A GIS Based Digital Land Resources Framework for Optimal Soil Management in Barda and Awaje Basin, Syria

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Abstract

Barada and Awaje Basin is located in the southwest part of Syria and includes the capital of the country, the city of Damascus and its suburbs. It covers an area of approximately 8596 km^2 and constitutes a hydrologically closed basin. It has a far higher population density than any of the Syrian regions. The estimated population living within the borders of this region is more than 4 millions.

Population growth in the study area causes competition on land resources between different sectors and pressure on limited water resources. The national development plans aim to conserve arable lands, improve its productivity, and sustain the land and water resources.

Therefore, providing accurate and integrated information about land resources is a must, especially with the accelerated progress of information technology. Such information would be the base for planning, decision making and research needs. Various available information and database systems were employed (e.g. ArcGIS, ERDAS IMAGINE and ENVI). Data of previous soil survey activities were the bases for the created GIS digital database. Soils survey maps (SCALE 1:100,000), were prepared as GIS ready maps. Urban settlements were updated using recent ETM+ and SPOT satellite images. An intensive field investigation was performed in the study region, with the purpose of representing the soil units and collecting ground control points and soil samples for laboratory analyses. The created digital land resources database was used to figure the distribution of soil units and to evaluate and map land suitability on the bases of FAO, 1985 [1].

It was found that the Aridsols soil order characterize most of the alluvial fan soils of Barada, while Inceptisols were found in the western plains and intermountain areas. The soil orders Entisols were found dominating the western mountain areas. The results showed that 28.6 % of the areas are classified as highly suitable for irrigated agricultural production, corresponding with Typic Haplocambids and Typic Haploxerepts soil sub-great group. The moderately suitable soils, exhibit 14.7 % of the areas. The marginally suitable soils represent 14.6 % of the areas. The not suitable soils dominate the soils of eastern lacustrine and desert deposits, representing 21.2 % of the areas. It could be pointed out that achieving such detailed digital land resources database for local administrations is a great step towards the implementation of sustainable development and management programs. It is characterized by its comprehensiveness, geographical accuracy and updatability. In the information technology, such data can be handled, enhanced and exchanged by different users and authorities. The most striking findings noticed was the urban encroachment on the account of most fertile soils; hence shrinkage in areas of high agricultural capabilities. On the other hand, urbanization doesn't extend largely to low capable land.

Keywords: GIS, Remote Sensing, Soil Survey, Land Evaluation.

1. Introduction

Population increasing in the study area (*Barada and Awaje Basin)* caused competition on land resources between different sectors and pressure on limited water resources. The national development plans aim to conserve arable lands and to improve its productivity, Moreover to sustain the land and water resources. However, realizing these purposes requires availability of accurate documented data for integrated natural resources. Techniques of remote sensing and Geographical Information Systems (GIS) provide suitable means for inventory monitoring and documentation of natural resources, as they are characterized by satisfactory resolution and multi-spectrality. Also, distribution of the natural resources and detection of their changes are accessible by multi-temporal space data nature. The objectives of the former are to build database of available natural resources data and combine them into suitable format and make them ready for use by the land use planning recommendation component.

2. Material and methods

2.1. Study area

Barada and Awaje Basin is located in the southwest part of Syria (a country in southwest Asia bordered by Turkey, Iraq, Jordan, Lebanon and the Mediterranean Sea) and includes the capital of the country, the city of Damascus and its suburbs (Fig.1). It covers an area of approximately 8596 km^2 and constitutes a hydrologically closed basin (there is no excess water flowing out of the basin). It has a far higher population density than any of the Syrian regions. The estimated population living within the borders of this region is more than 4 millions. This basin is a rewarding subject for investigation, as it is a very heterogeneous landscape containing many different types of climates, topography, soil, vegetation and land uses. The drainage system of this basin is represented mainly by two rivers (*Barada River* and *Awaje River*) and a few valleys that have dry river beds filled with water only during the rainy season. There are also two dry lakes (*Al-Outaibe* and *Al-Haijaneh*) which are usually salty and drainless and only during the rainy season are covered by a thin layer of water. The topography is characterized by low mountain systems outlining the flat central Damascus depression with its lowest elevation point 600 above the sea level. Maximum height of the mountain is 2814 m (Fig.2).

