Original Article

Monitoring the Loss of Tree Cover in Talassemtane National Park from 2001 to 2023 using Global Forest Change through Cloud Computing Platform

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Abstract

In Talassemtane National Park, a protected area in northern Morocco, tree cover is subject to several factors. Few studies have attempted to assess the extent of this problem. This study aims to assess and quantify tree cover and loss in the area from 2001 and 2023 using global forest change data. Google Earth Engine and ArcGIS Pro software was used to display and analyze this dataset. Google Earth Engine displayed the dataset through a JavaScript code, evaluate tree cover extent, loss, and annual loss in this region. ArcGis Pro was used to perform a geoprocessing analysis to evaluate tree cover extent, loss, and annual loss per province and per commune. The results showed that tree cover comprised 36331 ha in 2000, or 56% of the area of the park, 70% of which was in the communes of Bni Selmane, Tassift, and Talambote. Tree cover loss according to Global Forest Change analysis, was 2989 ha, or 8% of tree cover in 2000. These results provide valuable information for decision-makers and managers to better assess the impact of programs aimed at the restoration and conservation of forest ecosystems.

Keywords: tree cover, loss, Talassemtane, Global Forest Change, Google Earth Engine

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Introduction

Deforestation is a worldwide-phenomenon affecting the 3.97 billion hectares of forests which constitute 30.8% of the planet's land area (17). Regardless of the reasons, deforestation is defined as the conversion of forest to other land uses (17). Between 2000 and 2010, deforestation affected 11 million hectares worldwide, while between 2010 and 2020, it damaged 7.8 million hectares. Nearly 90% of these losses were due to agricultural operations, 38.5% to pasture, and 50% to cropland expansion (17). Forest decline is not solely caused by deforestation. Only 27% of global forest loss was due to deforestation, while the balance was caused by urbanization, forestry, agricultural change, and wildfires (15).

Alfa plants constitute more than 3 million of the 9,631,896 hectares of Morocco's national forests, which cover 13.5% of the country's total area (2). It is estimated that 17,000 hectares of these areas are degraded each year (3), and up to 30,000 hectares are lost each year (5). Humans (high forest pressures), environmental factors (long-term drought) and management factors (predominance of a

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repressive approach) are the causes of this degradation (8). Between 1984 and 2014, the main causes of forest and agro-sylvopastoral loss in the northern region of Morocco, renowned for its biodiversity, were soil erosion, forest fires, drought, and population growth (13). In Talassemtane National Park (TNP), a protected area in northern Morocco, forest fires and deforestation related to cannabis cultivation are the main factors contributing to deforestation (12). This deforestation leads to a loss of biodiversity and threatens the last endemic species such as the Moroccan fir (Abies maroccana Trabut) and the black pine (Pinus nigra).

The high-resolution (30 m) 21st century global forest cover change map, known as the Global Forest Change (GFC) by Hansen et al. (2013), has quantified forest cover losses at the global scale using Landsat satellite imagery (20). Several studies have focused on analyzing the accuracy of the GFC and its potential use at the national scale. In Gabon, the GFC was considered a viable alternative for mapping the country's tropical forests, but with the addition of a calibration at the level of percent forest cover (22).

The Global Forest Resources Assessment 2020 relied on GFC for strata design and distribution of sampling points selected for the assessment study across strata (17). Amanda et al. (2023) used GFC to assess forest cover loss in Madagascar over the past 20 years, during which 25% of its forest cover was lost (23). The GFC dataset is freely available and can be accessed via (https://glad.earthengine.app/view/global-forest-change). Two methods can be employed to use this data, i.e., by downloading the 10x10 degree tile containing the desired study area via the link https://storage.googleapis.com/earthenginepartners-hansen/GFC-2021 or directly via the Google Earth Engine (GEE) platform using the dataset identifier UMD/hansen/global forest change 2023 v1 11.

GEE is a cloud computing platform for global geospatial analysis via Google's cloud infrastructure. This continually-updated platform allows users to display, analyze, and process multi-petabyte geospatial data from various providers (19). It provides fast satellite image processing and algorithms via Google's infrastructure, making them accessible for analyzing large geographic data (24). With its application programming interface based on two programming languages (JavaScript and Python), GEE allows users to create scripts to address big data processing challenges (15)(24). The most common domains GEE addresses include agriculture, climate change, and land use (1)(21). The use of GEE in natural disaster management, especially in flood management, improves the performance of algorithms (18). Access to GEE is free but requires registration via a personal email address. This study used cloud computing via the GEE platform to display GFC data and calculate forest cover and loss that occurred between 2001 and 2023 in the TNP. Geoprocessing Tools Extract by mask, raster to polygon and dissolve was used through ArcGIS Pro software to quantify tree cover, loss, and annual loss by province and commune during the same period.

Materials and Methods

Study area

The TNP is located in the Rif region of Morocco (Figure 1) and is known for its ecological diversity because of its morphology and favorable climatic conditions, as well as for its high rate of deforestation. This region is also characterized by a high frequency of wildfires, that affect an average annual area of 39.78 sq. km (11). The main factors for degradation are the fires coupled with land clearings for cannabis cultivation by the local population (6). Created in 2004, the TNP covers 64,000 ha. Its particularity lies in the fact that it shelters endemic species such as the fir (Abies maroccana Trabut), black pine (Pinus nigra), and Atlas cedar (Cedrus atlantico Manetti).

The mixed Moroccan fir-Atlas cedar woodland is one of the world's rare ecosystems (7). The presence of these species and others fully justifies the effort made by the Moroccan authorities for the conservation and sustainable management of these resources.

Geologically, the park area extends broadly on a limestone ridge, and its geo-morphology is characterized by the presence of the highest peak in the region, the 2159-m Jbel Lakraa. Given the extent of the park, the bioclimate ranges between the temperate subhumid and the per humid or humid superior (9). The presence of the process of rubefaction characterizes the soils of the park, with ferrallitic and brown soils dominating [9]. The park is known for its endemicity and biodiversity (6) that is characterized by the presence of four vegetation zones, i.e., thermomediterranean, mesomediterranean, supramediterranean, and montane Mediterranean.

The main forest species in the park include the Moroccan Fir (Abies maroccana), Atlas Cedar (Cedrus atlantica), Cork Oak (Quercus suber), Maritime Pine (Pinus pinaster), Thuja (Tetraclinis articulata), and others (4). In terms of fauna, the park harbors over 37 species of mammals, 117 bird species, and more than 30 species of reptiles and amphibians (4). The population density in the park area is considered among the most important in Morocco, with a density of 117 inhabitants/km^2 in Chefchaouen and 285inhabitants/km^2 in Tetouan (9).

