Suitable Areas Determination for Rain Water Harvesting (Case Study: Kerman Province)

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Abstract— **The average annual precipitation in Iran is less than one-third of the world average. Also, distribution of rainfall on temporal and spatial scales is poor. For combat water shortage, rain water harvesting (RWH) is the best option in the arid regions like Iran. The main purpose of this study was site selection of water harvesting systems. At the first stage, factors influencing site selection of RWH systems and rainwater storage were determined. The four main criteria including physiographic, rainfall, vegetation and soil factors were selected. At the second stage, standardized and weighted factors based on analysis hierarchy process (AHP) and finally, each layer was multiplied by its weight. Results showed that the most important factor for site selecion of RWH is slope factor. But the importance of elevation classes factor was greater than the slope factor in the pitting method in comparison with farrowing method.**

Index Terms— **Site selection, Rain water harvesting (RWH), Analysis hierarchy process (AHP), Pitting method, Farrowing method.**

I. INTRODUCTION

Iran country located in an area of the world where annual rainfall is less than one third of the world's annual rainfall. In addition due to poor distribution of rainfall on temporal and spatial scales, even some of the rainiest parts of the country need to irrigation during the summer season [1]. In the arid areas low rainfall, irregular occurrence of rainfall, and high evaporation [2], [3] are the most important limiting factors for use of surface water resources. Thus, access to water throughout year need a proper management in these areas, especially in Iran.

Methods of rain water harvesting, grey water reuse and wastewater recycling have been stated as alternative water sources [4]. Among different methods, rainwater harvesting (RWH) expressed as the best method because rain water is fresh in nature and can be easily collected [5]. Therefore, site selection of sutiable areas for implementation of Rain Water Harvesting (RWH) systems in arid regions like iran is essential. However, Suitable areas determination for Rain Water Harvesting (RWH) by traditional methods is so difficult and it may be causing the error while also is very costly and time consuming.

Therefore, using a strict system with high performance such as geospatial information system (GIS) and analytic hierarchy process (AHP) for planning is very important [6]. The AHP technique allows to assessment of the subject as hierarchically as well as takes into account qualitative and quantitative criteria to resolve the issue [7]. This method provides collaboration for decision-making and manegers among many option chose the best option.

Welderufael et al., 2013; [8] stated that implementation of RWH systems had a significant effect on water resources feeding and the use of thess systems have hydrological impacts on down-stream catchment. Rahman et al., 2012 [5] stated that capability of RWH in water storage, reliability as well as economic benefit made to be used as a sutiable method in Australia. Nekoii-mehr, 2013 [9] examines RWH by using isolation surfaces in Zagros region and showed isolation surfaces have an important role in the Rainwater harvesting and storage of enough water for future periods of drouth. Hence, using AHP and GIS leading to be analyze of large volume of data and on other hand evaluatoin of criteria and indicies with each other comprehensively by using AHP make access possible to be the target.

Due to large extent of Kerman province and need water in this region, hence evaluation and determination of sutiable locations for rain water harvesting (RWH) is essential. Therefore, in this study, sutiable locations for rain water harvesting (RWH) were determined by using AHP and GIS. Also, the main object of this study was determining effective factors in the choise of sutiable areas for RWH systems.

II. MATERIALS AND METHODS

a. Study area

The northern part of the Kerman province in southeast Iran includes about 14136093.5 hectare of the country's land and situated in northern 20'25" and Eastern 31' 57" (Fig. 1). The maximum elevation is 4471 m a.s.l in Kerman province.

b. Methodology

In this study, important parameters for determining appropriate areas of RWH systems were selected. Produced layers of these parameters in the ArcGis software then each of them evaluated by several experts and then all parameters were standardized and inserted to EXT-AHP software and integrated diferent wightes with their layers and finally, produced finall maps.

c. Site selecetion stages of RWH is following:

1. Collected of required data and informations in the study area:

At this stage, the characteristics of the study area including climate, topography, geology, landuse, vegetation and etc, were drived from previous reports.

2. parameters influencing site selection of RWH:

a) Physiographic factors (maps of slope, slope orientation and elevation).

