Accuracy Assessment

2009 Landcover Classification for Rimba Raya

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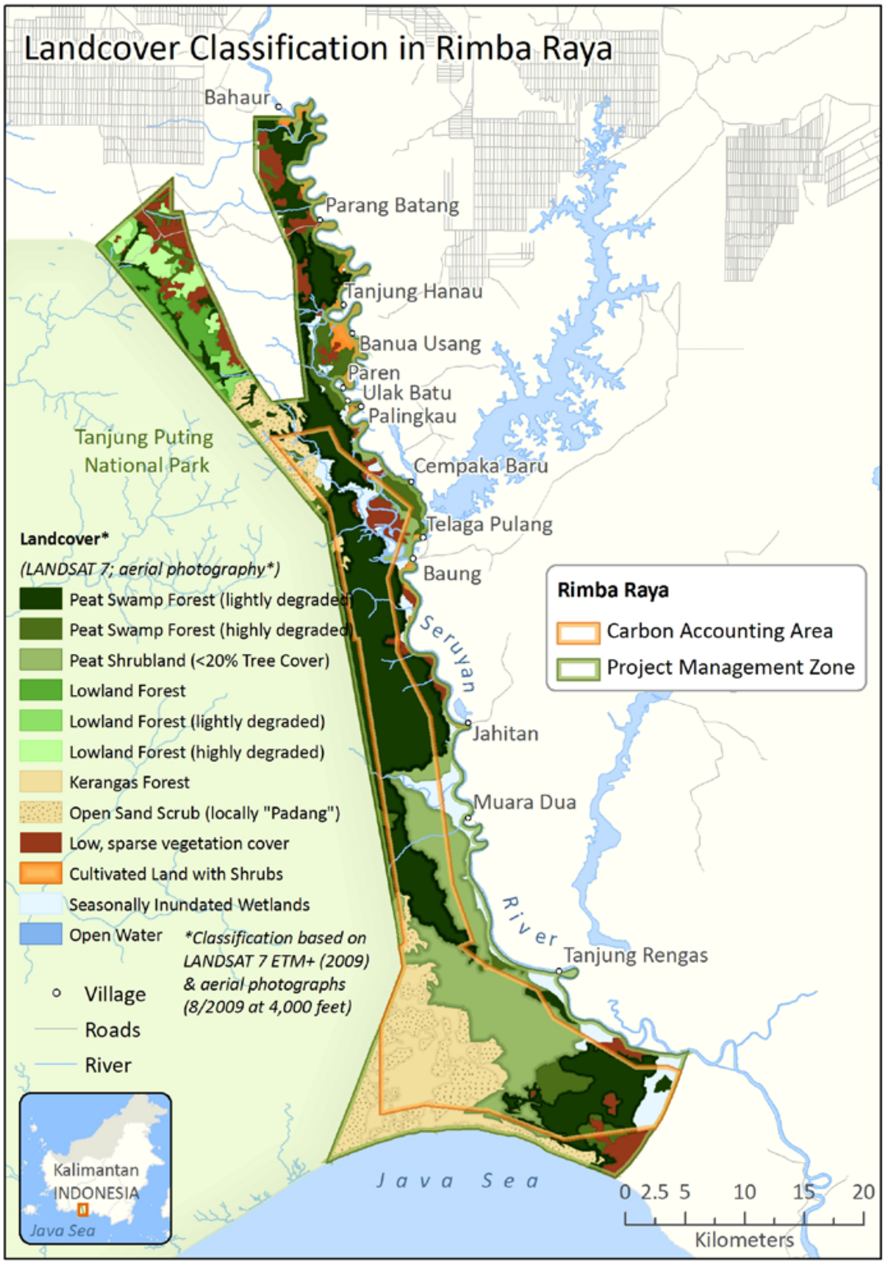
Executive Summary

