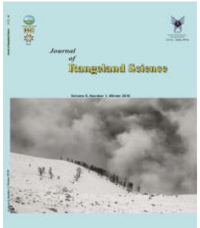
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Site Selection for Rainwater Harvesting for Wildlife using Multi-Criteria Evaluation (MCE) Technique and GIS in the Kavir National Park, Iran

Masoud Jafari Shalamzari[A]*, Atefeh Gholami[B], Shahram Khalighi Sigaroudi[C], Afshin Alizadeh Shabani[D], Hosein Arzani[E]

[A] PhD, Attended University of Agriculture and Natural Resources, Gorgan, Iran, *(Corresponding Author), email: msdpardis@hotmail.com
[B] PhD Candidate, University of Agriculture and Natural Resources, Gorgan, Iran,
[C] Associate Professor, Watershed Management, University of Tehran
[D] Associate Professor, Wildlife Ecology- Landscape Ecology, University of Tehran, Iran
[E] Professor, Range Management, University of Tehran, Iran

Received on: 17/01/2017
Accepted on: 17/06/2017

Abstract. This research is an integration of GIS and multi-criteria decision making into a joint framework for identifying suitable areas for rainwater harvesting structures. The Kavir National park in Iran has been evaluated for suitability of rainwater harvesting. To this end, slope gradient, distance to guarding stations, distance to watering points for transporting collected water, distribution of wildlife species of interest, access to roads, evaporation, elevation, water scarcity index, and annual precipitation during rainy season were incorporated. Data collection and field visits took place during 2014-2015. Rainwater harvesting in this area is primarily intended for *Ovis orientalis*, *Gazella dorcas* and *Acinonyx jubatus* known as Persian Cheetah. The primary layers were standardized using a proper Fuzzy Membership Function, which assigns a weight between 0 and 1 to each layer, to include the inherent tradeoff between data layers in producing the final suitability map. The results suggested that precipitation and water scarcity (each by the relative weights of 0.3 and 0.2, respectively) were the most influential factors. The northern foothills of the Mount Siahkouh have shown to hold the highest suitability for rainwater harvesting. The suitability changes from lower than 100 to the east to higher than 200 to the west. The result of this study might be used to guide future endeavors for rainwater harvesting for wildlife on the ground. The methodology adopted here could be replicated in other studies with respect to its simplicity and practicality. This is recommended to run pilot small-scale rainwater harvesting practices and receive the outcomes and then, in case of a positive feedback, extend its application to other areas identified in this research.

Key words: Rehabilitation, MCE, Wildlife, Water Development, Kavir National Park, GIS

Introduction

Water is the vital element of life (Matlock, 1981). However, water supplies in arid and semi-arid areas are often scarce, and highly variable and of inferior quality (Goodall *et al.,* 2009). Climate changes have resulted in an increased number of drought events and greater intensities (Nabhan, 2013). The situation is compounded by human interventions and mismanagement of water resources (Foltz, 2002).

Water is an essential component of wildlife habitat. It attracts a wonderful variety of wildlife from songbirds to small mammals, reptiles, amphibians and beneficial insects (Dodson, 2000). Availability of water largely determines the distribution and abundance of animals in arid and semi-arid environments, influencing the carrying capacity of protected areas (Wolff, 2001). Lack of water prevents wildlife from reaching its optimum population within the habitat (Deal, 2010) and will definitely result in an uneven utilization of habitat's resources if not preventing all (Bone *et al.,* 1992). As an extra burden, human use of nature has narrowed down the field not only for human itself, but also for wildlife to meet its demands. Human utilizes nature indiscriminately while neglecting the others' rights to live. Consuming surface and underground water reservoirs from wells and dams has limited water accessibility for wildlife. As a good case in point, Daniali *et al.* (2009) evaluated the role of illegal water extraction from springs and wells on wildlife in the Ghamishloo National Park, Iran and reported fragmentation and loss of wildlife of the area. On the other hand, human intervention in nature such as constructing roads and utility lines has resulted in the fragmentation of wildlife habitats, disappearance of animal corridors, and less reproduction rates (Leslie and Douglas, 1980). Batool and Hussain (2016) believe that agriculture and urban expansion are the main causes of water pollution and scarcity for wildlife. Releasing nutrients and consuming considerable amounts of water could result in both water quality deterioration and shortage in places mostly needed for wildlife. Wurtsbaugh *et al.* (2016) reported on the attempts to revive the Salt Lake in the USA, which previously started to move towards desiccation. They believe that agriculture by consuming 63% of the resources feeding the lake was the one to blame for the lowering levels of the Salt Lake, and the possible future issues. Beside water utilization, human intervention through water governance could also lead to water scarcity for wildlife. For instance, Huntsinger *et al.* (2017) argue that strict water governance could cause the unintended consequences for biodiversity and environmental quality. They believe that measures considered to increase water price and prevent water leakage have resulted in water shortage for California Black Rail (*Laterallus jamaicensis coturniculus*).

Water development for wildlife is increasingly gaining favor during the recent decades, yet in some cases without a sense of realism (Matlock, 1981). Where water is lacking but other habitat essentials are available to benefit wildlife, water may be developed using artificial or natural means or by a combination thereof (Brigham and Stevenson, 2003). Tavasoli *et al.* (2016) investigated a number of islands in the Lake Urmia, Iran and proposed rainwater harvesting through rock catchments and subsurface barriers as the good practices for providing water for wildlife. Artificial or modified water sources (i.e., catchments) are widely used for wildlife management in the arid western United States, where thousands of such catchments have been built to enhance wildlife populations and compensate for the loss of natural water sources (Krausman *et al.*, 2006; Harrison, 2016; Kluever *et al.,* 2016; Kluever and Gese, 2016). In spite of the existence of some controversy around water development for wildlife, most studies testify the acceptance of these watering sources from different wildlife species (Dolan, 2006; Bone *et al.,* 1992; Manning and Edge, 2001; Kluever *et al.,* 2016)).

There are not many options before the managers to decide how to provide wildlife water demand. Inter alia, rain harvesting, dew and fog harvesting, solar distillation and pumping, wind pumps, rock catchments and small surface and sub-surface dams may be regarded as the possible ways to overcome the situation while satisfying both economic and ecological conditions (Burkett and Thompson, 1994; Halloran and Deming, 1958; Jafari Shalamzari *et al.,* 2015).

Rainwater harvesting in its broadest sense can be defined as the collection of rainwater run-off for domestic water supply, agriculture and environmental management (Worm, 2006). Rainwater harvesting has proven to be a good, low-cost, and simple water supply technology for domestic, agricultural and environmental purposes (UNEP, 2003). Rain water harvesting (hereafter referred to as RWH) is an attractive option because the water source is near and convenient and requires minimum energy to collect. However, the main disadvantage of RWH is that one can never be sure how much rain will fall (Worm, 2006).

