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Strategic Financial Management Approaches for Optimization and Improvement of Urban Green Spaces: A Case Study of Isfahan

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Abstract

Urban green spaces (UGS) not only enhance urban aesthetics but also play a significant role in air purification and noise pollution reduction, making them a fundamental element in urban management. However, many citizens and urban planners often overlook the economic importance of these spaces, perceiving them as non-revenue-generating assets. This is while, with increasing population and urban development, the need for such spaces becomes more pronounced. Establishing a sustainable financial model to cover urban costs is a key factor in urban sustainability, which, in addition to cost savings, enables investment in the development of urban infrastructure and green spaces. Plants with diverse capabilities can address various societal needs and even fulfill other urban management objectives. In this study, various criteria for the sustainability of green spaces among the dominant trees and shrubs in Isfahan have been examined. Items such as drought resistance, pest and disease resistance, pollution absorption, leaf and flower diversity, and aesthetic appeal of plant species have been assessed, along with the longevity of species and their maintenance costs. Palm trees, western oak, bitter olive, hackberry, and Shiraz cypress showed the highest value in terms of drought and pest resistance and longevity, while catalpa, viburnum, pride of Barbados, and mulberry demonstrated the highest pollution absorption. The ranking of plants using the AHP method led to cost reduction and increased productivity of green spaces.

Keywords: Analytic Hierarchy Process (AHP), Drought and Pest Resistance in Green Spaces, Financial Management

1. Introduction

The lack of green spaces in large cities has always been associated with psychological, emotional, and physical challenges for residents. Environmental pollution also remains a persistent challenge for urban areas, and energy supply is another critical issue. In many parts of the world, the use of non-level green spaces has become common to increase per capita urban green space. Trees, through oxygen release, particulate absorption, air pollution reduction, stress alleviation, air cooling, pleasant fragrance emission, noise pollution reduction, and energy consumption reduction, offer a practical and cost-effective solution to these problems. According to researchers, green spaces enhance physical activities, provide recreational opportunities in open areas, absorb dust and particulate matter, reduce air pollution and pollutant absorption, lower temperatures and related illnesses, reduce stress, mitigate flooding, decrease noise pollution, create a sense of calm, and increase property values in surrounding areas (Khajehoddin *et al.* 2011). Even in hospitals and prisons, green spaces have been shown to improve the psychological and physical behaviors of residents (Nedučin *et al*. 2010).

Table 1. Green Space Costs (In Billion Rials) and Green Space Area (in Hectares)

One billion Iranian Rial (IRR) is equal to $23,752.97 (USD) (During 2024-2025)

Region	Area (Hectares)	Cost (Billion Rials)	Region	Area (Hectares)	Cost (Billion Rials)
1	54	190	10	227	320
2	201	160	11	44	90
3	70	280	12	242	340
4	901	620	13	175	310
5	375	410	14	125	170
6	363	790	15	76	210
7	270	260	Nazhvan	239	300
8	131	270	Total	3617	4950
9	124	230	Average	226.0625	309.375

