A Proposed Simplified Method to Improve Land-use Mapping Accuracy

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Abstract: Updating land-use maps with current methods through aerial photos interpretation is costly and time consuming. This paper develops and proposes a systematic methodology to derive and update land-use classes for sustainable land resources. Ismailia Governorate is selected as a case study for the present work. This study utilized data sets obtained from several sources such as remotely sensed imagery, land-use maps, knowledge-based and soil maps. Landsat (ETM+ 2006) images were used, and enhanced using contrast enhancement. False color composite, different spectral ratio, also indices such as NDVI (normalized difference vegetation index) was implemented to decide the best band. The Optimized Index Factor (OIF) and correlation techniques were employed to determine the best band sets for classification analysis. Unsupervised and supervised classification methods were used. Spatial reclassification method was applied to increase maps accuracy. Six land-use/land-cover categories (urban, vegetation, waterlogged 1 and 2, bare/sand dunes/rocks, and water) were identified. Band set (2-NDVI-PCA) caused the highest classification accuracy. The highest overall accuracy and Kappa coefficient related neural network method is 93.04% and 80.65%. The obtained results from this study are expected to be beneficial to land evaluation studies and policy makers.

Keywords: accuracy assessment, remote sensing, land-cover, GIS, Landsat ETM+, land-use, knowledge-based approach, Ismailia.

INTRODUCTION

Land-use has generally been considered a local environmental issue, but it is becoming a force of global importance (Foley *et al.*, 2005). Unplanned changes of land-use have become a major problem and central issues in the study of global environmental change (Adger *et al.*, 2005). Land-use maps are useful tools for agricultural and natural resources studies as a base data. Due to dynamism of natural resources, land-use map updating is essential. Decisions concerning updating land-use for sustainable land and water management play a major role in the strategies for adaptation and mitigation of climate change. Land-use map updating is essential to overcome the problems of haphazard, air pollution, deforestation, urban growth, soil erosion, desertification, and loss of prime agricultural lands. Land-use and vegetation (o) is also one of the Jenny (1941) factors of soil formation (climate, cl; organisms, o; relief, r; parent material, p; and time, t) which influence the soil type and land evaluation. The function of land evaluation is to bring about an understanding of the relationships between the condition of the land and the uses to which it is put, and to present planners with comparisons and promising alternative options (Beek, 1980). However, a very important question that is not clear so far is "Is the current land-use mapping methodology worth worked for sustainable land and water management e.g., land evaluation". Traditional methods through aerial photos interpretation to produce such maps are impractical due to large amounts of data to be collected (in space and time) which make it costly and time consuming. The paper map, as a product of traditional mapping, appears to be increasingly irrelevant to many users and does not have a market with land managers and policy makers at different scales (Omran, 2008). Many maps are not being used for research and application because they are not available in digital format (Omran, 2005; Omran *et al.*, 2006). So, the potential of other forms of remote Sensing needs to be explored.

Temporal analysis of remote sensed imagery has the potential to identify land-use over large areas in a more consistent and efficacious manner. Data from Landsat Thematic Mapper with its spatial resolution, low cost of multispectral data and repeated coverage appear to offer possibilities and potential for land-use map production (e.g., Ramsey *et al.*, 2004; Clark *et al.*, 2001). The use of remote sensing techniques seems most promising to obtain actual land-cover information (De Gloria 1984, Anuta *et al.*, 1984, Chen *et al.*, 1986, Williams *et al.*, 1987, and Dawbin and Evans 1988, Cihlar 2001, Loveland *et al.*, 2003, Yang and Liu 2005). Remote sensing technique has ability to represent of land-use categories by means of classification process. Satellite remote sensing, in conjunction with geographic information systems (GISs), has been widely applied and been recognized as a powerful and effective tool in analyzing land-use categories (Ehlers *et al.*, 1990; Treitz *et al.*, 1992; Harris and Ventura, 1995; Weng, 2001). However, the question that not answers yet is: "How to improve the accuracy of the current methods of land-use mapping".

Many classification methods are exist to produce land-use maps, but the most used one is the maximum likelihood classification. Land-use mapping is significantly improved using combination of different techniques (Manier *et al.*, 1984). One example is to use knowledge-based approach which utilizes additional geographical data beside satellite images (Hutchinson 1982, Peddle and Franklin 1992, Janssen and Middeloop 1992, Bronsveld *et al.*, 1994) and GIS. To the best of my knowledge, producing land-use maps using neural network and knowledge-based approach is rare. So, the main objective of this study is "To develop a rapid procedure to produce a high land-use map accuracy by using knowledge-based approach, neural

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network, Landsat 7 ETM+ images, and GIS". To achieve this goal, land-use mapping method is to focus on the following research objectives:

1-Develop an appropriate image processing technique for developing and update the existing land-use data.
2-Realize an accurate land-use data base, containing detailed information on the spatial distribution of main agricultural crops, water, soil, and built-up area.
3-Define additional activities to improve the land-use classification accuracy and to get accurate land-use information.