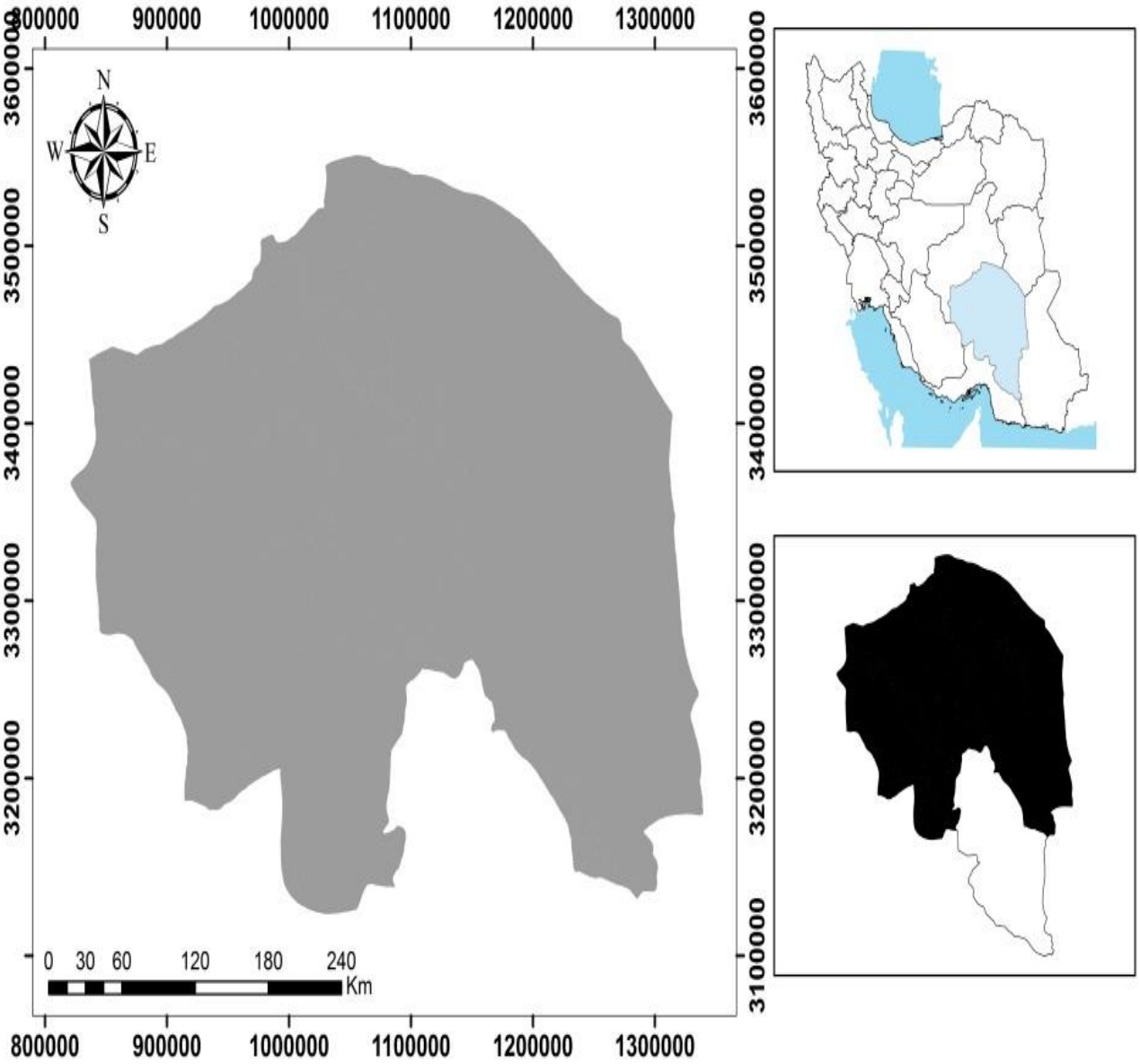

Fig.1. Location map of the northern part of the Kerman province in southeast Iran.

b) Vegetation factors (percent of stone, canopy cover, bair soil).
c) Precipitation factors (maps of gradient rainfall and maximum 24-hour rainfall).
d) Pedology factors (maps of soil depth, soil texture and soil hydrologic groups).

3. Provided different data layers in the ArcGIS software:

In this study, Slope , slope orientation and elevation classes layers were produced based on DEM layer of the study region. The required data to prepared of bair soil%, stone%, canopy cover%, soil texture and soil depth maps obtained from the office of natural resources of Kerman province. Climatic information obtained from synoptic stations (68 stations) and finally prepared gradient rainfall layer for Kerman province. In this way the data is collected from different stations in the study region, then created a regression euation between average ranilfall and 24-hour rainfall of different stations with hight of different stations. Applied the regression euation to DEM layer. Finally, average ranilfall and 24-hour rainfall maps were prepared in ArcGIS software.

