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

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Introduction

Enhacing 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). Crop production in arid and semi-arid countries like Afghanistan is limited by precipitation deficiencies (primarily due to poor temporal distribution of rainfall and high evapotranspiration) and it is resulting that residence of the territories produce less food for their livelihoods (Critchley & Siegert, 1991).

Technology of water harvesting (WH) can utilize some amount of available water to provide a supplementary irrigation source and maximize evapotranspiration rate as well as mitigate to water scares. Food and agriculture organization (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 WH projects.

Study Area

The study area is Khulm watershed with 10230 km² area, located in Northern Afghanistan (Figure 1). The land is covered by irrigated lands (4.8%), rain-fed lands (17%), forests (0.2%), barren lands (13%), rangelands (58%), water bodies (2%), sand cover (13%) and urban areas (4%) (Figure1). The elevation ranges from 271 m to 4061m. Dominant soil type is Entisols with silty loam texture. Mean monthly climatic data from 2002 to 2012 is collected from eight stations surrounding Khulm district and average rainfall is 189 mm. Temperature varies from -5 to 37 Cº during a year.

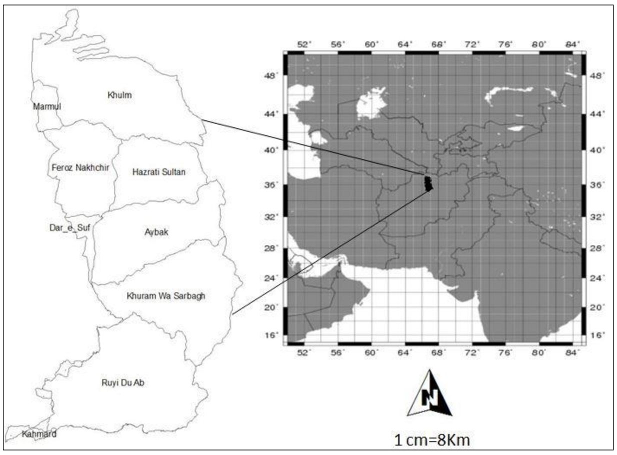

Figure1: Khulm watershed and district boundries of study area

Methodology

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.

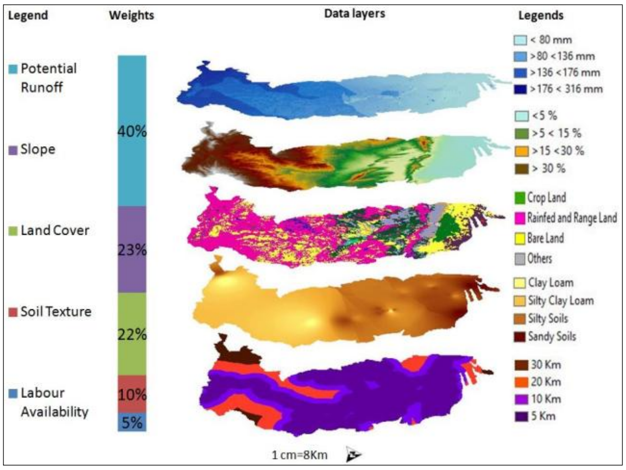

Figure 2: Data layers and their weights (coefficients)

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Decision rules for site selection of WH structures was 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 2).

Result and Discussion

Potential runoff varied from 2 mm/year^{-1} in lower watershed to 316 mm/year^{-1} in upper parts of the watershed (Figure 2). Hydrological Soil Group HSG shows only three classes; HSG-A (low runoff), HSG-B (moderate runoff) and HSG-C (high moderate runoff).

The resulted maps were generated after multiplying the given weighted and the constrain criteria. It was determined that the minimum value calculated by the WLC method will be 1, while the maximum value will be 4. The difference between these two numbers was divided into classes respectively; 1 (unsuitable), 2 (less suitable), 3 (moderately suitable), and 4 (suitable) shown in figure 4.

The site suitability result for each structure is as follow;

Terrace Types: The suitable sites for terrace type of WH structure are 1009 ha (0.35%). Moderately suitable sites are 632673 ha (62.1%), about 384305 ha (37.6%) is less suitable and 0.05 % is not suitable (Figure 3). The suitability for terrace is suited in slopes between 20-50 %, and other criteria are similar as micro catchments (Figure 4).

Micro Catchments: Potentially 39882 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).

Khulm watershed is an absolute water stressed region of Afghanistan. As the potential runoff analysis shows that, significant water depth is generating during the year. The Geomorphology of the study area is steeply. Hence, the rainfall immediately flows into the Khulm River. Therefore, management of rainwater in the selected area is needed. It helps the community as an effective way for sustainable crop production for their livelihood.

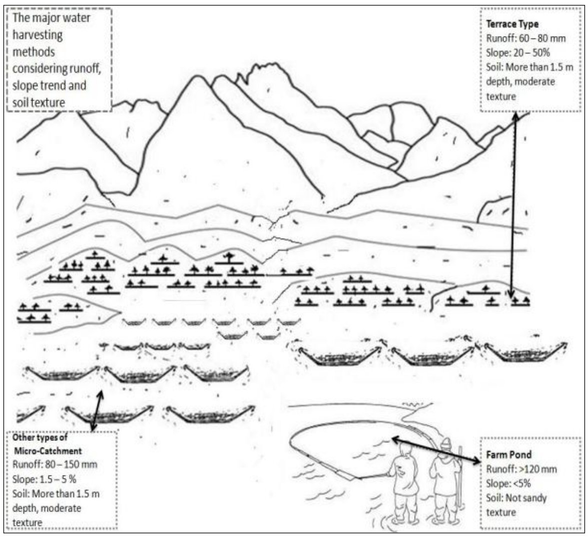

Figure 3: Detailed diagram of WH techniques

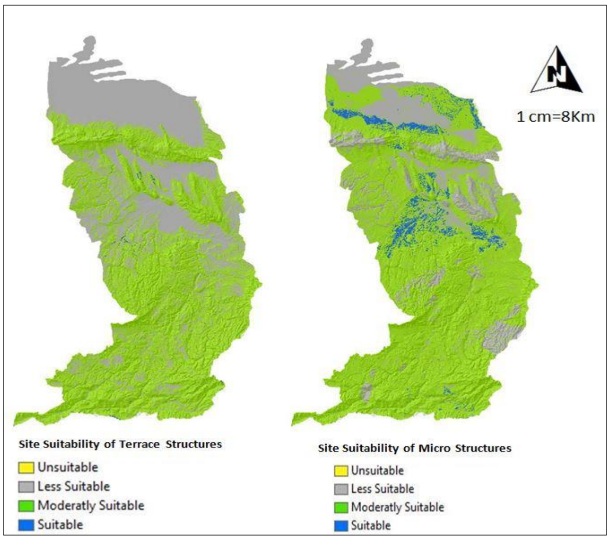

Figure 4: Potential sites of water harvesting structures in Khulm

The research 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 areas with the same similarities. Finally, it's recommended that field work must be carrying out on the suitable sites before implementation of the projects.

References

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