Knowledge of the present land-use, agricultural area, as well as information on their changing proportions, is needed by legislators, planners, and local governmental officials to determine better land evaluation policy. The results may support policy-makers to achieve long-term sustainability of land and water resources in Ismailia Governorate.

MATERIALS AND METHODS

Location of the Study Area:

The study area is located in northern Egypt, Ismailia Governorate, between 31° 40' to 32° 50' Longitude and 30° 10' to 31° 00' Latitude, (Figure 1). The choice of the Ismailia Governorate implies that the local specific land-cover/land-use is represented. Environmental protection in Ismailia Governorate is faced critical problems due to several factors as the increasing population, demolishing natural resources, environmental pollution, land-use planning as well as others. The study area covers an area of 539426.43 Hectare (1284348.64 feddan).

Methodology:

Figure 2 shows the methodology used to improve the current land-use accuracy. Overall, the research methodology can be divided into the following major components: (i) data acquisition and collection; (ii) data preprocessing; (iii) classification scheme design; (iv) spatial reclassification; (v) accuracy assessment; and (vi) map presentation and analysis.

Data Acquisition and Collection:

There are a variety of data acquisition types that could be used and, normally, images with higher spatial and/or spectral resolutions are preferred for land-use mapping. But higher resolution data are generally more expensive. Therefore, there is a cost effectiveness issue that needs to be considered for any remote sensing project. Because of the budget constraint and the time availability, Landsat ETM+ imagery was chosen as the primary data source.

A reconnaissance field check was performed for the study area to get aquented with different landscape features; land-use and land-cover patterns. On the basis of the preliminary interpretation of satellite images, combined with results of reconnaissance field check, eight sample areas were chosen; El-Ballah, El-Ferdan, Abu Khalifa, New Salhiya, East Bitter Lakes, El-Manaif, Abu Swair, and Sarbium. The field surveys were guided with a Global Positioning System (GPS) receiver. The data collected during the field surveys were used for three major purposes: (i) to determine the major types of land-use in the study area, which helped design a land-use and land-cover classification scheme; (ii) to associate the ground 'truth' of a specific type of land-use with its imaging characteristics, which helped classify images and produce land-use maps; and (iii) to collect sufficient data for image preprocessing. In addition, visual analyses of the enhanced images were carried out with the assistance of field and ancillary data such as knowledge-based, existing land-use and topographic maps.

