Evaluation of sustainable landscape services based on the analytic network process (ANP)

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Network analysis models play an effective role in understanding and identifying the mutual pattern-function relationship in the ecological landscape. The concept of landscape services has changed during the time following the changes in human behavioral patterns of satisfaction of needs and requirements from the nature and its resources. Accordingly, due to the changes in structural components, ecological processes and human activities, in the interaction between human and the environment, its value is not fixed environment following the time and place conditions and its valuation and this trend is of significance in the decision makings and metropolitan management. Changes in the structural components, ecological processes, and human activities in the human-environment interaction are a function of the time and place conditions. Therefore, the rate of these changes has not been fixed and such a trend is of significance in urban macro management. Considering the important role of landscape services in the developments of a sustainable urban landscape, the present study attempted to identify and prioritize the indices of sustainable urban landscape services. Evaluation of the landscape services of river valleys has a significant role in the structural and operational development of the urban environments as an ecological unit and helps to explain the share and role of different variables in the development of urban landscape sustainability. Quantitative analyses were used for identifying the influential factors; a survey method through questionnaire was used for this purpose. Based on the results related to identification and prioritization of the model criteria and alternatives, using a network analysis approach the factors were prioritized in five classes of indices include in provisioning, regulatory and maintenance, aesthetic, spatial structure and wellbeing, and a set of alternatives including sustainable, vulnerable and disturbance ecological network. The findings show that classification of different dimensions can improve the effectiveness and functionality of the indices in the pattern-function-value conceptual framework when making decisions. Furthermore, the sub-class of joy, health, and flow regulation have the largest importance in determining the sustainable landscape of urban ecological network and the highest priority among the alternatives was found to be for sustainable ecological network of the landscape.

**Keywords:** Evaluation, Network analysis, Landscape services, Ecological processes, Human activities

INTRODUCTION

Ecological systems are defined by biodiversity or heterogeneity and complexity. Complexity normally refers to the nonlinear interactions between a number of system components, which consistently lead to certain features such as unpredictable dynamicity and self-organization [15]. As a social-ecological system, city has dynamic components [6] and facilities and their use is influenced by direct and indirect factors of time and space scales. Resilience or capacity of System can help to protect the landscape identity in terms of function, structure and feedback through experience and in dealing with the disturbances [28]. Heterogeneous basis of landscape is a prerequisite for increased resilience of the ecosystem against environmental fluctuations, which is strengthened with the development of continuity and flows among the systems [1]. Urban planners have to converge with the ecologists in using urban landscape concepts for the purpose of urban development. Considering the consolidated views between urban ecology and landscape ecology, this planning system will be responsible in terms of urban sustainability [31, 32]. Landscape ecology is the study of the mutual effects of spatial models on the environmental processes at the large scale, which has three important aspects including structure (spatial model), function (interaction between spatial lements) and change (dynamic and constant changes during different time periods) [17]. Landscape ecology considers landscape as a heterogeneous physical mosaic with hydrological features and vegetation, which has a proportionate function, size and status for supporting the lifecycle of the native species [30] while ecological processes are highly influenced and controlled by human activities. Urbans have the largest heterogeneous landscapes, which need balance and sustainability in time and place because of the developmental system. Urbans’ sustainability requires protection of the environment, economic development, and social welfare and improved quality of the ecosystem services to be able to preserve the natural resources. The ecological landscape framework and social-ecological system of the urbans need close scrutiny to be sustainable [3,4]. As a comprehensive whole of ecological-human systems with a wide range of functions (as services), landscape is evaluated by human in economic, sociocultural and ecological dimensions, because these services are intended for human existence and wellbeing [7]. The concept of landscape services includes social dimensions and spatial pattern and originates from ecological and human processes in line with providing certain benefits to human [27]. Accordingly, multi-functional of the ecosystem services is examined and analyzed at different scales. Based on the integration and transdisciplinary concept of landscape, Termorshuizen and Opdam suggested that the concept of landscape services will be beyond ecosystemic services due to the combination of natural and cultural aspects taking into account the spatial pattern and participation of the beneficiaries particularly in the area of landscape planning at the local level. In fact, this study deals with human’s identification and understanding of the surrounding environment with regard to the tangible and intangible values that are directly or indirectly related to people’s social and cultural structure [23, 25]. Evaluation of the landscape services in the sense of evaluation can be described in terms of wellbeing, health, beliefs and biological values governing any social system in its relationship with the surrounding environment. The main question addressed in the present study was ‘what are the landscape services indices regarding sustainable, imbalanced and sensitive urban ecological network and what priorities do they have?’

