

The Combination of Indigenous Knowledge and Geo-Informatics for Water Harvesting Siting in the Jordanian Badia

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ABSTRACT

Jordan is located in an arid to semi arid region where around 90% of its land receives an average annual precipitation of less than 100 mm while only 3% of the land receives an average annual precipitation of 300 mm or more. Jordan is characterised as a “water scarce” country because the current *per capita* share of water is estimated to be of the order of 140 m³ per year which is well below the 1000 m³ threshold. Rainwater harvesting is the accumulating and storing, of rainwater. It has been used to provide drinking water, water for livestock, water for irrigation or to refill aquifers as a groundwater recharge. GIS has been widely used in selecting the best sites for water harvesting schemes. This research aims at selecting optimum sites for water harvesting schemes in the Jordan arid lands (Badia) using indigenous knowledge and geo-informatics. To achieve this aim, a community-based research and desktop investigating is applied. The community-based research focused on consulting with 200 stakeholders from local communities where they provided knowledge on opportunities and constrains from their experience on water management in the arid lands where they live and interact. Also they provided information on potential location for water collecting sites that has been used for ages to provide water to humans and livestock. On the other hand, desktop research is conducted on sitting criteria for water harvesting based on physical and socio-economic characteristics. The physical criteria include rainfall volumes, slope, distance to water courses (wadis), distance from geologic faults and soil texture, where socio-economic criteria include distance to groundwater wells, distance to urban area, distance to agriculture activities and distance to international brooders. This selecting criterion in combination with indigenous knowledge is used within GIS environment to identify optimum sites for water harvesting. GIS analysis resulted in identifying 118 potential sites. Of those, 30 sites had already recommended by the community consultations.

Keywords: GIS; Indigenous Knowledge; Water Harvesting; Arid Lands; Jordan

1. Introduction

Jordan is located in an arid to semi arid region where around 90% of its land receives an average annual precipitation of less than 100 mm while only 3% of the land receives an average annual precipitation of 300 mm or more [1]. Jordan is characterized by severe weather conditions, therefore great temporal and spatial variations in rainfall; runoff and evaporation amounts are expected [1].

Jordan is characterised as a “water scarce” country because the current *per capita* share of water is estimated to be of the order of 140 m³ per year which is well below

the international recognized threshold for water scarce countries of 1000 m³ [2-4].

The annual population growth rate in Jordan is estimated to be around 2.8%. Based on this percentage, it is estimated that the total population in Jordan will be around 10 millions by 2020 [5]. This will add more pressures on the existing water resources in the country leading to a massive decrease in per capita to 90 m³ per year by 2025 [6].

Rainwater harvesting is the accumulating and storing, of rainwater [7]. It has been used to provide drinking water, water for livestock, irrigation and ground water aquifers recharge. Various forms of water harvesting have been used traditionally throughout the centuries.

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Some of the very earliest agriculture, in the Middle East, was based on techniques such as diversion of “Wadi” flow (spate flow from normally dry watercourses) onto agricultural fields.

Water harvesting is adapted in arid and semi-arid regions where rainfall is either not sufficient to sustain a good crop and pasture growth or where, due to the erratic nature of precipitation, the risk of crop failure is very high. Water harvesting can significantly increase plant production in drought prone areas by concentrating the rainfall/runoff in parts of the total area [8]. Water harvesting has been practiced in Jordan throughout history for both irrigation and household purposes. There are indications of early water harvesting structures believed to have been constructed over 9000 years ago in Southern Jordan [8]. In the North Eastern of Jordan (Jawa), water was retained by deflection dams 5000 years ago [9].

GIS has been widely used in selecting the best sites for water harvesting schemes (e.g. [6,10-18]). The site selection criteria in most of these references are based on soil and topographic suitability, land cover and land use, and surface runoff generating potential. Hydrologic modeling, remote sensing, and GIS techniques are usually used in the site selection processes of these water harvesting schemes are used in these researches.

The integration between indigenous knowledge and geo-informatics for water harvesting has been explored in various researches (e.g. [19-25]).

There are two major techniques used within GIS environment to select the optimum site for any project; the Weighted Linear Combination (WLC) and the Boolean technique.

The Weighted Linear Combination (WLC) technique is based on standardizing the suitability maps, assigning weights of relative importance to the suitability’s maps, combining the weights and standardized suitability maps and obtaining an overall suitability score ([26-31]). While in the Boolean technique, the variables are either true or false. This technique provides site selection of a project based on using either the OR (*UNION*) or the AND (*INTERSECTION*) operations ([6,16,32-36]).

The main goal of this project is the development of site selection criteria for rain water harvesting systems in the Jordanian Badia based on the indigenous knowledge and the use of Geo-informatics. In this research, the approach suggested by ([16,23,33]) will be used for analyzing the data in order to select the optimum sites for water harvesting systems. All criteria will be given equal weights, and 0 and 1 will be used to rate all layers (0: not suitable and 1: suitable). This is in contradiction with ([6,15,35], who used WLC technique because weighting is a very complicated process and might lead to misleading results. According to [35], it is misleading to interpret

the weights as general measure of the importance. Incorrect specification of weights is an especially common error in the application of weighted linear combination method (WLC) to spatial problems [35].

2. Study Area

The study area is located in the Eastern part of the Jordan, and cover about 55.4 thousands Km², which comprise about 62% of the total area of Jordan. **Figure 1** shows the location of the study area which extends from north to south eastern parts of Jordan covering areas within Mafrqa, Zarqa, Amman, Karak, Ma’an and Aqaba governorates. About 100 thousands inhabitants live in this area **Figure 2** shows the population distribution within the study area.

