THE POTENTIAL OF GIS ANALYSES IN FARMING SYSTEMS DEVELOPMENT THE CASE OF AL FARIA'A BASIN- WESTERN OF THE JORDAN VALLEY

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Abstract

With the increasing population in Palestine, demand for agriculture resources has increased promoting farming system (land use) changes whereas water resources are becoming scarce. Current and accurate land use / land cover inventories are essential information for studying and monitoring farming systems and for make sound plans for the future. This paper presents GIS as a method using land use components into analysis the farming system development. Geographical information system (GIS) Land sat TM Thematic Mapper data was used as a tool to study the farming system in Al Faria'a basin- Western of the Jordan valley, Palestine. To derive the land use and land cover classes in the study area, satellite images from the years, 1990, 1996, 1999 were analysed with the help of supervised classification approaches based on spectral pattern recognition, and post classification to derive the land use change, GIS analysing method. The GIS analyses were applied with the help of image processing software, Erdas Imagine version 8.4; the inverse distance weighted (IDW) method was used to integrate the data from farm family survey. The analysis demonstrates that most of the changes in land use in Al Faria'a basin between the years 1990-1996 and the years 1996-1999 occurred in the vegetation cover, while urban or bare rock did not change much during the last ten-year interval. This change in the vegetation cover could be attributed to social, economical, and political issues. The differences in imaginary are also partly linked to technical factors such as the time of the image acquiring. While the GIS analysis shows an expansion in the vegetation cover, a simultaneous survey on farming system level shows that the water content has been continuously decreasing. This stresses the need to search for alternative water sources in order to support the agriculture in the basin such as low quality water reuse.

Introduction

The concept of farming system analysis is understood to especially deal with the linkages and interrelationships within a defined complex and its relation to outside world (Doppler, W., 1998). Farming system benefits from rapidly evolving geospatial information technologies, including global positioning system, geographic information system, yield monitors, remote sensing, and electronic sensors and controllers for variable rate application technology. The potential benefits of farming system from the micro level to higher aggregated levels include: (1) the determination of spatially referenced data for improved understanding of Farming systems; (2) the precise placement of Farming system inputs to improve net economic return, environmental quality, and global competitiveness; and (3) the accurate measurement of outputs such as yield. By allowing optimal use of farm inputs on a location-specific basis, farming systems may became economically consistent with, and in many cases superior to, conventional farming techniques. The geographical information system (GIS) is a system of hardware, software and procedures, designed to support the capture, management, manipulation, analysis, modelling and display of spatially referenced data for solving complex planning and management problems (Jennifer M. Olson, 1995). One of the most important applications of GIS, remotely sensed data, is the production of Land use / land cover maps. Knowledge about land use and land cover has become increasingly important to solve problems such as uncontrolled urbanization, deteriorating environmental quality, deforestation, desertification and destruction of important agricultural lands (Anderson, 1976). The dataset that are used in this study are obtained by Land sat satellite Thematic Mapper, which has a higher spectral and spatial resolution in comparison with its predecessor, the Multi Spectral Scanner (MSS) (Lillesand 1994). Particular importance is also given to the precision and accuracy of using remotely sensed data in creating such maps. When focusing on a farm field a user has the ability to store data layers as individual planes of data. Data can be categorized in different ways such as resource data, which changes little, or slowly over time (soil types, hydrology, etc.), or management data (seed varieties, fertility, seeding populations, etc.). All the categories can then be set within a regional context using Public Land Survey, county, boundaries, transportation networks, and other regional data. These data layers can then be fully integrated with aerial photography, videography, satellite imagery, and meteorological data when available.With the increase of population in the study region, demand for agriculture land increases while water resources becomes limited, because Israel has imposed restrictions on the amount of fresh water that can be used by Palestinian farmers. As such, irrigated agriculture in the West Bank becomes limited, comprising only approximately 6% of the entire cultured area (ARIJ, 1997). This paper attempts to assess the use of GIS in expressing farming systems adequately. Every potential application of GIS in farming system is different; however, there are certain underlying principles that remain the same. The main aims of this paper; through the analysis of a selection of remotely sensed multi-spectral datasets for the Al Faria'a, to produce land use and land cover maps and to extract the dynamic changes of land use and water availability, which have affected the farming system development in Al Faria'a basin during the last 10 years.

