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Detection and mapping of the land use/land cover (LULC) changes in the "Jordan Valley" using LANDSAT imageries

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Abstract: Information about change is necessary for updating Land Use/ Land Cover LULC maps and the management of natural resources (XiaoMei Y, & RongQing L.Q.Y., 1999). The paper aims to map the changes in the LULC using different classification methods and to quantify the land use/ land cover change that took place in the Jordan Valley. The paper promotes the classification of LULC based on remote sensing information (obtained mainly through the utilization of Thematic Mapper TM and Enhance Thematic Mapper ETM scenes) to generate data products that are both appropriate to, and immediately usable within different scientific applications. The advancement of remote sensing technology in the developing countries such as Palestine encouraged the use of remotely sensed data to monitor the land use changes in an effective and more frequent manner. Three classification approaches were deployed and the appropriateness of the classifications to derive accurate land use maps for the pilot area using Landsat scenes were evaluated. The results showed that the use of spectral mixture analysis classification approach enhanced the classification accuracy and the ability to categorise the LULC on the pixel level.

Keywords: Land use/land cover, Classification, Supervised, Unsupervised, Spectral Mixture Analysis Land Cover, LANDSAT TM, CORINE Standards, Karaburun Peninsula

Introduction and Literature Review

Information about change is necessary for updating land cover maps and the management of natural resources (XiaoMei Y, & RongQing L.Q.Y., 1999). The information may be obtained by visiting sites on the ground and/ or extracting it from remotely sensed data. Many researches have been undertaken to develop methods of obtaining change information. Change detected from different temporal images usually reflects natural and human activity impacts. As we know, the Jordan River because its semi dissert climatic conditions the area is susceptible to desertification thus monitoring the land use change using multi temporal images will provide an indication on the rate and the magnitude of change.

Many studies have demonstrated the effectiveness of using remotely sensed data as a powerful tool to detect land use change for critical environmental areas, vegetation dynamics and urban expansion. In some instances land use / land cover change may result in environmental, social, and economic impacts of greater damage than benefit to the area (Mohsen A., 1999). Thus, data on land use change are of value to planners in monitoring the consequences of land use change on the region. Such data are of value to resource management and planning agencies in assessing current land use patterns and in modelling and predicting future developments.

Previous research on land use land cover mapping and change was carried out by the Applied Research Institute to map the West Bank using remotely sensed digital data. The institute used both visual interpretation by screen digitising the main landscape features (e.g. urban fabrics, road network etc.) and numerical interpretation by applying different image processing algorithms. Part of their work in this research was published in the Atlas of Palestine 2001. Another study carried out by Ben Gurion University of the Negev, employed NOAA/AVHRR images for monitoring the spatial and temporal changes of the vegetation cover in Israel including the West Bank. The study demonstrated the potential of NOAA images to distinguish different vegetation cover types and temporal variability of vegetation cover.

Shoshany and Kutiel (1994) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of their research were use to produce four vegetation cover maps that provided new information on spatial and temporal distributions of vegetation in this area and allowed regional quantitative assessment of the vegetation cover. In 1997, the Applied Research Institute of Jerusalem in association with the Israeli and Jordanian counterparts started to model the effect of water content on the vegetation dynamics in the Jordan Valley. In addition, the University of Yale through their irrigation project named SWAP has taken the Jordan basin as the study area. This project attempted to analyse multi-temporal TM scenes to investigate trends in irrigated and rain-fed agriculture, urban and suburban sprawl, and the hydrologic and vegetative responses of desert and steppe systems to acute temporal variations in climate (Yale 1998).

It is evident in all previous research that the Jordan Valley is a sensitive indicator of environmental conditions that exhibit rapid temporal and spatial changes in this area. Thus, frequent monitoring of vegetation is important to understand the environmental processes in this area.

Aim

The objective of the study is to use traditional and advance image processing algorithms to generate change information from multi-temporal data sets. The various methods are then evaluated for efficacy and suitability.

Objectives

The paper addresses two specific objectives listed as follows:

1. To investigate the ability of different classification methods on mapping and detecting LULC changes using remote sensing data, this involves two traditional classification techniques (supervised, unsupervised) and spectral mixture analysis.
2. To quantify the extent of land use changes on the vegetation cover using the multi temporal datasets.

Rationale

The scope of this research is to provide a comprehensive review of different techniques and algorithms that are used to derive useful information from remotely sensed digital images (obtained mainly through the Thematic Mapper and Enhance Thematic Mapper) to generate data products that are both appropriate to, and immediately usable within different scientific applications. Monitoring the changes in the Jordan Valley will reserve the rich natural resources and develop the agricultural potentiality. The Jordan valley has natural resources that can be utilized to increase the agriculture production and thus, has great importance to the development of viable Palestinian State.

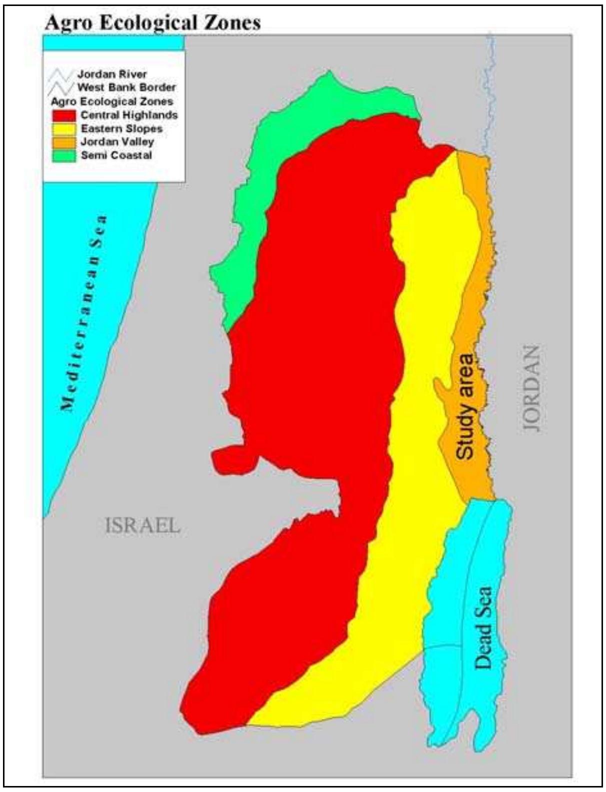

Figure 1. Agro Ecological Zones of the West Bank, the study area has the same geographical extent of the Jordan Valley ecological zone.

