GIS AND REMOTE SENSING APPLICATIONS FOR RAINWATER HARVESTING IN THE SYRIAN DESERT (AL-BADIA)

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ABSTRACT

This paper attempts to describe the state of Rainwater Harvesting (RWH) techniques and the contributions of GIS and Remote Sensing (RS) technologies for RWH in The Syrian Desert (AL-Badia). Studies were conducted using physiographic factors of The Syrian Desert (the natural factors, the climatic factors, the pastoral cover, and animal wealth) for the applications of GIS and Remote sensing techniques with the view to establishing it for Rainwater Harvesting activities. Images of the Indian satellite with ground resolution of 5 m^2 were used to identify tents of herds during the grazing seasons. The image processing software ERDAS IMAGINE and GIS software ARC/INFO were used to process the images and to establish a geo-information system comprising digital data sets of satellite imagery, topography, soil, vegetation, hydrology, and meteorology. This information was used to study the watershed network in the Syrian Desert (AL-Badia), and to identify areas generally suitable for water harvesting in order to determine water harvesting techniques for those sites.

Keywords: GIS, Rainwater Harvesting (RWH), Remote Sensing (RS), Syrian Desert (Badia)

INTRODUCTION

Water is a primary necessity, for the people, agricultural production and for the industries. Water is one valuable resource that is required for every day life but is fast depleting; this depletion of natural resources is a result of growing civilization and indiscriminate exploitation by the industries and wastage by the human population. It is therefore important that adequate supplies of water be developed to sustain such life. Modern life as we know also depends on our ability to match the supply and demand of water of appropriate quality to specific communities and users at specific times or rates. Large amounts of time and effort are invested in learning more about the spatial and temporal patterns and characteristics of individual hydrologic processes, so we can anticipate, manage, and modify system behavior to sustain modern lifestyles and prevent shortages (droughts), surpluses (floods), and resource impairment. In the other hand we have witnessed through the last years an enormous interest in application of GIS and remote sensing in hydrology and water resources. Remote sensing and its image processing technology provide access to spatial and temporal information on watershed, regional, continental and global scales. Further, new sensors and imaging technology are increasing the capability of remote sensing to acquire information at a variety of spatial and temporal scales. The scope of hydrological applications has broadened dramatically, although the problems of flood protection and water resources management continue to be of importance and relevance for the security of communities and for human, social and economic development. In this paper, illustration of how we can benefit from remote sensing and GIS technologies in Rainwater Harvesting techniques in the Syrian Desert (AL-Badia) is attempted; this is a combination of true desert and steppe extending over a vast area in addition to the description of the natural factors of AL-Badia and the accompanying Rainwater Harvesting methods within it.

Overview of Rainwater Harvesting:

