Identification of Tree Resources Outside Forest in Up Country of Sri Lanka Using Medium Resolution Satellite Imagery

K.T. Premakantha, D.K.N.G. Puspakumara[1] and N.K.D. Dayawansa[2]
Postgraduate Institute of Agriculture
University of Perdeniya
Peradeniya, Sri Lanka

ABSTRACT. *Tree Resources Outside the Forests (TROF) are fundamental to sustainable use of natural resources in Sri Lanka because of logging in natural forests has been banned since 1990. As a result, the country meet its timber and fuelwood demand mainly from TROF. However, the information on TROF is fragmented, sketchy and insufficient, leading to underestimate the contribution of TROF to national development. Thus, there is a need of assessing TROF in terms of their spatial distribution, quality and quantity. These data would be helpful in formulating policies as well as development of management strategies for TROF. Although ground based tree measurement is reliable, such technique is laborious, time consuming and expensive. Alternatively, availability of satellite imagery such as Landsat makes it possible to acquire information on large area basis at low cost. Thus, this study was conducted combining Landsat data, ground truth information and statistical analysis to identify, classify and estimate TROF in Nuwara Eliya district. Satellite images were classified in to five land cover classes where TROF were found. Automated classification of Landsat imageries allowed classifying land cover into TROF systems with overall accuracy of 80.1%. Major TROF systems in the area were identified as tea based systems followed by home gardens and annual crop based systems.*

INTRODUCTION

FAO defines Trees Resources Outside the Forests (TROF) as "trees on woodland not defined as forest and other woodland" (FAO, 2001). TROF can be viewed as trees available in urban areas, human settlements, agricultural lands, trees associated with tea, rubber and coconut plantations, along roads, railways, canals, ponds, orchards, parks and gardens which are outside the officially designated forest areas. TROF, though different in configuration and distribution with the forests, has not much difference in functional, ecological and economic terms; their products can often be substituted for forest products such as wood and non wood products, medicines, recreation, protection of soil and water resources, habitat for animal, carbon sequestration and other environmentally important functions (Bandarathilake, 2001; FAO, 2001). TROF is important since logging in natural forests has been banned since 1990 and Sri Lanka meets its timber and fuelwood demand mainly from TROF. For example, in Sri Lanka, 70% of the industrial timber and 80% of biofuel demand is supplied from TROF systems (FSMP, 1995; Ariyadasa, 2002).

[1] Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

[2] Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka.
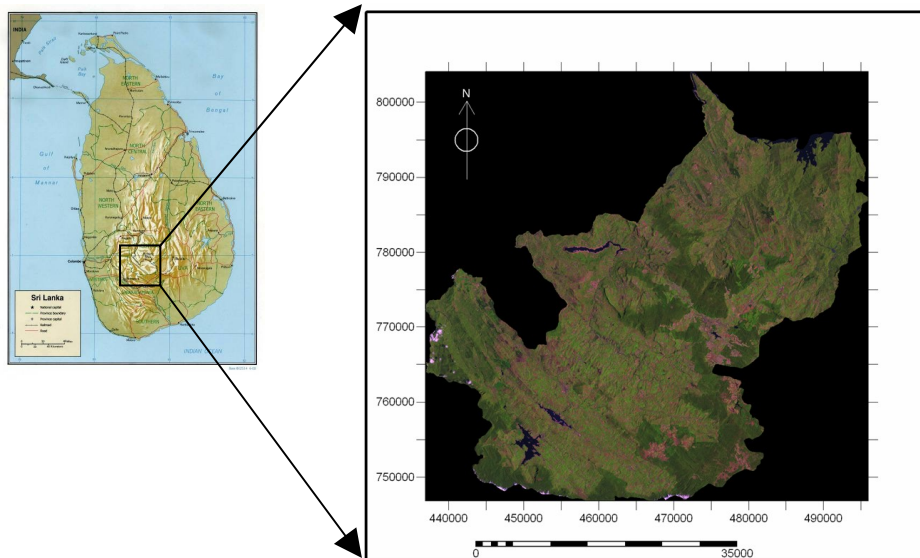
Figure 1. The study area –Nuwara Eliya district of Sri Lanka.

