Steps towards Mapping Forest Degradation

Technical Report

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1 Introduction

Forest degradation is different from deforestation. Deforestation occurs when forests are converted to non-forest uses, such as agriculture and road construction. The term forest degradation is used to indicate the destruction or reduction in quality of specific aspects of forests. Unsustainable commercial logging is still common practice, resulting in forest degradation and considerable damage to soils and waterways. A number of cases of illegal logging were reported in recent years, and although the majority were small-scale, illegal over-cutting and undeclared timber in licensed forest projects may be significant. Rehabilitation measures are rarely applied and silvicultural treatments of logged-over forests are widely unknown. Alongside sawn timber for domestic use, forests are also a source of fuel wood for communities living in or around forests. Fuel wood is sourced from the fringes of forest near villages while construction timber is often harvested from easily accessible natural forest areas and pine woodlots. Charcoal continues to be used throughout the islands and is often made from mangroves. One tradition that causes significant forest degradation is the burning of forests for pig hunting and easy land clearance. In natural forests this normally affects forest edges, but which often burn out of control.

Utilising free satellite images such as Landsat and Sentinel, selective logging can only be detected within a period of three months by due to logging tracks or roads with clear contrast of yellowish or red soil within the green canopy. After this time the detection of logging tracks is difficult as they are covered by shrubs and tree ferns. The high timber production by very low deforestation is a signal for deforestation. The work concentrated on the mapping of indicator species which grow after degradation such has Merremia umbellata (hogvine), Cyathea medullaris (tree ferns), Spathodea campanulata (African tulip).

2 Investigation African Tulip

Figure 01: *African tulip during the flower season.*

The introduced species African tulip is a problem as such increasingly covering open farmland and at the same time an indicator for forest degradation as moving into open forest.

2.1 Description African Tulip

African tulip Spathodea campanulata is known for its bright red, trumpet-shaped flowers and was introduced to Fiji as an ornament tree. Now they are amongst one of the most invasive trees in Fiji. They tend to crowd out the natural forest as well as agricultural areas and are very challenging to remove due to its fast growing nature. They typically grow from root fragments and can cultivate on its own from cut off branches. This rapid growth rate is a cause for concern in Fiji as it can lead to massive ecological and economic impacts.

African tulip tree is a large tree that can grow up 25 m. The trees have simple pinnate compound leaves, 30 – 40 cm long, about 7 pairs of leaflets and are slightly hairy and shinny above. The flowers – large, showy and reddish-orange, see figure 1 and figure 2. The African tulip tree invades both abandoned agricultural land and open forest. It also invades natural ecosystems in the Cook Islands, Guam, Hawaiʻi, Samoa and Vanuatu. Although the African tulip tree favours moist and wet areas below 1000 m, it grows up to 1,200 m in French Polynesia.

The African tulip tree does not tolerate frost and demands full sun for fast growth and best flowering. The biggest trees grow in moist sheltered ravines. This species loves rich soil, but puts up with just about anything with a little fertility to it, including lime rock. It will also survive in a bit of salinity. Seed and runners reproduction, seeds germinate in two weeks after falling into the soil and short runners germinate faster than long ones.

Figure 02: *The flower of an African tulip*

African tulip normally grows in groups and not as single trees. The flowering season in Fiji starts beginning of June and it fades out end of September.

2.2 Spectral Separability of African Tulip from Natural Forest

The results illustrated that it is possible to map African tulip during and after flowering season based on its spectral signature. During the flowering season a separation from African tulip and other forest vegetation is plausible, however, the spectral signature of the leaves also allowed a separation between October and end of May. Figure 03 shows that the standard deviation in the near infra red channel does not overlap with other trees of the surrounding forest.

2.3 Investigating the Reflection of African Tulip

To investigate in the spectral signature of African tulip areas, identified as stocked with this tree species with Landsat data recorded during the flowering season, were overlaid with WorldView-2 image data. This satellite has a sensor which not only records in very high resolution but also has more spectral bands than the Landsat satellite[1].

