Hungarian University of Agriculture and Life Sciences

A Comprehensive Approach for Forest Fires Restoration and its Implementation in the Spatial Decision Support Systems

The Thesis of the PhD dissertation

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I. Introduction

The past decade witnessed a noticeable increase in the frequency of forest fires, causing considerable losses. According to the European Fire Center, the number of fires from 2011 to 2018, covering areas over 25 hectares, and the total burned areas amounted to 103,000 hectares out of 525,000 hectares (Barros et al., 2018). In recent decades, forest fires have increased dramatically as a result of climate changes and others human factors, which leads to significant environmental and socioeconomic losses. Therefore, forest restoration is indispensable for preserving the ecological integrity of forests. From the sustainability perspective, it is necessary to restore forests after fires (Barros et al., 2018; Alayan, Rotich and Lakner, 2022).

Restoration is an interdisciplinary field of science that requires practice including diverse perspectives that is important for ensuring effective environmental monitoring and restoration on a large scale. Therefore, it is essential to provide a protocol for stakeholders involved in post-fire forest restoration. This protocol aims to generate a extensive data to determine regional references values and improve restoration efforts ,outputs and associated benefits (Scheper, et al et al., 2021). Additionally, the criteria for restoration and the establishment of a comprehensive evaluation protocol extend beyond the perspective of a single actor (e.g., individual, industry, sector, or organization). Instead, multiple stakeholders are involved in the restoration process (Scheper, et al et al., 2021). The restoration protocol should also be based on a comprehensive understanding of the impacts of wildfires on forest ecosystems by integrating environmental, social, and economic factors to support the restoration of burnt forests and suggest enhanced restoration strategies as well as tried-and-true adaptive value approaches in fire-prone populations (Lanta et al., 2019; Alayan, Rotich and Lakner, 2022). Moreover, utilizing spatial support systems involves integrating data layers and evaluating the impacts of different methods in ways that objectively inform decision-making. This proves highly beneficial for decision-makers and analysts who are not experts in inference systems and geographic data.

Spatial Decision support systems are integrated information systems with contemporary structural functions designed to help in the prevention and suppression of forest fires (Sakellariou et al., 2017). These systems are represented by suitability class maps that provide critical information for various decision-making levels. Monitoring and assistance landscape restoration enable analysis of landscape restructuring and provide information on crucial restoration phases (Poccard-Chapuis et al., 2021). This not only reduces fire risks but also increases the region's resilience to climate change, strengthens local value chains, creates a network of local producers for capacity building, exchanges, and fundraising (Arduino, 2021).

Based on this rationale, this study focused on analyzing the forest restoration after

fires from a comprehensive perspective including various criteria, indicators, models/techniques. Cultural/spiritual aspects, political/legal aspects and infrastructure and services aspects, are among the varied criteria explored in this investigation (Leberger *et al.*, 2020; Alayan, Rotich and Lakner, 2022). Addressing these diverse criteria in investigating post-fire forest restoration in this study aims not only to acknowledge their relevance in managing forests under normal conditions but also to underscore their importance in the aftermath of fires. This emphasis is particularly crucial in developing countries where forest restoration often occurs in rudimentary and marginal ways, posing challenges for effective recovery and exacerbating degradation. Additionally, this study employs mixed methods and techniques, bridging a methodological gap in prior research by integrating the Analytical Hierarchy Process (AHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) methods. These two methods were incorporated into a Spatial Decision Support Systems (SDSS) (Segura, Ray and Maroto, 2014). Finally, fill the graphical gap, Syrian forests are considered as the primary case study in this research.
The primary objective of this study is to provide a comprehensive and current overview of the latest developments in post-fire forest restoration criteria integrated into regional decision-making processes, employing multi-criteria analysis tools such as the Analytical Hierarchy Process (AHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL). The outcomes of these tools are visually represented in maps and tables, presenting the most restorable places followed by the least recoverable ones. This prioritization is established through a comprehensive framework that encompasses six criteria: Economic, environmental, social, infrastructural and educational, cultural and aesthetic, and managerial and legal. This holistic approach assists decision-makers in effectively and sustainably restoring forests after fires, enhancing the overall comprehensiveness, utility, and sustainability of the study outcomes. It also facilitates time and cost savings since the decision-making process is integrated into national frameworks or regional/long-term planning development tracks, based on a broad and objective scientific background.

1.1.Research problem

The lack of appropriate spatial planning for forest restoration and forest degradation due to fires has led to a lack of integrated restoration studies from all aspects, including environmental, economic, social, cultural, legal, and infrastructure. Previous studies focused on one or two aspects at most, and the inadequacy of results in spatial decision support systems after years of effective forest restoration has created uncertainty and doubt about the validity of decisions. This has resulted in negative consequences such as rare large fires, decreased biodiversity, and invasion of forest insects.
The lack of integration of other aspects of forest restoration has made post-fire management complex, environmentally and economically stressful, and a burden

on local communities. This knowledge gap requires the need to integrate knowledge and domains to make optimal decisions when restoring forests after fires, mitigate potential obstacles and resource constraints such as available knowledge, lack of information, reliable scientific sources, technology, and financing. Additionally, there is a lack of support, desire for change, and awareness among the local community, making it difficult to determine the appropriate level of intervention for decision-makers.

1.2. Research gap

Upon examining previous studies in post-fire forest restoration, it becomes evident that the findings highlight three main research gaps. The first gap is that many of these studies focused on a single aspect or criterion, indicating the inadequacy or incapacity of strategies or reforestation plans designed within a coherent framework to fulfill requirements or objectives in the medium or long term .

1.3.Research aims

The current study aims to provide a comprehensive framework for post-fire forest health restoration, to fill gaps, and to provide an updated and comprehensive review of the latest developments in post-fire forest restoration implemented and integrate them into spatial decision support (multi-criteria analysis tools using Analytic Hierarchy Process(AHP) and decision-making and evaluation methods (DEMATEL) and using the outputs of these tools from maps and tables to guide decision makers in the process of making the correct and sustainable decisions by applying them on the spot, making a known number of changes in the weighting of the criteria to save time and money, because the decision is based on a wide and researched scientific base without prejudice and its integration into the regional/long-term planning development line or national frameworks.

1.4.Research questions

The primary questions addressed in this study include: Do comprehensive criteria mitigate hesitation, confusion, and bias among stakeholders and decision-makers during post-wildfire recovery efforts?

- Can the location maps of the most suitable areas for wildfire recovery indicators, as presented in this publication, be employed for long-term decision-making?

1.5. Research Hypothesis

1.Determining the methodology of spatial decision support systems integrated with decision-making and evaluation methods will lead to more effective and sustainable strategies for forest fire restoration.

2. Adopting a comprehensive framework for post-fire forest restoration will help accurately determine the most suitable places for restoration when making decisions..

3. Identifying the most suitable places for restoration will result in better-informed decisions, leading to more effective outcomes in forest fire restoration projects.
4. This method aids decision-makers in analyzing investment contracts, spending levels, and maximizing social benefits using Knapsack method.

II. Materials and methodology

2.1. Research Methodology

The research is based on a working mechanism and methodology, which is a set of steps that stem from the theoretical background and current and previous concepts about forest restoration after fires, in addition to analyzing the results of theoretical studies and global experiments.

Method by reviewing and following up on all theoretical parts and arriving at the research questions.

The results are therefore used to make the best decision to restore forests in the Al-Ghab Plain, which is the area most affected by the Syrian forest fires. The area of burned forests in the study area is about 4,718 hectares, which is equivalent to 12% of the total area until the end of 2020.

2.2. Data collection

The study collected data in vector format and converted it into a 30x30m network to improve spatial integrity and avoid shape distortion. The ArcGIS10.8 program was used for the analysis, with sites carefully selected for good restoration and focusing on stimulants in constituent structures. The study also included data from various bodies and sources, including the Regional Planning Authority, General Authority for Remote Sensing, and General Company for Engineering Studies.

