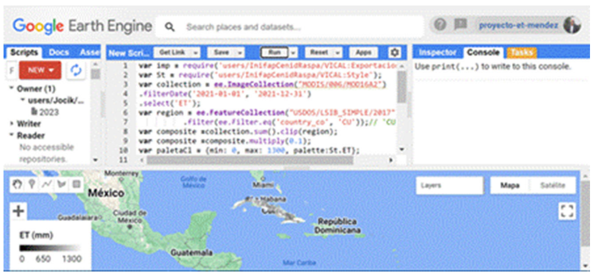

FIGURE 1. GEE code editor.

An API developed in JavaScript (Jiménez, 2022) was used, which was modified for the conditions of Cuba. In Figure 2, the results are shown.

The results are made up of Evapotranspiration images for the requested periods. In Figure 3, they are shown in the cloud.

RESULTS AND DISCUSSION

The greatest risks for food security are given by the alternation of dry periods (in which rainfall is insufficient to meet the water needs of crops) with other rainy periods (where over-wetting and flooding occurs) (PMA-Cuba, 2001). For this reason, the response capacity directly involves irrigation and drainage.

Figures 4 and 5 show the results of evapotranspiration (ET) processing (in DN. Digital image number 0-255) with 8-day averages of the dry period from November to April and the wet period from May to October, during the years from 2018 to 2022.

Few works of evapotranspiration mapping using spatial remote sensing techniques are reported in Cuba. Méndez (2011) developed a geographic model through the direct use of the FAO-PM Equation and spatial remote sensing techniques adjusted by means of artificial neural networks, from a spatially exhaustive behavior with 86% precision and relative error of 14% for spatial resolution of 1000 m and temporal resolution of 10 days.

The results presented with spatial resolution of 500 m and temporal resolution of 8 days can be considered an advance as reported in the literature (Modis, 2023b), by reaching precisions between 70 -90% and mean absolute errors of 24.1%. - 24.6%.

Other Cuban authors have used different methods to map evapotranspiration such as interpolation of point data by weighted inverse distance (González & Gagua, 1979; Ramírez, 1989; Solano *et al.*, 2003) and probabilistic or geostatistical methods such as the Kriging Method (Hernández *et al.*, 2001; Zamora-Herrera & Chaterlán-Durruty, 2001; Chaterlán-Durruthy *et al.*, 2002; González *et al.*, 2004; Méndez *et al.*, 2008). The results, in general, follow the patterns presented in this paper.

CONCLUSIONS

- The first results in Cuba of the processing of satellite images of evapotranspiration using the MODIS 16 radiometric product are presented.
- The information generated is the starting point for scheduling irrigation and the way to start the irrigation forecast and monitor the water situation of the crops.
- The premises are established to create dialogue mechanisms between farmers, so that they can make better decisions regarding the irrigation management of their crops.
- The introduction of these technologies will have an impact on saving water and energy resources and contribute to the sustainability of the use and management of water resources.

```
var imp = require('users/InifapCenidRaspa/VICAL:Exportaciones');
var St = require('users/InifapCenidRaspa/VICAL:Style');
var collection = ee.ImageCollection("MODIS/006/MOD16A2")
.filterDate('2018-05-01', '2022-10-31').select('ET');
var region = ee.FeatureCollection("USDOS/LSIB_SIMPLE/2017")
. filter(ee.Filter.eq('country_co', 'CU'));// 'CU' de Cuba
var composite =collection.mean().clip(region);
var composite =composite.multiply(0.1);
var paletaCl = {min: 0, max: 25, palette:St.ETO};
var panL = imp.Leyenda('EThumedo (mm)', paletaCl);
Map.centerObject(region)//centrar a la region
Map.addLayer(composite, paletaCl, ' mean_ET');Map.add(panL);// leyenda
Export.image.toDrive({ image: composite,
description: 'ET_Export', folder: 'EThumedo',
fileNamePrefix: 'EThumedo', scale: 500, maxPixels: 1e10})
```

FIGURE 2. JavaScript API to estimate ET for Cuban conditions.

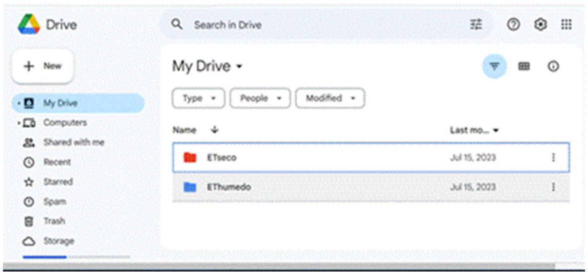

FIGURE 3. Result of processing in Google Drive.

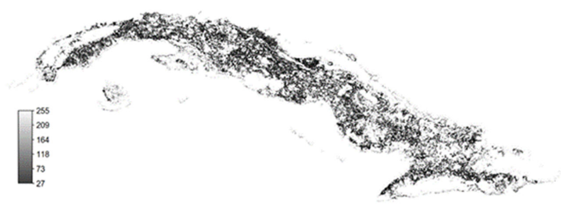

FIGURE 4. Average evapotranspiration (ET) every 8 days of the wet period, from May to October, since 2018 to 2022.

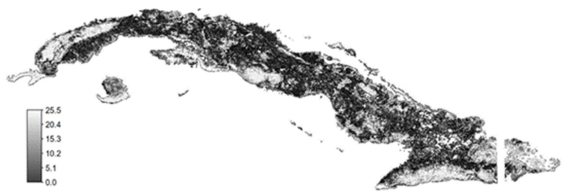

FIGURE 5. Average evapotranspiration (ET) every 8 days of the dry period, from November to April since 2018 to 2022.

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