The cost effectiveness of using remote sensing technology and the advancement in computing techniques to extract LULC information from digital images makes it more viable for developing countries such as Palestine and so gives more reasons for studying the Jordan Valley area. Further more, many remote sensing techniques are still experimental, however, sufficient understanding and expertise has been acquired to supplement accurate data collection with large-scale mapping. Thus, the research will offer good chance to investigate the appropriateness of available techniques to derive LULC in the Jordan valley.

The monitoring of land change using data from the Landsat Thematic Mapper is adequate for general extensive synoptic coverage of large areas. As a result this reduces the need for expensive and time-consuming ground surveys conducted for validation of data. In general, satellite imagery is able to provide more frequent data collection on a regular basis, unlike aerial photographs which although may provide more geometrically accurate maps is limited in respect to its extent of coverage and expensive, which in turn means it is undertaken less often.

Moreover, the fact that we don't have access to all parts of the West Bank to obtain ground truth points and restrictions on obtaining aerial photos at fairly frequent level due to security reasons, force us to use Satellite remotely sensed scenes as the most reliable source of data to map this region.

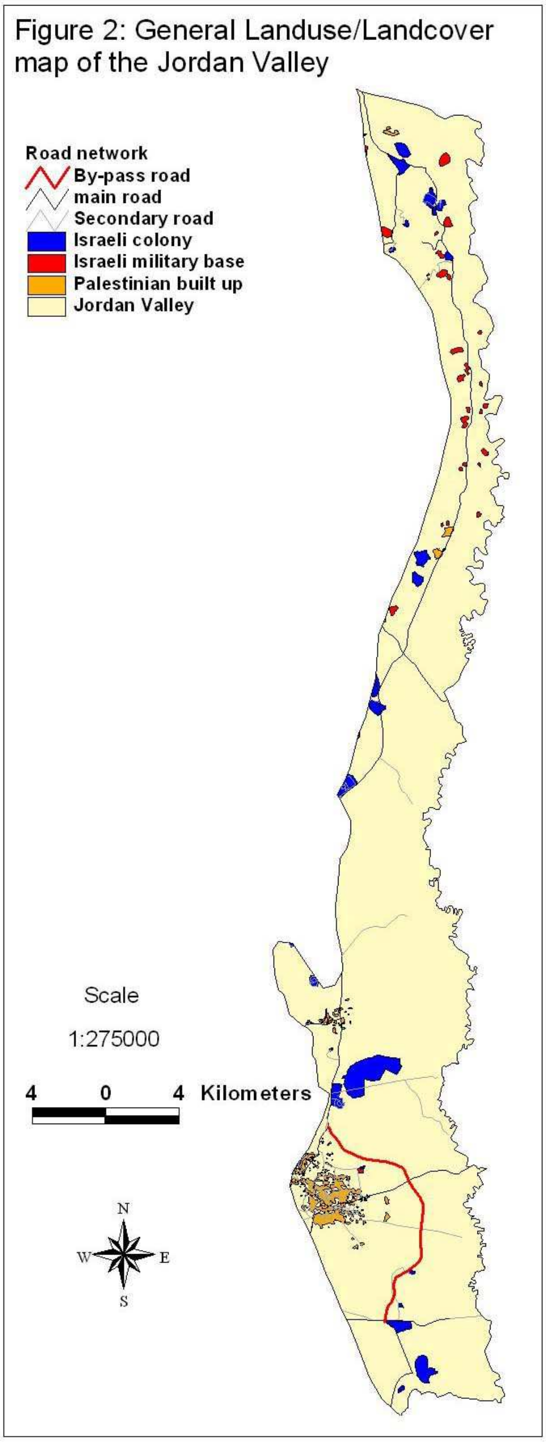

Figure 2. General Land use/Land cover map of the Jordan Valley

Background

Study area geographic location and physical characteristics

The Jordan Valley area, mainly due to its unique nature, is selected as study area. It is located between the eastern slopes strip and the Jordan River (fig 1). The study area geographic extent covers Al Auja and part of the Israeli agricultural colonies located to the north of Jericho city.

While to the south the study area extends to the Dead Sea (fig 2). The principal sources of water for agriculture and domestic purposes are the Jordan River and the groundwater. The region is known for its high temperature with an average minimum temperature in January range from 7.4o C to 19.7o C and average maximum temperature in August range from 22.4o C to 37.6o C (ARIJ, 1997).

The study area is characterised by rich fertile soils such as alluvial and brown soils loessial serozenms (ARIJ Report, 2001), which is combined with high temperature weather conditions, create prime agriculture land. The area grows a variety of crops (herbaceous vegetation subtropical and tropical fruits, such as citrus, banana, and dates as well as winter vegetables) and has multiple growing seasons producing two crop types per year in certain regions due to warm winter in the Jordan valley which provide optimum conditions to grow certain crops or fruits. Farmers in the Jordan Valley use the latest technology and agricultural methods such as green houses, different irrigation techniques and they diversify their crop cultivation every season depending on the market demand and the water supply.

The study area more recently was affected by severe water deficiency due to decrease in the annual rainfall over the West Bank. Consequently, the LULC pattern in this region has been affected. This further demonstrates the need for more research on this area.