Training areas, which are areas where African tulip dominates the canopy, were selected and the spectral signatures of all image points analysed in terms of reflection mean and standard deviation from the mean. Figure 03 shows that it is very difficult to separate African tulip from other forest vegetation in the visible bands, however, red-edge and the first near infrared channel allows a separation already in a two dimensional presentation. A maximum likelihood classifier uses a multi dimensional separation.

1 Sentinel data was not available at that time

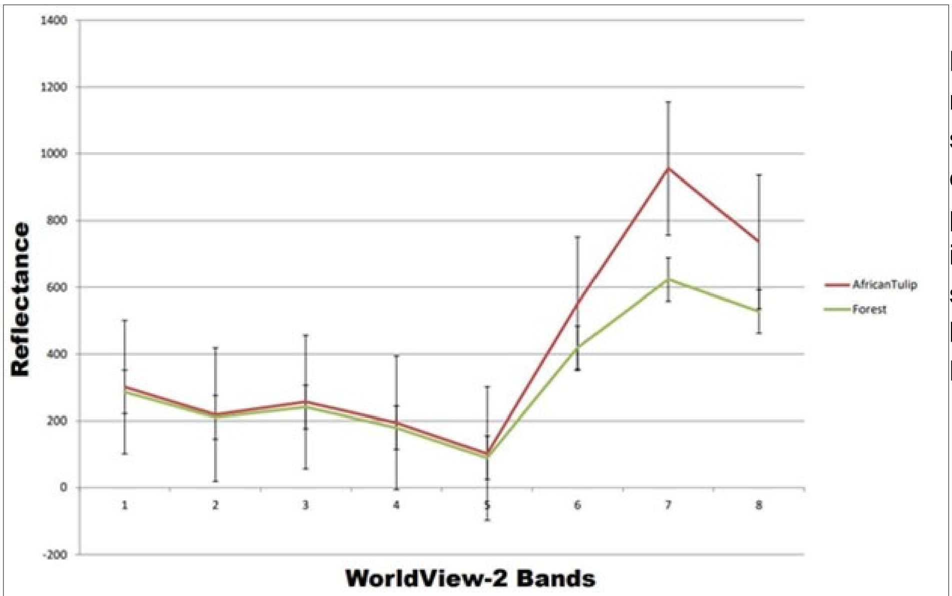


Figure 03: *Reflection of African tulip in different spectral bands of the sensor on board of WorldView-2 saetllite.*

2.4 Conclusion

Knowing that the species normally grows in groups a semi automatic classification might be possible using the near infrared band. This spectral band is covered by the sensors on board of Landsat and Sentinel.

3 Investigating Climbers

Climbers are additional indicator plants for forest degradation. In Fiji Merremia umbellata is the most dominant one.

3.1 Description Merremia Umbellata

Figure 04: *Dense mats of Merremia umbellata near Pacific Harbor in Fiji.*

Merremia umbellata is a thin vine growing a maximum thickness of 2 cm. The species is widely distributed in tropical regions throughout the world. It is one of the commonest and most widespread species of Merremia. Due to its attractive yellow flowers, it has been introduced as an ornamental plant in Fiji. It is found in disturbed and degraded forests.

Leaf blades are about 6.5-9.5 x 4-4.5 cm, petioles about 1.5-2.5 cm long. Petioles and leaf bearing twigs densely clothed in erect white hairs. Upper and lower surfaces of the leaf blade densely clothed in hairs. Flowers about 5 cm see figure 06. Umbellata is a plant of the humid tropics occurring along the edges of forests, in degraded forests, roadsides and waterways. Although it is common in forest situations, it favours more open situations along the edges of fields, plantations and water bodies.

Figure 05: *Merremia umbellata leaves*

Figure 06: *Flower of Merremia umbellata*

Merremia umbellata is a perennial vine, reproducing mainly by seed, but not much information is available on its reproductive biology. The flowers apparently remain open throughout the day . The sowing depth is ca. 1 cm, and the germination temperature is 22-25°C. The seeds germinate within 2-4 weeks. Merremia umbellata is a sun species that tolerates a wide range of conditions throughout its range including partial shade, dry or poor soils. It prefers well drained soils.

