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Riparian Forests as Nature-Based Solutions within the Mediterranean Context: A Biophysical and Economic Assessment for the Koiliaris River Watershed (Crete, Greece)

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Abstract: The Mediterranean Basin is severely impacted by anthropogenic changes affecting both natural ecosystems and human livelihoods. The region is highly vulnerable to natural hazards, with floods being considered the most important, due both to their frequency and impacts. Koiliaris watershed (northwest of Crete Island, Greece) represents a relevant case study as past land-use changes via deforestation and intense cultivation practices induce soil organic matter losses, making soils susceptible to water erosion and desertification. The restoration of native riparian forests has been identified as the most effective nature-based solution (NBS) for the area. Through modeling, our study assessed the effectiveness of this NBS in addressing flood risk and erosion while providing additional ecosystem services (carbon sequestration and biodiversity conservation). A cost–benefit analysis has been then implemented to also investigate the sustainability of the investment from an economic point of view. Our results show the NBS would be successful in ensuring a better flow of targeted ecosystem services compared to the business-as-usual conditions. The associated investment would result in economic sustainability and associated costs would be paid back in five years. Though site-specific, our study provides lessons learned for dealing with future land-restoration challenges in the Mediterranean to cope with climate change-related challenges.

Keywords: ecosystem services; flood; carbon; climate change; habitat; WEFE Nexus; hazards; cost–benefit analysis

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1. Introduction

The Mediterranean Basin is severely impacted by anthropogenic changes affecting both natural ecosystems and human livelihoods. Based on climate projections, it has been labeled as a hotspot of change, with rates of warming and reduction in precipitation above the global average, especially in the southern and eastern Mediterranean countries [1,2]. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change [3] highlights that the Mediterranean is among the most vulnerable regions in the world because of the impacts of climatic and meteorological phenomena increasingly resulting in both long-term impacts and more frequent and severe extreme events (e.g., droughts, wildfires, floods, etc.). These changes depend on and combine with multiple drivers, including (but not limited to) population increase, pollution, and unsustainable land use and management practices [4], potentially leading to severe impacts on water security, food security, ecosystem health, and, ultimately, human wellbeing and security [5]. The emergence of the Nexus approach [6] in the last decade highlighted the importance of accounting for these dynamics, with a specific emphasis on the mutual interlinkages between water, energy, food (WEF), and, more recently, ecosystem (WEFE) management [7–9]. The WEFE Nexus is a mainstream concept at the core of many recent policy initiatives for the Mediterranean area. For example, it plays a pivotal role within the Water Policy Framework for Actions 2030 developed by the Union for the Mediterranean [10] and the Partnership for Research and Innovation in the Mediterranean (PRIMA) Foundation introduced the WEFE Nexus as a new thematic stream of funding in 2019 [11]. Although the Nexus concept has been widely promoted in policies and research since 2011 [12] and despite some progress in the last decade emphasizing its role and increasing policymakers' awareness [13], operationalizing the WEFE Nexus remains challenging [14,15], including for the Mediterranean region [12,16–18]. A recent review of the WEFE Nexus research in the Mediterranean [18] highlighted that existing research is dominated by a focus on water-energy interlinkages within the agriculture sector, while "ecosystems" is the least represented component of the WEFE Nexus in the Mediterranean. This implies, for example, that non-agriculture ecosystems, such as forest ones, are way less explored within the framework of the WEFE Nexus and, even more importantly, that despite a general agreement about the importance of integrating natural ecosystems and their services into the Nexus approach [15,19,20], this remains very patchy in practice and is mainly limited to provisioning services [21,22]. Finally, existing research has investigated the WEFE Nexus mainly from a biophysical perspective, while socioeconomic dimensions have been identified as important but not fully addressed yet [18,23,24]. Existing gaps are due to several barriers and limiting factors, ultimately referring to the fact that the sustainable management of the WEFE Nexus constitutes a 'wicked' problem from a technical standpoint but it becomes even more complex when ecosystem-related aspects are considered, together with their policy and socioeconomic implications [24].

Different approaches have been suggested to integrate and mainstream the ecosystem dimension within the WEFE framework. Among them, a strong emphasis has been given to nature-based solutions (NBS) defined as "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*" [25]. The NBS concept builds on the ecosystem approach [26,27] to incorporate different forms of nature-based (i.e., green) interventions [28]. By supporting ecosystem processes and structures, NBS can deliver a broad range of ecosystem services, with a potential opening for transformational pathways toward sustainable societal development [29]. In such a perspective, NBS can play an important role in addressing major social challenges, including climate change mitigation and adaptation, disaster prevention and reduction, economic and social development, human health, food and water security, ecological environment degradation, and biodiversity loss [30,31]. Though not yet univocally defined and still addressed from different angles [32,33], the NBS concept is increasingly integrated within policies and research activities [29,34] and mainstreamed as an innovative and cost-effective set of measures within different socioecological contexts [35–37]. However, despite reviews of NBS's effects on enhancing available ecosystem services (e.g., [38–40]), when compared to traditional approaches (e.g., grey infrastructures), NBS is still rarely considered as a first choice and poorly operationalized [41], in particular with regard to the management of natural hazards [42,43] that are becoming more extreme over time and are among the main concerns of emergency management authorities in Europe and beyond [40,44]. Moreover, attention given to NBS varies significantly depending on the targeted context, so, for example, NBS research in the case of river landscapes so far received comparatively less scientific attention than NBS within urban areas [45]. Among the several barriers to NBS operationalization identified within the existing literature [27,46], the need for more research efforts in terms of costs and benefits assessment to inform decision making and support investment scaling has been highlighted as one of the most relevant [43,47], including within the Mediterranean context [48,49].

