UDC 630*652

D. Karamanolis

EVALUATION OF FOREST ECOSYSTEM FOR WATER AND WOOD PRODUCTION

The aim of this work was to study the process of producing wood and water from the University Forest of Taxiarchi Chalkidikis with the help of multiple decision support, part of which was the pairwise comparison method and to find which forest units are valuable for each of these processes. Based on this aim the University Forest was divided into 15 zones of four forest units. Afterwards, the criteria factors of influencing the process of each production were named and their relative weights were estimated with the help of this method. These relative weights show the importance of the factors for each production. For wood production, the rank importance is land (0.550), aspect (0.180), relief (0.155), elevation (0.078), forest species (0.037), forest production precipitation (0.601), vegetation (0.224), geological substratum (0.116) and relief (0.059).

Key words: *wood and water production, weight, analytic hierarchy process AHP, multiple decision support.*

Introduction. It is generally accepted that forest is one of the most significant sources of life and one of the most important sources of energy. Therefore, its management needs special care. What will the forests be like in the future? What kinds of products, services and experiences will they supply? What kind of activities will be executed in the future? These are the questions which were studied by the specialists, foresters and environmentalists and led to the improvement of the section of forest management. Forest management can be defined as a medium and macro-term forest plan at the level of one or more forest utilizations. This forest plan which takes into account ecological, economical, operational and social views ensures the benefit of forest [1]. Forest management is aimed at maintaining the sustainability of forest exploitations.

Natural ecosystems are in the center of interest, on the one hand, because much more products and services are required from them, and on the other hand, because the sensitivity of the public opinion related to the protection of the environment has significantly increased. This situation needs the development of one successful structure of management of those ecosystems, which in order to be fulfilled demand sufficient and reliable information [2]. All these lead to the complex value of the use of forest and to the multiple purposes of forestry. This multiple operation describes the modern forestry [1]. The purpose of this work is to study two forest uses, the wood production and the water production at the borders of the University Forest of Taxiarchy of Chalkidiki. These two procedures of production will be surveyed at the forest sections of this area with the help of the method of multiple decision support, in order to find the rank of importance based on their weights related to these procedures of productions and to find which production is superior against the other on those sections in the forest. The next step will be to map these weights and also the areas where one production is better than the other using the ArcGIS program.

Area of interest. University forest of Taxiarchi of Chalkidiki geographically situated on the south and southwest aspects of the mountain Cholomonta in prefecture of Chalkidiki. Its area is 58.62 km^2 where the 3.45 is communal area which is not under the responsibility of the forest inspection. The climate of the area can be described as terrestrial Mediterranean with short, warm and dry summers and moderate winters. According to Koppen, it belongs to the subtype of Csb [3]. The larger percentage of the area is covered with limestone and mica schist. The grounds are oxide, and its depth varies between 5 and 100 cm. The dominating forest species are *Quercus conferta* and *Quercus dalechampii* [4].

Materials and methods. The data for the study of the productive procedures of wood and water which were used refer to the stands, the elevation, the slope, the basic rock, the constitution and the depth of the ground, as well as the percentage of canopy. This data was also used for the management plan of the area during the period 2002-2011, the current increase of the growing stock per stand. Moreover, the map of the forest sections of the University Forest was used, which is divided into 15 zones of four sections. The study of the production procedures creates a problem of multiple decision support. At the beginning, the criteria-factors which influence the production of wood and water were determined. The next step is to account their relative weights and the following step is to find out the weights of zone, in order to discover their significance

Multiple criteria decision support.

General. The problems of multiple criteria decision support involve a set of alternative solutions which are estimated based on conflicted and disproportional criteria. Criterion is a general term which consists both the term of characteristic/feature as the term of goal. Characteristic is a countable quantity or quality of a geographical integrity or the relationship between the geographical integrities. The goal is the appearance of the desired situation of the system which is under control [5]. A problem of estimation of multiple criteria can be faced through the following steps: a) Definition and composition of the problem, b) Generation of the alternatives, c) Choice of a set of evaluation criteria, d) Identification of the preference of the decision maker e) Choice of total preference [6].