To determine the importance of criteria and sub-criteria, some questionnaries designed and provided to local and academics experts then insert their oponions to these questionnaries and finally inserted to EXT-AHP software. In fact, the average were taken of experts opinions about the importance of each of the layers and sub-criteria.

4. Re-classification and weighting data layers

Each layer divided into several category then assigned the values of one to ten based on table (1) to each category in relation with differents methods of RWH, which in this study pitting and farrowing methods were evaluated. After initialization to methods of pitting and farrowing, these informations inserted to EXT_AHP software.

Table 1. Characteristics of the most sutiable areas for the rain water harvesting treatments.

FACTOR	PITTING	FARROWING
SLOPE %	5 – 12	12 – 20
SOIL TEXTURE	LOAM-SANDY	LOAM-SANDY
HIGHT (M)	1926 - 4471	1926 - 4471
MAEN RAINFALL (MM)	250 - 500	250 - 500
CANOPY COVER %	33 - 35	25 - 35

5. Whighting and determine the importance of data layers:

According to the purpose of each RWH methods, data layers prepared have the different importance and effectiveness in determining of the final map of sutiable sites for RWH. By applying coefficients in different layers, eventually, produced maps of each RWH methods.

6. Prepared of optimal maps:

After the determination of criteria normal weight, the each layer multiplied in weight of its layer and finally, prepared different maps (such as vegetation, soil depth maps and etc) by using Raster Calculatar command in the ArcGIS software.

I. RESULTS

To gain weight of the main criteria in the each of pitting and farrowing methods, combined the sub-critria together. Table (2) shows weight data layers for each RWH techniqes.

Table 2. The weight of criteria for the rain water harvesting treatments.

MAIN CRITERIA	SUB-CRITERIA	PITTING	FARROWING
PHYSIOGRAPHIC	SLOPE %	0.7008	0.6805
	SLOPE ORIENTATION	0.1349	0.1794
	ELEVATION CLASSES	0.1643	0.1401
VEGETATION	BAIR SOIL %	0.4738	0.5260
	STONE %	0/2682	0.2217
	CANOPY COVER %	0.2580	0.2523
PEDOLOGY	SOIL DEPTH (CM)	0/3696	0.2241
	SOIL TEXTURE	0.4131	0.4280
	SOIL INFILTRATION	0.2173	0.3480
RAINFALL	ANNUAL MEAN RAINFALL	0.5423	0.5759
	MAX. 24-HOUR RAINFALL	0.4577	0.4241

In this section, the weight of each main criteria was provided of the integration of the sub-criteria for each RWH technique that the results are shown in table (3).

At first prepared the maps of main criteria then maps related to four main criteria were combined together and finally, prepared map of sutiable regions on the basis of qualitative classification to implementation any of RWH methods. Finally, prepared finall map of sites classification based on the qualitative classification for pitting and farrowing methods (Fig. 2). Also, the frequency and area of appropriate sites for pitting and farrowing methods are given in table (4). The results showed that to locate pitting and farrowing methods physiography, rainfall, pedology and vegetation; and physiography, rainfall, vegetation and pedology factors were the most imortant, respectively.

IV. DISCUSSION

The result showed that integration of GIS and decision-making systems such as AHP can be powerful and useful tool for site selection of sutiable areas of RWH which accordanced with [10, 11, 12, 13].

Table 3. The weight of main criteria for the rain water harvesting treatments.

