Report USAID

GIS&RS Component of USAID Food Security Project

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1 Introduction

This report provides a summary of activities, outputs and outcomes for all project activities carried out by the GIS&RS Unit of SPC-GSD. The report provides an overview, details can be read in special reports written throughout the project running time. Most outputs are not really visible for example digital map layers – the main output – can only be seen if they are printed or displayed with a GIS. The same applies to satellite image data – the main input to the work of the GIS&RS Unit – they are only visible in computer environment or when printed. They are essential for creating output but not being an output by itself.

2 Digital Land Cover Maps

Often "Land Cover Maps" are showing the actual land cover such as natural forest, plantation, grass land, etc. Such maps are also called "Land Use Maps" a term which avoided in this report as "Land Use" can the official or supposed utilisation of land documented on the title but not the actual "Land Cover".

2.1 Creation and Nature of Land Cover Maps

Still two decades ago land cover maps were produced by the Lands Departments as mapping required detailed knowledge of photogrammetry as the remote sensing source were aerial photographs with central projection which cannot be directly transferred to orthogonal projection. Special instruments (stereo plotter) are required. This has totally changed since satellite image data is available for 1:50,000 scale mapping and later for 1:10,000 scale mapping[1]. Mapping suddenly could be performed on a simple desktop computer with user friendly software. This allowed to utilise the technical knowledge of forest and agriculture specialists.

The project utilised officers from agriculture and forestry to delineate different land cover classes on the screen where the project developed different image backdrops allowing the interpreter to toggle between different image data of the same area. Different image data are different band combinations of the same image data set, normally (i) a natural band combination with the blue, green and red, (ii) false colour infra-red with green, red and near infra-red band and (iii) vegetation index layer. A vegetation index is based on an image ration where each image point of the near infra-red band is divided by the corresponding image point of the red band. This reduces shadow effects and increases the difference between vegetation types. These combination of image data available for the interpretation is far more than a black and white aerial photograph can provide.

The delineation of the interpreter created a vector layer showing polygons of the boundaries between the different vegetation types. The next step was the discussion and agreement between forest and agricultural officers of a common forest and agriculture boundary. Before the forestry departments and agriculture department created their own maps and the boundaries of forest and non forest land were overlapping. It was the first time for Fiji, Samoa, Solomon Islands[2] that both stakeholder were sitting together and created common boundary.

The next technical step was the conversion of the polygons to a raster layer where the project

1 Beginning of the eighties the first Landsat TM provided data for 1:50,000 scale thematic mapping and 2000 IKONOS data allowed 1:10,000 thematic mapping.

2 The low lying islands don't have a forestry department

developed different approaches. The raster layer then was cut into parts covering exactly a map sheet each. Raster data allow a fast counting and having the number of grid cells for each land cover class within a map sheet the area is known of each land cover is known for the map sheet. This was stored in a relational database.

The project created for every map sheet two products (i) an area statistic indicating how much hectare each land cover type is spread within one map sheet and (ii) a digital thematic map layer showing which parts are covered by which land vegetation or land cover type. Later the products were change for Fiji, 10 x 10 km tiles of each topographic map (40 x 30 km) were produced as digital map layer and statistic. In addition, the natural combination of the image data for each map tile were produced. Map and image data are available as PDF file small enough to display on mobile devices in the field.

2.2 Need and Utilisation of Land Cover Maps

In Fiji and Samoa it is the first time ever that a 1:10,000 land cover map was produced. Operational scale (1:10,000) is needed for: (I) every status analysis for questions how much forest is available within a logging concession or how much agricultural crop land is available in a sub-area such a mataqali; (ii) for every planning with questions where we can develop a crop, plantation, etc.

Agriculture and forestry in all countries wanted since 10 years such maps. It will be utilised in all field offices for planning and field operations. It will allow planning and monitoring of resources and contributes directly to food security.

2.3 Land Cover Map Solomon Islands 1:50,000

2.4 Land Cover Map Fiji 1:10,000

In Fiji the forest is mapped with satellite image data since 1991 and prior the start of the project for Vanua Levu and Viti Levu the first ever agriculture map was produced. However, the mapping was carried out at 1:50,000 scale, which is insufficient information for small area such as farms or forest units and for the outer islands.