Multiple criteria decision support in forest management.

For sustainable management of forest due to the current demands, the correct plan and the organization of actions which will be applied to the forest are necessary. In order to make this possible, the evaluation and the estimation of a suitable management way is necessary. One way to implement this is via Multicriteria Decision Aid (MCDA) [6].

Methods of estimating criteria. The methods of estimating the criteria can be categorized as follows: ranking, rating, pairwise comparison and trade-off analysis [5]. In this paper, the third method was used for estimating the weights. The pairwise comparison method was developed by Saaty in 1980 in the frame of Analytic Hierarchy Process (AHP) [7–8]. This method includes comparisons between pairs in order to formulate a ratio table and employ an underlying scale with values from 1 to 9 to rate the relative preferences between two criteria or two objects.

Pairwise comparison method. The pairwise comparison method involves the following: a) creation of pairwise comparison matrix, b) evaluation of criteria weights, c) examination of consistence ratio [5].

Criteria weights are accounted for each of the factors, with the next step being to account the weight for every alternative solution for these factors [8].

Results. Two forest uses were studied in the University Forest of Taxiarchi, namely the wood production and the water production. For this purpose, the forest sections were divided into fifteen (15) zones of four sections each and some general characteristics were accounted and estimated for these. In order to find out these characteristics, the description sheets per stand and the details from the management plan of the period 2002–2011 were used, including the elevation, the slope, the aspect, the forest species, average increase and the canopy. The separation of the zones was done because consistency check can be done for a maximum of fifteen criteria since the Ratio Index (RI) comes from tables with this specific number of criteria. Wood production in the forest depends on several criteria factors such as the ground, the aspect, the relief and the forest species [9–10]. The pairwise comparison method was applied and table 1. was formed.

Table 1

Pairwise comparison of the factors which influence wood production

Criterion	Ground	Elevation	Aspect	Relief	For. species
Ground	1	8	5	5	8
Elevation	0.125	1	0.333	0.25	4
Aspect	0.2	3	1	2	5
Relief	0.2	4	0.5	1	5
For. species	0.125	0.25	0.2	0.2	1

Computation of the criterion weights. This step involves the following operations: (a) sum the values in each column of the pairwise comparison matrix; (b) divide each element in the matrix by its column sum (the resulting matrix is referred to as the normalized pairwise comparison matrix), and (c) compute the average of the elements in each row of the normalized matrix, that is, divide the sum of normalized scores for each row by 5 (the number of criteria). These averages provide an estimate of the relative weights of the criteria being compared (Table 2 operations a,b,c) Using this method, the weights are interpreted as the average of all possible ways of comparing the criteria. As we can see, the criterion weights are **0.55, 0.077, 0.18, 0.156** and **0.037** for the ground, elevation, aspect, relief and forest species respectively.

Estimation of the consistency ratio. In this step we determine if our comparisons are consistent. It involves the following operations: (a) determine the weighted sum vector multiplying the weight for the first criterion (ground) times the first column of the original pairwise comparison matrix, then multiply the second weight (elevation) times the second column, the third criterion times the third column of the original matrix, finally add these values over the rows; and (b) determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously (see table 3).

Table 2

Determining the Relative Criterion Weights.