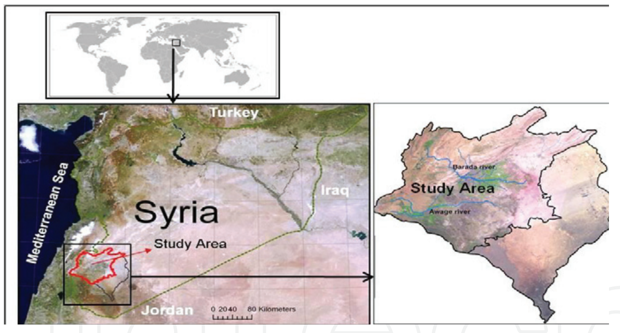

Fig 1. Shows location of the study area.

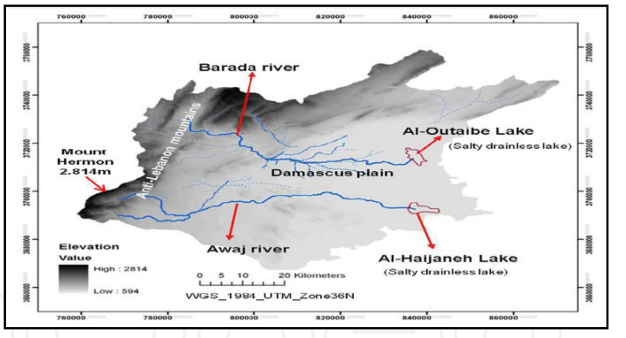

Fig 2. Shows a Digital Elevation Model of the study area along with vector data (river channels and lakes) draped over it.

The major part of study area lies in the transition zone between the arid climate on the plains to the moderate humid climate at the heights above 2000 m. The year is subdivided into seasons:

- The dry summer season (from April to October) with high average monthly air temperatures from 25-27 Cº on the plains to 19 Cº and less at the heights above 2000 m; with a low precipitation rate and dry winds.

- The humid cold season (from November to March) with the average monthly air temperatures from 10-15 Cº on the plains to zero and less at the heights above 1500-2000 m; with periodic precipitation (up to 80-90 % of the annual rate) and cold north-eastern winds.

The soils of the drainage basins of the Barada and Awaje rivers relate to the soil-bioclimatic formation of cinnamon and low-alkaline, grey brown soils of a dry subtropic climate. Diversity of the relief, climatic, hydrogeological and other environmental conditions account for a mixed character of the soil mantle of the area.

2.2. Materials used

Soil survey to a scale of (1:100,000) was performed by Leningrad State Institute for Design of Water Resources Development Projects (LENGIPROVODKHOZ) as part of the project of Water Resources Use in Barada and Awaje Basins For Irrigation of Crops (USSR, 1986). Soil survey covers 3408 km^2 of the study area, a total of 556 soil observations pits and profiles were done. The soil maps exist as analogue format, the collected maps consist of two map sheets (sheet for soil mapping units and sheet for soil observation points) at scale of 1:100,000. Soil survey data were interpreted and classified according to Russian soil classification USSR. The soil maps of Barada and Awaje basin are the main materials collected and converted to the digital format. Satellite ETM+ image of 2006, a scene (Path174 / Row37), covering the whole basin, was collected and processed to be included in the GIS land resources database and be used in thematic mapping processes. The recent SPOT images of 2009 were obtained from General Organization of Remote Sensing (GORS) in Syria, and processed for updating different thematic maps and detecting changes in urban area. The Shuttle Radar Topographic Mission (SRTM) images of 30 pixel size resolution, in addition to driven Digital Elevation Module (DEM) for the study area and its surrounding were consulted to represent the area landscape [2] and [3].

2.3. Methodologies

2.3.1. Coding the Soil Units

In order to input the soil maps in the geographic information database, it was necessary to codify the mapping units. The original map units classified according to Russian soil classification USSR [4]. Soil data was reclassified according to American Soil taxonomy USDA [5]. Coding the soil units ought to be indicative to the soil Taxonomy, properties, as well as the landscape.