Originally Fiji Forestry and Fiji Agriculture Department wanted financially contribute to the purchase of the 1:10,000 scale satellite image data. This was not necessary as other donors contributed to the purchase of image data in other countries e.g. JICA in Samoa. However, both departments contributed with their staff and conducted image delineation and with staff and vehicles to the field work. The image analysis was conducted at SPC-GSD only during the first year. Then both departments worked in their own offices but met every Friday at SPC-GSD to discuss and agree on a common forest agriculture boundary. Both departments have the full[3] set of digital maps and utilise the data for their operation, monitoring and planning. This makes the operation easier, allows a quantitative monitoring and increases the accuracy of planning. Forest and food production and forest protection contributes to food security. It is the first time that the land cover of the outer islands of Fiji is mapped with satellite data.

In Fiji the utilisation of 1:10,000 scale satellite image data stimulated Lands Department to change their policy and use satellite image data instead of aerial photographs. Lands Department will from

3 Forest and agriculture areas

2016 onwards distribute this image data to all Government departments and receives already from the project the lands cover map, statistic and enhanced image data cut to map tiles of 10 x 10 km.

2.5 Land Cover Map Samoa 1:10,000

JICA financed for Samoa a forest inventory where part of this inventory was a land cover mapping. Therefore JICA financed the image data purchase and the training of officers in Suva. They conducted under guidance of the project team the land cover mapping using WorldView-2 image data. Like in Fiji and Solomon Islands Forestry and Agriculture Department worked together and agreed on a common boundary.

2.6 Land Cover Choiseul, Solomon Islands 1:10,000

In addition to the 1:50,000 land cover mapping

2.7 Land Cover Map Espiritu Santo, Vanuatu 1:10,000

GIZ financed a carbon inventory for Espiritu Santo in Vanuatu including the land cover mapping, which was conducted by staff financed by GIZ.

2.8 Land Cover Map Kiribati 1:10,000

Already in 2003 the Agriculture Department in Kiribati contacted SOPAC to map the existing land cover in Kiribati. The Agriculture Department listed following reasons for this request: (i) the available amount of bread fruit and pandanas is unknown and the Department has to manage this resource as it is the main crop in case rice import stops, it is an essential part of food security; (ii) the coconut resource has to be monitored as it is the only income generation in outer islands required to keep people in outer islands and avoiding drift to overpopulated Tarawa; (iii) the monitoring of mangroves mirrors effects of global warming and sea level rise as mangroves are sensitive to change in water level or salinity; (iv) to attract any coconut utilisation projects the available resource has to be known.

The complete country of Kiribati was mapped at 1:10,000 scale where the mapping started already before the USAID project. The mapping was conducted by staff from the Agriculture Department in Kiribati and by one staff from Kiribati sitting at SPC-GSD. Following land cover classes have been delineated:

- Coconut dense > 150 palms / hectare
- Coconut semi dense > 50 and < 150 palms / hectare
- Coconut scattered > 25 and , 50 palms / hectare
- Mangroves
- Forest patches
- shrub
- grassland
- Settlement area (75 buffer around villages)

- Inland water bodies

The mapping is available as (i) report including area statistic and map display, (ii) as digital layer at SPC-GSD and at the Agriculture Department in Kiribati, (iii) as database available at SPC-GSD and at the Agriculture Department in Kiribati.

The digital layers and the statistic is utilised by Agriculture Department and will be included in the biannual report to UNCCC[4]. There is also information about the change of vegetation for 16 of Kiribati's islands. The available land cover layers initiated to see the change and the digital layer was superimposed over vegetation maps created 1972 from aerial photographs recorded 1969. In nearly all cases mangrove and coconut area is growing not shrinking during the last 40 years.

All reports are available on SPC website.

3 Coconut Resource Mapping

For Pacific Island Countries the coconut palm is the "tree of life". This especially true for all low lying or atoll islands. There is often no other income in outer islands in the Pacific and to avoid the drift to urban centres the resource coconut has to produce again. If there is any development to reactivate the neglected resource the current situation must be known. It is important to have a picture of (i) the area which is stocked with coconut palms, (ii) the stocking density, (iii) the age structure and fertility, (iv) the amount of hybrids and (v) the standing timber volume. These main parameters are essential to monitor the resources and to plan any development or utilisation.

