Determining Potential Sites of Water Harvesting Structures Using Multi-Criteria Evaluation and GIS in Khulm Watershed, Afghanistan

ICID2015
26th ERC & 66th IEC

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INTRODUCTION

Enhancing water productivity is very important to improve food security among the growing population in arid regions of the world, which is one of the main objectives of millennium development goal (MDGs). These regions are receiving less precipitation annually than potential evapotranspiration and it causes high crop failure (Oweis et al. 2009).

Water harvesting can utilize some amount of available water to provide a supplementary irrigation source and minimize evapotranspiration rate as well as mitigate to water scarcity. FAO reports that arid and semi-arid regions have the potential to expand their agricultural lands, increase rain-fed crop yields, engage in well management best practices and the wise use of water resources. Hence, finding the suitable sites of WH was goal of this study as it is one of the giant tasks for planners and decision makers to give the correct idea of possible location of water harvesting projects.

Figure 1: *Major water harvesting types in Afghanistan; A_ Inter-row, B_Terrace, C_ Pond structures*

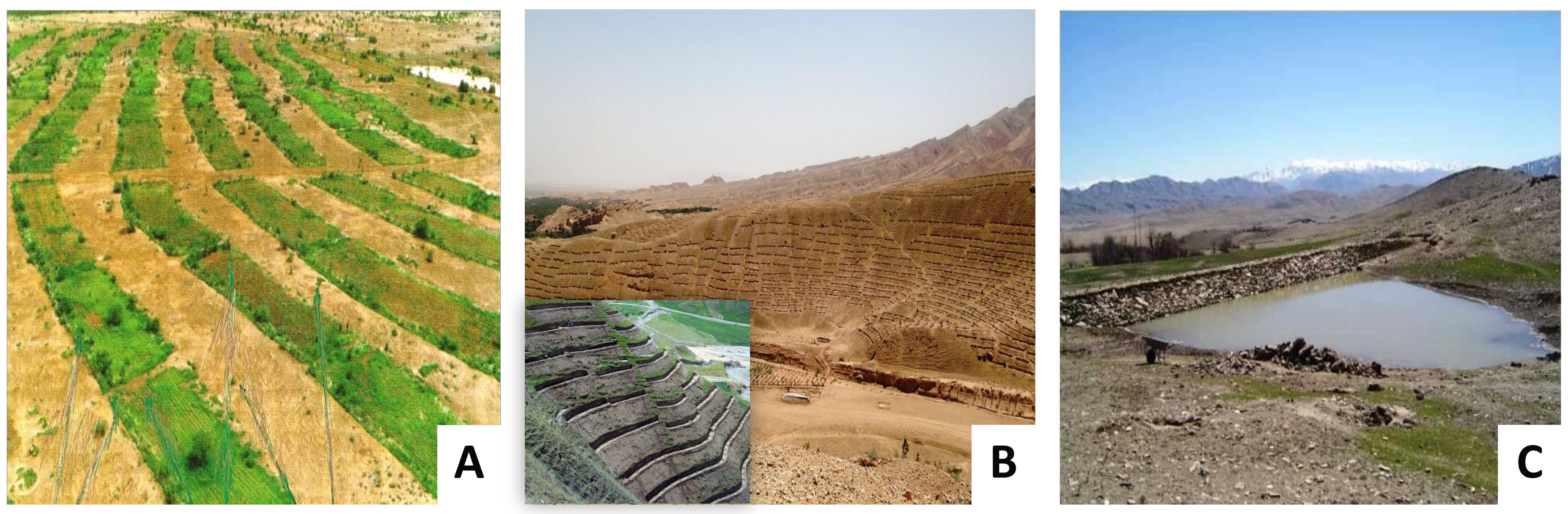
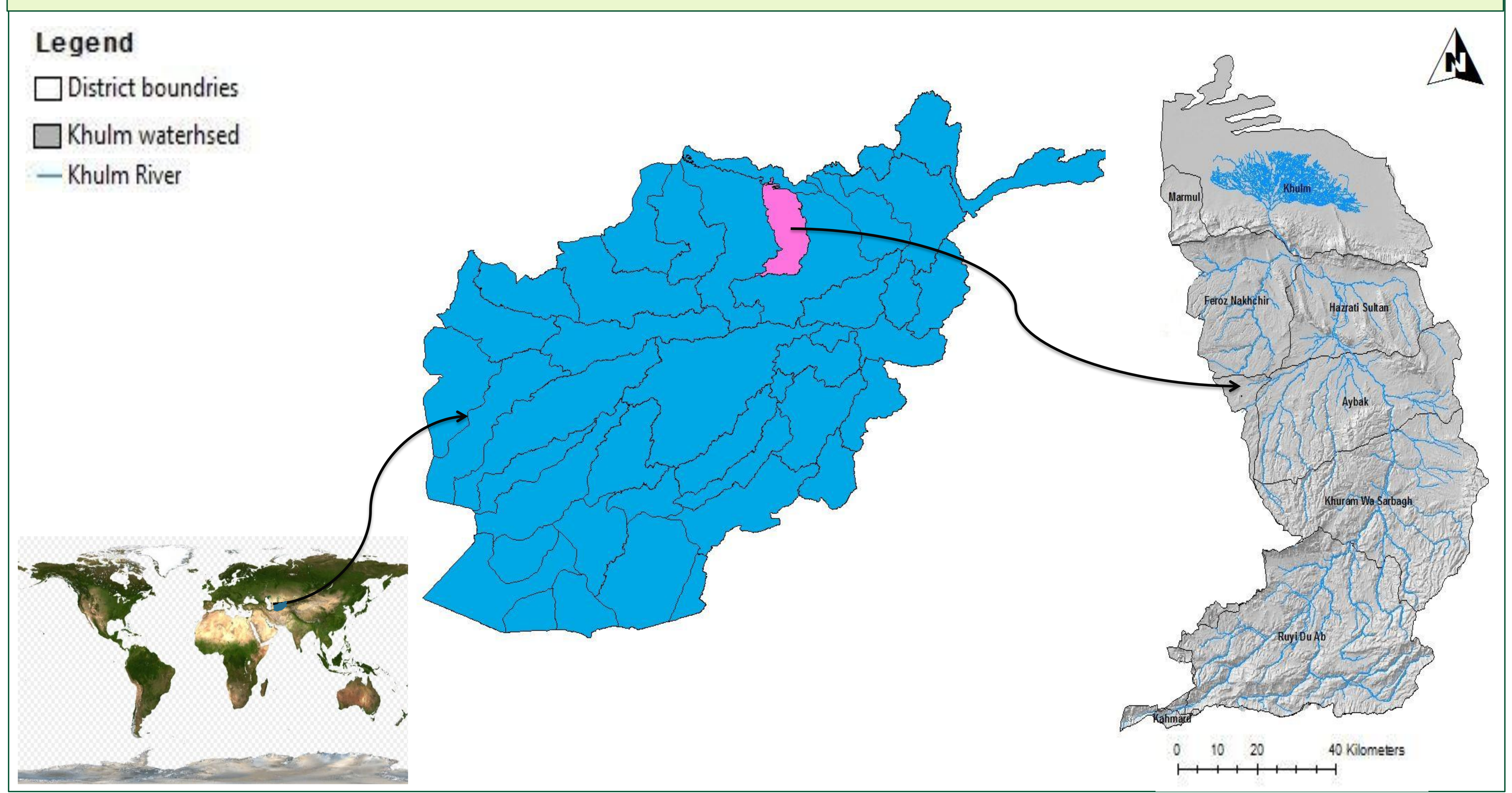