In many locations, direct rainfall is insufficient for crop growth and increasing the amount of water available through water-harvesting techniques is the most appropriate way to ensure sustainable production and to reverse desertification. Rainwater Harvesting concentrates rainfall by allowing and encouraging it to run off catchment's surfaces in a controlled way and then storing the harvested water for subsequent use. Water may be stored in a number of ways: small dams, cisterns, shallow aquifers, or in the soil profile. It is then made available to a target crop, shrub, tree or domestic purposes. The use of rainwater-collection systems is known to have existed 4,000 years ago, in the semi-arid and arid regions of the Negev desert, in Palestine, which receives less than 15 cm of rainfall a year. Hillsides were cleared to increase runoff, and contour ditches helped collect water for crop irrigation. Rainwater Harvesting (RWH) is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture and other things in arid and semi-arid regions (Boers and Ben-Asher, 1982). More specifically, in crop production, water harvesting is essentially a spatial intervention designed to change the location, where water is applied to augment evapotranspiration that occurs naturally. It is relevant to areas where the rainfall is reasonably distributed in time, but inadequate to balance potential evapotranspiration (ET) of crops. More precisely, Rainwater Harvesting can be defined as the process of concentrating rainfall as runoff from a larger catchment's area to be used in a smaller target area. This process may occur naturally or artificially. Rainwater Harvesting techniques may be grouped into two categories: Techniques that directly supply water to target crops and store water not immediately transpired in the soil profile around the root zone may be considered micro-catchment's techniques because the catchment's area is small and no artificial storage structures are required. The other categories are macro-catchment's techniques that concentrate run-off flows and store them in prepared reservoirs for subsequent application to the target crop. The application of stored water can be considered a form of supplemental irrigation, in the sense that the harvested run-off water is used to supplement the rainfall that directly falls on the target crop. The choice of technique and target crop depends on local circumstances, including topography condition, soil type and depth, rainfall characteristics (amount, distribution and variability), run-off coefficients and available technologies. The knowledge of rainfall characteristics (*intensity and distribution*) for a given area is one of the pre-requisites for designing a water harvesting system. The availability of rainfall data series in space and time and rainfall distribution is important for rainfall-runoff process and also for determination of available soil moisture. The land forms along with slope gradient and relief intensity are other parameters to determine the type of water harvesting. The terrain analysis can be used for determination of the length of slope, a parameter regarded of very high importance for the suitability of an area for macro-catchment's water harvesting. The suitability of a certain area either as catchment or as cropping area in water harvesting depend strongly on its soils characteristics viz. **(1)** surface structure; which influence the rainfall-runoff process, **(2)** the infiltration and percolation rate; which determine water movement into the soil and within the soil matrix, and **(3)** the soil depth and texture; which determines the quantity of water which can be stored in the soil. The hydrological processes relevant to water harvesting practices are those involved in the production, flow and storage of runoff from rainfall within a particular project area. The rain falling on a particular catchment area can be effective (*as direct runoff*) or ineffective (*as evaporation, deep percolation*). The quantity of rainfall which produces runoff is a good indicator of the suitability of the area for water harvesting. Additionally, socio-economic factors and preferences have to be taken into due consideration and before selecting a specific technique, due consideration must be given to the social and cultural aspects prevailing in the area of concern as they are paramount and will affect the success or failure of the technique implemented. The socio-economic conditions of a region being considered for any water harvesting scheme are very important for planning, designing and implementation. The chances for success are much greater if resource users and community groups are involved from early planning stage onwards. The farming systems of the community, the financial capabilities of the average farmer, the cultural behavior together with religious belief of the people, attitude of farmers towards the introduction of new farming methods, the farmers knowledge about irrigated agriculture, land tenure and property rights and the role of women and minorities in the communities are crucial issues. This is particularly important in the arid and semi-arid regions and may help to explain the failure of so many projects that did not take into account the people’s priorities. In addition to the socio-economic considerations, a water harvesting scheme will be sustainable if it also fulfils a number of basic technical criteria, and in general, all Rainwater Harvesting systems have three components: a collection area, a conveyance system, and a storage area.

GENERAL BACKGROUND

Syria is located on the eastern coast to the Mediterranean Sea in the arid and semi-arid zone. Its climate is Mediterranean with continental influence: cool rainy winters and warm dry summers, with relatively short spring and autumn seasons. Large parts of Syria are exposed to high variability in daily temperature. The country is mountainous in the west and south-west, but otherwise largely flat. Syria is considered one of the limited water resources countries in terms of increasing demand to all the needs, The rainfall is different in distribution between the coast and the inside areas and diminishes sharply as one moves eastward to inland. Because of rainfall shortage, agriculture in Syria is dependent on other water resources; most areas are irrigated with groundwater. The water resource in Syria is divided into seven principal water basins having different volume of surface and underground water resources. Water resources in Syria are distributed among the following: al-Jazira basin; Aleppo basin, which consists of Quiq basin and Jabboul basin; the group of the Syrian desert basins which consists of al-Dawe, Palmyra, Khansar, al-Zalf, Wadi Miyah, al-Rasafa, al-Tanf and al-Sabai Byar; Houran basin; Damascus basin, Orentos basin and the coastal basin.

