Introducing a Learning Tool (QSVI): A QGIS Plugin for Computing Vegetation, Chlorophyll, and Thermal Indices with Remote Sensing Images

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Abstract. Remote sensing technology can be used to monitor environmental changes using satellite imagery. However, to obtain a more precise model, it is necessary to process high-resolution and multilayered data, which requires high-capacity software. Commercial software is often difficult to access by students and researchers because of its high cost and complex interface. This paper introduces a plug-in called QSVI (QGIS Sentinel Vegetation Indices (QSVI) designed in open-source QGIS (Quantum GIS) software using Python. The QSVI can quickly process and automatically calculate many environmental indices on a single platform. These included the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Atmospheric Resilient Vegetation Index (ARVI), Leaf Area Index (LAI), Chlorophyll Vegetation Index (CVI), Urban Thermal Field Variation Index (UTFVI), and Thermal Disturbance Index (TDI). The performance of the QSVI was tested in the Sarıyer District of Istanbul, Turkey. The results indicate that for Sentinel-2 data, QSVI reduces processing time by an average of 2.1 minutes compared to common commercial software such as ArcGIS, GRASS, and SAGA-GIS. Sentinel-3 data were processed 13.6 seconds quicker than with the same software. The findings indicate that QSVI can be an alternative tool for researchers and students because of its easy accessibility and low cost. Because of its speed and simple interface, it can provide practical solutions for both researchers and students.

Keywords: python ; Qgis-plugin; sentinel data; environmental indices

1 Introduction

In recent years, the use of digital software for monitoring environmental dynamics in remote sensing areas has increased widely. These technologies are faster and more effective than the traditional methods. This is why researchers are increasingly preferring this approach. Research has indicated that when people use digital software, their performance increases by 15% to 25% (Bernard et al., 2014; Sung et al., 2016; Wulandari et al., 2021). Moreover, when interacting with software during the process, they may perform their own analysis and share information with other people (Dinçer, 2017; Gomez et al., 2010); therefore, this process can be executed rapidly, iteratively, and quickly with complex multi-layer datasets at different scales rather than traditional methods.

Some research shows that using environmental indices such as the Normalized Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), which are used for land use monitoring, show better performance (Aldhebiani et al., 2018). Moreover, these indices have often been used in many studies (Bastiaanssen et al., 2000; Wachendorf et al., 2018). Conversely, in addition to software, it is crucial to identify open-access data to achieve economic results for education and research purposes. This is because high-cost data cannot support many users.

Landsat imagery is preferred for classification and environmental monitoring, because it is freely downloadable and includes multispectral and thermal bands (Narine et al. 2009; Ran et al. 2017). The Copernicus program supplied a free dataset that included sentinel images. Sentinel-2 Level 2A (L2A) is the preferred choice with atmospherically corrected data, and is thus available in a directly analyzable format. The Sentinel-3 satellite is also advantageous owing to its thermal band, which is used for temperature and climate research (García, 2022).

These remote sensing images often prefer many areas, such as grassland monitoring (Potočnik Buhvald et al., 2022), risk management (García-Fernández et al., 2020), land classification and agricultural studies (De Fioravante et al., 2021; Segarra et al., 2020), surface temperature, soil moisture, oil spill detection (Liu et al., 2021; Nie et al., 2021; Zakzouk et al., 2024), NDVI, EVI, and water index (Choudhary and Ghosh, 2022; Peddinti et al., 2021; Ran et al., 2017; Roßberg and Schmitt, 2023). Currently, these analyses, owing to spectral indicators, produce accurate and reliable results in monitoring and detection (Carless et al., 2019), but are still time-consuming and difficult. To overcome these challenges, many software packages and plug-ins have already been used. One of them is QGIS (Quantum GIS), a Geographic Information System software.