Isfahan, with an area of 550 square kilometers and an elevation of 1,570 meters above sea level, is one of the major and polluted metropolises in Iran. With an average annual rainfall of 120 millimeters and an average annual temperature of 16°C, the city has a population of approximately 1,961,000 and a per capita green space of 27 square meters. Isfahan is divided into 15 districts and four complexes, including "The green spaces of the Nazhvan Complex, the fruit and vegetable market, and the public cemetery of Bagh-e Rezvan.", and terminals. In this study, the costs of establishing and maintaining green spaces (such as trees in parks, medians, etc.) during the years 2022-2023 were calculated and presented in the relevant tables. The costs associated with green spaces include water supply by tankers, agricultural inputs, pesticides, fertilizers, and contractual maintenance of green spaces. Considering global standards for green spaces, which recommend 20 to 30 square meters per capita for a healthy life, this study aims to identify and introduce species that enhance the cost efficiency of urban green spaces. Cost management is the process of planning and controlling budgets, where cost efficiency plays a significant role. Cost efficiency is the ratio of benefits to expenditures and is composed of cost effectiveness and cost efficiency. Air pollution, water scarcity, and the low per capita green space in Isfahan highlight the necessity of this research on cost efficiency and management in the realm of green spaces**.** Various studies have been conducted in recent years to select the best plant species for green spaces. For example, Jiménez examined 97 local and 30 native species for green roof planting (Jiménez *et al.*2014), considering criteria such as water requirements, ability to grow in poor soil, flowering period, and aesthetic appeal. Ultimately, four species suitable for the regional climate were identified. In another study, Azad Nejat used the Analytic Hierarchy Process (AHP) to select suitable species for arid and semi-arid regions, considering criteria such as tree form and structure, color diversity, adaptability, and air pollution reduction (Azad Nejat *et al.*2009). They evaluated tree form and structure, visibility within forests, color diversity, adaptability, carbon-to-nitrogen ratio, air pollution reduction, noise pollution reduction, and herbaceous or woody cover, employing fuzzy AHP. Other decision-making methods, such as multi-criteria value function and goal programming, have also been used for prioritization and selection. Asgarzadeh used a mathematical model to select suitable plants for arid and semi-arid regions (Asgarzadeh *et al.*2014). They grouped plants and selected parameters for each group, then ranked plant species for each parameter with the help of experts. To identify the most compatible species based on environmental tolerance, aesthetic appeal, and growth characteristics, they used both AHP and hierarchical cluster analysis, ranking the plants in a table. Generally, the selection of plant species should be based on environmental conditions. For instance, in water-scarce regions, drought-resistant plants should be chosen to withstand dry periods. In areas with alkaline soil, plants that are not sensitive to iron chlorides should be cultivated, as iron is more absorbable in acidic soils. Additionally, native plants resistant to pests should be prioritized (Rupp *et al* 1996), and selection should not be based solely on aesthetics but should consider various functionalities (Sjöman *et al.*2012). For example, street trees should be chosen not only for their visual appeal and suitable branch and leaf texture but also for their resistance to wind, drought, air pollution, and noise pollution. They should have good growth potential, be non-allergenic, and align with the cultural and historical context of the area. Furthermore, fruit trees should be avoided in road medians, and shade-providing, prunable trees should be used instead (Gul *et al* 2012). Sadeghian and Vardanian categorized the criteria for selecting trees and shrubs in Isfahan's urban parks into three groups: 1) compatibility with the climate, resistance to diseases and pests, and growth and propagation potential ,2) tolerance to urban stressors , 3) criteria related to the functional and recreational values of trees (their benefits to the environment) in urban areas (Sadeghian *et al.*2013).

2. Research Findings and Methodology

Various studies indicate that increasing plant species diversity can enhance the aesthetic appeal of urban parks and forests, strengthen urban identity, and improve resilience to diverse environmental conditions. Additionally, proper management of green spaces can reduce costs and increase their productivity (Sæbø *et al.*2013). Barker suggested that planting a variety of plant species can prevent pest outbreaks and promote biodiversity, recommending that no single species should constitute more than 5% of the total tree population (Barker *et al.*1975). Similarly, Smiley advised that no species should exceed 10% of the total population to enhance the resilience of urban forests against varying environmental conditions (Smiley *et al.*1979). Miller recommended limiting urban forest composition to ≤10% of any single species, ≤20% of species per genus, and ≤30% of species per family. These thresholds mitigate pest transmission risks, preserve genetic diversity, and enhance ecosystem resilience to environmental stressors (Miller *et al.*2015).

3.1 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is one of the most effective multi-criteria decision-making methods for weighting criteria and selecting the optimal option based on pairwise comparisons. Introduced by Thomas Saaty, this method determines the weights of criteria and prioritizes options using expert opinions(Saaty ;1980). The primary goal of AHP is to prioritize a set of criteria or options. In this method, after defining the objective, decision-making criteria are identified and weighted through pairwise comparisons. Finally, the options are compared pairwise based on each criterion, and their final priorities are determined. In AHP, increasing the number of elements in a cluster complicates pairwise comparisons, so decision-making criteria are typically divided into sub-criteria. If there is only one decision-maker, the standard AHP method is used, whereas if there are multiple decision-makers, the group AHP method is applied. In the group method, the geometric mean of expert judgments for each criterion or option is used, which, according to Saaty is the best approach for consolidating judgments in group AHP (Ghodsipour ;2009). This is because it preserves the reciprocal property (Asgharpour;2006). Comparisons in this method are based on a complete judgment scale, indicating the extent to which one element dominates another concerning a specific attribute.

4. Research Methodology

This study employs a descriptive research approach. After introducing the problem and defining assumptions, criteria and sub-criteria for species selection in Isfahan were determined using insights from experts and municipal green space executives, as well as collaborative projects with Isfahan University of Technology. Sub-criteria such as wind resistance or shading, which were not universally applicable, were excluded. Following the establishment of assumptions, criteria, and sub-criteria, the importance and relative weights of these factors were assessed through multiple meetings with green space experts and executives, using the group AHP method. In this study, 30 commonly used species, identified by experts as suitable for planting in all regions, were selected as the primary species for evaluation. Each species was scored by experts and compared pairwise in the AHP software matrix. Based on each criterion and sub-criterion, the species were rated on a 9-point Likert scale (ranging from 1 to 9), and their final values were determined.

