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Spatio-Temporal Evolution and Economic Assessment of Sediment and Nutrient Retention Service in Ifrane National Park Based on InVEST Models

[Oumayma Sadgui](#)*, [Abdellatif Khattabi](#), [Zouhir Dichane](#)

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Article

Spatio-Temporal Evolution of Water Regulating Ecosystem Services values in Ifrane National Park, Morocco

Oumayma Sadgui ^{1,*}, Abdellatif Khattabi ² and Zouhir Dichane ³

¹ Applied Economics and Social Sciences in Agriculture, IAV Hassan II, Rabat, Morocco

² National School of Forestry Engineering, Salé, Morocco;

³ Department of Geology, Faculty of Sciences, Moulay Ismail University, Meknes, Morocco

* Correspondence: sadgui.oumayma@gmail.com; Tel.: +21-2676-9377-78

Abstract: Water Regulating Ecosystem Services (WRES) play a crucial role in maintaining water quality and preventing soil erosion, particularly in watershed areas that are vulnerable to Land Use Land Cover Changes (LULCC) and climate change. This study focuses on the upper BEHT watershed, the most ecologically significant basin of the Ifrane National Park (INP), exposed to pressures from human activities and land use transformations. This research analyzed historical LULC data from 1992 to 2022 using Google Earth Engine platform. Next, employed the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST 3.10.2) models to quantify and map the impacts of ongoing LULCC on the watershed's capacity to retain sediments and nutrients. Finally, used the damage costs avoided method for economic assessment of WRES. Our findings demonstrate a notable improvement in the economic value of WRES following the establishment of the park, reaching an estimated 10,000 USD per year. In contrast, prior to its creation, this service experienced a decline of -7,000 USD per year. This positive trend can be attributed to the expansion of forest cover in areas prioritized for reforestation and conservation interventions. The study highlights the critical importance of continuous WRES monitoring, providing park managers with robust data to advocate for sustained conservation efforts and increased investment in restoration initiatives within protected areas. Moreover, these results can serve as a support for developing payment for ecosystem services schemes aimed at preserving water resources. Additionally, the findings can be used to raise awareness among local communities and encourage their active engagement in sustainable development initiatives.

Keywords: LULCC; Google Earth Engine; InVEST Models; SDR; NDR; economic assessment; Ifrane National Park

Introduction

Ecosystem services, defined as the benefits humans derive from natural ecosystems, ranging from the provision of resources, to the regulation of environmental processes. These services are indispensable for human well-being [1]. Their recognition gained prominence with the study of Costanza in 1997, which introduced economic valuation as a method to highlight their importance and integrate them into decision-making processes [2]. Water regulation ecosystem services (WRES) are key ecosystem services which play a critical role in maintaining water balance [3,4]. Provided by ecosystems such as forests, grasslands and wetlands, these services are vital for ensuring water quality, and mitigating soil erosion and flooding [5,6]. Monetizing these services become a necessity to support their inclusion in policy-making and environmental planning [7].

In Morocco, the importance of WRES is especially pronounced in regions such as the Middle Atlas, where forested watersheds are crucial for maintaining hydrological stability, supporting agricultural productivity, and ensuring urban water supply [8,10]. The upper BEHT watershed is one

of the INP's most ecologically and hydrologically significant basins. It encompasses extensive mountainous forests of Atlas Cedar (*Cedrus Atlantica*) and contributes over 80% of the country's mobilizable water resources. This watershed provides essential services for downstream water availability, agricultural productivity, and urban consumption [11,12].

However, the region's capacity to deliver critical WRES has been jeopardized by Land-Use And Land-Cover Changes (LULCC), including grasslands degradation, agricultural intensification, and urban expansion [13]. Established in 2004, the INP aims to mitigate these threats by conserving the region's unique biodiversity and maintaining essential ecosystem services. The park seeks to reconcile various land-use categories (state-owned, collective, and private lands) while promoting conservation and sustainable resource utilization through participatory approaches. The park's managers have implemented significant efforts to protect natural assets, such as: reforestation and restoration initiatives, wildlife conservation efforts, ecotourism projects, and eco-development programs [14]. Despite these efforts, few studies have specifically examined the impact of LULCC on conservation outcomes, especially regarding their effect on the economic value of WRES provided by the park's watersheds [11,15–20].

This study addresses this critical research gap by offering a localized and detailed assessment of WRES in the upper BEHT watershed. Using remote sensing data processed in Google Earth Engine (GEE) platform and spatial modeling tools—specifically the Sediment Delivery Ratio (SDR) and Nutrient Delivery Ratio (NDR) models within the InVEST models—the research quantifies and maps changes in sediment and nutrient retention as a principal WRES over three decades (1992–2022). This work incorporates on-the-ground verification to enhance the accuracy of its findings and provides robust insights into the evolution of WRES before and after the park's establishment. In addition to biophysical assessment, this study conducts an economic valuation of WRES using the damage costs avoided approach, highlighting their monetary significance.

By evaluating the evolution of WRES biophysical quantity and economic value in relation to LULCC and conservation efforts, this study underscores the importance of restoration activities in enhancing ecosystem resilience. It also demonstrates how economic valuation can inform sustainable conservation planning and policymaking, paving the way for innovative financing mechanisms that align ecological preservation with socio-economic objectives. The study first introduces the study area (Section 2.1) and outlines the methodological approach (Section 2.2), including the mapping of LULC for 1992, 2002, 2012, and 2022 (Section 2.2.1), the quantification of WRES for each year (Section 2.2.2), and the economic assessment of these services (Section 2.2.3). The results reveal a positive trend in the provision of WRES following the park's establishment, with significant improvements in areas targeted by reforestation and conservation. The economic value of WRES reaching 10,000 USD per year. This study highlights the necessity of ongoing WRES monitoring, equipping park managers with valuable data to support continued conservation initiatives, and advocate to integrate the economic value of WRES provided by protected area such the INP, into policy and decision making, environmental management planning, and financial mechanisms as payment for ecosystem services to preserve water resource.

Materials and Methods

2.1. Study Area

The study area encompasses the upper BEHT watershed; the most ecologically and hydrologically significant basin within Ifrane National Park, situated in the western part of the central Middle Atlas region in Morocco (Figure 1).

