UP TO DATE MAPPING OF REFORESTED AREA USING MULTI-DATES ETM+ DATA

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Commission IV, WG-IV/10

Key Words: ETM+, Reforested Mapping, Multi-dates imagery, Classification, Temporal PCA, Temporal Ratioing,

ABSTRACT:

This research presents and exposes advantages of using multi-dates images to classify and mapping reforested area in the Kordkoy, north of Iran. Three multi-dates ETM+ images from first and middle of spring 2001 and middle of summer 2000 were selected to classify and mapping reforested classes. The images geo-referenced using GCPs and registered by image to image method with total RMSe less than 0.5 pixels. In order to compare the single date images with multi-dates images, classification was done with each single date images separately. In addition, classification was done using multi-dates images produced by two methods, temporal principal component analysis and mathematical transformation. Classification was accomplished using six bands of both methods separately. A ground truth map of classes assessed results, which was produced by ortho-photo-mosaic of 1:40000 scale aerial photos. Results showed that overall accuracy of classification results of single date images were computed about 80 % for middle of spring and 76 % for middle of summer, respectively. Accuracy assessment of classification results using six bands of mathematical method was showed none improvement compared with single date images (79 %). Using PCA components generated from same bands in the classification was leaded a considerable improvement in overall accuracy about 7 percent (84%) and about 0.09 increasing in kappa coefficient (0.77) against single dates. The results of this study also showed that the summer data could not classify the reforested classes. This research exposed that using multi-dates images from different dates could better classify reforested classes than single date images. The results also showed that the PCA analysis could be introduced as suitable method to integrate multi-dates images and to classify reforested area with different vegetation covers. Using other techniques could be examined to improve the results.

1. INTRODUCTION

Forests are the main and important vegetation types in the world. Conservation and protection of forests is necessary due to their duties in human life. In the some places, forests are destroyed by human activities so that they should be again reforested by suitable and compatible hardwood or softwood species. Management and make decision of these reforested areas needs to have accurate different maps such as stand or types extension. In other hand, the reforested types or stands are timely changing due to growing up and substituting of domestic or unfavorable species between reforested species. So, the composition of dominant species, which comprised stands, would be altered and reforested area would be lead to a natural forest after many decades. Therefore, managing of these changeable reforested areas needs to have up to dated maps.

In other hand, forest and reforested area mapping or up to dating of maps trough current fielding ways is time consuming and cost-intensive. Using satellite Imagery and its potentials are new tools in order to managing and mapping forest/reforested covered area. Land cover and forest/reforested areas have been one of the first and main products from remote sensing data. Its dynamics are strongly influenced by socio-economic factors and political decisions, generating a need for adequate mapping and monitoring tools. Consequently, robust and sophisticated analysis methods are required for accurate information extraction and fast and efficient data analysis adapted to the rapid advances in image and sensor technologies. Furthermore, multi-temporal and multi-sensor approaches are becoming more and more important not only for change detection but also for more detailed classification approaches.

Forest or reforested extent mapping has been reported feasible with good certainty using satellite data in the northern mountainous forests of Iran (Darvishsefat & Shataee, 1997, Rafeian, 2002). The next step for forest managers was a feasibility study to apply satellite data to classify northern forest types.

Previous results in the other countries have shown that the discrimination of forest types that are composed only of one species, as pure types is very successful by using satellite data (Walsh, 1980; Mayer & Fox, 1981). When a forest type is composed of two or many species such as in the study area, separating the types will be difficult (Shataee and Darvishsefat, 2004). In the reforested area when natural and endemic species (i.e. hardwoods) based on succession of natural hardwood forest are growing up between conifer replanted species the classification of reforested types would be difficult using single satellite data imagery.

In other hands, the previous results (Najjarlou, 2005) showed that using only single date images couldn't accurately classified the main reforested types in the study area. Overlapping of spectral response of fruits gardens and wheat plants with natural hardwoods as well as low quality of radiometric conditions of images, have reported as causes of low accuracy of classification results. She suggested that using multi-dates images with different radiometric correction and from different seasons may be improved the results.

Sometimes, radiometric correction needs many parameters that accurately computing and determining of a clear condition would be difficult or impossible. Even applying proper radiometric correction of images, the spectral responses of objects wouldn't be true. Therefore, using multi-dates images, which have different radiometric conditions, might better help to classify vegetation covers.

Hobbs (1990) expressed those ecological aspects and differentiated between seasonal vegetation responses, inter-annual variability can be affected on the classification of images. Aldrich (1975) found that late spring and summer data considerably enhanced the discrimination of forest cover vegetation in Georgia. Jano and Pala (1984) stated that while the mapping of forest cut-overs in pure or predominantly coniferous stands was optimal with early spring imagery, summer data did better for cut-overs in deciduous stand. Multi temporal remote sensing data are widely acknowledged as having significant advantages over single date imagery (Towenshed et al., 1985).

