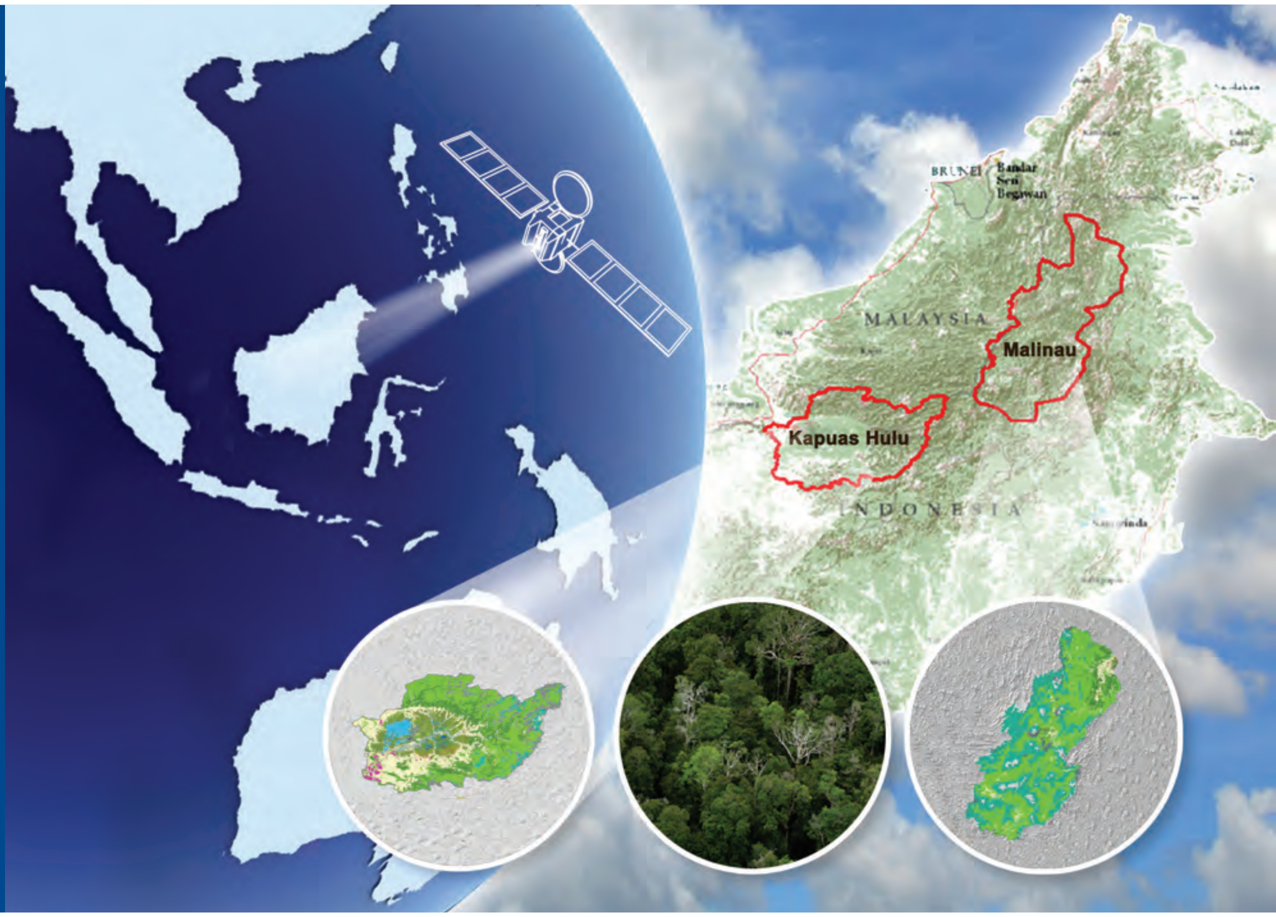
Climate Change



Land Cover Situation and Land-Use Change in the Districts of West Kalimantan and East Kalimantan, Indonesia

Assessment of District and Forest Management Unit Wide Historical Emission Levels

kerja sama jerman
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1 Introduction

The present report summarizes the methods and results from the survey on land cover and land cover change and associated carbon emissions in the two districts of Malinau and Kapuas Hulu conducted within the Indonesian-German Forests and Climate Change Programme (FORCLIME).

1.1 Study objectives and tasks to be performed

The main objective of this study is the determination of the land cover in the two districts. Malinau and Kapuas Hulu for the years 1990, 2000, 2005 and 2010 and analyze the land cover change and associated carbon emissions in the given time frame. In order to fulfill this principal objective the following tasks had to be performed:

- ☑ procure Landsat satellite data for the given time period
- ☑ minimize cloud cover for the study areas by multi-image compositing for each time step
- ☑ develop a standardized classification scheme valid for the two study areas
- ☑ perform a land cover classification for the four time steps
- ☑ validate the results of the land cover classification
- ☑ perform a land cover change analysis between the four time steps and for the overall observation period
- ☑ Analyze historic deforestation in the districts and calculate forest loss and deforestation rate
- ☑ Identify the drivers of deforestation
- ☑ perform a carbon change assessment based on carbon data from the scientific literature or field data
- ☑ Identify the drivers of carbon emissions

1.2 Study areas

The study was carried out in two districts in Kalimantan, as shown in the map in Figure 1. Due to the different geographic situation of the two districts, a short introduction is given in the following two sub-sections.

1.2.1 Malinau district

Malinau is located in the north-eastern part of Borneo in the province of East Kalimantan (Kalimantan Timur), bordering Malaysia (Sarawak) in the west, the Indonesian district Nunukan in the north, Bulungan, Berau and Kutai Timur in the east, as well as Kutai Kartanegara and Kutai Barat in the south. Malinau is part of the Heart of Borneo, a conservation agreement initiated by the World Wildlife Fund for Nature to protect 220,000 km² of forested region in Borneo, and covers a total area of 4 Mio hectares.

With the exception of the floodplains of the Mentarang and Malinau rivers in the north-east, Malinau is dominated by a mountainous landscape covering the full elevation range from 40 m to over 2,000 m a.s.l.. Large parts of the district are characterized by extremely rugged terrain which is largely inaccessible. This is considered the main reason that the district's forests are still in good condition when compared to other districts in Kalimantan.

Figure 1. Location of the two districts Malinau and Kapuas Hulu on the island of Borneo.

The entire west of the district consists of the Kayan Mentarang National Park which is part of the network of protected areas forming the Heart of Borneo region. The territory of the National Part consists of mostly pristine forest areas.

1.2.1 Kapuas Hulu district

The Kabupaten Kapuas Hulu is located in the central part of Borneo and belongs to the West-Kalimantan province of Indonesia. The district covers a total area of 3.1 Mio hectares. It borders Malaysia to the north, the districts Sintang to the west and south, Barut in the south and Kutai Barat in the east.

The major part of the district lies in a basin consisting of a complex pattern of peat domes, lakes, freshwater wetlands and the floodplain of the Kapuas, Borneo's largest river. These lowlands have an elevation between 25 m a.s.l. and 100 m a.s.l and have a generally low relief energy, with the exception of some rock outcrops. In the east and south-east of the district the terrain becomes more rugged, and the landscape gives way to the Müller mountains (southeast) and Kapuas Hulu mountain range (northeast). These mountainous areas are remotely populated and large parts are National Parks and protected forests (Hutan Lindung).

2 Data and methods

2.1 Used satellite data

In order to obtain a best possible wall-to-wall coverage of the two districts for four time steps, a very large number of Landsat satellite images needed to be procured. Since both study areas are characterized by heavy cloud cover except for a short time window in the dry season from June to September, up to four images were acquired for each Landsat footprint per time step, which resulted in a total of 112 Landsat satellite images used for this study. Table 37 in the annex gives a full list of all images procured and analyzed.

2.2 Design of classification scheme

In order to make the map products comparable to each other, and to other land cover maps in Indonesia, a standardized classification scheme was developed based on the FAO Land Cover Classification System LCCS (Di Gregorio 2005).

The classification scheme has a hierarchical structure with three Levels of thematic detail (Table 1). On the first level, the scheme distinguishes two broad land cover categories, namely Forest and Non-forest. This classification level will be used for the calculation of the deforestation rate. On the second level, the classification scheme introduces finer thematic detail, distinguishing up to eight different forest ecosystem types, as well as up to five different non-forest land cover categories. The third and finest classification level introduces a degradation status to each of the forest classes, distinguishing Primary (Intact) from Secondary (Degraded) forest.

2.3 Biomass and Carbon data

The biomass and carbon value calculations are based on an extensive database generated by RSS covering a range of land cover types throughout SE Asia at varying levels of detail. The database consists of over 200 literature-based sources corresponding to Kalimantan, the Indonesian archipelago and SE Asia as well as numerous field measurements. Biomass values were grouped into the respective land cover classes and for each class, the arithmetic mean, weighted mean and standard deviation was calculated.

Table 1. Land cover classification scheme.

Classification Level 1	Classification level 2	Classification level 3
Forest	Type	Disturbance status*
	Lowland Forest (0 - 300 m a.s.l.)	Intact
		Degraded
	Hill and sub-montane Forest (300-900 m a.s.l.)	Intact
		Degraded
	Lower Montane Forest (900 - 1500 m a.s.l.)	Intact
		Degraded
	Upper Montane Forest (> 1500 m a.s.l.)	Intact
		Degraded
	Peat Swamp Forest	Intact
		Degraded
	Heath Forest	Intact
		Degraded

Table 1. Continued

Classification Level 1	Classification level 2	Classification level 3
Forest	Riparian Forest	Intact
		Degraded
	Freshwater Swamp Forest	Intact
		Degraded
Non-forest	Plantation	
	Shrubs, shifting cultivation, smallholder agriculture, grassland	
	Wetland	
	Settlement	
	Bare Area	
	Water	

* Was determined by proximity to logging roads and visual image interpretation

The results of the biomass calculation and the details on the sources of values is shown in the Biomass report in the annex, and in pdf version in the deliverables. The biomass and carbon values for the land cover classes are also shown in Table 2. A average carbon content of 50% is assumed, a well accepted value in the literature (Gibbs et al. 2007, Goetz et al. 2009, Malhi et al. 2004).

2.4 Field data

In order to collect reference data for assessing the accuracy of the land cover maps, a land cover field survey has been conducted in each of the districts.

Table 2. Biomass and carbon values for the different land cover classes.

Land cover class	Map code	AGB [t/ha]	Carbon [t/ha]
Lowland Forest (0 -< 300 m a.s.l.)	111	470.07	235.04
Secondary Lowland Forest	112	276.60	138.30
Hill and Sub-montane Forest (300 -< 900 m a.s.l.)	121	334.39	167.19
Secondary Hill and Sub-montane Forest	122	193.85	96.92
Lower Montane Forest (900 -< 1500 m a.s.l.)	131	425.59	212.79
Secondary Lower Montane Forest*	132	268.34	134.17
Upper Montane Forest (> 1500 m a.s.l.)	141	304.35	152.18
Secondary Upper Montane Forest*	142	191.92	95.96
Peat Swamp Forest	151	215.32	107.66
Secondary Peat Swamp Forest	152	151.66	75.83

Table 2. Continued

Land cover class	Map code	AGB [t/ha]	Carbon [t/ha]
Heath Forest	161	223.95	111.98
Secondary Heath Forest	162	177.88	88.94
Riparian Forest	171	253.68	126.84
Secondary Riparian Forest	172	76.19	38.10
Freshwater Swamp Forest	181	208.47	104.24
Secondary Freshwater Swamp Forest*	182	199.35	99.68
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	47.44	23.72
Oil Palm Plantation*	22	78.00	39.00
Timber plantation*	22	194.00	97.00
Wetland	23	14.96	7.48
Settlement	24	0.00	0.00
Bare Area	3	0.00	0.00
Water	4	0.00	0.00
Data	99	0.00	0.00

* Mapped estate plantations in Kapuas Hulu were exclusively Oil Palm plantations, while in Malinau, it was exclusively timber plantations. Therefore the plantation class was attributed with two different biomass and carbon values in the two districts according to the appropriate plantation type.

The objectives of the field visits were to:

- ☑ collect reference data on land cover in the district
- ☑ train local personnel "on-the-job" on LCCS-based standardized land cover mapping

Table 3 shows the quantity of reference plots for the two districts. Each land cover sample was collected in 50 x 50 m plots, established by GPS. Land cover variables collected include:

- ☑ GPS coordinates of plot corners
- ☑ Main LCCS class
- ☑ Vegetation growth form, projective cover, height, distribution on plot
- ☑ Geo-located photos on each corner of plot into the plots

Data was recorded on a standardized mapping form. Vegetation cover was estimated based on comparative analysis of reference graphs, and classified into three classes: closed (>65% cover), open (15-65% cover), sparse (<15% cover). Vegetation height was measured by a trigonometric approach with either a laser distance meter (Leica Disto R8), or a clinometer (Hagloff).

Table 3. Quantity of field plots for the validation of the land cover classifications.

Land cover class	Kapuas Hulu	Malinau
Peat swamp forest	17	n/a
Lowland dipterocarp forest	16	11
Secondary dryland forest	7	33
Kerangas /Heath forest	6	n/a
Peat/ dryland transition forest	6	n/a
Agriculture	4	20
Shrubland	4	1
Plantation	3	3
Bare area	1	1

In total, over 133 land cover plots were mapped in the field. The spatial distribution in the two study areas is shown in Figure 2 and Figure 3.

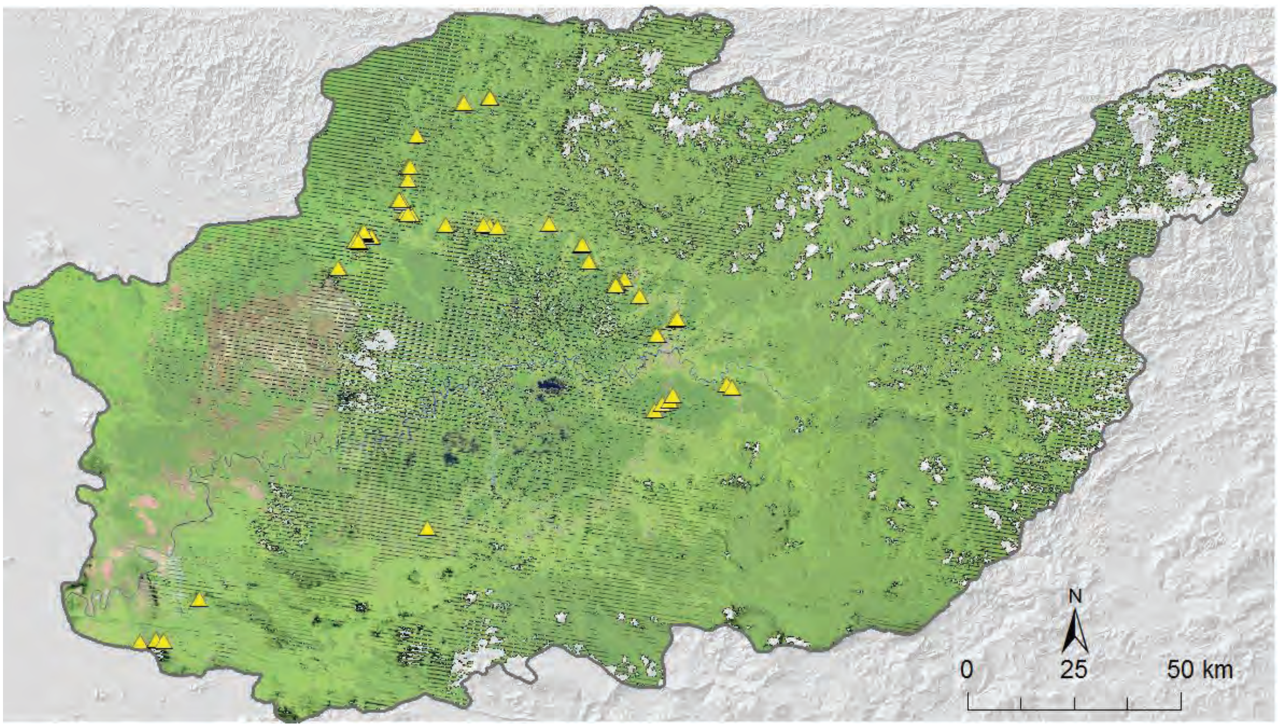

Figure 2. Location of the land cover plots mapped in Kapuas Hulu.

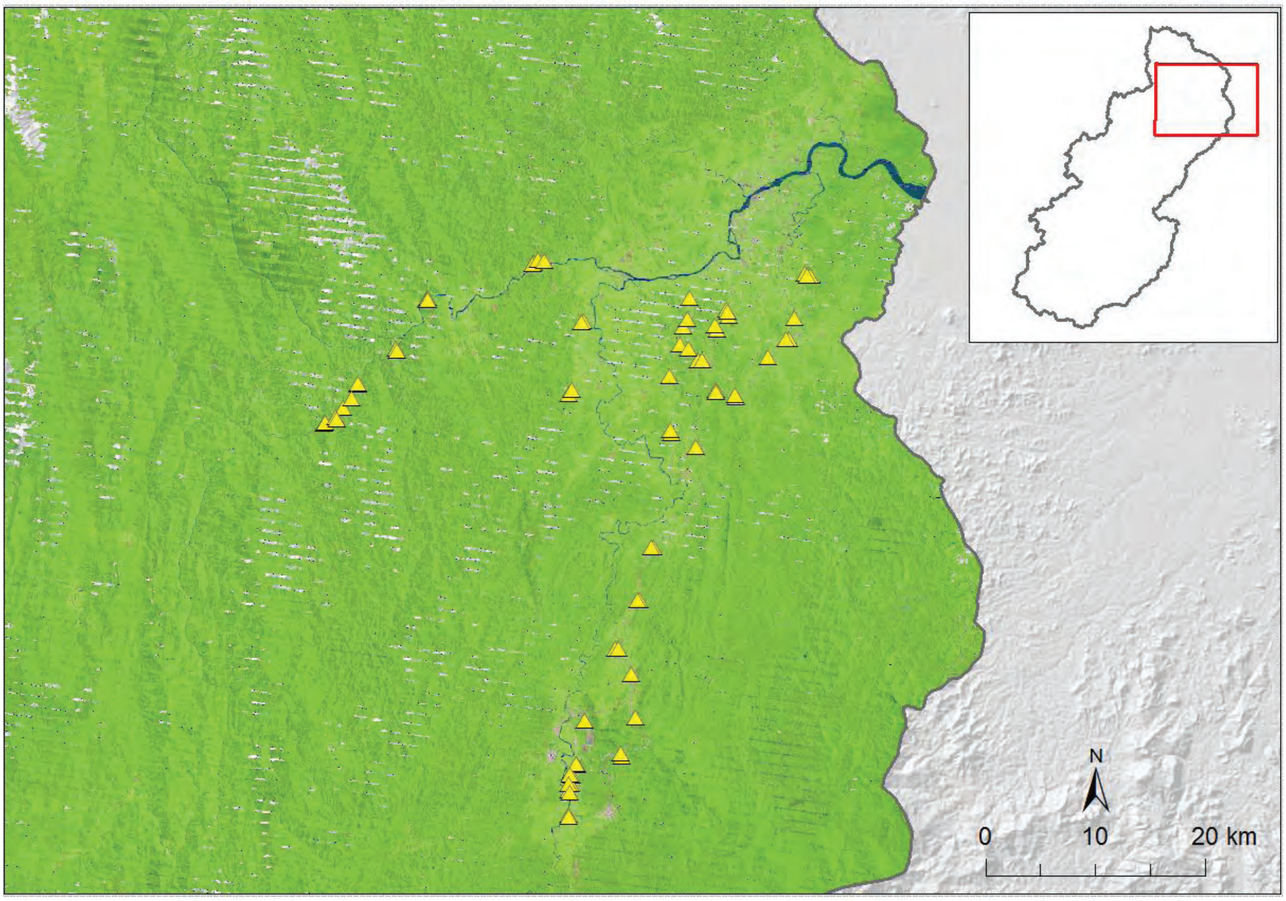

Figure 3. Location of the field plots in Malinau.

Due to the fact that large parts of the study areas were inaccessible and under the given time and budget restrictions, it was decided to complement the ground data with reference data collected from aerial photographs. Therefore, an over-flight was organized in each district with the objective of acquiring transects of aerial photos for use as validation data.

The aerial photos were geolocated in the post processing by GPS, rotated in flight direction and scaled. Then the images were mosaicked together into flight strips, which were finally georeferenced onto a RapidEye reference satellite image.

Land cover samples were extracted from the flight strips with a systematic sampling scheme, collecting a sample every 1000 m along the flight path. In order to facilitate comparability to the ground samples the aerial plots also had a spatial extent of 50 x 50 m.

Table 4 shows the quantity of validation plots extracted per class from the aerial photographs for the two districts.

Table 4. Quantity of aerial validation plots for the two districts.

Land cover class	Kapuas Hulu	Malinau
Peat Swamp Forest	64	n/a
Secondary Peat Swamp Forest	13	n/a
Dryland forest	0	136
Secondary dryland forest	6	61
Heath Forest	22	n/a
Secondary Heath Forest	8	n/a
Freshwater Swamp Forest	n/a	2
Riparian Forest	7	n/a
Secondary Riparian Forest	1	n/a
Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland	41	41
Water	3	4

2.5 Development of a district wide land cover map for four time steps, Land cover change analysis and carbon emission baseline assessment

2.5.1 Development of LU/LC map

2.5.1.1 Preprocessing

2.5.1.1.1 Atmospheric correction

The Landsat satellite imagery was delivered in Level 1 format. The DNs (pixel values) in the Level 1 format still represent a scaled "at-sensor-radiance", which means the radiance measured on the top of the atmosphere by the sensor.

In order to compensate for atmospheric disturbances (scattering, illumination effects, adjacency effects), induced by water vapor and aerosols in the atmosphere, seasonally different illumination angles etc., an atmospheric correction was applied to each image using ATCOR-2 (Richter 2006). This preprocessing step means a calibration of the data into an estimation of the surface reflectance without atmospheric distortion effects. This calibration method facilitates a better scene-to-scene comparability of the radiometric measurements, which is a necessary precondition for the segment-based rule-set classification method applied in this study (see 2.5.1.3). Furthermore the atmospheric correction facilitated the creation of high quality image mosaics during the cloud and gap-filling process (see 2.5.1.1.4).

2.5.1.1.2 Geometric correction

The Landsat-7 images were procured from the USGS archive in Level 1T preprocessing format. A geometric correction including terrain correction has already been applied by the data provider. It was found that this geometric preprocessing by USGS was very accurate so no further geometric correction was found to be necessary.

The Landsat-5 images available in the USGS archive were delivered in Level 1G format, which means that they are geocoded, but not rectified by a terrain correction. This meant that all Landsat-5 scenes were characterized by terrain distortions and were not co-registered to the Landsat-7 scenes. Therefore, an additional geometric correction procedure had to be applied to all Landsat-5 datasets.

The geometric correction was done by an semi-automated image-to-image co-registration implemented in the Erdas IMAGINE image processing environment. This procedure automatically identifies Tie-Points (identical points in the input and reference image) by comparing the grayscale statistics in one spectral band between the input and reference image, which are then used for rectifying the input image.

The Landsat-7 data of the year 2000 was used as a geometric reference because:

- ☑ all images were available in L1T format
- ☑ the ETM+ sensor was still intact, i.e. there were no SLC-gaps in the images

2.5.1.1.3 Cloud masking

The cloud masking was done by a semi-automatic object-based routine, with visual post-classification. Clouds are classified by a ratio based on the blue reflectance band and the thermal band, which allows for good cloud detection. Cloud shadows are masked by several thresholds in the visible and NIR bands. For both classification steps, the classification thresholds used are adjusted by the operator in order to facilitate the highest possible detection accuracy.

To further enhance the accuracy of the cloud mask, the results of the automatic classifier are manually edited in order to reduce errors of omission (cloud and cloud shadows which have not been classified as such) and commission (cloud free objects which are accidently classified as clouds/cloud shadow). Omissions occur mostly, if clouds are too small and mixed with non-cloud pixels, or if cloud shadows are not sufficiently dark. Commission errors occur primarily on very bright landscape features (bright sand, gravel beds along rivers, logging roads, settlements), or on very dark landscape features (hill-shades at very steep slopes, black-water).

A combination of the semi-automatic classifier and manual post-classification generates high quality cloud masked images.

2.5.1.1.4 Cloud and gap filling and image mosaicking

All Landsat 7 images acquired after May 2003 contain data gaps due to a scan-line corrector (SLC) failure within the imaging sensor. As a result approx. 22% of image data is missing. Consequently, these images are called SLC-off images.

In order to fill these regularly spaced gaps, we decided to apply a multi-temporal filling strategy, which means that the gaps in a given "Master" scene are filled with data from a different image ("Fill-scene").

This process stitches the images from the different image footprints together, creating a single image dataset for each time step. The images are therefore organized according to the quality (percentage of cloud-free pixels), and superimposed on each other so that the highest possible data coverage is achieved. "No data" areas in the datasets are translucent, and are thus filled with information from the underlying scenes.

In order to harmonize the spectral properties of the images, a color balancing is applied to the datasets.

Even though all usable images available in the USGS archive for the target years ± 1 year were used, it was not possible to generate completely cloud free image mosaics. Table 5 shows the residual cloud cover for the four time steps and two districts after classification.

Table 5. Residual no data area after SLC and cloud gap filling.

Year	1990	2000	2005	2010
Kapuas Hulu district	7%	9%	2%	9%
Malinau district	7%	7%	1%	3%

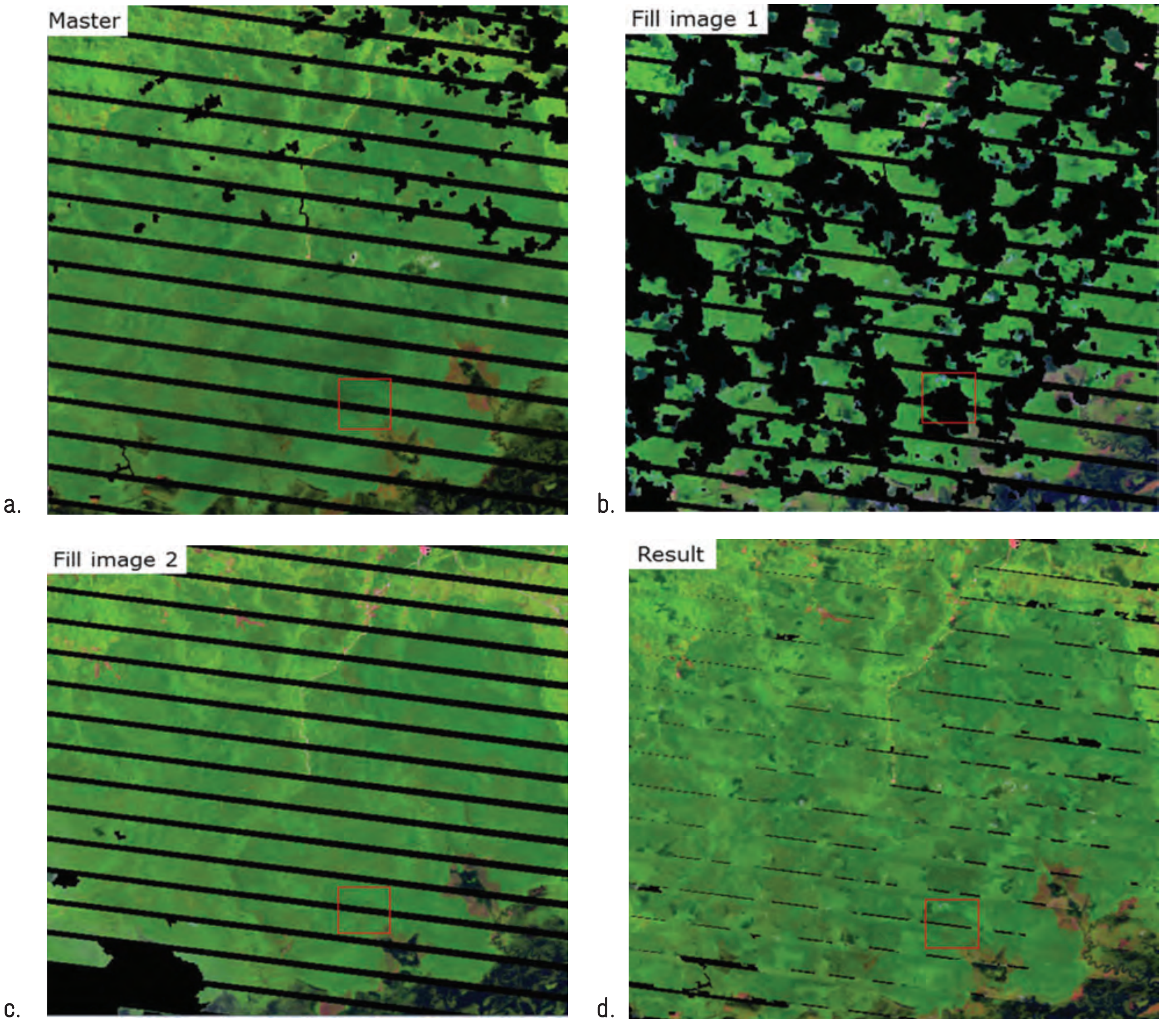

Figure 4. Example taken for the gap-filling process. A, B and C show the cloud-masked images, containing data gaps resulting from the slc-malfunction and clouds. In the fill process, the master scene is superimposed over the two fill scenes, and all no data areas are filled with data from the fill scenes.

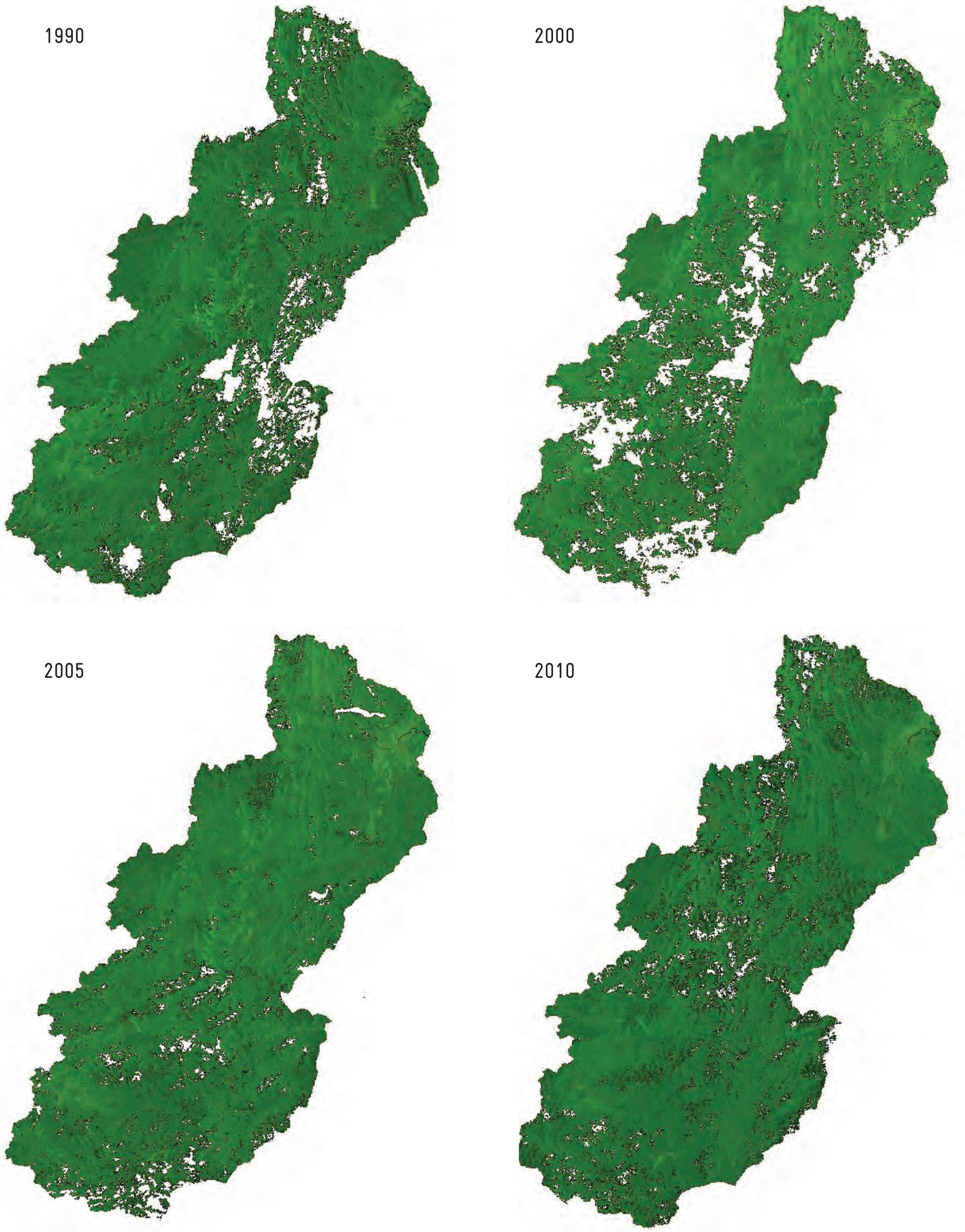

Figure 5. Image mosaics for the Malinau study area. Landsat images acquired in a time window of +1 year around the target year were used. Note that even though all available images with a cloud cover below 50% were used, a complete wall-to-wall coverage with cloud free data is not possible.

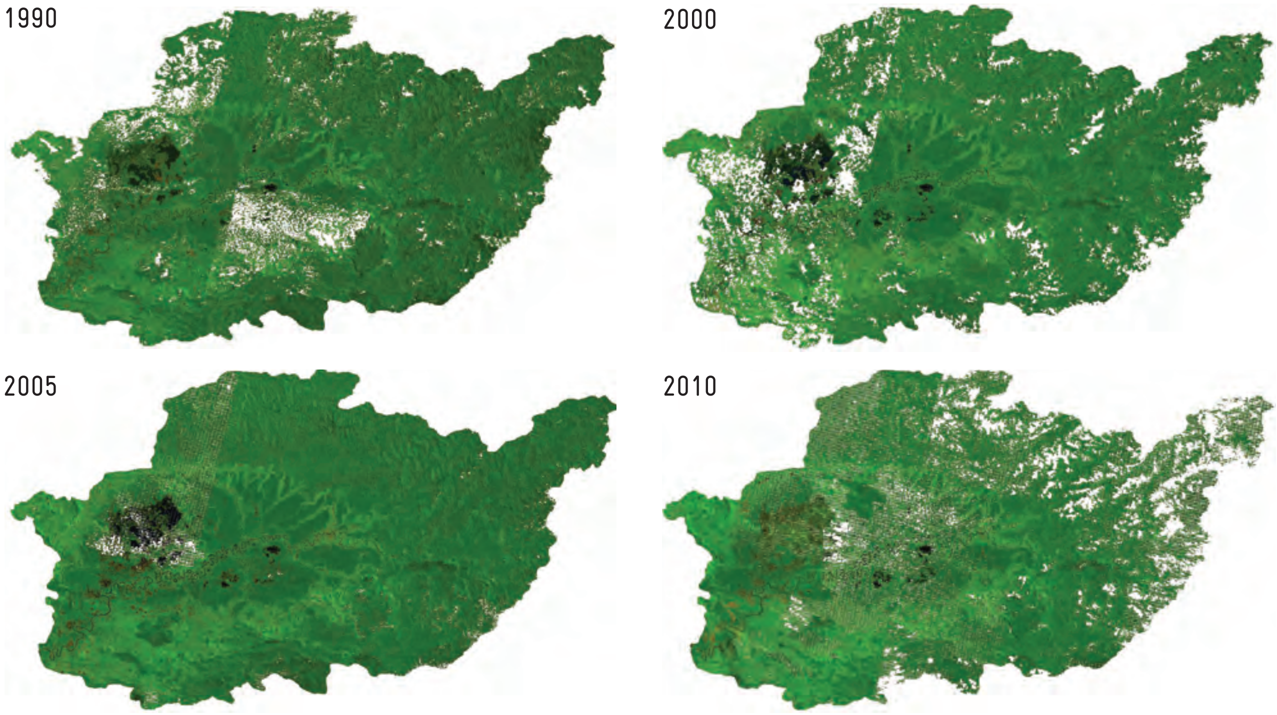

Figure 6. Image mosaics for the Kapuas Hulu district.

2.5.1.2 Mapping of logging roads

Since the spatial resolution of the used Landsat data is not sufficient to reliably detect forest degradation and distinguish Primary and logged over secondary forests (especially if the degradation took past a long time (> 1 year before the image was taken), it was decided in the project to use the logging road infrastructure as a proxy to identify secondary forests. Forests with no identifiable infrastructure or past evidence of logging activity were considered as Intact (Primary), while forests in the surrounding of infrastructure were considered as Non-intact, thus secondary.

The mapping of the logging roads was done based on the multi-temporal image mosaics for the four time steps. Logging roads mapped at an earlier time were carried over to the later time steps. Each polyline was labeled with the year when it was first mapped in order to be able to track temporal changes in the logging infrastructure (Figure 7).

