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Comparative Analysis Between Sentinal 2 , OLI Sensors and Field Mesurements to Estimate Leaf Area Index (LAI)

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ABSTRACT

This study validates the accuracy of Sentinel-2 satellite leaf area index (LAI) data obtained through SNAP software for assessing vegetation and guiding agriculture. The research demonstrates the potential of utilizing Sentinel-2 satellite data processed with SNAP software for the estimation of LAI. It compares this data with in-field measurements and global LAI outputs at spatial resolutions of 10 m and 20 m. The results revealed a significant level of concurrence between LAI obtained from Sentinel-2 satellite imagery and the LAI measured in the field, with coefficient of determination (R2) values of 0.81 (10 m) and 0.76 (20 m). This correlation was evidenced by lower values of Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) in comparison to the LAI derived from Landsat 8 data. Significant associations were identified between LAI and various crops, with potatoes exhibiting a high correlation (R2 > 0.8) compared to peanuts (R2 > 0.75). This finding underscores the possibility of variations in LAI estimation that are specific to different crops. The research highlights the significance of rectifying atmospheric correction errors in enhancing the precision of LAI measurements. Additionally, it implies the necessity of implementing local calibration techniques to improve the resilience of the system. The results highlight the significance of utilizing the SNAP-derived LAI to monitor agriculture on a large scale, thereby making a valuable contribution to global initiatives. Although SNAP-derived LAI has some limitations, it exhibits potential for extensive agricultural monitoring applications, thereby facilitating well-informed decision-making on both regional and global levels.

KEYWORDS: Leaf Area Index (LAI), Sentinel-2, Landsat8, Global LAI products, Remote sensing

1. INTRODUCTION

The enhancement of remotely sensed assessment of the biophysical parameters of plants holds significant importance for a variety of global applications (Shanmugapriya et al., 2019). In the present environmental context, there is an increasing imperative to effectively observe and assess crop conditions, predict crop yields, and diligently monitor irrigation practices and fertilization levels to mitigate potential adverse impacts. According to Kamenova and Dimitrov (2021), agriculture emerges as the predominant contributor to the pollution of phosphorus, nitrogen, and cadmium. Pollution poses significant risks to both human health and global ecosystems, as stated by the Food and Agriculture Organization (FAO) and the International Water Management Institute (IWMI) in 2018. To effectively address this matter in a timely and spatially appropriate manner, it is imperative to possess precise knowledge regarding the current condition of the crop and a comprehensive comprehension of the pertinent biological mechanisms involved (Weiss et al., 2020). The Leaf Area Index (LAI) can be calculated nondestructively from Earth observational information data has been a widely discussed subject for several decades. The measurement of the green leaf area per unit ground area, commonly referred to as the Leaf Area Index (LAI) (De Bock et al., 2022), holds significant importance as a essential climatic variable (ECV) (Wagner et al., 2012). The significance of remote sensing lies in its ability to provide fundamental data on vegetation development and productivity, encompassing factors Like plant vigour and foliar density, and functionality. Additionally, remote sensing facilitates the modeling of water, carbon, and energy exchanges occurring between the Earth's surface and the atmosphere (Chen et al., 2002; Verrelst et al., 2015). Leaf Area Index (LAI) is employed in the field of agriculture to monitor various aspects such as crop and rangeland production, Crop health and stress, volume of biomass, phenology, and yield estimation (Novelli et al., 2019; Kumar et al., 2022). The conventional method of direct communication on the contrary, LAI (in-situ) measurement methods are subjected to geographical and temporal limitations, as well as being expensive, time-consuming, labor-intensive, and potentially causing damage (Alexandridis et al., 2013). Consequently, the utilization of a remotely sensed effective Leaf Area Index (LAI), commonly referred to as LAI, presents a feasible option for the practical monitoring of agriculture. This approach aids in the pursuit of food security at the regional and global levels objectives, such with those mentioned in the United Nations Sustainability Objectives (Kganyago et al., 2020). The Copernicus program, previously referred to as the Global Monitoring for Environment and Security (GMES), was created with the help of European Commission and the European Space Agency (ESA). It is designed to facilitate worldwide earth observation. The European Space Agency is currently engaged in the development of the Sentinel satellites to preserve the operational capabilities of previous earth observation satellite initiatives, such as Landsat and SPOT, while simultaneously improving the monitoring capabilities of terrestrial surfaces. The major goal of the Sentinel-2 Satellite launch is to facilitate comprehensive ground surface monitoring, as highlighted by Potin et al. (2019). The inclusion of three spectral bands (705 nm, 740 nm, and 783 nm) within the red-edge domain is motivated by their perceived significance in the characterization of green vegetation, specifically in the evaluation of vegetation quality and health (Kamenova and Dimitrov, 2021). According to Phiri et al. (2020), the utilization of Sentinel-2 Satellite data enables the acquisition of imagery characterized by a spatial resolution ranging from 10 to 20 m. This advancement in technology presents novel opportunities for the monitoring of agricultural activities at a regional to global scale.The presence of freely accessible, high-resolution satellite datasets obtained from space-based sensors such as Sentinel-2, along with the Sentinel Application Platform (SNAP) and other powerful open-source applications, and the increasing availability of analysis-ready data (ARD), collectively contribute to the promising prospects of achieving precise, reliable, and practical Leaf Area Index (LAI) measurements.

