Ranking of strategic plans with GRA on the basis of recreation and water production; the case of belgrade forest

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Abstract: Forest management plans have been developed to help the contradictions between the number of goods and services demanded by the community and to regulate the time and place of forestry activities. Decisions on the use of forest resources are becoming complicated due to competing uses such as wood production, recreation and water production etc. As the complexity of decisions increases, it becomes more difficult for decision makers to identify a management alternative that maximizes all decision criteria. Planning in forest management are separated strategic, tactical and operational according to the planning time. Strategic plans have plan horizon is more than ten years. Functional planning can be cited as the main reason for strategy changes in forest management. Various studies have been carried out to produce alternative strategic plans for different objectives. Determining the most suitability one from alternative strategies based on various criteria can be accomplished by multi-criteria decision making techniques. This study aims to choose most suitable from six different strategies for water production and recreation purposes for the Belgrade forest. Seven criteria were used to evaluate the suitability of these strategies. Firstly the weights of seven criteria were calculated with AHP method since criteria weights are required for gray relational analysis. Then six strategies were scored according to seven criteria. These strategies were prioritized with Gray Relational Analysis (GRA).
Keywords: Multi-criteria decision making, GRA, Strategies for recreation, Strategic plans

1. Introduction

In general, a number of alternatives are ranked according to various criteria in the decision-making process and the best is selected by the decision-makers. It is necessary to select the criteria that may be influential in the selection relevant to the present problem. For this reason, decision makers frequently use Multi Criteria Decision Making methods (MCDM) in the planning of forest management (Kangas & Kangas, 2005). MCDM contributes to the policy process by solving complex forest management issues and it supports the decision-makers' intuitive decision-making procedures with rational analytical knowledge processes (Ananda & Herath, 2009). When the forestry system is examined, a high-level decision mechanism is required in the source where function priority is considered (Ok, 1999). Additionally, decisions taken within the framework of the Sustainable Forest Management, It is expected to fulfill social, economic and ecological requirements. Due to its ecological and biological qualities, forest resources may have different strengths to obtain product and service (output) on a regional basis.

Criteria setting process in forestry management is a process that is time consuming and requires different disciplinary components, for this reason, the scenarios produced by Zengin (2010) were used as an alternative and the technical components in the scenario were used as criteria. The use of GRA in the field of forestry in Turkey has not been achieved. The purpose of introducing the use of the GRA mathematical method in the study is a priority.

MCDM techniques in the forestry sector, and most of the published studies on forestry were published using two techniques together and about 90% were published after 1989 (Diaz-Balteiro & Romero, 2008). There are studies using different MCDM techniques such as ELECTRE (Ok, Okan, & Yılmaz, 2011), AHP (Daşdemir & Güngör, 2010), TOPSIS (Korkmaz, 2012) in forestry field in Turkey. Unlike the Forestry Administration in Turkey, it can be said that multi-criteria decision making methods are widely used in academic (Daşdemir & Güngör, 2002).

This study aims to choose most suitable from six different strategies for water production and recreation purposes for the Belgrade forest. Seven criteria were used to evaluate the suitability of these strategies for water production and recreation in forest planning. These criteria are periodic wood flows, adjacency restrictions, recreation income in periods, a number of water yields in periods, recreation value fluctuation, water yields fluctuation and harvest area constraints. The weights of seven criteria for calculation in AHP method has acquired from the questions that have been answered by expert since criteria weights are required for gray relational analysis. Then six strategies were scored according to seven criteria and a Preference Matrix was created. These strategies were prioritized with Gray Relational Analysis (GRA).

This paper is organized as follows. Section 2 introduces gray relational analysis and case study for problem description, while Section. 3 defines results of ranking the six scenarios is given. Next, Section 4 presents the discussion and concluding remarks.

2. Material and methods

Gray Relational Analysis (GRA) method was chosen as the basic method in the study. As an effective mathematical approach, GRA the evaluation criteria to be used must be weighted with an other method (Özcan & Tüysüz, 2016). Another multi-criteria decision-making method, AHP, was selected as the criterion weighting method. The AHP method compares criteria in pairs differently than other decision making methods and measures the consistency of the comparison. Because of its superiority, AHP is especially preferred for solving multi-criteria decision-making problems, as well as for determining the criteria weights for many applications. As a result of the literature, GRA and criteria weighting AHP method have been frequently used together (Kaygısız & Girginer, 2014).