BACKGROUND

*Landscape services indices*

The word ‘landscape’ has different meanings and landscape science has been a controversial issue from the very beginning [33]. The historical geographist Muir pointed out the following in reference to landscape: landscape history and landscape heritage, the practice of landscape history, the structure and scenery approach, landscapes of the mind, landscape, politics and power, the evaluation of landscape, the symbolic landscape, the aesthetic approach, landscape and place. According to Claval, landscape is a combination of geographical environmental relationships, spatial patterns, landscape quality, aestheticism and even social and cultural traditions[5]. As pointed out by Antrop [2], landscapes have holistic, perceptual and dynamic features. The holistic features need a hybrid and transdisciplinary approach in which the natural and cultural aspects of the environment have been structurally integrated [21]. As Humboldt (1769-1859) puts it, landscape perceptually is flowing, and changes in the dimensions of time and place. Man takes a role as a key element of landscape. Accordingly, human thought and understanding of the surrounding environment becomes a beginning for expressing the concept of landscape. Landscape refers to human understanding of the surrounding environment and the behavior he has shown and, consequently, his influence on the environment. As the nature, landscape will change without human interference; landscapes are always changing and developing [3]. Laitao and Ahren defined the functional and structural descriptive principle of landscape in four trends including physical planning, economic planning, social planning and integrated planning due to the extensive features of landscape. Naveh pointed out that cultural landscape is the tangible point between nature and mind and protection of its cultural assets should be an inseparable aspect of a holistic and dynamic landscape management [20]. This kind of landscape is more than a mosaic puzzle in the replicated models of an ecosystem because it preserves the complexity of a landscape in the form of an organized multi-dimensional landscape. The dynamic features of landscape refer to the processes and their function [13].

It seems that the more diverse the landscape is, the richer its social value will be. One of the main functions of landscape management is to help to have a better understanding of the formation process of the present landscape in a way that the future changes and the expected outcomes can be modeled based on this understanding. Understanding human cognitive ideas and concepts about the environment, evaluation of biodiversity, landscape variety and cultural diversity is essential for creating an intelligent and sustainable management system [10, 19]. Based on a holistic view, the hierarchical organization of landscape is an indication of the relationships between its elements [22]. Its material and immaterial dimensions show that landscape is not just a geographical unit consisting of abiotic, biotic and man-made elements but involves human understanding of the environment. Taking this conceptual aspect into account has a different meaning for human role compared to the ecological view approach [25], that is man is seen not just as an element that has influential positive and negative effects on the nature but as an inseparable part of landscape.It means that landscapes are the result of interaction between natural and human processes; people have been influenced in the context of landscape during the time to adapt themselves to their changing needs and, at the same time, and, at the same time, have been influenced by these landscapes [27]. Therefore, in the social-ecological system, the system components are dynamic and their facilities and feedbacks are affected by direct and indirect factors in a variety of spatial and temporal scales and it is system resilience or system capacity that can preserve the structure, feedback and identity of the landscape in terms of functioning [28]. Biodiversity, ecosystem functioning and human activities all happen at the landscape level and fragmentation greatly disrupts the ecological-social and economic processes [30]. In the structural and functional studies on ecological landscape, the output from the stability mechanism is in the form of services, profitability and protection of assets including three principles of dynamicity, balance and continuity. The processes between these two systems try to create a stable structure based on the principles related to any system. Using CICES (Common International Classification of Ecosystem Services) Valles-Planells presented landscape services based on the theories that emphasize human welfare services, classification of ecosystem services and also perception of landscape by human [27]. In the emphasis on the relationships between the systems and human activities, two views 1) one based on protection of nature from the echo-physical aspect of landscape and another 2) considering landscape as a culture, have been focused on, though based on the multifunctional view of landscape, natural and cultural aspects become one.)Figure 1(.