Its core team allows many independent organizations to contribute by integrating their own plugins. One of them was the Semi-Automated Classification Plugin (SCP), which is capable of downloading and performing analyses such as the NDVI and the Atmosphere Resistant Vegetation Index (ARVI) (Congedo, 2021). Open-source plugins such as the System for Automated Geoscientific Analyses (SAGA-GIS) (Conrad et al., 2015) and Geographic Resources Analysis Support System (GRASS-GIS) (GRASS, 2025) provide advantages in data filtering, classification, and spatial analysis in this application. However, the use of this popular software requires a high level of expertise and experience. However, most people prefer basic functions, simple calculations, and one-step processes.

To address this, this study aims to introduce a new tool integrated into QGIS, called the Sentinel Vegetation Indices (QSVI). It provides computational simplicity for environmental indices, which are commonly used in most remote-sensing applications. This tool can automatically and quickly calculate many indices, such as NDVI, EVI, Leaf Area Index (LAI), Canopy Vegetation Index (CVI), thermal indices, Urban Thermal Field Variance Index (UTFVI), and Thermal Discomfort

Index (TDI), on the same platform, even for large datasets. Owing to its simple and user-friendly interface, it offers an efficient and preferred solution for both beginner and advanced researchers.

2 Material And Methods

2.1 Development of the QSVI plugin

QGIS is a widely used open-source GIS platform that is recognized for its extensive capabilities in monitoring and analyzing geospatial data. Its ability to enhance GIS functionality combined with the support of a large development community contributes to its effectiveness and popularity. The QSVI plugin, developed by the QGIS plugin community, was written in Python 3.9 and designed using Qt Designer, a tool for creating integrated user interfaces within the QGIS. This design does not require any extra Python packages, making it compatible with the standard desktop versions of QGIS for all operating systems.

To install the plugin, users simply extract the ZIP file and navigate to "Plugins" -> "Manage and Install Plugins." After installation, the plugin was automatically integrated into the user interface and could be accessed directly from the raster menu in the QGIS toolbar. This allows users to immediately analyze the index data (Fig. 1a-b).

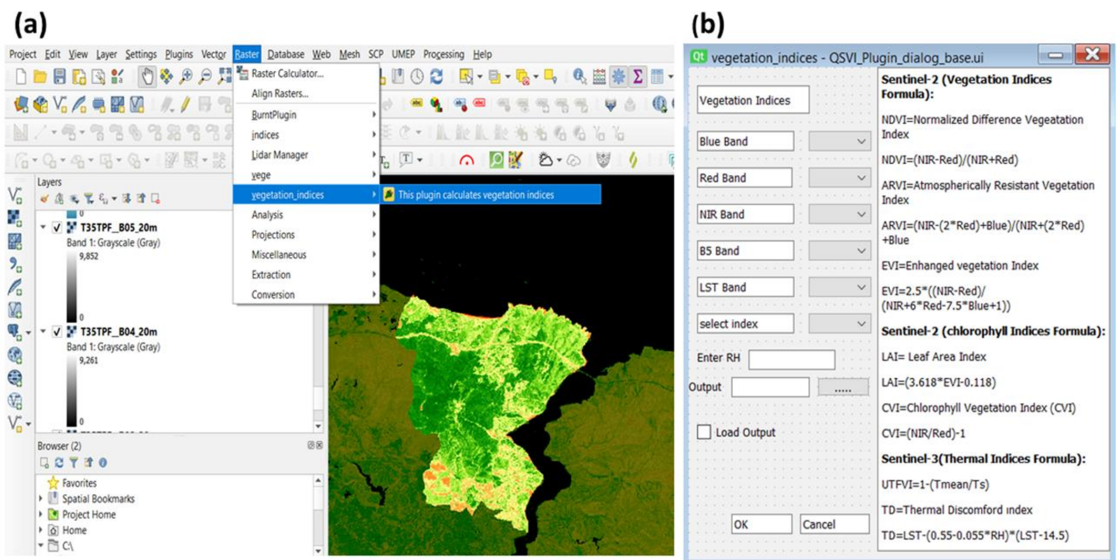

Figure 1. (a) Plugin menu tab on the QGIS platform, **(b)** Tabs of the QSVI graphical user interface.

This tool simplifies the processing of remote sensing images and allows for the effective calculation of different indices. To ensure optimal performance, particularly with images exceeding 1 GB, it is advisable to use a computer with at least 8 GB RAM.