Fig. (1): False color composite of ETM+ satellite image for the study area

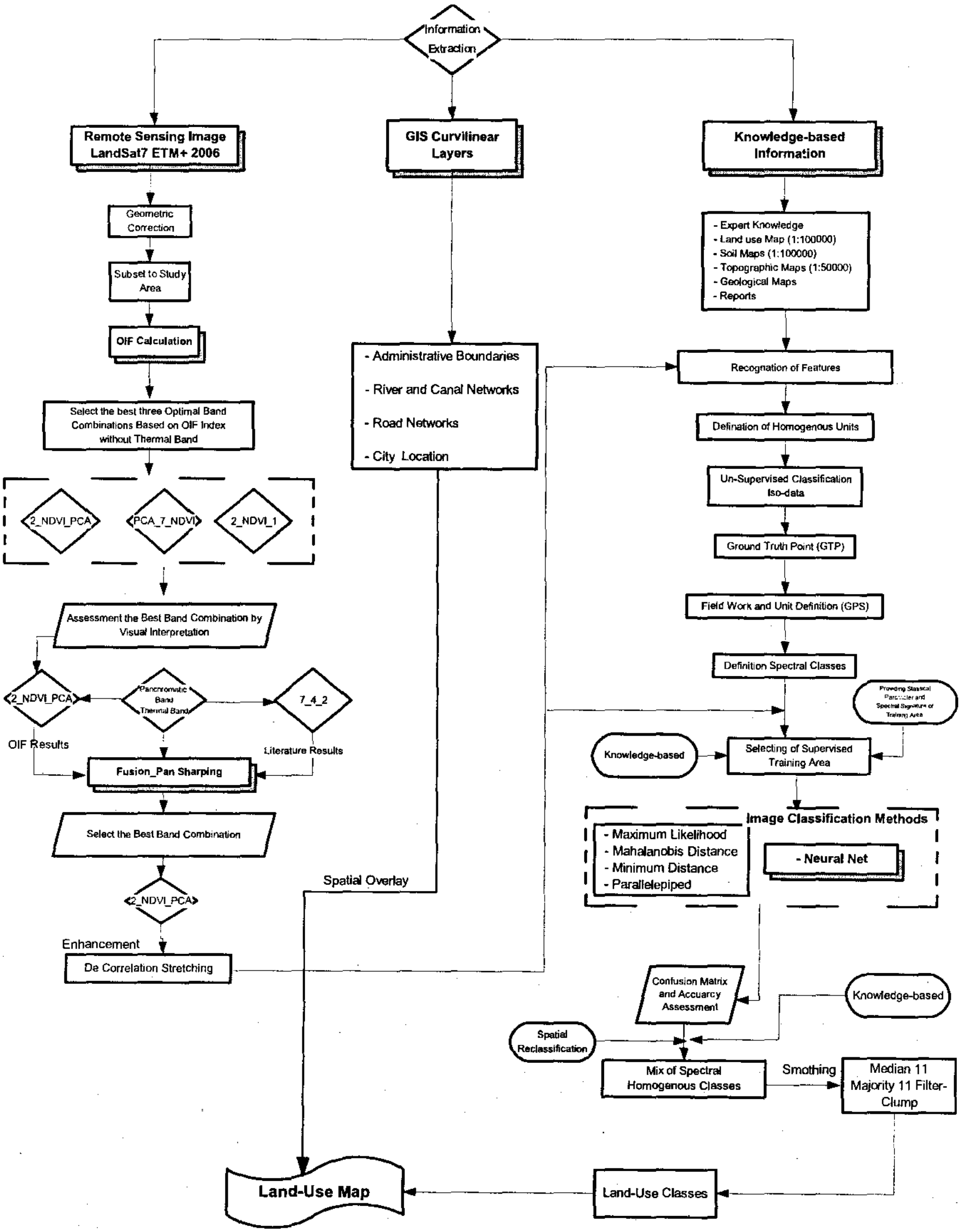


Figure (2): Schematic diagram for the research methodology steps

Data Preprocessing, Digital Analysis and Pan Sharping:

The Environment for Visualizing Images (ENVI 4.7) was used to process and analyze the data on a Personal Computer (PC) environment. Geometric correction was done for the image based on topographic map. Image to image registration was done in order to register the 2006 image. Keeping the root mean square error (RMSE) less than 0.5 pixels, an image to image transformation model (third order polynomial) and nearest neighbor resampling was calculated. Image enhancement was applied to improve the appearance of images for human visual analysis. For that purpose, band selection using Optimum Index Factor (OIF) was used for 2006 image. Because the Landsat 7 ETM+ image may be visually analyzed using only three bands at one time, we determined the three-band combination that had the greatest amount of variance within the scene by calculating the OIF (Jensen, 2005). All the bands (1-6 without thermal band) plus Normalized Difference Vegetation Index (NDVI) and Principal Component Analysis (PCA) were used to calculate OIF. The role of high OIF values is to give more spectral information of the object. The OIF ranked all possible three-band combinations of Landsat 7 ETM+ bands using equation (1).

$$OIF = \Sigma sk / \Sigma \, Abs(rj) \quad \ldots\ldots\ldots \quad Eq.1$$

Where:

s is the standard deviation for band k, and Abs(rj) is the absolute value of the correlation coefficient between any two of the three bands being evaluated.