Figure 2*: Afghanistan watershed boundary, Khulm watershed, and Khulm River*



STUDY AREA, METHOD and MATERIAL

1- STUDY AREA

The study area is Khulm Watershed of the Northern region of Afghanistan and it is bounded by longitudes 68º to 67º east and latitudes 35º to 37º north having geographical area of 10,230 km² (Figure 2). The study area has steep slopes the highest point is 4,051m and the lowest point is 271m above the sea level. Most of soil of the area is Entisols with silt dominant texture. Khulm land is covered by agricultural lands, pastures, water bodies, urban areas, and barren lands. Maximum of runoff goes down without any usage and causes many unexpected floods as well as soil erosion. The are some pilot projects of water harvesting which are terraces, and ponds at the Khulm watershed.

2- MATERIAL

To identify suitable areas of WH, the information of parameters such as potential runoff, water availability, slope degree, land cover and vegetation type, soil texture and depth, and labour availability are necessary. Soil Conservation Service-Curve Number method (CN) was used for calculating on mean monthly time step of potential runoff. DEM is derived from Aster GDEM to extract slope degree. Land cover map 2007 is derived from Ministry of Agriculture, Livestock and Irrigation of (MAIL) Afghanistan. Soil texture map and hydrological Soil Group HSG is prepared after analysis of 136 soil samples from study area. Labour availability map is created using buffering method considering accessibility to arable lands (Figure 4).