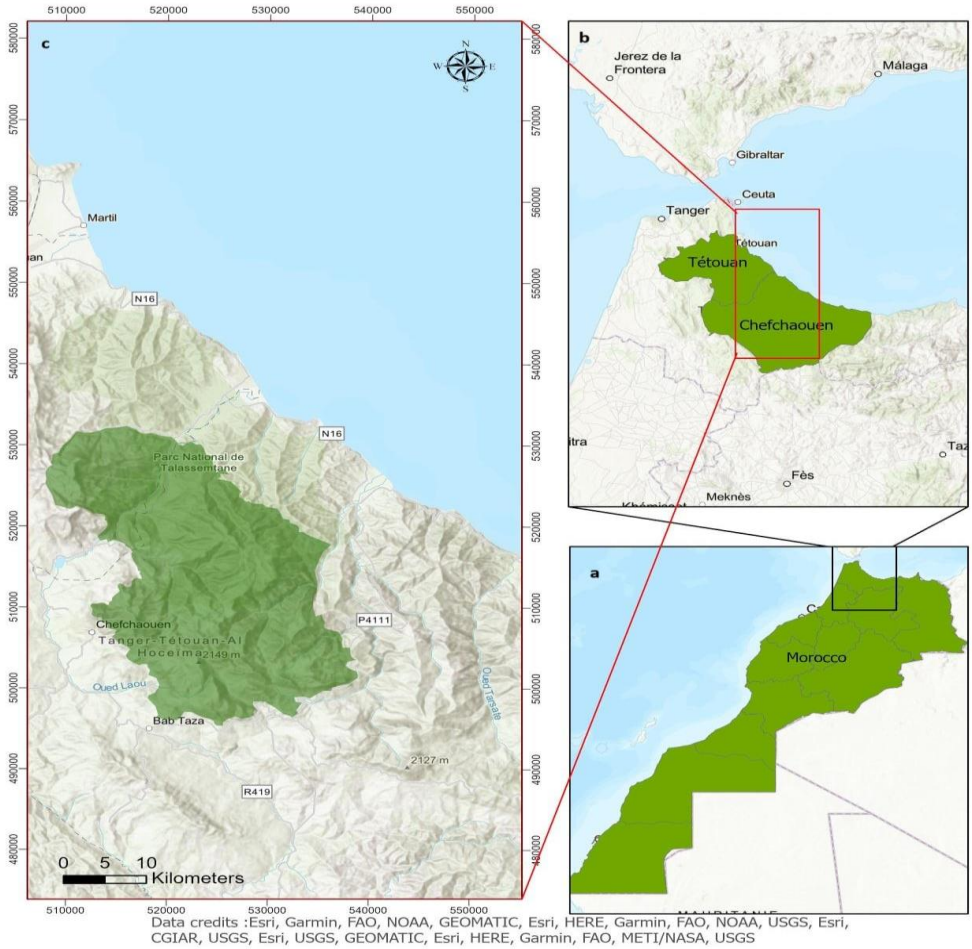

Fig. 1. Geographic location: (a) Morocco, (b) Chefchaouen and Tétouan Provinces, (c) Talassemtane National Park

Datasets
Global Forest Change

GFC can be directly accessed via the GEE platform using the identifier

UMD/hansen/global forest change 2023 v1 11. Through JavaScript in the code editor, three layers were generated and displayed i.e., tree cover in 2000 represented in green, indicating 5-m height vegetation and a density ranging from 0-100%, loss and loss year, indicating disturbance or transition from forest to non-forest, and coded as either 0 (no loss) or from 1 to 23 representing losses between 2001 and 2023. For calculating tree cover loss, reduce region is used to determine the number of pixels representing forest loss during a given period. EE image pixel area is then used to calculate the area represented by the pixels of loss. GEE is allowed to generate annual loss data and charts for the study period. In this study, a tree cover threshold of 10% was used to quantify the tree cover.

Province and Commune boundaries

These feature classes used online for visualization and analysis in this study were provided by Living Atlas (Figure 2).

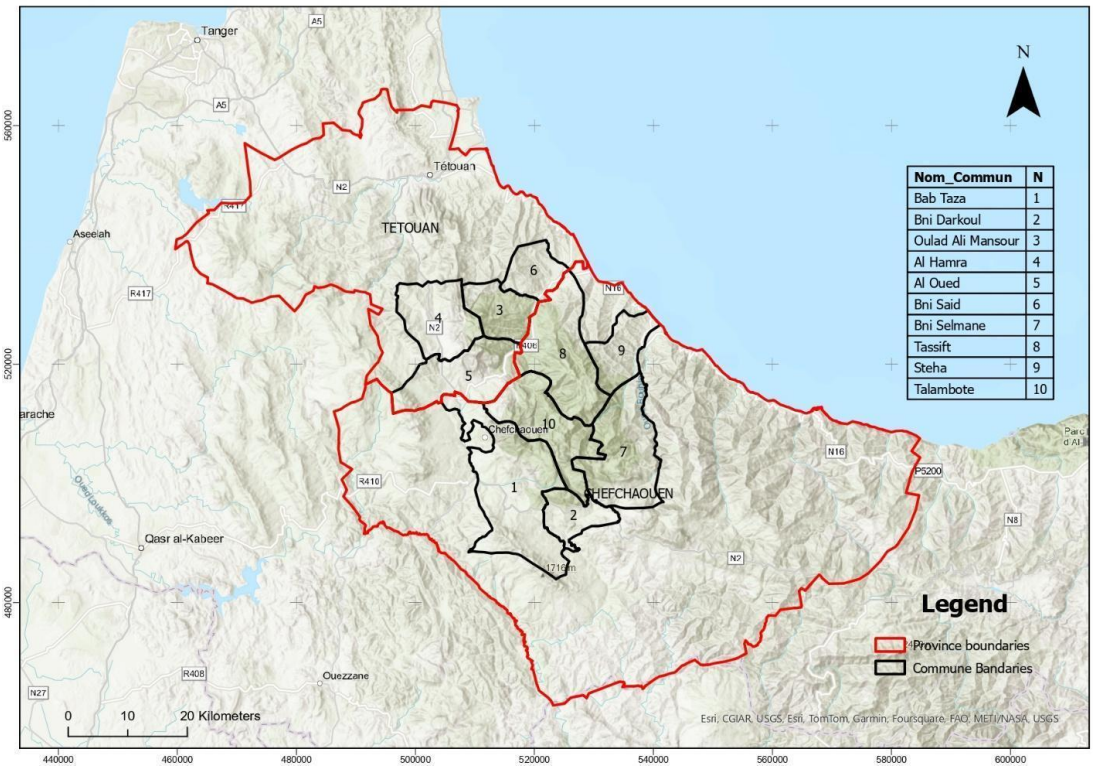

Fig. 2. Provinces and communes covered in the study

Method

Google Earth Engine Script

The java script developed in the present study allows visualization of GFC for the whole of Morocco, tree cover from 2000, tree loss from 2001 to 2023, and annual losses. The GFC bands extracted by this script were exported as an image or a Tagged Image File Format (Tiff) to Google Drive (Figure 3). Any Earth Engine user can view and apply the script using the link https://code.earthengine.google.com/b432983a79ef8e45e5e8b1d12f14b719

