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Changing Land Uses, using Spatial Multi-Criteria Decision Analyses

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Abstract

In the recent decades, the increase in population, industry developments, the non-suitable uses of land and partial development has made problems for the countries by influencing the stable uses of different resources. Land use which is the combination of economy, sociology and geography, is used for managing the interaction between human beings and their activities in a way that a stable development be achieved in different aspects; spatial characteristics of Land use in one hand and needed decisions in different aspects such as environment, economy and society in other hand, has made it necessary to use Spatial Multi-Criteria Decision Analysis. In this paper a conceptual model of changing Land uses using SMCDA is proposed, the model has combined the suitability and compatibility land use models; The compatibility model which is used for showing the levels of land use compatibility has been developed by using Delphi and Analytical Hierarchy Process methods and the suitability model which is used for showing the suitability of lands for different uses is developed using Multi-Attribute Decision Making methods like (SAW, TOPSIS, ELECTRE, AHP).

Keywords: GIS; Compatibility; Suitability; Spatial Planning.

1. Introduction

Any country in the world is trying to achieve stable development. Stable development may be defined as “suitable and efficient utilizing from natural, financial and human resources to achieve a desirable consumption pattern and utilizing suitable technical and organizational abilities which provide current and future necessities ”(sadough2001).

Spatial planning is trying to organize the human and activity in environment in such away that stable development would be achieved in various contexts. Spatial Planning is defined as adjusting the relationship between human, land and human activities in the land in order to have a stable utilization from all spatial and human possibilities to improve material and moral situation of society along the time (makhdoum1999). Having the presented definition of Spatial Planning it is clear that Spatial Planning aids us to reach this development. Thus to achieve stable development it is necessary to use the land respect to its abilities and possibilities, and the uses be used simultaneously which have not undesirable effect on each other and be compatible. In current research unsuitable and incompatible uses have been recognized by the use of compatibility of uses model and in accordance to conceptual model of use change, suitable use for change, is presented. To apply and utilize the conceptual of use change, combination of methods and existent tools such as GIS, Delphi model and SMCDA have been employed.

2. The conceptual model of use change

The conceptual model of use change is shown in fig.1 which would be explained after every stage of applying the use change model.

2.1. Current situation recognition

Prior to investigation of compatibility and suitability model of the land the existent resources in the land must be studied. Generally, resources are divided in two group of stable and unstable: stable resources are ones which are fixed in their physical position which included stones, land shape and soil and plant geomorphology. Unstable resources are ones which are not fixed in their position and changes of these resources per time unite would be slow even if they are not influenced from natural and human forces. In summary these resources include climate, climate, water resources and animals.

2.2. Use suitability model

Use suitability model evaluates the ability of the land for various industrial, agricultural, urban, touring, urban, conservation uses. Stages of applying and development of use suitability model, as a spatial decision tool for evaluating degree of land suitability for every use includes following issues.

2.2.1. Evaluation criteria specification

In specification of the use of a land, stable and unstable resources must be noted. Regarding literature (makhdoum2000), (keshavarzi1999), (Sharifi2002), (yazdani2004), (jafari2005) various criteria must be studied to specify suitability of agricultural, industrial, and touring uses. These criteria generally include slope, aspect, elevation, soil, water resources, climate, erosion, plants. The maps of slope, aspect, elevation, soil and plants are of stable resources and the maps of climate criterion and water resources are of unstable resources. For example a suitable land of type one for agricultural use has climate conditions: light warm or wet temperate or semi wet temperate, slope percent: below 5%, soil tissue: clay, soil structure: small to medium granulation without gravel-stone, erosion: very small, amount of water per year: 6 to 10 hundred m3 per hectare. After specification of criteria series for space unit evaluation, for every use every criterion is shown as a map layer in GIS data base. The layers representing map evaluation criteria are known as criteria. Therefore in this study, providing the maps of slope, aspect, elevation, climate, erosion, soil and plants in GIS is necessary.