Project Dataset

This paper utilized two types of datasets. The first type was remotely sensed data as a major data for processing and thematic map production. The second type was the supplementary datasets mainly obtained from the GIS datasets available at the Applied Research Institute – Jeursalem (ARIJ) spatial database.

Remotely sensed data

Landsat TM & ETM digital data of March 1, 1985, and May 5 2001 were employed in this study. This data set was supplied by the Mediterranean Agronomic Institute of Chania MAICH. Criteria to the selection of the multi-temporal Landsat data set involved assessment of cloud cover percentage, time of acquisition, and sensor type so that LULC mapping and change detection scope was optimized.

In order to obtain the maximum information from Landsat imageries used for image processing for land use/land cover change study, the selection of optimum Landsat TM images were taken. One of the advantages of the Jordan Valley scenes is that the chance of having cloud is rare thus the Jordan Valley is always successfully imaged by TM and ETM sensors without cloud contamination.

Supplementary data

High-resolution aerial photographs of 1:20000 scale covering the study area captured on May 1995 was used mainly to verify the accuracy of the Landsat imageries classification. Other supplementary data was incorporated to improve the accuracy of the derived LULC were listed as follows:

1. General land use map showing the main landscape features such as Palestinian urban development, road networks and Israeli colonies (fig. 2).
2. Rainfall map covering the study area with 50mm isohyets.

3. Digital Terrain Model DTM extracted and clipped from Stereo Panchromatic scene with grid size of 10 meter.
4. Ground truth points randomly distributed in the Jordan valley area employed to rectify remotely sensed data and to pinpoint training site for the supervised classification. It was not easy to collect ground truth data, thus, the only and the ultimate solution were to deploy ground truth data collected from previous field surveys.

Methodology

The demonstration of the stages and final results of the study area presented with focus on the major steps that were employed:

1. Image pre-processing
    a. Radiometric correction
    b. Geometric correction
2. Pre classification processing
    a. Training selection
3. Digital classification
    a. Supervised approach
    b. Unsupervised approach
    c. Spectral Mixture Analysis SMA
4. Accuracy Assessment

Image pre-processing

Digital image processing involves the manipulation and prepossessing digital images. Since this paper is based on image processing to analyse remotely sensed data the radiometric and geometric corrections were carried out.

Radiometric correction

Perfect remotely sensed data from satellites have not yet developed. So it is expected that error creeps into the data acquisition process and can degrade the quality of the remote sensor data collected (Duggin and Robinove, 1990; Lunetta et al., 1991 cited in Jensen 1996). Radiometric error in remotely sensed data might be introduced by the sensor system itself when the individual detectors do not function properly or due to atmospheric attenuation that the energy recorded by the sensor does not resemble that which was reflected by the terrain (Jensen 1996). The Landsat scenes used in the research were radiometrically corrected so there is no need to repeat the process that may bias the quality of the spectral data. By checking the header of Landsat imageries it was found that Landsat TM 1985 was acquired as 8-bit data where the Landsat ETM 2001 was captured as 16-bit data. For later processing Landsat ETM 2001 was synchronised to 8-bit data by rescaling the image.

The images were normalised. The spectral distribution of TM bands of Landsat ETM 2001 were normalised to Landsat TM 1985, which was chosen as a standard scene. This radiometric correction was conducted because it is impossible to obtain radiometric measurements for historical Landsat images. In such cases the only way to have images with approximately the same radiometric characteristics is to run image match equation. The purpose of image normalisation was to reduce variations in pixel brightness between different images acquired at different dates so that variation in spectral reflectance could be interpreted as real change on the landscape.

Geometric correction

Originally, all of the remotely sensed data and ancillary data are geocoded to the Universal Transverse Mercator (UTM) projection but to attain precise results all the satellite imagery were rectified using Ground Truth Points GTP collected from previous field survey carried in the study area. As a first step, satellite scenes were loaded in to Erdas Imagine software then geometric correction was run to rectify the satellite scenes to Universal Transverse Mercator (UTM) map projection. Rectification would correct the distortion within the scene as well as georeference the scene to UTM co-ordinate system. The first scene to be geocoded was the Landsat 1985 scene. Twenty-five ground control points (GCPs) were collected with Root Mean Square (RMS) equal to ±13 for which map co-ordinates were known. The recording was done on image to GCP base, where input GCPs from the Landsat TM 1985 scene was made to agree with reference GCPs. At the same time the image was resampled to 30 X 30-m pixels using the Nearest Neighbour rule. The points were precisely collected on the road network intersections and spatially well distributed features to guarantee precise transformation without twisting or geometric error. Polynomial transformation model was adopted due to its simplicity and because such a model is highly recommended for flat areas such as Jordan Valley.

The same procedure was carried out to rectify the Landsat ETM 2001 scene. Again around 30 Ground Truth Points (GCPs) were collected in order to have precise Landsat scene that are rectified to the same reference scene and resampled to 30x30 m pixels using Nearest-Neighbour resampling technique. The results of these transformation models are listed in Table 1.

Table 1. Landsat scenes Root Mean Square Error

NO.	Landsat scene	No. of GCPs	RMS
1	Landsat 1985	25	13
1	Landsat 2001	30	10

Classification approaches

Classifications procedures were applied on each Landsat scene separately by using different classification methods including (1) hard classification using supervised and unsupervised classification (Erdas Inc., (1999). (2) Spectral Mixture Analysis that often involves the use of ancillary information (Chart 1).