The process steps of the AHP method developed by Saaty (1980) were given in the application section of the study, but the methodology was not explained.

2.1. Gray relational analysis

Deng (1982) introduced the "Gray System Theory". There are a number of methodologies developed on the basis of Gray System Theory. These ; Gray System Analysis, Gray Clustering, Gray prediction, Gray combined models, Gray programming, Gray input-output models, Gray control and Gray Decision Making (Gray Relational Analysis) (Wen, 2004). Gray Relationship Analysis is a MCDM technique.

In a MCDM problem where the alternative number is "m" and the number of criteria is "n", the initial decision matrix showing the values of the alternatives according to the criteria is formed primarily.

$$X = \begin{bmatrix} x_1(1), x_1(2), ...x_1(n) \\ x_2(1), x_2(2), ...x_2(n) \\ .... \\ .... \\ x_m(1), x_m(2), ...x_m(n) \end{bmatrix}$$

This $x_i(k)$ i. alternative value according to the criterion *k*. Criterion weights and preference values determined by the decision maker or calculated with objective approaches should be examined (Yang & Chen, 2005).

Table 1: Steps of grey relational analysis (Özcan & Tüysüz, 2016)

Steps	Explanation	No	Equation
In first step of gray relational analysis, data sets of different sizes from different sources are transformed into dimensionless units. After the **normalization phase**, while the best value within the benefit-oriented criteria approaches "1" for the cost-effective criterion, this best value will approach "0".	For benefit-type factor (bigger is better, benefit maximize)	(1)	$x_i(k) = \dfrac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)}$
	For cost type (smaller is better, cost minimize)	(2)	$x_i(k) = \dfrac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)}$
	For medium-type or best rated (better than the one with a certain standard value)	(3)	$x_i(k) = \dfrac{\lvert x_i(k) - x_0(k)\rvert}{\max x_i(k) - x_0(k)}$
Second step is **computing absolute values**	Absolute differences of the comparison series and the reference series should be obtained and maximum and minimum differences should be found.	(4)	$\Delta x_i(k) = \lvert x_0(k) - x_i(k)\rvert$
Third step The gray relational coefficient expressed as ξ calculated.	The separation coefficient *p* is between 0 and 1. In general, the separation coefficient is fixed at 0.5. The distance of the values of each alternate from the reference series.	(5)	$\xi_i(k) = \dfrac{\Delta \min + p\Delta \max}{\Delta x_i(k) + p\Delta \max}$
Finally, The relationship grade is determined and then alternatives rank by the highest grade.	The gray relational grade gives the relation between the reference series and the comparable series in a problem.	(6)	$r_i = \sum [w(k)\xi(k)]$

2.2. Case study

Scenarios developed by Zengin (2010) are shown in the table 2. Zengin (2010), after developing the main planning model with the mathematical model, six alternative strategies were created to examine the effect on the results.

- Scenario 1 periodic wood flow and adjacency restriction are not controlled. This means that you can produce unlimited wood at any time.
- Scenario 2; wood fluctuation rates (Rwood=0,10) were %10, The recreation income in different periods should not drop down below an actual recreation income (R≥ActR) and The amount of water yields in periods should not drop down below an actual amount of water yields (W≥ActW).
- Scenario 3; Rate of wood fluctuation, recreation income and amount of water yield are the same as scenario 2., There should not be more than three stands adjacent to each other (maxadjacency≤3).
- Scenario 4; periodic wood flows, adjacency restrictions, recreation income and amount of water yields in periods are the same as scenario 3, recreation value fluctuation, water yields fluctuation should not exceed %10 to ensure a water yield and recreation value are generated during each time period.
- Senario 5: periodic wood flow is not controlled, There should not be more than three stands adjacent to each other (maxadjacency≤3). The amount of water yields in periods should not drop down below amount of water yields in the sixth period (W≥ActW6), recreation value fluctuation, water yields fluctuation are not controlled.
- No constraint is checked in the scenario 6 without amount of water yields and The amount of water yields in periods should not drop down below amount of water yields in the sixth period (W≥ActW6)

Table 2: Six alternative plan strategies of forest management plan (Zengin, 2010).

