Twenty year changes in forest cover in North-East New Caledonia (1989-2000-2009)

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Chapter 8

Twenty year changes in forest cover in North-East New Caledonia (1989-2000-2009)

Evolution du couvert forestier au Nord-Est de la Nouvelle-Calédonie (1989-2000-2009)

Ralf-D. Schroers and François M. Tron

SUMMARY

This study developed a method to detect changes of forest cover, within a study area of ca. 1,500 km^2 covering the communes of Hienghène, Pouébo and Ouégoa in north-eastern New Caledonia. It includes the Mt. Panié wilderness reserve and the 2010 RAP sites.

Detected changes were based on image sequences from the years 1989 (Landsat TM5), 2000 (Landsat TM7) and 2008/09 (SPOT5). The imagery was geo-referenced, Landsat TM7 serving as a reference for an image-to-image registration. Supervised classification using the RandomForest approach produced a sequence of landcover representations, which then were used as a base for detecting changes. Changes based on SPOT5 data were affected by a root mean square (RMS) registration error data of 2 pixels (ca 60 meters) due to poor registration of the image product as well as distortions derived from the nature of hilly terrain. Field assessments of landcover representations provided an overall accuracy of 85% for the year 1989, 88% for the year 2000 and 74% for the 2008/9 maps.

The results show a forest loss of 26 630 hectares over 20 years, representing a 29.8% decline of the 1989 forest cover estimate. This deforestation appears to be more active in the period 2000–2008/9 than in the period 1989–2000, with an average annual deforestation rate of 1.9%/year. Native lowland forests are more threatened by deforestation. Deforestation mostly occurs outside mining, urban or major agricultural areas, while local evidence was demonstrated of forest destruction occurring on burnt areas by human induced bushfires. Reforestation of savannah is however identified in significant extent.

This study provides new evidence to significant modern deforestation in New Caledonia. This should lead to further investigation of the potential role of bushfire in this process and support the development of bushfire management policy and practice, including related conservation activities, noteworthy invasive species management.

RÉSUMÉ

Cette étude propose une méthode d'évaluation du changement du couvert forestier sur une région d'environ 1500 km^2 comprenant les communes de Hienghène, Pouébo, Ouégoa au nord-est de la Nouvelle-Calédonie. Cette zone d'étude comprend la réserve de nature sauvage du Mont Panié et les sites RAP 2010.

Les changements détectés sont basées sur une analyse d'images satellites pour les années 1989 (Landsat TM5), 2000 (Landsat TM7) et 2008/2009 (SPOT5). Ces images ont été géoréférencées en utilisant celle de Landsat TM7 comme référence pour une registration d'image à image. Une classification supervisée en utilisant l'approche ForestRandom a produit trois représentations cartographiques de la végétation qui ont ensuite été utilisées pour détecter les changements de végétation. Les changements impliquant l'utilisation des images de SPOT5 ont une erreur carrée moyenne (RMS) de deux pixels (environ 60 mètres) à cause d'une mauvaise registration de l'image, ainsi que de distorsions due à la forte topographie de la zone d'étude. La vérification terrain (pour la carte 2008/2009) ou d'après des photos aériennes (pour les cartes 1989 et 2000) des représentations cartographiques de la végétation fournissent une validité à 85% pour 1989, 88% pour 2000 et 74% pour 2008/2009.

Les résultats révèlent une perte de forêts de 26 630 hectares au cours des vingt années couvertes par l'étude, représentant un taux de déforestation de 29,8 % de déclin par rapport à l'estimation du couvert forestier de 1989. Cette déforestation apparait plus active sur la période 2000–2008/2009, avec un taux moyen de déforestation de 1,9%/an. Les forêts primaires de basse altitude sont plus menacées par cette déforestation. La déforestation implique principalement des zones éloignées des activités minières, agricoles ou urbaines. Cette déforestation a pu être localement mise en relation avec des feux d'origine anthropique. La reforestation spontanée des savanes est par ailleurs démontrée sur des surfaces conséquentes.

Cette étude fournit une nouvelle démonstration de l'importance actuelle de la déforestation en Nouvelle-Calédonie.