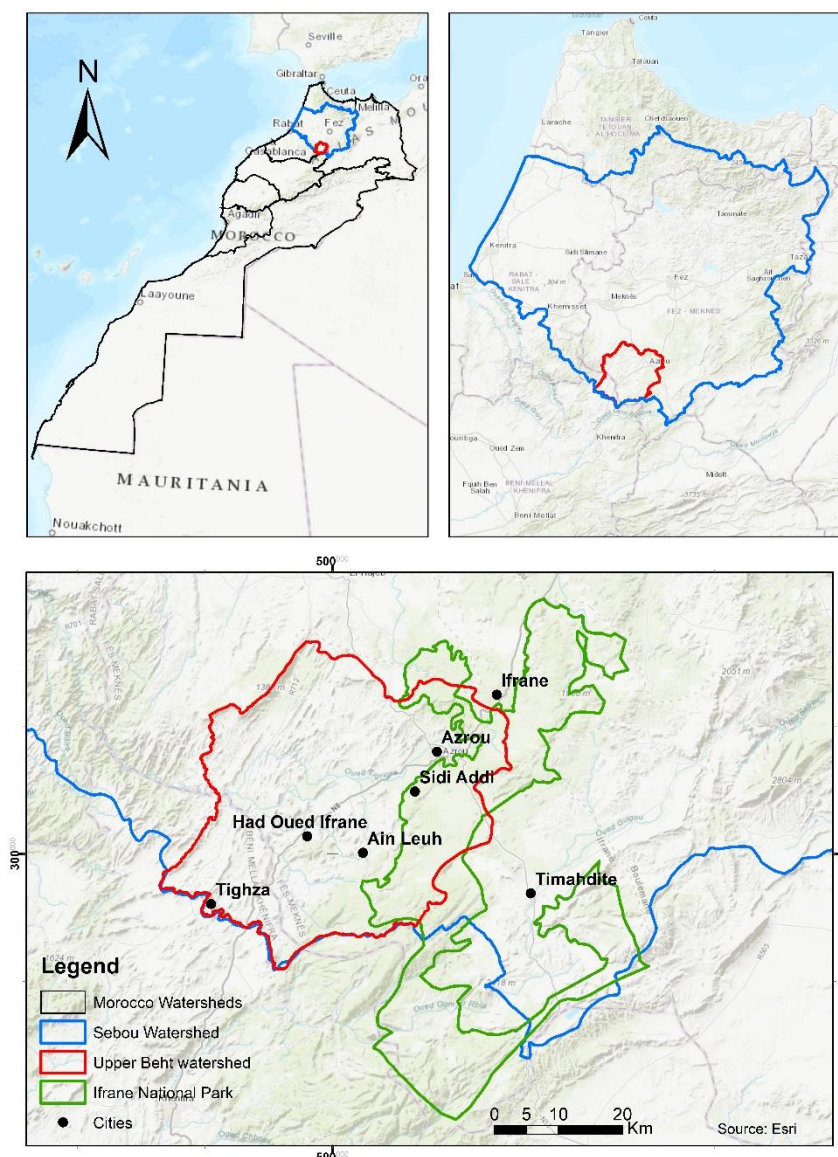


Figure 1. Map of the geographical location of the study area.

The INP aims to conserve the region's unique biodiversity and ecosystems while promoting the sustainable management of natural resources. It also supports local development by fostering environmentally responsible practices and sustainable economic activities, such as ecotourism and agro ecology [21]. The park's watersheds contribute over 80% of Morocco's mobilizable water resources, with the upper BEHT watershed representing a particularly vital hydrological basin, which plays a critical role in water regulation and supply, serving as a primary source for downstream reservoirs and agricultural systems. Its significance lies in its capacity to capture precipitation, regulate seasonal flows, and mitigate sediment transport, making it essential for sustaining water availability in the region [21]. Three main soil types within the park based on substrate are: volcanic, calcareous, and dolomitic. The park is characterized by two distinct bioclimates: subhumid and humid. These climates exhibit cool conditions at mid-altitudes, cold temperatures across the plateau, and very cold extremes at the summits of the eastern mountain ranges [21]. The park hosts 22% of Morocco's vascular plant species, with a high endemism rate of 25%, exemplified by the iconic Atlas cedar (*Cedrus atlantica*). Additionally, it supports 33% of the country's mammalian species, including the endangered Barbary macaque (*Macaca sylvanus*) [22].

2.2. Mapping Historical LULCC

Satellite data for the years 1992, 2002, 2012, and 2022 were analyzed to assess LULCC within the INP over three decades. These datasets, obtained from the Google Earth Engine (GEE) platform, were derived from the Landsat 5, Landsat7, Landsat 8, and Landsat 9 satellite series. The analysis incorporated all available spectral bands, as well as the Normalized Difference Vegetation Index (NDVI), to enable a detailed examination of spatial and temporal LULCC.

Preprocessing steps, including radiometric and atmospheric corrections, were applied to ensure consistency and comparability across the different time periods [23,24]. LULC classification was performed using the Random Forest (RF) machine learning algorithm, selected for its reliability and high accuracy in remote sensing studies [25,26]. RF leverages ensemble learning by aggregating predictions from multiple decision trees, reducing overfitting and increasing model stability. Its inherent feature selection capabilities are particularly useful for identifying significant variables, such as spectral bands or vegetation indices, critical for accurate classification. RF has been shown to perform well in various LU/LC studies, including integration with advanced techniques like Markov chain models and multi-layer perceptrons for change prediction, achieving high accuracy and interpretability [27]. Combining RF with multi-sensor data, such as optical and SAR images, has further enhanced classification accuracy, achieving over 96% accuracy in some studies [28]. While RF generally excels, challenges remain in distinguishing spectrally similar classes and achieving consistent precision and recall measures, especially in heterogeneous landscapes [29]. Despite these limitations, RF’s balance of simplicity, accuracy, and computational efficiency makes it a preferred choice for large-scale LULC classification in GEE.

In this study, supervised classification categorized LULC into six classes: forests, shrubs, crops, built-up areas, water, and bare soil. The selection of study years, encompassing both pre- and post-establishment periods of the park (created in 2004), provided insights into the evolution of LULC before and after the park’s creation. Validation of classification results was conducted using confusion matrices and the Kappa index, demonstrating satisfactory accuracy levels for all time periods analyzed.

2.3. Quantifying Water Regulating Ecosystem Services Using InVEST

After analyzing historical LULCC, we quantify WRES using the InVEST models, in particular the Sediment Delivery Ratio (SDR) and Nutrient Delivery Ratio (NDR) models [17–20]. Annual soil loss and the sediment delivery ratio, defined as the proportion of soil loss reaching the stream, are computed by the SDR model, and it is assumed that sediment is transported from the source to the stream and then to the watershed outlet. The Revised Universal Soil Loss Equation (RUSLE) is employed by the model to estimate annual soil loss. The spatial movement of nutrient masses is explained by the NDR model through a simple mass balance methodology, in which LULC and loading rates are considered to determine nutrient loads [30]. The input rasters for the InVEST models are presented in Table 1.

Table 1. InVEST models data source.

Models Inputs	InVEST Models	Source of Inputs
LULC	All InVEST models	Obtained using Google Earth Engine platform
Biophysical tables (*)	All InVEST models	From literature [31,32]
Rasters of precipitation	“Nutrient Delivery Ratio”	Obtained from the website of CHIRPS: Rainfall Estimates from Rain Gauge and Satellite Observations, Climate Hazards Center (https://www.chc.ucsb.edu/data/chirps) accessed on 03/09/2024) [33]

Digital Elevation Model	“Sediment Delivery Ratio” “Nutrient Delivery Ratio”	From the website of Earth Science Data Systems (ESDS) Program of the National Aeronautics and Space Administration of the United States of America (https://earthdata.nasa.gov (accessed on 15/08/2021) [34]
Erosivity raster (R Factor)	“Sediment Delivery Ratio”	Calculated from annual and monthly precipitation averages over a 30-year period (1992–2022) Obtained from the website of CHIRPS, using the formula of Rango and Arnoldus (1987) [33,35]
Soil erodibility raster (K factor)		From literature [31]

(*)Appendix A.

2.4. Economic Assessment of Water Regulating Ecosystem Services

In this study, a revealed preference economic valuation method is employed, specifically, the damage costs avoided method, which quantifies expenses that would have been incurred in the absence of a specific environmental function [36,40]. Damages related to the absence of Water Regulating Ecosystem Services are primarily associated with potential degradation affecting agricultural lands and rangelands.

Loss in agricultural yields is obtained using the relationship of Den Biggelaar et al. (2004) [41] (Equation (1)).

$$r = EwP^{1.224} * 0.0114 \tag{1}$$

with:

- r: Relative decrease in yield due to erosion (%).
- EwP: Erosion rate (t/ha/year).

Then, the relative decrease in yield due to erosion was multiplied by the average crop yield to determine the decline in yield in t/ha (2).

$$\Delta R = r * \text{Average crop yield} \tag{2}$$

with:

- ΔR: Relative decrease in yield due to erosion (t/ha);
- r: Relative decrease in yield due to erosion (%).

Forage yield losses are determined using Table 2, which provides the percentage of forage productivity losses for each erosion class [42].