MAIN CRITERIA	PITTING	FARROWING

PHYSIOGRAPHIC	0.3971	0.4442
VEGETATION	0.1169	0.1413
PEDOLOGY	0.1241	0.1058
RAINFALL	0.3618	0.3087

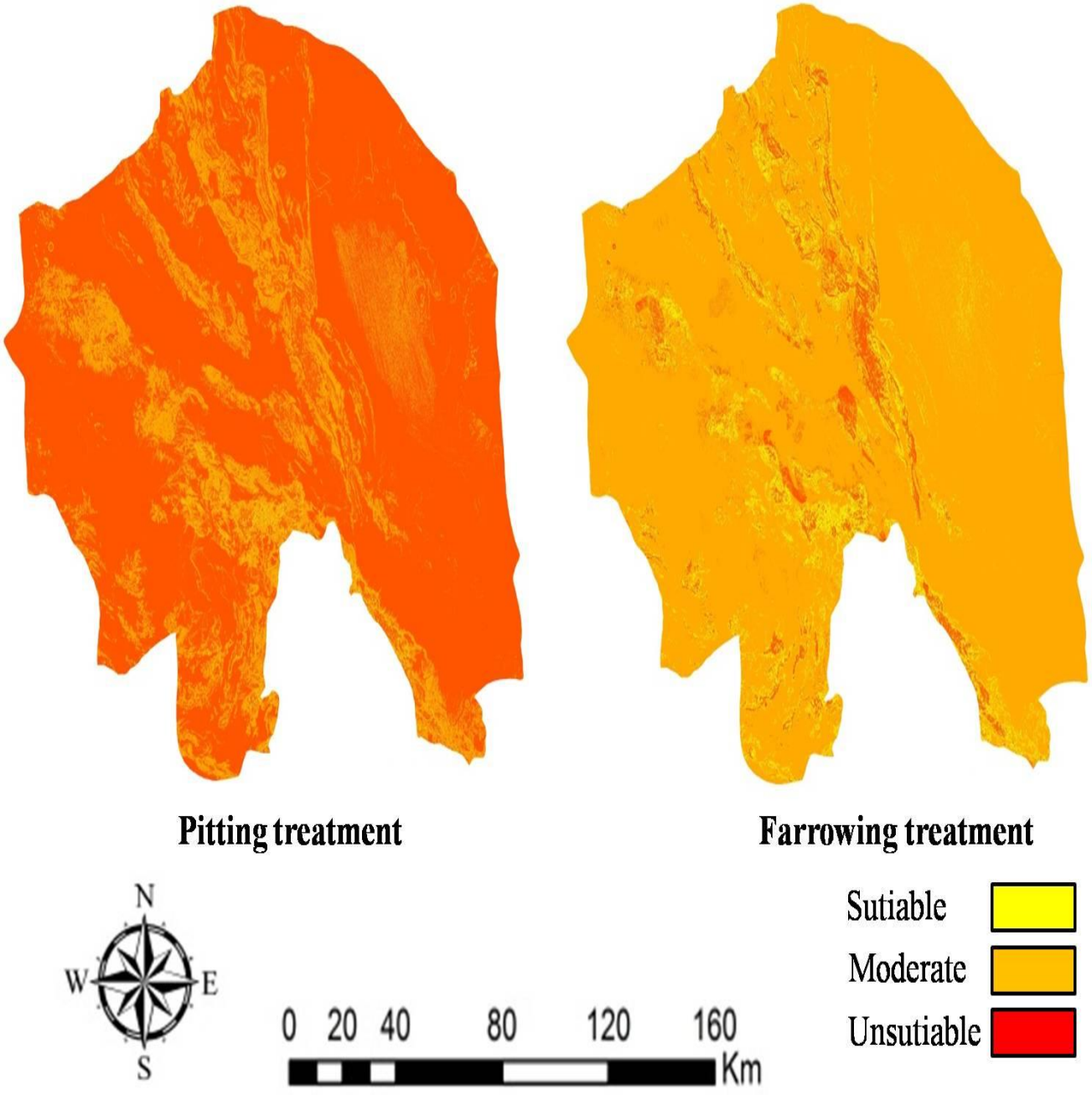

Fig. 2. Finall maps of pitting and farrowing treatments in the northern part of the Kerman province in southeast Iran.

Table 4. Area and percent of areas sutiable for the rain water harvesting treatments. ha

RWH TREATMENTS	AREAS SUTIABLE	
	PERCENT OF AREA	AREA (ha)
PITTING	2.54	359056.77
FARROWING	65.96	9324167.27

Utilization of pitting and farrowing leading to storage of runoff within the soil layers. These techniques dependent on the climatic conditions such as intensity and volume of precipitation as well as require beneficiaries [5].

In this study the most important factor for site selecion of RWH was slope factor. In the site selection for pitting treatment the importance of elevation classes factor was greater than the slope factor and in the farrowing treatment was contrary; which accordanced with [8].

If implemented RWH methods especially pitting method in low slope lands, can be desired results. Therefore slope factor is the only limiting factor for water harwesting projects [14].

For implementation of farrowing method, slope factor is the most imortant factor because the slope to determine the size and distance of the farrowing has a key role. In the pitting treatment the importance of soil depth layer is the greater than infiltration, while in the forowing treatment is contrary [15].

Implement of forrow treatment in the sandy soils is sutiable. If the goal is to increase underground water storage, implementation of both methods are efficient on sandy soils [16, 17].