How the multi-dates images can be used for classification of reforested types to improve the accuracy the results of classification as compared to single date images? Since, many techniques have applied to use the multi dates images. One of the common and current techniques is linear data transformation.

Two linear data transformation techniques are frequently applied to multi-date imagery that has been stacked in 2n-dimensional space (where n is the number of input bands per images): principal component analysis (PCA) and tasselled cap (Coppin & Bauer, 1996). The PCA as a linear data transformation technique can be used to concentrate correlated information of multi-date imagery. The PCA analysis applied by Richards (1984) to two-date MSS imagery to monitor brushfire damage and vegetation re-growing over extensive areas in Australia. The first three components of Principal Component Analysis contain more information contrary to each band individually.

One of the other techniques that can be used to reduce atmosphere effect on the imagery and decreasing of variations in DNs of multi date imagery recorded at the different radiometric conditions is mathematical transformation or called as ratio transformation. The Ratio transformations are often used in image processing to reduce radiometric effects of slope, illumination angle or seasonal variability (Ivits & Koch, 2002).

With these mentioned causes, the goals of this research were reforested type classification and up to date mapping of reforested area by means of multi dates ETM+ data using techniques which apply the multi date imagery in classification process.

2. MATERIALS

2.1. Study area:

The study area is located at the southern reforested area of Kordkooy region in the Golestan Province, Iran (Fig. 1). The study areas are relatively flat (slop <10 %) and altitude ranges between –20 to 100 metres with about 600 hectares area.

Before plantation, the study area had been deforested and shifted from hardwood forests to farm lands by rural peoples to extend their farmlands. In 1985, in order to prevent of deforestation and recovering of farm lands to natural forest lands, the area was planted with conifers species of pine (*Pinus teda, Pinus eldarica, Pinus broucia*), cypresses (C*upressus horizantalis, Cupressus sempervirens)* and hardwood species of eucalyptus (E*ucalyptus camaldulensis*) and walnut (*Juglans nigra*). After 20 years, the some endemic and domestically hardwood species were growing between plantations so that in the somewhere they were dominated on conifer species.

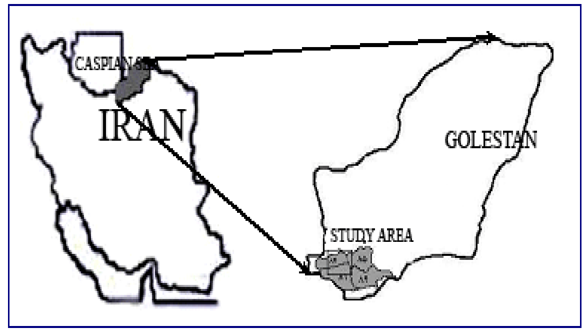

Figure 1: location of the study area in the south of Kordkooy, Golestan province, north of Iran

2.2. Data

In this study, small windows on 163-34 Scene were selected from two successive available dates of spring (19th April 2000, 2nd April 2001) and summer data from 16th July 2001. In addition, a digital aerial ortho photo-mosaic with scale of 1:40000 was used to generate ground truth map. To geo-referencing of images and selecting of GCPs, two 1:2500 scale digital maps of study were also used.

3. METHODS

3.1. Pre-processing of images

Geometric correction of images was done in two steps: first the image of 19^{th} April 2000 was geo-referenced by GCPs gathered from 1:25000 scale digital maps with total RMSe less than 0.5 pixel. The two other dates images were then rectified to geo-referenced images by image to image registration method with RMSe less than 0.45 pixel. Using of nearest neighbour technique to preserve initial radiometric conditions did resampling of the DNs of all geometric corrected images.

3.2. Multi-temporal Analyses

In addition to apply single date imagery to classify reforested classes individually, two methods were applied to multi-date imagery to reduce impact of radiometric condition and seasonal differentials: Temporal Principal Component Analysis (TPCA) and Temporal Averaging Transformation (TAT). The results of these methods were used to classify reforested type and comparison with other data from single date imagery.

3.2.1 Temporal Principal Component Analysis (TPCA)

PCA can be used to reduce the information included in the raw data into two or three bands without losing significant information (Monger, 2002). In spit of currently PCA analysis that compresses the correlated bands of a source, it is used to merge similar bands of multi-date imagery. Because of high correlated similar bands from multi-date imagery, they can be transformed to many components. The first component would be containing more information from used three date bands. Therefore, the six first components were extracted from six similar bands from three dates.