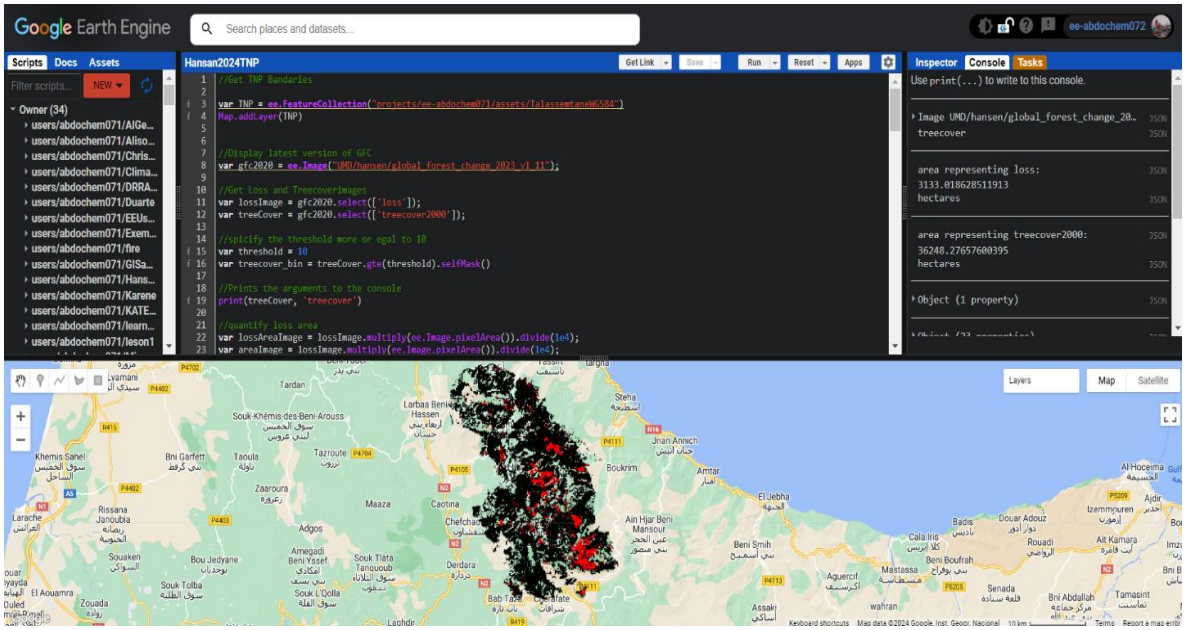

Fig. 3. Displaying Global Forest Change using Google Earth Engine

Ge-processing using ArcGIS Pro 3.3.0

The 2000 tree cover, loss and loss year rasters were exported as a Tiff and used to generate a Feature Class through ArcGIS Pro 3.3.0. The analysis steps in ArcGIS Pro are as follows:

Mask spatial Analyst Tool was used to extract the cells of a raster corresponding to the area defined by a mask (Figure 4).

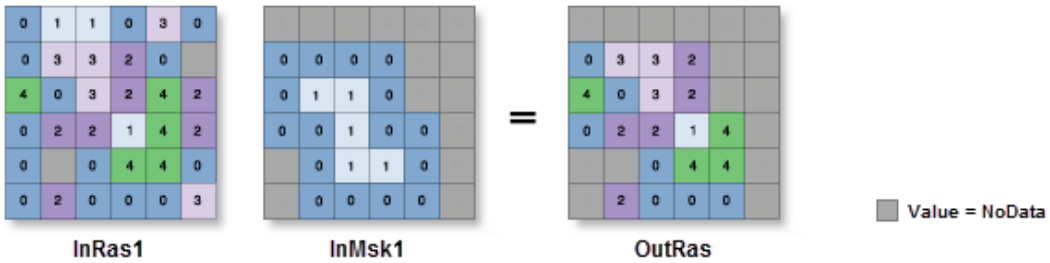

Fig. 4. Extract by mask tool [16]

Project is a data management tool for projecting spatial data from one coordinate system to another. This tool was used to achieve the transformation from WGS84 to Nord Maroc.

Raster to polygon is a geoprocessing tool used to convert a raster dataset to polygon features. The input raster is vectorized when it is converted to a polygon feature output (Figure 5).

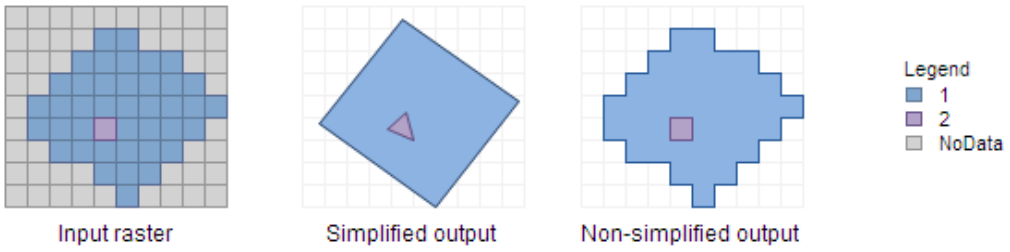

Fig. 5. Raster to polygon tool [16]

Spatial join is a geoprocessing tool used to join attributes from one feature to another based on the spatial relationship.

• The Dissolve Data management tool was used to aggregate features based on specified attributes (Figure 6).

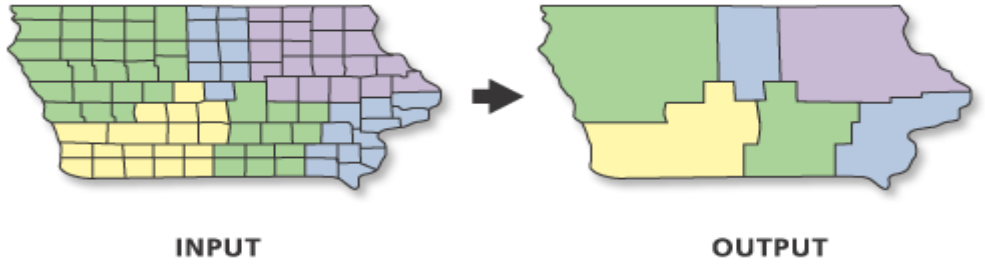

Fig. 6. Dissolve tool [16]

The methodology used in this study is summarized in the flowchart (Figure 7).

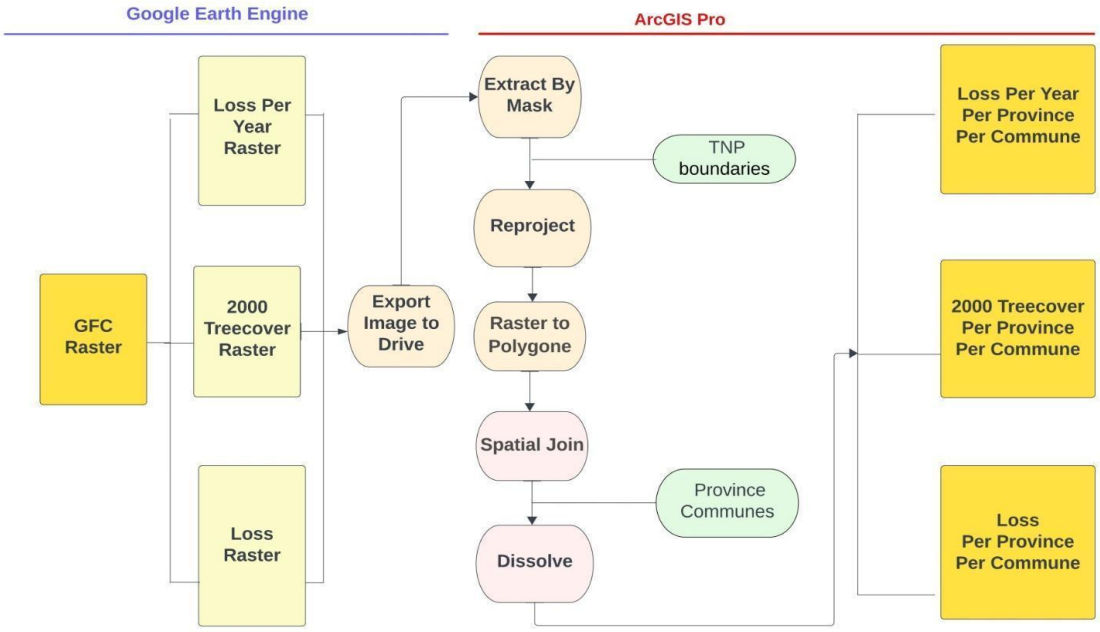

Fig. 7. Flowchart of the methodology adopted for this study

Results and Discussion

Results

Tree cover in TNP in 2000

GFC analysis showed that for 2000, the TNP's tree cover with a threshold exceeding 10% extended over 36248 ha, corresponding to approximately 56% of the area of the Park (Figure 8).

