S E S 2 0 2 3
Nineteenth International Scientific Conference
SPACE, ECOLOGY, SAFETY
24 – 26 October 2023, Sofia, Bulgaria

EVAPOTRANSPIRATION ESTIMATION, CASE STUDY IN BULGARIA WITHIN DRAGON-5 PROGRAM

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Keywords: *Evapotranspiration, Sen-ET plugin, SNAP platform, Dragon-5 Cooperation, ESA*

Abstract: *This publication comprises some results from Dragon-5 project "ID.57160: Monitoring Water Productivity In Crop Production Areas From Food Security Perspectives". Accurately measuring the amount of water (e.g., evapotranspiration—ET) and energy (e.g., of latent and sensible heat) that are exchanged at the Earth's surface is crucial for various applications in fields such as meteorology, climatology, hydrology, and agronomy. Having reliable estimations of these fluxes, particularly of ET, is considered essential for effective natural resource management. The distributed ET models are important tool for policy planning and decision-making in terms of calculating the water productivity in agricultural crops. However, the model calibration and validation present a crucial challenging task. The Sentinel-2 and Sentinel-3 satellite constellation contains most of the spatial, temporal and spectral characteristics required for accurate, field-scale actual evapotranspiration (ET) estimation. The one remaining major challenge is the spatial scale mismatch between the thermal-infrared observations acquired by the Sentinel-3 satellites at around 1 km resolution and the multispectral shortwave observations acquired by the Sentinel-2 satellite at around 20 m resolution. The Sen-ET SNAP Plugin bridges this gap by improving the spatial resolution of the thermal images. We have implemented the model for Purvomaj municipality study area in Bulgaria.*

ОЦЕНКА НА ЕВАПОТРАНСПИРАЦИЯТА НА ТЕРИТОРИЯ В БЪЛГАРИЯ, ИЗСЛЕДВАНЕ В РАМКИТЕ НА ПРОГРАМАТА DRAGON-5

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Ключови думи: *Евапотранспирация, Sen-ET модул, SNAP, Dragon-5, ЕКА*

Резюме: *Тази публикация включва резултати от проекта Dragon-5 „ID.57160: Мониторинг на водната продуктивност в области с отглеждане на селскостопански култури с оглед повишаване на продоволствена сигурност". Точното измерване на количеството вода (напр., евапотранспирация - ET) и енергия (напр., скрита топлина на изпарение и турбулентен топлинен поток), които се обменят на повърхността на Земята, е от съществено значение за различни приложения в области като метеорология, климатология, хидрология и агрономия. За ефективното управление на природните ресурси е важно да има надеждна оценка на тези енергийни потоци и особено на ET. Наличните модели за изчисление на реалната ET са важен инструмент за планиране и за вземане на решения във връзка с изчисляването на водната продуктивност на селскостопанските култури. Калибрирането и валидирането на моделите представляват важна и предизвикателна задача. Сателитните мисии Sentinel-2 и Sentinel-3 имат на борда си инструменти които разполагат с пространствените,*

времевите и спектралните характеристики, необходими за оценка на реалната евапотранспирация (ET) на полета засети със земеделски култури. Все още седи предизвикателството за преодоляване на несъответствието на пространствената разделителна способност между данните от термалният инфрачервен диапазон, получавани от спътниците на мисията Sentinel-3 с пространствена разделителна способност от 1 км, и многоканалните наблюдения, получени от сателитите Sentinel-2 с резолюция около 20 м. Sen-ET SNAP Plugin преодолява това несъответствие, като повишава пространствената разделителна способност на термалните изображения, посредством регресионно моделиране с данните от Sentinel-2. Реализирахме модела за изследваната територия, община Първомай в България.

Introduction

This publication comprises some results from Dragon-5 project "ID.57160:Monitoring Water Productivity In Crop Production Areas From Food Security Perspectives" [1]. Accurate and spatially distributed estimates of evapotranspiration (ET) are increasingly important with the growing global population and economy putting strain on fresh water resources and food supplies [2]. The utility of ET maps has been demonstrated in a variety of applications, ranging from water rights management, through drought and food shortage monitoring, to more efficient use of land and water in agriculture and crop stress assessment [3, 4].