The study area

Figure1: Al Faria'a basin, Western of the Jordan Valley, Palestine.

Al Faria'a drainage basin (Figure 1), lies in the northeastern part of the West Bank. It lies within the following Palestinian co-ordinates 160000 - 195000 mN (32° 2´ - 32° 12´ N) and 175000 - 200000 m E (35° 12´- 35° 35´E) (Ghanem, M., 1999). Al Faria'a basin has mainly two agro-climatologically zones; 1) The mountainous zone, which is located about 704m above the sea level, in the western parts, with 590 mm/year as an average annual rainfall; and 2) Jordan valley in the east, about 302 m below the sea level with only 160 mm/year (Meteorological Station in Nablus City, GIS data 2000). The area is divided in two zones; the semi – arid zone; which is limited to areas of Al Faria'a, Al Bathan, & Al Nassria; and the arid zone in the area of Frush Beet Dajan, and Al Jeftlik. The complexity of the farming systems in the study area origin from the interaction and linkages between water, environment, marketing, and economics.

Methodology

The principal method for assessing the land use changes in the study area was the analysis and interpretation of satellite images from MSS LANDSAT imagery. The image analysis was based on three sets of Multi-spectral, seven bands Land Sat TM images, for the years 1990, 1996 and 1999. The first three bands are called the visible band, which reflect the Red, Green and Blue colours. The fourth band is the infrared band, the fifth is the near infrared, sixth is the thermal band (not used in the land use classification) and the seventh band reflects part of the infrared spectrum. The images of the years 1990 and1996 were acquired in May in both years thus represent similar seasonal surface patterns in terms of land use and vegetative cover. The image of 1999 was acquired in August, and therefore displays different seasonal surface patterns. The GIS analysis was supplemented by a household survey data were integrated into GIS by (IDW) method. In addition information from historical documents, governmental reports and scientific articles have been used in the compilation of information regarding the population on the Al Faria'a area. This refelectd to the demand for unification of interpretation by literature reviews, official reports and statistics, and survey data, the equivalent of ground trusting in remote sensing analyses.

Image processing

Processing of digital image involves their manipulation and interpretation (Lillesand 1994). Analysis of radiometric-sensed data used on a 2-step process of Radiometric Correction and Geometric correction, was used to derive results based on image processing to analyze remotely sensed data. Radiometric correction implied synchronization of all images to 8-bit data, geometric correction focused on geocoding all of the remotely sensed data and ancillary data are geocoded to the Universal Transverse Mercator (UTM) projection. In order to attain precise results all the satellite imagery were rectified to the SPOT scene 1997.

Classification

Classification of land use / land cover include supervised approaches based on spectral pattern recognition and survey data on farming fields. Supervised classification provides a statistical description of land use /land cover based on a class structure and training data selected and provided in a signature table. In this study various classification algorithms were tested to assess the suitability of each to classify the Jordan Valley area with its unique nature and reflectance characteristics. The two classifications that were used in this study are minimum Distance to Means Classification Algorithm as parametric rule and Parallelepiped classification algorithm as non-parametric rule. The parametric rule focuses on statistics and makes assumptions on the distribution form of the data, while the nonparametric rule evaluate whether pixel are in the region or not and makes no assumption of the distribution form of the data.

Change Detection

The assumption in using remotely sensed data for change detection is that changes in the land cover result in significant differences in the remote sensing measurements between two or more dates (Abuelgasim et. al 1999). The change detection approach compared to a post classification comparison. The first step was to classify and rectify Land sat scenes. Both classified maps were there compared on a pixel-by-pixel basis by subtracting one thematic map from the other. The output maps have 255value (8bit data), which shows the change between the classes. Only the change in the vegetation was displayed on the thematic maps Since the major land use / land cover changes in the Jordan Valley is vegetation.