5. Research Results 1

The hierarchical structure of the objective, main criteria, and sub-criteria of the problem was illustrated in a diagram. The geometric mean of the opinions of 20 experts regarding the weights of the criteria and sub-criteria was calculated, and their values and weights were determined using specialized software. The consistency ratio (CR) was approximately 0.08 or lower in all three cases, indicating that the results are reliable. It is worth noting that 30 samples of ground cover plants and seasonal flowers were also evaluated alongside trees and shrubs. However, due to the increased complexity of the analysis and their relatively lower value scores, the results and related diagrams for these plants were not included in this study.

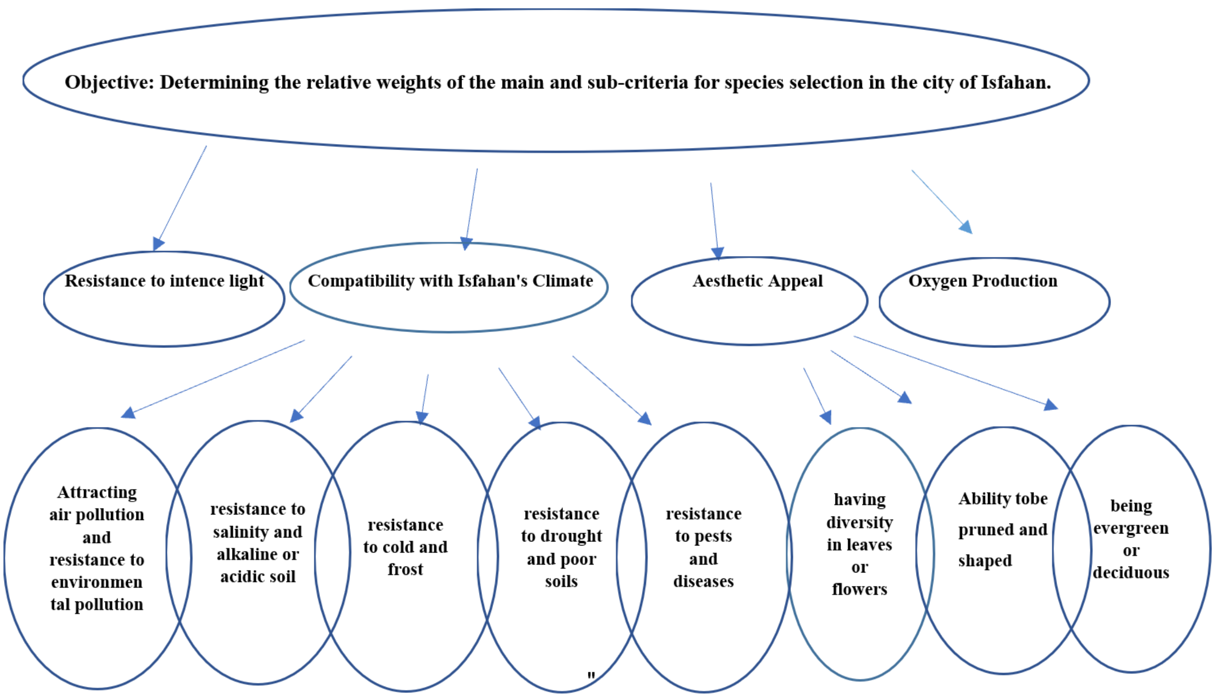

Diagram 1: Hierarchical structure and relative weights of the criteria and sub-criteria of the problem

(The diagram visually represents the hierarchical relationship between the main criteria and their sub-criteria, along with their calculated relative weights).