Though rain falls infrequently in arid lands, it comprises considerable amount of water; 10 mm of rain equals 100,000 L of water per ha. Harvesting this can provide water for regions where other sources are too distant or too costly to collect, or where wells are impractical because of unfavorable geology or excessive drilling costs (National Research Council, 1974). Human-made rainwater harvesting systems are collectively known as guzzlers. These are mobile structures that can be relocated if needed, and can help to re-establish wildlife that has previously left because of water scarcity and drought. Guzzlers include a solid roof-like structure, a tank and a float switch, and gravity feed. Roof-like structure is a tilted plain which directs runoff towards a tank – usually 8.5 m^3 in volume, or an adjacent location to be fed to the water trough via a floating switch (Kinkade-Levario, 2013).

Many spatial decision-making problems such as site selection for water guzzlers in this case require the decision-maker to consider the impacts of difference factors and multiple dimensions (Fisher, 2006; Forzieri *et al.,* 2008). This process could be aided by the application of the Multi-Criteria Decision Support Systems (MCDS).

Site selection is a generic term noticing the process of finding locations or features meeting specified conditions. For various purposes, it is often expressed as site suitability. Site suitability is the process of finding the most suitable location(s) for a particular purpose (Davis, 2001). One major drawback of spatial multi-criteria decision making methods is their required time. GIS enables the managers to implement these types of analysis in a timely manner as it can analyze the spatial data which may be available from various sources in an integrated and graphical way (Ray and Acharya, 2004).

Far too little attention has been paid to site selection for rainwater harvesting structures especially for wildlife water provision. There remains a paucity of evidence on the successful application of multi-criteria decision making analysis in this context. Thus, this study set out to determine the most suitable sites to plan structures for artificial RWH systems for wildlife in an arid area inside Iran. Here, Rainwater harvesting as a permanent resource could provide enough water for the wildlife of the area. Using a simple water budget, water deficit is determined and a remote attempt to locate suitable places for RWH is carried out. This study considers the application of a joint venture of GIS, field works and multi-criteria decision making.

Materials and Methods

Study area

Located south of Tehran city, Kavir National Park comprises an area exceeding 6810 km^2. The outer limits are located between 51º25'10'' to 53º03'05''eastern longitudes and 34º17'15'' to 35º12'30'' northern latitudes. Based on the statistics provided by the Semnan Weather Organization, precipitation mainly occurring during winter in the Kavir National Park reaches up to merely 100 mm. Hot and harsh summers and bitterly cold winters are typical of the central parts of Iran. The park is already lacking in water resources for wildlife. A large proportion of the area is flat with scarce topographic outcrops like SiahKouh in the west and some negligible elevations in the east. The dominant wildlife species of the park include *Ovis orientalis* (with body weight between 25-85 Kg), *Gazella dorcas* (with body weight between 15-25 Kg) and *Acinonyx jubatus* (with body weight between 20-72 Kg) known as Persian Cheetah (Semnan Department of Environment, 2005). The sketch of the area is illustrated in Fig. 1.

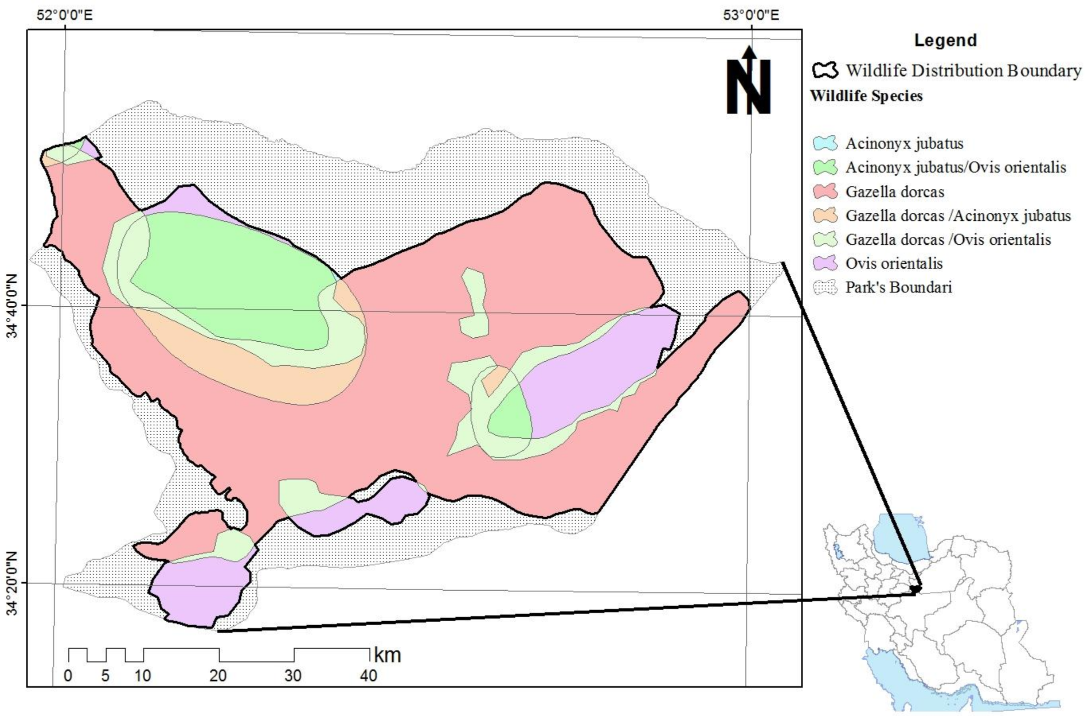


Fig. 1. Location of the study area related to the Kavir National Park's and Iran's boundary

Wildlife and water shortage in the area

According to the latest statistics of the Semnan Department of Environment (direct interviews), Kavir National Park is the home to 13 cheetahs, 900 *Gazella dorcas* and 2100 *Ovis orientalis*. Gazelles are diurnal, mostly active at dawn and dusk. They may become nocturnal under pressure from diurnal predators. Gazelles feed on Gramineae and Zygophyllum (according to direct observations). Depending on the season, methods for obtaining food change. In summer, gazelle dig holes in the sand to feed on stems and bulbs. After winter rains, they eat fresh sprouted leaves (Lawes and Nanni, 1993). They are tolerable animals and can endure high temperatures and water scarcity. *Gazella dorcas* drinks water as much as 10% of its body weight (depending on the body condition and temperature) or 2.5 liters per day. This animal can get as far as 5.6 Km from its water sources (Mendelssohn *et al.*, 1995). Desert bighorn sheep (*Ovis orientalis)* are mainly diurnal and spend most of their day foraging. They presumably feed on grasses and shrubs and prefer steep to undulating grassy terrain. Their lifespan ranges between 8-12 years (Valdez *et al.*, 1982). These sheep require a minimum of 3–4% of their body mass in water/day and drink water for at least 2-3 minutes at a rate of 2.8 liter per minute (Bashari and Hemami, 2013). During summer, drinking occurs at dawn and dusk. These sheep can walk as long as 3.2 km from water sources (Dolan, 2006). *Acinonyx jubatus* preferred habitats including grassland and deserts (Caro, 1994). They live approximately 6-8 years and maintain a territory. They have a carnivorous diet, of which a large portion includes gazelles and obtain water from their prey or by concentrating urine.