The species climbs over the trees often forming dense mats which can reduce the tree grows, however, it does not cover the complete crown. Training area selection is dificult as between even dense mats of the plant branches are without Merremia coverage.

Figure 07: *Test area at Nabukasi, close to Pacific Harbour*

3.2 Spectral Separability of Merremia Umbellata from Forest and Shrub

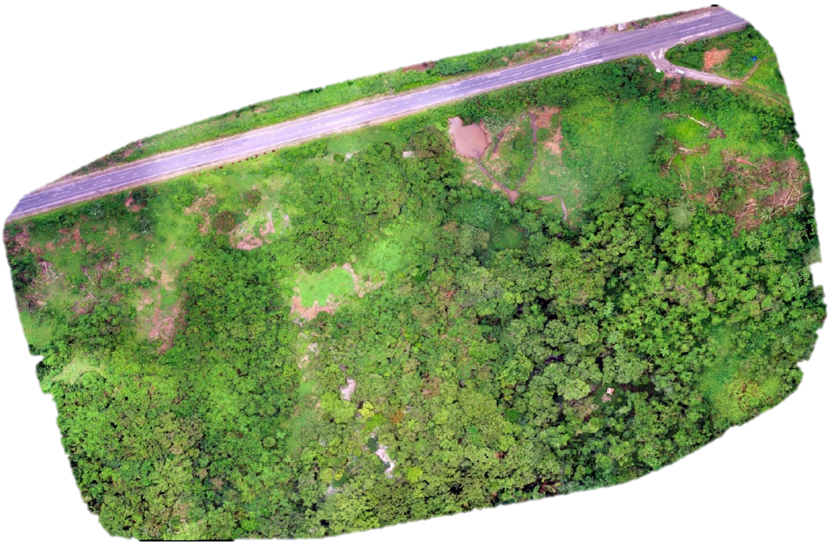
A separation of Merremia from forest patches and from shrub was possible in the test area close to Pacific Harbor. A supervised maximum likelihood classification was performed with reasonable results see Figure 11.

3.3 Identifying the Reflectance

To see the spectral signature of Merrenia training areas have to be delineated, which are areas covered to 90% with Merrenia only. Then the reflection has to be analysed where the statistical mean is calculated for every spectral band and the standard deviation from the statistical mean. For a comparison these two values have to be known from shrub and forest vegetation as well, because these are the two classes with similar reflection and misclassification is possible.

3.3.1 Delineation Training Areas

An in vestigation area was selected where Merrenia heavily overgrew the shrub and forest vegetation. It was not possible to delineate Merrenia, shrub and forest vegetation in the WorldView-2 data set directly. Image enhancement can stratify the reflection over the vegetation partly covered by Mirrenia but not to an extent that visual interpretation allows a clear identification.



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igure 08: *Area capture by a UAV mounted camera.*

The area was then overflown by a drone and captured by a camera providing image data of 1.6 cm resolution. Such a high spatial resolution allows the visual identification of Merrenia by its texture information. Merrenia patches have a more smooth appearance than shrub or forest. This allowed the delineation of training areas. Several training areas of Merrenia of 60 pixels minimum size[2]. They were first checked individually in terms of mean and standard deviation and then joined to one one training area. The same was performed with shrub and forest.

