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Comparison Between Supervised and Unsupervised Classifications for Mapping Land Use/Cover in Ajloun Area

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ABSTRACT

This research was undertaken in Ajloun area, located north west of Jordan, to assess the accuracy of Land Use/Cover maps derived from supervised and unsupervised classification techniques of Landsat TM imagery. Digital image processing techniques included geometric correction, resampling, registration, subset of study area, application of unsupervised classification with ISODATA algorithm and identification and merging of the output classified image into four major classes. Output from the previous stage was used to identify the number of training areas and to collect ground data to implement supervised classification for the same image. Accuracy assessment was made for both classifications with confusion matrices based on ground visits. Results of digital classification showed that unsupervised classification was more accurate than supervised classification with high classification accuracy for forested area, with variations in accuracy among classes and between the two classifications. These variations were mainly attributed to the complex and fragmented patterns of cultivation and the scattered pattern of urban area. Therefore, the study recommends the use of higher spatial and spectral resolution data to increase the obtained level of accuracy.

KEYWORDS: Remote Sensing, land use/cover, Ajloun, ISODATA.

INTRODUCTION

Western and northern highlands of Jordan are considered the most productive agricultural lands in the country. Productivity of other lands is very limited, because the mean annual rainfall is less than 200 mm (Fig. 1). Rainfed highlands, however, are suffering from rapid shifting from natural ecosystem to agricultural system. A good example on this shift is Ajloun area that suffers from rapid land fragmentation and conversion of forest area into irrigated/agricultural lands. This shift needs quantification to enable better planning and utilization of the area's resources (GEF, 2004). Mapping of Land Use/Cover (LU/C), however, requires efficient methods of detection and analysis. Tools of Remote Sensing (RS) and Geographic Information Systems (GIS) can be used for this purpose at reasonable cost within short periods of time.

In the last two decades, remotely sensed images provided useful spatial and spectral information at relatively reasonable costs for mapping LU/C. In Mediterranean Maritime Syria, the technology of remote sensing was used for tracing land cover and mapping natural vegetation cover and urbanized areas by digital analysis of Landsat satellite imagery (Khreim and Lacaze, 1997). In Egypt, land use mapping was possible from supervised classification of Landsat TM imagery with relatively high accuracy (Salem *et al.*, 1995; Ayyad *et al.*, 1997), similar techniques were used in Syria (Hirata *et al.,* 2001) to map land cover with an overall accuracy of 85%. Supervised and unsupervised classification techniques were also used to map LU/C in

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the United Kingdom (Miller *et al*., 1997; Baban and Luke, 2000), the Amazon (Brondizio *et al.*, 1996) and the Mediterranean (Grignetti *et al.,* 1997). These studies and further ones indicated the successful application of RS and GIS for studying LU/C. In Jordan, few studies were carried out to map LU/C in the Badia (Milligton *et al*., 1999; Al-Bakri, 2000; Al-Bakri *et al*., 2001). Recently, Rababa'a (2003) used the unsupervised classification of Landsat TM imagery to map LU/C in the Dead Sea basin. Results of the study showed variations among mapped classes and between digital classification algorithms, with an overall accuracy of less than 80 %. Al-Jitan (2005), on the other hand, obtained a mapping accuracy of less than 76 % from supervised classification of high-resolution imagery for a study area in the Jordan Valley.

Results and findings from the above studies were varied depending on the digital classification method, study area and the corresponding LU/C type. Therefore, this study was carried out to investigate mapping accuracy from digital classification methods (supervised and unsupervised) based on ground data samples arranged within confusion matrix. The overall aim of the research was to determine the most accurate digital image classification method for mapping LU/C, particularly the forests in Ajloun area.

Study Area

The study area is located between 35˚49´ E Longitude, 32°24' N Latitude and 35˚51' E, 32˚23' N (Fig. 1). The total area of the location is about 850 square kilometer. The climate of Ajloun is a sub-humid Mediterranean, with the annual rainfall ranging from 300 to more than 600 mm. The area is characterized by cool temperature in winter and mild temperature in summer; the highest temperature occurs in August (mean maximum temperature is 34˚C) and the lowest temperature in January is – 4 ˚C. The annual relative humidity ranges from 63% up to 77 % (JMD, 2000).