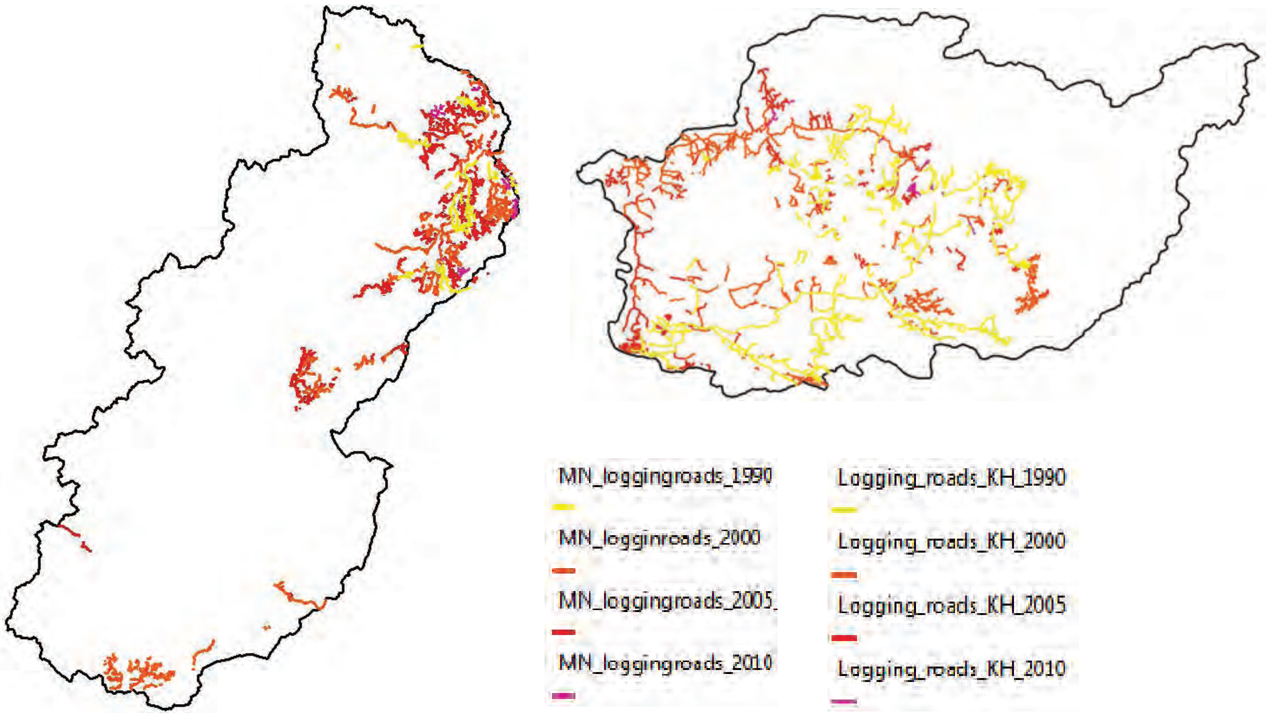

Figure 7. Logging road network for Malinau (left) and Kapuas Hulu (right), evolving over time.

The area of secondary forests was then determined by applying a buffer to the logging roads with a given buffer width. This width was determined empirically for the two districts by measuring the impact zone of forest degradation along all active logging roads in the given time step. For both districts, an impact distance of 300 m was found to be adequate, so this was used as a buffer distance (Figure 8).

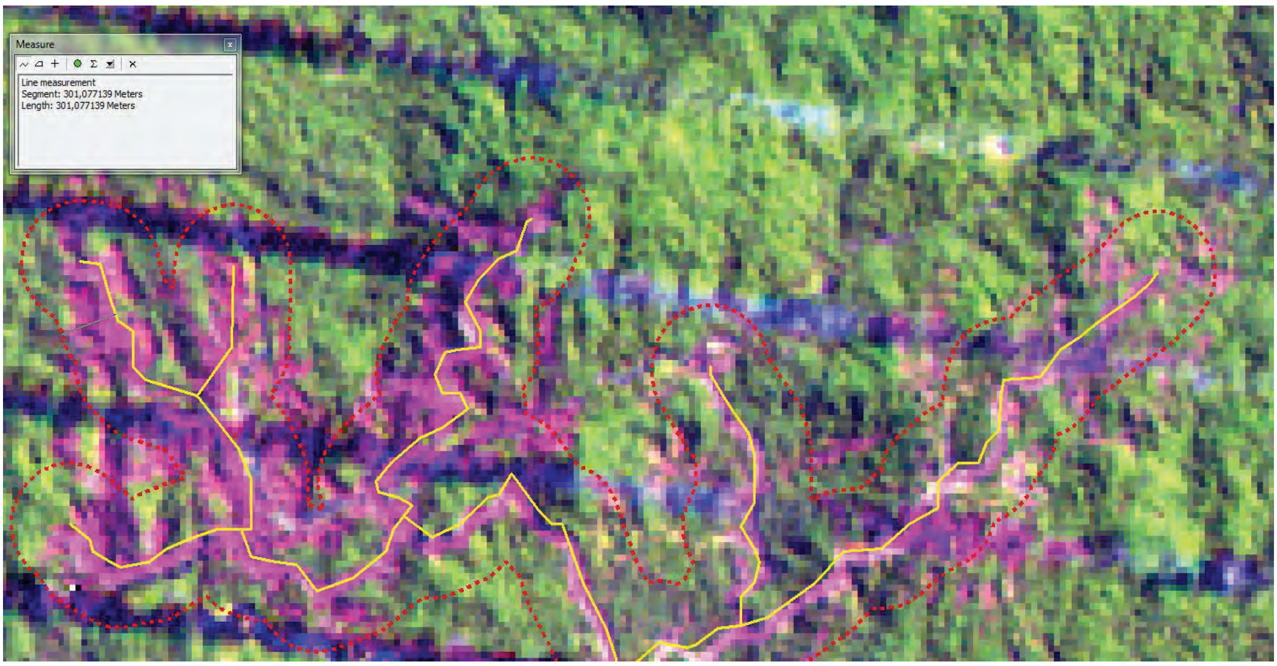

Figure 8. Measurement of impact zone of logging activity and application of a buffer to logging roads for determining Secondary forest.

2.5.1.3 Object-based image classification

For the satellite image classification a segment-based classification approach based on a predefined hierarchical rule-set was chosen. This methodology classifies spatially adjacent and groups of pixels, so called image objects, rather than individual pixels of the image and consists of three basic procedures:

- ☑ **Design of class hierarchy**: Definition of classes and inheritance rules between parent and child classes.
- ☑ **Image segmentation**: The input image raster dataset was segmented into homogeneous image objects according to their spectral characteristics.
- ☑ **Classification**: The image objects were assigned to predefined classes according to decision rules which can be based on spectral, spatial, shape, thematic or topologic criteria.

The first step in the in the classification process is the definition of the class hierarchy on the basis of the classification scheme introduced for the district level classifications (see chapter 2.2). The *e Cognition* software allows a hierarchical grouping of classes into parent and child classes, in which child classes inherit their classification rules from their parent class. In this study, the hierarchy levels were designed in accordance the FAO LCCS.

The hierarchy of the LCCS has proven to be very suitable for implementation into hierarchical rule-sets, because it is tightly adapted to remote sensing based classification tasks. Figure 9 illustrates the hierarchical structure of the classification hierarchy. On the highest level, the unclassified image objects are classified according to the presence (or absence) of vegetation cover. This decision is based on the mean NDVI value of the image objects in a binary decision rule. In the next hierarchy level only the objects classified as “Primarily vegetated” were treated and classified into “Forest” and “Non-forest”, and so on.

Decision rules for the rule-set were based on the spectral bands of the Landsat satellite images, the SRTM (Shuttle Radar Topography Mission) Digital Elevation Model (90 m resolution), as well as a Minimum Noise Fraction Transformation (MNF) of the spectral bands.

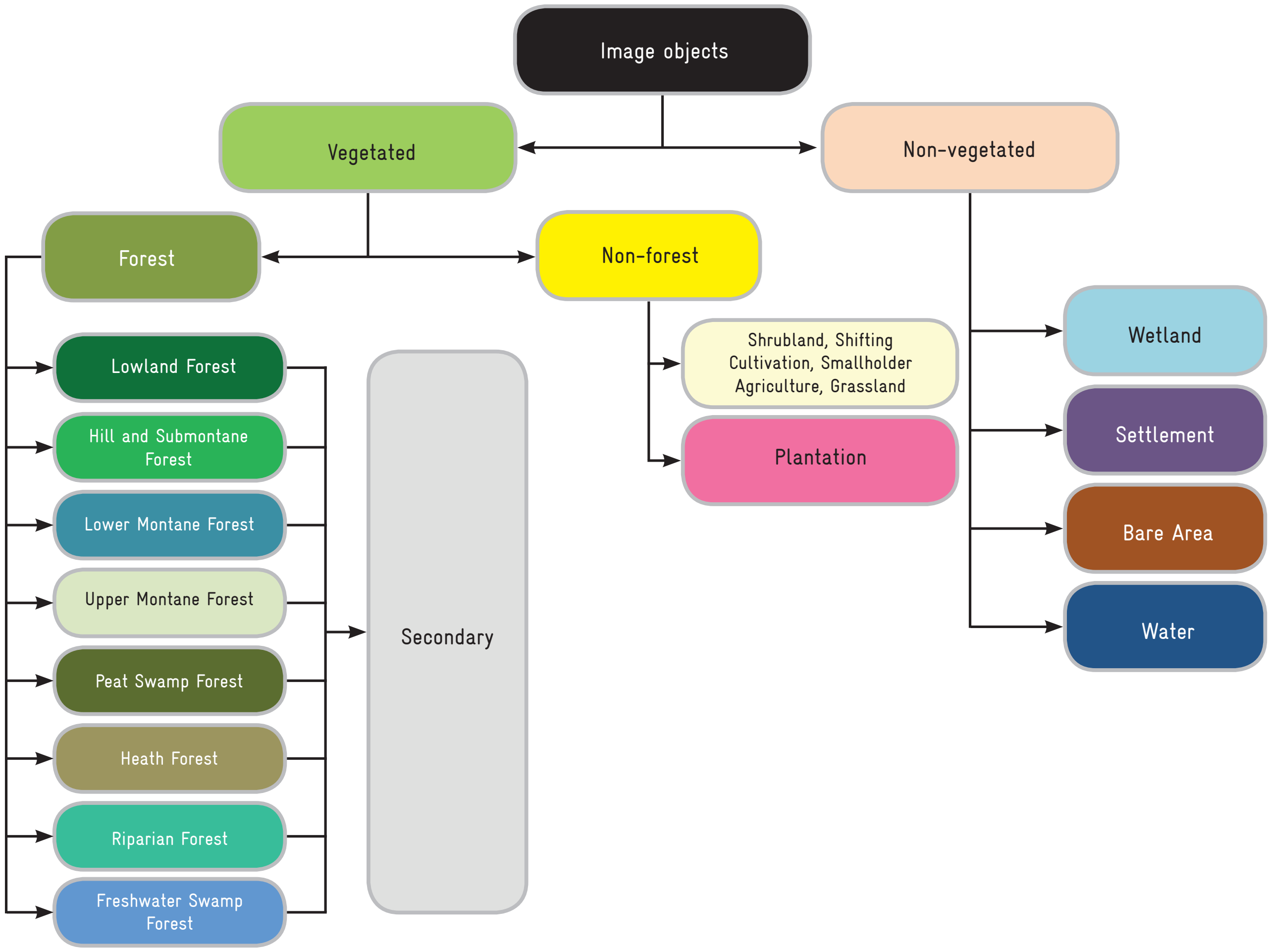

Figure 9. Class hierarchy used in the classification rule-set.

2.5.1.4 Validation/Accuracy assessment

In order to assess the quality of the land cover maps and therefore the accuracy of the study results, an accuracy assessment has been conducted. For the most recent time step 2010, validation data collected during the field survey was used. This data consisted of field plots as described in chapter 2.4, and was complemented by aerial validation plots generated based on very-high resolution aerial photos.

The accuracy assessment was done by confusion matrices and reference datasets. Based on the confusion matrices, the overall accuracy (percentage of correctly classified reference samples among all reference samples) and the Kappa Index of agreement were calculated. For the individual classes, the Producer's accuracy (the probability that a validation sample of class A is classified as class A) and the User's accuracy (the percentage of pixels classified as class A which actually are class A, among all objects classified as A). These two accuracies are correspondent to the 'error of omission' and 'error of commission'.

2.5.2 Land cover change analysis and carbon emission assessment

2.5.2.1 Land cover change detection methodology

To assess changes in biomass and carbon stock the stock difference method based on a post classification change detection method, was applied. **All change analysis, in particular the carbon change assessment and the assessment of net forest loss and deforestation rate, was conducted exclusively on areas which contain no "No data" in any of the classification time steps.** The classification results (land cover map) from two time periods are overlaid and the change vectors (from-to-changes from one class into another) between the two layers were determined.

Based on the biomass values assigned to the individual land cover classes, the change in biomass and carbon stock for each polygon was calculated. The creation of the change layer was done by a proprietary GIS routine, which is linked to a biomass database (see chapter 2.3).

Due to the high number of change vectors resulting from the intersection of two classifications (up to 24x24=576 possible change vectors) and the resulting complexity of the change map, coded labels were created that group several change vectors into meaningful classes. The change code table is shown in Table 46 in the annex.

2.5.2.2 Carbon calculation for Land cover classes

The carbon values for the different land cover classes have been calculated based on available data, which is a mixture of field data available at RSS and literature values from South East Asia (mostly the Indonesian archipelago).

For some classes, there were no carbon values available yet, in particular "Secondary Freshwater Swamp Forest", "Secondary Lower Montane Forest" and "Secondary Upper Montane Forest". In order to facilitate the assignment of a preliminary value to these classes, we calculated the percent difference between Primary and Secondary class of all other forest types, which resulted in 37%. This percentage was then subtracted from the carbon value of the Primary "Lower montane forest", "Upper montane forest" and "Freshwater swamp forest". It is suggested to collect biomass data for these missing classes during the project.

For the plantation class, individual values have been assigned for the two districts due to the fact that in Kapuas Hulu, there are only Oil Palm plantations and in Malinau there was only one plantation mapped which is likely to be Acacia.

Table 6 shows the Classification legend and the assigned carbon values. A detailed report and the sources of the carbon values used for each class is appended to this document.

Table 6. Biomass and carbon values assigned to the land cover classes.

Land cover class	Map code	AGB [t ha^{-1}]	Carbon [t ha^{-1}]
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	111	470.07	235.04
Secondary Lowland Dipterocarp Forest	112	276.60	138.30
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	121	334.39	167.19
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Upper Montane Rainforest (> 1500 m a.s.l.)	141	304.35	152.18
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Secondary Peat Swamp Forest	152	151.66	75.83
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Secondary Heath Forest	162	177.88	88.94
Riparian Forest	171	253.68	126.84
Secondary Riparian Forest	172	76.19	38.10
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Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	47.44	23.72
Plantation**	22	194.00/78.00	97.00/39.00
Temporarily Flooded Wetland	23	14.96	7.48
Settlement	24	0.00	0.00
Bare Area	3	0.00	0.00
Water	4	0.00	0.00
Gap	99	0.00	0.00

* Carbon values calculated based on relation of Primary and Secondary forest values for all other classes

** Individual values for Kapuas Hulu and Malinau. In Kapuas Hulu, all large plantations are in fact "Oil Palm plantations" while in Malinau, the only plantation mapped was an Acacia plantation.

2.5.2.3 Calculation of the deforestation rate for the study area

In order to determine the deforestation rate all forest type classes were combined into a single "Forest" class and the other land cover classes (Water, Shrubs, Bare Area, Wetland, Plantation) were merged into a single "Non-forest" class, which corresponds to Level 1 of the classification scheme (see chapter 2.2). A new Forest/Non-forest data layer for each point in time was created. These classification layers were then overlaid for the four change periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010, in order to determine the area change of the forest class and calculate the deforestation rate (% yr^{-1}) in relation to the baseline forest area identified during the first point in time. **"No data" values in any of the classifications were excluded from analysis.**

The deforestation rate was then calculated by the equation:

$$r = ((A2-A1) * A1^{-1}) * \Delta t^{-1}$$

r = Deforestation rate

A1 = Forest area (ha) Time Step 1

A2 = Forest area (ha) Time Step 2

Δt = Time difference (yr) between the time steps

2.5.2.4 Identification of drivers of deforestation

For the identification of drivers of deforestation, the land cover change maps were quantitatively analyzed. All areas which change from a forest class into a non-forest class, thus representing deforestation, were selected for the time steps 1990-2000, 2000-2005, 2005-2010 and 1990-2010. Then, the change vectors (from-to change) were used to identify the land cover class into which the forest has been converted. Area statistics were then calculated for each land cover class, as well as percentage of total deforestation.

3 Results

3.1 Malinau district

3.1.1 District wide Land use/Land cover maps

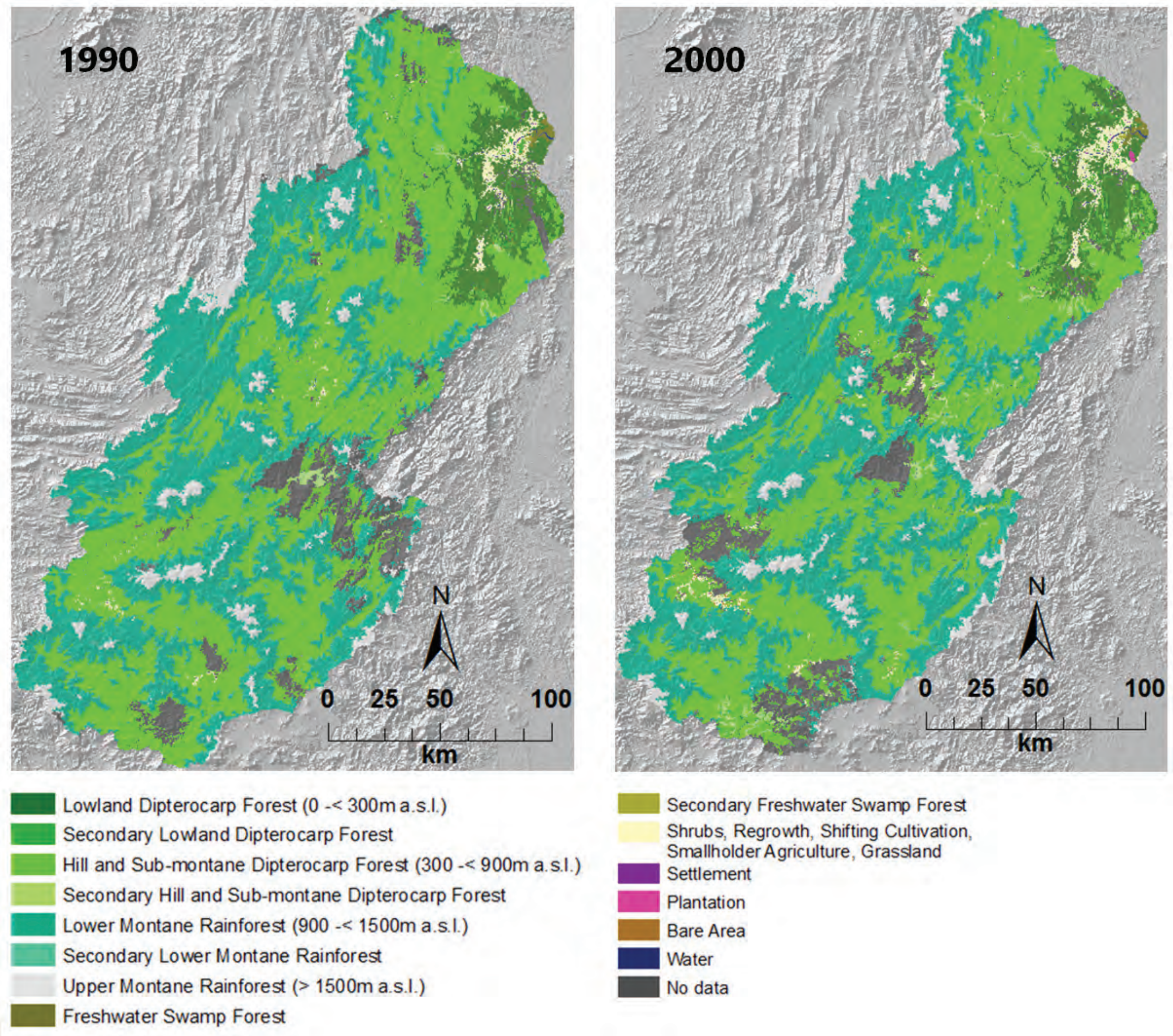


Figure 10. Land cover maps of Malinau for the time steps 1990 and 2000.

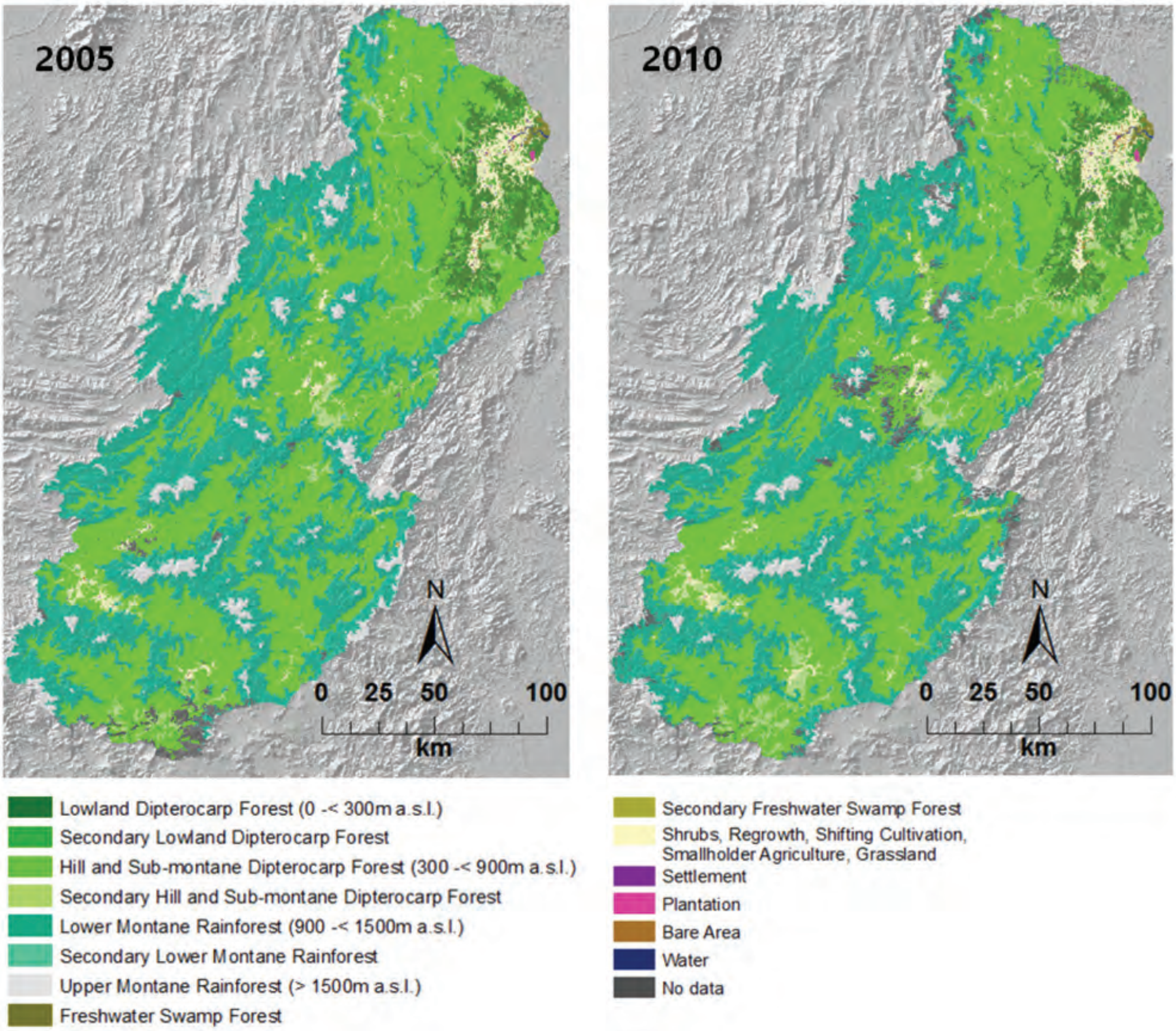


Figure 11. Land cover maps of Malinau for the time steps 2000 and 2005.

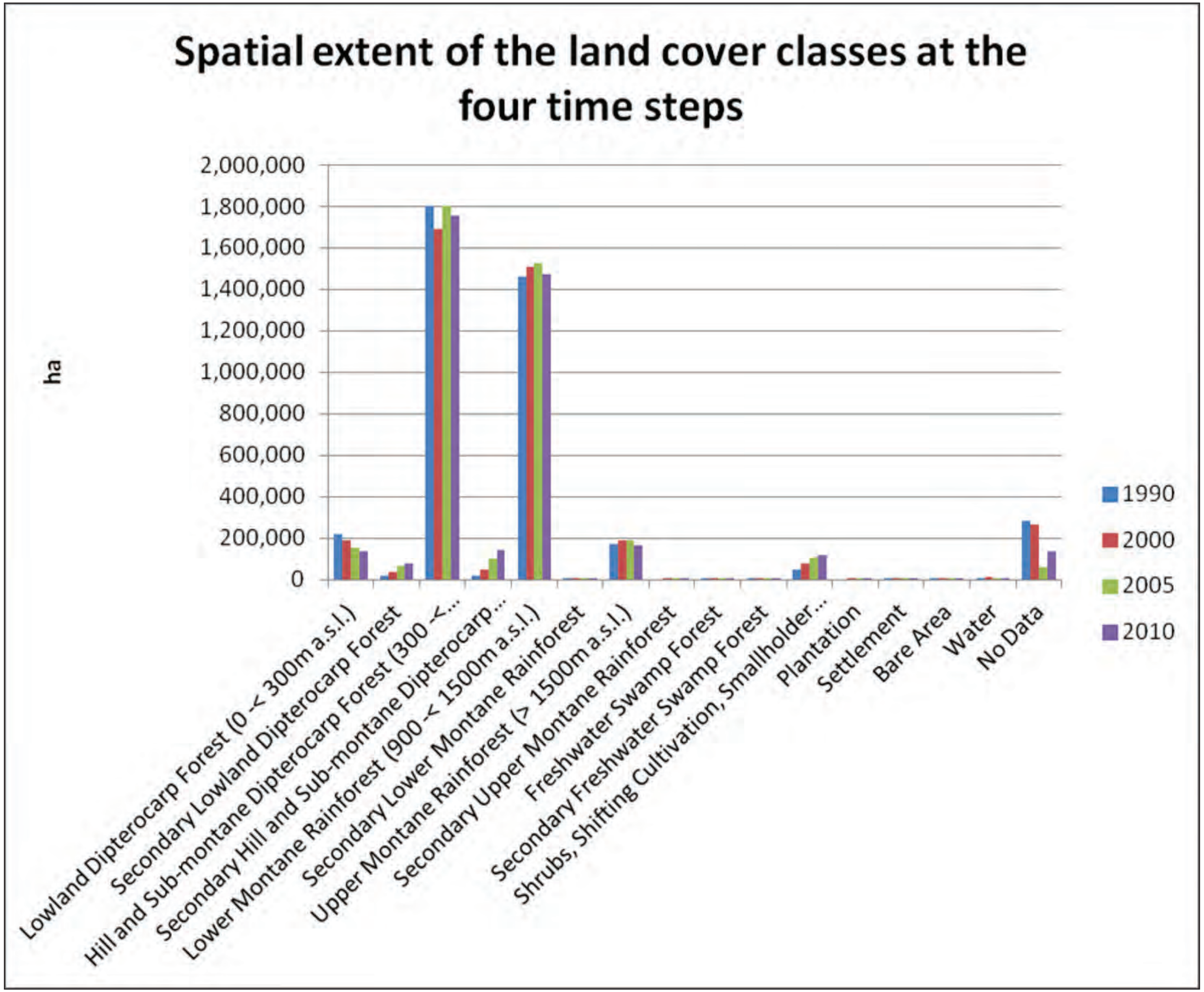


Figure 12. Spatial extent of the land cover classes at the four time steps.

Table 7. Spatial extent of the the land cover classes at the four time steps.

Land Cover Class	1990	2000	2005	2010
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	216,241	187,563	150,932	135,775
Secondary Lowland Dipterocarp Forest	18,086	37,968	66,788	75,512
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	1,800,727	1,690,776	1,800,261	1,758,102
Secondary Hill and Sub-montane Dipterocarp Forest	15,611	47,664	100,642	139,150
Lower Montane Rainforest (900 -< 1500 m a.s.l.)	1,458,126	1,510,811	1,526,199	1,472,127
Secondary Lower Montane Rainforest	168	3,153	5,577	8,990
Upper Montane Rainforest (> 1500 m a.s.l.)	173,526	188,035	187,246	164,876
Secondary Upper Montane Rainforest	0	186	95	110
Freshwater Swamp Forest	5,320	5,174	4,946	4,832
Secondary Freshwater Swamp Forest	615	570	203	200
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	47,076	75,450	107,173	117,287
Plantation	0	1,029	911	1,045
Settlement	224	363	462	366
Bare Area	1,551	4,394	6,486	5,880
Water	7,003	9,551	7,215	6,313
No data	280,757	262,425	59,747	134,210

3.1.2 Validation of the land cover maps

An accuracy assessment was conducted for all four land cover maps, as described in chapter 2.5.1.4. Table 8 shows the overall accuracy and Kappa Index for the three observation times. The complete confusion matrices are given in Table 38, Table 39, Table 40 and Table 41 the Annex.

Table 8. Overall accuracy and Kappa index for the four land cover classifications of Malinau district.

	1990	2000	2005	2010
Overall accuracy	88.77%	86.47%	84.58%	79.62%
Kappa	0.87	0.85	0.83	0.69

These results indicate a high accuracy throughout all time steps.

In order to assess the classification accuracy for the individual classes, the producer's and user's accuracy were calculated (correspondent to the 'error of omission' and the 'error of commission'). Table 9 and Table 10 list the accuracies per class for the three observation times, which are visualized in Figure 13 and Figure 14.

Table 9. Producer's accuracy for the land cover classification of Malinau.

Producer's accuracy	1990	2000	2005	2010
Bare area	90.91%	84.85%	86.49%	100.00%
Water	84.21%	92.45%	88.24%	100.00%
Shrubland, Agriculture etc.	77.97%	70.69%	71.21%	90.32%
Timber Plantation	-	100.00%	97.87%	0.00%
Settlement	100.00%	100.00%	84.09%	0.00%
Dryland Forest	95.51%	86.00%	91.89%	93.20%
Secondary Dryland Forest	90.28%	68.97%	69.12%	55.32%
Freshwater Swamp Forest	97.30%	97.78%	89.13%	0.00%
Secondary Freshwater Swamp Forest	78.33%	86.00%	97.78%	-

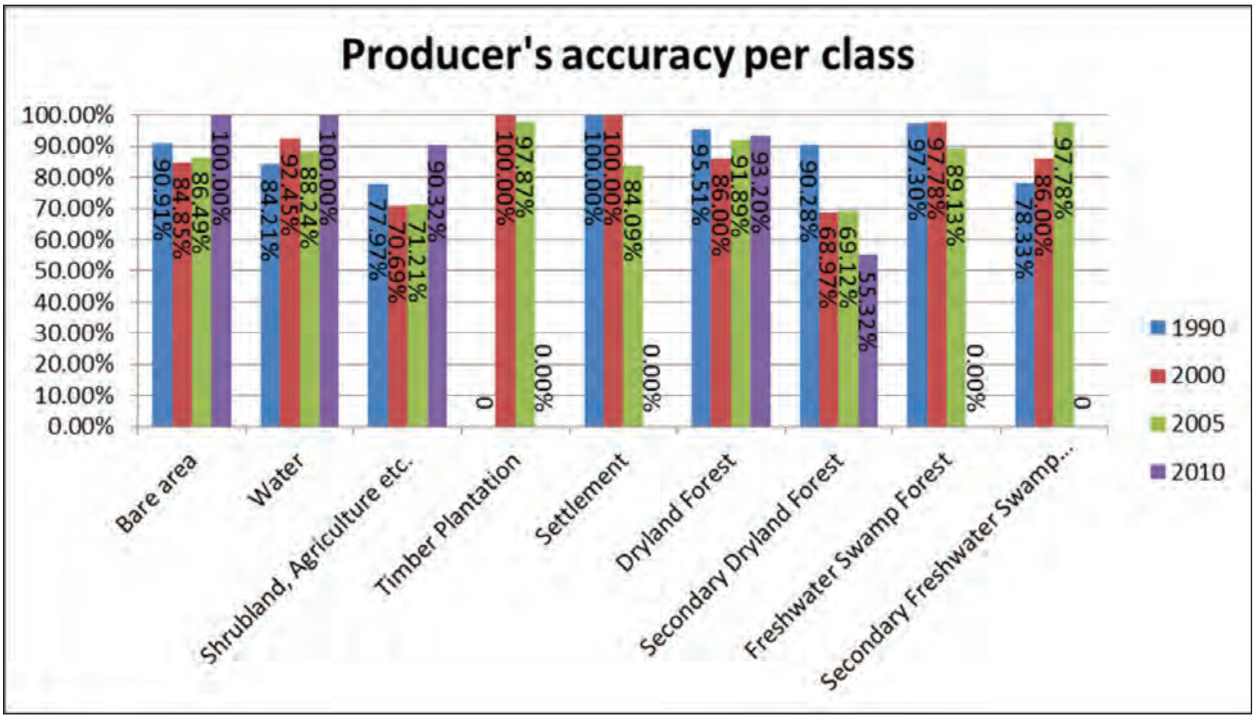


Figure 13. Producer's accuracy for the land cover classification of Malinau.

Since the validation samples for the different dryland forest classes ("Lowland Forest", "Hill and Submontane Forest", "Lower Montane Forest" and "Upper Montane Forest") were distinguished only by the elevation range, which could not be identified by the independent image interpreter, all dryland forest samples were combined into "Dryland Forest" and "Secondary Dryland Forest", according to their degradation status.

The Producer's accuracy represents the percentage of validation samples of each class correctly classified into this class, and corresponds to the error of omission, i.e. the underestimation of the class.

Producer's accuracy remained very high with values around 85% or more in all four land cover maps for the classes "Bare Area", "Water", "Settlement", "Dryland Forest", and "Primary Freshwater Swamp

Forest". The "Plantation" class was also very accurately classified, however, it was absent in the 1990 map and for the 2010 map, there have been no validation samples. The class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" was classified with a slightly lower producer's accuracy of 78% (1990), 70.7% (2000) and 71.2% (2005) in the first three time steps, but with a very high accuracy of 90.3% in 2010. "Secondary Dryland Forest" was classified with a very high producer's accuracy in 1990, but with lower accuracies in the following three time steps. This reflects the difficulty in detecting forest degradation long after the logging happened, when the forest canopy closes again and the degradation is thus not clearly visible to the interpreter anymore. "Secondary Freshwater Swamp" reached a producer's accuracy of 78.3% in 1990, and higher producer's accuracies of 86% (2000) and 97.8% (2005) in the later time steps.

Table 10. User's accuracy for the land cover classification of Malinau district.

User's accuracy	1990	2000	2005	2010
Bare area	80.00%	59.57%	64.00%	14.29%
Water	96.00%	100.00%	91.84%	80.00%
Shrubland, Agriculture etc.	100.00%	82.00%	94.00%	65.12%
Timber Plantation	-	100.00%	92.00%	0.00%
Settlement	76.60%	78.00%	74.00%	-
Dryland Forest	92.39%	95.56%	77.27%	88.39%
Secondary Dryland Forest	94.20%	88.89%	97.92%	86.67%
Freshwater Swamp Forest	72.00%	88.00%	82.00%	-
Secondary Freshwater Swamp Forest	94.00%	86.00%	88.00%	

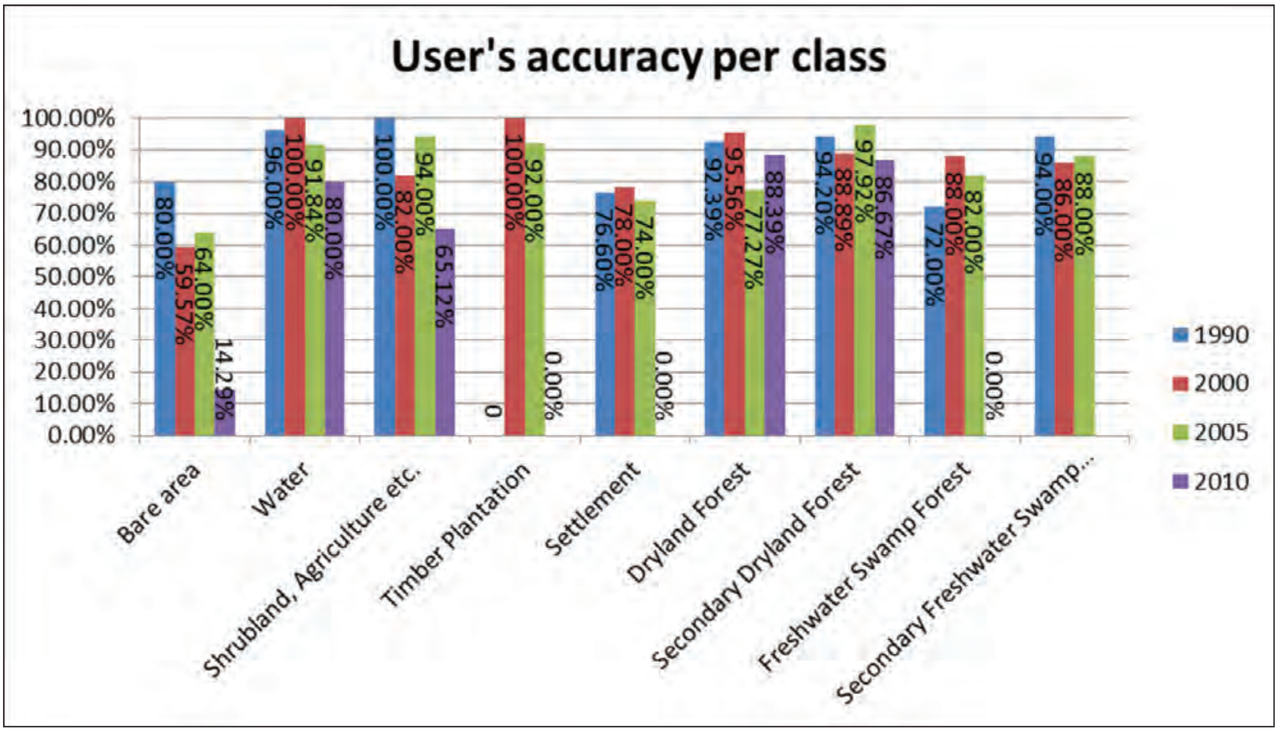


Figure 14. User's accuracy for the land cover classification of Malinau.