The annual rainfall volumes in the study area vary between 250 mm in the north western parts to less than 50 mm in the southern parts. **Figure 3** shows spatial distribution of annual rainfall volumes in the study area.

The topography of the study area is gentle in general. The ground surface elevation varies between 500 m above sea level (m a.s.l) in the middle parts to about 1000 m a.s.l. in the southern parts and 1200 m a.s.l. in the northern parts. **Figure 4** shows the change in topography of the study area.

The soil textures in the study area comprise of Sandy Loam (South eastern parts of the study area), Loam (Eastern and South Eastern parts of the study area) and small areas with Silty Loam, and Silty Clay Loam textures as shown in **Figure 5**.

3. Research Methods

3.1. Data Collection

There are two types of data collected for this research, primary data and secondary data. The primary data include the following:

- 1) Suggested sites by the local communities for water harvesting in the Badia,
- 2) Suggested constraints by the local communities for selecting an optimum site for water harvesting which include:
 - Distance to International Borders (the allowed distance from borders for livestock owners in the Badia region to graze their livestock),
 - Distance to Roads,
 - Distance to Urban centers,
 - Distance to Agricultural activities,
 - Distance to Groundwater wells.

As part of the primary data collection which were mainly from local community, three community consultations were organized with local community members. The participants in these consultations cover livestock owners,

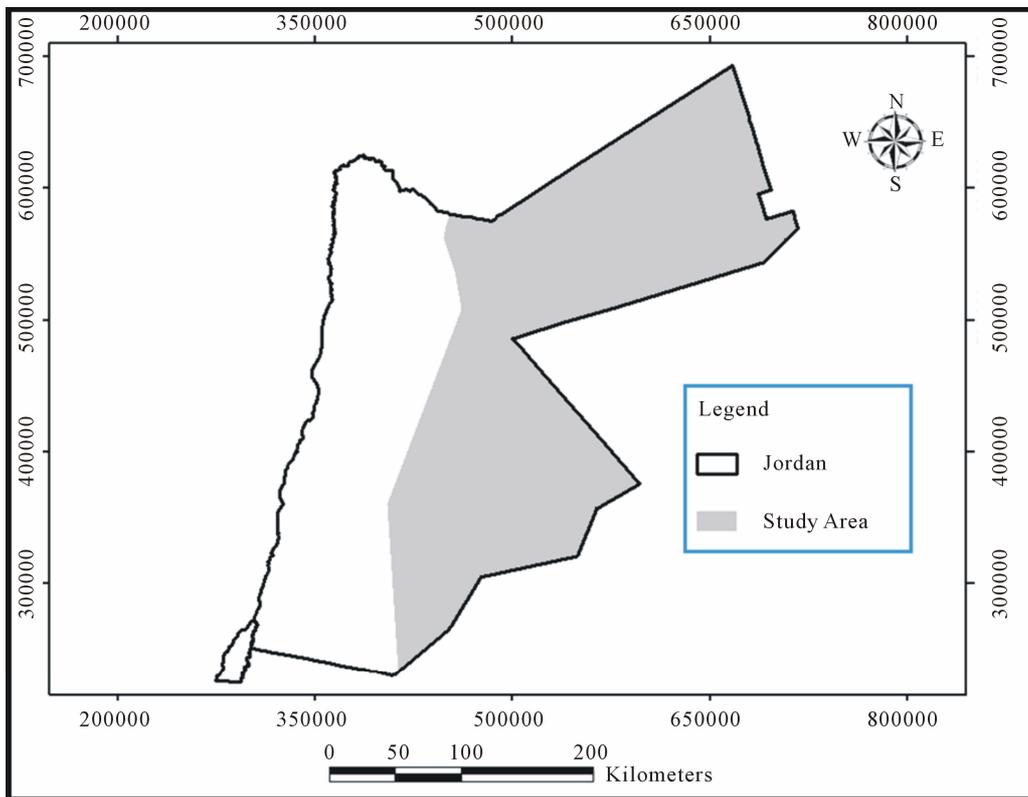


Figure 1. The study area location within Jordan.