Scenario No	Restrictions	Level
Scenario 1	No control periodic wood flows No control adjacency restrictions	Rwood≥0 maxadjacency≥1
Scenario 2	control periodic wood flows No control adjacency restrictions control recreation income in periods control amount of water yields in periods	Rwood=0,10 maxadjacency≥1 R≥ActR W≥ActW
Scenario 3	control periodic wood flows control adjacency restrictions control recreation income in periods control amount of water yields in periods	Rwood=0,10 maxadjacency≤3 R≥ActR W≥ActW
Scenario 4	control periodic wood flows control adjacency restrictions control recreation income in periods control amount of water yields in periods control recreation value fluctuation control water yields fluctuation	Rwood=0,10 maxadjacency≤3 R≥ActR W≥ActW Rrecreation=0,10 Rsu=0,10
Scenario 5	No control periodic wood flows control adjacency restrictions control amount of water yields in sixth periods No control recreation value fluctuation No control water yields fluctuation	Rwood≥0 maxadjacency≤3 W≥ActW6 Rrecreation≥0 Rsu≥0
Scenario 6	No control periodic wood flows No control adjacency restrictions control amount of water yields in sixth periods No control recreation value fluctuation No control water yields fluctuation No harvest area constraint	Rwood≥0 maxadjacency≥1 W≥ActW6 Rrecreation≥0 Rsu≥0 Maxarea≥0

3. Results

1. Establishing the Pairwise Comparison Matrix : This matrix is created from the average measurement by expert about the Comparison between two criteria. For this design, the Standard Preference Scale with scale 1 – 9 is used. Table 3 shows the Pairwise Comparison Matrix for each criterion for water production.

Table 3: Pairwise Comparison Matrix for Water Production.

		C1	C2	C3	C4	C5	C6	C7
		Periodic wood flows	Adjacency restrictions	Recreation income in periods	Amount of water yields in periods	Recreation value fluctuation	Water yields fluctuation	harvest area constraint
C1	Periodic wood flows	1	4	7	0,33333	5	0,25	0,5
C2	Adjacency restrictions	0,25	1	2	0,2	3	0,2	0,33333
C3	Recreation income in periods	0,14286	0,5	1	0,11111	0,25	0,11111	0,2
C4	Amount of water yields in periods	3	5	9	1	7	0,33333	5
C5	Recreation value fluctuation	0,2	0,33333	4	0,14286	1	0,14286	0,33333
C6	Water yields fluctuation	4	5	9	3	7	1	5
C7	harvest area constraint	2	3	5	0,2	3	0,2	1
	Total	10,5929	18,8333	37	4,9873	26,25	2,2373	12,3667

2. Establishing the Normalized Matrix; the value of each column in Table 3 is summed and for modifying the value into demical value. The result of *Normalized Matrix* for the criteria is shown in Table 4. Next the value of each rows in Table 6 is summed and averaged. Average values are weighted value .

Table 4: Normalization (With AHP).

	C1	C2	C3	C4	C5	C6	C7
C1	0,0944	0,21239	0,18919	0,06684	0,19048	0,11174	0,04043
C2	0,0236	0,0531	0,05405	0,0401	0,11429	0,08939	0,02695
C3	0,01349	0,02655	0,02703	0,02228	0,00952	0,04966	0,01617
C4	0,28321	0,26549	0,24324	0,20051	0,26667	0,14899	0,40431
C5	0,01888	0,0177	0,10811	0,02864	0,0381	0,06385	0,02695
C6	0,37761	0,26549	0,24324	0,60153	0,26667	0,44697	0,40431
C7	0,18881	0,15929	0,13514	0,0401	0,11429	0,08939	0,08086
Total	1	1	1	1	1	1	1

3. Test of Consistency: According to Saaty (1980), a consistency ratio of 0.10 or less is acceptable. If it exceeds 0.1 an inconsistency can be mentioned. In this study Consistency ratio is less then 0.1. So, it is clearly can be said that the results are consistent (Table 5).

Table 5: Consistency Ratio (CR) (With AHP).

