http://fenbil.trakya.edu.tr/tujs
Trakya Univ J Sci, 6(2): 27-38 , 2005
ISSN 1305-6468
DIC: 191LGCT620512050106

Research Article/Araştırma Makalesi

A COMPARISON OF LANDSAT THEMATIC MAPPER AND INDIAN REMOTE SENSING DATA FOR LAND USE AND LAND COVER CHANGE ASSESSMENT

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Alınış : 04.07.2005
Kabul Ediliş : 26.10.2005

Abstract: The objective of this research focuses on comparing Landsat TM and IRS data and determining if similar classification can be achieved from datasets for certain land cover types. Supervised classification was performed using information from a combination of digital aerial photographs, a priori knowledge of the study site by the authors and existing Land Use Land Cover (LULC) maps.
The "upland forest," "*open water,*" "*tree crops*" and "*palmetto prairie*" categories show strong agreement in terms of percentage of LULC found in both Landsat TM+ and IRS classified images. Conversely, the "*open land,*" "*cropland and pastureland*" and "*wetlands*" categories display differences based on the land cover area. Based on the overall classification accuracies similar results were produced for both TM and IRS data of 86.3% and 88.4% respectively. On the other hand, certain LULC categories did not perform so well, such as the golf course. Temporal resolution between the TM and IRS images was six weeks, and this was considered a factor in the confusion between LULC category discrimination. This study showed that using Landsat TM and IRS in same study provide promising results for LULC studies

***Keywords**:* Accuracy, Classification, Indian Remote Sensing, Landsat TM

Landsat TM ve IRS Uydu Görüntülerinin Arazi Kullanımı ve Bitki Örtüsü Değişimlerini Belirleme Çalışmalarında Kullanımlarının Karşılaştırılması

Özet: Bu çalışmanın ana hedefi Landsat TM ve IRS görüntülerinin arazi sınıflaması sonuçlarının benzerlik gösterip göstermediği araştırmaktır. Kontrollü sınıflama yapmak için dijital hava fotoğrafları, çalışmada yer alan araştırmacıların önceki çalışmaları ve varolan arazi kulanım ve bitki örtüsü haritalarından faydalanılmıştır.
Araştırma sonucunda, "*ormanlık alanlarda*", "*açık su alanlarında*", "*meyve bahçelerinde*" ve "*palmetto ağaç*" sınıflarında, her iki uydu görüntüsü (Landsat TM IRS) arasında benzerlikler olduğu gözlenmiştir. Buna karşın "*açık alanlarda*", "*sebze ve otlak alanlarda*" ve "*bataklıklarda*" oldukça farklılıklar gözlenmiştir. Genel toplam doğruluk analiz sonuçlarına göre Landsat TM %86.3 ve IRS %88.4 doğrulukta kategorileri sınıflamıştır. Buna karşın golf alanı kategorilerindeki sınıflamada problem olduğu gözlenmiştir. Zamana bağlı çözünürlükte Landsat TM ve IRS görüntülerinin arasındaki 6 haftalık bir zaman diliminin bazı sorunların oluşmasına ve kategoriler arasında sınıflama hataların meydana

gelmesine neden olduğu düşünülmüştür. Araştırmaya göre Landsat TM ve IRS görüntülerinin arazi kulanım ve bitki örtüsü değişim çalışmalarında birlikte kullanılmasının mümkün olduğu tespit edilmiştir.

Anahtar kelimeler: Doğruluk Analizi , Sınıflama, Indian Remote Sensing (IRS), Landsat TM

Introduction

Space-based multi-spectral sensing satellite systems are now commonly used as tools to detect land cover and vegetation changes over time. The utility of this type of data for detecting and monitoring changes in land cover has become widely recognized (Price et al., 1992, Ram and Kolarkar, 1993). The rate and scale at which environmental changes occur requires broad-scale coverage that only satellite imagery can provide (Lunetta and Balogh, 1999).

Many Land Use Land Cover Change (LULCC) studies incorporate remote sensing satellite imagery such as the TM or the IRS. The greater availability of TM images over the IRS has meant that most LULCC published studies have been done using TM images (Richards and Jia, 1999). However, IRS images became available as an alternative since 1996.