The aim of this study is to calculate and map the ET in Parvomay municipality (Fig. 1), located in the Upper Thracian Lowland, utilizing satellite data from Sentinel-2 and Sentinel 3. This ET map will be used in further steps in the Dragon-5 project, as input data for calculation and analysis of the water productivity on a regional level. For that purpose we have utilized the SenET plugin that has been developed by ESA [5]. The SenET plugin is working with SNAP platform. The Sen-ET SNAP Plugin has a specific module design to improve the spatial resolution of the thermal images from Sentinel 3 SLTR at 1 km to 20 m spatial resolution, using regression models with Sentinel-2 MSI data [6]. We have briefly compared the results achieved from SenET plugin with Landsat L3 Provisional Actual Evapotranspiration. The main objective of this study is to calculate and map the evapotranspiration (ET) in Parvomaj municipality (Bulgaria). To compare results achieved by SenET SNAP plugin and Landsat L3 Provisional Actual Evapotranspiration Product.

Materials and methods

Parvomay Municipality, the study area in Bulgaria, is located in the Upper Thracian Lowland, in the southern part of the country (Fig. 1). The area is dominated by winter wheat, maize and sunflower but many other crops such as rice or vegetables, making the agricultural landscape diverse. The production much depends on irrigation infrastructures which are poorly maintained. The area is characterized by medium to high baseline water stress which affects farming.

The Sen-ET plugin relies on data sources from Copernicus. Its main inputs are derived from optical data collected by the Sentinel-2 MSI sensor, thermal data obtained from the Sentinel-3 SLSTR sensor, and meteorological data from the ERA-5 dataset. The Sentinel-2 MSI optical data is used to characterize the biophysical state of the land surface at 20 m resolution. The MSI data is also be used to sharpen the lower resolution SLSTR data (Fig. 2). Since the land surface temperature (LST) is acquired at around 1 km spatial resolution, it is sharpened to 20 m using another Sen-ET operator before being used within the evapotranspiration (ET) model.

The land-surface energy fluxes are always modelled at the time of Sentinel-3 overpass. This is because changes in vegetation are not as dynamic as the changes in LST. The meteorological data is essential for establishing the atmospheric conditions that drive factors like air temperature and modulate elements such as wind speed, affecting the energy exchange between the surface and the atmosphere. This meteorological information is sourced from fields within the ECMWF ERA-5 reanalysis dataset. The main output of the Sen-ET plugin are the four modelled instantaneous land-surface energy fluxes: sensible heat flux, latent heat flux, ground heat flux and net radiation. The fluxes represent conditions at the time of Sentinel-3 overpass and are in Wm^{-2}. The latent heat flux is converted to daily ET, in mm/day, representing the total daily ET on the day of Sentinel-3 overpass (Fig. 3). We have briefly compared the results achieved from SenET plugin with Landsat L3 Provisional Actual Evapotranspiration (Fig. 4).

