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Site Selection of In-situ and Ex-situ Methods of Rain Water Harvesting In the Arid Regions of Iran

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Abstract - *Due to low rainfall (220 mm y^{-1}) and its poor distribution in the country, Iran is considered among the arid countries which faced with water shortage. Many methods have been proposed to deal with water shortage so far that among these methods rainwater harvesting (RWH) expressed as the best method. Therefore, site selection of suitable areas for implementation of RWH systems such as in-situ and ex-sith methods in arid regions of Iran is essential. The main purpose of present study was site selection of suitable sites for implementation of trracese (in-situ) and ex-situ methods by using Geospatial Information Systems (GIS) and Analytical Hierarchy Process (AHP). The results showed that, physiographic is the most important criterion to implement both trracese and ex-situ methods. Also the results showed that, 6.18% and 83.4% of study region are suitable to implementation of terracese and ex-situ methods, respectively. Generally, result showed that this region is suitable to implement ex-situ method, that to implement this method water transmission channels and other euipments are needed.*

***Key Words*: Site selection, Rain water harvesting (RWH), In-situ method, Ex-situ method, Arid regions, Iran.**

INTRODUCTION

Due to low rainfall (220 mm y^{-1}) and its poor distribution in the country, Iran is considered among the arid countries which faced with water shortage [1]. Around 70% of Iran's agricultural lands are located in arid and semi-arid regions of the country. Therefore, have to solve this problem.

Many methods have been proposed to deal with water shortage so far. However, among different methods, rainwater harvesting (RWH) expressed as the best method to comat water shortage in the arid regions like Iran, because rain water is fresh in nature and can be easily collected [2].

Therefore, site selection of suitable areas for implementation of Rain Water Harvesting (RWH) systems such as in-situ and ex-situ methods in arid regions of Iran is essential. However, site selection of Rain Water Harvesting (RWH) systems by traditional methods is so difficult and it may be causing the error while also is very costly and time consuming. Therefore, the use of geospatial information system (GIS) and analytic hierarchy process (AHP) for planning for solve problems of tradition approaches are very perfect and essential.

Oweis, 2006 [3] evaluated rain water harvestig (RWH) techniques by using geospatial information system (GIS) and reported that soil depth and rainfall layers have the high importance for implementation of RWH techniques. Rahman et al., 2012 [2] stated that capability of RWH in water storage, reliability as well as economic benefit made to be used as a sutiable method in Australia. Welderufael et al., 2013 [4] 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. Nekoii-mehr, 2013 [5] 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 evaluation of criteria and indices with each other comprehensively by using AHP make access possible to be the target.

Kerman province with the mean annual rainfall 129.2 mm is a arid region of Iran that faced with water shortage. Therefore, provide alternative water sources

in this region is very essential. In this research, in-situ and ex-situ methods of rain water harvesting were assessmented and also site selectioned of this methods to implemented them in this region.

materials and methods

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). Based on data obtained from the meteorological station in Dehloran city (southwest Iran), the total annual precipitation is 129.2 mm and the mean annual temperature is 39.6°C, respectively. The climate type is classified as hyper arid region according to the De-martonne classification, with a distinct dry season during summers and relatively humid during the winters.The maximum elevation is 4471 m a.s.l.