Social-ecological systems management seeks a stability system based on the need for moving toward the development of a holistic framework for creating a balance between the two systems and preservation of values, human welfare and natural resources. The views about the development of landscape have been changing in line with profitability due to the presence of human [2]. Therefore, landscape processes are bottom-up and at the local level in the form of demand and change of economic, social and ecological values and functions. This scientific effort and knowledge provides the opportunity for the relationship between the landscape physical structures and functions [25].The existence of a relationship between the capacity spaces of landscape prepare the ground for activities and social encounters in the complex space for discovery and learning. Even using disturbance buffers can help to create a friendly environment for the people and increased opportunities for enjoyment [14]. Landscape services classifies a set of concepts like process, function, and patterns of the two systems, which includes the ecosystem services, in the form of values and profitability based on the needs and demands of the beneficiaries (human).The concept of landscape function was classified into provisioning, regulatory and cultural services, the concept of landscape structure was classified by presenting spatial structure services, buffer, and the concept of landscape values were classified in terms of aesthetic services, welfare, and wellbeing. Table (1) presents the criteria and the sub-criteria identified in evaluation of landscape services



**Fig. 1.** Ecosystem services and Landscape services in Social-ecological systems

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**Table 1.** presents the criteria and the sub-criteria identified in evaluation of landscape services

| **Landscape Service** | **criteria** | **sub-criteria** | **Definition** | **Reference** |
| --- | --- | --- | --- | --- |
| **Provisioning** | **Biodiversity** | Fauna |  Fauna Diversity  | [9, 12] |
| Flore |  Flore Diversity  | [9, 12] |
| Naturness | Native |  Native adapted specie domination | [12] |
| Tree and shrub combination |  Diversity in structure of biodiversity | [9, 12]  |
| Daily activates | Place to live | Provision of a space for residential location, a home. | [7, 34]  |
| Place to work | Provision of open spaces or urbanized areas where people develop their job. | [7, 34]  |
| Place to move | Provision of spatial communication. It is not only related to transport networks but also to open spaces that allow people to commute, travel, or just access other services. | [7, 34] |
| **Regulation&Maintenance** | Regulation of wastes | Bioremediation | Improvement of water quality  | [18] |
| Dilution and sequestration | Improvement of soil quality  | [18] |
| Flow regulation | Air flow regulation | The structure and continuity of airflows in corridors | [18] |
| Water flow regulation | The structure and continuity of water flows in corridors | [18] |
| Mass flow regulation |  The structure and continuity between the elements of corridors | [18] |
| Regulation of physical environment | Atmospheric regulation | Adjusted anthropogenic on the micro-scale climate | [18] |
| Water quality regulation | Adjusted anthropogenic on the micro-scale climate | [18] |
| Regulation of biotic environment | Lifecycle maintenance and habitat protection | Dynamics and persistence of biological cycle and environment | [18] |
| Gene pool protection | Species and their habitats in the ecosystem | [18] |
| Pest and disease control | Strengthening the biological systems to combat invasive species at micro-scale  | [18] |
| Regulation of the spatial structure | Connection of spaces | Ability to facilitate ecological, visual, or functional connectivity between different areas | [12]  |
| Buffer disturbing use | ecological or perceptual point of view Ability to separate incompatible uses and temper negative interactions from an | [12] |
| Provision of spatial complexity of the place | Related to the degree of diversity and richness of landscape elements that may improve possibilities for exploration, resilience, and visual absorption capacity | [13] |
| **Aesthetic** | Enjoyment | Mental health | Contribution to the enhancement of physical fitness by facilitating walking or other alternative ways of transportation and the practice of open air sports. | [8] |
| Physical health | Opportunities to relax, recover from stress, escape from our daily routine, find tranquility, be calm, or just fulfill our need ofmental space | [18] |
| **Well being**  | Health | Passive enjoyment |  Enjoyment of attractive vistas, a quiet place to read a book, the possibility of seeing wildlife, or cultural heritage. | [35] |
| Active enjoyment | Related to more dynamic ways of enjoying spare time like opportunities for hiking, climbing, gardening, hunting, fishing, or providing a place for children to play.  | [35] |
| Self-fulfillment | Way-finding |  Provision of cues that enhance our spatial orientation, our sense of where we are, and how to get where we are going. | [16, 34] |
| Scientific resources | Source of research for a wide range of fields such as history, geography, botany, ecology, geology, or archaeology. | [14] |
| Didactic resources | Opportunities to learn about rock formation, flora and fauna species, past civilizations, or traditional farming practices. | [7, 34] |
| Spiritual experience | Provision of sacred places for religious practices or sites connected to legends or myths. | [14] |
| Source of inspiration | Inspiration for art, literature, music, architecture, cinema, or advertising. | [7] |
| Social fulfillment | Social interactions | Provision of social surroundings | [14, 34] |
| Place identity | Contribution to shaping of community identity by providing icons and distinguishing it from others. | [14, 34] |
| Sense of continuity | Provision of stable reference points through the life course. | [14, 34] |
| **Regulation of the spatial structure** | Spatial structure | Connectivity | Ability to communicate between the environmental features, visual, and function in different regions | [12] |
| Fragmentation | An inverse relationship between fragmentation and sustainability | [12] |
| Buffer | Buffer disturbing | The possibility of separating incompatible land uses and negative interactions of point of view environmental and perception | [12] |

