https://doi.org/10.5194/gi-2024-8
Preprint. Discussion started: 24 March 2025

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

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Abstract:

Recent advances in remote sensing technology have increased the demand for software that supports educational and research activities. However, commercial software often comes with high costs and complex interfaces, presenting challenges for users. In contrast, open-source software offers a more accessible and cost-effective solution, making it increasingly popular for remote sensing and image processing applications. This study introduces a new computational approach for widely used vegetation indices, including the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Atmospherically Resistant Vegetation Index (ARVI). It also presents new tools for assessing chlorophyll, specifically the Leaf Area Index (LAI) and Chlorophyll Vegetative Index (CVI), as well as thermal indices like the Urban Thermal Field Variation Index (UTFVI) and Thermal Discomfort Index (TDI). Developed using Python, a popular programming language, within QGIS, the QSVI plugin features rapid processing capabilities and a user-friendly interface, making it particularly accessible for both researchers and educators. The effectiveness of the application was evaluated in the Sarıyer district of Istanbul using remote sensing data from the European Space Agency's Sentinel-2 and Sentinel-3 satellites. The results indicate that the QSVI plugin significantly reduces computation time compared to popular geographic information system (GIS) software, including ArcGIS, GRASS GIS, and SAGA GIS. For Sentinel-2 datasets, QSVI is, on average, 2.1 minutes faster than these applications. Additionally, for Sentinel-3 datasets, QSVI performs approximately 13.6 seconds faster than the others. These time savings highlight QSVI's efficiency in handling large datasets and demonstrate its advantages in environmental monitoring and analysis.

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

1 Introduction

Digital software applications have become important resources in both education and research, particularly in the field of remote sensing. These tools facilitate the integration of traditional methods, enhance student motivation, and provide researchers with new ways to conduct personalised data analysis. By simplifying complex analytical processes, digital software also makes it easier and faster to complete research tasks, allowing more effective use of time and resources. A number of studies have demonstrated that technology-based approaches can enhance student performance by between 15% and 25% in comparison to traditional methods (Bernard et al., 2019; Sung et al., 2021; Zheng et al., 2022). This is particularly evident in the field of remote sensing, where specialised software facilitates the interpretation of data (Surampalli et al., 2020).

To support these educational and research needs, this paper presents an open source plugin specifically designed for remote sensing applications. This plugin includes several functionalities aimed at both supporting

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computer-based learning for students and facilitating advanced data analysis for researchers. In particular, open-source platforms have become important in this context as they encourage active interaction, self-directed experimentation and shared learning (Gomez et al., 2010; Dinçer, 2017). These tools provide users, including students and researchers, with the ability to explore complex datasets, test applications, and contribute to scientific knowledge in ways that may not be possible using traditional methods.

In the field of remote sensing, this capability is of particular significance, as open-source software facilitates the efficient and repeated analysis of environmental changes, making use of spatial, spectral, and temporal data from extensive and remote regions. For example, the application of open-access Normalized Vegetation Index (NDVI) analysis has been effective in detecting changes in vegetation and land cover in a range of ecosystems, as observed in Wadi Yalamlam (Aldhebiani et al., 2018). This approach demonstrates how open-access software in remote sensing not only supports educational objectives but also advances environmental research and monitoring, thereby providing a comprehensive understanding of ecological changes (Bastiaanssen et al., 2000; Wachendorf et al., 2018).

In addition to software advancements, the accessibility of open-source data sets has further facilitated educational and research activities in the field of remote sensing. To consider an example, the Landsat imagery, which is widely recognised for its multispectral data, makes it possible to analyse the spectral relationships across pixels, which is valuable for precise environmental classification and monitoring (Ran et al., 2017; Narine et al., 2019). Furthermore, the Copernicus programme's Sentinel satellites provide open-access data that is crucial for environmental analysis. Sentinel-2 Level 2A (L2A) data, which has been corrected for atmospheric effects by the European Space Agency (ESA), offers users data that is ready for direct analysis. Sentinel-3 extends this utility by including a thermal band, which allows for studies that are focused on temperature dynamics an essential aspect of environmental and climate research.