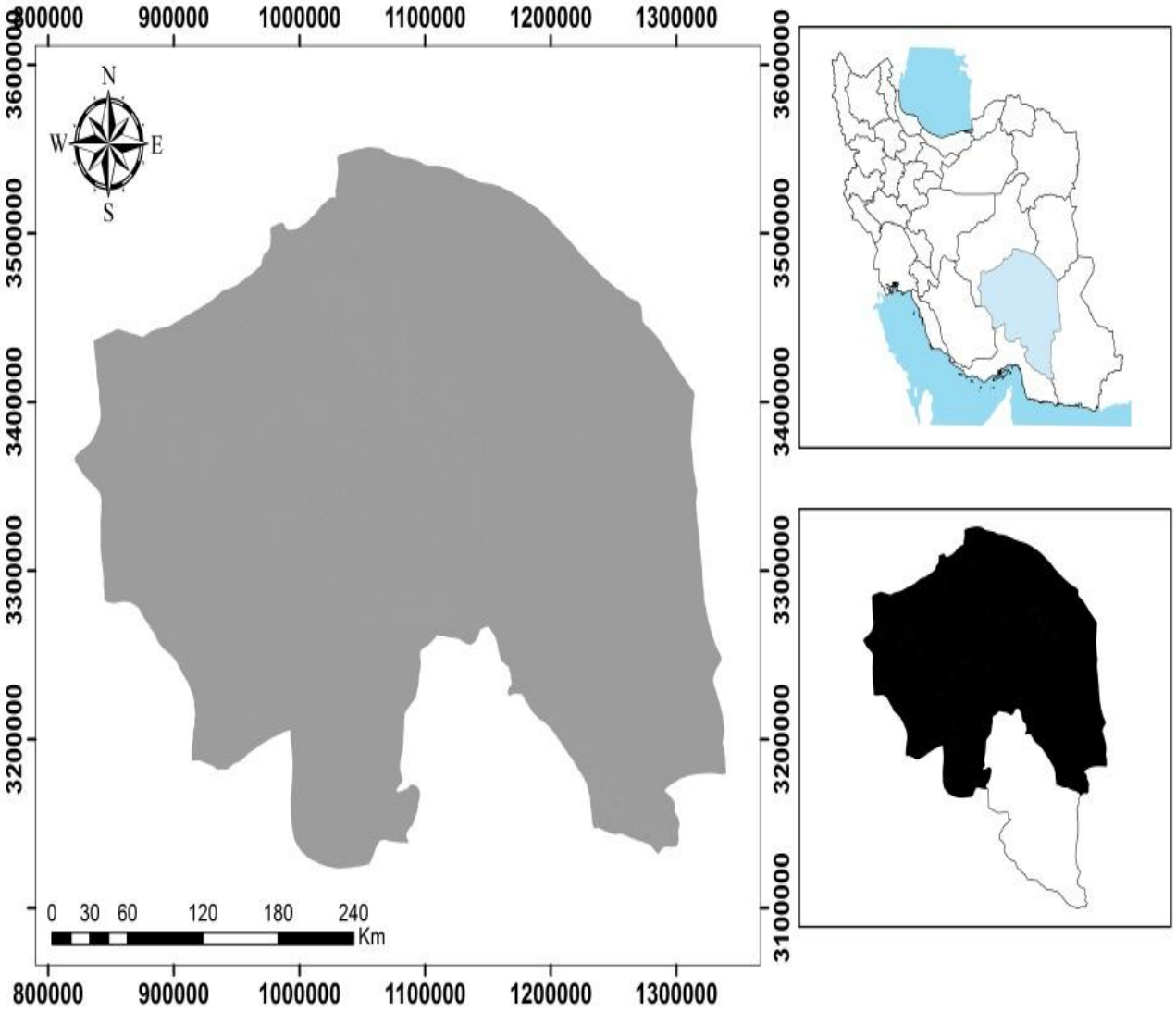

Fig.1. Location map of the northern part of the Kerman province in southeast Iran.

Methodology

Selected important factors for determining appropriate areas of RWH systems then produced layers of these factors 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 different weights with their layers and finally, produced finall maps. It is noteworthy in this study the effective factors to implement both in-situ and ex-situ methods were evaluated, which defined as following:

in- situ rain water harvesting:

In this method, collection and storage of water in natural areas is carried out. This means that the collected water is used in a nearby store place. This method is include farrowing, terraces, pitting and etc. in this study, terraces method was evaluated as one of the in- situ rain water harvesting methods.

Ex-situ rain water harvesting:

Collection and storage of water in artificial places, residential and natural areas is carried out. This method, has a water transmission system to a another location for storage and consumption.