2.3.2. Satellite images processing

Pre-processing activities were performed, to reduce some undesired variations/noises and to enhance other desired features. It commonly comprises a series of sequential operations, including radiometric correction or normalization, image registration, geometric correction, masking and image enhancement (e.g., for clouds, water, irrelevant features). Geometric rectification of the imagery was applied using ERDAS IMAGIN. This becomes especially important when scene to scene comparisons of individual pixels in applications such as change detection are being sought [6]. Image enhancement techniques (e.g. contrast stretching, Gray-level threshold, Level slicing, and spatial stretch) were tested to improve the visual interpretability of the used images by increasing the apparent distinction between the features.

2.3.3. Building GIS database

The digitizing specification of maps was defined according to the available themes. The different digital maps were corrected from different errors and edge-matched after the geo-referencing processes. Edge matching, as a spatial adjustment process that aligns features in adjacent map sheets, was performed according to Tomlin, 1990. This process was applied on the soil maps (scale 1: 100,000). The descriptive thematic data related to all layers were attached as additional attribute tables.

2.3.4. Spatial adjustments

It was noticed, after edge matching, that there is a kind of deviation (constant in many places in its direction and magnitude) between the produced maps and the well registered topographic ones as well as the satellite images of the study area. It was possible to attribute the deviation to two reasons; lack of coordinate system in some original map sheets and the rubber-sheeting accompanied the edge-matching task [7]. In order to overcome this problem another spatial adjustment (transformation) has been performed. Well registered topographic maps and accurately georeferenced satellite images have been used to perform the transformation process. The transformation tools of ArcGIS systems were found to be very effective in performing the spatial adjustment of the soil maps [8] and [9].

2.3.5. Compilation of laboratory analysis results

A number of 12 soil profiles, representing the soil units of the studied regions were morphologically described according to FAO [10]. A number of 56 disturbed soil samples were collected for laboratory analysis, following the laboratory methods manual [11]. The results of these analyses have been compiled in the database and then incorporated into the attribute tables of the digital GIS soil maps [12].

3. Results and discussions

3.1. Soil Resources

Soil Taxonomy has been used to classify the soils of the study area up to family and phases of families (Soil Survey Staff, 1999 and 2010). Soil Taxonomy is a hierarchical system of soil classification that identifies six levels. At the highest level, twelve orders are recognized worldwide, but only three have been recorded within the study area: Aridisols, Entisols, and Inceptisols. At the subsequent levels of classification eight suborders, fourteen great groups, and thirty subgroups have been recorded. The identified great groups and their coverage are: Haplocambids (comprising 34.7 % of the study area); Haplocalcids (2.9 %); Haplogypsids (2.7 %); Petrogypsids (2.19 %); Aquisalids (1.1 %); Haplosalids (1.85 %); Calcigypsids (0.77 %); Torriorthents (11.78 %); Torrifluvents (3.7 %); and Haploxerepts (11.88 %). Bedrock occupies about 18 % of the study area.

Aridisols cover almost all of the central and eastern part of the basin where the annual precipitation drops below 250mm. In addition, Aridisols are characterized by an aridic (hot and dry) soil moisture regime, and they have light colour as there is not enough vegetation to add organic matter to the soil profile. Furthermore, they often accumulate calcium carbonate, gypsum, and other materials that are readily leached from soils in more humid environments [13].

Entisols are soils that have little or no indication of development of pedogenic horizons [5]. This soil order includes recently developed soils, which do not have the requirements of the other soil orders. Entisols cover the western north mountain in the study area.

Inceptisols are soils of semiarid to sub-humid environments that generally show only moderate degrees of soil weathering and development. Even though they are better developed than Entisols, they are still young soils and resemble very closely the parent material [14].

3.2. Urban areas

The urban area, according to soil survey that performed in 1986, was occupying about 2.24 % of the study area (77.18 km^2). Whereas, urban area, according to visual interpretation of Spot image satellite taken in October 2009, was occupying about 4.17 % of the study area (143.46 km^2). For example, the area of Damascus city in 1986 was 58.03 km^2 and the area of Damascus in 2009 was 124.49 $km^{2,}$ it is important to indicate that the extension of urban area especially Damascus city occupy the soils of alluvial fan that have high potential for agriculture. The urbanization rate in the study area reaches to 100 % through 23 years (from 1986 to 2009).

