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Information Technology Tools in Rubber Cultivation

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Abstract

A project on development of rubber information system was initiated with an idea to bring various themes and aspects of rubber cultivation into a database management system, Remote sensing (RS) and Geographical Information System (GIS). An attempt has been made in this study to identify rubber clones and their distribution in Kanyakumari area in Tamil Nadu, using remote sensing technology. Temporal variation in spectral reflectance from different rubber plantations was studied. Ground truth surveys were conducted on the dates of satellite passes over path 101 and row 68 i.e. on 24 February 2004 and 19 March 2004 to ascertain the situation on the ground as far as canopy characteristics are concerned. The use of digital elevation model (DEM) obtained by SRTM (Shuttle Radar Topographic Mission) at 90 meter resolution was helpful in understanding the terrain in which rubber is grown. Superimposition of satellite images over DEM revealed that rubber in this area was grown on different terrains varying from gently sloped plain land to hilly areas with altitudinal differences. The brightness values from different rubber plantations fielding various clones with different ages were observed from satellite imagery. Hand held GPS (global positioning system) receiver was used to increase the precision of identifying clones on the satellite imagery. Use of modern tools like application of remote sensing and GPS helped in visualizing the terrain in which rubber is grown, differences in spectral reflectance due to clonal characteristics and clonal differences in wintering behaviour, etc.

Introduction

Rubber plantation industry has got a tremendous influence on the economy of Kerala State of India, which produces more than 90 per cent of natural rubber in India and occupies more than 20 per cent of total cultivated area in the state. With the delicensed system in place, there is no mandatory registration of plantations with the Rubber Board, resulting in presence of several unregistered/unknown plantations. However, better statistics are always needed for productivity estimates and for effective policy making. Obviously, application of remote sensing technology is a promising tool that could give area statistics with higher precision. There were studies on the spectral reflectance characteristics of rubber vegetation (Rao, 2000; Rao *et al.*, 2000; Rao, 2002; Rao, 2003; Rao[a] *et al.* 2003, Rao[b] *et al.* 2003; Rao[c] *et al.* 2003) spatial and temporal variation to understand the spectral behaviour of rubber canopy and to establish a method to map rubber plantations in the State of Kerala in addition to GIS applications. With the experience and realization of the potential of these modern tools, a project on the development

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of Rubber Information System using Remote Sensing and GIS Techniques was initiated (Rao *et al.* 2003).

Rubber growing region in this part of India represents rugged terrain containing hills and valleys with slopy lands under plantations, highlighting the necessity to study the terrain that could also be represented digitally by digital elevation models (DEM). DEM is a digital representation of the relief of the earth's surface and consists of arrays and values that represent topographical elevations measured at equal intervals on the earth's surface (Tey *et al.* 2000).

Terrain attributes have shown to be important in delineating soil properties important to crop production (Kravchenko *et al.* 2000). Jaynes *et al.* (2003) indicated that with a DEM, primary terrain attributes such as slope (SL), aspect (AS), plan curvature (PL) and profile curvature (PR) can be calculated, which influence crop yield in a given terrain. In a study, they observed that the clusters were roughly equivalent to landscape position. There was considerable research on the influence of terrain attributes on the plant performance also. For instance, the work done by Kaspar *et al.* (2003) showed that the yield of corn was negatively correlated with relative elevation, slope and curvature during the years of subnormal rainfall, while it was positive during the years of rainfall greater than normal ones. The relationships between soil physical properties and landscape attributes indicate that landscape attributes including slope, aspect and elevation affect plant growth through indirect influences involving soil physical properties (Rezaei and Gilkes, 2005). All these leads to the invariable necessity to understand the terrain for an efficient management and monitoring of natural resources.

Literature is available with reference to characterisation of soils under rubber in Kerala State of India, in both discrete as well as comprehensive fashion. Krishnakumar (1989) reported the characteristics of some soils under rubber in traditional region. Rao (2000) documented the taxonomical variations among soil profiles which were studied at the top, middle and bottom of the slopes in different physiographic units that supported rubber cultivation. Rubber Research Institute of India went ahead with the idea to get the soils under rubber in 1: 50,000 scale surveyed and mapped (NBSS & LUP, 1999), where crop based soil survey was conducted for the first time in India. However, the two-dimensional maps do not reveal the terrain of rubber growing areas, which are generally hills and valleys. Use of DEM is a better option in understanding the landscape and soil interrelationship for better and profitable management of natural resources. Considering the importance of the available IT tools, an exercise was taken up to highlight the usage of these tools to our advantage, keeping rubber cultivation as the focal point with the objectives to:

- use remote sensing to study the temporal changes in reflectance from rubber vegetation
- verify the possibility to separate different rubber clones

- attempt 3D analysis of the terrain of rubber growing region using the digital elevation models and
- extract the information about the soils influenced by the landscape (from the available soil maps).

Materials and Methods

A set of relevant operations were taken up to achieve the objectives set forth for study.

Remote sensing applications

LISS III imagery acquired by Indian remote sensing satellite, Resourcesat, (23 m resolution) are used as inputs. Images pertaining to path 101 and row 68 acquired on 24 February and 19 March 2004 were used in the present study to verify the spectral reflectance temporally to find out the possibility to separate prominent rubber clones grown in Kanyakumari district of Tamil Nadu. Both the images were geo-referenced using toposheet no. 58 H/7 in 1:50,000 scale. The RMSE was kept below one pixel while georeferencing these two images. False color composites were created for initial image interpretation. The image enhancement was done using histogram equalization algorithm. GPS readings were taken using a handheld GPS receiver from the selected fields planted with different rubber clones to test the assumption that clones are separable based on the wintering pattern. Around each point where GPS reading was taken, a circle covering several pixels was drawn to get the training site statistics. Signature separability analysis was performed to verify whether the different rubber clones could be separated from each other for mapping purposes.