Lillesand and Kiefer (2000) and Jensen (2000) pointed out that the TM and IRS sensors are almost identical in the visible and near-infrared portions of the electromagnetic spectrum. LULCC studies are done primarily using TM data sets alone or IRS data sets alone.

When conducting a long term LULCC study using TM imagery, the data sets must be available for the specific dates. However for various reasons such as cloud cover, TM images of the desired quality may not be obtained. To solve this problem, the researcher must have another dataset that could be used in the same study with the TM images. The objective of this study was to compare TM and IRS imageries for LULCC studies using supervised classification and accuracy assessment as tools.

Methods

Study Area and Dataset

The study site selected for this research is located in Polk County (Figure 1) Florida, United States of America and represents an area of 118 km^2. The reasons for selecting this study site are as follows: (a) both images (TM taken in 1999, IRS taken in 1999) were virtually cloud-free within the study site, (b) the study site displays large areas of homogeneous land cover, which is desirable since heterogeneous systems produce mixed reflectance values due to mixing of sub-pixel elements, and (c) the study site has a diverse combination of upland and wetland vegetation over a relatively small area.

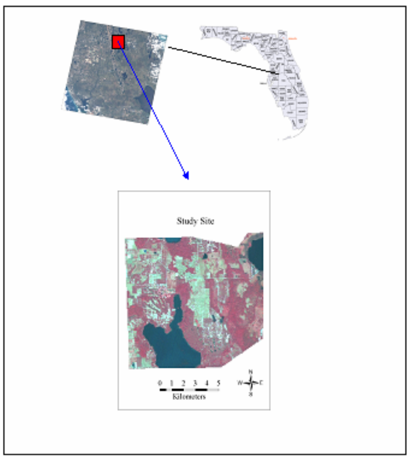


Figure 1. Study Site

The TM and IRS images were "Level 1G" products; system corrected images. System corrected images have been radiometrically and geometrically "corrected." (Smith, et al, 1998).

The aerial photos were those from which the Digital Ortho Photo Quadrangles (DOQ's) were taken in January 1999 (USGS, 2002). This was 10 to 11 months before the satellite imagery (Table 1). However, both the DOQ's and multi-spectral imagery are from the same season (winter) and the site had relatively little change in LULC over this period. Therefore, it was thought acceptable to use the DOQ's as a means of control. The DOQ's were re-projected to UTM Zone 17, Datum WGS 1984 to match the projection of the TM 1999 image**.**

Table 1. Digital Orthophoto Quads (DOQ's)

DOQ #	USGS Quad Name	Ground Resolution	Image Acquisition Date
1	Lake Hatchineha	1 m	1/6/1999
2	Dundee	1 m	1/6/1999
3	Lake Wales	1 m	1/6/1999
4	Hesperides	1 m	1/6/1999

Image Preprocessing

Preprocessing generally comprises of a series of sequential operations including atmospheric correction, image registration, geometric correction and masking (e.g. clouds, cloud shadows). In this project, the satellite images were radiometrically and geometrically corrected prior to acquisition.

An "area of interest" was selected and initial study sites from both full scenes were subsetted and designated the TM 1999 and the IRS 1999 (Figure 2a-2b). Subsets of the preferred area of study from the full image scene sized the image into a more manageable file (ERDAS, 2001). The preprocessing and the processing methods are shown in Figure 3.

The IRS 1999 image was registered to the previously registered TM 1999 base year image with UTM Zone 17, coordinates in metres, Datum WGS84, and a pixel size of 30 metres. The base year image and image to be registered were displayed simultaneously using dual displays in ERDAS Imagine and Ground Control Points (GCP) were selected (e.g. road intersections, distinguishing features). A two-dimensional Affine coordinate transformation was used along with nearest neighbour resampling (30m pixels) (Wolf and Dewitt, 2000; ERDAS, 2001).

After registration of the images, further refinement of the initial subset images was required. The presence of clouds and cloud shadows was detected and so sub-setting of the TM 1999 and the IRS 1999 images produced the final virtually cloud-free study area images. For this research, these study site images were designated the IRS 1999 (Figure 2b) and TM 1999.

According to Richards and Jia (1999), spectral reflectance information of common, earth surface materials is acquired in the visible and near to mid-infrared range. The mid-infrared band had a noise (line drop) problem for IRS 1999 image. From the results of the multivariate image statistics, a decision was made to omit the mid-infrared band from this research. And band 1, 2, and 3 were selected to do further analysis.