TPCAi = PCAi (Bandit1, Bandit2, Bandit3) (1)

Where TPCAi is the first component of PCA on the three date similar bands (i)

3.2.2 Temporal Averaging Transformation (TAT)

Atmosphere or other radiometric distortion parameters often may effect on spectral reflectance of vegetation at different dates so that the similar bands will have different digital numbers for an equal object as noises. To ignore and reducing of seasonal radiometric effects on bands and improving classification results of the reforested types, the simple mathematical operation as multi data averaging was applied to the three temporal similar bands. This operation was respectively applied to all six bands from three date bands so that results of operation were six images with reducing of variance of certain pixels.

$$\mathbf{TAT_{ij} = Average\ (Bandit1,\ Bandit2,\ Bandit3)} \quad (2)$$

Where TATij is the average of three date similar bands (i)

3.3. Classification

Classification of imagery was accomplished with different combinations (table 1). In order to test effectiveness of new data set produced from multitemporal principal analysis (C5) and temporal averaged bands (C4) to improve reforested type classification results, classification of reforested types accomplished with the new data sets i.e. TPCA and TAT. In addition, the single date data sets (C1, C2 and C3) were individually classified to compare the best date for forest type classification.

Also classification of reforested types was done with two seasonal data sets (spring and summer data). In other hand, the 12 combined bands from 22nd April 2000 and 17th July 2001(C6) and also the 12 combined bands from 6th April 2001 and 17th July 2001 (C7) were individually classified in order to using the multi-seasonal data set.

Following many studies, where the maximum likelihood classifier was reported as a suitable classifier (Hopkins et al., 1988; Williams, 1992; Darvishsefat, 1994; Shataee et al., 2004), this classifier was applied to separate reforested types.

Combination	data set (bands)
C1	6 April 2001 (6)
C2	22 April 2000 (6)
C3	17 July 2001 (6)
C4	Temporal averaging (6)
C5	Temporal PCA (6)
C6	22 April 2000 & 17 July 2001 (12)
C7	6 April 2001 & 17 July 2001 (12)

Table 1: Image band combinations used in classification

3.4. Ground truth generation and accuracy assessment

The accuracy of classification results was assessed with a ground truth map. The ground truth map including reforested area map (four classes of hardwoods, softwoods, mixed plantations and non-forested area) have generated by visual interpretation of digital orthophotomosaic and field check (figure 2). The digital orthophotomosaic was produced using with eleven 1:40000 scale aerial photos from autumn of 2001. The camera parameters, fiducial marks, ground control points and digital elevation model have been used for orthorectification of aerial photos.

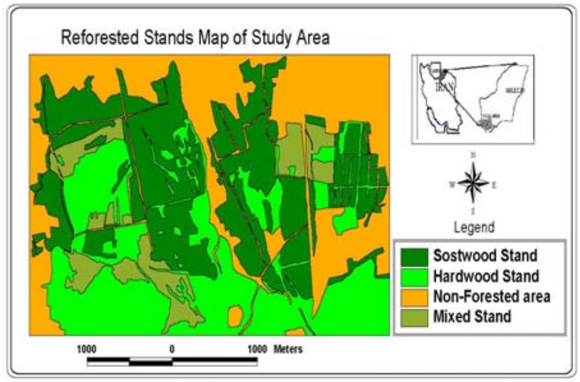

Figure 2: ground truth map of reforested types at the study area

4. RESULTS AND DISCUSSION

As a result of a field study and visual interpretation of aerial photography (1: 40000 scale) of the study area, four major reforested types or classes were delineated, and fields were selected to collect representative pixels for the classes to be used in classification processes. Thus, a ground truth image containing a total of all reforested areas was generated for study area.

Temporal comparisons of images to classify reforested types need to have equal geometric condition for all images. It should be evident that accurate spatial registration of the multi-date imagery is essential to compare results. The results of geometric corrections and rectification showed that images have almost rectified with suitable geometric conditions (RMSe under 1 pixel and the study area have no relief displacement due to be flat).

Signature seperability analysis using both Bhattacharya distance and transformed divergence indices showed that the mixed and broadleaf classes have lower seperability than other classes.
The accuracy assessment of the classification results showed that the imagery on 22 April 2000 among other dates could better classified reforested area (table 2). This result showed that the best date to classify forest and reforested types is middle of spring when the forest and reforested area have reached their maturity in growth. Although, having the uncommon radiometric responses of images on different dates may be effected on the quality of results.