These images offer a wide range of potential applications across various academic disciplines, including agriculture (Segarra et al., 2020), grassland studies (Potočnik Buhvald et al., 2022), risk assessment (García-Fernández et al., 2020), and land cover classification (De Fioravante et al., 2021). Furthermore, they have been instrumental in studies related to land surface temperature (Nie et al., 2021), soil moisture (Liu et al., 2021), and oil spill detection (Kolokoussis et al., 2018). Such studies commonly make use of a variety of remote sensing indices, including the NDVI, (Peddinti et al., 2021; Roßberg, 2023), the Enhanced Vegetation Index (EVI),(Ram et al., 2009; Nepita-Villanueva et al., 2019), and the Water Index (Choudhary and Ghosh), which have been developed for the assessment and characterisation of environmental phenomena.

Nevertheless, the precise and rapid extraction of environmental information from images for monitoring purposes remains a time-consuming and challenging task (Carless et al., 2019; Kalacska et al., 2021). In addressing this challenge, QGIS provides a variety of plugins, offering a range of professional GIS applications that are easily accessible to users and can be downloaded directly. In addition to plugins developed by the QGIS team, independent organisations and developers contribute by creating and integrating their own plugins into the QGIS software, thereby demonstrating the collaborative approach that characterises the project. To provide an example, the Semi-Automatic Classification Plugin (SCP) is an especially valuable tool for the downloading, preprocessing and analysis of remote sensing data (Congedo, 2016; Congedo, 2021). Moreover, the SCP allows for the calculation of environmental indices, including the NDVI and the Atmospherically Resistant Vegetation Index (ARVI). Furthermore, the System for Automated Geoscientific Analyses (SAGA-GIS) (Conrad et al., 2015) and

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the Geographic Resources Analysis Support System (GRASS-GIS) are widely adopted tools for filtering, classifying, and analysing spatial data (GRASS-GIS, 2023). However, despite the usefulness of these popular plug-ins, non-experts may find it difficult to understand the manual input requirements of each tool. In addition, many users only need a partial set of the available functions, making the full software package unnecessarily complex. A simplified design with automated, single step calculations could effectively address these usability challenges. In this research, a novel plugin called QSVI (QGIS Sentinel Indices plugin) was designed with the primary purpose of improving the calculation of several indices that are crucial for remote sensing applications.

The plugin provides an easy-to-use interface that simplifies the calculation of several indices, including NDVI, EVI, ARVI, LAI, CVI, UTFVI and TDI. While indices such as NDVI and EVI are well known, the QSVI plugin improves the calculation process, allowing users to perform efficient analysis of large datasets and calculate multiple indices simultaneously. Its design supports fast computations on large datasets, providing scalability that benefits both beginners and experts.

In addition to simplifying analysis for students and researchers, the QSVI plugin is designed to improve the efficiency of environmental monitoring within an open source GIS environment. Unlike other tools such as SAGA-GIS and GRASS-GIS, which offer extensive but complex functionality, QSVI focuses on providing a simplified experience with automated, single-step calculations of basic indices such as NDVI, EVI, ARVI, and LAI. While these indices are widely recognised, QSVI differs by simplifying their calculation processes, making it easier to analyse large datasets quickly and reliably. This simplification is particularly valuable for users with less experience in remote sensing, promoting accessibility and operability.

The QSVI plugin therefore provides a double benefit: it supports basic education in environmental data analysis while facilitating advanced researchers. By providing an accessible interface with rapid processing capabilities, QSVI allows users to monitor critical environmental metrics with more ease and speed, helping to support informed decisions about environmental monitoring. In summary, QSVI is an adaptable and time-efficient tool that serves as both an educational resource and a practical application for environmental management, marking a significant advancement within the open source GIS community.

