INTERPRETATION OF TROPICAL VEGETATION USING LANDSAT ETM+ IMAGERY

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ABSTRACT:

Monitoring of tropical forest is important as it plays a vital role in Global biodiversity and terrestrial carbon dynamics. Remote sensing can be effectively used to monitor the tropical vegetation. However, an operational tool for interpretation and monitoring of tropical forest has not yet well developed. Therefore, the current study aimed to generate an interpretation key and a spectral library for the forests of south-eastern Bangladesh. The study used Landsat ETM+ imagery. Geometrically corrected imagery was obtained from USGS and later was adjusted in the field using GPS. Atmospheric correction was done by modified dark object subtraction method. Eight different vegetation types could be separated from the satellite image. The study has developed an interpretation key, which can be effectively used for monitoring tropical vegetation. A discrete spectral library was also developed from Landsat ETM+ image bands. The result of the study will be quite useful for interpretation and monitoring of tropical forests in similar ecosystem.

1. INTRODUCTION

1.1 Monitoring of Tropical Forest

Forests of the tropical zones, which constitute about half of the world's forests and which are mostly occurring in developing countries, are overexploited in some regions, under harvested in others, and unmanaged in nearly all. Those forests consist of World's largest biodiversity and play an important role in global terrestrial carbon budget. Scientific management of tropical forests needs a large amount of reliable information that can only be obtained in a time and cost effective way with the help of aerial photographs and other forms of remote sensing. In spite of importance and urgency, relative less progress has been made in recent years in the use of air and space-borne imagery of tropical forest vegetation than that of temperate and boreal vegetation (Lund 1997). Therefore, the objective of this study is to generate a visual-interpretation key and spectral library for monitoring vegetation of south-eastern Bangladesh, which are currently not available.

1.2 Elements of Visual Interpretation

The six primary elements of visual interpretation are tone or colour, size, shape, texture, shadow and pattern (Estes and Simonett, 1975). In addition of those height, size and association may be added (Howard, 1970). Tone refers to the relative brightness or colour of objects on imagery. Size, shape and position (site), are combined under the term contextual information. Size of the object often help to identify it, which includes the recognition of old over-mature trees, maturing trees, saplings, seedlings and shrubs on an image. Shape relates to the configuration or the general outline of objects as recorded on imagery. Man-made feature sometimes follow a regular boundary, but the natural features usually follow natural boundary. Site refers to topographic or geographic location and is a particular important aid in the identification of vegetation types. Texture is the frequency of tonal change on the photographic image. It determines the overall visual 'smoothness' or 'coarseness' of image features. Pattern relates to the spatial arrangement of objects. Association refers to the occurrence of certain features in relation to others (Lillesand and Kiefer, 2000; Howard, 1991).

1.3 Visual-interpretation Keys

An image-interpretation key is a set of guidelines used to assist interpreters in rapidly identifying features on a remote sensing image. Depending on the method of presenting diagnostic features, image-interpretation keys may be grouped into two classes: selective keys and elimination keys. Selective keys are usually made up of typical illustration and descriptions of objects in a given category. In contrast, elimination keys require the user to follow a step-by-step procedure, working form the general to the specific. One of the more common forms of elimination keys is the dichotomous type. Here, the interpreter must continually select one of two contrasting alternatives until he or she progressively eliminates all but one item of the category, which is correctly describing the feature under investigations (Avery and Berlin, 1992).

Following the above principles several interpretation keys have been developed both for tropical and temperate forests based on

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aerial photographs, satellite and radar imagery. For example, selective interpretation keys were developed for tropical woodland of Tanzania (Howard, 1959), and for coniferous and hardwoods of Middle-European trees (Grundman, 1984; Anthony, 1986; modified by Hildebrandt, 1996). On a SPOT false colour composite natural forest, bamboos, scattered trees, brush, plantation, reed forest could be identified in northeastern Bangladesh (Arquero, 1997). On 1:50,000 scale aerial photographs covering moist tropical forest of Kerala and Tamilnadu, India, the following forest cover and land use types were delineated: tropical evergreen, tropical semi-evergreen, moist deciduous, dry deciduous, teak plantation, eucalyptus plantation, reeds, bamboos, rubber plantations and tea estates (Tomar, 1968).