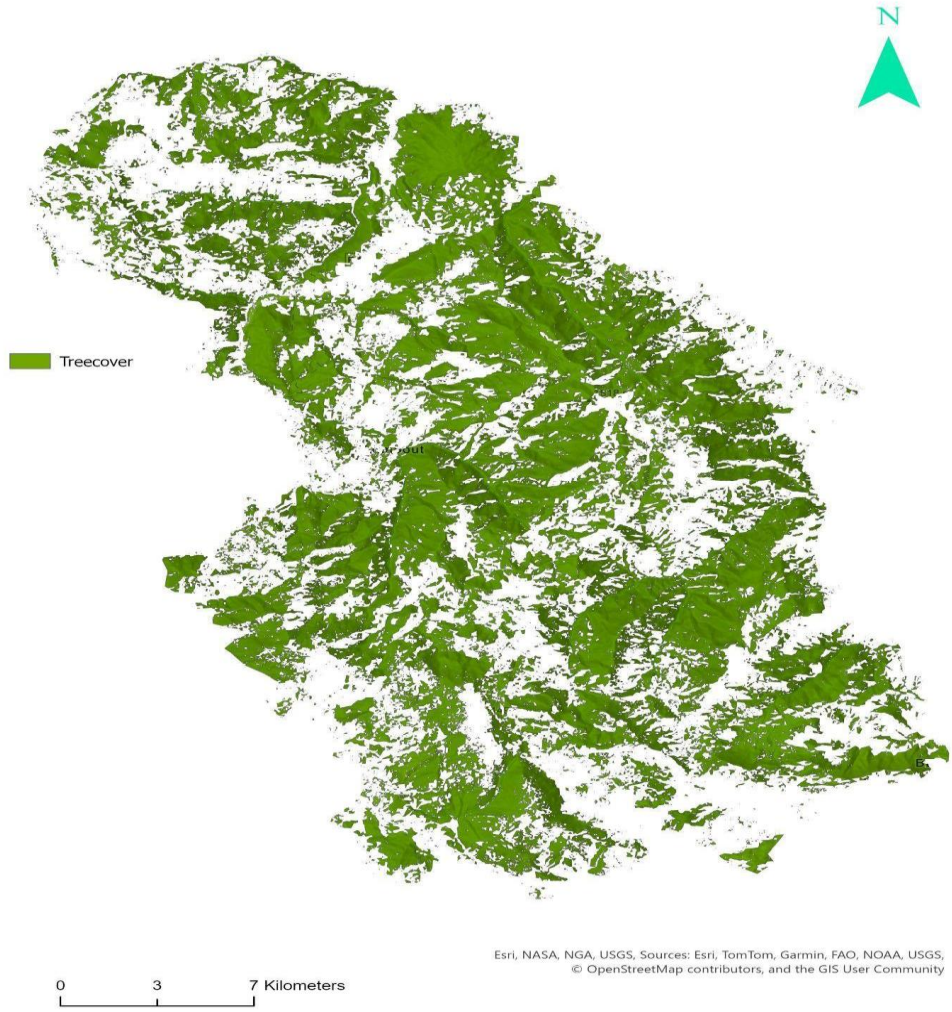

Fig. 8. TNP tree cover for 2000

Tree cover per province in 2000

Table 1 shows the distribution of tree cover by province in TNP. GFC analysis showed that Chefchaouen province contained 91% of the park's tree cover area in 2000**.**

Table 1. Area of tree cover for each province (ha.)

Province	Tree cover per ha.	Tree cover (%)
Chefchaouen	33077	91
Tétouan	3254	9
Total	36331	100

Tree cover by commune in 2000

Table 2 shows the distribution of tree cover by commune in the park. The GFC analysis shows 70% of the tree cover being located in the three communes of Tassift, Talambote, and Beni Selmane (Figure 9).

Table 2. Area of tree cover for each commune (ha.)

Communes	Tree cover per ha	Tree cover (%)
Al Hamra	199	1
Al Oued	531	1
Bab Taza	28144	77
Bni Darkoul	55	0
Bni Said	4	0
Bni Selmane	3229	9
Oulad Ali Mansour	2622	7
Steha	107	0
Talambote	753	2
Tassift	688	2
Total	36332	100

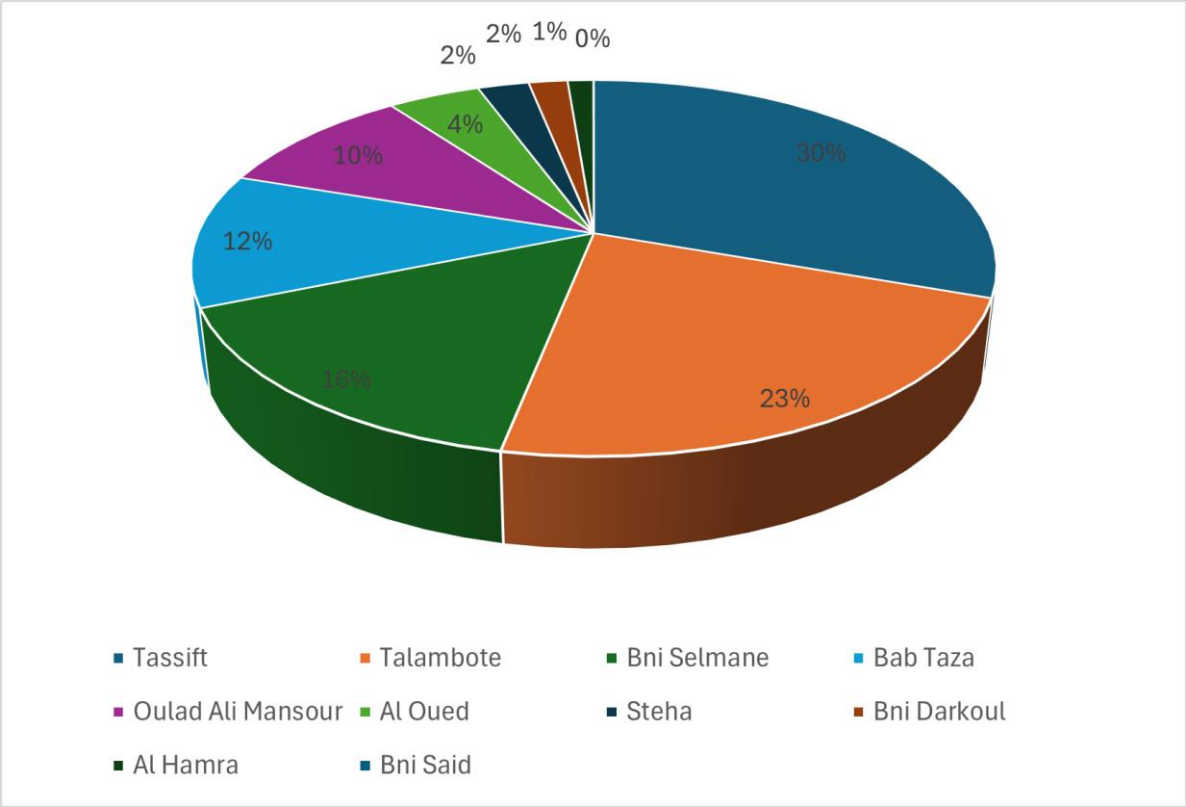

Fig. 9. Tree cover by commune, 2000

Tree cover loss in TNP

Tree cover loss in TNP between 2001 and 2023, according to GFC analysis, was 2989 ha. Figure 10 shows the most affected areas.