	Total	Average (w(k))	Consistancy measure
C1	0,90547	0,12935	7,54861
C2	0,40149	0,05736	7,5143
C3	0,1647	0,02353	7,42468
C4	1,81242	0,25892	8,29952
C5	0,30223	0,04318	7,20113
C6	2,60582	0,37226	8,17774
C7	0,80788	0,11541	7,96795
		Average	7,73342
		CI	0,12224
		RI	1,32
		C.ratio	0,0926

Table 6 shows the original data (preference matrix) for water production. Each scenario was scored according to each criterion by expert.

Table 6: Original Data (Preference Matrix) For Water Production.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	10	10	10	10	10	10	10
S1	2	2	0	0	0	0	0
S2	8	2	3	9	0	0	0
S3	8	5	3	9	0	0	0
S4	8	5	3	9	3	10	0
S5	2	5	0	5	1	1	0
S6	2	2	0	5	1	1	2

After normalization preference matrix next processes can be perform. Therefore preference matrix is normalized as scale of between 0-1 (Table 6).

Table 7: 0-1 Normalization.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	1	1	1	1	1	1	1
S1	0,2	0,2	0	0	0	0	0
S2	0,8	0,2	0,3	0,9	0	0	0
S3	0,8	0,5	0,3	0,9	0	0	0
S4	0,8	0,5	0,3	0,9	0,3	1	0
S5	0,2	0,5	0	0,5	0,1	0,1	0
S6	0,2	0,2	0	0,5	0,1	0,1	0,2

In this study all factors are benefit type. Thus Table 8 is created using Eq. 1

Table 8: Benefit Type of Criteria.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	1	1	1	1	1	1	1
S1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
S2	1,0000	0,0000	1,0000	1,0000	0,0000	0,0000	0,0000
S3	1,0000	1,0000	1,0000	1,0000	0,0000	0,0000	0,0000
S4	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	0,0000
S5	0,0000	1,0000	0,0000	0,5556	0,3333	0,1000	0,0000
S6	0,0000	0,0000	0,0000	0,5556	0,3333	0,1000	1,0000

Absolute differences of the comparison series and the reference series obtained using Eq. 4 (Table 9).

Table 9: Difference of The Compared Series And The Referential Series.

Scenario number	C1	C2	C3	C4	C5	C6	C7
S1	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
S2	0,0000	1,0000	0,0000	0,0000	1,0000	1,0000	1,0000
S3	0,0000	0,0000	0,0000	0,0000	1,0000	1,0000	1,0000
S4	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0000
S5	1,0000	0,0000	1,0000	0,4444	0,6667	0,9000	1,0000
S6	1,0000	1,0000	1,0000	0,4444	0,6667	0,9000	0,0000

Using Eq.5 "Grey Relation coefficient" table obtained. The weights in this stage was achieved by AHP

Table 10: Grey Relation Coefficient.

Scenario number	C1	C2	C3	C4	C5	C6	C7
w(k)	0,12935	0,05735	0,02352	0,25891	0,04317	0,37226	0,11541
S1	0,33333333	0,33333333	0,333333	0,333333	0,333333	0,333333	0,333333
S2	1	0,33333333	1	1	0,333333	0,333333	0,333333
S3	1	1	1	1	0,333333	0,333333	0,333333
S4	1	1	1	1	1	1	0,333333
S5	0,33333333	1	0,333333	0,529412	0,428571	0,357143	0,333333
S6	0,33333333	0,33333333	0,333333	0,529412	0,428571	0,357143	1

After Grey relation coefficients calculation, all scenario values processed using their weights by Eq.6. Table 11 that given below, shows ranks of each scenarios. It is clearly seen that Scenario 4 is first and Scenario 3 is second ranked according to GRA for "Water Production".

Table 11: Ranking of Scenario.

Relational degree	Grey analysis of the influence criterias	The ranking of the scenario	
0,333333	6	S4	0,923059
0,607865	3	S3	0,646102
0,646102	2	S2	0,607865
0,923059	1	S6	0,474017
0,435314	5	S5	0,435314
0,474017	4	S1	0,333333

All steps and processes are same for "Recreation" So that following tables (Table 12-17) are given for recreation without explanation.