2.2 Process description

The QSVI processing functionality was divided into three categories: vegetation, chlorophyll, and thermal indices, which were designed for comprehensive environmental analysis (Fig. 2). The QSVI plugin requires a remote-sensing image as its primary input. Users can load an image directly from the interface or select it from a list of images already available in QGIS. The supported image formats include TIFF and JPEG. The calculation process begins after selecting the image and desired index from the provided options. Once completed, the resulting image is saved in the user-selected output folder.

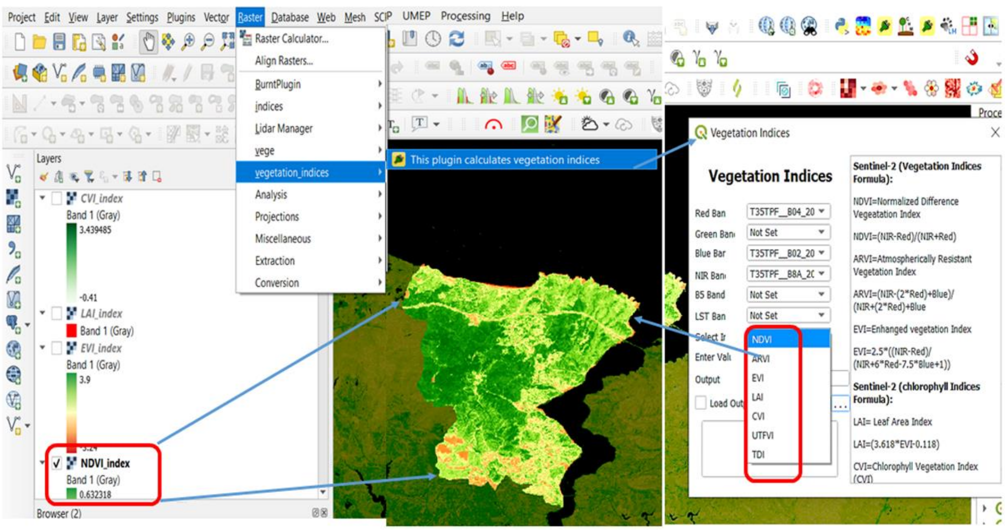

Figure 2. Overview of QSVI plugin functionalities (Developed by Nuray Baş).

The process was divided into two main steps: loading the remote sensing image and selecting the necessary indices from the icons at the interface. Users then specify the output folder and the file names. QSVI automatically calculates the selected indices and then generates a raster output file, either in the TIFF or JPEG format, containing the calculated indices. Table 1 presents all indices, along with their corresponding formulas.

Table 1. The environmental indices were computed using the QSVI plugin.

	Index	Formula	Reference
Vegetation	NDVI	$NDVI=\frac{NIR-RED}{NIR+RED}$	(Crippen, 1990; Huete, 1988; Rouse et al., 1974),
	ARVI	$ARVI=\frac{NIR-(2*RED)+Blue}{NIR+(2*RED)+Blue}$	(Kaufman, 1984; Tanre et al., 1992)
	EVI	$EVI=2.5\frac{NIR-RED}{(NIR+6*RED-7.5*Blue+1)}$	(Huete et al., 2002)
Chlorophyll	LAI	LAI=3.618*EVI-0.118	(Boegh et al., 2002)
	CVI	$CVI=\frac{NIR}{RED}-1$	(Jiang et al., 2006)
Thermal	UTFVI	UTFVI = 1 - (Tmean/Ts)	(Weng et al., 2004)
	TDI	TDI=LST-(0.55-0.055*RH)*(LST-14.5)	(Thom, 1959)

In the vegetation category, the NDVI, EVI, and ARVI indices can be accessed easily. These indices are important for monitoring the health and dynamics of the vegetation on Earth. NDVI determines vegetation change by calculating the difference between near-infrared and red-band reflections. These analyses were performed quickly and practically, owing to the plugin's integrated calculation processes. Even large raster datasets can be processed within a short time. Different indices showed different sensitivities to environmental variables in the analysis. For example, EVI provides a more accurate representation of vegetation than NDVI, because it focuses more on ground brightness and atmospheric effects. On the other hand, ARVI uses blue light reflectance information, which is advantageous for studies in areas with high atmospheric pollution. In fact, all these indices do more than monitor ecological health. They also measured the responses of plants to environmental changes and presented these changes to researchers and practitioners (Jombo and Adelabu, 2022; Lei et al., 2024).