Collected of required data and information's in the study area:

At this stage, the characteristics of the study area including climate, topography, geology, landuse, vegetation and etc, were derived from previous reports. In this research determined four factors influencing site selection of RWH systems which incluning Physiographic factors (maps of slope, slope orientation and elevation);Vegetation factors (percent of stone, canopy cover, bair soil); Precipitation factors (maps of gradient rainfall and maximum 24-hour rainfall) and Pedology factors (maps of soil depth, soil texture and soil hydrologic groups).

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 height 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 questionnaires designed and provided to local and academics experts then insert their opinions to these questionnaires 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.

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 different methods of RWH, which in this study terraces and ex-situ methods were evaluated. After initialization to methods of trraces and ex-situ, these information's inserted to EXT_AHP software.

Whitening 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.

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.

RESULTS

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

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

FACTOR	TERRACES	EX-SITU
SLOPE %	12 – 20	12 – 20
SOIL TEXTURE	LOAM-SANDY-GRAVELY	LOAM-SANDY-GRAVELY
HIGHT (M)	1370-2480	1370-2480
MAEN RAINFALL (MM)	250 - 500	250 - 500
CANOPY COVER %	0-25	25 - 33

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

MAIN CRITERIA	SUB-CRITERIA	TERRACES	EX-SITU
PHYSIOGRAPHIC	SLOPE %	0.6795	0.6891
	SLOPE ORIENTATION	0.1282	0.1524
	ELEVATION CLASSES	0.1923	0.1584
VEGETATION	BAIR SOIL %	0.4902	0.5911
	STONE %	0/2619	0.2061
	CANOPY COVER %	0.2478	0.2027
PEDOLOGY	SOIL DEPTH (CM)	0.3480	0.2976
	SOIL TEXTURE	0.4198	0.4091
	SOIL INFILTRATION	0.2322	0.2934
RAINFALL	ANNUAL MEAN RAINFALL	0.6414	0.6865
	MAX. 24-HOUR RAINFALL	0.43586	0.3135

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

MAIN CRITERIA	TERRACES	EX-SITU
PHYSIOGRAPHIC	0.4834	0.4479
VEGETATION	0.1416	0.2448
PEDOLOGY	0.1085	0.1954
RAINFALL	0.2665	0.1120

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 suitable 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 terraces and ex-situ methods (Fig. 2, 3). Also, the frequency and area of appropriate sites for terraces and ex-situ methods are given in table (4). The results showed that to locate trracese and ex-situ methods physiography, rainfall, vegetation and pedology; and physiography, vegetation, pedology and rainfall criteria were the most important, respectively. Also the results showed that, 6.18% and 83.4% of study region is suitable to implementation of terraces and ex-situ methods, respectively.

