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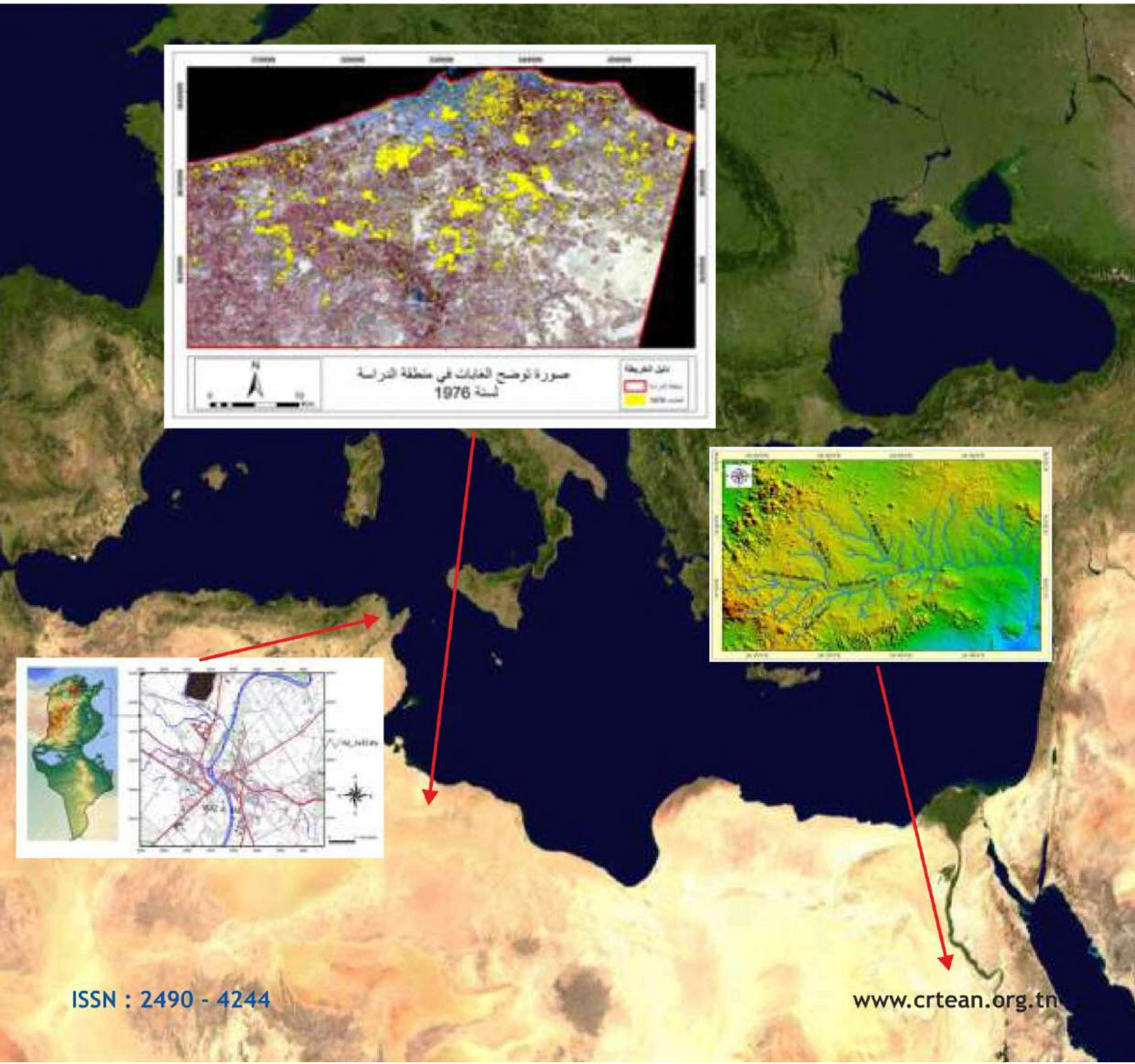

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JOURNAL OF SCIENCE SPACE TECHNOLOGIES

Journal of Science and Space Technologies (JSAST)

The Science and Space Technologies Journal is a peer-reviewed journal publishing basic and applied research articles in the fields of space sciences and technologies. Accepted types of contributions include: original basic and applied research papers, review articles, books and theses reviews and technical notes.

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11. Acknowledgements: if any, this section should be located before references; expressing gratitude to institutions, laboratories and people who supported specially all or part of the research.
12. References: References should be cited chronologically in the text by author (s) and date, e.g. (Ali and Hadi, (2000); Mustafa *et al*., (2005) and Gad (2010), and are not numbered. The total number of references mentioned should not exceed 20 references, at least halve of them should not be more than 10 years date.

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EDITORIAL

The third issue of the Journal of Space Science and Technology comes in the framework of unifying the objectives and efforts of basic, applied and technological scientific research of both the Regional Center for Remote Sensing of North Africa States and the Union of Arab Scientific Research Councils, with focus on accuracy and inclusiveness. This issue deals with a number of topics of interest to researchers concerningspace science, its applications and related systems.It targets research and academic institutions, and competent technical structures in the Arab world. This issue meets their demands, tries to raise the challenges of the future and to participate in the establishment of comprehensive economic and social development on the basis of modern knowledge, high performance and competitiveness.

We hope that this humble work, prepared by the editorial staff and evaluated by the Board of Directors,would contribute to the progress of scientific research of our member states. We aim to create a solid research structureestablished according to scientific methodology in order to facilitate the access to andthe acquisition of information for researchers. This issue is edited in three languages: Arabic, English and French.

We hope that with the guidance of Allah the Almighty, we would be able to acknowledge our ignorance, to be ready and willing to learn and that we would be able to make great achievement.