Les résultats soutiennent l'approfondissement des investigations sur les feux de brousse d'origine anthropique et le développement de leur gestion, sur un plan pratique et réglementaire, y compris dans le cadre d'activités de conservation impliquant la gestion des espèces envahissantes.

INTRODUCTION

New Caledonia is considered a hotspot among tropical islands that are richest in biodiversity (Kier et al. 2009). It is particularly remarkable and recognised for its unique forests (Mittermeier et al. 2004) and lagoons, listed as a world heritage site in 2008 (UNESCO 2008).

The vascular flora of New Caledonia is characterised by its high level of richness with 3371 species, and especially by its remarkable distinctiveness with endemism at the species level reaching 74,7% (Morat et al. 2012).

New Caledonian forest ecosystems are not only important for the many endemic plants, reptiles, birds and other wildlife species, but they also provide significant ecosystem services to the society, including game and medicine provision, climate and water regulation, erosion control and various cultural, touristic and spiritual services (Papineau 2006, CI, 2011). The north-eastern coast, focus of this study, has been identified as a buffer zone for the lagoon as several of the main environmental pressure over the lagoon and reef have a terrestrial origin (UNESCO op cit).

Habitat loss, and especially deforestation -forest loss- or forest degradation, is commonly considered as a major cause of species extinction and ecosystem services degradation, particularly on tropical islands (Brooks et al, 2002), including New Caledonia (Jaffré et al, 2010). Efforts to reduce deforestation are bound in New Caledonia to sectoral or provincial legislation. Some efforts are being developed to control the main pressures over the environment such as: mining regulation (DIMENC, 2009), agricultural and urban development, bushfires and invasive species management and protected areas development (DDEE 2012).

There is, however, very limited data on historical trends on deforestation and on critical areas currently being deforested in New Caledonia. Ibanez et al. (2012) analysed aerial photos over an area of 2.4 km^2 in Mt. Aoupinié over the period 1976–2000; the deforestation was estimated to be 24% of original forest cover extent. There is also very limited (spatially explicit) evidence on deforestation causes.

In this study, forest types are not distinguished, and the change detection of forest cover has been based on the use of multispectral satellite imagery over the area of investigation. Remote sensing has been a proven tool for landcover assessments and monitoring over the past decades, including over large areas (Lathem, 2006, Redo, D. et al., 2012). This also accounts for detecting changes of the landcover based on the analysis of image time series using both Spot and Landsat data (Bontemps et al., 2012; Griffiths, P., 2012).

Deforestation areas are overlayed with land-use data (DTSI, 2008) to discuss its origin.

STUDY AREA

The study area covers 149,382 ha, including the communes of Hienghène and Pouébo as well as part of Ouégoa, to the East of the Diahot river and to South of the main road. The recorded mean annual rainfall between the years 1991 to 2000 (DTSI, 2002) is 2254 mm/year within the study area, with a relatively dry period between 2003 and 2007 (Casola et Tron, 2013). It ranges from 720 mm/year as minimum to a maximum of 4820 mm/year. The altitude within the area ranges from sea level up to 1629 m (Mt. Panié summit), with a mean elevation of 406m.

See Figure 1 on p. 27.

According to the latest landcover assessment (DTSI, 2008) the study area is mainly composed of forest, and shrub land on volcano sedimentary substrate, as well as savannah. The southern parts of the commune of Hienghène are composed of forests and 'Maquis' on ultramaphic substrate.

DATA

The data employed for the study was multispectral imagery, with a spatial resolution ranging between 10m (SPOT5) and 30m (Landsat TM5 and TM7).

SPOT5 images were acquired for the years 2008 and 2009 as the most recent snapshot available from the Asterium Geo "Planet Action" project. SPOT5 is multispectral imagery with 4 bands in near-infrared (NIR), red, green and mid-wave infrared, with minimum cloud occurrence. For this reason, the SPOT5 scenes from July 31st, 2008, and May 12th, 2009, were obtained. The 2009 scene covered the southern part, approximately 20% of the study area, showing 4% of cloud cover. The remaining area was represented by the 2008 scene, with almost no cloud cover. Both SPOT5 images were received with the processing level 2A.