Figure 2. Imagery used in study **a)** TM 1999 Initial subset image , **b)** IRS 1999

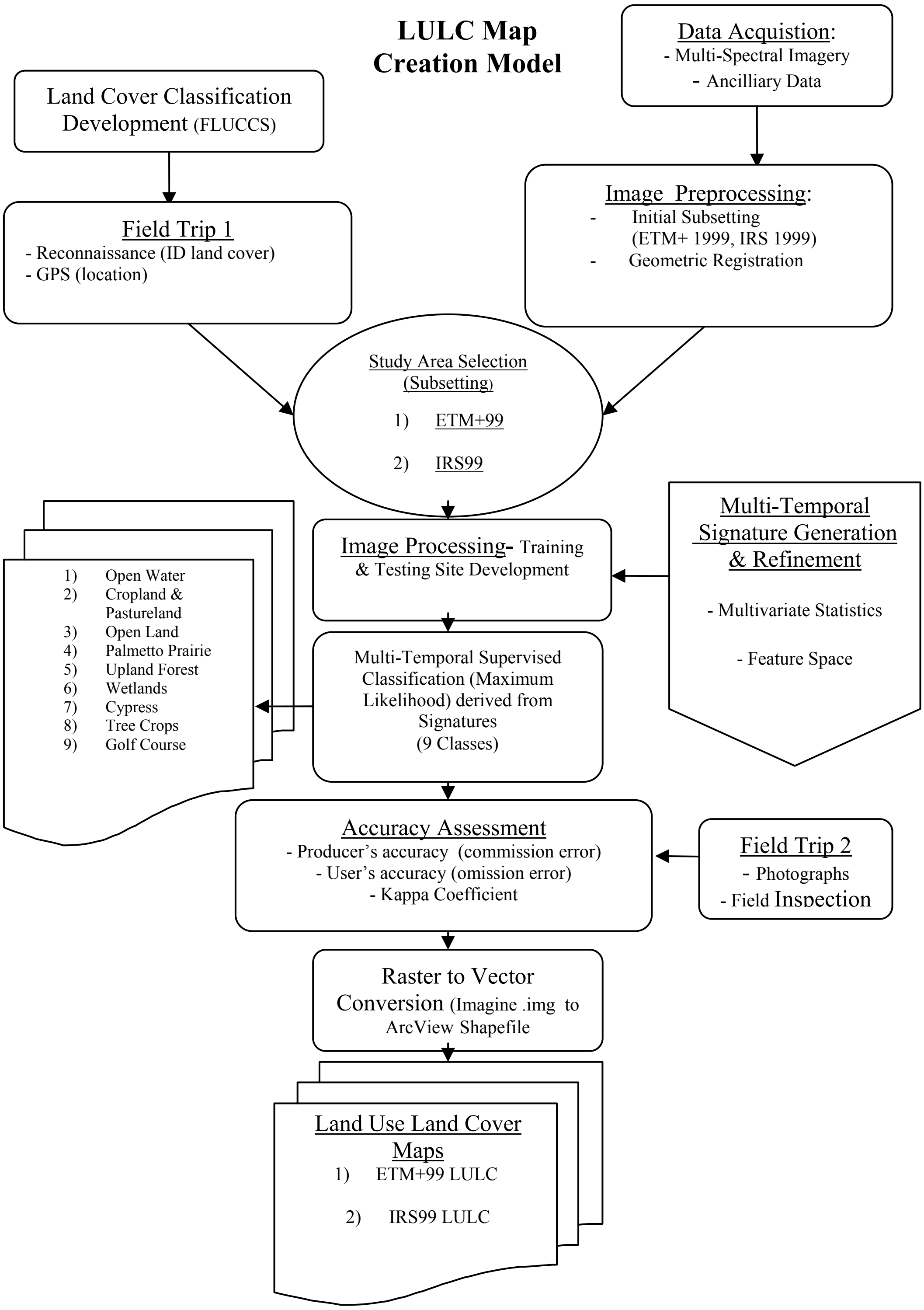


Figure 3. Procedural Flow Charts for LULC maps

Image Classification and Accuracy Assessment

Within the scope of this research, nine land use land cover categories were selected for the supervised classification. It was determined that these classes were most representative of the land cover types found in the study site. These land use land cover classes were adapted from the Florida Land Use and Covers Classification System (FLUCCS) and classified according to Anderson et. al. (1976).