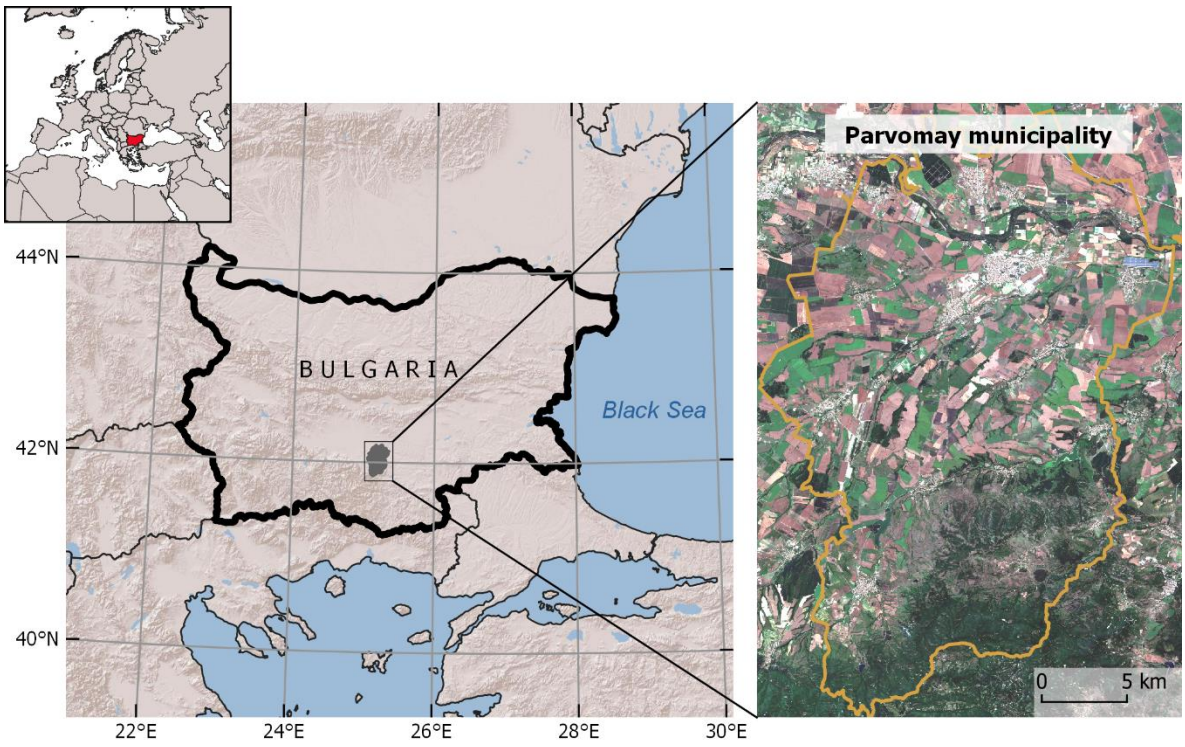

Fig. 1. Parvomay Municipality, the study area in Bulgaria, is located in the Upper Thracian Lowland, in the southern part of the country

Results

In Fig. 2, we can observe an RGB image from the Sentinel-2 MSI sensor and a thermal image from the the Sentinel-3 SLSTR sensor captured over the same area. Additionally, the image presents the result of a model that enhances the thermal channel. This model plays a critical role as it significantly improves the spatial resolution of thermal images, from 300 meters to 20 meters. In the zoomed-in section (Fig. 2), details like land parcels are visible. Thermal images are of utmost importance as they provide essential information for evapotranspiration calculations in SenET plugin.

The calculations for evapotranspiration are conducted on a specific date when Sentinel-3 SLSTR data is available. This approach is particularly crucial because the temperature dynamics are a vital factor in the calculations. These dynamics can vary significantly, in comparison to the dynamics of vegetation for which Sentinel-2 MSI data is used. It's important to note that images from the two satellite systems can be offset by up to 10 days in the calculations While images from Sentinel-3 are available daily, cloud cover can pose challenges for the calculations, and a daily time series cannot always be relied upon. In Fig. 3, we can see a map of daily evapotranspiration for the studied area as of June 30, 2021. This map represents the final result of the SenET plugin.

Within the scope of the study, a comparison was made between the results obtained with the Sen-ET plugin and the Landsat L3 Provisional Actual Evapotranspiration product provided by the USGS. Fig. 4 presents a graph comparing these two types of results. This comparative analysis was performed within a specific agricultural field sown with winter wheat. The time series includes data from all available cloud-free images from the Sentinels and Landsat satellites. Both sensors indicate that evapotranspiration is lowest in the autumn when the wheat is in its initial growth stage. During this period, the plants are relatively small, and the weather is cooler, resulting in lower evaporation rates. This general pattern of reduced evapotranspiration in the autumn is evident with both sensor systems and aligns with observations of the plant growth cycle.