2 Material And Methods

2.1 Development of the QSVI plugin

QGIS is a widely used open-access GIS platform that provides extensive support for monitoring and analyzing geospatial data. Its ability to extend GIS functionality and the support of a large development community contribute to its popularity. The QSVI plugin, developed within the QGIS plugin community, is written in Python 3.9 and designed using Qt Designer, a tool for creating integrated user interfaces within QGIS. This design does not require additional Python packages, making it compatible with standard desktop versions of QGIS across all operating systems.

After installation, the QSVI plugin is accessible from the Raster menu on the main QGIS toolbar (Figure 1a-b).

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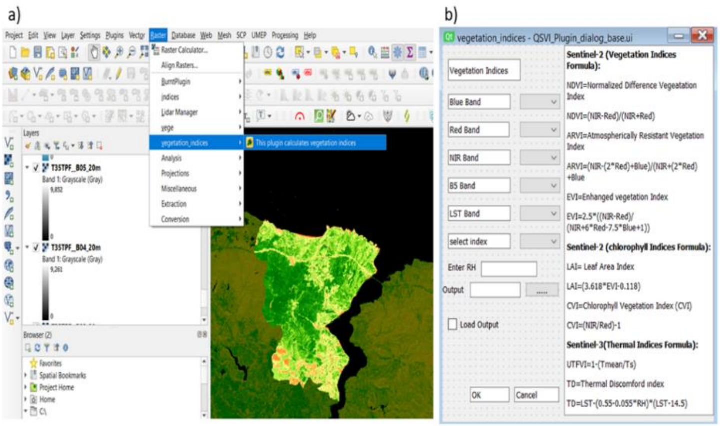

Figure 1. a)Plugin menu tab in Qgis software b) The tabs of QSVI graphical user.

To install the plugin, users simply extract the ZIP file and navigate to "Plugins" -> "Manage and Install Plugins." The tool simplifies the processing of remote sensing images and allows for the efficient calculation of various indices. For optimal performance, especially with images larger than 1 GB, a computer with a minimum of 8 GB RAM is recommended.

The QSVI plugin requires a remote sensing image as its primary input. Users can load an image either directly from the interface or select it from a list of images already available in QGIS. Supported image formats include tif and jpg. After selecting the image, users can choose the desired index from the provided options, and the calculation process will begin. Once complete, the resulting image is saved in the user-selected output folder.

2.2 Process description

The QSVI plugin's processing functionality is divided into three categories: vegetation, chlorophyll, and thermal indices, which are designed for comprehensive environmental analysis (Figure 2).

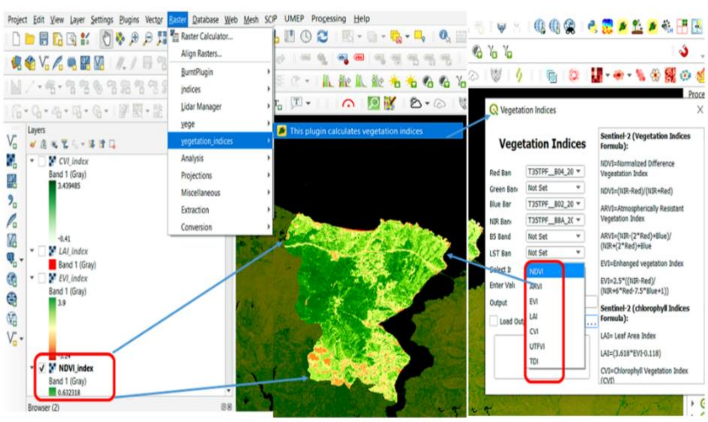

Figure 2. Overview of QSVI plugin functionalities (Developed by Nuray Baş)

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Table 1 lists these indices along with their corresponding formulas. Once a remote sensing image is selected from the pop-up window, the plugin automatically calculates the chosen indices.