Dr. ElHadi GASHUT
DG. CRTEAN
Editor Chief of the JSST

Assessment of Aru dam as Water Harvesting Project in the Upper Sub-Catchment of Wadi El Ku in North Darfur State

By Dr. A. M. Siyam[1] and E. A. Adam[2]

ABSTRACT:

North Darfur State suffers from acute shortage of water during most time of the year. This led to food shortages and in many occasions tribal conflicts that threaten the sustainable development of the region. On the other hand a sizable portion of the State is endowed with ephemeral Wadis that carry large quantities of water during rainy season. Proper water harvesting systems are seen as the only solution for sustainable development of the region. In this regard Wadi El Ku system, which runs from north to south through the State, is the largest Wadi both in terms of catchment area and annual yield. Though there are many water harvesting structures and projects in the middle and lower sub-reaches of the Wadi El Ku the upper sub-reach lacks development. This paper studied the feasibility of one of the proposed dams, namely Aru dam on Wadi Baralk-Allah which is a tributary of Wadi Kutum, as a water harvesting project based on the interest and actual need of the local community. The characteristic of the proposed dam and its reservoir have been made possible with the help of two GIS software. Ground-truthing was performed via a site visit and measurements of wadi x-section, longitudinal slope and dam length. Hydrological techniques were employed to quantify the annual yield and maximum probable discharge. The water demand side has been quantified taking into account water requirements for community, livestock, and agriculture. On such bases the dam height was determined and designed. Analysis for the dam cost against the expected generated benefits proved that the proposed water harvesting project is feasible. The paper recommends implementation of the project with community participation. The process could be equally repeated for other proposed dam sites identified in this study, taking into account the sustainable development of the whole Wadi El Ku basin in an integrated approach.

Key words: Small dams, water harvesting, Wadi El Ku, Wadi Kutum, Wadi Barak-Allah, Aru Dam

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INTRODUCTION:

Darfur region is endowed with many natural resources of which water resource is the most important. Water is available in the form of seasonal rainfall which falls within three months July, August, and September. Groundwater from deep boreholes or shallow beds of the manyephemeralwadis, represent the main source in the dry period. The scarcity of water in Darfur region increases from South to North in parallel with the climatic zones.

Along wadis competition on the scarce resource during summer time led to many conflictsbetween nomads and the stabilized people. During drought yearscondition of human, livestock and crop production are seriously affected to the extent of wide spread of famine as inevitable phenomena. Even during normal years people spend most of their time fetching water and watering their livestock (Photo 1).On the other hand sometimes devastating flood occurs in Wadis andcreates great damages in properties as well as fatal losses in live.

To mitigate water shortage and drought in general local people have practiced various forms of water harvesting methods. These techniques range from traditional to most sophisticated ones. Based on their complexitythey can be arranged in the following order: -1) Shallow hand-dug wells in wadi beds which is also known locally as Tamed or Mashish; 2) Terraces: small hand-made dykes created along the contour lines for runoff collection. It is an indigenous water harvesting technique used for production of some crops, like water melon, okra, wild Tobacco and vegetable crops; 3) Rahad: small water pond built across small water courses or localized depressions near villages and used for livestock watering as well as for domestic purposes; 4) Hand Pumps; 5) Haffir:Shallow water pond dug in the ground to store water runoff during rainy seasons.Haffir typically range in size from 500 to 10,000 m^3 and provide water for both livestock and domestic purposes. Previously, haffirs were dug by hand but recently heavy machineries were introduced for creation of large haffirs; 6) Small dams.

Currently there is a growing attention to the issue of equitable and sustainable water resources development. In this respect Northern Darfur State rely very much on water resources of wadi El Ku to end suffering of communities live in towns, including its capital El Fashir, and villages across the watershed of the wadi and benefiting beyond. So far a number of water harvesting projects and/or structures have been implemented. These include: Golo reservoir, Malleit Dam, Haloof dam, Door dam, Khirban dam, Abujidad Dam, Damra dam, Gadid reservoir and many others. Most of these structures are in the middle or lower sub-reaches of wadi El Ku except Damra dam which is located in the upper sub-reach.

The upper sub-reach of wadi El Ku system, in which the site of this study resides, has many favorable conditions for water harvesting projects. The sub-reach is characterized with relatively high annual rainfall, suitable dam sites (narrow gorges), and availability of good materials for constructing rock fill dams.

The general objective of this study is to assess the feasibility of the proposed dam as a water harvest project. The specific objectives are; 1) to determine the characteristics of the proposed dam, select size based on actual water demand and carry out preliminary design; 2) to study the economics of the project based on shared water uses by different sectors i.e. domestic water supply and irrigation.

2. Study Areaand Potential Water Harvesting Projects.

The study area is located in the upper sub-catchment of Wadi Elku system which from hydrological and topographical point of view can be divided into three interrelated/interlinked sub-catchments (Fig.1). Wadi Elku catchment covers a total area of 28,000 km2 extending from eastern Jebel Marra–Kutum high lands (North Darfur) to Mahageria in East Darfur State. It is bounded from the western and eastern parts by sandy soils underlain by shallow impervious rocks (Abel Salam et al 2016).

Wadi Kutum represents the upper sub- catchment and extends from the eastern Jebel Marra –Kutum high lands (upstream) covering an area of about 11500 km2. Here the area is drained by a number of short and high–gradient channels (Fig 2). The area is of a relatively high rainfall amounting about 350 mm/year. The steep gradient and the impervious nature of the terrain facilitate fast run off induced by the earlier rains (June/July) in the area.

The name of the Wadi has been stemmed from Kutum City which lies in the North West direction about 120 km from El-Fasher city, the capital of Northern Darfur State. This Wadi is one of the longest Wadis in Northern Darfur State. It runs passing through many villages and towns, such as, Naro village, Fata Bornoe,Kutum town, Goba and Umm Sayyala after which the Wadi turns to southeast direction passing through Abusakin village, Kafod,Um Eshera and Cimayat east. Wadi Kutum has many tributaries of local names such as Wadi Barakallah, Wadi Amu, Wadi Manu, Wadi Birka, Wadi Bowa and Wadi Fulu.Wadi Kutum and its tributaries arefamous of cash crops production on their limited alluvial lands.

There are many dam sites which are thought of as potential water harvesting projects. The following are four proposed dams with locations as shown in Fig (2) besides the existing Damra dam across Wadi Fulu.

1-Kassab dam across Wadi Bowa; 2- Sunger dam acrossWadi Kutum;
3-Aru dam across Wadi Barakullah; 4-Salo Karral dam across Wadi Amu

The topography of the study area is obtained from Shuttle Radar Topography mission (STRM) of USA at 3 arc seconds, 90 m resolution. Fig (2) shows the 90 m resolution DEM of the study area and the drainage pattern together with the potential dam sites after being processed with the Global Mapper Software.