There are many TROF systems in Sri Lanka; mainly home gardens and coconut, rubber and tea based systems. Home gardens are the traditional agroforestry system in Sri Lanka that provides food, fruits, medicine and timber. Coconut and rubber are commercial plantations which end up as a source of timber after their economic lifespan. Shade trees in tea plantations are also used for timber and fuelwood. These systems could be considered as sustainable systems of TROF which produce timber and other products and services.

Although TROF represents an important component of the ecosystem, information on TROF is fragmented, sketchy and insufficient. However, detailed information on TROF in terms of spatial distribution, quality and quantity is essential for planning of both forestry and agricultural sectors. Therefore, the objectives of the study were to: (1) classify existing TROF systems in the Nuwara Eliya District; (2) map existing TROF systems; and (3) make a quantitative assessment of TROF in the study area.

MATERIALS AND METHODS

Study area

Nuwara Eliya district in the Central Province of Sri Lanka has been selected for the study (Figure 1) due to the availability of 14 out of 48 agroecological regions of Sri Lanka with a considerable variation in the environment. Nuwara Eliya district spreads over two major climatic zones, namely the wet and intermediate zones (NRMC, 2003). The wet zone covers a major portion of the district, extending from the lowlands of the south western slopes up to the central hills where sub-montane and montane type vegetations occur. The physiography is generally mountainous, with significant areas above 1,500 m in altitude. The mean annual rainfall varies between 2,500 and 3,500 mm (NRMC, 2003). At the higher elevations in the Nuwara Eliya district the mean annual temperature is around 15 ^{0}C. Further, three major

ethnic groups, namely Sinhalese, Tamils and Muslims live here equally and their attitude towards tree growing is expected to be different. Furthermore, Nuwara Eliya district is considered as the most environmentally sensitive district in Sri Lanka. Due to these reasons several initiatives have been made to improve the tree cover outside the forests and multi dimensional factors may have influenced on the spatial distribution of TROF in the area.

Satellite images

Landsat 7 satellite ETM+ sensor provides six spectral bands of imagery, each with a spatial resolution of 28.5 m (~30 m). Landsat ETM+ data collected on 14th March 2001 (path 141 and row 55) was used in this study. The 28.5 m resolution of Landsat images are considered to be detailed enough for classification as the most land use/cover types in which TROF is expected to be found is larger than 0.1 ha.

Secondary data

Secondary data used in the classification stage include (i) forest cover map prepared by the Forest Department (1999) using Landsat imageries; (ii) maps of forest reserves in Nuwara Eliya district prepared by ground surveying under the Forest Resources Management Project (FRMP) during 2002-2008; (iii) digitized thematic layers of 1:50,000 topographic map sheets (54, 55, 61, 62, 68, 69, 75, 76) prepared by the Survey Department of Sri Lanka (1994-1996).

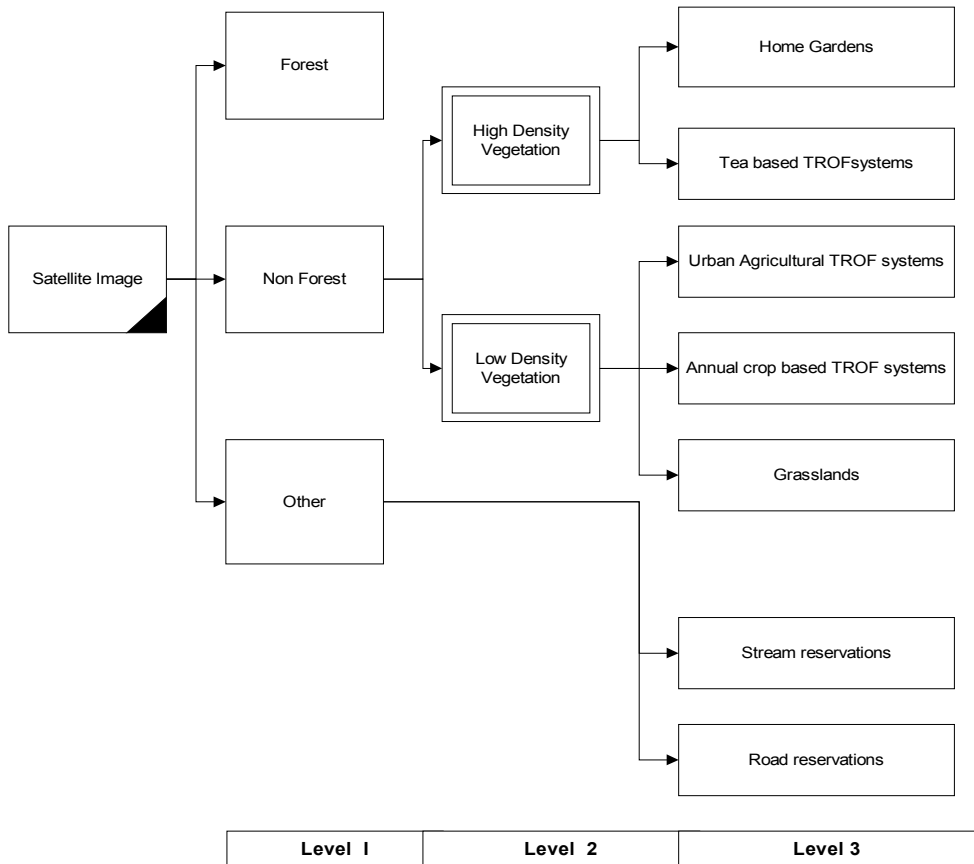**Classification of TROF systems in Sri Lanka**