A better understanding of the economic value generated by NBS and the ecosystem services they provide could facilitate the adoption of efficient policies and measures to preserve and enhance them [50,51] as well as their effective incorporation within the

WEFE Nexus framework [52]. It could also function to raise stakeholders' awareness and participation in decision-making processes [53] and would help in supporting the inclusion of NBS within ecosystem restoration and management planning [54]. However, there is still a lack of cases demonstrating the support of NBS economic assessment for decision making in planning activities within the framework of the WEFE Nexus, which would help the feedback loop between WEFE components to be closed [18]. The use of ecosystem approach and ecosystem service knowledge to assess alternative scenarios within the WEFE Nexus requires selecting and implementing appropriate indicators for measuring the expected outcomes [55]; the adoption of appropriate economic approaches and methodologies to identify and analyze costs and benefits associated with alternative scenarios [47]; and considering the specific needs of various stakeholder groups [56].

NBS offers integrative strategies to reduce climate risks while providing a range of additional benefits. They could contribute to operationalizing the WEFE Nexus framework within the Mediterranean region, including by supporting the incorporation and a-dressing the ecosystem component while ensuring synergies with the other WEFE components. In such a perspective, they fit into the mainstream policy avenues addressing climate change and ecosystem restoration issues at the European scale and beyond.

Building on the above-reported problems and research gaps, our research aims to contribute to advancing scientific and practical knowledge in the field of the WEFE Nexus, by supporting the operationalization of NBS assessment in the Mediterranean region. We aim to analyze the costs and benefits associated with NBS solutions to support decision making about their implementation and explore their potential contribution to the WEFE Nexus. We decided to focus on NBS designed to address and mitigate natural hazards to which the Mediterranean region is particularly vulnerable due to its unique geographical and climatic characteristics [57]. We considered floods as they are the most important risk in the Mediterranean region, both due to their frequency and impacts [58,59]. All components of flood risks, i.e., hazard, exposure, and vulnerability, are projected to increase due to climate change effects and socioeconomic developments [60]. Floods in the region are mainly a consequence of flash-flood events [58] due both to the steep orography that might favor the occurrence of intense precipitation events [61] and the morphology of the Mediterranean basin, which includes several small and steep river catchments that can turn the intense runoff generation into severe devastating flash-floods and flooding [62]. Moreover, flash-floods are connected to land use intensification as well as land use changes and associated increased vulnerability [58,63]. Within such a framework, NBS can be considered a cost-effective solution in "*reducing vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters*" [64]. We use a Mediterranean watershed prone to flood risks as a case study (see Section 2.1 for details) to analyze NBS development and management costs vis-à-vis biophysical and economic benefits in terms of selected ecosystem services expected from the NBS implementation. By comparing the current scenario (business as usual (BAU), corresponding to current land use, and management practices) with the alternative future scenario (NBS), we expect to derive possible gains/losses associated with management choices. Our research results can therefore support and inform future decision making about management options regarding the selected study area while contributing to advancing knowledge on the use of NBS as tools for supporting the implementation of the WEFE Nexus approach.

2. Materials and Methods

The methodological approach and workflow adopted for this study are summarized in Figure 1, while the main steps are described in the next subsections.

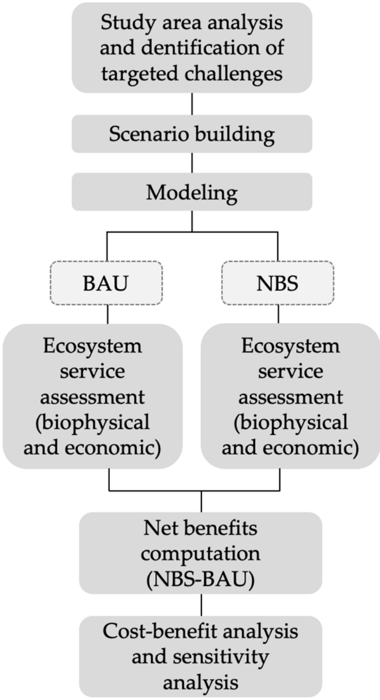
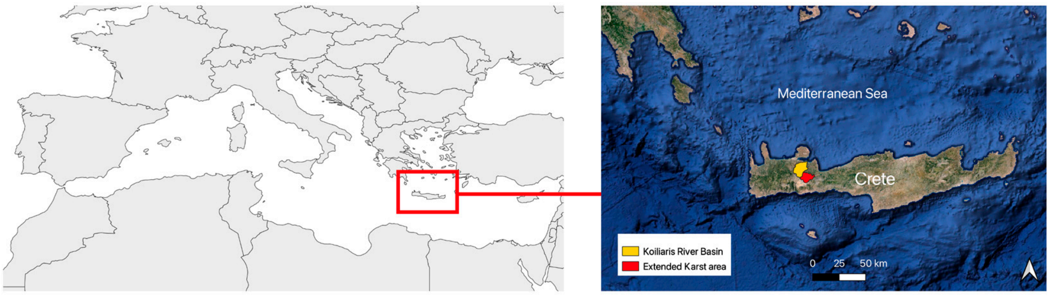


Figure 1. Methodological outline.

2.1. Study Area

We selected Greece as a study area because the country is highly exposed to climate change risks and natural hazards [3]. This has been empirically confirmed by the large wildfires [65] and storm Daniel [66] that hit vast areas of the country in the Summer of 2023 as well as previous events of great severity [67]. We focused on the Koiliaris River Watershed in the northwest of Crete (Figure 2), covering a total area of 132 km^2 at an altitudinal range between 0 and 2120 m above sea level.



(**a**) (**b**)

Figure 2. Study area: (**a**) Crete Island within the Mediterranean basin and (**b**) Koiliaris River Basin and the extended Karst area.