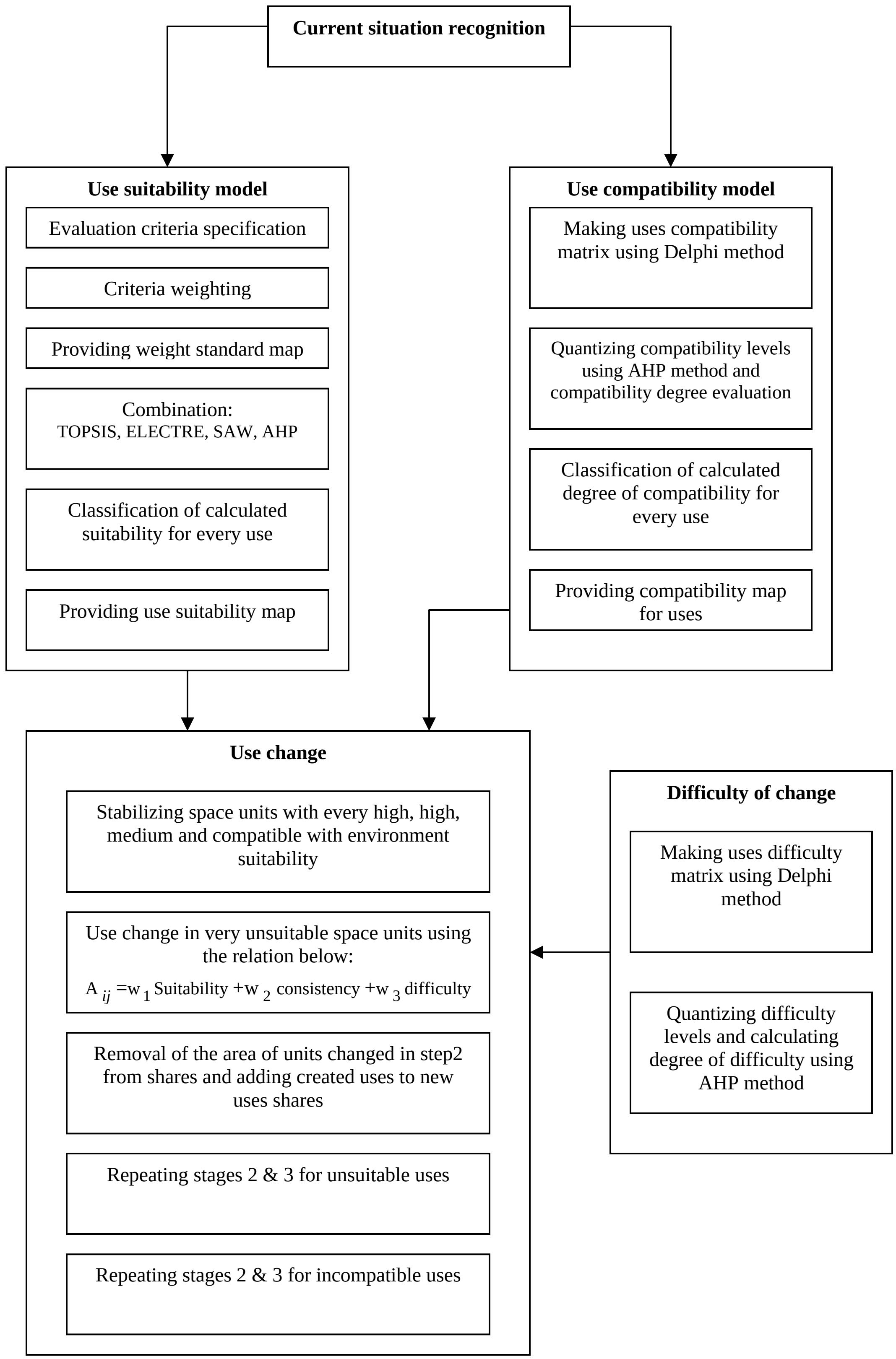

fig.1: Conceptual model of use change

2.2.2. Criteria weighting

After providing criterion maps related to every use, they must be weighted according the use type in this stage. For instance slope criterion map for various uses of industry, agriculture, urban, touring, etc. are not of same importance. In other words, the way in which slope influence in every use is different. For example the value of soil criterion is more than slope in agricultural use and gains more weight. In this stage by special science, performed studies and using Delphi method, evaluation criteria of every use would be weighted.