On the other hand, ecological units are based on human activities under the conditions of change in terms of landscape function and services, their level of adaptability and resilience capacity or flexibility; the effects occur in two dimensions of time and place. The relationship between elements of ecological units of a city in an ecological-social system can be described in the following three states or situations: **Sustainable ecological unit**: which has such features as promotion of the methods of protection and development of natural corridors, increased sustainability and continuity in the ecosystem processes, development of environmental and human life infrastructures, species diversity, development of social values (an adapted combination of changes in Land Use/Land Cover (LULC) with regard to the beneficiaries and landscape services) .**Vulnerable ecological unit:** vulnerability is indicative of a time when the system is exposed to some disturbing factors. Sensitivity, on the other hand, shows the effect of disturbing factors on the system and its potential adaptive capacity for regulating or confronting with them. This level of sensitivity along with transparency can, to a large extent, facilitate understanding their effects, interaction or merger with the twisted coil of vulnerability. A vulnerable social system and environment generally loses its resilience [11]. In other words, a system can have high resilience, but by being exposed to disturbing factors and high sensitivity, this system can be considered as vulnerable. This concept has wide applications in ecological-social studies. **Disturbance ecological unit**: disturbance is an event that can lead to a change in the structure or functioning of a system to a great extent by changing its model. In ecological units, this process leads to disturbance by fragmentation and disintegration of a habitat and by conversion of an ecosystem into smaller units.

*Analysis of network process*

Analysis of network process (ANP) provides a holistic framework for decision-making without taking into account presumptions about the independence of high-level factors from the low-level factors and independence of the factors at one level as a hierarchy [24]. Due to the simultaneous use of qualitative and quantitative methods, ANP can examine adaptability in judgments and has the ability to rank the final alternatives and can, therefore, determine the interdependence between criteria and the relationship between the elements of a complicated urban system. For comparing and judging the sub-criteria, Saaty’s quantitative table was used for developing a questionnaire and seeking experts’ views.The ANP technique is used as an option from three unconventional perspectives because in the framework of evaluating landscape cultural values, objective and subjective data are used in two biological and physical dimensions [6]. Accordingly, the need for selecting and consolidating subjective (conceptual) and objective parameters by the people for analysis the pattern-function process of the landscape makes multiple structural development or combination of the results a requirement for defining the goal [26]. Although indices are used mainly in evaluation of Land Use/Land Cover changes, during the recent years, landscape services criteria have been widely used for determining the diversity of ecosystem services and landscape functioning.