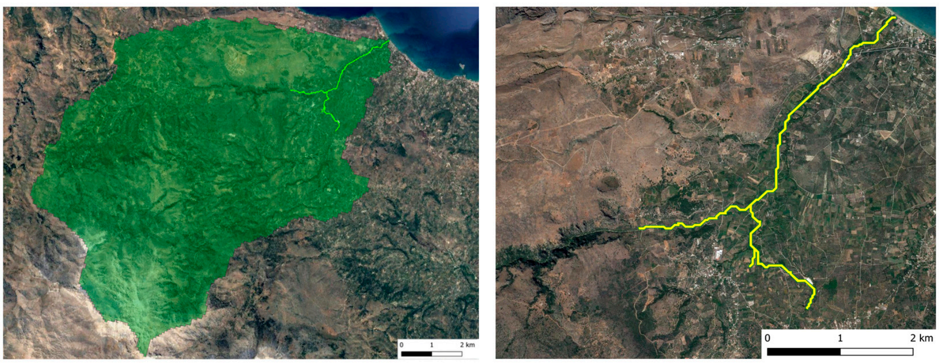
The overall length of the drainage network totals 44.8 km, consisting of the intermittent tributary of Keramianos (13.8 km), two ephemeral streams providing surface runoff feeding the Anavreti tributary (27.2 km), the karstic springs of Stylos (permanent flow), and the karstic spring of Anavreti (intermittent flow), which merge with the rest of the streams to form the main segment of the Koiliaris River (37 km). These springs are fed by an extended area of karst, which is located outside the basin boundaries and stretches over an estimated 80 km^2 [68]. The main land uses are intensively grazed shrublands and pastures, olive, citrus groves, vines, and vegetables, with marginal degraded mixed forest remnants (0.6% of the total area) [69].

Most of the watershed has steep slopes up to 45% that level out at the valley and become mild (1%–2%) [70]. The valley is prone to flooding due to high precipitation events that exceed the infiltration rate of the karst [71] and generate significant quantities of surface runoff. The Keramianos tributary loses most of its water in the two faults that crosscut the gorge and generate flash-floods when the precipitation in the sub-basin exceeds 120 mm [72]. The watershed is a Critical Zone Observatory (CZO) (www.koiliaris-czo.tuc.gr accessed on 24 March 2024) presenting severely degraded soils [73,74]. The main type of soil degradation in the basin is water erosion due to the conversion of riparian forests into farmland for olive trees, citrus, avocado plantations, and other crops and pastures and livestock grazing that occurred before 1945. The few remaining small forest patches along the river are highly degraded and prone to bank erosion. Past land-use changes via deforestation and intense cultivation practices induce soil organic matter losses, making soils susceptible to erosion and desertification. The area presents Mediterranean soils under imminent threat of desertification (i.e., soil carbon loss) due to climate change that is predicted by the UN IPCC for the region over the next century [70].

2.2. Future Alternative NBS Scenario

We defined the future alternative NBS scenario to mitigate flood risks in the study area based on [70] who identified the restoration of the native riparian forest as the most effective NBS for the area and codesigned it with the support of local stakeholders. Riparian forests are one of the most threatened ecosystems in the Mediterranean region due to land-use intensification and water extraction; however, though restoration of degraded riparian areas has gained momentum in the last few decades [75], proper evaluation of restoration projects is usually lacking and research on the effects of riparian restoration on ecosystem service supply is still limited [76].

The restored riparian forest was originally planned to be established along the river for about 11 km, covering 20 m-wide buffer stripes on each riverbank for a total of 200,000 m^2. Focus group sessions with experts involved in previous studies in the area [70–72,77] and the preliminary NBS conceptualization [70] were organized to discuss technical aspects and key features of the restored riparian forest. This brought a recalibration of the size of the area in which NBS is planned to be implemented, resulting in a final total area of 335,450 m^2. Based on field assessments, the existing forest remnants have been classified as Helleno-Balkanic riparian plane forests [70] (EUNIS habitat type G1.381 [78]) that will represent the reference habitat for the selection of reforestation species. These forests fall within the broader Oriental plane (*Platanus orientalis*) gallery forests family and may host a variety of tree and shrub species, such as willow (*Salix alba*, *Salix elaeagnos*, *Salix purpurea*), alder (*Alnus glutinosa*), Judas tree (*Cercis siliquastrum*), Mediterranean hackberry (*Celtis australis*), poplar (*Populus alba*, *Populus nigra*), common hawthorn (*Crataegus monogyna*), common dogwood (*Cornus sanguinea*), and others. Figure 3 shows the area in which the NBS was planned.



(**a**) (**b**)

Figure 3. Focus on the study area: (**a**) Koiliaris watershed (dark green) and the area aimed for riparian forest restoration (light green) and (**b**) focus on the planned area for riparian forest restoration (in yellow).

2.3. Scenario Assessment Methodology

For both the BAU and NBS scenarios, we assessed flood risk mitigation capacity using the InVEST 3.14.1 [79] flood risk mitigation model. Besides addressing the main natural hazard faced by the area, we also assessed possible co-benefits associated with NBS development. Since within the existing literature ecosystems are the least represented component of the WEFE Nexus and climate implications have been marginally considered [18], we focused on habitat quality as a proxy for biodiversity conservation and enhancement, consistently with [80], which identifies habitat protection as an ecosystem service group, and [64] that refers to habitat creation and maintenance as one out of 18 categories of nature's contributions to people. We also considered carbon sequestration as a proxy for NBS contribution to climate change mitigation. InVEST 3.14.1 [79] models for habitat quality and carbon storage and sequestration were used.

Details about the data inputs and methodological aspects for ecosystem services assessed and models/approaches adopted, including details about monetary estimations, are provided in Section 2.4 below.