The first approach used was the unsupervised classification where the classification is based on the aggregation of the classes depending on the spectral reflectance. The iterative Self-Organising Data Analysis Technique (ISODATA) was employed as a clustering algorithm. ISODATA requires relatively little human input to specify few criteria before running the algorithm. These steps are as follows:

First step, specify the maximum number of clusters to be identified (Cmax). Ten clusters were obtained, and then the number was reduced by splitting and merging of classes depending on the image spectral reflectance. Second step, identify the maximum percentage of pixels whose class values are allowed to be unchanged between iterations (M). The ISODATA algorithm terminates when this number is reached. Third step, specify the maximum number of iterations (T), where ISODATA classify pixels and recalculate cluster mean vectors. Finally, specify the maximum standard deviation not to be exceeded during the classification. In the first iteration, each candidate pixel is compared to each cluster mean and assigned to the cluster whose mean is closest in euclidean distance. During the second iteration, a new mean is calculated for each cluster based on the actual spectral locations of the pixels assigned to each cluster. After the new cluster mean vectors are selected, every pixel in the scene is once again assigned to one of the new clusters. The split and merge process continues until there is little change in class assignment between iterations, the T threshold is reached or the maximum number of iteration is reached (M). Then the spectral classes were identified by comparing the classified image to ground truth points or aerial photos, the next step is to combine and label the spectral clusters into information classes.

Training site selection

Training sites were selected within the image that are representative of the land use / land cover classes of interest. Five to ten training sites for each class were collected and merged to give the best representation of the class spectral reflectance. Much care was taken to sub divide semi natural areas to two classes to reduce the topographic effect, hence, semi natural areas in the shade shows different spectral reflectance from semi natural areas exposed and illuminated by the sun. It was obvious that introducing prior knowledge especially about the topography aided in collecting separable signatures. Much attention was given to pick homogeneous areas in the Landsat image to ensure good classification results. Moreover, the training sites were trained with minimum number of pixels for each class sufficient to compute the variance-covariance matrices required by some classification algorithms. The ancillary data (Ground Control Points and land use layers) were converted from shape file format to Arc / Info format, which is readable on remote sensing software. These files were then displayed over the Landsat scenes to aid in picking representative training sites.

The second approach is the supervised classification where minimum distance to means, and maximum likelihood classifiers were run on the landsat scenes (TM & ETM). This approach is totally dependent on the spectral pattern recognition (Lillesand, 1994). The supervised classification technique is preferred, because the data of the study area is known and the prior knowledge about the nature of the study area was available. 14 training area were used for the supervised classification of each image. These training areas were delineated from a false colour composite image. These training sites represent agricultural areas, semi natural areas and water bodies. To avoid misclassification, these training areas were homogeneous. Ancillary data such as aerial photos, ground truth points, and DTM were considered during the selection of training areas in order to obtain the best accuracy of the classification results.

Steps of Classification Procedures

The classification scheme given in chart 1 shows the top down steps followed to produce the land use / land cover thematic maps. The first step was to define specific land use land classes within the study area to be delineated as output classes. The second step was to define the remotely sensed data with its entire characteristics (sensor type, geometry, resolution and etc.). The third step was to define the relevant ancillary data that could help to attain accurate training sites to train the remotely sensed data. These ancillary data were Ground Truth Points (GCP), aerial photos, Digital Terrain Model (DTM) and irregular polygonal Arc/Info coverages. The forth step, three classification schemes were adopted supervised, unsupervised and Spectral Mixture Analysis (SMA). Unsupervised classification employs ISODATA algorithm to derive land use / land cover classes. On the other hand, the supervised classification uses a non-parametric Parallelepiped algorithm coupled with a parametric decision rules Minimum Distance to Means and a Maximum Likelihood. The output classified thematic maps were geometrically corrected by running the transformation matrixes in order to attain planimetric maps.

Actual change can be obtained by a direct comparison between classification outcomes from one date with that from the other date. Temporal changes that have occurred between the two dates can be measured by performing change matrix (Howarth and Wickware, 1981 cited in Somporn S., 1995). However, in this study only direct comparison between the two scenes was performed to identify the temporal affect.

The third approach is the Spectral Mixture Analysis (SMA). This approach was adopted to perform an inventory of landscape objects that are significantly smaller than the size of the pixel in remotely sensed imagery. The adoption of this classification approach was deployed to test the appropriateness of this technique to derive accurate land use maps for the pilot area using Landsat images. TM and ETM bands were used interactively to locate pure pixels within the dataset. The pure pixels are derived through Pixel Purity Index (PPI) which is a means of finding the most 'spectrally pure' (extreme) pixels in multispectral and hyperspectral images (Boardman 1994, cited ENVI tutorial). The pixel purity index is computed by repeatedly projecting n-dimensional scatter plots onto a random unit vector. The PPI is typically run on a Principal Component transformation image excluding noise bands. The extreme pixels in each projection are recorded and the total number of times each pixel is marked as extreme is noted. A 'pixel purity image' is created in which the DN of each pixel corresponds to the number of times that pixel was recorded as extreme. These spectrally pure pixels derived from the multispectral images are plotted in an n-dimensional Scatter plot. The n-Dimensional scatter plot allows for interactive rotation of data in n-D space, selection of groups of pixels into different classes (Boardman 1994, cited ENVI tutorial). The Scatter plot of the pure pixels of TM and ETM bands enabled to locate, identify, and cluster the purest pixels and most extreme spectral responses in the data set. Here in this study this procedure was followed to isolate different groups of pixels representing different materials. Several groups of pixels such as soil (bare fields), vegetation areas and water bodies were isolated and mostly projected at the corners of the scatter plot or completely isolated in the interactive scatter plot.

Accuracy assessment

Once the classification was done, further knowledge of the area was obtained through the use of previous data collected from the field. These data provided better detail as to what types of land use are likely to be present within the study area, especially in the location where heterogeneous canopy is distributed. High-resolution aerial photos were used as valuable source of data for the purpose of validating the classification accuracy. Hence, it was impossible to conduct field surveys due to the unstable political situation, where the Israeli Defense Force IDF imposing closure and siege around the Palestinian cities and denying the Palestinians the right to access most of the Occupied Palestinian Territories OPT.

Results and Discussion

To investigate the land use change in the Jordan valley intuitive analysis was implemented on the Landsat TM 1985 and Landsat ETM 2001 images. This involves the use of two classification techniques to derive LULC inventories for the two years in order to compare the changes on the spatial trends during sixteen years.