No validation samples were available for the 2010 time steps for the classes "Settlement", "Freshwater Swamp Forest" and "Secondary Freshwater Swamp Forest".

The user's accuracy represents the percentage of validation samples classified as a certain class which actually belong to this class, among all samples classified as this class. This equals to the 'error of commission', i.e. the overestimation of the class.

Primary "Dryland Forest" was classified with very high user's accuracy for the time steps 1990 (92.2%), 2000 (95.56%) and 2010 (88.4%), and with a slightly lower user's accuracy in 2005 (77.27%). This means a slight overestimation of "Dryland Forest" in the 2005 map. All classifications reached a high user's accuracy for "Secondary Dryland Forest", with 94.2% (1990), 88.9% (2000), 97.9% (2005) and 86.67% (2010), respectively. "Freshwater Swamp Forest" was overestimated in the 1990 map, with an user's accuracy of 72%, i.e. 28% more validation samples were classified as "Freshwater Swamp Forest" than actually belonged to this class. In 2000, "Freshwater Swamp Forest" reached a higher user's accuracy (88%) and 82% in 2005. For 2010, no validation samples were available for this class. "Secondary Freshwater Swamp" was classified with very high user's accuracy in all time steps, with 94%, 86% and 88%, respectively.

"Settlement" was slightly overestimated in all three time steps which had validation samples, with an user's accuracy of 76% (1990), 78% (2000) and 74% (2005). For 2010, there were no validation samples available. "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" was classified very accurately in the 1990 map (100%) and 2005 (94%), and with a high user's accuracy in 2000 (82%). In the 2010 map, this class was overrepresented, which is expressed in a low user's accuracy of 65.1%, i.e. there were 35% more samples classified as "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". "Water" was classified with a very high user's accuracy in the first three time steps, with 96% (1990), 100% (2000) and 91.8% (2005), and a slight overestimation in 2010 with 80% user's accuracy. "Plantation" was again very accurately classified in 2000 (100%) and 2005 (92%). In the map for the year 1990, this class was not existent, and for 2010, no validation samples for this class were available. "Bare area" was overestimated in all classification time steps, reaching user accuracies of 80% in 1990, 59.6% in 2000, 64% in 2005 and only 14.3% in 2010.

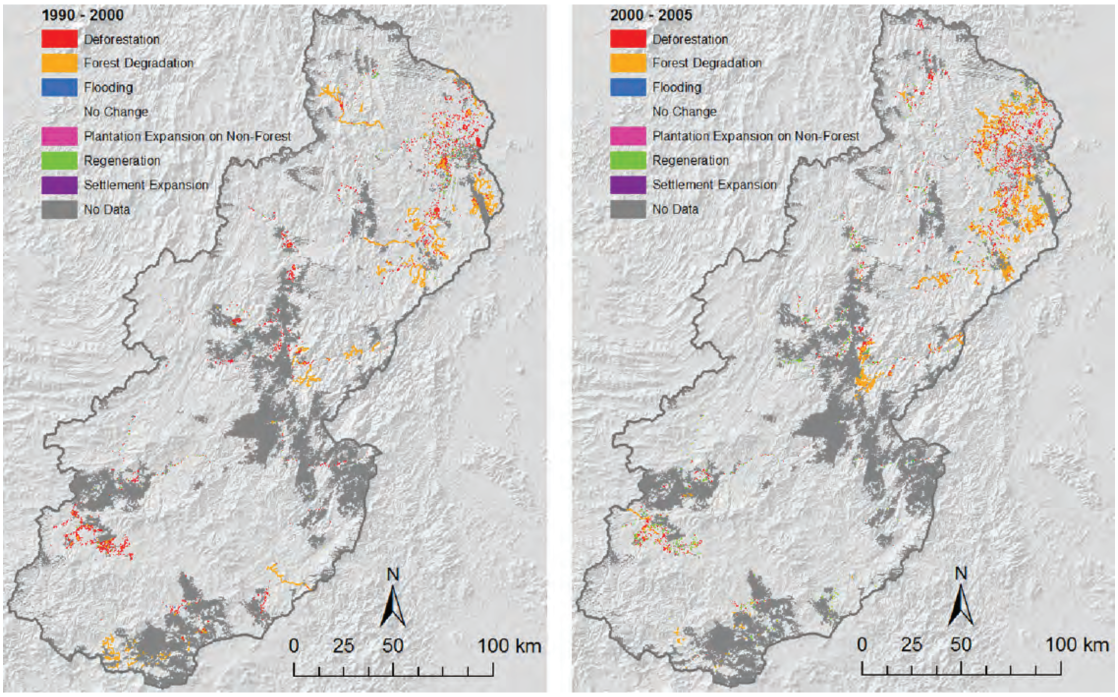


Figure 15. Land cover change maps of Malinau district for the time periods 1990-2000 and 2000-2005.

3.1.3 Land cover change assessment

The change detection was performed for the four different combinations possible with four observation times: 1990-2000, 2000-2005, 2005-2010, and the overall change 1990-2010. The resulting maps are presented in Figure 16 and Figure 16. **Areas, which had no data in any of the input classification layers, were not considered in this analysis.**

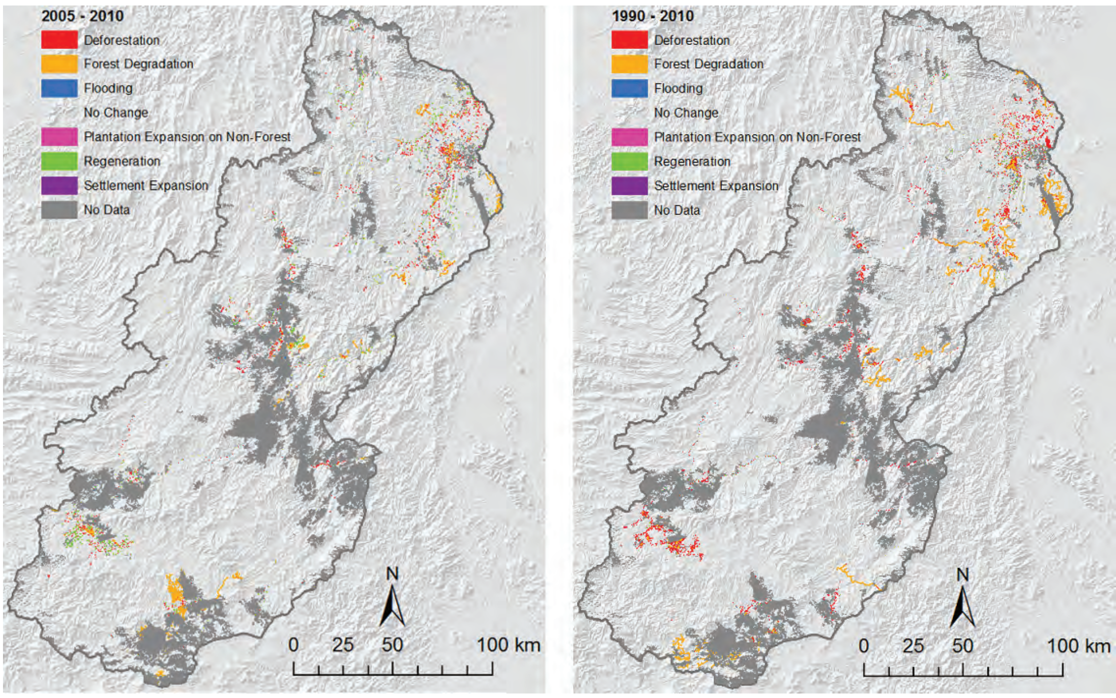


Figure 16. Land cover change maps of Malinau district for the time periods 2005-2010 and 1990-2010.

Table 11 shows the results quantitative analysis of change processes for the four time periods. Over all time periods investigated, as well as the overall investigation period, Malinau only experienced very minor land cover change. Between 1990 and 2000, 97.2% of the investigated area showed "No Change", between 2000 and 2005, 96.55% remained unchanged and between 2005 and 2010, 97.8% experienced "No Change". This is reflected also by the results for the overall investigation period 1990-2010 with 93.2% of the investigated area unchanged.

The most dominant land cover change process in Malinau over all change periods was "Forest degradation": Between 1990 and 2000, 50,882 ha or 1.5% of the overall investigated area were affected, between 2000 and 2005 another 65,331 ha (1.91%) and between 2005 and 2010 29,111 ha (0.85% of the investigated area). In the overall investigation period 1990-2010, 4.66% or 159,079 ha of the investigated area was affected by "Forest Degradation".

"Deforestation" was the second most dominant change process in Malinau district in all three individual investigation periods 1990-2000, 2000-2005 and 2005-2010, as well as in the overall investigation period 1990-2010. Between 1990 and 2000, 38,015ha or 1.1% of the investigated area was affected by "Deforestation", between 2000 and 2005 another 35,580 ha or 1.04%. Even though this figure is almost similar between the two periods, the reader is reminded that almost the same area has been deforested in the two periods in only 50% of time in the second (10 years against 5 years). In the third period 2005-2010, another 25,400 ha or 0.74% of the investigated area have been affected by "Deforestation". In the overall investigation period, 64,813 ha have been subject to "Deforestation".

The third most dominant land cover change process in Malinau was "Regeneration", the growth of new secondary forest. Between 1990 and 2000, 5,664 ha or 0.17% of the investigated area showed "Regeneration", which was increased in the following period 2000-2005 to 15,976 ha (0.47%) and then to 19,076 ha (0.56%) between 2005 and 2010. In the overall investigation period 1990-2010, 6,572 ha or 0.19% were subject to regeneration in comparison to the baseline year.

Table 11. Change processes in Malinau in the four time periods investigated. The percentage was calculated based on the area of the change process in relation to the total investigated area. Please note that "Plantation development on Non-Forest" only considers area change on Non-Forest in this table. Therefore, the overall change period 1990-2010 cannot be directly compared to the change area of this process in the individual change periods.

Change process	1990 - 2000	2000 - 2005	2005 - 2010	1990 - 2010
	Ha %	Ha %	Ha %	Ha %
Deforestation	38,015 1.11%	35,580 1.04%	25,400 0.74%	64,813 1.90%
Flooding	972 0.03%	812 0.02%	774 0.02%	448 0.01%
Forest Degradation	50,882 1.49%	65,331 1.91%	29,111 0.85%	159,079 4.66%
No Change	3,317,599 97.20%	3,295,412 96.55%	3,338,739 97.82%	3,182,108 93.23%
Plantation Expansion on Non-Forest	6 0.00%	0 0.00%	121 0.00%	5 0.00%

Table 11. (Continued)

Change process	1990 - 2000	2000 - 2005	2005 - 2010	1990 - 2010
	Ha %	Ha %	Ha %	Ha %
Regeneration	5,664 0.17%	15,976 0.47%	19,076 0.56%	6,572 0.19%
Settlement growth	137 0.00%	178 0.01%	71 0.00%	250 0.01%
Total	**3,413,275**	**3,413,289**	**3,413,292**	**3,413,276**

Table 12 and Figure 17 show the area change per class for the three change periods 1990-2000, 2000-2005 and 2005-2010, as well as the overall investigation period 1990-2010.

The largest loss in area was observed in Primary "Hill an Submontane Forest" with 49,163 ha lost between 1990 and 2000, 46,439 ha lost between 2000 and 2005 and another 26,636 ha lost between 2005 and 2010. Overall, 122,228 ha or 7.6% of the 1,612,332 ha of Primary "Hill and Submontane Forest" of 1990 have been lost between 1990 and 2010. While the parts of these losses were the result of deforestation (i.e. conversion into other land covers), the majority was in fact affected by selective commercial logging, i.e. forest degradation. This is reflected in the land cover change statistics by the increase in area of "Secondary Hill and Submontane Forest". Between 1990 and 2000, the area of "Secondary Hill and Submontane Forest" increased by 30,020 ha, between 2000 and 2005 by 42,491 ha and between 2005 and 2010 by another 25,301 ha. In the overall investigation period, the area of "Secondary Hill and Submontane Forest" increased by 97,782 ha or 261% of the 11,517 ha of the area of this class in 1990. This shows that 80% of the Primary "Hill and Submontane Forest" lost were subject to logging and were consequently converted to "Secondary Hill and Submontane Forest".

The class with the second most intense loss in area was Primary "Lowland Forest". Between 1990 and 2000, the area of this class was reduced by 29,499 ha, then by 39,916 ha between 2000 and 2005 and another 12,662 ha between 2005 and 2010. Overall, 82,076 ha or 39.7% of the original Primary "Lowland Forest" area of 206,898 ha were lost between 1990 and 2010. At the same time, the class "Secondary Lowland Forest" experienced increases in area in all three change periods: From 1990 to 2000, its area increased by 17,925 ha, between 2000 and 2005 by 24,944 ha and from 2005 to 2010 by another 7,689 ha. In the overall investigation period, the area of "Secondary Lowland Forest" increased by 50,558 ha or 304% of the original area of 16,637 ha of the year 1990, i.e. 61.6% of the Primary "Lowland Forest" lost was subject to "Forest degradation" and 38.4% was converted into other land covers (i.e. subject to deforestation).

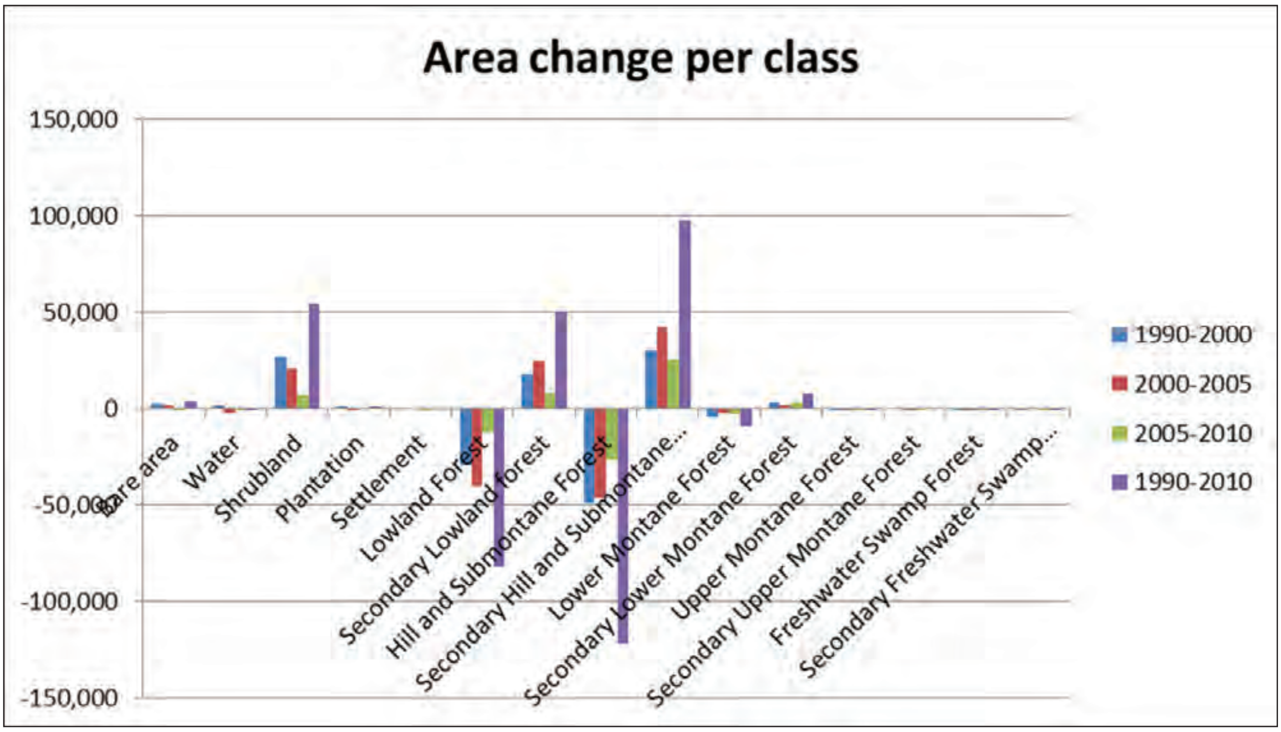


Figure 17. Area change per class and time period in Malinau district.

Primary "Lower Montane forest" was affected in a much less intense manner. Between 1990 and 2000, the area of this class decreased by 4,269 ha, then between 2000 and 2005 by 1,954 ha and another 3,060 ha from 2005 until 2010, amounting to a total loss of 9,283 ha in the overall investigation period 1990-2010. At the same time, "Secondary Lower Montane Forest" increased by 2,829 ha (1990-2000), 1,891 ha (2000-2005) and 3,163 ha (2005-2010), amounting to an increase in area between 1990 and 2010 of 7,884 ha or a factor of 45 in comparison to the original area of this class in 1990. 85% of the loss of Primary "Lower Montane Forest" were due to degradation and only 15% due to deforestation.

The "Upper Montane Forest" class experienced almost no change in the investigation period.

Apart from the forest, the class "Shrubland, Shifting Cultivation, Smallholder Agrculture, Grassland" experienced the most significant changes. Between 1990 and 2000 an increase in area of 26,830 ha was observed, then an increase of 20,472 ha between 2000 and 2005 and another increase of 7,146 ha between 2005 and 2010. In the overall investigation period 1990-2010, the area of "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" increased by 54,448 ha or 127% of its original area of 42,791 ha, i.e. the area in agricultural use more than doubled.

"Bare Area", which in Malinau can be mostly attributed to coal mining activities, increased by 2,301 ha from 1990 to 2000, by another 1,702 ha between 2000 and 2005 and slightly decreased by 174 ha from 2005 to 2010. Overall, "Bare Area" experienced an increase in area of 3,830 ha or 270% of its original area of 1,414 ha since 1990.

All other land cover classes experienced only minor to no changes.

Table 12. Area change per class and time period in Malinau district.

Land Cover	1990-2000	2000-2005	2005-2010	1990-2010
Bare area	2,301	1,702	-174	3,830
Water	2,081	-2,544	-707	-1,170
Shrubland	26,830	20,472	7,146	54,448
Plantation	1,005	-111	130	1,025
Settlement	135	84	-72	147
Lowland Forest	-29,499	-39,916	-12,662	-82,076
Secondary Lowland forest	17,925	24,944	7,689	50,558
Hill and Submontane Forest	-49,163	-46,430	-26,636	-122,228
Secondary Hill and Submontane Forest	30,020	42,461	25,301	97,782
Lower Montane Forest	-4,269	-1,954	-3,060	-9,283
Secondary Lower Montane Forest	2,829	1,891	3,163	7,884
Upper Montane Forest	-87	-2	-1	-90
Secondary Upper Montane Forest	83	-4	-4	75
Freshwater Swamp Forest	-146	-227	-113	-485
Secondary Freshwater Swamp Forest	-45		-3	-415

3.1.4 Deforestation rate

Deforestation rates were calculated as described in chapter 2.5.2.3. The calculation of the forest cover for the four time steps 1990, 2000, 2005 and 2010, the **calculation of forest loss and the annual deforestation rate was based only on areas where none of the classifications contain "No data" areas**, in order to make the outcomes of the individual time periods comparable. Figure 18 shows the forest cover maps for the four time steps 1990, 2000, 2005 and 2010, and Figure 19 shows the resulting deforestation maps for the time periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010.

Table 13. Spatial extent of forest and non-forest areas in Malinau district.

Malinau	1990	2000	2005	2010
Forest	3,361,908	3,329,570	3,309,968	3,303,645
Non-Forest	51,368	83,720	103,323	109,648

Table 14. Net forest loss in Malinau district.

Net forest loss	1990-2000	2000-2005	2005-2010	1990-2010
ha	-32,351	-19,590	-6,338	-58,279
%	-0.96%	-0.59%	-0.19%	-1.73%

Forest area in Malinau was reduced by 32,351 ha from 3,361,908 ha to 3,329,570 ha, or approximately 1% in the ten years from 1990 to 2000 (Table 13 and Table 14). Of the 3,329,570 ha forest area in 2000, another 19,590 ha were lost until 2005, which equals to a net forest loss of 0.59% in this five year period. Between 2005 and 2010, forest loss was reduced and amounted to 6,339 ha or 0.19% of the 3,309,968 ha of 2005.

In total, Malinau lost 109,648 ha of forest cover from 1990 to 2010, which equals to a net forest loss of 1.73% of the 3,361,908 ha of forest in 1990.

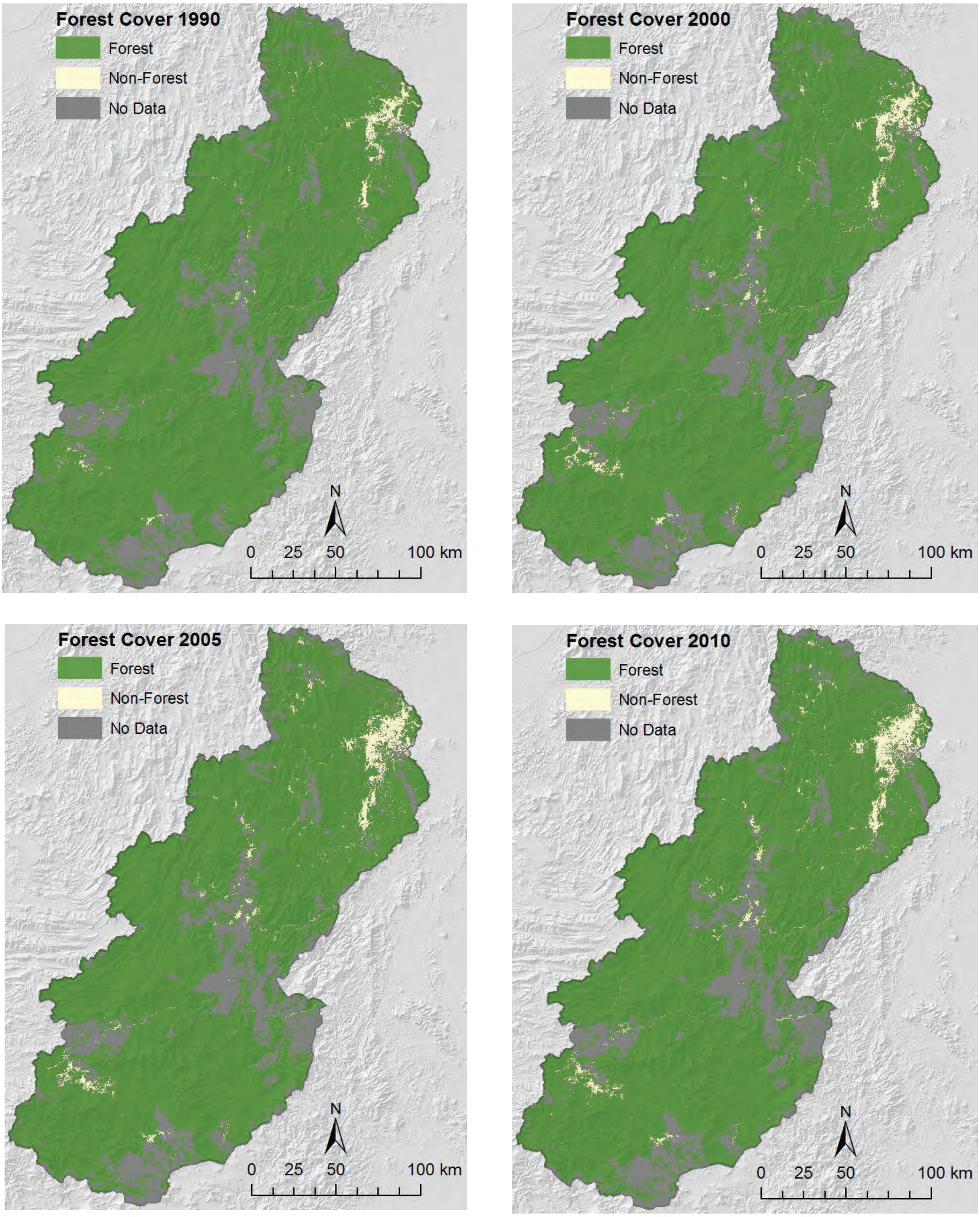


Figure 18. Forest cover maps of Malinau district for 1990, 2000, 2005 and 2010.

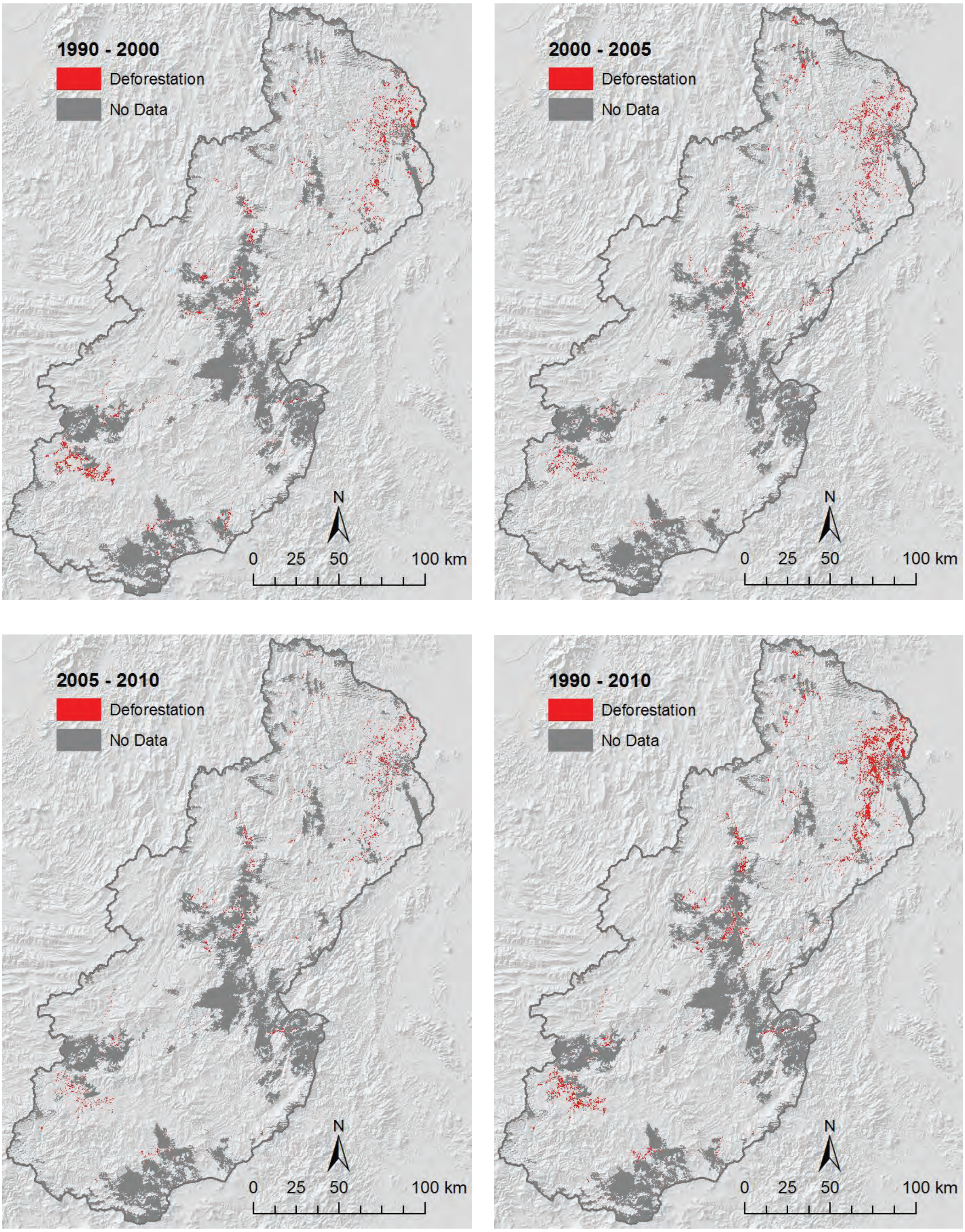


Figure 19. Deforestation maps.

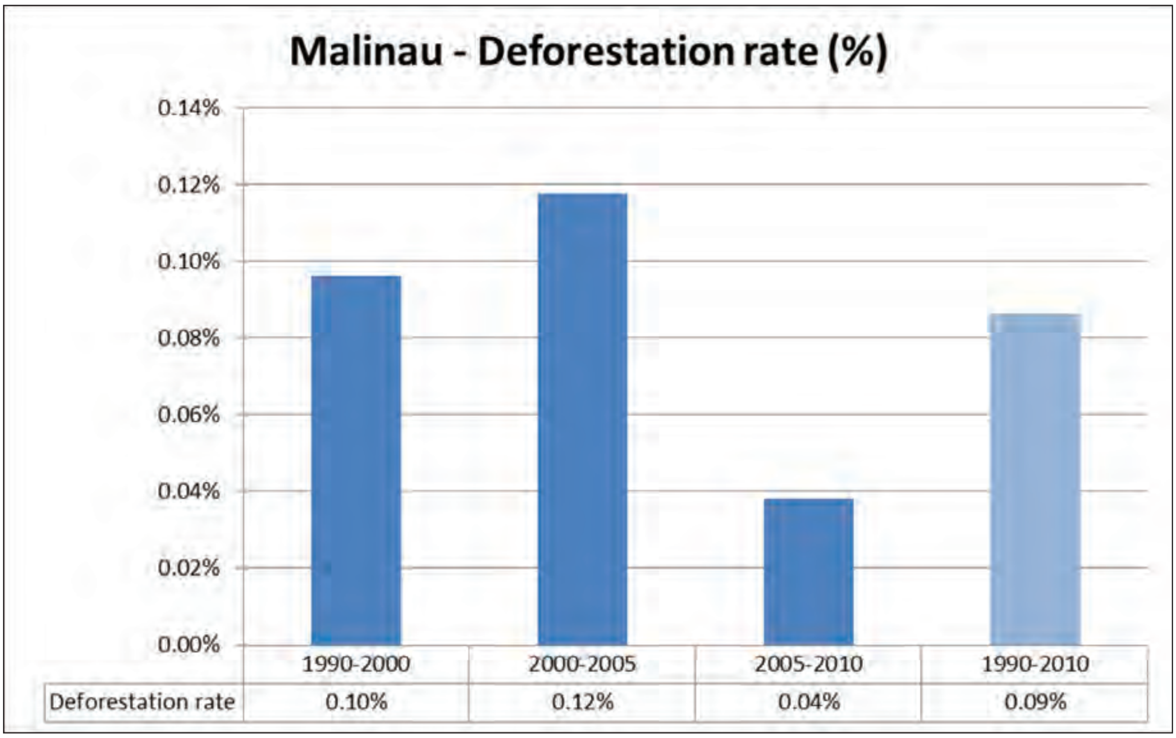


Figure 20. Deforestation rate [% yr-1] in the three change periods and the overall time period.

Table 15. Deforestation rate [% yr-1] in Malinau district.

	1990-2000	2000-2005	2005-2010	1990-2010
Deforestation rate	0.096%	0.118%	0.038%	0.087%

Table 15 and Figure 20 show the annual deforestation rate for Malinau for the three change periods 1990- 000, 2000-2005 and 2005-2010, as well as the overall annual deforestation rate for the investigation period 1990-2010. The deforestation rate in Malinau district is very low over the entire evaluation period, being 0.10% yr^{-1} (1990-2000), 0.12 yr^{-1} (2000-2005), 0.04 yr^{-1} (2005-2010) and 0.09 yr^{-1} in the overall time period 1990-2010. The deforestation in Malinau is considered to be frontier deforestation, with the area in anthropogenic use slowly expanding.

3.1.5 Drivers of deforestation

This chapter analyses the drivers for deforestation by the use of the change detection dataset. All areas which were identified as "Deforestation" in the dataset were analyzed for the land classes into which they were converted, in order to find out the reasons for their conversion. The reader is reminded that this analysis is based on gross deforestation area, excluding any forest regeneration. This is in contrast to the net forest loss described in chapter 3.1.4, therefore the figures on forest loss cannot be directly compared.

In Malinau district, total gross deforestation amounted 38,016 ha between 1990 and 2000 or on average 3,802 ha yr^{-1}. Between 2000 and 2005, another 35,581 ha have been deforested (i.e. annual gross deforestation was increased to 7,116 ha yr^{-1}) and between 2005 and 2010 it was again reduced to 25,401 ha (or 5080 ha yr^{-1}). Overall, 64,814 ha of forest land have been subject to deforestation between 1990 and 2010 (Table 16).

Table 16. Deforestation and its drivers in Malinau district.

Driver	1990-2000	2000-2005	2005-2010	1990-2010
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	30,854 81.16%	31,660 88.98%	22,564 88.83%	59,356 91.58%
Plantation	999 2.63%	107 0.30%	69 0.27%	1,020 1.57%
Settlement	11 0.03%	0 0.00%	0 0.00%	7 0.01%
Bare Area	2,806 7.38%	2,388 6.71%	1,497 5.89%	2,591 4.00%
Water	3,346 8.80%	1,425 4.01%	1,270 5.00%	1,838 2.84%
Total deforestation	**38,016**	**35,581**	**25,401**	**64,814**

Between 1990 and 2000, 81.2% of deforestation was due to conversion of forest into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland", i.e. forest was cleared for the purpose of agricultural use. 2.6% of deforested land was converted into "Plantation", however, it cannot further be specified whether this was timber or other, e.g. oil palm plantation. Conversion into "Bare Area" amounted to 7.4% of all forest land converted, which can mostly be attributed to the establishment of coal mining areas. 8.8% of deforested land was converted into "Water", which is difficult to explain in Malinau. One of the reasons for this development is intensive meander erosion due to the very high discharge and associated erosive power of the rivers in Malinau district. When the streams exit the mountainous areas (where rivers flow in enclosed meanders) into the lowlands, they change their flow into free-swinging meanders. Due to the erosive power of the high run-off the location of the riverbanks is constantly changing in downstream direction on the erosion banks, which lead to intense changes in waterways in the lowland areas within the ten year observation period. Conversion of forest into "Settlement" only plays a very minor role with 0.03% of all deforestation, i.e. most extension of settlement area takes place on non-forest land.

Between 2000 and 2005, deforestation due to conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" increased to 89% which reflects that areas in agricultural use were significantly extended at the cost of forest area during that time period. This can be attributed to a significant growth in population. Conversion into "Bare Area" amounted to 6.7%, which means another expansion of mining area. Conversion of forest to "Water" continued with the same pace as before and amounted to 4.01%, which underlines that these changes are due to non-anthropogenic reasons. Conversion of forest into "Plantation" was almost not observable (0.3%).