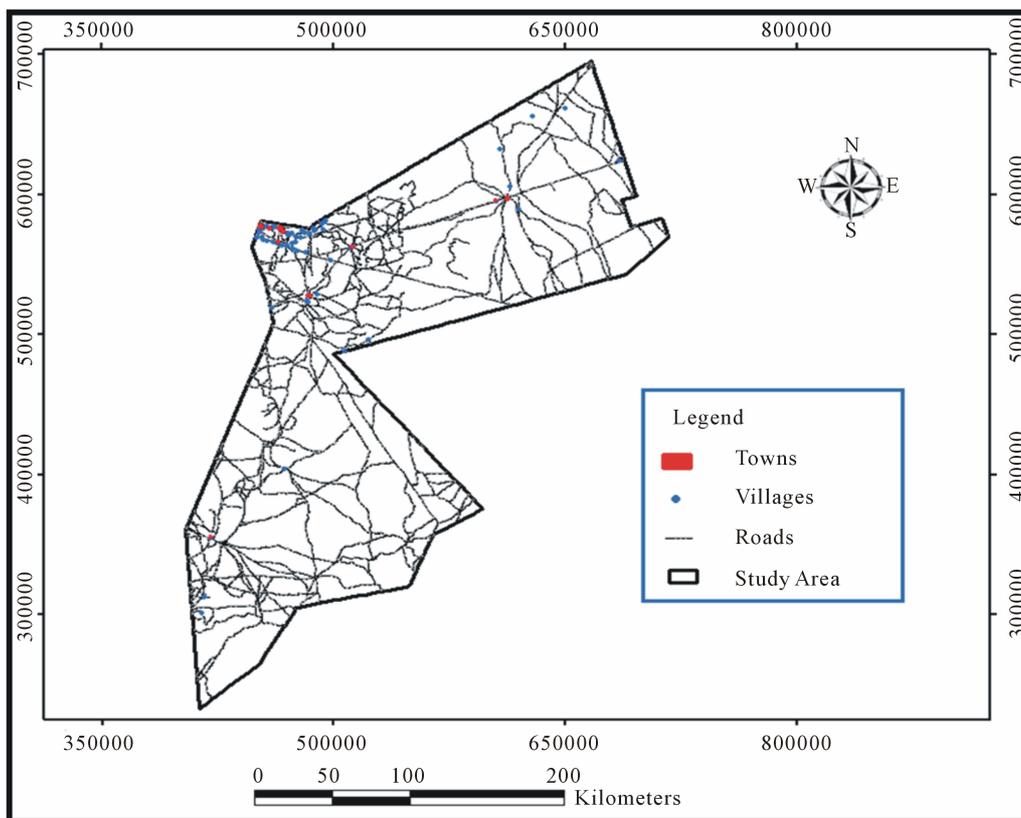


Figure 2. The population centres within the study area.

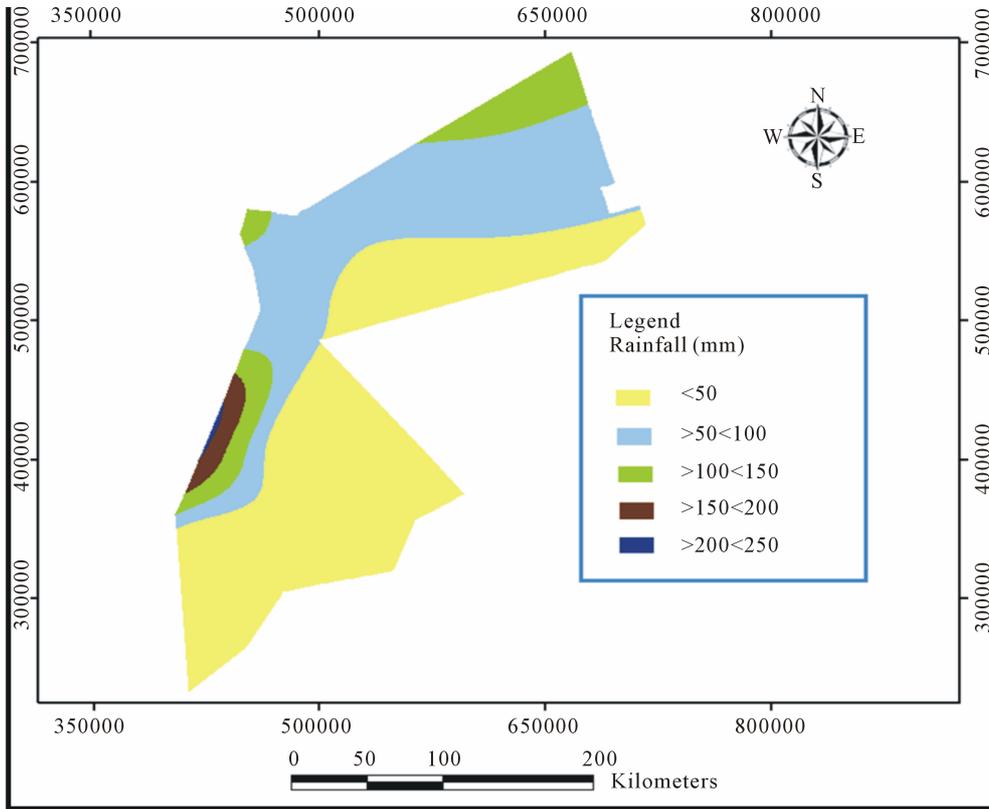


Figure 3. Rainfall isohyets for the study area.