For each of the targeted ecosystem services, supply was first evaluated in biophysical and economic terms under both scenarios (BAU and NBS). Then, according to the "with and without" principle [81], net ecosystem service supply was calculated as a difference between the NBS and BAU scenarios. To this aim, data were analyzed through basic statistical analysis performed via QGIS LTR 3.28.15 and MS Excel 16.84. By summing all net monetary values, the total net benefits associated with BAU and the NBS scenarios have been calculated and compared.

To allow a more direct comparative assessment of BAU and NBS scenarios, we considered summary indexes highlighting different ecosystem service supply levels. To this aim, we referred to the runoff retention index, i.e., runoff retention relative to precipitation volume, and the habitat quality index, i.e., the level of habitat quality and integrity relative to their potential within a given context: both are provided as outcomes of the corresponding InVEST models used for the study (see Section 2.4). As for carbon, a carbon sequestration index was calculated by normalizing carbon sequestration values provided by the InVEST model (see Section 2.4) via linear normalization on a 0–1 scale. All indexes range between 0 and 1, where 0 corresponds to a null level of the corresponding ecosystem service and 1 to the highest level within the given context. They were computed for both scenarios and then comparatively analyzed, also by plotting them on maps and radar charts.

As for the economic assessment, a cost–benefit analysis (CBA) was performed. Costs associated with the NBS implementation were retrieved from [70] and distributed over time according to [82]. Therefore, 75% of implementation costs have been allocated to the first year and 25% to the second one, to consider additional implementation costs that might occur after year one (e.g., to address seedling mortality after planting). Maintenance costs have been assumed to be equal to 5% of the total costs. Benefits have been introduced from the fifth year, assuming the NBS will start delivering benefits when the forest reaches a minimum growth stage. Using the guidelines provided in [83], we calculated both profitability indicators (i.e., the net present value, NPV, and the benefit/cost ratio, B/C) and risk exposure ones (i.e., the payback period). We adopted a 3.5% discount rate and a 20-year investment duration [84]. To check the robustness of the CBA results, we finally performed a sensitivity analysis with the aim of addressing the main risks and uncertainties that could affect the targeted NBS investment. We did this by running the CBA and calculating profitability and risk indicators under different discount rate values. Moreover, to test cost and benefit uncertainty over time, we also ran the CBA considering possible fluctuations of costs and benefits.

2.4. Models and Data Inputs

Different InVEST 3.14.1 [79] models were used for this research. For details about the rationale and functioning of flood risk mitigation and habitat quality models, reference can be made to [85,86]. Input and output data for the two models are reported in Tables 1 and 2, respectively.

Table 1. Input and output data for the assessment and evaluation of flood risk mitigation.

Input Data	Description
Land cover map	Raster of land use/land cover (LULC) for each pixel (resolution 5 m × 5 m), developed from [87]
Biophysical table	csv file reporting Curve number (CN) values for each LULC type and each hydrological group. CN values were derived from [88]
Depth of rainfall (mm)	120 mm as the critical depth of rainfall generating flash-floods in the area, identified from [72]
Soils Hydrological Group Raster	250 m spatial resolution raster of categorical hydrological groups from [89]
Economic value	Replacement cost method. Surrogate good: lamination basin. Unit cost: 400 EUR/m^3 [83]
Output data	**Description**
Retained runoff volume (m^3)	Raster with runoff retention values (in m^3) indicating the capability of each pixel to store runoff
Runoff values (mm)	Raster with runoff values
Runoff retention index	Raster with runoff retention values (unitless, relative to precipitation volume)

Table 2. Input and output data for the assessment and evaluation of habitat quality.

Input Data	Description
Land cover map	Raster of land use/land cover (LULC) for each pixel (resolution 5 m × 5 m), developed from [87]
Threats data	csv file reporting information on each threat's relative importance and the maximum distance over which each threat affects habitat quality. For all threats, impacts were assumed to decay according to a linear decay function. A total of six threats were identified (each of them corresponding to a specific land use type, e.g., residential continuous medium-dense urban fabrics, industrial areas, railways, etc.). A raster file was developed for, and named after, each threat.
Sensitivity of land cover types to each threat	csv file reporting, for each LULC type, whether or not they are considered habitat (either 1 or 0) and, for LULC types that are habitat, their specific sensitivity to each threat; these are according to a [0–1] range and based on the Biological Territorial Capacity Index [90]
Accessibility	Vector of areas subject to environmental restrictions and protection
Half-saturation constant	0.5. Default value set by the InVEST model
Economic value	Adjusted benefit transfer. Average unit value (EUR/m^2) for different land use conversions/transformations into the riparian forest from the available literature [91–93] multiplied by 25 (i.e., the pixel size in m^2) and then by the corresponding habitat quality index for each pixel through the raster calculator function in QGIS 3.16.
Output data	**Description**
Habitat quality	Raster file reporting the habitat quality index; this shows the relative level of habitat quality, ranging between 0 and 1, where values closer to 1 indicate better habitat quality vis-à-vis the distribution of habitat quality across the rest of the landscape. Areas on the landscape that are not habitat are given a quality score of 0

As for carbon storage and sequestration, the corresponding InVEST model was used [85]. It estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. It aggregates the biophysical amount of carbon stored in up to four carbon pools (aboveground living biomass, belowground living biomass, soil, and dead organic matter) based on land use/land cover maps provided by users. Through a future land use/land cover map, the carbon sequestration component of the model estimates the expected change in carbon stocks over time. The model returns a value of carbon stocked in the targeted pools in tons per pixel; therefore, to determine the corresponding weight of carbon dioxide, we multiplied model outputs by 3.67, i.e., by the ratio between the weight of carbon dioxide (44) and the atomic weight of carbon (12).

Input data for the model, as well as outputs, are shown in Table 3.

Table 3. Input and output data for the assessment and evaluation of carbon storage and sequestration.