Table 1 Environmental indices computed by the QSVI plugin.

	Index	Formula	Reference
Vegetation indices	NDVI	$NDVI=\frac{NIR-RED}{NIR+RED}$	Rouse et al.(1974), Crippen (1990)
	ARVI	$ARVI=\frac{NIR-(2*RED)+Blue}{NIR+(2*RED)+Blue}$	Kaufman (1984); Tanre
	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. [60]
	CVI	$CVI=\frac{NIR}{RED}-1$	Vincini et al. (2007)
Thermal indices	UTFVI	UTFVI = 1 - (Tmean/Ts)	Zhang et al.
	TDI	TDI=LST-(0.55-0.055*RH)*(LST-14.5)	Gartland (2011)

The process is divided into two main steps: first, loading the remote sensing image, and second, selecting the necessary indices from the icons in the interface. Users then specify the output folder and file name. Upon completion, the plugin generates a raster output file, either in Tiff or Jpeg format, containing the calculated indices.

In the vegetation category, users can access the NDVI, EVI and ARVI. These indices are an important remote sensing tool for monitoring vegetation health and dynamics. While NDVI is a widely recognized metric for assessing vegetation cover by measuring the difference between near-infrared and red reflectance, its effectiveness is further enhanced within the QSVI plugin through optimized computational processes. This allows the effective management of large datasets, which is essential in studies where rapid and adaptable data analysis is required. EVI is a modification of NDVI that is more sensitive to high biomass concentrations. It accounts for atmospheric conditions and provides a more accurate representation of vegetation density, which is particularly advantageous in regions with dense vegetation. The ARVI is also designed to address the issue of atmospheric disturbance by taking into account the reflectance of blue light, thereby making it an effective method for correcting the potential biases. Together, these vegetation indices not only facilitate the monitoring of ecological health but also contribute to the understanding of plant responses to environmental changes (Lei et al. 2024; Jombo & Adelabu, 2022).

The advanced capabilities of the QSVI plugin allows researchers to apply the indices effectively across extensive geographical areas, facilitating a comprehensive and timely analysis of vegetation dynamics with high accuracy. In addition to the vegetation indices, the chlorophyll indices play a vital role in understanding plant physiology and ecosystem functionality. The CVI and LAI are of great importance in evaluating plant health and photosynthetic capacity at the canopy level. The CVI provides insights into chlorophyll concentration, which is critical for assessing crop health and productivity, while the LAI quantifies leaf area and helps to understand overall plant growth and canopy structure. Furthermore, the thermal indices category, which includes UTFVI and the TDI, is crucial for understanding the thermal dynamics of urban environments. The UTFVI is a valuable tool

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for urban planners in their efforts to mitigate the Urban Heat Island (UHI) effect, as it allows for the assessment of the intensity of thermal stress on urban vegetation. TDI evaluates thermal discomfort in human populations, informing public health initiatives and urban design strategies aimed at enhancing community well-being. Together, these thermal indices are essential for assessing the impacts of urbanization on ecological health and developing strategies for climate adaptation. (Ren et al. 2023).

3 Study Area and Data

The study area selected is the municipality of Sarıyer, covering an area of 177km² on 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, the Bosphorus to the east, and the Black Sea to the north (Figure 3).