3- METHOD

Decision rules for site selection of WH structures were prepared using the water harvesting manual of (FOA, 1991). The Weighted Linear Combination (WLC) of Multi-Criteria Decision Process (MCDP) (Boerboom et al. 2009), supported in Geographic Information System (GIS), was settled to overlay the parameters with aim of detecting potential sites for WH structures (Figure 4).

Weighted Linear Combination

$$F(y) = \sum_{j=i}^{M} Fj\,Hj$$

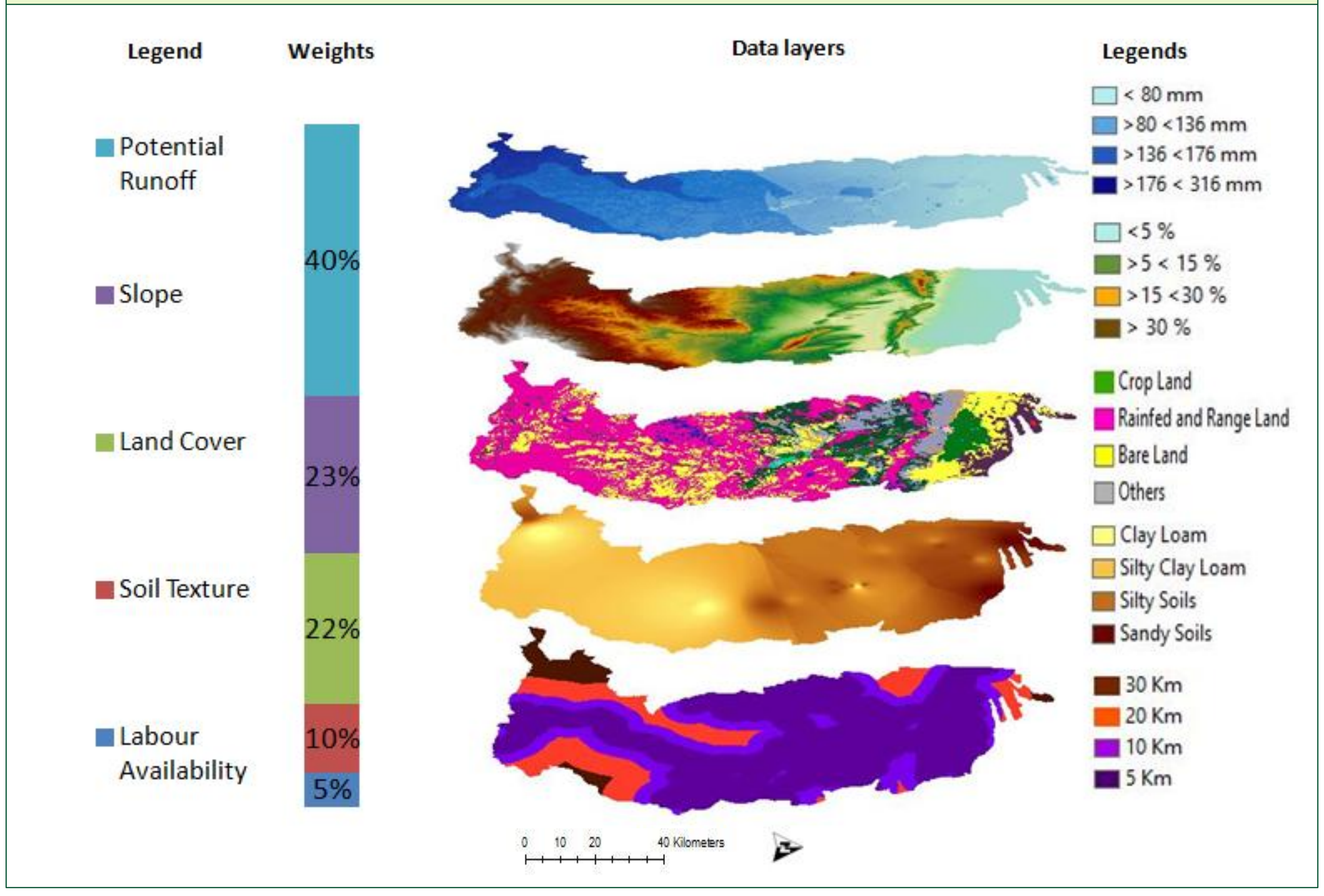
Fj = Weight of criterion
Hj = Score of alternative
M = Number of criteria
Fy= Overall score

