Developing a Geoinformatics Based Approach to Manage Water Resources in Southern Kurdistan

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Abstract: The region is currently experiencing an increase in water demand due to an expanding population, improvements in life quality and development activities. Consequently, Water Resource Managers and decision makers will be required to balance a dwindling supply with an escalating demand. These decision makers will need to use every aid available to them in order to identify management options for optimising the use of these limited water resources. The applicability of Geoinformatics as a water resources management tool in Southern Kurdistan and the relevance and the potential success of a range of applications, including water supply, hydrological catchment management, and managing sedimentation in reservoirs, floods and agriculture are examined. Based on the outcome of these assessments a Geoinformatics based hydrological management system is proposed. This management system will use Remote Sensing as an information source and GIS as an analytical tool within the management system. The system will enable decision makers to extrapolate, predict, update, plan, evaluate, compare, simulate and visualise various management actions and to anticipate the consequences of implementing each action over different periods of time in an objective manner, ultimately enabling them to optimise management decisions.

Keywords: *Geoinformatics, Southern Kurdistan, hydrological management system*

1. Introduction.

In Southern Kurdistan like the rest of the Middle East water resources are limited, and are currently decreasing, whilst the demand for water consumption is increasing for reasons such as the expanding industrialisation, agriculture, population growth and the increase in living standards. This combination makes the distribution of this limited resource very difficult and potentially explosive. In fact a recent investigation by the centre for strategic and International Studies in Washington, DC, concluded that the situation is likely to become so acute that, in the near future, water not oil will be the dominant resource of the Middle East [1]. This prediction is most likely to be realised due to geopolitical reasons as water resources are not restricted by international boundaries [2]; natural problems hindering the full use of the available water resources due to, for example sedimentation problems [3, 4] and; The third problem is the weaknesses of the decision-makers, some managers in the region may have a poor general knowledge of the problem due to their appointment for political reasons [5]. Consequently and for obvious reasons, the decision making process becomes subjective rather than objective.

In order to actively promote political and social stability, sustainable development and environmental safety, water managers and decision makers should use every aid available to them as they attempt to best mange their limited water resources. They will also need the ability to reflect upon, and anticipate, the consequences of their decisions. A logical way of making informed and objective decisions is to base them upon all available information and use an objective approach in arriving at appropriate decisions [6].

The shortage in reliable and accurate data sets can be best handled by using Geoinformatics, which encompass Remote Sensing, Geographical Information Science (GIS) and Global Positioning Systems (GPS). Geoinformatics contains the necessary tools to collect, handle and analyse the necessary data sets as well as expanding our knowledge of the processes involved at the appropriate scales [7].

The principal purpose of Remote Sensing (RS) is to extract environmental and natural resources data needed for a better understanding of various components of our environment [8]. The fundamental basis of most remote sensing investigation is based on the wavelength-distribution of electromagnetic energy transmitted or reflected by land use/cover types, which provides signatures of the materials involved. This information is used to distinguish between different types of vegetation, soil, water and rock [9, 6]. The quality of the information depends on the number of spectral bands, their spectral width and their location within the electromagnetic spectrum (Fig 1). A number of satellites have been designed to take advantage of this phenomena and record information for specific applications; these include the Landsat-TM and the Super-Spectral Satellite Remote Sensing ASTER (Fig 1). The analysis of remotely sensed data is primarily concerned with mapping and quantifying such characteristic spectral signatures of all the relevant features to environmental management. However, at first the raw image will need to be adjusted and numerically processed through a number of stages (e.g. correcting the image for any distortions and degradations, increasing the apparent distinction between the features to optimise visual interpretation, and to maximise the contrast between features of interest) producing an optimised image for use. Finally, the image will need to be calibrated with a number of measured relevant parameters on the ground (ground referenced samples) [10]. In addition the researcher will need to be familiar with the basic concepts of spatial, spectral, temporal and radiometric Resolutions [11].

Fig 1

Geographical Information Science (GIS) has evolved for handling diverse data sets for specific geographic areas by using co-ordinates as the basis for an information system. GIS also promotes spatial thinking, which is a method of assessing a situation based on perception of information that includes location, and also promotes a structural approach to problem solving. Therefore, based on the spatial nature of the acquired data, GIS can be used effectively to: firstly, input, store, organise and analyse the ground referenced data, then to integrate these data with data from satellite imagery and other sources [6]. Secondly, to employ the spatial analysis, visualisation and query capabilities of GIS to answer what is where and why? questions in order to identify hydrological catchment degradation water quantity and quality as well as the geographical distribution of population, industrial locations and agricultural lands [12]. These answers will increase our understanding of the environment. Furthermore, GIS can be used to construct and simulate various water resources management scenarios responding to various conditions of the identified problem. Then, to establish which is the most suited scenario for a location under a given set of constraints [13, 7]. GIS can also be used at operational, management and strategic planning levels by a variety of water specialists and users in Southern Kurdistan including the scientific community, universities (which must be capable of playing a leading role in the process) and decision makers and legislative bodies [6].