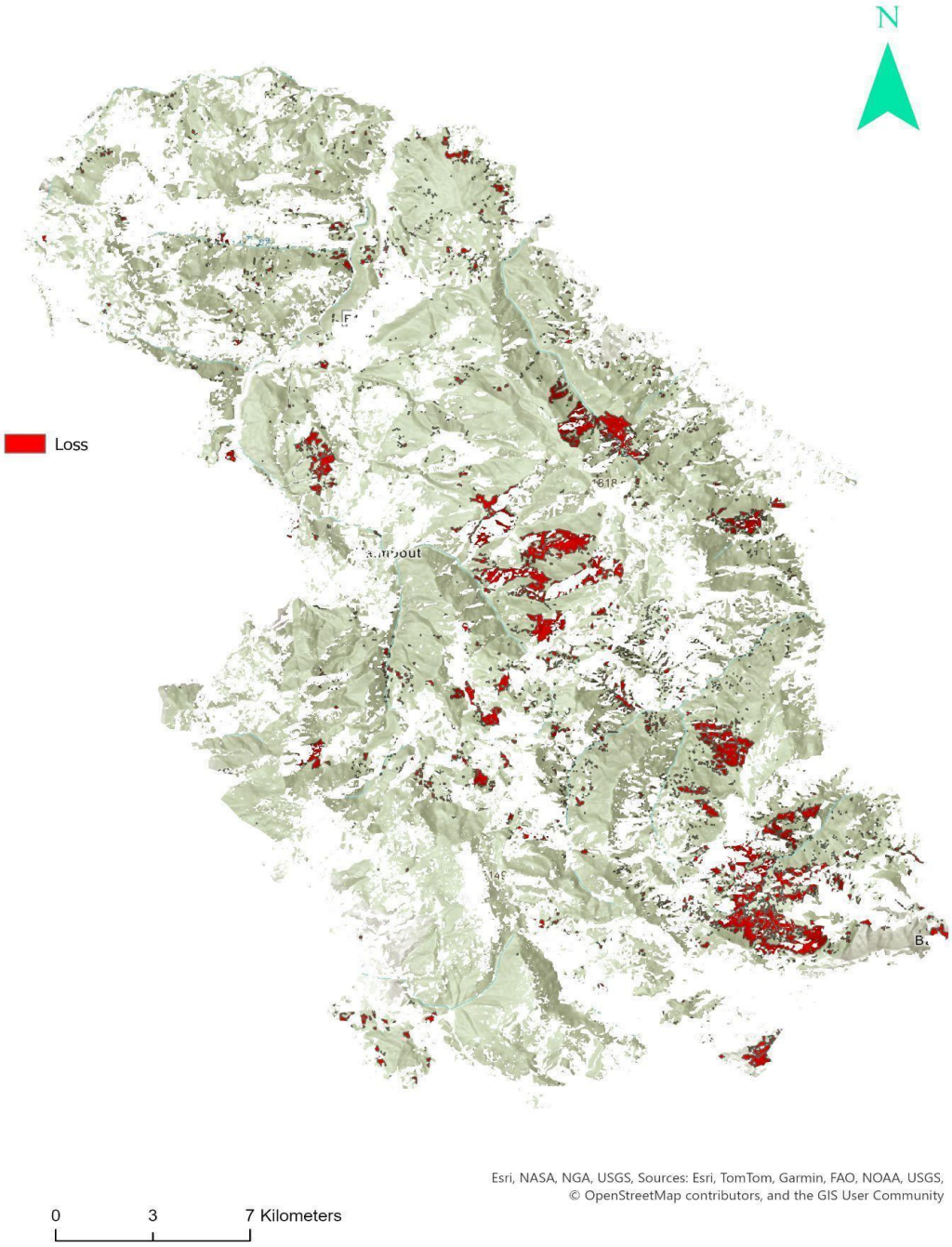

Fig. 10. Areas affected by tree cover loss in TNP

Tree cover loss by province

Table 3 shows the distribution of tree cover loss by province in TNP according to GFC analysis. The most affected were the provinces of Chefchaouen and Tetouan which lost 8% and 4% of their tree cover respectively.

Table 3. Tree cover loss by province and per ha.

Province	Loss Per Ha	Loss (%)	Tree cover per Ha	Loss (%)
Chefchaouen	2851	95	33077	8.6
Tétouan	138	5	3254	4.2
Total	2989	100	36331	8.2

Tree cover loss per commune

Table 4 shows the distribution of tree cover loss by commune in TNP according to GFC analysis while Figure 11 shows the communes most affected. The communes of Bni Selmane, Tassift, and Talambote suffered losses of 38 %, 36%, and 14%, respectively. Since 2001, they lost 20 %, 10%, and 5% of their tree cover, respectively.

Table 4. Tree cover loss by commune and per ha.

Commune	Loss Per Ha	Loss (%)	Tree Cover Per Ha	Tree Cover (%)	Loss Per Ha
Bni Selmane	1130	38	5680	16	20
Tassift	1074	36	11065	30	10
Talambote	412	14	8221	23	5
Oulad Ali Mansour	99	3	3535	10	3
Bab Taza	96	3	4190	12	2
Al Oued	87	3	1612	4	5
Steha	87	3	893	2	10
Al Hamra	4	0	449	1	1
Bni Darkoul	0	0	678	2	0
Bni Said	0	0	8	0	0
Total	**2989**	**100**	**36331**	**100**	**56**

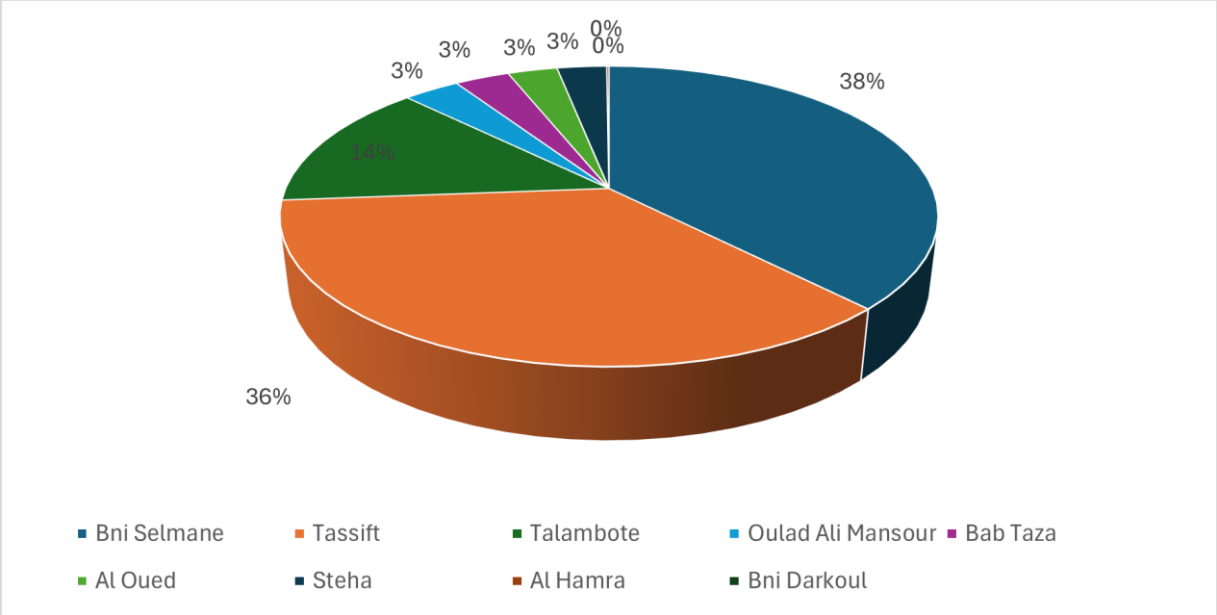

Fig. 11. Tree cover loss per commune

Annual tree cover loss in TNP

Figure 12 shows that tree cover loss was highest in 2012, 2019, 2018, 2020, and 2023,

totaling 250 ha. while the low-loss years were 2006, 2009 and 2005, comprising less than 50 ha.