The QSVI provides a simplified and practical application of these dynamics with remotely sensed imagery over large geographic areas. CVI and LAI, which are partially different and also focus on plants, monitor plant growth and development. Thus, it contributes to the sustainability of agricultural and forestry activities.

3 Study Area and Data

The study area is the Sarıyer municipality, which covers 177 km² of the European side of Istanbul (41°9'44.28″ " N 29°2'50.64"″ E). Sarıyer is bordered by the districts of Beşiktaş and Kâğıthane to the south, Eyüpsultan to the west, Bosphorus to the east, and the Black Sea to the north (Fig. 3).

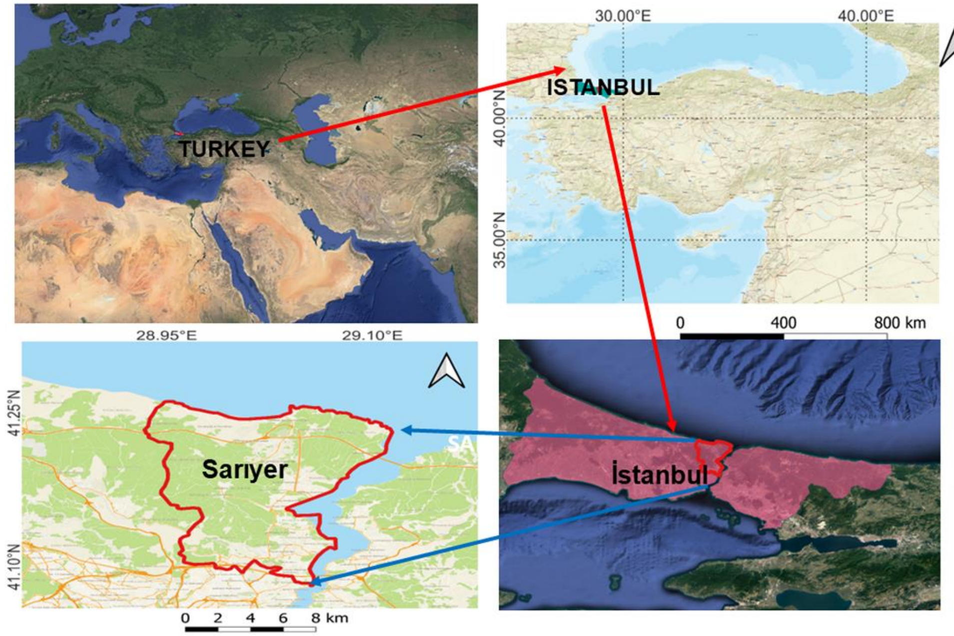

Figure 3. Location of the plugin's testing area (Basemap: Esri ArcGIS Online, 2024).

The coastline along the Bosphorus is characterized by steep cliffs and crags, while Sarıyer is renowned for its rich biodiversity, including the eastern end of the Belgrade Forest, which is situated within the municipality's boundaries. Furthermore, the area defined by the Rumelikavağı-Rumelifeneri-Kilyos triangle is characterized by a high degree of forestation. However, this has been partially affected by the recent construction of residential buildings. Sarıyer has a Black Sea climate characterized by seasonal variations in temperature and humidity, especially along the coastline.

During the measurement period (1950–2023), Sarıyer recorded its lowest temperature of -9 °C in February and highest temperature of 40.6 °C in July, with an average annual precipitation of 662.5 mm (Turkish State Meteorological Service, 2023). The majority of Sarıyer's land area is covered by rich natural vegetation (Turkish State Meteorological Service Official Web Sites 2025). The image data from Sentinel-2 and Sentinel-3, which were atmospherically corrected and in the TIFF format, were utilized in this study. The data were downloaded from https://scihub.copernicus.eu on July 9, 2022, with a total disk size of 1010 MB.