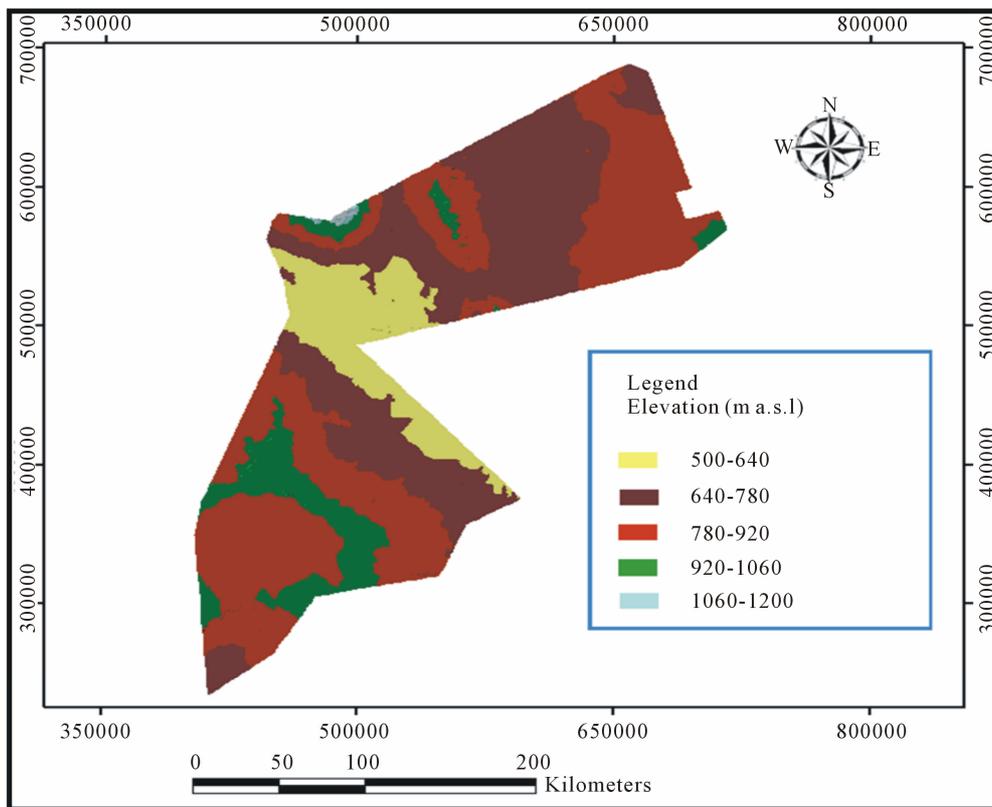


Figure 4. DEM for the study area.

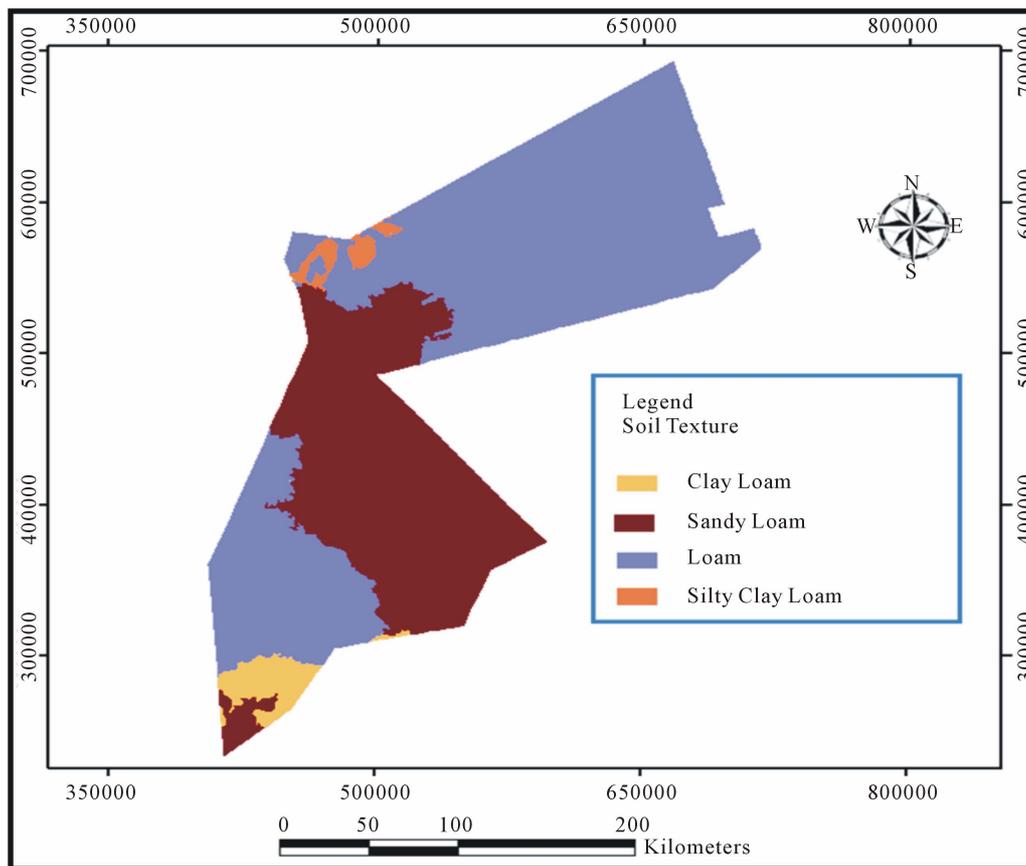


Figure 5. Soil textures within the study area.

farmers, and community leaders. The first workshop was held in the Northern Badia, where sixty persons attended the workshop. The second workshop was held in Azraq Town in the Middle Badia, where sixty persons attended the workshop. The third workshop was held in Al-Husainyya Town in the Southern Badia, where eighty persons attended the workshop.

In these workshops, the attendants were asked to select ten sites within their area and locate them on Google Earth imageries (Figures 6-8). Also, they were asked to agree on the distances to international borders, distance to roads, distance to urban centers, distance to agriculture activities, and distance to wells (Table 1). The suggested constrains by the local communities were in agreement with the available cited literature ([6,15,16,23]). The only difference is the distance to international border. Participants agreed that the distance between the suggested water harvesting systems should be at least 5000 m in unpopulated areas and at least 250 m in populated areas close to the international borders of Jordan.

The other type of data are secondary data which are collected from various national organizations working in the study area. These data are geo-maps for different physical and socio-economic aspects of the study area.

Table 2 lists the geo-data collected and their sources.

3.2. Data Analysis and Results

The socio-economic criteria for water harvesting systems, Table 1 and the physical sitting criteria, Table 3 were applied to the study area within GIS environment using ArcGIS 9.3. The methodology of analyzing the data is summarized in Figure 9.

