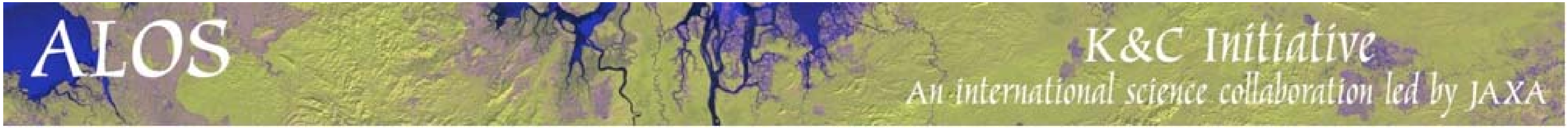


K&C Phase 3 – Brief project essentials

Climate-Relevant Modernization of the National Forest Policy and Piloting of REDD+ Measures in the Philippines

Mari Trix L. Estomata [1], Jose Don T. De Alban [2], Angelica Kristina V. Monzon [2], Enrico C. Paringit [3] and Francisco B. Tavora, Jr. [1]

[1] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ PH)
[2] Fauna & Flora International (FFI)
[3] Department of Geodetic Engineering, University of the Philippines (UP-DGE)

Science Team meeting #21 – Phase 3 Result Presentations
Kyoto Research Park, Kyoto, Japan, December 3-4, 2014

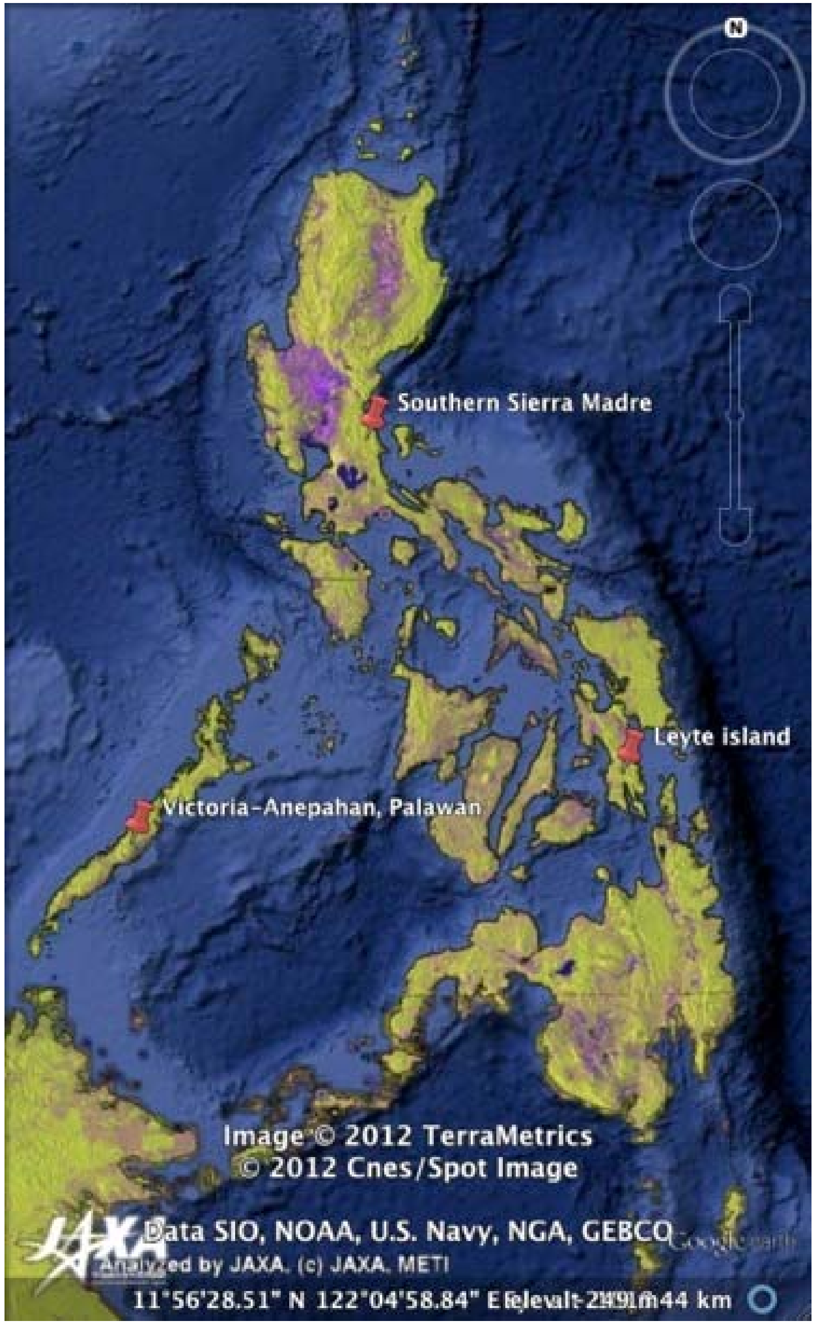
K&C Project Collaborators and Partners

Project Collaborators

1. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
2. Fauna & Flora International (FFI)
3. Department of Geodetic Engineering, University of the Philippines (UP-DGE)

Partners & Supporting Organisations

1. Non-Timber Forest Products – Task Force / Exchange Programme
2. TEaM Energy Foundation in the Philippines (supported by Tokyo Electric Company & Marubeni)
3. European Commission
4. International Union for the Conservation of Nature – Ecosystem Alliance
5. Department of Environment and Natural Resources: Forest Management Bureau & National Mapping and Resource Information Authority



Project areas: Philippines

<u>Sub-national REDD+ Pilot Sites</u>

1. Southern Sierra Madre mountain range (General Nakar)
2. Leyte island
3. Victoria-Anepahan mountain range, Palawan island

Project objectives

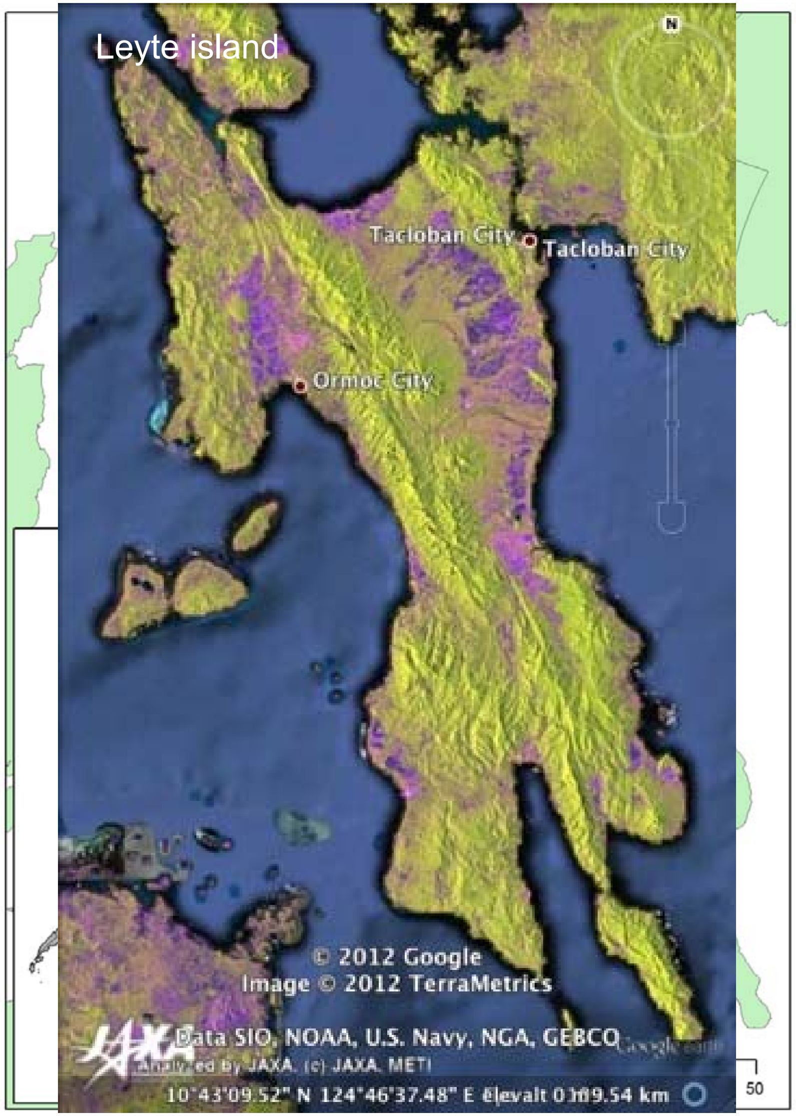
For each of the three identified REDD+ pilot sites, the project aims to:

1. Establish baseline forest carbon stocks
2. Pilot forest carbon inventory and monitoring methods in support of validating ALOS PALSAR imageries
3. Determine reference deforestation rate

Deliverables

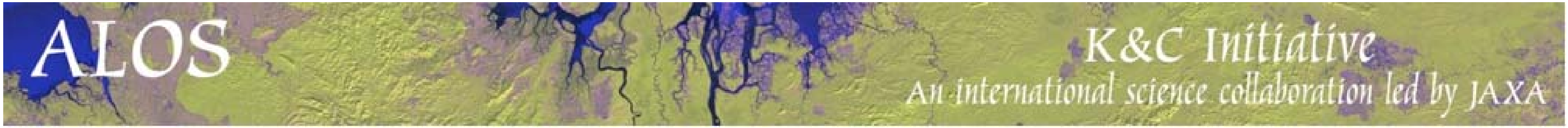
<table>
<tr><th></th><th>LEYTE</th><th>PALAWAN</th><th>GENERAL NAKAR</th></tr>
<tr><td>1. Forest cover and change maps produced</td><td>Completed</td><td>Completed</td><td rowspan="4">Not completed since permits to conduct fieldwork were not secured.