There is no use of a classification system unless it has clear class boundaries among TROF systems in terms of species composition, land use, spatial arrangement of trees etc. Most important factor is that the TROF classes should give an in depth picture of the resource in a way that decision maker could formulate interventions that lead to increase the productivity of the system. Any information generated on TROF therefore should be in line with the requirements of institutions who manage this resource. In Sri Lankan context, trees outside the forest are managed under different political and administrative institutions and the management decisions are taken at different levels of management by these institutions. TROF classification basically depends on the definition of forests as FAO defines TROF as "trees and tree systems occupying other than those defined as forests and other wooded lands. In this study TROF is considered as all trees outside the legal forest boundaries.

Classification scheme

Hierarchical classification accommodates different levels of information, starting with structurally broad classes which allow further systematic subdivision into more detailed sub classes (Di Gregorio, 2005). At each level, the defined classes are mutually exclusive. Figure 2 shows the classification system adopted in this study.

Image classification

Image classification converts image data into thematic information by categorizing spectral data into classes with respect to statistical decision rules introduced by classification algorithm. However, accuracy of image classification can be improved by incorporating ancillary data. On the first level of classification forest and non forest areas were distinguished (Figure 2). Forest cover map prepared in 1999 by the Forest Department using Landsat imageries and maps of forests reserves prepared by ground surveying under the Forest Resources Management Project (FRMP) during 2002-2008 were used for masking the Landsat image to exclude the forest areas. Then, water bodies were also masked using maps prepared by Survey Department of Sri Lanka (1994-1996).

Figure 2. Classification scheme of TROF systems in Nuwara Eliya district.

In the second level of classification, the Non forest area was further divided into high density and low density vegetation based on Normalized Difference Vegetation Index (NDVI) value. The NDVI is an index that was developed to monitor vegetation. NDVI is a quasi-continuous field that is calculated as a normalized difference between the reflectance of two biologically meaningful bands of the electromagnetic spectrum. Actively photosynthesizing leaves absorb the red wavelengths (Landsat TM band 3) as a source of energy for photosynthesis. Leaves reflect the short-wave infrared (Landsat TM band 4), so

the difference between the two is proportional to the amount of photosynthesis. NDVI responds to changes in biomass and chlorophyll content, and hence serves as a useful measure of primary productivity. Interactive method of assigning threshold values for vegetations was done from the information generated based on aerial photographs. The NDVI values used in the second level of classification are shown in Table 1.

Training data

The training areas are used to extract the digital values from the imagery to produce signatures or statistical definitions of each land use/land cover class. Training samples were selected for all TROF classes over the image, ensuring that they are good representatives of each land use class. Reference data used in the study were acquired in the field using Trimble Geo Explorer XT GPS receiver. Care was taken to avoid recording positions in the edges of the land use/cover classes to minimize mixing of spectral signatures. Considering the inaccessibility and the cost of transport, high resolution aerial photos acquired in 1999 were also used to derive some training data for classification. Maximum likelihood classifier clusters pixels into information classes by means of training data based on probability distribution models for the cases of interest. In the third level of classification, high density vegetation was further classified into home gardens and tea based TROF system using maximum likelihood algorithm based on the training samples collected. Low density vegetation category was classified into urban agricultural TROF system, grasslands and annual crop based TROF system using the maximum likelihood algorithm.