Digital elevation model

The SRTM (Shuttle Radar Topographic Mission) digital elevation model in 90 m resolution, available via Internet was used for visualization of terrain. Using the public domain software 3DEM, visualization of the terrain was attempted. The bitmaps of the false color composites created earlier were draped to visualize the surface features in 3D perspective.

Extraction of terrain attributes from DEM. Various terrain attributes like aspect, slope and contour map were extracted from the digital elevation model to aid in understanding the given area under rubber cultivation.

Results and Discussion

Application of remote sensing technology

The false color composite (FCC) shown in Figs 1 and 2 show various surface features in the given geographical area of Kulasekharam, an important area of rubber cultivation in Kanyakumari district of Tamil Nadu. These images showed the temporal changes in vegetation as well as different kinds of vegetation in addition to other features like rivers, reservoirs and road net work etc. However, the present article deals mainly with the results of remote sensing of wintering pattern of different clones which can help in identification and mapping of clones. Wintering is a term used to describe the annual shedding of senescent leaves which renders the trees wholly or partially leafless for a short period (Pardekooper, 1965). The data on temporal changes in spectral reflectance consequent to refoliation after leaf fall (and probably with different intensities of Oidium leaf disease development also) in certain popular rubber clones in this area are presented in Table 1.

Table 1: Spectral reflectance from different rubber clones

Clone	Channel	24 February 2004		19 March 2004	
		Mean	Std. dev	Mean	Std. dev
PB 86-1968	Red	170.1	8.20	151.0	6.04
	Green	37.4	1.58	48.3	1.76
	Blue	96.8	5.20	106.8	3.78
RRII105-1995	Red	150.5	6.87	147.6	10.79
	Green	34.2	3.46	48.7	3.35
	Blue	81.6	4.51	101.1	2.56
GT1-1987	Red	106.1	15.50	107.0	2.77
	Green	56.4	7.85	73.0	3.75
	Blue	93.3	4.61	114.6	9.09
GG1-1965	Red	158.8	12.13	163.5	11.41
	Green	35.6	2.84	51.8	6.53
	Blue	86.9	3.24	105.3	3.42
PB28/59-1987	Red	124.7	3.94	173.0	4.86
	Green	54.4	5.15	43.5	1.24
	Blue	94.8	3.45	103.5	2.25
PB235-1985	Red	174.1	3.97	155.9	8.24
	Green	30.7	0.97	41.6	1.83
	Blue	87.4	1.87	96.9	2.75
RRIM600-1994	Red	126.0	7.43	159.7	12.43
	Green	55.0	5.25	47.1	5.89
	Blue	92.3	3.19	102.2	2.69