Additional reports using ALOS/PALSAR data in other sites (Cebu, Leyte) were submitted instead.</td></tr>
<tr><td>2. Deforestation rates determined</td><td>Completed</td><td>Completed</td></tr>
<tr><td>3. Baseline forest carbon stocks established</td><td>Completed</td><td>Completed</td></tr>
<tr><td>4. Image processing methodologies and accuracy assessments documented</td><td>Completed</td><td>Completed</td></tr>
</table>

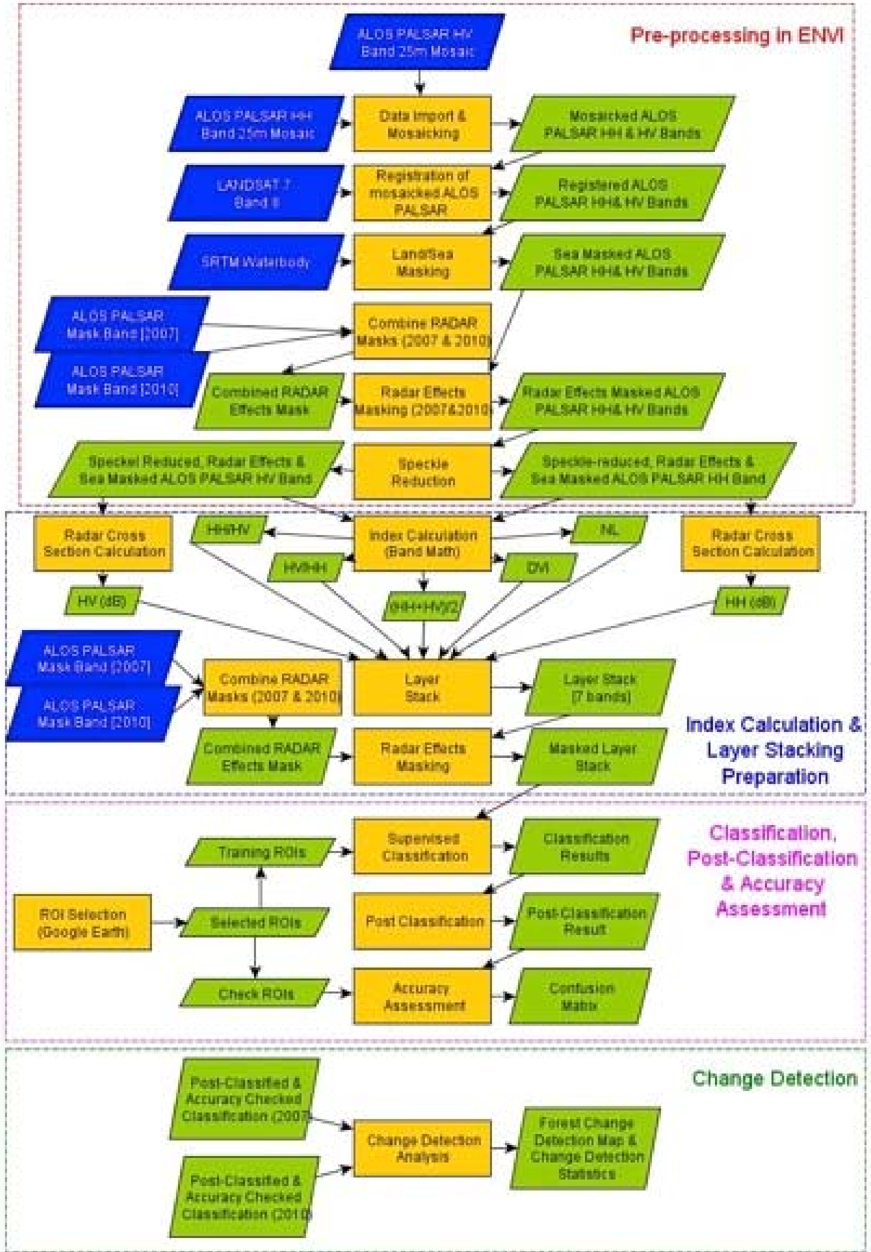


Final Report

LEYTE ISLAND

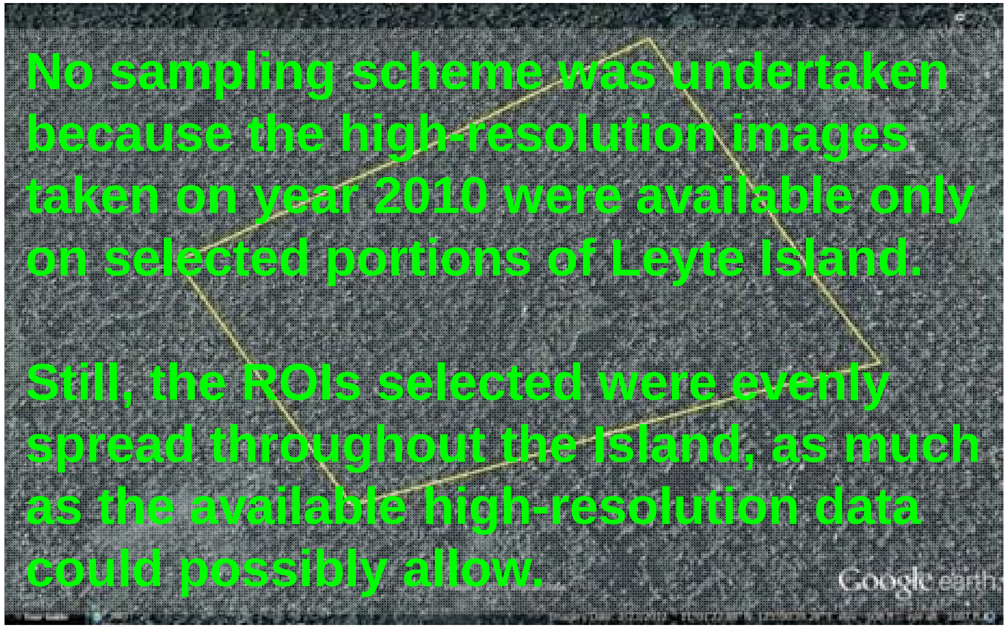


RS Workflow of Methodology:

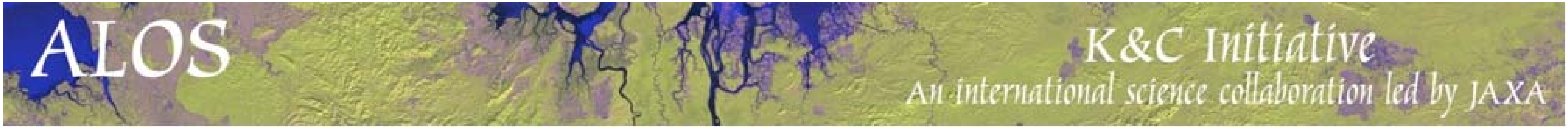


Methodology: Bands & ROIs

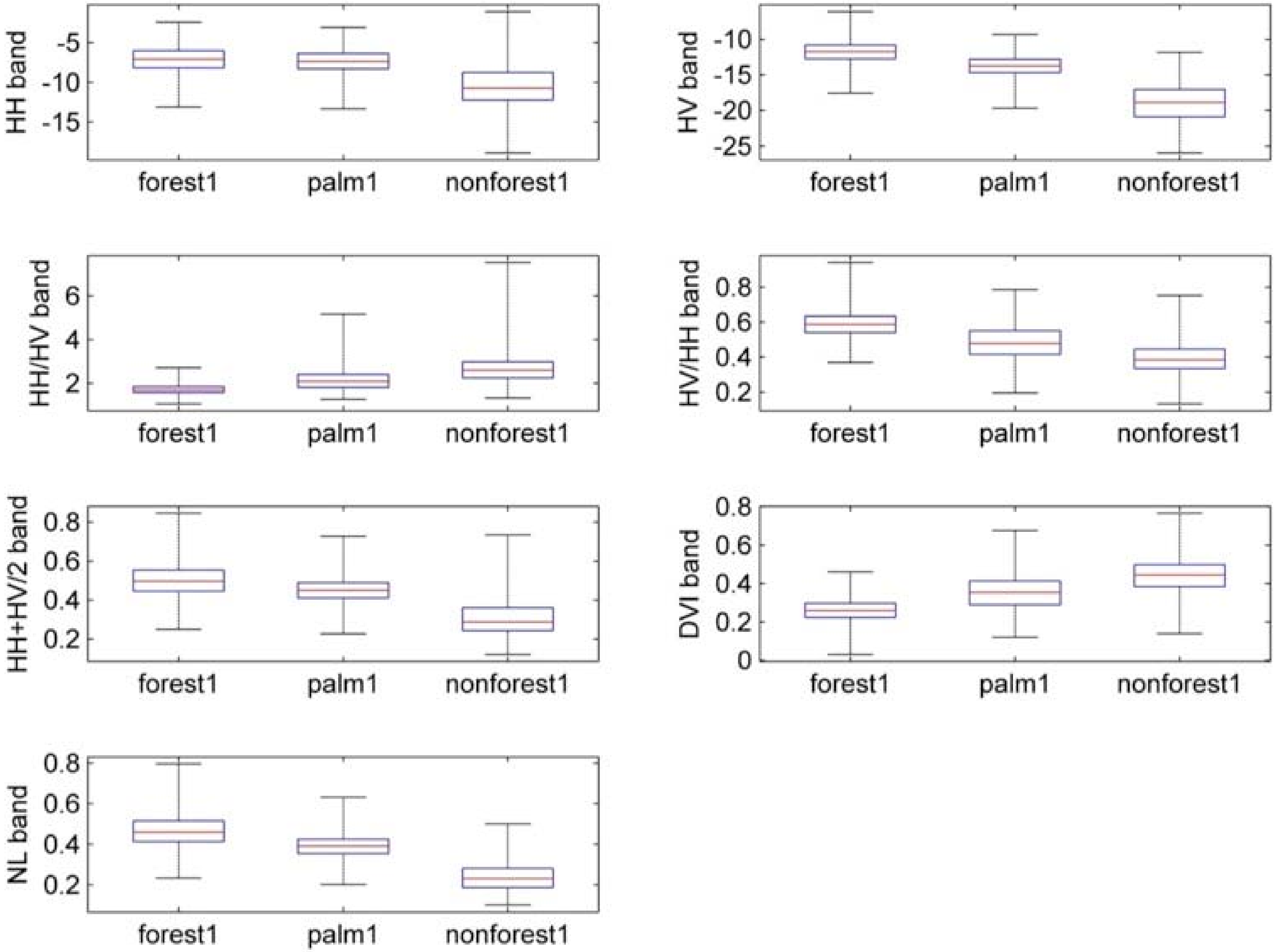
- 7-Layer Stack:
  - Radar Cross-section Values of:
    - HH Band → HH_dB
    - HV Band → HV_dB
  - Indices:
    - $\frac{HH}{HV}$
    - $\frac{HV}{HH}$
    - $HH \cdot HV_{ave} = \frac{HH+HV}{2}$
    - $NL = \frac{HH*HV}{HH+HV}$
    - $NDI = \frac{[HH-HV]}{[HH+HV]}$, Normalized Difference Index