Two Landsat images were acquired, one each for the year 2000 and 1989 (Landsat TM5 for 1989 and TM7 for 2000). The former was Landsat TM7 dated May 4th, 2000. The scene for 1989 was Landsat TM5 from April 7th, 1989. Landsat scenes were acquired with processing level 1T. Cloud cover of the Landsat scenes ranges between 10% for 2000 and 15% for 1989. The southernmost area of Hienghène commune were cuts off from the Landsat TM5 scene and therefore are not considered in the change assessment review.

METHODS

The change detection using satellite imagery requires image preparation in form of geo-referencing, ortho-rectification, as well as atmospheric and radiometric correction. All image data were acquired with standard processing levels (Spot5 Level 2A, Landsat level 1T) with applied radiometric and atmospheric correction.

Landsat TM7 (year 2000) was chosen as a reference for all other imagery using an image-to-image registration because of its high level of georeferencing accuracy. However, this report concentrates on presenting results of detected changes between 1989 and 2008/09.

Although more sensitive to errors, the change detection was based on comparing supervised classification results (instead of generating change classes) as the generation of land cover maps of individual dates was desired as a useful resource for planning purposes.

Data preparation

The data preparation included georeferencing, ortho-rectification, mosaicking, and histogram equalisation. GPS field points were collected with a hand held unit (positional accuracy of 3 to 5m) to establish a reference source for geocorrection.

Change detection relies on high geometric registration accuracy of all temporal image sequences in order to eliminate potential spurious results when detecting changes in reflectance for land cover (Phinn and Rowland, 2001). The imagery was geometrically corrected by using ground control points (GCPs) that were collected on prominent positions (eg. crossroads, river bridges).

Both Landsat images were relatively well registered with a RMS error for Landsat TM7 of 16.0 m. An image-to-image registration of Landsat TM5 revealed an RMS error of 5.9 m. Both results showed a geometric reference accuracy of sub-pixel level.

The SPOT5 images were 2A level processing products with a location accuracy of around 30m regardless of errors induced through relief. They are georeferenced without using GCPs based on global DEM grid with 1 km resolution (Spot image, 2010). As the two SPOT5 images were acquired with different viewing angles, distortions occurred especially within hilly regions of the scenes. Both SPOT5 images were ortho-rectified using the 10m DEM (DTSI, 2009), and an image-to-image registration was based on 707 registration points with the pan sharpened Landsat TM7 scene as reference. As mis-registration of the SPOT5 images was not systematic, the geometric offset between the SPOT5 scenes themselves and SPOT5 with the Landsat TM7 were geometrically rectified by "forcing" the map and source points being congruent. This resulted generally in some distortion of SPOT5 images but helped to improve the overall quality of registration with the Landsat TM7 scene.

The SPOT5 images were then mosaicked using The Geospatial Data Abstraction Library (gdal 1.7). A histogram equalisation was performed in order to adjust contrast values of both scenes.

The mosaic was resampled to 30m using a low-pass kernel in order to match the spatial resolution of both Landsat scenes.

All images were then clipped to the study area extent.

Supervised classification

A supervised image classification was conducted with assistance from the local organization Dayu Biik, supporting the establishment of training areas through detailed local knowledge of the terrain. This was especially useful when relating current field data of 2012 to 2008/09 SPOT5 derived imagery.

Training classes

The following classification was established (shown in Table 1) to be compatible with DTSI 2008 landcover map.

The spatial distribution of the training areas (hand drawn polygons of homogenous vegetation classes) concentrated to accessible areas within Hienghène commune, but also on forested areas that were characterized by their visual homogeneity in the reference photos and imagery. The latter described delineation was always backed up by local knowledge. As reference data, aerial photos from 2011 and 2006 were available (Source: DITTT, Province nord, DTSI). Accuracy of the aerial photography was verified with collected GCPs. The accuracy ranged below 10m (RMS error).