4 Results

This study provides important findings regarding the processing and analysis of various environmental indices. Many indices, including vegetation, chlorophyll, and thermal indices, have been calculated using the QSVI tool, and their potential applications in research and education have been investigated.

Various steps were performed to generate output data. After the raster remote sensing data are displayed on the screen, the QSVI algorithm computes the indices and generates the corresponding result files. The processing tab is divided into three categories: vegetation, chlorophyll, and thermal indices. Users must select a preferred category before proceeding with index calculation. The NDVI, ARVI, and EVI indices were generated within the vegetation category to assess vegetation greenness. In this study, Sentinel-2 Level 2A products were used as a real data source to test the QSVI plugin outputs. Owing to its open-access data policy, users can access four spectral bands (10 m resolution) and six spectral bands (20 m resolution).

NDVI and EVI are valuable for monitoring vegetation status, especially in areas characterized by high biomass densities. EVI, which is more sensitive than NDVI, especially in densely vegetated areas, offers nuanced insights because it is less susceptible to atmospheric conditions. (Bounoua et al., 2000; Huang et al., 2021; Xiao et al., 2003). These differences provide EVI preferences for agricultural and forest health applications. The results are illustrated in Figure 4a-b, which shows that the NDVI vegetation spectral reflectance range was smaller than that of the EVI (Tucker, 1977),(Figure 4a-b). Additionally, ARVI corrects for atmospheric scattering effects by utilizing blue-light reflectance, thereby influencing red-light reflectance (Fig. 4c).

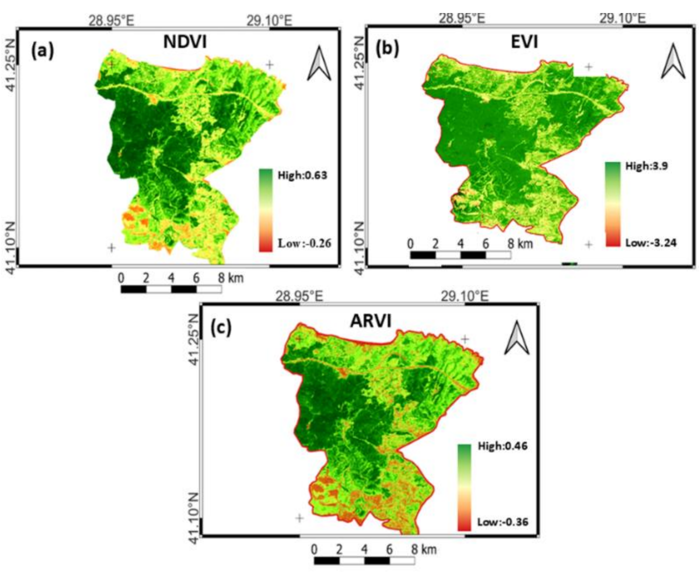

Figure 4. Calculated from Sentinel-2 images with plugins (a) NDVI indices, (b) EVI indices, and (c) ARVI indices.

In the second category, the CVI and LAI were generated to quantify the chlorophyll index, which provides information at the canopy scale. These indices can be estimated from the overall photosynthetic capacity of the canopy (Broge and Leblanc, 2001) (Fig. 5a-b).