Local rainfall and snowfall constitute the main source of underground water for these basins, except for the Jazirah and the Orentos basins, which are fed by external sources. The rainfall water is considered as the only water resource for feeding the underground sources. Water is a scarce resource in Syria as it is throughout the Middle East, but Syria is more fortunate than many other countries. Sufficient rainfall supports cultivation in an arc from the southwest, near the border with Palestine and Lebanon, extending northward to the Turkish border and eastward along the border to Iraq. The country is divided into five distinct agro-climatic zones based on the level of annual precipitation received. These are:

Zone I: covering some 2.7 million hectares. Average annual rainfall is normally more than 350 mm, within a range of 300 to 600 mm.

Zone II: with a total area of around 2.5 million hectares and annual rainfall 250-350 mm.

Zone III: with a total area 1.3 million hectares and average annual rainfall of 250 mm.

Zone IV: This is agriculturally marginal with a total area of around 1.8 million hectares and annual rainfall of 200-250 mm.

Zone V: **(AL-Badia)** which is the study area with a total area of 8.3 million hectares with an average of less than 150 mm of rainfall annually.

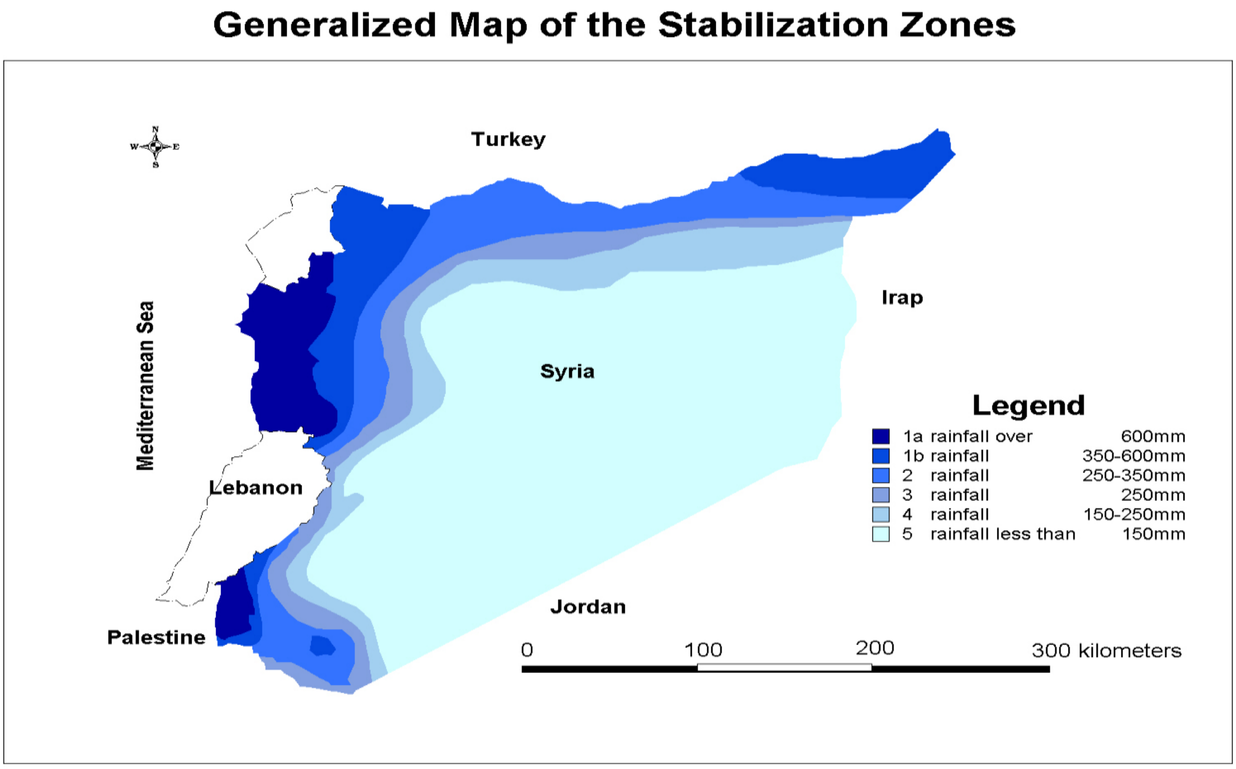

Fig. 1: Syria's Map of Stabilization Zones

Characteristics of the Syrian Desert (AL-Badia):