Table 2. Correspondence between forage productivity loss and level of soil degradation.

Erosion Classes (t/ha/year)	Loss of Forage Productivity (%)
0–5	2.5
5–25	25
>25	45

Once the damage quantities had been determined, their economic costs were estimated. For agricultural damages, the market prices of cereals were applied, as more than 58% of the cultivated land in the study area is dedicated to cereal crops [43]. For rangeland damages, the price of fodder barley was relied upon, since the value of one forage unit is considered equivalent to one kilogram of barley. The evaluation was carried out for multiple reference years (1992, 2002, 2012, and 2022).

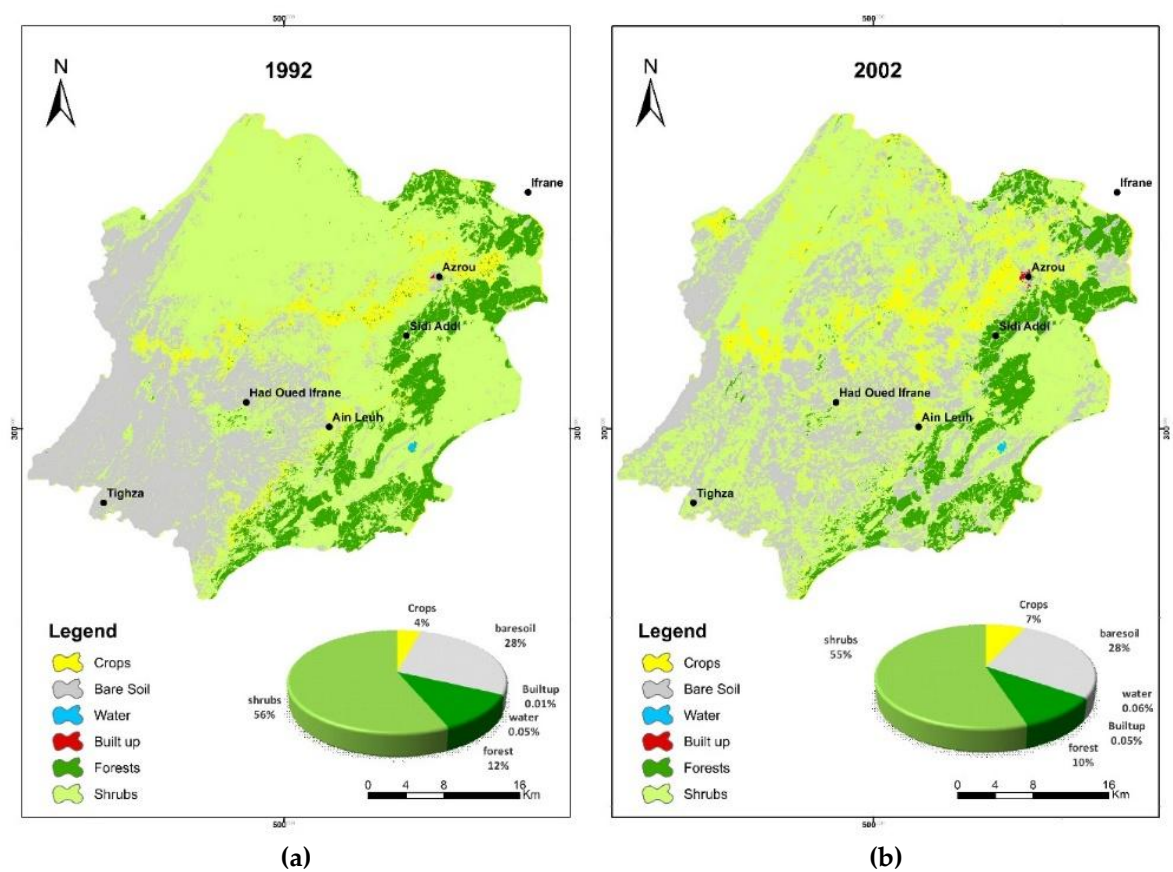
Accordingly, the market prices of cereals and barley corresponding to each year were used to ensure accurate cost estimation [44].

3. Results

3.1. Historical LULCC Within the INP Watershed

The analysis revealed a significant increase in forest cover between 2012 and 2022, the decade following the park’s creation (Figure 2). Prior to the park’s creation, the region experienced a gradual decline in forested areas due to various anthropogenic activities, including deforestation and land conversion for agricultural purposes. However, the implementation of conservation measures and sustainable management practices within the park has led to a remarkable recovery and expansion of the forest ecosystem.

An analysis of conservation initiatives implemented within the park reveals significant achievements. During the period 2012/2022, more than 2,000 hectares were successfully reforested, and over 4,000 hectares were placed under protection or designated for restoration and reforestation. These areas were managed through a participatory approach involving local communities. The number of local associations engaged in park management increased from 5 at the park’s inception to 12 at present, reflecting a growing community commitment. Furthermore, there was a nearly 50% reduction in forest-related offenses during this time. These positive indicators align with the findings from remote sensing analysis, which demonstrated an increase in forest cover, thereby confirming the tangible impact of these conservation efforts [45].



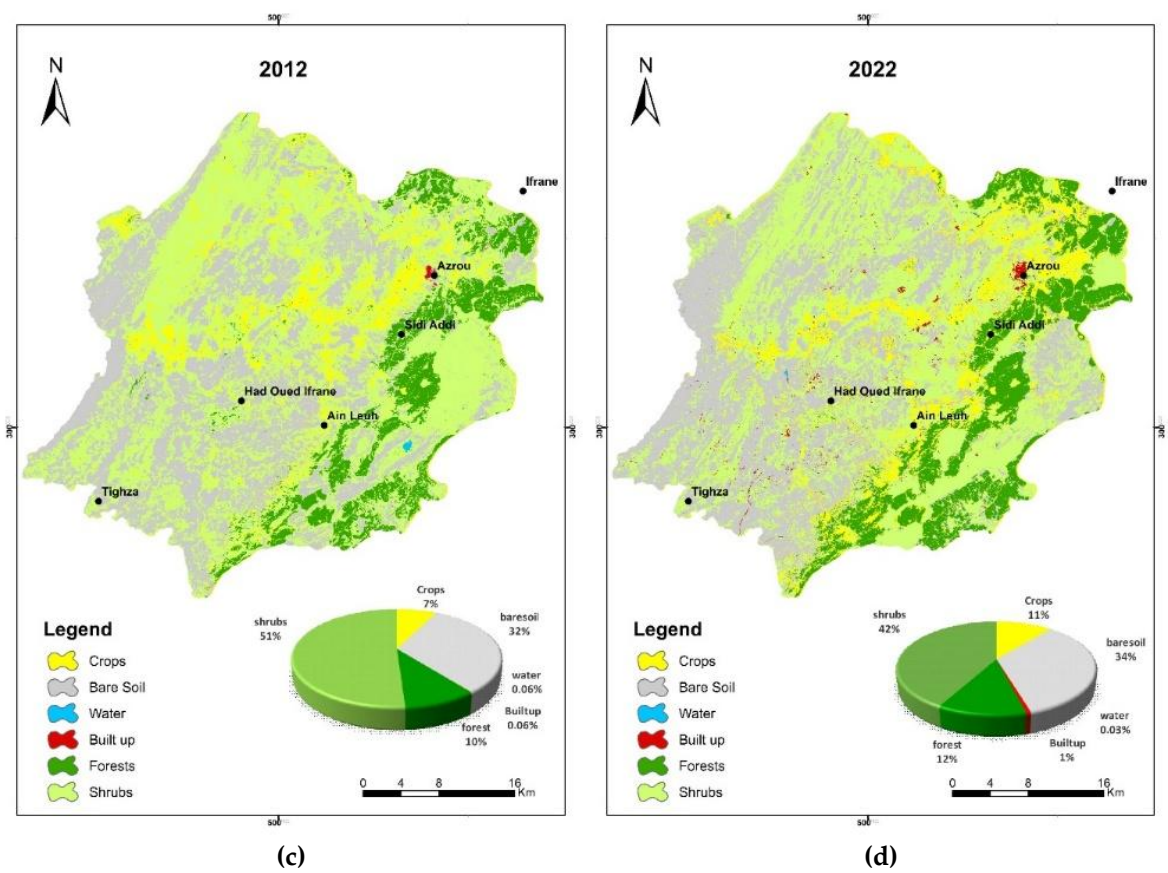


Figure 2. LULCC within the INP watershed: (a) and (b) represent the period before park establishment, while (c) and (d) illustrate the period after park establishment.