Input Data	**Description**
Present land cover map	Raster of land use/land cover (LULC) for each pixel (resolution 5 m × 5 m), developed from [87]
Biophysical table	csv file reporting carbon density of the selected pools for each LULC class. Values for the different carbon pools have been elaborated and adapted from [94–97]
land cover map	Raster of land use/land cover (LULC) for each pixel (resolution 5 m × 5 m), developed from [87]. For the NBS scenario, the land cover map integrated the NBS as a new LULC class
Economic value	Market price of EUR 7.70 per tCO_2eq [98]
Output data	**Description**
Carbon stock	Raster file reporting the amount of carbon stocked in the targeted pools in tons per pixel

3. Results

3.1. Ecosystem Services Assessment

3.1.1. Biophysical Assessment

Flood risk is the main natural hazard faced within the study area; therefore, flood risk mitigation is considered a key benefit expected from the NBS development. When passing from the BAU to the NBS scenario, the total retained runoff volume increases by about 2.689 m^3, while the unit value, i.e., per single m^2, increases from 0.5 to 0.6 m^3 run-off/m^2 (Table 4). According to these figures, the riparian forest has a retention capacity that is about 15% higher compared to the current land use under the BAU scenario. When passing from the BAU to the NBS scenario, the other targeted ecosystem services also show an improvement. The net change in carbon storage and sequestration corresponds to 5819.71 tons of carbon, i.e., 0.02 tons of carbon per m^2. As for the habitat quality, a significant increase in the corresponding index is also observed when passing from the BAU to the NBS scenario.

Table 4. Biophysical valuation of ecosystem services generated under the BAU and NBS scenarios.

Ecosystem Services	**BAU Scenario**		**NBS Scenario**		**NBS-BAU**	
	Total Value	**Value per m^2 ***	**Total Value**	**Value per m^2**	**Total Value**	**Value per m^2**
Flood Risk Mitigation						
Retained runoff volume (m^3)	17,931.96	0.05	20,620.84	0.06	**2688.88**	0.01
Runoff retention index (0–1) *	0.45 (0.42–0.47)		0.52 (0.46–0.56)		**0.07 (0.04–0.09)**	
Carbon Storage and Sequestration						
Carbon stock (tons of carbon)	3941.88	0.01	9761.59	0.03	**5819.71**	0.02
Carbon sequestration index (0–1) *	0.29 (0.19–0.33)		0.73 (0.19–0.75)		**0.44 (0–0.42)**	
Habitat Quality						
Habitat quality index (0–1) *	0.20 (0.05–0.61)		0.97 (0.05–0.99)		**0.77 (0–0.38)**	

* mean values (minimum–maximum values).

Figure 4 visualizes the spatial distribution of indexes for each of the targeted ecosystem services, calculated for BAU and the NBS scenarios, as well as their difference, while Figure 5 reports the average value of each index for both scenarios.

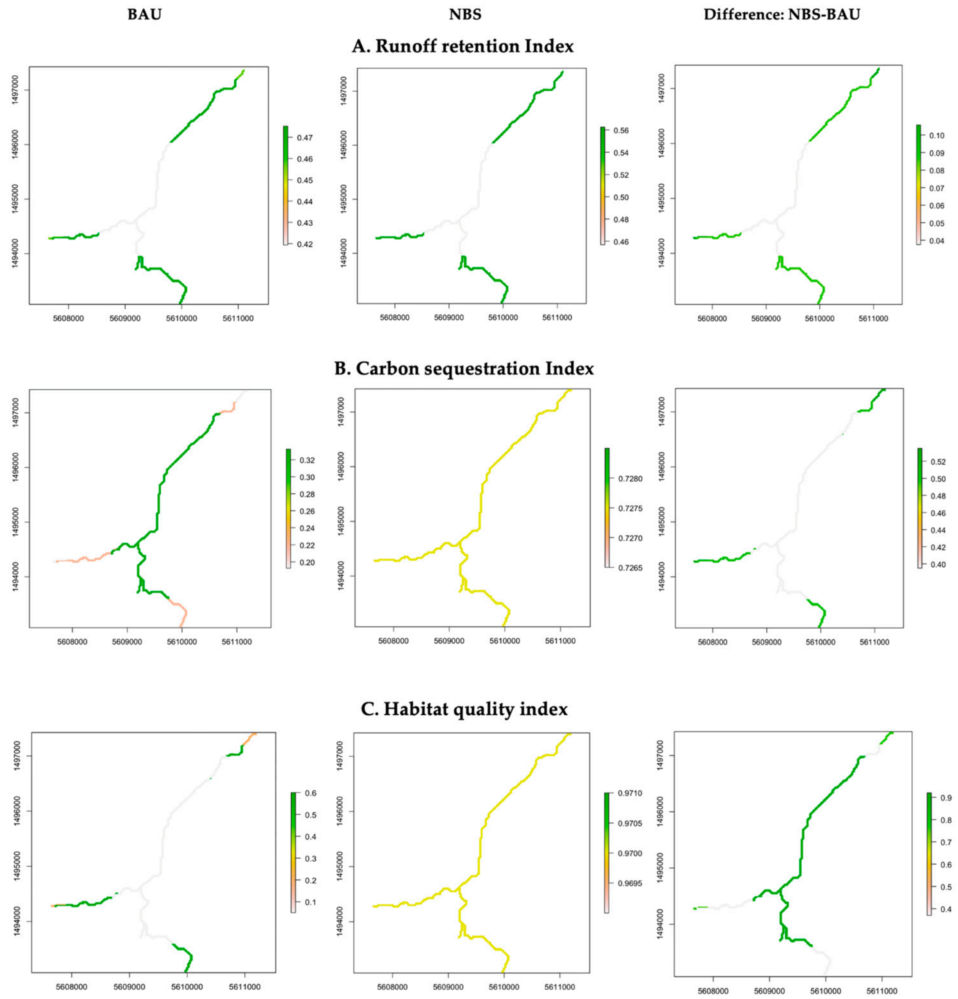


Figure 4. Spatially explicit comparative assessment of targeted ecosystem services, expressed via 0–1 indexes, under the BAU and NBS scenarios as well as their difference.