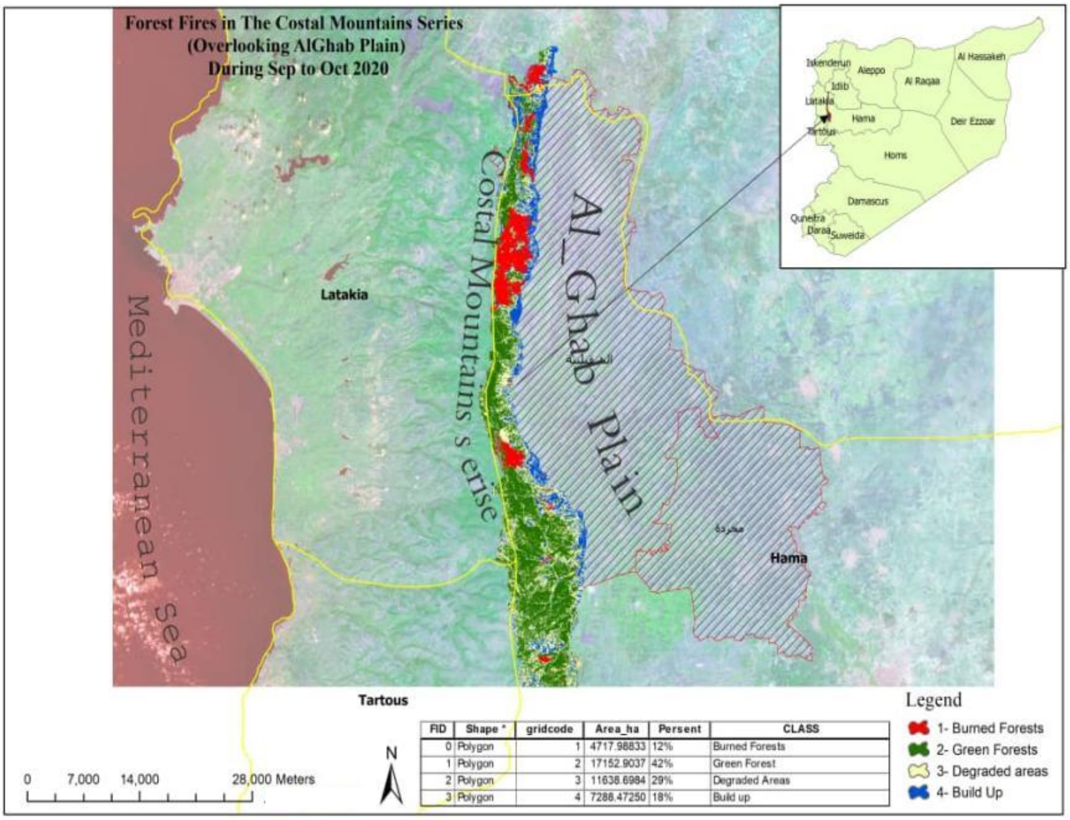
The study classified six criteria into five classes on a scale of 1 to 4, allowing for comparison and comparison of maps. Scientific articles, national and international assessments, and reports were also used. The initial data was gathered through Medicine Obstetrics, public and private sector institutions, educational institutions, and unimportant organizations. Two stages were designated for the study: the first open answer questions focused on the development criteria of three sustainability criteria: economic and social criterion, and the effect of forest fires on the theory of Hierarchy analysis. Interviews were conducted with relevant frameworks, such as the owners of intermediaries, to retrieve information about policy formulation processes.

Many of the factors attributed to these factors include the influence of various institutions and the extent of human and financial resource deficiency in the field of forest management in Syria. The study aimed to measure the weights of the determined criteria and provide insights into the suitability of recovery strategies for forest management in Syria. The majority of people believe that more funding is needed to fully implement a forest management strategy, as it lacks clarity on responsibilities and reforms. This leads to overlapping administrative duties, duplication of work, and inefficiency. The strategy's owners also receive inactive implementation due to insufficient financing from the government and international donors. This raises questions about government financing and the effectiveness of studying milestones, administrative changes, and current work relationships between relevant institutions. The research's impact on decision-making has prompted the government to take measures to address forest fire management.

2.3. Study area

The Al-Ghab Plain is located northwest of the city of Hama Governorate in central Syria and covers about 47 km2. Its height ranges between 146-176 m above sea level(Khallouf, Shamsham and Idries, 2022) It also has a strategic geographical location (in middle of the road between Aleppo and Damascus), and close to the most natural tourism and archaeological sites(Barakat et al. *et al.*, 2019).

The site has a humid and temperate Mediterranean climate. The rainy season extends from October to the end of May. The rains reach their peak in December when the annual rainfall reaches 1000 mm. The declining clusters of 'Quercus Calliprinos Webb' are scattered within the true Mediterranean vegetation in different environmental conditions in terms of slope and height above the surface level of the sea. This slope has significant topographical variations and slopes starting at 180 meters above sea level and reaching the highest peak (Nabi Mouttah) at 1560 meters up to 10 kilometers. There are many forest villages inside and outside the site. The residents have used different forest resources for a long time, setting a model for the mutual relationship between forest and man in areas as wide as the selected area (Almahmoud, 2016). The number of residents of Al -Ghab plain, according to the statistics of 2014, was 575,000 (Khadka et al. *et al.*, 2015) ,and the projects, Structural Planning for Al-Ghab Area ', 2011 where the population ratio of those in the age of 18-20 years at 60 %, or 345,000 workers, including 163635 people do agricultural work where the percentage of workers is about 47.43 %, while those working in the industry sector are their rate is 4.54 %, while the percentage of workers in the services sector and the rest of the sectors is 48.03 % of the total number of residents of the region, and the percentage of females is 52 %, or 299,000 females, while the rate of male is 48 %, or 276,000 males of total number of residents of the alleged area(‘Agaropolis studies and projects,Structural planning for Al-Ghab area’, 2011, Khadka et al. *et al.*, 2015) It should be noted that the percentage of fertile agricultural soil is 62%, 26% is forests, 2.3% is pastures, and 9.6% is slopes and unsuitable for agriculture. The total for the area is approximately absorbed by industrial and commercial activities related to agriculture to support it (‘Agaropolis studies and projects,Structural planning for Al-Ghab area’, 2011). where the percentage of the area cultivated for wheat is 56.31%, while the percentage of the area cultivated for sugar beets is 6.63%, cotton is 17.31%, and tobacco is 19.75% (Khadam et al. et al., 2019).In addition to potatoes, where production can reach 32,240 tons, and yellow and white corn. While the interest in cultivating the fruits (grape-olive-two-pomegranate) decreases a measure of other cruises, as this agriculture in the western parts increases as the dryers are made (Allaham, 2010).



FID	Shape *	gridcode	Area_ha	Persent	CLASS
0	Polygon	1	4717.98833	12%	Burned Forests
1	Polygon	2	17152.9037	42%	Green Forest
2	Polygon	3	11638.6984	29%	Degraded Areas
3	Polygon	4	7288.47250	18%	Build up

Figure 1.The amount of forest fires in the case study

Source: (Sentinel -2A, satellite image with high spatial resolution 10*10 m^2)

2.4. Forest fire Effects and Management in Study area

The initial costs for restoring forests after a fire were estimated at $400, including labor wages and material costs. The total production costs amounted to 275$/ha, with the capital required in the first year being higher than the rest of the years due to the high costs of agricultural machinery and digging holes. Forest protection areas are a priority as they contribute to preserving forest wealth and keeping the area clean. About 180 hectares were reforested by the General Authority for Forest Management and Development (GAFMD) of the Syrian Ministry of Agriculture and Agrarian Reform (MAAR) in sites exposed to encroachments and fires during the last period. Over 100,000 plants of various forest species were planted in the sites of Jurin, Shatha, Ain al-Krum, Annab, and Ma’rin al-Salib. In 2023, surgical roads were built for a distance of four kilometers out of the total planned plan, amounting to 13.5 kilometers.

A forest planting project was implemented in the Salhab nursery, which has a production capacity of 2 million plants and currently produces 1.2 million plants from different forest types suitable for providing farmers with windbreaks and constructing homes. Ensuring the need for artificial afforestation projects in vacant and degraded forest sites is essential.
In the study area, work was limited to compensating local residents for those who have olive trees and appointing seasonal workers in accordance with the firefighting plan. The fire rate in the villages reached 8-10%, meaning 1,500 olive trees. Compensation for each affected farmer was 12$ for each affected farmer over a period of three years. The region also suffers from social, economic, and environmental problems, such as the lack of irrigation water necessary for agricultural crops in some regions due to bad manipulation of current dams. Additionally, random urban expansion leads to limited agricultural production, and there is a scarcity of laboratories in the forest. Despite large agricultural production, a variety of agricultural crops and livestock, merchants control the marketing process, leading to a decrease in farmers' profits and the spread of private markets.The main drawback is in assessing time trends in environmental and social (ES) flux that extends over decades due to unequal or limited data from official information sources for different years of study and on different spatial scales.

2.5. Method steps

A total of 23 questions were obtained to meet consistency requirements, and a weight was assigned to each of them,where the limitation of the analytical transmission process is that the person who is a open answer questions must be an expert in this field.Therefore, there is a need to find more experienced experts to participate in the work,where the results of evaluation can be divided into four levels: highly suitable and moderate suitable and not suitable to restore.
Based on 6 basic criteria and 25 sub-criteria or indicators were reached(economic, social, environmental, administrative, legal, cultural, aesthetic, infrastructure and education. As shown in the following table(1):

Table 1.The used Criteria and indicators that used in the study area

Criterion	Indicators
Economic	1- Economic benefits of restoration(Timber and non-timber products and density), production and investment to multiple types of capital (Human, natural, social and financial).-projects"-inputs). 2- Economic assessment self-sufficiency after the restoration. 3- Changes in Local Economy and Business: Employment and new opportunity job created, incomes “Changes in sources and quantities." and local business related to reforestation(GDP local level of forest sector).

	4-Costs of restoration : cost of fences, value of lands, labor cost, monetary cost, Willingness/ability to pay for fire mitigation actions-Evacuation costs and burn properties- costs of site preparation-treatments, seeding, planting and Irrigation costs, budget sufficiently-resources-,future funding and partnerships (external-local) and payments of services or preservation.
Environmental	1-Changes in Environmental Soundness: quality, flexibility , resilience-self maintenance, richness of species. 2-Changes in biodiversity of species after restoration ,biological community ,Genetic diversity ,reproduction habitat :Birds-Flora-Fauna-Fungi (Biota) (Planted ,species lists endangered). 3-Landscape connectivity ,land cover and use changes. 4- Forest characteristic(Biomass accumulation, Shrubs and the regeneration and treatment of invasive species) and forest Structure. 5-Changes in forest components (Soil: Physical , biological and chemical characteristic-Erosion costs -Succession -Hydrology: Flow-Storage-Water and air quality).
Social	1- Life quality changes, health impacts and well-being of local communities, Therapeutic value and productivity after forest fire. 2- Local communities benefits of outcomes of restoration(Collaborative participation),and livelihood opportunities (Provision of wood, sustainable tourism products and fuel),and food security and provision from plantation(High quality for a community in reasonable prices). 3-Contribution to the restoration (number of volunteers), Communities Engagement, responsibilities and communications.
Infrastructural and Educational	1-Access of Infrastructure networks, and Services to sites that need to be restored. 2- Knowledge acquisition and outreach benefits: scientific researches purposes , technical support ,education , training , and awareness(Traditional knowledge and understanding based on local history: migration, settlement, the length of the growing season and blooming time over time) to reduce risk of forest fires. 3-Number of institutions that involved and responsible for and supportive of restoration. 4-Understanding of fire sciences : suppression and limitations.