The study area has the highest forest cover in Jordan (GEF, 2004). The indigenous forests included Pinus, Quercus and Ceratonia species. In addition to wild relatives of Pistachio, Apricot and Almond are scattered in different parts of the area. Ancient local cultivars of olives are grown and cultivated in the area. Wild relatives of wheat, barely and forage species are also abundant. Local varieties of onion and garlic were introduced in the farming systems of the study area and were mainly irrigated from natural springs and from groundwater wells in the low altitude areas.

The area is dominated by steep slopes, valleys, and numerous springs. As a result, most of soils in this region are shallow, particularly at steep slopes where no conservation measures are available. The dominant soil subgroups are Lithic and Typic Xerochrepts, in addition to Lithic Xerothents and Haploxeroll. On the flat sites, true vertisols (cracking clay soils) occur (MoA, 1994). Most of the soils had low content of calcium carbonate and organic matter. However, intensive cultivation of field crops, orchards and other crops of legume is taking place.

Methodology

Image Preprocessing

A full scene of Landsat Thematic Mapper (TM) imagery of 1998 was used in the study. The TM imagery, held at the University of Jordan (UoJ), was acquired in April and was used by a previous research (Al-Bakri, 2000). The TM image included seven bands (Blue, Green, Red, Near Infrared, Short-wave Infrared, Thermal Infrared and Mid Infrared). All bands, except the thermal, were used in the analysis and had a resolution of 30 meters.

Before carrying out digital classifications, geometric correction of the TM imagery was needed to compensate for distortions inherited in the raw imagery and to register the output image into the real world coordinates (Schowengerdt, 1997). An image-to-image correction (PCI, 1998) was implemented using a geo-coded SPOT imagery, digitally merged with Landsat TM and originally used by the UoJ. Thirty well-distributed

Ground Control Points (GCP's) were collected interactively between the geo-coded and the distorted images and were used to apply a third-order polynomial transformation to calculate the new coordinates of the output image with an overall error of less than one pixel. The TM imagery was then resampled by the Nearest Neighbor (NN) method. This method was preferred as it determined the gray level from closest pixel to the specified input coordinate and assigned that to the output coordinate so that original data were preserved i.e. no alteration to original brightness values of pixels occurred. In addition, the NN method preserves the original visual appearance of the image and preferred prior to digital classification methods (Schowengerdt, 1997). By the end of this stage, the output TM image of 1998 was registered in the geographic coordinate system with a pixel size of 30 m.

A vector file defining the study area was imported into the image processing software to subset the image to the borders of the study area and to mask the surroundings. This vector file was limited to Ajloun Governorate, including Jarash, and was obtained from the Royal Jordanian Geographic Center (RJGC). The file was converted to a binary bitmap mask and overlaid onto the TM scene. An Arithmetic model was then applied by multiplying the bitmap mask by each of Landsat TM bands. The output file contained Ajloun study area without altering the original pixel values.

Digital Classification

Classification is the process of sorting pixels into a finite number of individual classes, or categories, of data based on their brightness values. The overall aim of classification was to automatically categorize all pixels in an image into LU/C classes. Two classification methods were used in this study as following:

1- The unsupervised classification: Pixels of the TM imagery were assigned to classes by calculating the distances between specific pixels within feature space, and assigning them to cluster-centers. The algorithm, which was used for assigning pixels to classes, was known as ISODATA (Iterative Self-Organizing Data Analysis Technique). This algorithm enabled grouping of pixels with similar spectral characteristics by deriving statistics (mean and standard deviation) of groups and assigning a class to each pixel according to its distance from mean. The output classes were then identified by ground survey.

2- Supervised classification: Representative areas for each desired class were located in the image with sufficient number of pixels covering the known class. The number and percentage of training area were identified from the results of unsupervised classification. A statistical file known as spectral signature was then generated, by the image processing software, for each class. Each pixel was then assigned to the most likely class based on the maximum likelihood algorithm, the most commonly used classification algorithm (Jensen, 1996; Schowengerdt, 1997).

Results from supervised and unsupervised classifications were assessed to find the overall accuracy for each classification and for each class. The assessment was made by confusion-matrix procedure in which a set of random samples of classified data of the TM imagery and reference data collected from the field visits were compared. Reference data were collected from several field visits. Colored aerial photography of the year 2000, topographical maps obtained from RJGC and a Global Positioning System (GPS) aided this stage by tracking the best routes for target locations and identifying the classified pixels or parcel.

Accuracy assessment was implemented by selecting random samples from the 1998 imagery and comparing these classified pixels with ground data. The accuracy for each class was calculated by dividing the diagonal element of each class with the total number of samples. The diagonal element of the confusion matrix represented the agreement between both classified and ground data. The overall accuracy was calculated by dividing the total number of all samples diagonals (agreement) by total number for all random samples.