METHOD

The present study is applied research in nature and the method used in this study is descriptive/survey-based. The target population included university experts and managers of municipalities in 22 districts of Tehran. The data collection methods included the field and library methods. In the first, phase of the study, the related concepts were extracted from the literature and then a questionnaire was used for evaluating and ranking the factors. The sample population included 350 participants, out of which 149 were selected using the Cochran's sample size formula. Simple sampling method was used for this purpose. The questionnaire was distributed to the expert participants and their view about any of the dimensions was sought. The collected data were analyzed using Analytic Network Process (ANP). Super Decision software was used for this purpose. Geometric mean of experts’ views was used for find out the significance of the criteria, sub-criteria and the research alternatives. Five criteria, 35 sub-criteria and three alternatives related to landscape services and based on the theoretical framework were selected. Then, taking into account the conditions and features of Tehran metropolis and also data accessibility needed in the related scales, they were prioritized using the pattern-function framework, landscape services value, and based on network analysis steps.

IMPLEMENTATION OF THE ANALYTICAL HIERARCHY MODEL

*Formulating the network structure of the research problem*

One of the first steps of ANP is to draw the network structures of the problem. For developing the network structure of the problem, first the research criteria and alternatives are detected. Using the information in the review section and experts’ views, the influential criteria in evaluation and selection of sustainable urban landscape ecological network screened and prioritized. After identifying and classifying the research criteria, the research alternatives were identified. Urban ecological units, i.e., river valleys were selected as the area of study. An analysis of the landscape services in the ecological-social system of this units requires a study of the effects of human interference (*Anthropisation*) on dynamicity and heterogeneity of landscape and necessitates human understanding of the environmental processes [29]. What was analyzed as a stable and dynamic ground for urban ecological units in the process of welfare and health benefits of sustainable landscape services were extracted in three states of sustainable ecological network, vulnerable ecological network, and disturbance ecological network landscape. After examining landscape services and the relationship of landscapes’ physical structure and function with their values, sustainable landscapes were selected as the research alternatives. Table (2) presents the identified criteria and alternatives.

With the research criteria and alternatives being determined, the relationship between structural factors should be identified. In this study, an analysis of the related literature and experts’ views, it was found that besides a linear bottom-up relationship in the hierarchical structure, other relationships seem to also exist, as shown in Figure 1:

* The provisioning services criterion has an effect on the regulatory criterion. It means that if urban ecological network sustainable landscape wants to balance biodiversity, naturalness and daily activities, it should manage and regulates the processes, Regulation of waste management, physical environment, the biotic environment, and the spatial structure from functional perspective otherwise urban ecological units will tend to be vulnerable and disturbed.
* The four criteria including provisioning, regulatory and maintenance, aesthetic, and well-being and d recreation are always influenced by spatial structure. In other words, if spatial structure (spatial connectivity and/or buffer) are the components of a dynamic landscape, this criterion can influence other dimensions of landscape services besides a relationship with the main criteria. That is, the existence of such a spatial structure in ecological units’ landscape of a urban will not only have landscape functional services but will also lead to value services and landscape patterns dependent on these services. The conditions of change in landscape values during the time appear as an opportunity.
* Regulatory and maintenance criteria also influence aesthetic and wellbeing and recreation criteria. This means that functional landscape and sustainable urban ecological network may cause damage to landscape or disturb it in provisioning of or responding to the aesthetic and wellbeing and recreation needs due to the large volume of human interference in the ecology of the region by changing structural and functional capacities.
* Aesthetic criterion can be also related to recreational and wellbeing, and also regulatory and maintenance criteria. Desire for enjoying and human understanding of the environment in line with the promotion of objective and subjective values, may change landscape into human-oriented landscape and, accordingly, change the services.
* Recreation is also related to the other four criteria including provisioning, regulatory and maintenance, aesthetic and wellbeing, and spatial structure.