Water shortage in the area is more acute during dry period covering June through October which is totally 150 days. As a rough estimate during hot season in which water is scarce, these animals are in demand of 1867.5 m^3 water. Based on the discharge of all springs, fresh water distribution in whole area was interpolated using Inverse Distance Weighting Interpolation Technique (known as the IDW technique). The IDW is a method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points see (Vieux, 2004). The resulting raster layer was divided by the total water demand for wildlife to produce the water scarcity layer.

$$\mathrm{WSI} = \frac{TDW}{WD} \qquad \text{eq. 1}$$

Where:

WSI= the water scarcity index

TDW= the total discharged water during the warmest months, and

WD= the water demand for wildlife during the same period, which is calculated based on the number of animals multiplied the daily water requirement times the duration of period.

Multi-criteria Decision Making

Decisions about the allocation of land typically involve the evaluation of multiple criteria according to several, often conflicting, objectives. With the advent of GIS, we now have the opportunity for a more explicitly reasoned environmental decision making process (Eastman *et al.*, 1995). Consideration of different choices or courses of action becomes a multiple criteria decision making (MCDM) problem when there may exist such standards which conflict to a substantial extent (Belton and Stewart, 2002). There are two categories within MCDM, namely, multiple objective decision making (MODM), and multiple attribute decision making (MADM often referred to as multi-criteria evaluation (MCE)). MODM refers to select the best alternative subject to certain constraints. MADM is applied to the problem of selecting the best alternative among a set of finite alternatives (Herath and Prato, 2006). In this paper, a raster-based MCE is applied to identify suitable areas for using rainwater harvesting. There are two fundamental classes of multi-criteria evaluation methods in GIS: the Boolean overlay operation (non-compensatory combination rules) and the weighted linear combination (WLC) method (compensatory combination rules) (Malczewski, 2006b). The approach adopted in this paper is based on the combination of standardized and weighted raster layers based on the weighted linear combination in Arc GIS 10.2. The weighted overlay function, embodied in the Arc GIS toolbox, enabled the combination of layers. The distribution of wildlife species as a Boolean layer was superimposed on the final suitability map to exclude the areas outside the animal presence's boundary.

Standardization of Criteria Maps

First step in using MCE method is to define a set of decision criteria in line with decision maker's objectives. Next, one needs to develop a suitable GIS database for the layers (Salim, 2011). To be able to utilize criteria and their spatial representation, they should be associated with a common scale of measurement. The process of translating the various inputs of a decision problem to a common scale to allow for comparison, analysis and synthesis is termed standardization (Voogd, 1983). Among different standardization schemes, the Fuzzy Membership function was used to transform the input data to a 0 to 256 scale. A value of 256 indicates full membership in the fuzzy set while membership decreasing to 0 indicates that it is not a member of the fuzzy set [1].

Definition of WLC

Weighted linear combination (WLC) together with the analytic hierarchy process (AHP) has been widely used for different spatial analyses (Chandio and Bin Matori, 2011, Malczewski, 2006a, Gorsevski *et al.,* 2012, Şener *et al.,* 2010). In this theme, different data layers are combined linearly with the assigned weights attached to them denoting the priority of one layer in determining final decision to define appropriate sites for making use of rainwater (Mbilinyi *et al.,* 2007). The assigned weights were calculated on the basis of the AHP method firstly proposed by Saaty (1980). The AHP decision making technique uses weights on a continuous scale from 1-9 or equally important to absolutely most important. Relative influence of each raster layer was determined with the aid of questionnaires distributed among managers and experts of wildlife management.

WLC procedure allows full tradeoff among all factors. The amount any single factor can compensate for another is, however, determined by its factor weight (Eastman, 2003). WLC is on the basis of applying weights on the layers and summing the results to yield a suitability map as given in Eq. 2:

$$S = \sum_1^n W_i X_i \qquad \text{eq. 2}$$

Where:

S= suitability score,

W^i= the weights of factor for the i[th] factor and

X^i= the score for the certain factor.

The whole process is described in Fig. 2.

Site Selection Criteria

Different studies have used various criteria for rain water harvesting. Weerasinghe *et al.* (2011) believe that elevation, soil depth, soil type, land use and land cover are determinant factors for RWH. Rishab and Khitoiiya (2006) in a review proposed rainfall volume and intensity, vegetation cover percent, land use, slope gradient and length, evaporation rate, soil type, socio-economic factors and ecologic consequences of action as the influential factors for RWH site selection. Mbilinyi *et al.* (2007) reported that precipitation volume, soil texture and depth, slope, land use and cover and drainage network have to be included for a RWH site selection study. In this study, slope gradient, distance to guarding stations, distance to watering points for transporting collected water, distribution of species of interest, access to roads, evaporation, elevation, water scarcity index, and annual precipitation during rainy season were incorporated to locate the suitable areas for the installation of water guzzlers. Slope gradient was calculated in percentage from the digital elevation model and fuzzified using the MSmall fuzzy membership function (FMF) where higher slopes (the steep slopes of the Siahkouh Mountain and the eastern elevations of the area) becomes increasingly unsuitable for RWH structures, either for the installation of equipment or inaccessibility of the areas. During the field visits, the location of

[1] Adopted from the ArcGis 10.3 manual available at: http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-fuzzy-membership-works.htm

guarding stations were recorded via GPS and introduced into the Arc GIS. This layer was then converted to a Euclidean distance map where farther areas are considered less suitable. This was carried out via the Small FMF. The data on access roads were acquired from the Natural Conservation Service in Semnan Province and converted to a distance map using a similar approach. Data on watering points (wells, springs, and water troughs) were acquired from the Natural Conservation Service and then similarly converted to a distance map. Evaporation was measured from the data available for the evaporation gauging stations and converted to an interpolated surface using the Kriging technique. Higher evaporation levels are considered unsuitable as it would result in the loss of stored water. Thus, an MSmall FMF was adopted for data standardization. As there is no weather stations in the area, precipitation layer was prepared based on the established relationship with elevation. This layer was standardized using MLarge membership functions. Water scarcity layer (as previously explained) was standardized so that the areas with higher scarcity values receive higher priority. This layer was standardized using Small FMF. Distribution of wildlife species was determined during the field visits and improved by the incorporation of the opinions of the guards. This layer was converted into a layer of 0 and 1 to be further applied on the final suitability map as the limiting factor. The final suitability formula has been obtained as following (eq. 3):

$$FS=(0.1\times DG+0.05\times Evap+0.05\times DR+0.1\times Sl+0.3\times Precp+0.2\times WS+0.1\times DWS+0.1\times Elev)\times WDM \quad \text{eq. 3}$$

Where:
DG= distance to guarding posts (m),
Evap = evaporation (mm),
Dr =distance to roads,
Sl =slope (%),
Prec =precipitation during the wet season (mm),
WS =water scarcity,
DWS =distance to watering points (m),
Elev =elevation (m), and
WDM =wildlife distribution layer.