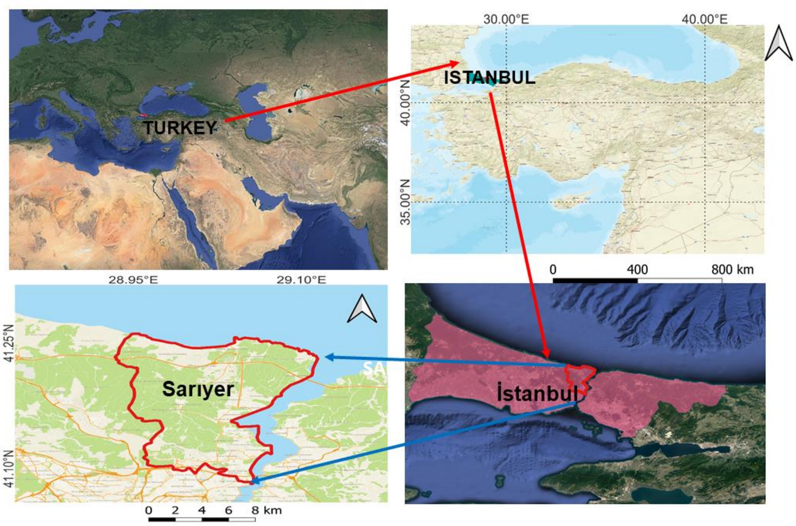

Figure 3. Location of the plugin's testing area (Basemap: Esri ArcGIS Online, 2024).

The coastline along the Bosphorus is characterised by steep cliffs and crags, while Sarıyer is known 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 characterised by a high degree of forestation. However, this has been partially affected by the construction of residential buildings in recent times. Sarıyer displays a Black Sea climate, with temperatures and humidity levels that vary seasonally, particularly along the coastline.

During the measurement period (1950 - 2023), Sarıyer experienced its lowest temperature of -9 °C in February and its 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, 2022). As of 2022, the population of Sarıyer is reported to be 350,454 (Turkish Statistical Institute, 2022).

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The image data from Sentinel-2 and Sentinel-3, atmospherically corrected and in TIFF format, were used in this study. The data were downloaded from https://scihub.copernicus.eu on 9 July 2022, with a total size on disk of 1010 Mb.

4 Results

The results obtained in this study provide important findings the processing and analysis of various environmental indices. The methods and tools used were effectively applied to the calculation of vegetation, chlorophyll and thermal indices, allowing the monitoring of environmental changes over the defined region. The detailed results of these analyses are presented in this section.

Once the necessary raster remote sensing data has been uploaded to the screen, the QSVI algorithm proceeds to calculate the indices and thus generate the related results as output files. The processing tab are categorized into three sections: vegetation, chlorophyll, and thermal indices. Users must select a preferred category before proceeding with the index calculation. Under the vegetation category, NDVI, ARVI, and EVI indices are generated to assess vegetation greenness. In this paper, to test the QSVI plugin outputs, Sentinel-2 Level 2A products were used as real data source. Thanks to its open-access data policy, users have access to four spectral bands (10m resolution) and six spectral bands (20m resolution).

NDVI and the EVI are of significant value in the monitoring of vegetation status, particularly in areas characterised by high biomass densities. EVI, being more sensitive in densely vegetated areas compared to NDVI, offers nuanced insights due to its lesser susceptibility to atmospheric conditions (Xiao et al., 2003; Bounoua et al., 2000; Huang et al., 2021). This difference is illustrated in Figure 4a-b and NDVI vegetation spectral reflectance range is smaller than EVI (Tucker, 1977);(Figure 4b).

Additionally, ARVI corrects for atmospheric scattering effects by utilizing blue light reflectance, thereby influencing red light reflectance as well (Figure 4c).