2. MATERIALS AND METHODS

2.1 The Study Area

The study area is located in the southeastern Bangladesh (Figure 1). The forests of the study area can be classified as tropical wet evergreen forests and tropical semi-evergreen forest (Champion *et al.,* 1965). This forest type is characterized by the presence of a considerable amount of evergreen trees in the upper canopy. The top canopy reaches a height of 40-60 meters. A few semi-evergreen or deciduous species may occur, but usually they do not change the evergreen character of the forest. The forest is rich in epiphytes, orchids, woody climbers, ferns, mosses and palms particularly in shady moist places (Das, 1990).
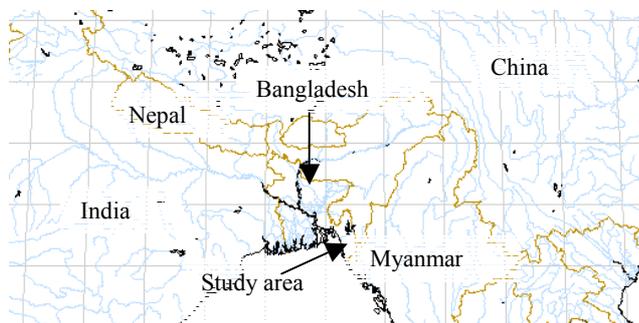
Figure 1 Location of the study area

2.2 Remote Sensing Data

The study selected Landsat ETM+ data, which is relatively cheap and available. It could be easily used by developing countries where most of the tropical forests lie. The study has decided to develop a selective interpretation key for the Landsat ETM+ sensor for the following reason. Because of the relatively poor spatial resolution of satellite imagery (in compare with aerial photographs, where mostly dichotomous keys are widely used), image color, texture and location are important image characteristics that must be used to interpret vegetation types; these characteristics can easily be presented in selective keys.

2.3 Image Pre-processing

The Landsat ETM+ image was received with geometric correction form USGS. However, a linear shipment was discovered during the field mission and therefore the image was shifted accordingly. The current study area consists of small hills. But topographic normalization could not be applied due to lack of appropriate digital elevation model. The accuracy of geo-coding was checked using a portable GPS from the known location of the geodetic points of Survey General of Bangladesh. The study used a modified dark object subtraction method namely COST method (Chavez, 1989; 1996). One percent minimum reflectance was fixed for atmospheric haze correction (Chavez, 1996; Moran *et al.,* 1992). Using the model maker of ERDAS Imagine software the digital count was converted to surface reflectance.

2.4 Visual Interpretation and Field Verification

A computer-aided unsupervised classification scheme was applied to the Landsat ETM+ image. Simultaneously a variety of image channels were displayed on computer-screen and tried to find an optimal combination where a variety of vegetation classes were distinguishable. Additionally a correlation matrix of different spectral bands for the sample pixels was calculated to ease the band selection process. Interpretation could delineate eight different vegetation classes. All variety of vegetation classes was reached during 2002-2003. The location was identified by a portable GPS (GPS 12, Garmin). A detail description of vegetation was recorded and a panoramic camera photo was taken for the field-plots. A total number of seventy sample plots were collected.

3. RESULTS AND DISCUSSION

3.1 Selection of Optimal Band Combination

The correlation matrix of the spectral bands contains useful information about the redundancy of information and selection of optimal band combination for interpretation purpose. If the bands show strong correlation (value near to 1.000) this indicate the bands usually contain similar information to each other. When those bands are visualized the minimum separibilty among different feature would be noticed. The following table 1 represents the correlation matrix of the selected sample plots where field sampling was carried out.

Table 1. Correlation matrix of the representative pixels of Landsat ETM+ image for the study area

Bands	1	2	3	4	5	7
1	1.000					
2	0.861	1.000				
3	0.856	0.942	1.000			
4	0.070	0.175	0.012	1.000		
5	0.609	0.809	0.847	0.210	1.000	
7	0.660	0.832	0.898	0.096	0.978	1.000

From table 1 it is observed that among visible (band 1-3) and mid-infrared bands (band 5-7) high correlation exist. It means that there is a high redundancy of information within those bands in the vegetated areas. So it makes more sense to select the bands, which contain minimum redundancy. Therefore, one

band from the visible region, the near infrared and one from mid-infrared can be selected for the best separibilty in the vegetated areas using Landsat ETM+ image. As it is common to use band 3 from the visible bands and 5 from the mid-infrared bands the current study has also decided to do so. Therefore, bands 3, 4 and 5 were finally selected for the interpretation purpose.