Integrating the Socio economic data

Inverse distance weighted method (IDW), was used to create surfaces from the data points. In this method the observational points are weighted during interpolation in a way that the influence of one point relative to another declines with the distance from the new point. Weighting is assigned to observational points through the use of a weighting power that controls how weighting factors drop off as the distance from new point increases. The greater the weighting power, the less effect origin from points far from the new point during interpolation. As the power increases, the value of new point approaches the value of the nearest observational point (ESRI web page 2002).

Further Application of GIS and Farming System Development

Using GIS allow analysing different components of the farming system; the following table (Table 1) shows some application of GIS in assessing the current and future situation of the farming system development. GIS offers farmers various opportunities to increase production, reduce input costs, and manage the land in their care more efficiently. From handheld computer mapping in the field to the scientific analysis of production data at the farm manager's office, geography plays a part. These examples of applications of GIS at the farm level are meant to provide users, with some ideas for implementation in collecting data in the field, combining agricultural data from different sources, geographic data interpolation for agriculture analysing, spatial data on the farm and interpreting and delivering results for farm management (Albert Lin, 1994).

GIS analysis of Al Faria'a basin

One of the major aspects of this study focused on changes in the land use in the study area during the years 1990, 1996, and 1999? In which classes of the land use these changes occurred and, which development in the farming system took place during the last 10 years. The statistical results of analysis of Land sat TM scenes obtained on May 26, 1990 and May 18, 1996 is given in Figure 2 and 5. The thematic maps indicate that the dominant land use / land cover in Al Faria'a basin was bare rock followed by bare field and scrub area respectively. Vegetation represented about 4% of the study area in the year 1990 and about 5% in 1996. A summary about the area of each land cover / land use pattern in the farming system in Al Faria'a is given in Figure 2.

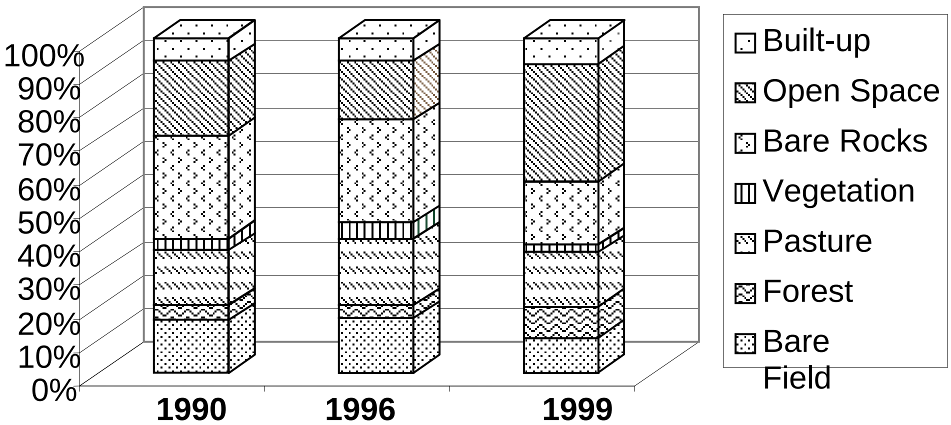

Figure 2: Development of land use cover (%), Al Faria'a basin, Western of the Jordan Valley, 1990, 1996 and 1999

Eight land use / land cover classes were successfully discriminated. Bare rocks and bare fields have the highest coverage within the classified scene. The increasing in the vegetation cover in the basin comes mainly because of the beginning of the peace process and the farmer getting some of their water rights from the Israeli specially after signing the Oslo agreement at the end of 1993.

Table 1: Some applications of GIS in farming system development.