Table 1. Criteria used in second level of classification.

TROF system	NDVI
High density vegetation (Home garden and Tea)	≥ 0.525
Low density vegetation (Urban Agricultural TROF systems, Grasslands and Annual crop based TROF systems)	< 0.525

Accuracy assessment

Classification represents only a generalization of the real world. Therefore, it is necessary to compare the classification results with the true land use/land cover types in the field. An error matrix analysis provides a natural framework for the convenient display of classification accuracy. This is an effective tool of presenting producer accuracy and user accuracy as well as overall accuracy of the classification. Accuracy of classification was assessed by taking 221 reference points.

RESULTS AND DISCUSSION

Seven TROF systems identified from Nuwara Eliya district, their characters and stakeholders who manage the systems are given in Table 2 and illustrations of six TROF systems are given in Figure 3.

NDVI image prepared using Landsat band 3 and Landsat band 4 is shown in Figure 4. Forest cover and water bodies were masked out from the NDVI image as these two land covers do

not represents TROF. Masked NDVI image is shown in Figure 5. When the NDVI image was examined with ground data collected in the field, it was observed that NDVI values were high in tea based TROF system and in home gardens. Those areas were masked as high density vegetation and rest of the area was classified as low density vegetation. Then, 4, 3, 2 Band combinations of Landsat was used for further classification using maximum likelihood algorithm. These colour composite maps of high density vegetation and low density maps are given in Figure 6 and 7, respectively. Maps showing spatial distribution of high density and low density TROF systems in Nuwara Eliya district are shown in Figure 8 and 9, respectively.

Table 2. Classification of TROF systems in Nuwara Eliya district.

TROF System	Description	Major stake holders
Urban Agricultural TROF systems	Urban and semi urban areas with permanent concentration of buildings, and other man-made structures and activities. Intensive agriculture is practiced in residential land plots.	MC, PS, DOA
Home garden	Traditional system of mixed cropping of trees in a multi layered arrangement yielding timber, fuelwood food, fruits, spices, fodder, medicines, and other cash crops	PS, DOA, DAS
Annual crop based TROF systems	Both rainfed and irrigated rice and vegetable cultivations are included here. At some times rice and vegetables are grown alternatively.	DOA, DAS
Tea based TROF system	Tea is a plantation crop which cultivated in the central hills and in wet south west lowlands. This system has several tree components as shade and in boundaries.	TC, TSHA, SLTB
Grasslands	Grasslands are found mostly in mountain tops and rocky areas and named differently according to structure, species composition, climatic zone etc. Density of trees is low.	FD, DWLC
Road reservations	Tree planting in roadside is common in Sri Lanka, although planting trees along roadside has been done unsystematically. Majority of roadside planting is found in major roads as hardly any space is available for planting along minor roads.	RDA
Stream reservations	Naturally grown trees are protected while tree cover is improved by cultivating more trees around water bodies. Under the state land ordinance, reservation for water bodies has been gazetted and trees are protected within the reservations.	ID

Note: MS=Municipal Council; PS=Pradeshiya Sabah; DOA=Department of Agriculture; DAS=Department of Agrarian Services; TC=Tea Commissioner; TSDA= Tea Small Holding Authority; SLTB=Sri Lanka Tea Board; FD=Forest Department; DWLC=Department of Wildlife Conservation; RDA=Road Development Authority; ID=Irrigation Department.