3.2 Interpretation of Tropical Vegetation

Figure 2 shows a spectral library for the vegetation in southeastern Bangladesh.
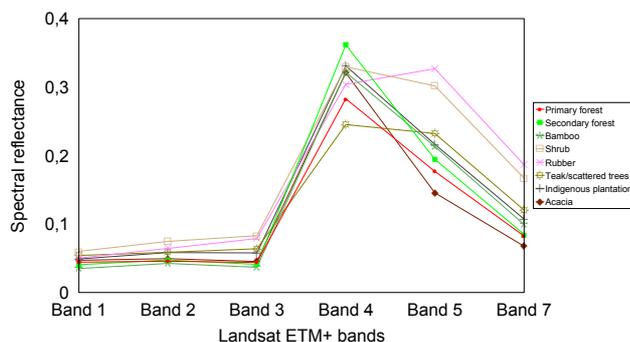
Figure 2. Comparison of spectral reflectance from different vegetation types in south-eastern Bangladesh

Band 1, 2 and 3 of Landsat ETM+ represent to the visible light of blue-green, green and red reflectance respectively. The reflectance of vegetation in the visible spectrum dominates due to the presence of leaf pigments. Shrubs usually contain a little amount of biomass, which has a high reflectance in all the visible bands. In contrast, bamboo, which is a monocotyledon, appears with a high absorption in this region. Vegetation, which contains a huge amount of green leaves and biomass (i.e. bamboo, natural forest, Acacia plantation etc.) usually shows more absorption in the visible green and red spectral region. On the other hand, vegetation that has fewer amounts of those components (i.e. shrub, rubber) exhibits relatively higher reflectance in that spectral region. It should be noted that vegetation having little amount of green biomass might contain some reflectance from the soil underneath. It is interesting to note that the reflectance in visible-red region is higher than that of the green for vegetation containing little amount of biomass, however, the relationship is opposite for those vegetation having high amount of biomass, because red light is largely absorbed by chloroplasts and used in photosynthesis. Therefore, it can be concluded that the first derivative of visible red to green reflectance might contain some useful information on the green biomass content of tropical broad-leave vegetation. As band 3 provides the highest variability among the visible channels and consequently it makes sense to use this channel for interpretation of vegetation (Figure 2).

Band 4 corresponds to the reflectance of near infrared region, which is very high for vegetation and therefore, it is widely used to separate vegetation from other type of landuse. Usually reflectance in this band is transparent by chloroplasts, but highly reflected by spongy mesophyl. Young secondary forest

shows the highest reflectance in this region and teak/scattered trees have the lowest. Mature natural forest shows relative lower reflectance than the young secondary forest. Though mature forests have the similar species composition as the young secondary forests, the difference might be the result of the difference of the structure of mesophyl tissue. The mesophyl tissue of the leaves of younger vegetation provides the stronger reflectance than that of the mature vegetation leaves. In addition, presence of more shadows on mature forest canopy might have some influence on it. As band 4 shows a high variability among vegetation classes it would be useful to use this for vegetation interpretation.

Band 5 corresponds to the shortwave-infrared region, which is quite sensitive to the amount of water present in plant leaves. Rubber and shrub usually shows a higher reflectance in this region. This might occur that those classes have a less amount of water or reflectance was dominated by soil-background. Acacia plantation exhibits the lowest reflectance. This vegetation does not contain any true-leaf. Leaves usually shed at the seedling stage and the phyllod become swollen and act the function of leaf. Probably those modified phyllods contain large amount of water than the leaves of other vegetation. This spectral region has a high variability for different vegetation classes. It indicates that the band could be useful for the separation of different types of vegetation. All the spectral lines of figure 2 have been crossed each other in between the near-infrared and mid-infrared region. Consequently, the first derivative between bands 5 to 4 might contain valuable information for vegetation class separation in the tropics.

Band 7 also contains the information of shortwave-infrared channel, which is also an indicator of the presence of water on leaf. However, all the lines in figure 2 from bands 5 to 7 did not cross each other. So, it contains only the redundant information as band 5 does. Hence, if band 5 is already used band 7 will not improve the interpretation capability of tropical vegetation.