3.3. Land Suitability Classification of the Barada and Awaje soils for Irrigated Agriculture

Rating criteria (land use requirements for irrigated agriculture) were developed based on an international and regional review of the arid and semi-arid conditions prevailing in the neighboring Countries. These include JAZPP project (2001) in Jordan [15]. Evaluation analysis preformed according to FAO (1985). These requirements were matched with land attributes that were derived from soil survey data using average and mode method which utilizes the soil map units and the observation points, (by averaging land characteristics within soil mapping units). Simple limitation method was used in suitability analysis. Suitability analysis was performed by using Arcview 3.2, Query comment (select by attribute). About 28 % of study area was classified highly suitable for irrigated agriculture (S1), 15 % of study area was classified moderately suitable (S2), 15 % of the study area classified as marginally suitable (S3), and 21 % of the study area classified not suitable for irrigated agriculture. Most of soils Typic Haplocambids and Typic Haploxerepts classified as highly suitable for agriculture production. Soil depth, Rocks outcrops, stones in the surface horizon, salinity are the most important limiting factors that lowering suitability classification of 20.9 %, 14.5 %, 8.1 % and 10.3 % of the study area respectively. Figure.3 shows distribution of suitability classes within the study area.

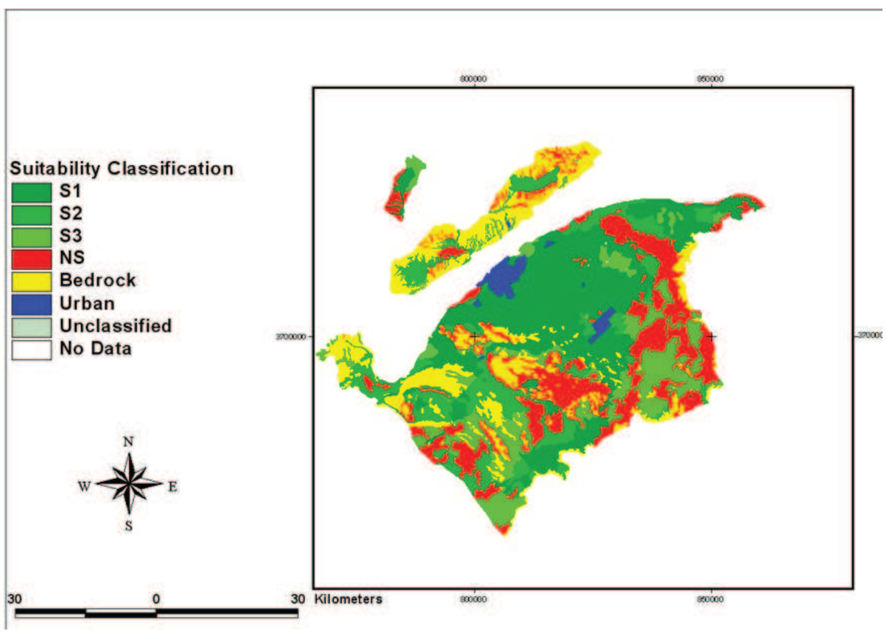

Fig 3. Land suitability classification for irrigated agriculture.

4. Conclusions

It could be concluded that the creation of land resources database is rather important in documenting the environmental themes. Such documentation leads to data harmonization and maximization of its value. It also allows an easy data processing, and updating. The land resources databases are rather useful in elaborating site selection for sustainable development projects, in addition to decision support and early warning. Remote sensing, with its multi-concept approach, provides up-to-date information on different themes. Multi-dates images allow detecting the changes occurring in the different environmental conditions. Also, the multi spectral satellite images reflect the environmental elements characterized by a variety of spectral signature. Moreover, GIS and its integrated functional nature with remote sensing, facilitate the creation and developing land resources databases.

5. Acknowledgements

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