Table 2. 9-Point Likert Scale

Value	Equal Preference	Intermediate	Slightly Better	Intermediate	Better	Intermediate	Much Better	Intermediate	Absolutely Better
Priority	1	2	3	4	5	6	7	8	9

Table 3. Values of Selected Criteria for Tree and Shrub Species Using the AHP Method

Value in Shrubs	Value in Trees	Criteria for Plant Species Selection
0.236	0.522	Drought Resistance
0.168	0.284	Resistance to Pests and Diseases
0.135	0.066	Air Pollution Absorption
0.461	0.128	Aesthetic Appeal (Leaf and Flower Diversity, Pruning, and Shaping Capabilities)

Table 4. Values of Compatible and Dominant Tree Species in Isfahan's Green Spaces Across Different Criteria and Their Rankings Using the AHP Method

Row	Species	Drought Resistance	Rank	Pest & Disease Resistance	Rank	Air Pollution Absorption	Rank	AestheticAppeal (Leaf, Flower, Pruning)	Rank
1	*Celtis australis*	0.394	4	0.522	4	0.307	7	0.324	8
2	*Melia azedarach*	0.356	5	0.700	2	0.529	4	0.151	13
3	*Fraxinus excelsior*	0.232	9	0.180	10	0.106	12	0.144	14
4	*Cupressus arizonica*	0.286	7	0.281	6	0.094	13	0.386	5
5	*Pinus eldarica*	0.203	11	0.219	9	0.117	11	0.204	10
6	*Morus papyrifera*	0.112	13	0.139	11	0.650	2	0.326	7
7	*Catalpa bignonioides*	0.048	15	0.049	15	1.000	1	0.529	4
8	*Olea europaea*	0.852	2	0.088	12	0.312	6	0.140	15
9	*Ulmus spp.*	0.146	12	0.082	13	0.431	5	0.787	2
10	*Quercus spp.*	1.000	1	0.656	3	0.568	3	0.199	11
11	*Robinia pseudoacacia*	0.101	14	0.068	14	0.274	9	0.359	6
12	*Phoenix spp.*	0.830	3	1.000	1	0.067	15	0.749	3
13	*Juniperus spp.*	0.206	10	0.238	8	0.079	14	0.188	12
14	*Cupressus sempervirens*	0.347	6	0.425	5	0.226	8	1.000	1
15	*Pinus mugo*	0.235	8	0.274	7	0.164	10	0.238	9
	Average	0.3565		0.3280		0.3282		0.3942	

Table 5. Values of Compatible and Dominant Shrub Species in Isfahan's Green Spaces Across Different Criteria and Their Rankings Using the AHP Method

Row	Species	Drought Resistance	Rank	Pest & Disease Resistance	Rank	Air Pollution Absorption	Rank	Aesthetic Appeal (Leaf, Flower, Pruning)	Rank
1	*Nerium oleander*	1.000	1	0.401	5	0.135	12	0.114	13
2	*Cercis siliquastrum*	0.965	2	0.820	2	0.111	13	0.270	7
3	*Ligustrum spp.*	0.509	5	0.483	3	0.345	6	0.389	6
4	*Berberis thunbergii*	0.401	8	0.224	10	0.199	10	0.076	15
5	*Chaenomeles japonica*	0.118	15	0.085	14	0.417	4	0.431	5
6	*Berberis julinae*	0.458	6	0.434	4	0.075	15	0.140	12
7	*Lagerstroemia indica*	0.419	7	0.194	11	0.183	11	0.454	4
8	*Hibiscus syriacus*	0.341	9	0.289	9	0.281	8	0.521	3
9	*Viburnum spp.*	0.221	11	0.362	7	1.000	1	1.000	1
10	*Cotoneaster spp.*	0.155	14	0.434	4	0.092	14	0.170	11
11	*Pyracantha spp.*	0.236	10	0.191	12	0.360	5	0.218	8
12	*Forsythia intermedia*	0.183	12	0.331	8	0.186	9	0.214	9
13	*Lantana camara*	0.173	13	0.172	13	0.326	7	0.746	2
14	*Yucca spp.*	0.842	3	1.000	1	0.538	3	0.090	14
15	*Caesalpinia gilliesii*	0.739	4	0.395	6	0.616	2	0.210	10
	Average	0.4506		0.3876		0.3242		0.3362	

Table 6. Scores and rankings of selected plant species based on various criteria using the AHP (Analytic Hierarchy Process) method.