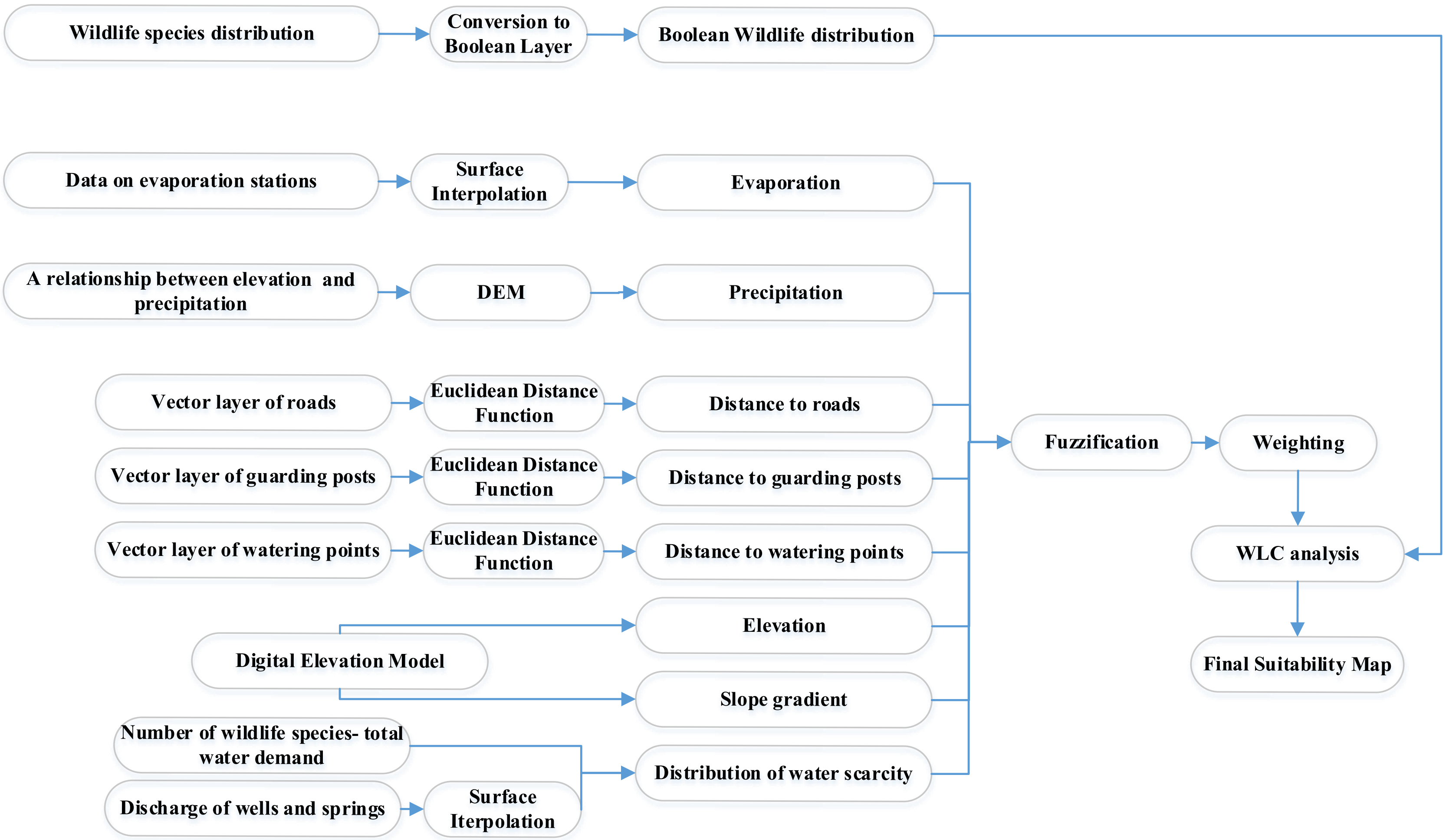
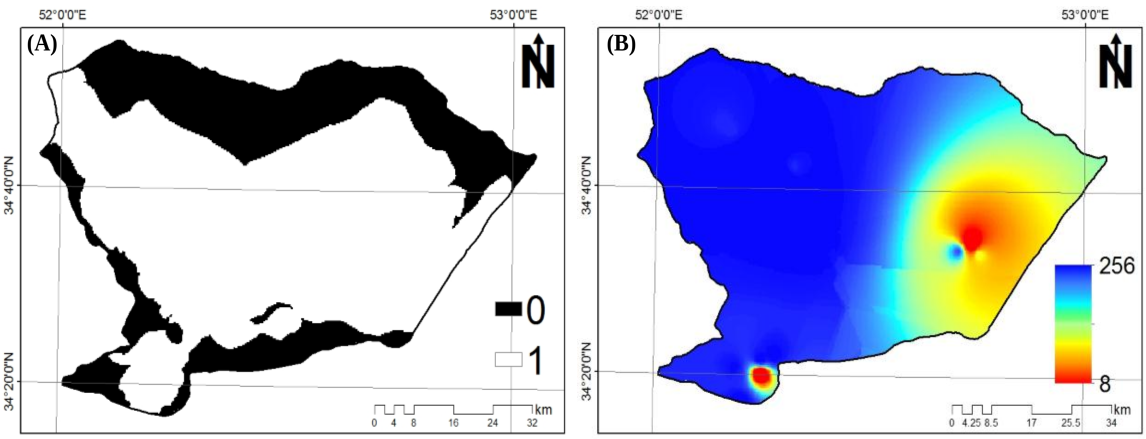


Fig. 2. Flow chart for identification of potential sites for RWH systems for wildlife

Results

The final suitability map was the result of the integration of nine data layers including slope gradient, elevation, evaporation, distance to roads, distance to watering points, distance to guarding posts, distribution of water scarcity, precipitation, and wildlife distribution. The values of each map were ranked on a continuous fuzzy scale of not suitable (0) to highly suitable (256), and a relative weight was then assigned to each layer. The corresponding fuzzified maps are provided in Fig. 3.

Based on the results of the AHP method (calculated according to the results of the questionnaires filled by the experts in the fields of hydrology, wildlife management, climatology, and watershed management), 0.3 of the total weight was assigned to precipitation, 0.2 to water scarcity, 0.1 to distance to watering sources, 0.1 to elevation, 0.1 to slope gradient, 0.1 to distance to guarding posts, 0.05 to distance to roads, and 0.05 to evaporation. Based on the WLC method, layers were integrated based on their weight to produce the final suitability map. The final map which is provided in Fig. 4 illustrates a range of 90-181 for the total suitability within the boundary of wildlife distribution. As illustrated, highly suitable areas correspond to the foothills of the Mount Siahkouh and the mountain ranges towards the east of the area. Yet, neither elevation nor slope gradient resulted in the limitation of RWH installation. It seems that the final suitability map has been mainly the product of the annual precipitation and water scarcity. There is a general increasing trend in water scarcity from the eastern parts towards the western areas. This trend, however, is not observable for precipitation as it mainly depends on elevation. Less distance to roads, watering points and guarding posts also contributed to high suitability values in the western parts. The eastern to north-eastern areas have obtained lower suitability values that are the result of a combination of factors, mainly less access to roads, guarding posts, water scarcity and watering sources. Evaporation also appeared to have the least effect on the final suitability.



