Determining forest priority areas by using multi-criteria decision making method and geographic information system in Kahramanmaraş City

Mahmut Reis[1], Hurem Dutal[1,*], Bulent Abiz[1], Seda Tat[1]

[1] Department of Forest Engineering, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Turkey
[*] Corresponding author: huremdutal@ksu.edu.tr

Abstract: Nowadays, the importance of water resources increases a lot depends on rapid population growth, industrialization and climate change. Lands in a certain area must be used in accordance with their characteristics to achieve sustainable water resource management. Forest ecosystems are one of the most protective measures which allow us to benefit from water resources both effectively and without harming natural life. Thus, it is too important to determine priority forest areas in a certain area. Benefits of afforestation or rehabilitation practices to water resources in relatively more priority areas are higher than less priority ones. In this study, priority forest areas in Kahramanmaras city which has important water resources of Turkey were determined. In order to determine priority forest areas, analytic hierarchy process (AHP), one of the Multi-criteria decision making methods, and Geographic Information System (GIS) were used. Elevation, slope, land capability class, soil type, soil depth and erosion status were considered as criteria in AHP. A score between 1 and 4 was assigned to sub-criteria of each criteria considering forest priority level. Weight score of each criterion was calculated with the help of pairwise matrix. Weight scores of criteria and scores of the sub-criteria were reached by the help of expert opinion and literature. Then, each criteria map was overlaid by using weighted overlay tool in ArcGIS, and priority forest map was produced. According to results, first grade forest priority areas constituted 31.43% of study area, whereas second, third and fourth grade forest priority areas constituted 40.29%, 15.78% and 9.17% of study area. Consistency ratio of pairwise matrix was calculated as 0.02.
Keywords: Water resource, Priority forest areas, AHP, GIS

1. Introduction

It is known that forest ecosystems have a rehabilitative impact on water resources (USDA, 2000). This impact is due to ecological function of forest (hydrological, erosion prevention, climatic, community health care, nature conservation, esthetics, recreation, etc.) (Führer, 2000). There are many effects of forest on quality, quantity and flow pattern of water resources. For example, some studies reported that forest areas receive 15%- 50% more rain compared to other areas. It was determined that forest made 44% of rainfall received into usable water, whereas this ratio in non-forest areas was 14 % (Mizrakli et al., 2008).

Recently, climate change and global warming due to primarily industrialization get to become efficient. It was reported that increases in number and frequencies of natural disasters will occur along with climate change in different parts of the World (IPCC, 2012). It is expected that global warming may cause ecological degradations relating to water resource decrease, forest fires, drought and desertification in Turkey which is among the risk countries in terms of potential effects of global warming (Turkes et al., 2000). Climate change may also lead to adverse effects on agriculture, forestry and water resource in particularly semi-arid and semi humid regions (central Anatolia, southeastern Anatolia, Aegean and Mediterranean) under desertification threat in Turkey (Turkes, 1998). In this context, forest, known as one of the most significant CO_2 sinks, has an important role in combating against climate change. Forest lands together with agricultural, rangeland, wetland and green areas in settlements; sequestrate average 25% of CO2 emitted to atmosphere (CSB, 2013).

One of the positive impacts of forests on water resources is to reduce erosion and sedimentation (Gellis et al., 2006). So, forest prevents to decrease in storage capacity of dam some of which has recently larger area than natural ones, and takes an important place in human life due to its services such as potable and utility water supply and energy generation. Soil removed from any place of watershed reduces water storage volume by entering dam systems, and gives rise to shorten economics life of dams (Sabir et al., 2013).

Water is one of the important components in agricultural production. In Turkey, water use of agricultural sector is more than domestic and industrial water (Evsahibioglu et al., 2010). Major part of water in agricultural production is supplied from dams and draw well. Especially areas where water was not supplied by irrigation canal, groundwater becomes very important and ensures sustainability of production (Evsahibioglu et al., 2010). Therefore, increasing of groundwater quantity and quality is essential. Forest ecosystems reduce runoff and infiltrate more water into soil. Litter composing of decayed leaves, needles, branches, etc. under forest trees constitutes a spongy layer. A well-developed spongy layer covering soil, conserves soil surface structure, reduces runoff due to its very high water holding capacity, and increase water amount infiltrating into soil(FAO, 2008; Gomyo and Kuraji, 2016; Neri et al., 2013). Besides, ıt is known that litter layer has an effect increasing water quality (Fulton and West, 2001; Neary et al., 2009).