2.2.3. Providing weight standard map

Criterion haves various scale. In order to combine criterion maps, various maps must be standardized. Generally, the criterion maps are classified to quality and quantity criterion maps. Soil types, plant types and so on maps are samples of layers based on quality data according which quality criterion maps could be extracted. Elevation, slope, etc. map might be examples of quantity criterion maps. Noting various criterion maps and wide range of scale which may be used in measuring these criterions, to combine different layers of criterion maps, scales must be used proportional relative to each other. These are many ways to make the criterion maps comparable. Such as linear scale conversion, the method based of value function or desirability, probability theory and fuzzy theory etc. But the method which is used in this model is as follow:
First, all evaluation criterion are classified and each class is weighted using special science and Delphi method. For example slope class in range management and agricultural use is weighted and classified as below. After classification of aforesaid maps, every class is multiplied by related weight and standardized weight map would be obtained.

Table2:classification of slope for agricultural use

Weight	Slope percentage	Class
0.42	0 - 2	Class1
0.28	2 - 5	Class2
0.20	5 - 8	Class3
0.07	8 - 12	Class4
0.03	12 - 15	Class5
0	15 - 30	Class6
0	30 - 65	Class7
0	More than 65	Class8

Table1:classification of slope for range management use

Weight	Slope percentage	class
0.35	0 - 2	Class1
0.31	2 - 5	Class2
0.15	5 - 8	Class3
0.09	8 - 12	Class4
0.08	12 - 15	Class5
0.02	15 - 30	Class6
0	30 - 65	Class7
0	More than 65	Class8

2.2.4. Combination stage

In this stage, combination is done using TOPSIS, ELECTRE, SAW and AHP, and it would be known that each space unit is suitable for which use and to what extent. Following, afore said methods are explained in details.

2.2.4.1. TOPSIS method

According to this method, best option is the option that simultaneously is the nearest unit to ideal point and the hindmost minus ideal unit. The ideal unit is a hypothetical option that is the most desirable standardized weight level from each criterion between considered options and similarly minus ideal point includes worst standardized weight level between options (Hwang and yoon1981). TOPSIS involves either uniform increscent of desirability (the smallest criterion value or uniform decrement of it the better).