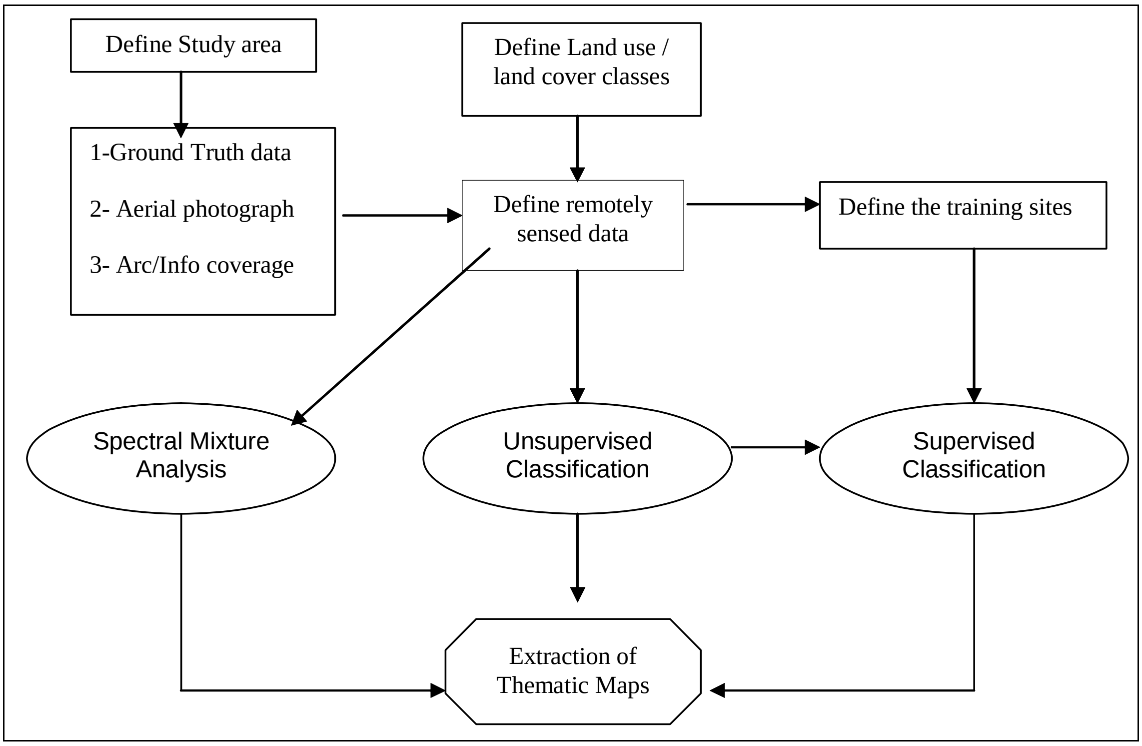

Chart 1. The flow chart shows the major steps of the study

Supervised classification results

Supervised classification was used to derive general LULC of the pilot area (figs. 3 and 4). Before starting with the analysis using the above method unsupervised classification (isodata algorithm) was run in order to attain pure spectral signature that represent real LULC. The modified signatures obtained from the unsupervised classification were used to derive ten LULC classes. Also pure signature was collected using ground truth points obtained from the field. The first level of CORINE nomenclature was adopted to produce standardized classes. Thus the ten classes were aggregated to three classes to have compatible and universal spatial data that can be stored in databases for other scientific purposes. Visually, the output results were fairly good and represent the real classes in the field to about 70 to 75 percent. It was planned that another field survey should be conducted in order to increase the accuracy of the derived thematic maps. Unfortunately, due to limitation on time and movement, carrying out the field survey was impossible. Table 2 portray the attributes and the areas derived from the processed Landsat TM scene 1985 for each land use class, while the attributes derived from Landsat ETM 2001 was given in table 3.

The classification of the Landsat TM 1985 scene, given in Table 2 shows that the Jordan valley is occupied by bare rocks and semi natural vegetation. Chart 2 shows that only 13 percent of the valley is occupied by vegetation while the rest is semi natural vegetation (bare fields and grazing land). The classification of Landsat TM 2001 scenes shows that the vegetation progression was increased from 13 percent in 1985 to 27 percent in 2001(chart 3). However, this increase in the vegetation does not only represent the agricultural areas but also the natural vegetation. There was no mean to differentiate between the two types of vegetation due to spectral reflectance similarity. Of course, this implies that the annual rainfall for the year 2001 was higher than that on the year 1985. Thus, higher vegetation intensity and progression was depicted from the analysed Landsat ETM 2001 scene.

The results imply that the Jordan valley is very sensitive to the annual rainfall levels where the aridity index shows that during drought seasons the greenness level decline dramatically in the Jordan Valley. The interpretation of the produced thematic data shows that the increase in the vegetation cover can be attributed to the high rainfall levels in year 2001 and to the excessive utilization of the surface and groundwater resources by the Israeli agricultural colonies to cultivate vineyards, banana and citrus.