Table 3 illustrates the evolution of each LULC class within the INP watershed.

Table 3. Evolution of LULC class within the INP watershed (1992/2022).

LU class	Surface in 1992 (Ha)	Surface in 2002 (Ha)	Surface in 2012 (Ha)	Surface in 2022 (Ha)
Crops	6,999	11,762	12,456	18,502
Bare soil	47,150	46,535	54,074	58,242
Water	89	97	96	49
Built-up	14	79	106	976
Forest	19,564	17,592	16,058	20,476
Shrubs	95,365	93,116	86,391	70,936
Total	169,181	169,181	169,181	169,181

For the different years analyzed, we achieved a Kappa coefficient value equal to or greater than 90% (Table 4), indicating a near-perfect agreement between the reference classification and the automated classification performed using Google Earth Engine. This high level of concordance signifies that the model accurately replicated the reference data.

Table 4. Kappa coefficient for the classifications.

	1992	2002	2012	2022
Kappa coefficient	89%	91.3%	93.8%	98.14%

The classification accuracy results for the years 1992, 2002, 2012, and 2022 show a clear trend of improvement in the model’s performance over time, as indicated by the increasing overall accuracy and the decreasing disagreement metrics. The overall accuracy increased progressively, starting from

87.5% in 1992 and reaching an impressive 98.96% in 2022. This steady improvement suggests significant advancements in the classification model's ability to align with reference data. The high accuracy achieved in 2022 highlights the impact of improved input data quality and enhanced feature extraction or modeling techniques over the study period.

The quantity disagreement, which reflects errors related to mismatches in class proportions, exhibited an initial increase from 2.78% in 1992 to 6.45% in 2002. This could be attributed to limitations in the availability or representativeness of the training data during that period. However, this metric showed a consistent decline thereafter, reducing to 4.26% in 2012 and further to 1.04% in 2022. The observed reduction in quantity disagreement over time indicates that the classification model has progressively become better at predicting the correct number of pixels for each class, aligning more closely with the reference data distributions.

Similarly, allocation disagreement, which measures spatial misallocations of classes, was notably high in 1992 (9.72%) and 2002 (11.29%), indicating significant challenges in correctly assigning class locations during the earlier years. However, this metric saw a dramatic reduction to 2.13% in 2012 and was completely eliminated in 2022 (0.00%). The absence of allocation disagreement in 2022 demonstrates a perfect spatial alignment between the predicted and reference data, suggesting substantial advancements in the classification model's spatial accuracy. These improvements may be attributed to better-distributed training data, higher-resolution satellite imagery, or the adoption of more robust classification algorithms.

Overall, the results indicate that the classification process has undergone considerable refinement over the study period. The observed improvements in both accuracy and disagreement metrics emphasize the critical role of evolving data quality and modeling techniques in achieving reliable LULC mapping. These trends highlight the importance of continuous innovation in remote sensing methodologies to ensure accurate and spatially coherent classification outcomes.

3.2. Water Regulating Ecosystem Services Evolution

Our results indicate a notable reduction in soil erosion within the INP watershed following the establishment of the park (2012/2022) (Figure 3). This decline can be attributed to the significant expansion of forest cover, which has enhanced soil stability and reduced erosion vulnerability. These findings underscore the critical role of forest restoration and protection within protected areas in mitigating soil degradation.

However, the observed reduction in erosion could have been more substantial if not for the simultaneous expansion of agricultural activities. The increase in agricultural lands has heightened soil sensitivity to erosion, partially offsetting the benefits provided by forest cover recovery. This highlights the importance of integrated land management strategies that balance agricultural development with ecosystem conservation to maximize the benefits of soil erosion control.

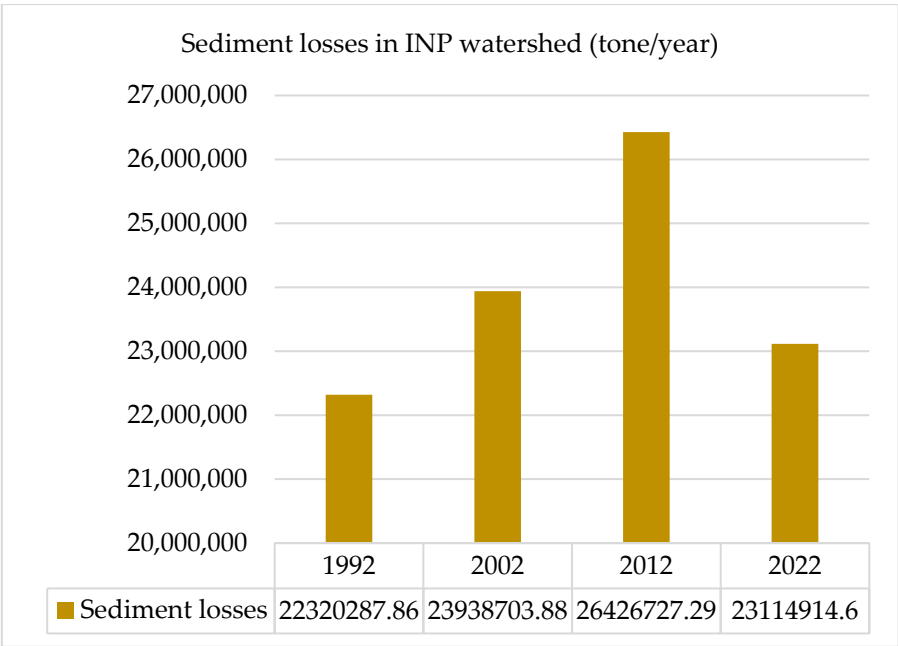
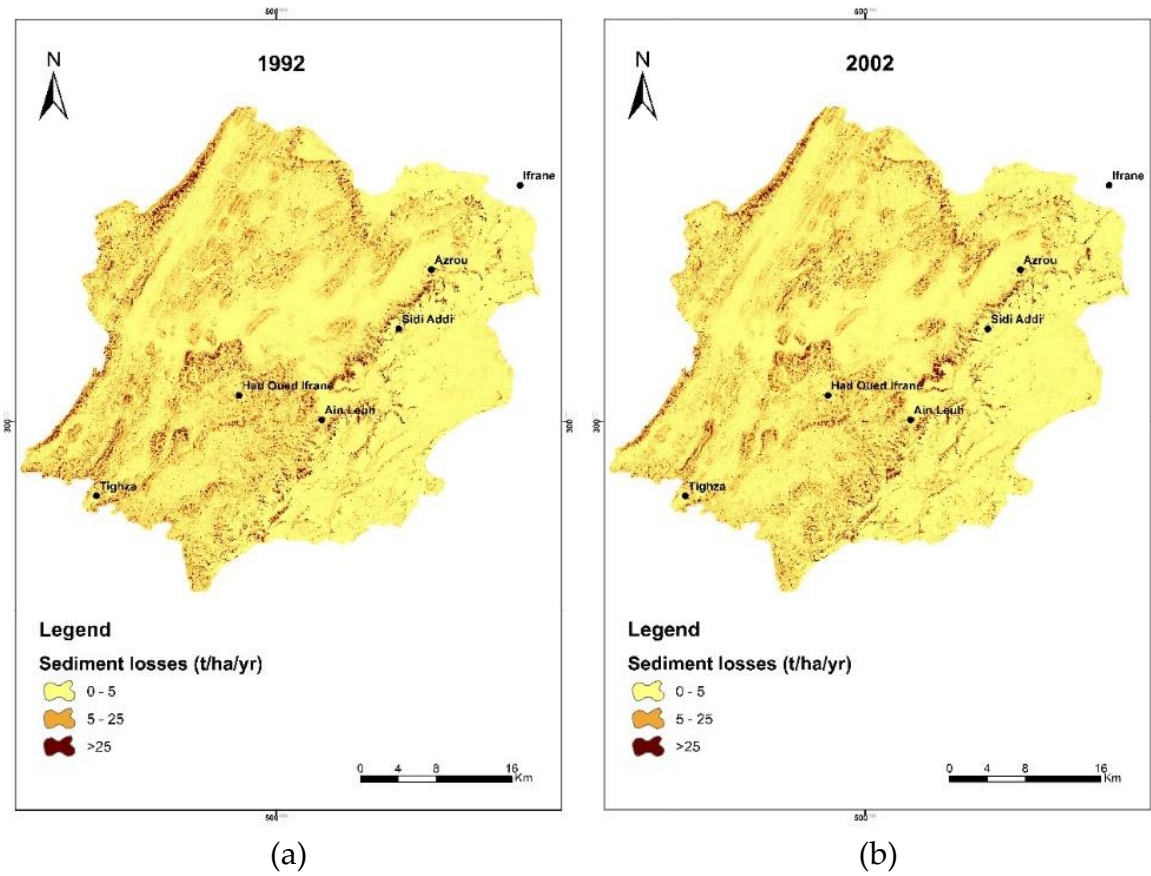