2 This number allows the calculation of a statistical sound mean.

3.3.2 Visualisation of Separability

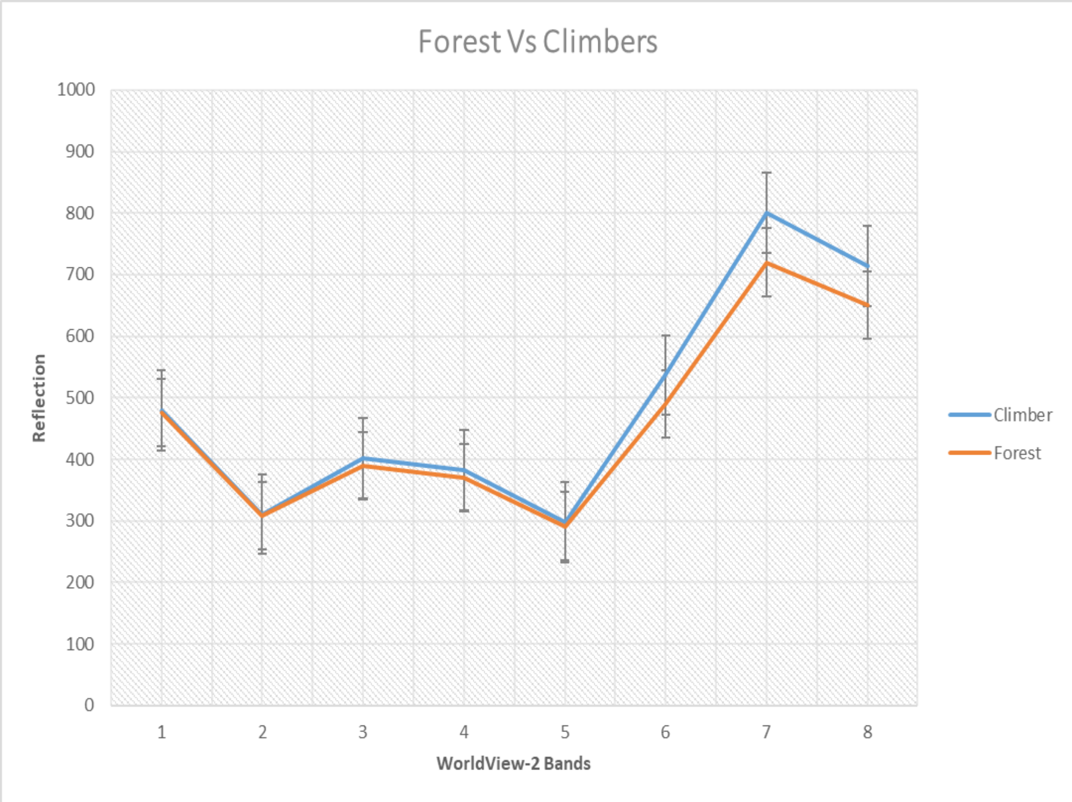

Figure 09 *Reflectance in different spectral bands of WorldView-2 image data forest vegetation and climber. Like with shrub vegetation In the red edge and near infrared the standard deviation is still overlapping but the classification results show separability.*