Nowadays, water becomes important political and economic power (Selby, 2003). So, we have to benefit from water resources effectively and sustainable. Forest ecosystems are one of the most protective measures which allow us to benefit from water resources both effectively and without harming natural life (Kreye et al., 2014). Therefore, practices such as expanding forest area and rehabilitation have to be performed. When these practices are performed, priority forest areas are prioritized to get the highest efficiency.

Recently multi criteria decision making methods have become a widespread methods used to solve problems regarding to ecosystem functions (Altunel and Akyuz, 2007). MCDM includes selecting among alternatives and grouping and arraying alternatives by taking a few alternatives into consideration (Esen, 2016). AHP, one of the MCDM methods, tackles problems hierarchically and based on pairwise comparison (Saaty, 1980). Priority areas can be determined by using AHP with geographic information systems (Akbulak, 2010).

Kahramanmaras city center is located in Mediterranean region where is expected to be influenced by climate change in Turkey. In the city center which has large water reservoir, dams and weirs in commissioning, under construction and planned stages and streams exist (Yücel et al., 2013). In irrigated farming areas, groundwater is also used as both irrigation and potable water (CSB, 2012). Erosion which is one of the most important problems in Mediterranean belt poses a threat to dams in study area (Verheye, 2009).

In this study, it is aimed to determine forest priority areas whose essential function is natural protection such as especially soil and water conservation, and so generate data considered in land use planning in future.

2. Material and method

2.1. Study area and data

Study area is 33626.89 ha and covers city center and immediate area (98% of Kahramanmaras administrative border) of Kahramanmaras located in Mediterranean region (figure 1). Average elevation is 568 m, and it increase up to 3000 m above in north part of study area. Average slope is 44.6%. Annual average rainfall and temperature are 727.7 mm and 16.9 °C respectively. Average maximum temperature is 47.5 °C in August, while average minimum temperature is -9.6 °C in February (DMI, 2017). Winters are warm and rainy, summers are hot and dry. In the study area, Menzelet, Klavuzlu, Sır, Ayvalı, Sarıguzel, Suçatı ve Cataloluk dams exist. Dominant land use types are forest, rangeland, cultivated and settlement areas.

Figure 1. Location of study area on satellite image

In order to generate maps used in the study, contour, land capability class, soil type, soil depth and erosion maps were used. Results obtained were evaluated in conjunction with current forest management plan including study area.

2.2. Method

In this study, it was aimed to determine priority forest areas in Kahramanmaras city. A gıs based AHP method was used to produce priority forest areas map. This method is a robust and flexible decision-making tool that is used for finding solutions of complex multicriteria problems such as a determining the priority of conservation practices (Fallah et al., 2016; Valente and Vettorazzı, 2008), landslide susceptibility mapping (Pektezel, 2015) or soil erosion risk assessment (Wu and Wang, 2007; Rahman et al., 2009).

The AHP method consists of four steps:

(1) Structure the problem into a hierarchy having different levels, i.e., goal, criteria, sub criteria, and alternatives
(2) Make pair-wise comparison matrix $A=[aij]n \times n$, where n is matrix size and $aij \geq 0$ $aij \times aji=1$, aij – importance of the ith decision factors over the jth decision factors by using table 1.
(3) Calculate the relative weights (priorities) of decision factors using prioritization method, e.g. eigenvalue (EV) method (Srdevıc, 2005).
(4) Make synthesis of the priorities. All matrix must satisfy consistency test by using formula 1, i.e., judgment matrix are accepted if consistency ratio (CR) obtained using consistency index (CI) and random index (RI) is less than 0.10 (Vulević et al., 2015) or if also first eigen value equals matrix size (Arslan, 2010).