Trees	Value in All Criteria	Rank	Shrubs	Value in All Criteria	Rank
Celtis australis	0.079	6	*Nerium oleander*	0.067	8
Melia azedarach	0.084	5	*Cercis siliquastrum*	0.091	2
Fraxinus excelsior	0.038	11	*Ligustrum spp.*	0.077	5
Cupresus arizonica	0.054	7	*Berberis thunbergii*	0.025	15
Pinus eldarica	0.039	10	*Chaenomeles japonica*	0.054	10
Morus papyrifera	0.035	12	*Berberis julinae*	0.046	11
Catalpa bignonioides	0.033	13	*Lagerstroemia indica*	0.066	9
Olea europeae	0.097	3	*Hibiscus syriacus*	0.073	7
Ulmus spp.	0.044	9	*Viburnum spp.*	0.128	1
Quercus brantii	0.147	2	*Cotoneaster spp.*	0.036	14
Robinia pseudoacacia	0.026	14	*Pyracantha spp.*	0.043	12
Juniperus spp.	0.039	9	*Forsythia intermedia*	0.040	13
Cupressus sempervirens	0.085	4	*Lantana camara*	0.082	4
Pinus mugo	0.046	8	*Yucca spp.*	0.087	3
Phoenix spp.(Palm)	0.156	1	*Caesalpinia gilliesii*	0.076	6
Average	0.0663		Average	0.0660	