GIS application in farming system	Description
GIS data conversion for water and waste water systems	With GIS it's possible to assess the current and future demands on water and sewer lines. The GIS can calculate sewage flows by combining land use, total population, and employment data for each "sewer shed."
Forestry	Incorporation of satellite remote sensing into forest inventory and mapping allows updating inventories more frequently and at less costs than conventional methods. Successful implementation of will mean more accurate field data for tactical and operational planning.
Spatial Analysis & GIS Modelling	The new spatial analysis tool helps to discover the "hidden" information in the spatial data, whether it's in forestry, marketing, road planning, or countless other fields that depend on GIS. GIS helps to determine the total fruit crop acreage. This helps to better understand marketing positions and to price and promote products (ESRI, 1999a). GIS lets farmers perform site-specific spatial analyses of agronomic data.
Agricultural Risk Assessment with GIS	GIS allows scientific analysis and an ultimate calculation of risk that can vary across an agricultural landscape. Incorporating historical climatic data, claim type, and degree data allow a more accurate picture, with the a fairer assessment for farming clients (ESRI, 1996).
Post Harvest Processors and GIS	Companies and institutions in the industry that process raw food materials into more recognizable food products often manage huge volumes of commodities and assets across large distances and through many locations. Rapid data management and exchange between locations requires integrated GIS software solutions built around a robust data server (ESRI, 2001a).
Building Agricultural Land Management Scenarios with GIS	Either at the local farm level or at national scales, events outside of the control of the farmer can have substantial impact on his livelihood. Climatic change, increased population pressure, legislation controlling certain farming activities and commodity prices are but a sample of events that need to be considered. The future solution comes in the form of computer modelling and implementing a GIS to take into consideration the natural variations found in any piece of farmland (ESRI, 1999b).
Agro biodiversity and GIS	GIS offers at the agro biodiversity level exciting possibilities that include the documentation of sites and locations of potential collection areas based on varying biophysical parameters and for the assessment of risk to genetically diverse locations. Utilizing GIS in a coordinated manner is a management tool for the exploration, exploitation, and conservation of genetic material essential to the development of improved varieties of basic food commodities (ESRI, 2001b).

Results

Land use change has taken place in the context of the farming systems development adjacent to the Western Jordan valley. The physical barrier between two separate farming systems (arid and semi arid farming systems), historical cultural, social and economic legacies continue to affect farming systems. Several factors affect the farming system in the basin, mainly the vegetation cover and its changes. The results from applying post classification comparison change the detection maps. Only the vegetation cover was displayed in these maps (Figure 3,4 and 5). Figure 3 shows the change from vegetation to other classes between May 26, 1990 and May 18, 1996. Figure 4 shows the change from vegetation cover to other classes between May 26, 1990 and August 15, 1999 and figure 5 shows the change from other classes for the same date. In addition Figure 5 show all the possible changes between land use / land cover classes for the multi date scenes.

Explanation Land Cover Changes 1990-1996

The results discussed in this section concentrate on the land cover changes detected using satellite image for 1990 and 1996. Significant changes are the emergence of land uses associated with national policies, and the expansion of the vegetation cover.The results of the study indicate that there is an increase in the vegetation cover with about 40 % of the vegetation area in Al Faria'a Basin during this period as shown in Figure 3. The increase in the area of the vegetation cover was not a consequence of the expansion of smallholder agriculture as would be indicated by the concerns of national policy-makers and donor agencies, or an increasing in the investment projects in the area, but an increase of the total green area and the biodiversity.