Figure 3. Sediment losses within the INP watershed in tone per year.

Figure 4 illustrates the spatial evolution of the biophysical quantity of sediment loss within the INP watershed, highlighting variations across the study period.



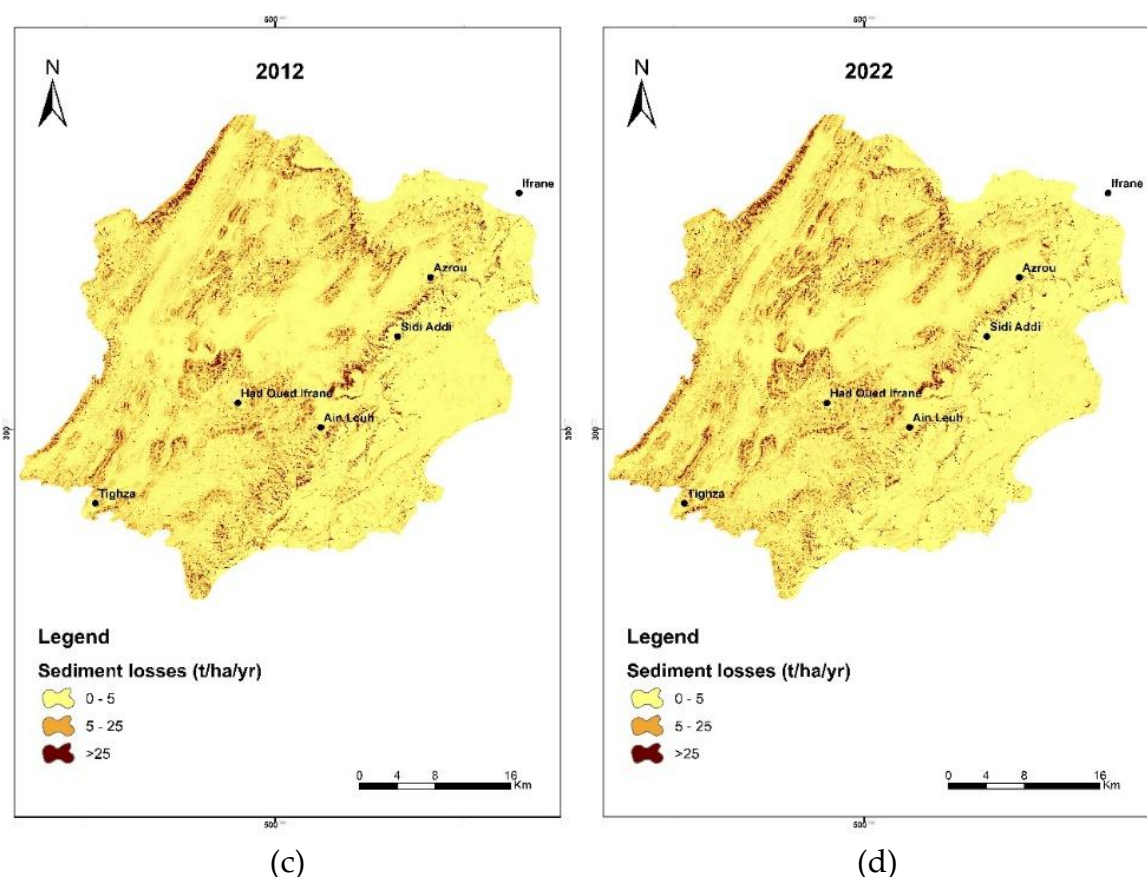


Figure 4. Sediment losses maps within the INP watershed: (a) and (b) represent the period before park establishment, while (c) and (d) illustrate the period after park establishment.

Our results also indicate a significant reduction in nutrient export, specifically nitrogen and phosphorus, within the INP watershed following the establishment of the park (2012/2022) (Figure 5). This decline can similarly be attributed to the expansion of forest cover, which demonstrates a higher efficiency in nutrient retention compared to other LULC types. These findings further highlight the pivotal role of forest restoration and protection in enhancing ecosystem services.

However, this reduction could have been significantly greater if not for the concurrent expansion of intensive agricultural activities and the substantial decrease in grasslands. These grasslands, which play a vital role in nutrient retention and erosion control, have either been degraded into bare soil due to overgrazing or converted into agricultural fields. This shift in land use has not only compromised the ecological benefits provided by grasslands but has also amplified nutrient runoff. Intensive agricultural practices often involve excessive use of fertilizers, which, combined with the loss of natural vegetation, exacerbate nutrient leaching into downstream systems. As a result, while reforestation efforts have improved certain ecosystem services, the negative impacts of agricultural expansion have partially offset these gains.

This duality highlights the critical need for integrated and sustainable land management strategies that balance forest conservation with the growing demands for agricultural development. Policies should prioritize sustainable practices such as agroforestry, soil conservation techniques, and the restoration of degraded grasslands to mitigate the environmental impacts of agriculture. Encouraging local communities to adopt such practices through education and incentives can play a key role in maintaining the functionality of nutrient retention services.