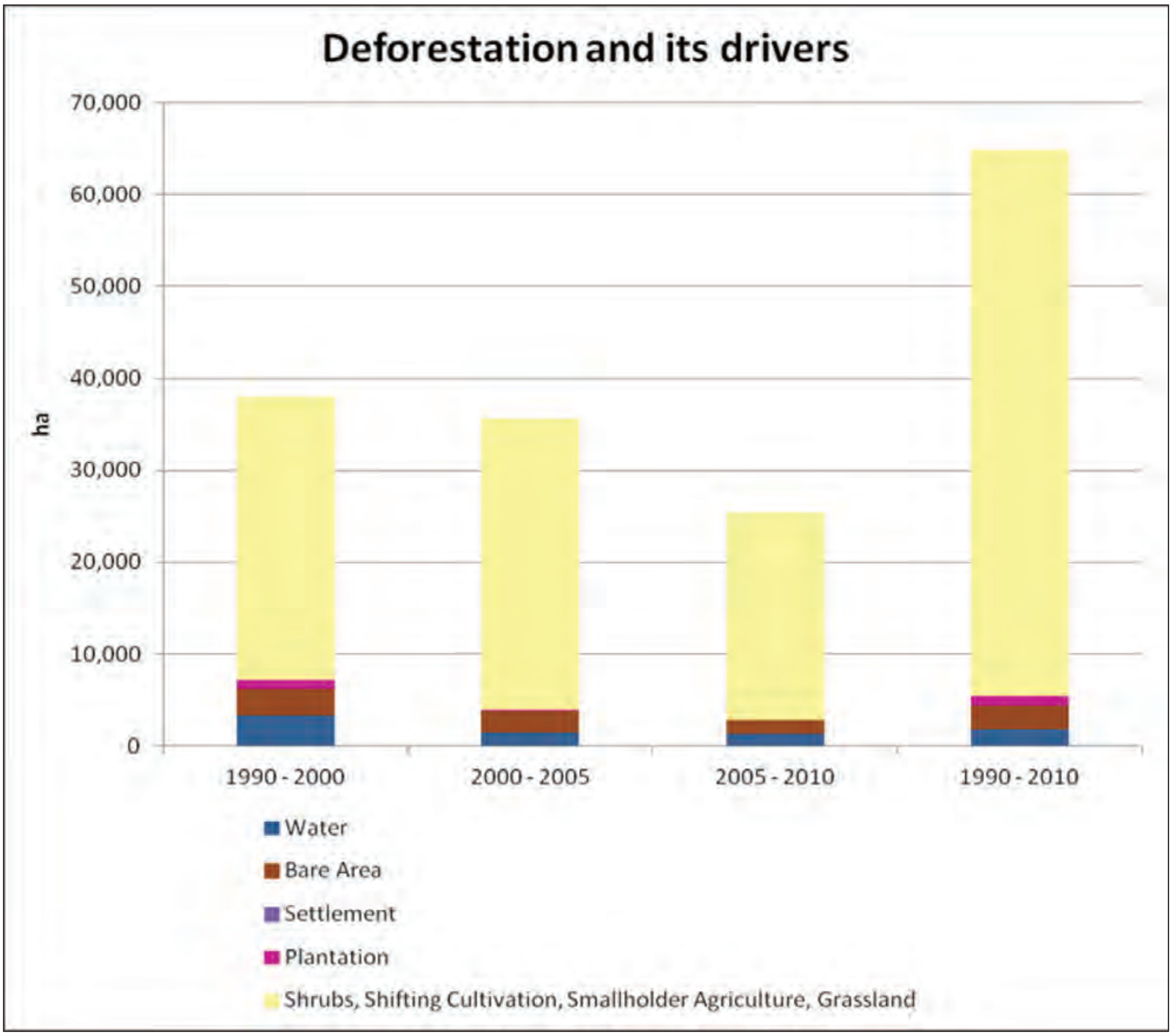


Figure 21. Deforestation and its drivers in Malinau district.

In the last observation period 2005-2010, deforestation due to conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" retained the same percentage of all deforested land with 88.8% as before. Conversion into "Bare Area" was slightly reduced to 5.89% of all deforested land. Conversion into "Water" slightly increased in importance to 5%, and conversion into estate "Plantation" remained constant at 0.3%.

A look at the overall investigation period 1990-2010 reveals the overall trends of drivers of deforestation in Malinau district. The vast majority of all deforestation is happening because of forest conversion into agricultural use (91.5%). The second most dominant reason for deforestation is conversion into "Bare Area" which can mostly be attributed to coal mining activity (4% of all deforested land). Especially in the lowland areas, meander erosion of weakened secondary forests is another source of forest loss with 2.84% of deforested area on the long-term average. Conversion into estate "Plantation" plays only a minor role in Malinau so far, with only 1.57% of all deforested land converted into "Plantation" so far. However, it has to be stated that we observed numerous smallholder oil palm plantations during the field visit in Malinau, but these are mostly in mixed agricultural areas and are therefore contained in the "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" class.

3.1.6 Estimation of carbon emissions on district level

The estimation of carbon emissions presented in this chapter is conducted based on a stock difference approach of the carbon stock stored in the different land cover classes in each time step (1990, 2000, 2005, 2010) as presented in Figure 22 and Table 17, and the difference between those carbon stocks for the respective time periods in between (1990-2000; 2000-2005; 2005-2010; 1990-2010) (Table 18 and Figure 23).

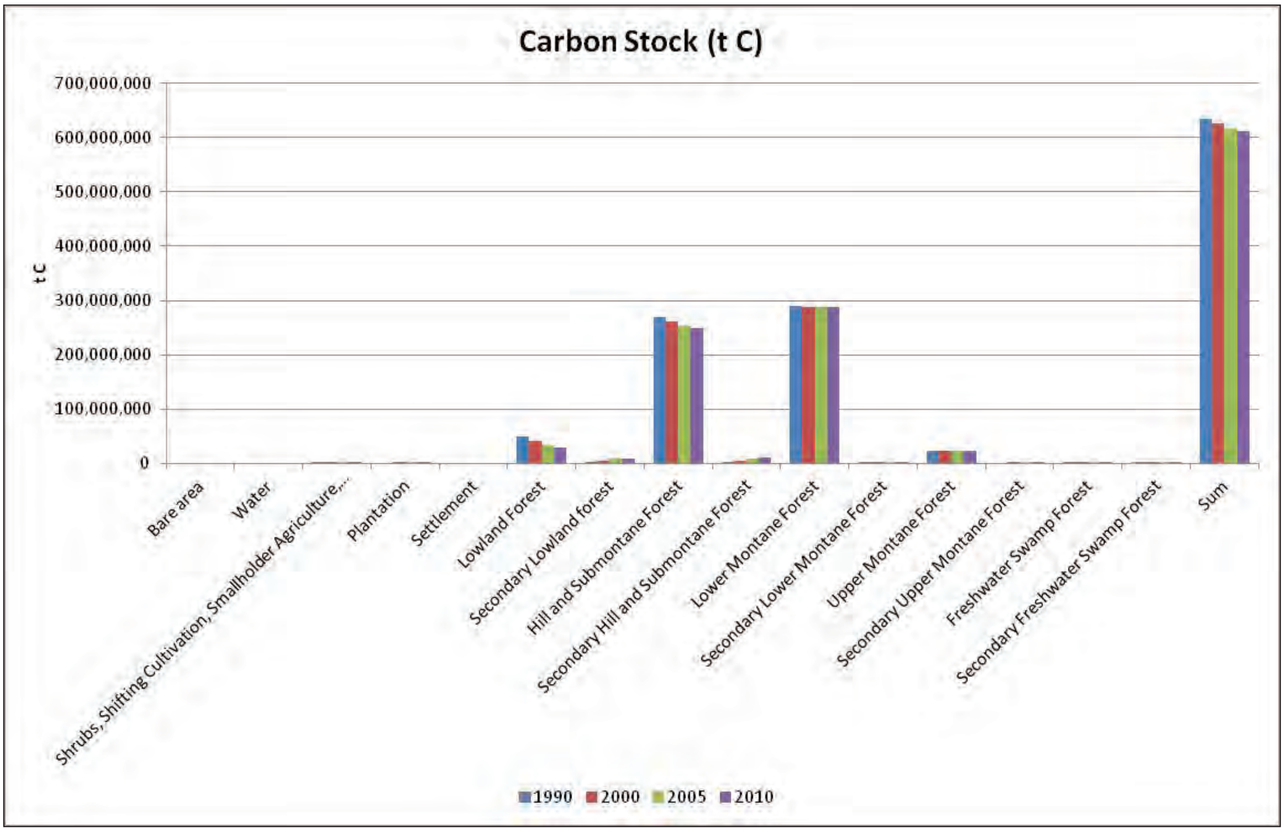


Figure 22. Carbon stock of the different land cover classes for the four time steps.

The carbon stock of Malinau was and is mostly stored in the "Lower Montane Forest" and the "Hill and Submontane Forest" with 289,471,320 tC and 269,565,862 tC in 1990, respectively. Carbon stocks in Primary "Lower Montane Forest" decreased only slightly due to very limited deforestation and degradation, losing 908,470 tC in the first ten year investigation period 1990, then another 415,805 tC between 2000 and 2005 and 651.121 tC from 2005 until 2010. In total, the carbon stored in Primary "Lower Montane Forest" decreased by 1,975,381 tC or 0.7% from 1990-2010.

In comparison, the class Primary "Hill and Submontane Forest" lost much more carbon in the investigation period: From 1990 to 2000, 8,219,567 tC were lost, then between 2000 and 2005 7,762,554 tC and another 4,453,240 tC between 2005 and 2010, amounting to a total of 20,435,362 tC or 7.6% of its original stock between 1990 and 2010. Not all of these carbon losses were due to deforestation which is reflected in the increase in carbon stocks in the "Secondary Hill and Submontane Forest" class. Between 1990 and 2000, the carbon stock increased by 2,909,495 tC, then by 4,115,293 tC between 2000 and 2005 and another 2,452,211 tC between 2005 and 2010. In total, between 1990 and 2010, carbon stock in "Secondary Hill and Submontane Forest" increased by 9,476,999 tC, or a factor of 8.5 since 1990.

Table 17. Carbon stock of the different land cover classes for the four time steps.

Land Cover	1990	2000	2005	2010
	t C			
Bare area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	1,015,010	1,651,406	2,137,008	2,306,507
Plantation	0	97,489	86,764	99,417
Settlement	0	0	0	0
Lowland Forest	48,629,250	41,695,843	32,314,091	29,338,060
Secondary Lowland forest	2,300,949	4,780,043	8,229,760	9,293,095
Hill and Submontane Forest	269,565,862	261,346,295	253,584,037	249,130,540
Secondary Hill and Submontane Forest	1,116,273	4,025,769	8,141,062	10,593,273
Lower Montane Forest	289,471,320	288,562,850	288,148,814	287,495,977
Secondary Lower Montane Forest	22,569	402,172	655,884	1,080,298
Upper Montane Forest	22,531,916	22,518,713	22,518,913	22,518,262
Secondary Upper Montane Forest	0	7,992	7,578	7,206
Freshwater Swamp Forest	554,182	538,993	515,370	503,635
Secondary Freshwater Swamp Forest	61,309	56,815	20,266	19,970
Sum	**635,268,641**	**625,684,381**	**616,359,545**	**612,386,241**

Primary "Lowland Forest" experienced the second highest losses in carbon stock. While the losses from 1990 to 2000 were less than in the Primary "Hill and Submontane Forest" class between 1990 and 2000 with a decrease of 6,933,406 tC, they exceeded the latter between 2000 and 2005 with 9,381,832 tC. Between 2005 and 2010, another 2,975987 tC were lost, amounting in the overall investigation period 1990 - 2010 to 19,291,189 tC or 39.7% of its original carbon stock. The carbon stock in "Secondary Lowland Forest" increased by 2,479,049 tC between 1990 and 2000, 3,449,700 tC between 2000 and 2005 and another 1,063,372 tC between 2005 and 2010, amounting to an increase of 6,992,146 tC between 1990 and 2010, which equals to and increase by a factor of three.

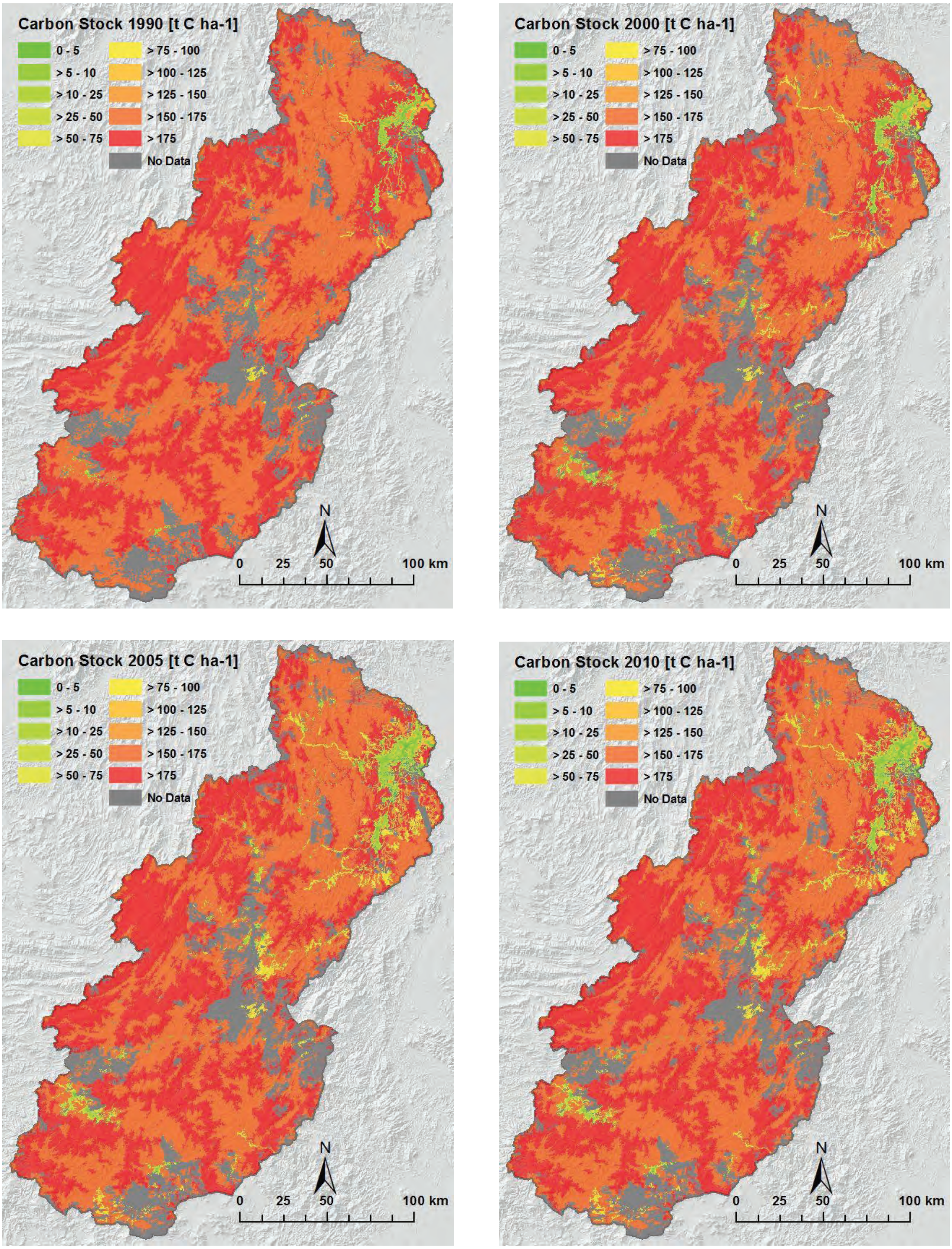


Figure 23. Carbon stock maps of the Malinau study area for the four time steps.

The forest class Primary "Freshwater Swamp Forest" also experienced intense losses in carbon stock. Between 1990 and 2000, 15,189 tC were lost, followed by a further decrease by 23,623 tC between 2000 and 2005 and another 11,735 tC between 2005 and 2010. In total, Primary "Freshwater Swamp Forest" lost 50,546 tC between 1990 and 2010, which equals to 9.1% of its original carbon stock in 1990. The carbon stocks in "Secondary Swamp Forest" also decreased in the investigation period. Between 1990 and 2000, 4,495 tC were lost, then another 36,549 tC between 2000 and 2005 and 296 tC between 2005 and 2010. Overall, 41,339 tC were lost between 1990 and 2010, which is 67.4% of the carbon stock stored in this class in 1990. This development in the "Freshwater Swamp Forest" shows that this forest type is subject to intense deforestation and forest degradation, which can be explained by the close proximity to the developed settlement and rural areas in the floodplain of the Mentarang river, where demand for agricultural land is high.

Carbon stock in the "Upper Montane Forest" class remained almost constant over all investigation periods because almost no changes were observed (see chapter 3.1.3).

Table 18. Carbon stock change per class and time period in Malinau district.

Land Cover	Code	1990-2000	2000-2005	2005-2010	1990-2010
		tC			
Bare area	3	0	0	0	0
Water	4	0	0	0	0
Shrubland	21	636,396	485,594	169,507	1,291,497
Plantation	22	97,489	-10,725	12,653	99,417
Settlement	24	0	0	0	0
Lowland Forest	111	-6,933,406	-9,381,832	-2,975,987	-19,291,189
Secondary Lowland forest	112	2,479,094	3,449,700	1,063,372	6,992,146
Hill and Submontane Forest	121	-8,219,567	-7,762,554	-4,453,240	-20,435,362
Secondary Hill and Submontane Forest	122	2,909,495	4,115,293	2,452,211	9,476,999
Lower Montane Forest	131	-908,470	-415,805	-651,121	-1,975,381
Secondary Lower Montane Forest	132	379,603	253,712	424,424	1,057,730
Upper Montane Forest	141	-13,203	-301	-150	-13,654
Secondary Upper Montane Forest	142	7,992	-415	-372	7,206
Freshwater Swamp Forest	181	-15,189	-23,623	-11,735	-50,546
Secondary Freshwater Swamp Forest	182	-4,495		-296	-41,339
Sum		**-9,584,260**	**-9,290,956**	**-3,970,734**	**-22,882,478**

Land cover classes showing increases in carbon stock were few. The major increases were observed in the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". Between 1990 and 2000, the increase in carbon stock amounted to 636,396 tC, then between 2000 and 2005 carbon stock increased by 485,594 tC and by another 169,507 tC between 2005 and 2010. Total increases in carbon stock in "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" amounted to 1,291,497 tC between 1990 and 2010. In the "Plantation" class, carbon stock increased by 97,489 tC between 1990 and 2000, decreased by 10,725 tC between 2000 and 2005 and increased by 12,653 tC between 2005 and 2010, totaling to 99,417 tC between 1990 and 2010.

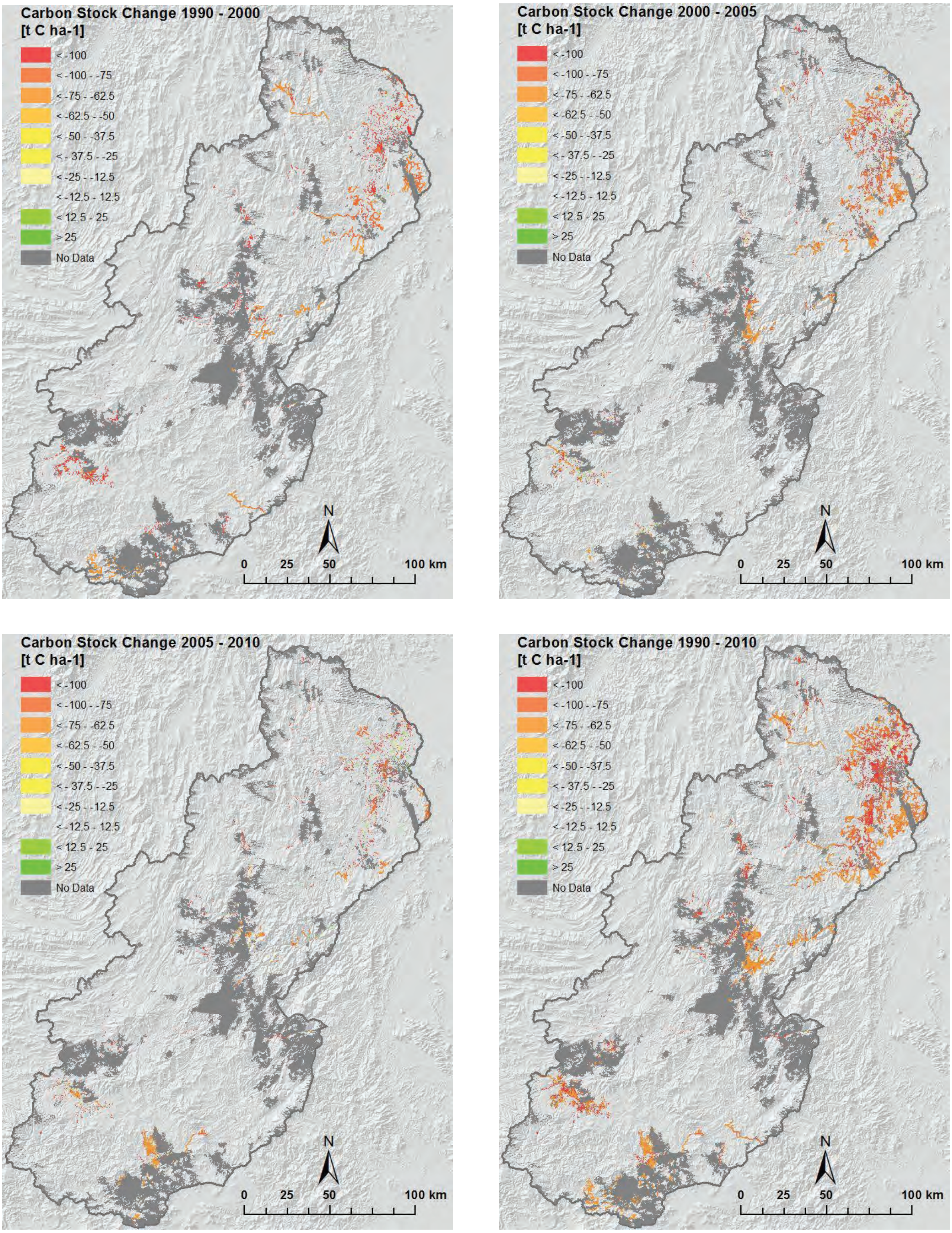


Figure 24. Carbon stock change maps for the time periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010.

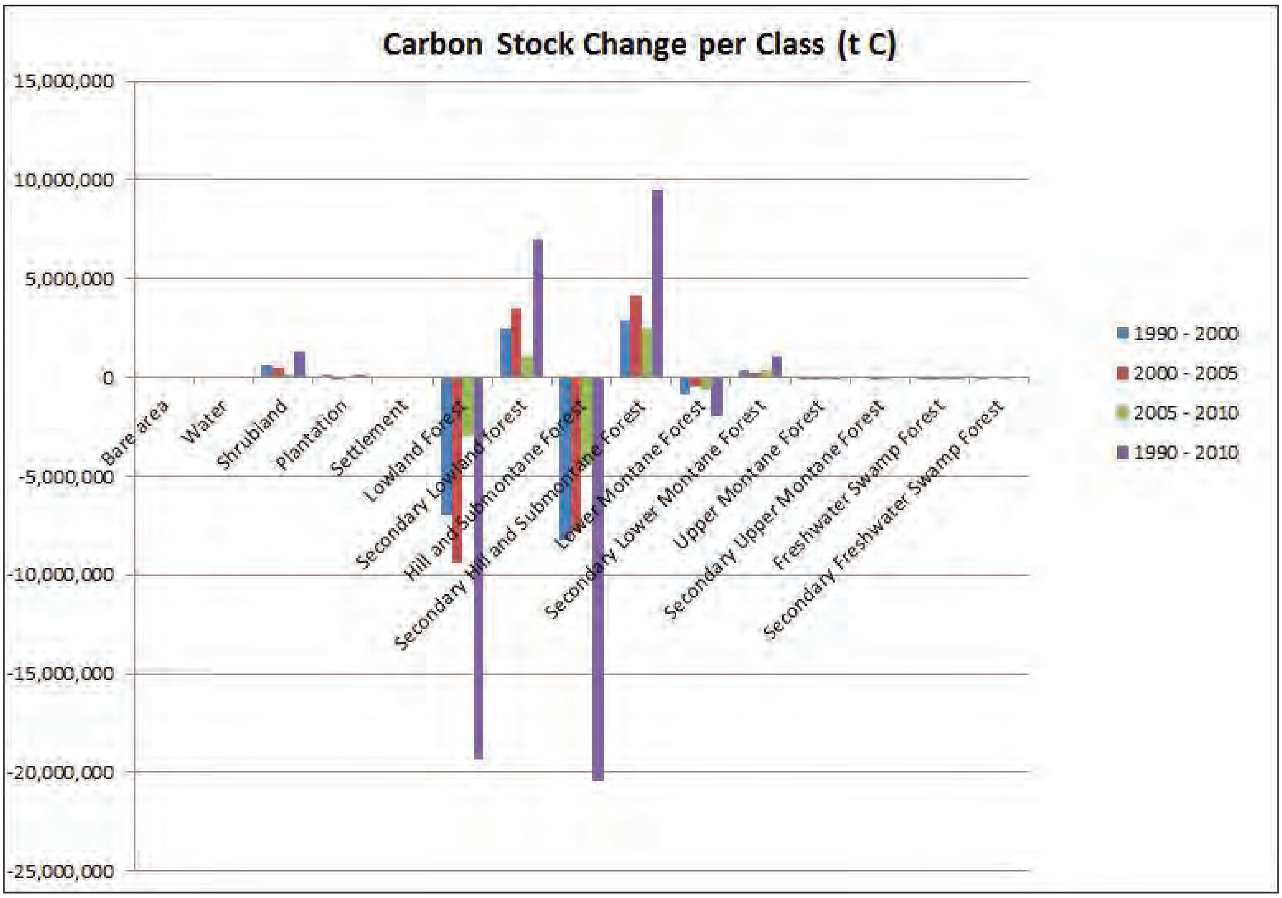


Figure 25. Carbon stock change per class and time period in Malinau district.

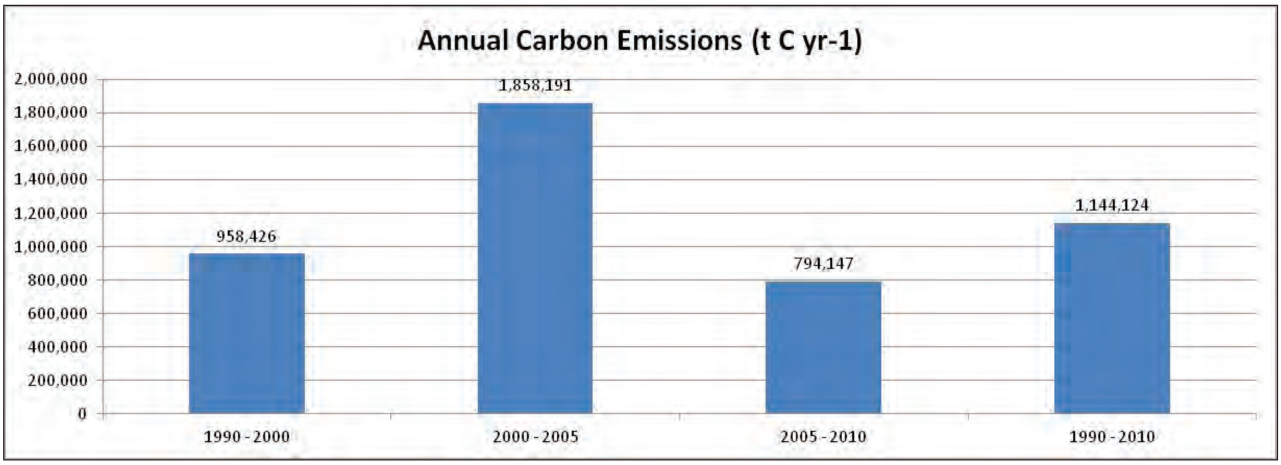


Figure 26. Annual carbon emissions of Malinau district in the investigation period.

Annual carbon emissions of Malinau district are shown in Figure 24. In the first change period 1990-2000, annual carbon emissions amounted to 568,426 tC yr^{-1}. This annual emission rate was almost doubled in the second change period 2000-2005 with 1,858,191 tC yr^{-1}. In the following time period, annual emissions again decreased to 794,147 tC yr-1. On the long term average, 1,144,124 tC yr^{-1} were emitted annually.

The development of the total carbon stock in Malinau is visualized in Figure 25. In 1990, it amounted to 635,268,641 tC and decreased by 9,584,260 tC to 625,684,381 tC until 2000. Then between 2000 and 2005, another 9,327,504 tC were lost, leading to a total carbon stock of 616,359,545 tC in 2005. In the last investigation period 2005-2010 another 3,970,734 tC were lost, amounting to a total loss of carbon stock of 22,882,478 tC from 1990 until 2010. Total carbon stock in 2010 amounted to 612,386,241 tC.

In order to provide a prediction of carbon stock for the next 20 years, different regression models were tested on the carbon stock development of the past 20 years in order to select the best fitting model for the prediction of a business-as-usual scenario. The results are shown in Table 19 and Figure 25.

Table 19. Prediction models for total carbon stock trend until 2030 in Malinau district.

Method	Trend function	R^2	2015	2020	2025	2030
			10^6 t C			
Logarithmic	$y = -13.73\ln(x) + 636.48$	0.9201	611.879	609.763	607.929	606.312
Exponential	$y = 641.86e^{-0.009x}$	0.9798	608.119	602.670	597.271	591.919
Polynomial 2nd order	$y = -0.1788x^2 - 4.8763x + 640.55$	0.9817	604.855	597.655	590.096	582.181
Linear	**$y = -5.9234x + 641.68$**	**0.9804**	**606.140**	**600.216**	**594.293**	**588.369**

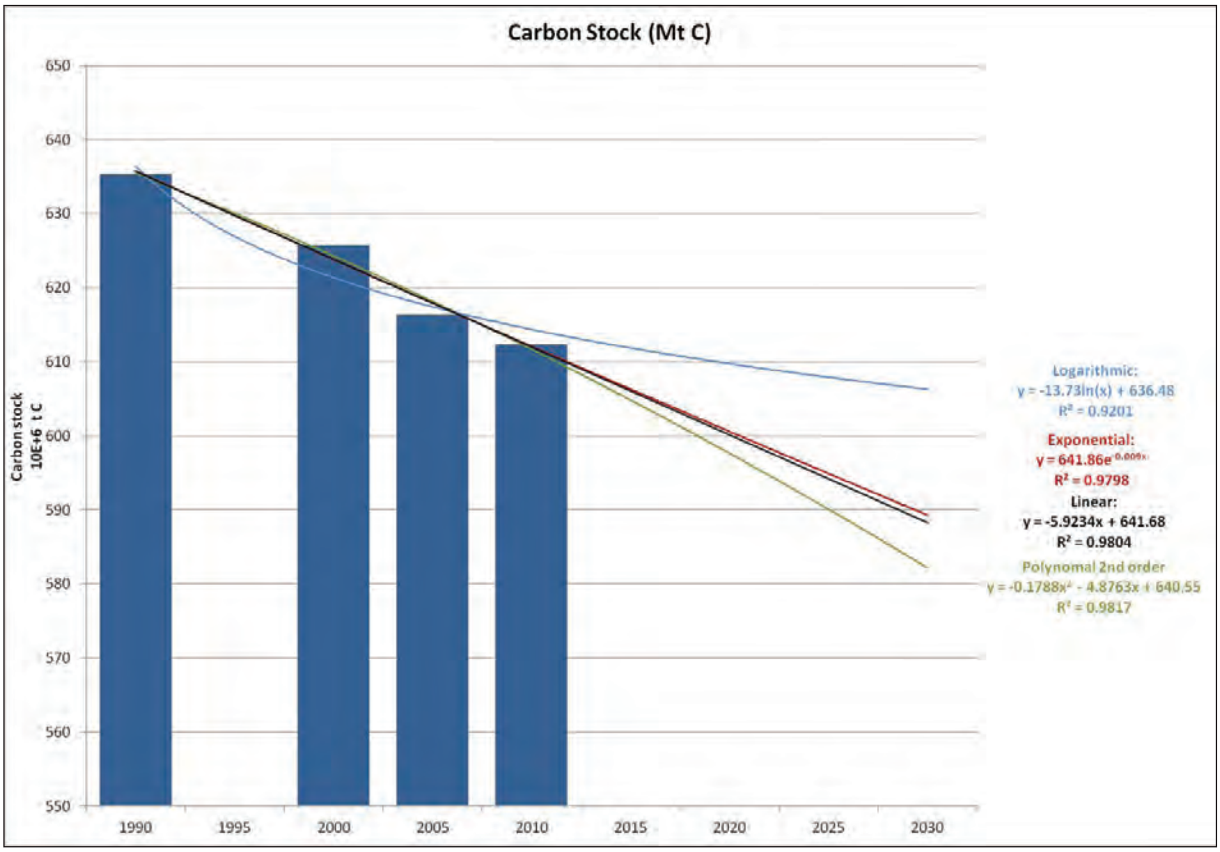


Figure 27. Total carbon stock development in Malinau and forecast until 2030 with different projection methods.

The best fitting regression model for Malinau is Polynomial 2nd order, which achieves a R^2 of 0.9817, followed closely by the linear prediction model with a R^2 of 0.981. The exponential regression model is has a R^2 of 0.9798, and the logarithmic prediction model is clearly inferior with an R2 of 0.9201.

Even though the polynomial regression model has the best fit, we would recommend either the exponential or linear model for the prediction of carbon stock development for the next 20 years. The reasons are two-fold:

- ☑ Model correlation of both models is only slightly lower than for the polynomial order
- ☑ the modeled carbon stock for 2030 is higher, i.e. the predicted carbon emissions until 2030 are lower, which means that this estimate is more conservative than the Polynomial model

The prediction of the carbon stock development by statistical regression models based on the overall carbon stock of 4 points in time requires to be carefully interpreted. The limitations of this kind of prediction are various:

- ☑ the models are only based on 4 points in time
- ☑ the models only predict the overall trend in carbon stock development
- ☑ the models are not spatially explicit and thus do not consider the spatial trends in land cover/land use

Therefore, these predictions must be treated as a very preliminary result, and further investigations of the historic trend should be conducted in order to reduce uncertainty in this respect.

3.1.7 Drivers of carbon emissions

In addition to the drivers of deforestation described in chapter 3.1.5, an analysis of the drivers of carbon emissions was conducted, taking into account the amount of carbon emitted and the source land cover classes of the carbon emissions.

Figure 26 shows the results of the analysis of drivers of carbon emissions for the overall observation period 1990-2010. A larger size version of the figure, as well as the underlying carbon change matrix can be found in the Annex in Figure 51 and Table 50. The same analysis was conducted for the individual change periods 1990-2000 (Table 47; Figure 48), 2000-2005 (Table 48; Figure 49) and 2005-2010 (Table 49; Figure 50).

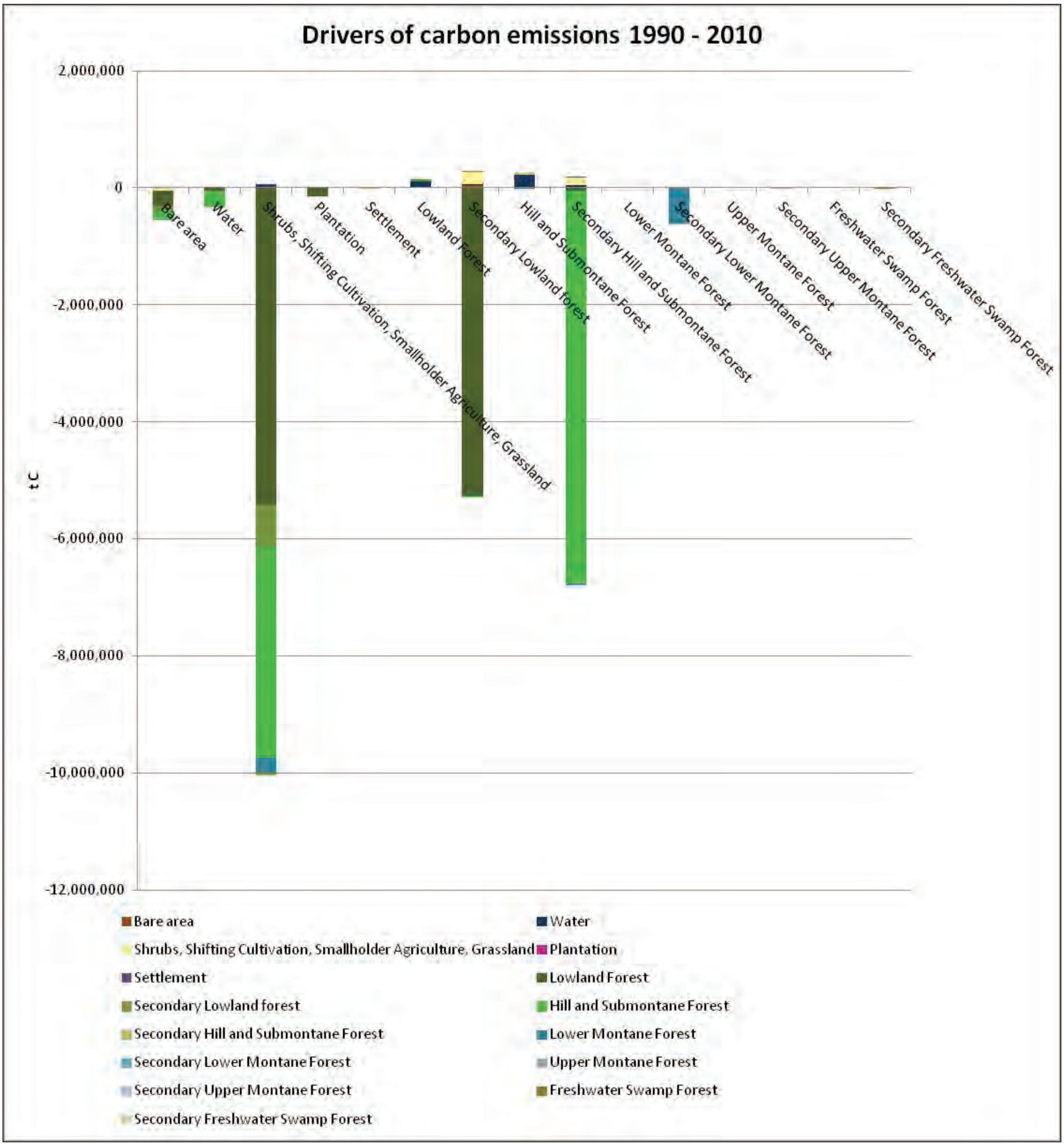


Figure 28. Drivers and source areas of carbon emissions in Malinau for the time period 1990-2010. The land cover classes on the x axis are the drivers which cause the carbon emissions (i.e. the areas at the later change time step), while the color coding of the bars indicates the source land cover class from which the carbon was emitted.