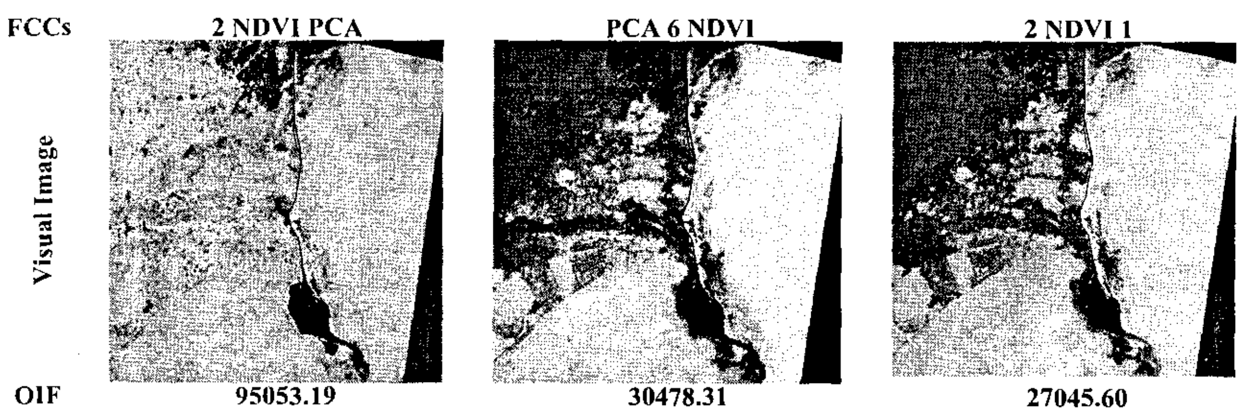
To determine the best band set, OIF and correlation method were used. 215 FCCs combinations are prepared to select the best images for land-use mapping. The OIF formula (eq.1) is applied for different spectral composite. The band combination with the highest OIF has the highest variance and lowest duplication for the scene, and thus contains the greatest amount of information about the scene (Figure 3).

According to Figure 3, the highest OIF (95053.19) is allied to band set: 2, NDVI and PCA. Correlation among bands demonstrates that the bands 2, NDVI and PCA are a suitable set for land-use mapping. The accuracy of classification is high when one uses 2, NDVI and PCA band set, instead of using all bands. It can be concluded that this is due to the high correlation among bands. Sabins (1996) stated that high correlation among bands means replication of data.

The image processing technique is not so simple methods need to be study about logically derived spectral information (absorption, reflection, emissive) about individual land-use. Color variation in the remotely sensed image due to different band combinations should be interpreted by considering possible absorption features. Fusion, pan sharping and decorrelation stretching tools were used to sharping the image. Decorrelation stretching is simple stretches applied to each band separately i.e., it allows to stretch the principal components of an image. It means that can turn the original image with poor contrast into one with a full range of brightness.

Classification Procedure:

In the third phase of the methodology, ISODATA (Interactive Self-organizing Data Analysis) algorithm was applied to avoid the impacts of sampling characteristics, and as a preliminary step to identify and classify spectral clusters from image data excluding the thermal band. The aim of the image classification process is converting image data to thematic data. The ISODATA algorithm was implemented without assigning predefined signature sets as starting clusters. ISODATA which is clustering method, classifies pixels iteratively, redefine the criteria for each class, and classifies again. So the spectral distance pattern in the data gradually emerges (Goksel, 1998). A number of 7 land-use types for Ismailia are identified including: urban or built-up land, barren land, green areas, water, roads and water logged. Figures 4 and 5 show the visual results of classified images.



FCC=False color composite, 1-6= normal band, OIF= Optimum index factor, NDVI= Normalized difference vegetation index, PCA= Principal component analysis.

Fig. (3): The highest OIF values for different spectral composite.

The supervised classification was executed using the different classification algorithm, supported by visual interpretation and the application of post processing techniques. Visual interpretation of the satellite images plays an important role during the classification stage. Therefore, three optimal bands were required to be selected for graphical display. Training samples were first selected from various spectral classes. After selecting the training samples, classification was run on the data using different methods and algorithm. Grouping of spectral classes were done on the basis of land-cover types. The Landsat ETM+ image was first classified to the seven different land-uses (Figure 5). More than 100 digital photos were taken for different types of land-use and land-cover, along with hundred of GPS point readings.

Spatial Reclassification:

The initial land-use map after classification came with the accuracy of approximately 77%. For this study, however, higher accuracy was needed. Therefore, further research effort was attempted to reduce image classification errors and improve accuracy. For this purpose, a spatial reclassification procedure has been developed to recode those pixels being labeled wrongly. Spatial reclassification was implemented through the use of image interpretation procedures, knowledge-based approaches, auxiliary data and a variety of GIS functions.

Accuracy Assessment Procedure:

At the last stage of image processing, calculation of accuracy assessment of classification was performed. Accuracy assessment is an important feature of land-use mapping as a guide to map quality and reliability. The value of the classified map is a function of the accuracy of the classification. A mixed quantitative/qualitative accuracy assessment procedure was applied in the current research. The available reference maps were used for a quantitative assessment of classification accuracy. Using aerial photographs and topographical maps, the land-cover types which do not change much in time were qualitatively assessed.