The proposed Aru dam is located across Wadi Barakallahwhich is a tributary of Wadi Kutum. The total catchment area upstream the dam site is 343 km^2. Most people in the study area generate their income from the small scale irrigated farms as well as livestock breeding. The estimated population of the study is forecasted to be 27000 persons within the coming 10 years. The cultivable land is within 700 Feddans.

3. Methodology.

To accomplish this study many activities were performed. These include data acquisition; site visits and survey works; and extensive desk works. In the following brief description of each activity is illustrated.

Digital elevation Model with 90 m resolution is obtained from the Shuttle Radar Topography mission (STRM) of USA. Historical maximum annual rainfall data for the period1931 to 1983 is obtained fromFederalMeteorological Authority and another set of temperatures and total annual rainfall data for the period 1990 to 2010 were obtained from Elfashir Meteorological station. Local data on population, livestock, crop types, potential irrigation area and its extension downstream of the proposed dam site are obtained from Kutum Agricultural Society.

Ground-truthing was performed to confirm the remotely sensed data. A site visit to the dam site was carried out in March 2014 in addition to one day survey work. The work includes: visual inspection of the natural rock material; measuring three x-sections and the longitudinal slope of Wadi Barak-Allah;and measuring width of the proposed Aru dam.

Theextensive desk works involve:a) determination of the dam-reservoir capacity-area elevation curves;b) calculation of annual yield and maximum probable discharge of the catchment at Aru dam site; c) calculation of water demand which comprise water requirements for human, livestock and irrigation; d) selecting the suitable size of the dam-reservoir, perform preliminary design for the dam and its appurtenant structures; e) performing financial analysis to determine the feasibility of the proposed water harvesting project.

4. Sizing and Designing of Aru Dam:

Sizing and/or designing of a water structure such as a dam is a complex process that involves participation of a multi-disciplinary team of experts. Also it requires historical data to set out reliable hydrological, hydraulic and structural design parameters. On the other hand community participation and acceptance of such massive and negative impact-induced structures is vital for their sustainability and feasibility.This study is carried out with sole purpose of assessing the initial feasibility of the project though the data available is limited. The study is also driven by the community need and willingness to participate in the construction of the project. Nevertheless the study shows that with the help of remote sensing data much can be done to accomplish water resources studies that help decision makers to take actions towards realization of water harvesting projects.

4.1 Aru dam-reservoir characteristics:

The obtained DEM for Aru dam site is processed with GIS software and the derived contour map is as shown in Fig (3). The contours are bounded between a minimum elevation of 1178 m a.m.s.l. and 1200 m a.m.s.l. The same software was used to calculate the area at different elevation. Then a spread sheet in Excel program was used to determine the storage capacity at different contour levels. The area-capacity curves of the anticipated reservoir are as depicted in Fig (4)

4.2 Sizing of Aru Dam

Dam- reservoir sizing involves comparison and balancing between water demand, losses, and sedimentation on one hand and the reliable catchment yield on the other.

4.2.1 Water Demand

The water demand at the project site comprise water demand for domestic consumption, animal watering and irrigation during the dry season which is taken as 9 months from October to June. As the study area is considered as a rural area only 50 liters/capita/day is assumed for estimating the domestic water consumption. The estimated population of 27000 persons are distributed in 50 villages along the Wadi in arrange of 10 km downstream the proposed site. For livestock table (1) gives the types, waterconsumptionrates and total water demand.As pointed out earlier the total available agricultural area is estimated in order of 700 Feddans (Yasir 2014). The commonly cultivated crops are Fruits, Vegetables, Onion and Potatoes. The respective area distribution is 140, 175, 280 and 105 Feddans. Rigorous water demand calculations for the agricultural were performed using the respective areas and crop coefficients. The relevant meteorological data pertaining to Kutum town were used.Three well known methods were chosen for estimating the reference evapotranspiration (ET_o). These are: Blaney-Criddle approach,hargreaves-Samani modeland FAO-Penmann-Monteith method. The last method gave the highest evapotranspiration values and was selected as it is the standard method adopted by FAO. Table (2) gives the summary of total water demand for domestic consumption, animal watering and irrigation. The combined demand amounts to 3.2 Mm^3/season.

4.2.2 Catchment yield

The catchment yield at the dam site is estimatedusing the following equation:

$$Y=CRA$$

WhereYis the total annual water yield of the catchment area, C is a runoff coefficient, R is the average annual rainfall (mm), and A is the area of catchment.

The average annual rainfall for Kutum town is considered representative for the project area. The average for 20 years is found to be 236 mm. Due to its rocky nature, poor vegetation and steep slope(> 4%) of the catchment area the runoff coefficient C is taken as 10% (Satya 2002). Hence the estimated annual yield of the catchment is in order of 8 Mm^3.

4.2.3Estimation of losses

To determine the total water storage needed or reservoir capacity, there are natural losses that need to be taken into consideration.As a rule of thumb about 50% of the water in a reservoir is lost each year to evaporation.

According to the general potential evaporation map of Sudan 2m meters depth of water per year can be lost from an open reservoir in the project area.Thus for a good estimate of this loss the surface area of water must be known. As the reservoir is usually operated and the level varies, estimate of losses at different levels ranging from 1184 m above mean sea level (AMSL) to 1192 m AMSL were calculated and the average considered for the dry period. This is estimated in order of 0.9 Mm^3/season.

Seepage loss is also difficult to estimate because dam reservoirs are built on various soil types which result in varying degrees of seepage. Nevertheless, another common rule of thumb states that seepage may account for about half that of evaporation or 25% of the water in a reservoir.1.10 Mm^3 of water is considered as a good estimate for seepage loss. From another perspective and with due consideration to the dam safety,most of the seepage will contribute to downstream subsurface flow which will induce positive effect on hand-dug wells in Wadi bed to a considerable reach.

4.2.2 Dam layout and reservoir capacity

Because of the availability of a good rock material a rock fill dam type has been selected. The dam is confined between two hills with a length of 47 m at natural ground level at elevation of 1184m AMSL and 177 m at elevation of 1192 m AMSL. This gives an average capacity of (6.4Mm^3). The computed combined seasonal water demand and the expected loss is in order of 5.2 Mm^3. A larger reservoir capacity is considered to account for the inevitable process of sedimentation.A free board of 3 m above the crest level of un-gated spillway is considered. The side slopes are selected as (1V:1H) for upstream face and (1V:2H) for downstream face.