The main driver of carbon emissions in Malinau in the time period 1990-2010 **was Conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland",** which caused total net carbon emissions of 10,017,551 tC or 44% of the overall emissions. The majority of the carbon emitted originated from Primary "Lowland Forest" with 5,416,233 tC, and Primary "Hill and Submontane Forest" with 3,590,934 tC. "Secondary Lowland Forest" contributed another 713,697 tC, and all other forest types together 339,632 tC.

The driver which caused the second highest amount of carbon emissions was Logging of **"Hill and Submontane Forest",** which emitted net total emissions of 6,618,312 tC or 29% of the total emissions in Malinau. Of course, the main contributing class was Primary "Hill and Submontane Forest" which contributed 6,713,417 tC, which was slightly offset by regeneration of "Secondary Hill and Submontane Forest" on former "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (130,001 tC), "Water" (17,341 tC) and "Bare Area" (22,433 tC).

Table 20. The four most important drivers of carbon emissions in Malinau between 1990 and 2010, the land cover classes converted and the contributing carbon emissions and sequestration resulting from the conversion.

	Driver			
Land Cover	Conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland	Logging of "Hill and Submontane Forest"	Logging of "Lowland Forest"	Conversion into "Bare Area"
Bare area	13,099	22,433	46,564	0
Water	28,931	17,341	10,655	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	0	130,001	217,815	-55,189
Plantation	0	0	0	0
Settlement	916	87	0	0
Lowland Forest	-5,416,233	-41,954	-5,273,556	-256,834
Secondary Lowland forest	-713,697	-924	0	-78,018
Hill and Submontane Forest	-3,590,934	-6,713,417	-15,835	-128,246
Secondary Hill and Submontane Forest	-23,493	0	1,709	-5,792
Lower Montane Forest	-251,564	-31,879	0	-18,976
Secondary Lower Montane Forest	0	0	0	0
Upper Montane Forest	-2,123	0	0	0
Secondary Upper Montane Forest	0	0	0	0
Freshwater Swamp Forest	-29,842	0	129	-19
Secondary Freshwater Swamp Forest	-32,610	0	0	-1,830
Sum	**-10,017,551**	**-6,618,312**	**-5,012,519**	**-544,904**

The third most dominant driver of carbon emissions was **Logging of "Lowland Forest"** causing total net carbon emissions of 5,012,519 tC or 22% of the overall emissions of Malinau. The source area of emissions was "Lowland Forest" (5,273,556 tC). Offsets by regeneration of "Secondary Lowland Forest" was observed on former "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (217,815 tC), "Bare Area" (46,564 tC), and "Water" (10,655 tC).

Other drivers of carbon emissions were **Logging of "Lower Montane Forest"** (-598,669 tC), **Conversion into "Bare Area"** (544,904 tC) and **Conversion into "Plantation"** (140,510 tC).

3.1.8 Status of protected areas

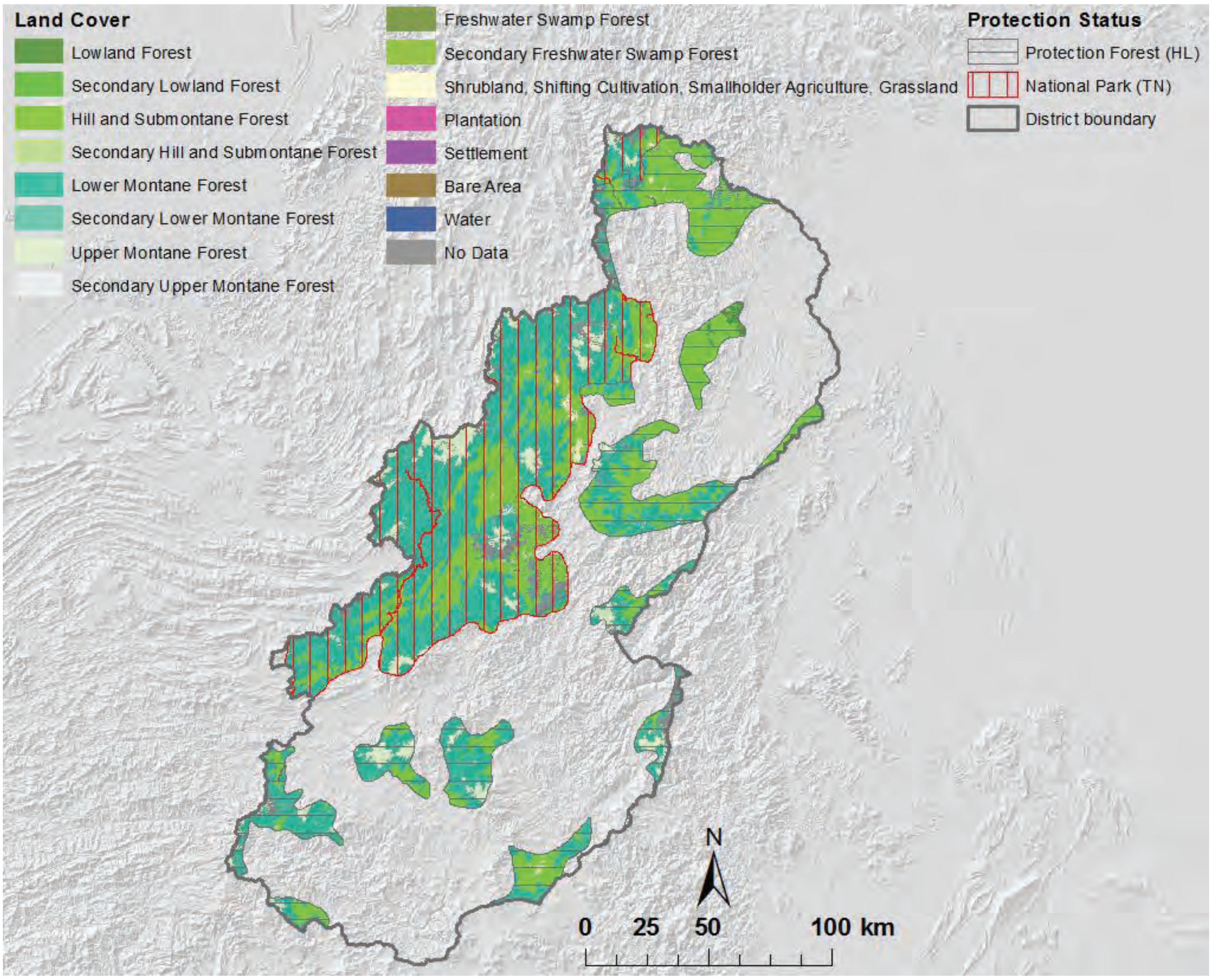


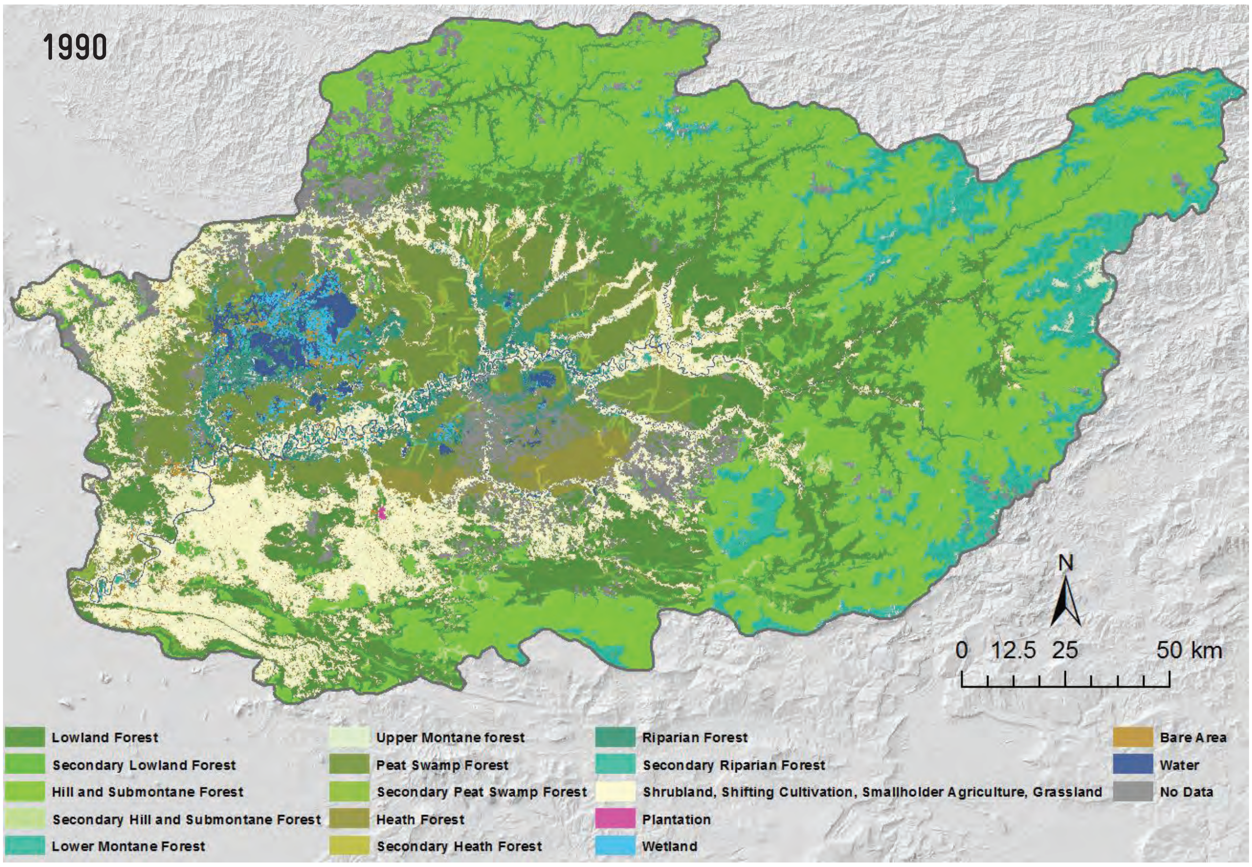
Figure 29: Land cover of the protected areas in Malinau district and their protection status.

Table 21. Status of the protected areas in Malinau district and their protection status.

Land Cover	Protection Forest (HL)	National Park (TN)	Total
	ha		
Lowland Forest	6,804	25	6,829
Secondary Lowland Forest	1,070	0	1,070
Hill and Submontane Forest	295,777	266,487	562,264
Secondary Hill and Submontane Forest	2,886	3,163	6,049
Lower Montane Forest	285,979	596,438	882,417
Secondary Lower Montane Forest	769	1,019	1,787
Upper Montane Forest	43,514	71,785	115,299
Secondary Upper Montane Forest	30	0	30
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	2,623	9,080	11,703
Settlement	0	8	8
Bare Area	178	143	320
Water	45	406	452
No Data	37,165	56,577	93,742
Sum	**676,840**	**1,005,130**	**1,681,970**

3.2 Kapuas Hulu district

3.2.1 District wide Land use/Land cover maps



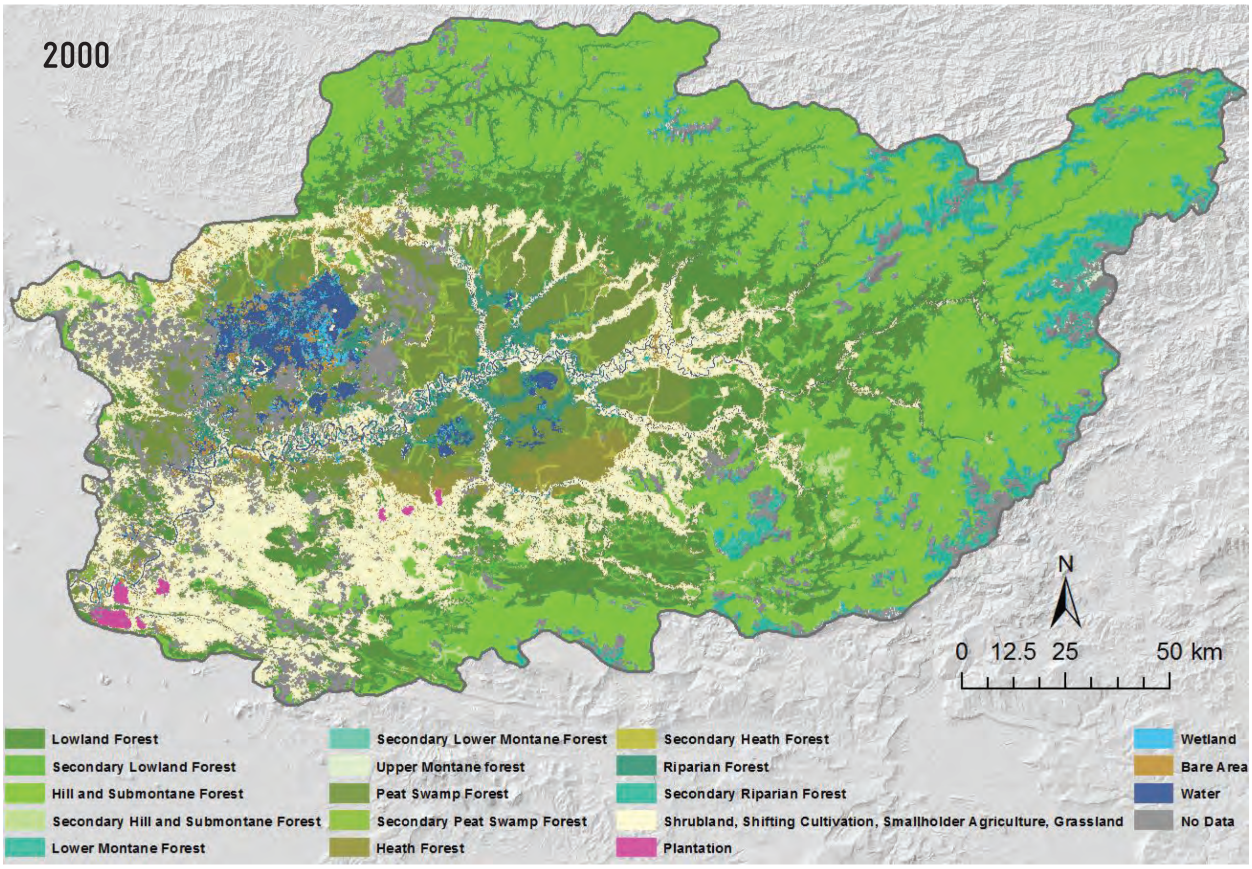
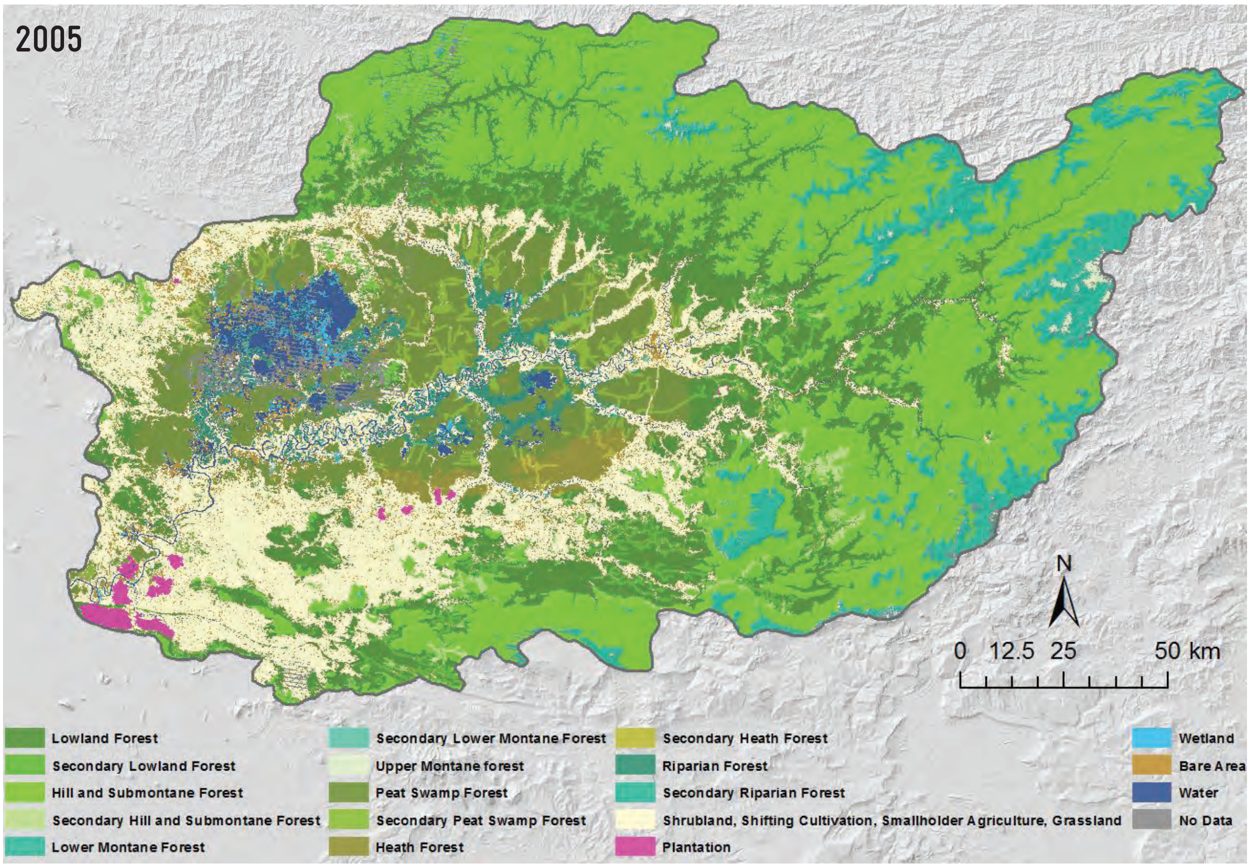


Figure 30. Land cover maps of Kapuas Hulu district for 1990 and 2000.



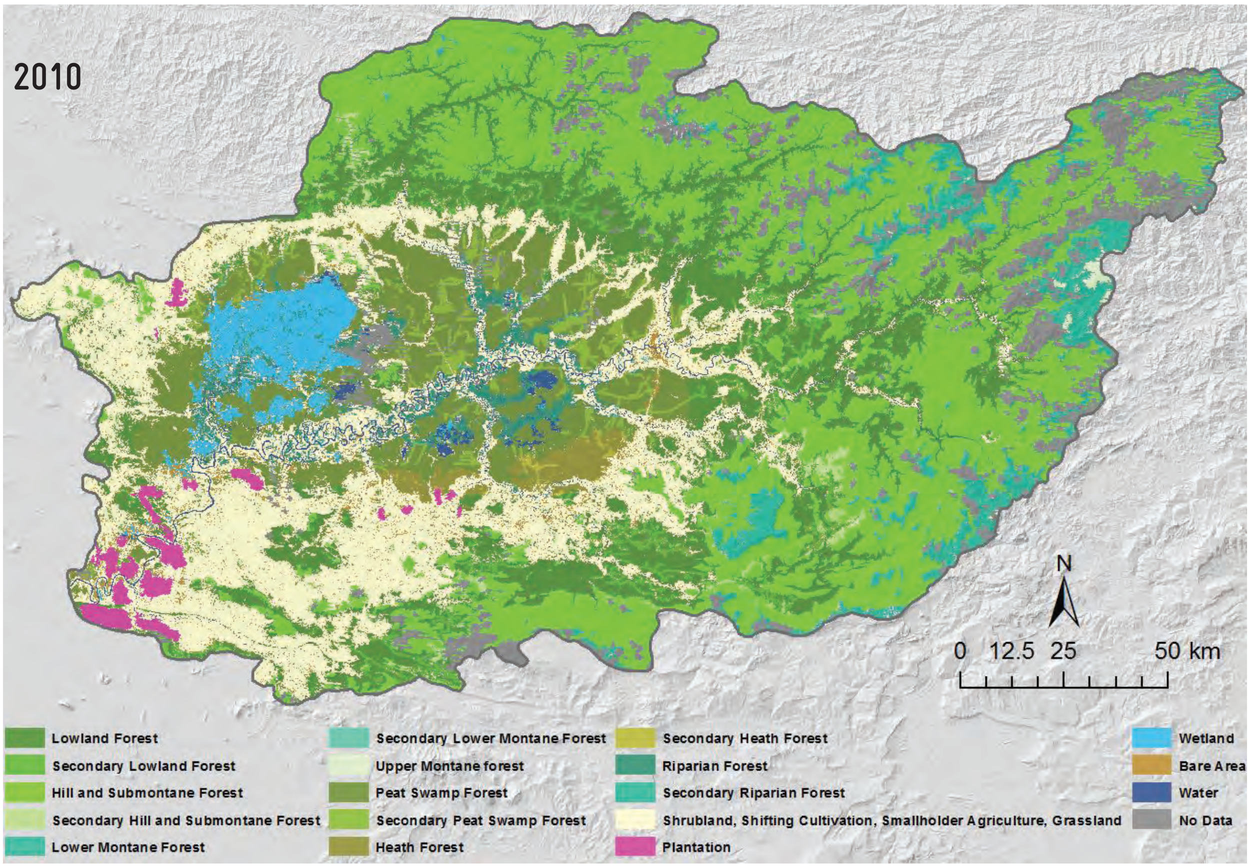


Figure 31. Land cover maps of Kapuas district for 2005 and 2010.

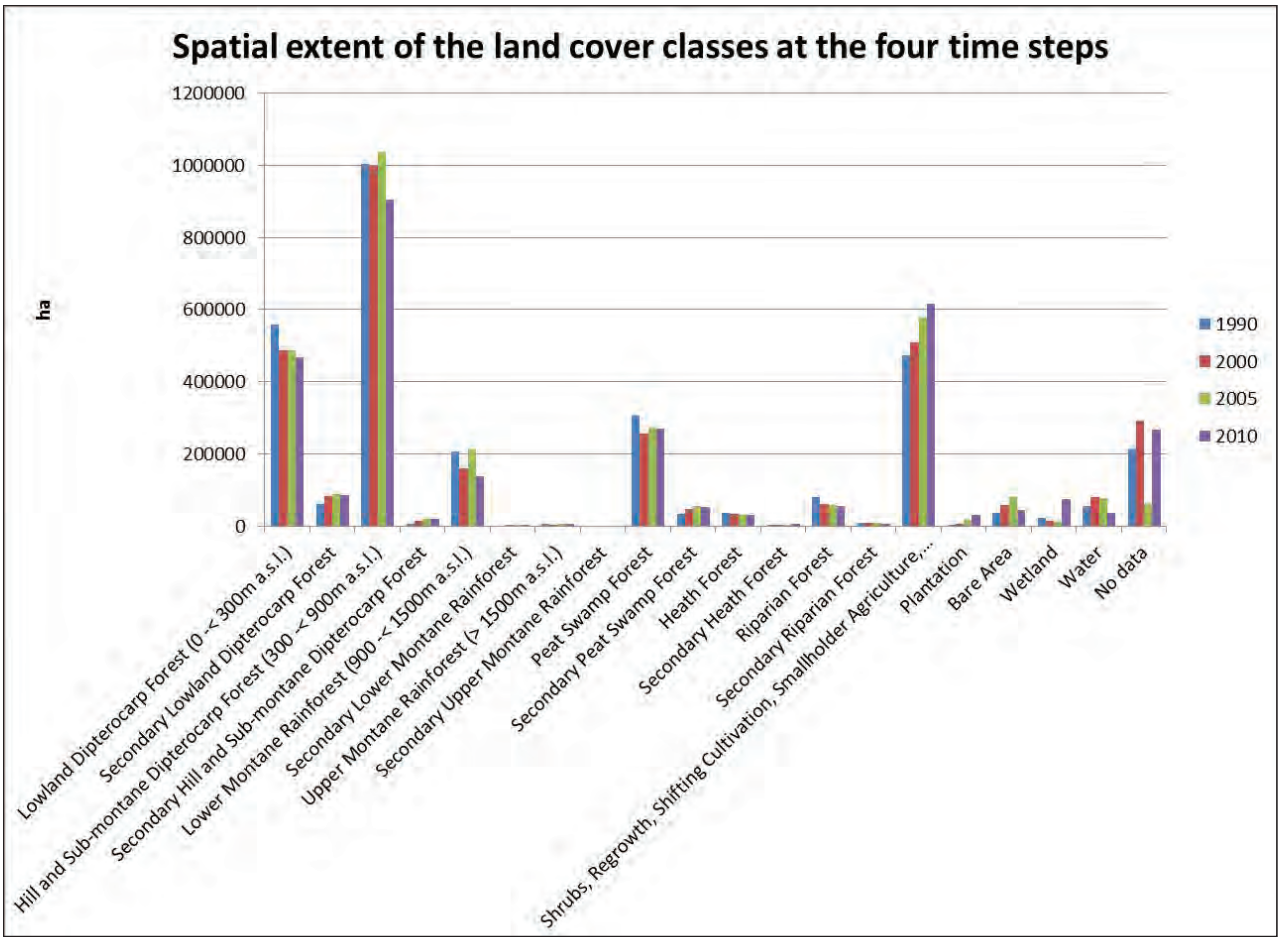


Figure 32. Spatial extent of the land cover classes at the four time steps in Kapuas Hulu district.

Table 22. Spatial extent of the land cover classes at the four time steps in Kapuas Hulu district.

Land Cover Class	1990	2000	2005	2010
	ha			
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	558,538	487,286	488,416	467,893
Secondary Lowland Dipterocarp Forest	60,930	82,270	88,867	84,884
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	1,003,022	998,150	1,038,065	905,394
Secondary Hill and Sub-montane Dipterocarp Forest	7,338	14,137	20,639	19,758
Lower Montane Rainforest (900 -< 1500 m a.s.l.)	206,189	160,957	212,828	137,342
Secondary Lower Montane Rainforest	0	8	8	7
Upper Montane Rainforest (> 1500 m a.s.l.)	6,143	1,767	5,681	5,139
Secondary Upper Montane Rainforest	0	0	0	0
Peat Swamp Forest	305,846	255,238	273,912	268,699
Secondary Peat Swamp Forest	33,965	46,453	55,066	53,865
Heath Forest	37,412	33,328	31,649	29,949

Table 22. (continued)

Land Cover Class	1990	2000	2005	2010
	ha			
Secondary Heath Forest	1,987	2,870	4,418	4,722
Riparian Forest	79,122	60,608	58,673	56,157
Secondary Riparian Forest	8,506	8,721	8,102	6,909
Shrubs, Regrowth, Shifting Cultivation, Smallholder Agriculture, Grassland	473,144	509,375	577,256	615,181
Plantation	436	6,814	16,059	31,753
Bare Area	36,925	59,136	80,750	45,275
Wetland	23,729	13,232	11,512	74,476
Water	54,987	79,344	76,877	35,823
No data	212,376	290,899	61,816	267,368

3.2.2 Validation of the land cover maps

An accuracy assessment was conducted for all four land cover maps, as described in chapter 2.5.1.4. Table 23 shows the overall accuracy and Kappa Index for the four observation times. The complete confusion matrices are given Table 42, Table 43, Table 44 and Table 45 in the Annex.

Table 23. Results of the accuracy assessment of the Land cover maps of Kapuas Hulu district.

	1990	2000	2005	2010
Overall accuracy	86.45%	87.52%	86.44%	72.98%
Kappa	0.853	0.865	0.853	0.704

The accuracy of the Land cover maps remains high over all time steps, with 86.45% (1990), 87.25% (2000), 86.44% (2005) and 72.98% (2010) overall accuracy. Kappa coefficients were 0.853 (1990), 0.865 (2000), 0.853 (2005) and 0.704 (2010), respectively. Figure 31 and Figure 32 show the results of the class-wise accuracy assessment, which highlight which classification errors occurred.

Again, the dryland forest classes "Lowland Forest", "Hill and Submontane Forest", "Lower Montane Forest" and "Upper Montane Forest" were combined into a single class "Dryland Forest", since they were distinguished only by the elevation range which was unknown to the image interpreter during validation sample generation. The same was done for the non-intact dryland forest classes, and they were grouped into "Secondary Dryland Forest".

The Producer's accuracy represents the percentage of validation samples of each class correctly classified into this class, and corresponds to the 'error of omission', i.e. the underestimation of this class.

Producer's accuracy (Table 24, Figure 31) for the class "Bare Area" was very high in the 1990 and 2000 classifications, with 93.9% and 94%, and lower for the 2005 and 2010 time step with 82% and 62.7%. Misclassifications occurred mostly with the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (Table 44; Table 45 in the Annex). "Water" was classified with a very high producer's accuracy in all classifications, with values of 98% (1990 and 2000), 86% (2005) and 86% (2010). "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" also reached very high producer's accuracy of 94% (1990), 92% (2000) and 96% (2005) in the first three time steps, and a lower accuracy in 2010 with 74.5%. Most of the confusion occurred with "Secondary Dryland Forest" and "Plantation" (Table 45).

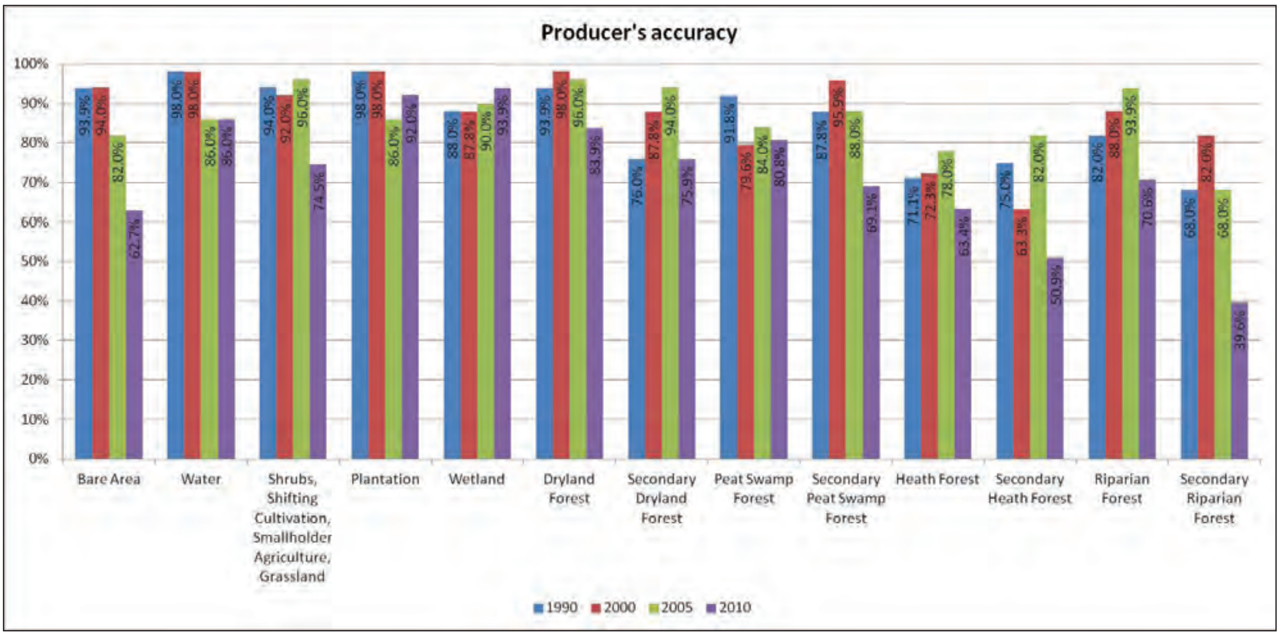


Figure 33. Producer's accuracy per class for the four time steps.

Table 24. Producer's accuracy per class for the four time steps.

Producer's accuracy	1990	2000	2005	2010
Bare Area	93.9%	94.0%	82.0%	62.7%
Water	98.0%	98.0%	86.0%	86.0%
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	94.0%	92.0%	96.0%	74.5%
Plantation	98.0%	98.0%	86.0%	92.0%
Wetland	88.0%	87.8%	90.0%	93.9%
Dryland Forest	93.9%	98.0%	96.0%	83.9%
Secondary Dryland Forest	76.0%	87.8%	94.0%	75.9%
Peat Swamp Forest	91.8%	79.6%	84.0%	80.8%
Secondary Peat Swamp Forest	87.8%	95.9%	88.0%	69.1%
Heath Forest	71.1%	72.3%	78.0%	63.4%
Secondary Heath Forest	75.0%	63.3%	82.0%	50.9%
Riparian Forest	82.0%	88.0%	93.9%	70.6%
Secondary Riparian Forest	68.0%	82.0%	68.0%	39.6%

“Plantation” was also classified with a very high producer’s accuracy of 98% in 1990 and 2000, 86% in 2005 and 92% in 2010. Confusion with other classes were very few, only 1 sample was misclassified as “Bare Area” in 1990, misclassifications in the later time steps were due to confusion with “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland”. “Wetland” was also classified with high producer’s accuracies in all time steps with 88% (1990), 87.8% (2000), 90% (2005) and 93.9% (2010).

Primary “Dryland forest” featured very high producer’s accuracies of 93.9% (1990), 98% (2000) and 96% (2005), and a slightly lower producer’s accuracy of 83.9% in 2010. Confusions were found to occur mainly with “Secondary Dryland Forest” (6 samples), a result of the difficulty to distinguish degradation happened a long time in the past from primary forest.

“Secondary Dryland Forest” were very accurately detected in 2000 and 2005 (87.8% and 94%) producer’s accuracy, and less accurately in 1990 and 2010. Confusions occurred exclusively with “Primary Dryland Forest” and “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland”. Primary “Peat Swamp Forest” was classified with a very high producer’s accuracy of 91.8% in 1990, with high producer’s accuracy in 2005 and 2010, and with a slightly lower producer’s accuracy in 2000. The majority of confusions were found in all classifications with “Secondary Peat Swamp Forest” (Table 42, Table 43, Table 44, Table 45).

Primary “Heath Forest” was classified with lower producer’s accuracies of 71.1% (1990), 72.3% (2000), 78% (2005) and 63.4% (2010). Confusion occurred mostly with Primary “Peat Swamp Forest”, “Secondary Heath Forest” and “Secondary Heath Forest” (Table 42, Table 43, Table 44, Table 45). “Secondary Heath Forest” was classified with a high producer’s accuracy of 82% in 2005, but with lower producer’s accuracies of 75% (1990), 63.5% (2000) and 50.9% (2010) in the other three time steps. In the 1990 map, most of the confusion happened with the class “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland” and “Secondary Peat Swamp Forest” (Table 42). In the 2000 map, the majority of confusions happened with “Secondary Peat Swamp Forest” (Table 43), while in 2005 it was mainly confused with “Secondary Peat Swamp Forest” and Primary “Heath Forest”. In the 2010 map, class confusion was observed mainly with Primary “Heath Forest”, “Secondary Peat Swamp Forest”, and also Primary “Peat Swamp Forest”. The reasons for these class confusions is the very low spectral separability of Peat Swamp Forest and Heath Forest in Kapuas Hulu, because the boundary between these two forest types is not a discrete one, but rather is a gradient. Field observations by FFI showed frequently vegetation composition typical for Peat Swamp Forest on non-peat sandy soil typical for Heath forest, and vice versa.

Primary “Riparian Forest” was classified with high producer’s accuracy of 82% (1990), 88% (2000) and 93.9% (2005) in the first three time steps, and with lower producer’s accuracy of 70.6% in the 2010 map. Confusions were manifold, the main problem occurring with “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland” and “Peat Swamp Forest”. “Secondary Riparian Forest” reached producer’s accuracies of 68% (1990), 82% (2000) and 68% (2005), and a low producer’s accuracy in 2010 with 39.6%. In the first three time steps, confusion was limited to Primary “Riparian Forest”, “Wetland” and “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland” (Table 42, Table 43, Table 44). In the 2010 map, The majority of confusions also were with Primary “Riparian Forest” and “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland”, as well as “Wetland”, but some validation samples were also classified as “Dryland Forest”, “Peat Swamp Forest” or “Secondary Peat Swamp Forest”.