Operation	**Criterion**	Ground	Elevation	Aspect	Relief	For. species
a	Ground	1	8	5	5	8
	Elevation	0.125	1	0.333	0.25	4
	Aspect	0.2	3	1	2	5
	Relief	0.2	4	0.5	1	5
	For. species	0.125	0.25	0.2	0.2	1
	Sum	**1.65**	**16.25**	**7.033**	**8.45**	**23**
b	Ground	0.60	0.49	0.71	0.59	0.35
	Elevation	0.075	0.062	0.047	0.030	0.17
	Aspect	0.12	0.18	0.14	0.24	0.22
	Relief	0.12	0.25	0.071	0.12	0.22
	For. species	0.075	0.015	0.028	0.024	0.04
	Sum	**1**	**1**	**1**	**1**	**1.00**
c		**Weight**				
	1	**2**				
	Ground	(0.60 + 0.49 + 0.710 + 0.590 + 0.350) / 5 = **0.55**				
	Elevation	(0.075 + 0.062 + 0.047 + 0.03 + 0.170) / 5 = **0.077**				
	Aspect	(0.120 + 0.180 + 0.140 + 0.240 + 0.220) / 5 = **0.180**				
	Relief	(0.120 + 0.250 + 0.071 + 0.120 + 0.220) / 5 = **0.156**				
	For. Species	(0.075 + 0.015 + 0.028 + 0.024 + 0.04) / 5 = **0.037**				
	Sum	**1.00**				

Table 3

Determining the Consistency Ratio

Criterion	**Operation (a)**	**Operation (b)**
Ground	(0.55)*(1)+ (0.077)*(8)+(0.180)*(5)+(0.156)*(5)+(0.037)*(8) = 3.15	3.15/0.55 = **5.73**
Elevation	(0.55)* (0.125)+(0.077)*(1)+(0.180)* (0.333)+(0.156)*(0.25)++(0.037)*(4)=0.39	0.39/0.077=**5.06**
Aspect	(0.55)*(0.2)+(0.077)*(3)+(0.180)*(1)+(0.156)*(2)+(0.037)*(5) = 1.02	1.02/0.180 =**5.67**
Relief	(0.55)*(0.2)+(0.077)*(4)+(0.180)*(0.5)+(0.156)*(1)+(0.037)*(5) = 0.67	0.67/0.156=**4.29**
For. Species	(0.55)*(0.125)+(0.077)*(0.25)+(0.180)*(0.2)+(0.156)*(0.2)+(0.037)*(1)=0.19	0.19/0.037 **= 5.13**

Now that we have calculated the consistency vector, we need to compute values for two more terms, lambda (λ) (eigen value) and the consistency index (CI). The value for ***lambda*** is simply the average value of the consistency vector:

$$\lambda = (5.73+5.06+5.67+4.29+5.13) / 5 = 5.176$$

The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration ***(n)*** for positive, reciprocal matrixes, and $\boldsymbol{\lambda = \eta}$ if the pairwise comparison matrix is a consistent matrix. Accordingly, $\boldsymbol{\lambda - \eta}$ can be considered as a measure of the degree of inconsistency. This measure can be normalized as follows:

$$CI = (\lambda - n) / (n - 1) = (5.176 - 5) / (5 - 1) = 0.044$$

The CI term, referred to as the ***consistency index,*** provides a measure of departure from consistency. Further, we can calculate the ***consistency ratio*** (CR), which is defined as follows:

$$CR = CI / RI = 0.044 / 1.12 = 0.039$$

Where RI is the random index, the consistency index of a randomly generated pairwise comparison matrix. This index is given and depends on the number of elements being compared. The consistency ratio (CR) is designed in such a way that if CR<0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR > 0.10, the values of the ratio are indicative of inconsistent judgments. In such cases one should reconsider and revise the original values in the pairwise comparison matrix. In case of our problem, the estimations which were done had a suitable consistency ratio as CR = 0.039 < 0.10, a precondition which must be fulfilled.

In the same way, the method was applied for the case of water production. Water production in the forest depends on four factors, namely the climate-precipitation, the relief, the ecological substratum and the vegetation [11],[12]. Precipitation involves the destructive factor on the geological substratum, whereas vegetation (where it exists), acts protectively. Relief has a compromise regulative influence. The geological substratum of the watersheds is represented by the rocks they consist of (Stefanidis, 1991). In table 2, the comparison of the factors which influence water production is illustrated.