Table 1. The fundamental scale of absolute numbers (Saaty, 2008)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation A reasonable assumption

$$CR = CI / RI \quad (1)$$

Where; CR = Consistency Ratio

CI = Consistency Index, CI= (λmax-n) / (n-1)

RI = Random Index (table 2), λmax = First eigen value, n = Numbers of factor

Table 2. RI values for different values of n. (Triantaphyllou and Mann, 1995)

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Elevation, slope, land capability class, soil type, soil depth and erosion status were considered as criteria in AHP. A score between 1 and 4 was assigned to sub-criteria of each criteria considering forest priority level. 1 represented the lowest priority, while 4 represented the highest priority in this study. Weight score of each criterion was calculated with the help of pairwise matrix. Weight scores of criteria and scores of the sub-criteria were reached by the help of expert opinion and literature.

Criteria maps were classified taking sub criteria score into account in ArcGIS environment. All maps must be raster format and same grid size in this study. So, vector maps were converted to raster maps with 30x30 m grid size. Finally, each criteria map was overlaid by using weighted overlay tool in ArcGIS, and priority forest map was produced.

Results were examined considering current forest management map of study area. Thus, forest priority map was overlaid with current forest management map.

3. Results and discussion

Main goal of this study was to determine areas on which forest practices must focus so that effectiveness and efficiency principles were provided in water and soil protection. In order to determine these areas, AHP method and GIS were used. Elevation, slope, land capability class, soil type, soil depth and erosion status were considered as criteria in AHP method.

It is clear that soil resources must be primarily protected for water resources protection. Erosion had the highest weight value because it is the leading factor posing a threat to soil resources. Criteria following the erosion, slope and elevation had 0.24 and 0.14 weight values respectively. Table 3 shows criteria weight and sub criteria score obtained from AHP method, expert opinion and literature.

Table 3. Weight values of criteria and scores of sub criteria

Criteria	Weight	Sub criteria	Score
Elevation (m)	0.14	<800	1
		800 - 1000	2
		1000 - 1400	3
		1400 - 2000	4
		>2000	1
Slope (%)	0.24	0 - 2	1
		2 - 6	1
		6 - 12	1
		12 - 20	2
		20 - 30	3
		> 30	4
Land capability class	0.12	1	1
		2	1
		3	1
		4	2
		5	4
		6	3
		7	4
		8	1
Soil type	0.04	Alluvial	1
		Brown	2
		Reddish brown mediterranean	2
		Reddish brown	3
		Colluvial	4
		Brown forest	4
		Non-calcareous brown forest	4
		Non-calcareous brown	3
Soil depth (cm)	0.07	<30	4
		30 - 60	3
		60 - 90	3
		90 - 150	2
		>150	1
Erosion	0.39	No or very low	1
		Moderate	2
		High	4
		Very high	4

After determination of criteria weight and sub criteria score process, each criteria map is overlaid in GIS environment. As a result of this process, forest priority map obtained is presented in figure 2.

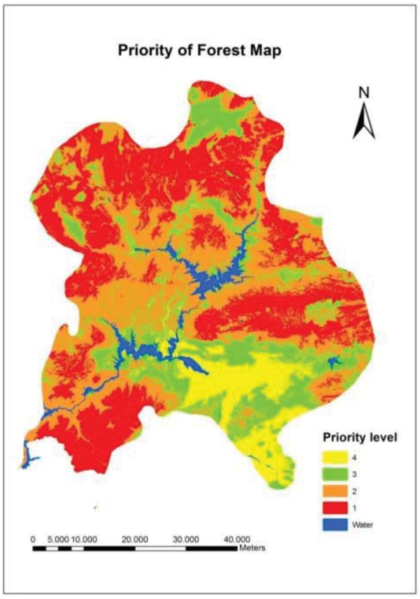

Figure 2. Forest priority classes map

Study area was divided into 4 classes in terms of priority. Areas with highest priority, called first degree priority areas, constituted 31.43% of study area, while second, third and fourth degree priority areas constituted 40%, 15% and 9.17% of study area respectively (table 4).