4.3 Design of Aru Dam

4.3.1Stability Analysis:

Detailed stability analysis was carried to determine factors of safety against sliding, overturning and floatation for the above dam layout. Factor of safety against sliding is found to be 3.1 where the recommended value is not less than 1.5. The factor of safety against overturning is found to be 1.75 where the recommended value is not less than 1.5 and the factor of safety against floatation is found to be 2.10 where the recommended value is not less than 2.0. Further other checks are required before implementation. Such checks are stability analysis where the dam at maximum flood level and the downstream water level is controlling. Another situation is the case when the foundation is taken as an integral part of the dam body and hence the upstream dam face can be changed accordingly.

4.3.2 Design of Spillway:

Because of the many cases of small dam failure in Sudan due to poor design of spillways, special consideration is given here to this dam component in this study. Hence the maximum probable discharge is first estimated using two methods. These are by field measurement as well as using the rational method. The field measurement gave an estimate of 313m^3/s for the maximum discharge at dam site. For the rational method the maximum daily rainfall in Kutum from year 1931 to 1983 were obtained and used. The maximum probable discharge at the dam site is calculated to be366m^3/s. The latter is adopted for the design of spillway and energy dissipation structure. Fig (6) shows the general layout of the dam and the spillway.

5. Feasibility Analysis of Aru Dam:

To assess the financial feasibility of Aru dam the cost/benefit analysis of the project must be carried out. The total construction cost of the dam is estimated December 2015 to be in order of 20 Million SDG. The revenues are expected to be generated from all sectors that will be benefited from the dam, namely domestic use, livestock watering and agriculture. The water rate at normal conditions is in order of 4 SDG/m^3 and goes to 10 SDG/m^3 at stress conditions. Tentative water rates of 2, 4 and 1 SDG/m^3 are considered justified for the three sectors respectively. However, 25% of the calculated demand is considered as a loss. Hence the expected benefit per season is found to be in order of 3.8 Million SDG.

To calculate the time when the project pays back its cost, a discount rate of 12% is used to calculate the present value of the expected future revenues. Though the rates were assumed to be fixed a period of Nine years will beenough for project to pay back its cost.The positive impact on the social aspect of the project is not considered. Thus the socioeconomic feasibility of the project is far evident than the financial feasibility in such water resources project that is vital for sustainable development of rural ommunities

6. Conclusions and Recommendations:

6.1Conclusions

1. Remote sensing data and GIS software are vital tools at all stages of managing water resources projects, namely during planning, implementing, operating and monitoring. This study proves such usefulness by obtaining the main characteristics of the proposed dam and reservoir.

2. There are many potential dam sites in upper sub-catchment of Wadi El Ku that were identified in this study. Similar procedures can be adopted in assessing their feasibility with due consideration to downstream current and projected uses. An integrated approach for sustainable development of the water resources of the whole Wadi El Ku basin is of a paramount importance to the region.

3. The design capacity of the proposed dam is in order of 5.2 Million m^3 whereas the catchment yield is in order of 8 Million m^3.The proposed Aru dam does not affect the downstream uses beside there are many other tributaries to Wadi Kutum which are not currently utilized and not considered in this study.

4. Taking into consideration the actual water demand for the livelihood of the local community in the project area, the construction of the proposed Aru dam was found to be financially feasible apart from the far reaching positive socioeconomic impacts.

5. Willingness of the local community to participate in construction of the dam by availing the rock material will contribute positively to the feasibility as well as to the sustainability of the project.

6. The dam site is located in a favorable geological and topographical condition. It has only a length of 47 m at the ground level and 177 m at the top.According to technical guidelines adopted

by many countries for small dams the location is classified as very good as it has an extremely very low ratio of dam top length to reservoir capacity (Akode and Abo Shimaila (2003)).The selected dam has an optimum height of 12 m with 9 m depth of water a free board of 3m. The chosen width of the spillway is 60m and the maximum height of water above spillway level is calculated tobe 1.97m.Further Technical studies are required to be carried out before selecting the most economical dam for the proposed site if a decision of implementation is taken by the responsible authorities.

6.2 Recommendations

1. Water resources development in Darfur states need to receive greater attention from the State authorities. The water harvesting project must be selected in accordance with the actual water demand and use and in comparison with the catchment yield. Construction of small dam in Wadi Kutum sub-catchment is a feasible water harvesting project. However, an option of construction of subsurface dams needs to be considered in future studies.

2. Rain gauges and Wadi discharge measurements are very important for designing sustainable water harvesting projects. It is recommended that a number of rain gauges and discharge measurement stations be installed in Wadi El Ku catchment.

3. As the local communities are eager to solve the problem of water shortages and suitable construction material is available in the vicinity of the dam a participatory approach can be applied. An example of supply of rock material for dam construction by local people to reduce the construction has been tried in the past.

4. Wadi Kutum is a sub-catchment of Wadi El Ku and located in the upper sub-catchment. For sustainable development of water resources an overall planning of the Wadi basin must be considered taking the most promising sites for water harvesting projects and the need of the communities in upper, middle and the lower sub-reaches of the basin.

5. Further Technical studies are required to be carried out before selecting the most economical dam for the proposed site if a decision of implementation is taken by the responsible authorities.

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Photo (1): Fetching water from shallow wells in Wadi's bed using buckets (Dalue).