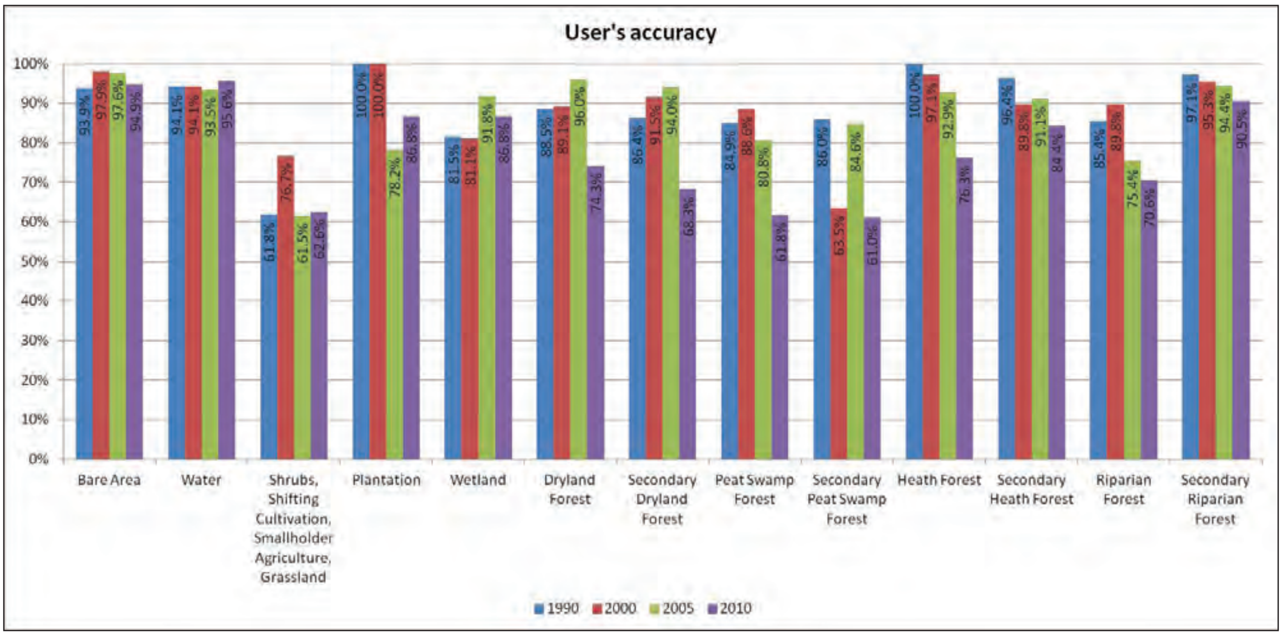


Figure 34. User's accuracy per class for the four time steps.

The user's accuracy represents the percentage of validation samples classified as a certain class which actually belong to this class, among all validation samples classified as this class. This equals to the 'error of commission', i.e. the overrepresentation of the class.

Table 25. User's accuracy per class for the four time steps.

User's accuracy	1990	2000	2005	2010
Bare Area	93.9%	97.9%	97.6%	94.9%
Water	94.1%	94.1%	93.5%	95.6%
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	61.8%	76.7%	61.5%	62.6%
Plantation	100.0%	100.0%	78.2%	86.8%
Wetland	81.5%	81.1%	91.8%	86.8%
Dryland Forest	88.5%	89.1%	96.0%	74.3%
Secondary Dryland Forest	86.4%	91.5%	94.0%	68.3%
Peat Swamp Forest	84.9%	88.6%	80.8%	61.8%
Secondary Peat Swamp Forest	86.0%	63.5%	84.6%	61.0%
Heath Forest	100.0%	97.1%	92.9%	76.3%
Secondary Heath Forest	96.4%	89.8%	91.1%	84.4%
Riparian Forest	85.4%	89.8%	75.4%	70.6%
Secondary Riparian Forest	97.1%	95.3%	94.4%	90.5%

"Bare Area" and "Water" were classified with very high user's accuracies of over 90% in all four land cover maps. "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" reached lower user's accuracies of 61.8% (1990), 76.2% (2000), 61.5% (2005) and 62.6% (2010) which reflects that more samples were classified as this class than actually belong to it (i.e. it is overrepresented in the map). Confusion of validation samples were observed with most of the secondary forest classes and "Wetland", but in the 2005 and 2010 map also an increasing number of "Plantation" and "Bare Area" samples were found in this class. The confusion with Secondary Forests is due to a partly very poor spectral separability of "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" and especially young secondary forest. The same is true for "Plantation" which is a spectrally very diverse class, and can often only be identified by contextual information, such as the presence of a regular pattern of roads or drainage canals, or even by the size of a large continuous area featuring similar spectral or contextual pattern.

The class "Plantation" itself, on the other hand, was classified with very high user's accuracies of 100% in the 1990 and 2000 map, 78.2% in 2005 and 86.8% in 2010. This reflects that once a plantation pattern is recognized by the classifier, only very few other land covers are confused with it. "Wetland" was classified with high user's accuracy in the 2000 and 2010 map, and with very high user's accuracy in 2005 (91.8%) and 2010 (86.8%).

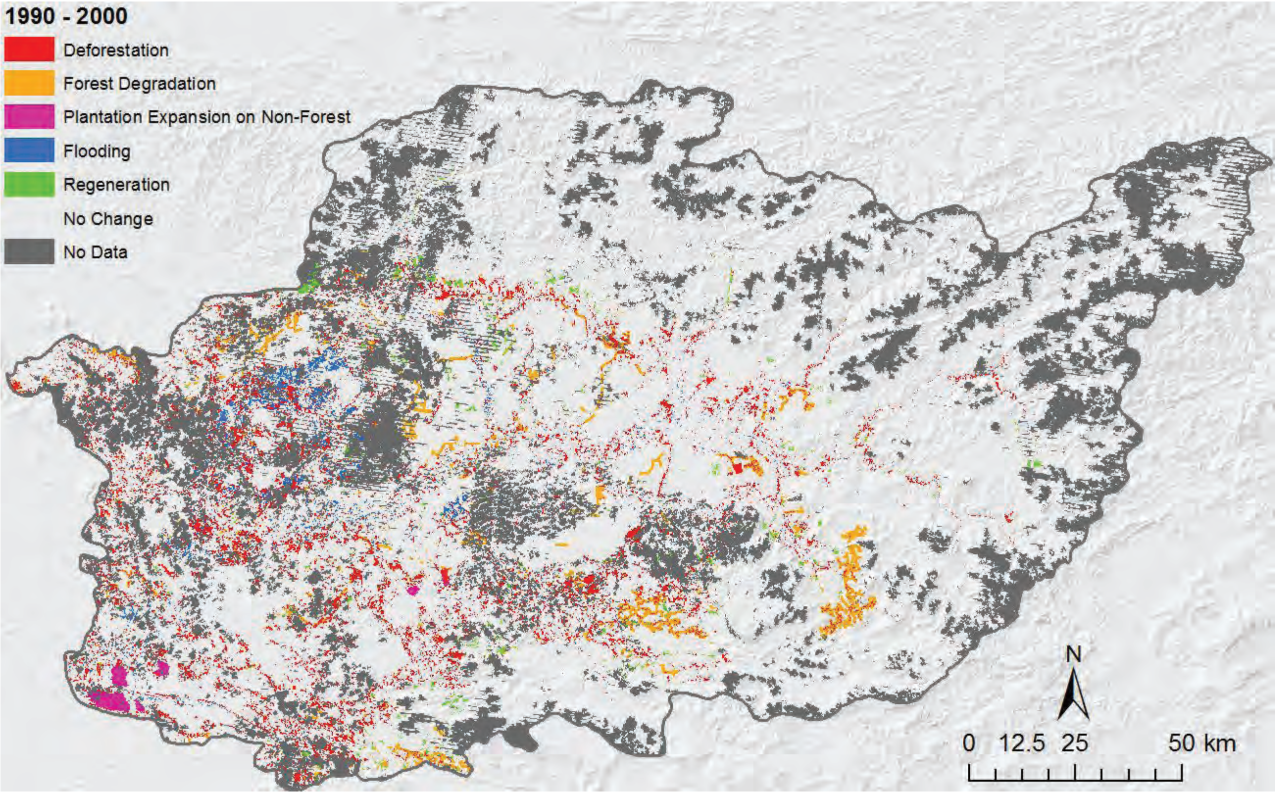
Primary "Dryland Forest" also featured very high user's accuracies of 88.5% (1990), 89.1% (2000) and 96% (2005) in the classifications for the first three time steps. In the 2010 map, user's accuracy was 74.3%, with the majority of misclassified samples coming from the "Secondary Dryland Forest" class (Table 45). This again reflects the difficulty in accurately identifying forest degradation which happened a long time ago in the past. The same pattern was observed for the "Secondary Dryland Forest" class itself. User's accuracy for the maps of the first three time steps was high, with 84.9% (1990), 88.6% (2000) and 94% (2005), and lower for the 2010 classification with 68.3%. Commission errors hereby occurred mostly from the samples of "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" and Primary "Dryland Forest" (Table 45).

Primary "Peat Swamp Forest" showed high user's accuracies of 84.9% (1990), 88.6% (2000) and 80.8% (2005) in the maps of the first three time steps, and lower user's accuracy in the 2010 map of 61.8%. Most confusion happened with "Heath Forest" and "Secondary Peat Swamp Forest", but also "Secondary Heath Forest" and "Riparian Forest" (Table 45). "Secondary Peat Swamp Forest" was classified with a high user's accuracy in the 1990 map (86%) and the 2005 map (84.6%). Lower user's accuracy was achieved in the 2000 (63.5%) and the 2010 map (61%). In both time steps, confusions were mostly observed with "Secondary Heath Forest" and "Primary Peat Swamp Forest", both related to the poor spectral separability of these classes.

The class Primary "Heath Forest" was classified with very high user's accuracy in the first three time steps with 100% (1990), 97.1% (2000) and 92.9% (2005) in the first three time steps, and with 76.3 in 2010. Most confusions happened with "Secondary Heath Forest". This class featured very high to high user's accuracy over all observation times. "Riparian Forest" was reliably classified in 1990 and 2000, and with lower user's accuracy in 2005 and 2010. In both time steps, confusion was mainly observed with "Secondary Riparian Forest" (Table 44, Table 45).

3.2.3 Land cover change assessment

The change detection was performed for the four different combinations possible with four observation times: 1990-2000, 2000-2005, 2005-2010, and the overall change 1990-2010. The resulting maps are presented in Figure 33 and Figure 34. **Areas which had "No Data" in any of the input classification layers were not considered in this analysis** in order to facilitate comparability of the quantitative results.



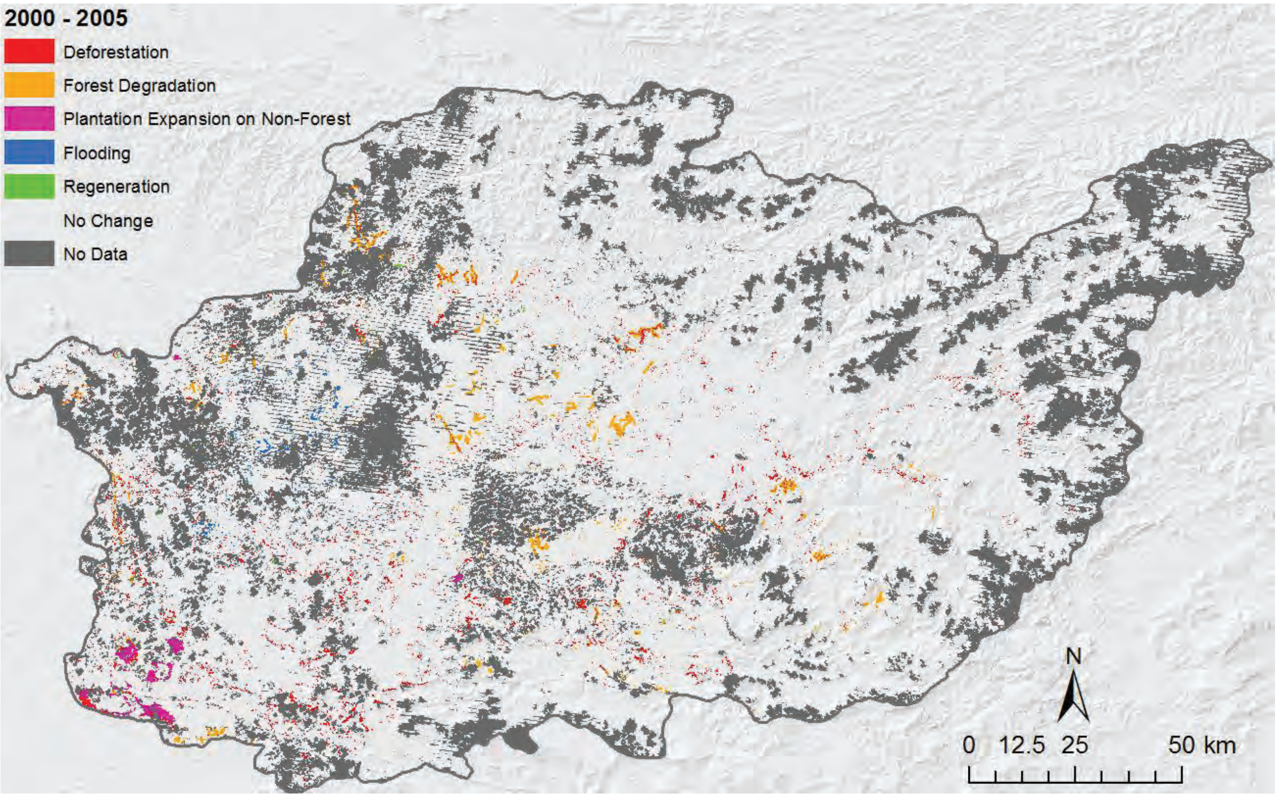


Figure 35. Land cover change maps of Kapuas Hulu district for the time periods 1990-2000 and 2000-2005.

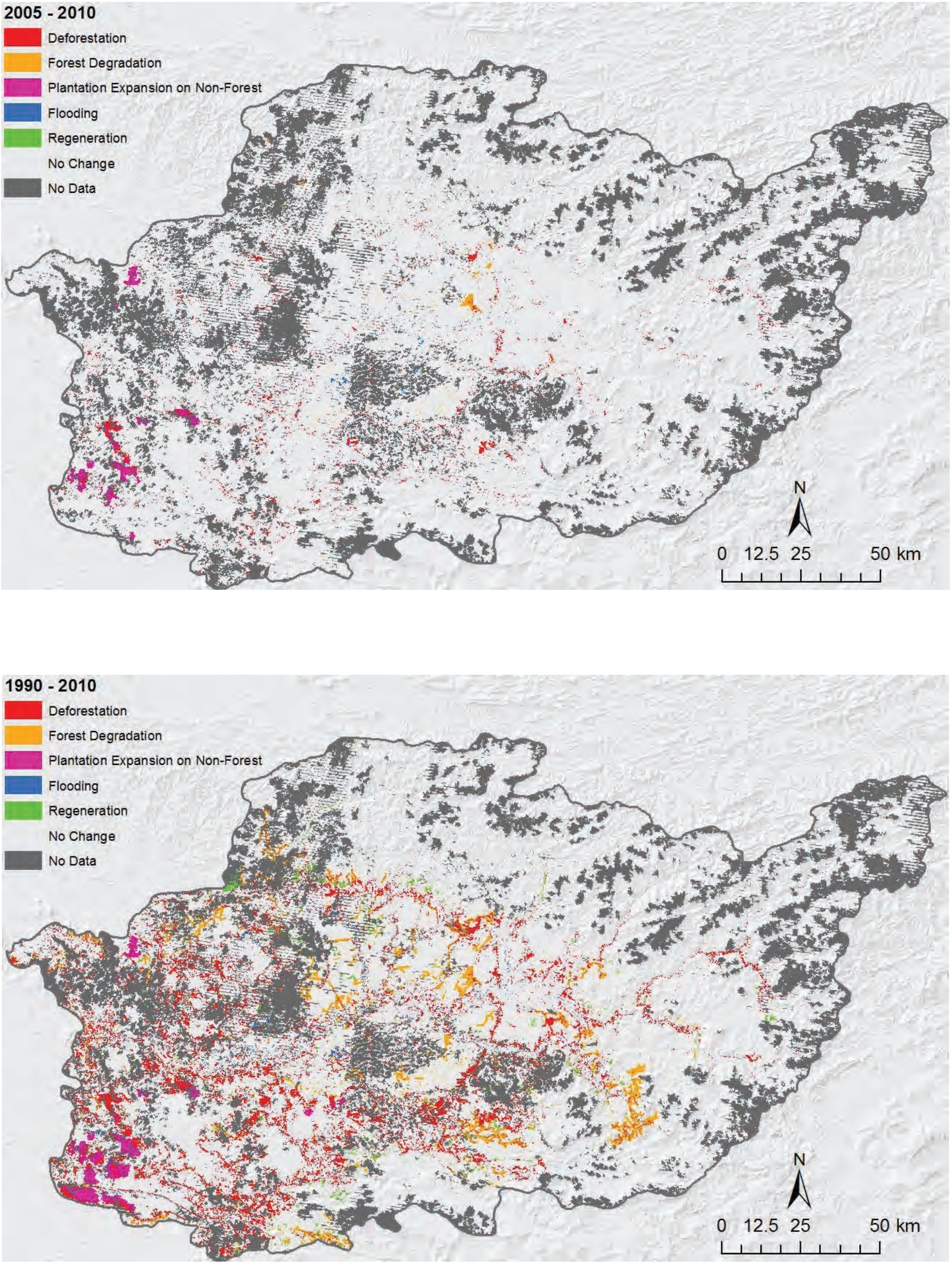


Figure 36. Land cover change maps of Kapuas Hulu district for the time periods 2005-2010 and 1990-2010.

Table 26 shows the summary of change processes for the four time periods. Land cover change in Kapuas Hulu showed high dynamics in the first investigation period. Between 1990 and 2000, only 92.3% of the investigated area featured “No change”, which means that 7.7% of the district land cover has changed. Between 2000 and 2005, 97.51% of the investigated area showed “No Change” and between 2005 and 2010, 98.3%. In the overall investigation period, “No Change” was observed in 89.2% of the investigated area, i.e. 10.8% of the investigation area featured changes.

The most dominant land cover change process over all observation periods was “Deforestation” with an affected area of 103,351 ha or 4.33% of the investigated area between 1990 and 2000, 29,245 ha or 1.22% between 2000 and 2005 and 24,713 ha or 1% between 2005 and 2010. Overall, between 1990 and 2010, 156,721 ha or 6.6% of the area investigated was affected by deforestation.

“Forest Degradation” was the second most dominant land cover change process with 46,632 ha or 1.95% of the investigated area between 1990 and 2000, 20,101 ha between 2000 and 2005 and 3,598 ha between 2005 and 2010, which shows a clear backward trend for “Forest Degradation” in the overall investigation period. Overall, 65,803 ha of forest or 2.8% of the investigated area showed “Forest Degradation” between 1990 and 2010.

“Flooding” was the third most important change process between 1990 and 2000 with 15,414 ha or 0.65% of the investigated area affected, but was less important in the later change periods with 3,869 ha (0.16%) between 2000 and 2005, and 1,940 ha (0.08%) between 2005 and 2010. Overall between 1990 and 2010, “Flooding” was observed on 6,795 ha or 0.28% of the investigated area.

Table 26. Change processes in Kapuas Hulu district in the four observation periods.

CHANGECODE	1990-2000	2000-2005	2005-2010	1990-2010
	ha %	ha %	ha %	ha %
Deforestation	103,351 4.33%	29,245 1.22%	24,713 1.03%	156,721 6.56%
Flooding	15,414 0.65%	3,869 0.16%	1,940 0.08%	6,795 0.28%
Forest Degradation	46,632 1.95%	20,101 0.84%	3,598 0.15%	65,803 2.76%
No Change	2,205,491 92.36%	2,328,533 97.51%	2,347,889 98.32%	2,128,954 89.16%
Plantation Expansion on Non-Forest	5,700 0.24%	5,758 0.24%	9,731 0.41%	18,459 0.77%
Regeneration	11,322 0.47%	405 0.02%	41 0.00%	11,179 0.47%
Total	**2,387,911**	**2,387,911**	**2,387,911**	**2,387,911**

“Plantation expansion on Non-Forest” was a change factor of increasing importance over the observation period. Between 1990 and 2000, 5,700 ha or 0.24% of the investigated area were affected, and approximately. the same amount of 5,758 ha between 2000 and 2005 (albeit in only half the time). In the last change period another 9,731 ha (0.41%) of “Plantation expansion on Non-Forest” was observed. Overall, between 1990 and 2010, 18,459 ha or 0.77% of the whole investigated area were affected.

“Regeneration” of secondary forest, while being the fourth most important change process between 1990 and 2000, was insignificant in the later change periods. Regeneration was observed mostly on long abandoned agricultural areas in the north west of Kapuas Hulu close to the Malaysian border, and in former logging areas along logging roads, where 5,664 ha of regeneration was observed.

Table 27. Area change per class in Kapuas Hulu district for the three change periods.

Class	1990-2000	2000-2005	2005-2010	1990-2010
Bare Area	20,737	13,463	-26,624	7,576
Water	20,808	-663	-34,418	-14,272
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	49,429	9,136	30,837	89,401
Plantation	6,255	6,964	11,934	25,153
Wetland	-5,199	-60	42,943	37,684
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	-74,129	-22,761	-11,587	-108,477
Secondary Lowland Dipterocarp Forest	20,494	3,706	-2,087	22,113
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	-6,588	-5,371	-1,689	-13,648
Secondary Hill and Sub-montane Dipterocarp Forest	6,067	3,333	54	9,455
Lower Montane Rainforest (900 -< 1500 m a.s.l.)	0	-28	-10	-38
Secondary Lower Montane Rainforest	4	3	0	7
Upper Montane Rainforest (> 1500 m a.s.l.)	0	0	0	0
Peat Swamp Forest	-32,411	-10,613	-6,804	-49,828
Secondary Peat Swamp Forest	11,691	6,547	1,147	19,384
Heath Forest	-3,546	-2,449	-1,433	-7,427
Secondary Heath Forest	843	1,447	335	2,625
Riparian Forest	-14,662	-2,120	-1,952	-18,733
Secondary Riparian Forest	207	-533	-647	-974
Total	**0**	**0**	**0**	**0**

The area change per class for the three individual observation periods 1990-2000, 2000-2005 and 2005-010, and the overall observation period 1990-2010 is shown in Table 27 and Figure 35.

The largest loss in area was observed for the Primary “Lowland Forest” class of 74,129 ha between 1990 and 2000 and 22,761 ha between 2000 and 2005. From 2005 to 2010, the area of Primary “Lowland Forest” decreased by another 11,587 ha, amounting to a total decrease of 108,477 ha in the overall investigation period 1990-2010. “Secondary Lowland Forest” increased by 20,494 ha between 1990 and 2000, and another 3,706 ha between 2000 and 2005 , but then also decreased by 2,087 ha between 2005 and 2010. This shows that while Primary “Lowland Forest” was subject to both “Deforestation” and “Forest Degradation” in the first two investigation periods, “Deforestation” clearly dominated between 2005 and 2010. Overall, “Secondary Lowland Forest” increased in area by 22,113 ha.

The second largest losses in area were observed in “Primary Peat Swamp Forest” with 32,411 ha (1990-2000), 10,613 ha (2000-2005) and 6,804 ha (2005-010), amounting to a decrease of 49,828 ha between 1990 and 2010. “Secondary Peat Swamp Forest” increased in area in all observation periods: Between 1990 and 2000 by 11,691 ha, then by 6,547 ha from 2000 to 2005 and another 1,147 ha between 2005 and 2010. In total the area of “Secondary Peat Swamp Forest increased by 19,384 ha between 1990 and 2010.

The area of Primary “Riparian Forest” decreased by 14,662 ha from 1990-2000, another 2,120 ha from 2000 to 2005 and by 1,952 ha between 2005 and 2010. “Secondary Riparian Forest” only showed a very small increase between 1990 and 2000, and then also losses of 533 ha between 2000 and 2005 and 647 ha between 2005 and 2010. Overall, Primary “Riparian Forest” lost 18,733 ha between 1990 and 2010, while “Secondary Riparian Forest” increased only by 974 ha. This means that almost all changes in “Riparian Forest” can be attributed to deforestation.

Primary “Hill and Submontane Forest” decreased in area by 6,588 ha (1990-2000), 5,371 ha (2000-2005) and 1,689 ha (2005-2010). “Secondary Hill and Submontane Forest” increased in area by 6,067 ha between 1990 and 2000, then by another 3,333 ha (2000-2005) and 54 ha (2005-2010). This shows that while in the first time period, almost all changes in “Hill and Submontane Forest” could be attributed to logging in between 1990 and 2000, there was an equal relation between logging and deforestation between 2000 and 2005, and an absolute dominance of deforestation between 2005 and 2010. Overall, Primary “Hill and Submontane Forest” lost 13,648 ha between 1990 and 2010, and “Secondary Hill and Submontane Forest increased in area by 9,455 ha in the same period.

Changes in the montane forest classes “Lower Montane Forest” and “Upper Montane Forest” showed very little magnitude and could hardly be observed.

The largest increase in area was observed for the class “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland” with 49,429 ha between 1990 and 2000, 9,136 ha between 2000 and 2005 and 30,837 ha between 2005 and 2010. Overall, “Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland” increased in area by 89,401 ha between 1990 and 2010. This shows that the expansion of agricultural area was and is the most dominant land cover change driver in Kapuas Hulu district.

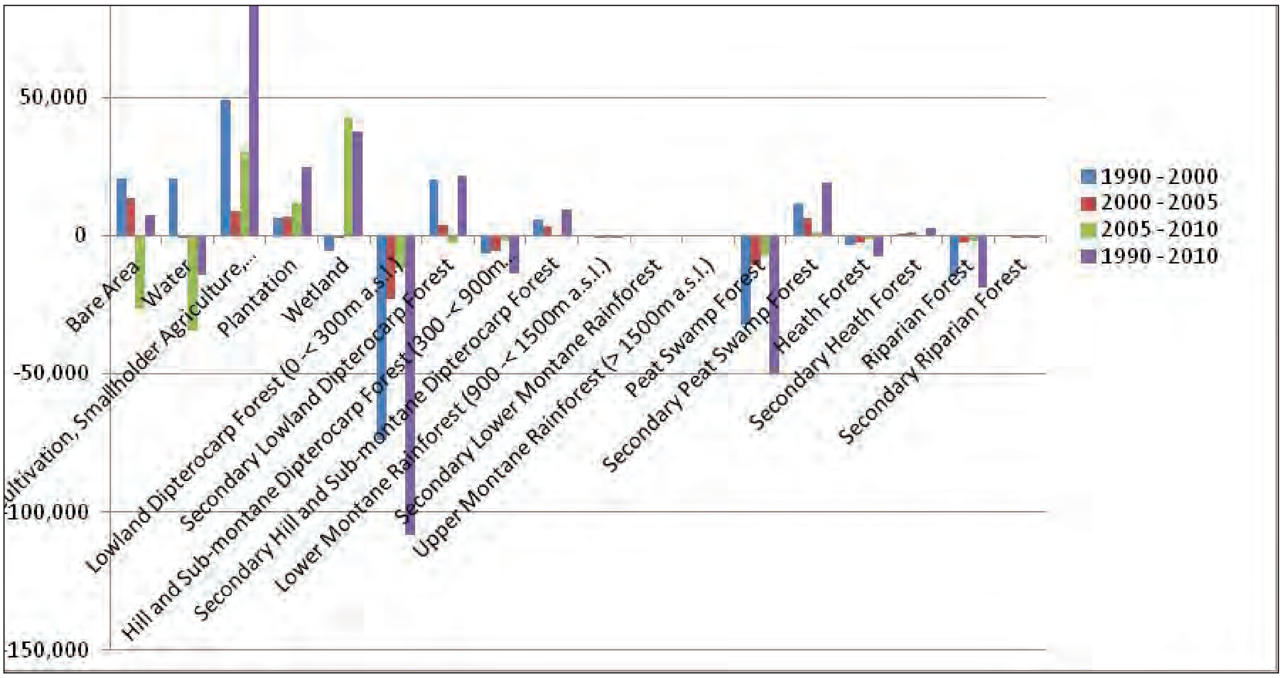


Figure 37. Area change per class in Kapuas Hulu district for the three change periods.

The second highest increases in area were observed for the class "Wetland" in the overall investigation period 1990-2010 with 37,684 ha. It is interesting to observe how this increase happened (see also description of drivers of deforestation in chapter 3.2.5). Between 1990 and 2000, large areas of "Riparian Forest" were cleared in the adjacency of the Danau Sentarum lake between 1990 and 2000, presumably by fire during the intensive drought of the 1997/98 El Nino catastrophe. However, in 2000 and 2005, the water levels in the lake were extremely high during the image acquisition, so the newly emerged wetland could not be observed because it was flooded an thus classified as "Water". Then, in 2010, the Landsat image used for the classification of Danau Sentarum area was taken in the mid dry season when the lake was almost completely desiccated (see land cover maps in chapter 3.2.1). Therefore, the increase in "Wetland" area was observed only in the latest observation period 2005-2010 and the overall observation period 1990-2010.

Finally, the third highest increases in area were observed for the "Plantation" class. "Plantation" area expanded with increasing intensity: First, between 1990 and 2000, "Plantation" area increased by 6,255 ha, then by 6,964 ha in half the time between 2000 and 2005. The sharpest increase was observed between 2005 and 2010 with 11,587 ha, amounting to a total increase of 25,153 ha from 1990 to 2010.

3.2.4 Deforestation rate

Figure 36 and Figure 37 show the forest cover map for Kapuas Hulu for the four time steps. The deforestation maps highlighting the changes in forest cover are shown in Figure 38 and Figure 39. The reader is reminded that, in order to make the calculated deforestation rates comparable, we applied a common no data mask to the data, i.e. **only areas which are cloud free in all 4 time steps are considered in the assessment.** The forest area estimates for the four time steps are shown in Table 28, the net forest loss is shown in Table 29 for the different observation periods and the resulting deforestation rates for the three change periods and the overall time period is shown in Figure 40.

Table 28. Spatial extent of forest and non-forest areas in Kapuas Hulu district.

	1990	2000	2005	2010
Forest	1,886,412	1,794,382	1,765,543	1,740,870
Non-forest	501,500	593,529	622,369	647,041

Forest area in Kapuas Hulu was reduced from 1,885,412 ha in 1990 by 92,029 ha to 1,794,382 ha until 2000. This equals to a net forest loss of 4.88% in this period. Between 2000 and 2005, forest area decreased by another 28,840 ha or 1.6% to 1,765,543 ha. In the last period 2005-2010, another net decrease in forest by 24,673 ha (1.4%) was observed. In the overall observation period 1990 - 2010, a total of 145,542 ha forest have been lost, which is 7,7% of the total forest area in 1990.

Table 29. Net forest loss in Kapuas Hulu district.

Net forest loss	1990-2000	2000-2005	2005-2010	1990-2010
ha	-92,029	-28,840	-24,673	-145,542
%	-4.88%	-1.61%	-1.40%	-7.72%

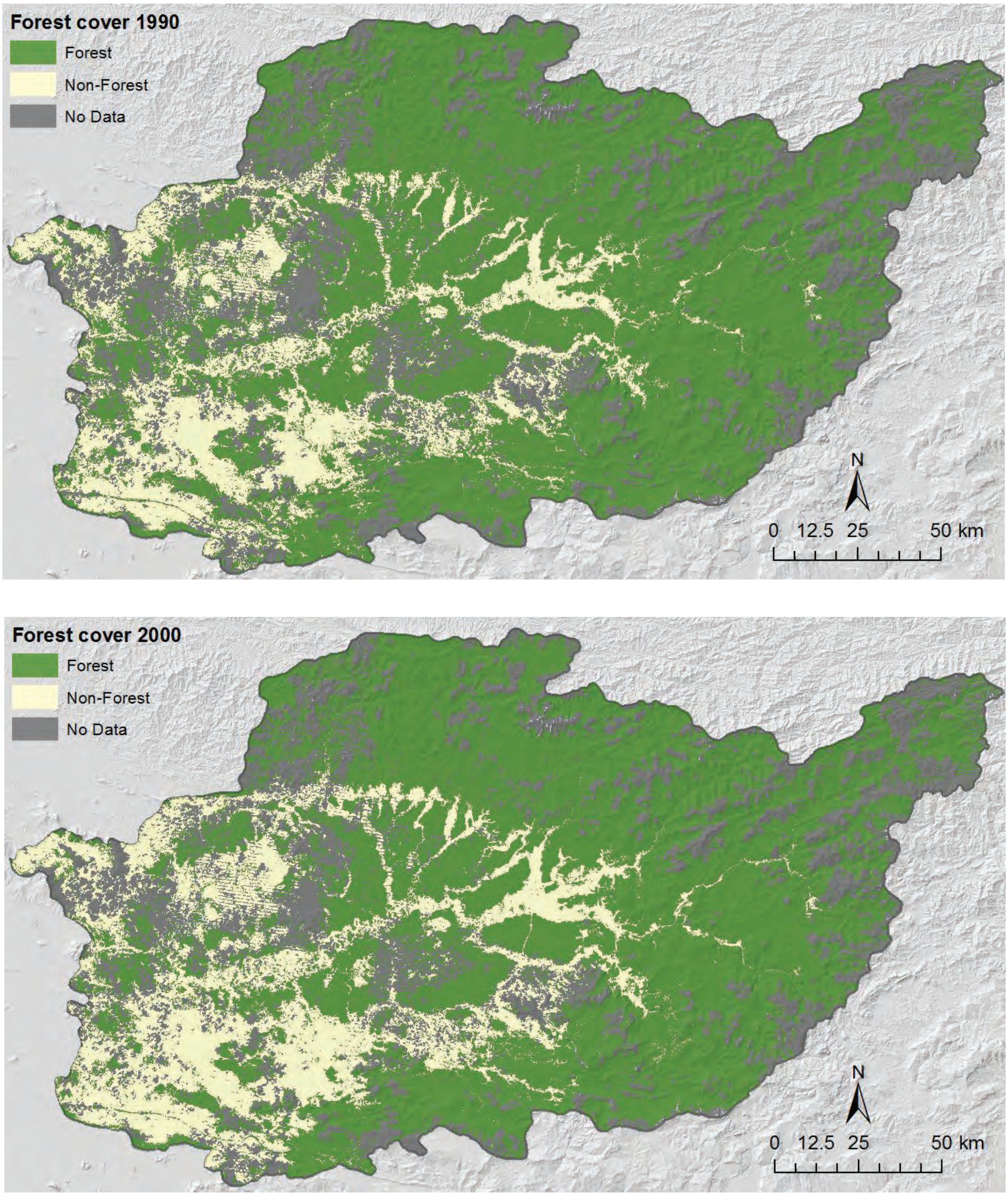


Figure 38. Forest cover maps of Kapuas Hulu district for 1990 and 2000.

Deforestation happened mainly along at the forest frontier bordering agricultural areas in the well accessible lowlands of Kapuas Hulu, since conversion of forest into agricultural land was identified as the most dominant driver of deforestation. Apart from this, deforestation was also observed along all major rivers, which act as a main means of transportation for frontier deforestation. This enabled an extension of anthropogenic activities even far into the mountains (see Figure 36; Figure 37; Figure 38; Figure 39).