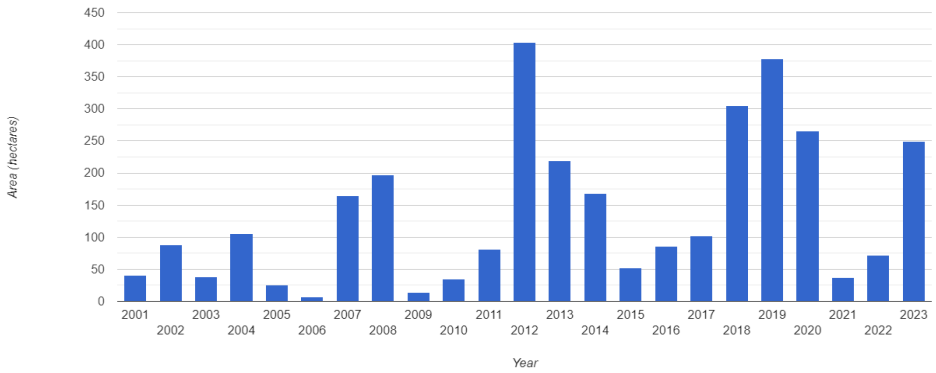

Fig. 12. Tree cover loss per year in TNP

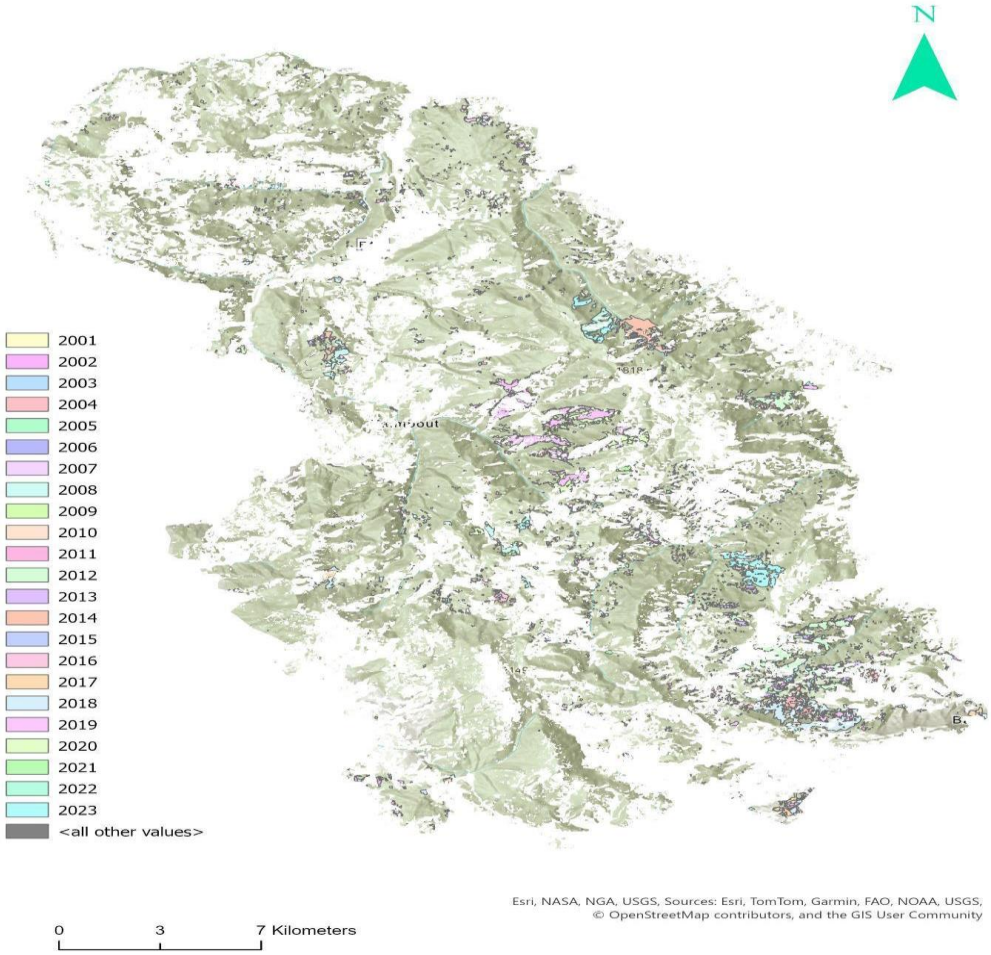

Fig. 13. Annual tree cover loss in TNP

Loss per year and by province

GFC shows the annual loss of tree cover at the global level, but geoprocessing tools can narrow it down to annual figures at the local level as seen in Figure 13. For the province of Chefchaouen, the description is as depicted in Figure 14, which shows an upsurge in forest loss beginning in 2012 and reaching a peak in 2019.

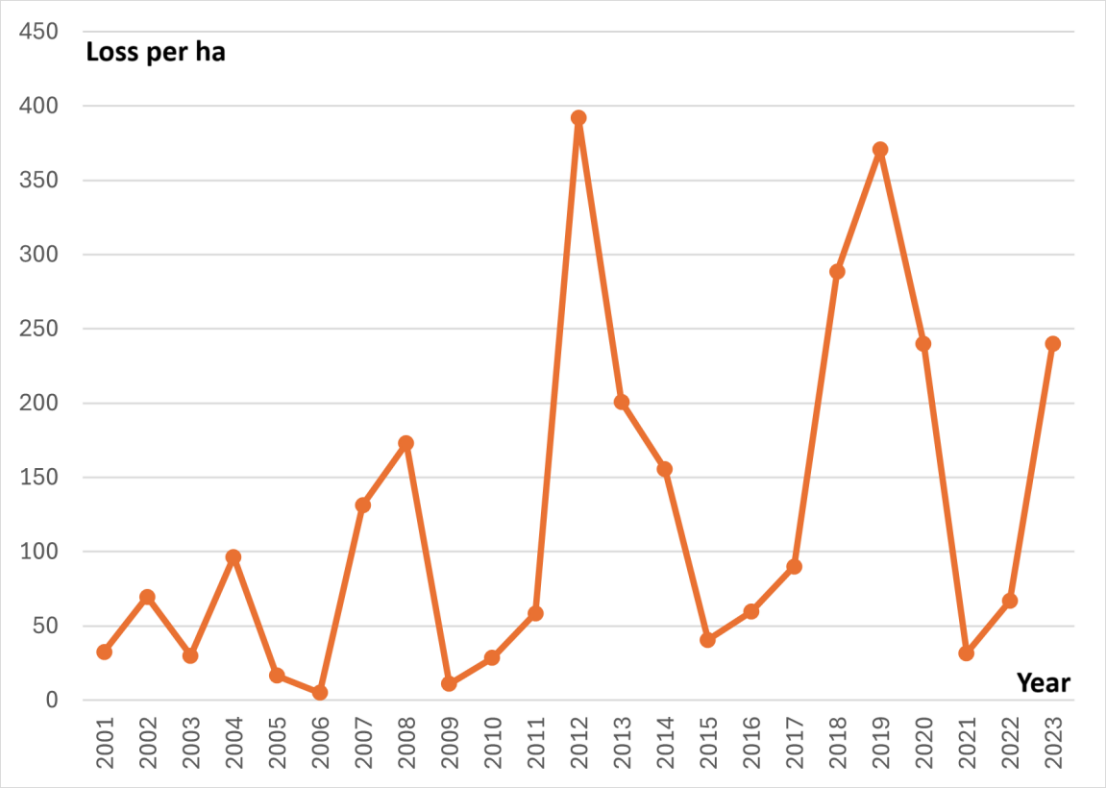

Fig. 14. Annual tree cover loss in Chefchaouen province, 2001-23

For Tetouan, Figure 15 shows the upsurge in tree cover loss from 2011 with the peak in 2016.