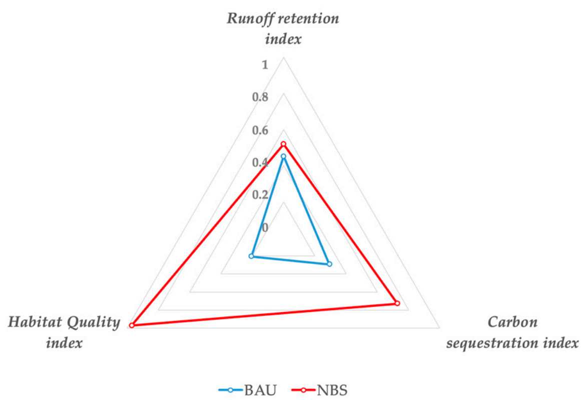


Figure 5. Summary comparative assessment of targeted ecosystem services, expressed via 0–1 indexes, under the BAU and NBS scenarios as well as their difference.

All indexes show higher values for the NBS scenario compared to the BAU one and even more importantly, they show higher improvements for co-benefits rather than the main targeted ecosystem service. Indeed, on average, the BAU runoff retention index is 0.45 (range: 0.42–0.47), i.e., under current land use conditions, the study area can retain about 45% of rainwater generating flash-floods in the study area while the remaining proportion generates runoff that contributes to flooding and erosion. In the NBS scenario, the average runoff retention index is 0.52 (range: 0.46–0.56), showing a +15% increased capacity to retain runoff compared to the BAU and, therefore, a lower flood risk. The carbon sequestration capacity increases by +149% when passing from the BAU to the NBS scenario (i.e., the latter has a sequestration capacity that is about 1.5 times higher compared to the BAU) and the habitat quality by +372%.

3.1.2. Economic Assessment

Building on biophysical values reported in Section 3.1.1, economic values for targeted ecosystem services have been calculated as net values, i.e., as a difference between the NBS and the BAU scenarios (Table 5). As for carbon storage and sequestration, carbon stock values returned by the model were converted into carbon dioxide equivalent values by multiplying model outputs by 3.67. As for habitat quality, a unit value derived from the literature (see Section 2.4) was transferred to the study area using the corresponding habitat quality index as an adjusting factor.

Table 5. Net estimated value of targeted ecosystem services generated by the NBS scenario.

Ecosystem Service	Economic Assessment Criteria and Methods	Unit Value	Biophysical Value (NBS-BAU)	Estimated Value (EUR)	Estimated Unit Value (EUR/m^2)
Flood Risk Mitigation	Replacement cost method	400 EUR/m^3	2688.88 m^3	1,075,554.07	3.21
Carbon Storage and Sequestration	Market Price	7.70 EUR/tCO2eq	21,358.35 tons of CO2eq	164,459.29	0.49
Habitat Quality	Benefit transfer	1.36 EUR/m^2	335,450 m^2	442,525.64	1.32
Total estimated value				**1,682,539.00**	**5.02**

The total net estimated value of the three ecosystem services provided under the NBS scenario corresponds to about EUR 1.68 million, 64% of which depends on flood risk mitigation, 26% on habitat quality, and 10% on carbon storage and sequestration. Overall, this is equivalent to 5.02 EUR/m^2.

3.2. Cost–Benefit Analysis

The CBA returns information about the economic profitability of the NBS scenario by computing and assessing the NPV and the benefit/cost ratio B/C and its level of exposure to risk by computing the payback period. Results of the CBA are reported in Table 6. While a 3.5% discount rate was considered as the most appropriate based on the existing literature [84], we also calculated the above-mentioned indicators adopting different rates, to perform a sensitivity analysis and check project investment results under different conditions.

Table 6. Results of the cost–benefit analysis considering different discount rate values to test its robustness.

r	1%	2%	3.5%	5%
NPV (EUR)	21,857,387.60	19,268,742.50	**16,028,861.35**	13,408,945.37
B/C	12.27	11.49	**10.41**	9.42

When considering a 3.5% rate, the NPV is about EUR 16.03 million and the B/C is significantly higher than one (10.41), indicating that discounted benefits overcome discounted costs. The NPV remains positive, and the B/C ratio stays higher than one with all the discount rates tested, showing that the investment results are profitable under different conditions. As for the payback period, it is five years regardless of the rate considered for the CBA, indicating that the investment associated with the NBS building and maintenance pays back, i.e., total discounted revenues exceed total discounted costs, in five years from the investment.

We also considered possible fluctuation in costs and benefits within the NBS scenario while keeping a 3.5% discount rate. We first considered costs to increase by 2%, 5%, and 10%, respectively, and then benefits to decrease by 2%, 5%, and 10% (Table 7). The investment results are profitable in any case, with NPV diminishing while costs increase and benefits decrease; however, they still result in values higher than zero. Moreover, the payback period does not change under the different conditions tested.

Table 7. Results of the cost–benefit analysis considering variations in both costs and benefits.