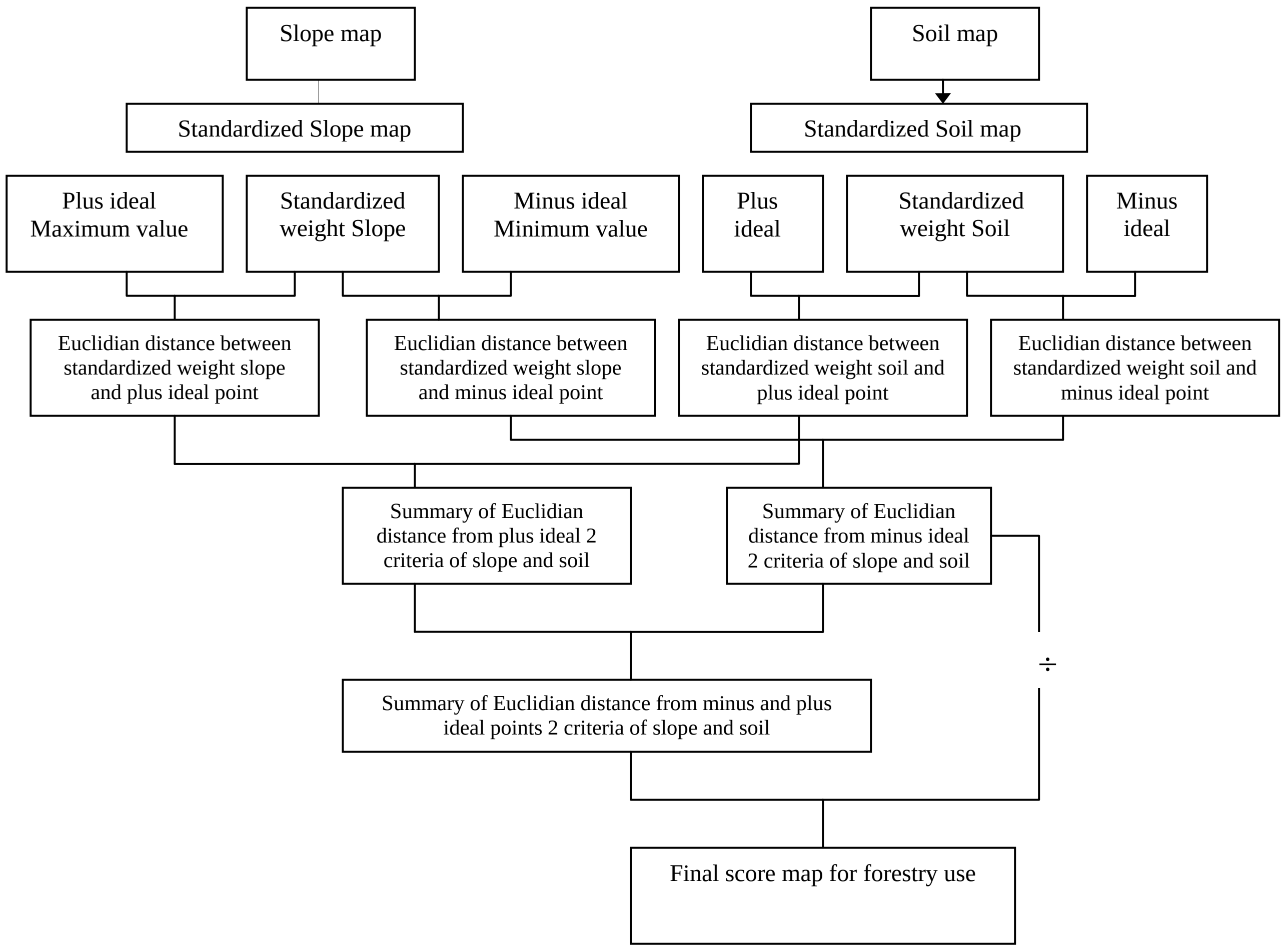

Fig.2: Stages of TOPSIS method for forestry use

2.2.4.2. ELECTRE method

This method is based on two by two comparing of space units, and gives an ordered ranking of space units in such a manner that when two space units are compared just the preference of space unit A relative to B might be obtained from this method and the value of the space units could not be achieved using it. Two by two comparing in this method is based on some limits in which criteria scores and their related weights, are propounded in agreement or disagreement whit dominant two by two relations between options (Benayoun1966). Fundamental elements in this method are concordance gauges (which are based on a cooperator and concordance series and are a subset of all criteria about them, i option is not in a worst situation relative to i'). According to Massam method (1980) for specification of total score, following relations might be used.

Relation (1): $c_{ii'} = \dfrac{\sum_j w_{jii'}}{\sum w_i}$ and Relation (2): $c_{ij} = \sum_i c_{ii'}$

Such that $\sum_j w_{jii'}$ represents total weights due to these criteria when option i is not worst than option i' . For example concordance matrix for aquaculture use in a 4 space unit case is shown in table4.