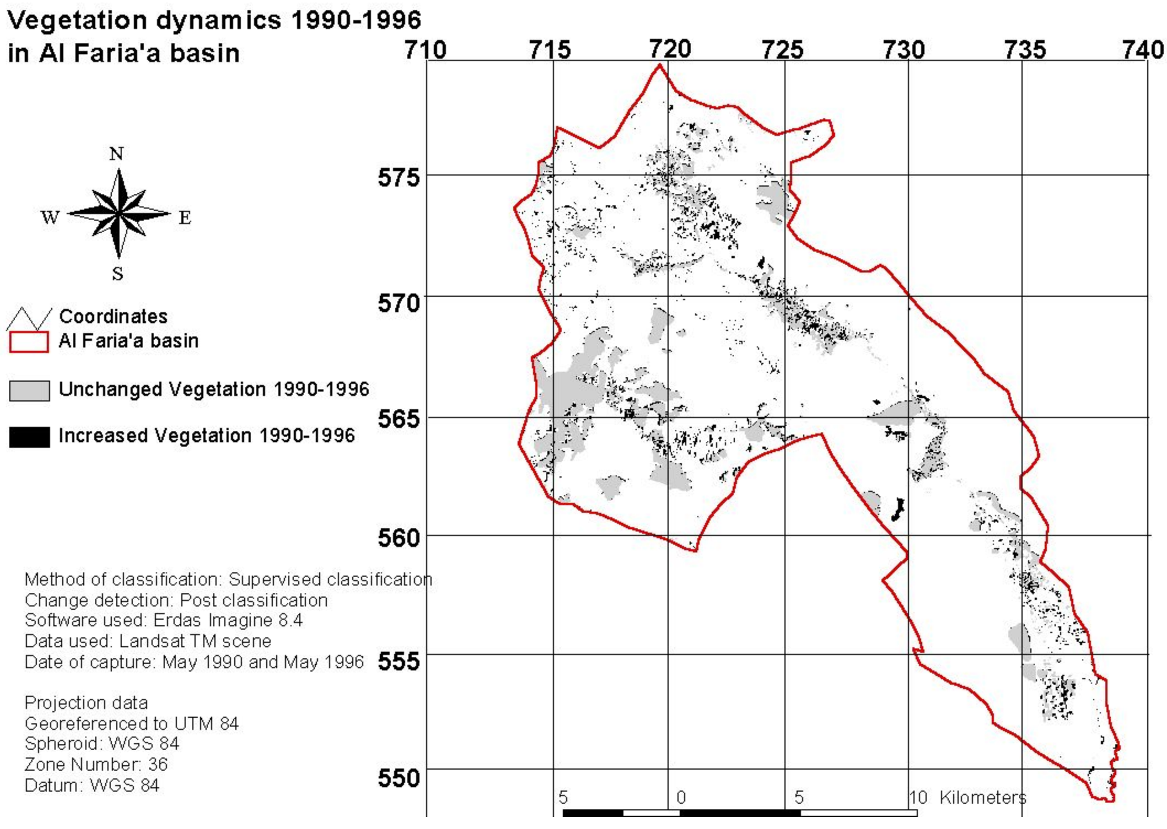

Figure 3: Change detection/ land use change, Al Faria'a basin, Western of the Jordan Valley, 1990-1996.

Explanation of Land Cover Change 1996-1999

The results indicate that there was a decrease in the vegetation cover in Al Faria'a basin deriving that period, but the seemingly decline of the vegetation cover (Figure 4) is only a result from Seasonal differences in imagery. The August scene (1999) represents the dry season in this part of Palestine; while the May image (1990, 1996) captured the wet- season appearance of the landscape. These differences were problematic regarding change detection. In fact there was an increase in the vegetation cover between 1996 and 1999, which was higher than the increase between the years 1990- 1996. The vegetation cover derived from the classification of Land sat scenes obtained in May 1990 and 1996 represent perennial and annual vegetation in the valley, while Land sat scenes captured on August 1999 mostly represent perennial vegetation. An attempt to discriminate between the perennials and the annual vegetation was not possible and due to multiple growing seasons per year in Al Faria'a basin. One reason is that the annual crop field's distribution tends to change every year depending on the market demand and on the rainfall rates.