Table 4. Areal distribution of priority classes

Priority level	Area (ha)	Percent (%)
1	105894.3629	31.43
2	135734.1500	40.29
3	53171.3300	15.78
4	30881.7800	9.17
water surface	11245.2600	3.34
Total	336926.8829	100.00

When examine current management plan of study area, 43.35% of 1st degree areas comprised of degraded stands, while 28.41%, 12.22% and 0.53% of 2nd, 3rd and 4th degree areas comprised of degraded stands respectively. In addition to this, it was determined that forest was dominant land use in 1st and 2nd degree priority areas; whereas agriculture was dominant in 3rd and 4th degree priority areas (table 5).

Table 5. Land use distribution of priority classes

Priority level of forest	Areal distribution (ha)		Percent (%)
1	agriculture	7253.4885	6.85
	settlement	278.0031	0.26
	open space	19818.0700	18.71
	rangeland	463.7776	0.44
	degraded stand	44849.6040	42.35
	afforestation	1583.3760	1.50
	Stands with 1,2,3 crown closure	31300.0700	29.56
	others	347.9737	0.33
	total	105894.3629	100.00
2	agriculture	26215.7900	19.31
	settlement	1709.9000	1.26
	open space	23135.2500	17.04
	rangeland	109.3400	0.08
	degraded stand	38558.5700	28.41
	afforestation	1080.1590	0.80
	Stands with 1,2,3 crown closure	43937.8600	32.37
	others	987.2810	0.73
	total	135734.1500	100.00
3	agriculture	19482.9900	36.64
	settlement	4380.8500	8.24
	open space	11345.3100	21.34
	rangeland	0.0300	0.00
	degraded stand	6497.5600	12.22
	afforestation	434.0260	0.82
	Stands with 1,2,3 crown closure	9605.3000	18.06
	others	1425.2640	2.68
	total	53171.3300	100.00
4	agriculture	25479.9200	82.51
	settlement	3385.2700	10.96
	open space	950.9300	3.08
	rangeland	0.0000	0.00
	degraded stand	164.9300	0.53
	afforestation	80.4400	0.26
	Stands with 1,2,3 crown closure	800.2000	2.59
	others	20.0900	0.07
	total	30881.7800	100.00

It was seen that 3rd and 4th degree areas were generally located in lower slope areas according to slope map (figure 3).

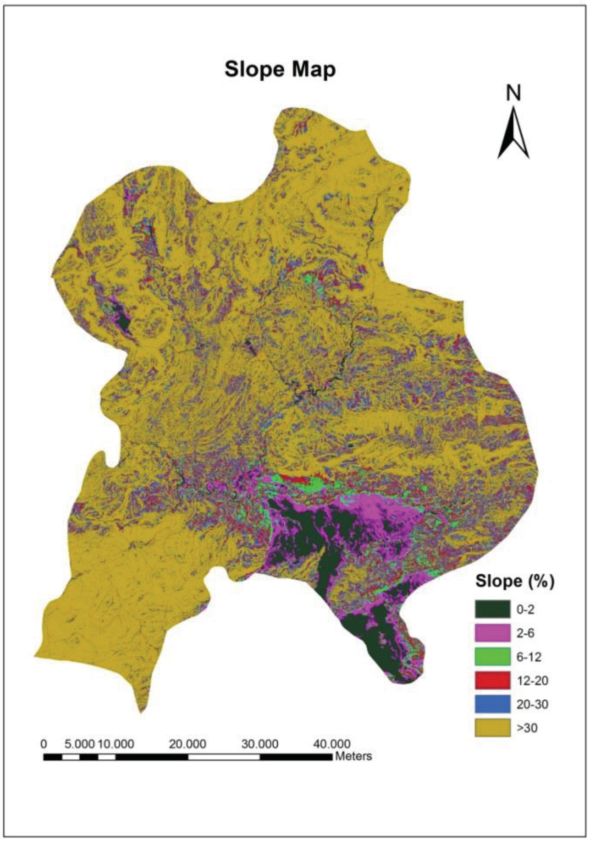

Figure 3. Slope classes map

Relatively lower agricultural area ratio (6.85%) in 1st degree areas indicated forest rehabilitation and afforestation practices may make more contribution than measures in agricultural areas to water and soil protection practices, when compared to other priority classes. When afforestation practices in priority classes are evaluated, 1st degree priority class has the highest value as both area and ratio (1.50%), while afforestation ratios of 3rd, 2nd and 4th degree priority classes are 0.82%, 0.80% and 0.26% respectively (table 5). This situation indicates that priority area approach is not considered adequately in study area.