From the above discussion it can be concluded that the use of bands 3, 4 and 5 could be optimal interpretation of vegetation. As we can use maximum three channels as the basic colour combinations. The next question arise which band should be used on which colour combination. If 5 4 3 bands are assigned to red, green and blue the vegetated area will appear as green. If 4 5 3 combination is the vegetation will be red. As human eye can distinct red better than green the latter combination could separate vegetation classes in a better way. However, working continuously with red on computer screen is a stressful for eye, the other combination is recommended for certain time.

3.3 Separation of Individual Class

As figure 2 shows only the mean of value of reflectance, further graphs were developed to show the variability of reflectance in each class (Figure 3). In this figure, high-low graph represents the mean value at the centre with a plus and minus of 95% confidence limit, which means that a chance at this probability level the mean value of reflectance lies within this threshold.

Visible blue-green reflectance(0.45-0.52μm)

Infrared reflectance(0.78-0.90μm)

Visible green reflectance(0.53-0.61μm)

Mid-infrared reflectance(1.55-1.75μm)

Visible red reflectance(0.63-0.69μm)

Mid-infrared reflectance(2.09-2.35μm)
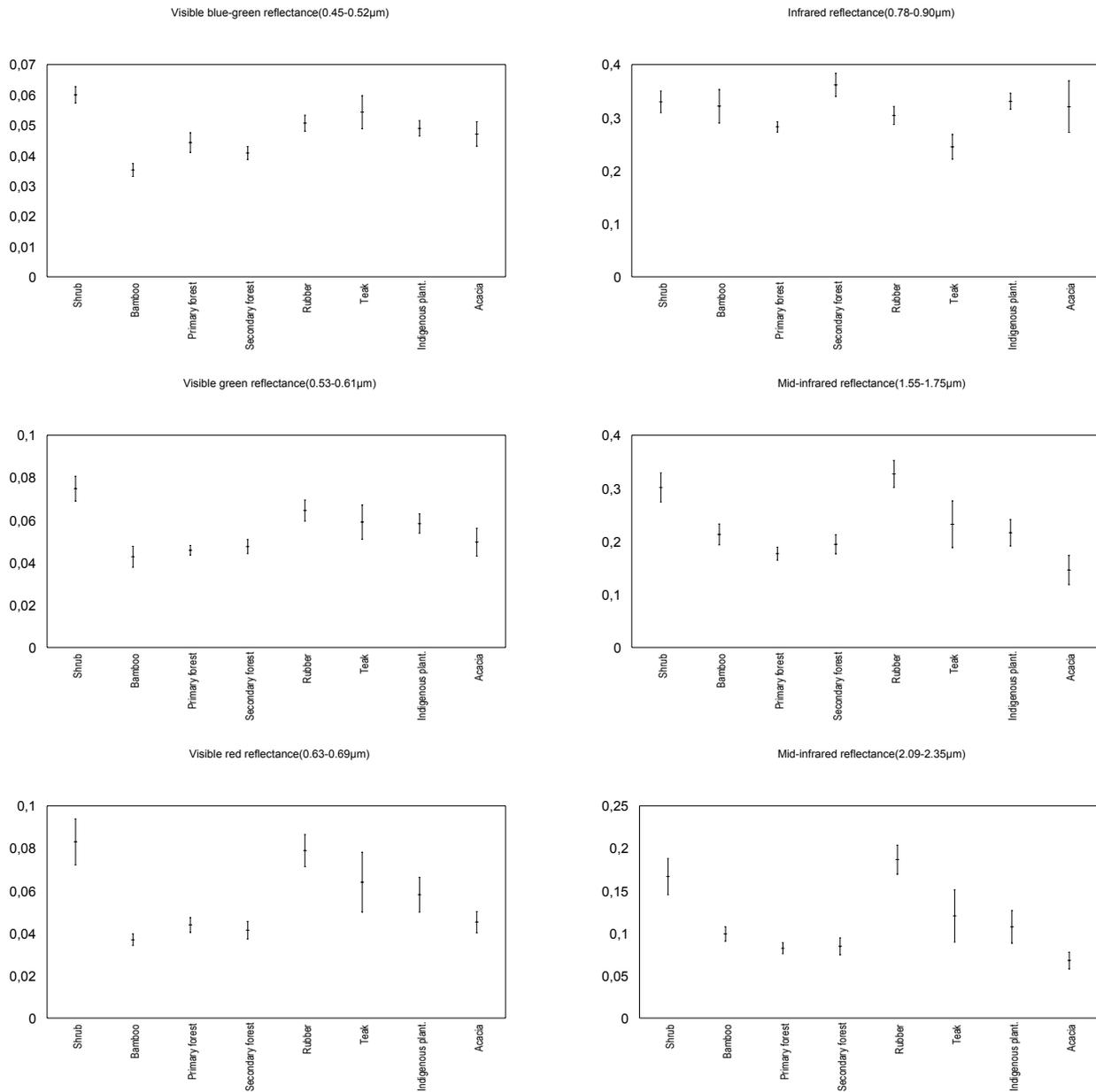
Figure 3. Spectral reflectance from different vegetation types. Vertical lines show mean values with 95% confidence limit