In both methods the importance of rainfal factor is greater than vegetation and pedology factors because these projects are implement in the regions with enough precipitation and poor vegetation [16, 18, 19]

REFERENCES

[1] P. Kordavani, "Resources and Water Issues in Iran, Groundwater and Surface Water and their Exploitation". vol. 1, 5th ed. Tehran University Press, 2000, p. 567.

[2] H. Fathizad, B. Azad, A. Yousefi, A. jafarian, "Using Remote sensing technique for estimation of real evapotranspiration". International Journal of Engineering and Adv anced Research Technology (IJEART), ISSN: 2454-9290, March 2016, 2, 3, pp. 51-57.

[3] A. Nilsson, "Groundwater Dams for Small-Scale Water Supply". Intermediate Technology Publications, London, 1988. pp. 78.

[4] Y. hang, A. Grant, A. Sharma, D. Chen, L. Chen, "Alternative water resources rural residential development in Western Australia". Water Resour Mana, 2010. 24:25–36.

[5] A. Rahman, J. Keane, M. A. Imteaz, "Rainwater harvesting in Greater Sydney: Water savings, reliability and economic benefits". Resources, Conservation and Recycling, 2012. 61, 16-21.

[6] T. L. Saaty, "The Analytical Hierarchy Process". McGraw Hill, New York, 1990. pp.350.

[7] N. J. Raju, T. V. K. Reddy, P. Munirathnam, "Subsurface dams to harvest rainwater—a case study of the Swarnamukhi River basin, Southern India". Hydrogeology Journal, 2006. 14(4), 526-531.

[8] W.A. Welderufael,Y.E. Woyessa, D.C. Edossa, "Impact of rainwater harvesting on water resources of the modder river basin,central region of South Africa". Agricultural Water Management, 2013. 116: 218–227.

[9] M. Nekoii-Mehr, "water harvesting using isolation surfaces undr the water crisis in the Zagros region". The National Conference of the Zagros environmental hazards, Khoram-Abad, Administration of crisis management, Lorestan, 2013. Pp. 1-14

[10] J. C. M. Andersson, A. J. B. Zehnder, G. P. W. Jewitt, H.Yang, "Water availability, demand and reliability of in situ water harvesting in smallholder rain-fed agriculture in the Thukela River Basin, South Africa". Hydrology and Earth System Sciences, 2009. 13(12), 2329-2347.

[11] B. Biazin, G. Sterk, M. Temesgen, A. Abdulkedir, L. Stroosnijder, "Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa". Physics and Chemistry of the Earth, 2012. 47: 139-151.

[12] K. Madan, V.M. Chowdary, Y. Kulkarnia, B.C. Mal, "Rainwater harvesting planning using geospatial techniques and multicriteria decision analysis". Resources, Conservation and Recycling, 2014. 83: 96– 111.

[13] B. P. Mbilinyi S. D. Tumbo, H. F. Mahoo, F.O. Mkiramwinyi, "GIS-based decision support system for identifying potential sites for rainwater harvesting". Journal of Physics and Chemistry of the Earth, 2007. 32: 1074–1081.

[14] B. Russell, L. Thomas, M. J. Kirisits, D. J. Lye, K. A. Kinney, "Rainwater harvesting in the United States: a survey of common system practices". Journal of Cleaner Production), 2014. 1-8.

[15] M. Azad, "Report flood spreading project of Haftoman Khor, Isfahan". deputy watershed of administration of Natural Resources in Isfahan province, pp. 118.

[16] A. Al-Shamiri, F. M. Ziadat, "Soil-landscape modeling and land suitability evaluation,the case of rainwater harvesting in a dry rangeland environment". International Journal of Applied Earth Observation and Geo information, 2012. 18: 157–164.

[17] I. A. Gommah, "Double furrow with raised bed—A new improved mechanized water-harvesting technique for large-scale rehabilitation of arid rain-fed areas". Soil and Tillage Research, 2011. 113(1), 61-69.

[18] Y. Z. Wanga, S. S. Xiea, C. Malhib, Y. V. Zhanga, Z. Guo, "Effects of gravel–sand mulch, plastic mulch and ridge and furrow rainfall harvesting system combinations on water use efficiency, soil temperature and watermelon yield in a semi-arid Loess Plateau of northwestern China". Agricultural Water Management, 2011. 101: 88–92.

[19] S. Nijhof, B. Jantowski, R. Meerman, A. Schoemaker, "Rainwater harvesting in challenging environments: Towards institutional frameworks for sustainable domestic water supply". *Waterlines*, 2010. *29*(3), 209-219.

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