The "golf course" and "open land" are sub-categories of the "urban and built-up" level-one category. The "*urban and built-up"* category consists primarily of land that is occupied by man-made structures. Urban development, bare soils and transportation (roads) was aggregated to form the "*open land"* category. "*Cropland and pastureland"* and "*tree crops"* are sub-categories under "agriculture." Agricultural lands are lands that are cultivated to produce food and raise livestock. "*Palmetto prairie*" is a sub-category of "*rangeland,"* a natural vegetation category. "*Upland forest*" is an upland area with a tree canopy closure greater than or equal to ten percent. Included in this category are pine, hardwood and mixed forests. "*Open water*" consists of streams and waterways, lakes, reservoirs, bays and estuaries, major springs and slough waters. "*Wetlands"* are areas in which the land is at or near the water table for most of the year. These areas are able to support various types of aquatic and hydrophilic vegetation. "*Cypress"* is a sub-category of the "*wetlands*" category and is a coniferous wetland forest (FOF, 2002).

Training sets were created with the help of field trips, land use land cover maps, aerial photographs and image interpretation of colour composites from the satellite imagery. Groups of pixels known as "training sets" were digitized onto a colour composite of the TM 1999 image. Training sets are used to compute statistics to characterize each class and are intended to be representative samples of the entire land cover class being classified. (Thomas et al, 1987). A minimum of "n +1" training pixels per category is required for supervised classification (n = number of classes) (Swain and Davis, 1978). The training sets selected all met this requirement (Table 2).

Supervised classification is the procedure most often used for quantitative analysis of remotely sensed data (Robinove, 1981; Jensen, 1996; Richards and Jia, 1999). Once good spectral separation of the training sets was determined, a supervised "Gaussian Maximum Likelihood Classification" was performed on both images (TM 1999 and IRS 1999). This classification incorporated the pixel values from the Green, Red and NIR bands from each scene, based upon the signatures generated for each land cover category.

Table 2. Training Set for Statistics.

Classes	Upland Forest	Cypress	Open Land	Crop & Pastureland	Wetland Forest	Open Water	Golf Course	Tree Crops	Palmetto Prairie
Pixel Number	140	135	136	139	110	213	16	60	160

Before the spectral signatures for each LULC class were generated, each training set was evaluated to determine their spectral response patterns. In the study site, certain categories displayed similar spectral characteristics, categories such as: "*Urban Development," "bare soil"* and "*transportation"* classes did not have unique spectral signatures. These classes had a large amount of overlap spectrally. To minimize confusion, these areas were aggregated to form the "*Open Land*" category.

Wetlands occur where the water table is at or near the earth's surface or where land is covered by shallow water. Water absorbs the energy of infrared wavelengths resulting in lower reflectance values for water-saturated land than for dry land (Lunetta and Balogh, 1999). Using an IRS false-colour composite image, it was relatively easy to identify cypress forest. Cypress has low reflectance in the infrared band and, therefore, low brightness values. Conversely, the wetland category (primarily hardwoods) has different spectral characteristics. Wetland hardwoods reflect more infrared and have higher brightness values. Therefore, wetland hardwoods appear dark red in the false colour image. The "*upland forest"* category and the "*wetlands"* category were found to be spectrally similar in certain regions of the study site. This resulted in misclassification in these categories.

The delineation of training sites representative of land cover types is most effective when the analyst has knowledge of the geography of a region and experience of the spectral properties of the cover class. Both the training and testing data were developed as a result of a priori knowledge of the study (field trips) area along with help from reference data i.e., DOQ's, and ancillary vector data. In order to see the differences between classified images, the TM 1999 nine-category classified image was subtracted from the IRS 1999 nine-category classified image. This map shows graphically and statistically the differences in LULC between the TM 1999 and the IRS 1999 images using the same classification methods for each image.