Global Positioning Systems (GPS) are space-based radio positioning systems that provide 24 hour three-dimensional position, velocity and time information. The satellites transmit timing information, satellite location information and satellite health information. The user requires a special radio receiver - a GPS receiver - to receive the transmissions from the satellite. The GPS receiver contains a specialized computer that calculates the location based on the satellite signals [6, 11].

This paper seeks to illustrate the potential and pitfalls of employing Geoinformatics to manage water resources in southern Kurdistan. Based on the success of these applications an information system is proposed to store, integrate, manage and analyse data relating to water resources. Southern Kurdistan was chosen as a case study area for three reasons. First, the region is experiencing a fast rate of development and the demand for water can outpace supply. Secondly, water shortages in Southern Kurdistan have parallels in almost every other country in the region. Thirdly Southern Kurdistan is likely to be faced with a unique water shortage scenario in the future due activities in the neighboring countries and Geoinformatics might help to manage available water resources in a sustainable manner.

2. An examination of the potential use of Geoinformatics in Southern Kurdistan.

The main sources of water are the rivers Tigris, Euphrates, the great Zab, the lesser Zab, Serwan and Diyala, which flow into Southern Kurdistan from neighboring Syria, Turkey and Iran (Fig 2). These countries have plans for using larger amounts of the river water, which consequently will reduce the flow into Southern Kurdistan. For example, Syria reduced the flow to less than 10% of normal when it was filling its giant Assad dam; Turkey has reduced flows substantially in recent years as the first phase of filling a series of dams (Atta turk dams) was in progress. Further reductions are likely in later phases [2]. On both occasions some crops failed, water quality declined due to increased salinity, groundwater storage was reduced and, overall, Southern Kurdistan was subjected to a variety of water-related hazards [4]. The water supply to Southern Kurdistan is falling and this trend is liable to continue. As a result water is likely to become an even more precious resource in Southern Kurdistan in the future. Consequently accurate and judicious management of limited water resources are of great importance. The more information the manager has about water resources in the region, the better he/she is able to make decisions in terms of effectively allocating available water at specific times for consumption, industrial use, irrigation, power generation and recreation. In times of excess, flood control may become the primary task; in times of shortage, irrigation and power generation may be primary concerns [4, 6].

Fig 2

In Southern Kurdistan obtaining accurate information on the geographical distribution as well as the quantity and quality of water resources is a problem [6]. Geoinformatics holds great potential for deriving information in this context as well as contributing practically towards the effective management of water resources in southern Kurdistan. This is the case due to;

1. Remote Sensing has a great potential for use in the region, which has little or no cloud cover each summer (June to September). Agricultural systems are simple, pollution is limited and regular ground referenced data can be gathered from the establishments which are in charge of rivers, dams and reservoirs, irrigation and reclamation schemes [4]. It should be indicated that the potential of satellite remote sensing is sometimes difficult to realise. This is because the current civilian satellites lack the necessary spatial and temporal resolution for some applications, as well as suffering from interface from cloud cover [14]. The spatial and temporal resolution of these satellites, however, is suited to all the potential applications discussed in section 3 of this paper.

2. Remote Sensing as a mapping, monitoring and management tool has a number of advantages, including accessibility, synoptic viewing, uniformity of collected information, repetitive coverage and cost effectiveness. These advantages will provide an opportunity to adopt a holistic approach, enabling water resources to be studied as an integrated system rather than individual entities. The holistic approach, using GIS, will allow managers to observe, study and monitor, for instance, the effects and consequences of a particular

decision on water resources within a large geographical area concurrently and over appropriate periods of time. It will also provide data for areas which have no ground measurements based on the interpolation of area-based information from sampled sites with similar attributes; subject only to the size of the area and the spatial resolution of the imagery.

3. The GPS can be used to assist with deriving the geographical co-ordinates for specific hydrological catchments and water bodies of interest in the field as well as mapping and verifying the outcomes from the remotely sensed data. The GIS can after that be utilised to examine and spatially analyse the data and to suggest a range of possible management scenarios to sensibly utilise a particular natural resource under a given set of conditions based on reliable information.