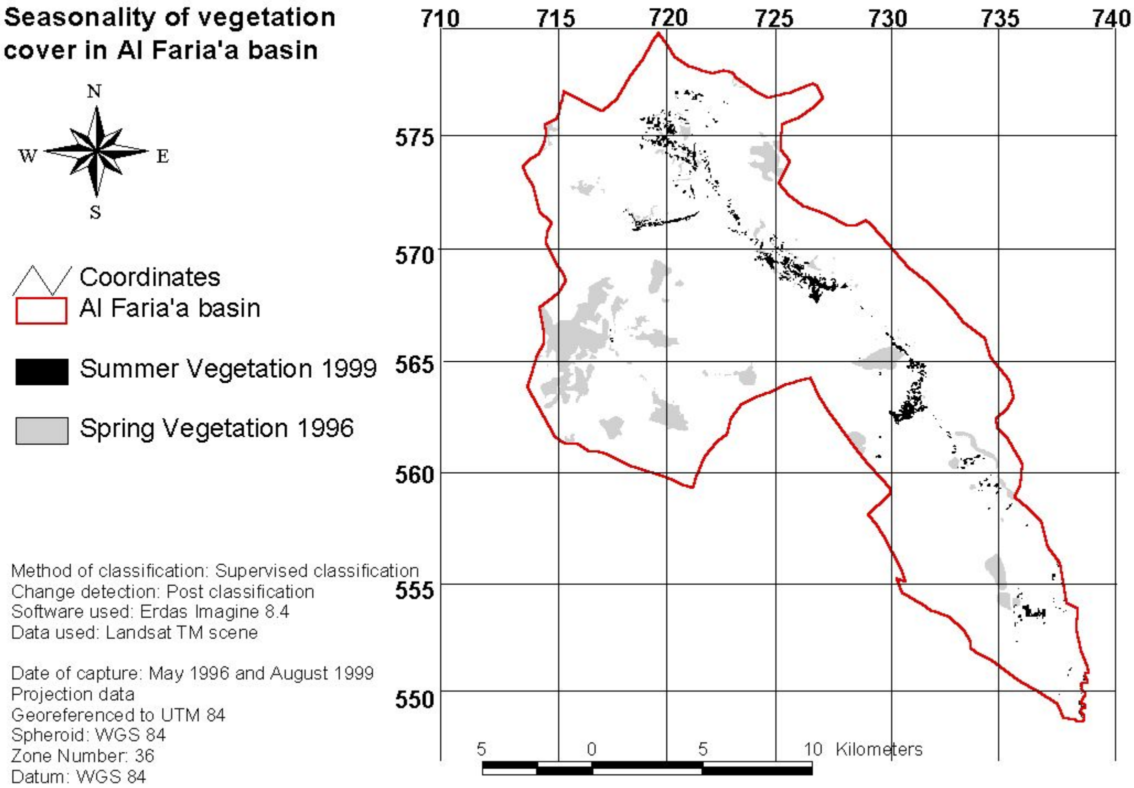

Figure 4: Change detection/ land use change, Al Faria'a basin, Western of the Jordan Valley, 1990-1999.

The increase in the vegetation area engendered an increase water abstraction during the last 10 years, where the annual abstraction ranges from 10.7 MCM in the year 1990 to 24.8 MCM in the year 99/00 (Palestinian water authority (PWA) records). The increase in the water abstraction from the ground water explains the increase in the vegetation cover and the deterioration in the water quality in Al Fraia'a basin deriving last decade. Data from the family system survey showed that about 11.90 MCM/year was used in the high quality water users group about 15.93 MCM was used by the brackish water quality users group and only 5.05 MCM of water was used in the mixed quality water users group in 1999/2000. The total amount of water used during the year 99/00 is estimated with 32.88 MCM in three farming system, which is more than the estimated amount that was used in the whole of Al Faria'a basin. The reason is that the amount of water in the PWA records doesn't include the wastewater, which is mixed with the surface water and used in the mixed quality water users group.

An example of integrating the socio economics results into GIS

The results discussed in this section concentrate on integrating the micro level data results into GIS in order to study the farming system development. The result of the socio economics data analysis shows that there is significant difference in the family income between the three faming systems in the basin. The results of the data analysis was integrated into GIS and interpolated (Figure 5) the results indicate that there are a differences between the faming system activities. The reason behind that are the resources availability (land and water), which has direct impacts on the living standard and farming system development in the basin.