The most usual way of assessing the accuracy of classified remote sensing images is by selection of a sample of pixels from the classified image and checking their labels against classes determined from reference data (desirably gathered during field work). To insure the reliability and to enable the determination of the confidence limits of the accuracy estimates, a specific statistical sampling scheme was required. The sampling must be, as far as possible, representative of the whole classified area. A random distribution of such sampling points over the whole region must be sought (Van Genderen *et al.*, 1978).

The ground reference collection strategy was chosen to collect data because the cost, time and logistics required for a random sampling of all distinguished strata are prohibitive. It is much easier and cheaper to visit a few large areas than it is to visit many smaller areas. Also, satellite images from previous years are often used, implying that during field work reliable information on agricultural land-cover generally cannot be gathered anymore. For those areas ground reference maps can often be used.

The accuracy assessment was conducted through a standard method described by Congalton (1991). Accuracy assessment of classification was calculated using an error matrix (Lillesand and Kiefer, 2000) which showed the accuracy of both the producer and the user. The classification accuracy in remote sensing shows the correspondence between a class label allocated to pixel and true class. The true class can be observed in the field, either directly or indirectly from a reference map (Janssen and Vander Well, 1994).

At least 20 test points per class were taken through a stratified random sampling scheme. For accuracy assessment, 250 pixels were randomly selected from the ground truth coverage. Land-use maps and photographs taken for documentary purposes were used as reference data to observe true classes. The overall accuracy and a Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis. A standard for land-use maps is set between 85 (Anderson *et al.*, 1976; Bektas, 2003) and 90 % overall accuracy.

Fig. (4): Visual results of the classified image.

Map Presentation and Analysis:

The result of digital satellite image classification is a pixel by pixel labeling of the entire image. Raster data was pre processed to reduce the large amount of data. Before conversion to vector format, the image was simplified to reduce the pixel by pixel classification to some smaller number of polygons. Raster to vector translation was occurred for the purpose of presentation and analysis in a GIS layer. The vector files of river networks, road networks and administrative boundaries for Ismailia were superimposed on the geocoded satellite imagery to update road, river and boundary features through screen digitization in ESRI ArcMap v 9.3 (ESRI, 2008). The updated vector files were then overlaid on the digital land-use map and sectored to the size of the Governorate boundary.

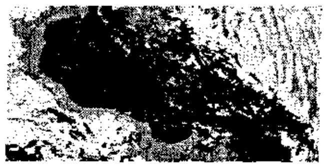
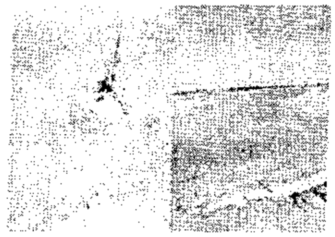
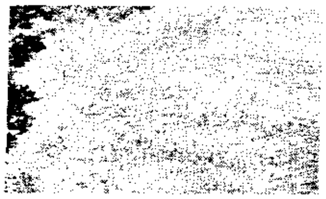
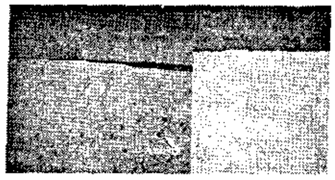
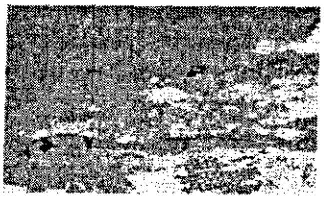
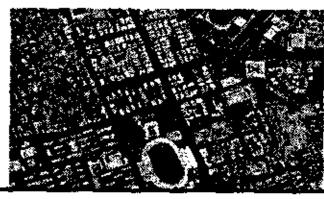
Class	Class description	ETM+ Image, 2006	Selected digital photos for different types of land-use
Water	**Relatively deep water**: mainly the Suez Canal, but also some extreme waterlogged areas. In the last case, the soils are also very saline.		
Waterlogged	**Shallow water**: still some background reflection of the soil influencing the pixel values. Poorly drained soils with a shallow groundwater table in winter time; during summer time, when the groundwater table is lower salt crusts will be formed.		
Barren land	**Barren land** includes areas that have been covered with sand, sand dunes, and rocks.		
Vegetation	Including different types of vegetation, such as trees, crops, orchards and desert shrubs.		
Reed vegetation	Occurring exclusively on waterlogged and saline soils. This is possible because the absolute growth reduction for reed is situated around 14 to 15 dS/m. It can thus be concluded that these waterlogged soils have soil salinity less than the above mentioned EC-values.		
Roads	Areas covered with primary and secondary roads.		
Urban	Areas that have been populated with permanent residents.		