Cultural and Aesthetic	1-Cultural identity and spiritual values changes. 2-Changes of cultural purposes. 3-Changes in Ecotourism or recreational visits and archaeological sites.
Managemental and Legal	1-long-term Restoration Plans for the main factors and drivers (Social, economic and environmental diagnosis)- implementation, schedule, networks effectiveness and feedback. 2-Stakeholder Engagement(Policy makers practitioners ,managers and educational institutions). 3-Managing Local Communities, cooperative participation, restoration practices and challenges. 4-Strategic Monitoring in the natural and planted forests (complete and update data repository assets: human, financial, natural, physical and social). 5-Strengthen and Revise of Laws and rules to aid restoration process and to resolve tenure disputes and measures of governing forests scale and integration(stimulation or discourage restoration activities). 6-Historical Management Records on the exist one and data analysis (Process management-ecosystem approaches).

(Own editing, 2022)

2.5.1. GIS-AHP method step

A number of steps are implemented by using the spatial analysis of the tools in the dialogue in the interior of the ArcGIS 10.8: The region of each criterion is divided into categories to suit the requirements, and then it estimates a suitable weight for each category to determine the final map based on the current criteria. It is the option with the highest value (priority that includes all criteria and then re-ranked in consultation with local experts from different aspects of forest restoration after fires (field of Environment and biodiversity - Forest policies - Ecotourism - Ministry of Agriculture and Agrarian Reform) via correspondence, interviews by mail and telephone to evaluate the importance of each criterion and indicator within each layer to make a decision according to the desired goal (recovery), to create maps for each criterion and each overall goal, examine the sensitivity of the results, and to prioritize risk management areas in decision aid maps and economic(Chabuk *et al.*, 2017; Alkaradaghi *et al.*, 2021, Sathiyamurthi *et al.*, 2022).To calculate productivity, habitat dispersion, degree of resilience, natural regeneration, and the most affected villages, then Reclassification with the aim of obtaining images in a specific format.

With a unified classification, the grade is determined according to color and multiplied by the AHP values to obtain the final map, as well as according to the color gradation.

Due to random human intervention, such as: cutting, logging, and building roads to facilitate fire extinguishing, all of this caused an increase in grass due to the presence of sunlight that was blocked by the dense tree canopy.

As for forests, their regeneration was weak and the height was less than 1, noting that the southern regions are more exposed to the sun and thus a higher quality of growth (NDVI=(NIR-Red)/(NIR+Red).

Δ NDVI = Prefire NDVI - postfire NDVI.

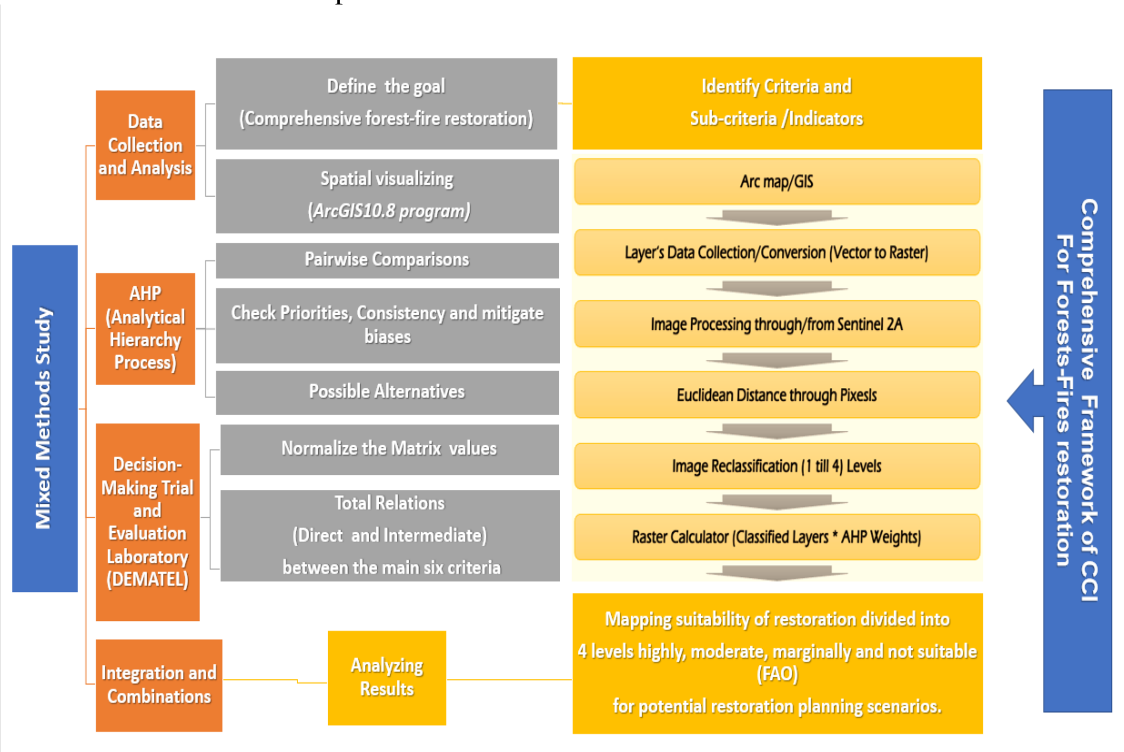


Figure 2. Diagram illustrates the hierarchical structure of both AHP and DEMATEL methods

(Own editing, 2023)

Table 2. Input data, Source and processing method

Characteristic (Layer)	Source/Resolution	Processing Method - platform
Villages – Settlement– Roads- Restaurants-Shrines Institutions and Local Facilities	Google maps- http://maps.google.com / 1meter	Spatial Analysis toolbox – Inverse Distance Weighted

LULC – NDVI – NBR-Slope-Aspects Biodiversity changes: Biomass/Carbon sequestration	Satellite Image Sentinel-2A -/ 10meter https://scihub.copernicus.eu/dhus/ Normalized Burn Ratio (NBR) | UN-SPIDER Knowledge Portal NDVI changes by Satellite Image	Maximum Likelihood classification-Image analysis Spatial analyst toolbox Vector to Raster then raster - calculator Reclassify classification
Soil erosion	Remote and traditional approaches	Soil loss equation USLE Formula Spatial Analysis toolbox – Inverse Distance Weighted

(Own editing, 2023)

III. Research Results and Discussion

3.1. Using AHP method for the six main Criteria

The first order of the hypothesis of principles: economic - social - environmental – management and legal - infrastructure and education– culture.

Table 3.Pairwise comparisons between main six criteria of forest fire restoration

	ECO	SOC	ENVI	MANG	INFRA	CULT
ECO	1	2	4	3	6	5
SOC	0.5	1	3	2	5	4
ENVI	0.25	0.33	1	0.2	4	2
MANG	0.33	0.5	5	1	5	3
INFRA	0.16	0.2	0.25	0.2	1	0.5
CULT	0.2	0.25	0.5	0.33	2	1
SUM	2.45	4.28	13.75	6.73	23	15.5

In table(3), pairwise comparisons are made, which in turn determine the differences between different criteria according to their importance in the decision-making process, and then the value of each cell in one column (criterion value) is divided by the final sum. Then a normal pairwise comparison matrix is generated, and the weight of the criterion is divided by the sum of the results by the number of criteria (the mean).The first order of the criteria hypothesis is: economic - social - Managemental - environmental - culture - infrastructure. We note that the economic evaluation index is the heaviest or relatively largest in the economic criterion, 17.637% of the total percentage occupied by the economic criterion of 36.583%, while the index of the number of institutions contributing to the restoration in the infrastructure criterion occupied 0.293% of the total percentage of 3.972%.

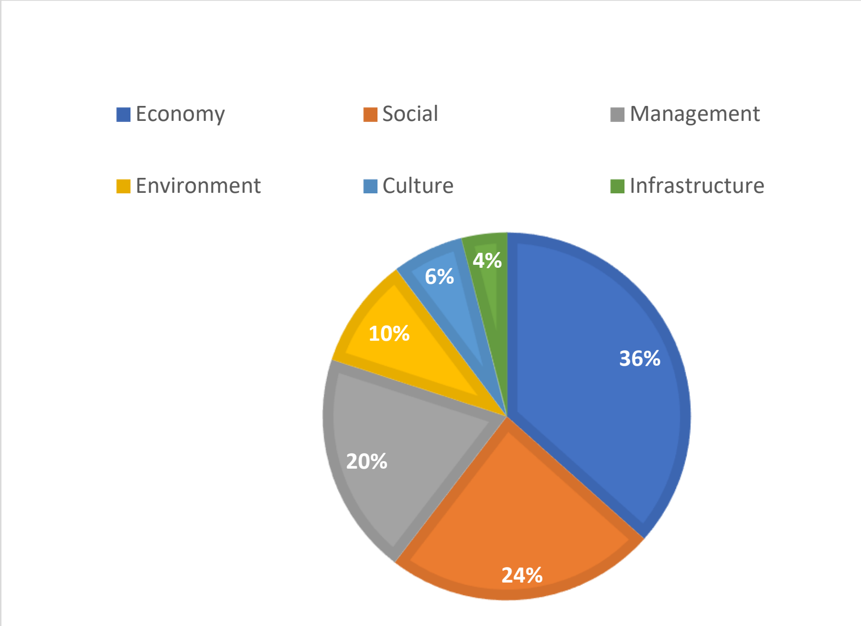


Figure 3.The six Criteria weights and their percentages

Table 4.Ranking of the Main Six Criteria

Economic	1
Social	2
Management and legal	3
Environmental	4
Culture/Aesthetic	5
Infrastructure /Educational	6

3.2. AHP for the Four Alternatives

By applying the AHP method that was applied to the criteria, it is applied also to the sub-criteria to the four alternatives:

- Forest Restoration Techniques (Passive-Active-Nucleation-Site preparation-Salvaging).
- Integrated Forest- Fire Decision Making.
- Forest-Fire Investment Planning System.
- Suitable and Subsequent Treatments and comparing them for each of the six basic criteria separately.