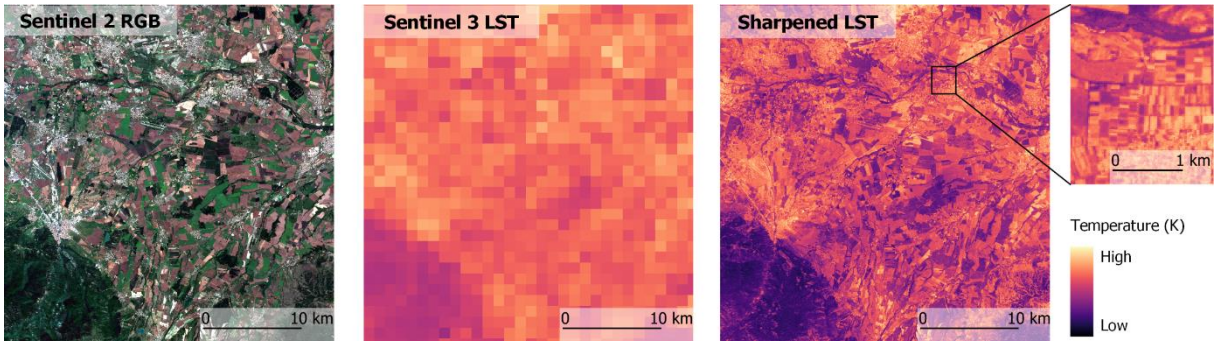

Fig. 2. Images used in the sharpening process of SLSTR data and its results

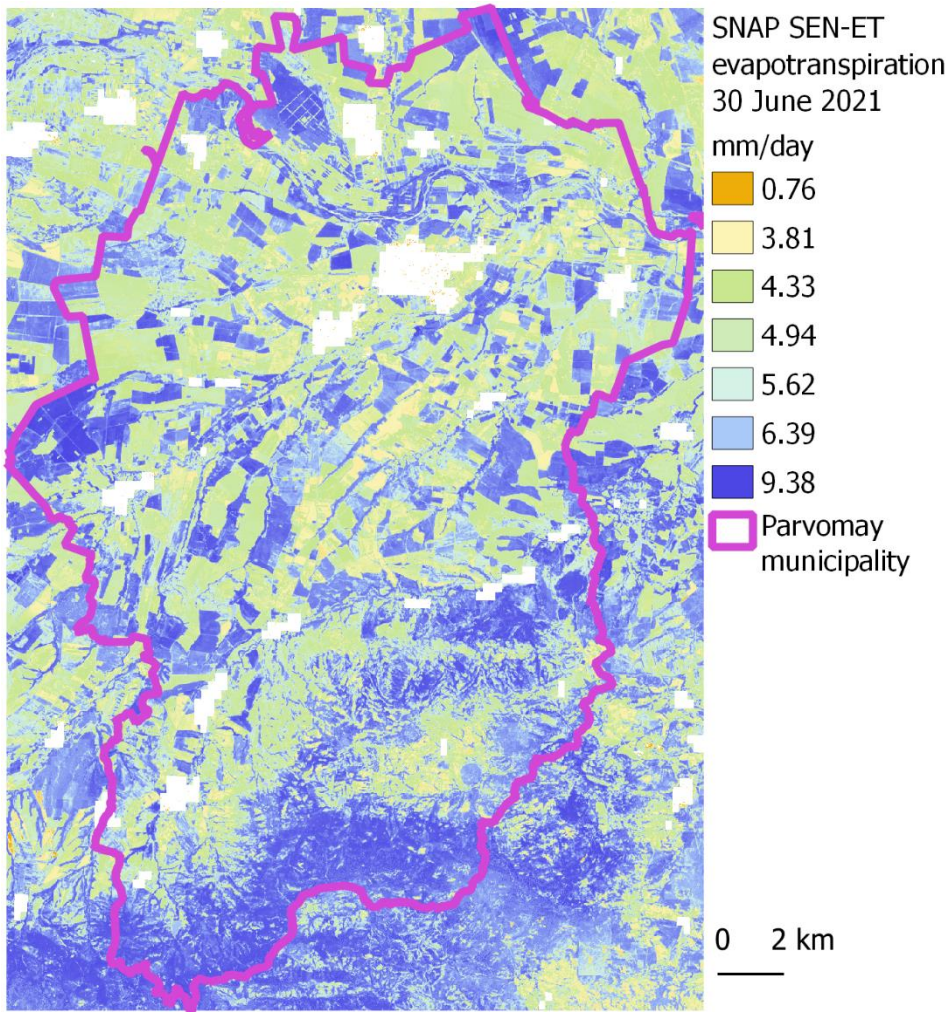

Fig. 3. Evapotranspiration map, 30 June 2021

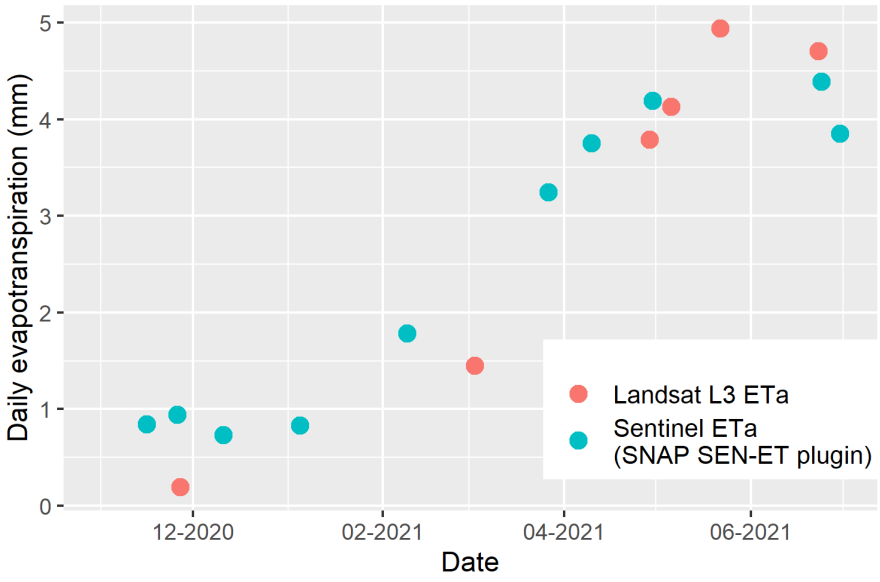

Fig. 4. Comparison of daily ET in a winter wheat plot between Landsat L3ETa and Sentinel ETa

Conclusions

For the Bulgarian agronomical conditions, the SenET plugin gives results with very good spatial resolution, allowing registering ET variation even in small agnomical fields in highly fragmented landscape. Another advantage is the high temporal resolution of Sentinal 3 imagery for monitoring purposes. The results achieved by the SenET plugin are superior to Landsat product in terms of both spatial and temporal resolution. Nevertheless, there is potential for Landsat data to complement Sentinel data where gaps exist. Further research is needed to explore the harmonization and synergies between these two modeling approaches. One drawback to note is that the SenET plugin is computationally intensive and lacks an automated workflow, requiring multiple manual steps and interactions. To address this limitation, our partner VITO is developing a Python module that implements the SenET approach with the aim of automating the entire process.

Acknowledgements

This study was carried out within the Dragon 5 project ID.57160: Monitoring water productivity in crop production areas from food security perspectives. This work was supported under contract № 4000137730/22/I-NB with the European Space Agency as part of the program “Support to European Senior & Young Scientists within the Dragon 5 Cooperation“. We want also to thank the European Space Agency (ESA) for providing free access to Sentinels data. We are appreciative of the United States Geological Survey (USGS) for their valuable contribution of free Landsat L3ETa products. These contributions have enriched our research and fostered meaningful connections in the scientific community.

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