The final map (Figure 10) shows the selected sites based on selection criteria suggested by the local communities and the available literature (118 sites). Based on the comparison between the selected sites using GIS and the suggested sites by the local communities (30 sites), it was found that there is a high degree of agreement between both outcomes. Local communities selected water harvesting sites within a reasonable proximity to the selected ones by GIS. The distances between GIS outcomes and local communities' suggestions were within 1000 m. Most probably this difference might result from pointing on a wrong location on Google Earth imageries during the consultation workshops, or due to the satellite imageries resolution (zooming in and out). However, all sites (30) were visited in order to record their exact coordinate (*i.e.* the most suitable location within the selected site

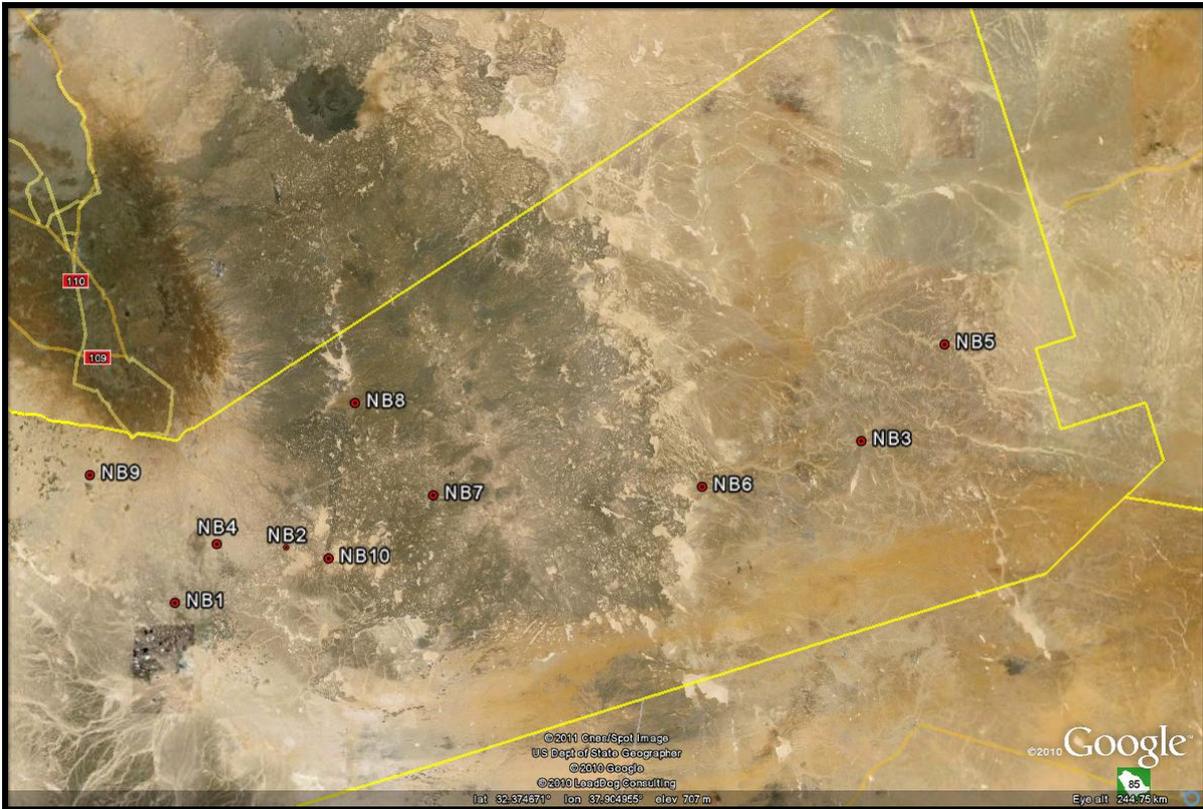


Figure 6. Suggested Water harvesting sites by local communities in North Badia.