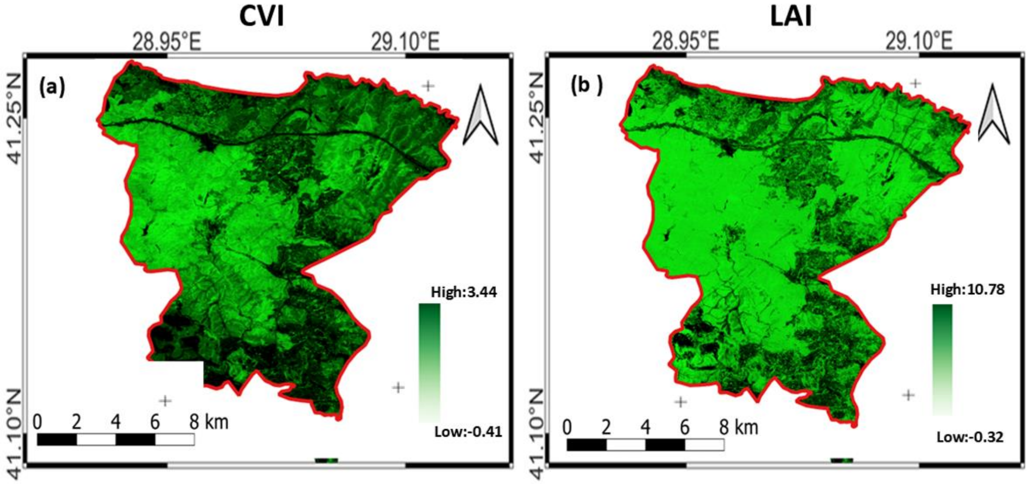

Figure 5. Calculated from Sentinel-2 images with plugins (a) CVI indices and (b) LAI indices.

Plants on Earth are often subjected to stress owing to environmental factors. As a result, vegetation changes have occurred. The LAI, which is used to detect these changes, was designed to monitor and analyze this negativity in plants (De Bock et al., 2023). CVI measures chlorophyll content in plants under stress (Broge and Leblanc, 2001; Poletaev and Lisetskii, 2024). LAI provides information on the density and distribution of plants, whereas CVI identifies changes in plant health and chlorophyll content. The CVI is an important index that assesses the level of physiological stress induced by chlorophyll reduction in plants, thereby enabling timely intervention in plant management (Vijayalakshmi et al. 2024).

Unlike Sentinel-2, the Sentinel-3 satellite includes a thermal band obtained with a Sea and Land Surface Temperature Radiometer (SLSTR) sensor, which enables the acquisition of detailed information about the Earth's temperature. Thus, owing to the strong correlation between UTFVI and Land Surface Temperature (LST), thermal effects in urban areas can be identified (Naim and Kafy, 2021; Sharma et al., 2021). This process is performed by grouping all pixel values in the image according to the thermal stress level. Another extremely important thermal index is the TDI. This index was used to assess the combination of heat and humidity perceived by the individuals. It is a psychophysical measure of the discomfort experienced by individuals under different environmental conditions. The TDI categories define comfort levels as follows: temperatures ranging from 15 to 19.9°C are considered comfortable, temperatures between 26.4 and 29.9°C are categorized as very hot, and temperatures exceeding 30°C are classified as torrid, according to TDI . Additionally, psychological parameters play a role in influencing thermal comfort, as noted by de Dear and Brager (1998). The combined impact of these factors underscores the need to comprehend and mitigate the effects of Urban Heat Islands (UHI) on human well-being. The UHI effect negatively affects the quality of life in cities and increases energy consumption due to high temperatures, especially during summer months. The UTFVI measures the UHI effect on the surface and helps reduce its negative impacts on the city (Degerli and Cetin, 2023). The relationship between the UTFV and UHI provides important data for urban planning and public health strategies. Moreover, it can help assess ecosystem health by monitoring vegetation changes. Bu olumsuzlukların yanında bitki örtüsünde zamanla beklenemdik değişimler meydana gelebilir. Figure 6a illustrates the thermal stress (TDI, °C), whereas Figure 6b displays the UTFVI thermal comfort levels. Red indicates the highest level of thermal stress, whereas green indicates the lowest level of thermal discomfort.

