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Climate Protection through Forest Conservation in Pacific Island Countries

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

Detection and Quantification of Deforestation during 2000 – 2013 on Choiseul, Solomon Islands

SPC Secretariat of the Pacific Community

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Executive Summary

Choiseul is one of the last larger islands in Solomon Islands that still have a significant cover of natural forests. Hence, the indigenous people on Choiseul are highly dependent on that resource for their subsistence. However, logging operations are ongoing, leading to forest degradation and deforestation. This report was commissioned to quantify the deforestation between 2000 and 2013 using remote sensing data, and to produce a deforestation map (page 12), which can serve as a basis for policy decisions and reference for future forest monitoring.

During the period 2000 – 2013, 1,998 ha or 154 ha/year were deforested on Choiseul. That equals about 0.65 % of the total forest area in 2010 (307,701ha). Most of the deforestation occurred in the coastal areas. This rate is most likely underestimating the true deforestation rate, due to cloud coverage of 66,961 ha or 21.4 % of the land area (312,623 ha), which could not be included in the analysis. Furthermore, one has to bear in mind that logging operations lead to forest degradation rather than deforestation, which means that the impact of those operations on the resource and the environment is much higher than only the deforestation.

As follow-up to this study, two tasks are of the highest priority:

- Accuracy assessment of the used data sets through ground truthing; and
- Continuing updates with Landsat 8 data to further reduce the cloud coverage on the present state of the forest.

This study adds to the observations this project has made, that the main problem for forest management and carbon balance in the forestry sector in Pacific Island Countries is forest degradation, not deforestation. Future efforts in building structures for measuring, reporting and verifying carbon emissions from the forestry sector should focus on this element.

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Acronyms & Abbreviations

FBD	Fine resolution model dual polarization
FNF	Forest/non-forest
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
IPCC	Intergovernmental Panel on Climate Change
JAXA	Japan Aerospace Exploration Agency
MMU	Minimum mapping unit
MRV	Measurement, reporting, and verification
REDD+	Reducing emissions from deforestation, forest degradation, conservation, sustainable management of forests and enhancement of carbon stocks
RS	Remote sensing
SAR	Synthetic Aperture Radar (SAR)
SBSTA	Subsidiary Body on Scientific and Technological Advice
SRTM	Shuttle Radar Topography Mission
UNFCCC	United Nations Framework Convention on Climate Change
VHR	Very-high resolution (VHR) optical data
WGS	World Geodetic System
WRS	World Reference

1 Introduction

Reducing emissions from deforestation, forest degradation, sustainable management of forests, enhancement and conservation of forest carbon stocks (REDD+) is considered one of the most cost-effective options to mitigate climate change. The Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) frames REDD+ as one of the building blocks of the post-Kyoto mitigation architecture. Convened in November 2013 in Warsaw, COP 19 consolidated the modalities for developing National Forest Monitoring Systems (NFMS), for MRV, and for the technical assessment of Forest Reference Emission Levels and Forest Reference Levels (FREL/FRL), which together with other decisions on form the so-called *Warsaw Framework for REDD-plus* (FCCC/CP/2013/10, par. 44).

Small-island states face particular challenges in establishing their reference level. Their national territory is a discontinuous, composed of islands differing in size, vegetation, socio-economic development, and topography. Poor satellite coverage, cloud cover, and rough topography hampered land-use change monitoring in the past. The German Environment Ministry, facilitated by the Gesellschaft für Internationale Zusammenarbeit (GIZ), is supporting the Solomon Islands' REDD+ process with its regional Project "*Climate Protection through Forest Conservation in the Pacific Island Countries*". Amongst the islands forming the territory of the Solomon Islands, CVhoiseulstill shows a considerable forest cover. However, growing pressure on its natural resources is being reported. This report assesses the forest cover loss on CVhoiseulduring the last 13 years. With most of the South Pacific island states, Solomon Islands share the challenges of data scarcity, particularly regarding the past. Due to the geographic location, all available optical scenes for the past are to a lesser or larger extend covered by clouds. Both challenges complicate the assessment of past deforestation rates. To overcome these challenges, data generated from processing multispectral optical imagery has to be combined with information from other types of data sources. Here, an approach has been chosen which has been developed for deforestation detection in Vanuatu. The approach generates vegetation and humidity sensitive indexes using multispectral optical data (Landsat, ASTER, SPOT) to derive land cover and land use change patterns (Herold et al. 2007). As the persistent cloud coverage impedes the wall-to-wall detection of a forest cover, a coarser 2010 forest mask has been used, provided by the Japan Aerospace Exploration Agency (JAXA). JAXA processed ALOS PALSAR synthetic aperture radar (SAR) data to develop a new global 50m-resolution PALSAR mosaic and Global Forest / Non-forest map.