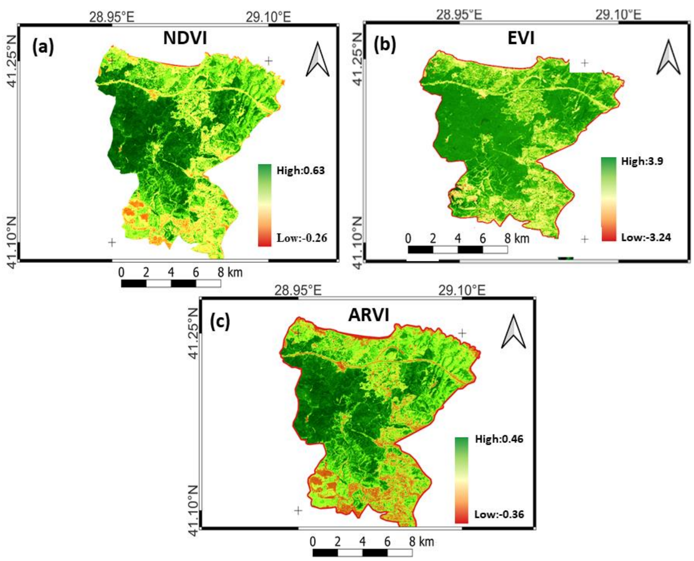

Figure 4 Calculated from Sentinel-2 images with plugin (a) NDVI indices (b) EVI indices (c) ARVI indices.

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In the second category which is CVI and LAI index were generated in to quantify chlorophyll index which are particularly providing information at the canopy scale. These index can be estimated overall photosynthetic capacity of a canopy (Broge and Leblanc, 2000); (Figure 5b-c). Figure 5a depicts the study area as observed through Google imagery.

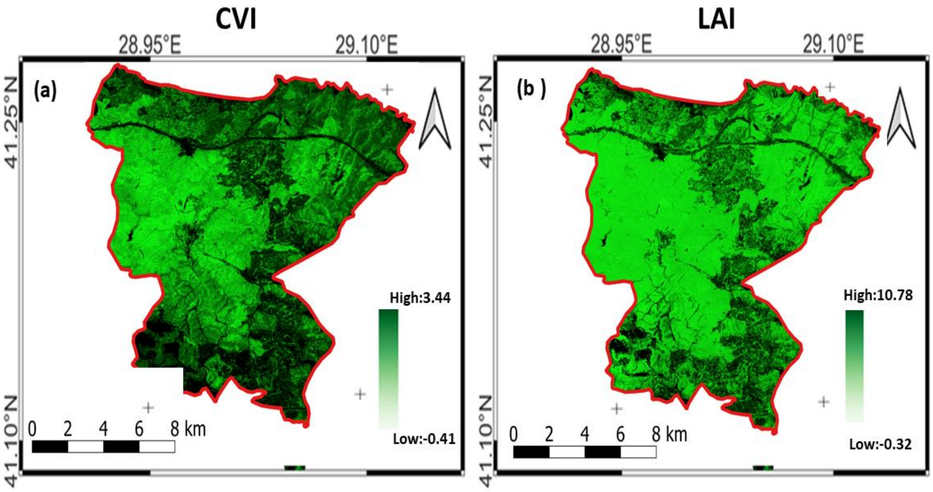

Figure 5. Calculated from Sentinel-2 images with plugin (a) Google image (b) CVI indices (c) LAI indices.

The addition of a thermal band to the Sentinel-3 satellite, which is not present in the Sentinel-2, makes it an optimal choice for the calculation of thermal indices such as UTFI and TDI. The UTFVI is a frequently used method in ecological thermal studies due to its correlation with Land Surface Temperature (LST) and its consideration of thermal impact. This index is designed to assess environmental well-being by evaluating the UHI effect across the whole study area, categorizing pixels into six levels ranging from excellent to worst (Sharma et al., 2021; Naim et al., 2021). The ecological conditions are represented visually through a colour gradient, with red representing the most severe conditions and green representing the least severe conditions (Figure 6c). Moreover, the monitoring of the intensifying UHI impact provides valuable data for the development of urban planning and public health strategies. UHI refers to the rising temperatures experienced in urban areas relative to surrounding rural areas due to human activities and infrastructure. These effects have been found to have significant impacts on human health.

TDI is a psychophysical measure used to assess how individuals experience and perceive a combination of heat and humidity. It quantifies the discomfort experienced by individuals in different environmental conditions. Figure 6b in the study illustrates the estimated thermal comfort levels (in °C) based on these conditions. Additionally, psychological parameters play a role in influencing thermal comfort, as noted by De Dear et al. (1998). 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 Thom (1959). The combined impact of these factors serves to underscore the necessity of comprehending and mitigating UHI effects for human well-being.