With the criteria, alternatives and their relations being determined, the following network structure (see Figure 2) was obtained.

*Calculating the relative weight of the criteria, sub-criteria and research alternatives*

For calculating the relative weight of the criteria, sub-criteria and research alternatives, first *related paired comparisons questionnaire* was developed. The developed questionnaire was then distributed to the experts. The collected data was analyzing using the Super Decision software to evaluate and calculate the weight of different factors. If the incompatibility of the paired comparison matrix of the factors is acceptable (i.e., less than 0.1), the comparisons will be of a high validity otherwise the questionnaire should be returned to the experts to be revised. Figure (3) shows paired comparison matrix obtained from the respondents and entered into the software. Table (2) also shows the normal and ideal weight of the research criteria as well as the compatibility rate.

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**Fig. 2.** Relations structure between criteria and alternative

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 9 | 8 | **7** | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | **7** | 6 | 5 | **4** | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | **7** | **6** | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | **5** | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | **2** | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | **4** | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | **4** | 5 | 6 | 7 | 8 | 9 |
| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | **2** | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

**Fig. 3.** Paired comparison matrix of the main criteria taking into account the alternatives

**Table 2.** Normal and ideal weight of the criteria along with the compatibility rate

|  |  |
| --- | --- |
| *Alternatives Provisioning Reg & Main Aesthetic Well & Rec Norm weight* | *Ideal weight* |
| Alternatives 1 7 4 6 3 0.17 | 0.42 |
| Provisioning 1/7 1 1/5 1/2 1/4 0.40 | 1.00 |
| *Reg & Main* 1/4 5 1 3 1/4 0.21 | 0.53 |
| Aesthetic 1/6 2 1/3 1 1/2 0.07 | 0.17 |
| Well & Re 1/3 4 4 2 1 0.06 | 0.15 |

As shown in the table, one of the main criteria, i.e., provisioning, obtained the largest weight, which is an indication of its high importance in achieving the research goal. After provisioning come regulatory and maintenance criteria and spatial structure, aesthetic, wellbeing and recreation come next. Based on the calculations related to the external relationship among the criteria, alternatives have more importance and are higher in position compared to the criteria. For example, from the perspective of spatial criterion, it was found that alternatives have a higher significance compared to the alternatives and provisioning, regulatory and maintenance, wellbeing and recreation, spatial structure and finally aesthetic criteria are next in importance. Furthermore, for examining the alternatives , the same procedure is used based on which the obtained information related to landscape, biodiversity comes first as the main sub-criteria for provisioning of the sustainable ecological network. Disturbance ecological network and vulnerable ecological network come next. From the perspective of regulatory criterion, wastes are the main sub-criteria for regulatory and maintenance criteria while all the other alternatives have an equal value and priority. In terms of active enjoyment, disturbance ecological network is the first and vulnerable and sustainable networks come next in importance. Finally, with regard to the health criterion as the main sub-criterion for wellbeing and recreation and spatial relationship as the main sub-criterion for spatial structure, sustainable ecological network is in the first position and after that come disturbance and vulnerable ecological networks.