A landcover accuracy assessment was conducted to validate the 2009 land cover classification for Rimba Raya and quantify map accuracy, by comparing the satellite image-based landcover map to reference data from aerial photos flown July 2009. Aerial survey flight lines cover approximately 40% of the Rimba Raya Project Management Zone and all major landcover classes were represented in the aerial photos. Lowland forest classes, representing 5.9% of the total Project Management Zone, were not represented by aerial photos. All classes in the carbon accounting area were represented in the aerial photo reference data. A total of 342 sample points were used for the accuracy assessment. Allocation of sample points to land cover classes was through stratified random sampling based on land cover class area, with a 20-sample minimum for the smallest classes where reference data were available. Map labels for the sample points were compared with reference labels and an error (confusion) matrix generated. An overall classification accuracy of 81.3% was obtained. The predominant class by area, lightly degraded peat swamp forest which covers 30,445 ha or 33.5% of Rimba Raya, was mapped with 90.0% accuracy. A weighted kappa coefficient of 0.78 indicated there is good agreement between map classes interpreted from satellite imagery and aerial photo data. Landcover is used as the primary stratification for carbon accounting; therefore results of this analysis will be used to quantify uncertainty for carbon estimation. The landcover accuracy assessment will also be used to improve map classification and design a field-based survey for quantitative vegetation analysis for the project.

Background and Purpose

Rimba Raya Landcover Mapping

Landcover mapping provides essential data for natural resource assessment and land management and provides the basis for stratification of forest biomass for carbon accounting. Landcover classification and mapping of the Rimba Raya Project Management Zone and Carbon Accounting Area (Figure 1) was conducted based on automated classification and visual interpretation of 2009 Landsat ETM+ satellite imagery (Bolick 2010). Landcover mapping was updated to improve 2009 map accuracy and develop 2010 land cover and land change maps for year 1 monitoring.



Accuracy Assessment

Classification accuracy assessment is recognized as a key component of any mapping project (EPA 2002) as it is necessary for assessing data quality and comparing the performance of various classification techniques, algorithms, or interpreters (Congalton and Green, 1998). The comparison of mapped data to reference data, summarized in a confusion or error matrix, has become the standard medium for reporting the accuracy of maps derived from remotely sensed data (Congalton and Green, 1993).

This accuracy assessment was undertaken in order to validate the map and methods of the 2009 Rimba Raya landcover classification and provide an objective, quantitative, statistical approach to evaluating map accuracy (ACOE 1995). In addition to communicating map data quality, the Rimba Raya land cover accuracy assessment will be used to quantify uncertainty in carbon accounting estimation and inform project managers about project implementation and future landcover map improvement.

Methods

Reference Data Classification Scheme

A stratified random sample of 347 geo-referenced aerial images were interpreted and assigned a class name based on the Rimba Raya landcover classification scheme (Table 1).

Table 1. Rimba Raya Land Use / Land Cover Classes

Class Name	Description
Lowland forest	Lowland mixed dipterocarp forest on mineral soils. This is a “dry land” or non-swamp forest type and is found only in the northwestern portion of the PMZ where there are elevation gains of ca. 30-40 meters asl.
Lowland forest (lightly degraded)	Lowland mixed dipterocarp forest on mineral soils with some apparent logging damage, adjacent to lowland forest. Note that the term “degraded” is used rather than the Ministry of Forestry term “secondary” which implies forest succession from clear-cutting.
Lowland forest (highly degraded)	Lowland mixed dipterocarp forest on mineral soils with heavy damage from logging and fire. Occurs in the northwestern portion of the PMZ between lowland forest and low, sparse vegetation cover associated with burning and land clearing adjacent to WSSL palm oil plantation.
Peat swamp forest (lightly degraded)	Peat swamp forest, locally “hutanrawa” denoting seasonally wet forests on peat substrate. All peat swamp forests in Rimba Raya are lightly to highly degraded by selective logging.
Peat swamp forest (highly degraded)	Peat swamp forest patches bordering areas of intensive human activity and/or recent deforestation. These areas remain in forest cover but have more apparent damage and therefore lower expected biomass than lightly degraded forest. These forests are at high risk of loss.
Peat shrubland	Formerly peat swamp forests, these areas were deforested by fire in the last ten years. Seasonally wet areas characterized by shrubby regrowth and scattered remnant trees.
Kerangas forest	Heath and scrub forest on sandy soils. Isolated patches in peat swamp forest along the western border of RR, including survey transect 7. More prevalent in the south, where air photos show loose canopies of even