- 40 samples/polygons per ROI
- At least 4 hectares for each polygon
- 20 polygons used to train the classifiers; 20 polygons used for accuracy assessment – selected using Random Generator Code (Excel)



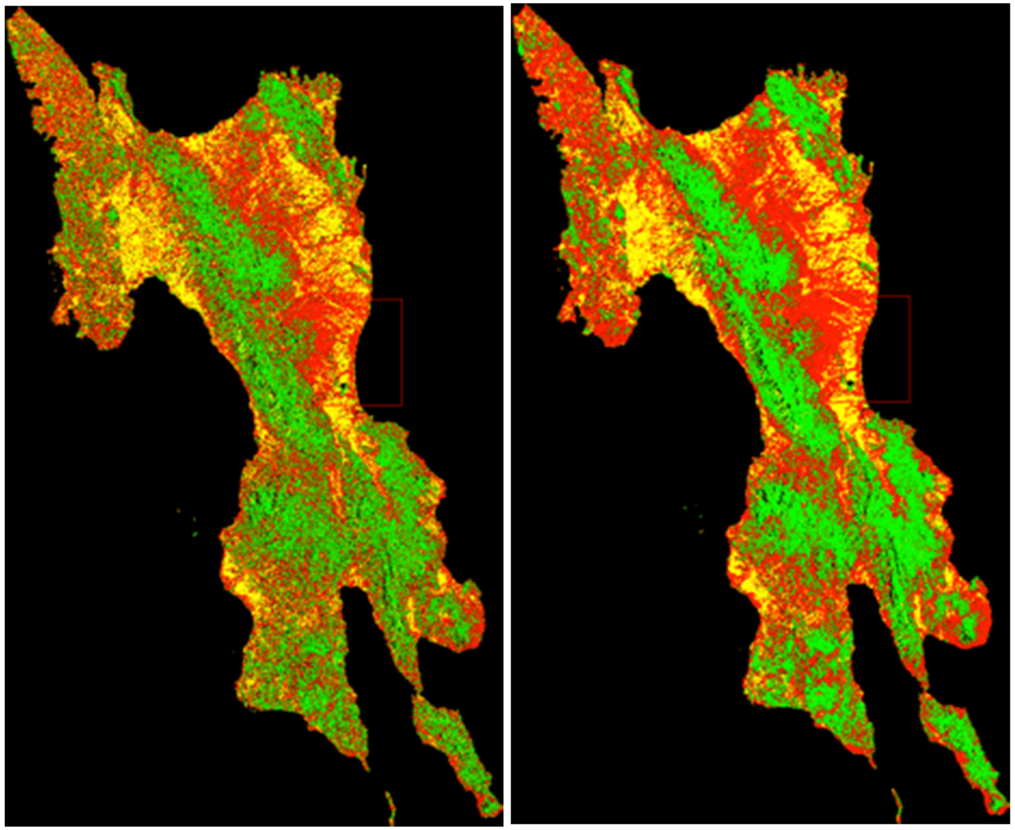
ROI Separability



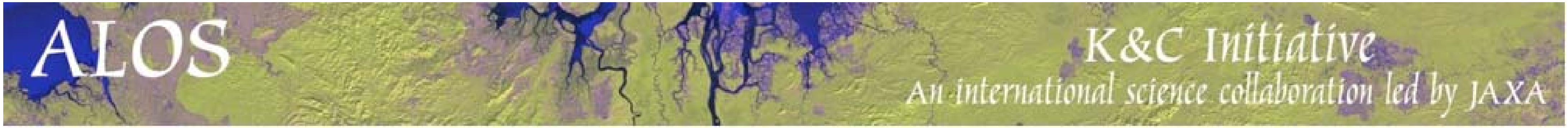
Methodology: Classification & Post-Classification

- Classification:
  - Maximum Likelihood Classification (MLC)
  - Support Vector Machine (SVM)
  - Neural Network Classification (NNC)

- Post-Classification:
  - Majority analysis (5x5 kernel)
  - Clumping of classes (default setting)



Black – mask Green – Forest Red – Coconut
Yellow – Agriculture/Non-Forest



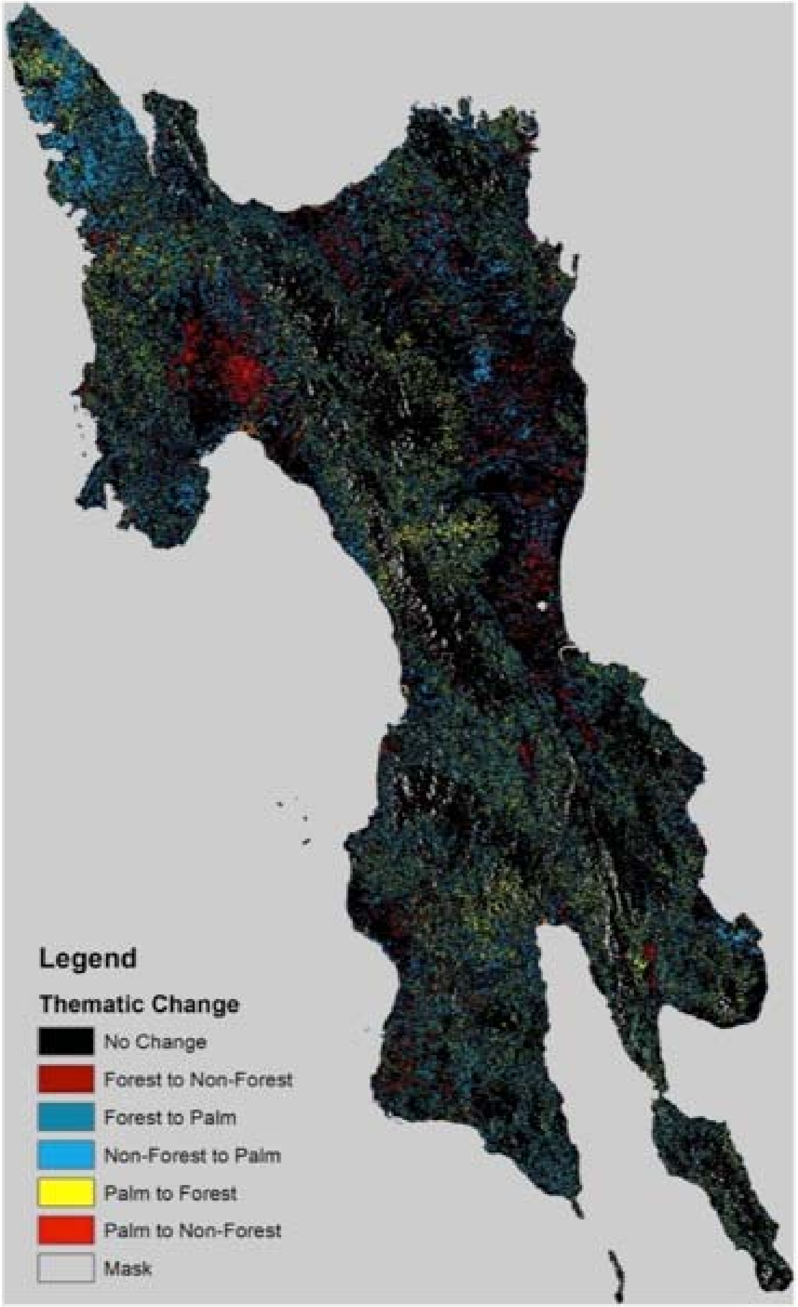
Results & Discussions: Accuracy

Complete error matrix for the post-classified neural network classification results for the 2010 radar image					
Class	Forest [%]	Non-Forest [%]	Palm [%]	Total [%]	User's Accuracy [%]
Unclassified	0.69	0.84	0.31	0.62	
Forest	90.98	0.00	10.71	33.96	89.60
Non-Forest	3.62	89.32	0.94	31.51	95.17
Palm	4.70	9.83	88.04	33.91	85.63
Error of Omission	9.02	10.68	11.96	Overall Accuracy	89.4533
Error of Commission	10.40	4.83	14.37	Kappa Coefficient	0.8423

All **Producer's Accuracies** and **User's Accuracies** reach at least 85% and the errors of commission and omission are at a maximum of 15%. This is the reason why the NNC was the chosen classifier for the 2007 radar image.