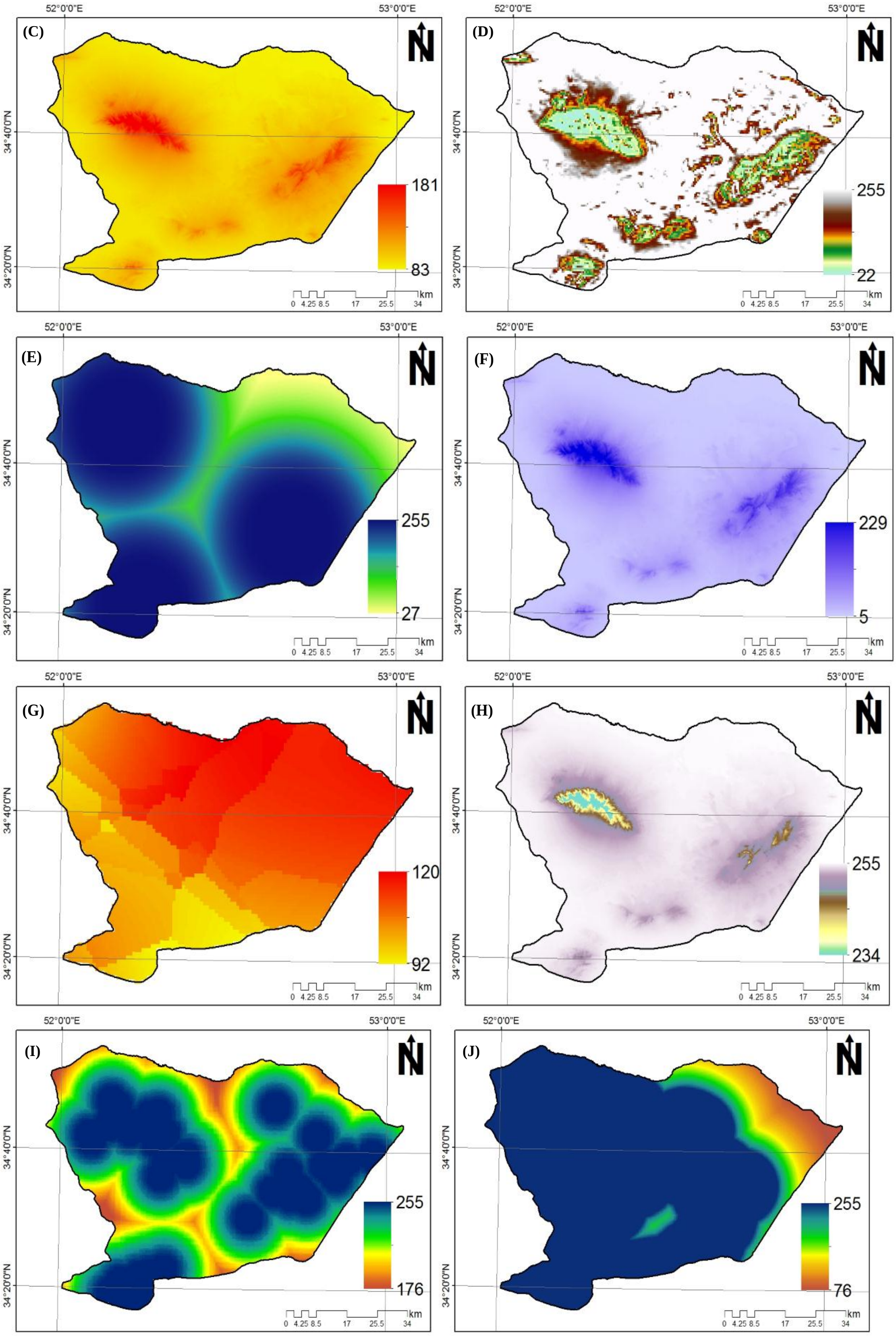


Fig. 3. Factor layers for the determination of suitable areas for RWH structures, A: wildlife presence in Boolean (limiting factor); B: water distribution fuzzified; C: temperature fuzzified (evaporation was subsequently used as a proxy of temperature and water loss); D: slope gradient fuzzified; E: distance to guarding posts fuzzified; F: precipitation fuzzified; G: evaporation fuzzified; H: elevation fuzzified; I: distance to watering sources fuzzified; J: distance to roads fuzzified.

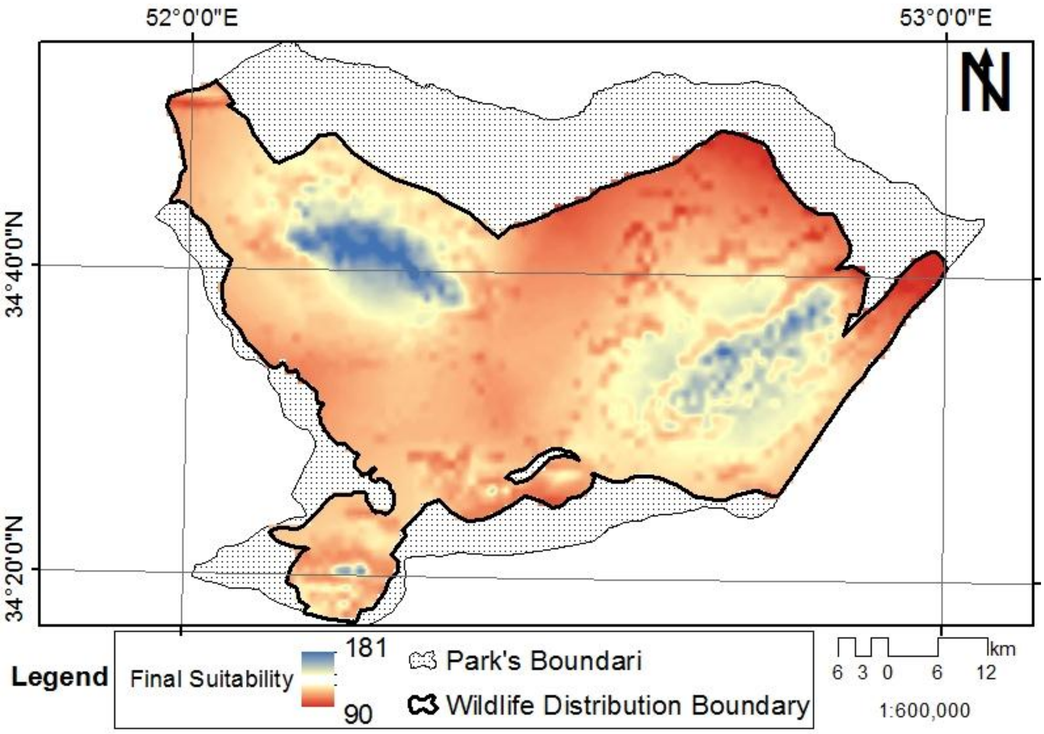


Fig. 4. Map of potential sites for RWH structures in the Kavir National Park

Discussion

The integration of GIS and decision support systems in this paper has been successful in the identification of suitable areas for the installation of RWH structures. The methodology applied in this paper has prioritized the large extent of the Kavir National Park (larger than 6810 km^2) in a quick and efficient manner. This paper is unique in combining GIS and MCDM techniques for site selection for wildlife water development. We believe that GIS can be very useful in water development and conservation planning (Nikolakaki, 2004; Singh *et al.*, 2017).