The Syrian Desert (AL-Badia) or steppe is largely barren, except for irrigated areas near the Euphrates River and its tributaries. To the south, the desert occupies an ancient volcanic area. Volcanic rock has been cleared from the land so that it can be used for agriculture. The Syrian Desert (AL-Badia) is a combination of true desert and steppe extending over a vast area, which takes parts of modern Syria and also of Jordan and Iraq and represents about 55% from the country square and the minimized annual rainfall rate of about /100/ mm. This area characterized flat area included some mountain series, clayey sandy firm atoms soil, little rains, and hard wind in the summer, high rate vaporization. The relative humidity changes according to the temperature. Syrian Desert (Badia) is considered as a suitable environment for meadows growth and is the main source for feeding animal , specially the sheep which is counted 16 million heads sheep, a lot of demographic gatherings exist within it, their number estimates 1.5 million person (called Nomadic or Bedouins). The plant cover is threatened by the very heavy grazing of nomadic pastoralists' livestock (sheep, goats and camels), which can penetrate even the remotest areas now due to the construction of wells and of roads which allow the transportation of water in tankers. And for the insufficiency in rains in this area, the government established many vital project foundations to develop botanical cover in the area as well as through Rainwater Harvesting projects, for drinking aims, livestock, and irrigation in some areas.

METHODOLOGY

Remote sensing and GIS techniques have significantly contributed to the activities of rainwater harvesting. Images of the Indian satellite with ground resolution of 5 m^2 were used to identify tents of herds during the grazing seasons. Socio-economic surveys in the area indicate the average number of animals at each herd; this is also estimated by daily grazing distance. This information was used to evaluate the grazing pressure in one hand and to determine proper water harvesting sites in other hand. In addition to that, T. M. images and topographic maps were used to study the watershed network in the monitoring area .The approximate amount of rainwater to be collected in the major valleys and their branches were calculated. As a result a map showing demographic gatherings distribution, grazing pressure, watershed network, contour lines and roads were produced. This map was used as a guide for the field technical team to locate sites for rainwater harvesting. The image processing software ERDAS IMAGINE and GIS software ARC/INFO were used to process the images and to establish a geo-information system comprising digital data sets of satellite imagery, topography, soil, vegetation; hydrology and meteorology. This information was used to study the watershed network in the Syrian Desert (AL-Badia), and to identify areas generally suitable for water harvesting and to determine water harvesting techniques for those sites.

Rainwater Harvesting Techniques followed in Syrian Desert (AL-Badia):

Since water resources assessment is a pre-requisite for the sustainable development and management of water resources, and as a result of the previous methodology and sequels to part of a wider regional weather phenomenon which has affected a number of countries in the Middle East, the worst drought in four decades has seriously affected crop and livestock production in Syria. This, in turn, has had serious repercussions on the food security of a large segment of the population as incomes have fallen sharply. Although the Government has made extensive efforts to reduce the effects of the drought, especially on herders which is in AL-Badia by providing extra resources, feed rations, water and veterinary supplies, the scale and severity of the problem is such that these measures have not been sufficient. Availability of water for human and animal uses in AL-Badia areas during grazing seasons is a decisive factor (Bakir, Mohammad. 1998). Rainwater harvesting has significant importance in AL-Badia due to the following reasons:

- Natural surface water resources (e.g. the Euphrates River) occur at a great distance from the largest grazing the area.
- Only a very limited number of water wells exist in the area.
- The geological nature of the mountain with frequent gypsum and loose sand strata has encumbered efforts to dig new wells.
- Water carrying strata are several hundreds of meters deep.
- Absence of good roads represents another problem for vehicles transporting water from other areas.

Rainwater harvesting activities were mainly executed during the period (1990 -2001). They include:

Consulting herds and using the maps possible sites for earth dams were identified. Final decision concerning these sites was taken after a field examination of natural conditions including soil and geology of each site. As a result, 37 small earth dams with storing capacity of about 50 millions m^3 were built; some have small net irrigation, like AL-Qaryateen Dam, and Wade AL-Abeead Dam.