Table 5.Pairwise comparisons between the four alternatives

Alternatives	Forest Restoration Techniques	Integrated Forest-Fire Decision Making	Forest-Fire Investment Planning System	Suitable and Subsequent Treatments
Forest Restoration Techniques	1	0.4	0.6	3
Integrated Forest-Fire Decision Making	2.5	1	4	7
Forest-Fire Investment Planning System	1.66	0.25	1	5
Suitable and Subsequent Treatments	0.33	0.14	0.2	1
Sum	**5.5**	**1.79**	**5.8**	**16**

C.I=0.0441 , C Ratio=0.049

Table 6.Ranking of the four alternatives

Alternatives	Ranking
Forest Restoration Techniques	3
Integrated Forest- Fire Decision Making	1
Forest-Fire Investment Planning System	2
Suitable and Subsequent Treatments	4

When taking the first and second alternatives with the highest percentages, namely Integrated Forest-Fire Decision Making and Forest-Fire Investment Planning System, and comparing them with each of the six criteria separately using the AHP method. It was found that the third criterion, Forest-Fire Investment Planning System, was the most important among the four alternatives. With a very slight difference of 0.71% between the second and third alternatives, this shows the importance of the AHP method as an accurate method and an aid in making the decision regarding the restoration of Syrian forests after fires.

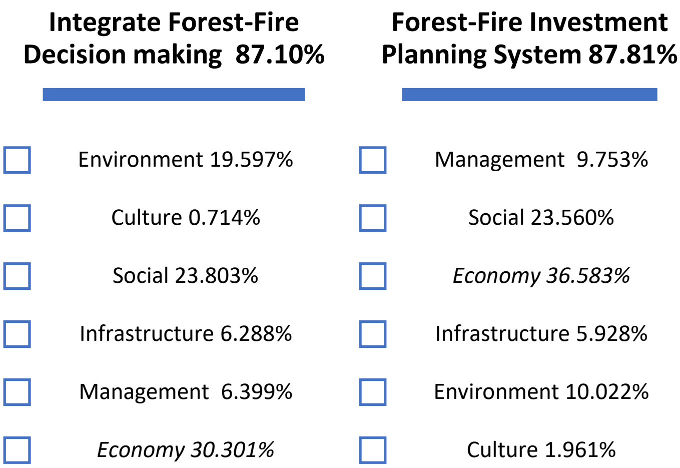


Figure 4.Alternatives weights and percentages for each of the criteria

3.3. Using spatial decision support systems (AHP-DEMATEL) of the six criteria for forest restoration after fires

After the fires spatially was selected slice from the Al-Ghab Plain and considering it as a study area or as a practical model in which the criteria for forest restoration after fire are tested, and then the results are circulated to all of the Al-Ghab Plain so that the appropriate area for each criterion is determined separately in relation to the six criteria specified for restoration, and thus the results are used to make the optimal decision to restore forests in the Al-Ghab Plain, which represents the area most affected by fires in relation to the Syrian forests. The Sentinel 2A satellite image has been downloaded before the forest fires 09/18/2019 and beyond Forests 09/17/17 and the data of the land use/the land cover this is classified as an additional manner to the code of the mask by the hiding of the reserve forests, the rocks of the urban reserves, and the flatness Aquaculture for the acquisition of each worker one of the methods of adaptation.

Table 7.Relationship Pairwise comparisons between the main six criteria

	ECO	SOC	ENVI	MANG	INFRA	CULT	SUM
ECO	0	3	4	3	4	3	17
SOC	4	0	3	3	3	3	16
ENVI	4	3	0	4	2	2	15
MANG	4	3	3	0	3	3	16
INFRA	3	2	1	2	0	2	10
CULT	3	4	2	2	1	0	12

Based on the figure and the table, the order of the alternatives using the AHP method and the decision maker's options are C3 > C2 > C1 > Based on the results, C1 is the preferred resource that corresponds to the decision maker's choices, while the social criterion (C2) and the administrative criterion (C3) were the second highest effect compared to the other cultural criterion As for the weaker effect, the results were acceptable for the criterion infrastructure because it corresponds with the decision maker's choices to make the best recovery option. The decision maker rated C4 as least favorable because of the lower yield.

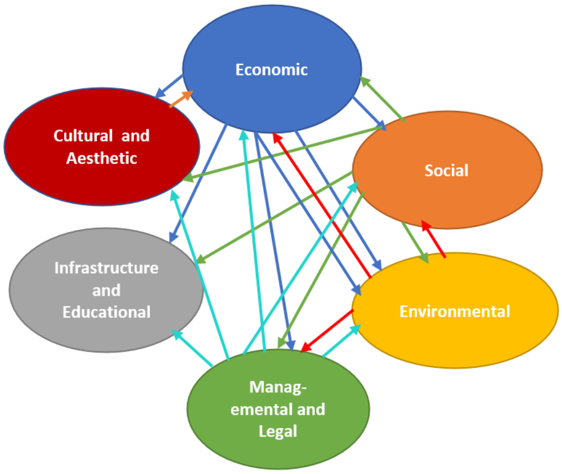


Figure 5. The causal relationship between the criteria.

The relationship between the criteria was evaluated using the DEMATEL method. Based on the table, due to the positive values in each of the economic, infrastructure and cultural criteria, R + D, while the criteria that belong to the causative group were both social, environmental and administrative criteria based on negative values in D-R(Falatoonitoosi et al., 2013; Gardas et al., 2019).As shown in the figure, there are no criteria affected by the infrastructure criterion (C5), but rather those criteria that are affected by the economy criterion, just as the culture criterion only affected the economic criterion and the social criterion, which affect all criteria, while it increases .The social criterion over the economic is also causative for the rest of the restoration criteria. The environmental criterion is causative only for three criteria, which are economic, social and administrative, where the administrative criterion is considered causative for all restoration criteria. Finally, the cultural and aesthetic criterion affects the economic criterion only, while the infrastructure criterion does not affect any one of the other criteria. This means that if the decision maker places more emphasis on recall suitability, the other four criteria will also be focused automatically especially for the criteria in the effect group as they can be easily influenced by the other criteria in the cause group.

3.4. Evaluation the aforementioned development economic projects using Knapsack method

3.4.1. The Economics projects in AL-Ghab plain

Economic projects established locally within the framework of the cooperation program between the Ministry of Agriculture and Agrarian Reform, the General Authority for Fisheries and Aquatic Resources, and the Food and Agriculture Organization (FAO)of the United Nations to activate development work to support rural families in villages, starting from 4/15/2022 until 10/31/2022. Qatrat Al-Rayhan village has a moderate population (about 660 people). On the other hand, neither the local communities nor any of the homes were damaged which led to the absence of the need to provide shelter centers or any fees for evacuation and its arrangements, including fuel and drivers' wages. When calculating the restoration costs incurred so far by the government, they are: The costs required to feed firefighters throughout the fire season are about 70 million Syrian pounds/season. By estimating the need for fire extinguishers (water hoses, fuel, and maintenance) is about 40.000$/season, while disbursing a firefighting bonus to each worker is approximately 25,000 multiplied by 500 workers during the fire season, i.e., 5000$. And costs for equipment and individual tools for firefighters (back pumps, shovels, axes, scythes, and drinking water bottles).In addition the costs of uniforms and shoes for firefighters are about 34.000$ per season(Nassour, 2023).

3.4.1.1. Propagation and cultivation of important non-traditional forest species "Al-Ghab-Salhab Nursery"

Project duration: 6 months (1.5 preparation - 4.5 months implementation)

i. Knapsack method

The restoration index (SI) is a tool used to evaluate and rank alternatives for restoration projects, based on decision-makers' priorities. It involves data collection, project decision-making, and evaluation stages. After reviewing previous studies, seven initial groups of indicators have been modified, and six are selected by the most representative and independent of them. These indicators can be expanded by including new restoration features and local reconciliations.

The quantitative measurement process is essential for any development project analysis, and local databases can be used to evaluate these indicators. Knapsack models can be applied to determine the most beneficial groups, considering economic benefits, preferences of owners of interest, and local systems. The complete approach is valid and applied, and the quantitative measurement process should be followed for each indicator.

The problem of choosing elements that increase from total profit with the accumulation of weight is a significant concern in various applications. The solution involves arranging elements for a period of the product to exaggerate sacrifice and transportation costs while preserving capabilities. A one-back fact is necessary to obtain a compulsory equivalent of an expected approach. When the weight of the item exceeds the target bag capacity, a negative reward is given. Restoration management aims to maximize benefits by addressing changes in fateful sites. This approach helps decision-makers explore investment contracts and determine optimum spending levels. Support and evaluation play a crucial role in improving accuracy and transparency in investment evaluation. By understanding the costs and benefits of alternative treatments, decision-makers can form the ideal investment strategy. Transparency and explanation of amendments to parties involved ensure administration provides social benefits to the greatest extent possible.