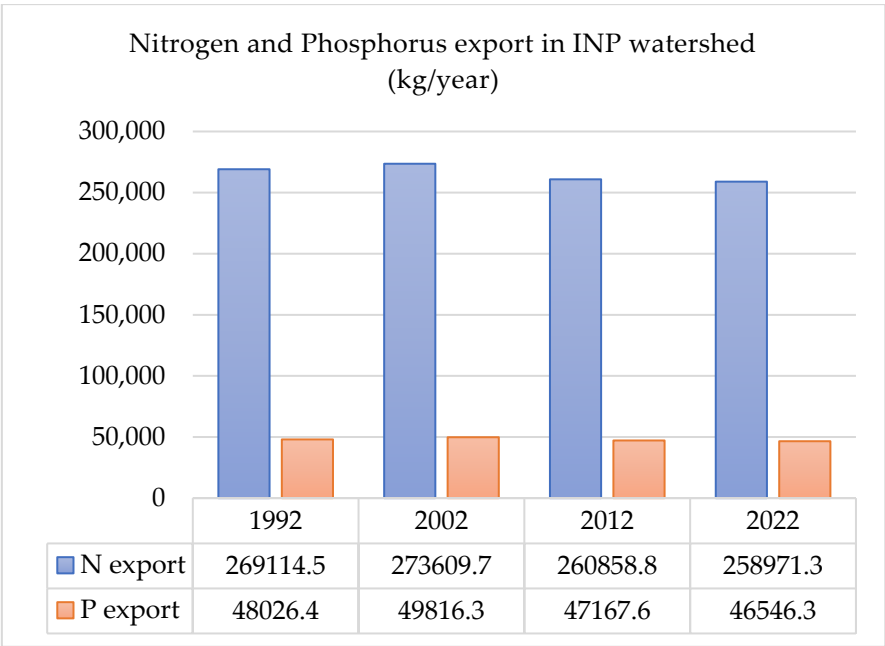
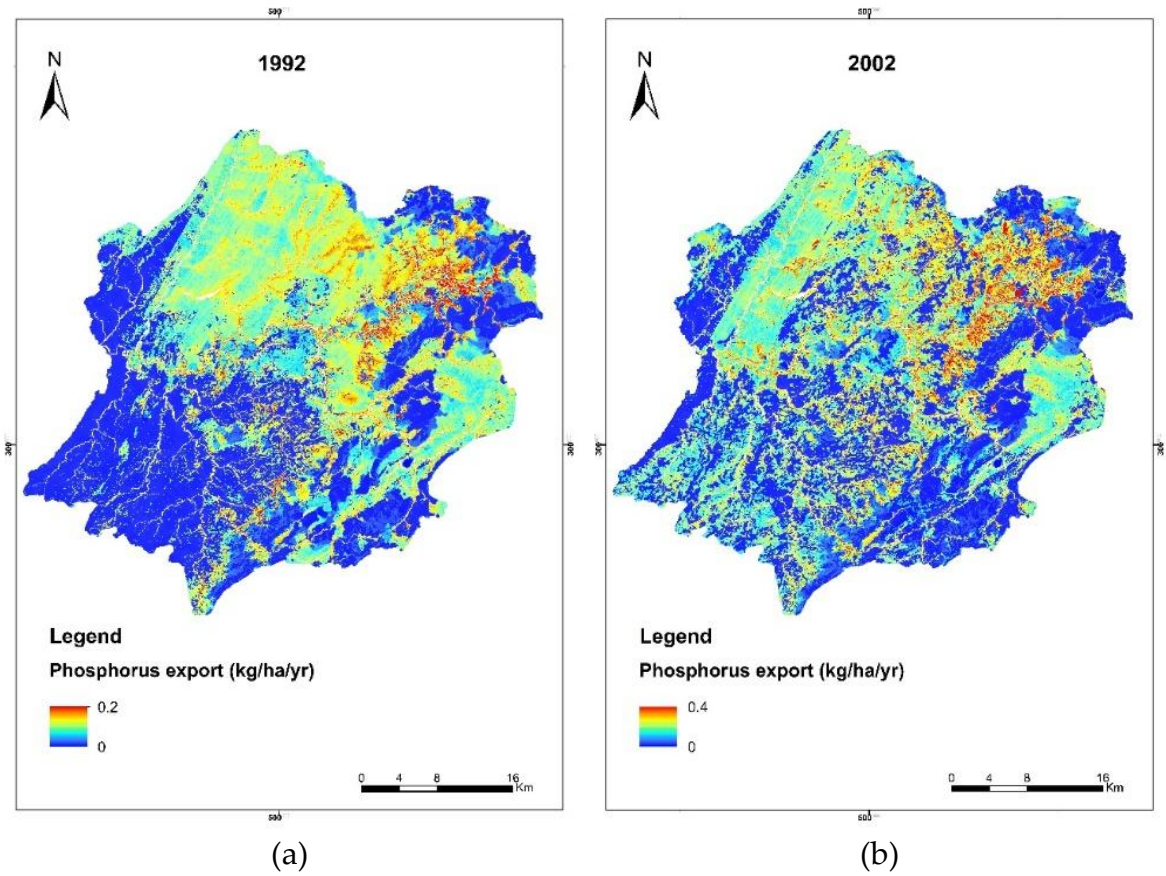


Figure 5. Nitrogen and Phosphorus export in the INP watershed in kg per year.

Figures 6 and 7 presents the spatial evolution of the biophysical quantity of Nutrients export within the INP watershed. Highlighting variations from 1992 to 2022.