References

Akbulak, C. 2010. Analitik hiyerarşi süreci ve coğrafi bilgi sistemleri ile Yukarı Kara Menderes Havzası'nın arazi kullanımı uygunluk analizi. *Uluslararası İnsan Bilimleri Dergisi* [Bağlantıda]. 7:2. Erişim:http://www.insanbilimleri.com

Altunel, A.O. ve Akyüz, F. 2007. Orman Nakliyat Planlamasında Arazi Sınıflandırmasının Önemi. TMMOB Harita ve Kadastro Mühendisleri Odası Ulusal Coğrafi Bilgi Sistemleri Kongresi 30 Ekim –02 Kasım 2007, KTÜ, Trabzon.

Arslan, E. T. 2010. Analitik hiyerarşi süreci yöntemiyle strateji seçimi: Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi'nde bir uygulama. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 15 (2), 455-477.

CSB (Çevre ve Şehircilik Bakanlığı), 2013. Türkiye İklim Değişikliği 5.Bildirimi. T.C. Çevre ve Şehircilik Bakanlığı, Ankara.

CSB, 2012. Kahramanmaraş il çevre durum raporu. Çevre ve Şehircilik Bakanlığı.

DMİ, 2017. https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=K.MARAS, 26 Temmuz 2017' de erişildi.

DOĞAKA, 2015. Tr63 bölgesi mevcut durum analizi: sürdürülebilir çevre ve iklim değişikliği. Doğu Akdeniz Kalkınma Ajansı.

Esen, F. 2016. Coğrafi Bilgi Sistemleri (Cbs) Ve Analitik Hiyerarşi Süreci (Ahs) İle Bingöl Ovasi Ve Yakin Çevresinde Optimal Arazi Kullaniminin Belirlenmesi. Akademik Sosyal Araştırmalar Dergisi, Yıl: 4, Sayı: 38, Aralık 2016, s. 176-193.

Evsahibioğlu, A. N., Aküzüm, T. ve Çakmak, B. 2010. Su Yönetimi, Su Kullanım Stratejileri ve Sınıraşan Sular. Türkiye Ziraat Mühendisliği VII. Teknik Kongresi.

Fallah, M., Kavian, A. and Omidvar, E. 2016. Watershed prioritization in order to implement soil and water conservation practices. Environ Earth Sci (2016) 75:1248 DOI 10.1007/s12665-016-6035-1.

FAO, 2008. Forests and water. Fao forestry paper 155, Issn 0258-6150.

Führer, E. 2000. Forest Functions, Ecosystem Stability And Management. Forest Ecology And Management 132, 29-38.

Fulton, S. and West, B. 2001. AQUA-3: Forestry Impacts on Water Quality. Southern Forest Resource Assessment Draft Report.

Gellis, A.C., Webb, R. M. T., McIntyre, S. C. and Wolfe, W. J. 2006. Land-Use Effects on Erosion, Sediment Yields, and Reservoir Sedimentation: A Case Study in The Lago Loíza Basin, Puerto Rico. Physical Geography, 27, 1, Pp. 39–69.

Gomyo, M. and Kuraji, K. 2016. Effect of the litter layer on runoff and evapotranspiration using the paired watershed method. J For Res (2016) 21:306–313, DOI 10.1007/s10310-016-0542-5.

IPCC, 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 3-21.

Kreye, M.M., Adams, D.C. and F.J. Escobedo. 2014. The value of forest conservation for water quality protection. *Forests* 5(5):862-884. doi: http://dx.doi.org/10.3390/f5050862

Mizrakli, A., Güzenge, E. ve Yalçin, Ş. A. 2008. Ormanlarin Su Kaynaklari Potansiyeli Üzerine Etkileri, Bu Alanlarin Belirlenmesi, Korunmasi ve Dim Planlama Örneği. Tmmob 2. Su Politikaları Kongresi.

