METHODS OF DETERMINING EVAPOTRANSPIRATION USING SPACE TECHNOLOGIES

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Abstract

Finding out how much water crops use is very important for agriculture and water management today. Evapotranspiration (ET) is the main indicator that helps us understand this water loss from soil and plants. In the past, people used tools on the ground to measure ET, but these traditional methods take too much time and are very expensive for large regions. Today, space technologies and remote sensing give us a much better way to map ET directly from space. This paper reviews different satellite-based methods used to find ET. We look at the role of various satellite sensors, such as MODIS (which provides daily images at 250m and 500m resolution), Landsat, Sentinel, and the newer ECOSTRESS sensor on the International Space Station. We also briefly discuss the common energy balance models used with these satellites, like SEBAL and METRIC. The main goal of this paper is to compare these different satellite technologies. In the discussion, we analyze which satellite or model is better for specific tasks, comparing them by spatial resolution and how often they take pictures. This comparison will help researchers and farmers choose the right remote sensing tool for specific water saving projects.

Keywords: Evapotranspiration, Remote Sensing, Satellite imagery, MODIS, ECOSTRESS, SEBAL, METRIC, Water management, Precision agriculture.

Introduction

Water is one of the most important resources on Earth, especially for agriculture. To grow crops efficiently, we need to know exactly how much water they are using. This is where Evapotranspiration (ET) comes in. Simply put, ET is the total amount of water that evaporates from the soil and transpires (or "sweats") from plant leaves. When we know the ET, we know exactly how much water a farm or a region needs to survive *(Figure-1)*.

In the past, researchers measured ET using ground-based tools like lysimeters or weather stations. While these traditional tools are very accurate, they only show data for a small point in a single field. They are also expensive to build and take too much time to manage. Today, because of global water scarcity, we need to monitor water use across huge areas, not just single point [1].

This is why space technology is completely changing water management. Instead of measuring from the ground, we can use satellites looking down at the Earth. Satellites work like giant space thermometers. When crops have enough water, they transpire properly and stay cool. When they lack water, their temperature goes up. By using thermal sensors on satellites, we can measure this temperature difference and map the ET for every pixel of an area *(Figure-2)*.

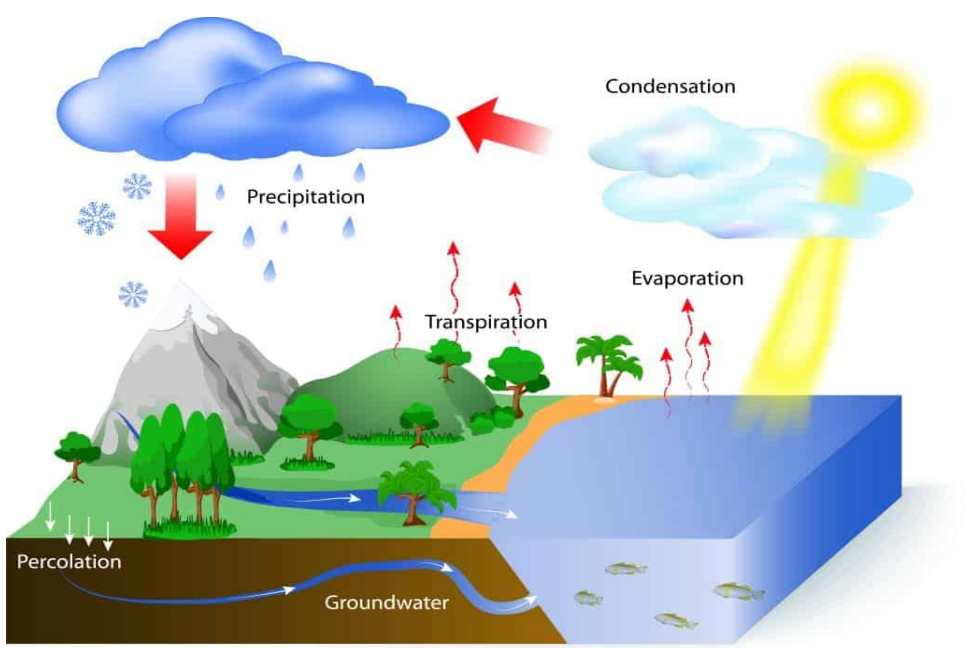

Figure 1. The basic process of evapotranspiration, showing water loss from plant leaves (transpiration) and the soil surface (evaporation).