According to the estimates, tea plantations covered 79,182 ha in Nuwara Eliya district, which is 46% of the total land area of the district. Tea based TROF system distributed mainly in higher elevations (Figure 8). The estimated extent of tea based TROF system in this study is higher than the estimated extent by Anon. (2001), mainly due to identification of the system rather than the area of cultivation. This TROF system is surrounded by natural forests where any type of timber extraction has been banned which has created a scarcity of fuelwood among estate community. As the population density is very high, demand for fuelwood is also very high. Spatial distribution of estate sector indicates that the tree planting as blocks for fuelwood and awareness programmes for energy efficient fuelwood usage methods should be introduced. Further, there is a potential for tree replacement, substitution and management and increasing the number of individuals of some shade tree species along with boundary planting.
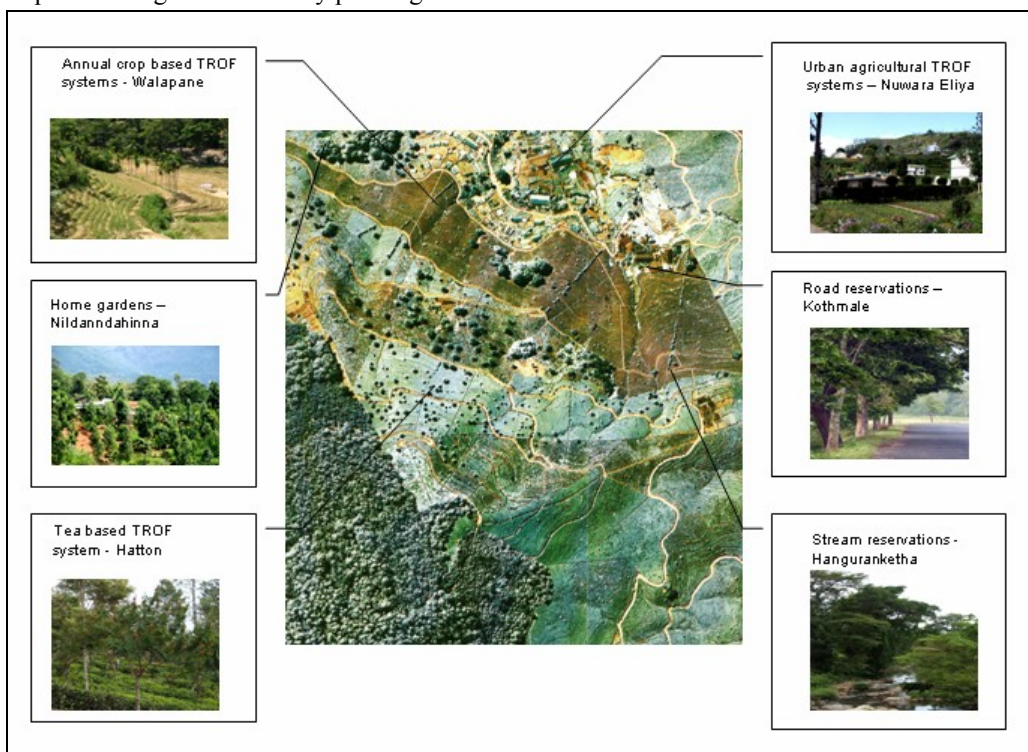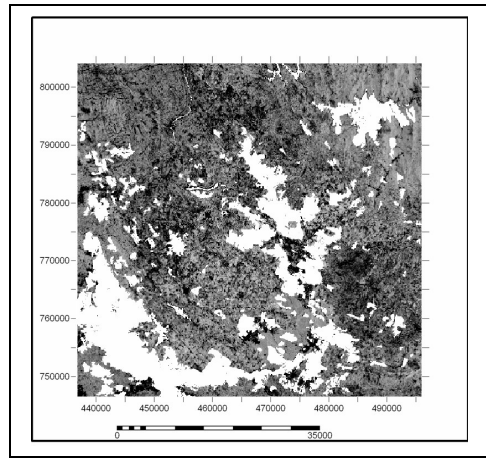

Figure 3. TROF systems found in Nuwara Eliya district.

The estimated home garden area of Nuwara Eliya district was 27,440 ha or 16% of total land area. These home gardens are mainly found at the lower elevational areas of the intermediate zone (Figure 8). It was observed during field work that these home gardens are well occupied with trees. According to study carried out by Jewell (1995), the extent of home gardens in Nuwara Eliya district was 9,172 ha (5.3% of total land area) which was far less than the current estimation. Although Landsat imageries were used in both studies, a methodology adopted by Jewell was different from the method adopted in the present study. All orchards and other plantations (i.e. coffee, export agricultural crops) with home except forest plantations were included as home gardens in the present study those were excluded from Jewell's (1995) estimation. Jewell (1995) also indicated that the extent of home