Table8 .Heuristics algorithms: Profit to weight ratio(pi/w1)

I	Food processing unit (1)	Agricultural Seeds (2)	Compost and Vermicompost (3)	Aquariums (4)	Sprouted barley (5)	Green fodder (6)	Opuntia Ficus Indica planting (7)	Trial loans (8)
Weight Wi	10	270	1	22	15	15	19	5
Profit Pi	38168000	18000000	2611275	31000000	25000000	3600000	21600000	1000000
Ratio Pi/Wi	3816800	66666.6667	2611275	1409090.9	1666667	240000	1136842.105	200000
Heuristics3 xi	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**

Total Profit max=38168000+2611275+25000000+31000000=96,779,275

Total weight max=10+1+15+22=48

The taken Items are: 1,3,5,4

Max Allowable weight C=50

Max Allowable profit Q=100.000.000

3.5. Suitability Analysis for the sixth criterion of forest fire restoration

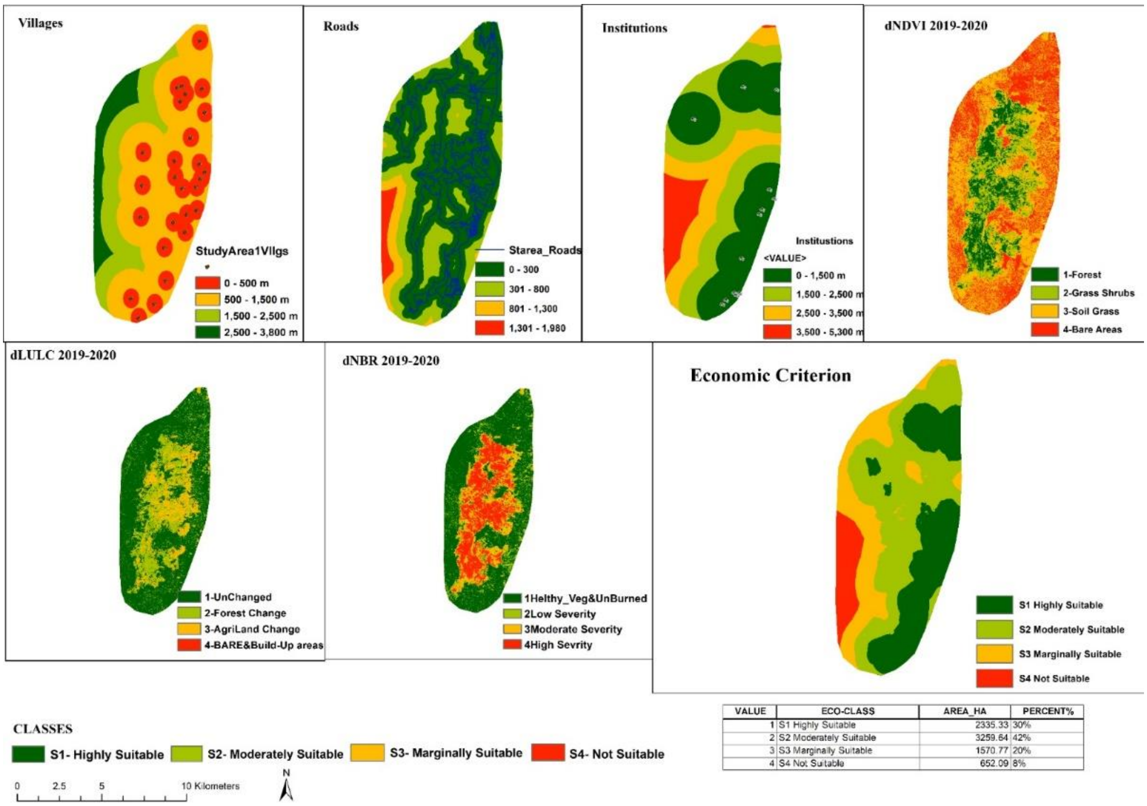
The previous studies were also visited by curricula that are based on the intended analysis (MCA) and the geographical information systems (GIS), which have been successful in a varied group of applications related to the capacity and management of the forests, and their processing and planning. Where the analysis provides multiple criteria a variety of tools and techniques to organize the problems of decision in addition to the establishment, analysis and arrangement approximately for every standardized standard, and design options for priority resetting regions. The suitability analysis depends on: (1) Determining a set of recovery criteria(2) Obtain GIS datasets available for each standard (3) Establishing maps for each standard (4) Visualization of the analytical analysis models (5) Designing the potential sites of the restoration(Guidelines for Resilience Systems Analysis: How to Analyse Risk and Build a Roadmap to Resilience, 2014).Then, it is possible to evaluate criteria maps, different criteria through a multi-criteria approach and obtaining a suitability map for each criterion, then combine them all to create the final suitability rating

(Rajaonarivelo and Williams, 2022).The areas that should be given priority for restoration are selected based on a group among the

Environmental,Social,Economic,Cultural,Infrastructural and Managemental criteria. These results may change depending on the level of accuracy we provide by adding more criteria to the analysis .

A) Economic Criterion

The maps depicted in Figure (7) was represented the criteria specified for the economic criterion were collected between 2019 and 2020, one year after the fire, and encompass the following aspects: (1) evaluating changes in land uses and coverage, combined with fire intensity, to determine the average economic loss in both wood and non-wood products in forests or private agricultural lands resulting from the fire; (2) calculating the average amount of fuel or wood; (3) estimating the damage to residences and the number of properties in small villages within the research region, along with their proximity to roads; and (4) assessing the government's presence at administrative points and connected community assistance centers, as well as its willingness to fund restoration efforts by determining the expenses incurred in restoration thus far.

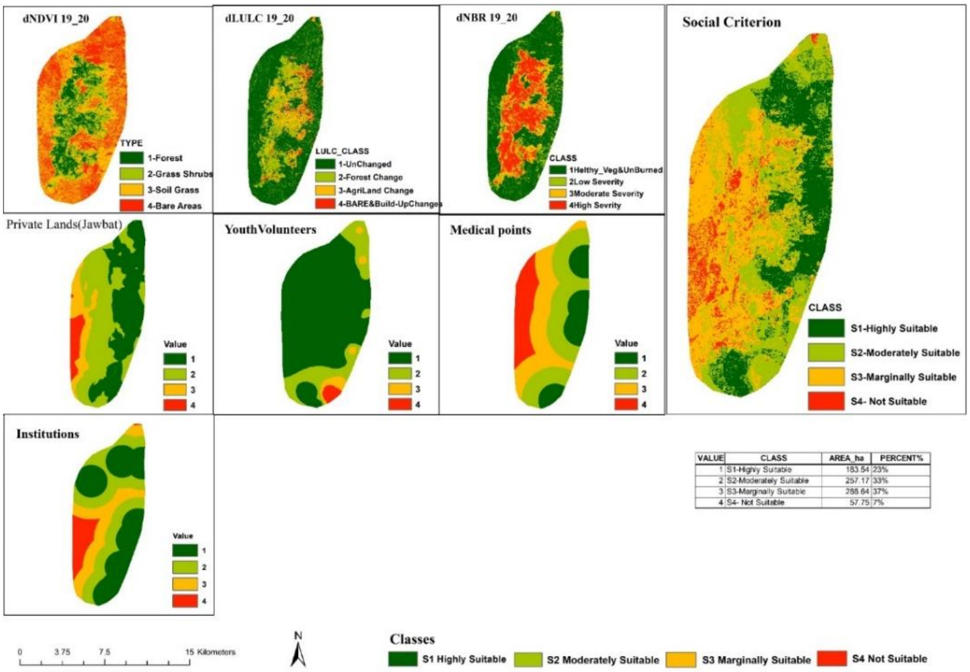


VALUE	ECO-CLASS	AREA_HA	PERCENT%
1	S1 Highly Suitable	2335.33	30%
2	S2 Moderately Suitable	3259.64	42%
3	S3 Marginally Suitable	1570.77	20%
4	S4 Not Suitable	652.09	8%

Figure 6 .Economic Criterion and its suitability classes in ArcGIS

B) Social Criterion

The population of the Al-Ghab Plain region, as per the 2014 census, was approximately 575,000 people (‘Agaropolis studies and projects, Structural planning for Al-Ghab area’, 2011), with the working-age population (18-20 years old) constituting nearly 60%, totaling 345,000 workers. Of these, 163,635 workers are engaged in agricultural activities, making up approximately 47.43% of the workforce (Khadka et al., 2015). The suitability analysis method involves five major phases: (1) selecting restoration criteria, (2) compiling available datasets for each criterion, (3) generating condition maps for each criterion, (4) establishing a suitability analysis model, and (5) identifying appropriate restoration locations. It encompasses social criterion eligibility criteria that define the quality of life, (6) changes in land use and coverage, and their combination with fire intensity to reflect the extent of ecological security, natural damage, and habitat.