Complete error matrix for the post-classified neural network classification results for the 2007 radar image					
Class	Forest [%]	Non-Forest [%]	Palm [%]	Total [%]	User's Accuracy [%]
Unclassified	0.69	1.15	10.16	3.97	
Forest	91.83	0.54	9.23	33.94	90.50
NF	4.01	87.17	7.90	33.21	88.12
Palm	3.47	11.14	72.71	28.88	83.04
Error of Omission	8.17	12.83	27.29	Overall Accuracy	83.9608
Error of Commission	9.50	11.88	16.96	Kappa Coefficient	0.7640

Lowered accuracies could be due to the fact that the ROIs used to classify the 2007 radar image and ROIs used to check its results were selected during the year 2010 because high resolution images for year 2007 were very limited in Google Earth.



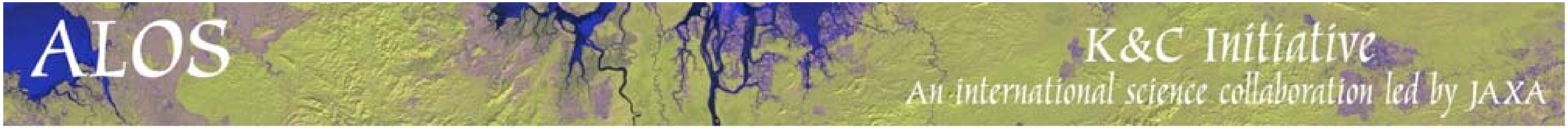
Results & Discussions: Accuracy

Thematic Change Detection Statistics		
Change	Area (ha)	Percentage
Non-Forest to Forest	2,678.19	0.38
Non-Forest to Palm	41,656.50	5.88
Forest to Non-Forest	3,251.25	0.46
Forest to Palm	59,091.38	8.34
Palm to Non-Forest	16,272.56	2.30
Palm to Forest	33,094.88	4.67

Doubtful change: 33,000 ha of palm areas changed back to forest in 3 years' time:

- might be due to the misclassification of palm areas in the 2007 forest cover map, as indicated by the low PA (72.71%) and high errors of commission (16.96%) and omission (27.29%).
- Misclassifications could be due to the fact that the ROIs used to generate the said map were of year 2010.

Thus, in order to get a better change detection analysis/result, better classification would be required for year 2007.



Accuracy of Change Detection Map

To further strengthen the study, quantifying the accuracy of the change detection maps would be recommended. It would require the ff.:

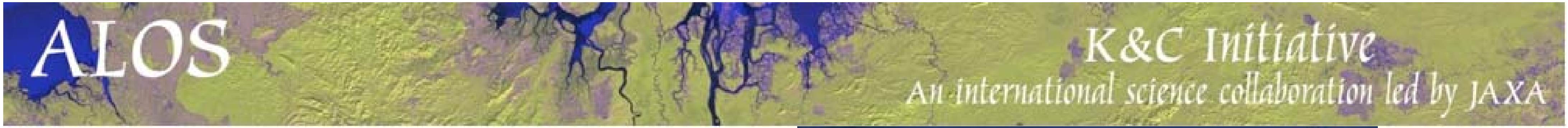
- ➢ Valid reference data for year 2007 (Congalton & Green, 2006) such as high resolution optical images , which can easily depict palms from forest.
- ➢ Problem: High resolution images for 2007 are rarely available on Google Earth.

Conclusion

- ❖ With an overall accuracy of 89.45% for the 2010 forest cover map (κ =0.84) and 83.96% (κ=0.76) for the 2007, it can be concluded that the classification was able to achieve a result that is fairly consistent with reality.
- ❖ Unfortunately, no change detection accuracy assessment was conducted but based on Stow (1980), since the accuracies of the individual classification results are quite good, it may also be concluded that the change detection map achieved from these individual classification results may also have good accuracy.

Recommendations

- ❖ To achieve better classification results and accuracies for the 2007 radar image, ROIs used to classify it should be of the same year and not of year 2010.
- ❖ It is challenging to acquire high resolution images, which are rarely available in Google Earth. However, if they are available, these can be used to further improve the classification maps and verify and quantify the accuracy of the change detection maps.
- ❖ EnviSAT and other available data may be used to support future analysis of ALOS PALSAR data and to further improve results of this research.