The restrictions of coarse spatial accuracy (300-1000 m) LAI products, such as those derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Houborg et al. 2016), Advanced Very-High-Resolution Radiometer (AVHRR) (Garca-Haro et al. 2018), Satellite Pourl'Observation de la Terre Vegetation (SPOT-VGT), and Proba-v (Baret et al. 2013)., have certain limitations. One of the primary advantages of Sentinel-2 Satellite, in comparison to other sensors that are freely accessible, is its temporal resolution. In addition to its higher spatial resolution capabilities,in addition Sentinel-2 data offers a temporal resolution of 5 days. This frequency is generally adequate for agricultural monitoring purposes, assuming cloud-free conditions. The SNAP application provides users with the capability to carry out atmospheric correction using the tool of Sen2Cor (Pflug et al., 2020). Additionally, it enables the estimation of biophysical parameters through the utilization of a physically-based radiative transfer model called PROSAIL, combined with a robust machine learning technique known as Neural Networks (Wolanin et al., 2019). Limited research has been conducted to examine the accuracy of the Leaf Area Index (LAI) derived from Sentinel-2 Satellite data using the SNAP software, as well as its compatability with established LAI products (Campos-Taberner et al., 2018; Dugesar et al., 2022). The importance of ensuring the consistency and comparability of biophysical indicators, such as the Leaf Area Index (LAI), cannot be overstated in the context of precise agricultural monitoring (Alexandridis et al., 2019). The research concern regarding the viability and predictive capabilities of this type of data, specifically concerning environmental conditions, particularly the state of agricultural vegetation, continues to be of significant importance in contemporary studies. This is particularly relevant given the substantial volume of data provided by Sentinel-2. The study also aims generally to examine the relationship between Sentinel-2 satellite imagery and in field measurements of biophysical parameters. Moreover, there is a need for additional research to investigate the uncertainties surrounding the impact of data processing level as well as spatial resolution on generated biophysical indicators, such as the Leaf Area Index (LAI). This is especially crucial in the context of Africa, where studies on this topic are limited. The quantification of uncertainty in remotely sensed products holds value for both consumers and developers who are interested in the operational utilization and future advancement of the product. Therefore, the primary aim of this study is to verify and contrast Leaf Area Index (LAI) obtained from Sentinel-2 imagery with spatial resolutions of 10 m accuracy and 20 mas well, using field data and worldwide LAI outputs such as Landsat 8 LAI with 30 m spatial resolution.

2. MATERIALS AND METHODS

2.1.Study Area

The El-Salhia project, located in the eastern region of the Nile Delta, was selected as the study area. It is located between latitudes 30o 22' 35" and 30o 31' 19" on one side, and longitudes 31o 55' 24" and 32o 02' 38" on the other side, as shown in Figure 1. The project encompasses an estimated area of 32,857 Fed. The project utilizes two distinct irrigation systems, namely center pivots and drip irrigation. Pivot irrigation is commonly employed in the cultivation of field crops, while drip irrigation is typically utilized in the irrigation of orchard trees. The project consists of approximately 130 pivots. Each pivot unit can irrigate approximately 151 acres of land. The average length of the pivots in the project is approximately 450 meters.

2.2.Climate Conditions

Based on the Köppen Climate Classification System, the study region predominantly experiences a dry climate, characterized by precipitation levels that typically fall short of meeting more than half of the total potential evapotranspiration in most years. The mean annual temperature exceeds 18 °C. The annual precipitation typically amounts to approximately 20 millimeters. The peak intensity of winter precipitation occurs in the month of January, during which the average rainfall is recorded at 6.9 mm. According to El-Shirbeny et al. (2021), the average maximum temperature in the month