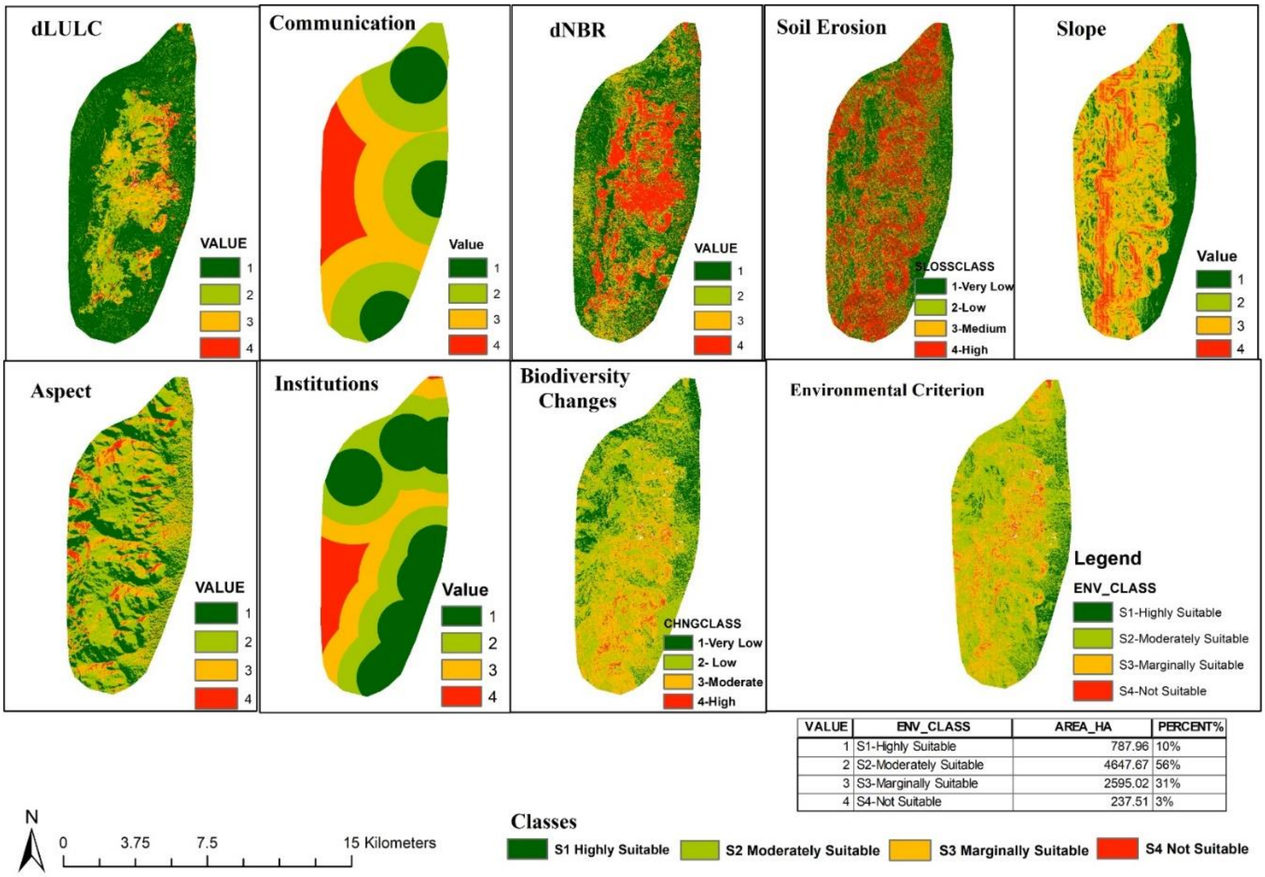
VALUE	CLASS	AREA_ha	PERCENT%
1	S1-Highly Suitable	183.54	23%
2	S2-Moderately Suitable	257.17	33%
3	S3-Marginally Suitable	288.64	37%
4	S4- Not Suitable	57.75	7%

Figure 7. Social Criterion and its suitability classes in ArcGIS

C) Environmental Criterion

In the study area, it was observed that slopes exceeding 35 degrees are more prone to recurrent fires due to their rapid spread and decreased fire control capabilities, compared to the preferred gentle slopes ranging from 0-10%. Gentle slopes aid soil retention and enhance water storage, contributing to biodiversity stability. Plant species, humidity, and rainfall rates are influenced by elevation, with fir and cedar trees thriving at altitudes exceeding 1000 m. Aspect, referring to the slope or orientation preference for southern, southeastern, and southwestern

slopes, impacts sunlight exposure, resulting in a more favorable natural regeneration process in the forested regions categorized into four types.
Carbon sequestration accounts for half of the biomass in the vegetation cover (50%). Temperature exhibits minimal diversity in the study area due to its relatively small size compared to the entire Syrian Region. The Natural Diversity Vegetation Index (NDVI) serves as a method for estimating the C-factor from remote sensing data, commonly employed in vegetation and biomass assessments(Sathiyamurthi *et al.*, 2022). Ranging from 0 to 1, NDVI values above 0.26 indicate healthy plants in equilibrium with infrared reflectance. The suitability criteria for the environmental criterion encompass: (1) assessing changes in land use and coverage combined with fire intensity to gauge vegetation cover resilience/resistance; (2) identifying alterations in environmental services, including carbon sequestration; (3) determining changes in biomass indicative of dispersal, loss, and deviations in vital habitats (flora-fauna); (4) evaluating changes in biodiversity, encompassing alterations in soil characteristics, soil loss/erosion, and changes in hydrology post-fire; (5) assessing variations in the humus or fuel layer after the fire through vegetation cover changes; and (6) considering the presence of administrative points and local community support centers affiliated with the government.

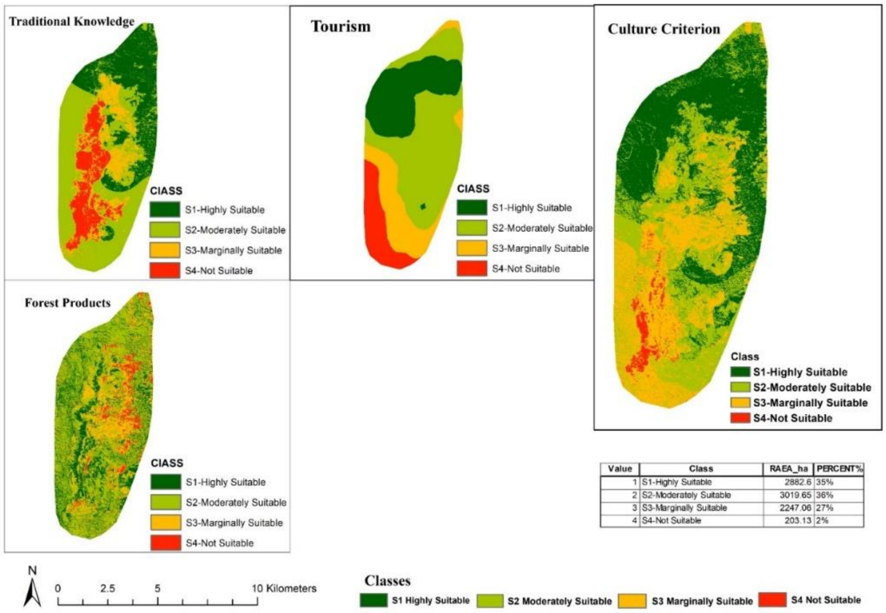


VALUE	ENV_CLASS	AREA_HA	PERCENT%
1	S1-Highly Suitable	787.96	10%
2	S2-Moderately Suitable	4647.67	56%
3	S3-Marginally Suitable	2595.02	31%
4	S4-Not Suitable	237.51	3%

Figure 8 .Environmental Criterion and its suitability classes in ArcGIS

D) Cultural and Aesthetic Criterion

For the cultural criterion, the following factors were considered in the suitability analysis approach, encompassing five key steps: (1) identification of restoration criteria, (2) acquisition of available datasets for each criterion, (3) generation of suitability maps for each criterion, (4) formulation of the fitness analysis model, and (5) delineation of potential restoration locations. Cultural and aesthetic appropriateness involves factors such as (a) proximity to monuments and restaurants, (b) land cover classes, (c) distance to settlements, (d) proximity to roadways, (e) distance to walkways, and (f) proximity to local market locations. The ensuing Figure (11) illustrates the suitability maps based on these aforementioned criteria.