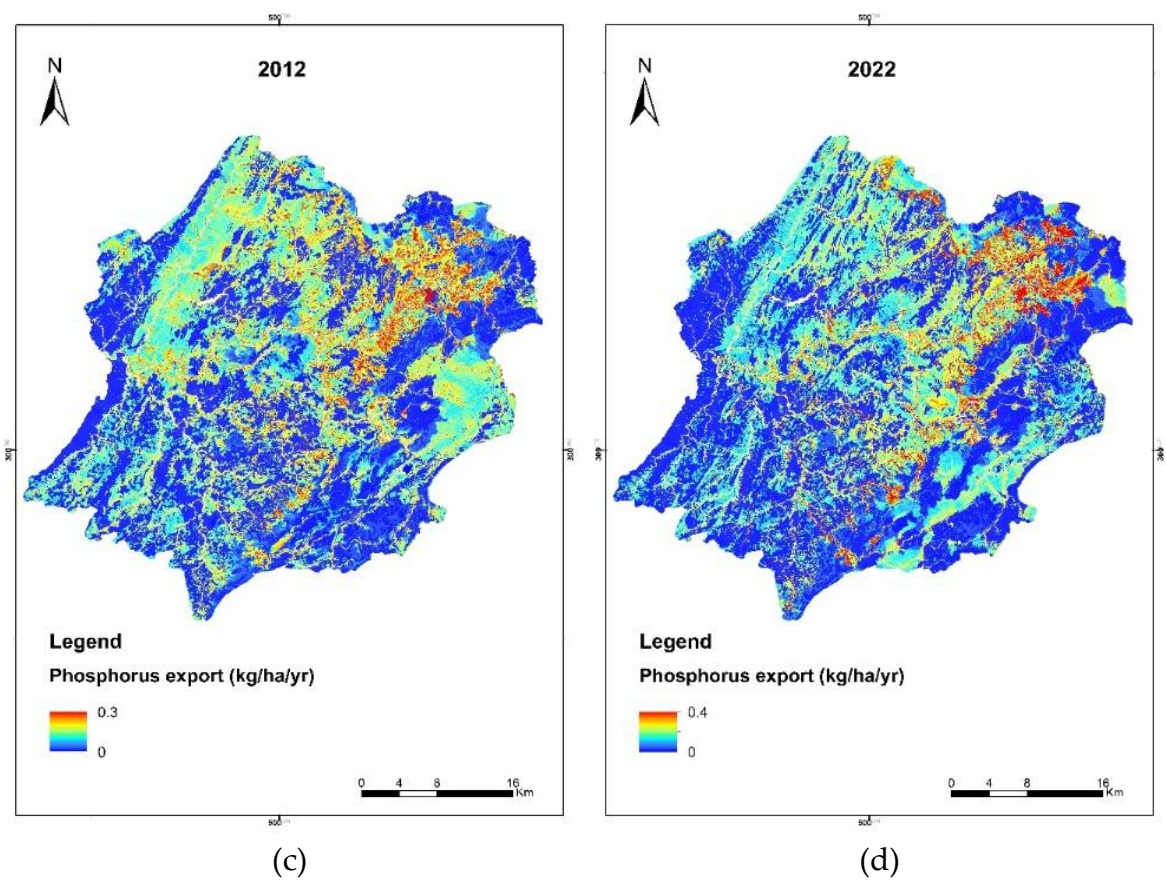
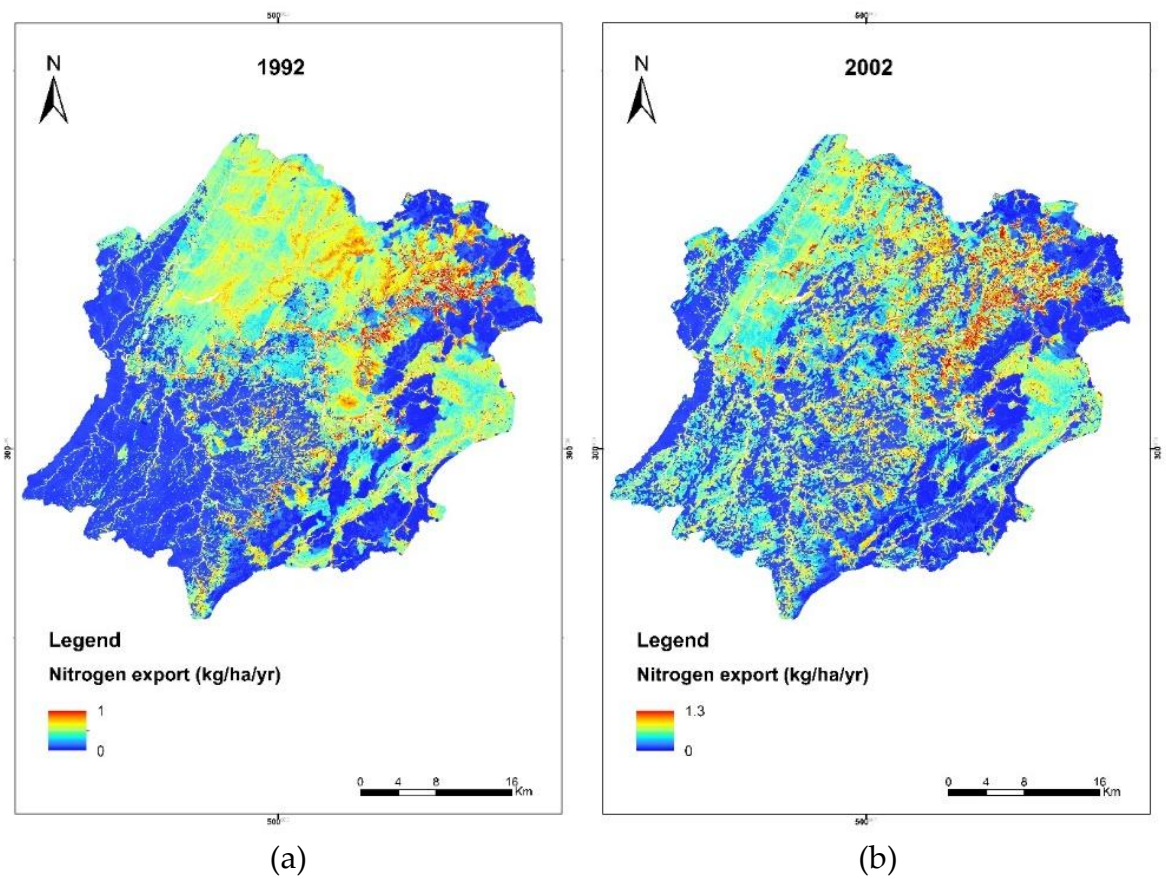


Figure 5. Phosphorus export maps within the INP watershed: (a) and (b) represent the period before park establishment, while (c) and (d) illustrate the period after park establishment.



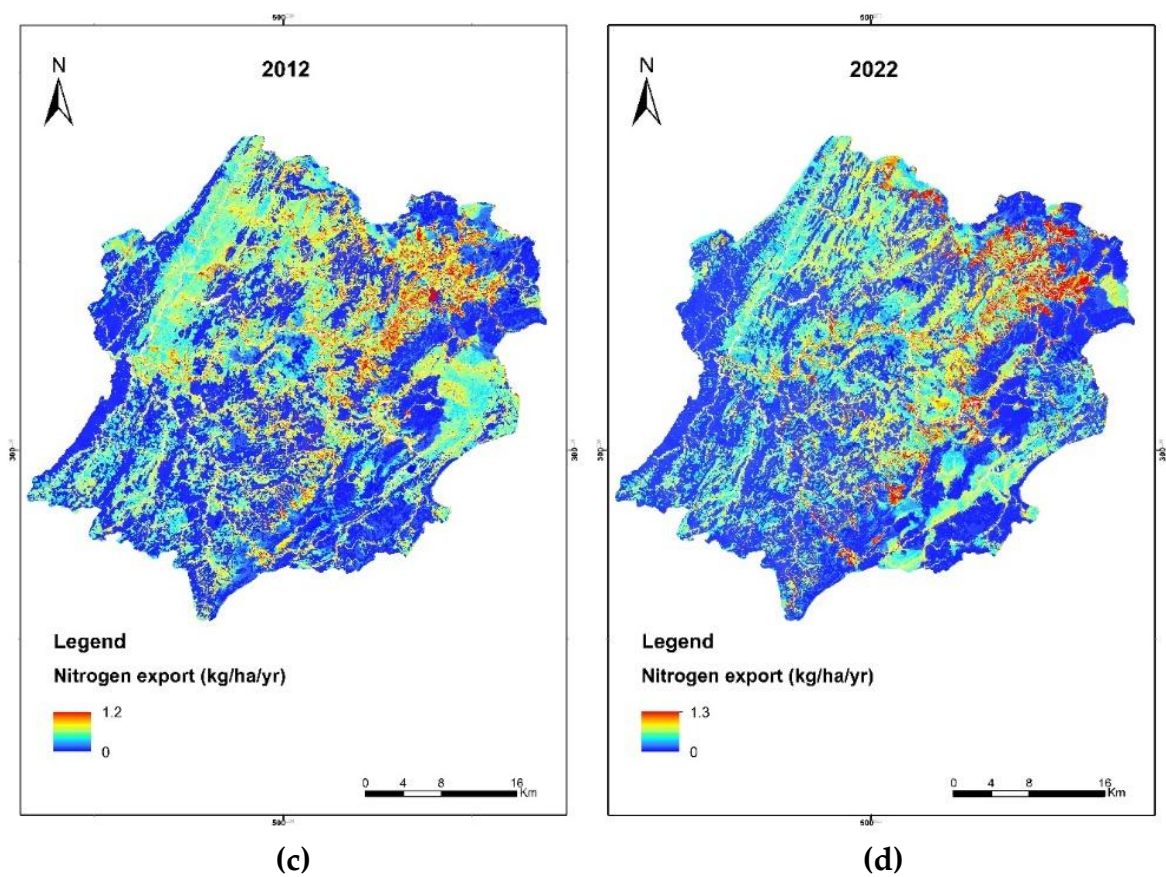


Figure 6. Nitrogen export maps within the INP watershed: (a) and (b) represent the period before park establishment, while (c) and (d) illustrate the period after park establishment.