3. Potential Applications of Geoinformatics in Southern Kurdistan.

In the Southern Kurdistan region obtaining accurate information on the geographical distribution as well as the condition of water resources is a problem. Remote sensing can assist with the identification and the mapping of these two critical aspects. Remotely sensed data can also provide information for mapping and monitoring change on a regional scale, the topography and relief and data for areas that have no ground measurements [15, 6]. Furthermore, it has been used successfully to provide relevant information on catchment characteristics, e.g. mapping and monitoring the spatial extent of various types of land use/cover including; changes in agricultural land [16], mapping parent material type, soils, vegetation type and canopy densities [8, 14] as well as turbidity in rivers, lakes and reservoirs [17]. Remotely sensed data can also be utilised to provide the necessary area based land use/cover parameters to run conventional mathematical models used to simulate environmental response to different water resources management scenarios [18, 4]. Potential applications can be broadly grouped into;

3.1. Applications in surface water.

These applications are based on the fact that water absorption is less than 10% of incoming electromagnetic radiant energy in the visible wavelength (0.4 0.6?m), while it will increase rapidly above this limit to reach about 60% at 0.7?m. Satellite sensing wavelength bands are designed to benefit from these characteristics [14,15]. Sensors operating in the wave band 0.6 0.7?m show good contrast between land features and vegetated and non vegetated areas [19], while sensors operating in the 0.8 1.1?m are best suited to reveal most contrast between land and water features. Potential applications within this group include;

i. Flood Management. The rivers (Tigris, Euphrates, the great Zab, the lesser Zab, Serwan and Diyala) in Southern Kurdistan inundate their floodplains on regular basis (Fig 3). Immense areas are regularly flooded and levees often collapse resulting in wide scale damage. Satellite imagery of these rivers and their basins before, during or even few days after the flood can provide good coverage for a vast area [20]. Improved contrast between land and water boundaries can be obtained by rationing and contrast stretching techniques [8]. This will furnish crucial information concerning the flood, help appraise the spatial extent of flood-prone areas and rapidly estimate the economic consequences of flooding; particularly with respect to infrastructure and agriculture. This information can be used for the planning of flood control and the development of flood protection measures [18]. The existence of cloud-free skies, and the duration of the flood which usually extends for a week or more, makes this application possible as at least one satellite coverage can be obtained for this purpose (Fig 3). Fig 3

ii. Monitoring the River System. Satellite imagery can provide frequent images of the larger rivers, such as Tigris and Euphrates, configurations. Comparing multi-date images can clearly indicate the vulnerable portions of the embankments and spurs where the rivers are concentrating their erosional attack [18, 20, 21]. The information will help the engineers to plan erosion control works. This application is also possible as the increase in inflow takes place in late spring and the conditions are suitable for obtaining many satellite images (Fig 3).

iii. Managing Water quality. Detecting the chemical, physical and biological characteristics of all water bodies in the region, and identifying the source of any possible pollution or contamination which might cause degradation of the water quality, is also possible with Remote Sensing [22, 23, 24]. This application will become more important as the effects of eutrophication are speeded up and magnified due the reduction in water quantity (when further developments are carried out by neighboring countries). Industrial discharges to the waterbodies will then represent a real threat to water quality, particularly in the summer season, where the temperature and light, the other two necessary parameters for algal growth, are available [17, 22]. By using satellite imagery and remote sensing techniques all waterbodies can be classified trophically and monitored regularly for updates. Representative individual members for each class could be selected for ground referenced data collection and calibration purposes.

iv. Effective and Timely management of available water resources. Regular and timely information on the quantity of water available in storage reservoirs and lakes in Southern Kurdistan is required for judicious utilisation for irrigation, hydropower development etc. Satellite data can help by estimating the volume of storage either through mapping depths (if possible) and extensions of water or establishing statistically significant relationships between water area and stored water volume [23, 25, 26, 27] (Fig 4). The repetitive coverage will help in the estimation of water availability not only in the beginning of the agricultural season, but also help to monitor its depletion with time so that irrigation targets can be realistically fixed and achieved [4, 15, 24]. This application will become extremely important when neighboring countries carries out further developments and the water inflow into Southern Kurdistan reduces. Water development and irrigation project calculations should be based on the available water storage within Southern Kurdistan. This application is possible, although cloud cover may be the major limiting factor in monitoring efforts during winter and early spring seasons.

Fig 4

v. Managing sedimentation problems in reservoirs. Sedimentation in reservoirs is a serious problem with most impoundments in Southern Kurdistan. Sedimentation reduces their capacity and shortens their productive life [27] (Fig 4). Remote sensing techniques can map concentrations of suspended solids/turbidity in the surface water [23, 25]. This may help in eliminating or tracing sediment sources, usually as a result of bank or soil erosion. Cloud cover might be a serious limiting factor in the winter and early spring seasons, particularly in northern Southern Kurdistan, where most of the tributaries exist.

vi. Snow cover mapping. The extent of snow cover, which represents the stored amount of water in the Zagros mountains, and the state of the snow are both important for river flow forecasting. This information is necessary for water power generation, irrigation, domestic water supply, flood control and planning by water management generally [8, 9]. If a multiple purpose reservoir is to maintain a specified storage capacity to leave room for flood control, and at the same time keep a minimum water volume stored in order to improve the low flows, its successful operation depends on short-term and seasonal forecasts of inflow [10, 18]. This application is possible, but the cloud cover might prevent useful application during the winter. Such an application requires scientific coordination between Southern Kurdistan and Turkey.