	Costs (K)			**Benefits (B)**		
	+2%	**+5%**	**+10%**	**−2%**	**−5%**	**−10%**
NPV	15,994,782.10	15,943,663.23	15,858,465.10	15,674,204.87	15,142,220.16	14,255,578.97
B/C	10.20	10.20	9.46	10.20	9.89	9.37
PB	5 years	5 years	5 years	5 years	5 years	5 years
% variation with reference to original K				**% variation with reference to original B**		
NPV	0%	−1%	−1%	−2%	−6%	−11%
B/C	−2%	−2%	−9%	−2%	−5%	−10%

4. Discussion

4.1. Ecosystem Service Assessment

Research results show that the NBS scenario succeeds in improving the flow of all selected ecosystem services, thus contributing to addressing a key challenge in the study area (i.e., flood risk) while ensuring additional benefits in terms of carbon sequestration and biodiversity conservation and enhancement. Benefits are considered in relative terms, i.e., in terms of variation between a BAU and an NBS scenario: they therefore depend on changes in land use and land cover conditions. While runoff retention capacity improves by 15% when passing from the BAU scenario to the NBS one, variations regarding carbon sequestration (+149%) and habitat quality (+372%) are significantly higher.

Our results are in line with the existing literature and studies reporting positive impacts of forests in reducing flood risk management are mainly in terms of reduction in the peak flow both temporally and spatially [99,100]. Moreover, they are consistent with a vast body of the existing literature on the benefits provided by riparian forests in terms of ecosystem services and their high potential as an NBS, far beyond water-related ecosystem services (e.g., [101–105]). This emphasizes cascading effects of restoration projects in terms of potential ecosystem service enhancements (e.g., [106]). Our results also confirm that restored riparian forests can increase the supply of regulating ecosystem services in comparison with degraded land, including cropland fields [76]. The provision of multiple benefits is a core aspect within the NBS concept [33], together with the balance of trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits [31]. In such a perspective, our findings support the idea that reinforcing the ecosystem component within the WEFE Nexus and promoting an ecosystem approach is not only needed to address biodiversity losses and decline [52] but can also have positive spillover effects on the other Nexus components, creating synergies with them. The recovery of biodiversity goes hand in hand with improvements in important ecosystem functions and services, ultimately promoting ecosystem multifunctionality.

Some trade-offs can also occur, in particular between targeted ecosystem services and provisioning ones. This may mainly regard food production, i.e., the food security component of the Nexus because of land use/land cover changes when passing from the BAU scenario to the NBS one. While systematic trade-offs and synergy analysis among the Nexus components are beyond the scope of this study, it is important to highlight that the NBS scenario, though likely reducing crop production due to land use transformation from farmland/cropland to forest, may also provide indirect benefits to the food component. Indeed, avoided costs due to, for example, avoided crop losses because of reduced flood risks [107], avoided soil losses due to reduced bank erosion, and avoided/reduced sediment transportation, which may result in better water quality for multiple uses, including irrigation [108,109], should also be accounted.

4.2. Cost–Benefit Analysis

The CBA confirms that the proposed NBS scenario also performs well in economic terms, suggesting it would represent a safe and sustainable investment from a public perspective aiming to pursue the valuing of public goods. The sensitivity analysis highlights that investment performances in terms of profitability (NPV and B/C) are up to 10 times more sensitive to decreasing benefits rather than increasing costs. Nonetheless, the analysis confirms that the investment would remain economically profitable even when considering less favorable conditions, i.e., either cost increase or benefit reduction. We considered cost/benefit variations within a 10% range that is fully consistent with current annual inflation rates in Greece [110]; therefore, we can conclude that this analysis simulates realistic conditions and indicates the NBS would remain a realistically viable investment anyway. At the same time, no changes were observed in terms of the payback period when modifying the discount rate, initial costs, or expected benefits: in all cases, discounted benefits would allow the recovery of initial costs in five years from the investment. This means risk exposure would not vary under less favorable conditions and investors would need to bear the risk of the investment for five years. Although a comparison between NBS and traditional (i.e., grey) infrastructure is beyond the scope of this study, it is a worthwhile reminder that water-management infrastructures are typically capital-intensive and present high sunk costs, implying high initial investments followed by 20–30 years-long payback periods [111]. Moreover, additional social benefits could be considered and accounted for in terms of, e.g., employment opportunities associated with restoration projects. All in all, the positive outcomes of the CBA highlight the potentialities of NBS and, more in general, restoration initiatives as investment opportunities that may attract funds from different sources, including public, private, and blended financing mechanisms [112].

4.3. Planning and Management Implications

While existing literature on the WEFE Nexus, both at the global [52] and at the Mediterranean scale [18], is mainly focused on agricultural practices, the link between forest resources and the Nexus has often been considered too complex and, sometimes, even controversial [113]. Our research provides additional inputs and arguments to accommodate forests within the Nexus framework, consistent with the idea that forest and landscape restoration is a promising strategy for improving the Nexus and contributing to sustainable development and resilience of socioecological systems [114]. However, since the Nexus can be seen as a step beyond silos planning toward a more holistic approach to planning [115] NBS cannot be effectively managed in isolation [31], they should rather be framed within planning strategies at a landscape scale or even beyond [116]. Though often covering a small proportion of agricultural landscapes, riparian forests nestled in crop-intensive areas can contribute remarkably to biodiversity and the support of several ecological processes as well as the supply of ecosystem services, thus ensuring multifunctional landscapes [76]. To improve positive impacts and successfully contribute to a full WEFE Nexus implementation, the riparian forest assessed in our study should be preferably combined with additional measures within the same area, such as more sustainable agricultural and grazing practices, e.g., by adopting agroecology solutions [117], as well as the development of ecological connectivity with other natural habitats and environments within the watershed [118,119]. As observed by [75], more than half of river and riparian restoration projects in Europe are not part of a larger restoration strategy, just being designed and implemented on a site basis, and thus often missing proper planning and vision at a broader scale. On the contrary, NBS integration across spatial scales is essential [45] to avoid overlooking the multi-directional effects of NBS and allow for effective NBS implementation [120] as well as contribute to multiple policy goals [121]. This can also help synergies via interconnected networks of multiple (semi-) natural areas [120] and reduce trade-off risks. For example, when creating new forest areas, attention should be paid to other possible natural hazards that are on the rise due to climate change effects, such as wildfires. Unregulated and unplanned forest building may otherwise contribute to the shortcomings of fire prevention strategies [122].