Training areas for Landsat imagery were established for the years 2000 (TM7) and 1989 (TM5) with help of aerial photography from 1991, 2000, 2001 and 2002 (Source : Province nord, DTSI, DITTT) and Google Earth historical imagery from 2002.

The 1991 photos were georeferenced based on larger visual feature recognition on both photos and the georeferenced Landsat TM5 true-colour image. The result was sufficient for visual identification of landcover information and for establishing training areas for the 1989 image classification. These photos then later also served as reference for validation.

Classifiers

The classifier "RandomForest" (Liaw et Wiener. 2002) in the statistical software R (r-project.org) was used to perform a supervised classification. "RandomForest" (Breiman and Cutler, 2001) is a classification method that consists of several uncorrelated decision trees (contrary to single decision tree algorithms). All decision trees in "RandomForest" grow in a way of randomisation during a learning process. Every tree established can make a decision so that eventually a class will be created when it was mostly voted for.

For this study the sampling for a classification was set to select 1000 random sample points within each class, over an area which is represented by several polygons (ie training areas). Some data within the training areas is kept to undertake predictive testing and establishing a final decision tree.

Error assessment and reduction

Errors of change detection in this study were identified mainly as a result of geometric mis-registration of SPOT5 imagery and clouds and haze.

Table 1: Classes established for the supervised classification

Vegetation classes	Definition
Clouds	Clouds.
Cloud shade	Clouds or steep slopes shade.
Water	Open water bodies, such as rivers.
Bare soil	Bare soil such as crags, rocks, landslides, bare ridges, rocky river bed and tracks.
Forest	Forest with closed canopy.
Tree savannah	Savannah with trees, with a canopy covering at least 20% of ground surface.
Herbaceous savannah	Savannah of grassland, with less than 20% of ground surface covered by sparse tree canopy.

Geometric mis-registration of imagery

As mentioned earlier, both Landsat images showed a geometric reference accuracy of sub-pixel level.

Skewed appearance of hilltops based on varying viewing angles between the SPOT5 and Landsat TM7 scenes was identified as a major cause of mis-registration. By setting 50 randomly distributed points pairs across the 30m resampled SPOT5 image and referencing it to the Landsat TM7 image, the mean error was of 63m (i.e. 2 pixels).

Change detection results imply errors due to comparing different image acquisition parameters, especially within areas of hilly terrain as view angles vary between images. This also accounts for images acquired by different sensors or instruments. Geo-referencing Level2A SPOT5 imagery was a difficult task as correction had been already applied by the producers. Through applying appropriate geometric models, ortho-rectification and ground control point registration the geo-referencing errors were reduced (see *Data preparation* chapter and section above).

Clouds and haze

Haze can lead to misclassification, especially at the edge of clouds.

The multispectral reflectance characteristics of bare soil and clouds are indeed relatively similar (Fisher and Danaher. 2011). In order to reduce such misclassification and errors, a post classification correction therefore concentrated around the immediate areas around clouds and was applied for all images. A directed region grow (expand following shrink) by up to 5 pixels (150m) was applied as these feature representations were assumed to account for haze.

Even in the absence of clouds, hazy areas may occur, especially in 1989 on eastern slopes of the Mt. Panié. Tree savannas appear in these areas where old-growth native forest was visible from the ground in 2012, suggesting a misclassification. An attempt to run a classification using "Forest" training areas from these hazy areas resulted in obviously erroneous classification at a wider scale. Reforestation is therefore likely to be overestimated in this area.

Assessment of training classes

Supervised classification results are first assessed looking at spectral feature spaces and confusion matrices of the "RandomForest" tree classifier method.

The established classes generally appeared as relatively distinct spectral areas, looking at the NIR/RED two dimensional feature space (Figure 2, p. 27 for an example).

The overlaps between "Tree savannah" on one hand and "Herbaceous savannah" and "Forest" on another hand is visible in the feature plot and occurs in the confusion matrix below (Table 2 and Figure 2, p. 27).

Explanatory variables included the 6 bands of the Landsat TM5 image. With 500 decision trees and 2 variables tried at each split, the classification resulted in an out-of-bag estimate of error rate of 1.9%.