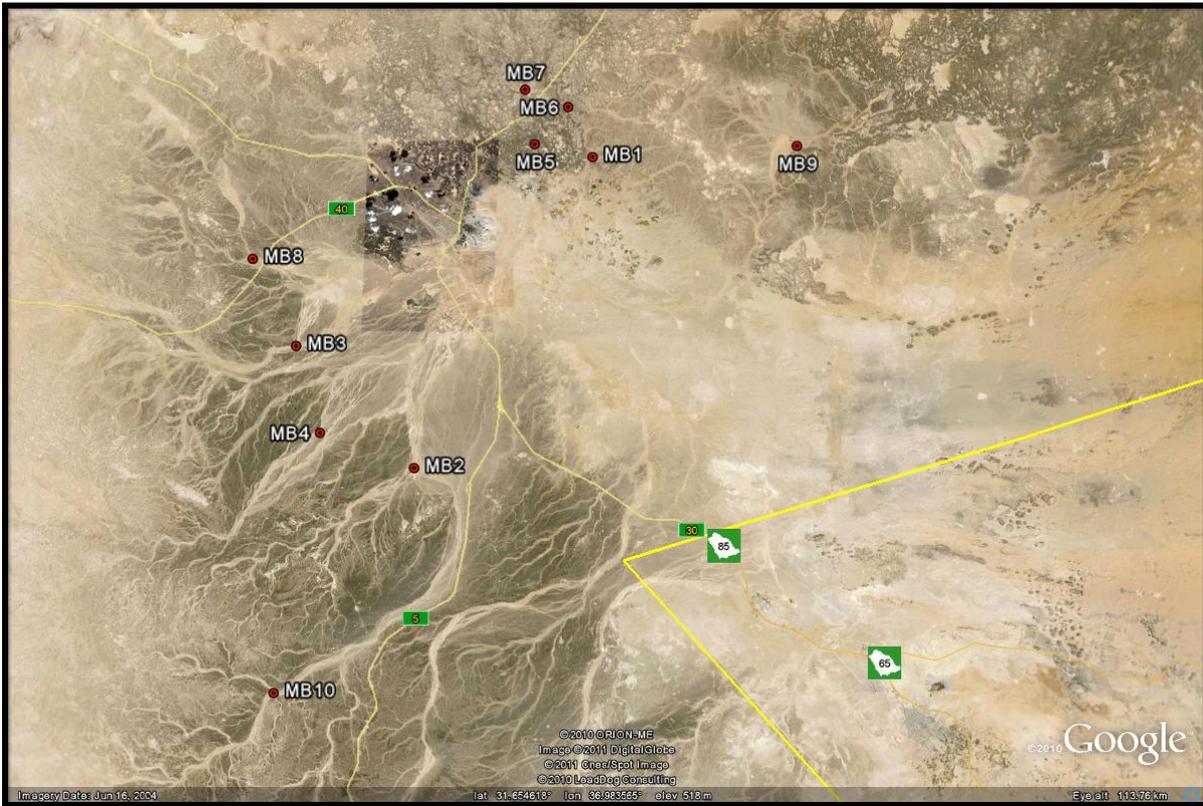


Figure 7. Suggested water harvesting sites by local communities in Middle Badia.

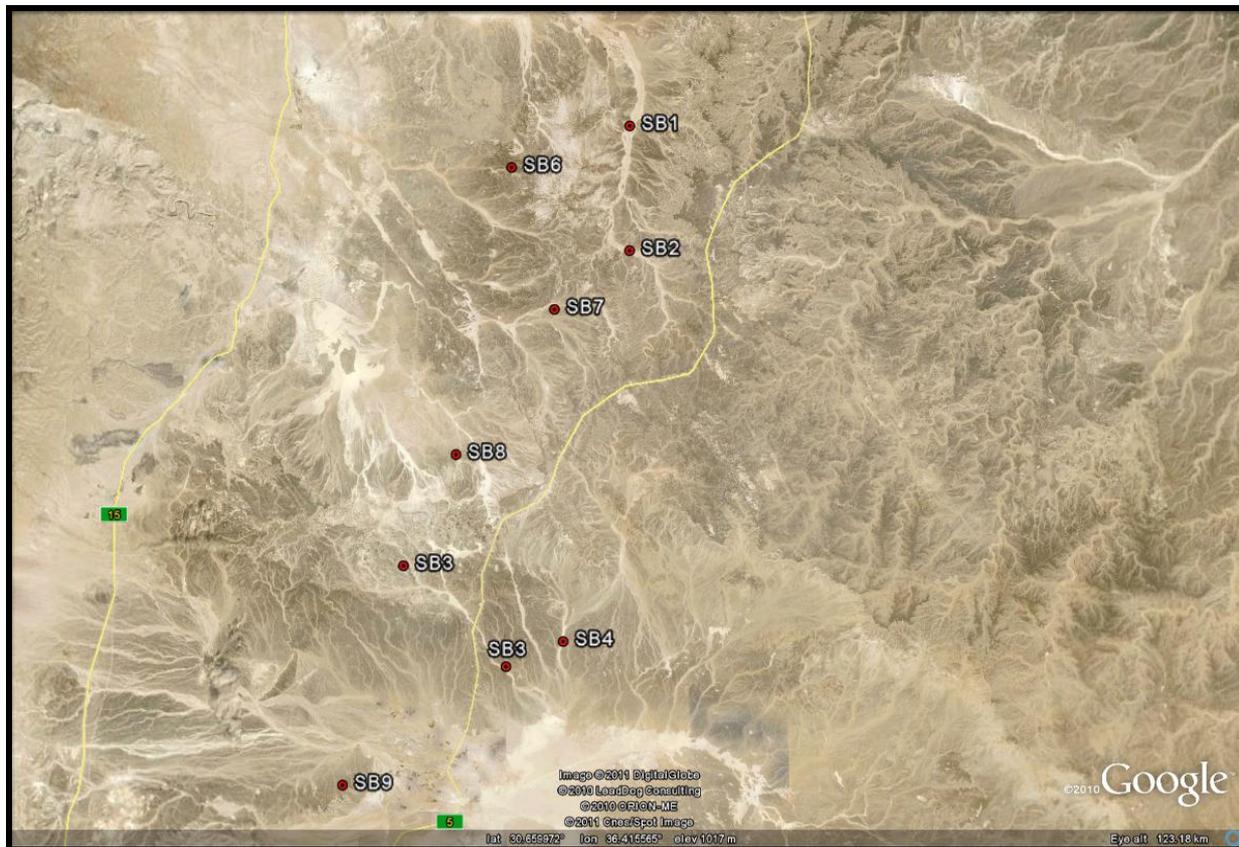


Figure 8. Suggested water harvesting sites by local communities in South Badia.