The following section describes the processing steps and the integration of different data products. Section 3 presents the results of the 2000 – 2013 deforestation assessment and discusses further options to improve the results.

2 Methods and data to assess 2000 – 2013 forest cover change

Processing of the forest/non-forest mask and deforestation for the period 2000-2013 follows the processing developed by Herold et al. (2007). This section provides an overview on the processing steps. The optical processing chain has been implemented in ERDAS Imagine 9.1. Figure 1 at the end of this section gives an overview of the processing chain. Step (1)–(4) cover the image preprocessing.

2.1 Data

Although The United States Geological Survey (USGS) provides a decent Landsat coverage of Choiseul Island, most of the scene are partially covered by clouds. A set Landsat scenes has been selected from the archive[1], downloaded and evaluated. 40 Landsat, 7 ETM and Landsat 8 images were processed (cf. Annex 1), covering World Reference System (WRS2) scenes P90R65 and P89R65.

2.2 Processing

2.2.1 Image pre-processing

(1) Image registration: All Landsat scenes for 2000 and 2013 were co-registered to a common reference. The panchromatic band of the least clouded image for both scenes was chosen as a reference.

(2) No-data Masking: In the 2000 images, clouds were delineated manually. Landsat 7 ETM suffers data losses due to the scan-line-correction (SLC) error. Thus, the 2007 SLC-error mask provided together with the raw data was included. Sea area was masked out using the coastline derived from the Global Administrative Boundaries data base. The three no-data masks were combined into one mask using Map Algebra and applied to the mosaics. Landsat 8 comes with spatial information on the spatial extent of cloud cover within each scene. The Landsat Land Data Operational Product Evaluation (LDOPE) Tool belt[2] was used to extract the cloud cover to be masked out.

(3) Normalization: The mosaics will require a certain degree radiometric normalization to reduce radiometric image differences (Herold et al. 2007). Thus, histogram matching was applied to all scenes.

***(4) Mosaicking*:** All images were mosaicked for the two years.

2.2.2 Pseudo spectral channel processing

(5) Pseudo spectral channel processing: The 2000-2013 deforestation detection is using pseudo spectral channels based on image ratios and principal components "to reduce effects of different illumination conditions due to topography" (Herold et al. 2007). The method uses the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI) which are both sensitive to vegetation. Additionally, a principal component analysis (PCA) has been applied to the images.

The NDVI is calculated as the difference between the near infrared channel (NIR: Landsat TM/ETM band 4; Landsat 8 band5) and the red channel (RED: Landsat TM/ETM band 3; Landsat 8 band 4) normalized by the sum of both bands (Equ. 1):

$$(1) \qquad NDVI = \frac{NIR-RED}{NIR+RED} = \frac{band\ 4_{ETM}-band\ 3_{ETM}}{band\ 4_{ETM}+band\ 3_{ETM}}$$

The NDWI shows a similar structure building on the near and shortwave infrared (SWIR) channels. It maximizes the vapor reflectance suppressing at the same time the reflection of vegetation (McFeeters 1996; Jackson et al. 2004). Corresponding RED (Landsat 5/7 band 4; Landsat 8: band 5) and SWIR bands (Landsat 5/7 band 5; Landsat 8: band 6) were used to build the Index :

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1 **http://earthexplorer.usgs.gov/.**

2 Available at: **https://lpdaac.usgs.gov/tools/ldope_tools.**

(2) $$NDWI = \frac{NIR - SWIR}{NIR + SWIR} = \frac{band\ 4_{ETM} - band\ 5_{ETM}}{band\ 4_{ETM} + band\ 5_{ETM}}$$

As the first component of the PCA reflects the surface illumination patterns and topographic variations, the remaining 4 components conserve information not influenced by those factors (Herold et al. 2007). All components are stacked to create a pseudo spectral composite of PCA 2-4, NDVI and NDWI.

2.2.3 2000 – 2013 Deforestation detection

(6) PCA of bi-annual channel pairs: The change from forest to non-forest is expected to cause a change of the intensity in several multispectral bands (RED, SWIR) and pseudo spectral channels (NDVI, NDWI). Bi-annual Layer stacks for each band and channel were created (NDVI_2000_2013, RED_2000_2013, etc.). A PCA was applied to each stack. The first component captures the information both bands have in common (e.g. low RED intensity of forest in 2000 and 2013), while the second band highlights the differences. Consequently, the second component of each pair should capture land cover and land use change.