gardens in Nuwara Eliya district has declined by 19.5% during the period from 1983 to 1992. However, recent estimations of home gardens in Sri Lanka revealed that the extent of home gardens has increased over the years (Ariyadasa, 2002). During field works, it was identified that within home gardens, tree replacement, substitution and management and increase in the number of individuals of several tree species can substantially improve the productivity and contributes to the welfare of the communities living in the area. In addition, well stacked and properly managed home gardens can play a similar role as a forest in watershed management especially with regard to Mahaweli catchments (Ariyadasa, 2002; FSMP, 1995).
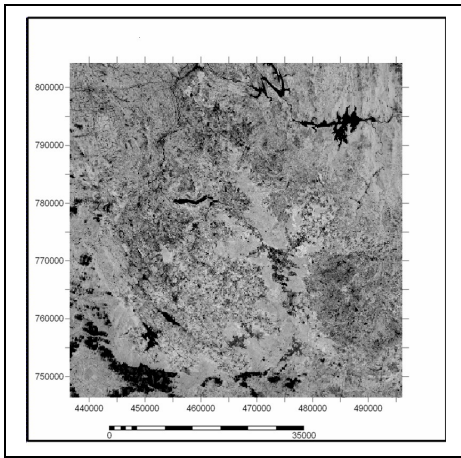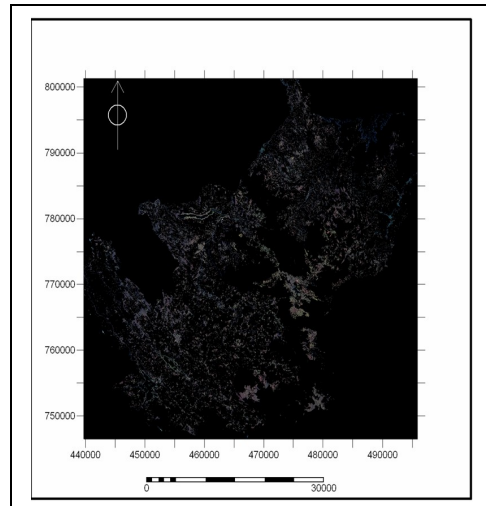

Figure 4. NDVI map of study area

Figure 5. Masked image with forest and water
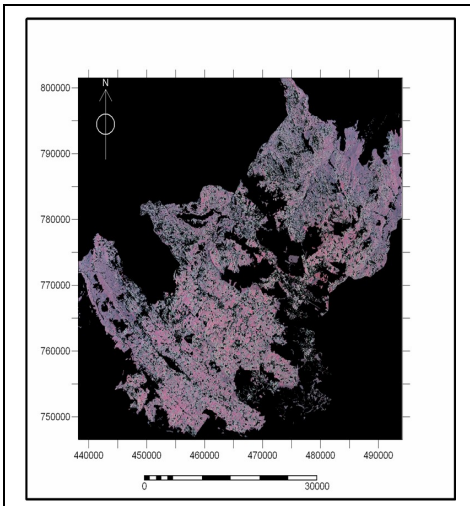
Figure 6. Masked image for high density vegetation.

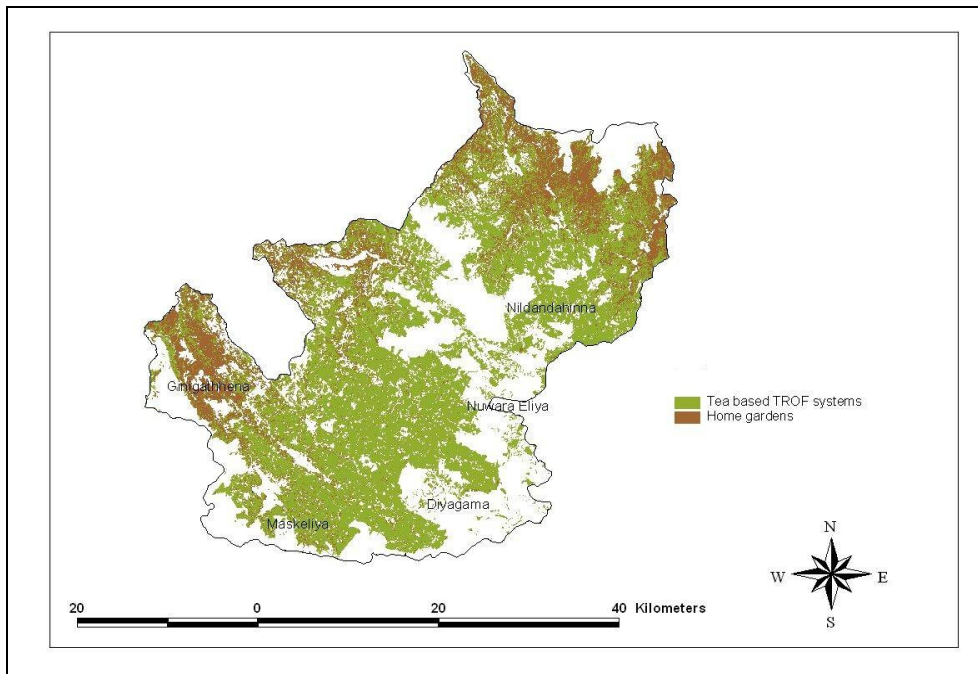**Figure 7. Masked image for low density vegetation.**