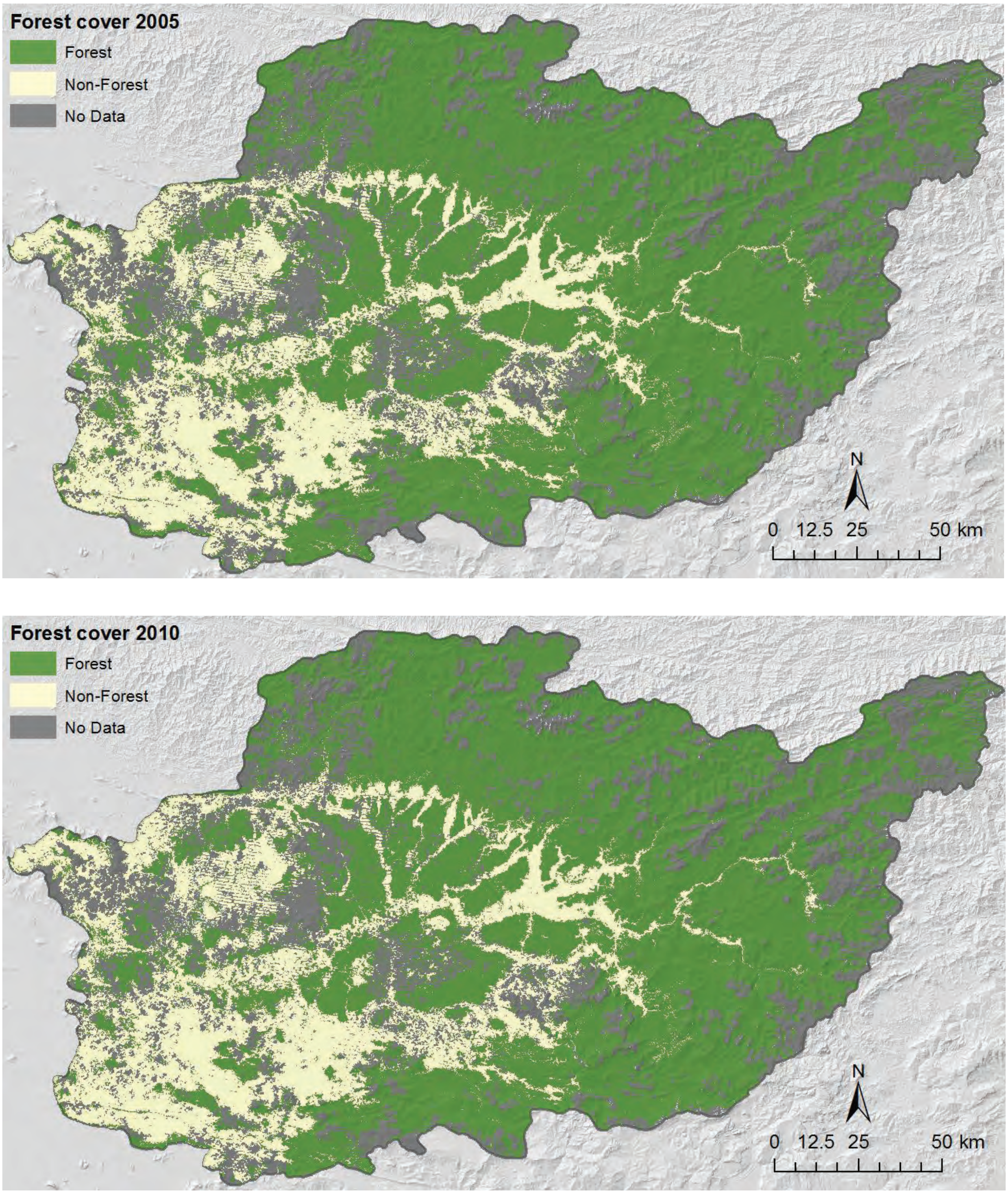
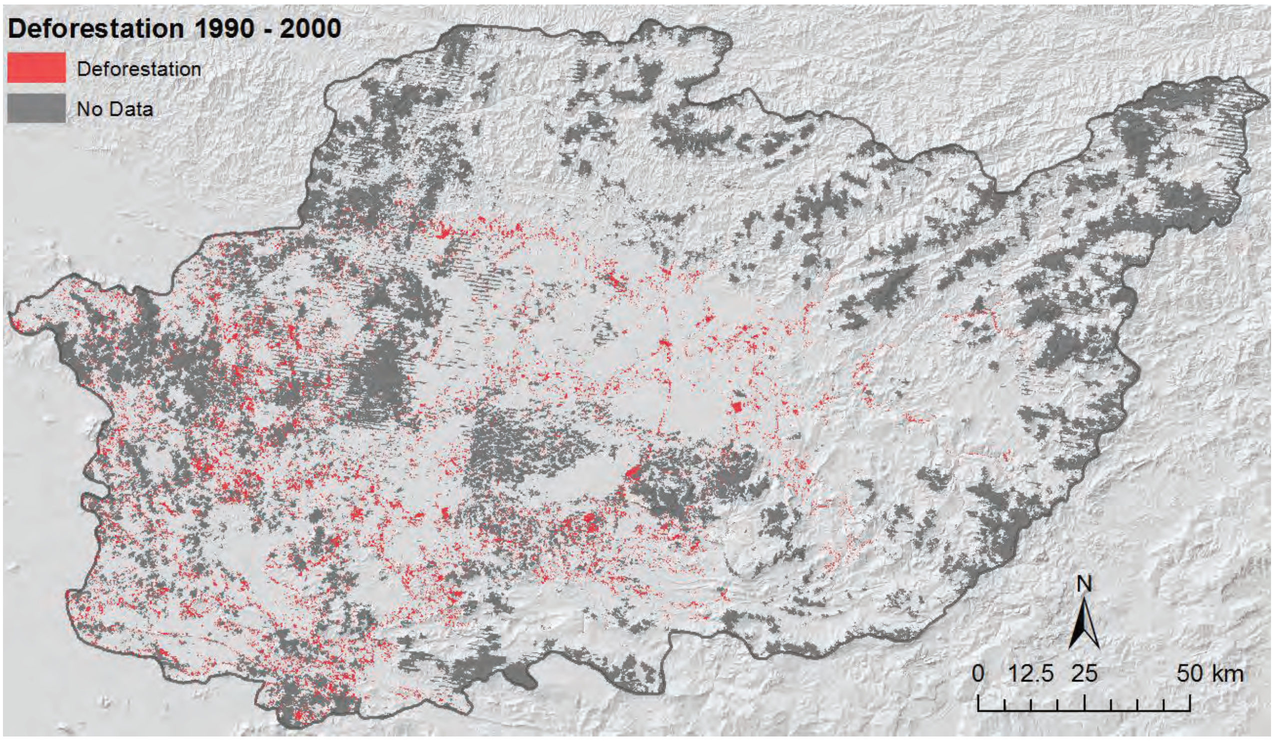


Figure 39. Forest cover maps of Kapuas Hulu district for 2005 and 2010.



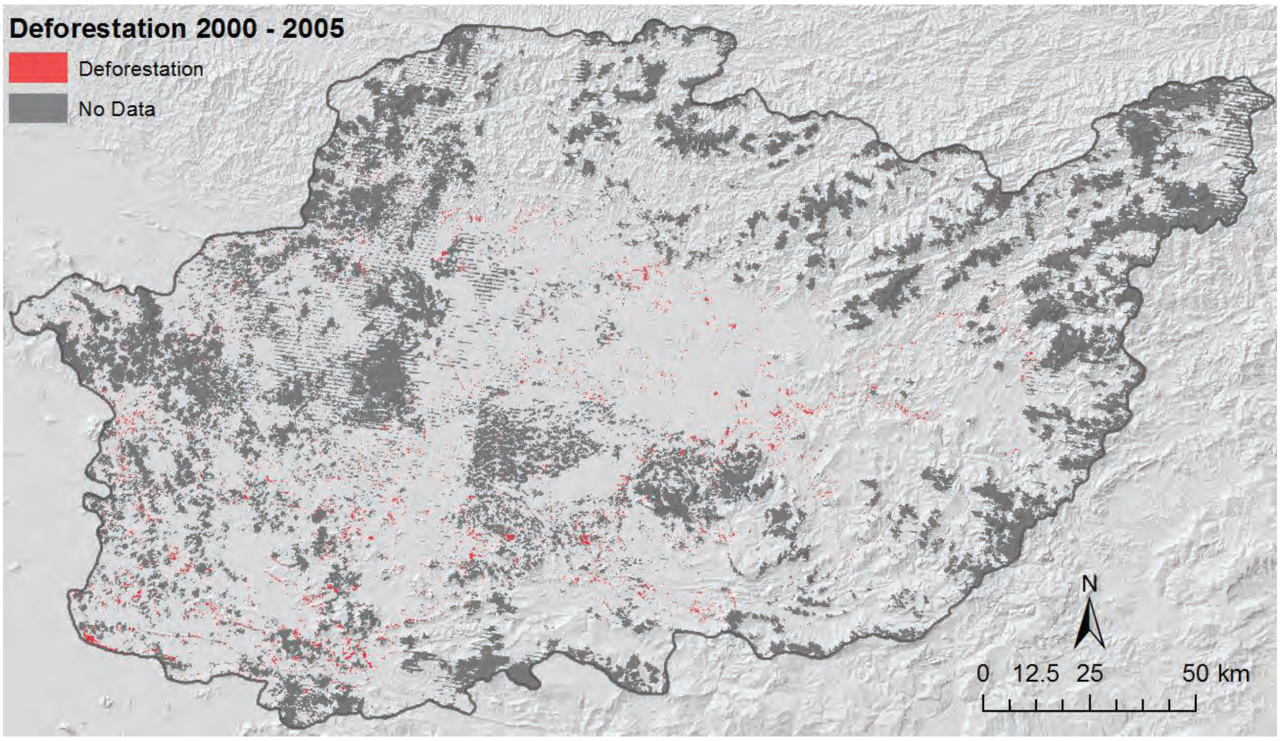
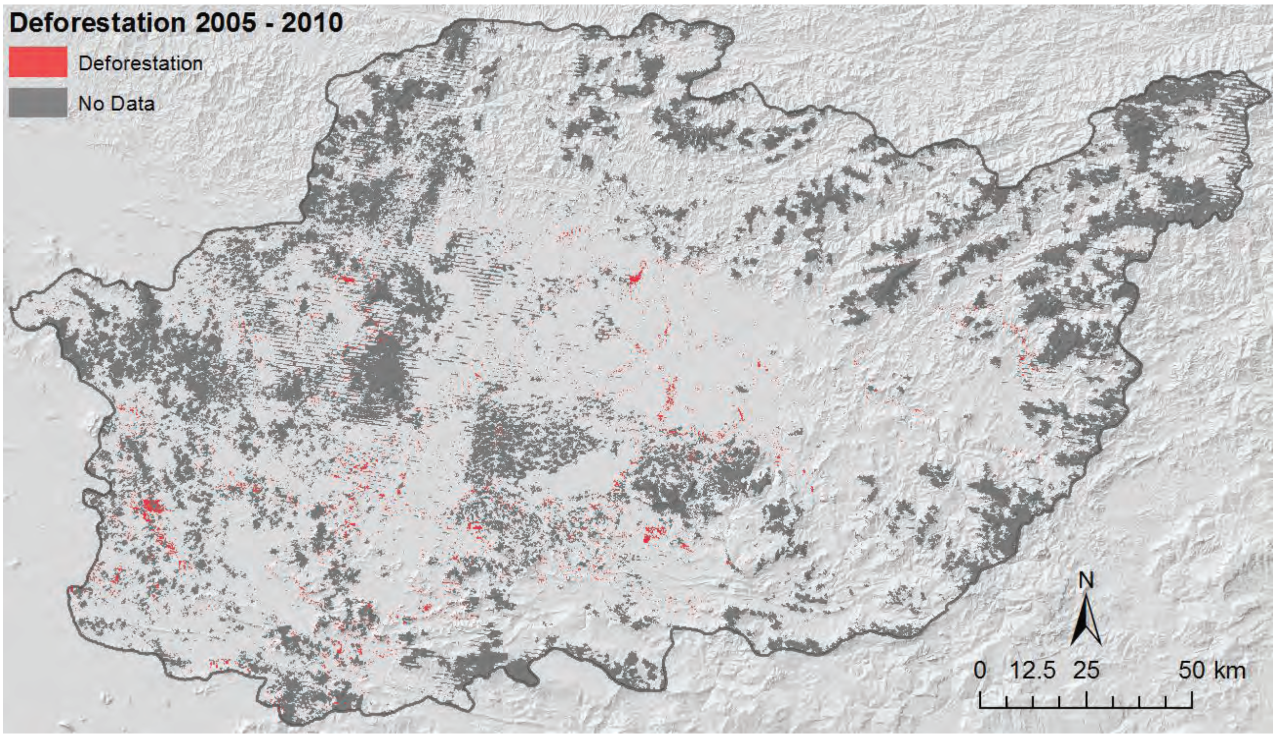


Figure 40. Deforestation maps of Kapuas Hulu district for the time periods 1990 - 2000 and 2000-2005.



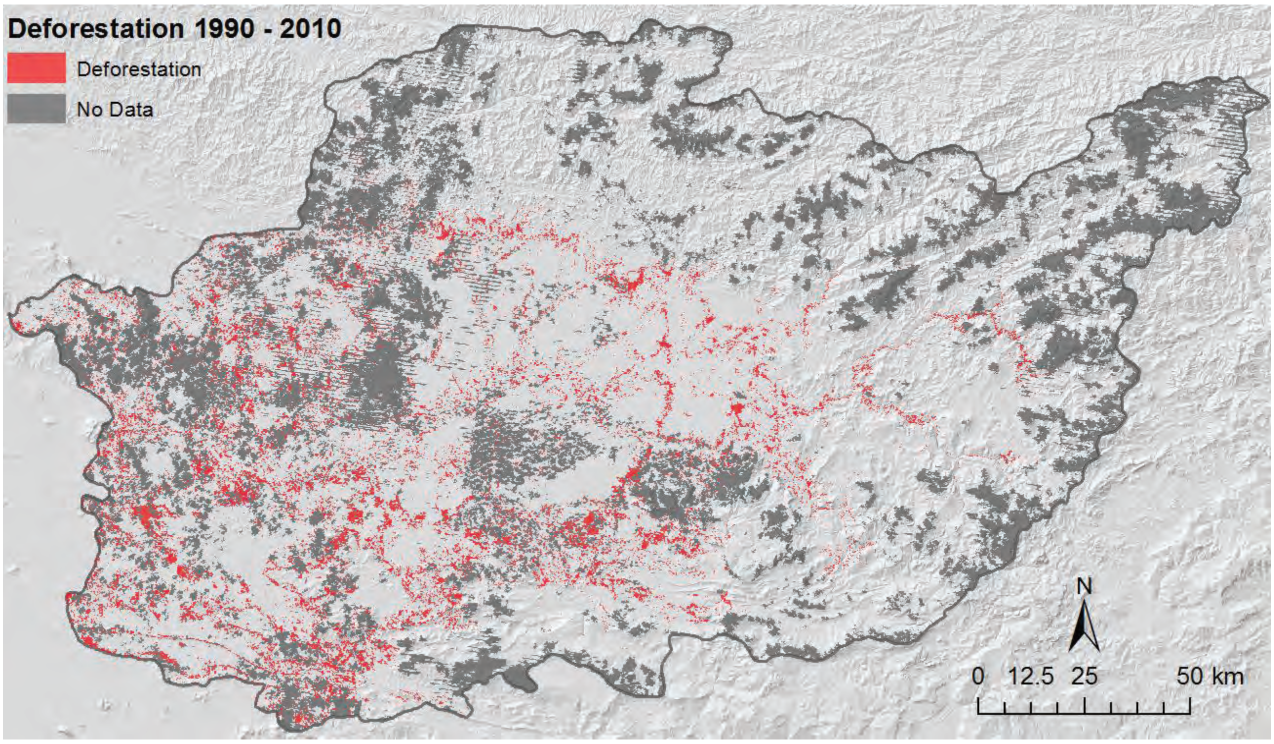


Figure 41. Deforestation maps of Kapuas Hulu district for the time periods 2005-2010 and 1990-2010.

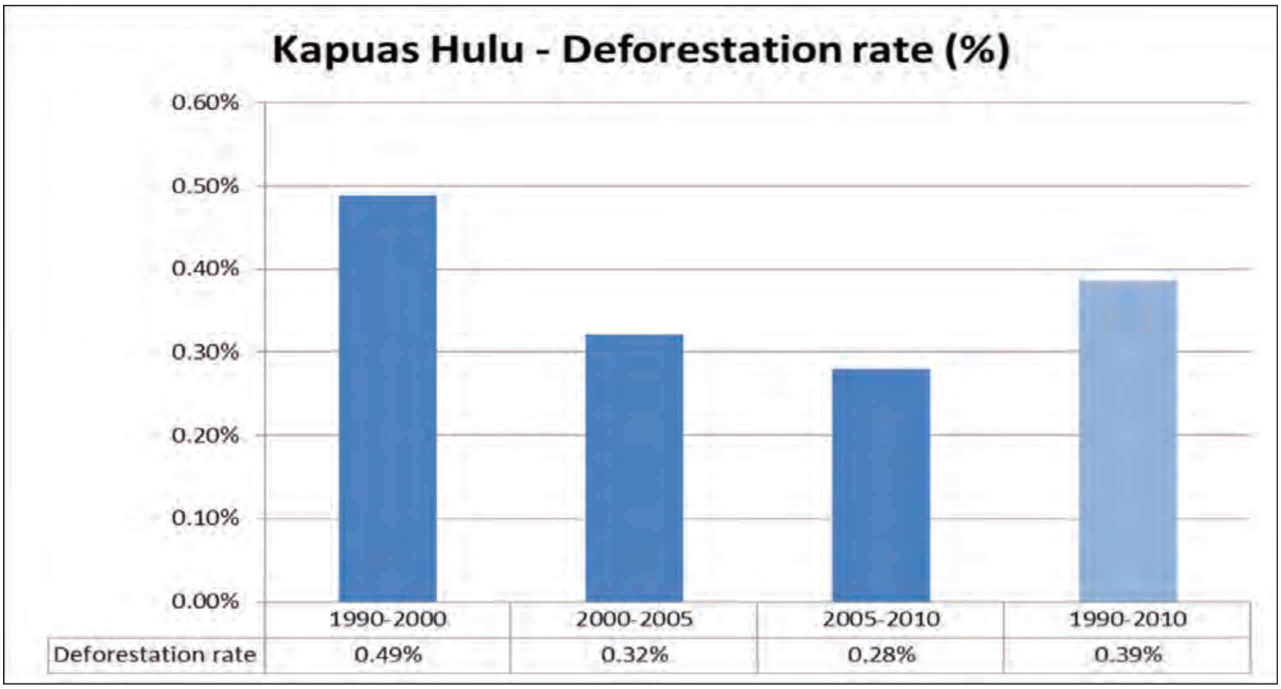


Figure 42. Deforestation rate [% yr-1] for Kapuas Hulu district in the three change periods and the overall time period.

Table 30. Deforestation rate [% yr-1] in Kapuas Hulu district.

	1990-2000	2000-2005	2005-2010	1990-2010
Deforestation rate	0.49%	0.32%	0.28%	0.39%

Deforestation in Kapuas Hulu district was significantly higher than in Malinau district, with 0.49% yr^{-1} (1990-2000), 0.32% yr^{-1} (2000-2005), 0.28% yr^{-1} (2005-2010) and 0.39% yr^{-1} in the overall observation period.

3.2.5 Drivers of deforestation

This chapter analyses the drivers for deforestation by the use of the change detection dataset. All areas which were identified as "Deforestation" in the dataset were analyzed for the land classes into which they were converted, in order to find out the reasons for their conversion. The reader is reminded that this analysis is based on gross deforestation area, excluding any forest regeneration. This is in contrast to the net forest loss described in chapter 3.2.4, therefore the figures on forest loss cannot be directly compared.

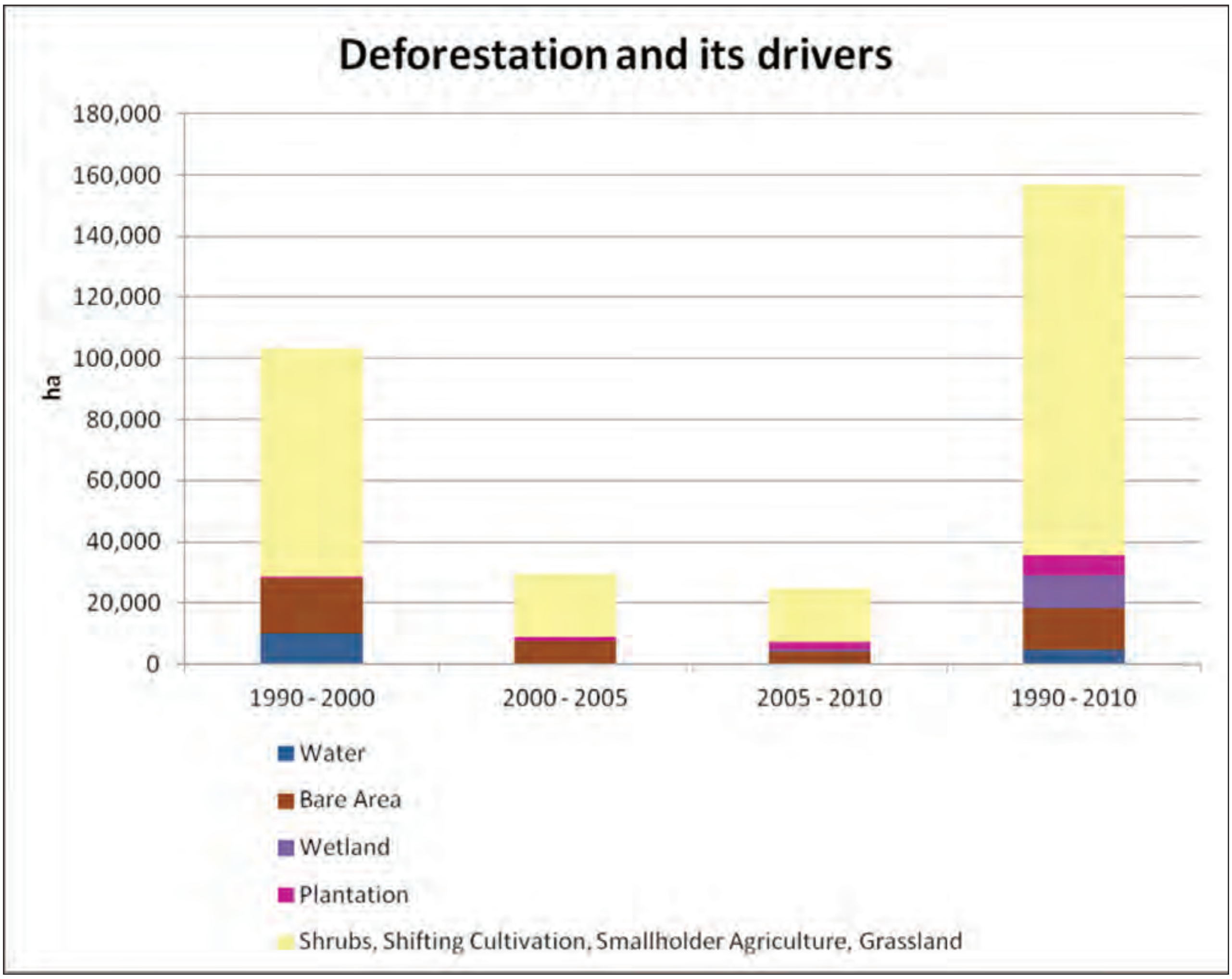


Figure 43. Deforestation and its drivers in Kapuas Hulu district.

Total gross deforestation in Kapuas Hulu was by far highest between 1990 and 2000 with 103,351 ha which results in 10,335 ha yr^{-1} annual average. This was reduced to 29,245 ha between 2000 and 2005 and then further to 24,713 ha between 2005 and 2010, which equals to 5,849 ha yr^{-1} and 4,943 ha yr^{-1} on average, respectively.

Between 1990 and 2000, 72.7% of deforestation was due to conversion of forest into agricultural land, i.e. the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". Only 0.5% of deforested land was converted into estate "Plantation". In Kapuas Hulu, estate crop plantation consist almost entirely of oil palm. 17.4% of deforested land was converted into "Bare Area" which contains no vegetation cover, but cannot be further specified. Large areas of forest have been converted into "Water" (9.81% of all deforested land). This development mostly happened in the adjacency of the Danau Sentarum wetland, where large areas of forests in the tidal areas have been lost in this period. The reasons for these large forest areas are not totally clear, but it can be assumed that this deforestation can attributed to extensive fires during the 1997/98 El Nino catastrophe, where the swamp and Riparian forests at Danau Sentarum experienced intensive drought, and became subject to vast forest fires.

Table 31. Deforestation and its drivers in Kapuas Hulu district.

Driver	1990-2000	2000-2005	2005-2010	1990-2010
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	74,690 72.27%	20,582 70.38%	17,652 71.43%	121,173 77.32%
Plantation	555 0.54%	1,205 4.12%	2,369 9.58%	6,699 4.27%
Wetland	15 0.01%	9 0.03%	728 2.95%	10,659 6.80%
Bare Area	17,953 17.37%	7,390 25.27%	3,796 15.36%	13,490 8.61%
Water	10,139 9.81%	59 0.20%	168 0.68%	4,700 3.00%
Total deforestation	**103,351**	**29,245**	**24,713**	**156,721**

In the following investigation period between 2000 and 2005, the percentage of deforestation due to conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" remained almost constant to the previous period with 70.4%. Conversion of forest into "Plantation" increased significantly to 4.1%, which equals to a factor of eight. Furthermore, conversion into "Bare area" also increased in percentage to 25.3%, which might be due to land being cleared with the intention of a later conversion into "Plantation" or other land uses. The conversion of forest into "Water" practically came to a halt, with only 0.2% of deforestation.

In the last time period between 2005 and 2010, conversion of forest land into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" was again the most dominant driver of deforestation with 71.4%. Conversion into "Plantation" experienced another sharp increase with 9.58% of deforested land affected, i.e. it's importance as a driver of deforestation doubled in comparison to the previous period. Conversion into "Bare Area" decreased to 15.4%. Conversion into "Water" was again negligible with only 0.68%. However, conversion of forest into "Wetland" amounted to 3%. The "Wetland" class represents periodically flooded land in the adjacency of the great lake areas in Kapuas Hulu district.

Looking at the overall change period 1990-2010 allows a summary of the drivers of deforestation over the past 20 years. 77.32% of all land deforested was converted into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". The increased percentage in comparison to the individual change periods shows that land previously converted into "Bare Area" was in fact later put into agricultural use. 4.3% of all deforested land was converted into "Plantation", which equals to the overall average importance of this driver found in the three individual time periods. In Kapuas Hulu, almost all large estate "Plantations" consist of Oil Palm. Conversion into "Wetland" amounted to 6.8% which is due to the usual interchanging flooding situation in the large wetlands of Kapuas Hulu. The lakes frequently almost desiccate in the dry season which leads to changes from "Water" to "Wetland". Conversion of forest into "Bare Area" amounted to 8.6% between 1990 and 2010. Conversion to "Water" has only a minor importance, as already seen in the last two individual change periods, with 3% of deforested land affected.

3.2.6 Estimation of carbon emissions on district level

The estimation of carbon emissions in this chapter is conducted based on a stock difference approach of the carbon stock stored in the different land cover classes in each time step (1990, 2000, 2005 and 2010), calculated based on the spatial extent of the classes and the biomass and carbon values presented in chapter 2.5.2.2. The carbon stock for each land cover class and the development over time is shown in Figure. 42 and Table. 32. Based on these calculation the stock difference was calculated during the change detection analysis and the carbon stock difference is shown in Figure 43 and Table 33.

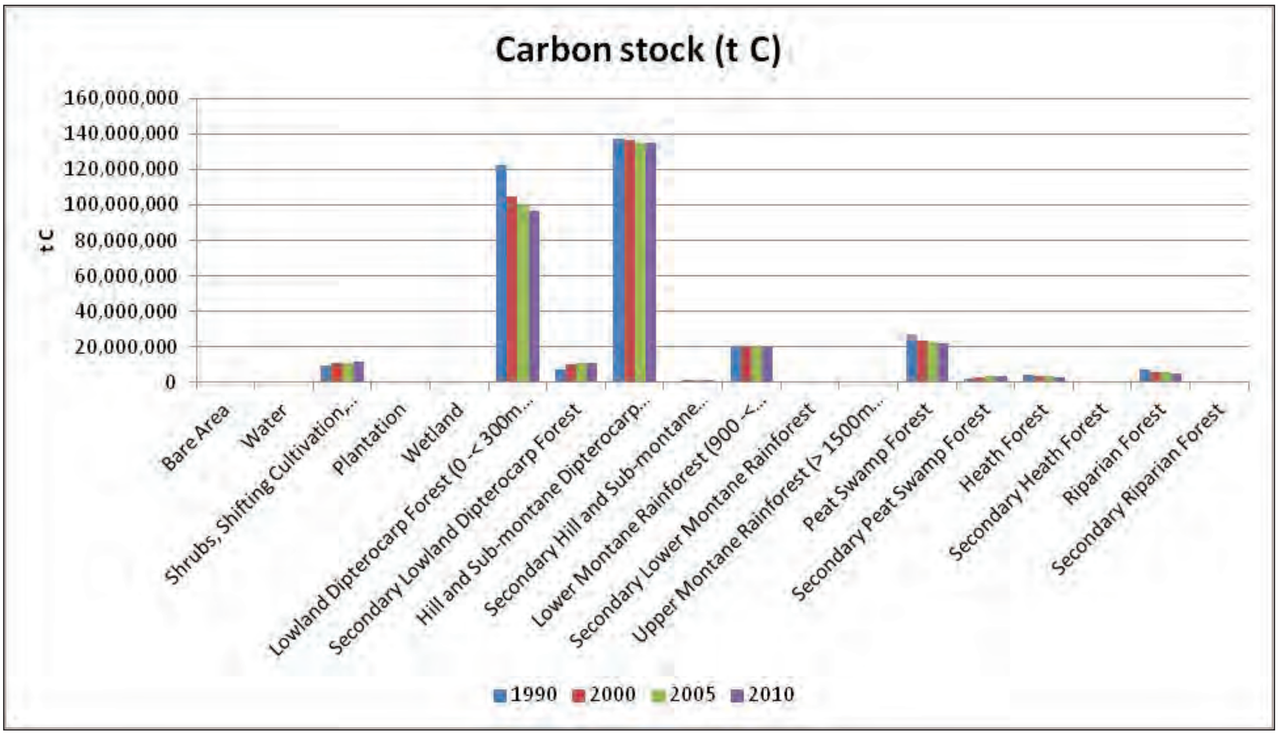


Figure 44. Carbon stock of the different land cover classes for the four time steps.

The land cover class storing the highest carbon stock is and was Primary "Hill and Submontane Forest", with 137,475,798 tC in 1990. This decreased by 1,101,463 tC (8%) until 2000 to 136,374,335 tC. In the next 5 year period 2000-2005, another decrease by 897,981 tC was observed and between 2005 and 2010, 282,419 tC were lost in this class. In the overall observation period 1990-2010, carbon losses in Primary "Hill and Submontane Forest" amounted to 2,281,863 tC, or 1.7% of the original carbon stock in 1990. In the same time, carbon stock in "Secondary Hill and Submontane Forest" increased by 916,339 tC from 572,818 tC (1990) to 1,489,156 tC in 2010, which equals to an increase by 160%.

The second highest carbon stock in Kapuas Hulu was and is stored in Primary "Lowland Forest" and this class also experienced the most intensive losses in carbon stock. From the original 122,389,876 tC stored in 1990, 17,423,184 tC were lost until 2000 alone, then another 5,349,830 tC between 2000 and 2005 and another 2,723,420 tC between 2005 and 2010. In total, 25,496,434 tC or 20% were lost in this class, leading to a reduced carbon stock of 96,902,442 tC in 2010. Since not all this carbon was lost due to deforestation, but also forest degradation, the carbon stock in "Secondary Lowland Forest" increased in the overall investigation period (1990-2010) by 3,058,253 tC. However, increases were limited to the first change period 1990-2000 (2,834,306 tC) and the second period 2000-2005 (512,530 tC), while in the third change period there was also a decrease observed by 288,584 tC.

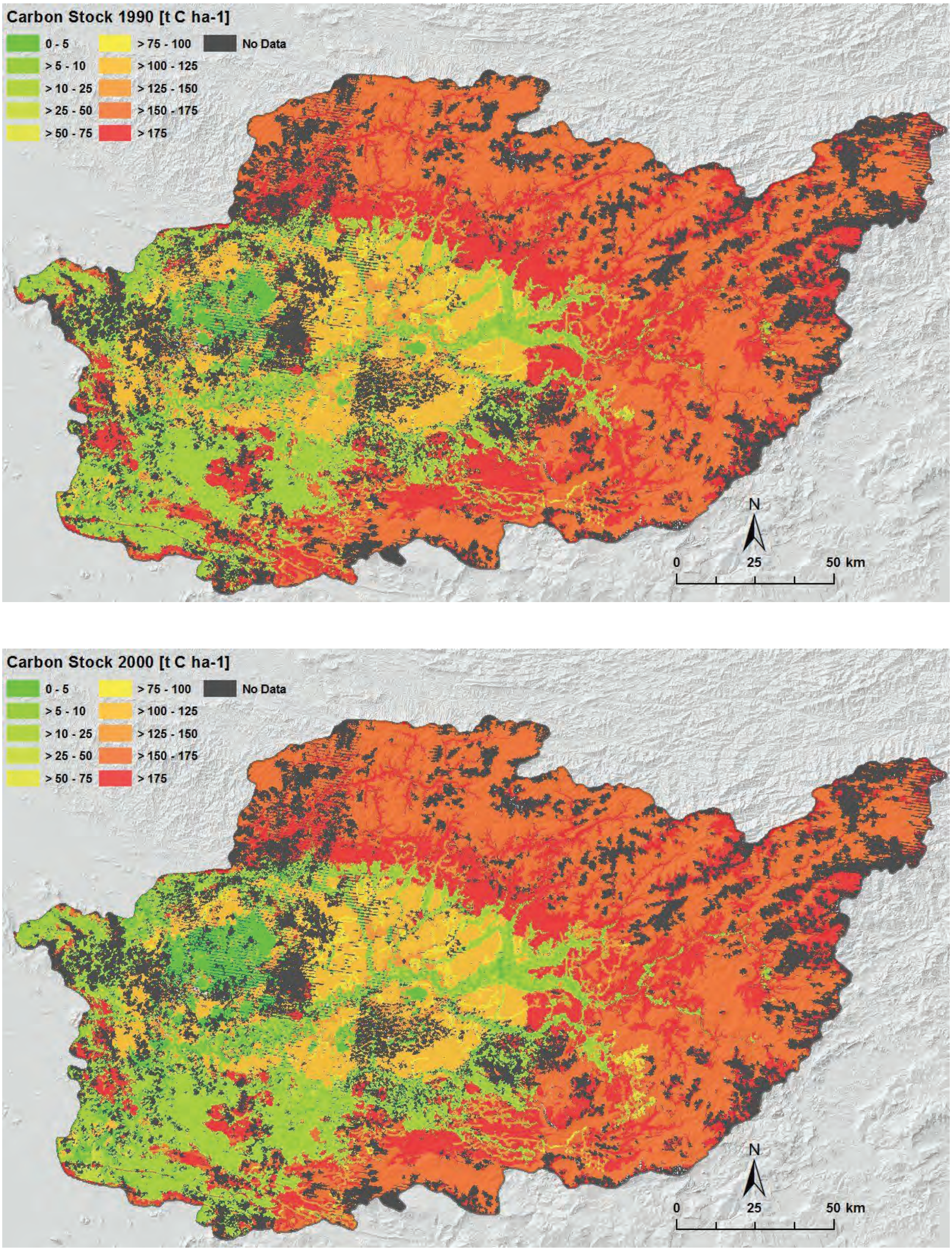
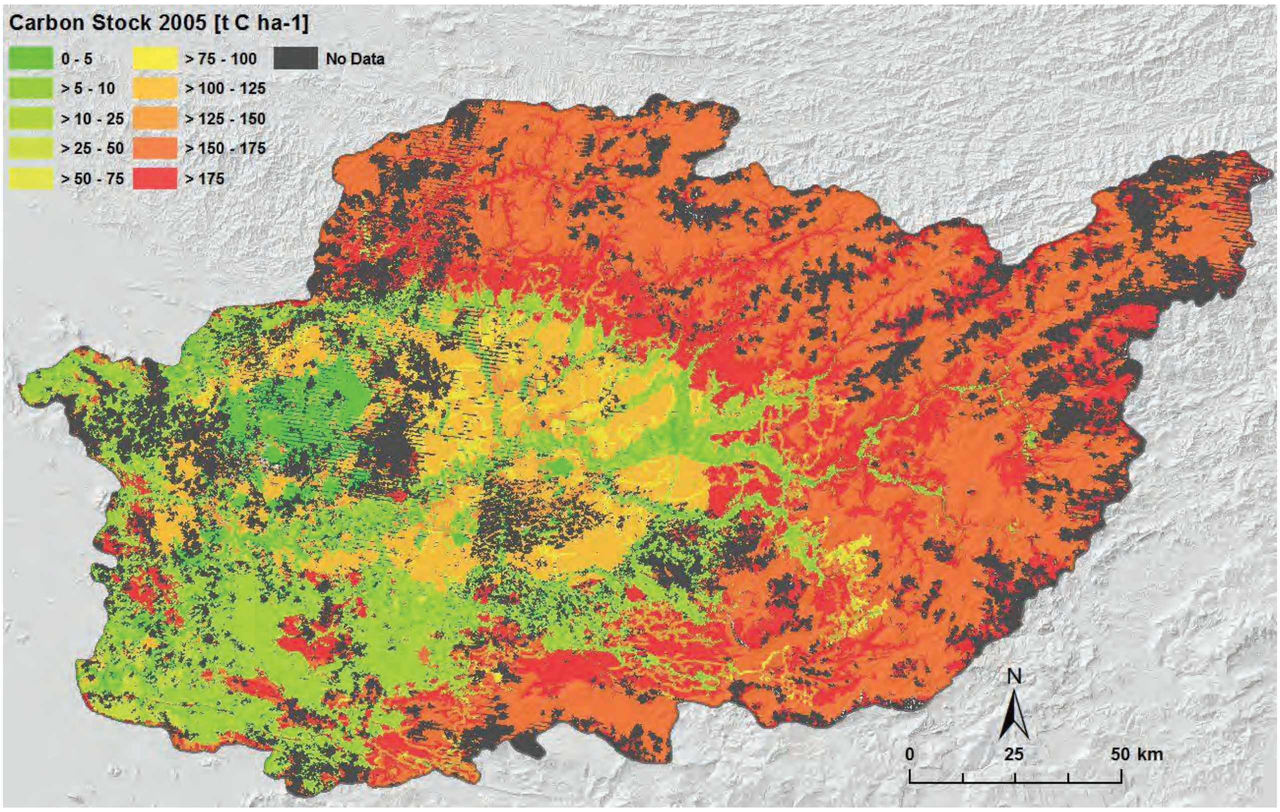


Figure 45. Carbon stock maps of the Kapuas Hulu study area for the time steps 1990 and 2000.