Table 12: Original Data for Recreation.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	10	10	10	10	10	10	10
S1	7	1	0	0	0	0	0
S2	3	1	4	3	0	0	0
S3	3	7	4	3	0	0	0
S4	3	7	4	3	8	3	0
S5	7	7	0	2	2	6	0
S6	7	1	0	2	2	6	1

Table 13: 0-1 Normalization.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	1	1	1	1	1	1	1
S1	0,7	0,1	0	0	0	0	0
S2	0,3	0,1	0,4	0,3	0	0	0
S3	0,3	0,7	0,4	0,3	0	0	0
S4	0,3	0,7	0,4	0,3	0,8	0,3	0
S5	0,7	0,7	0	0,2	0,2	0,6	0
S6	0,7	0,1	0	0,2	0,2	0,6	0,1

Table 14: Benefit Type of Criteria.

Scenario number	C1	C2	C3	C4	C5	C6	C7
Referential series	1	1	1	1	1	1	1
S1	1,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
S2	0,0000	0,0000	1,0000	1,0000	0,0000	0,0000	0,0000
S3	0,0000	1,0000	1,0000	1,0000	0,0000	0,0000	0,0000
S4	0,0000	1,0000	1,0000	1,0000	1,0000	0,5000	0,0000
S5	1,0000	1,0000	0,0000	0,6667	0,2500	1,0000	0,0000
S6	1,0000	0,0000	0,0000	0,6667	0,2500	1,0000	1,0000

Table 15: Difference of The Compared Series And The Referential Series.

Scenario number	C1	C2	C3	C4	C5	C6	C7
S1	0,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
S2	1,0000	1,0000	0,0000	0,0000	1,0000	1,0000	1,0000
S3	1,0000	0,0000	0,0000	0,0000	1,0000	1,0000	1,0000
S4	1,0000	0,0000	0,0000	0,0000	0,0000	0,5000	1,0000
S5	0,0000	0,0000	1,0000	0,3333	0,7500	0,0000	1,0000
S6	0,0000	1,0000	1,0000	0,3333	0,7500	0,0000	0,0000

Table 16: Grey Relation Coefficient.

Scenario number	C1	C2	C3	C4	C5	C6	C7
w(k)	0,097462	0,3115	0,148994	0,06853	0,294561	0,050843	0,028109
S1	1	0,333333	0,333333	0,333333	0,333333	0,333333	0,333333
S2	0,333333	0,333333	1	1	0,333333	0,333333	0,333333
S3	0,333333	1	1	1	0,333333	0,333333	0,333333
S4	0,333333	1	1	1	1	0,5	0,333333
S5	1	1	0,333333	0,6	0,4	1	0,333333
S6	1	0,333333	0,333333	0,6	0,4	1	1

Table 17: Ranking of Scenario.

Relational degree	Grey analysis of the influence criterias	The ranking of the scenario	
0,398308	6	S4	0,890864
0,478349	3	S3	0,686016
0,686016	2	S5	0,677783
0,890864	1	S6	0,488855
0,677783	5	S2	0,478349
0,488855	4	S1	0,398308

After Grey relation coefficients calculation, all scenario values processed using their weights by Eq.6. Table 17 that given above, shows ranks of each scenarios. It is clearly seen that Scenario 4 is first and Scenario 3 is second ranked according to GRA for "Recreation". Ranking of scenario for "Recreation" is S4, S3, S5, S6, S2, S1.

4. Discussion and conclusions

As a result of the calculations for "Water Production" and "Recreation" ranking of alternative scenarios, first (S4) and second (S3) ranking were similar. The constraints that are set when creating scenarios are suitable for both water production and recreation. For example, the control of wood flow and the adjacency restrictions are wanted constraints in the forest management planning process. Scenario 1 (S1) was selected the worst scenario for both functional objects. Because it is not preferable not to control constraints for recreation and water production which are functional goals.

In multi-criteria decision making techniques, for the same problem is usually more than one method applied and the results are compared. If another method is used, the results could change. Our main aim in this study is to apply the GRA mathematical method, so the results were not compared with a second method. The study results do not include the economic and social measure but only the technical measure.

GRA is a multi-criteria decision-making method that can evaluate both qualitative and quantitative data as AHP, PROMETHEE, ELECTRE etc. GRA should be as widespread as at least another MCDM methods in forest management planning.

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