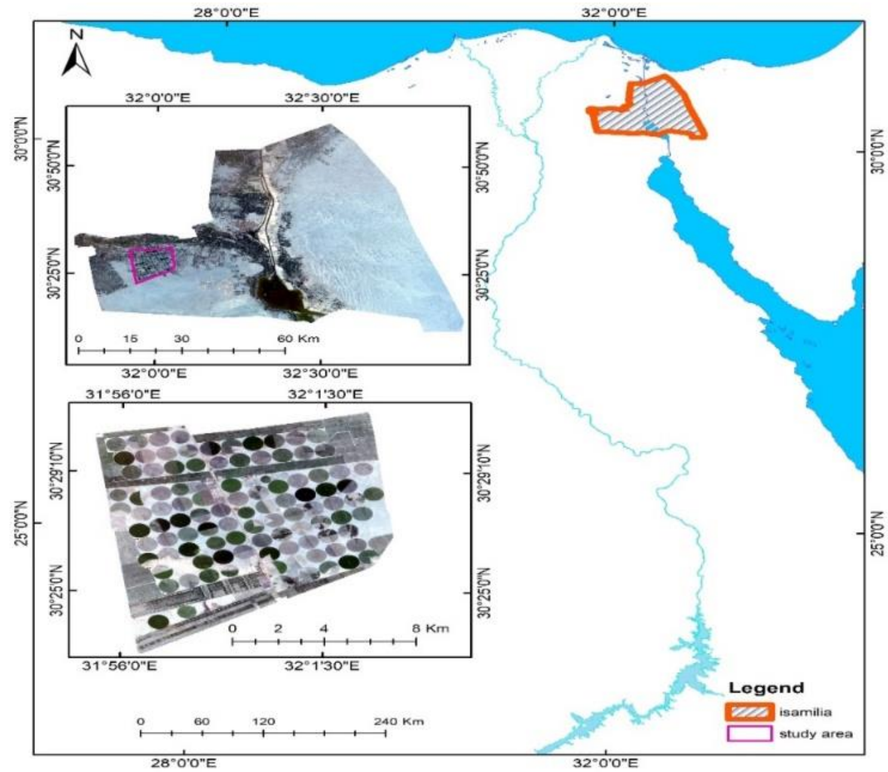


Fig. 1. illustrates the geographical location of the study area.

of June reaches 34.6°C. Conversely, January experiences the lowest temperatures, with an average of 19.0°C.

2.3.Data

2.3.1. Remotely sensed data

Sentinel images were obtained during two distinct agricultural seasons, (winter season of 2019 and the subsequent summer season of 2021). The images were obtained on April 9, 2019, for the first season and on August 11, 2021, for the second season, specifically during the peak of the season. The data was obtained from the ESA Copernicus Open Access Hub, accessible at the URL: https://scihub.copernicus.eu/dhus/. Using the Sentinel-2 resampling technique included in the SNAP application, the images were rescaled to two specified spatial resolutions for Sentinel-2, 10 m spatial resolutions and 20 m spatial resolutions.

2.3.2. Leaf Area Index Using SNAP (LAI)

The biophysical processor, which is a component of the SNAP application, was utilized to derive Leaf Area Index (LAI) from Sentinel-2 images. It is referred to Sentinel-2 land bio-physical processor (SL2P). LAI values were derived from processing Sentinel-2 images captured at both different spatial resolutions, namely 10 meters and 20 meters. The biophysical processor utilizes radiative transfer models (RTMs), specifically the Neural Networks and PROSAIL algorithm, to compute the solar zenith,viewing zenith, and relative azimuth angles for eight reflectance bands (B3, B4, B5, B6, B7, B8A, B11, and B12). Further information can be found in the publication by Weiss and Baret (2016). The Nearest Neighbour resampling method was employed to adjust the pixel resolution of the SNAP-derived LAI data (10 m) to align with the Landsat8 LAI output (30 m). This involved rescaling and co-registering the data. The resampled SNAP-LAI products at a spatial resolution of 30 meters were employed to compare them with the Landsat8 LAI products. We can calculate LAI from sentinel-2 image usin the equation that developed by (Boegh et al., 2002).

LAI = (3.618*EVI - 0.118)

EVI is Enhanced Vegetation Index value.

2.3.3. Landsat8 Leaf Area Index (LAI)

The collection of satellite images from Operational Land Imager (OLI), Landsat8 (L8) satellites, spatial resolution of 30 meters, a moderate revisit capacity of 16 days, and the ability to collect data over nine spectral bands that include visible band to shortwave infrared.during two different agricultural seasons, the first during the winter season of 2019 and the second during the summer season of 2021. It is worth noting that the images collected were required to have a cloud cover of less than 90%. The Landsat 8 Operational Land Imager (OLI) Collection 2 dataset was obtained from the United States Geological Survey (USGS) archive. The top-of-the-atmosphere (L1TP) and bottom-of-the-atmosphere (L2SR) reflectance measurements are included in this collection. The data has been orthorectified, flattened the ground, and compensated for atmospheric conditions. We can calculate LAI from landsat image usin the equation that developed by (Saito et al., 2001).

LAI=0.57exp(2.33NDVI).

2.3.4. Leaf area index in the field (LAI)

The AccuPAR device was utilized to randomly collect leaf area index readings from various points distributed throughout the field. The AccuPAR LP-80 is a portable linear Photosynthetically Active Radiation (PAR) comptometer. It consists of a probe equipped with 80 individual sensors positioned along an 80 cm rod, as well as a read-out/data-logger unit. The system designed for the detection of concurrent above-canopy radiation can be integrated with an additional external Photosynthetically Active Radiation (PAR) sensor if desired. The LP-80's integrated microprocessor utilizes the radiation transmission and scattering model Norman-Jarvis to calculate the leaf area index (LAI) based on the photosynthetically active radiation (PAR) values obtained from both above and below the canopy. Before each measurement session, the LP-80 probe underwent factory calibration to ensure consistency in the photosynthetically active radiation (PAR) interaction between the outside detector and the probe. Following the suggestions put forth by previous research conducted by LI-COR (2019) and the accompanying user manual. Three measurements were recorded at each data point, and the mean value was calculated from these measurements. The LAI measurements were obtained during periods of predominantly cloudless sky conditions on the specific day when the satellite passes over the designated study area, which corresponds to the peak of the growing season. Table 1 presents the summary statistics about the Leaf Area Index (LAI) in field.