(7) Layer stacking: The four second principal components of the pairs (NDVI_2000_2007, RED_2007_2010, etc.) will be stacked together for further joint processing.

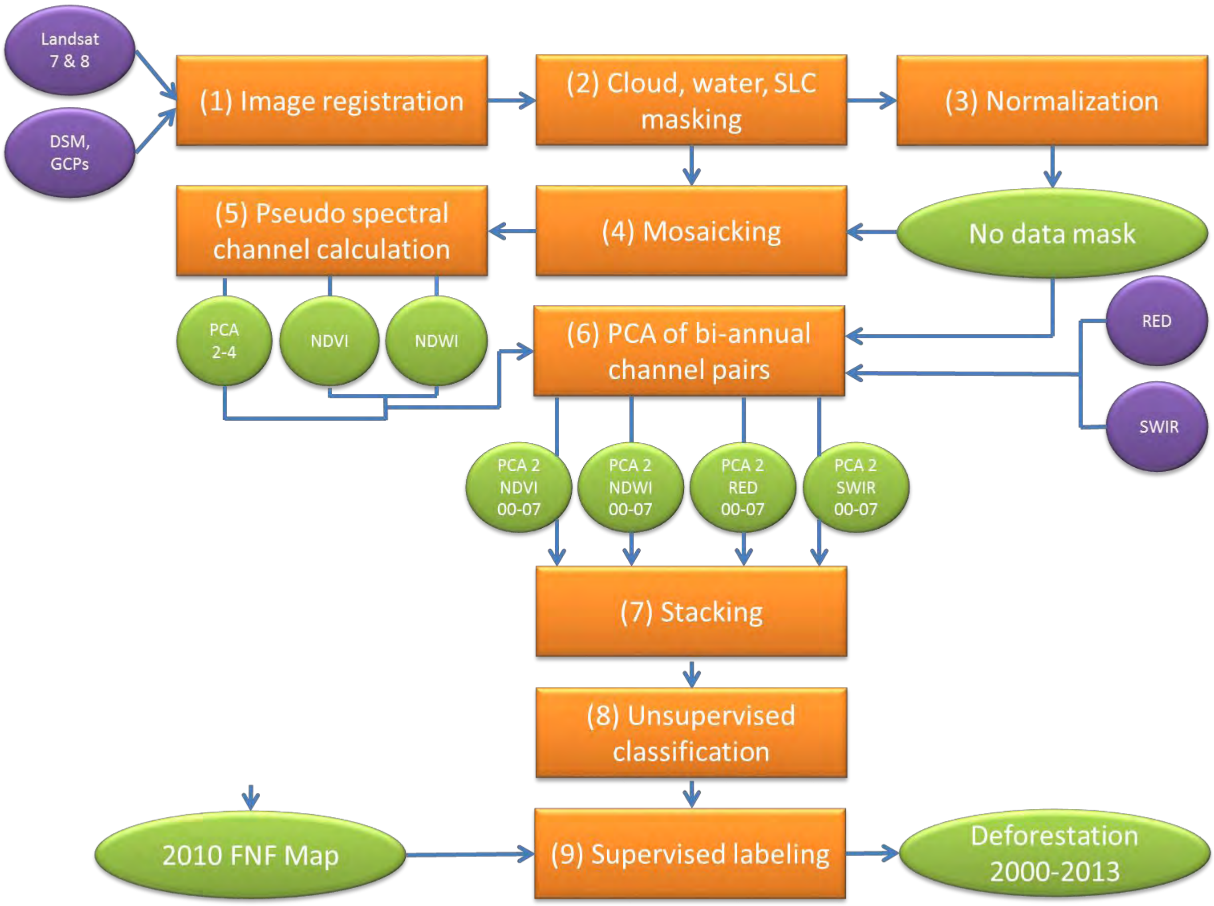
(8) Unsupervised classification: The layer stack will be classified using the ISODATA algorithm.

(9) Supervised labeling: The 2010 forest mask provided by JAXA was used as a reference to focus the visual inspection of areas showing a change signal (higher intensities in each channel). The Forest/Non-Forest map was derived from ALOS PALSAR dual polarization (HH, HV) SAR data[3].

Figure 1 gives an overview on the processing chain.