FCC - 24 February 2004

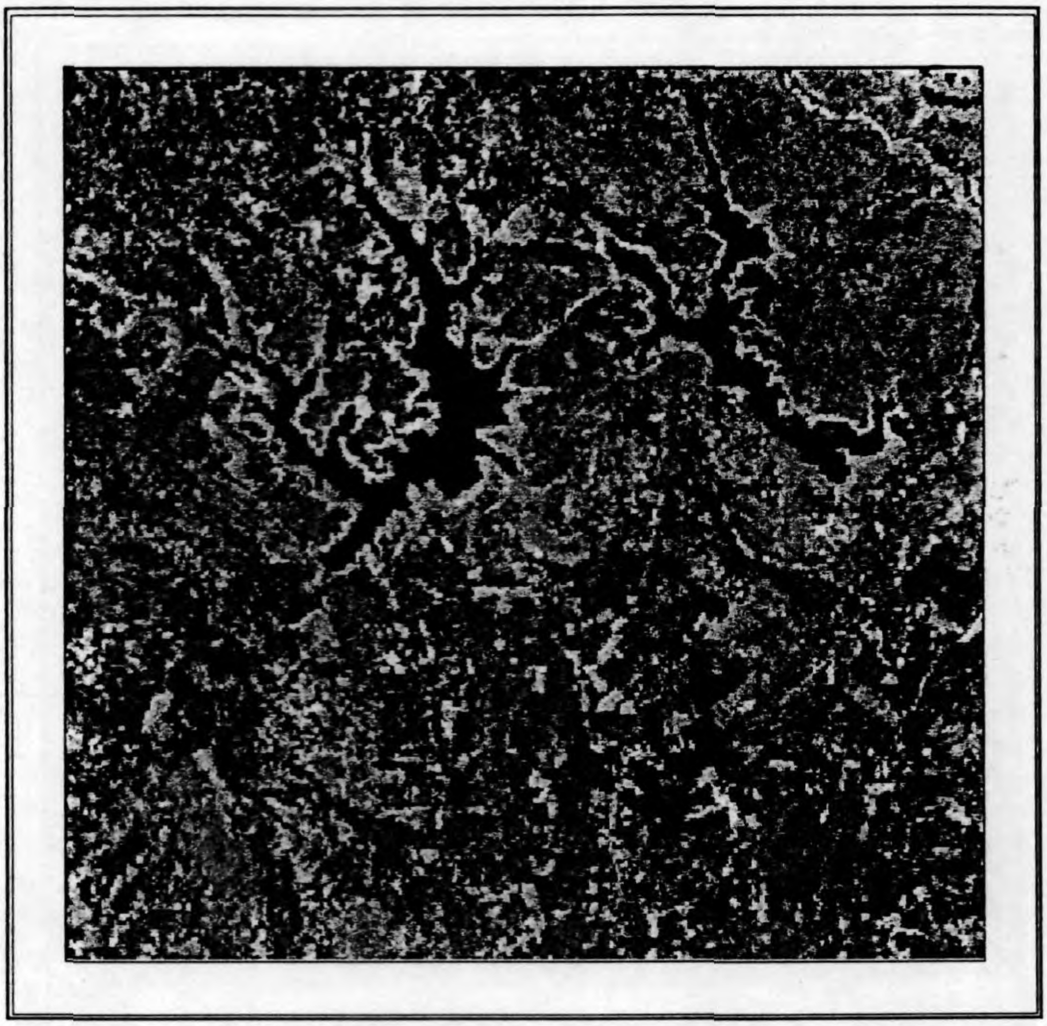

Fig. 1 FCC of LISS III image acquired on 24 February 2004

The observations made during ground truth survey conducted on the dates of satellite pass i.e. 24 February and 19 March 2004 to record the status of canopy are given in Tables 2 and 3. The changes in canopy developments subsequent to leaf fall varied among the rubber clones and for the intensity of disease development. It could be construed from the results that use of remote sensing technology would give a chance to observe rubber plantations in a given geographical area synoptically. Additional temporal studies showed how various clones registered differences in spectral reflectance