Preparation of water reservoirs with various capacities for water storage was done for various purposes. For instance, preparation of 150 small water reservoirs for daily family use. Pits with dimensions of (3 × 4 × 10) m were prepared following personal request of the herds.

- Preparation of 50 large water reservoir with storage capacity of 30.000-100.000 m^3 to be used by heads for animal watering, such as AL-Wazeeaia, AL-Sheheema, AL-Nazzera, and AL-Zarqa in separate places in AL-Badia.
- Preparation 7 spread water dikes in the flat wide valleys, Fig. 2, such as AL-Zaqareed in Homs, AL-Khoor and Kabaajeb on Der alzoor.

Fig 2 Spread Dike in Syrian Desert

- Digging of wells in separate places for drinking and irrigation such as L9 well in Palmyra, which irrigates about 200 hectares of Olive and Palm trees in Palmyra Oasis.
- Preparation of many Terraces in different places, and planted with suitable plants. Terraces can be defined as mechanical structures comprising a channel and a bank made of earth or stone. They are systematically constructed perpendicular to the

slope. Thus terraces intercept runoff, and encourage it to infiltrate, evaporate or be diverted towards a predetermined and protected safe outlet at a controlled velocity to avoid channel erosion.

- Principal objectives of terraces:
  - To reduce the velocity of runoff.
  - To reduce the volume of runoff.
  - To reduce the losses of soil, seed and fertilizer;
  - To increase soil moisture content through improved infiltration;
  - To reduce peak discharge rates of rivers;
  - To smooth the topography and improve the conditions for mechanization

Preparation of Contour farming along the lines of equal contour is one of the most simple and efficient practices for the control of erosion, Fig. 3. It consists of planting the crops according to the curved lines which follow the land surface at equal heights above sea level, or in other words, perpendicularly to the lines of steepest slope gradient. Contour farming is only recommended as an isolated erosion control measure for limited areas where the slope is less than three percent and the slope length is not long. And thus many places followed this system in different areas along AL-Badia.

Fig 3. Contour farming in AL-Badia

All these constructions were prepared to provide free water sources for herds during the grazing season, and to provide water for drinking and irrigation in some places in AL-Badia. Both direct seeding and rainwater harvesting techniques will be practiced during the coming years .There are close cooperation with local population. Extensive training on participatory approaches has been carried out for the local extension staff in order to coordinate field activities with local population.

CONCLUSIONS AND RECOMMENDATIONS

Remote sensing and Geographic Information Systems can help in the determination of areas suitable for water harvesting (Prinz et al. 1998).At the same time, on a much broader geographic scale, remote sensing and GIS technologies are being applied to assess and select suitable areas for large-scale water harvesting applications within AL-Badia. Digitized sets of satellite images, topographic information, soil types, vegetation, hydrology, and meteorology are combined with specific water harvesting techniques to provide an expert system for decision making for large-scale development investments. In the dry areas, where water scarcity is increasing, generally water, not land, is the most limiting resource. In arid and semi-arid regions, where precipitation is low or infrequent during the dry season, it is necessary to store the maximum amount of rainwater during the wet season for use at a later time, especially for agricultural and domestic water supply. Rainwater harvesting should suit its purpose, be accepted by local population, and be sustainable in local environment. In dry areas (and without storage facilities), field crops with deep rooting and drought resistant trees constitute the most promising application (Boers 1982).The decision making process concerning the best method applicable in particular environmental and geo-physical conditions depends on kind of crop to be grown and prevalent socio-economic and cultural factors. One of the crucial social aspects for the success is the involvement/ participation of the stakeholders or beneficiaries. All stakeholders have to get involved in planning, designing and implementation of water harvesting structure. Rainwater harvesting is based on the utilization of runoff and requires a runoff producing area and a runoff receiving area, and because of the intermittent nature of runoff events, storage is an integral part of the water harvesting system. Water harvesting initiatives and interventions need projects aimed at improving existing individual farmer's practices of water harvesting in Syrian Desert and before selecting a specific technique, due consideration must be given to the social and cultural aspects prevailing in the area of concern as they are paramount and will affect the success or failure of the technique implemented. This is particularly important in the arid and semi-arid regions.

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