Accuracy Assessment of the multi-date (IRS 1999 and TM 1999) image classifications was calculated by comparing photographic interpreted reference data (testing sets) to the classified images. ERDAS Imagine was used to generate error matrices as well as percent errors of commission (user accuracy) and percent errors of omission (producer's accuracy) as well as Kappa statistic (.Congalton, 1996; Congalton and Green, 1999).

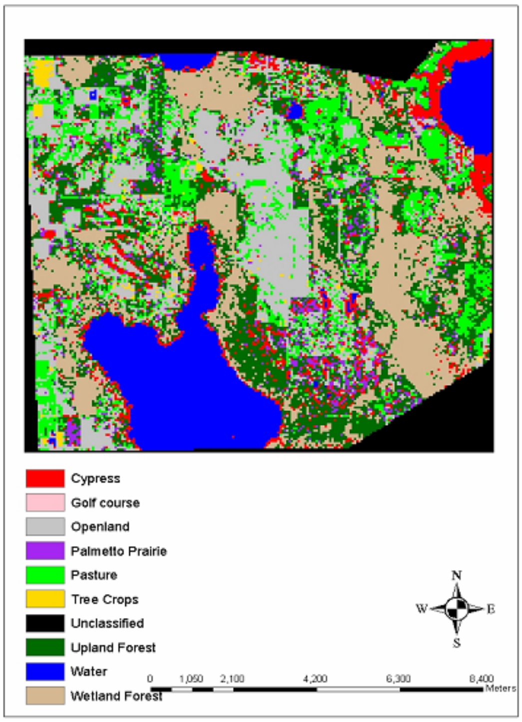
Results and Discussion

LULC Comparisons

Land cover maps for TM 1999 and IRS 1999 were produced and presented in Figure 4 and Figure 5, respectively. The LULC Difference (comparison of TM 1999 and IRS 1999 classified images) map is presented graphically in Figure 6 and shows the percentage land use land cover that is present in the TM 1999 and IRS 1999 classified images.

The "upland forest," "*open water,"* "*tree crops,"* and "*palmetto prairie"* categories show strong agreement in terms of percentage of LULC found in both classified images. "*Upland forest"* is 22.6 % of the TM 1999 classified image and 22.0 % of the IRS 1999 classified image. "*Open water*" is 13.4 % of the TM 1999 classified image and 14.1 % of the IRS 1999 classified image. "*Tree crops"* is 0.9 % of the TM 1999 classified image and 1.0 % of the IRS 1999 classified image. "*Palmetto prairie"* is 3.9 % in both images. The "*cypress"* category shows moderate agreement in both images. "*Cypress"* is 6.4 % of the TM 1999 classified image and 7.5 % of the IRS 1999 classified image Figure 6.

Conversely, the "*open land,"* "*cropland & pastureland,"* and "*wetlands*" categories display differences within the TM 1999 and the IRS 1999 classified images. "*Open land*" is 25.6 % of the TM 1999 classified image and 19.2 % of the IRS 1999 classified image. *"Cropland & Pastureland*" is 9.9 % of the TM 1999 classified image and 12.3 % of the IRS 1999 classified image. "*Wetlands"* is 17.2 % of the TM 1999 classified image and 19.9 % of the IRS 1999 classified image. The confusion among these three categories can possibly be attributed to the temporal resolution of six weeks.



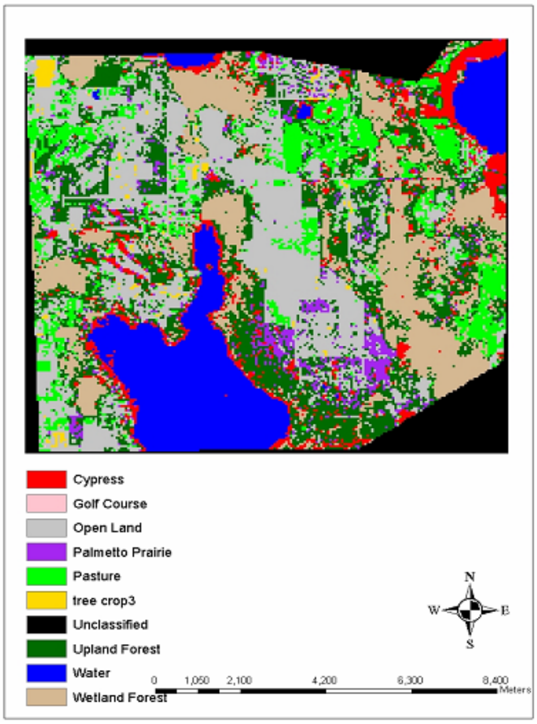


Figure 4. Land use land cover map for TM image taken in 1999 **Figure 5.** Land use land cover map for IRS image taken in 1999