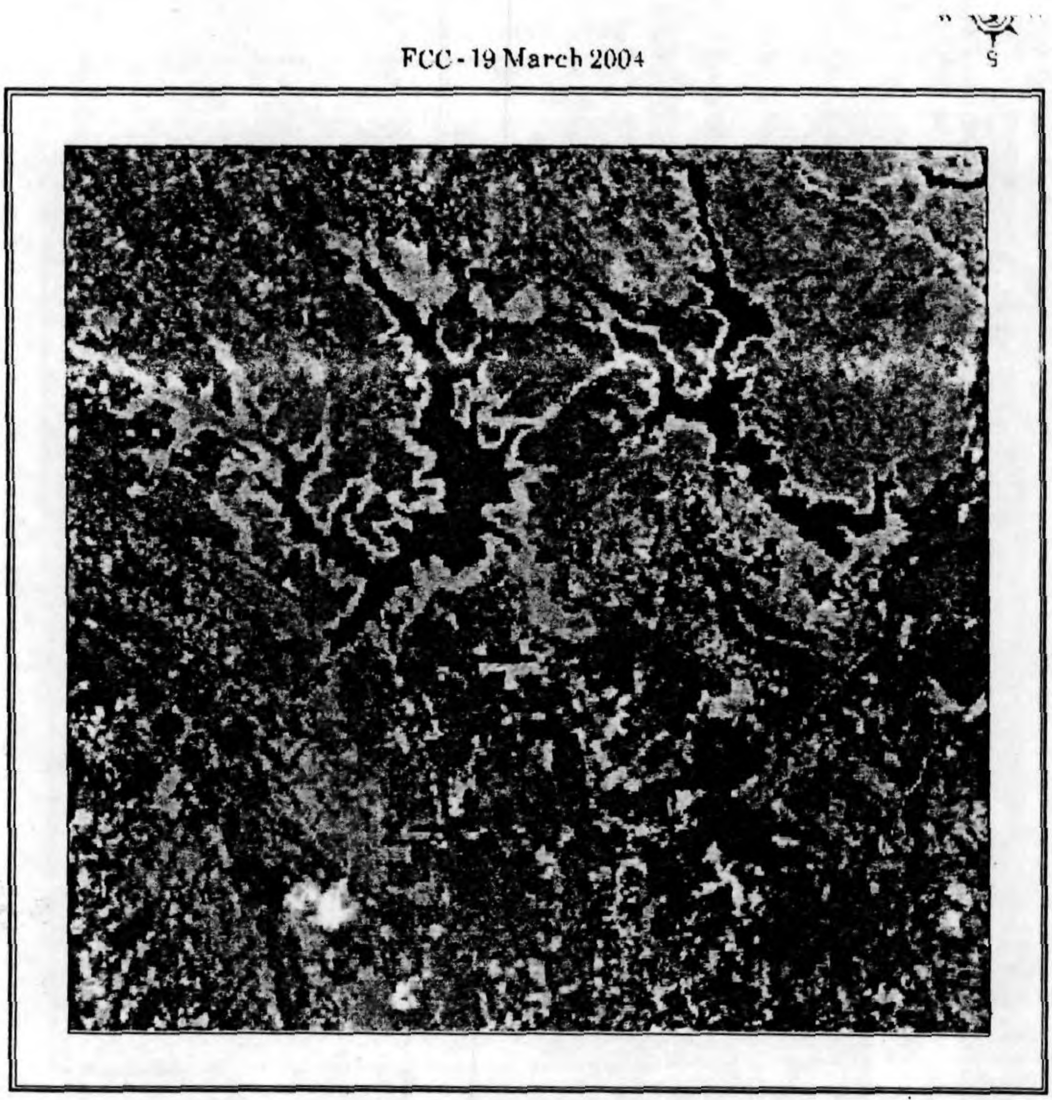

Fig. 2 FCC of LISS III image acquired on 19 March 2004

consequent to leaf development and/or disease development. Remote sensing provided an opportunity to monitor a given area under rubber for all practical purposes. Similarly, inclusion of another data acquisition tool, the GPS improved the precision in the sense that each clone could be located precisely. Signature separability analysis clearly showed as how each clone was either close or far from other clones (Tables 4 and 5). It was indicated that some clones which got higher separability could be mapped, thus making it possible to attempt mapping of rubber at clonal level.