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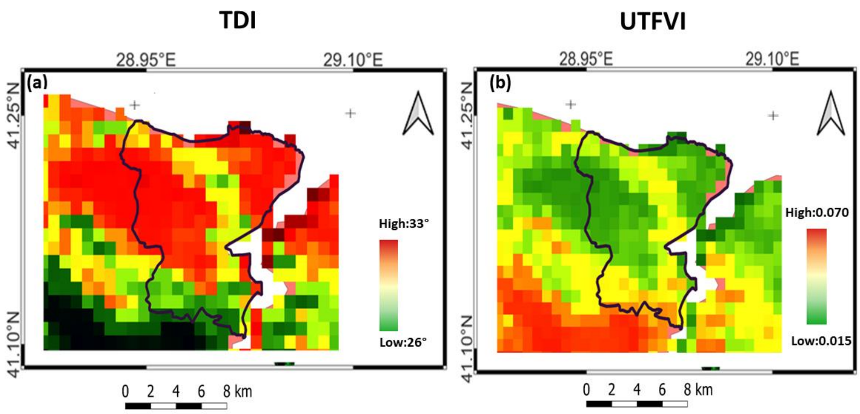

Figure 6. Calculated from Sentinel-3 images with plugin (a) TDI indices (b) UTFVI indices.

These calculated indices can contribute to assessing ecosystem health by monitoring changes in vegetation. Since environmental factors have the potential to induce stress and result in alterations to vegetation, as well as affect plant growth patterns, LAI is designed to monitor plant density and growth. This allows for the detection and analysis of these changes.

The CVI measures the amount of chlorophyll in plants and can be used to detect and manage stress in plants (Broge and Leblanc, 2000; Xu et al., 2023). The analysis of temporal variations in LST using the UTFVI can help reduce the impact of urban heat islands (UHI) by providing a means of quantifying the UHI effect (Çevik Degerli, B., & Cetin, M., 2023).

QSVI was compared to other widely used applications, such as SAGA-GIS, GRASS-GIS, ArcGIS, and the QGIS raster calculator menu, in order to assess its performance. The computations were conducted on a computer with 8 GB of RAM and for a 500 MB Sentinel-2 dataset and a 510 MB Sentinel-3 dataset.

Table 2 Comparison of Index Calculation Times between QSVI and different 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

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As shown in Table 2, the QSVI plugin performed significantly faster in calculating certain indices compared to other popular GIS software when considering total calculation times. For instance, the QGIS raster calculator required a total of 148 seconds to complete the calculations, whereas the QSVI plugin finished in just 32.1 seconds, resulting in a processing time reduction of approximately 1.93 minutes. Similarly, the ArcGIS raster calculator required 146.5 seconds, with QSVI saving around 1.90 minutes. The GRASS GIS process took 159.3 seconds, while QSVI reduced this by approximately 2.12 minutes. SAGA GIS required 160.2 seconds, and QSVI saved about 2.14 minutes. In total, QSVI reduces computation time by about 2.1 minutes compared to other popular software, particularly for 1 GB datasets.

These results demonstrate that the QSVI plugin not only offers significant time savings but also enhances overall efficiency in processing remote sensing data. Its ability to significantly reduce computation time makes it a valuable tool for both educational and practical applications in environmental monitoring and analysis.

5 Discussion

This study introduces the QSVI plugin, a novel tool designed for integration with QGIS, which facilitates the calculation of a variety of indices related to vegetation, chlorophyll, and thermal characteristics. While vegetation indices such as NDVI, EVI and ARVI are well established in remote sensing for monitoring ecological health, the QSVI plugin differs by simplifying the computational processes required to calculate them. This makes it much more efficient to use with large datasets, allowing users to perform fast, scalable analyses that are particularly useful in environmental monitoring applications.