3 Data and the FNF product are available at: http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm

Figure 1: Optical based deforestation processing chain



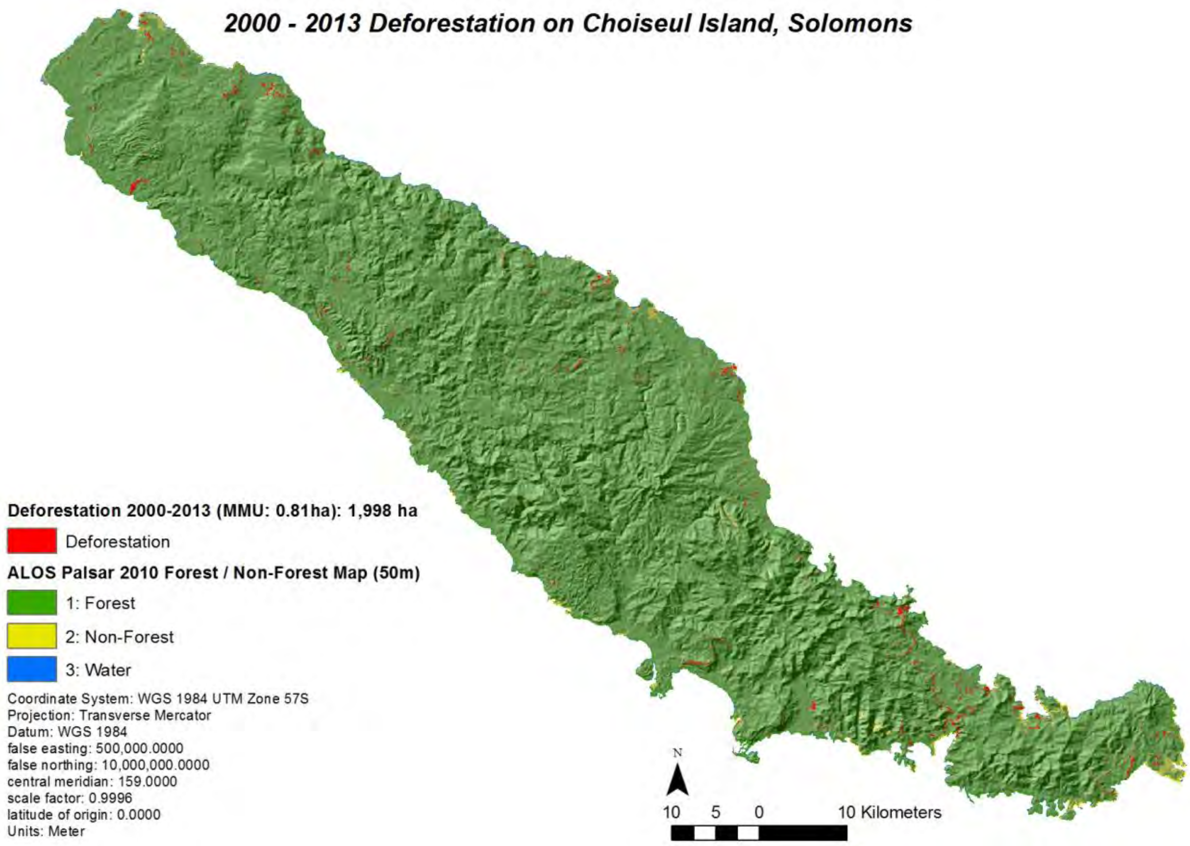
The output of this processing path is a 2000-2013 deforestation map, which requires further validation using independent higher-resolution data as a reference (GOFC-GOLD 2013; GFOI 2014).

Considering the complexity of the processing, particularly the combination of bands and indexes over multiple steps, a minimum mapping unit (MMU) of 0.81 ha equivalent to a 3x3 pixel Moore neighbourhood deems appropriate (Knight and Lunetta 2003). Consequently, raster data representing the deforestation pattern was converted into vector data. The polygons were merged and exclude all smaller than 0.81 ha, based on the assumptions that change signals smaller than 3x3pixels (30 x 30m = 0.81 ha) in size have to be considered inherent processing noise.

3 Results and discussion

Figure 2 shows the extent of deforestation on Choiseul Island. Based on the minimum mapping unit, 1,998 ha or 154 ha/year were deforested during the period 2000 – 2013

Figure 2: Deforestation on CVhoiseulduring 2000 and 2013



Most of the deforestation occurred in the coastal areas. However, one has to keep in mind that this rate is probably underestimating the true deforestation rate. First, applying a conservative MMU leading to change signal of 22,203 pixels rules out almost half (19,076 pixel or 46%) of the uncorrected change signal (41,279 pixel). Ground observations and suitable reference data for verification (GFOI 2014) are required to assess whether such a conservative MMU should be adjusted.