3.2. Applications in subsurface water

Mapping includes both groundwater and soil moisture. Groundwater is mapped indirectly. This is done by mapping a significant number of groundwater-related phenomena such as detecting fractures, and the intersection of linear fractures or lineaments, which correlate with the occurrence of groundwater or, by locating anomalous areas of temperature in streams or coastal regions, which might be due to groundwater outflow [28, 29]. Soil moisture is also an important water resource as it is the immediate water supply for crops. The presence of soil moisture affects the characteristics of electromagnetic radiation reflected or emitted from soil due to the basic effect that moisture has on reflectance. This field is well established and applications include estimating soil water content [30, 31] and evaluating soil moisture [32, 14]. Potential applications within this group include;

i. Detecting Groundwater. Satellite data are useful for mapping zones of potential groundwater resources. From satellite imagery a significant number of groundwater-related phenomena can be surveyed qualitatively and, occasionally, quantitatively [8, 9, 28]. Examples include landforms, drainage patterns, structural lineaments, geological formations of interest (mostly limestone and conglomerates) vegetation patterns, recharge and discharge areas. This information is of great value in large scale preliminary investigations of available groundwater resources (thus saving time, labour and the expense of ground-search procedures). This would be valuable in many parts of central and western Southern Kurdistan, where groundwater is the main source of water. Such groundwater resources can be used to supplement the limited sources of surface water for irrigation in most parts of the country. This application is possible as all the necessary conditions are fulfilled for successful ground coverage during the long dry summer season.

3.3. Applications in Hydrological catchment characteristics

Potential applications in Southern Kurdistan include;

i. Mapping physical characteristics, mapping of landforms and drainage networks is important in delineating catchment boundaries and the major physical dimensions affecting the occurrence of stream flow. Both automated and visual analyses of satellite data can detect changes in the drainage pattern, land cover/land use (forest, agriculture, barren land, settlement, wetland, waterbody) in river basins accurately [8, 9, 18]. The reconnaissance and development of water resources in many developing countries, including Southern Kurdistan, is based on simple regression models relating stream flow to catchment characteristics. Near infrared bands (0.7 1.0?m) in satellite imagery (Fig 1) are reliable for preparing maps of the Tigris and Euphrates networks, catchment boundaries, catchment areas, drainage density (total length of channel per unit area) and stream frequency (number of junctions per unit area). These are the most important parameters in developing regional (national) hydrologic models and can be involved in many calculations and predictions concerning the development of water resources in rivers. This application is again possible as many coverages could be obtained under suitable conditions.

ii. Mapping land cover/use. Land cover/use are important for hydrological studies in Southern Kurdistan, first, because they determine to a large extent the process of runoff generation. Secondly, they are excellent indirect indicators of the hydrologic conditions and the geophysical characteristics, which determine them. Information on land cover/use is also of indirect, but fundamental, importance to the estimation of current and future demands for water. In Southern Kurdistan the principle use of water is for irrigation. It is very difficult, by conventional means, to accurately survey the areas sown each season to each type of crop, and yet without such information it is impossible to design and operate agricultural water supply schemes in an effective manner. This application is possible as many successful coverages can be obtained under cloud free conditions.

3.4. Applications in Agriculture

Potential applications in Southern Kurdistan include;

i. i. Mapping soil moisture. Soil moisture information is important to the agriculturist. A deficit in moisture may lead to the wilting of plants, and timely remedial action through irrigation can save the crops. Remote sensing has a crucial role to play in this field by ensuring the optimum use of water and the best possible conditions for various crops.