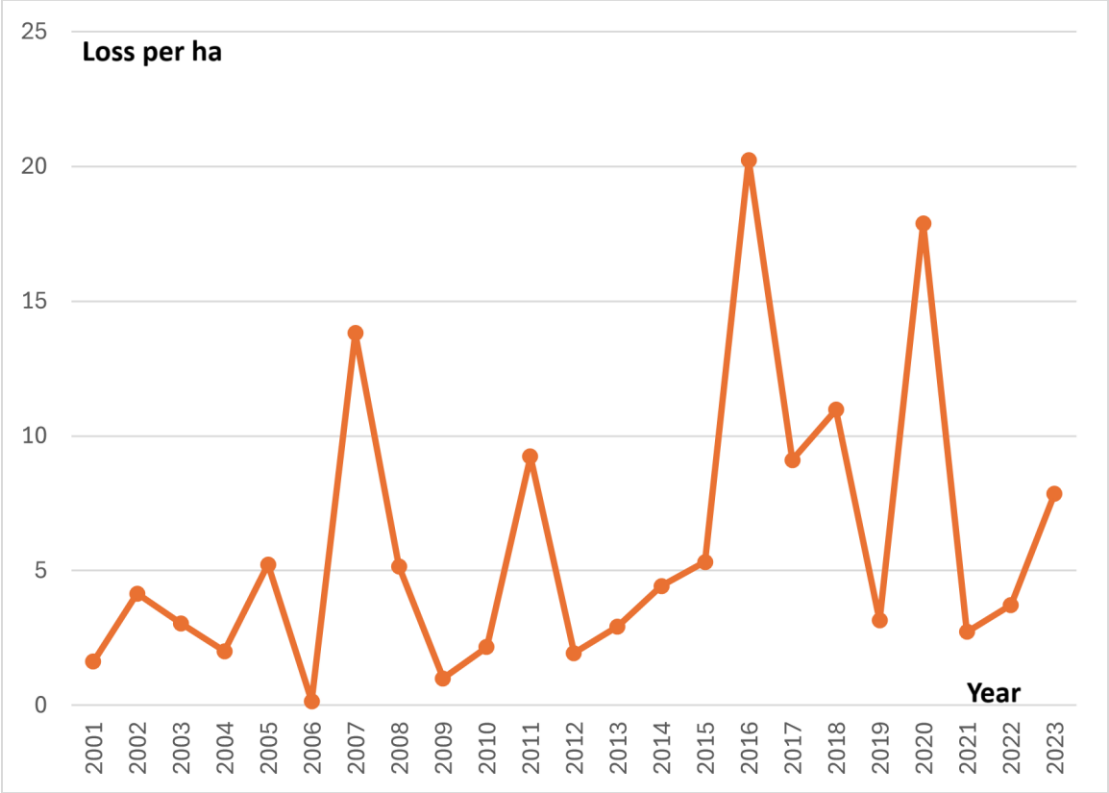

Fig. 15. Annual tree cover loss in Tetouan province, 2001-23

Loss per year and per commune

Similar to the above, GFC combined with geoprocessing tools allowed further analysis to quantify the annual loss of cover based on commune. For the communes of Beni Selmane and Tassift, the tree cover losses amounted to 1130 ha and 1074 ha as shown in Figures 16 and 17, respectively. For Beni Selmane, the annual losses fluctuated up to 2011 but remained below 100 ha. Thereafter the loss rate increased, peaking in 2012, 2013, 2018, and 2023, and recording more than 130 ha.