Table 2: Observations during ground truth survey on 24 February 2004

No.	Clone	YOP	Field observations
1	PB86	1968	Leaf fall complete. Refoliation started. Small leaflets.
2	RRII 105	1995	Wintering complete. In some trees little brown leaflets seen.
3	GT 1	1987	Bud break stage seen. Yellow leaves on lower strata. Many trees had leafless twigs seen.
4	GG1	1965	Refoliated. Medium sized laminae in majority trees. Light green leaf stage.
5	PB 28/59	1987	Three staged canopy. Majority trees in bud break stage.
6	PB 235	1985	Majority trees had large lamina. Green leaves als seen.
7	RRIM 600	1994	Small leaves in majority trees. In some trees medium sized laminae. Certain trees were in bud break stage.

Table 3: Observations during ground truth survey on 19 March 2004

No.	Clone	YOP	Field observations
1	PB86	1968	Dull green developed leaves. Oidium in moderate intensity
2	RRII 105	1995	Fully developed canopy. Oidium light to moderate level
3	GT 1	1987	Refoliation complete. Dull green and fully developed leaves. Oidium in light level
4	GG1	1965	Fully developed green leaves. Oidium but less intensity
5	PB 28/59	1987	Uniform Refoliation. Development of leaf complete. Concentration of chlorophyll is on and healthy canopy
6	PB 235	1985	Uniform Refoliation and complete. Concentration of chlorophyll is on and healthy canopy
7	RRIM 600	1994	Moderate to severe infestation. Leaf fallen giving broom like appearance. However, top leaves are present.

Terrain visualization

Terrain visualization is an important idea to analyse the terrain in three dimensions for all practical purposes. There are software packages available which render capability to show an area in 3D perspective and to extract the elevation, slope, aspect and profile curvature etc. The 90 meter DEM obtained during the Shuttle Radar Topographic Mission (SRTM) digital elevation model pertaining to the study area is shown in Fig. 3. This was used for extraction of other terrain attributes like slope, aspect etc. The contour map of the study area was generated with ease from the DEM (Fig. 4). It would

Table 4: Signature separability among rubber clones during February 2004

	PB 86	RRII 105	GT 1	GG 1	PB 28/59	PB 235
RRII 105	1.709357					
GT 1	1.990934	1.837509				
GG 1	1.322005	0.874087	1.850448			
PB 28/59	1.999956	1.984728	1.395891	1.986352		
PB 235	1.971073	1.955991	1.999312	1 404924	2.00000	
RRIM 600	1.999799	1.980773	1.079132	1.976348	1.199857	2.00000

Table 5: Signature separability among rubber clones during March 2004

	PB 86	RRII 105	GT 1	GG 1	PB 28/59	PB 235
RRII 105	1.386652					
GT 1	1.999999	1.996493				
GG 1	1.975462	1.696696	1.974614			
PB 28/59	1.924286	1.747580	2.00000	1.664394		
PB 235	1.728171	1.409325	2.00000	1.859037	1.568051	
RRIM 600	1.594797	0.901027	1.975735	1.261890	1.331867	1.470851

be a tedious exercise to manually digitize the contour lines Terrain visualization is an important idea to analyse the terrain in three dimensions for all practical purposes. There are software packages available which render capability to show an area in 3D perspective and to extract the elevation, slope, aspect and profile curvature etc. The 90 meter DEM obtained during the Shuttle Radar Topographic Mission (SRTM) digital elevation model pertaining to the study area is shown in Fig. 3. This was used for extraction of other terrain attributes like slope, aspect etc. The contour map of the study area was generated with ease from the DEM (Fig. 4). It would be a tedious exercise to manually digitize the contour lines to extract DEM, which depends initially on the availability of toposheets; besides it has restricted access. The contour map could be used to plan the operations that could be undertaken in undulating terrain for example: planning terraces for planting rubber, soils conservation practices etc. Similarly, the aspect analysis of the terrain was possible with relative ease, which otherwise would be difficult to generate the aspect map (Fig. 5). Literature is available with reference to the effect of aspect on growth of different crops including rubber (Saseendran, 1993). Aspect analysis provides an idea to assess the possible performance of rubber plantations in different aspects. The 3D perspective generated from the DEM is given in Fig. 6, which shows the hills, slopes, valleys etc. that support rubber in this region. Similarly, the FCC draped on this undulated surface showed the distribution of rubber