Results and Discussion

Initial results of the unsupervised classification showed twelve spectral clusters. Based on field visits, the resulted clusters were merged into four major classes of urban, forest, non-cultivated areas, and mixed agricultural areas. Identification of these classes is shown in table(1). The LU/C map produced from unsupervised and supervised classifications, figures 2 and 3, show that forest occupied less than 22 and 20 % of the total area of Ajloun, respectively. Similarly, low variations were observed in the percentage area of urban class from both methods (Table 4).

Variations in classification accuracy and area percentage were observed for the agricultural areas. Intercropping and small parcel sizes were the major characteristics of mixed agriculture class. In Ajloun, a unique farming system was practiced. In this area, farmers depended on the traditional agriculture practices. Generally, in a single small farm or in a field more than one or two crops were planted in the same season. For example, fig and olive grove orchards had strips of annual crops of lentil, onion, garlic, tomato, potato, melon, and watermelon. This resulted in spectral mixing between classes and made the separation of the individual land use (crop), at the level of Landsat TM imagery, more difficult. Accordingly, classification accuracy was variable among classes and between the two methods.

Results of accuracy assessment of unsupervised and supervised classifications (Tables 2 and 3, respectively) showed that the overall accuracy was less than 80 % and 71 % for the unsupervised and supervised classifications, respectively. The highest accuracy of unsupervised classification was about 96% for forest. This high accuracy indicated the possibility of separating forests from other LU/C classes in Ajloun region. Similar findings from many researches on global land cover mapping showed that forested areas were mapped within acceptable and high accuracy, even with coarse resolution data (Defries *et al*., 1998; Hansen *et al*., 2000). In Jordan, the forestry area was also accurately mapped from coarse resolution satellite imagery (Al-Bakri and Taylor, 2003).

Other classes were mapped by unsupervised classification with less accuracy, more than 72% to less than 78%. These results agreed with Rababa'a (2003) and were also comparable with Ayyad *et al.* (1997). The high accuracy of classification of forest could be attributed to the distinguished spectral characteristics of this class and the high percentage cover of this class in Ajloun, while the low accuracy for other classes could be attributed to the intercropping and the mixed patterns of cultivation practices in the area.

Results of supervised classification (Table 3) showed less accuracy than the unsupervised classification. The overall accuracy was less than 71%. The highest accuracy was for forest while the minimum accuracy was for mixed agricultural areas. These results indicated the need for more training locations and subsequently more ground surveys to include all possible spectral classes in the area. Results, however, were comparable with other research in other areas in Jordan (Al-Bakri, 2000; Al-Jitan, 2005).

The relatively low classification accuracy for mixed agricultural areas, including all subclasses, could be attributed to the small landholdings in Ajloun and the mixed agricultural patterns that resulted in spectral mixing of pixels' brightness values. Although classification accuracy was relatively low, however such methodologies could be considered as alternative approaches to ground survey, particularly for large study areas where the accuracy of ground surveys and visual interpretation of satellite imagery might not be higher than the digital classification methods. A comparison between these results with other results (Al-Bakri, 2005) obtained from methods of visual interpretation and ground survey showed some similarities in LU/C percentages, particularly for forested areas. According to Al-Bakri (2005) the percentages of LU/C were 9.2, 38.6, 33.2 and 19.1 for urban, non-cultivated, mixed agricultural and forest areas, respectively. Results from this study, therefore, could be compared with the results of visual interpretation of the TM imagery. The percentage of forest area was nearly similar between both classifications and results obtained by Al-Bakri (2005). Also, results indicated that mapping of agricultural areas from supervised classification would give good results, compared with visual interpretation and ground surveys.

It should be kept in mind that one big advantage of such classifications was the output maps (figures 2 and 3) where spatial distribution of LU/C classes could be obtained. The output maps could indicate the complex patterns and mixing of farming in Ajloun that could not be obtained from small-scale aerial photography or from field survey. Therefore, the level of accuracy could be accepted for this large area and justified the usefulness of digital classification of remote sensing data. Area correction for the LU/C classes, however, should be made before generalizing the results, particularly for classes with relatively low mapping accuracy. In this study, estimate of area and the correction needed for such estimate was not investigated, as more ground samples (at least 50 samples for each subclass) were needed. However, more details on the methodology was tackled and discussed by previous research (Al-Bakri, 2000; Rababa'a, 2003).