A similar process was used for 2008/9 image:

Explanatory variable for this 2008/9 classification included the 4 bands of the SPOT5 mosaic. With 500 decision trees and 2 variables tried at each split, the classification resulted in an out-of-bag estimate of error rate of 10.32%.

The overlaps between these vegetation classes can be explained by a continuous gradient between "Herbaceous savannah", "Tree savannah" and "Forest". These errors could also be the result of employing ground reference data (2012) being collected a few years later than the time of image acquisition (2008/09).

Validation of classification results

Using field data for the 2008/9 classification and visual interpretation of historical aerial pictures for 1989 and

Table 2: Confusion matrix for the RandomForest classification, year 1989

Observed/ Predicted	Water	Forest	Shade	Cloud	Tree savannah	Herbaceous Savannah	Bare soil	Class error
Water	751	0	0	0	0	0	0	<0.000001
Forest	0	728	4	0	34	1	0	0.050847
Shade	0	0	752	0	0	0	0	<0.000001
Cloud	0	0	0	749	0	2	0	0.002663
Tree savannah	0	42	0	0	705	8	0	0.066225
Herbaceous Savannah	0	0	0	1	8	745	0	0.011936
Bare soil	0	0	0	0	0	0	750	<0.000001

2000 classifications, error matrices were generated and used for final validation of results.

The points were distributed in a random stratified manner, allowing in each vegetation class at least one point, and a minimum distance of 45 m from each other (due to 30m spatial resolution).

Years 1989 and 2000

100 points were randomly stratified over the five classes ("Forest", "Tree savanna", "Herbaceous savannah", "Water" and "Bare soil"), within the extent of aerial photographs of 1991 outside of training areas initially delineated and used for the classification. Areas consisting of cloud and shade were not selected and excluded from this validation. A matrix including user and producer accuracy is shown below (Table 3).

The validation of the landcover classification for the year 1989 showed an overall accuracy of 85%.

A similar process provides 88% of accuracy for the classification of the year 2000.

Year 2008/9

The validation of the SPOT5 2008/09 classification results had been composed of two exercises: A field survey with sampling 32 points in August 2012 in Hienghene valley near Thoven, and additional field data taken in December 2012 in form of sampling polygons south of Mt. Panié. These polygons were delineating homogenous areas, mainly tree and herbaceous savannah (18, 13), and also a few large forest patches (5). The sampling was set to 78 points to be stratified throughout these polygons, with calculated points per area size, with at least one, maximum 4 points in each polygon. The result is shown in the error matrix below (Table 4).

The validation of the landcover classification for the SPOT5 image of 2008/9showed an overall accuracy of 74%.

Assessing NDVI within deforestation classes

Change detection errors resulting from comparing landcover classification (i.e. errors of commission or omission of individual classification results) were further examined by looking at Normalized Difference Vegetation Index (NDVI) differencing results within individual change classes. The NDVI is a measure of photosynthetic activity and NDVI differencing is commonly used to highlight changes in active vegetation cover over time.

Assessing deforestation classes using ancillary data

Ancillary data such as landcover, mining and bushfire occurrence information was overlayed on areas of detected forest decrease in order to identify potential deforestation causes. This overlay data included:

- the mining cadastre information (active, prospective and mining areas under investigation; DITTT 2010),
- agricultural and urban areas (Occupation du sol, DTSI 2008) and
- 2009 bushfire data in part of Hienghène commune (Tron et al, 2011). Bushfire occurrence using MODIS data was

Table 3: User/producer matrix for the classification of Landsat TM5 image (year 1989)

Field/Map	Forest	Tree savannah	Herbaceous savannah	Water	Bare soil	*Total*	Producer
Forest	40	2		1		43	0.93
Tree savannah	6	21	5			32	0.66
Herbaceous savannah			19		1	20	0.95
Water				4		4	1
Bare soil					1	1	1
Total	46	23	24	5	2	100	
User	0.87	0.88	0.79	0.8	0.5		**85%**

Table 4: User/producer matrix for the SPOT5 classification (year 2008/9)

Field/Map	Water	Forest	Tree savannah	Herbaceous savannah	Bare soil	*Total*	Producer
Water	1	1			1	2	0
Forest		19	1	1		21	0.91
Tree savannah		8	36	10		54	0.67
Herbaceous savannah			6	23		29	
Bare soil				1	2	3	0.67
Total	1	28	43	35	3	110	
User		0.68	0.84	0.66	0.67		**73.6%**

initially considered as too broad and insensitive in relation to field observations and could therefore not be used for this analysis.