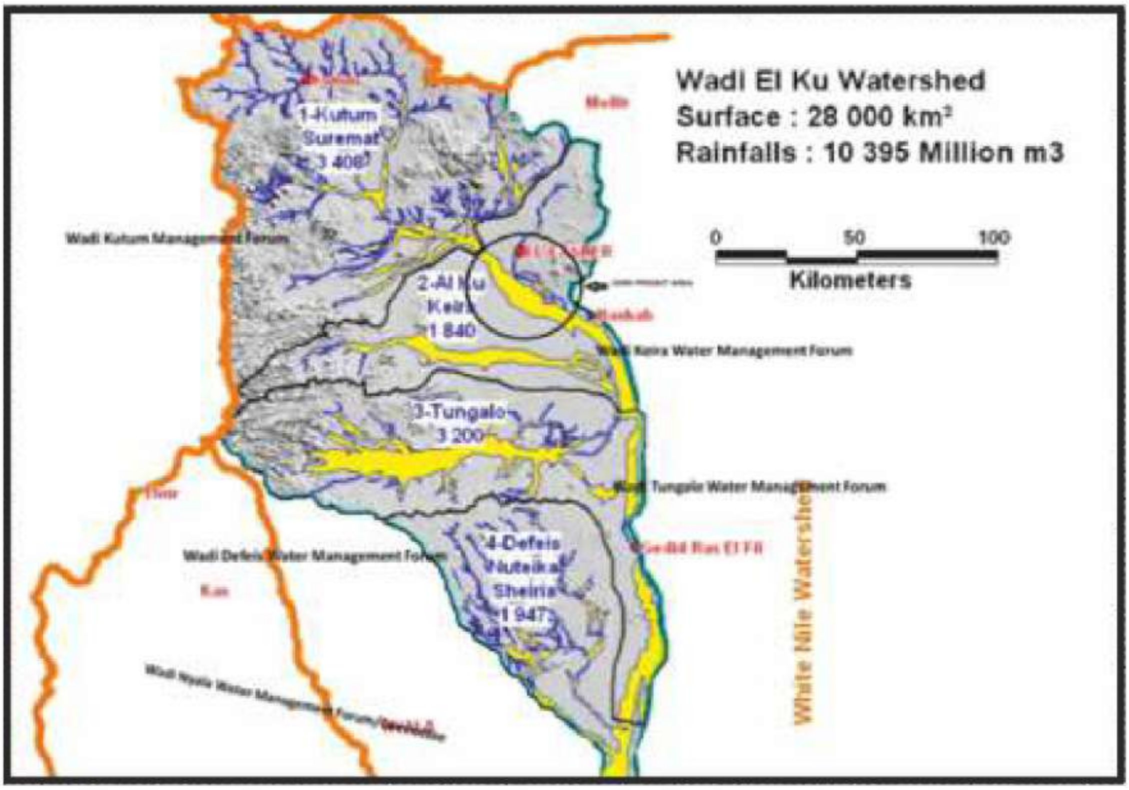
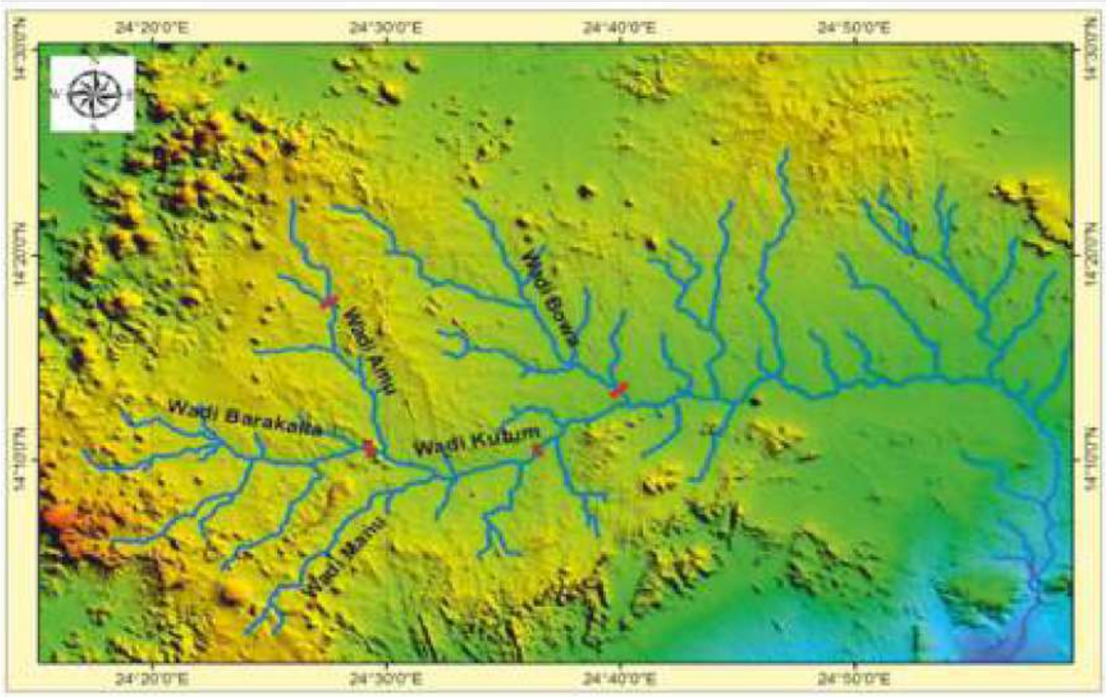


Fig (1): Location map of Wadi El Ku showing the three main sub-catchments



1=Aru proposed dam, 2=Salo-Karral Proposed dam, 3= Damra existing dam, 4=Kassab proposed dam, 5=Sunger proposed dam