Neary, D.G., Ice, G.G. and Jackson, C. R. 2009. Linkages between forest soils and water quality and quantity. Forest Ecology and Management 258 (2009) 2269–2281.

Neri, J., Tejedor, M., Rodríguez, M., Fuentes, J. and Jiménez, C. 2013. Effect of forest floor characteristics on water repellency, infiltration, runoff and soil loss in Andisols of Tenerife (Canary Islands, Spain). Catena 108 (2013) 50–57.

Pektezel, H. 2015. Coğrafi Bilgi Sistemleri ve Analitik Hiyerarşi Yöntemi Kullanılarak Gelibolu Yarımadası'nda Heyelana Duyarlı Alanların Belirlenmesi, Turkish Studies - International Periodical for the Languages, Literature and History of Turkish or Turkic Volume 10/6 Spring, p. 789-814, ISSN: 1308-2140, www.turkishstudies.net, DOI Number: http://dx.doi.org/10.7827/TurkishStudies.8182, ANKARA-TURKEY.

Rahman M.R., Shi Z.H., Chongfa C. 2009. Soil erosion hazard evaluation - An integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. Ecol. Model. 220, (13-14), 1724.

Saaty T. L. 2008. Decision making with the analytic hierarchy process. Int. J. Services Sciences, Vol. 1, No. 1.

Saaty, T. L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill Comp., U.S.A.

Sabir, M. A., Shafiq-Ur-Rehman, S., Umar, M., Waseem, A., Farooq, M. and Khan, A. 2013. The Impact of Suspended Sediment Load on Reservoir Siltation and Energy Production: a Case Study of the Indus River and Its Tributaries. *Pol. J. Environ. Stud. Vol. 22, No. 1, 219-225.*

Selby, J. 2003. Water, power and politics in the middle east: the other Israeli- Palestinian conflict. I.B. Tauris & Co Ltd, New York.

Srđević B. 2005. Combining different prioritization methods in the analytic hierarchy process synthesis. Comput. Oper. Res. 32, (7), 1897.

Triantaphyllou E., Mann, H. S. 1995. Usıng The Analytıc Hıerarchy Process For Decısıon Makıng In Engıneerıng Applıcatıons: Some Challenges. Inter'l Journal of Industrial Engineering: Applications and Practice, Vol. 2, No. 1, pp. 35-44.

Türkeş, M. 1998. 'İklimsel değişebilirlik açısından Türkiye'de çölleşmeye eğilimli alanlar, DMİ/İTÜ II. Hidrometeoroloji Sempozyumu Bildiri Kitabı, 45-57, Devlet Meteoroloji İşleri Genel Müdürlüğü, Ankara.

Türkeş, M., Sümer, U. M. ve Çetiner, G. 2000. 'Küresel iklim değişikliği ve olası etkileri', Çevre Bakanlığı, Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi Seminer Notları (13 Nisan 2000, İstanbul Sanayi Odası), 7-24, ÇKÖK Gn. Md., Ankara.

USDA, 2000. Water & the forest services. United States Department Of Agriculture, Forest Service Washington Offıce, Fs-660, January 2000.

Valente R.O.A., Vettorazzi C.A. 2008. Definition of priority areas for forest conservation through the ordered weighted averaging method. Forest Ecol. Manag. 256, (6), 1408.

Verheye, W. H. 2009. Land Use, Land Cover and Soil Sciences: Land use planning. Eolss Publishers Co. Ltd., Oxford, United Kingdom.

Vulević, T., Dragović, N., Kostadinov, S., Simić, S. B., Milovanović, Irina. 2015. Prioritization of Soil Erosion Vulnerable Areas Using Multi-Criteria Analysis Methods. Pol. J. Environ. Stud. Vol. 24, No. 1 (2015), 317-323.

Wu Q., Wang M. 2007. A framework for risk assessment on soil erosion by water using an integrated and systematic approach. J. Hydrol. 337, (1-2), 11.

Yücel, P., İşliyen, K., Tekin, E., Akgün, İ. ve Ünsal, M. 2013. Kahramanmaraş'taki Barajlar ve Kullanım Amaçları. BEU Journal of Science 2(1), 109-118, 2013 2(1), 109-118.