Final Report

VICTORIA-ANEPAHAN MOUNTAIN RANGE, PALAWAN

ALOS

K&C Initiative
An international science collaboration led by JAXA

Project Site

Field data collected

<u>FNF ground truth data</u>

May & Aug 2011

409 training points

119 validation points

+ supplemental GE points

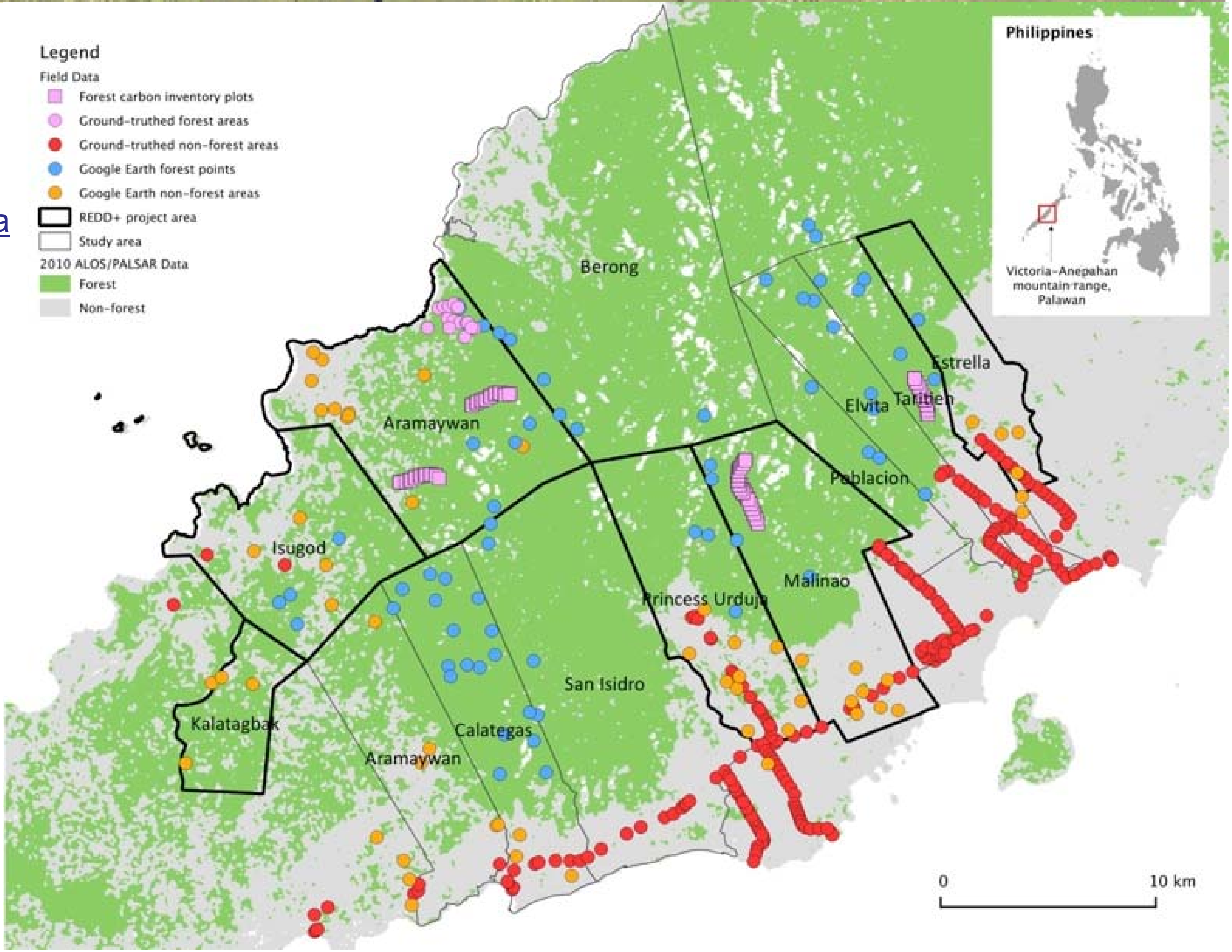
<u>Transect/plot data</u>

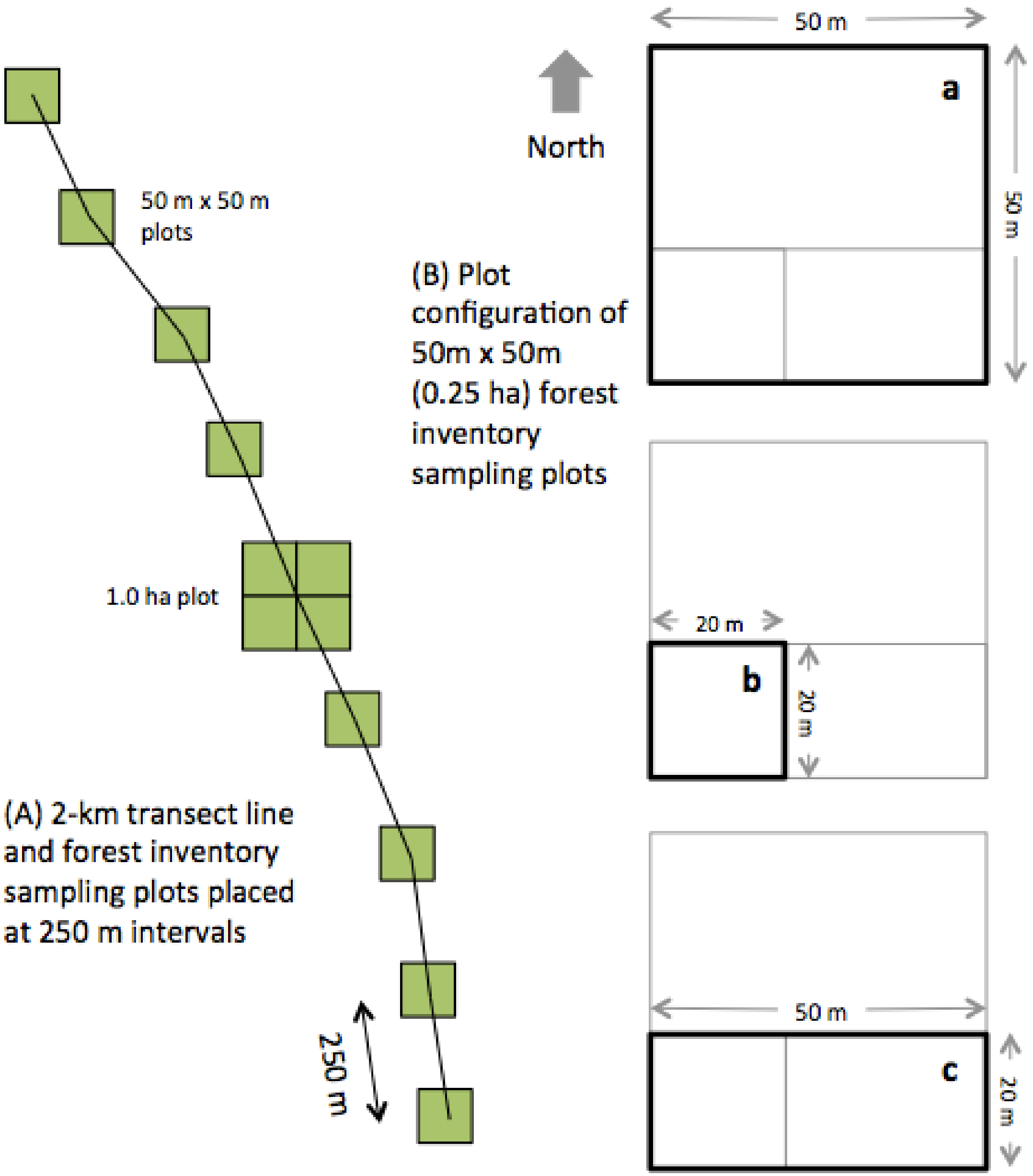
Jun to Aug 2013

5 biodiversity transects

5 1.0 ha plots

45 0.25 ha plots





Transect & Plot Design

A. Integrated biodiversity transect and forest plot design showing position of 1.0 ha and 0.25 ha square plots along 2 km transect line. All plots are north orientated.

B. Nested plots within 0.25 ha plots at:

  (a) 50m x 50m: Trees ≥ 30cm DBH

  (b) 20m x 20m: Trees 10 to 30cm DBH

  (c) 20m x 50m: Trees ≥ 10cm DBH *

C. 1.0 ha plots measured trees ≥ 5cm DBH

D. Parameters: tree species name, tree diameter, dead wood

E. Location of transects established based on pre-stratification

- Intended to fit and contribute to the National Forest Inventory plots

Methodology

A. ALOS/PALSAR Data Processing
- ALOS/PALSAR mosaic data (2007 and 2010)
- Geometric and radiometric correction; geocoding and re-projection; speckle filtering; normalization; image ratio; masking
- FNF classification (SVM); accuracy assessment; change detection

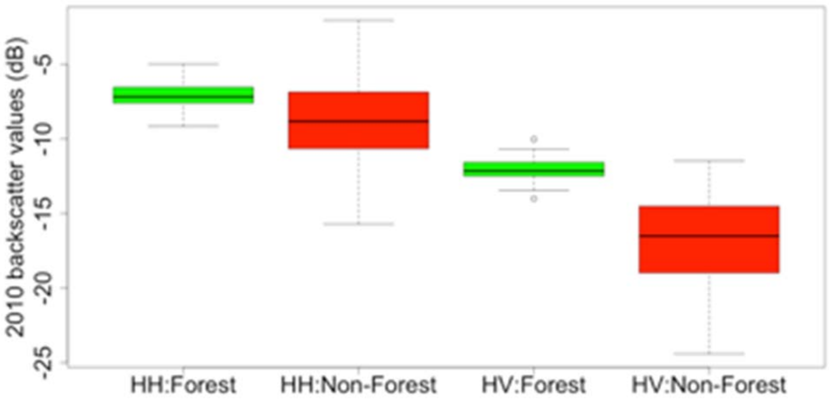
B. Carbon Stock Assessment using Forest Inventory Plots
- Aboveground biomass estimation using Brown's allometric equation for moist forestlands (Brown 1997)
- Carbon stock computation

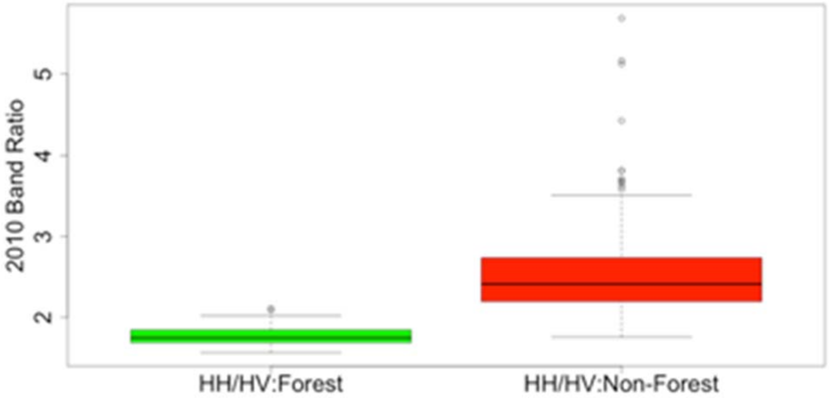
C. Estimation of Aboveground Biomass from Radar Backscatter
- Regression modeling between AGB and radar backscatter using two groups of plot sizes: (1) nested 1.0 ha and 0.25 ha plots (DBH ≥ 5cm); and (2) nested 0.25 ha and 0.10 ha plots (DBH ≥ 10cm); uncertainty assessment
- To enhance AGB and radar backscatter relationships beyond saturation levels, we used:(1) HH/HV image ratio to reduce topographic bias and forest structural effects (Foody et al. 1997); and (2) GLCM contrast texture measure derived from HV polarisation (Sarker et al 2012)

ALOS

K&C Initiative
An international science collaboration led by JAXA

ROI Separability and Accuracy Assessment





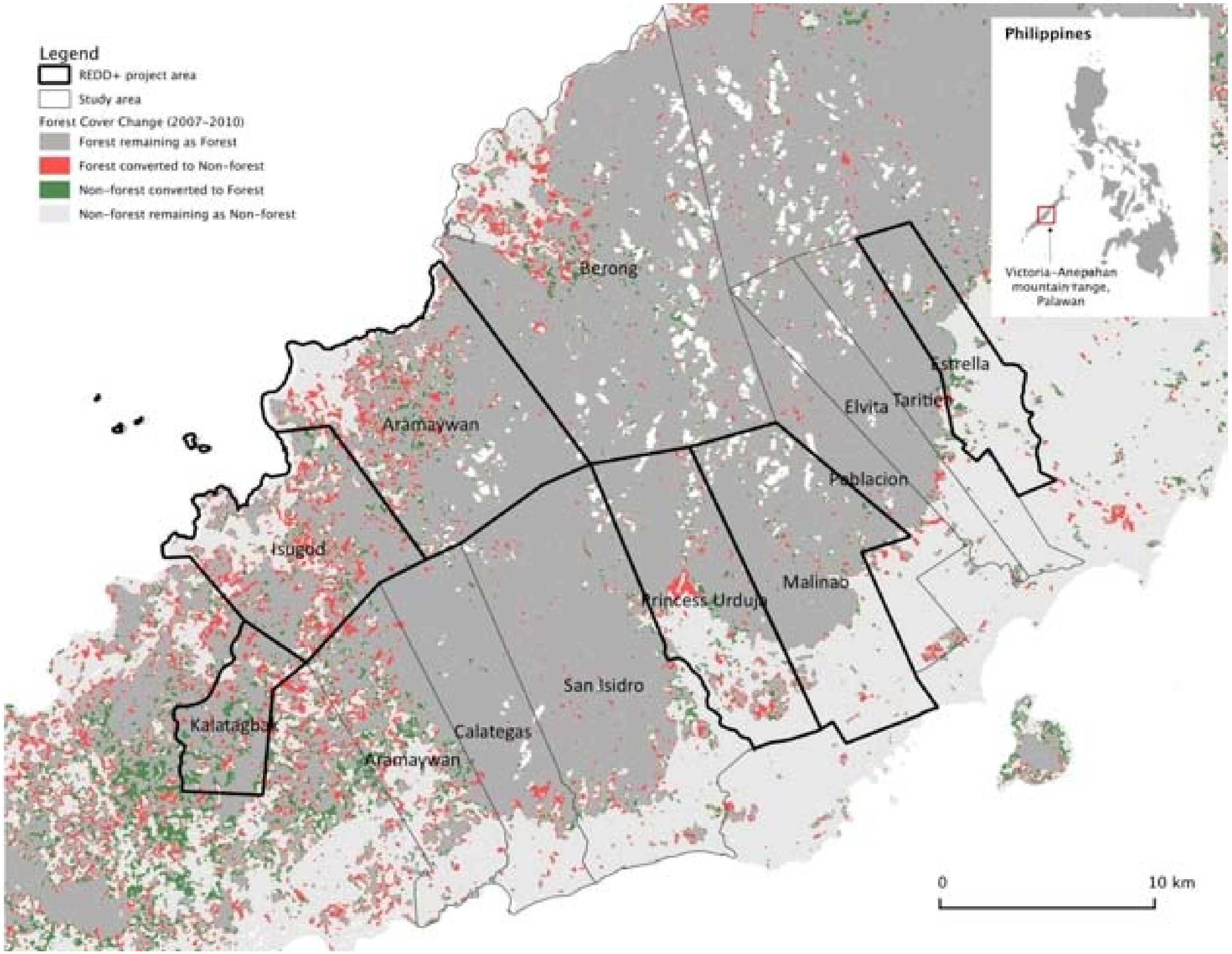
Computed ROI separability between forest and non-forest = 1.928