Fig (2): DEM for Upper Sub-catchment of Wadi El Kuand the Potential Dam Sites

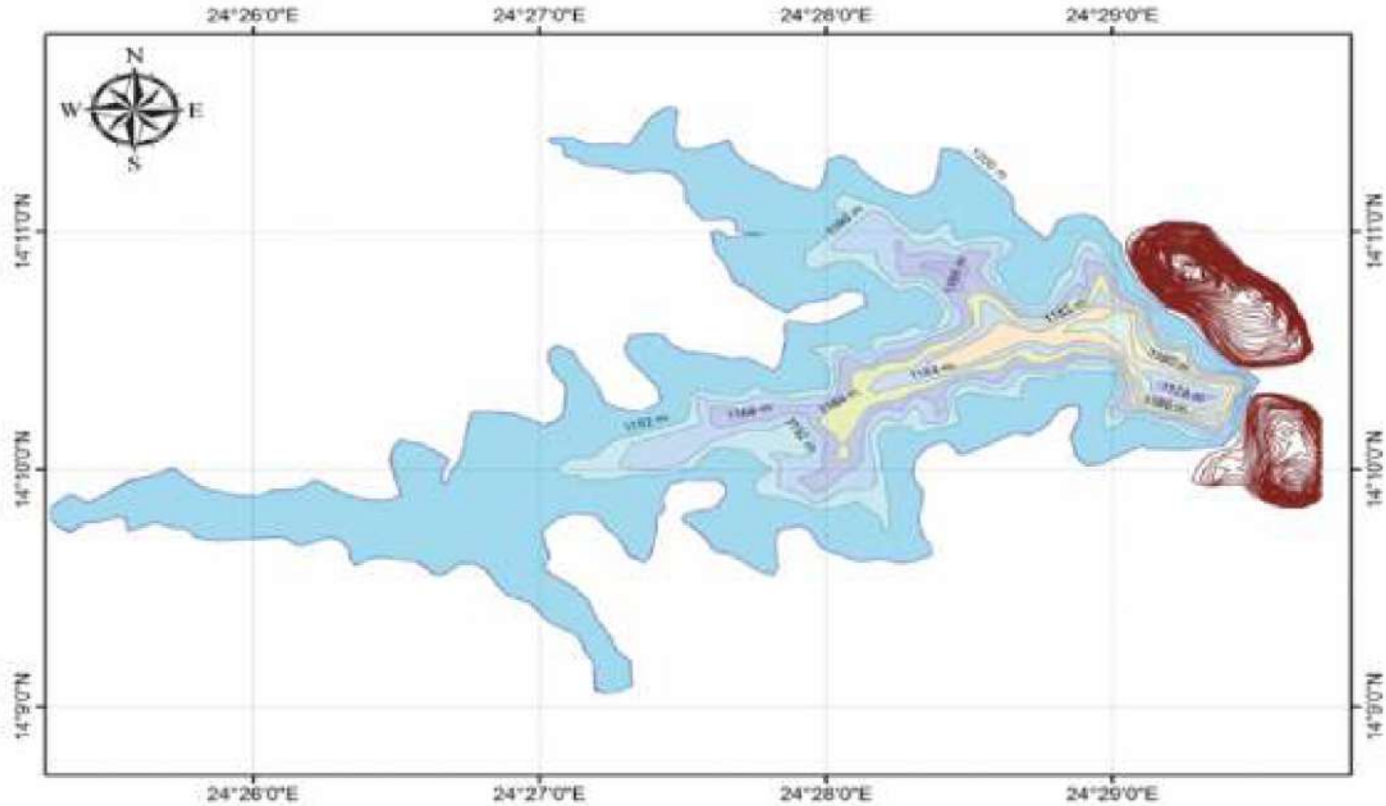


Fig. (3): The derived contour map for the proposed Aru reservoir.