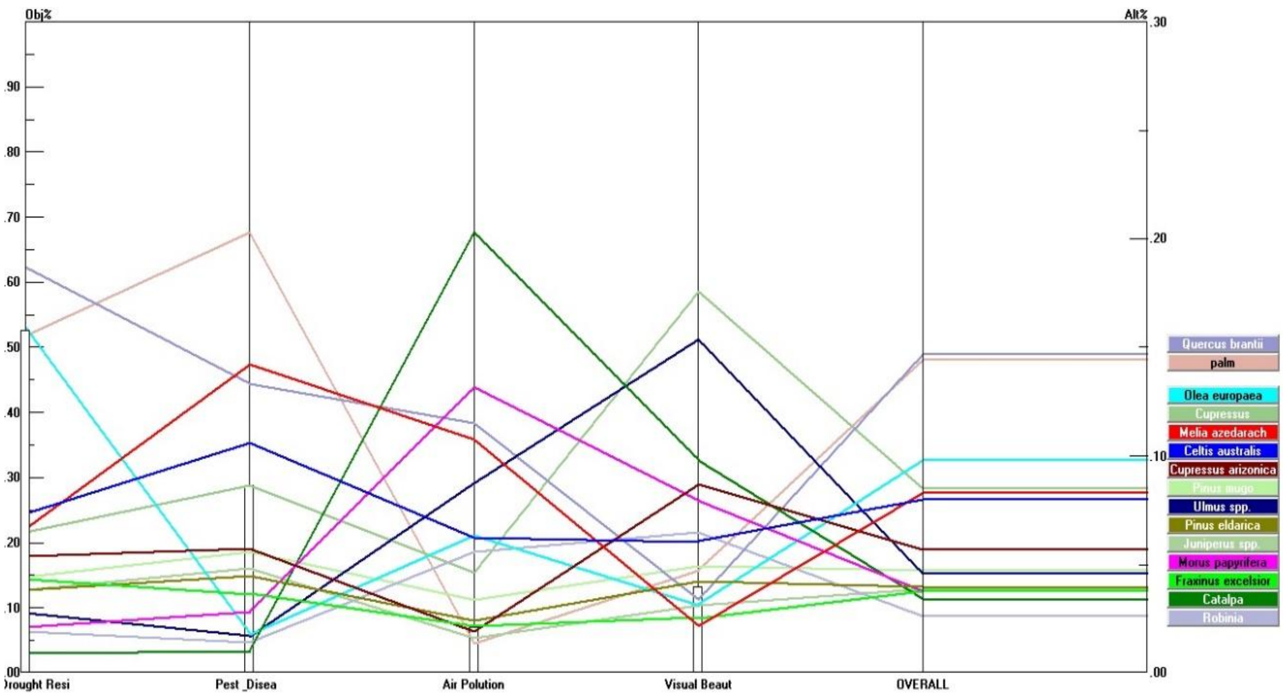

Chart 1: Comparing the Value of trees in Relation to Selected Criteria

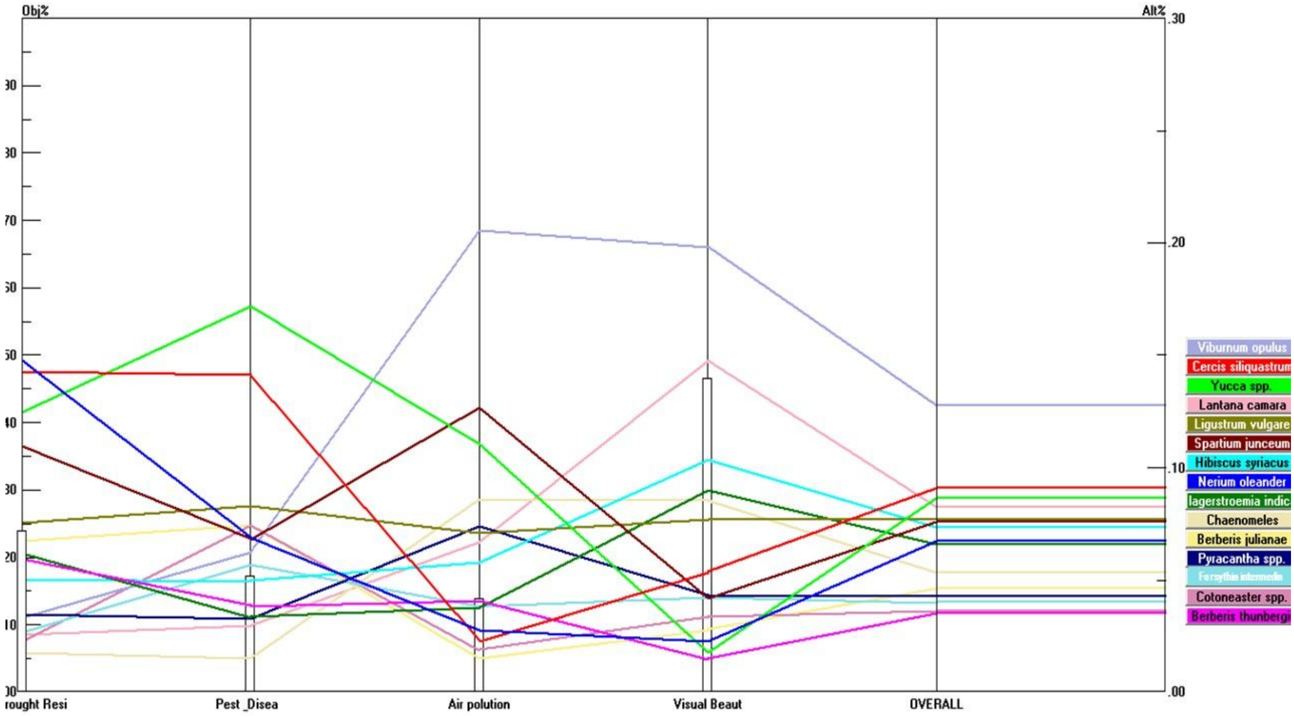

Chart 2: Comparing the Value of shurbs in Relation to Selected Criteria

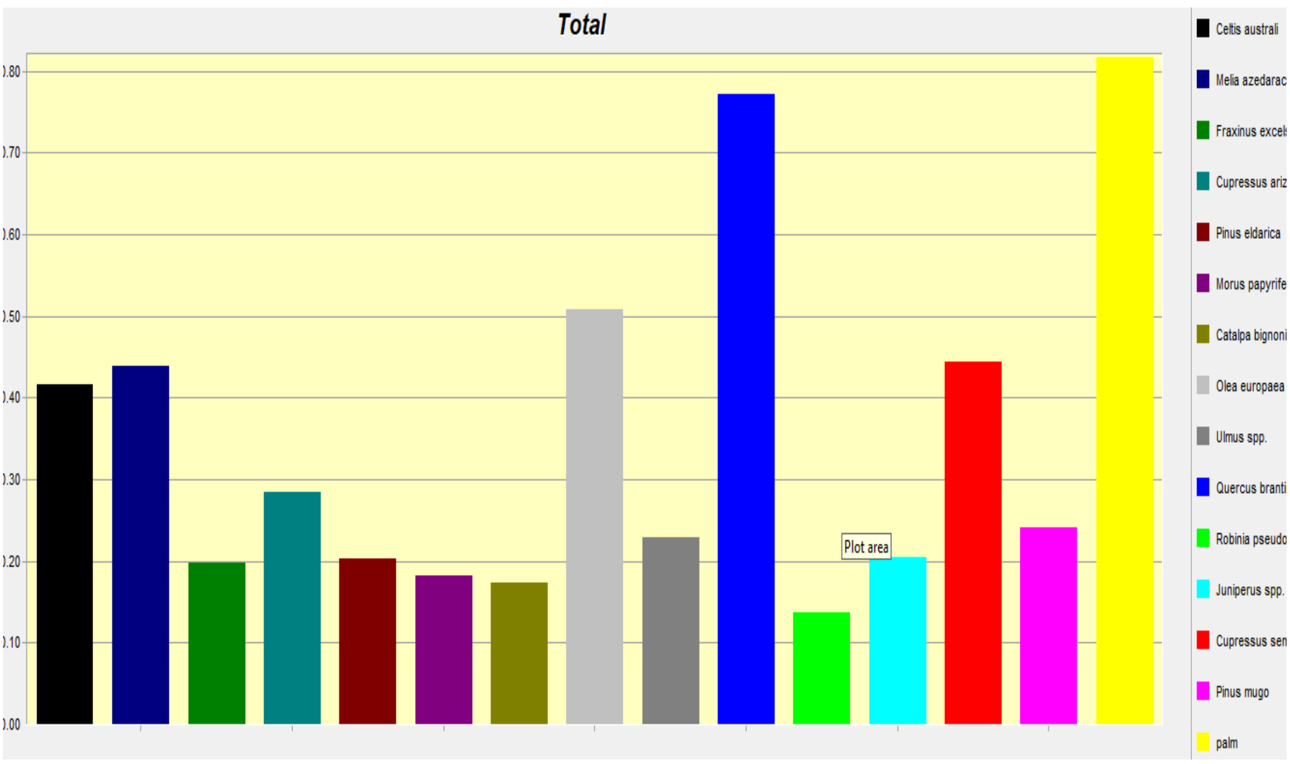

Chart 3: Comparing the Value of Trees in Relation to Selected Criteria

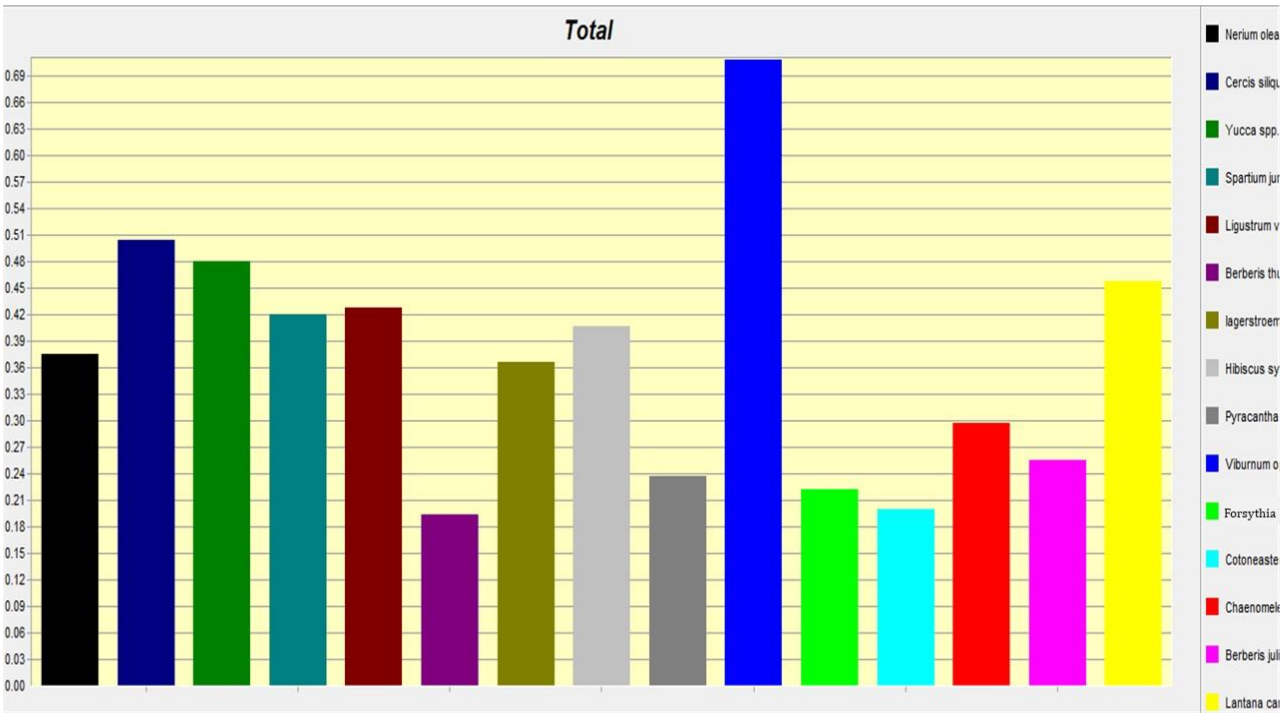

Chart 4: Comparing the Value of shrubs in Relation to Selected Criteria

6.Research Results 2

The hierarchical structure of the objective, main criteria, and sub-criteria of the problem was illustrated in a diagram. The geometric mean of the opinions of 20 experts regarding the weights of the criteria and sub-criteria was calculated, and the values and weights were determined using software. The consistency ratio was approximately 0.08 or less in all three cases, indicating that the results are reliable. It should be noted that 30 samples of ground cover plants and seasonal flowers were also examined alongside trees and shrubs. However, due to the extensive scope of the work and their lower value scores, the related results and diagrams were not included in this study. To demonstrate that our proposed method enhances green space productivity compared to the current situation, the cost productivity index was considered as the ratio of the total value score generated in the city to the total cost of establishing and maintaining green spaces.