Conclusions and Recommendations

Accuracy assessment showed that the overall accuracies were less than 80% and 71% for unsupervised and supervised classifications, respectively. Results of classification were affected by classification schemes at subclass levels, mixed pixels, and the complex intercropping and sparse vegetation and scattered urbanized areas. The advantage of supervised classification over unsupervised is that classes were previously known. However, the accuracy of classification depended on the quality of training data and the possibility of including all spectral classes in the training process.

Based on the results of the study, the following recommendations can be made:

1. More spatial and spectral resolution data are recommended to map LU/C from digital classification. The implementation of such study with higher resolution data, therefore, is a future objective.

2. Mapping of forested areas from the unsupervised classification technique is highly recommended as the expected mapping accuracy is high. This could contribute to the area of monitoring the deforestation and afforestation in Ajloun and similar agroecosystems.

3. The need for appropriate classification schemes is emphasized, particularly for use with remote sensing data.

Table 1: Land Use/Cover classification scheme used in the study.

Class	Description
Urban (U)	Residential, built-up, industrial and commercial areas
Non-Cultivated Areas (NCA)	Bare rocks, bare soils, and shrub and herbaceous rangelands.
Mixed Agricultural Areas (MAA)	Horticultures, field crops, and orchards.
Forest (F)	Low, medium, and high density forests.

Table 2: Accuracy of the unsupervised classification.

	Reference data						
		U*	NCA	MAA	F	Total	User Accuracy (%)
Classified data	**U**	**11**	3	0	1	15	73.3
	NCA	12	**111**	7	13	143	77.6
	MAA	8	19	**113**	16	156	72.4
	F	2	2	0	**86**	90	95.6
					Total = 404		
Overall accuracy = {(11+111+113+86)/404} 100 = 79.5 %							
* Class abbreviation: U = Urban, NCA = Non-Cultivated Areas, MAA = Mixed Agricultural Areas, F = Forest.							

Table 3: Accuracy of the supervised classification.

	Reference data						
		U*	NCA	MAA	F	Total	User Accuracy (%)
Classified data	**U**	**2**	1	0	0	3	66.7
	NCA	14	**207**	36	27	184	72.9
	MAA	2	21	**37**	13	73	50.7
	F	2	15	6	**79**	102	77.5
					Total = 480		
Overall accuracy = {(2+207+37+79)/480} 100 = 70.8%							
* Class abbreviation: U = Urban, NCA = Non-Cultivated Areas, MAA = Mixed Agricultural Areas, F = Forest.							

Table 4: Percentage Land Use/Cover derived from unsupervised and supervised classifications.

Class Name	Unsupervised	Supervised
Urban	12.2	12.9
Non-Cultivated areas	40.6	35.6
Mixed Agricultural Areas	25.6	31.8
Forest	21.6	19.7

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مقارنة التصنيف الرقمي المراقب وغير المراقب
لإنتاج خرائط استعمالات الأراضي/الغطاء الأرضي في منطقة عجلون

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ملخــص

أجري هذا البحث على منطقة عجلون، شمال غرب الأردن، لتقييم دقة خرائط استعمالات الأراضي/الغطاء الأرضي المنتجة من التصنيف الرقمي المراقب وغير المراقب لصور القمر الصناعي الأمريكي لاندسات. تم عمل التصحيح الهندسي، النقل الرقمي، التسجيل، التجزيء، وتطبيق التصنيف الرقمي غير المراقب باستخدام خوارزمية ISODATA وتعريف ودمج الصفوف الناتجة في أربعة صفوف. استخدمت نتائج المرحلة السابقة لتحديد عدد مناطق التدريب واجراء المسوحات الأرضية اللازمة لاجراء التصنيف المراقب وتقييم دقة التصنيف من خلال مصفوفة الالتباس. أظهرت النتائج أن التصنيف غير المراقب كان أكثر دقة في تصنيف استعمالات الأراضي/الغطاء الأرضي وخصوصاً لمناطق الغابات، مع ظهور فروقات في صحة التصنيف بين الطريقتين وبين الصفوف المختلفة. عزيت هذه الفروقات الى النمط المعقد والمفتت للأراضي الزراعية والمناطق الحضرية. لذلك توصي الدراسة باستخدام صور ذات عزل مكاني وظيفي عال لزيادة مستوى دقة التصنيف الرقمي.

كلمات دالة: استشعار عن بعد، تصنيف رقمي، عجلون، استعمالات أراض.

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