Table 1. presents the descriptive statistics of the measured Leaf Area Index (LAI) in square meters per square meter (m2 m-2) to validate the Sentinel 2 LAI derived from the Sensor Network and Analytics Platform (SNAP).

type of crop	Number of samples	Minmum	Mean	Maximum	STDEV
Potato	23	2.32	3.22	4.22	0.48
Peanuts	15	5.43	6.28	7.14	0.38
Overall	38	2.32	4.43	7.14	1.56

2.3.5. Performance indicators

The validation process for the Leaf Area Index (LAI) involved assessing its accuracy through various statistical metrics. These metrics included the coefficient of determination (R2), which gauges how well the observed and predicted values align; the Root Mean Squared Error (RMSE), which quantifies the average magnitude of the prediction errors; and the Mean Absolute Error (MAE), which measures the average absolute difference between observed and predicted values.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Y_{p,i} - Y_{a,i}\right)^2}$$

where Yp,i is the predicted output and Ya,i is the actual output.

$$MAE = (1/n) \Sigma(i=1 \text{ to } n) |y\_i - \hat{y}\_i|$$

where: n is the number of observations in the dataset, y_i is the true value, ŷ_i is the predicted value.

In order to conduct this validation, the LAI values obtained from on-site or in field data were juxtaposed with those derived from global LAI products, which are likely generated through remote sensing techniques. By comparing these values, researchers were able to assess the consistency and reliability of the estimated LAI from earth observation data. This validation process serves to verify the accuracy of the estimation method and the suitability of global LAI products for practical applications.

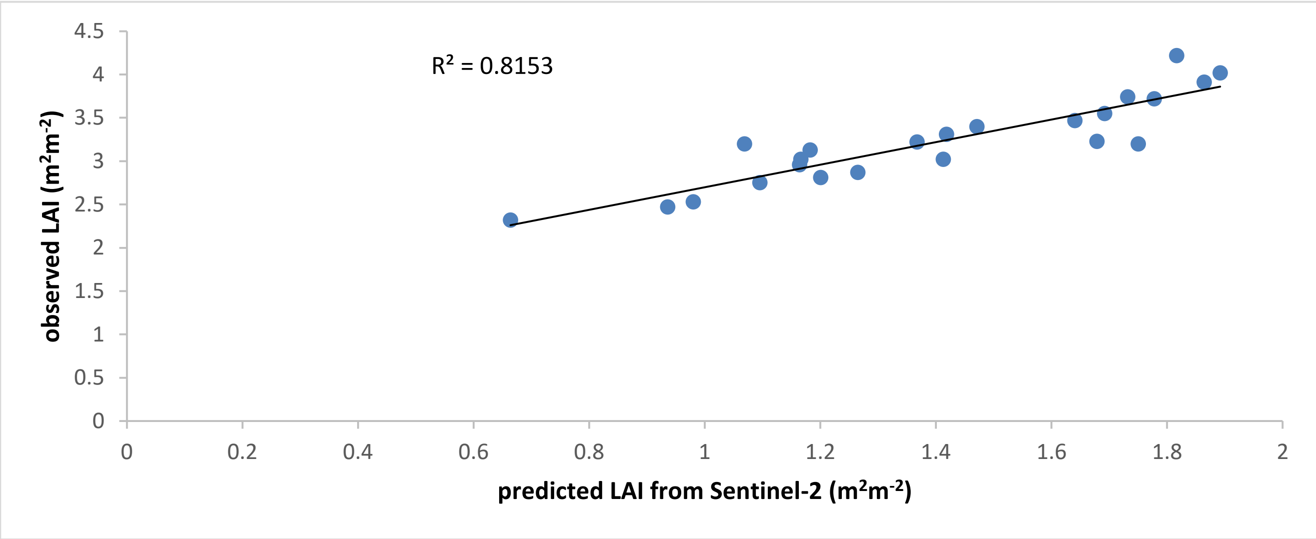
3. RESULTS AND DISCUSSION

The Leaf Area Index (LAI) obtained from Sentinel-2 row data using the SNAP software was validated by comparing it with in field LAI measurements. The validation process was conducted for two different spatial resolutions. The findings presented in Figures 2 and 3 demonstrate variations in Leaf Area Index (LAI) extracted from SNAP software at different pixel resolutions. The results indicate that the Leaf Area Index (LAI) extracted from SNAP software at both 10 m and 20 m pixel size resolutions exhibited comparable agreement with the observed LAI values obtained through in field measurements. For instance, the R-squared (R2) was found to be 0.81 for the 10 m resolution. When comparing the results, it was observed that there were only slight variations in the overall agreement at resolutions of 10 m and 20 m. Specifically, the coefficient of determination (R2) values were found to be 0.78 and 0.76, respectively, for one of the crops. However, the error metrics exhibited a high degree of similarity for both resolutions. The Leaf Area Index (LAI) obtained from SNAP analysis in this study, based on reflectance data at a Pixel size of 10 m, was found to be more effective compared to the findings reported by Pasqualotto et al. (2019), exhibiting a higher R2 value of 0.54.