*Forming the super matrix*

After developing the network structure of the study and paired comparisons and obtaining the relative weights, the super matrices were developed. The first super matrix is the unweighted super matrix, which is formed by entering the weights obtained from paired comparisons in the matrix. As the sum of the factors in some of the columns of the super matrix does not equal 1, we cannot conclude that the final effect of the respective control criterion on all the factors has been shown. Therefore, the weight of any of the factors in the clusters of super matrix column should be multiplied by their relative importance vector so that the sum of the factors in all the super matrix columns becomes 1. The super matrix formed in this way is called a weighted super matrix. After formation of the weighted super matrix, it should be exponentiated by an optional big number so that the relative long-term effects for any of the factors in the super matrix on one another can be gained. In this way, all the factors in the super matrix rows become equal. This super matrix is then called limit super matrix. In other wise,the eigenvector obtained from the cluster level comparisonis applied to the initial supermatrix as a cluster weight. The result is the weighted supermatrix[24]. In the final step, the weighted supermatrix is made to converge to obtain along-terms table set of weights. The supermatrix is raised to a limiting power to obtain the limit supermatrix, where all the columns are identical and each gives the global priority vector.

**Table 3.** Limit super matrix of the research model

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Alternatives | Provisioning | Reg & Main | Aesthetic | Well being  | Regulation |
| S | D | V | BIO | NAT | DACT | WAS | FL | PH | BI | SP | GA | EC | SE | SO | HE | VH | AH |
| Alternatives | S | 0,00 | 0,00 | 0,00 | 0,15 | 0,09 | 0,00 | 0,09 | 0,15 | 0,13 | 0,13 | 0,15 | 0,00 | 0,09 | 0,150,070,78 | 0,09 | 0,09 | 0,09 | 0,09 |
| D | 0,00 | 0,00 | 0,00 | 0,07 | 0,09 | 0,00 | 0,09 | 0,07 | 0,08 | 0,08 | 0,07 | 0,00 | 0,09 | 0,09 | 0,09 | 0,09 | 0,09 |
| V | 0,00 | 0,00 | 0,00 | 0,79 | 0,82 | 0,00 | 0,82 | 0,79 | 0,79 | 0,79 | 0,79 | 0,00 | 0,82 | 0,82 | 0,82 | 0,82 | 0,82 |
| Provisioning | BIO | 0,50 | 0,50 | 0,13 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,00 | 0,00 | 0,00 |
| NAT | 0,50 | 0,50 | 0,87 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,00 | 0,00 |
| DACT | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Reg & Main | WAS | 0,07 | 0,14 | 0,130,050,400,390,03 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,58 |
| FL | 0,07 | 0,14 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,88 | 0,88 | 0,00 | 0,83 | 0,00 |
| PH | 0,53 | 0,43 | 0,00 | 0,00 | 0,00 | 0,75 | 0,88 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,13 | 0,13 | 0,00 | 0,17 | 0,23 |
| BI | 0,20 | 0,14 | 0,00 | 0,00 | 0,00 | 0,25 | 0,13 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,13 |
| SP | 0,13 | 0,14 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,06 |
| Aesthetic | GA | 0,00 | 0,00 | 0,00 | 0,00 | 0,28 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| EC | 0,25 | 0,13 | 0,25 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Well being | Se | 0,51 | 0,50 | 0,05 | 0,00 | 0,00 | 0,00 | 0,00 | 0,14 | 0,39 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| So | 0,23 | 0,10 | 0,03 | 0,00 | 0,00 | 0,00 | 0,00 | 0,43 | 0,06 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| He | 0,08 | 0,10 | 0,29 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Regulation | SP | 0,14 | 0,20 | 0,07 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| BU | 0,14 | 0,20 | 0,22 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,17 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

In the limit super matrix, the weights of all the factors are determined. In this matrix, the numbers shown in each row indicate the weight for the corresponding factor. For instance, the number 0.096011 is a limit weight for naturalness criteria (Table 3). To be able to use these weights in our analysis and ranking, we should normalize these weights. Normalized weight and also limit weight of the factor are presented along with their rank in Table 4.