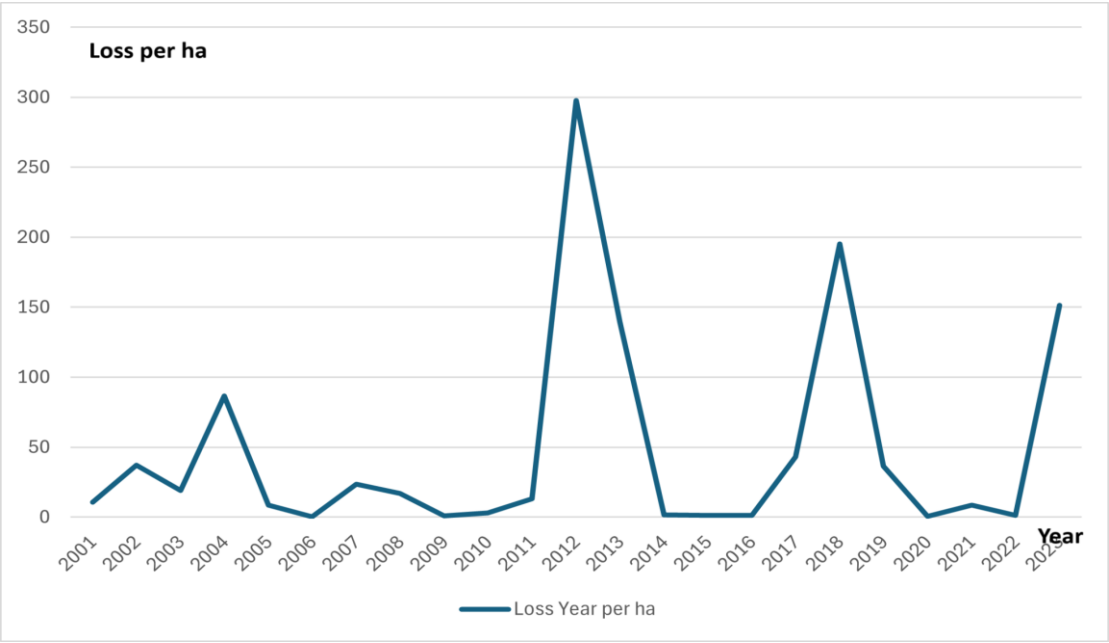

Fig. 16. Annual tree cover loss in Beni Selmane, 2001-23

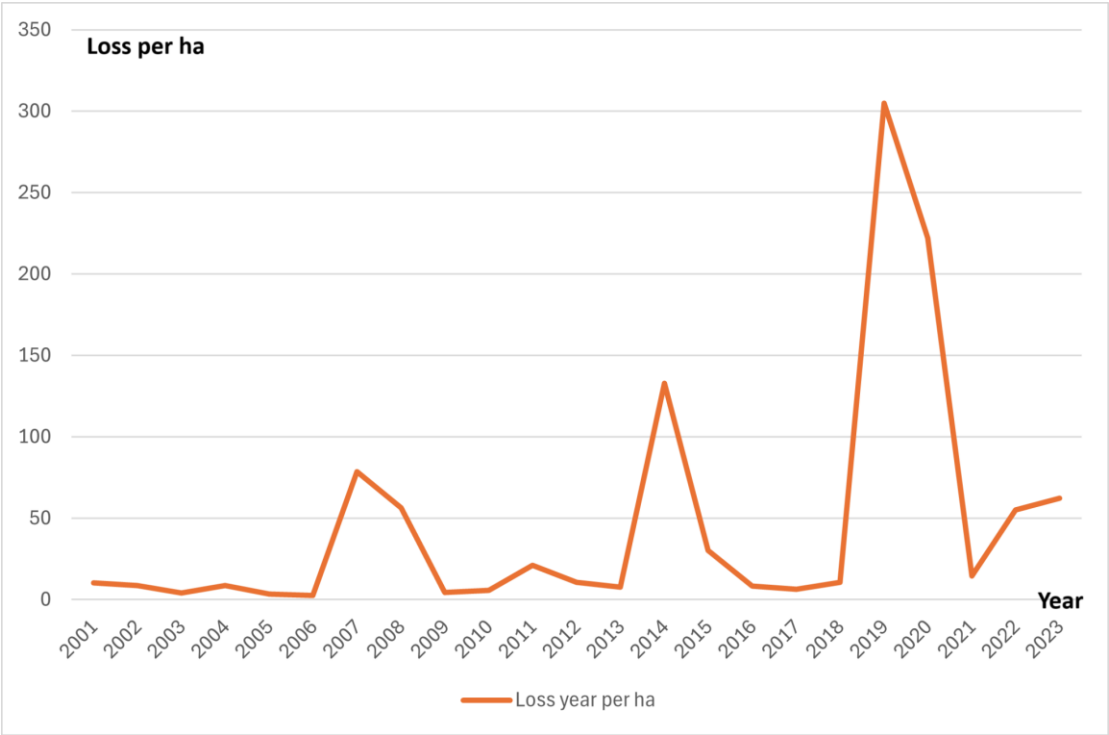

Fig. 17. Annual tree cover loss in Tassift, 2001-23

For Tassift, the analysis of Figure 17 shows that the loss in tree cover fluctuated but does not exceed 150 ha. up to 2017. However, from 2018 onwards, the loss increased, reaching a peak in 2019 at more than 300 ha. before declining to a minimum, before rising again.

Discussion

By using GFC data through the GEE platform, this study shed light on tree cover, loss, and annual loss in TNP. These were quantified, mapped, and analyzed by province and commune for a deeper understanding of the issue. Tree cover in the TNP was estimated at 36331 ha in 2000 corresponding to 56% of the area of the park. Seventy percent of the tree cover in the park was contained in the three communes of Bni Selmane, Tassift, and Talambote. The tree cover loss in TNP according to GFC analysis was 2989 ha, corresponding to 8% of the tree cover in the park. This correlates with the results found in other studies. Castro et al. (2022) showed that the park loses an average of 106 acres of tree cover annually, or 0.3% of its forest area (12).

A recent study evaluated a gross loss of 8.39% of the Western Rif Forest capital between 2001 and 2020, equivalent to a total area of 272.37 km2 (10). This study identified the TNP as one of 26 deforestation fronts in the Western Rif region. Another study showed that the park's forests, which extended over 43,600 hectares in 1990 (representing 67% of its surface area), experienced a loss of more than 18% of their cover over the study period, i.e., an average annual decline of 240 hectares (14). For the same time interval, the study showed a regression similar to this research, with a loss of forest cover of approximately 3,093 hectares between 2000 and 2024 (14). The key limitation of this study lies in not identifying the main drivers of deforestation and the need to distinguish permanent conversion from temporary loss. This gap will be addressed in a future study.

Conclusion

The loss of forest cover is a challenge to the survival of all human beings. It poses a serious threat to the environment and contributes significantly to global warming. It has never been easy to quantify this threat scientifically on the local, regional, and global scale. However, these constraints have been overcome thanks to the development of remote sensing methods and the accessibility of high-

resolution satellite images. The Global Forest Change is a universal standard for assessing deforestation. It is not commonly used at the local scale level. This resource was used in this study to examine forest cover in the TNP between 2001 and 2023 using the GEE platform.

As there have been no updated national data since the 2004 national forest inventory, this resource serves as a guide to address and manage the situation. This study was able to calculate the annual and total loss, and the extent of forest cover in the park. Managers and decision makers can use this tool to monitor and evaluate the results of forest ecosystem conservation and restoration initiatives

Supplementary Materials
None.

Author Contributions
Conceptualization: Abdelazziz Chemchaoui and Ziri Rabea; Methodology: Abdelazziz Chemchaoui; Software: Abdelazziz Chemchaoui, Hassana Ismaili Alaoui, Hassan Boukita; Validation: Najiba Brhadda, Ziri Rabea and Abdelazziz Chemchaoui; Formal analysis: Abdelazziz Chemchaoui; Investigation: Abdelazziz Chemchaoui; Resources: Abdelazziz Chemchaoui; Data curation: Abdelazziz Chemchaoui; Writing, original draft preparation, Abdelazziz Chemchaoui; Writing, review and editing: Abdelazziz Chemchaoui; Visualization: Abdelazziz Chemchaoui, Hassana Ismaili Alaoui, Hassan Boukita; Supervision: Ziri Rabea; Project administration: Najiba Brhadda. All authors have read and agreed to the published version of the manuscript.

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None.

Data Availability Statement
None.

Conflicts of Interest
The authors declare no conflict of interest.

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مقالة أصيلة

رصد فقدان الغطاء الشجري في منتزه تالاسمطان الوطني باستخدام التغير العالمي في الغابات من خلال منصة الحوسبة السحابية من عام ٢٠٠١ إلى عام ٢٠٢٣

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الخلاصة

في منتزه تلاسمطان الوطني، وهي منطقة محمية في شمال المغرب، يتعرض الغطاء الشجري لتأثيرات عدة عوامل لفقدان الغطاء الشجري. وقد حاولت دراسات قليلة تقييم مدى هذه المشكلة. تهدف هذه الدراسة إلى تقييم وقياس الغطاء الشجري وفقدانه في هذه المنطقة المحمية بين عامي ٢٠٠١ و٢٠٢٣ باستخدام بيانات تغير الغابات العالمية. استخدمنا برنامج Google Earth Engine وArcGIS Pro لعرض مجموعة البيانات هذه وتحليلها. تم استخدام Google Earth Engine لعرض مجموعة البيانات من خلال كود جافا سكريبت وتقييم مدى الغطاء الشجري والخسارة والخسارة السنوية في هذه المنطقة محل الاهتمام. تم استخدام ArcGis Pro لإجراء تحليل المعالجة الجغرافية لتقييم مدى الغطاء الشجري وفقدانه والخسارة السنوية لكل مقاطعة وكل بلدية. وأظهرت النتائج الرئيسية أنه تم تقييم الغطاء الشجري بمساحة ٣٦٣٣١ هكتارًا في عام ٢٠٠٠ بما يعادل ٥٦٪ من مساحة المنتزه. ٧٠٪ من الغطاء الشجري للحديقة موجود في ثلاث بلديات بني سلمان وتاسيفت وتلامبوت. تبلغ خسارة الغطاء الشجري وفقًا لتحليل تغير الغابات العالمي ٢٩٨٩ هكتارًا، أي ما يعادل ٨٪ من الغطاء الشجري لعام ٢٠٠٠. توفر هذه النتائج معلومات قيمة لصانعي القرار والمديرين لتقييم تأثير البرامج التي تهدف إلى استعادة النظم البيئية للغابات والحفاظ عليها بشكل أفضل.

كلمات مفتاحية: الغطاء الشجري، الخسارة، التلاسمطان، تغير الغابات العالمي، محرك جوجل إيرث

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