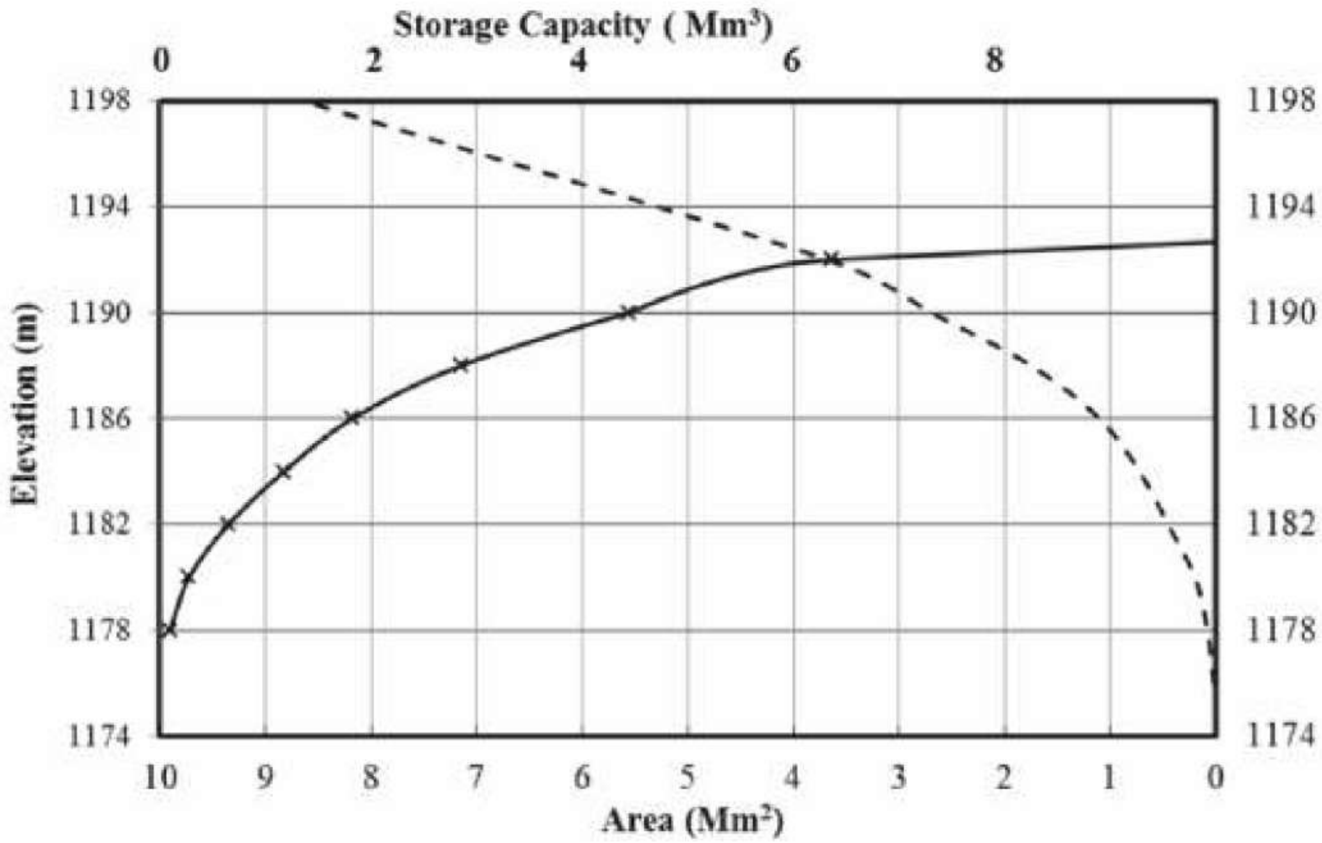


Fig (4): Proposed Aru Dam Area-Capacity curves

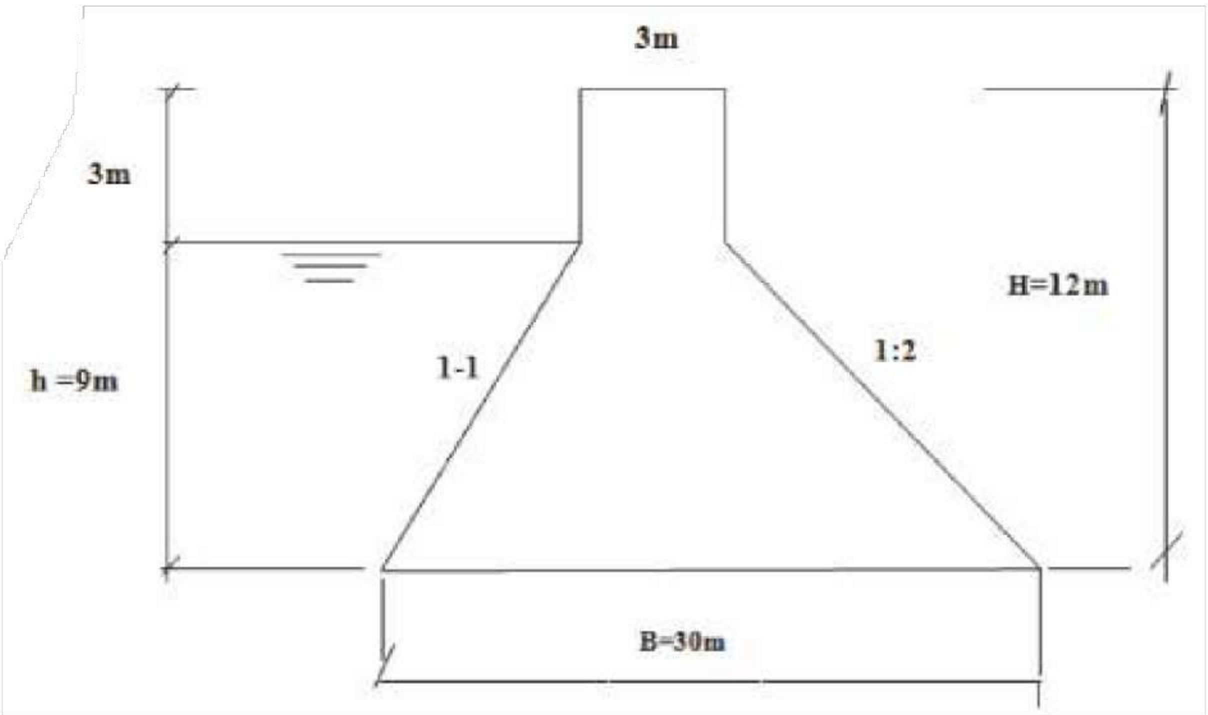


Fig (5): Cross section of the proposed dam.

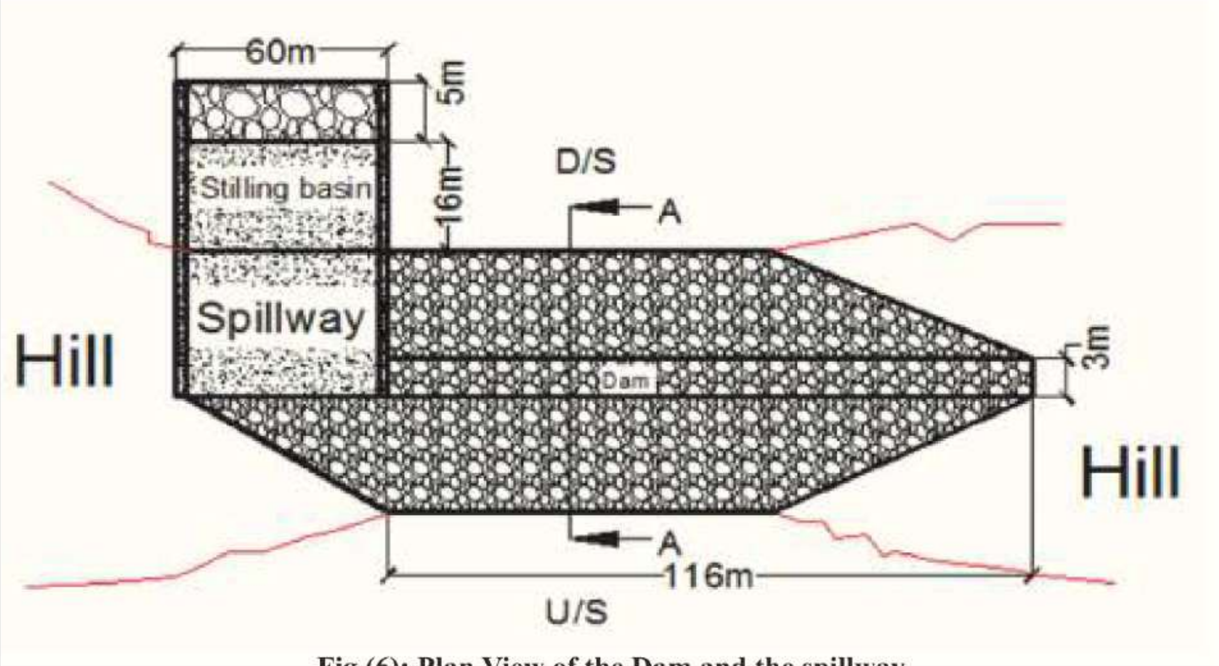


Fig (6): Plan View of the Dam and the spillway

Table(1): livestock Population and Water Consumption

Type	Number of heads (10^3)	Water Demand (litters/head/day)	Total Water Demand (10^3 m^3/year)
Cows	8	35	76
Camels	21	65	369
Donkeys	6	25	41
Goats	4	18	19
Sheep	28	20	15
Horses	0.7	25	5
Total			525

Table (2): Estimation of Water Requirement

No	category	Water Demand ($10^3 m^3$/year)
1	Human	365
2	Livestock	525
3	Agriculture	2327
Total		3217