Parameters:

(i): Plant species

(Ci): Value of plant species *i*

(j): Region

(ei): Annual planting and maintenance cost per unit of species *i*

(Ei): Annual green space budget of region *j*

(a): Required area per unit of species *i*

(A): Plantable area in region *j*

(Xij): Number of species *i* planted in region *j*

(Z): Total value score generated in the city by green spaces

The maximum total value score in (15 regions + Najvan) = Value of plant species × Number of species planted (Xij) × MAX Z = Ci.

The annual green space budget of the region = Annual planting and maintenance cost per unit of species × Number of species *i* planted in region *j* (ei × Xij) = E.

The plantable area in the region = Required area per unit of species × Number of species *i* planted in region *j* (Xij × ai) = A.

The plantable area in the region and the annual green space budget of the region were extracted from Table 1, and the species and required area per species were determined by experts. Based on this, the total value score generated by green spaces was estimated at 8 million (without a specific scale or measurement) (Masoumzadeh *et al.*2016).

For example, if each region is filled with species of high value, considering the constraints of annual planting and maintenance costs, the required area per species, and the allocation of the number of species (Xij) proportional to the value of each species relative to the total value of species, the total value score of green spaces created in Isfahan city using the above formula would be approximately 10.89 million, which is 36% higher than the current situation.

7. Results

Financial and risk management in the development of urban green spaces, especially in cities like Isfahan, requires a comprehensive and sustainable approach that simultaneously ensures sufficient financial resources and mitigates risks associated with green space projects. The case study of Isfahan demonstrates that the use of modern financial models to attract private investments, participatory models (such as public-private partnerships), and advanced technologies (such as smart irrigation systems, planting low-water-demand species, and eliminating high-water-demand species) can improve financial management and reduce the maintenance costs of green spaces. On the other hand, citizen participation, precise planning, and the identification and management of financial, social, and environmental risks (such as drought and climate change) through continuous evaluation and flexibility in project implementation play a key role in the sustainability and success of green space projects.

Every year, we witness an increase in the costs of green spaces and, consequently, a demand for higher budgets. Therefore, given this issue and the scarcity of water resources, the best approach is to reduce costs. Implementing green spaces using the proposed method will increase cost productivity by 36%. For example, if the total value score generated by green spaces in terms of visual appeal, air purification, pollution reduction, climate compatibility, and water savings is 4950 Billion Rials, the proposed method will increase the total value score of green spaces by 1.36 times. If diversity is not considered and more resistant trees, such as oak, are planted, this value can reach up to 1.46 times, resulting in significant cost savings. In fact, to achieve this value, instead of spending 4950 Billion Rials, 6730 Billion Rials would need to be invested, meaning that implementing this method would lead to a cost reduction and savings of approximately 1780 Billion Rials.

This method involves several steps:

1) Determining the correct criteria for species selection and establishing their hierarchy.
2) Surveying experts to identify species and score each one based on the criteria, determining their weights.
3) Valuing and ranking the species.
4) Determining the optimal combination of species and using them in the green spaces of different regions.

Trees, in addition to consuming less water compared to other plants, are more effective in reducing pollution. Therefore, it is recommended that, considering the soil and water conditions of wells in each region, as well as the value-added of species, a combination of trees, ground cover plants, and seasonal flowers be planted. Criteria such as pollution reduction, resistance to pests and diseases, drought tolerance, aesthetic appeal, and diversity in color and flowering should be considered. Finally, if non-level green spaces (such as green roofs with renewable design systems) or vertical green spaces (green walls) are added, significant energy savings can be achieved. For example, incorporating green wall systems into the initial building design while eliminating the costs of building façade construction will be economically beneficial.

Additionally, the impact of trees on the climate, which contributes to creating suitable tourist spaces by attracting both domestic and international tourists, thereby boosting the city’s and country’s economy, is a point that should not be overlooked. It is hoped that Isfahan’s experiences will serve as a model for other cities in Iran in pursuing sustainable urban green space development.

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Authors contributions

Dr. Narges Karimi was responsible for the study design and revisions. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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