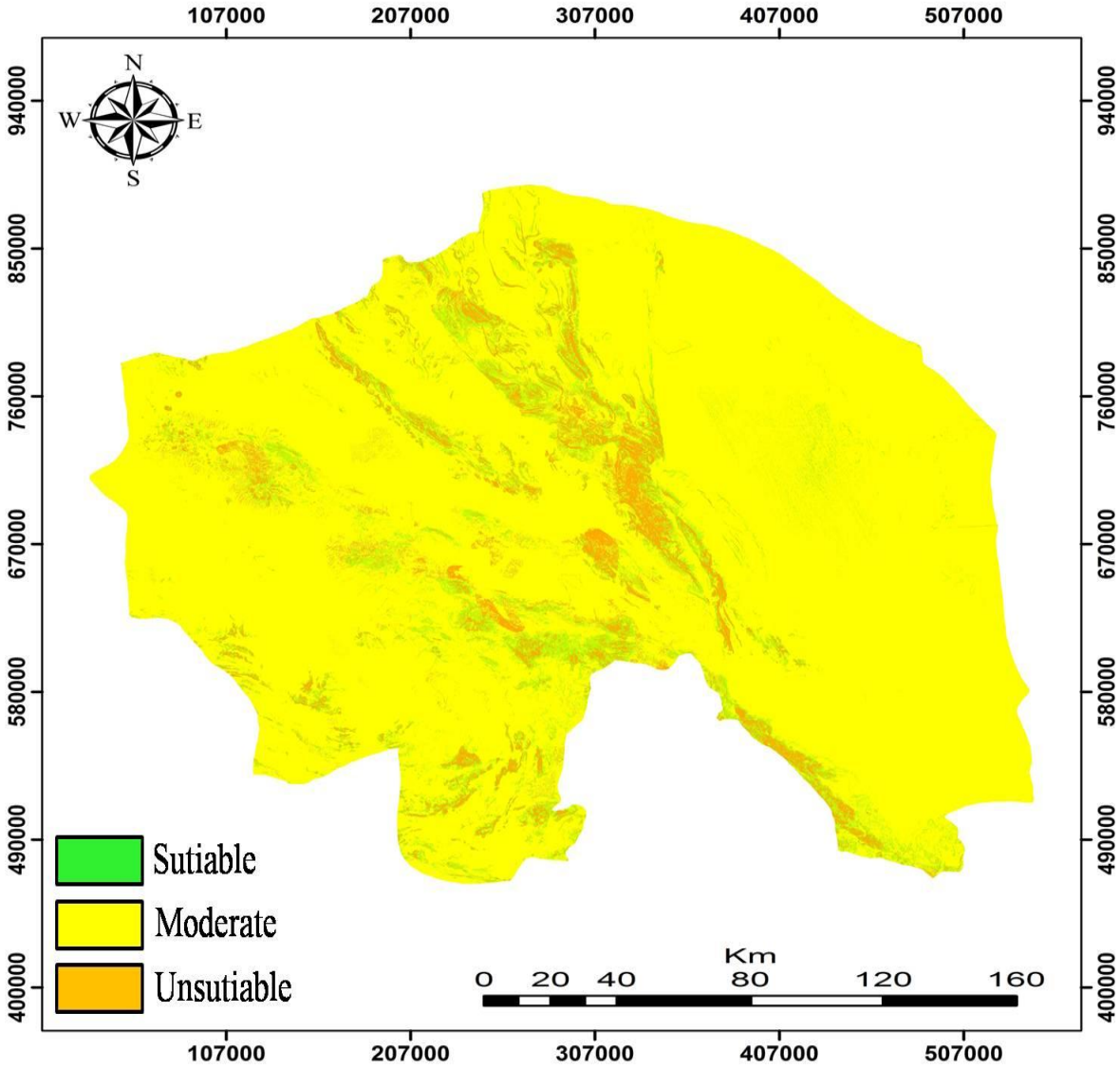

Fig. 2. Finall maps of trraces treatment in the northern part of the Kerman province in southeast Iran.