Fig. (5): Description of the different units of the image.

RESULTS AND DISCUSSION

Data Processing, Analyzing and Classification:

Data presented in Table (1) show the accuracy of different classification methods and algorithms. Neural network and maximum likelihood methods have a good result on out coming maps. The overall accuracy and Kappa coefficient of these methods are quite higher than the other algorithms such as: Minimum distance and parallelepiped classifiers.

Table (1): Accuracy of different classification methods and algorithms.

Classification Methods	Overall Accuracy (%)	Kappa Coefficient (%)
Parallelepiped	14.39	03.92
Minimum Distance	85.46	62.74
Maximum Likelihood	92.11	79.40
Mahal distance	87.94	67.96
Neural Network	93.04	80.65

Booth and Oldfield (1989), and Alvipanah *et al.* (2001) have emphasized on the priority of maximum likelihood algorithm in compared to minimum distance and parallelepiped classifiers. For the 2006 dated image, overall classification accuracy for the land-use classes was established as 93.04% and the Kappa coefficient was computed as 0.8065.

Spatial Reclassification and Accuracy Assessment of the Land-use Classification:

The first result of the accuracy assessment was an overall accuracy of 77% with Kappa Coefficient = 0.72. That is way bellow the "85%" cutoff level between acceptable and unacceptable result (Congalton and Green, 1999). Users' accuracies were good (above 85%). The data were analyzed and reclassified again to bring this result to a wider acceptable level of accuracy. I used a simple hierarchical scaling strategy (Wu, 1999) to identify similar types to be combined and simplify the map and evaluate the accuracy improvement. The steps for simplification were chosen based on the classes' similarities taken from their participation on each other in the error matrix and the qualitative justification for their misclassification.

Taking into consideration that reed vegetation in this area are kept in a physiognomic state very similar to "vegetation" and that it presented the lowest users accuracy in the error matrix, all reed vegetation polygons were reclassified into "vegetation". "Small trees" and "big trees" were the next class chosen for combination, first because they had both users and producers low accuracies. Also, because those low accuracies can be easily explained. Not even high-resolution aerial photos are suitable to tell apart the height differences used as boundaries for those types. This procedure improved the overall accuracy to 93%, with Kappa coefficient = 0.81. However, the question at that point is more related to the objective of the land-use mapping than to improve the accuracy.

Table (2) shows the result of the land-use validation using a confusion matrix. The result showed that the overall accuracy for the land-use classes was 93.04%. The overall land-use Kappa coefficient was 80.65%.

Table (2): The confusion matrix result of the land-use validation.

Land-use Class	Producer accuracy (%)	User's accuracy (%)
Water	97.03	72.08
Waterlogged area 1	61.55	88.19
Waterlogged area 2	45.87	23.28
Vegetation	93.68	87.42
Barren Land	97.84	99.04
Built-up Land	76.43	45.95
Overall Accuracy	**93.04**	
Kappa Coefficient	**80.65**	

OVERALL DISCUSSION

This study assesses the capability of knowledge-based approach with field observations and remote sensing data to map land-use in Ismailia Governorate. This objective could be achieved through: derivation of land-use information from land-cover classes by using the out dated land-use maps supported by combination of the field knowledge on land-cover and using remote sensing image in order to produce land-use map.

The use of remote sensing sources for land-use mapping is becoming a very common use. However, not much attention is given to the accuracy of those maps. The performance of the knowledge-based classification with multi-source information classification was tested by comparing with conventional visual interpretation and different classification methods (e.g., maximum likelihood and neural network). A confusion matrix was used to assess the accuracy of each resulting land-use by comparing or cross-tabulating the classified land-use to the actual land-use observed in the field and existing land-use map. The overall accuracy before and after these processes was ranged from 77 to 93 percent. A land-use map with 20 classes could be produced with this methodology where the best of advanced technology and careful interpretation was used with a lot of work hours. That could convince most of the managers and decision makers. This study showed however that a map with reasonable overall accuracy produced from this image interpretation could only have about 5-10 classes (Figure 6).

Hence the questions that need to be answered now are: "Is this data worth worked with for land-use management of the Ismailia Governorate?"; "What is the impact of land-use on the sustainable development plan of the Ismailia Governorate". If the public agencies and private organizations are to know what is happening, and are to make sound plans for their own future action, then reliable information is critical. One of the prime prerequisites for better use of land is information on existing land-use patterns. Land-use data are needed in the analysis of environmental processes and problems.