Nine thematic maps were used to produce the final suitability including slope gradient, elevation, evaporation, distance to roads, distance to watering points, distance to guarding posts, distribution of water scarcity, precipitation, and wildlife distribution. Precipitation in the area ranges from 100 to 270 mm with the highest precipitation falling in the Mount Siahkouh area. Almost all of the precipitation in the area occurs from December to May. The precipitation events include erratic and high-intensity rainfalls with heavily biased spatial distribution which significantly reduces the total suitability due to its high weight (Amarasinghe and Sharma, 2007). An innovative criterion was used in this study to prioritize the areas. This factor, which is formed by dividing the total water available by the total water demand during the period of interest, was ranked as the second important determiner of RWH suitability (by the weight of 0.2). The results suggested that water scarcity is ruling mostly in the western part of the region. Of total area, 3697 km^2 falls into water scare category and is in need of providing fresh water for wildlife. Evaporation is also believed to affect the suitability for RWH (see the studies by Li and Gong (2002), Farreny *et al.* (2011) and Mahmoud (2014) for more information on the importance of considering the loss of stored water). Evaporation increases from 830mm in the west and southwestern areas to more than 1100 mm in the eastern and north-eastern parts of the Kavir National Park. Areas with less evaporation were assigned higher priority for RWH during the standardization process. One important criterion was suggested by Malesu (2007) as the ratio of P/ETP of 60% for suitable areas for rainwater harvesting. Yet, no part of the area was found to be satisfying the criterion. However, high-intensity rainfalls could compensate for the gap between precipitation and evaporation in the area up to an extent. Mbilinyi *et al.*(2007), Malesu (2007) and Mahmoud (2014) have suggested the slopes of less than 30% as the suitable areas for rainwater and runoff harvesting. Except for the minor elevations, more than 80 percent of the area is flat with slopes less than 30%, and this factor poses no limitation on the final suitability. Distance to roads, guarding posts, and watering points also did not seem to pose any limitation, except for some areas in the north-eastern parts of the Park. The findings of this study suggested that suitability for RWH mainly follow the general trend of precipitation and water scarcity, and other constituents are of less importance to the final results. Most suitable areas are concentrated in the western part of the Kavir National Park where suitable precipitation and higher water scarcity have provided the condition for RWH for wildlife.

Providing information on the spatial distribution of RWH suitability is a vital step for promoting rain harvesting technologies (De Winnaar *et al.*, 2007). This study benefits from using an integration of the MCDM techniques and GIS for finding suitable areas for rainwater harvesting for wildlife. Although the approach employed here is not unique, the application for wildlife water development is distinctive in this regard. There are ample research articles related to the application of GIS and MCDMS for RWH. Singh *et al.* (2017) used the same approach to identify areas for rainwater harvesting and artificial recharge. They found 69 suitable sites for percolation tanks and 33 sites for check dams. Sayl *et al.* (2016) used an RS-GIS-based method to identify potential areas for RWH. Adham *et al.* (2016) also employed GIS and MCDM to identify suitable sites for traditional runoff harvesting structures such as Tabia and Jesst. They finally found 58 potential sites for developing RWH structures. However, to the time of writing this article, our attempts to find similar studies for wildlife water development were futile.

The major recommendation arising from this article is that GIS and MCDM techniques, when integrated, are powerful tools at the disposal of managers to produce suitability maps for water harvesting projects. Yet, the application of this technique and the possible consequences of artificial rainwater development for wildlife are the two major areas needing further studies. Sharing water resources between wildlife species and local livestock could result in the transmission of diseases, and care must be taken to avoid the unintended results (Carrasco-Garcia *et al.,* 2016). The chance for the hunters (both carnivores and humans) increases as the result of wildlife crowding near artificial water sources (Ndaimani *et al.,* 2016). Thus, the implementation of RWH techniques must be considered with utmost care, and it is recommended not to rely solely on the results of site selection. Other important measures include socio-economic aspects of water harvesting, hygiene aspects of water storage and conveyance, cost to benefit ratios, etc.

Acknowledgement

We owe debts of gratitude to Majid Ghandali, staff of Environmental Protection Organization, without whom, this study couldn’t have reached its purpose. We hereby appreciate Department of the Arid and Mountainous Areas, University of Tehran for its provisions and helps.

References

Adham, A., Riksen, M., Ouessar, M. and Ritsema, C. 2016. A Methodology to Assess and Evaluate Rainwater Harvesting Techniques in (Semi-) Arid Regions. Water, 8: 198.

Amarasinghe, U. A. and Sharma, B. R., 2007. Strategic Analyses of the National River Linking Project (NRLP) of India. Series 2, 9-10 October 2007. Proceedings of the Workshop on Analyses of Hydrological, Social and Ecological Issues of the NRLP, New Delhi, India. Iwmi.

Bashari H, Hemami MR. 2013. A predictive diagnostic model for wild sheep (Ovis orientalis) habitat suitability in Iran. Journal for Nature Conservation, 21(5):319-25.

Batool, S. and Hussain, M., 2016. Wildlife in the perspective of environmental degradation: A review. Journal of Entomology and Zoology Studies, 4: 508–511.

Belton, V. and Stewart, T. J. 2002. Multiple Criteria Decision Analysis: An Integrated Approach, Kluwer Academic Publishers.

Bone, T. L., Cantu, R. and Brownlee, S., 1992. Water for west Texas wildlife. Texas Parks and Wildlife Department. Texas Parks and Wildlife Department (USA), 26 pages.

Brigham, W. R. and Stevenson, C. 2003. Wildlife water catchment construction in Nevada.Technical Note, Bureau of Land Management Papers (USA), 27 pages.

Burkett, D. W. and Thompson, B. C., 1994. Wildlife Association with Human-Altered Water Sources in Semiarid Vegetation Communities. Asociación entre vida silvestre y fuentes de agua alteradas por actividades humanas en comunidades de vegetación semi-árida. Conservation Biology, 8: 682-690.

Caro, T., 1994. Cheetahs of the Serengeti Plains: group living in an asocial species. Illinois: University of Chicago Press.

Carrasco-Garcia, R., Barasona, J.A., Gortazar, C., Montoro, V., Sanchez-Vizcaino, J.M. and Vicente, J., 2016. Wildlife and livestock use of extensive farm resources in South Central Spain: implications for disease transmission. European Journal of Wildlife Research. 62: 65–78.

Chandio, I. A. and Bin Matori, A. N., 2011. GIS-based Multi-criteria Decision Analysis of Land Suitability for Hillside Development. International Journal of Environmental Science and Development, 2: 469-472.