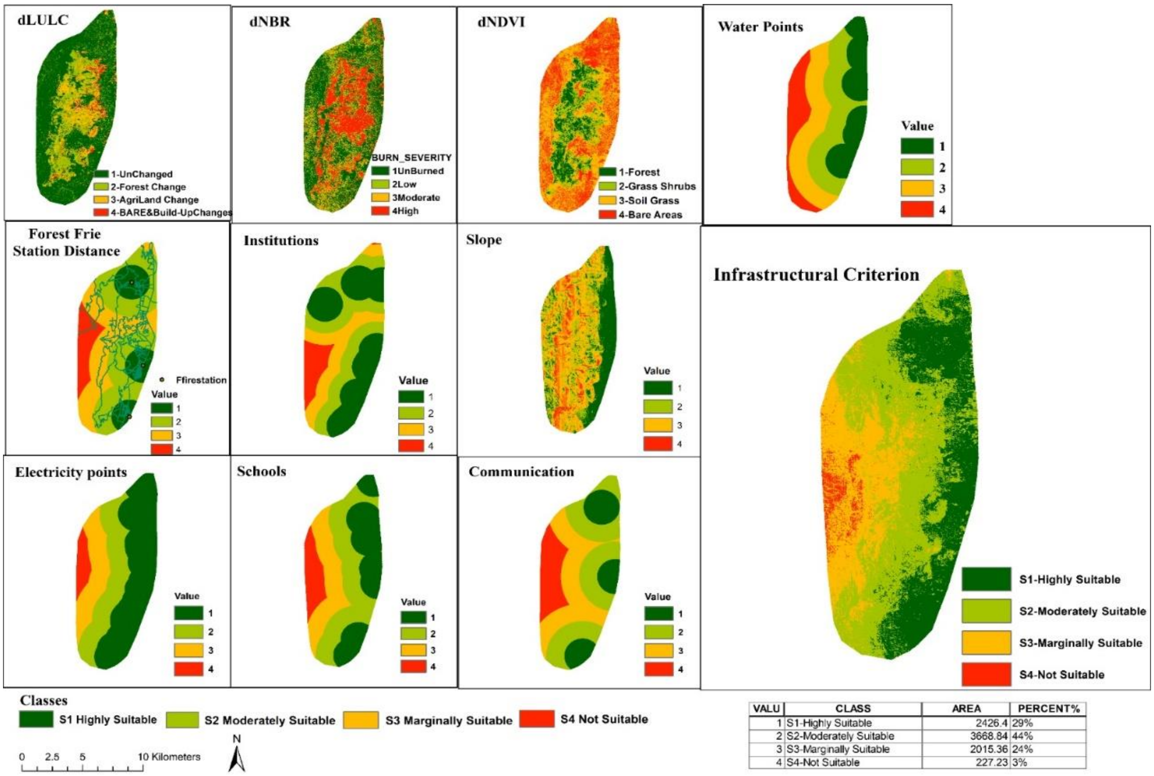


Value	Class	RAEA_ha	PERCENT%
1	S1-Highly Suitable	2882.6	35%
2	S2-Moderately Suitable	3019.65	36%
3	S3-Marginally Suitable	2247.06	27%
4	S4-Not Suitable	203.13	2%

Figure 9.Cultural and Aesthetic Criterion and its suitability classes in ArcGIS

E) Infrastructural and Educational Criterion

The total number of wells in the region is approximately 5,200, with an annual extraction volume of around 176 million m3(‘Agaropolis studies and projects,Structural planning for Al-Ghab area’, 2011). The combined length of primary and secondary roads in Al-Ghab amounts to 361.628 km (National Framework of Regional Planning, Syria 2030, 2019, Allaham, 2010). Sufficiency requirements for the infrastructure and education criterion include (1) evaluating changes in land use and coverage to estimate the extent of damage to infrastructure networks caused by fires, encompassing major and minor roads, sewage systems, communication networks, and power lines; (2) identifying the location of fire stations, considering their proximity to roads, slope, and estimating their response speed and effectiveness in reaching fire-affected areas; (3) incorporating traditional ecological knowledge from the local community, integrating it with stakeholders, and consulting experts and scientists. This involves considering the historical fire data in the study area, integrating it with fire severity, seasonality, behavior, and frequency, particularly in inclined regions; and (4) assessing the presence of governmental and international organizations' administrative offices, research or training facilities, and local community training resources.



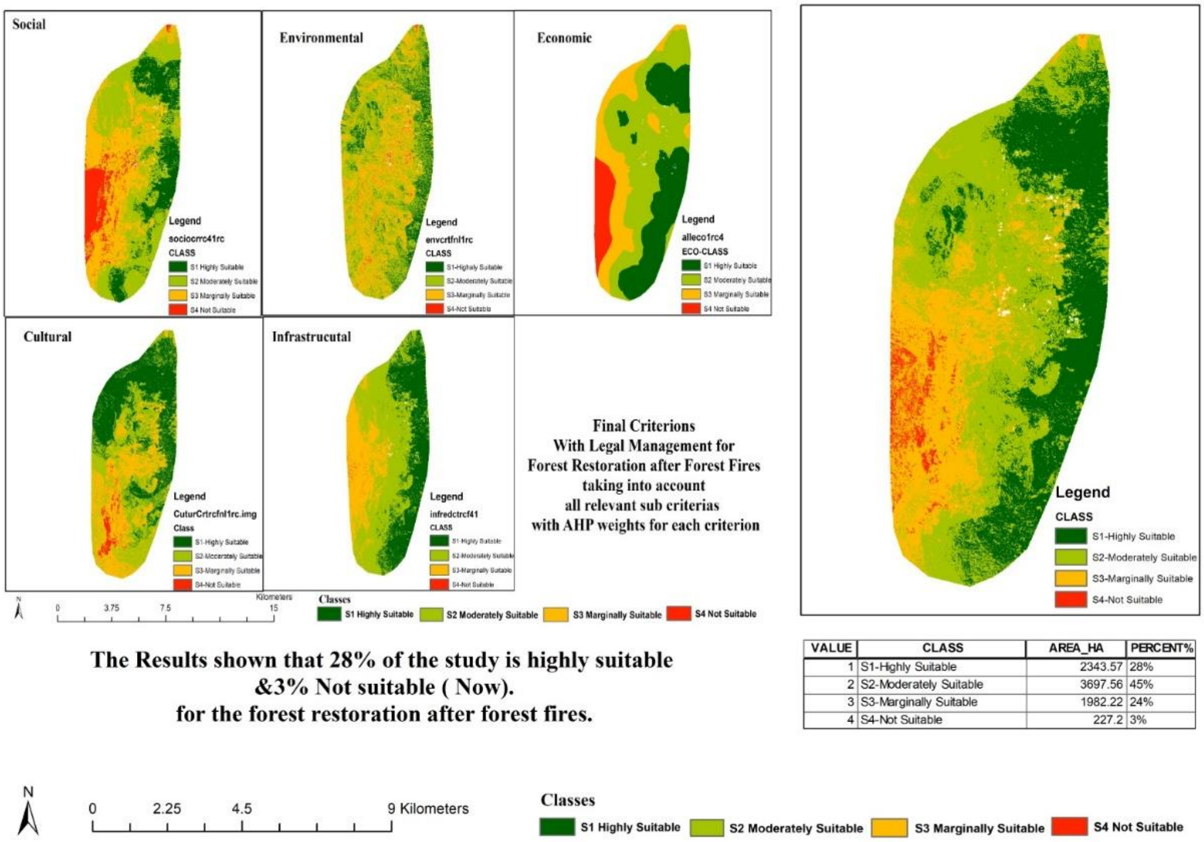
VALU	CLASS	AREA	PERCENT%
1	S1-Highly Suitable	2426.4	29%
2	S2-Moderately Suitable	3668.84	44%
3	S3-Marginally Suitable	2015.36	24%
4	S4-Not Suitable	227.23	3%

Figure 10.Infrastructure and educational criterion and its suitability classes in ArcGIS

F) Managemental and Legal Criterion

This criterion incorporates all previously considered factors and drivers (social, economic, environmental diagnosis, and historical management). It cannot be directly represented in spatial maps or layers as it has been included in each previous criterion separately. However, there were managerial indicators identified in each criterion, suggesting a potential influence on effective forest regeneration management post-fire. The concept of flexible management, explored in this study, seeks to balance the optimization of benefits for local communities with the imperative of environmental preservation.

In Conclusion, areas less likely to undergo successful restoration may incur restoration costs that are over 32% higher during a specific timeframe compared to the benefits gained in less suitable or unsuitable areas. Our findings indicate that 28% of the study area is well-suited for post-fire forest restoration, with 44% moderately suitable for restoration, allowing for adaptive management expansion. In contrast, 3% of the lands are marginally suitable for restoration, suggesting unsuitability due to factors such as steep slopes exceeding 35 degrees or elevations above 1000 meters, leading to substantial soil erosion and the transformation of these areas into barren lands.



VALUE	CLASS	AREA_HA	PERCENT%
1	S1-Highly Suitable	2343.57	28%
2	S2-Moderately Suitable	3697.56	45%
3	S3-Marginally Suitable	1982.22	24%
4	S4-Not Suitable	227.2	3%

Figure 11.Managemental suitability classes in ArcGIS

3.6. Discussion

Summarizing the results of the methods employed in this study, the priorities ranking, based on open answer questionss distributed to decision-makers in the Syrian government, indicates that the economic criterion holds the top position. This underscores the economic challenges faced since the beginning of the Syrian war, emphasizing the need for local authorities to strategically utilize leftover wood and coal as resources for forest fire restoration. The social criterion, ranked second, highlights the importance of involving local communities in restoration efforts. This involves selling traditional materials and products, fostering a sense of connection between locals and the forests, and enhancing resilience against future fires. The significant gap in management methods in Syrian forest restoration is recognized, suggesting potential challenges, as each criterion encompasses management-related indicators.

In terms of the ranking of forest restoration strategies, economic considerations play a pivotal role for decision-makers facing obstacles or delays in restoration efforts. The top-ranking alternative is Integrated Forest-Fire Decision-Making, focusing on developing a comprehensive fire control plan to support landscape, land use, and forest management. The second alternative, Forest Fire Investment Planning System, aims to conduct risk-based analyses of wildfire outcomes and management operations. The third alternative, Forest Restoration Techniques, encompasses various interventions to accelerate natural regeneration. The fourth alternative, Suitable and Subsequent Treatments, involves standardizing the classification of forests, wooded land, and other land, emphasizing the importance of notification in areas with recurrent wildfires.

Analyzing the suitability maps, the eastern and northern parts emerge as the most suitable for restoration, with moderate to high fire intensity and severity. Notably, the infrastructural and environmental criteria suitability maps show almost no red areas, indicating a high potential for restoration in terms of these criteria. However, the western-southern parts are less suitable for restoration in terms of economic, social, and cultural criteria. The assessment of fire effects reveals that approximately 35% of the study area has been moderately affected by fires, represented by light green and yellow areas.