The main contribution of this paper is not in the novelty of the indices themselves, but in the improvement of their computational efficiency. By facilitating the processing of multiple indices, the plugin provides both beginners and experts with an accessible and effective tool for large-scale data analysis. Furthermore, the open source nature of QSVI allows for continuous adaptability and ensures its long-term applicability in the changing field of environmental monitoring.

In the field of remote sensing software, widely used packages available such as ArcGIS (Redlands, C.E.S.R.I. (2011), SAGA-GIS, and GRASS GIS are known for their sophisticated algorithms in data processing and analysis. However, there is a need for an easy interface and shorter computational times. Consequently, QSVI offers advantages in terms of processing time and ease of use. Its user-friendly interface facilitates the automation of calculations and the implementation of a simplified, set of functions, making it accessible to non-expert users. While there is potential for further improvement by incorporating additional functionalities in the future, it is crucial to maintain the current concise and logical structure of the plugin. For instance, considering the addition of a function to download satellite data alongside calculation tools could enhance its utility.

In a comparative context, QSVI can be compared with other existing remote sensing plugins, such as PI2GIS (Correia et al., 2018). While QSVI shares similarities with PI2GIS in terms of its learning strategy, it distinguishes itself by incorporating not only vegetation indices but also chlorophyll and thermal indices within its user interface. There is potential for further development, particularly by developing the range of available indices.

It is also worth mentioning the Q-LIP add-on, designed for users with limited experience in remote sensing. 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.

After comparing QSVI with other plugins, QSVI is a new alternative, particularly in its basic interface and index calculations capability. Additionally, QSVI have a reduced processing time of approximately 2.1 minutes for Sentinel images on standard systems (8 GB RAM, 1 GB disk space). Using GDAL/OGR and NumPy, QSVI minimizes installation requirements by forgoing external dependencies, enhancing accessibility. Although not intended to replace specialized platforms, QSVI consistently delivers reliable, compatible results, supporting its use in environmental monitoring and analysis.

6. CONCLUSIONS

In both higher education and research, the use of computational tools in remote sensing can be challenging, especially for beginners. The complex interfaces of these tools can make visualisation, analysis and experimentation difficult for students and early career researchers too. In addition, the detailed set of tasks involved in remote sensing applications often requires considerable time and effort, which can further affect accessibility and ease of learning in the field

The primary objective of this study was to develop a new plugin for QGIS with a user-friendly interface, specifically designed for beginners. Aimed at university students and researchers, this plugin provides a graphical user interface (GUI) that enables users from various disciplines to perform remote sensing tasks without needing extensive background knowledge in the field.

This study introduces QSVI, a plugin for QGIS that is designed not only as an educational tool but also as a practical application for environmental monitoring and analysis. Unlike standard tools, QSVI includes calculations for vegetation, chlorophyll, and thermal indices, streamlining their use through a user-friendly interface while significantly reducing processing time. While NDVI is a well-established index, the QSVI plugin distinguishes itself by also offering chlorophyll and thermal indices, which are crucial for comprehensive environmental assessments. These additional indices make it particularly useful for tracking vegetation health and thermal patterns, areas of significant importance in environmental research. This combination of functions makes QSVI a valuable tool for environmental researchers who need an efficient, open-source solution for remote sensing analysis. With processing times as low as 2.1 minutes for Sentinel data on standard systems, QSVI offers a practical alternative to more complex software by enabling the efficient calculation of indices across diverse environmental applications. In conclusion, integrating open-source, computer-based tools into university education provides essential resources for both teaching and research, especially in the field of remote sensing. QSVI not only serves as an accessible and practical option for educational purposes but also as a reliable tool for researchers focused on environmental monitoring and index calculation. Its simple interface and efficient processing make it a promising alternative for users interested in studying a wide range of environmental indices using remote sensing data.

Code and data availability. All Sentinel-2 and Sentinel-3 imagery 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 has declared that none of the authors has any competing interests.

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