4.4. Policy Implications

Our findings can also be considered vis-à-vis some recent and emerging policies addressing climate change and its impacts on socioecological systems. NBS is widely viewed as a means of achieving the objectives of existing and proposed European policies [116] that are conceptually and practically connected to the WEFE Nexus. These include, among others, the EU Strategy on Adaptation to Climate Change [123], EU Water [124] and EU Floods Directives [125], EU Biodiversity Strategy for 2030 [126], and the EU Nature Restoration Law [127]. According to the latter, passed by the EU Parliament in 2023 after lengthy consultations but still waiting for final approval by the EU Environment Council for entering into force, EU member states will have to implement measures to restore degraded ecosystems on at least 20% of the EU land by 2030 and all ecosystems in need of restoration by 2050 [127]. Scaling up ecosystem restoration is high on the international agenda, beyond the European one, as the United Nations decade on ecosystem restoration (2021–2030) calls for increased global efforts to halt the degradation of ecosystems. The restoration of a degraded riparian forest within the Koiliaris River Watershed would therefore be in line with mainstream directions within the global policy agenda and represent an example of compliance with the EU Nature Restoration Law. It would confirm that climate adaptation and disaster risk reduction can contribute to the EU nature restoration agenda within the umbrella of the Green Deal, enhancing biodiversity while ensuring valuable co-benefits [128]. NBS costs and benefits assessment should be an integral part of investment projects, to engage stakeholders, assess the economic viability of investments, and evaluate the impacts of the NBS [46] as stressed also by key policy tools such as, for example, the European Union (EU) Water Framework Directive and, more recently, the Kunming-Montreal Global Biodiversity Framework. It is important to note that forest restoration activities are encouraged also by the Greek National Forestry Strategic Development Plan 2018–2038, according to which there is significant scope for doing so in Greece [129]. In such a perspective, a National Reforestation Plan has been recently announced by the Greek government. Funded by the National Recovery and Resilience Plan under the Recovery and Resilience Facility, the plan is aimed at supporting the restoration of degraded forest areas and afforestation across the country. The plan is supposed to invest some EUR 224 million from 2021 to 2025 [130].

Despite adopting a case-study approach, it should be noticed that challenges addressed by the research are consistent with the larger picture observed at a country level, as the main reported pressures and threats to terrestrial habitats in Greece relate to land use changes and are mainly linked to agriculture and urban development [130]. Since the 1950s, Greece, including insular territories like Crete, has experienced socioeconomic developments resulting in deep social, economic, and environmental changes, the impacts of which have ultimately decayed local resources and jeopardized the country's environmental sustainability in the long term [131,132]. Although our study is site-specific in terms of focus, the generalization of our results should not be readily discounted; this paper contributes to advancing research on ecosystem service assessment in Greece and enlarges its scope to forest ecosystems and nature restoration initiatives, while research efforts in the country so far focused mainly on marine and coastal ecosystems and their services [133].

4.5. Research Limitations

Despite our efforts, the paper presents some limitations. By selecting only three ecosystem services as the benefits of the NBS, we likely caught the most important services within the specific case; nevertheless, we did not consider additional ones among regulating (e.g., improved water quality due to sediment retention and filtration by riparian vegetation) and cultural ecosystem services (e.g., recreational opportunities offered by the restored forest). This likely resulted in an underestimation of the total value of benefits generated by NBS under the NBS scenario. While grasping the total economic value of the NBS was beyond the scope of this paper, future developments in our research may expand the range of benefits. On the other hand, we did not consider foregone benefits, e.g., under the form of forgone revenues from agriculture due to the cropland conversion into forests. Future research might try to incorporate them as well. Finally, the use of software-based models required some a priori simplifications or assumptions in modeling, due to technical constraints or data gaps in terms of quality/scale and quantity.

5. Conclusions

We analyzed the costs and benefits associated with a riparian forest restoration as an NBS to mitigate flood risks in the Koiliaris River Watershed (northwestern Crete, Greece). Our results confirm that the proposed NBS has a good potential for facing flood risk and, simultaneously, delivering co-benefits that can positively contribute to addressing the global environmental and societal challenges impacting at a local level. Indeed, the NBS scenario resulted in a higher capability to retain runoff in comparison with the BAU scenario, as well as a higher carbon sequestration capacity and habitat quality. The economic analysis, via a CBA, highlighted that the NBS scenario provides positive results and is sustainable under different conditions tested sensitivity analysis.

Our study builds on [70], which developed a vision-based decision-making methodology and participatory process carried out in the study area to discuss challenges, identify possible solutions, and design pathways toward them. Local actors' engagement and their close cooperation with experts is a key preliminary step to facilitate the identification of effective solutions as well as ensuring they are technically sound and socially acceptable. In continuation with this, the biophysical and economic assessment of the proposed solutions provided by our research allows moving further by gaining a more in-depth view of the project and associated impacts. Overall, this workflow allows a multidisciplinary and collaborative approach to the topic and informs policy and decision-making processes.

Our paper contributes to research on the incorporation of the ecosystem dimension of the WEFE Nexus through the implementation of NBS and the deepening of associated economic aspects. While NBS are typically tailored to local biophysical, socioeconomic, political, and cultural conditions, the development and systematization of scaling approaches, i.e., scaling out, scaling up, and scaling deep [134], necessarily builds on a broad basis of empirical and scientific experiences as well as case studies. In such a perspective, our research contributes to a growing body of case studies and to the advancement in emerging concepts within the framework of climate change mitigation activities in the context of the Mediterranean region and beyond.

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