3.3. Economic Assessment of Water Regulating Ecosystem Services

The results show also an increase in agricultural yield losses cost (Table 5), driven by the expansion of agricultural areas, even after the park’s establishment, leading to greater erosion-related damages. Conversely, forage yield losses cost has declined (Table 6), primarily due to a significant reduction in grazing land, which has been converted to agriculture or built-up areas. These findings highlight that, despite efforts to restore forest ecosystems and enhance ecosystem services, agricultural expansion continues to undermine these gains, resulting in a low economic value, which would have been much higher. This underscores the need for interventions to modify agricultural practices and promote sustainable land use for grazing areas to improve environmental outcomes.

Table 5. Losses in agricultural yields as a function of soil losses.

Soil Loss Class (t/ha/year)	Erosion Rate Ewp (t/ha/year)	Decrease in Yield: r (%)	Decline in Yield $\Delta R = r \times \text{Average}$ Yield (2 t/Ha) (t/ha)	Annual Cost 1992/2002 (USD/year)	Annual Cost 2002/2012 (USD/year)	Annual Cost 2012/2022 (USD/year)
0–5	2.5	0.04	0.07	9255.9	1427	2219.8
5–25	15	0.31	0.06	-81.6	177	501.6
>25	25	0.59	0.12	-6.8	8.6	46.9
Total				9167.6	1612.7	22741.4

Table 6. Losses in forage yield as a function of soil losses.

Soil Losses (t/ha)	Loss of Forage Productivity (%)	Loss of Forage Productivity (UF/ha)	Annual Cost (USD/year)	Annual Cost (USD/year)	Annual Cost (USD/year)
0–5	2.5	3.3	-902.1	-6,284.8	-20,784.5
5–25	25	32.9	-1,307.4	-3,618.6	-10,803.3
+25	45	59.3	-104.7	-179.8	-1,122.9
Total			-2314.2	-10083.1	-32710.8

Note: Negative values in the tables indicate a reduction in the cost of lost productivity, reflecting an improvement in WRES, while positive values indicate the opposite.

The economic value of the WRES is determined based on the potential on-site losses in agricultural and forage yields that would occur in the absence of this ecosystem service. The results show that the WRES value was negative before the park’s establishment. However, after the park’s creation (in 2004), the WRES value became positive, estimated at 10,000 USD/Year (Figure 8).

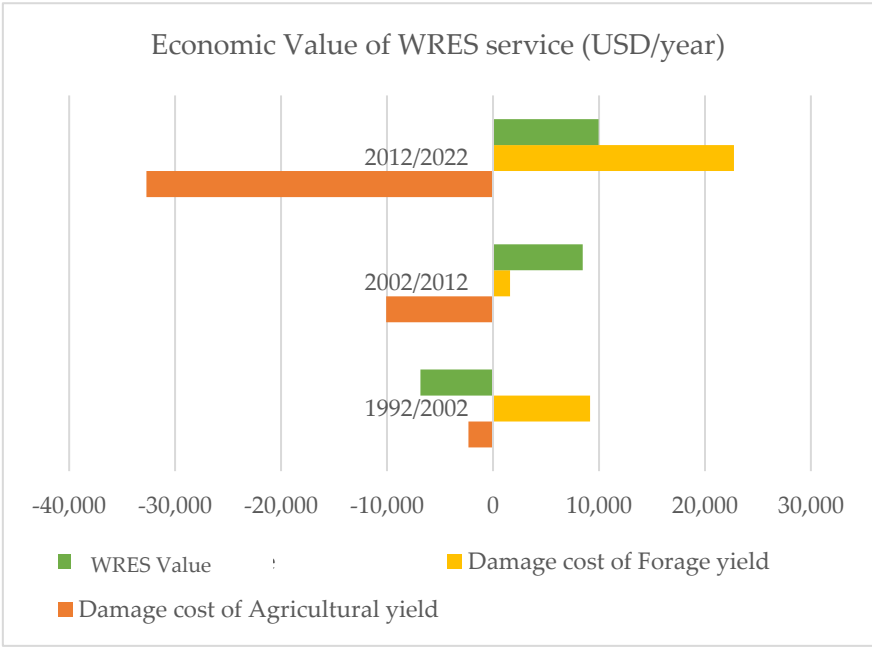


Figure 8. Economic Value of WRES in USD per year.

4. Discussion

The results of the spatio-temporal and economic assessment of the WRES in Ifrane National Park highlight significant trends at both spatial and economic levels. Prior to the establishment of the park in 2004, the WRES value was negative, estimated at -7,000 USD/year. This negative value was primarily attributed to agricultural expansion, which led to increased sediment and nutrient losses, negatively impacting both the environment and agricultural yields.

However, following the creation of the park, the WRES value became positive, reaching 10,000 USD/year. This positive shift can be attributed to the expansion of forest cover, which enhanced sediment and nutrient retention, thereby reducing erosion-related losses and contributing positively to the ecosystem. The improvement in soil quality and reduction in erosion were particularly notable in areas where forest cover was restored. Despite this positive trend, the WRES value could have been significantly higher had it not been for the continued agricultural expansion and land conversion to built-up areas after the park’s establishment.

The conversion of grazing lands into agricultural lands and built-up zones further negatively impacted nutrient retention. While agricultural yields increased, this growth was accompanied by a

heightened vulnerability of soils to erosion, reducing the park’s ability to provide optimal sediment and nutrient retention services. The decrease in grazing land area, primarily converted into agricultural land considered more profitable, led to a loss of the land’s retention capacity [46–51].

These findings underscore the importance of integrated land management strategies that balance ecosystem protection with agricultural development. Despite efforts to restore forest ecosystems, the continued expansion of agriculture and urbanization continues to mitigate these environmental gains. The results suggest the need for sustainable agricultural practices and the preservation of grazing lands to optimize ecosystem services such as sediment and nutrient retention. Sustainable land management strategies should be implemented to maximize nutrient retention and limit negative environmental impacts while supporting local economic activities [52–57].

It is crucial for park managers to invest in advanced tools focused on the continuous mapping and assessment of the evolution of the park ecosystem services. This approach would support data-driven decision-making and more adaptive management strategies to address ecosystem changes effectively [58].

The findings from this study can serve as a powerful tool for advocating sustained conservation efforts among policymakers and relevant stakeholders. By showcasing the dynamics of ecosystem services, these insights can drive support for the implementation of more comprehensive and long-term conservation policies [59].

Awareness campaigns highlighting the value of ecosystem services should be prioritized to encourage land-use practices that align with the park’s conservation goals and enhance its ecological resilience [60].

The results of this study should be systematically integrated into the upcoming revisions of the Park Management and Development Plan (PAG). Considering the trends in ecosystem service evolution will inform more effective conservation strategies and contribute to the sustainable management of park resources [61].

Author Contributions: Conceptualization, O.S. and A.K.; methodology, O.S.; software, O.S. and Z.D.; validation, A.K.; formal analysis, O.S.; investigation, O.S.; resources, O.S.; data curation, O.S.; writing—original draft preparation, O.S.; writing—review and editing, O.S.; Z.D. and A.K.; visualization, O.S.; supervision, A.K.;

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A: Biophysical Tables of SDR and NDR Models

Table A1. Biophysical tables of SDR model.

Lucode	LULC_Desc	Usle_c	Usle_p
1	Crops	0.19	1
2	Baresoil	1	1
3	Water	0.04	1
4	Built up area	0.1	1
5	Forest	0.003	1
6	Shrubs	0.5	1

Table A2. Biophysical tables of NDR model.

lucode	LULC_desc	load_n	eff_n	load_p	eff_p	crit_len_p	crit_len_n
1	Crops	12.42	0.25	2.21	0.25	150	150
2	Baresoil	1	0.05	0.1	0.05	150	150
3	Water	0	0	0	0	150	150
4	Built up area	12.78	0.08	4.17	0.05	150	150
5	Forest	2.2	0.83	0.275	0.8	150	150

6	Shrubs	6.28	0.1	1.35	0.25	150	150
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