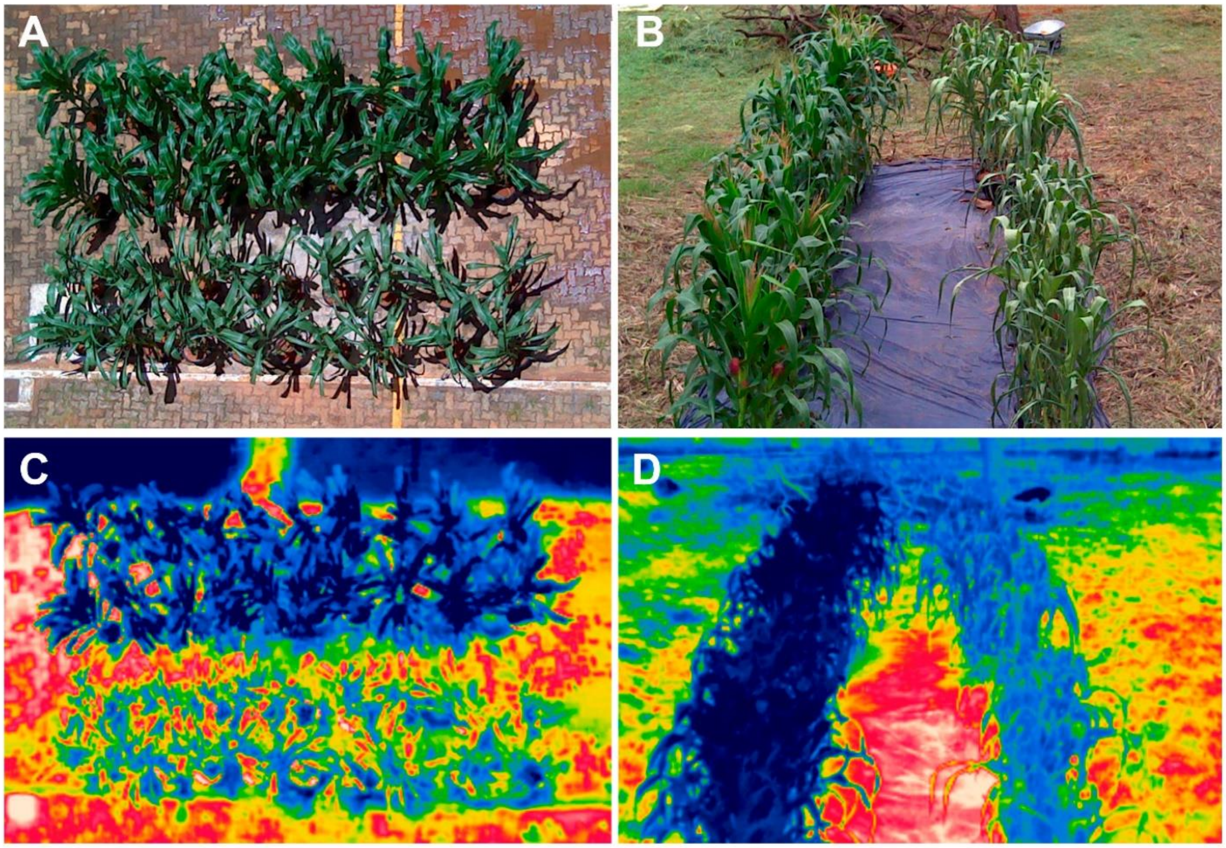

Figure 2. Satellite thermal imagery showing crop temperatures. Cooler areas indicate higher transpiration rates, while warmer areas show water stress.

There are many satellite missions today that help us do this, such as MODIS, Landsat, and the newer ECOSTRESS sensor on the International Space Station. They all have different spatial resolutions and revisit times. The main goal of this paper is to review these different satellite technologies and show how they are used to map ET. We will also briefly look at how energy balance models like SEBAL and METRIC process this satellite data. By comparing these space-based methods, we can understand which satellite tool is the best choice for specific agricultural and water monitoring tasks.