Table 1*: Decision criteria for selecting suitable site of targeted water harvesting structures*

Parameters	Potential Runoff	Slope	Land Cover	Soil layer	Labor Availability
Inter-Row	>200 mm	5-12 %	Bare & Rainfed lands	Fine, deep	<5 km
Terrace	>180 mm	13-30 %	Bare & Rainfed lands	Fine, deep	<5km
Pond	>250 mm	<5 %	Except urban area	Clay , deep	<5 km

RESULTS and DISCUSSION

Figure 3*: Material with their weights and weighted Layer Combination Process*



Potential runoff varied from 2mm/year to 316mm /year (Figure 3). Hydrological Soil Group HSG shows only three classes; HSG-A (low runoff), HSG-B (moderate runoff) and HSG-C (high moderate runoff).
The site suitability result for each structure is as follow;
Terrace structure: The suitable sites for terrace type of WH structure are 1009 ha (0.35%). Moderately suitable sites are 632673 ha (62.1%), about 38,4305 ha (37.6%) is less suitable and 0.05 % is not suitable (Figure 4). The suitability for terrace is suited in slopes between 20-50 %, and other criteria are similar as micro catchments (Figure 4).
Micro Catchments: Potentially 39,882 ha (3.9 %) lands are suitable to construct the micro catchments in order to harvest water for growing more crops. 65.2% of study area is moderately suitable, 33.2% is less suitable and remaining 0.1% is not suitable (Figure 3). The suitability of sites for micro catchments can be confirmed, as it is located in a terrain where potential runoff is moderate, slope is between 5 – 10 %, land cover is bare or rain-fed and soil texture is silty (Figure 4).
Pond: The study highlighted that the suitable sites for farm ponds covered 2.06% of the total area, followed by 49.2% moderately suitable, 44.3% less suitable, and 4.4% unsuitable area (Figure 4).