Table 4: concordance matrix

Rank	Total rows	Erosion	Climate	Soil	Slope	**Criteria**
4	1	0.4	0.3	0.3	-	Space unit1
1	2	0.8	0.5	-	0.7	Space unit2
2	1.5	0.3		0.5	0.7	Space unit3
2	1.5	-	0.7	0.2	0.6	Space unit4

Table3: standardized criterion scores

Rank	Total rows	Erosion	Climate	Soil	Slope	**Criteria**
0.0	1.0	1.0	0.4	0.4	0.5	Space unit1
1.0	0.6	0.6	0.6	0.6	0.0	Space unit2
0.4	0.4	0.4	0.4	1.0	0.3	Space unit3
0.5	0.5	0.5	0.5	0.0	1.0	Space unit4
0.4	0.1	0.1	0.1	0.3	0.2	weight

2.2.4.3. SAW method

Simple additive weighting (SAW) is one of the ways which is used for combining criterion. Officially to make a decision for evaluating on option A_i following formula is used:

Relation (3): $$A_i = \sum_j w x_{ij}$$

Such that x_{ij} is ith option due to jth criterion and w_i is a standardized weight such that $\sum_j w_j = 1$. Weights represent relative importance of every criterion. Specifying maximum value $A_i (i = 1,2,...,m)$ would be selected as the most prior option.

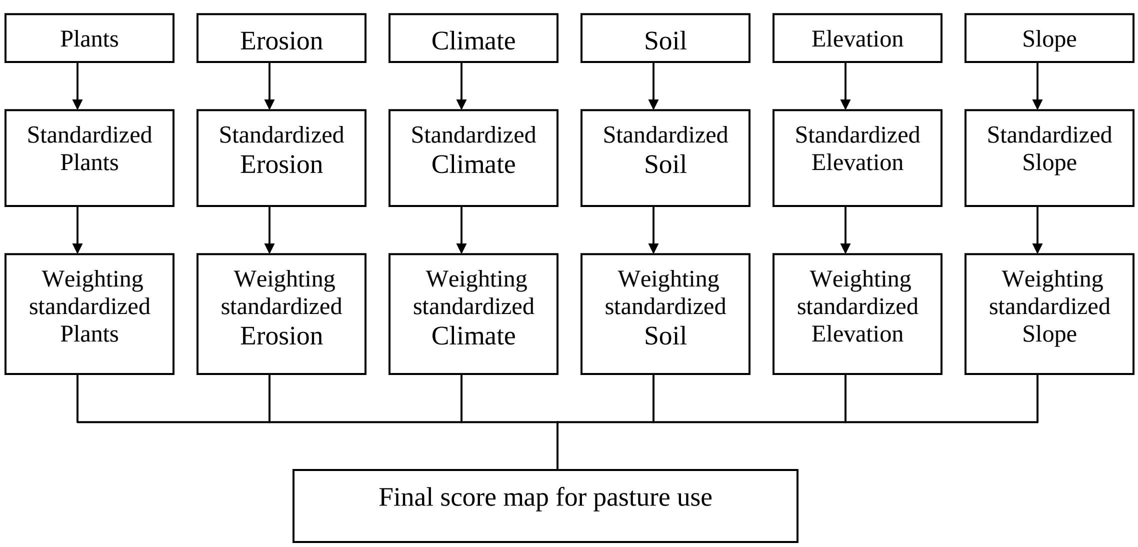

Fig.3: Stage of SAW method for range management use

2.2.4.4. AHP method

This method which introduced by Saaty (1980) has been used in many regional programming, localization etc. activities.

- **AHP creation**

In this stage, main goal, sub goals, deciding criteria and options are determined.