Table 2. The attribute data derived from the supervised classification of Landsat TM scene, captured on 1985

Land use / land cover	Histogram value	Area in hectare
Agricultural Areas	58,232	5,233
Semi Natural Areas	388,114	34,878
Water Bodies	91	8

Table 3. The attribute data derived from the supervised classification of Landsat ETM scene, captured 2001

Land use / land cover	Histogram value	Area in hectare
Agricultural Areas	119,680	10,765
Semi Natural Areas	324,164	29,159
Water Bodies	2,096	188

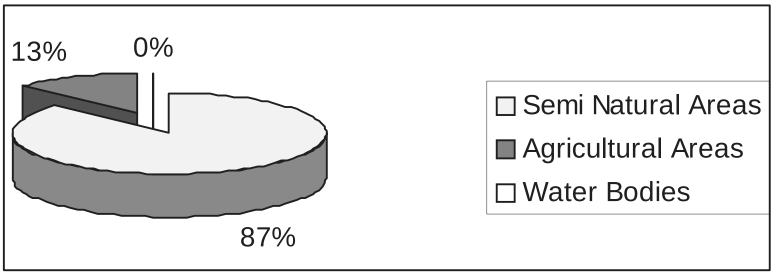

Chart 2. Land cover statistics derived using supervised classification of Landsat TM 1985 of the Jordan Valley

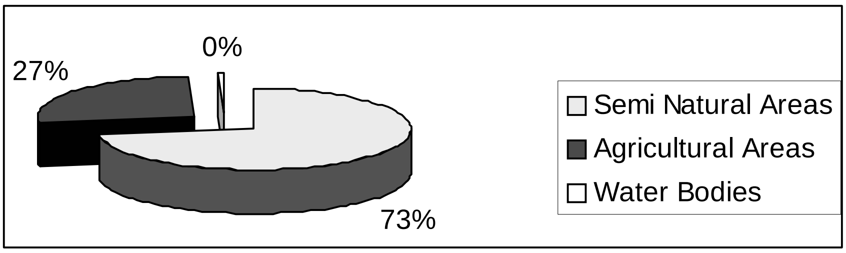

Chart 3. Land cover statistics derived using supervised classification of Landsat ETM 2001 of the Jordan Valley

The interpretation and the analysis of remotely sensed data (Landsat TM and ETM) were dependent on the multispectral characteristics of the scenes. However the large pixel size of Landsat TM (30 * 30 meter) make the classification is inevitably biased. Since, it is impossible in most of the cases to have landscape objects covering 100 percent the pixel area. This phenomenon is clearly found in the pilot area (Jericho ecological zone) where the land plots used for agriculture is smaller than the pixel size and share many other land use components such as urban development and bare rocks. In order to attain better results that represent accurately the real LULC, a new classification approach was applied, which is termed Spectral Mixture Analysis (SMA). It is worth mentioning that SMA classification is considered a new approach of remotely sensed data categorization on the pixel level that needs experienced technician and further results verification.

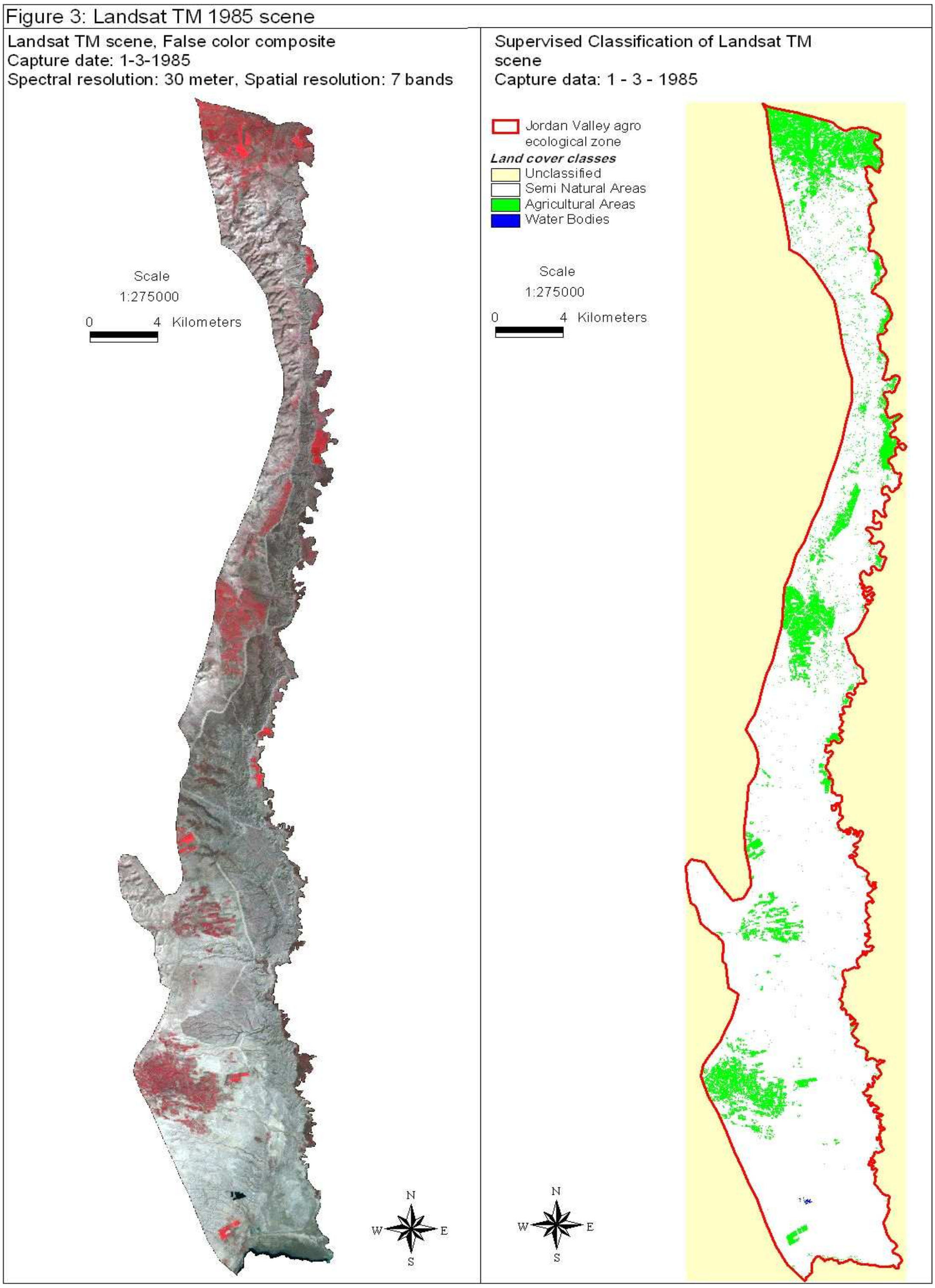

Figure 3. Shows landsat TM scene on the left side and the derived thematic data of the supervised classification on the right side.