Figure 3: Cloud cover within the 2000 Landsat 7 (left) and the 2013 Landsat 8 mosaics (right)

Secondly, the persistent cloud cover affects particularly the scarce 2000 Landsat imagery. Figure 3 illustrates to what extent both mosaics are affected by clouds. While the 2013 coverage can be improved over time by factoring in recently acquired Landsat 8 data (its acquisition frequency is 16 days), cloud cover in the 2000 coverage is difficult to reduce. As the 2000 coverage is largely covered by clouds, some deforestation having occurred inside the island has certainly been missed on the assessment.

In any case, the assessment should be updated in the near future to close the data gaps in the 2013 coverage, converting it into a reference for future deforestation assessments. As stated, a sound accuracy assessment should be conducted as well, following agreed guidelines and best practices (GOFC-GOLD 2013; GFOI 2014; Fichet et al. 2013).

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Annex 1: Landsat scenes used in the deforestation assessment

2000	Scene ID	Date	Cloud coverage
P90R65 (West)	LE70900651999222SGS00	10-Aug-99	
	LE70900651999254EDC00	11-Sep-99	good image
	LE70900652000129EDC00	8-May-00	
	LE70900652001003EDC00	3-Jan-01	some haze but suitable to fill gaps
	LE70900652001019EDC00	19-Jan-01	some haze but suitable to fill gaps
	LE70900652001211EDC00	30-Jul-01	some clouds, no haze. Download!
	LE70900652002342EDC00	8-Dec-02	some clouds, no haze. Download!
	LE70900652003089EDC00	30-March_03	lot of clouds; only suitable for small areas
	LE70900652003105EDC00	15-Apr-03	lot of clouds; only suitable for small areas
P89R65 (East)	LE70890652000042EDC00	11-Feb-00	
	LE70890651999263EDC00	20-Sep-1999	
	LE70890652000154EDC00	2-Jun-00	
2007	**Scene ID**	**Date**	**Cloud coverage**
P90R65 (West)	LE70900652007004EDC00	4-Jan-07	Partially cloudy anchor image
	LE70900652007020EDC00	20-Jan-07	Good complement to 04-JAN-07
	LE70900652007180EDC00	29-Jun-07	Partially cloudy
	LE70900652008039EDC00	8-Feb-08	Partially cloudy
	LE70900652008327EDC00	22-Nov-08	Cloudy, partial complement
P89R65 (East)	LE70890652007157EDC00	6-Jun-07	Cloudy, east ok anchor image
	LE70890652008080EDC00	20-Mar-08	Cloudy, center ok
	LE70890652008112EDC00	21-Apr-08	Cloudy, but good complement
	LE70890652008320EDC00	15-Nov-08	Cloudy, partial complement
	LE70890652008336EDC00	1-Dec-08	The least cloudy! but western scene P90R65 almost completely covered
2013	**Scene ID**	**Date**	**Cloud coverage**
P90R65 (west)	LC80900652013140LGN01	20-May-13	Base image, scattered clouds
	LC80900652013156LGN00	5-Jun-13	Cloudy, some spots cloud free
	LC80900652013204LGN00	23-Jul-13	Hazy, less clouds (best complement)
	LC80900652013220LGN00	8-Aug-13	Very cloudy, only two spots cloudfree
	LC80900652013236LGN00	24-Aug-13	Cloudfree in the center
	LC80900652013252LGN00	9-Sep-13	Cloudy, center parts are ok.
	LC80900652013268LGN00	25-Sep-13	reasonably cloud free
	LC80900652013300LGN00	27-Oct-13	reasonably cloud free
	LE70900652013292EDC00	19-Oct-13	L7! Only western part SLC error-free
	LC80900652013316LGN00	12-Nov-13	good
2013	**Scene ID**	**Date**	**Cloud coverage**
P89R65 (east)	LC80890652013229LGN00	17-Aug-13	Base image, least clouds
	LC80890652013213LGN00	1-Aug-13	Cloudy, eventually complementary
	LC80890652013165LGN00	14-Jun-13	Cloudy, small parts are ok.
	LC80890652013181LGN00	30-Jun-13	Cloudy, small parts are ok.
	LC80890652013197LGN00	16-Jul-13	Cloudy, small parts are ok.
	LC80890652013261LGN00	18-Sep-13	reasonably cloud free
	LC80890652013293LGN00	20-Oct-13	reasonably cloud free
	LC80890652013309LGN00	5-Nov-13	Cloudy, small parts are ok.