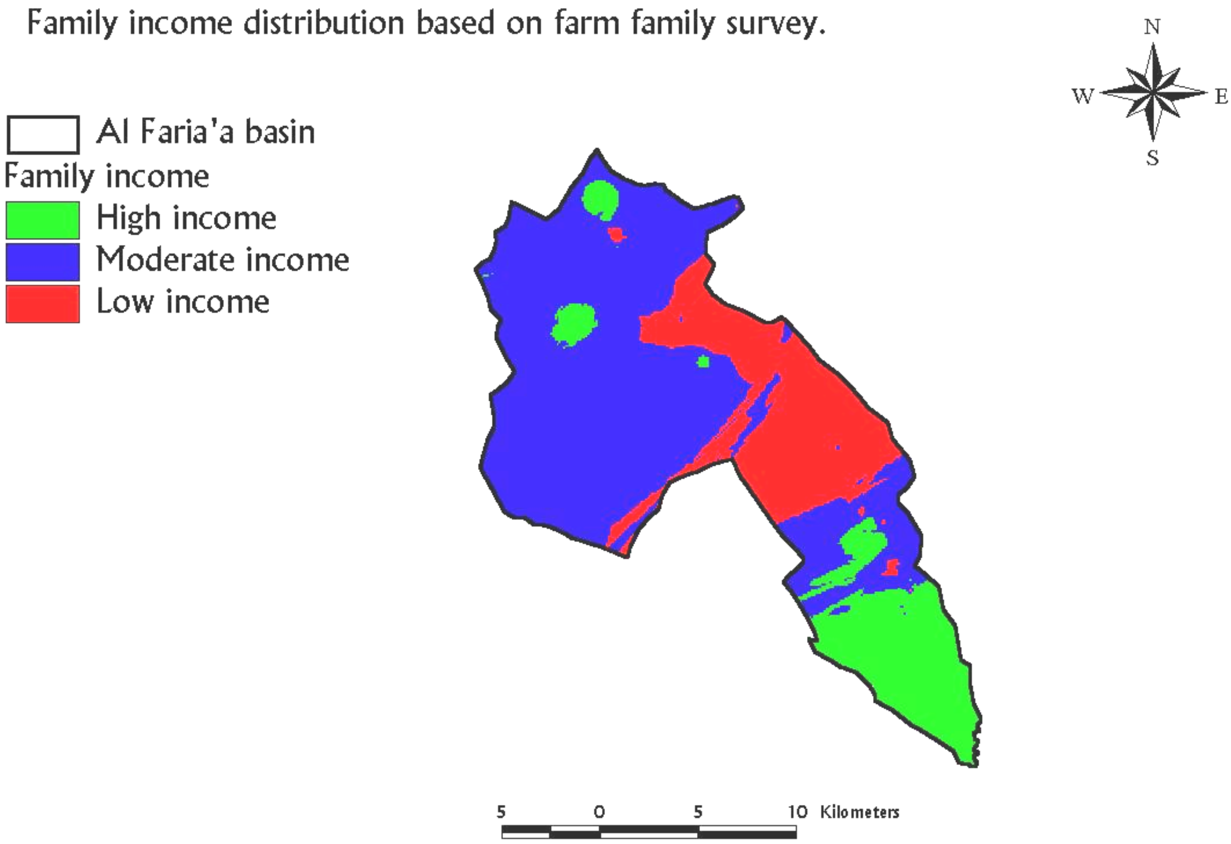

Figure 5: Integrating the socio economics results into GIS (Family income Jd/year), Al Faria’a basin, Western of the Jordan Valley, 1999/2000.

Conclusion

Satellite images and remote sensing data plays an important role in studying farming systems. Data from Thematic Mapper proves to be a viable source of information and have considerable benefit in producing land use / land cover maps for large areas. The vegetation in Al Faria’a basin seems to be very much controlled by the season, which was demonstrated as a high greenness peak and high expansion rates in May of every year. One of the most important findings of this work is that the vegetation expansion has increased at a significant rate in the last decade. Conversely, the water content has been continuously decreasing in the aquifers as a result of an increasing abstraction rate and a reduction in rainfall. These emphasize the role of alternative water sources such as the wastewater reuse, or a change in the agricultural irrigation methods in supporting agriculture in the basin. The change detection demonstrates that most of the changes in land use in the basin occurred in the vegetation cover, which may be a result of seasonal effects or of farmers changing the cultivated fields every year, while the size of urban or bare rock did not change much during the last ten-year interval.

The research also provide important facts about the land use and vegetation production in the basin and adds valuable information for decision-makers in planning and managing the land, especially with regard to sustain the agricultural growth. Integrating micro level data into GIS provides decision-support tool for farming system and natural resource management. Moreover, GIS helps to easily in discover information in the spatial data, whether it's in forestry, marketing, road planning, or other fields.

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