When comparing leaf area index (LAI) between multiple crops, specifically potato, and peanut, the findings indicate significantly stronger correlations with observed LAI for potatoes. This is evident through an R2 value exceeding 0.8 across various Pixel size and processing levels. In contrast, the analysis of peanuts revealed moderate effects with an R2 value exceeding 0.75, indicating a substantial degree of explained variance. Additionally, there were marginal disparities observed across different levels of processing. The error measures, such as RMSE and MAE, were determined for potato and peanut crops at two different scales, specifically 10m and 20m. The resulting values are as follows. The root mean square error (RMSE) for potato cultivation was found to be 1.83 m2 m–2 and 1.81 m2 m–2 at spatial resolutions of 10m and 20m, respectively. Similarly, the mean absolute error (MAE) for potato cultivation at the same spatial resolutions was determined to be 1.81 m2 m–2 and 1.82 m2 m–2, respectively. In the case of the second crop, namely peanuts, it was observed that the root mean square error (RMSE) values at two different levels of spatial accuracy, namely 10 m and 20 m, were 1.32 m2 m–2 and 1.35 m2 m–2, respectively. In a congruent manner, the mean absolute error (MAE) magnitudes corresponding to equivalent spatial precision thresholds were determined to be 1.31 $m^2 m^{-2}$ and 1.33 $m^2 m^{-2}$, in sequential order. The deviations discerned during the computational determination of the Leaf Area Index (LAI) utilizing the SNAP software exhibit a potential linkage to the persistent residual discrepancies inherent in the process of atmospheric correction (AC) executed through the utilization of the Sen2Cor methodology, as discerned and documented within the confines of the present investigation. This phenomenon can be attributed to the findings of several studies, which have demonstrated that different approaches to atmospheric correction exhibit varying levels of performance depending on the specific characteristics of the environment, spectrum bands and land cover categories under consideration (Pahlevan et al., 2021; Doxani et al., 2018). The susceptibility of the visible spectral bands employed in the Biophysical processor of Sentinel-2 to perturbations induced by Rayleigh

Table 2. The validation parameters for the predicted LAI derived from Sentinel-2 imagery at a spatial resolution of 10 meters

Crop	R^2	RMSE	MAE
Potato	0.81	1.833306	1.818726
Peanuts	0.78	1.327536	1.315267



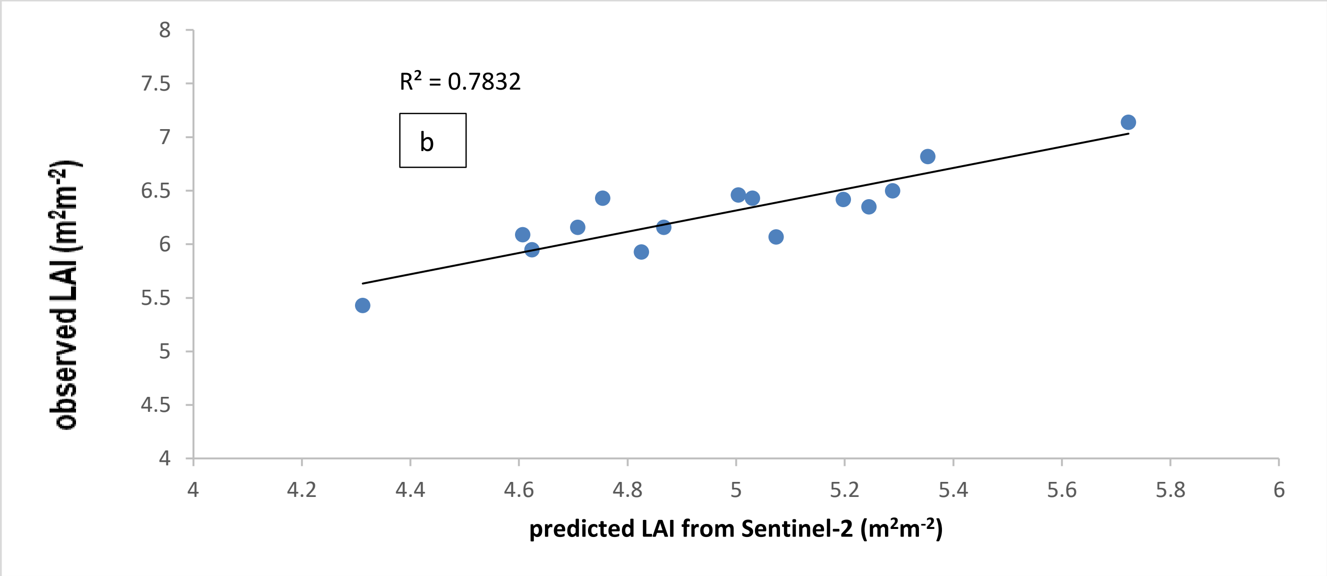


Fig. 2. displays scatterplots and the corresponding statistical metrics comparing the observed (in-field) Leaf Area Index (LAI) with the LAI calculated derived from imagery Sentinel-2 at a spatial resolution of 10 meters. The scatterplots are presented separately for the potato crop (a) and the peanut crop (b).