Figure 8. Spatial distribution of high density TROF systems in Nuwara Eliya district.
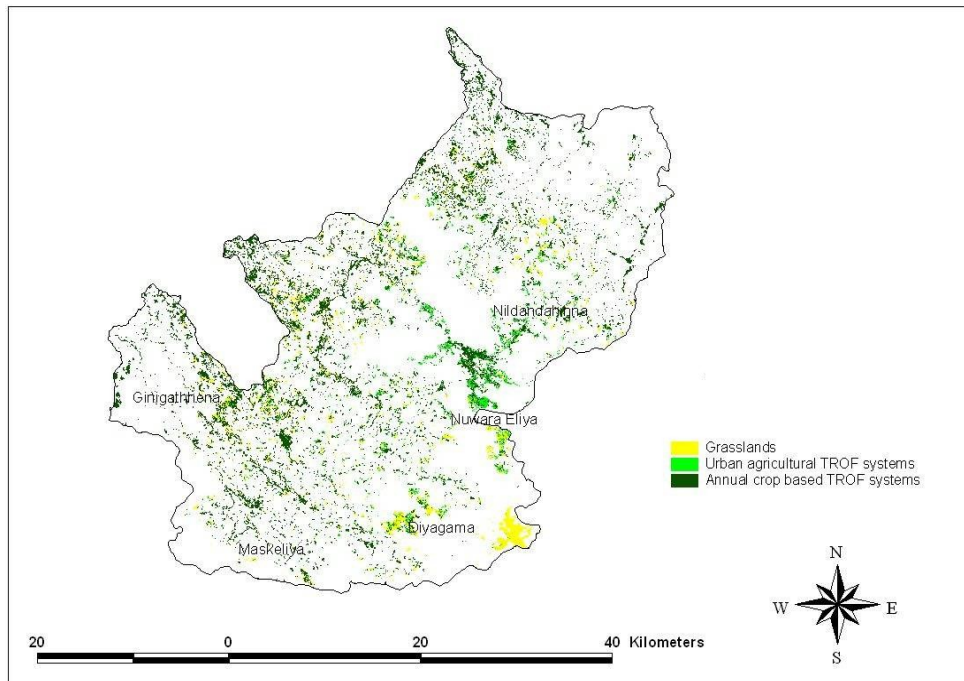

Figure 9. Spatial distribution of low density TROF systems in Nuwara Eliya district.

When compared to other districts in Sri Lanka, the land area for annual corps in Nuwara Eliya was 13,154 ha which is 8% of total land area (Figure 9). The area under this system is low and this may be due to the reason that a large extent of natural forest is kept untouched for water and soil conservation. Furthermore, high slopes in up country do not encourage farming with annual crops. Potential for introducing more trees into the system is also low as shade from the taller trees can reduce the yield of annual crops grown in the system. No statistics are available to compare the estimated extent.

Grasslands are less recognized as a TROF system at present and occupied 4,289 ha. Grasslands were found all over the district and field observation shows that very low density of trees in the system due to forest fires (Figure 9). Forest officers in the area suggest that prevention of forest fires and assisting natural regeneration of tress would help in increasing tree resource base in the grasslands.