In pressured environmentally sensitive and ecologically important regions, such as the Ismailia Governorate, there is a continuing need for up-to-date and accurate land-use information that can be utilized in the production of sustainable land resources policies. The aim of land-use planning in Ismailia Governorate is reusing the land in such a way that crops were cultivated in relatively large areas, reducing waste in land resources, minimizing and organizing pest control on a large scale, improving mechanical operation on the farm.

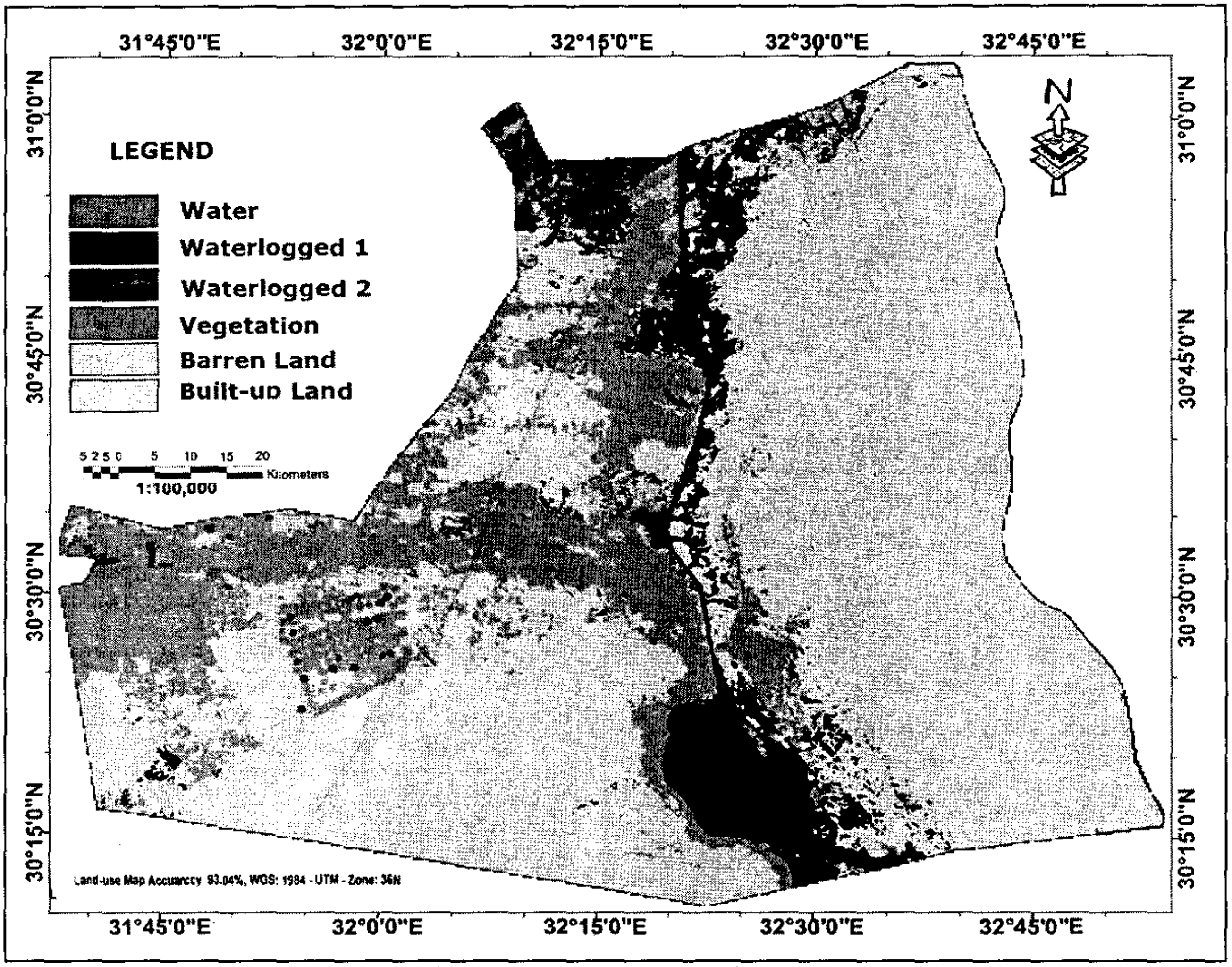


Fig. (6): Final land-use map of the Ismailia Governorate.