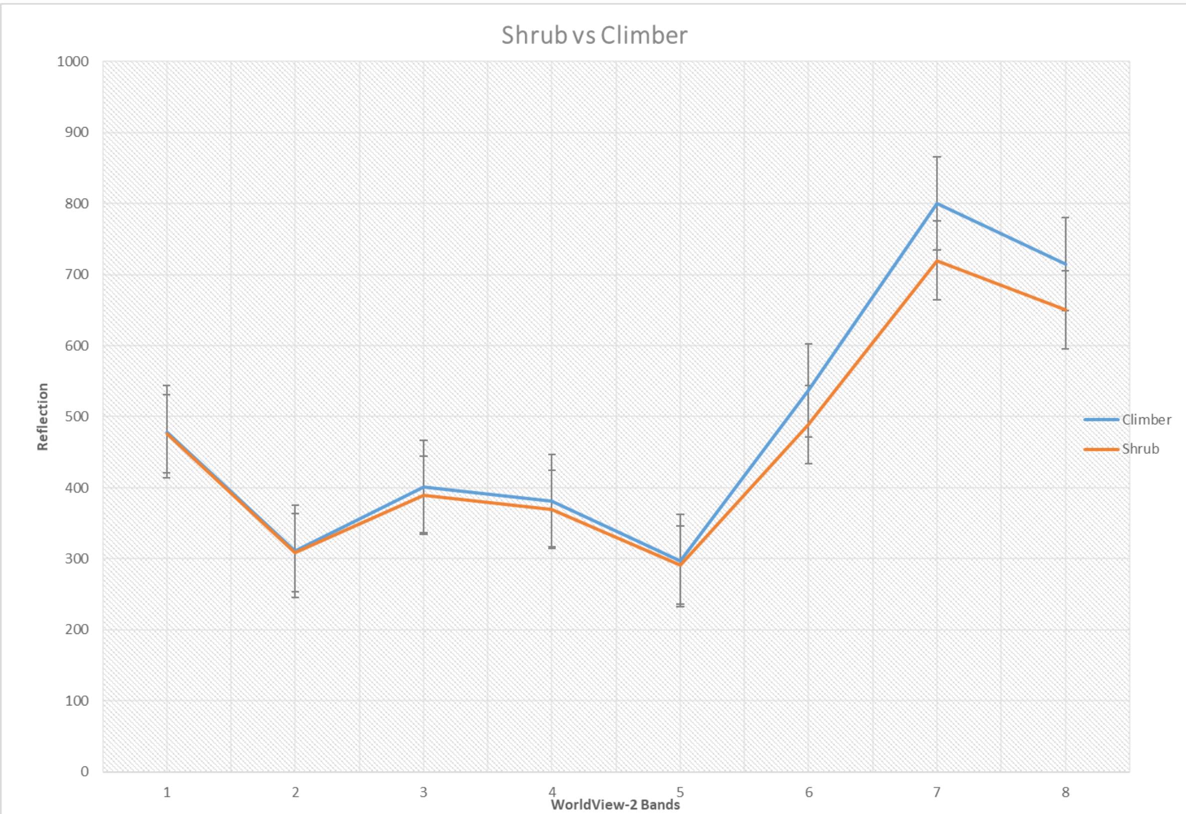

Figure 10 *Reflectance in different spectral bands of WorldView-2 image data shrub vegetation and climber. Like with forest vegetation In the red edge and near infrared the standard deviation is still overlapping but the classification results show separability.*

ERDAS software allows to calculate mean and standard deviation and the figures were exported to an Excel spread sheet. In Excel the plus and minus standard deviation was calculated and included into graphs, shown above figures 09 and 10. Another visualisation method is a constituency matrix. For this all picture elements of Mellenia, forest and shrub training areas are put into one space and classified. The number of pixels (in percentage) which is classified back into the own training areas gives an indicator of possible separability.

	Forest	Shrub	Climber
Forest	93.91	3.02	1.67
Shrub	4.75	90.29	0.71
Climber	1.34	6.69	97.63

Table 01: *Contingency matrix of the three main classes in percentage.*

Such a contingency matrix shows the maximum possible separability which a semi automatic image classification can archive it is not the accuracy of classification. Normally the separability of this matrix is not reached by a maximum likelihood classification.

3.3.3 Maximum Likelihood Supervised Classification

To test a possible semi automatic classification a supervised maximum likelihood classification was performed. Additional test areas had to be identified for (i) shadow areas, (ii) grass land, (iii) road and bare soil, (iv) housing areas. The classification test showed reasonable results shown in figure 11.

Figure 11: *Supervised maximum likelihood classification of the World View 2 image. Legend: grey = road, blue = water body, cream = barren land, black = shadow, brown = shrub, bright green = climber, dark green = forest.*

3.4 Conclusion

Although the two dimensional graph does not really show spectral separability of climber from other vegetation separation seems to be possible in the multi dimensional space of a maximum likelihood classifier.

Necessary would be more detailed training areas and very high spatial resolution and high radiometric resolution such as two near infrared bands and red edge. Landsat and Sentinel do not provide this, however, with WorldView image data a mapping of forest degradation could work. The data utilised were not atmospherically corrected and cover flat terrain. Further investigation is required to implement mapping of forest degradation mapping through semi automatic classification.

4 Tree Ferns

Cyathea medullaris commonly called tree ferns or balabala in Fiji occurs throughout the lowlands and mid-altitudes of the Island. It prefers warm, wet areas, and is a common coloniser of hillside slips. Cyathea medullaris is a tall emergent species that occurs mostly in broadleaved forest. It can be abundant in the initial forest formed on slips and other disturbed sites undergoing regeneration.

This tree fern grows in forest openings and apparently has a high reflection in the near infrared. Openings covered by this species seem to be dense forest in Landsat TM datasets.

A detailed investigation is pending. It was difficult to identify test areas big enough to delineate training areas.