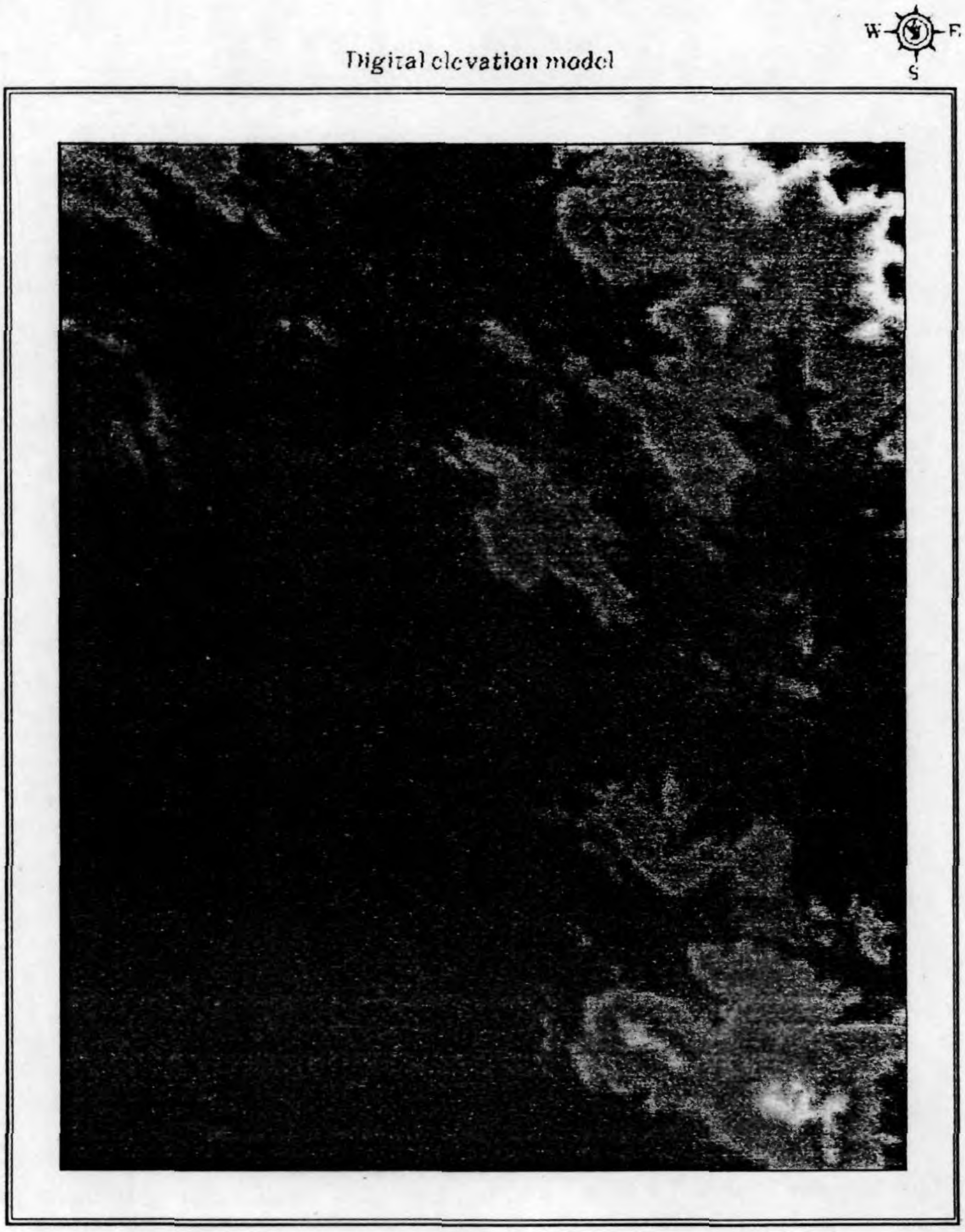

Fig. 3 Digital elevation model of the study area

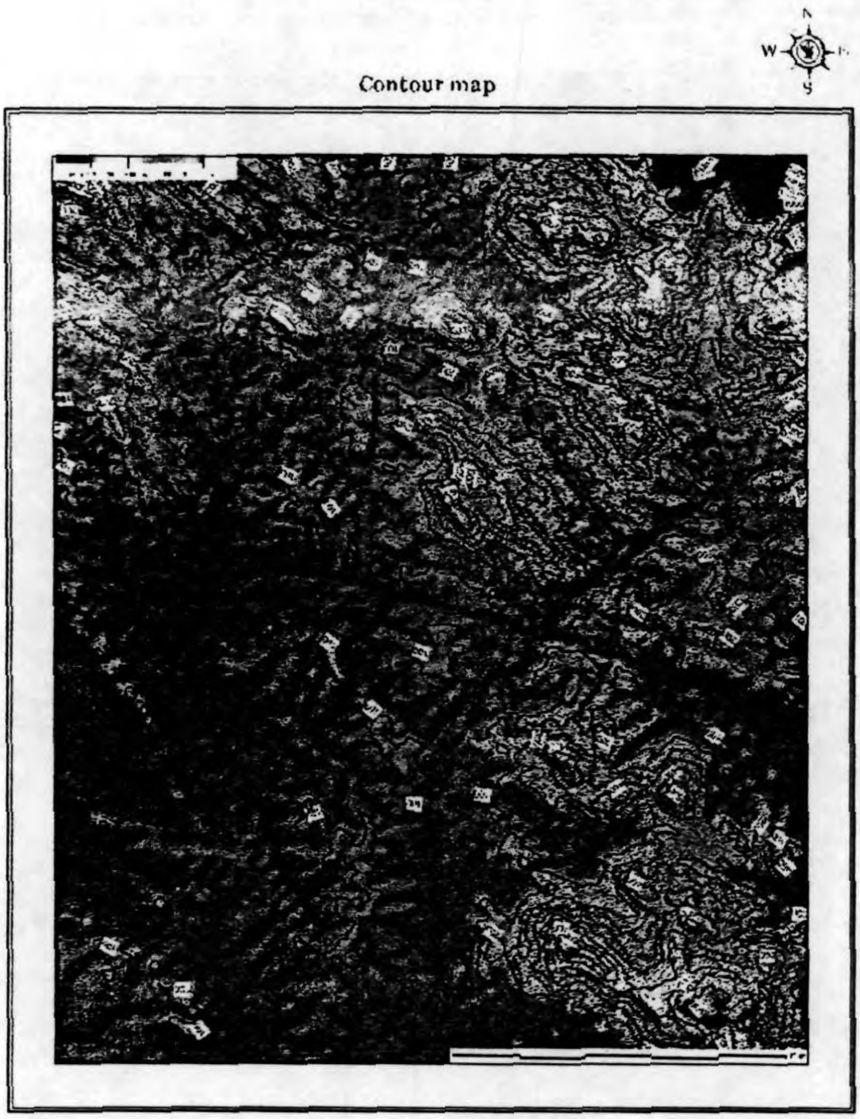

Fig. 4 Contour map derived from DEM of the study area

and surface features is shown in Figs 7 and 8. This kind of visualization essentially gave an idea about the landscape of area of interest which is not possible from 2D maps or satellite imagery. The 3D perspective gave an overview of the area as to how rubber was distributed in the undulated terrain so that appropriate measures in controlling soil and water erosion, efficient use of fertilizer materials etc. can be planned. Normally, fertilizer requirements are calculated based on the soil test values and the stage of the crop. However, the fertilizer application method does not really regard the undulated terrain ultimately leading to loss of fertilizer material in addition to the possible deficiency on hill slops because of loss of fertilizer in runoff waters to bottom slopes.