CONCLUSIONS

The overall research objective of the current study is to develop a rapid procedure to produce a high land-use map accuracy using combination of different techniques. Remote sensing technology has great potential for acquisition of detailed and accurate land-use information for management and planning of land and water resources of the Ismailia Governorate. However, the determination of land-use data with high geometric and thematic accuracy is generally limited by the availability of adequate remote sensing data, in terms of spatial and temporal resolution, and digital image analysis techniques.

This study introduces a methodology using combination of different techniques to map and update land-use data base. The data base contains detailed information on the spatial distribution of main agricultural crops, water, waterlogged areas, barren land and built-up areas. The results show that the database containing information on actual land-use is necessary for various applications, such as land evaluation, soil erosion and desertification. The results have raised some essential concern about land-use map accuracy. First, band sets 2-NDVI-PCA is the best band combination give the highest (optimized index factor, OIF) accuracy. Second, the knowledge- based classifications which are less field work and neural network classifications of images gave comparable higher overall accuracy of 16 percent (from 77% to 93%). The highest overall accuracy and Kappa coefficient related neural network method is 93.04% and 80.65%.

In general, there are certain limitations to this research that need to be addressed in the future. Land-use changes are complex and involve many factors that influence land-use not directly but in a complex interaction. Anthropogenic land-use activities are altering at high rates the natural ecosystems of the Ismailia Governorate. Biodiversity is lost, natural resources depleted and ecosystem services reduced. However, the questions which not answer yet are "Which forces drive land-use change in the Ismailia Governorate?" "How to develop an operational procedure for land-use change detection and assess its impacts on climate change?" So, one of the future research areas is to develop and build land-use change model. Up to now, however, little progress has been made in this direction. There is not yet a land-use change model available that can be used in scenario-studies because of its effects on the hydrology and ecology of the Ismailia Governorate.

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طريقة مقترحة لتحسين دقة عمل خرائط إستخدامات الأراضى

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تعتبر خرائط إستخدامات الأرض وسيلة مفيدة لدراسة المصادر الطبيعية للتربة والمياه والحفاظ عليها حيث تعتبر كخرائط أساس لمختلف ألتطبيقات مثل تقييم الأراضى والتصحر. إن تحديث هذه الخرائط بالطرق الحالية يعتبر مكلف مادياً بالاضافة إلى إهدار الوقت والجهد، لذا فمن المهم البحث عن وسيلة سريعة وإقتصادية للحصول على درجات إستخدامات التربة المختلفة وتحديثها. تعتبر بيانات الأقمار الصناعية مناسبة لهذا الغرض. يقترح هذا البحث طريقة جديدة للحصول على درجات إستخدامات التربة بغرض التنمية الزراعية المستدامة ولقد تم إختيار محافظة الإسماعيلية كحتلة للدراسة. ويتم الحصول على خريطة إستخدامات التربة باستخدام مصادر مختلفة من البيانات والتى تشمل صور الأقمار الصناعية والخرائط الحالية والخبرة الشخصية وخرائط التربة، حيث تم إجراء بعض المعاملات على صور الأقمار الصناعية بغرض زيادة الدقة الايضاحيه لها ثم تم استخدام معامل Optimized Index Factor للحصول على أفضل Band Combination لاستخدامه فى عملية تقسيم صور الأقمار الصناعية حيث وجد أن أعلى دقة لدرجات استخدامات الأرض ترجع إلى 2-NDVI-PCA band. أستخدمت طرق مختلفة لتقسيم إستخدامات التربة حيث وجد أن طريقتى التصنيف بأقصى إحتمال وكذلك طريقة الشبكة العصبية Neural Network من أفضل الطرق التى تعطى دقة عالية. ولزيادة دقة الخريطة الناتجة تم أعادة تقسيم استخدامات التربة بناء على الخبرة الشخصية بالمنطقة، حيث تم التعرف والتحقق من وجود ٦ درجات مختلفة لاستخدامات التربة وهى المناطق الزراعية، والمياه، والاراضى المغمورة، والمناطق السكنية، والمناطق غير المنزرعة والصخرية. ومن النتائج المتحصل عليها إتضح ان أعلى دقة للخرائط تم الحصول عليها هى ٩٣ % وذلك باستخدام طريقة الشبكة العصبية بزيادة ١٦% عن الطرق المستخدمة حالياً باستخدام طريقة التصنيف بأقصى إحتمال. تعتبر نتائج هذه الدراسة مفيدة لمخططى ومتخذى القرار وكذلك لدراسات تقييم الأراضى وإستدامة الاستغلال الزراعى للتربة والحفاظ على المصادر الطبيعية للتربة والمياه.