Daniali, S. R., Idoghmish, F. M. and Foroush, S. H., 2009. Evaluating the role of Kal qanatas and seasonal springs on the life of Ghamishloo national park wildlife. 4th Iranian special conference on environmental engineering, November 1st, Tehran, Iran (In Persian).

Davis, B. E., 2001. GIS: A Visual Approach, Delmar Thomson Learning. Cengage Learning (USA), 438 pages.

De Winnaar, G., Jewitt, G. and Horan, M., 2007. A GIS-based approach for identifying potential runoff harvesting sites in the Thukela River basin, South Africa. Physics and Chemistry of the Earth, Parts A/B/C, 32: 1058-1067.

Deal, K., 2010. Wildlife and Natural Resource Management. Cengage Learning, 384 pages.

Dodson, R. G., 2000. Managing Wildlife Habitat on Golf Courses. John Wiley & Sons (USA), 174 pages.

Dolan, B. F., 2006. Water Developments and Desert Bighorn Sheep: Implications for Conservation. Wildlife Society Bulletin, 34: 642-646

Eastman, I. R., Jin, W., K' Kyem, P. A. and Toledano, J., 1995. Raster Procedures for Multi-Criteria/Multi-Objective Decisions. Photogrammetric Engineering & Remote Sensing, 61: 539-547.

Eastman, J. R. 2003. IDRISI Kilimanjaro Guide to GIS and Image Processing: Clark University (USA).

Farreny, R., Morales-Pinzón, T., Guisasola, A., Taya, C., Rieradevall, J. and Gabarrell, X., 2011. Roof selection for rainwater harvesting: quantity and quality assessments in Spain. Water Research, 45: 3245-3254.

Fisher, P., 2006. Classics from IJGIS: Twenty years of the International Journal of Geographical Information Science and Systems. CRC Press (USA), 572 pages.

Foltz, R. C., 2002. Iran's Water Crisis: Cultural, Political, and Ethical Dimensions. Journal of Agricultural and Environmental Ethics, 15: 357-380.

Forzieri, G., Gardentia, M., Caparrini, F. and Castelli, F. 2008. A methodology for the pre-selection of suitable sites for surface and underground small dams in arid areas: A case study in the region of Kidal, Mali. Physics and Chemistry of the Earth, 33: 74–85.

Goodall, D. W., Perry, R. A. and Howes, K. M. W., 2009. Arid Land Ecosystems: Volume 2, Structure, Functioning and Management, Cambridge University Press (USA), 624 pages.

Gorsevski, P. V., Donevska, K. R., Mitrovski, C. D. and Frizado, J. P., 2012. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average. Waste Management, 32: 287-296.

Halloran, F. and Deming, O. V., 1958. Water Development for Desert Bighorn Sheep. The Journal of Wildlife Management, 22: 1-9.

Harrison, R.L., 2016. Badger Behavior at Anthropogenic Water Sources in the Chihuahuan Desert. Western North American Naturalist. 76: 1–5.

Herath, G. & Prato, T. 2006. Using Multi-criteria Decision Analysis in Natural Resource Management. Ashgate Publishing, Ltd (UK), 239 pages.

Huntsinger, L., Hruska, T. V., Oviedo, J.L., Shapero, M.W.K., Nader, G.A., Ingram, R.S. and Beissinger, S.R., 2017. Save water or save wildlife? Water use and conservation in the central Sierran foothill oak woodlands of California, USA. Ecol. Soc. 22, art12.

Jafari Shalamzari, M., Khalighi Sigaroudi, S., Gholami, A. and Alizadeh Shabani, A., 2015. Site Selection for Small-Scale Solar Ponds to Provide Wildlife with Fresh Water using MCE and GIS. The first national conference on the application of modern sciences in geographic research. Mashhad, Iran. (In Persian)

Kinkade-Levario, H., 2013. Design for Water: Rainwater Harvesting, Stormwater Catchment, and Alternate Water Reuse, New Society Publishers (Canada), 240 pages.

Kluever, B.M. and Gese, E.M., 2016., Spatial response of coyotes to removal of water availability at anthropogenic water sites. J. Arid Environ. 130: 68–75.

Kluever, B.M., Gese, E.M. and Dempsey, S.J., 2016. The influence of wildlife water developments and vegetation on rodent abundance in the Great Basin Desert. J. Mammal. 97: 1209–1218.

Krausman, P. R., Rosenstoc, S. S. and Cain, J. W., 2006. Developed Waters for Wildlife: Science, Perception, Values, and Controversy. Wildlife Society Bulletin, 34: 563-569.

Lawes, M. and R. Nanni., 1993. The density, habitat use and social organisation of dorcas Gazelles (Gazella dorcas) in Makhtesh Ramon, Negev Desert, Israel. Journal of Arid Environments, 24: 177-196.

Leslie, D. M. and Douglas, C. L., 1980. Human Disturbance at Water Sources of Desert Bighorn Sheep. Wildlife Society Bulletin, 8: 284-290.

Li, X.-Y. and Gong, J.-D. 2002. Compacted microcatchments with local earth materials for rainwater harvesting in the semiarid region of China. Journal of Hydrology, 257: 134-144.

Mahmoud, S.H., 2014. Delineation of potential sites for groundwater recharge using a GIS-based decision support system. Environ. Earth Sci. 72: 3429–3442.

Malczewski, J., 2006a. GIS-based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science, 20: 703–726.

Malczewski, J., 2006b. Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis. International Journal of Applied Earth Observation and Geoinformation, 8: 270–277.

Malesu, M. M., 2007. Mapping the Potential of Rainwater Harvesting Technologies in Africa: A GIS Overview and Atlas of Development Domains for the Continent and Nine Selected Countries, United Nations Environment Programme. World Agroforestry Centre (Kenya), 120 pages.

Manning, J. and Edge, W. D. 2001. Relationship between mule deer biology and the 2001 federal environmental decisions on the Klamath Reclamation Project.. University of California (USA): Water Allocation in the Klamath Reclamation Project: An Assessment of Natural Resources Economic, Social and Institutional Issues with a focus on the Upper Klamath Basin , Chapter 17: 327-335 .

Matlock, W. G., 1981. Realistic Planning for Arid Lands: Natural Resource Limitations to Agricultural Development, Harwood Academic, CRC Press (USA), 261 pages.

Mbilinyi, B. P., Tumbo, S. D., Mahoo, H., and Mkiramwinyi, F. O., 2007. GIS-Based Decision Support System for Identifying Potential Sites for Rainwater Harvesting, Physics and Chemistry of the Earth, 32: 1074–1081.

Mendelssohn, H., Yom-Tov, Y. and Groves, C.P., 1995. Gazella gazelle, Mammalian Species, 490:1-7.

Nabhan, G. P. 2013. Growing Food in a Hotter, Drier Land: Lessons from Desert Farmers on Adapting to Climate Uncertainty, Chelsea Green Pub. (UK), 272 pages.

National Research Council. 1974. More Water for Arid Lands: Promising Technologies and Research Opportunities : Report of an Ad Hoc Panel of the Advisory Committee on Technology Innovation, Board on Science and

Technology for International Development, Commission on International Relations. National Academy of Sciences (USA), 153 pages.