2. Materials and Methods

2.1. The Energy Balance Concept

To calculate Evapotranspiration (ET) from space, satellites do not actually see the water moving into the air. Instead, they measure heat. Most satellite methods use the Surface Energy Balance (SEB) equation to find ET. Think of this like a daily energy budget. The sun gives energy to the earth (Net Radiation). The earth spends this energy in three main ways: heating the soil (Ground Heat Flux), heating the air (Sensible Heat Flux), and evaporating water (Latent Heat Flux). In this process, Latent Heat Flux is the energy used for ET. If a crop has enough water, it uses most of the solar energy to "sweat" (evaporate), so its surface temperature stays cool. If the soil is dry, the plant stops sweating, and its temperature goes up very fast [2].

2.2. Satellite Sensors Used for ET

Different satellites have different jobs and cameras. We usually use three main types of satellite data to monitor ET:

- **MODIS (Moderate Resolution Imaging Spectroradiometer):** MODIS is very useful because it takes pictures of the earth every single day. The problem is that its pixels are large (250m to 1km). This means it is great for mapping water use for a whole country or a big agricultural zone, but it is not detailed enough for one small field [3].

- **Landsat:** Landsat satellites provide much clearer pictures. Their thermal sensors have a 100m resolution, which is perfect for looking at individual crop fields. However, a Landsat satellite only passes over the same field every 8 to 16 days. If the sky is cloudy on that day, we lose the data [2].

- **ECOSTRESS:** This is a newer thermal camera attached to the International Space Station (ISS). Normal satellites always cross the sky at the exact same time every day. But ECOSTRESS measures plant temperatures at different times of the day. It has a high resolution (about 70m) and helps us see exactly when plants start to get thirsty during a hot afternoon [4].

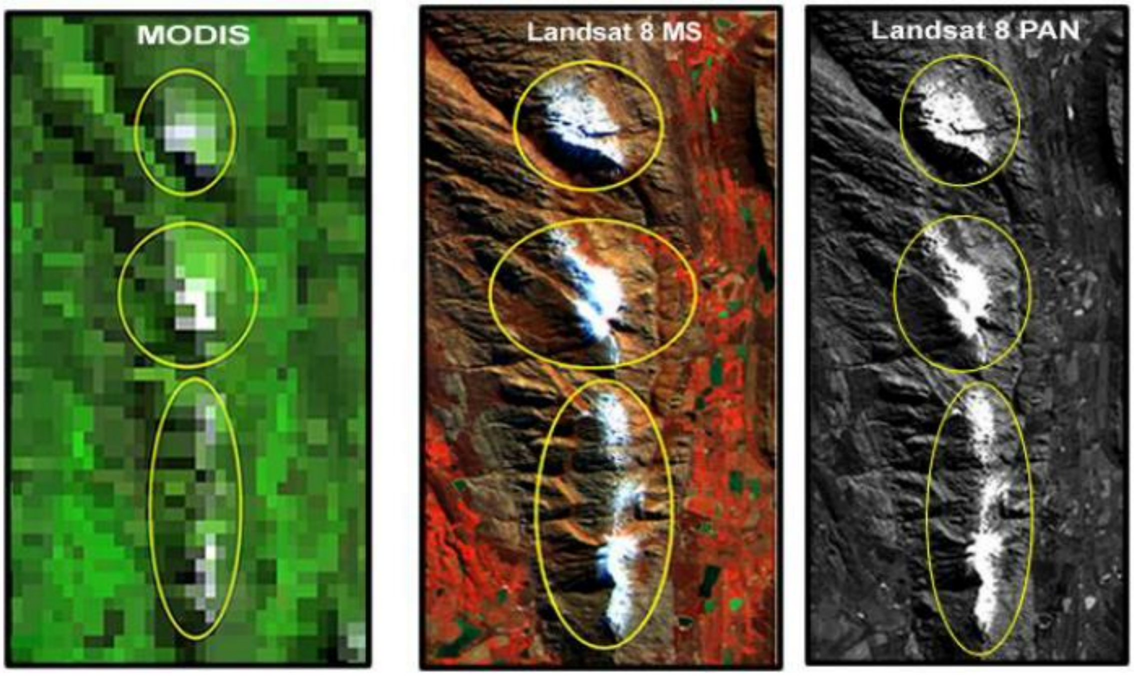

Figure 3. Comparison of satellite resolutions. High-resolution images (like Landsat) show individual fields, while low-resolution images (like MODIS) are better for large regional trends.