Urban agricultural based TROF systems are mainly concentrated in major cites (Figure 9) and the estimated extent was 3,885 ha. In city centres, parks and avenues tresses can be planted systematically for the ornamental purposes and urban forestry.

On average, width of the roadside planting was 10 m and the estimated extent of road reservations was 1,235 ha. Stream reservations were kept at a width of 50 m in average and the estimated extent was 2,300 ha. There is high possibility of systematic introduction of trees as roadside and stream bank plantations which in turn enhances the value of the environment.

Table 3 shows the accuracy of classification of each TROF system. Tea based TROF systems and home gardens had high producer accuracy in classification while low density TROF classes had low producer accuracy. According to estimates, the overall accuracy obtained for all TROF classes was 80.1% ((51+42+27+29+28)/221) (Table 3).

Table 3. Accuracy of estimated extents of TROF systems.

	TA	HG	AC	GR	UA	Total	User Accuracy
TA	**51**	4	2	4	1	62	0.82
HG	3	**42**	3	3	2	53	0.79
AC	2	1	**27**	3	3	36	0.75
GR	1	1	3	**29**	2	36	0.81
UA	1	2	1	2	**28**	34	0.82
Total	58	50	36	41	36	221	
Producer Accuracy	0.88	0.84	0.75	0.71	0.78		

Note: TA = Tea based TROF systems; HG = Home Gardens; AC = Annual Crop based TROF systems; GR = Grassland TROF systems; UA = Urban agricultural TROF systems.

The present study shows the distribution of TROF systems and the potential areas for further development of TROF in Nuwara Eliya District. However, information on spatial distribution of TROF systems alone is not sufficient for decision makers to develop management strategies. Spatial distribution map of different TROF systems along with, population density, species composition, agro ecological zone data in Nuwara Eliya district would help in formulating development projects in the future. These data should provide information on the extent of TROF at present, the potential of TROF systems in wood production, where and to what extent should TROF system be promoted, to what extent should more trees be planted on each TROF systems and how to ensure the products from TROF will continue to be available etc. Species composition, present volumes of timber for each TROF system should be investigated to fulfil the data requirement using ground sampling methods at a reasonable accuracy level.

CONCLUSIONS

A methodology was developed to identify TROF systems of Nuwara Eliya district using medium resolution satellite imagery. Seven TROF systems were identified with overall accuracy of 80.1%.

REFERENCES

Anon. (2001). Plantation sector statistical pocket book-2001. Planning and Development Division, Ministry of Plantation Industries, 55/75, Vaxhall Lane, Colombo 2.

Ariyadasa, K.P. (2002). Assessment of Tree Resources in the Homegardens of Sri Lanka. EC-FAO Partnership Programme (2000-2002). Food and Agriculture Organization, Bangkok, Thailand.

Bandarathilake, H.M. (2001). Impact and effectiveness of logging bans in natural forests: Sri Lanka. pp 137-166. In: Durst, P., Waggner, T.R., Enters, T. and Tan, L.C. (Eds). Forest Out of Bounds: Impacts and Effectiveness of Logging Bans in Natural Forests in Asia-Pacific. RAP Publication: 2001/08 Bangkok, Thailand, Food and Agriculture Organization of the United Nations.

Di Gregorio, A. (2005). Land Cover Classification System - Classification Concepts and User Manual. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2001). Global Forest Resources Assessment: 2000 Main Report. FAO Forestry Paper 140. Food and Agricultural Organization, Rome, Italy.

Forest Department (1999). Forest Cover Map. GIS Unit Forest Inventory and Management Branch. Forest Department, Battaramulla, Sri Lanka.

FSMP (1995). Forestry Sector Master Plan of Sri Lanka. Ministry of Lands, Agriculture and Forestry, Colombo, Sri Lanka.

Jewell, N. (1995). The use of Landsat TM data for estimating the area of home gardens. The Sri Lanka Forester (the Ceylon Forester) Special Issue in 1995: 79-86.

NRMC (2003). Agroecological Map of Sri Lanka. Natural Resources Management Centre, Department of Agriculture, Peradeniya.

Survey Department (1994-1996). 1: 50,000 Topographic Maps of Sri Lanka. Survey Department of Sri Lanka, Sri Lanka.