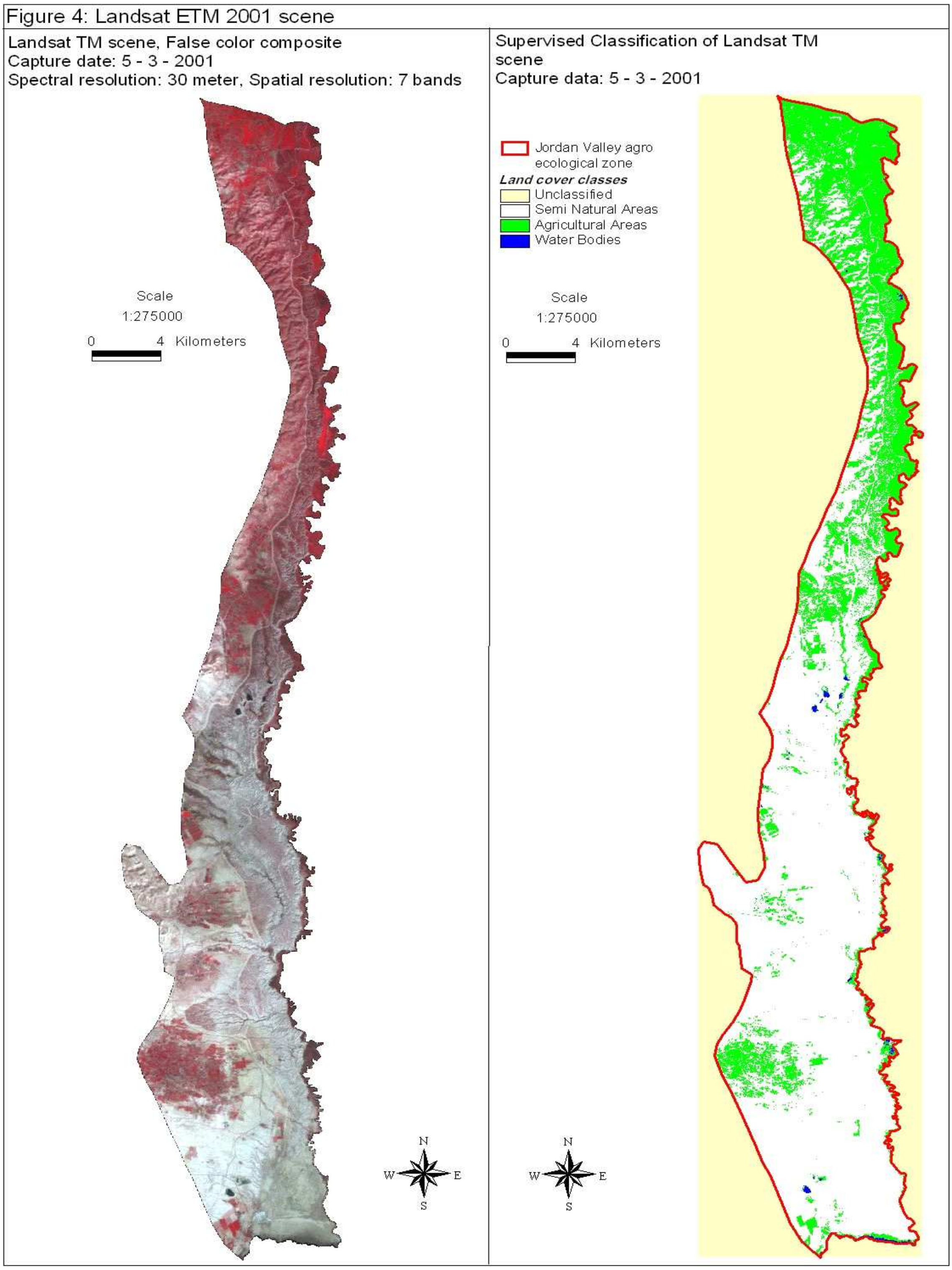

Figure 4. Shows landsat ETM 2001scene on the left side and the derived thematic data of the supervised classification on the right side.

Spectral mixture analysis

The mixed pixels in remotely sensed data are one of the main error sources resulting in poor classification accuracy using traditional classification methods. In order to improve classification accuracy, SMA has been used to handle the mixed pixel problems. Fig. 5 shows the extracted thematic data using the Spectral mixture analysis technique for the two scenes under investigation. Statistical data about the proportion of each end member in each pixel were derived from the thematic data and given in table 4, the data was aggregated to ten classes to simplify data reading. Each class starts with zero fractional abundance to 100 percent called pure pixel value. It is obvious, that most of the thematic data derived from the analysis is a mixture of many land use features and pure pixels are extremely rare (Boardman 1994, cited ENVI tutorial). This implies that the classification using spectral mixture analysis approach provide viable tool of quantitative and qualitative analysis of LULC patterns in the Jordan Valley.