ii. ii. Monitoring agricultural resources. Irrigation areas fed by reservoirs are distinctly visible on satellite imagery. Multi-date information could be used to monitor the irrigated cropland through time. This information could be used effectively in many applications such as establishing an agricultural base mapping programme, which is necessary to provide information on soils, percent vegetation cover and land use for establishing of new agricultural areas and information on topography which would be of assistance in irrigation planning and watershed management. It can also provide a significant input to water consumption models for large irrigation projects; Forecasting and estimating crop production. One approach is to identify agricultural crop types and estimate the area covered by the crops using classification techniques [16]. Another approach is to estimate the vegetation cover by using a vegetation index involving red and near infrared ratios. This will lead to better planning to meet flood and agricultural needs. Using multi-date information will have great potential for improving the recognition of crop species because different stages of growth of the crops will be taken into consideration for estimating crop production. The area is obtained by computer classified images and yield estimates can be obtained from statistical regression analysis relating crop yield to local meteorological conditions, notably precipitation and temperature; Determining the effectiveness of various irrigation and cropping methods. Different methods have varying levels of water application efficiency and recommendations regarding improved efficiency levels could be made particularly where non-efficient cropping patterns and irrigation methods are used [11]. These applications will increase in importance as water resources are reduced and better management is needed to make higher production and optimum crop selection possible with less available water. This application is possible through the summer. However the cloud cover will be the major limiting factor during the winter [4].

3.5. Applications in developing water supplies.

The majority of the applications discussed above are concerned with improving the understanding of the hydrology of Southern Kurdistan as basis for an assessment of its surface and groundwater resources. Landsat observations can also be used to aid in the location of potential dam sites, aqueducts and canals and in this way contribute directly to the planning of water resource projects designed to meet the national water demand [4, 8, 14]. This application is particularly important as the fate of reliable continuous water sources (Tigris and Euphrates) are likely to be subject to future reductions. More reservoirs and water storages are likely to be needed in order to fulfill the water needs of the country.

4. Water Resources in Southern Kurdistan, Challenges and Opportunities

The effective management of water resources in southern Kurdistan requires an approach that is regional in scale and holistic in scope. This can be achieved by examining, monitoring, understanding and modelling water bodies and their catchments, rainfall as well as the social and cultural impacts of local communities. In addition to examining the possible impacts of water development schemes (digging boreholes, digging artificial ponds, harvesting natural ponds, digging canals for river diversion or feeding irrigation schemes) on both the environment and the socio-economic settings of specific sites.

Planning and management of water resources at a regional scale will increasingly demand an integrated overview of different types of hydrological data gathered from different sources, by variety of means, and often maintained in separate establishments. Therefore, data homogenisation must be introduced by establishing organisational devices, such as a Regional Office for water resources and planning. Furthermore, it will be necessary to categorise the region it into a number of homogeneous areas based on physical and human factors and then focus the research on a number of representative sites. Remote sensing could be used to define the representative sites, guide the field work and generate a series of thematic coverages of the whole area for themes such as vegetation, rainfall and climate, geology and geomorphology, surface hydrology, and human impact [33, 34]. These properties should be arranged for thematic applications at the later step of information integration and analysis using the GIS. The remote sensing and the GIS through the repetitive coverage and the synoptic view can be used in change detection studies, enabling researchers to observe and quantify trends and to correlate these with local, regional or global changes, which might provide some relevant answers. The GIS could also be used for constructing, simulating and modelling various management scenarios responding to a range of environmental, physical, demographic and socioeconomic conditions and challenges [4, 33, 34].

The outcome from these operations will provide information for various interest groups, including the scientific community and legislative bodies in southern Kurdistan feeding information into, and assisting with the decision making process at the following levels [35, 4, 36].

1. Operational applications. Producing new maps at various scales, updating old maps and tabular information for specific thematic data relating to specific areas of interest.

2. Management applications. Using available information, including input from 1 above, and generating new information towards managing water resources in southern Kurdistan. Applications include measuring, mapping, monitoring, developing time series analysis and modelling processes related to water shortages and environmental degradation.

3. Strategic applications. These applications aim towards inducing change in processes or cultures. These include developing and testing scenarios in various contexts, taking actions such as defining minimum rules of exploitation and management for a livestock development and rangeland scheme and developing polices to carry out these actions effectively.

4.1. A Proposed Water Resources Management Information System.

The proposed system aims to optimise the management of water resources within southern Kurdistan by building upon the concepts developed and issues examined as well as including the likely changes facing Southern Kurdistan in the future. The system consists of the following components (Fig 5)

1. Data Input;

A. The Ground Referenced Information input which consists of two inputs;

   i. The Environmental and Physical information input consists of information on land cover/use, ground water, topography, geology, structure, soil etc. These can be used for checking and calibrating the remotely sensed data;

ii. The demographic and socio-economic information input, which can contain information on population, livestock, husbandry practices, crop types, industrial locations.

Information in (i) and (ii) above will be in a digital form and the GIS will facilitate data integration in terms of resolution, scale and projections.

B. The Remotely Sensed data input Having collected that data at the relevant spatial, spectral and temporal resolutions the selection and processing stage beings, the system starts performing all the necessary corrections on the raw data, followed by selecting individual and combinations of spectral bands, these are then subjected to image processing techniques in order to optimise the presentation of different spectral behaviour of relevant surface features. The combining stage follows, where various individual bands could be combined in different ways such as ratioing in order to create and enhance the required information.