Table 4

Pair wise comparison of the factors which influence water production

Factors	Precipitation	Vegetation	Geol. substratum	Relief
Precipitation	1	4	6	7
Vegetation	0.25	1	3	4
Geol. substratum	0.167	0.333	1	3
Relief	0.143	0.25	0.333	1

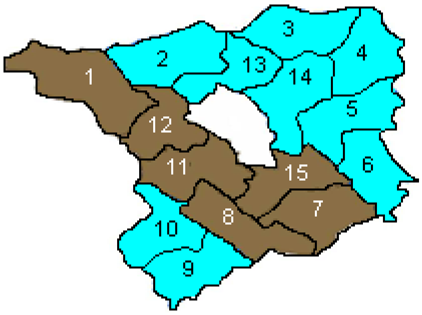
From Table 4, the weights of the criteria were derived with their values being : precipitation 0.601, vegetation : 0.224 geological substratum : 0.116 and relief : 0.059. The estimations which were done had a suitable consistency ratio as CR = 0.065 < 0.10, a precondition which must be fulfilled.

Afterwards, the weights of zones were accounted for each of the factors influencing the production of wood with the help of the pairwise comparison method. At the end, a weight was accounted for each zone for the wood production. For these purposes, the weight criteria of wood production were multiplied by the corresponding weights of zones for each case which resulted from the pairwise comparison and the resulting products were added. (the greater the weight, the greater the importance). Later the account of the criteria weights influencing the water production, the weights of zones were accounted for each of those factors. At the end a weight for each zone was found, which described the procedure of water production. Those weights reveal the rank of importance in this form of production.

Discussion. The pairwise comparison method reveals the rank of importance of the zones for each productive procedure. The values of zone weights for the wood production ranged from 0.031 to 0.138. The value 0.031 belongs to zone **9**, followed by zone **6** with the value 0.035, next zone **10** with 0.040, zone **14** with 0.044, zone **5** with 0.045, zone **7** with 0.048, zone **3** and **8** with 0.053, zone **13** with 0.071, zone **4** with 0.072, zone **2** with 0.077, zone **15** with 0.086, zone **11** with 0.095, zone **12** with 0.112 and, finally, zone **1** with value weight equal to 0.138.

On the other hand, the ranked importance for water production is as follows: zone **7** (0.034), zone **6** (0.036) zone **9** (0.038), zone **15** (0.04), zone **8** (0.05), zone **5** (0.051), zone **10** (0.055), zone **14** (0.059), zones **1** and **11** (0.064), zone **12** (0.092), zone **2** (0.094), zone **14** (0.1), zone **4** (0.101) and finally zone **3** (0.122). From weight values, it is obvious that zone weights don’t differ so much between wood and water production. Another point is that for the same production procedure, the weights don’t have a great range in both cases; particularly, two of the zones (3 and 8 for wood production, and 1 and 11 for water production) have the same value. The reason for this may be that the area of interest is small and in this occasion both the factors influencing wood production as the factors influencing water production can not change a lot. Another reason for this is that pairwise comparison method is a subjective method to a great extend.

These weights can be mapped (Fig.) in order to show the participation of zones in the wood and water production. This can be done by the program ArcGIS using zones and either wood weights or water weights as vectors. Moreover, if the weights of wood and water production were compared in the same zone, the conclusion derived is that some weights can be higher than the others and this means that this zone is more important for water or wood production depending on which weight is higher. This logic thought can help to find which zones are more important for wood production (these zones being 1, 7, 8, 11, 12 and 15) and which zones are more important for water production (these zones being 2, 3, 4, 5, 6, 9, 10, 13 and 14). These results can be mapped to show the areas which favor wood production and which favor water production. 32.62% of total area is more advantageous in wood production and the 54.49% is more advantageous in water production.