Table 3. The validation parameters for the predicted LAI derived from Sentinel-2 imagery at a spatial resolution of 20 meters

Crop	R^2	RMSE	MAE
Potato	0.81	1.837026	1.823448
Peanuts	0.76	1.350098	1.33682

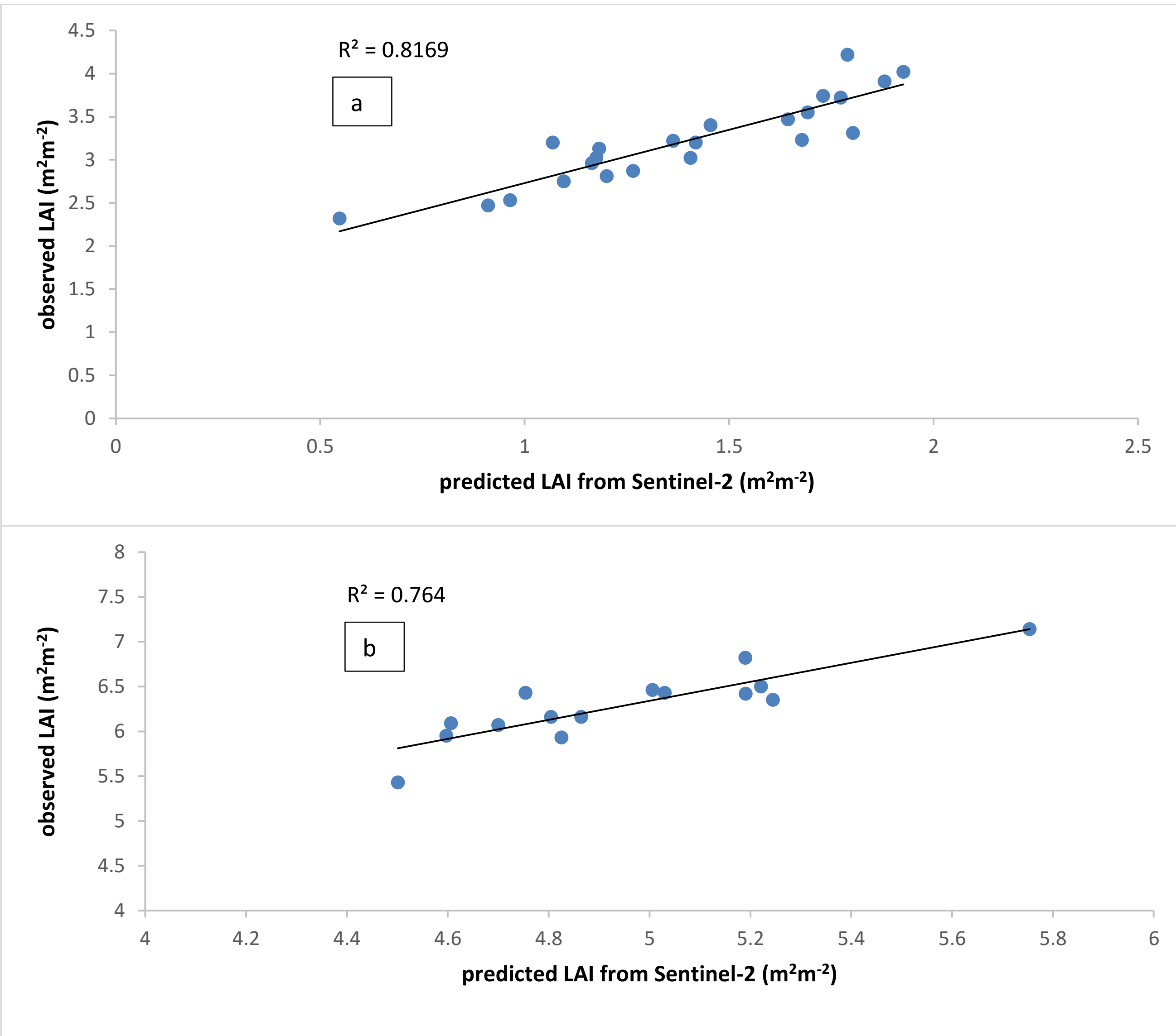


Fig 3. displays scatterplots and the corresponding statistical metrics comparing the observed (in-field) Leaf Area Index (LAI) with the LAI calculated derived from imagery Sentinel-2 at a spatial resolution of 20 meters. Panel A represents the results for the potato crop, while panel b represents the results for the peanut crop.

and aerosol scattering phenomena has been comprehensively elucidated and recorded in the scholarly work of Pereira-Sandoval et al. 2019.

According to the findings of Djamai and Fernandes (2018), it is evident that uncertainties associated with data have a direct impact on the accuracy of biophysical parameters derived from such data. Nevertheless, further investigation is required to delve into this aspect in subsequent research endeavors. For instance, there is a need to ascertain the impact of various atmospheric correction techniques on the retrieval of the Leaf Area Index (LAI) and other biophysical data obtained through remote sensing. Furthermore, the scatter plots presented in Figure 2 and Figure 3 demonstrate that the utilization of reflectances by the SNAP Biophysical Processor has led to an underestimation of Leaf Area Index (LAI) values across all crop types.

It is important to note that errors in in field measurements can significantly impact the validation of satellite-based Leaf Area Index (LAI) products and potentially result in misleading findings. Hence, it is imperative for future research endeavors to thoroughly examine this particular aspect. In light of the considerable uncertainties identified in this study, it is imperative to conduct additional research to enhance and refine the retrieval of the Leaf Area Index (LAI), Especially with regard to its utilization in expediting field-level agricultural management determinations, such as those integral to the practice of precision farming.