Figure 12: *Tree ferns in a forest opening.*

5 Delineating Degraded Forest through GNSS

On one to delineate degraded forest is the mapping in the field using GNSS equipment. This was performed by the Fiji Forestry Department. The Timber Production Officer observing the logging operation. He walks with the hand held Garmin equipment and follows the boundary harvest area and intact forest. This polygons and partly points are downloaded into MapInfo based GIS and edited. These logging areas are degraded forest areas and are included for each Forest Division in the quarterly reporting.

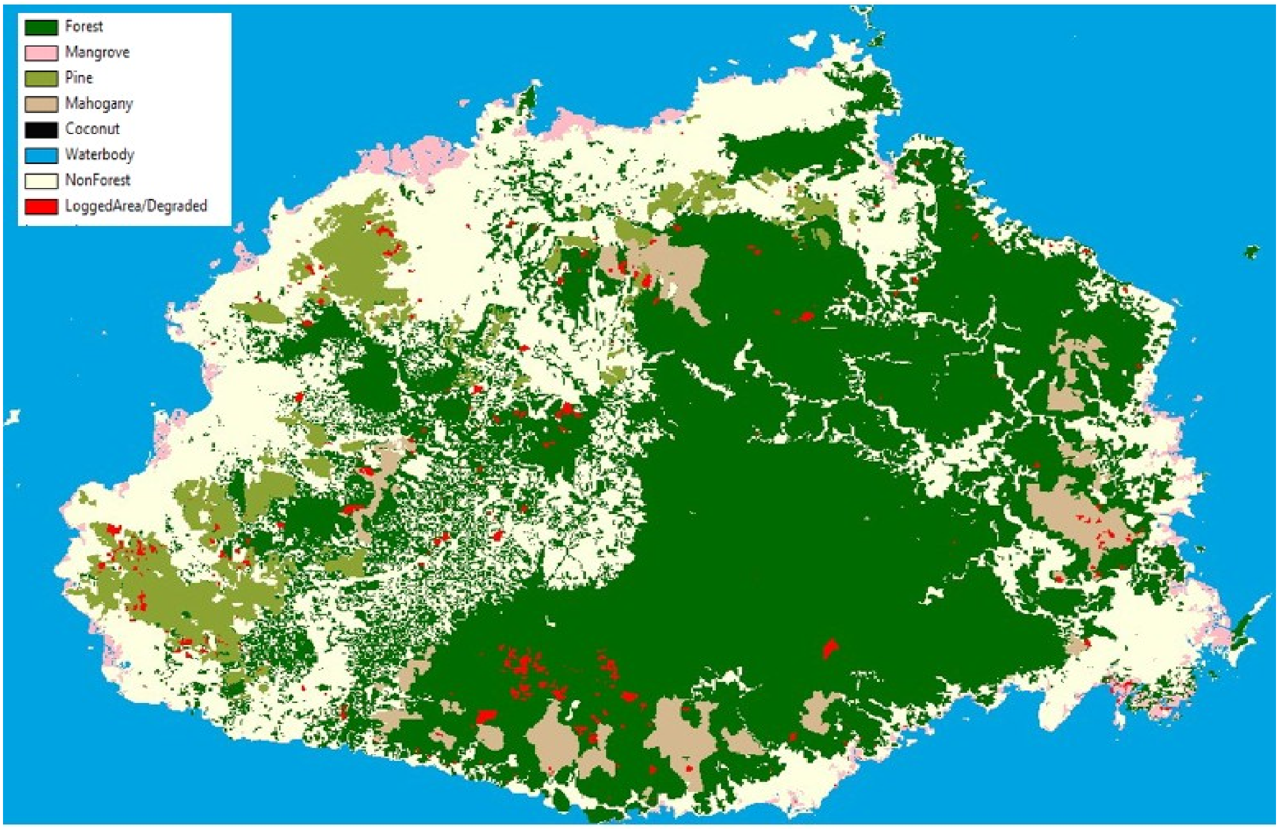

Figure 13: *Logged areas in Viti Levu captured by Timber Production Officers with GNSS equipment following the boundary harvest area and untouched forest.*

The logging was recorded within the time frame of the forest change detection between 2006 and 2016 conducted by Forestry Department and SPC-GEM for the World Bank. The standing forest for Viti Levu was recorded with 560,520 hectares and logging operation took place in 10,712 hectares, which is 2 % of the natural forest area.