**Table 4.**  Normalized weight and limit weight of the factors along with their rank

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factor (alternatives or criterion) | Sub-factors (sub-alternatives and sub-criteria) | Normalized weight based on classes | Limit weight | Rank based on class |
| Alternatives  | 1 Sustainable Ecological Network | 0.47 | 0.18 | 1 |
| 2 Disturbance ecological network | 0.28 | 0.11 | 2 |
| 3 Vulnerable ecological network | 0.25 | 0.09 | 3 |
| Provisioning  | 1 Biodiversity | 0.45 | 0.14 | 1 |
| 2 Naturalness | 0.31 | 0.09 | 2 |
| 3 Daily activities  | 0.24 | 0.07 | 3 |
| Regulatory and maintenance  | 1 Regulation of wastes | 0.37 | 0.06 | 1 |
| 2 Flow regulation | 0.29 | 0.05 | 2 |
| 3 Regulation of physical environment | 0.12 | 0.02 | 3 |
| 4 Regulation of biotic environment | 0.11 | 0.02 | 4 |
| 5 Regulation of the spatial structure | 0.11 | 0.02 | 5 |
| Aesthetic  | 1 Mental health Enjoyment | 0.75 | 0.04 | 1 |
| 2 Physical Health Enjoyment | 0.25 | 0.01 | 2 |
| Wellbeing and recreation  | 1 Health | 0.52 | 0.02 | 1 |
| 2 Self-fulfillment | 0.28 | 0.01 | 2 |
| 3 Social fulfillment | 0.20 | 0.01 | 3 |
| Spatial structure | 1 Spatial structure | 0.74 | 0.04 | 1 |
| 2 Buffer | 0.26 | 0.01 | 2 |

As shown in the table, among the research factors, passive enjoyment has the largest importance followed by spatial relation, health, and biodiversity. Among the research alternatives, on the other hand, sustainable ecological network has the largest weight this being in the first rank. This means that it will be the first choice for sustainable landscape network and vulnerable and disturbance ecological networks are next in rank.

CONCLUSIONS AND SUGGESTIONS

Based on the conceptual framework of the model, function and value in urban landscape, determining the services and their criteria in the framework of landscape services is accompanied by a set of classified data. By an evaluation of these services, it can be found that in response to the human demands and needs leads to the development of a hybrid thought and integration of physics, biology and meaning in urban systems. In socio-ecological systems, the three concepts of physics, biology and meaning require a physical realm of the environment in terms of human sustainability and dynamicity in his biological realm. Whatever explains this relationship is in the framework of the conceptual framework and dependent on the human’s perceptual aspect and evaluation. Perception and understanding without the ability to conceptualize about biological and physical phenomena does not make sense. In other words, it is the three-way human-centered relationship that explains the concept of landscape services and their positive role in human life. Accordingly, it can be understood that in the urban context and structure, any ecological, technological or economic activities cannot be implemented without taking cultural values and perceptual aspects into account and might even lead to disturbance and imbalance. In the mutual structure and functions of the two systems within it, a particular ecological unit creates a requirement based on benefit from the interactional processes and space. The analysis of the relationships and the mechanisms of human’s benefitting from the active process in nature (landscape services), presenting a conceptual framework emphasizes the importance of human’s level of understanding of the potential values, functions and also landscape patterns, in line with the sustainable ecological landscape unit and or human’s interference in it. The cognitive and passive dimensions such as enjoyment are prioritized as a part of the interactional ecological-social processes in spatial analysis of the landscape services in line with human wellbeing and satisfaction of his needs. The continuity of the spatial structure is also derived from human’s objective-subjective perception of the environment as another factor in landscape services for the purpose of developing sustainability. Health and biodiversity emphasize human’s valuation of the cultural and environmental aspects associated with the landscape and the beneficiaries of the landscape services. In this way, evaluation of the landscape services will play an important role in developmental plans and sustainability considering the social participation and its society-oriented processes, because the relationship between public knowledge and particular features of a region provide the ground for the relations between the pattern and landscape services. Finally, landscape services is a hybrid and integrated view of different thoughts related to beneficiaries’ understanding of landscape. Taking into account the role of cultural values not only helps to solve the problem of understanding fragmentation of landscape but also leads to the development of landscape sustainability.

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