In the visible red reflectance, shrub, rubber and teak are identically different than primary and secondary forest, bamboo and acacia (Figure 3). Differentiation between primary and secondary forests using only the reflectance is not possible in the visible bands. However, image texture might help to separate primary from secondary forests. Secondary forests usually have a smooth texture than the primary one. Shrub and rubber have quite similar and high reflectance. The reflectance of teak just follows them partly. Shrub is usually having a relatively thin layer of canopy than the other vegetation types and sometimes mixed with background soil reflectance. Though the canopy of rubber is quite different than the shrub, during the time of image acquisition rubber canopy was quite leafless, and therefore the understorey shrub layers dominated the reflection. Consequently the reflection is not identically different from the scrubby vegetation. Furthermore, teak has bigger leaves,

which usually are not dense enough to hide the understorey. This plantation strongly discourages the growth of understorey vegetation and therefore, the reflection perhaps was a mixture of upper canopy leaves which are intermixed with background soil reflectance. This assumption is likely being true for the scattered trees, which are also not differentiable form teak plantation

The reflection of primary forests and teak is identically lower than shrubs, secondary forests and indigenous plantation in the near-infrared spectral region (Figure 3). The reflection of the rest category lies in between these two types of vegetation. It is interesting to note that the reflectance from primary and young secondary forest is different though they are having the similar species composition on their top-canopy. This difference might be associated with the difference of age. So it can be concluded that the spectral

Table 2. Description of vegetation type and their appearance on a Landsat image (4→red, 5 → green and 3 → blue)

Vegetation type	Vegetation characteristic	Interpretation remark
Primary (tropical wet evergreen and semi-evergreen) forests	• Multi-storeyed forests with a number of matured trees in the upper canopy; shrubs and sometimes bamboo in lower canopy • In some areas a gregarious occurrence of *Dipterocarpus* species is noticed	• Dark brown with sometimes reddish brown spots • Rough texture • Irregular boundary
Secondary (young) forests	• Mixture of a number of species at pole-stage • Cleared several years ago and left undisturbed	• Red to reddish brown • Smoother texture than the mature forests
Mixed vegetation dominated by bamboo	• Dominated by bamboo (Muli: *Melocanna baccifera*, Mitinga: *Bambusa tulda*) with sometimes scattered trees in the upper canopy • Assoication varies with local topography, top and mid slope covered by small-sized bamboo (Muli) whereas foothill and valleys by larger bamboos (Mitinga)	• Yellow and yellowish brown • Texture varies with region • Difficult to distinguish from natural forests when bamboo is intermixed
Shrubs	• Shrubs intermixed with seedling and sapling of natural vegetation, bamboo and grasses • Formerly covered by natural forests, repeated disturbance resulted scrubby or bush type vegetation	• Light yellow with green, smooth texture • If canopy is closed appears light yellow but in case of exposed soil it appears green • Located nearby the habitation
Acacia plantation	• Plantation with *Acacia auriculformis* and *A. mangium* • Excellent growth was noticed	• Dark red with smooth texture, dark tone is sometimes identical • Identification between two species is not possible without ground information • Usually follows a regular boundary
Mixed plantation with indigenous species	• A variety of indigenous species: *Dipterocarpus turbinatus, Sysygium grande, Artorcarpus Chaplasha, Gmelina arborea, Chikrassia tabularis* etc.	• Reddish brown, smooth texture, regular boundary
Scattered trees, teak plantation, teak coppice	• This class has a large variability, all the mentioned class appears as the same spectral response on a Landsat image • Teak coppice appears if teak plantations were removed • Scattered trees appear due to the extreme human interference on natural forests	• Green with dark brown spots. Those spots might appear due to scattered remaining of natural vegetation inside this class • Teak trees have large leaves with no undergrowth, scattered trees with scrubby surrounding appears as same. • No difference can be made with teak plantation or coppice
Rubber plantation	• Introduced before one-two decades for the production of rubber • The spacing is variable • Rubber tree sheds leaves during winter. Beginning of January the leaves turn to pale; by the end of the month trees are complete leafless	• Green on Landsat image. This tone appears from bare soil because trees were leafless during the time of image acquisition