	2007 Accuracy (%)		2010 Accuracy (%)	
Class	Non-Forest	Forest	Non-Forest	Forest
Producer's	76.79%	96.77%	85.71%	96.83%
User's	96.77%	82.19%	96.00%	88.41%
Overall	87.28%		91.60%	
Kappa	0.74		0.83	

Error Matrix for 2007 Forest/Non-Forest Map			
	Ground Truth (%)		
Class (%)	Non-Forest	Forest	Total
Non-Forest	76.79	3.23	38.14
Forest	23.21	96.77	61.86
Total	100.00	100.00	100.00

Error Matrix for 2010 Forest/Non-Forest Map			
	Ground Truth (%)		
Class (%)	Non-Forest	Forest	Total
Non-Forest	85.71	3.17	42.02
Forest	14.29	96.83	57.98
Total	100.00	100.00	100.00

Forest change detection (2007 to 2010) derived from ALOS/PALSAR mosaics



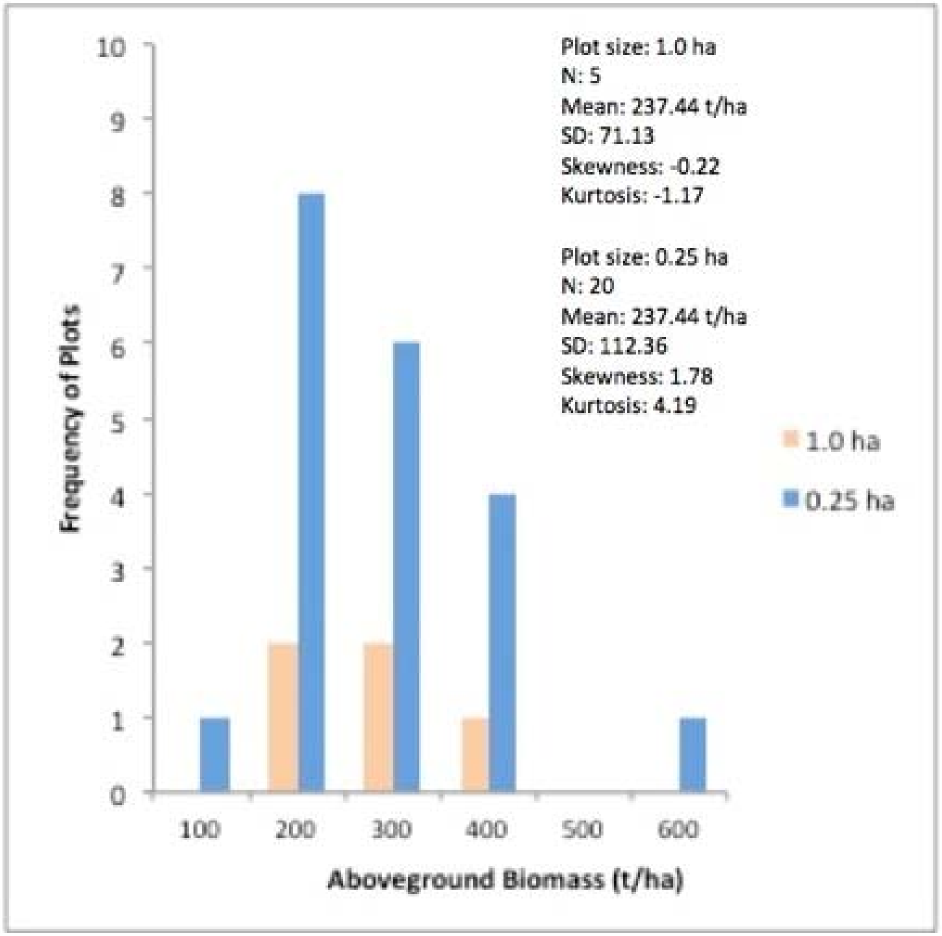
Forest/non-forest cover statistics

Item	2007 (ha)	2010 (ha)	Net Change
Study Area (within 13 barangays)			
Forest	66,092.97	64,570.21	(1,522.76) ↓
Non-Forest	26,340.59	27,863.36	1,522.76 ↑
REDD+ Project Area (within 6 barangays)			
Forest	24,795.98	23,936.56	(859.43) ↓
Non-Forest	12,306.04	13,165.46	859.43 ↑

Forest cover change statistics

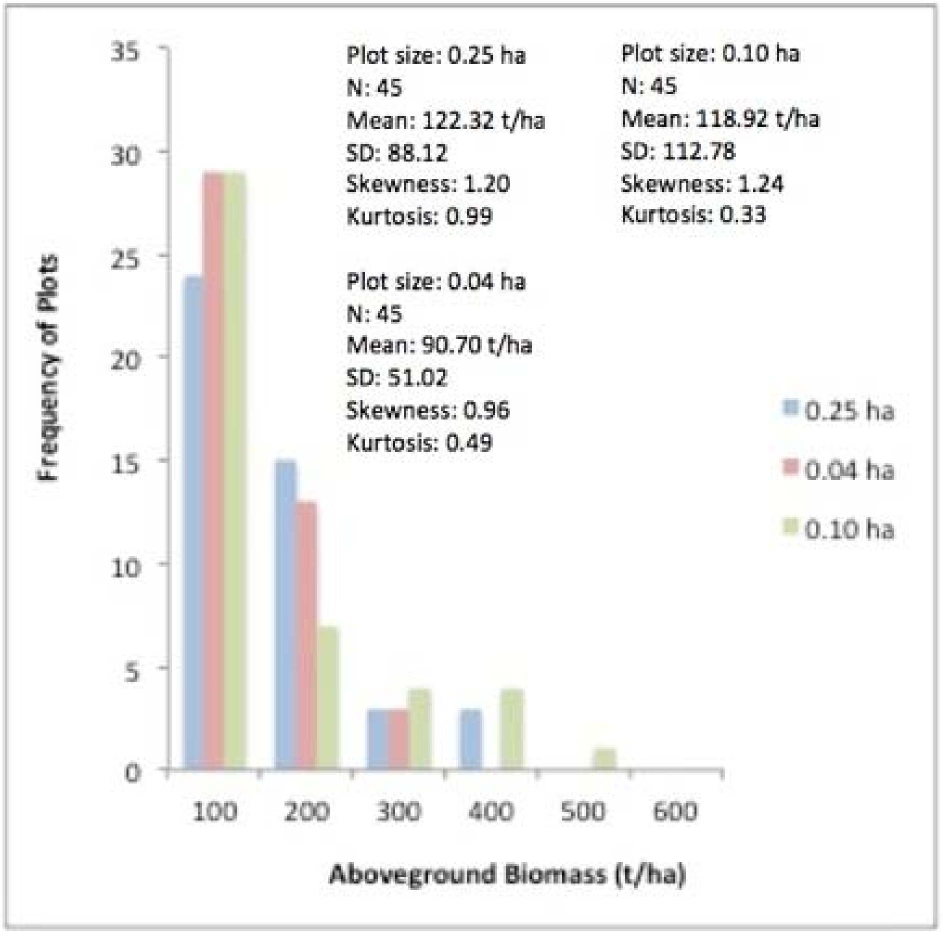
Item	Area (ha)	%
Study Area (within 13 barangays)		
Forest remaining as Forest	61,228.74	66.24
Non-Forest remaining as Non-Forest	22,999.12	24.88
Forest converted to Non-Forest	4,864.24	5.26
Non-Forest converted to Forest	3,341.47	3.62
REDD+ Project Area (within 6 barangays)		
Forest remaining as Forest	22,185.74	59.80
Non-Forest remaining as Non-Forest	10,555.22	28.45
Forest converted to Non-Forest	2,610.25	7.04
Non-Forest converted to Forest	1,750.82	4.72

Distribution of forest biomass sampled at various plot sizes



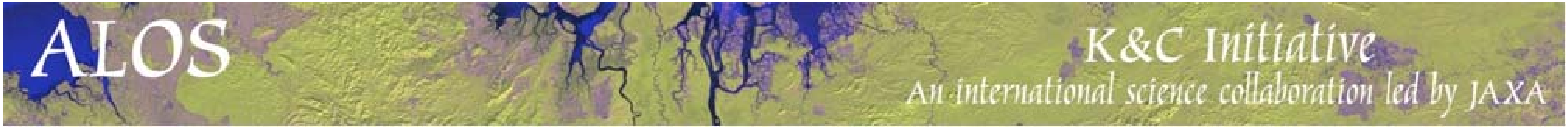
(a) 0.25 ha and 1.0 ha nested plots

Larger plots tend to be normally distributed with smaller deviations from the mean estimate, which is consistent with Saatchi et al (2011). Establishing larger plots is recommended to estimate AGB values.