	height, lacking the broad leaves of peat swamp and lowland forest. Visually distinct on satellite imagery(e.g. smooth in texture) but not recognized in Ministry of Forestry mapping which classifies this type with swamp or dry forest depending on location. Relatively rare type, highly susceptible to fire and conversion to open sand scrub.
Open kerangas scrub (locally "padang")	Open sandy soils with patches of scrub forest or thin scrubby vegetation. In West Kalimantan and Sarawak, these areas are known as kerangas, but in Rimba Raya are locally named "padang". These are former heath or kerangas forests that have burned. Bright white sand may be apparent on imagery, or not depending on whether herb cover is present. These areas are often underlain with a hardpan and may be flooded during the wet season. Presence of standing water has confused some previous land cover interpretations of the area (e.g. Ministry of Forestry mapped some areas in the south as "swamp"). These ancient beach areas may intergrade with peatland areas in Rimba Raya, as in the northwestern part of the PMZ.
Cultivated land with shrubs	Repeatedly burned cultivation land, locally "ladang", often abandoned after several years of cultivation. Active cultivation land may appear bright green on imagery from post-fire herbaceous growth. Old ladang often has woody shrubs and scattered trees.
Oil palm plantation	In the Rimba Raya vicinity, all plantation agriculture is oil palm plantation and is currently confined to the WSSL concession in the north, with some recent expansion into the PMZ.
Low, sparse vegetation cover	Areas with sparse grass or herb cover or bare ground, usually associated with recent, severe or frequent burning in areas of human activity. Most of these areas have been cleared by fire but are interpreted to be outside cultivation lands.
Seasonally inundated wetlands	Locally "danau" or seasonal lake, most of these areas were formerly peat swamp forests that have been logged and burned. Where these are adjacent to rivers, flooding may be semi-permanent. Most are sedge-dominated.
Open water	Deep water with no vegetation, especially on or near the Seruyan River and lower reaches of the Baung River

Sample Size

Sample size was determined using the binomial distribution, which is generally recognized as the most appropriate mathematical model for accuracy assessment statistics (Rosenfeld, 1982). The equation based on binomial probability theory that relates classification accuracy assessment sample size to overall classification accuracy and allowable error is:

$N= Z^2pq/E^2$

where,

N = Number of samples
p = Expected or calculated accuracy (in percentage)
q = 100-p

E = Allowable error
Z = Standard normal deviate for the 95% two-tail confidence level (1.96)

In order to perform this calculation, we assumed that the overall accuracy for the land cover map was between 60% and 95% based on typically reported land cover map accuracies. The minimum number of sample points was then calculated for this range of accuracies so that the calculated classification accuracy would have an allowable error of 5% or less at the 95% confidence interval. Results are summarized in Table 2.

Table 2. Minimum number of sample points, N_1 and N_2, required to achieve an allowable error of 5% (E_1) and 2.5% (E_2), respectively, at the 95% confidence interval and for accuracies ranging from 60% to 95%

N_1	N_2	Z^2	p	Q	E_1^2	E_2^2
369	1475	3.8416	60.00	40.00	25	6.25
360	1441	3.8416	62.50	37.50	25	6.25
350	1398	3.8416	65.00	35.00	25	6.25
337	1348	3.8416	67.50	32.50	25	6.25
323	1291	3.8416	70.00	30.00	25	6.25
306	1225	3.8416	72.50	27.50	25	6.25
288	1152	3.8416	75.00	25.00	25	6.25
268	1072	3.8416	77.50	22.50	25	6.25
246	983	3.8416	80.00	20.00	25	6.25
222	887	3.8416	82.50	17.50	25	6.25
196	784	3.8416	85.00	15.00	25	6.25
168	672	3.8416	87.50	12.50	25	6.25
138	553	3.8416	90.00	10.00	25	6.25
107	426	3.8416	92.50	7.50	25	6.25
73	292	3.8416	95.00	5.00	25	6.25

We decided to use the lowest expected land cover map accuracy (60%) in determining the minimum number of sample points (369) for the accuracy assessment. Map accuracy was later calculated to be higher than this value, resulting in a smaller allowable error (less than 5%) around our estimates at the 95% confidence interval.