Both (A) and (B) above will have a display facility in order to visualise and monitor the effects of the applied data manipulation processes.

2. Data integration and Processing

a. a) Relevant parts of (Ai) can be selected and combined to form specific physical and environmental units according to the purpose of the operation/research.

b. b) Relevant sections from (Aii) can be selected and combined to form specific demographic and socioeconomic units according to the purpose of the operation/research.

c. c) These units can be selectively combined with the physical and environmental units (a above) to form a purpose-acquired ground-referenced data map.

d. d) Established algorithms for the application(s) of interest using remotely sensed information could be used to extract, calculate/estimate, interpolate/extrapolate and store all of the necessary parameters for the whole area of interest.

e. e) The output from (d) above could be compared with values obtained from the ground reference information input (c above) by using standard statistical measures, and then the calibration stage follows for the remotely sensed data.

3. Data Analysis

a. The estimated values from the previous stage can be compared with previous values/estimates for the same parameters, and the differences or changes between images/maps presenting their concentrations and spatial distributions can be analysed and stored.

b. GIS facilities can be used to interpolate/extrapolate, display and compare between the value and distribution patterns of the output from (a) above and to establish variations between different parameters, update the information and storing it.

c. Based on (b) above, the GIS could be used to;

   i. Correlate data on the environment (ground water, vegetation cover, etc.) and human and related activities (population pressure and the impact of livestock) and prepare risk charts for water shortages and desertification.

   ii. Identify and geographically locate potential areas with environmental degradation and water shortage problems and select representative sites for intensive investigation.

   iii. Establish realistic management scenarios (i.e. based on all available information and involving all interested parties, the focus should be on what is actually feasible given a set of circumstances rather than what is desirable under ideal conditions) responding to various conditions of the identified problems in (ii) above such as the regeneration or restoration of degraded areas, declaring environmentally critical areas as forbidden for livestock and the collection of firewood temporarily or permanently.

   iv. Run these scenarios and reflect on the environmental, economic and social consequences of each action over various periods of time.

   v. Using the findings in (iv) in the decision making process in terms of adopting and devising various management plans and establishing policies to carry out these planes successfully. The scientific community, universities and decision making and legislative bodies could use this information at operational, management and strategic management levels.

5. Discussion

The economic growth in southern Kurdistan is most likely to be associated with a rapid rate of urbanisation, and population growth leading to a substantial expansion in industrial and agricultural development. These actions are expected to lead to increasing demand on ever decreasing water resources in the region. Consequently, there is a real need to plan and successfully manage future demands for water resources.

The lack of reliable and compatible data sets as well as the deficiency in the scientific knowledge regarding some of the processes involved represents a problem. However, this problem can be managed by adopting a holistic approach and using Geoinformatics, which contains the necessary tools (Remote sensing, GPS, GIS) to collect, handle and analyse the necessary data sets as well as expanding our knowledge of the processes involved at the appropriate scales. Having established the status and the distribution then the abundance can be monitored efficiently over time. The GIS can be used to understand, evaluate, simulate and manage the impact of various development projects. This information will allow effective sustainable development strategies to be developed, simulated and tested, within a GIS framework, for vulnerable regions.

The examination and analysis above indicates the suitability of Geoinformatics for managing water resources in southern Kurdistan. Providing that the following aspects of the Satellite imagery are suited for the application(s) of interest; spatial resolution, spectral resolution, radiometric resolution and temporal resolution as well as having cloud free skies. Encouraging factors for using Remote Sensing in this region include; the simple systems such as agricultural systems, in place, the limited amount of pollution and the public ownership of water resources.

Adopting the proposed approach will have a number of advantages: it will help managers to adopt an holistic approach and will update them with information concerning the quantity and quality of available water resources within a particular period, and through the GIS various management options can be examined, suggesting the best option to effectively manage these resources to satisfy a priority list (drawn by the managers); indirectly, it will promote objective thinking, planning and decision making.