Comparative analysis between the SNAP and Landsat8 derived (LAI).

The assessment of the Leaf Area Index (LAI) data derived from SNAP in comparison with well-established global LAI products, exemplified by the Landsat 8 LAI, assumes a position of paramount significance. This comparative undertaking seeks to ascertain the coherence and concordance of the SNAP-derived LAI with the prevailing landscape of existing LAI products. The outcomes of this comparative analysis, as showcased through the illustrative representation in Figure 4, delineate a noteworthy tendency. Specifically, the LAI data procured from SNAP demonstrates a heightened level of correspondence with the broader cohort of global LAI products.

Remarkably, the discernible trend in these results is coupled with quantitative validation metrics that endorse the credibility of the SNAP-derived LAI data. In particular, the Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values, established as key indicators of accuracy and precision, consistently portray a favorable disposition for the LAI data derived from SNAP. This discernible outcome holds particular relevance when contrasted against the LAI data derived from Landsat 8, where comparatively higher RMSE and MAE values are evident.

Consequently, this comparative investigation advances the understanding that the LAI data stemming from SNAP, propelled by its discernibly heightened alignment with established global LAI products and the favorable quantitative validation metrics, manifests as a robust and promising resource in the realm of LAI estimation. As such, these findings underscore the efficacy and utility of SNAP-derived LAI data in contributing to accurate and comprehensive assessments of vegetation dynamics and ecosystem functioning.

4. CONCLUIONS

Interesting outcomes from this investigation were found. In agricultural environments, SNAP-derived LAI correlates rather well with in field LAI data, the inaccuracies are notably high for field level agricultural management. Future research should further analyse this conclusion because crop-specific error assessment showed that SNAP-derived LAI values were overstated and accuracy varied by crop variety. Second, the spatial resolution and Sentinel-2 processing levels affect how well SNAP-derived LAI performs; nonetheless, the accuracy variation between various Sentinel-2 resolutions is minimal. Future research should therefore take into account this issue in more detail, for example, by measuring the impact of several atmospheric correction techniques, such as Sen2Cor, FORCE, iCor, and MAJA, on the retrieval accuracy of biophysical data. Third, SNAP-derived LAI is comparable to other LAI products available globally, such as Landsat LAI. This demonstrates its capacity to be applied globally and its potential for large-scale

Table 4. The validation parameters of the Landsat 8-derived Leaf Area Index (LAI) and SNAP-derived LAI at a spatial resolution of 30 meters.

n	Crop	R^2	MAE	RMES
154000	Potato (a)	0.72	0.575921	0.684131
154000	Peanuts (b)	0.87	0.598201	0.736302