Sampling Design

We selected a stratified random sampling design as the most appropriate for the land cover accuracy assessment because important minor classes could be satisfactorily represented (Van Genderen *et al.* 1978). This is the most widely used sampling scheme for accuracy assessment (Jensen, 1996). Sample point allocation among Rimba Raya land cover categories is shown in Table 3.

Most classes are adequately represented with the exception of lowland forest types comprising a total of 5.9% of the Project Management Zone. Lowland forest is known to occur only in the northwestern portion of Rimba Raya based on extensive field reconnaissance and mapping conducted by Orangutan Foundation International. These types do not occur in the carbon accounting area, which is predominated by low-lying peat soils with some kerangas-bearing sand ridges in the southwest. Future landcover mapping efforts will include lowland forest types in reference data.

Other poorly represented types are open water and oil palm plantation, which occur in discrete locations adjacent to the project boundary aiong the Seruyan River and KUCC oil palm plantation respectively. These types comprise a total of 0.7% so their absence in the reference data has negligible effect on the accuracy assessment. These types have unique signatures on satellite imagery and are therefore easy to accurately interpret on Landsat and other medium resolution satellite imagery, therefore it is expected class accuracy to be high and invariable for open water and oil palm.

Table 3. Minimum number of sample points per land cover class stratified by area

Landcover	Area (ha)	Proportion of Area (%)	Estimated samples	Samples available	Samples used
Cultivated Land with Shrubs	2297	2.5	9	9	9
Kerangas Forest	6845	7.5	28	79	28
low, sparse vegetation cover	7908	8.7	32	44	32
Lowland Forest	2762	3.0	11	0	0
Lowland Forest (lightly degraded)	772	0.9	3	0	0
Lowland Forest Degraded (highly)	1776	2.0	7	0	0
Oil Palm Plantation	319	0.4	1	0	0
Open Kerangas Scrub	10792	11.9	44	83	44
Open Water	228	0.3	1	2	2
Peat Shrubland	15163	16.7	62	215	62
Peat Swamp Forest (lightly degraded)	30445	33.5	124	327	124
Peat Swamp Forest Degraded (highly)	5242	5.8	21	24	21
Seasonally Inundated Wetlands	6250	6.9	25	58	25
Total	90800	100.0	369	841	347

Reference Sample Randomization

Reference sample locations representing aerial photo center points were spatially overlaid with the 2009 land cover classification to obtain map class information for each point. All samples for each class were extracted to a separate GIS data layer (summarized in Table 3). Randomization of reference sample data was performed for points in each map class using an ArcView software extension. Selected sample points were saved to new GIS files, then combined into a single GIS reference point file.

Reference Data Compilation

Aerial photo interpretation was performed by opening and viewing aerial images associated with reference sample points one at a time and assigning a class name to each record in the GIS data layer (ArcView shape file) in the “REF_CLASS” field. Sample points were buffered to create 2 ha viewing polygons within which the dominant landcover class was interpreted from aerial photos. The 2 ha area represents the Minimum Mapping Unit for the original landcover classification. Cloud cover obscured the ground view in 5 of 347 aerial images, so these samples were eliminated from the accuracy assessment.

Accuracy Assessment

Reference data and map class data were spatially merged to create a single GIS data file including 342 records containing reference data and map classes. This GIS file was exported to an EXCEL spreadsheet and a pivot table constructed to compare and summarize classified landcover to reference data. EXCEL was used to generate an error matrix and compute the accuracy of each category, including errors of commission ("users accuracy"), errors of omission ("producers accuracy") and overall accuracy.

The kappa statistic (coefficient of agreement) was computed using an online tool (http://graphpad.com/quickcalcs/Kappa2.cfm). KAPPA is a discrete multivariate technique developed by Cohen (1960) that permits two or more contingency matrices to be compared. The statistic adjusts overall accuracy to account for chance agreement, and has been utilized for land cover and land use accuracy assessment derived from remotely sensed data. Values of KAPPA greater than 0.75 indicate strong agreement beyond chance, values between 0.40 and 0.79 indicate fair to good, and values below 0.40 indicate poor agreement (SPSS, 1998).