Figure 4: *Potential sites of water harvesting structures in Khulm watershed*

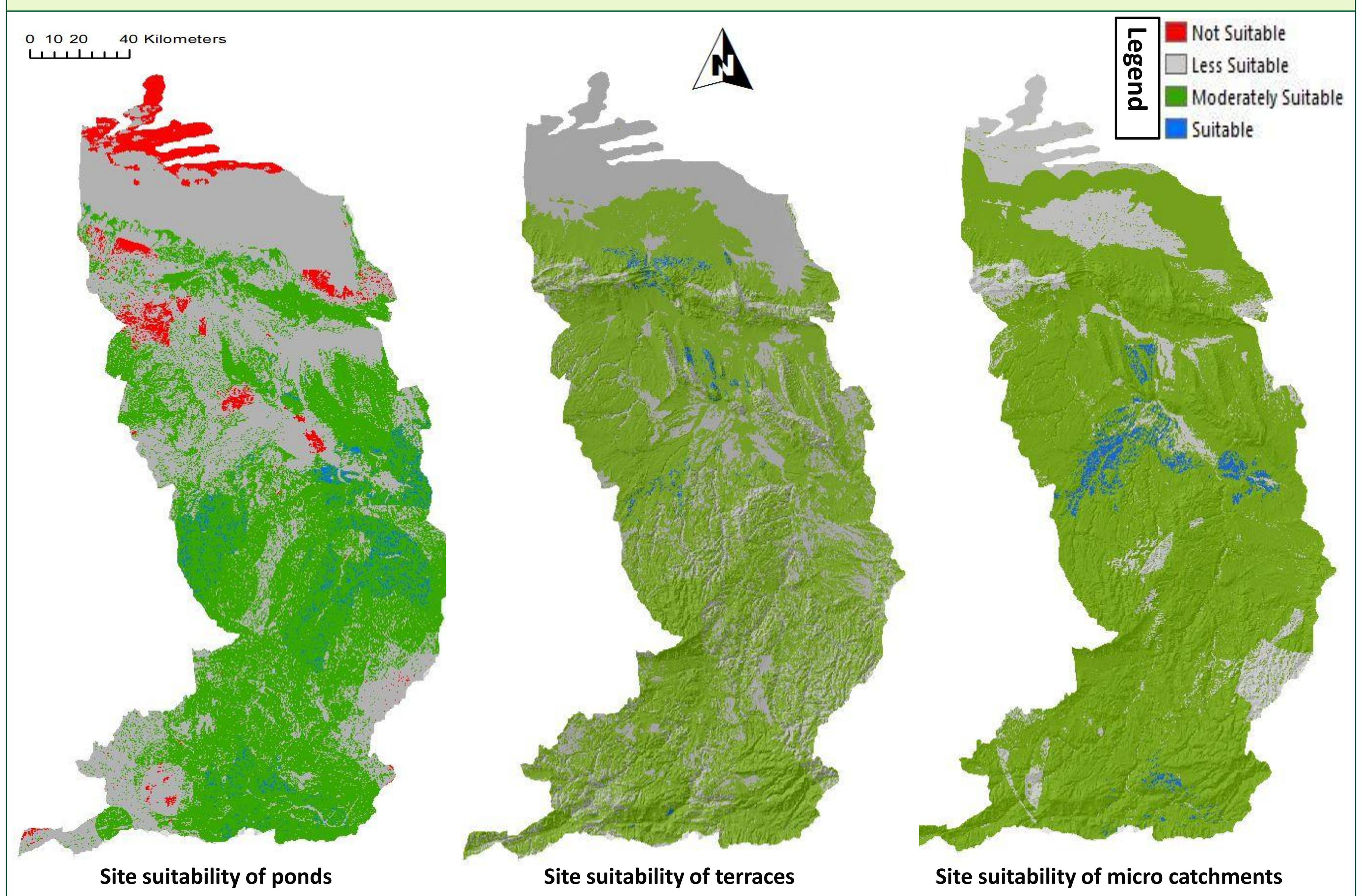
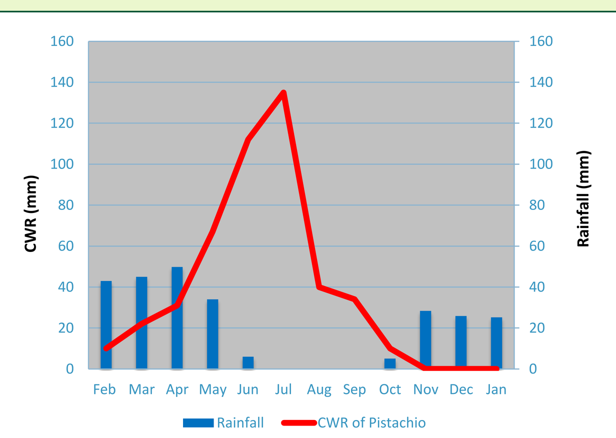
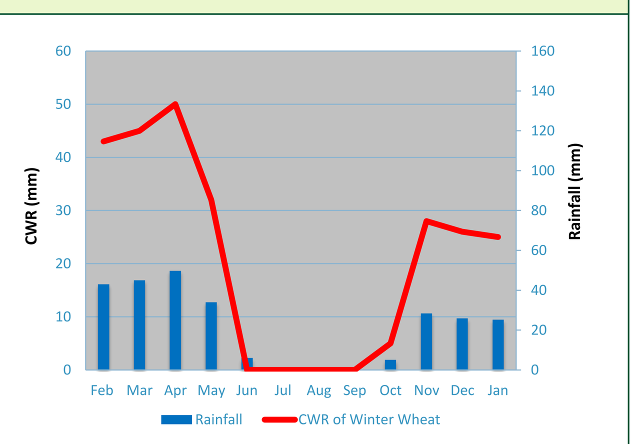


Figure 5: Catchment (C) and cultivation area (CA) analysis of the suitable areas



- The catchment and cropping area C:CA ratio for micro structures and terraces structure is calculated to be 3:1.
- 15,685 ha (C) : 5,126 ha (CA) is dedicated for growing winter wheat.
- 5,286 ha (C) : 1,762 ha (CA) is dedicated for reforestation of pistachio.



DISCUSSION and RECOMMENDATION

The research has demonstrated the powerful capability in order to select the optimum sites of WH. Using digital data sets with support of applications like GIS can support decision makers to save time and money needed for planning of projects and it is recommended for all Afghanistan governmental agencies. Also this methodology is applicable in other similar areas. As the selected structures cannot use majority of the runoff so,it is recommended for further studies on how to use rest of the runoff water for agricultural production with the aim of facilitating a sustainable livelihood for the living communities.
Finally, it's recommended that field work must be carrying out on the suitable sites before implementation of the projects.