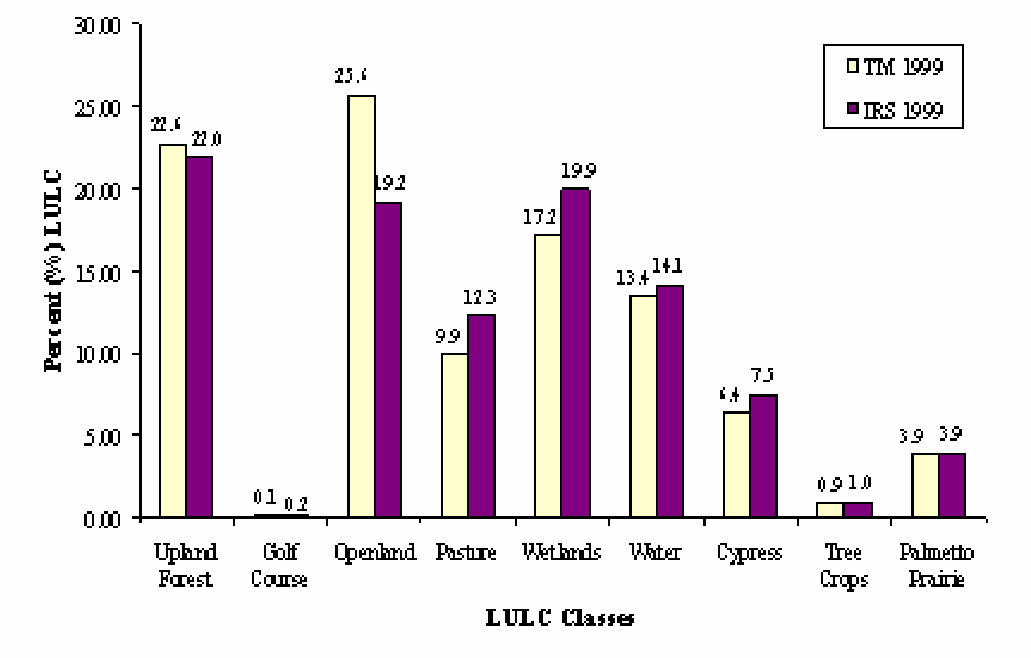


Figure 6. LULC Difference Histogram for TM 1999 and IRS 1999 classified images.

Accuracy Assessment

The Kappa coefficient was calculated for each categorized error matrix and provides a measure of classification accuracy as a whole. The two classifications yielded the following results:

- 1999 TM image, 86.3 % overall accuracy with a $\hat{K} = 0.84$
- 1999 IRS image, 88.4 % overall accuracy with a $\hat{K} = 0.87$

For this research, the USGS standard of 85% overall accuracy was used as a guideline for acceptable classification accuracy. The overall accuracies for both classified images (TM 1999 and IRS 1999) exceeded the USGS standard.

The Kappa values for the classified images fall in the range of strong agreement for classification accuracy (>80 %). The IRS 1999 classified image has a Kappa value of 87 % which represents a probable 87 % better accuracy than if the classification resulted from a random, unsupervised, assignment of pixels rather than the employed supervised classifier (maximum likelihood).

Producer's accuracy calculates the percentage of ground truth pixels that have been correctly labelled in the classified image. For example, the "upland forest" category in the TM 1999 and IRS 1999 classified images show that 88.6% and 87.1% of the "upland forest" pixels were actually classified as such in the classified images respectively (Table 3 and Table 4). The producer's accuracy is the probability that the classifier has labelled the image pixel, as "upland forest" given that the actual ground truth class is "upland forest." Similarly, the "open land" category in the TM 1999 and IRS 1999 classified images show that 100% and 99.3% of the "open land" pixels were actually classified as such in the classified images respectively. The lower producer accuracies were obtained in the category of "golf course" in the TM 1999 image (Table 3) and the "Palmetto Prairie" category in the IRS 1999 image (Table 4). The producer's accuracy was calculated according to Congalton and Green (1999).