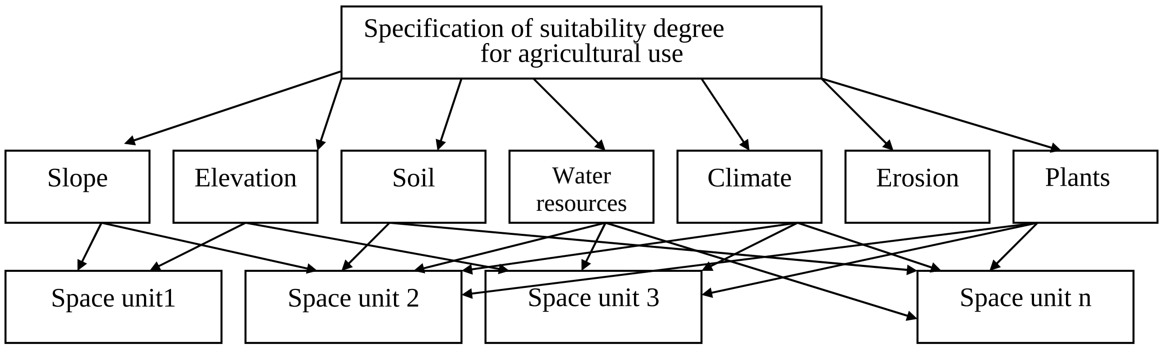

Fig.4: Hierarchy structure for evaluation of suitability degree of agricultural use

- **Comparing evaluation criterion in binary format**

In this stage decider should compare every pair of decision criteria.
Comparing the importance of the pairs of decision criteria relative to each other must be done qualitatively then it would be quantify in a numerical scale consisting 1-9.

- **Creation of even comparison matrix**

In this stage a matrix including results of even comparison of decision criteria is made from which at last relative weights of decision criteria would be derived.

- **Criteria weights calculation**

Calculation of criteria weights based on afore said matrix is as follow:
A: calculation of geometrical average of every row of matrix (nth root is obtained from multiplication of n criteria in every row)
B: calculation of total geometrical averages obtained in step A.
C: Standardization of every calculated geometrical average in step A by dividing it to summary result of step B (Ghodsypour2000).

- **Making a total ranking of preferences**

In the last step, relative weights due to criterion are added together. The result represents suitability degree of space units every use.

2.2.4.5. Conclusion from combination method

In this research different methods TOPSIS, ELECTRE, AHP, and SAW have been used to combine evaluation criteria and to specify use suitability.
The method based on SAW could be employed simply using any GIS system which has overlay ability. It is utilized widely nowadays in real-world cases due to its convenience, but in SAW method evaluation criteria must be independent and there is no dependency

among criteria other wise it would give incorrect results. Effective criteria in use, suitability method could not assume completely independent there by some errors would appear through using SAW method. AHP method has strong theoretical principals and flexibility for various applications there for nowadays, It find many applications specific in determination of land use which in wide field it is difficult applying this method due to abundance of comparisons. In ELECTRE method, least data is required but it couldn't be applied directly in GIS environment and doing this involves a particular designed method. In TOPSIS method dependency of evaluation criteria is not necessary, so this method usually is used in spatial determination problems which often include complex corresponding dependencies between criteria. TOPSIS method is ideal in determining land suitability in any use.

2.3. Uses compatibility model

Programmers are trying to summarize and classify compatible uses in one place moreover, separate incompatible uses. In this model corresponding effects among uses and outer effects (positive or negative) of every use on its adjacent uses are concerned.

2.3.1. Creation of use compatibility matrix using Delphi method

First the region is divided into zones due to use type. Zonal programmers define compatibility situation of various uses due to specified rules. To define these rules use matrix or in a more exact expression "use compatibility matrix" is used to represent permissible uses in adjacent zones.

Table5: different compatibility levels between uses

	Agriculture	Range management	Forest	Urban	Industry
Agriculture	HC	MC	MC	MC	HI
Range management	MC	HC	HC	MC	HI
Forest	MC	HC	HC	N	N
Urban	MC	MC	N	HC	N
Industry	HI	HI	N	N	HC

HC: High Compatibility
MC: Medium Compatibility
N: Neutral/Low Compatibility
MI: Medium incompatibility/very low compatibility
HI: High incompatibility

Noting that to specify compatibility degree between various extended zonal uses various factors must be considered.
It is evidence that quantizing negative and positive outcomes and their evaluation indices in very difficult thereby compatibility degree determination through this way would be difficult and complex, to overcome mentioned difficulty, compatibility matrix and Delphi model as construction frame to make the matrix, and determination of various physical compatibility levels which exist between different uses are used. Using this method, problems of quantizing different variables and relations between them noting the lack of

sufficient required models and data would be overcome and in a simpler way compatibility matrix between uses would be various compatibility levels include high, medium and low compatibility, neutral and high incompatibility.