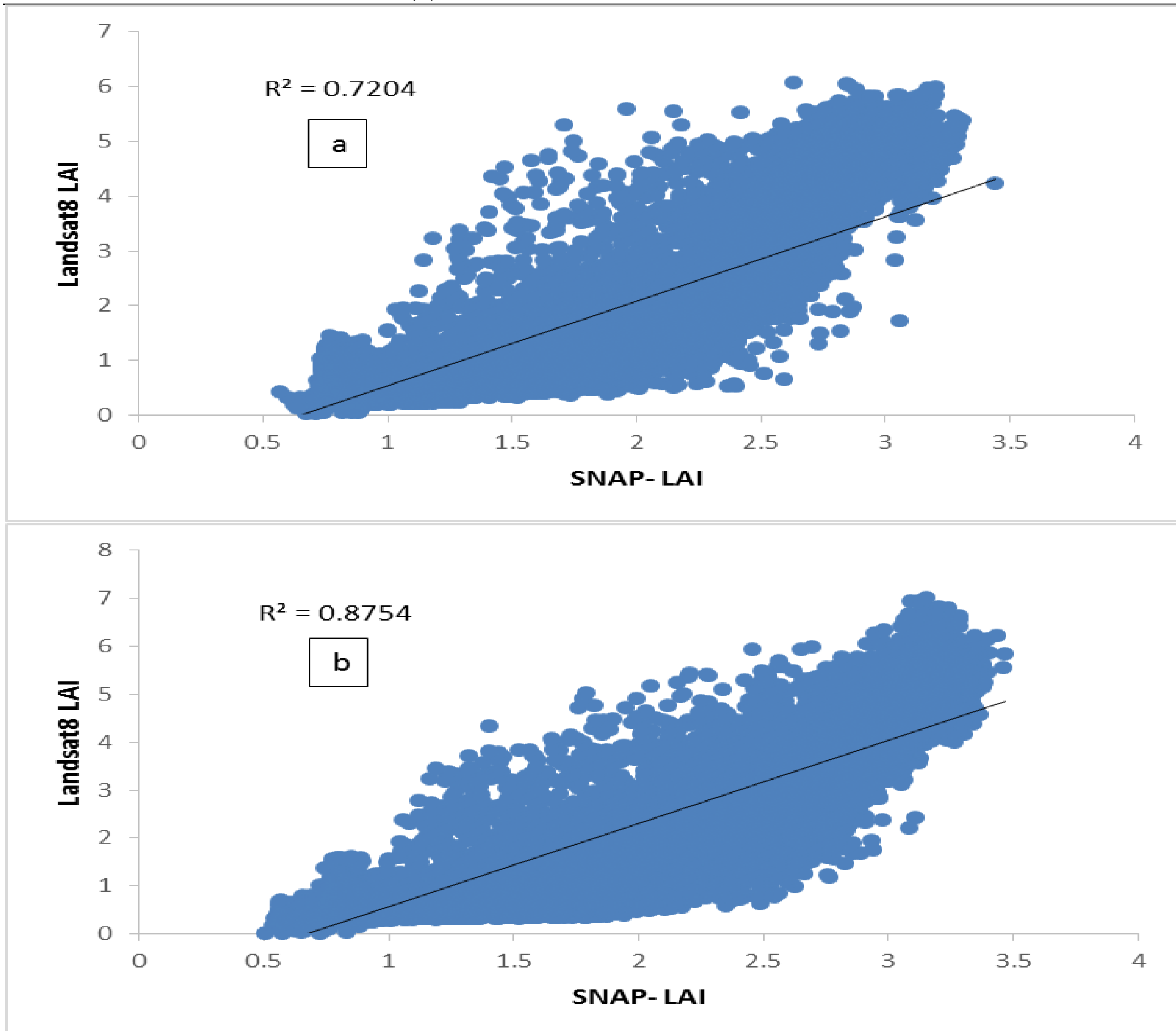


Fig 4. displays scatterplots illustrating the relationship between Landsat 8-derived Leaf Area Index (LAI) and SNAP-derived LAI at a spatial resolution of 30 meters. Panel (a) pertains to the potato crop, while panel (b) pertains to the peanut crop.

agricultural monitoring where within-field variability is not an issue. However, SNAP-derived LAI is not appropriate for precision agriculture due to poor field performance. If noise reduction and smoothing techniques were used on other global LAI products, such as MODIS data, a better match and decrease in errors between SNAP-derived LAI and global LAI products might be achieved, according to our hypothesis. Overall, further development of SNAP-derived LAI is required to support precision agriculture due to its poor performance when compared to in-field LAI data, but its relatively higher consistency with global LAI products indicates that it may be suitable and sufficient for large-scale agricultural monitoring. The findings have implications for the use of SNAP-derived LAI from Sentinel-2 imagery in the future and demonstrate the value of Sentinel2 data and SNAP Toolbox in supporting regional and national agricultural management decisions and policymaking in support of global mandates like Regions and places where such information is scarce..

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الملخص العربى

تحليل مقارن بين مستشعرات Sentinel 2 وOIL والقياسات الميدانية لتقدير مؤشر مساحة الورقة (LAI)

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تتحقق هذه الدراسة من دقة بيانات مؤشر مساحة اللأوراق التي تم الحصول عليها من خلال برنامج SNAP لتقييم الغطاء النباتي وتوجيه الزراعة. ويقارن هذه البيانات مع القياسات في الموقع ومخرجات LAI العالمية بدقة مكانية تبلغ ١٠ م و٢٠ م. كشفت النتائج عن مستوى كبير من التزامن بين LAI الذي تم الحصول عليه من صور القمر الصناعي Sentinel-2 وLAI المقاسة في الميدان، مع قيم معامل التحديد (R2) تبلغ ٠,٨١ (١٠ م) و٠,٧٦ (٢٠ م). وقد تم إثبات هذا الارتباط من خلال القيم المنخفضة لمتوسط الجذر التربيعي للخطأ (RMSE) ومتوسط الخطأ المطلق (MAE) مقارنة بـ LAI المستمدة من بيانات Landsat 8. تم تحديد ارتباطات مهمة بين LAI والمحاصيل المختلفة، حيث أظهرت البطاطس ارتباطًا أقوى (R2 > 0.8) مقارنة بالفول السوداني (R2 > 0.75). تؤكد هذه الظاهرة على إمكانية وجود اختلافات في تقدير LAI الخاصة بمحاصيل مختلفة. يسلط البحث الضوء على أهمية تصحيح أخطاء التصحيح الجوي في تعزيز دقة قياسات LAI. بالإضافة إلى ذلك، فإنه يعني ضمنا ضرورة تنفيذ تقنيات المعايرة المحلية لتحسين مرونة النظام. تسلط النتائج الضوء على أهمية استخدام برنامج LAI المشتق من SNAP لرصد الزراعة على نطاق واسع، وبالتالي تقديم مساهمة قيمة في المبادرات العالمية. يوضح البحث إمكانية استخدام بيانات القمر الصناعي Sentinel-2 التي تمت معالجتها باستخدام برنامج SNAP لتقدير LAI. على الرغم من أن LAI المشتقة من SNAP لها بعض القيود، إلا أنها تُظهر إمكانية لتطبيقات مراقبة زراعية واسعة النطاق، وبالتالي تسهيل اتخاذ قرارات مستنيرة على المستويين الإقليمي والعالمي.

الكلمات المفتاحية: مؤشر مساحة الورقة، القمر الصناعى سينتينال ٢، لاندسات٨، منتجات LAI العالمية والاستشعار عن بعد.