Table 4. Landsat TM captured on the 1 of March 1985

Pixel value		Vegetation		Bare Rock		Water	
Minimum	Maximum	Pixel No.	Vegetation Intensity	Pixel No.	Bare Rock intensity	Pixel No.	Water intensity
0	0	13500	No vegetation	1200	No bare rock	12700	No water
0	0.1	27700		588400		596800	
0.1	0.2	48200		5700		19200	
0.2	0.3	66900		12300		33500	
0.3	0.4	663900		20200		38200	
0.4	0.5	61000		28800		47700	
0.5	0.6	46200		53700		51200	
0.6	0.7	23800		79800		49200	
0.7	0.8	11800		88600		47600	
0.8	0.9	9400		80900		42500	
0.9	1	7100		50700		35300	
1	1	56800	Pure vegetation	26000	Pure bare rock	62400	Pure water

Conclusion and Recommendation

The results of the study disclose five major findings as followings:

1. Automatic classification using the hard classification approach proved to be a good indicator to estimate the magnitude and the type of LULC in the Jordan Valley.
2. The vegetation in the Jordan Valley seems to be very much controlled by the season, demonstrated as a high greenness peak and high expansion rates in May of every year.
3. One of the most important findings of this research is the significant increase in the vegetation cover during the last decade. On the other hand, the water quantities have been continuously decreasing in the aquifers as a result of decline in the annual rainfall. This should lead us to think seriously about other alternative of water sources to support the agriculture in the valley or change the irrigation methods. Failure to do so would expose the agriculture in the whole region to a potentially devastating situation in the near future due to this unbalanced water use.
4. The results show that the vegetation cover is changed dramatically during the sixteen year. This phenomenon could be attributed to two reasons: firstly, the Jordan valley is very sensitive to seasonal effects and secondly because farming practices have been changed between the sixteen-year period.

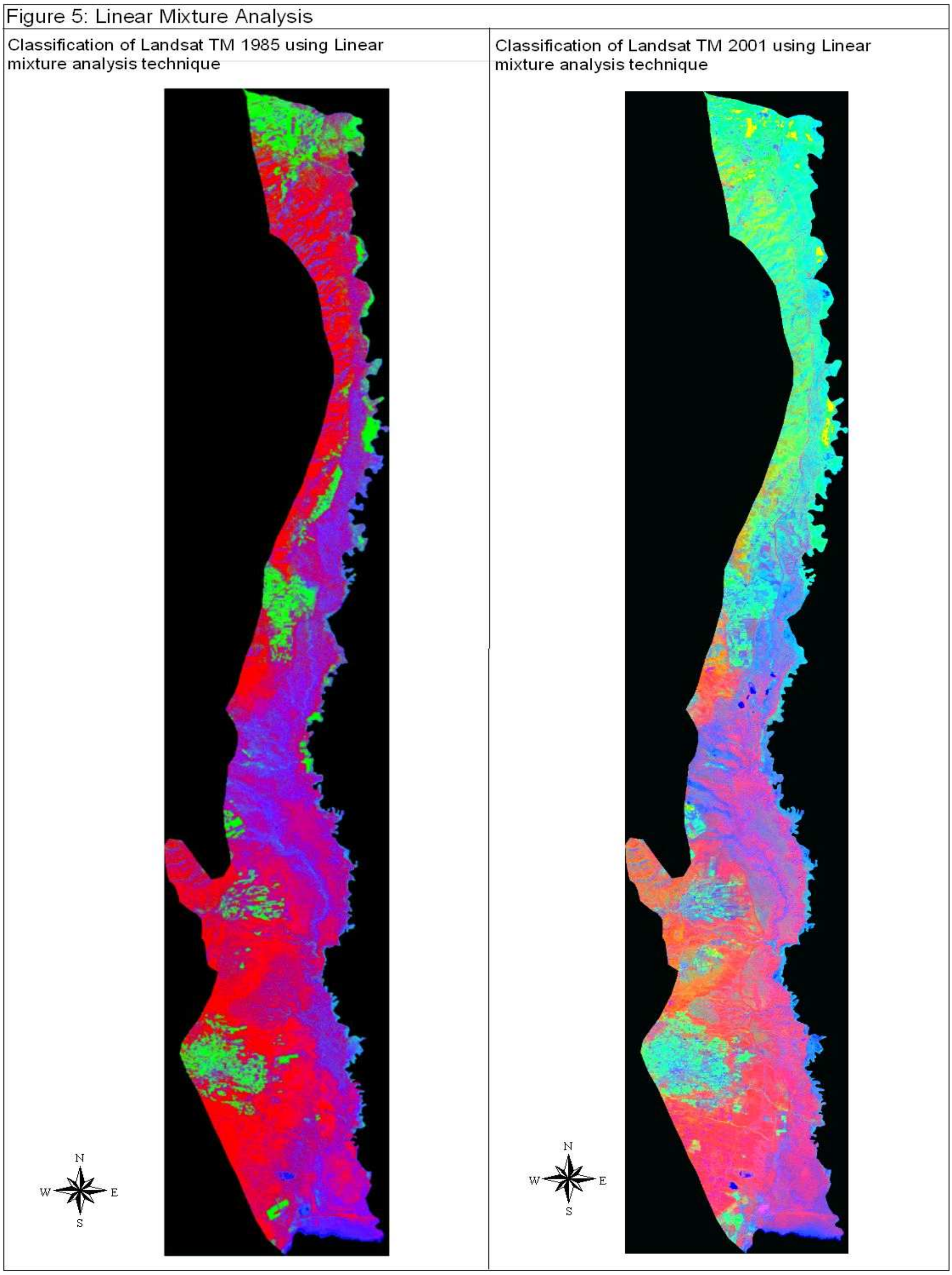

Figure 5. Shows the extracted thematic data for landsat TM 1985 (left) and landsat ETM 2001 (right) scenes using the Spectral mixture analysis technique

5. Spectral mixture analysis classification provides new prospective to acquire quantitative and qualitative information using remotely sensed data.

Finally, it is hoped that this study has provided the initial tools and background information about the automatic classification systems to produce quality thematic maps. It is expected that further work in similar studies would lead to greater understanding of image processing for LULC purposes. The value of digital processing has been proven to be very cost effective in such research and has been proven advantageous in previous studies that utilized Landsat data. This kind of data is increasingly suitable for use in developing countries such as Palestine, due to its consistency, reliability and availability. It may be concluded that the use of Landsat scenes for mapping LULC change in the Jordan valley area provided a satisfactory result if the appropriate techniques were used in data analysis. However, it is recommended to derive LULC on regular interval, so that the information can be updated through time.

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