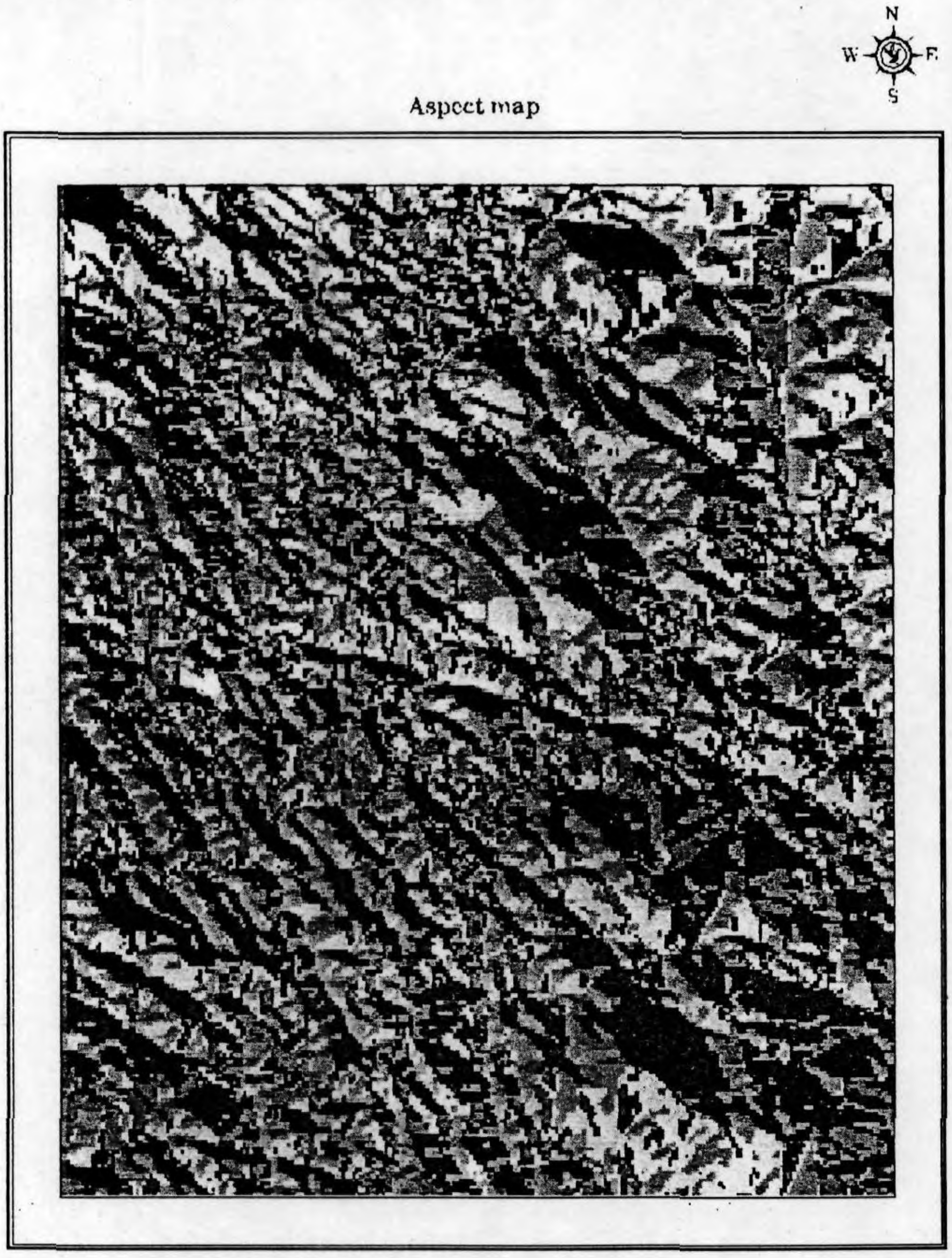

Fig. 5 Aspects derived from DEM of the study area

Fig. 6 Terrain of rubber growing area in Kanyakumari district

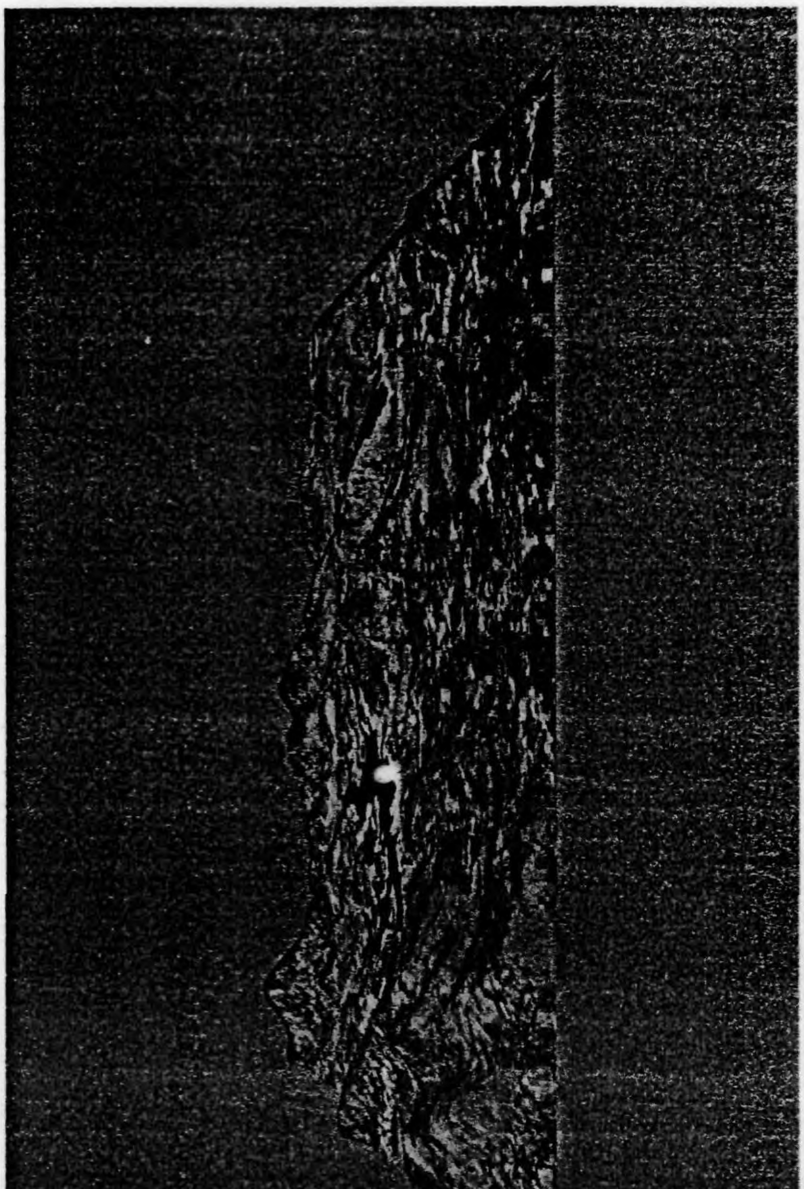

Fig. 7 FCC draped on DEM (image acquired on 24 February 2004)