2.3. ET Estimation Models

To turn these satellite thermal images into final ET maps, we use mathematical algorithms. Two of the most popular models are SEBAL and METRIC. SEBAL is powerful because it calculates ET without needing perfect ground weather data. It just finds the hottest pixel (dry soil) and the coldest pixel (well-watered crops) in the satellite image to create a baseline for the calculation [2]. METRIC works in a very similar way but uses data from local weather stations to make the ET numbers much more accurate for that specific farming area [3]. Another popular and faster method is the SSEBop model, which is widely used with MODIS and Landsat data for quick, automated mapping [5].

3. Result and discussion

In this study, we compared different satellite methods to find out which one is the best for monitoring Evapotranspiration (ET). The results show that there is no single "perfect" satellite. Choosing a satellite is like choosing a camera: it completely depends on what you want to take a picture of.

3.1. Comparison of Satellite Sensors

When we look at MODIS, Landsat, and ECOSTRESS, the biggest differences are their spatial resolution (pixel size) and temporal resolution (how often they take pictures).

- **MODIS:** We can think of MODIS as a street security camera. It takes pictures of the earth every single day and gives a very good big picture. This makes it excellent for monitoring water use across a whole country or a large river basin over a long time [3]. However, its pixels are large (250m to 1km). It cannot show the ET of one small farmer's field because everything blurs together.

- **Landsat:** Landsat is like a professional DSLR camera. Its thermal sensors have a 100m resolution, which is detailed enough to see exactly which part of a field is thirsty and which part has enough water. But there is a catch: it only passes over the same field every 8 to 16 days. If the sky is cloudy on that day, we lose the data and have to wait another two weeks [2].

- **ECOSTRESS:** This new sensor on the International Space Station (ISS) is like a fitness smartwatch for plants. Normal satellites usually cross the sky at the exact same time every morning. But ECOSTRESS measures temperatures at different times of the day with high detail (about 70m). Plants usually get the most stressed (thirsty) in the hot afternoon, and ECOSTRESS helps us catch that exact moment [4].

Table 1. Comparison of spatial and temporal resolutions

Sensor System / Mission	Spatial Resolution (approximate)	Resolution Category / Context

MODIS (on Terra & Aqua)	250 meters	Bands 1-2 (Red, Near-Infrared)
	500 meters	Bands 3-7 (Shortwave Infrared)
	1 kilometer	Bands 8-36 (Ocean Color, Thermal, etc.)
Landsat (8/9)	30 meters	Multispectral bands
	100 meters	Thermal Infrared bands (resampled from 100m)
	15 meters	Panchromatic band
ECOSTRESS (on ISS)	~70 meters	Varies slightly by ISS altitude; average pixel resolution is approximately 38m x 69m.

3.2. Comparison of ET Models

After getting the satellite images, we need mathematical models to calculate the actual ET. We looked at SEBAL and METRIC algorithms.

- **SEBAL:** The biggest advantage of SEBAL is that it is very independent. It does not need exact weather data from the ground. It just finds the hottest pixel (dry soil) and the coldest pixel (well-watered crop) in the satellite image and calculates everything based on that temperature difference [1]. It is a great choice for regions where we do not have good weather stations.

- **METRIC:** METRIC is like an upgraded approach for local areas. It uses real wind speed, humidity, and temperature data from local weather stations. Because it uses this real ground data, METRIC is usually more accurate than SEBAL for specific farming zones [2].

4. Conclusion

In conclusion, measuring Evapotranspiration (ET) from space is no longer just a theory; it is a highly practical tool for modern water management. By using satellites as thermal cameras, we can clearly see which crops are transpiring normally and which are experiencing water stress. As discussed, while sensors like MODIS provide a quick, daily overview of large regions, high-resolution tools like Landsat and ECOSTRESS allow us to monitor the exact water needs of individual farm fields.

When these satellite images are combined with energy balance models like SEBAL or METRIC, they turn into accurate daily or monthly water use maps. The next major step for precision agriculture is to automate this process, turning complex geospatial data into simple mobile tools that farmers can use directly in the field. As global fresh water becomes more scarce, relying on these space technologies is the most fast, cost-effective, and efficient way to save water and maintain high crop yields.

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