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Figures

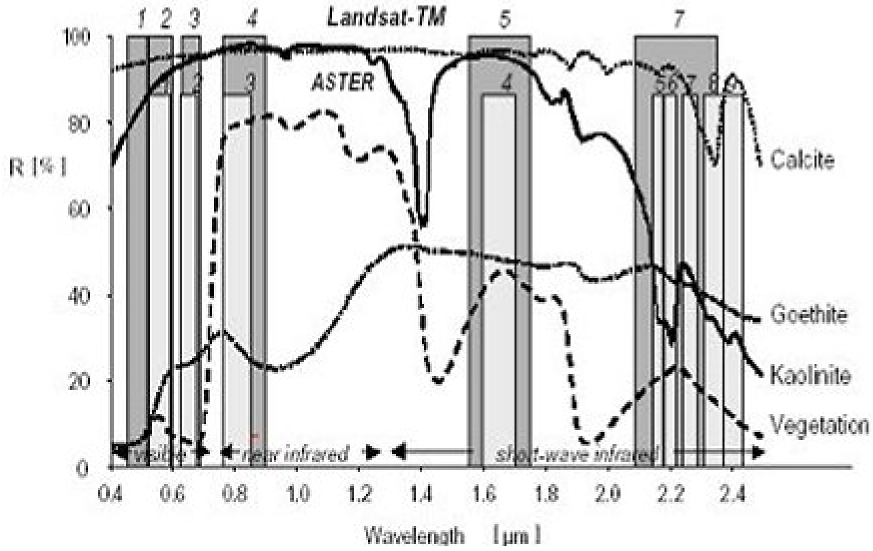

Fig 1. Spectral Bands of Landsat- TM (dark) and- the ASTER (light) instruments (http://www.dkkv.org/forum2001/Datei60.pdf)

Fig 2. Water Resources in Southern Kurdistan (http://www.releifweb.int/rw/rwb.nsf/db900SID)

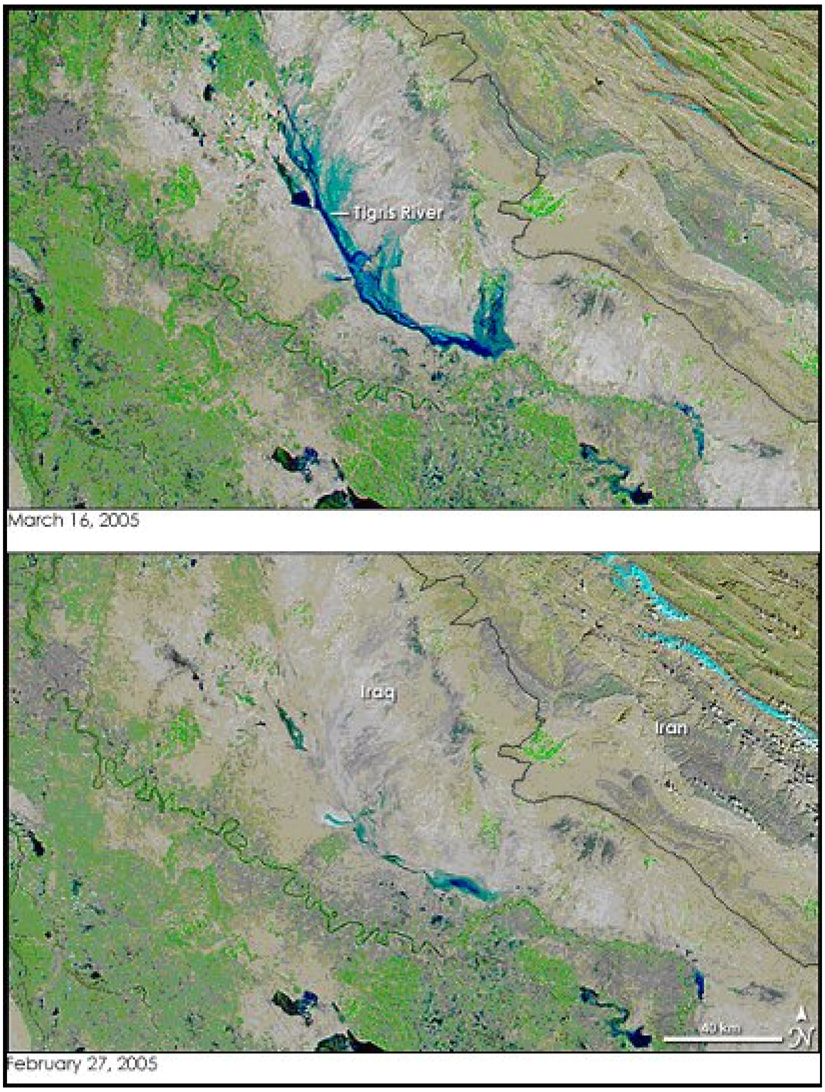

Fig 3. River Tiger floods during March 16, 2005.
(http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16852)