Results

A total of 342 points were used for the accuracy assessment with stratification by land cover area. The confusion matrix is shown in Table 4. Landcover map classification accuracy is summarized in Table 5 including producer's, user's, and overall classification accuracy, and the Kappa coefficient of agreement.

Table 4. Landcover classification confusion matrix

2009 Land Cover Map Classes	Reference Classes (2009 aerial photos)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Grand Total**
1	**7**	0	0	0	0	0	0	2	0	**9**
2	0	**25**	0	2	0	0	1	0	0	**28**
3	0	0	**17**	0	0	7	1	3	4	**32**
4	0	5	0	**36**	0	0	0	0	0	**41**
5	0	0	0	0	**2**	0	0	0	0	**2**
6	0	3	0	2	0	**55**	0	0	2	**62**
7	0	1	1	0	0	3	**104**	13	1	**123**
8	0	0	0	0	0	0	3	**16**	1	**20**

9	0	0	0	1	0	5	0	3	**16**	**25**
Grand Total	**7**	**34**	**18**	**41**	**2**	**70**	**109**	**37**	**24**	**342**

Table 5. Landcover classification accuracy summary

	Landcover Class Name	Map Total	Reference Total	Number Correct	Producer's Accuracy (%)	User's Accuracy (%)
1	Cultivated Land with Shrubs	7	9	7	100.00	77.78
2	Kerangas Forest	34	28	25	73.53	89.29
3	low, sparse vegetation cover	18	32	17	94.44	53.13
4	Open Kerangas Scrub	41	41	36	87.80	87.80
5	Open Water	2	2	2	100.00	100.00
6	Peat Shrubland	70	62	55	78.57	88.71
7	Peat Swamp Forest (lightly degraded)	109	123	104	95.41	84.55
8	Peat Swamp Forest Degraded (highly)	37	20	16	43.24	80.00
9	Seasonally Inundated Wetlands	24	25	16	66.67	64.00
overall accuracy = 81.3% Kappa= 0.769 95% confidence interval (0.718 to 0.820) Weighted kappa = 0.781						

An overall accuracy of 81.3% was obtained. The predominant class by area, Peat Swamp Forest, lightly degraded (33.5% of the project area) had a producer's accuracy of 94.4% (areas classified as Peat Swamp Forest, lightly degraded on the map were found to be this class on the aerial photos in 104 of 109 cases) and the user's accuracy was 84.6% (areas classified as Peat Swamp Forest, lightly degraded on the aerials were assigned to this class in 109 of 123 cases.) Subdominant landcover types in Rimba Raya, Peat Shrubland (16.7%) and Open Kerangas Scrub (11.9%) also had high user's and producer's accuracies with an average of ca. 83% and ca. 88% respectively.

There was some confusion in some less extensive classes. High user's accuracy (80.0%) but low producer's accuracy (43.2%) was found for Peat Swamp Forest, highly degraded. Examination of mismatches for this class, showed that intact canopies which may have appeared to be less degraded on satellite imagery were characterized by many small, short trees characteristic of forest regeneration from heavy degradation on aerial photos.

Disturbance classes in general were more easily confused in map classification. For example, although the producer's accuracy for the low, sparse vegetation class is 94.4%, the user's accuracy is only 55.1%. This means that most of the low, sparse vegetation sample areas examined in the aerial photos were also labeled as low, sparse vegetation in the 2009 landcover classification map. However, there were many areas in the map labeled 'low, sparse vegetation' that turned out to be some other class in the aerial photos including Seasonally inundated wetlands, peat shrubland and highly degraded peat swamp forest which intergrade in a fine mosaic along the Seruyan river.

The kappa statistic of 0.769 (weighted kappa 0.781) shows there is good agreement between map classes and reference data. This measure, together with high overall accuracy, especially for predominant land cover classes in Rimba Raya, indicates the 2009 landcover classification provides a good dataset for carbon accounting stratification and resource management in Rimba Raya. A more refined definition of forest degradation and human-disturbance classes together with ground-based training data for identifying these areas on satellite imagery will be used to further improve map classification in the future.

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