Ndaimani, H., Tagwireyi, P., Sebele, L., Madzikanda, H., Alleaume, S. and Said, S., 2016. An Ecological Paradox: The African Wild Dog (Lycaon Pictus) Is Not Attracted to Water Points When Water Is Scarce in Hwange National Park, Zimbabwe. PLoS One 11, e0146263.

Nikolakaki, P., 2004. A GIS site-selection process for habitat creation: estimating connectivity of habitat patches. Landsc. Urban Plan. 68: 77–94.

Ray, A. K. and Acharya, T., 2004. Information Technology: Principles and Applications. PHI Learning Pvt. Ltd. (India), 628 pages.

Rishab Mahajan, S. K. and R. K. Khitoiiya. 2006. Rain Water Harvesting : A Viable Solution To Conserve Water. National Seminar on Rainwater Harvesting and Water Management, the Institution of Engineers (India), Nagpur, India, November 2006:123-128.

Saaty, T. L. 1980. The analytical hierarchy process. McGraw Hill International. McGraw-Hill (USA), 287 pages.

Salim, M. G. 2011. Selection of groundwater sites in Egypt, using geographic information systems, for desalination by solar energy in order to reduce greenhouse gases. Journal of Advanced Research, 3: 11–19.

Sayl, K.N., Muhammad, N.S., Yaseen, Z.M. and El-shafie, A., 2016. Estimation the Physical Variables of Rainwater Harvesting System Using Integrated GIS-Based Remote Sensing Approach. Water Resour. Manag. 30: 3299–3313.

Semnan Department of Environment., 2005. Wildlife of the central plateau.95 pages (In Persian)

Şener, Ş., Şener, E., Nas, B. and Karagüzel, R., 2010. Combining AHP with GIS for landfill site selection: A case study in the Lake Beyşehir catchment area (Konya, Turkey). Waste Management: 30, 2037-2046.

Singh, L.K., Jha, M.K. and Chowdary, V.M., 2017. Multi-criteria analysis and GIS modeling for identifying prospective water harvesting and artificial recharge sites for sustainable water supply. Jour. Clean. Prod. 142: 1436–1456.

Tavasoli, A., Tabatabaee, J. and Hoseinnia, A., 2016. Rainwater Harvesting for Urmia Island (IR Iran) Wildlife. Iran. Journal of Rainwater Catchment Systems, 9(4): 57-71

UNEP., 2003. UNEP Annual Report, United Nations Environment Programme, UNEP/Earthprint (UK), 64 pages.

Valdez, R., C. Nadler, T. Bunch. March. (1978). Evolution of Wild Sheep in Iran. Evolution, 32: 56-72.

Vieux, B.E., 2004. Distributed hydrologic modeling using GIS. Springer Science & Business Media (Germany), 296 pages..

Voogd, H., 1983. Multicriteria evaluation for urban regional planning, Pion (UK), 367 pages. Weerasinghe, H., Schneider, U. A. and L¨Ow, A., 2011. Water harvest- and storage-location. 8: 3353-3381.

Wolff, F. 2001. Vertebrate ecology in caatinga: A. Distribution of wildlife in relation to water. B. Diet of pumas (Puma concolor) and relative abundance of felids. MSc Thesis, University of Missouri-St. Louis, Department of Biology, 65 pages.

Worm, J., 2006. AD43E Rainwater harvesting for domestic use. Agromisa foundation (Netherlands), 84 pages.

Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., 2016. Impacts of Water Development on Great Salt Lake and the Wasatch Front, Watershed Sciences Faculty Publications, Utah State University (USA), 10 pages.

مکان‌یابی استحصال آب باران برای حیات وحش با استفاده از روش آنالیز چند معیاره و سامانه اطلاعات جغرافیایی در پارک ملی کویر

مسعود جعفری شلمزاری[الف*]، عاطفه غلامی[ب]، شهرام خلیقی سیگارودی[ج]، افشین علیزاده شعبانی[د]، حسین ارزانی[ه]
[الف] دانش آموخته‌ی دکتری بیابانزدایی دانشگاه علوم کشاورزی و منابع طبیعی گرگان (نویسنده مسئول)، ایمیل: msdpardis@gmail.com
[ب] دانشجوی دکتری بیابانزدایی دانشگاه علوم کشاورزی و منابع طبیعی گرگان
[ج] دانشیار دانشکده منابع طبیعی دانشگاه تهران
[د] استادیار دانشکده منابع طبیعی دانشگاه تهران
[ه] استاد تمام دانشکده منابع طبیعی دانشگاه تهران

تاریخ دریافت: ۱۳۹۵/۱۰/۲۸
تاریخ پذیرش: ۱۳۹۶/۰۳/۲۷

چکیده. این مطالعه به ترکیب دو رویکرد چند معیاره و سیستم پشتیبان تصمیم برای شناسایی مناطق مناسب برای گردآوری آب باران می‌پردازد. برای این هدف، شیب، بازه تا ایستگاه نگهبانی، بازه تا آبشخور برای انتقال آب انبار شده، پراکنش گونه‌های حیات وحش مورد نظر، دسترسی به جاده، بلندی، شناسه کمبود آب، و میزان بارش سالانه در فصل بارندگی برای شناسایی این مناطق استفاده شدند. گردآوری داده‌ها و بازدید میدانی در سال‌های ۱۳۹۳-۱۳۹۵ در منطقه پارک ملی کویر انجام شد. شایستگی منطقه از نظر گردآوری باران برای سه گونه جانوری *Ovis orientalis*، *Gazella dorcas* و *Acinonyx jubatus* (یوز ایرانی) مورد بررسی قرار گرفت. لایه‌های ابتدایی با استفاده از تابع فازی بهنجار سازی شده و وزنی بین صفر و یک به هر لایه داده شده تا به توان میزان اهمیت هر شناسه را مشخص کرد. یافته‌های این پژوهش نشان داد که بارش و کمبود آب (هرکدام با وزن ۰/۳ و ۰/۲) اثر گذارترین شناسه‌ها بودند. دامنه شمالی سیاه‌کوه بیشترین شایستگی برای گردآوری باران را داشت. تغییر شایستگی از ۱۰۰ در شرق تا ۲۰۰ در غرب متغییر بود. یافته‌های این پژوهش را می‌توان در برنامه‌ریزی برای اجرایی ساختن گردآوری آب باران برای حیات وحش در آینده به کار بست. با نگاه به سادگی و کارا بودن رویکرد، روش پردازش اطلاعات در این پژوهش را می‌توان در دیگر برنامه‌های پژوهشی مورد استفاده قرار داد. با این وجود پیشنهاد می‌شود، چنین برنامه‌هایی در مقیاس کوچک انجام شده و در صورت بازخورد مناسب، به دیگر مناطق شناسایی شده در این پژوهش گسترش داده شود.

کلمات کلیدی: بازسازی، MCE، حیات‌وحش، گسترش منابع آب، پارک ملی کویر، GIS