User's accuracy is of more interest to users of thematic maps and is the measurement that should most often be used. Again, using "upland forest" as an example, it is the probability that the actual class is "upland forest" (classified image), given that the pixel has been labelled upland forest by the classifier. In the case of the "upland forest," only 67.4% of areas identified as "upland forest" within the classification are truly within this category in the TM 1999 image (Table 3).

Results shows that 88.6% of the time an area that is "upland forest" was identified as such, a user of this classification would find that only 67.4% of the time will an area visited on the ground that the classification says is "upland forest" actually be "upland forest".

The TM 1999 and IRS 1999 classified images produced similar overall classification accuracies, 86.3% and 88.4% respectively, using the same training and testing data (Table 3 and Table 4). These results are very acceptable and meant the TM 1999 and IRS 1999 classified images could be compared with each other with a degree of confidence.

Table 3 . Producer's and User's Accuracies for TM 1999.

	Producer's Accuracy (%)		**User's Accuracy (%)**	
Upland Forest	124/140*100 =	88.6	124/184 =	67.4
Golf course	0/16*100 =	0.0	0/0*100 =	0.0
Open Land	135/136*100 =	99.3	135/165 *100=	81.8
Crop &Pasture	109/139*100 =	78.4	109/123*100 =	88.6
Wetlands	109/110*100 =	99.1	109/120*100 =	90.8
Open Water	185/213*100 =	86.9	185/190*100 =	97.4
Cypress	130/135*100 =	96.3	130/159*100 =	81.8
Tree Crops	58/60*100 =	96.7	58/60 *100=	96.7
Palmetto Prairie	107/160*100 =	66.9	107/107*100 =	100.0

Overall accuracy = ((124+0+135+109+109+185+130+58+107)/1109) = **86.3**

Table 4. Producer's and User's Accuracies for IRS 1999.

	Producer's Accuracy (%)		User's Accuracy (%)	
Upland Forest	122/140*100 =	87.1	122/209 *100=	58.4
Golf course	14/16*100 =	87.5	14/14*100 =	100.0
Open Land	136/136*100 =	100.0	136/140*100 =	97.1
Crop & Pasture	139/139 *100=	100.0	139/141*100 =	98.6
Wetlands	110/110*100 =	100.0	110/128 *100=	85.9
Open Water	210/213 *100=	98.6	210/211 *100=	99.5
Cypress	134/135 *100=	99.3	134/151*100 =	88.7
Tree Crops	56/60 *100=	93.3	56/56*100 =	100.0
Palmetto Prairie	59/160 *100=	36.9	59/59*100 =	100.0

Overall accuracy = ((122+14+136+139+110+210+134+56+59)/1109)*100 = **88.4**

Summary Statistics

The LULC Difference study showed that four categories,"upland forest," "open water," "tree crops," and "palmetto prairie", had strong agreement in both classified images (Figure 6). These results were promising although spatial location of the LULC categories within each classified image was not taken into account. This issue was resolved using ERDAS Imagine's GIS analysis tools. Summary Statistics were generated showing the spatial relationship between images.

Each pixel in the TM 1999 classified image is compared to the corresponding pixel in the IRS 1999 classified image using summary statistics logic. A measure of "agreement" was calculated as follows:

- 63.0 percent of "upland forest" in the same pixel location
- 98.9 percent of "open water" in the same pixel location
- 54.3 percent of "tree crops" " in the same pixel location
- 26.9 percent of "palmetto prairie" in the same pixel location
- 50.9 percent of "cypress" in the same pixel location
- 57.3 percent of "open land" in the same pixel location
- 52.9 percent of "cropland and pastureland" in the same pixel location
- 87.0 percent of "wetlands" in the same pixel location

Temporal Issues

Normally, summer and winter are the best seasons for conducting change detection studies because of the phenological stability of vegetation in these seasons. In the study site, it rained more in October 1999 than compared to November 1999. Conversely, there were drought conditions the six weeks prior to the IRS image being taken on 4 December 1999 (Figure 7).