CHANGE DETECTION RESULTS 1989 – 2008/09

Change 1989 – 2008/09

The results showing changes over the entire time interval based on SPOT5 (2008/09) and Landsat TM5 (1989) is shown in Figure 3.

Associated area with vegetation changes are listed in Table 5, and absolute area changes stratified by altitude classes are shown in Figure 4 and Table 6.

Table 5: Forest cover change (in hectares) over the two periods

	1989–2000 (ha)	2000–2008/09 (ha)
Deforestation	9,734	16,896
Reforestation	13,943	9,202

Table 6: Vegetation changes between 1989 and 2008/09

Deforestation 1989–2008/09	Area (ha)
Forest ---> Tree savannah	12,092.3
Forest ---> Herbaceous savannah	4,287.8
Forest ---> Bare soil	136.8
Total	**16,516.89**
Reforestation 1989–2008/09	
Tree savannah ---> Forest	11,674.6
Herbaceous savannah ---> Forest	1,217.6
Bare soil ---> Forest	26.6
Total	**12,918.8**

Table 7 illustrates absolute forest cover changes according to altitude class ranges.

Table 7: Absolute area changes 1989–2008/09 per Altitude class

Altitude (m)	Absolute area change 1989–2008/09 (ha)
0–300	Deforestation 3,941.7
301–600	Deforestation 1,346.0
601–900	Reforestation 1,381.8
901–1200	Reforestation 267.1
> 1200	Reforestation 40.8

Potential causes of deforestation

The overlap of forest cover change (1989–2008/9) with mining, agricultural and urban area development shows insignificant (between 1 and 5%) intersections. It is therefore estimated that most of the change is resulting from other causes, most likely bush fires.

See Figure 3 on p. 28.

Out of 626 ha affected by fire in 2009 around Hienghène (Tron et al, 2011), 5.6% were forests (40 ha) that turned into savannah over the period 2000–2009. Remaining forests in fire affected areas are generally invasive pine (*Pinus caribaea*) forests that are more resistant to fire.

DISCUSSION AND RECOMMENDATION

The validation of classifications results provides an overall accuracy of 85% for the 1989 classification, 88% for 2000 and 74% for 2008/09. For the period 1989 to 2008/09 around 98% of detected deforestation also showed NDVI decrease.

According to our results, deforestation is still an active and major phenomenon in northeast New Caledonia. Over the two decades, 26,630 hectares of forest have been lost, representing a loss of 29.8% of the original forest (1989 estimate of 89,347 hectares), 16,896 hectares of it having disappeared in the last decade, thus being more active (Table 7). The deforestation rate is therefore around 1.9% per year.

Lowland forests (<300m) are particularly vulnerable to deforestation. They cover only 30.2% of the total lowland area and a large part of them is likely to be shade forest for crops or secondary forest of lower biological value. Large blocks of the native and rare old-growth lowland forest have the potential of high biological value and should be specifically considered for conservation priorities setting. This could be further explored through biological surveys.

Such significant deforestation is likely to have a negative impact on ecosystem services, including on soil erosion, water regulation and therefore on rivers, mangroves and reef ecosystems. Poor water quality will affect human wellbeing, the economic and public sectors. Deforestation will put pressure on coastal protection, related infrastructures and fisheries.

According to a conservative estimate, 146 t of Carbon are stored in 1ha of forest in New Caledonia (Durrieu de Madron, 2009). The deforestation detected in this study therefore equals to 14.3 $MtCO_2$ released over a period of approximately 9 years (2000–2008/09), which is approximately three times more than all emissions of economic activities of province Nord over the same period of time (Guerrere, 2009). Research into carbon dynamic in ecosystems is required to establish the national greenhouse gases inventory. It will also support the development of ecosystem-based carbon mitigation projects.