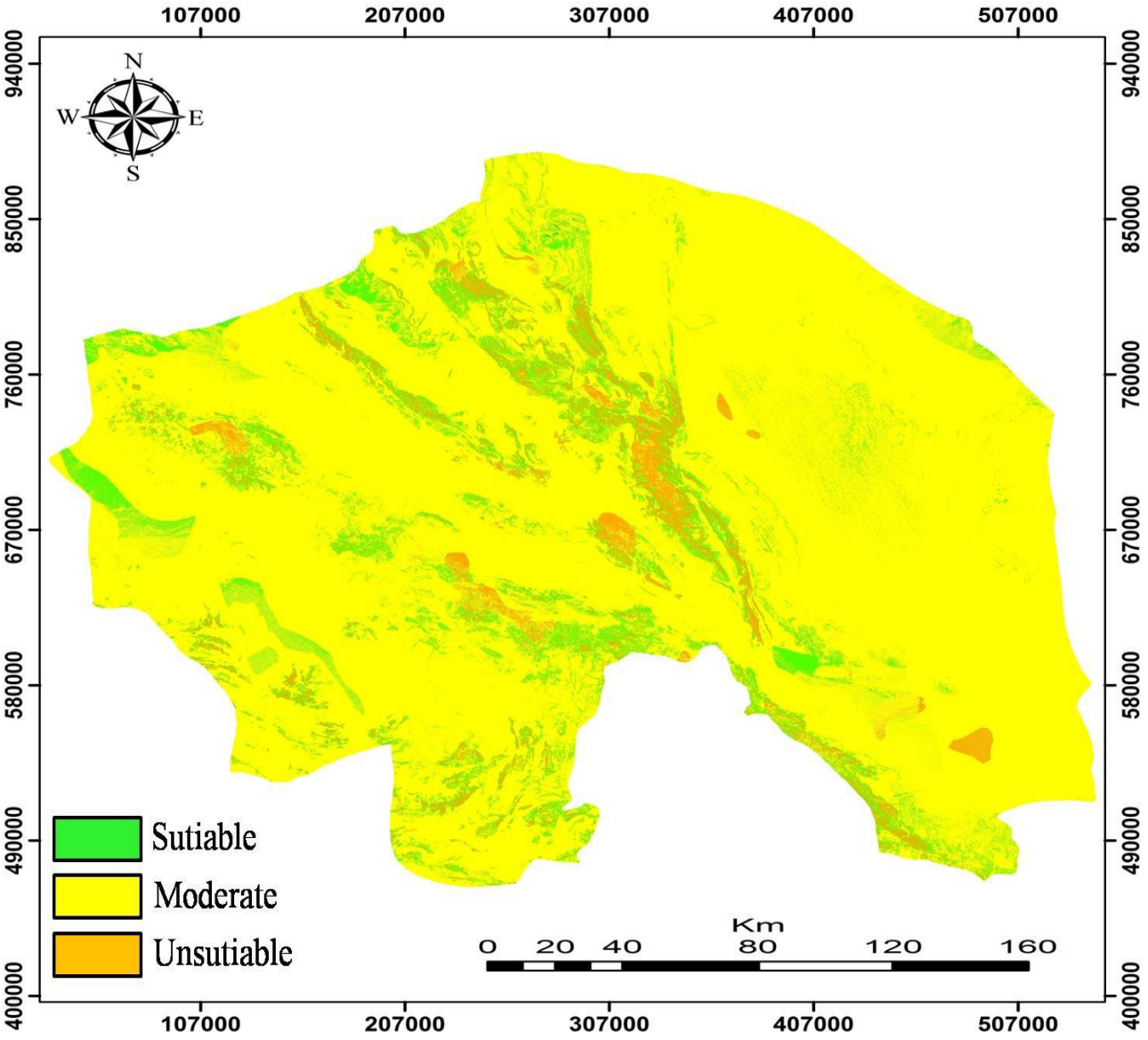

Fig. 3. Finall maps of ex-situ treatment in the northern part of the Kerman province in southeast Iran.

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

RWH TREATMENTS	AREAS SUTIABLE	
	PERCENT OF AREA	AREA (ha)
TERRACES	6.18	873795
EX-SITU	83.4	1179066

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 [6, 7, 8, 9].

The utilization of terraces and ex-situ methods 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 [2].

In this study the most important factors for site selecion of RWH were slope% and annual mean rainfall factors. Also, physiography was the most important criterion in the site selection of trracese and ex-situ treatments [4, 10].

Generally, result showed that this region is sutiable to implement ex-situ method, that to implement this method water transmission channel and other euipments are needed. Therefore, the government should have investment in this sector to solve the problem of water shortage in this region.

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BIOGRAPHIES

"He is interested in site selection of check dams and rain water harvestiong (RWH) systems"

"He is interested in soil and plant modelling and also water and wind erosion modelling. He studies the soil organig carbon dynamic modelling. He modelled SOC dynamic under water erosion, climate change and grazing "

"she worked on desertification modelling and evaluation different ways to prevent it and also reclamation of sesert areas"