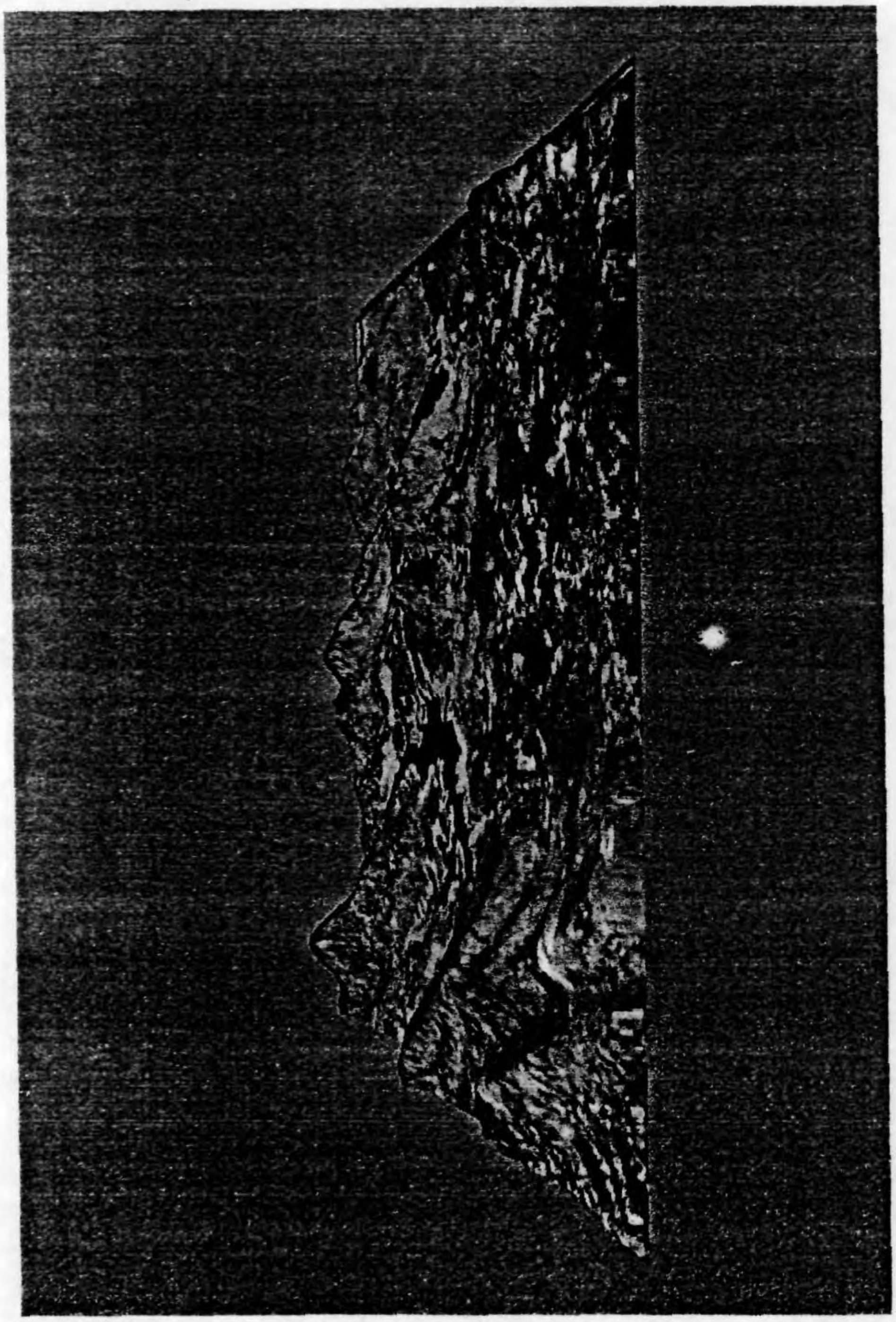

Fig. 8 FCC draped on DEM (image acquired on 24 March 2004)

Table 5: Signature separability among rubber clones during March 2004

	PB 86	RRII 105	GT 1	GG 1	PB 28/59	PB 235
RRII 105	1.386652					
GT 1	1.999999	1.996493				
GG 1	1.975462	1.696696	1.974614			
PB 28/59	1.924286	1.747580	2.00000	1.664394		
PB 235	1.728171	1.409325	2.00000	1.859037	1.568051	
RRIM 600	1.594797	0.901027	1.975735	1.261890	1.331867	1.470851

Tey *et al.* (2000) stated that the information on the soils in oil palm plantation and their properties played a key role in yield improvement in plantations and detailed and semi detailed soil surveys were carried out in several plantations so that productivity could be maximized on different soil types. However, in traditional rubber growing region in India, soil survey maps are available 1:50,000 scale (NBSS & LUP, 1999). Although there are scale limitations, the resource maps could be used in the initial approximations. However, it is essential to have detailed soil survey maps in digital format and use of GPS certainly proves beneficial.

Table 6 presents slope, elevation details along with the soil map units (NBSS & LUP, 1999) found out at the GPS points. The map unit 9 is the association of soil series; Kunnathur, Chandanikunnu and rock land and the other unit 48 is the association of soil series; Kadambanad, Chandanikunnu and Thrikkannamangal. Kunnathur soils series is designated as clayey-skeletal, kaolinitic, isohyperthermic Ustic Kanhaplohumults with 130 cm depth. The other series, Chandanikunnu is taxonomically clayey-skeletal, kaolinitic, isohyperthermic Ustoxic Dystropepts with a depth of 57 cm. The soil series Kadambanad was described as clayey-skeletal, kaolinitic, isohyperthermic, Ustic Kanhaplohumults with 100 cm depth. Thrikkannamangal soil series was classified taxonomically as clayey-skeletal, kaolinitic, isohyperthermic Ustic Kandihumults with 152 cm depth. Though it is very difficult to know identity of the soil series in the given soil map unit at the GPS points, Table 6 indicated that unit 48 was associated with gently sloped and low lying areas.

More accurate and complete estimation of slope can be achieved with the use of good DEM. More *et al.* (1993) demonstrated that terrain attributes (elevation, slope, aspect and wetness index etc.) derived from DEM at an appropriate scale could be used to enhance soil survey as a source of soil attribute data that are essential for soil specific crop management. Slope is one of the main factors affecting the costs of development, field operations, maintenance and upkeep, crop recovery and realized yield in any plantation agriculture. Conventional ground survey is tedious, limited in coverage and hence usually does not satisfactorily represent the actual conditions of the ground. Depending on the requirements, digital slope gradient data derived from DEM can be resampled into desired pixel sizes, classified and grouped for use in the prediction of site yield potentials, estimation of area that could be mechanized and identification of areas that require planting terraces. Rubber growing areas in traditional region could be benefited from modern information technology tools for a better management of resources in a profitable manner. Another potential use of DEM s is in the prediction of water catchment and stream flow (Tey *et al.*, 2000)

Table 6: Slope and elevation extracted from DEM and soil map units

Field	Clone	Slope (%)	Elevation (m)	Soil map unit
1	PB 86	18.5	88.9	9
2	RRII 105	42.9	171.1	9
3	GT 1	17.7	143.2	9
4	GG 1	22.7	174.4	9
5	PB 235	4.0	73.6	48
6	PB 28/59	4.4	76.8	48
7	RRIM 600	3.0	68.5	48

In the present study, freely available DEM at 90 m resolution acquired during STRM (Shuttle Radar Topographic Mission) were used to demonstrate the utility of the available technology in rubber cultivation. This research article indicated the advantages of using modern tools of information technology in understanding the terrain and reviewed the landscape and soil associations. With the advent of technological development in the sensor construction, possible high resolution DEM could be made available to public at less or nominal costs. Though not discussed in the present paper, application of GIS tools for bringing several themes into one environment; for multilayer analysis and decision making is very well known and being used effectively in several ways. Application of modern tools including remote sensing, digital elevation models along with GPS and GIS tools constitute effective usage of IT tools. Application of these tools to the cause of rubber is one among several possible applications of IT in agriculture. The proof of utility of these technologies described elsewhere as well as the present study emphasise large scale adoption of these technologies for efficient and scientific cultivation of rubber.

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