3.1 Coconut Resource Mapping in Kiribati

In addition to the land cover mapping of all islands in Kiribati the stocking was accessed through satellite image data. The coconut area was stratified into: (i) dense coconut palm stocking if more than 150 palms per hectare were counted, (ii) semi dense if the stocking was between 50 and 150 palms per hectare and (iii) scattered palm cover if there were between 25 and 50 palms visible. All results are published in reports and can be downloaded from the SPC website.

3.2 Coconut Resource Mapping in Abaiang, Kiribati

In addition to the mapping and palm counting with satellite image data field work was conducted in Abaiang and all parameters explained in the introduction paragraph were calculated.

Results

3.3 Coconut Resource Mapping in Vava'u, Tonga

The islands of the Vava'u Group in Tonga were mapped as described above and the coconut area was stratified into the three densities like in Kiribati. The corresponding report provides a clear picture about the fertility and age structure which is linked as overaged stands have low production. The figures provided show that the regeneration and younger age classes are very low which will result in decreasing production within the next decade. This might be typical for other islands as well as there are no coconut rehabilitation programs since the early eighties. The report

4 The statistic was not included in the official report to UNCCC in 2014.

also documents that there is a high amount of dead coconut trunks in the field which will the breeding place for the cancerous beetle, which when overpopulation is created further reduces the coconut fertility.

During the coconut resource inventory in Tonga a coconut form factor was established and the age estimation was further developed. This is more detailed in the development chapter. In addition, in Tonga it was possible to compare the density estimation with satellite image data with the field reality as high resolution GPS equipment allowed to visit exactly the same areas.

It is too early to see the project outcomes, however, it is expected that the results will lead to activities as the Tongan Conservator of forest responsible for the coconut resource monitoring and development was directly involved in the inventory field activities.

4 Method Development

During the running time of the project a number of methods had to be developed to enhance image data or collect information.

4.1 Vegetation Stratification in Settlement Areas

More than 10 years ago the Agriculture Department in Kiribati asked – at this time SOPAC – if it would be possible to map the still available bread fruit resources. The reason is that in situations where the rice import is limited this resource has to be re-activated. It was not possible to map the resource exactly, the available remote sensing data only allowed to map shrub within settlement areas. Beside breadfruit this stratum still can contain (i) pandanas, (ii) other trees and (iii) shrub vegetation.

WorldView-2 satellite image data have a new spectral channel "red-edge". Applying this spectral band in image backdrops or for semi automatic analysis the separation of breadfruit is possible. The investigation was carried out with USAID funding and presented at the Pacific Island GIS&RS User Conference. A paper will be published at USP.

4.2 Establishing Coconut Palm Form Factor

The chapter "Land Cover Map Kiribati 1:10,000" explains the need to have a clear picture of the available coconut resource. It also explains that it is necessary to know how much timber the palm trunks contain. The form factor is a figure allowing a calculation of trunk timber volume by measuring the diameter at breast hight and the height of the palm trunk. The form factor reduces the volume from a cylinder calculated from diameter and height to the volume of a truncated cone, which is the real form.

To establish this reduction factor for 62 palm trunks the diameter was measured every metre. The work is shortly described in the inventory report for the coconut resource assessment in Vava'u. A more detailed description of the form factor establishment will follow.

The calculation of palm trunk time volume was performed with average values before as there was no special "coconut palm form factor" available. The special form factor allows to calculate the timber volume more precise. The volume has to be calculated as the trunks have to be removed from the area as the trunks are breeding ground for the rhinoceros beetle which reduces the coconut production. The removal has to be planned and for the planning the exact amount of volume is essential.

4.3 Adjustment of Palm Age Estimation

The age of the coconut palm is one important factor of fertility. After 40 years of age the production declines. If coconut production is managed the average age of a stand must be known as exact as possible.

Normally the age is estimated by the number of leave scars of a trunk assuming that 11 leave scars indicate one year of age. As it is difficult to climb up the trunk and count all leave scars the length of 11 leave scars from 1.5 metres upwards is measured and the total length of the stem is divided by this length. This assumes that the density of leave scars per length is the same all over the trunk. However, this is not the case. On the upper part of the trunk the leave scars are more dense than on the bottom part.