Evaluation of criteria maps through a multi-criteria approach provides a suitability map for each criterion, contributing to the creation of a final suitability rating. Priority areas for restoration are selected based on a combination of environmental, social, economic, cultural, infrastructural, and administrative criteria. The results may vary with the inclusion of additional criteria, emphasizing the importance of accuracy in the analysis. Supporting and monitoring landscape restoration is crucial for reducing fire risk, enhancing resilience to climate change, and fostering local capacity building and fundraising.

Updating the master plan based on current land use and dividing areas according to the land suitability map offers guidance toward sustainable development. The unification of all criteria maps on a standardized scale facilitates comparison, and re-classifying maps allows for prioritization. Weight assignment to sub-criteria yields the final suitability map for primary restoration areas. The multi-purpose nature and planning of restoration applications contribute to naturalistic judgments, and the identification of priorities using a multi-criteria method aligns with protection projects encompassing social, economic, and environmental goals. Tools for quantity support are essential for examining spatial patterns and selecting preferences among various resetting technologies.

In conclusion, the study provides a comprehensive approach to post-fire forest restoration, integrating multi-criteria analysis tools, decision-making methodologies, and spatial decision support systems. The findings highlight the significance of economic, social, and environmental factors in guiding restoration strategies, emphasizing the need for adaptive management for long-term sustainability.

IV. New scientific results

1. The study is the first in the Mediterranean region to use a Comprehensive Criteria and Indicators framework for forest restoration after fires, focusing on creating sustainable restoration strategies.
2. The study aims to make forest restoration after fires spatially impartial by using the Analytic Hierarchy Process (AHP), Decision-Making Trial and Evaluation Laboratory (DEMATEL), and Spatial Decision Support Systems (SDSS). This mixed methodology offers a methodical, clear, and strong approach to forest restoration, considering both qualitative preferences and quantitative causal correlations among criteria. This comprehensive strategy can result in more informed and successful decision-making, ultimately improving the efforts for forest restoration's sustainability and success.
3. The study on post-fire forest restoration management has made significant scientific contributions, including the implementation of spatially explicit decision support systems, the integration of Multi-Criteria Decision Analysis (MCDA), quantitative assessment of restoration costs and benefits, ecosystem services assessment, and evaluation of restoration effectiveness and adaptation strategies, thereby improving the robustness and scientific rigor of decision-making processes.
4. The study effectively impacts data reliability and validity using the CCI framework and Knapsack methodology, making it more beneficial and cost-effective without bias, and eliminating deception in complex, multi-criteria decision-making processes.
5. The study identifies a percentage of the study area suitable for forest restoration after fires, while the remaining land is moderately vulnerable. A comprehensive framework using six criteria (economic, social, environmental, cultural, aesthetic, infrastructural, education, administrative, and legal) is used to make optimal decisions. This framework is particularly important in developing countries to prioritize the most suitable areas for forest restoration. This integration improves decision-making reliability and resilience, allowing for more methodical and transparent evaluation of repair options.

V. Conclusion and Recommendation

5.1. Conclusion

This research elucidates post-fire forest health restoration through the integration of regional decision-making, employing multi-criteria analysis tools (specifically, Analytical Hierarchy Process - AHP) and decision-making/evaluation methodologies such as Decision-Making Trial and Evaluation Laboratory (DEMATEL). The application of these tools, manifested in maps and tables, provides decision-makers with a comprehensive and scientifically grounded basis for making informed and unbiased decisions on the ground. This approach optimizes both time and resources, aligning decisions with a well-studied scientific foundation within national and regional development frameworks. The research underscores the synergy between general post-fire recovery and multi-criteria decision-making systems, aiding decision-makers in strategically allocating limited investments to regions most suitable for recovery. Evaluating the success of forest landscape restoration reinforces post-fire restoration methods, necessitating analyses of social consequences and environmental indicators across diverse spatial and temporal scales. To enhance the management strategy's precision, a micro-assessment monitoring and control system is essential, facilitating adaptive management for long-term sustainability. This necessitates a comprehensive framework encompassing economic, social, environmental, cultural, and aesthetic criteria and indicators, tailored to the unique circumstances of each nation. Priority should be given to areas more frequently damaged or affected after fires, ensuring a holistic approach to forest regeneration.

5.2. Recommendations

By summarizing the results of previous studies, a set of implications related to future research were reached, and they are summarized below as follows:
Post-fire forest restoration management faces several limitations, including fragmentation of responsibility, lack of coordination, unstable funding, and limitations in large-scale investigations. These challenges are exacerbated by social constraints, lack of environmental awareness, limited cooperation with neighboring countries, and lack of technical tools and laws.
To achieve optimal post-fire forest restoration, it is crucial to assess affected areas, determine fire severity, and collaborate among stakeholders like local communities, government officials, and scientists. This can be achieved through developing post-fire forest restoration protocols and identifying spatial and temporal trends in forest restoration.The long-term goal is to balance multiple goals of forest restoration or management by understanding which trade-offs are prioritized simultaneously.
A national database on forest fires based on statistics and open answer questionss

can link post-fire forest restoration to local development through agroforestry technology. This will create incentives for local people to support restoration projects and avoid intensive practices like logging and planting after fires. Amendments to existing legislation prohibiting the removal of burned trees and incorporating principles of environmental science and current knowledge of forest ecosystems can support both national and international networks.

Technical support for post-fire forest restoration includes rehabilitation of lands degraded by fires, determining fire lines in affected areas, reforesting burned lands, finding permanent technical staff trained to fight fires, applying strict penalties to those involved in forest fires, and spraying lands immediately after fires to prevent soil erosion during heavy rains.

In conclusion, post-fire forest restoration management faces numerous challenges, including fragmentation of responsibility, lack of coordination, and limited funding. To overcome these challenges, it is essential to develop post-fire forest restoration protocols, collaborate with local communities,and provide technical support to ensure successful post-fire forest restoration(Muhammad,Qarmouqa and Ibrahim, 2018).

5.3.Research limitations

Forest restoration management in post-fire areas faces numerous challenges, including urban wildfire risks, unstable funding, and management constraints. National governments control forest properties, limiting resources and environmental awareness. There is a lack of a quantitative decision support framework for identifying optimal recovery areas and examining trade-offs between restoration strategies. Rapid population growth, extreme weather events, and changing land use patterns also pose social constraints. Technical tools and data are limited, and knowledge gaps in forest restoration are not adequately addressed.

The ongoing conflict in Syria has hindered data access and decision-maker engagement, with security concerns and reluctance to share information limiting access to critical data banks and materials. The Syrian national development plan has not prioritized forest fire restoration due to the economic crisis, diverting government attention and resources away from environmental concerns. Future research should explore collaborative data-sharing mechanisms, streamline engagement with decision-makers, advocate for forest restoration integration into national priorities, and promote initiatives contributing to the existing body of knowledge on forest fire restoration in the Syrian context.

VI. Summary

Amidst the increasing frequency and severity of forest fires globally, the imperative of effective post-fire forest restoration has gained unprecedented significance. This study outlines a comprehensive approach to post-fire forest restoration and discusses its implementation through spatial decision-making systems. The methodology involves utilizing multi-criteria analysis (MCA) to identify and prioritize criteria based on their relative importance. This allows for the creation of easily assessable alternatives and their application to spatial maps, providing local officials with valuable information. To achieve optimal decision-making, the study utilized the Analytic Hierarchy Process (AHP) and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) methods along with Spatial Decision Support Systems (SDSS) to generate a suitability map to provide a comprehensive and up-to-date framework on the latest developments in forest restoration after fires and how forest restoration can be linked to sustainable development, whether local or regional, by defining requirements and a damage assessment mechanism and defining strategies, goals and operational plans to reach results. desired which includes all multiple planning levels using a variety of spatial and temporal strategies with monitoring and evaluation of forest restoration phases to better guide these strategies and enhance the accessibility of large-scale, multi-objective restoration according to the priorities and needs of the affected areas to rebuild all the values of burned forests combined, which can benefiting from these strategies when regional communication when collaborative integration is a prerequisite to reach a sustainable way and flexibly meets the requirements of changing reality. By examining the most recent advancements in forest restoration during the previous 22 years, this research is the first to frame post-fire forest restoration within an integrated framework.

Over the past ten years, wildfires have had an increasing detrimental influence on the environment, the economy, and society, they have resulted in large-scale, expensive fires that destroy forest and grassland vegetation, and negatively affect wildlife habitat, recreation, tourism, water quality, supply, and values, the consequences, which include expenses associated with restoration, changed habitat for wildlife, decreased tourism income, and adverse health impacts on people, are crucial elements of risk assessment and wildfire management.

Forest restoration is an important field of research that calls for accurate planning and management that involves a national program that promotes fuel processing and forest burning while assisting local economies by selling burnt timber or marketing goods, and all parties involved must be involved for forest restoration to be successful and more flexible. .The results highlight that 28% of the study area is well-suited for post-fire forest restoration, with 44% moderately appropriate, while 3% is deemed unsuitable for restoration until the end of 2023 due to severe soil loss or inherent geographical challenges.

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List of Publications

Journal Publications

1. Utilizing Comprehensive Criteria and Indicators for post- Fire Forest Restoration in Spatial Decision Support Systems (SDSS), Rahaf Alayan, Lakner Zoltán ,Forests, 15(2), p. 386. (2024), Available at: https://doi.org/10.3390/f15020386.

2. A Comprehensive Framework for Forest Restoration after Forest Fires in Theory and Practice: A Systematic Review. Forests 13 : 9 Paper: 1354 (2022). Publication:33067673 , Alayan Rahaf ; Rotich Brian ; Lakner Zoltán

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