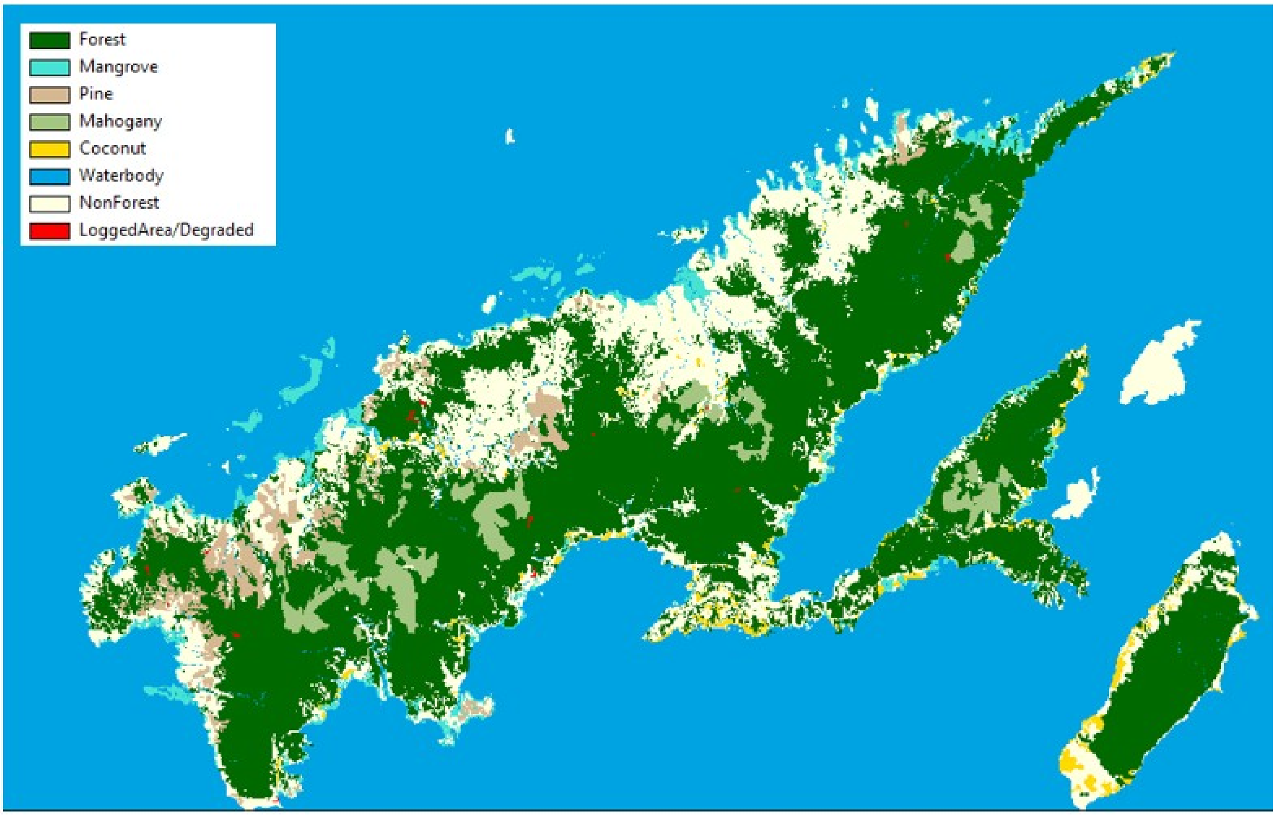

Figure 14: *Logged areas in Vanua Levu captured by Timber Production Officers with GNSS equipment following the boundary harvest area and untouched forest.*

The logging was recorded within the time frame of the forest change detection between 2006 and 2016 conducted by Forestry Department and SPC-GEM for the World Bank. The standing forest for Vanua Levu was recorded with 371,490 hectares and logging operation took place in 58 hectares only, which is 0.02 % of the natural forest area.

It is essential that there is a method developed to map forest degradation with remote sensing methods.