For 62 trunks the number of leave scars were measured every metre for the complete trunk. A correction factor was established which takes the increasing density of leave scares into account. Like for the form factor, the work is shortly described in the inventory report for the coconut resource assessment in Vava'u. A more detailed description of the age adjustment will follow.

4.4 Digital Surface Model Creation Sabeto, Fiji 1:10,000

One of the selected project pilot sites was Sabeto in the low lying western part of Viti Levu. This area was flooded just before the project started and farmers lost income. The project wanted to advise on alternative planting areas and discussed how to establish a digital surface model (DSM) at 1:10,000 scale. Such a DSM would allow (i) to predict the flooding area which is related to hight above mean sea level, (ii) provide exposure and slope information which help to identify alternative farming areas and (iii) enable the project to draw a water catchment map at 1:10,000 scale level. The most economic way was the DSM establishment from stereo satellite image data, something which was not performed at SPC before.

The project purchased corresponding software (Hexagon) and stereo satellite image data (WorldView-1). One staff had to work herself into the software there was very little help from ERDAS the Hexagon incorporated company. The software was handled and the DSM created. The establishment of ground control points (GCP) visible in the image data and surveyed on the ground. The company argued that 5 GCP are sufficient, however, it proved that about the double was necessary to create the acceptable accuracy for this large area with rugged terrain.

The DSM was delivered to the land use planning specialists which overlaid farm boundaries for subsequent analysis and planning. A by-product was the 3D view created by overlaying multi-spectral image data which shows a virtual landscape. This product was used in the planning workshops with the farmers and increased the understanding of shifting farming areas to alternative spots.

The capacity building within SPC enabled to produce additional DSM for other projects which also support food security. FAO established forest parks where the DSM will assist the projects to demarcate proposed forest reserves, monitor encroachment and observe land cover around the protected area boundaries. Farming areas will not move into forest parks as villagers visualised on the 3D images and agreed to stay outside the boundaries.

4.5 Image Pre-Processing for Pacific Islands

Image data arrives as raw data. The images are in tiles and not stitched together and every band often has an own file. These different files have to be stitched together and merged to homogeneous image layers. At the beginning of the USAID funded project the image data pre-processing was limited to image this process and object specific contrast enhancement. However, it was visible that especially for volcanic island countries such as Fiji, Solomon Islands and Vanuatu atmospheric correction was essential. In difference to the rest of the world cloud and haze building starts with few metres of elevation.

Atmospheric correction software was purchased, however, it was only possible to apply the technology to multi-spectral[5] image data and the countries required pan-sharpened[6] image data to utilise the high spatial resolution. Pan-sharpened data cannot be atmospherically corrected. To overcome this problem the project discussed the issue with the data seller DigitalGlobe and the company supplied the colour channels and black and white channel separately and the GIS&RS unit performed the pan-sharpening process. This enabled to carry out the atmospheric correction before the image data was pan-sharpened. After going through a learning curve the process worked very well and the unit produced enhanced image data nowhere else available at that point in time. DigitalGlobe granted for this approach the world wide recognised "Innovation Award" of the company to the GIS&RS unit of SPC-GSD.

Through this the USAID funds have long term impact to the region.

4.6 Data Storage and Data Monitoring

There have been several initiatives before to secure spatial and tabular data which did not work to full satisfaction. Also Fiji as country with early GIS and RS application has tried since beginning of the nineties to do inventories of available spatial data which resulted in "data catalogues". After a while the data catalogues were not updated as the management level did not see the need. In addition, Government departments were forced to charge for data provided to other Government departments where it sometimes were more cost and time effective to create the data again instead of getting the available data. The consequence was that clear data structure and storage was neglected. Subsequently very important data sets were lost. There are several reasons for data loss:

- ***Storage on unsuitable media***, image data were stored on CCT[7] or floppy disks which had very limited resistance to tropical environment, even CDs store data only for limited time without dry and temperate environment;
- ***Computer crash without available backup*** was most probably the most frequently data loss in Pacific GIS&RS applications in the last decade;
- Most probably the next frequent source of data loss is the ***overwriting of new versions by old versions*** due to missing data inventory and data structure. GIS operators often trying to safe their work frequently with the result that several copies with the same file name are located in different directories and storage devices and after a short time it is unclear which

5 Multi-spectral images = colour images

6 Pan-sharpened image data = images where the high resolution black and white channel is merged with the low resolution colour channels resulting in a high resolution colour image.