Strong NDVI reduction was noticed in some areas of the 'chaine centrale' (western part of this study area) and it has been suggested by local expertise that this could derive from the invasive fire ant (*Wasmannia auropunctata*) in forested areas and the invasive deer (*Rusa timorensis*) in grassland regions. The development of the fire ant induced *fumagine fungi* does indeed reduce the photosynthetic activity of the forested vegetation visible as black leaf cover in the landscape. The browsing pressure of deer on grasses, especially

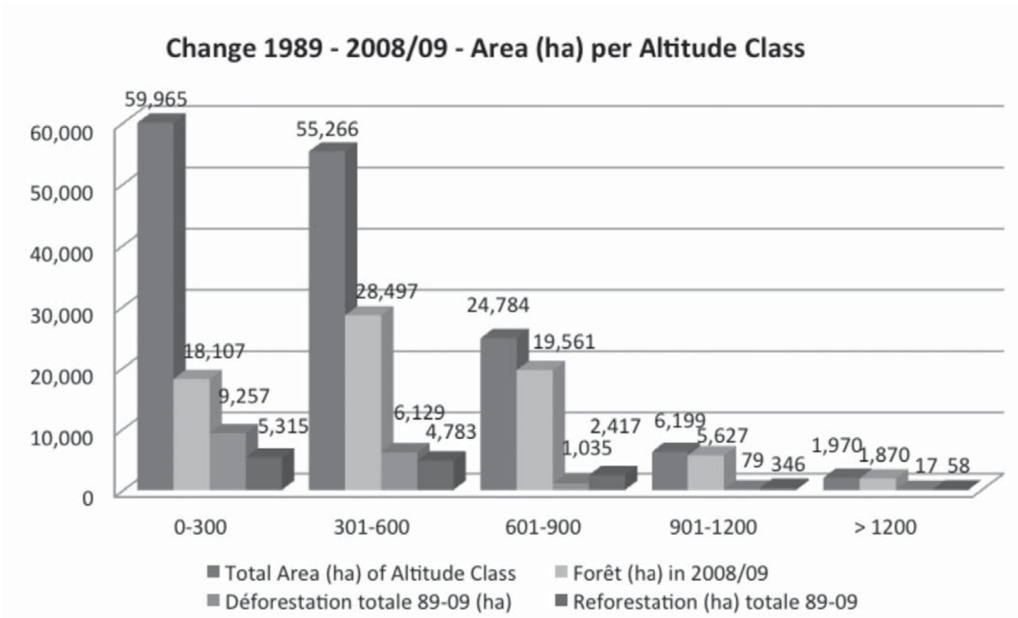

Figure 4: Changes 1989–2008/09 per altitude class

the softer -and more palatable- species may also reduce the overall photosynthetic activity of the herbaceous vegetation.

Reforestation of savannah appears to be significant. Field observations indicate that the Niaouli tree (*Melaleuca quinque-nervia*) is the main species involved in early stages of the reforestation process. Other pioneer species are also observed within older stands of Niaoulis as well as on landslide areas. According to preliminary observations and traditional knowledge, it is thought that the biological value of secondary forests is less than primary ones, at least over the first few decades; spontaneous reforestation or resilience should therefore not be considered as an effective mitigation of deforestation.

It has been estimated that man-made bushfires are a main cause for deforestation in New Caledonia (Jaffré et Veillon 1994, Ibanez et al 2012). Traditional management of invasive species (such as deer, pigs, pine trees) is widely recognised as a major motivation to light fires in New Caledonia (Bompy 2009). This study demonstrates that forest loss assessed by remote sensing does overlap at places with bushfire. Therefore, efforts to manage invasive species with appropriate techniques coupled with community involvement are recommended for achieving bushfire and deforestation reduction. Projects and programs targeting invasive species control should consider and monitor bushfire activities.

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