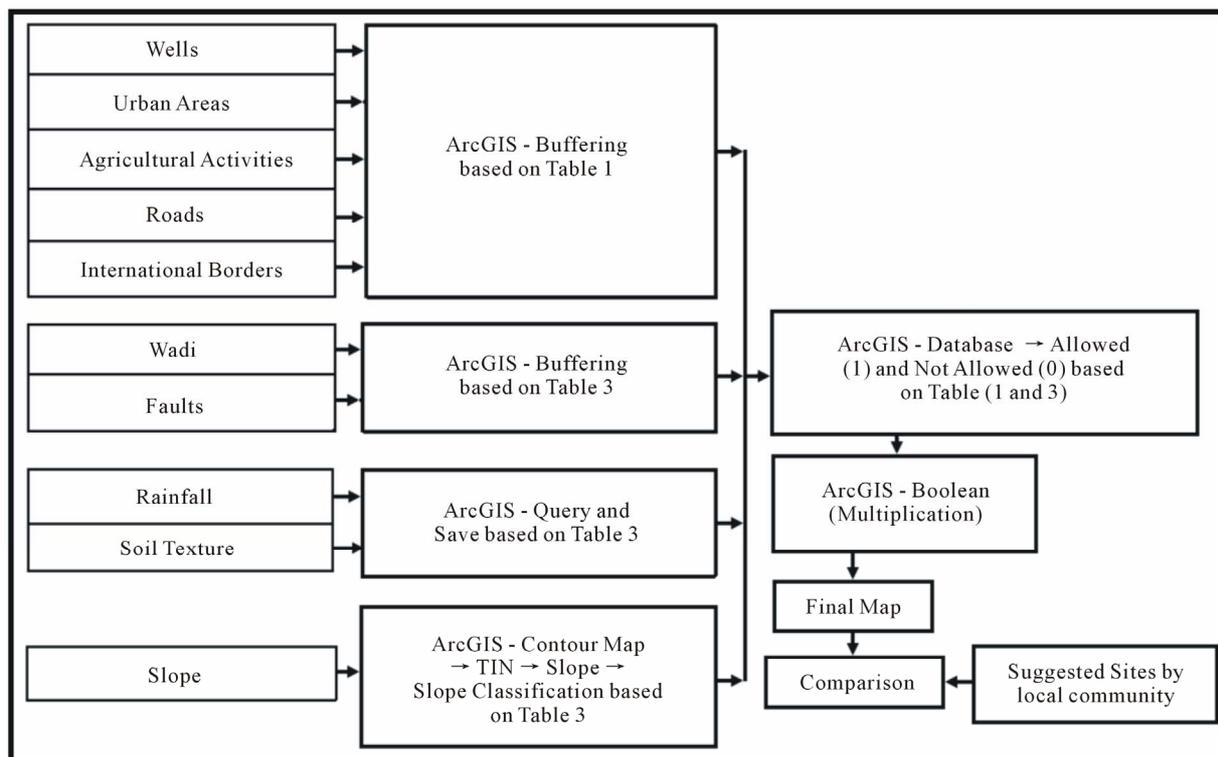


Figure 9. Data analysis methodology.

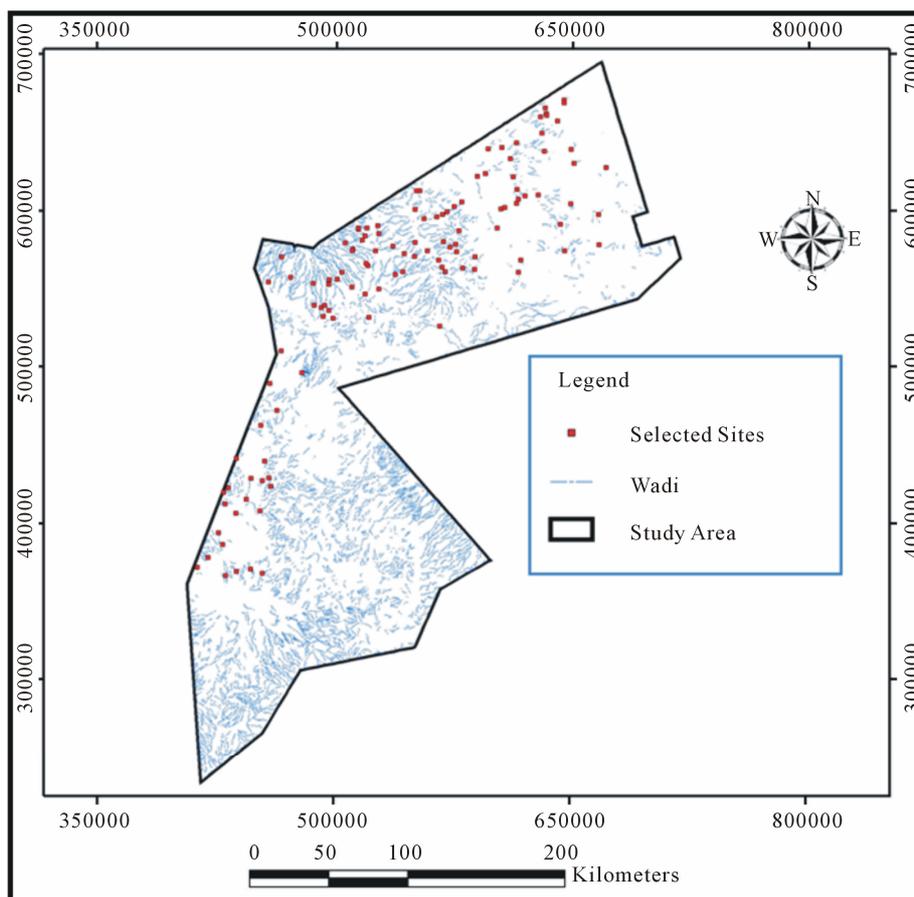


Figure 10. The selected sites using GIS.