7 CCT = Computer Compatible Tape

is the latest version.

- Data deletion due to ***incompetent data management*** typically happens when people move to a new position and somebody else operates the computer. If there is no computer cleaning with a data manager before handover and proper backup this data is lost;
- Data loss due to ***change of data format*** is another reason that data gets missing. There are ways to read historical data formats, however, in many cases no action is taken.

To avoid missing data through the listed sources of data loss two tasks have to be carried out: (i) The data has to be clearly structured before backup is performed and (ii) data inventories have to be executed in regular intervals. Both is new for GIS&RS units in Pacific Islands.

The GIS&RS Unit of SPC-GSD holds spatial data and reports for several countries out of a number of reasons: (i) all image data is purchased through the GIS and Remote Sensing Unit at SPC-GSD and the unit has to keep a copy of the original and the pre-processed data to be able to re-import to the countries in case data is lost; (ii) for several countries most special data is produced at SPC-GSD and the Regional Monitoring System automatically keeps a copy, which is the case for Solomon Islands, Tuvalu, Kiribati, Fiji, FSM and Tonga; (iii) some countries keep a structured data set as backup such as Solomon Islands, Tuvalu and Kiribati;

The data is and will be stored in three different media: (i) on external hard drives in the office; (ii) on a server in the SPC-GSD complex; (iii) there will be an additional server for data backup in the Lotus building in the SPC-ICT section in Suva; (iv) the server in the Lotus building has a backup in the cloud.

The external hard drives keep the master dataset with the advantage that they are always accessible independent from the network. Each country will have a hard drive of 2 to 4 terabyte, which is movable but normally securely stored.

The activity is of data structuring and data backup storage is not completed under the USAID funded project, however, it fits into tasks financed by other projects and will not finish by end of the project.

5 Training Activities

The listed training activities are output of a database storing all training courses and on-the-job training tasks of the GIS&RS Unit of SPC-GSD. The database also contains all persons who have received training where the training course ID is the key to select the participants. The country indicates the origin of the most participants. Details are shown in the table containing all trained persons.

5.1 Training Activities in 2012

5.1.1 Land Cover Mapping FJ 1:50,000

Training Course ID: SPC-LANDCOV-2012-01
Start date: 02/01/12, ***End date:*** 21/12/12

Country: Fiji
City: Suva

Number of participants: 3
Comments: Long term hands-On-Training

a) Satellite IMG rectification
b) Image enhancement
c) GIS Backdrop production
d) Image interpretation and delination

5.1.2 Geometric Correction

Training Course ID: LRD-TV-IMGCOR-2012
Start date: 13/03/12, **End date:** 20/03/12
Country: Tuvalu
City: Funafuti
Number of participants: 5
Comments: Aerial photographs needed to be rectified and one GIS-Officer of Tonga Lands Department was trained on-the-job.

(i) Theoretical background, II re-sampling methods demonstrated
(ii) Linear rectification
(iii)Polynomial 2nd degree
(iv)Rubber sheet rectification

a) Image data purchase
b) Image pre-processing

(i) ortho correction, (ii) mosaicing, (iii) convert 16 bit to 8 bit, (iv) haze removal, (v) atmospheric correction, (vi) img pan- sharpening

c) GIS backdrop production

5.1.3 Introduction Database for Forestry

Training Course ID: SPC-DB-RE
Start date: 21/06/12, **End date:** 22/06/12
Country: Fiji
City: Nadi
Number of participants: Most participants of the regional workshop for forest carbon assessment & monitoring

5.1.4 Introducing Image Pre-Processing to Lands Department

Training Course ID: SPC-LANDS-IMGPPROC-01
Start date: 19/09/12, ***End date:*** 19/09/12
Country: Fiji
City: Suva
Number of participants: 1