Determination of watershed's hydrological parameters using remote sensing and GIS techniques, Study case: Wadi Al-kangar, Sudan

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ABSTRACT

The need for information in user friendly formats and which is easy to update, query, manage and utilize, has popularized the use of GIS. Remote sensing and GIS techniques are increasingly becoming an important tool in hydrology and water resources development; this is due to the fact that most of the data required for hydrological analysis can easily be obtained from remotely sensed images. The main objective of this applied research is to implement new sound technologies such as remote sensing, GIS and GPS to determine the hydrological parameters. Digital Elevation model (DEM) of 30m resolution was used to drive the flow direction, flow accumulation, watershed boundaries, sub basins and drainage network. The catchment area was determined and found to be 475 km^2.The longest flow path was calculated and found to be 43.7 km. The drainage area centroid was determined. The derivation of such information through the using remote sensing and GIS would be very useful in site selection and designing of water harvesting project with minimum cost, efforts and time compared to the traditional methods in addition to giving an accurate results.
Keywords: Water harvesting, GIS, remote sensing, DEM, watershed parameters.

INTRODUCTION

Internally produced water resources in Sudan are rather limited. The erratic nature of the rainfall and its concentration in a short season places Sudan in a vulnerable situation, especially in rained areas. Water harvesting is the process of diverting, collecting, and storing rainwater from surface runoff and effectively using the water for beneficial purposes. It has many benefits, as it considered as an ideal solution of water problem in areas having inadequate water resources, contributes in rising the ground water level, mitigates the effect of drought and achieves drought proofing, reduces the runoff which causes flooding, improves the quality of water and reduce the soil erosion. The need for information in user friendly formats and which is easy to update, query, manage and utilize, has popularized the use of GIS.

Remote sensing and GIS techniques are increasingly becoming an important tool in hydrology and water resources development; this is due to the fact that most of the data required for hydrological analysis can easily be obtained from remotely sensed images. Moreover remote sensing can provide a measurement of many hydrological variables used in hydrological and environmental models applications, either as direct measurements comparable to traditional forms.

The possibility of rapidly combining data of different types in a GIS has led to significant increase in its use in hydrological applications. These tools can be used in hydrology through determining the watershed geometry, drainage network, and other map-type information and providing input data such as soil moisture or delineated land use classes that are used to define runoff coefficients. GIS applications are becoming popular in application of hydrologic modeling for parameters estimation and watershed partitioning; this feature of the GIS makes it a suitable tool to be used in this study.

Methodology

This study was conducted in Wadi Al-kangar, which located 65 km North of Khartoum, Sudan (Figure 1).

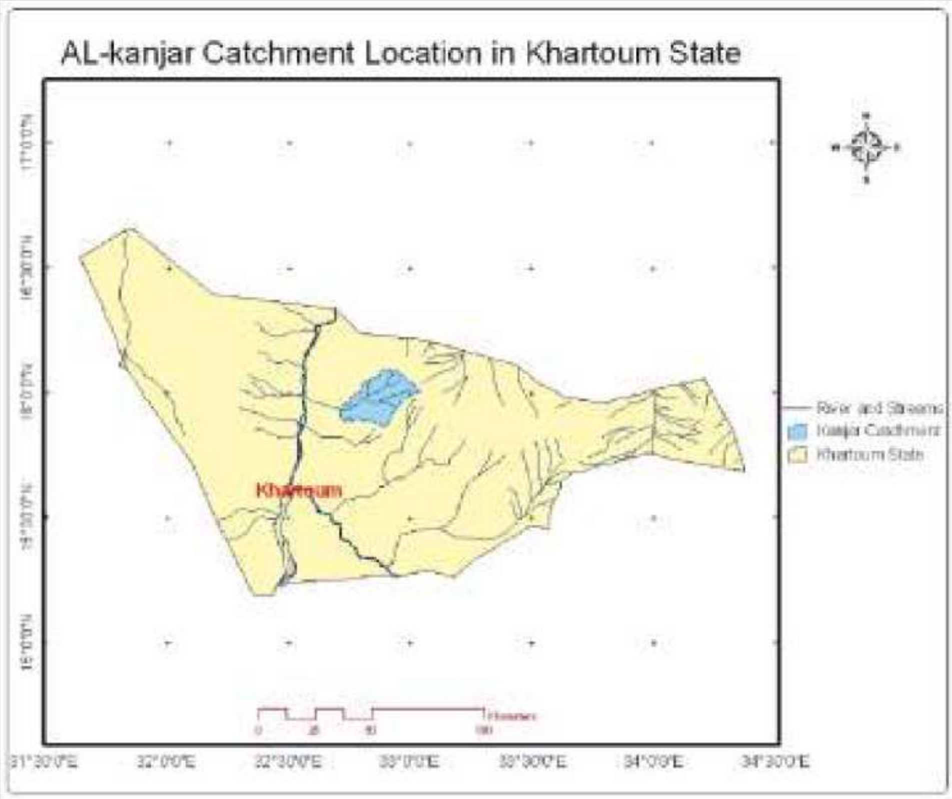

Figure (1): Location of the study area

The area is characterized by annual rainfall of 200 mm. Where it rains, the rainy season is limited to 2-3 months with the rest of the year virtually dry. Rainfall usually occurs in isolated showers, which vary considerably in duration, location, and from year to year. The coefficient of variation of the annual rainfall in this Northern half of the country could be as high as 100 percent. The mean temperature ranges from 30°C to 40°C in summer and from 10°C to 25°C in winter.

Digital GIS data was gathered from relevant authorities and developed from different sources. (i.e.) local organizations and relevant ministries.

All spatial manipulations, analyses, and representations, were done in a GIS environment that was used to produce pertinent spatial coverage. These included base map, topographic map and hydrological maps. For the first step, all needed spatial data were assembled either from paper source or digital format. Flow direction, flow accumulation, streams network and watershed boundaries were processed from the DEM using a predefined outlet point. ARCHYDRO tool module in the ARCGIS 9.3 environment was used to process the DEM and produce the fore saying maps.

From the field visit the location of the outlet point was determined using the Global Positioning System (GPS) Device. This outlet was used as a source to delineate the watershed boundary. It was observed that there are 4 water pipes with diameter of one meter installed in the outlet point in the middle of the dam body.