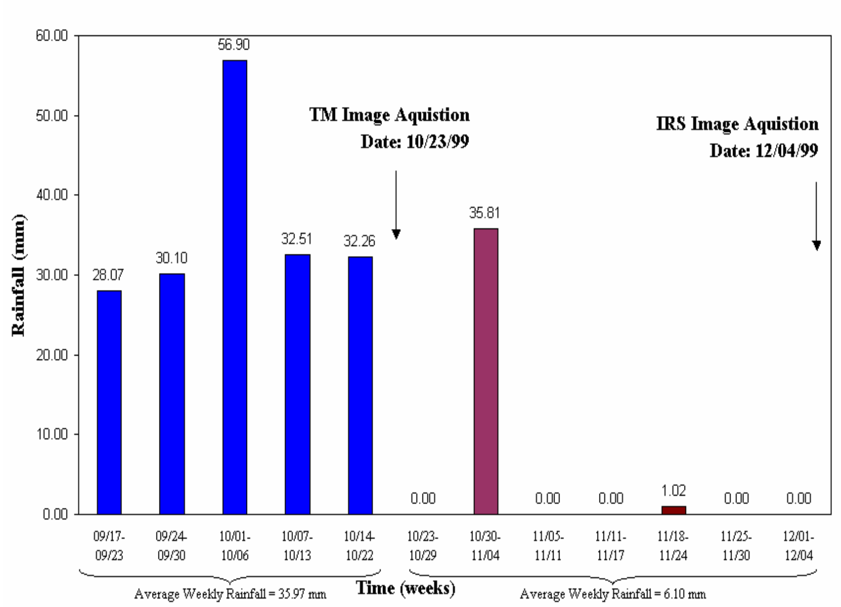


Figure 7. Rainfall Data (average of two rainfall gauges in the study area)
http://www.swfwmd.state.fl.us/data/rain/raindata.htm

These natural events could have been the cause of the differences found within the classified images. The LULC Difference study showed that five of the nine categories were classified almost the same in both images, based on percent land cover. "*Open land*" and "*cropland and pastureland"* categories did not perform so well. Both showed mixed results between the classified images. This research has shown that images taken within the same season can produce mixed results as far as classification is concerned. LULCC studies usually are performed using imagery with anniversary date synchronization. Using images taken within the same season has been common for conducting LULCC studies. The use of anniversary windows may not always be the best solution for change detection studies. Therefore, weather conditions are a factor that should be a consideration for change detection studies.

Spatial Issues

According to Lunetta and Balogh (1999), a pixel-to-pixel comparison between multi-date classified images produced mixed results. In this study, mixed results also occurred. For example, the "upland forest" and "tree crops" categories (63.0 and 54.3% respectively) showed large amounts of disagreement. On the other hand, the "open water" and "wetlands" categories were classified in the corresponding pixels in the TM 1999 and IRS 1999 classified images with a large amount of agreement (98.9 % and 87.0 % respectively). Image registration error could be a possible source for these mixed results.

The time interval (temporal resolution) of six weeks between the Landsat and IRS images being taken had an affect on the results of this research. LULCC studies usually are performed using imagery with anniversary date synchronization as a key. It is considered best. This research has shown that images taken within the same season produce varying results as far as classification is concerned. Climatic conditions prior to the images being taken were considered to have affected the results of the classifications. Therefore, it is important to consider climate before performing vegetation studies such as LULCC using TM and IRS.

Conclusions

Landsat Thematic Mapper and Indian Remote Sensing imagery has the potential to produce similar results in LULC studies although further investigation would need to be undertaken. The results and the following conclusions can be derived from this study:

- Temporal difference could be a factor in the confusion between classes. For instance, the “open land” and “cropland and pastureland” classes within 1999 ETM+ and 1999 IRS images show differences based on classification accuracy.
- Using the same training and testing data, classification accuracy shows that the 1999 ETM+ and 1999 IRS images produces similar overall accuracies: 86.3% and 88.4% respectively. This result is promising, but further investigations are required to derive an accurate conclusion.

This research shows that TM and IRS have the ability to produce similar results. TM and IRS could possibly be used in conjunction with each other for LULCC studies. This results would be used in other parts of world for LULC change studies. However, local level analysis on the topic is required in order to confirm this conclusion.

Acknowledgements
The authors thank Florida Environment Protection Ministry for providing the images via OHWL project.

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