reflectance due to the internal leaf structure varies with age, and young vegetation has a higher reflectance than the mature one in this spectral region though shadow might have an additional influence on it.

3.4 Selective Interpretation Key

The above result can be summarized and presented in table 2 for interpretation purpose. To ease the interpretation, Landsat image and its corresponding field photos have also been included (Figure 4 and figure 5).

4. CONCLUSION

The study generated an interpretation key and a spectral library, which can be used for interpretation and monitoring forest in the tropics. However, there are several limitations of this study. For example, variation in crown characteristics within a specific species can be a source of interpretation error leading to misclassification. Among the factors that can cause significant variation are tree age and stress. Trees growing on deep, fertile soils at low elevations tend to have different crown forms than their counterparts on shallow, rocky soils at high elevations. Position of a tree crown on a satellite image can also change its appearance. Trees on shaded slopes will appear darker and have

less contrast with their neighbours than trees in full sunlight. Further studies can be carried out to develop a profound interpretation key and spectral library by minimizing the above critics.
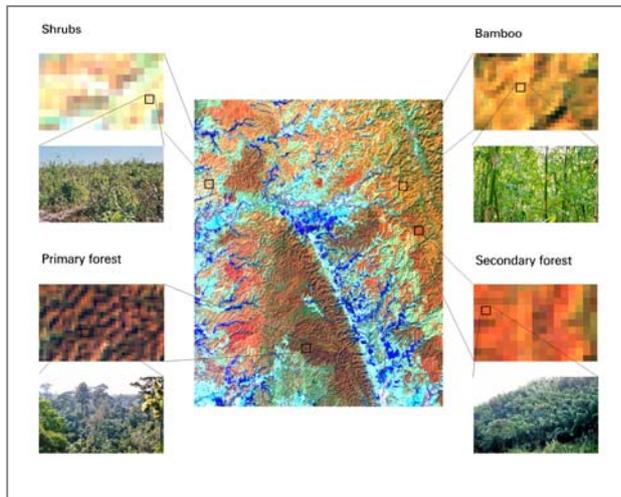
Figure 4. Interpretation of natural tropical vegetation on Landsat ETM+ imagery
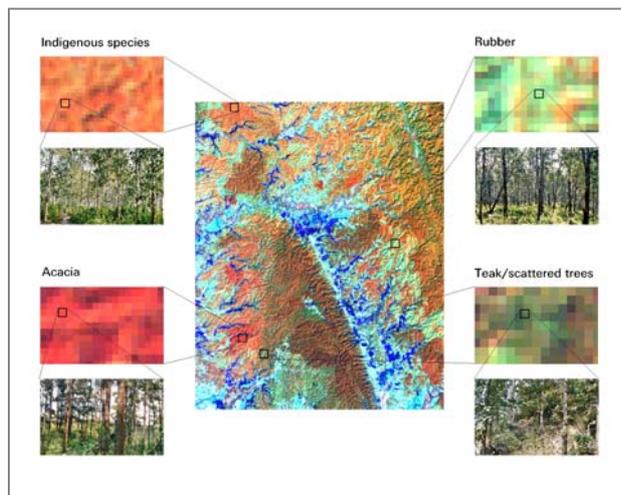
Figure 5. Interpretation of tropical plantation on Landsat ETM+ imagery

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