Scale 1:50000

Communal wood area

Water area

Evaluation of wood and waterproduction

Conclusions. Multiple criteria decision support is necessary for forest management. The pairwise comparison method which was used here for the estimation of weights is very significant, because it takes into account all the factors which influence the problem under consideration and gives an overall value (weight) for their description. These values allow an easier comparison between the factors and help to resolve the complexity of forest ecosystems. The factors which influence the production of wood (in rank of importance) are land, aspect, relief, elevation and (finally) forest species. On the other hand, water production is influenced in rank of importance by precipitation, vegetation, geological substratum and relief. Zones 1, 7, 8, 11, 12 and 15 have a greater value weight for wood production, whereas zones 2, 3, 4, 5, 6, 9, 10, 13, and 14 have greater value for water production. The zones which promote wood production occupy the 39.62% of the overall area of University Forest of Taxiarchy and the zones which have bigger participation in water production occupy 54.49% of the overall area.

References

1. *Karamanolis, D.* Forest Management II. Methods and Techniques for the Management of Forests and Natural Environment / D. Karamanolis, M. Kateris // Aristotle University of Thessaloniki, Thessaloniki, – 1998. – P.251
2. *Karteris, A. M.* Remote Sensing of Environment / A. M.Karteris // AUTH. University Press, 2004 – P. 276.
3. *Filippidis, A. E.* Geographical Information Systems and Quantitive Methods In Evaluation of Water (The case of University Forest of Taxiarchi, Chalkidiki*)* / A. E. Filippidis // Dissertation. Thessaloniki. – 2001. – P.312.
4. Fund of Management and Administration of University Forest. Administration of Forest Taxiarchi- Brastamon. /Forest Plan of University Taxiarchi- Brastamon 2002-2011, Taxiarchi, 2001. – P. 102.
5. *Malczewski, J.* GIS and Multicriteria Decision Analysis / *J.* Malczewski // Department of Geography University of Western Ontario, John Wiley & Sons, Inc., New York, Chichester, Weinheim, Brisbane, Singapore, Toronto, 1990. – P. 392.
6. *Munda, G*. Qualitative multicriteria evaluation for environmental management / G. Munda, P. Nijkamp, P. Riedveld // Ecological Economics. – 10. –1994. – P. 97-112.
7. *Saaty, L. T.* The Analytic Hierarchy Process / L. T. Saaty // New York: McGraw-Hill, 1980.
8. *Saaty, L. T.* Decision Making with Dependence and Feedback, The Analytic Network Process / L. T. Saaty // RWS Publications, – P. 376.
9. *Papamichos, Th. N.* Forest Ground. Formation, Attributes, Behavior. Section B' (revised) / Th. N. Paramichos // Aristotle University of Thessaloniki Publications. – 1996. – P. 414.
10. *Ntafis, A. S.* Forest Ecolog / A. S. Ntafis // Giachouli-Giapouli press, 1986. – P. 443.
11. Kotoulas, D. Die wildbache Suddeutschlands und Griechenlands. Teil 1. Bericht. Nr. 25. – Munchen, 1972.
12. *Stefanidis, St. P.* Natural Environment, Forest Fires, Hydrologic Consequences. Announcement, Number 21 / St. P. Stefanidis // Aristotle University of Thessaloniki, Faculty of Forestry and Natural Environment, Thessaloniki, 1991.

Статья поступила в редакцию 18.05.09.

Д. Караманолис

ОЦЕНКА ВОДООХРАННОЙ И БИОПРОДУКТИВНОЙ ФУНКЦИИ ЛЕСНОЙ ЭКОСИСТЕМЫ

Проведена оценка водоохранной функции и производства древесины университетскими лесами Таксиархи Халкидики с использованием множественного подхода по принятию решений. В связи с этим университетский лес был разделен на 15 зон, для которых определены критерии и степень их влияния на эти процессы. Для производства древесины важным критерием являются земля, сторона света, рельеф, высота местности, древесная порода.

Ключевые слова: *водное производство древесины, вес, аналитический процесс иерархии, множественный подход к принятию решений.*

КАРАМАНОЛИС Димитриус – профессор, Университет Аристотеля в Салониках, факультет лесного хозяйства и окружающей среды, лаборатория лесопользования и дистанционного зондирования. E-mail: karam@for.auth.gr.