Kappa coefficient	Overall accuracy (%)	Data sets
0.68	76.6	6 April 2001
0.73	80.4	22 April 2000
0.67	76	17 July 2001
0.762	83	Temporal averaging
0.773	**83.7**	**Temporal PCA**
0.776	**84**	**22 April 2000 & 17 July 2001**
0.74	81.22	6 April 2001 & 17 July 2001

Table **2**: accuracy assessment of classification results with different data set

With over viewing on the error matrices of accuracy assessments, it was seen a considerable error reducing for mixed type on 22 April 2000 imagery compared with two other dates. This may be referring to silviculture treatments on 2000. The non-forest class contains agriculture and bare lands could classify on summer date imagery (17 July) but the conifer class was poorly classified compared with other classes.

In order to reducing of radiometric effects on the single date imagery and improvement of classification results, temporal averaging transformation (TAT) was done on the three dates in compliance with equation (1). Accuracy assessment of results showed a higher overall accuracy (83%) and kappa coefficient (0.762) compared with using single date imagery individually.

This results exposed that single date imagery even on the best date due to atmospheric condition on the acquisition time or different phonological condition for classes can not well classify forest types and it should be used together other dates. Using temporal rationing on similar bands, we found that the broadleaf class could better classified rather than other last methods.

Regarding to three dates imagery were almost from 1 year anniversary, so that except for non-forested area all classes almost didn't change throughout 1 year, similar bands contain almost information with low variances and repeated information. With this assumption, the principal component analysis on similar bands may be integrated to create a first component that would have more variances. After temporal principal component analysis based on above assumptions, it was found a more improvement in accuracy (83.7% overall accuracy or 0.773 kappa coefficient) compared with other last methods and certified our theory basses (figure 3).

In this study, we also applied the two-date imagery directly (c6 and c7 combination) to classify the reforested types. Using c6 combination (22 April 2000 and 17 July 2001) with about 1.5 year temporal difference could little improved results of classification in comparison with TPCA. Although, using more channels in classification process may improve the results, but it was may lead to some problem such as redundancy and costly, especially, when multi temporal imagery with more than two date are used for classification. Therefore, this method can not be present as best method due to restricted mentioned causes.

Using c7 combination to classify could not improved the results (81.22% overall accuracy), but in comparison with single date imagery, those could better classified reforested types. This results shows that using beginning of spring data (6 April) corporate with summer data cannot be produce acceptable results and this refers to immaturity of vegetation and forest on that time.

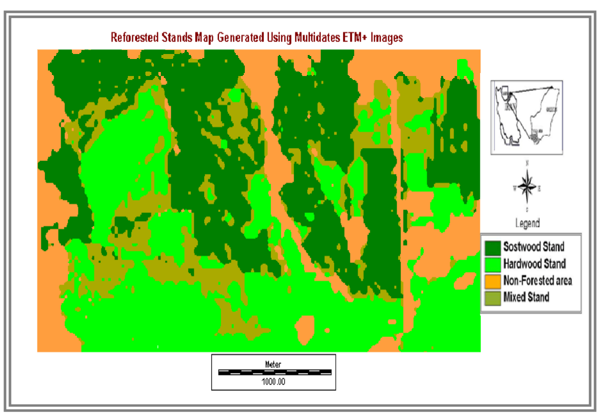

Figure 3: the classification map of reforested types using multi-dates ETM+ images

5. CONCLUSION

This study exposed the advantages of using multi dates imagery to classify reforested types in a small area. This research showed that using only single date imagery can not be classify interested classes due to atmospheric, phonological condition of classes together with different cultivation at the agriculture.

At this study we investigated the some methods to use multi-date imagery to classify four reforested types and non-forest class contained from different agriculture productions, orchards and non-cultivated lands. These lands and their productions on some date had reflectance overlaps with hardwood and mixed classes and this problem can not be solved only with multi seasonal or multi-date imagery.

At this research, the multi-dates images were selected based on at least changes for reforested types and natural forests in study area so that the temporal differences between three images was maximum one year (22 April 2000 to 17 July 2001).

The results showed that the overall accuracy of imagery on summer date was lower than other dates. Although, the July images (beginning of summer) provided phonological stability (seasonal maturity) for hardwood and softwood trees, but up growing of hardwood trees and shrubs between softwood trees causes mixed classes, which have reflectance overlap with both classes. This study certified other researches (knight et. al, 2004) that spring imagery is suitable to classify reforested types rather than summer imagery.

However, among investigated methods, the TPCA method can be introduced as a best method for classification to use multi dates imagery which, were acquired over a short periodic time and with no considerable change or difference on types (maximum 2 years). This method can be used to up to date mapping of other same reforested area like the study area and in particular, when the multi seasonal data were used to classify reforested or forests types.

Investigating on other multi-temporal and multi-seasonal classification methods should be studied at the other data and classification in future.

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