Table 1. Suggested constraints by the local communities for selecting an optimum site for water harvesting.

Criteria	Allowed (1)	Not Allowed (0)
Distance to Wells (m)	More than 500	Less than 500
Distance to Urban Area (m)	More than 500	Less than 500
Distance to Agricultural Activities	More than 500	Less than 500
Distance to Roads (m)	Less than 5000	More than 5000
Distance to International Borders (m)	More than 250 (Villages Area)	Less than 250 (Villages Area)
	More than 5000 (Uninhabited Area)	Less than 5000 (Uninhabited Area)

from hydrological point of view) as shown in Figure 11.

4. Conclusions and Recommendations

The integration between the local community knowledge and the Geo-informatics help decision makers in making the right decision. This research demonstrated such integration where 200 stakeholders from within the local communities in the Badia participated in providing the research team with some constrains that from their point of views are vital in choosing the suitable sites for water harvesting in their region. Also, they pointed out to

certain locations within the Badia that could be utilized as a water harvesting sites based on their knowledge of the area as a livestock owners. In conclusion, water harvesting site selection is a lengthy process and needs consultation with the stakeholders, intensive fieldwork and the use of appropriate tools within GIS environment. In this research, 30 sites are found to be the most suitable sites in the Jordanian Badia for water harvesting based on GIS analysis and local communities recommendation. This does not mean that the remaining 88 sites selected by GIS are not suitable for such purpose. The 30 sites

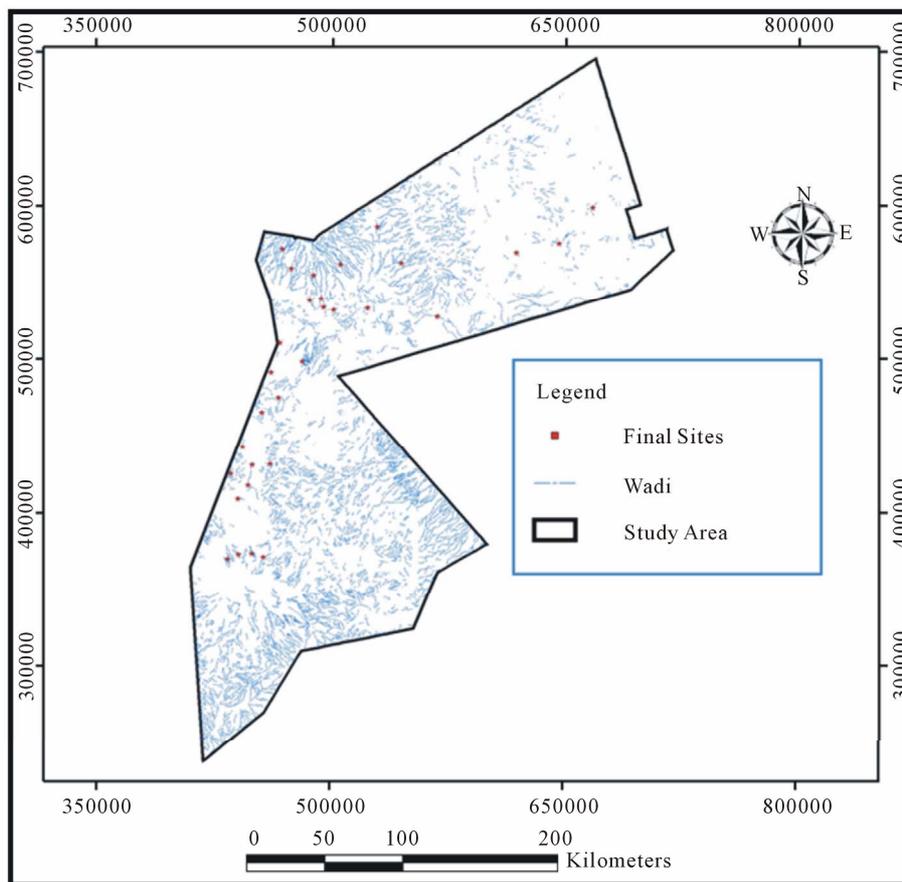


Figure 11. Final sites (GIS in combination with local communities' suggestions).

Table 2. The secondary data sets used in this research and their sources.

Map type	Date	Scale	Source
Town and villages	1995		
Roads	1995		
Borders	1995		
Wadis	1995		RJGC
Wadi spread	1995	1:250,000	
Contours	1995		
Wells	1998		WAJ
Rainfall	2007		[37]
Soil	2003	1:500,000	[37,38]
Faults	1974	1:750,000	[39]

were selected by the 200 stakeholders invited the consultation workshops. Other stakeholders might have extra sites which might be in agreement with the 88 sites.

Based on that, it is recommended that any future work

Table 3. The physical criteria (Modified from [6,15,16,27, 40,41]).

Criteria	1 (Allowed)	0 (Not Allowed)
Rainfall (mm/year)	>50	≤50
Slope (%)	>5	≤5
Distance to Wadi (m)	≤500	>500
Distance to Faults (m)	>1000	≤1000
Soil (Texture)	Silty Loam, Loam and Silty Clay Loam	Sandy Loam

on the use of GIS for siting any project, local communities must have their say in providing the constraints and in suggesting sites. The final say in choosing the appropriate site is the agreement between the outcome of the technology and the people requirements.

It is also, recommended that the selected sites must be investigated thoroughly to test their capability of having water harvesting schemes (dams). Such investigation could include:

- 1) Geophysical investigation,
- 2) Soil analysis,

3) Watershed analysis.

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