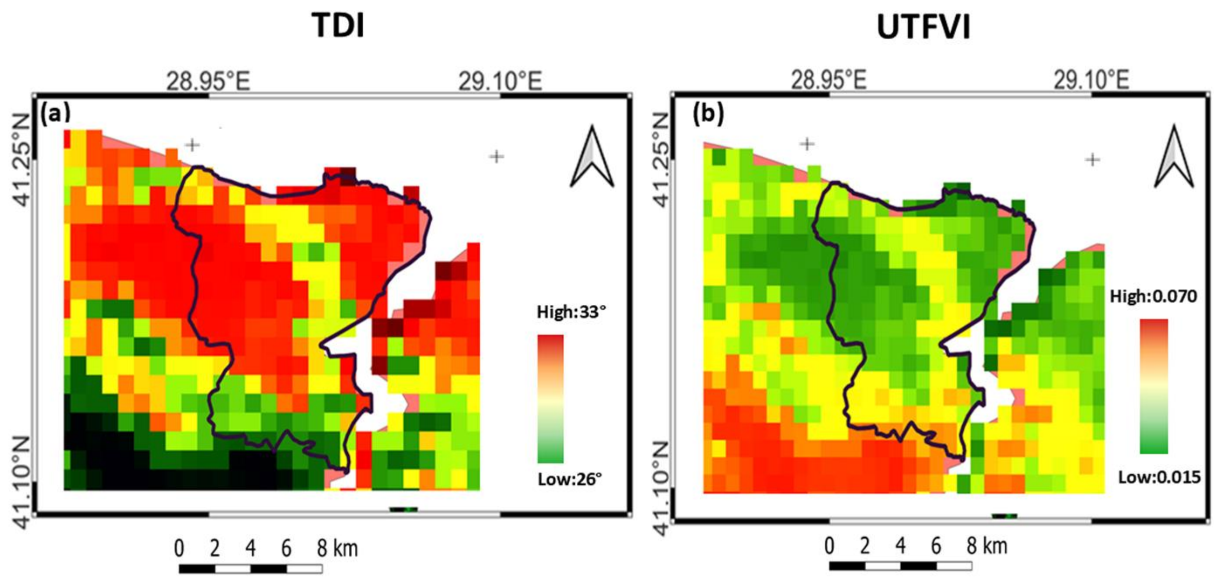

Figure 6. Calculated from Sentinel-3 images with plugins (a) TDI thermal stress and (b) UTFVI thermal comfort level.

The study also compared the raster calculation menu in other popular GIS software (SAGA-GIS, GRASS-GIS, ArcGIS, and QGIS) to determine the performance of the QSVI (Table 2).

Table 2. Comparison of computation times between QSVI and other popular software.

	Indices	Data-Size	QGIS raster calculator	ArcGIS raster calculator	GRASS GIS	SAGA GIS	QSVI-plugin
		(mb)	(sn)				
Vegetation	NDVI	Sentinel-2 (500)	21.2	20.5	23.4	24.4	4.2
	ARVI		26.7	25.8	25.2	26.8	5.5
	EVI		25.1	26.3	25.8	24.1	5.2
Chlorophyll	CVI		21.2	20.2	22.5	21.5	4.5
	LAI		18.3	19.3	23.7	22.7	4.2
Thermal	UTFVI	Sentinel-3 (510)	17.6	16.2	19.3	20.3	4.3
	TDI		17.9	18.2	19.4	20.4	4.2
	Total:	1010	148	146.5	159.3	160.2	32.1

The calculations were performed on a PC with 8 GB of RAM using a 500 MB Sentinel-2 dataset and a 510 MB Sentinel-3 dataset. The results indicated that QSVI significantly outperformed other GIS software in terms of the overall processing time. At the end of the process, the QGIS raster calculator took 148 s to complete, whereas QSVI finished in 32.1 seconds. Thus, QSVI reduced the processing time by approximately 116 seconds or approximately 1.93 minutes.

Similarly, the ArcGIS raster calculator takes 146.5 seconds to complete, whereas QSVI reduces this time by approximately 1.90 minutes (114 seconds). GRASS GIS required 159.3 seconds, while QSVI cut this time by about 2.12 minutes (127 seconds). Similarly, while SAGA GIS took 160.2 seconds, QSVI saved approximately 2.14 minutes. In particular, for 1 GB datasets, QSVI decreases the processing time by an average of 2.1 minutes compared with other popular software. These results demonstrate that the QSVI plugin not only provides high processing efficiency but also greatly simplifies the workflow for users by saving time when analyzing large datasets. QSVI is a valuable tool for both academic research and educational applications.