Comments: Special Training:

a) Ortho-Correction
b) IMG Mosaicing
c) Haze Removal
d) Atmospheric Correction
e) Pan-Sharpening
f) backdrop Production

5.1.5 Radar Processing and Analysis

Training Course ID: GIZ-RADAR-2012
Start date: 16/10/12 ***End date:*** 19/10/12
Country: Fiji

City: Suva

Number of participants: 3

Comments: The training was delivered by GIZ financed consultant for staff of the GIS&RS Unit, but three persons from Lands Department participated.

a) Radar Theoretical Background
b) Radar Processing
c) Radar Analysis

5.1.6 Land Cover Mapping Solomon Islands with THEOS Image Data

Training Course ID: GIZ-USAID-LANDCOV-SB
Start date: 25/10/12 ***End date:*** 22/12/12

Country: Fiji

Number of participants: 4

Comments:

1) IMG Rectification

2) IMG Enhancement
3) Backdrop Production

4) Image Analysis, Image Delineation

5.1.7 Land Cover Mapping 1:50,000 Solomon Islands

Training Course ID: UNDP-LANDCOV-SB

Start date: 04/11/12, ***End date:*** 11/12/12

Country: Solomon Islands

City: Suva

Number of participants: 5

Comments:

1) IMG Rectification
2) IMG Enhancement
3) Backdrop Production

4) Image Analysis, Image Delineation

5.1.8 Geometric Rectification of Ariel Photographs for Tonga

Training Course ID: IMGREC-TO-2012
Start date: 03/12/12, ***End date:*** 07/12/12

Country: Tonga

City: Suva

Number of participants: 1

Comments: Aerial photographs needed to be rectified and one GIS-Officer of Tonga Lands Department was trained on-the-job.

(i) Theoretical background
(ii) Linear rectification
(iii)Polynomial 2nd degree
(iv)Rubber sheet rectification

(v) All resampling methods demonstrated

5.2 Training Activities in 2013

5.2.1 IMG Analysis Land Cover Mapping 1:10,000

Training Course ID: IMG-LANDCOV-2013-01

Start date: 07/01/13, **End date:** 21/12/13

Country: Fiji

City: Suva

Number of participants: 3

Comments: Training on-the-job

1) Image pre-processing, image enhancement;
2) Image interpretation and delineation
3) Image segmentation

5.2.2 Trimble and Garmin GPS Training

Training Course ID: SPC-FJ-GPS-INTRO-2013

Start date: 23/01/13, **End date:** 25/01/13

Country: Fiji

City: Suva

Number of participants: 14

Comments: VT and NJ conducted the training:

a) Theory Diff. GPS

b) GPS preparation and data capture

c) Download to GIS

d) Hotlink utility in MapInfo

Report file name: 25_26February2013GPS TRAINING(2)

Start date: 01/03/15, **End date:** 01/12/15

Country: Fiji

City: Suva

Number of participants: 1

Comments:

- Satellite Imagery Rectification
- Image Enhancement
- Landcover classification and stratification
- Object Based Classification

5.4.3 Landcover Mapping 1:10,000

Training Course ID:

Start date: 01/06/15, **End date:** 24/07/15

Country: Fiji

City: Suva

Number of participants: 1

Comments:

- Landcover classification and stratification
- Object based classification

5.4.4 Image Segmentation and classification Training

Training Course ID:

Start date: 26/05/15, **End date:** 08/06/15

Country: Tonga

City: Suva

Number of participants: 2

Comments:

- Satellite Imagery Rectification
- Image Enhancement
- Landcover classification and stratification
- Object Based Classification

5.4.5 Image Segmentation and classification training

Training Course ID:

Start date: 26/05/15, **End date:** 17/07/15

Country: Solomon Islands

City: Suva

Number of participants: 2

Comments:

- Satellite Imagery Rectification
- Image Enhancement
- Landcover classification and stratification
- Object Based Classification

5.5.6 Image Segmentation and classification Training

Training Course ID:

Start date: 01/06/15, **End date:** 24/07/15

Country: Vanuatu

City: Suva

Number of participants: 2

Comments:

- Satellite Imagery Rectification
- Image Enhancement
- Landcover classification and stratification
- Object Based Classification