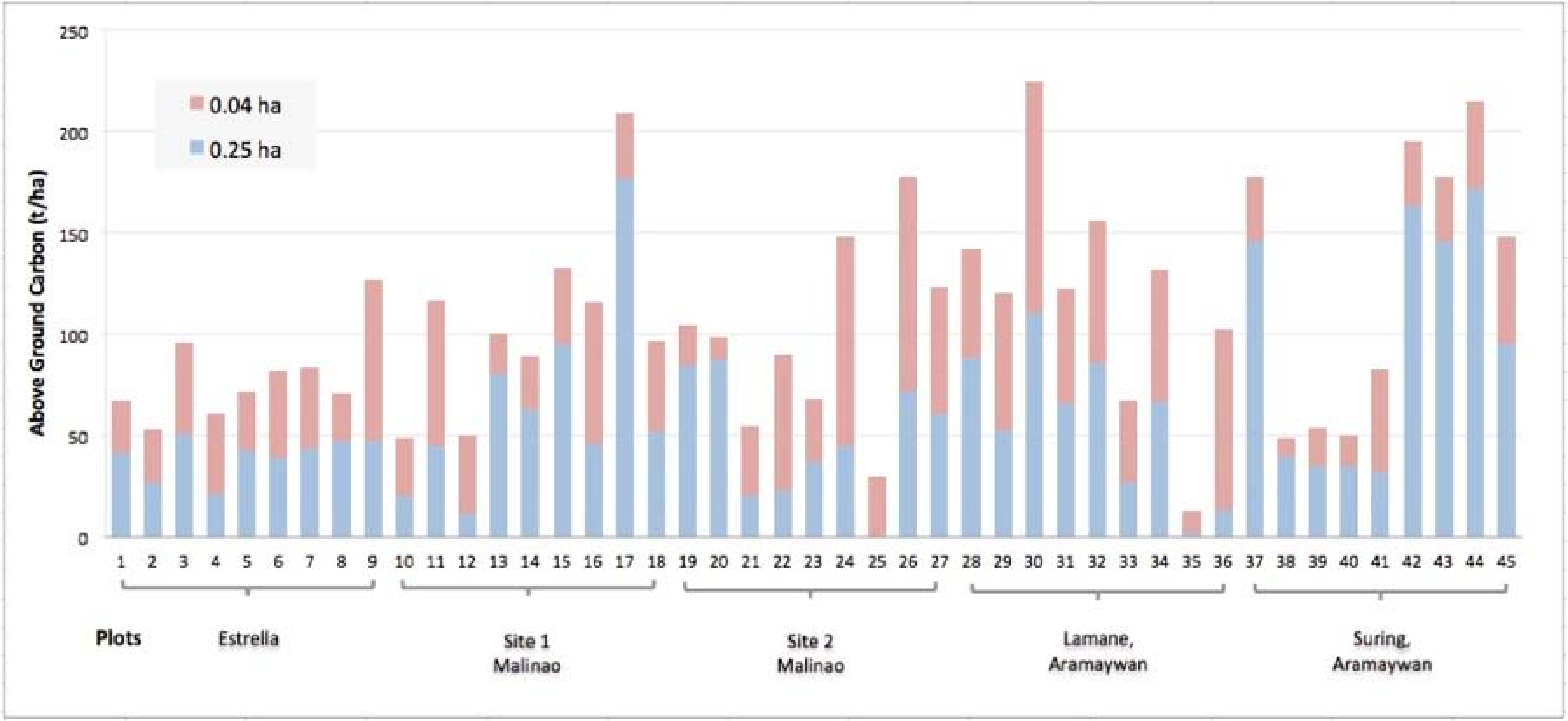


(b) 0.04, 0.10 ha, and 0.25 nested plots

Most plots were at lower range of AGB values (0 to 200 t/ha), regardless of plot size. Lower range of AGB values comprise the larger percentage of AGB estimates.

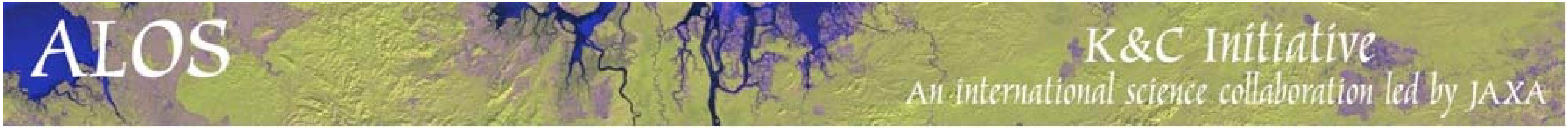


Above ground carbon content from the 0.25 ha nested plots



Range of aboveground carbon content varied from 50.2 to 209.0 tC/ha.

Carbon content estimated from the 0.04 ha nested plots comprised almost half of the total carbon content found at the plot level, indicating that smaller diameter trees (10 to 30 cm) contributed to almost half the carbon content found in any plot within the areas assessed.



Relationship of AGB from radar backscatter

Combination of Radar Channels	R^2	Adjusted R^2	SE
1.0 ha plots (Trees ≥ 5 cm DBH) AGB range: 145.04 to 325.28 t/ha			
HV	0.6546	0.5971	0.6172
HH/HV	0.7030	0.6535	0.5723
HV, HH/HV	0.7377	0.6328	0.5892
HV, HH/HV, C-HV	0.9387	0.8927	0.3185
HV, HH/HV, C-HH	0.8212	0.6871	0.5439
0.25 ha sub-plots (Trees ≥ 5 cm DBH) AGB range: 90.19 to 590.85 t/ha			
HV	0.6618	0.6457	0.3894
HH/HV	0.5914	0.5719	0.4280
HV, HH/HV	0.6635	0.6298	0.3980
HV, HH/HV, C-HV	0.6964	0.6485	0.3879
HV, HH/HV, C-HH	0.6884	0.6392	0.3929

(a) Nested 1.0 ha and 0.25 ha plots

Combination of Radar Channels	R^2	Adjusted R^2	SE
0.25 ha plots along transects (Trees ≥ 10 cm DBH) AGB range: 25.39 to 448.49 t/ha			
HV	0.5752	0.5660	0.3246
HH/HV	0.4505	0.4386	0.3692
HV, HH/HV	0.5807	0.5621	0.3261
HV, HH/HV, C-HV	0.5847	0.5564	0.3282
HV, HH/HV, C-HH	0.5846	0.5563	0.3283
0.10 ha sub-plots along transects (Trees ≥ 10 cm DBH) AGB range: 0 to 477.48 t/ha			
HV	0.3319	0.3170	0.4372
HH/HV	0.2581	0.2416	0.4607
HV, HH/HV	0.3347	0.3045	0.4412
HV, HH/HV, C-HV	0.3517	0.3065	0.4406
HV, HH/HV, C-HH	0.3492	0.3038	0.4414

(b) Nested 0.25 ha and 0.10 ha plots along transects

Relationship between AGB and radar backscatter improved as plot size increased.

Sensitivity to biomass was higher at 1.0 ha plot size using combination of HV, HH/HV ratio, and HV contrast texture.

Correlation of radar backscatter to AGB was better in 0.25 ha plots with complete inventory (100%, trees ≥ 5cm DBH) than in the 0.25 ha nested plots (i.e., trees 10-30cm DBH in 20mx20m, and trees ≥ 30cm DBH in 50mx50m).

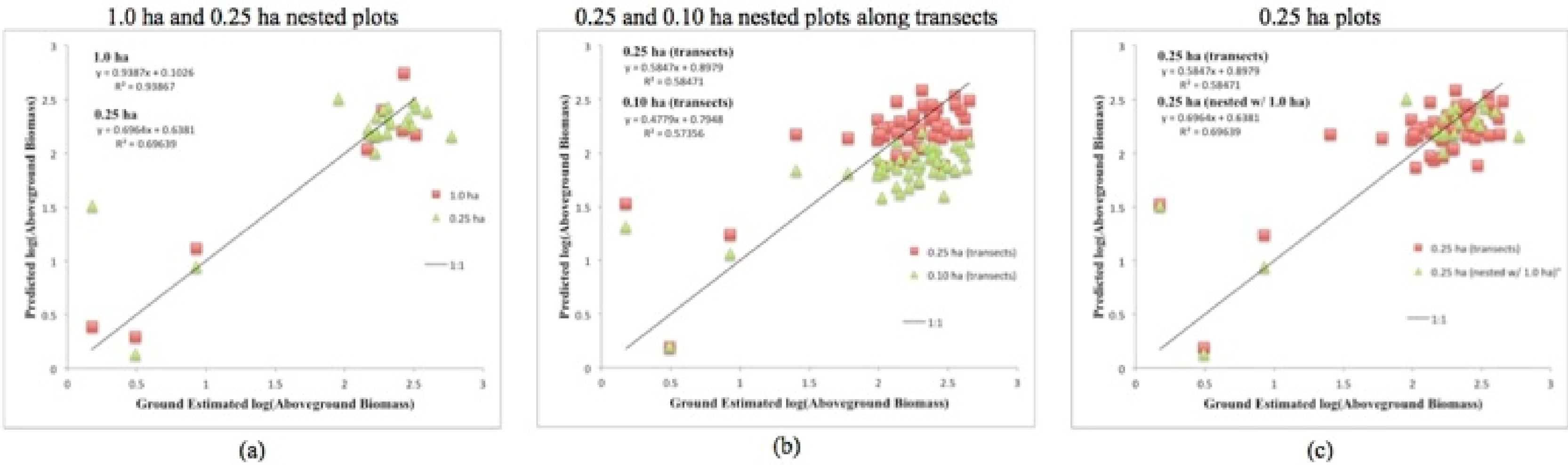


Figure 9. Ground estimated vs. predicted logarithmic aboveground biomass from radar backscatter measurements at different plot sizes: (a) 1.0 ha and 0.25 ha nested plots; (b) 0.25 and 0.10 ha nested plots along transects; (c) 0.25 ha plots along transect and within nested 1.0 ha plots.