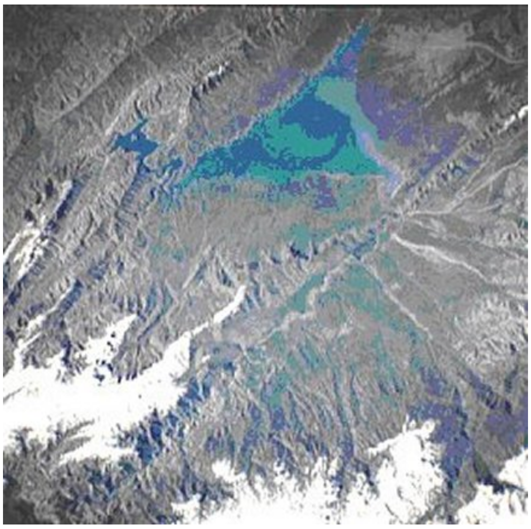

Fig 4. Dukan Dam image taken on 4.3.1990
(http://eol.Jsc.nasa.gov/scripts/sseop/changepage.pl

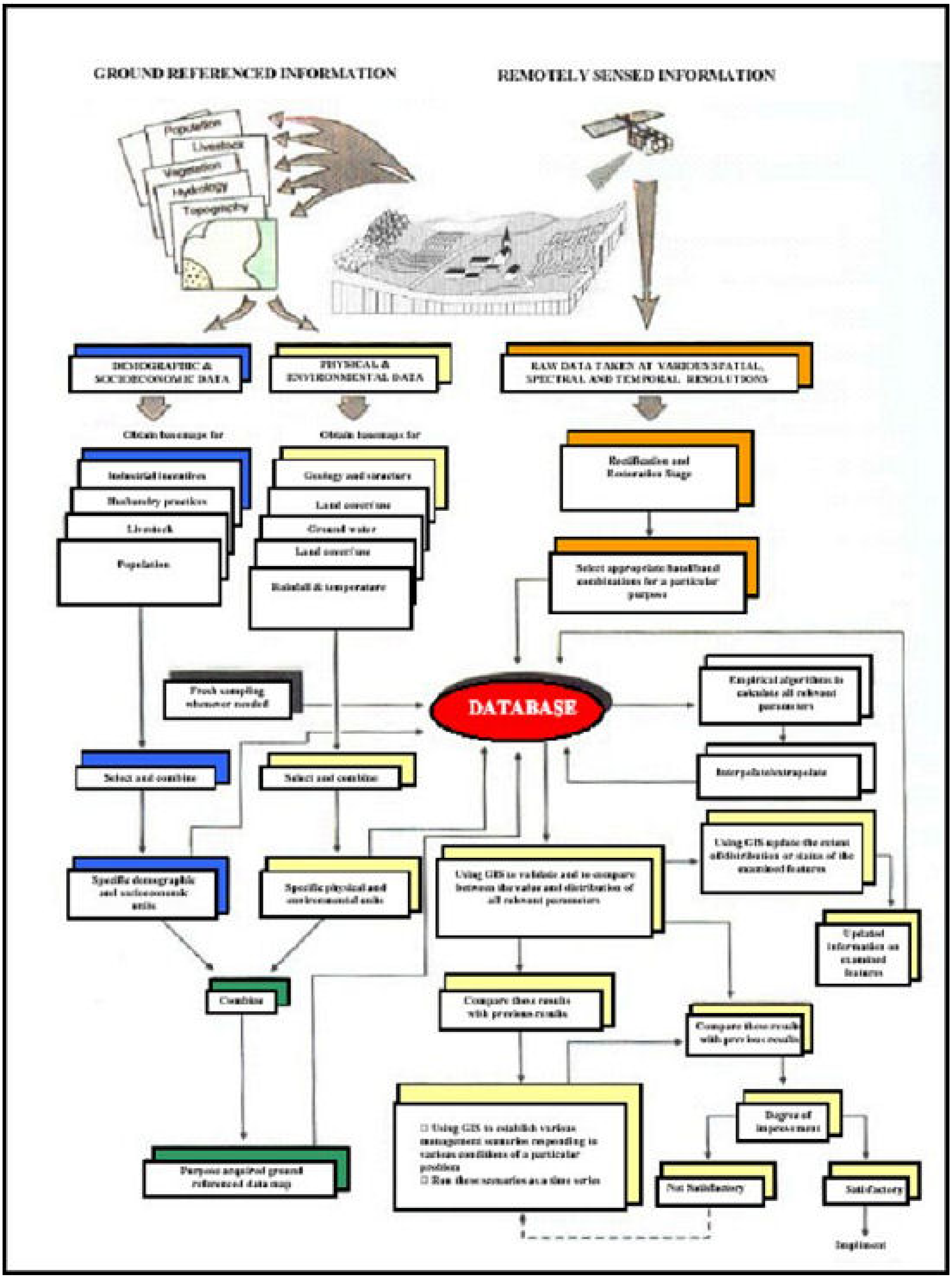

Fig 5. A Geoinformatics based water resources management system for Southern Kurdistan