2.3.2. Quantizing compatibility levels using AHP method and compatibility degree evaluation

In this step AHP and structured pair-wise comparison methods are utilized to convert qualitative results of pervious step (various levels of compatibility) into quantitative values.

Table6: Obtaining quantitative values from compatibility levels using AHP method

	HC	MC	N	MI	HI	Average geometrical	Standardized value
HC	1	2	3	5	7	2.9137	0.43
MC	0.5	1	2	4	6	1.8882	0.28
N	0.333	0.5	1	3	5	1.2011	0.18
MI	0.2	0.25	0.333	1	3	0.5492	0.08
HI	0.143	0.167	0.2	0.333	1	0.2756	0.04

After obtaining quantities from compatibility levels conversion, compatibility degree of uses is calculated using adjacent uses, considered use and developed compatibility matrix. In this step, compatibility values which results from adjacent and considered uses are added together to give a total value as the resultant or representative of them.
These values are in fact contributions of every adjacent use about its compatibility to considered use.

2.3.3. Classification of calculated compatibility value for every use

Since the results of compatibility evaluation model are used in changing use step, threshold limit of every space unit according to calculated total compatibility value for each one would be used to classify calculated values into different compatibility levels.
In this process, compatibility values are divided into five levels of high, medium, low, very low compatibility and incompatible.

2.4. Changing use

To achieve permanent development the land must be utilized according to its possibilities and abilities, and the uses which are used together don’t have destructive effect on each other as far as possible. In this step, using compatibility and use suitability, unsuitable and incompatible uses would be changed and the most suited use would proposed, before applying the changing use process it is necessary that share value and complexity value data be at hand. At this point, space unit with unsuitable and incompatible uses is distinguished using suitability and compatibility use models.
In changing use step, it is investigated that for which use there is more suitability for considered space unit, such that incompatibility problem would be solved too.

It is worth mentioning that degree of change complexity and the share attributed to every use in the region under study must be of concern as the effective factors in changing use besides of suitability and compatibility degrees.

2.4.1. Calculation of change complexity degree

If the only effective criteria for changing use are suitability degree of every space unit for a use and considering the problem of uses compatibilities, then many uses would be changed. But the subject which must be noted anyway is the security of execution for changing the use and noting that whether the cost of changing use is profitable or not. In relation to this matter, an index which is named “change complexity” is used. The way of estimating the complexity of use change is like the method as for uses compatibility.
First the change complexity matrix is made using Delphi method, then quantification of complexity levels and complexity degree calculation for every space unit would be done by AHP method.

Table7: different difficulty levels between uses

	Agriculture	Range management	Forest	Urban	Industry
Agriculture	-	LDC	LDC	NDC	HDC
Range management	NDC	-	NDC	MDC	NDC
Forest	HDC	HDC	-	MDC	MDC
Urban	HDC	HDC	HDC	-	NDC
Industry	HDC	HDC	HDC	NDC	-

HDC: High DIFFICULTY Change
MDC: Medium DIFFICULTY Change
NDC: Neutral/Low DIFFICULTY Change
LDC: very low DIFFICULTY Change

After collecting data due to the share and change complexity calculation, the change of use would be done using the output of uses compatibility and use suitability models according to proposed conceptual model.

3. Conclusion

To attain stable development potential possibilities of the land must be utilized as for as possible. To approach this goal, incompatible uses and the uses which their suitability is less than an accepted limit, must be changed. The use change model is developed concerning the aforesaid issues. This model has a high degree of execution security considering state shares, the costs of use change and utilizing space decision systems and is useful in spatial planning programs.

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