5. Discussion

In this study, a new plugin was introduced to assess the calculation of vegetation indices more practically and quickly. These indices are widely used in environmental monitoring using remote sensing technology. While they can be calculated on various platforms, the new plugin (QSVI) is designed to allow for a simpler solution. Simultaneously, its open-source code makes it accessible to a large number of users, making it an alternative study with large datasets.

The primary contribution of this research is not the development of new environmental indices; rather, it is faster and easier to use all the indices on the same platform. This provides an easily accessible choice for both beginners and experts studying vegetation dynamics.

Today, remote sensing digital software, which is widely used by researchers such as ArcGIS (ArcGIS Desktop, ArcMap & ArcCatalog | Esri's Legacy GIS Software, 2025), SAGA-GIS, and GRASS GIS, is known to be very provisional and for its sophisticated algorithms in data processing and analysis. However, not all users can perform powerful computational processes. QSVI facilitates the automation of calculations and implementation of a simplified set of functions, making it accessible to non-expert users. There is potential for further improvement by incorporating additional functionalities to maintain the current logical structure of the plugin. For example, adding a new function can enhance its utility.

However, QSVI can be compared with the existing remote sensing plugins, PI2GIS, which is very convenient for processing remote sensing data. (Correia et al. 2017). QSVI shares similarities with PI2GIS in terms of its learning strategies. OSVI distinguishes them by incorporating not only vegetation indices, but also chlorophyll and thermal indices. In the future, different indices could be added to the QSVI for further development.

It is also worth mentioning that the Q-LIP add-on is designed for users with limited remote sensing experience. Furthermore, the plugin developed by (Sebbah et al., 2021) for downloading and calculating various environmental indices using Landsat images is notable for its efficiency; it can process a 1.73 GB Landsat-8 image in just 3 minutes, whereas QSVI demonstrates its capabilities by processing an approximately 1 GB image in a total of 2.1 minutes for Sentinel-2 and Sentinel-3 datasets.

As a result, QSVI can be an alternative for education and research, especially because of its simple interface and computational capability. QSVI also reduced the processing time for Sentinel-2 images by about 2.1 minutes on standard systems (8 GB RAM, 1 GB disk space). For Sentinel-3, the time was reduced by 13.6 seconds. The QSVI is available without additional installation using GDAL/OGR and NumPy. However, QSVI is aimed at basic environmental analysis and is not intended to replace ARC-GIS, SAGA-GIS, and GRASS GIS-specialized platforms.

6 Conclusion

In particular, high-resolution remote sensing imagery requires extensive analysis and data processing. The complex interfaces and sophisticated algorithms of digital tools used for this purpose can be challenging, especially for beginner researchers or users from different disciplines. This study developed an innovative evaluation methodology and introduced a new Python plugin within the existing QGIS software. This plugin provides a graphical user interface (GUI) with a simple interface and practical computational capability that allows users from different disciplines to compute various environmental vegetation indices, without the need for extensive background knowledge in the field. In this respect, the tool is not only an educational tool but also a tool for researchers interested in the environmental problems of the Earth. Unlike standard tools, QSVI supports researchers working on vegetation health and thermal models with the ability to calculate the well-known NDVI index, as well as chlorophyll and thermal indices on a single platform. Compared with other GIS software, QSVI reduced the processing time for Sentinel-2 and Sentinel-3 data by 2.1 minutes for datasets ranging from 500 MB to 1 GB in the study area. With this performance, users can be provided with practicality and ease of use for large datasets.

Code and data availability. All Sentinel-2 and Sentinel-3 images used in this study were obtained from the Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus). The Python code for the QGIS Sentinel Indices plugin (QSVI) is not yet publicly available, but will be provided as supplementary material upon request.

Author contributions. Nuray Baş conducted all stages of the study, including conceptualization, design, Python plugin development, data analysis, and manuscript preparation.

Competing interests. The contact author declares that none of the authors have any competing interests.

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