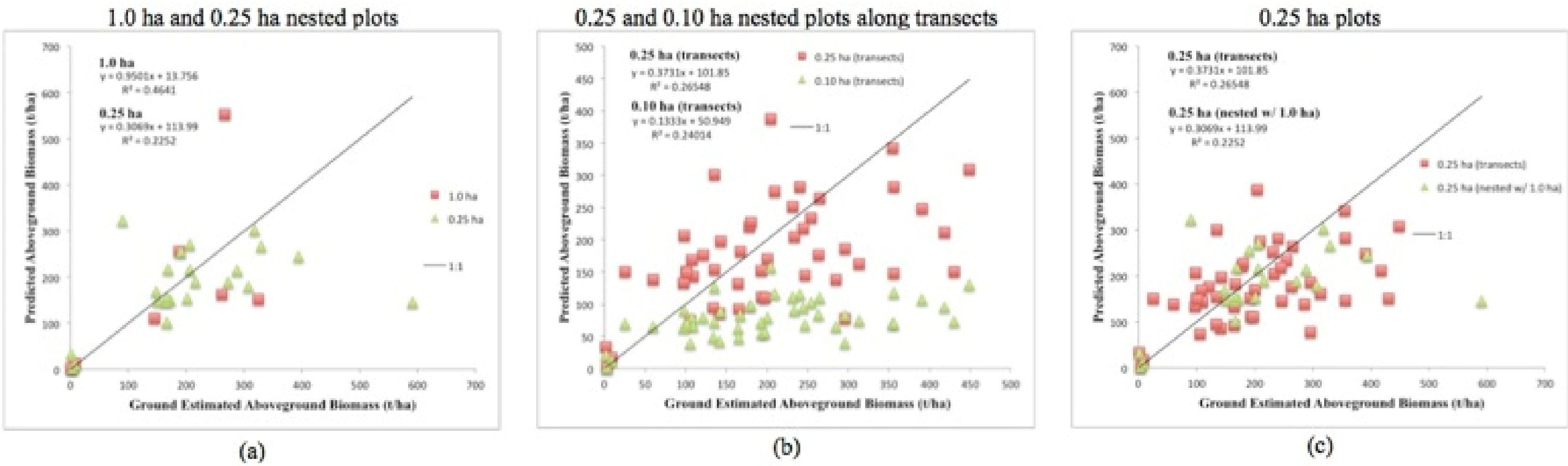
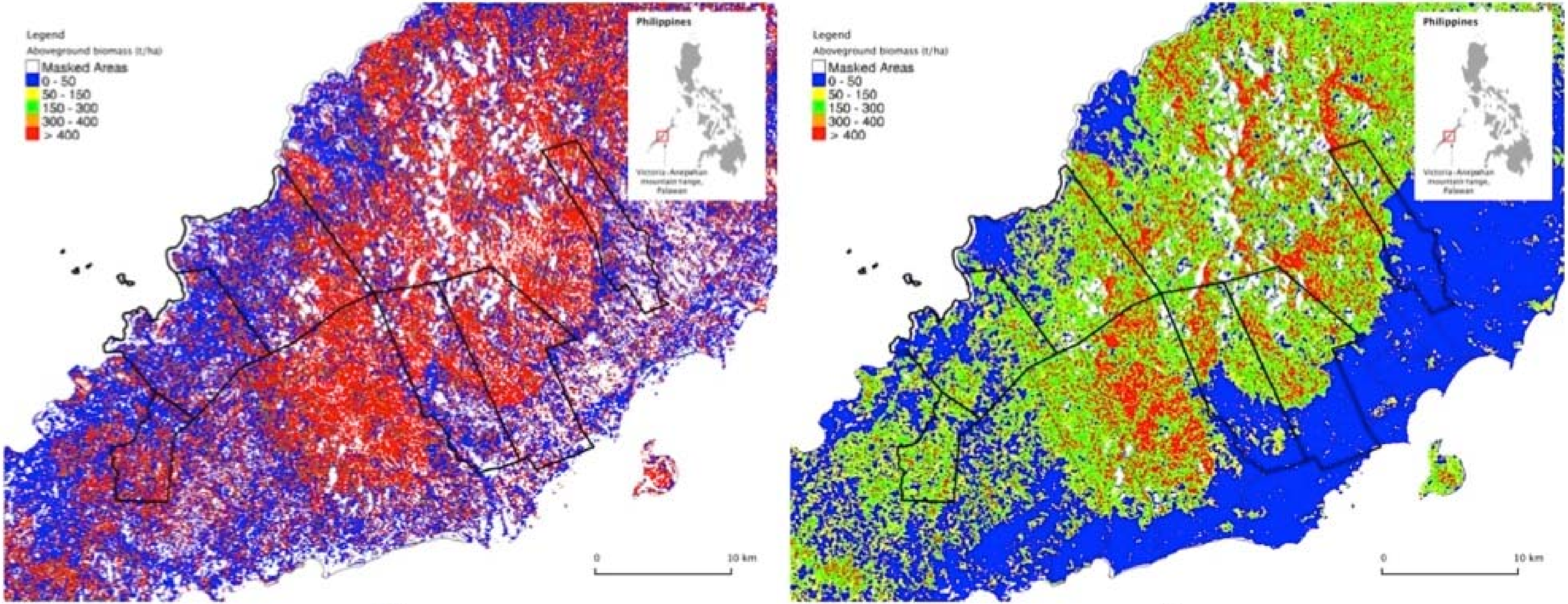


Figure 10. Ground estimated vs. predicted aboveground biomass from radar backscatter measurements in tons/hectare (t/ha) at different plot sizes: (a) 1.0 ha and 0.25 ha nested plots; (b) 0.25 and 0.10 ha nested plots along transects; (c) 0.25 ha plots along transect and within nested 1.0 ha plots.



(a) (b)

Figure 11. Distribution of aboveground biomass of the study area at southern portion of Victoria-Anepahan mountain range derived from ALOS/PALSAR 2010 data and (a) 1.0 ha plots, and (b) 0.25 ha plots nested within 1.0 ha plots.

Model	RMSE
1.0 ha plots	105.2915131
0.25 ha (nested within 1.0 ha plots)	127.7552194
0.25 ha (along the transects)	100.5497983
0.10 ha (along the transects)	157.7704100

Summary and Conclusions

- Overall classification accuracies at 87.28% and 91.60% were achieved using the SVM classifier for 2007 and 2010 PALSAR data, respectively
- A total of 4,864 ha of forests were converted to other land uses from 2007 to 2010 (1,621 ha/yr) within the study area
- Relationship of radar backscatter to AGB was observed to be higher at 1.0 ha plot sizes using combination of radar channels consisting of HV, HH/HV ratio, and HV contrast texture, which decreased for smaller plot sizes
- Inclusion of contrast texture measure improved the relationship of radar data to biomass
- Correlation of L-band SAR data to ground-measured biomass was observed to be better from complete inventory of trees within plots compared to AGB estimates extrapolated from tree measurements within nested plots of specific DBH ranges
- This study demonstrated the capability of ALOS/PALSAR mosaics for detecting and monitoring forest change; for generating activity data information, particularly between forest and non-forest cover types; and for generating spatially explicit distribution of aboveground biomass.

Deliverables –
Papers and reports

1. Published (please provide PDF file)

a. Final report
   - UN REDD Final Report
   - GIZ Technical Report

b. Conference presentations and papers
   - ACRS 2013
   - IGARSS 2013

Deliverables –

Data sets and Thematic products (mosaics, classification maps etc.)

Completed and Delivered to JAXA

- *GIZ (Leyte)*
  - *Step-by-Step Processing Manuals*
  - *Field Data – FRA and Metadata*
  - *Forest Cover & Change Detection Maps*
  - *ROI Polygons*
  - *Technical Reports (Field Data – FRA, Full Document on RS Processing)*
- *FFI*
  - *(Leyte): Field Data Sheets and Metadata, Photos*
  - *(Palawan): Field Data Sheets and Metadata*
  - *(Cebu): Field Data Sheets and Shapefiles, Photos*

Acknowledgements

This work has been undertaken within the framework of the JAXA Kyoto & Carbon Initiative. ALOS/PALSAR data have been provided by JAXA EORC.

This K&C project is also undertaken through the joint collaboration between GIZ, FFI, and UP-DGE.

Thank you!