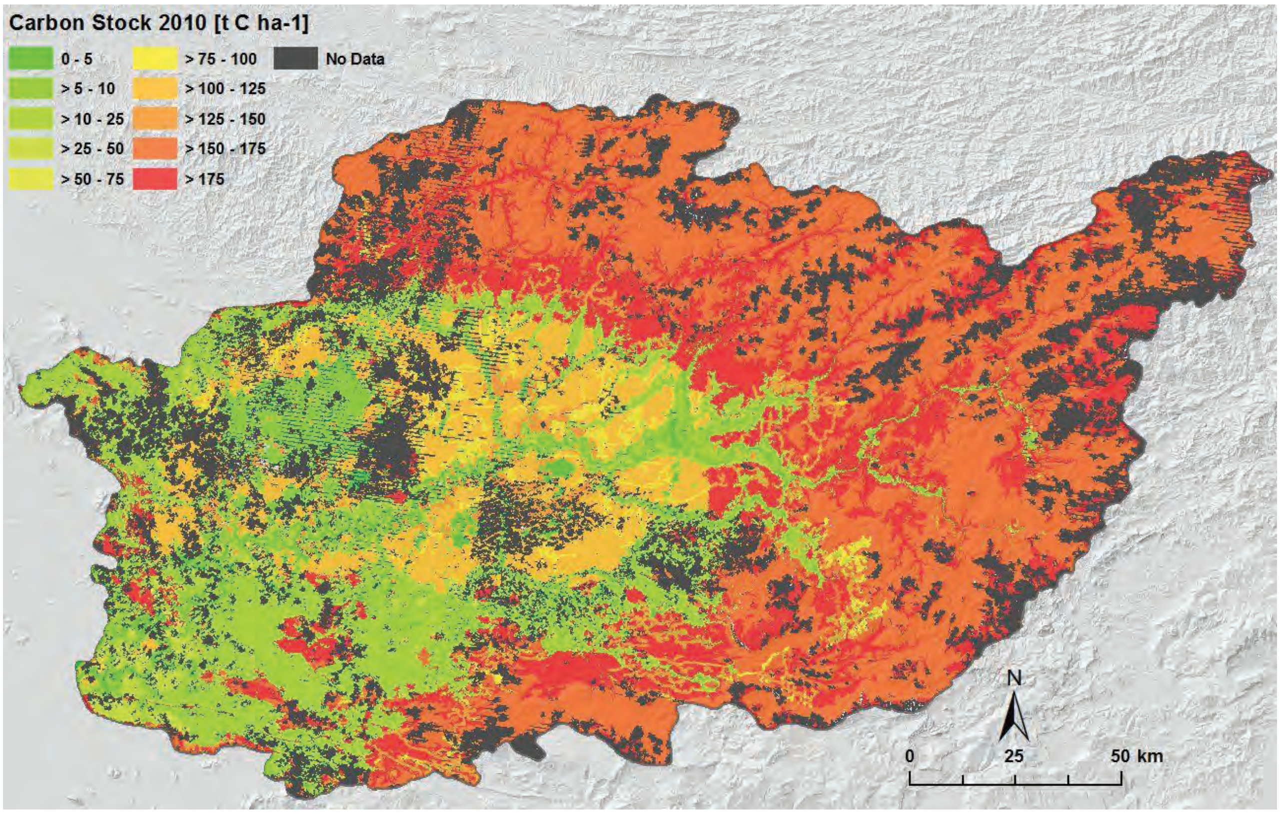


Figure 46. Carbon stock maps of the Kapuas Hulu study area for the time steps 2005 and 2010.

Primary “Peat Swamp Forest” was also subject to significant decreases in carbon stock in the investigation period. Between 1990 and 2000, 3,489,376 tC were lost, followed by 1,142,613 tC between 2000 and 2005 and another 732,499 tC between 2005 and 2010. In total, 5,346,488 tC were lost between 1990 and 2010. “Secondary Peat Swamp Forest” experienced an increase in carbon stock between 1990 and 2010 by 1,469,904 tC.

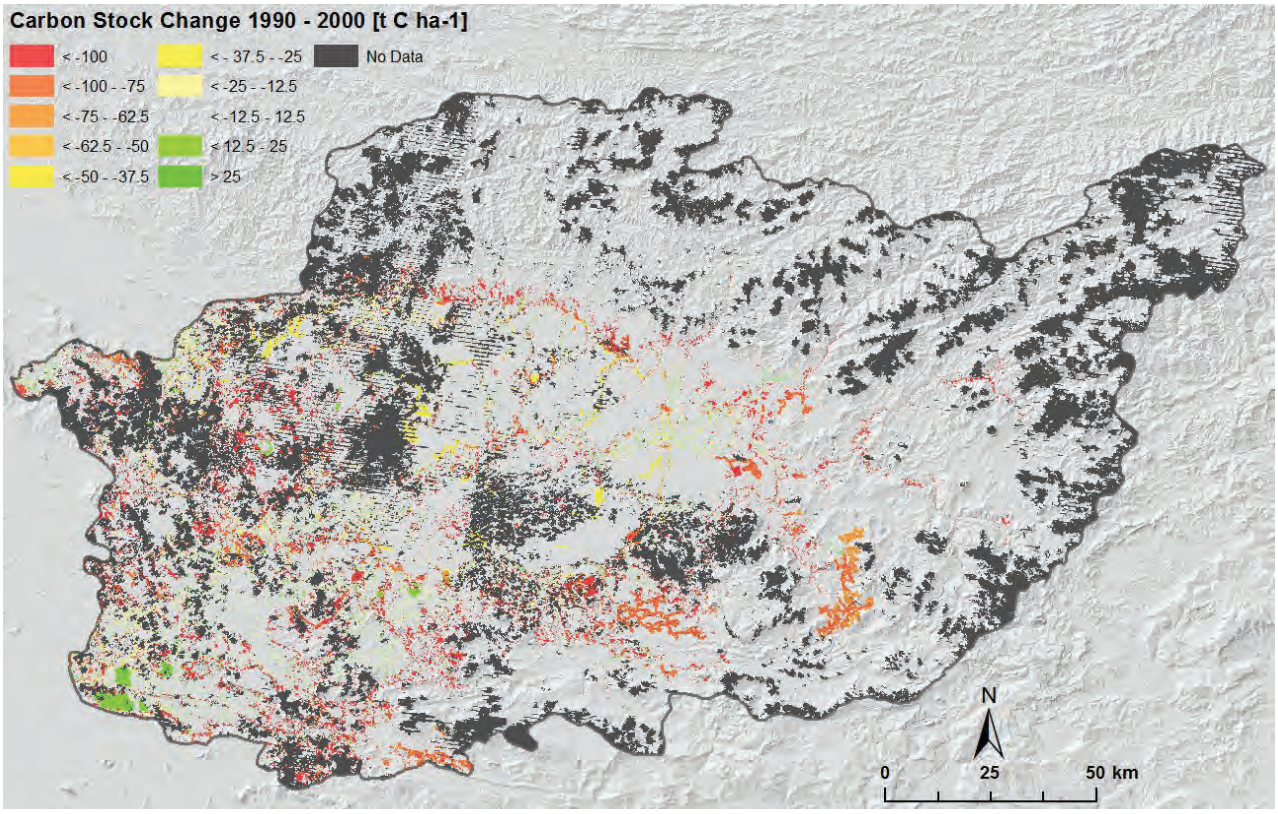
“Riparian Forest” lost a total of 2,376,157 tC between 1990 and 2010, with the majority of losses of 1,859,704 tC observed between 1990 and 2000. At the same time, “Secondary Riparian Forest” also experienced losses in carbon stock, not in the first change period when a slight increase of 7,873 tC was observed, but starting in the 2000-2005 period with 20,303 tC and another 24,668 tC between 2005 and 2010. Total loss of carbon in “Secondary Riparian Forest” amounted to 37,098 tC from 1990 until 2010.

“Heath Forest” also experienced carbon losses. Between 1990 and 2000, 397,041 tC were lost, then another 274,208 tC between 2000 and 2005 and 160,475 tC between 2005 and 2010, amounting to a total decrease of 831,724 tC between 1990 and 2010. Carbon stock in “Secondary Heath Forest” increased from 164,775 tC by 75,011 tC between 1990 and 2000, by 128,674 tC between 2000 and 2005 and another 29,825 tC between 2005 and 2010, amounting to a total increase by 233,510 tC between 1990 an 2010.

The montane forest classes experienced hardly any changes in carbon stock, because there was almost no land cover change observed (see chapter 3.2.3).

Table 32. Carbon stock of the different land cover classes for the four time steps.

Class	1990	2000	2005	2010
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	9,732,572	10,905,017	11,121,712	11,853,174
Plantation	16,880	260,825	532,404	997,847
Wetland	121,748	82,855	82,408	403,622
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	122,398,876	104,975,692	99,625,862	96,902,442
Secondary Lowland Dipterocarp Forest	7,696,005	10,530,311	11,042,841	10,754,258
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	137,475,798	136,374,335	135,476,354	135,193,935
Secondary Hill and Sub-montane Dipterocarp Forest	572,818	1,160,839	1,483,905	1,489,156
Lower Montane Rainforest (900 -< 1500 m a.s.l.)	19,832,745	19,832,745	19,826,808	19,824,740
Secondary Lower Montane Rainforest	0	543	881	881
Upper Montane Rainforest (> 1500 m a.s.l.)	165,532	165,532	165,532	165,532
Peat Swamp Forest	27,120,718	23,631,342	22,488,729	21,756,230
Secondary Peat Swamp Forest	2,241,395	3,127,910	3,624,339	3,711,299
Heath Forest	4,086,529	3,689,488	3,415,280	3,254,805
Secondary Heath Forest	164,775	239,786	368,460	398,285
Riparian Forest	7,651,283	5,791,579	5,522,707	5,275,126
Secondary Riparian Forest	281,764	289,637	269,334	244,666
	339,559,437	**321,058,438**	**315,047,559**	**312,225,999**



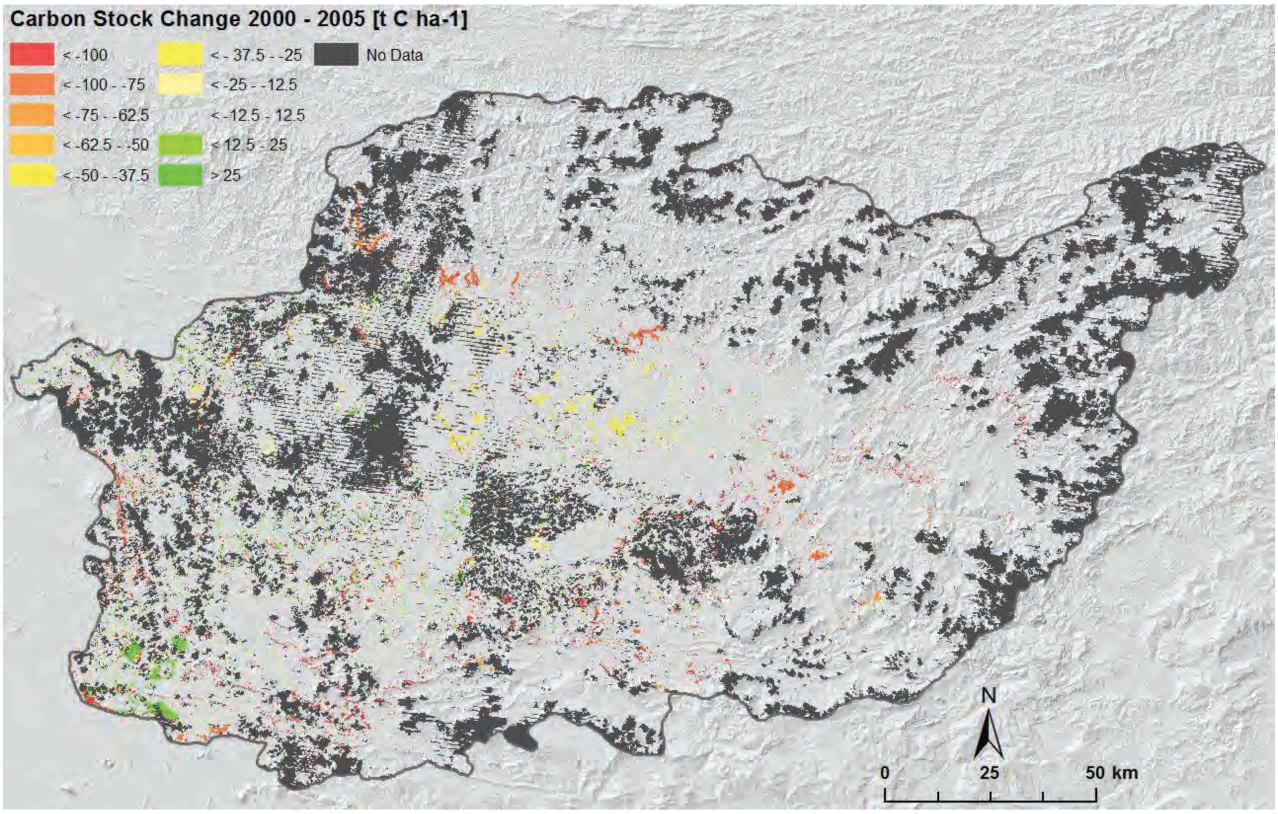
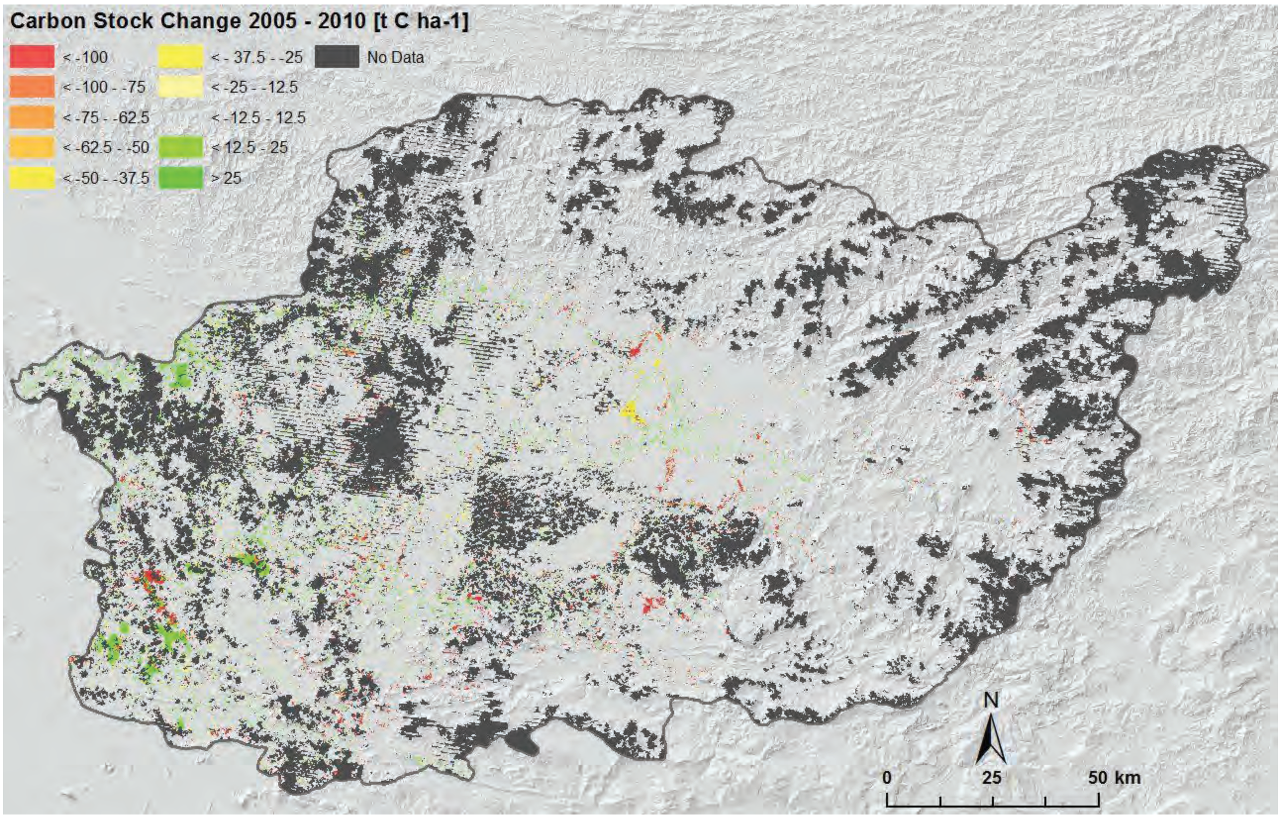


Figure 47. Carbon stock change maps of Kapuas Hulu for the time periods 1990-2000 and 2000-2005.



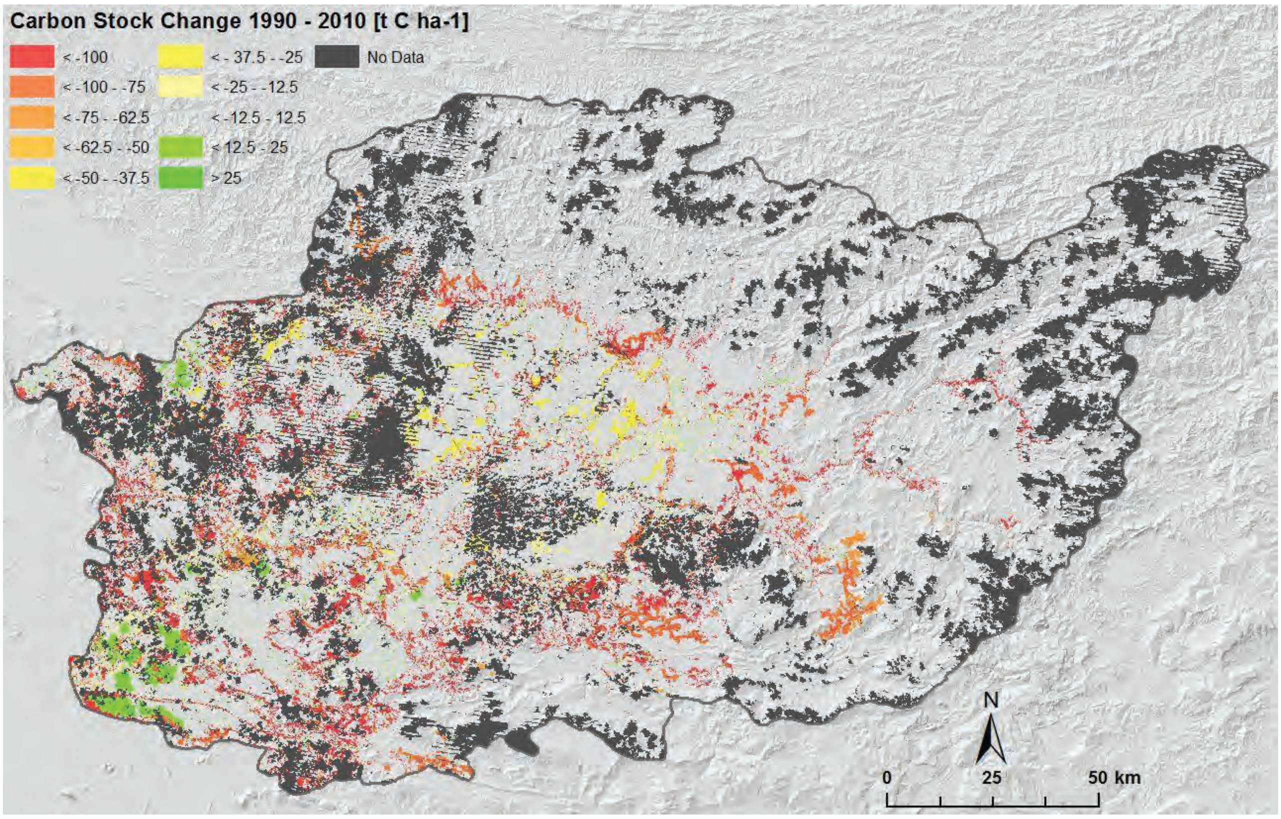


Figure 48. Carbon stock change maps of Kapuas Hulu district for the time periods 2005–2010 and 1990–2010.

In the non-forest classes, increases were observed in the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". Between 1990 and 2000, carbon stocks increased by 1,172,445 tC, then by 216,695 tC between 2000 and 2005 and another 731,461 tC between 2005 and 2010. In total, an increase by 2,120,601 tC was observed from 1990 to 2010, which equals to 21.8% adding to the 9,732,572 tC stored in 1990.

The class "Plantation" experienced also large increases in carbon stock. While in 1990, only 16,880 tC were stored in this class, the carbon stock increased by 243,945 tC until 2000, by another 271,579 tC from 2000 until 2005 and by 465,444 tC between 2005 and 2010. The total increase between 1990 and 2010 amounted to 980,968 tC, which equals to a factor of 58 in comparison to the original carbon stock.

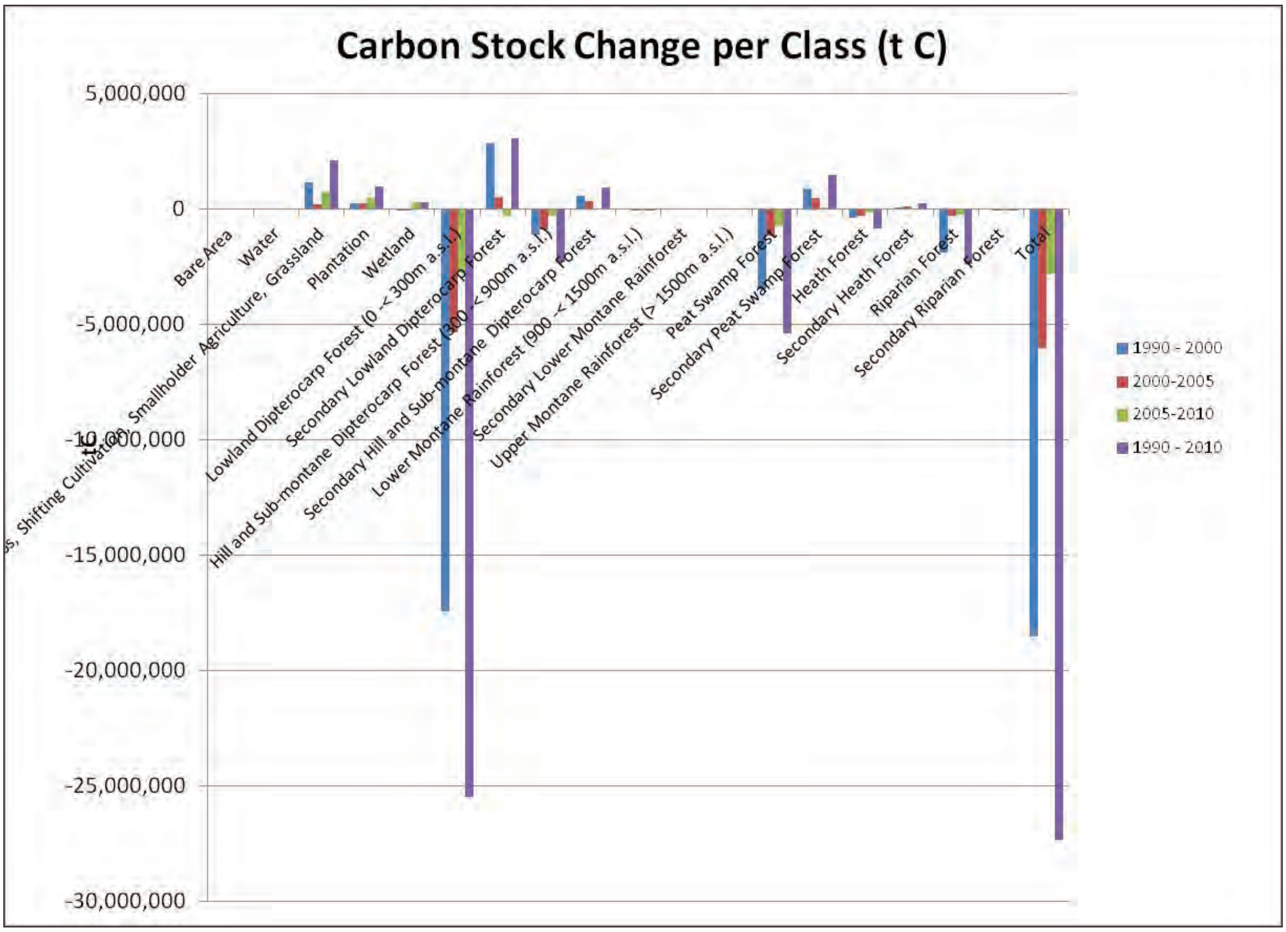


Figure 49. Carbon change per class in Kapuas Hulu district for the three change periods.

Table 33. Carbon change per class in Kapuas Hulu district for the three change periods.

Class	1990-2000	2000-2005	2005-2010	1990-2010
	t C			
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	1,172,445	216,695	731,461	2,120,601
Plantation	243,945	271,579	465,444	980,968
Wetland	-38,892	-447	321,214	281,875
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	-17,423,184	-5,349,830	-2,723,420	-25,496,434
Secondary Lowland Dipterocarp Forest	2,834,306	512,530	-288,584	3,058,253
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	-1,101,463	-897,981	-282,419	-2,281,863
Secondary Hill and Sub-montane Dipterocarp Forest	588,021	323,066	5,251	916,339
Lower Montane Rainforest (900 -< 1500m a.s.l.)	0	-5,937	-2,068	-8,005
Secondary Lower Montane Rainforest	543	338	0	881
Upper Montane Rainforest (> 1500m a.s.l.)	0	0	0	0
Peat Swamp Forest	-3,489,376	-1,142,613	-732,499	-5,364,488
Secondary Peat Swamp Forest	886,515	496,429	86,960	1,469,904
Heath Forest	-397,041	-274,208	-160,475	-831,724
Secondary Heath Forest	75,011	128,674	29,825	233,510
Riparian Forest	-1,859,704	-268,872	-247,582	-2,376,157
Secondary Riparian Forest	7,873	-20,303	-24,668	-37,098
Total	**-18,500,999**	**-6,010,879**	**-2,821,560**	**-27,333,437**

Figure 44 shows the annual carbon emissions in Kapuas Hulu for the three change periods 1990-2000, 2000-2005 and 2005-2010, as well as the overall observation period 1990-2010. Annual emissions were highest in the first change period 1990-2000 with 1,850,100 tC yr^{-1}. Annual emissions dropped significantly from 2000 on, amounting to 1,202,176 tC yr-1 between 2000 and 2005 and then 564,312 tC in the third change period 2005 to 2010. One of the reasons for this decrease in Kapuas Hulu is a reduction of logging activities in the third time period, which significantly reduced overall emissions. In the overall observation period 1990-2010, annual emissions amounted to 1,366,762 tC yr-1, which represents the long term average.

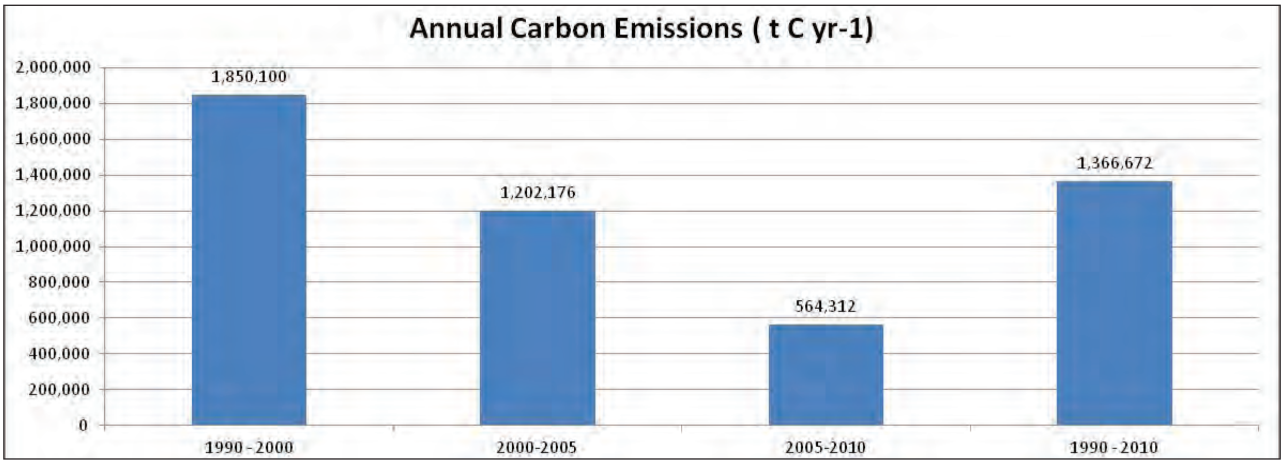


Figure 50. Annual carbon emissions of Kapuas Hulu district in the investigation period.

Figure 45 shows the development of the total carbon stock in the observation period 1990-2010. In order to provide a simple means of carbon stock prediction in terms of a "business-as-usual" scenario, different regression models for the overall carbon stock have been tested. An overview of the different models is given in Table 34.

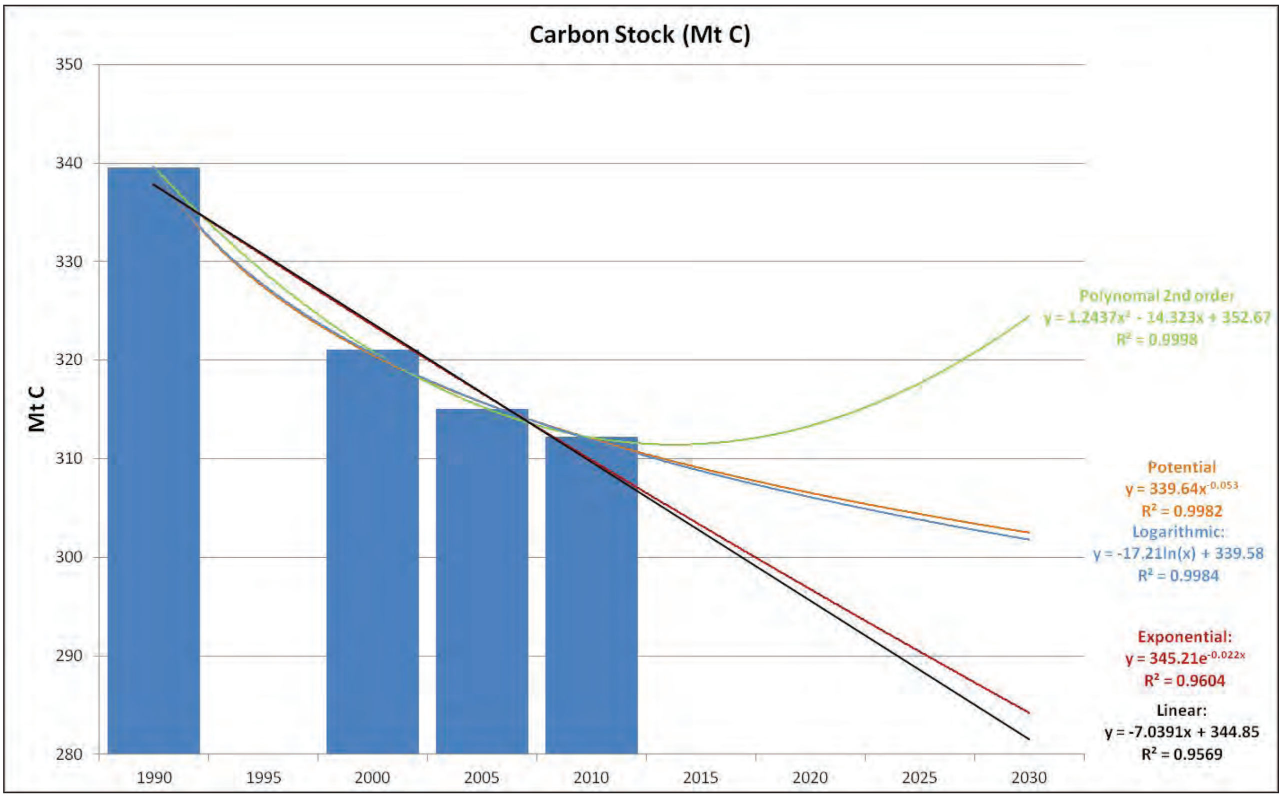


Figure 51. Total carbon stock development in Kapuas Hulu and forecast until 2030 with different projection methods.

The best fitting model (R^2=0.9998) is Polynomial 2nd order, however, it delivers an unrealistic trend projection into the future (a carbon stock increase) and therefore needs to be discarded. The linear model, as well as the Exponential model predict the lowest carbon stock in the future but have the lowest model fit with R2= 0.9569 (Linear) and R2 = 0.9604 (Exponential). The most realistic prediction as well as good model fit is produced by the Logarithmic and Potential regression models. The Potential model is the preferred projection model, since it predicts the higher carbon stock, i.e. lower emissions of the two, which is considered as conservative.

Table 34. Prediction models for total carbon stock trend until 2030 in Kapuas Hulu district.

Method	Trend function	R^2	2015	2020	2025	2030
Logarithmic	**$y = -17.21\ln(x) + 339.58$**	**$R^2 = 0.9984$**	**308.744**	**306.091**	**303.793**	**301.766**
Exponential	$y = 345.21e^{-0.022x}$	$R^2 = 0.9604$	302.522	295.939	289.499	283.200
Polynomial 2nd order	$y = 1.2437x^2 - 14.323x + 352.67$	$R^2 = 0.9998$	311.505	313.350	317.683	324.503
Linear	$y = -7.0391x + 344.85$	$R^2 = 0.9569$	302.615	295.576	288.537	281.498
Potential	**$y = 339.64x^{-0.053}$**	**$R^2 = 0.9982$**	**308.871**	**306.358**	**304.197**	**302.304**

The prediction of the carbon stock development by statistical regression models based on the overall carbon stock of 4 points in time requires to be carefully interpreted. The limitations of this kind of prediction are various:

- ☑ the models are only based on 4 points in time
- ☑ the models only predict the overall trend in carbon stock development
- ☑ the models are not spatially explicit and thus do not consider the spatial trends in land cover/land use

Therefore, these predictions must be treated as a very preliminary result, and further investigations of the historic trend should be conducted in order to reduce uncertainty in this respect.

3.2.7 Drivers of carbon emissions

In addition to the drivers of deforestation described in chapter 3.2.5, an analysis of the drivers of carbon emissions was conducted, taking into account the amount of carbon emitted and the source land cover classes of the carbon emissions.

Figure 46 shows the results of the analysis for the overall observation period 1990-2010. A larger size version of this figure, as well as the underlying carbon change matrix and the results for the individual change periods can be found in the Annex.

The dominant driver of carbon emissions in Kapuas Hulu was **Conversion of Forest into "Shrubland, Agriculture, Shifiting Cultivation, Grassland"**. Total net emissions caused by this driver amounted to 18,835,044 tC or 68% of the overall emissions from Kapuas Hulu in this time period. The emissions caused by this process consisted of 14,052,326 tC from Primary "Lowland Forest", 1,733,924 tC from "Secondary Lowland Forest", 1,540,549 tC from Primary "Peat Swamp Forest", 885,509 tC from Primary "Riparian Forest" and 577,683 tC from Primary "Hill and Submontane Forest". Other forest classes lost together 477,154 tC due to this land use conversion. These emissions were slightly offset by carbon sequestration due to conversion of "Bare Area" (369,331 tC), "Water" (54,151 tC) and "Wetland" (8,707 tC).

The driver causing the second highest amount of net carbon emission was **Conversion into "Bare Area"**, amounting to a total of 2,709,339 tC. The majority of these emissions originated from "Lowland Forest" with an amount of 1,448,429 tC, "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (445,008 tC), Primary "Peat Swamp Forest" (357,074 tC), "Secondary Lowland Forest" (139,108 tC) and "Riparian Forest" 119,156 tC. Conversion of other land cover types into "Bare Area" added another 200,564 tC.

The third largest driver of carbon emissions in Kapuas Hulu was **Conversion into "Secondary Lowland Forest"** which amounted to total net emissions of 2,053,060 tC. Logging of **Primary "Lowland Forest"** was the main contributor to those emissions with a loss of 3,013,528 tC. This was off-set by re-growth of "Secondary Lowland Forest" on "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland (856,047 tC), "Bare Area" (99,476 tC) and former "Water" areas (4,929 tC).

Conversion into "Water" was the fourth largest driver of carbon emissions, amounting to net emission of 756,441 tC between 1990 and 2010. Main contributing classes were "Lowland Forest" (244,578 tC), "Peat Swamp Forest" (184,602 tC) and "Riparian Forest" (173,471 tC). All other land cover classes contributed another 153,789 tC of carbon.

The fifth largest carbon emission driver was **Conversion into "Wetland",** which produced net emissions of 961,181 tC. The two main contributing classes were "Riparian Forest" (624,219 tC) and "Peat Swamp Forest" (491,662 tC). Other forest types and "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" contributed with another 50,663 tC. The emissions were off-set by conversion of "Water" (167,033 tC) and "Bare Area" (38,321 tC).

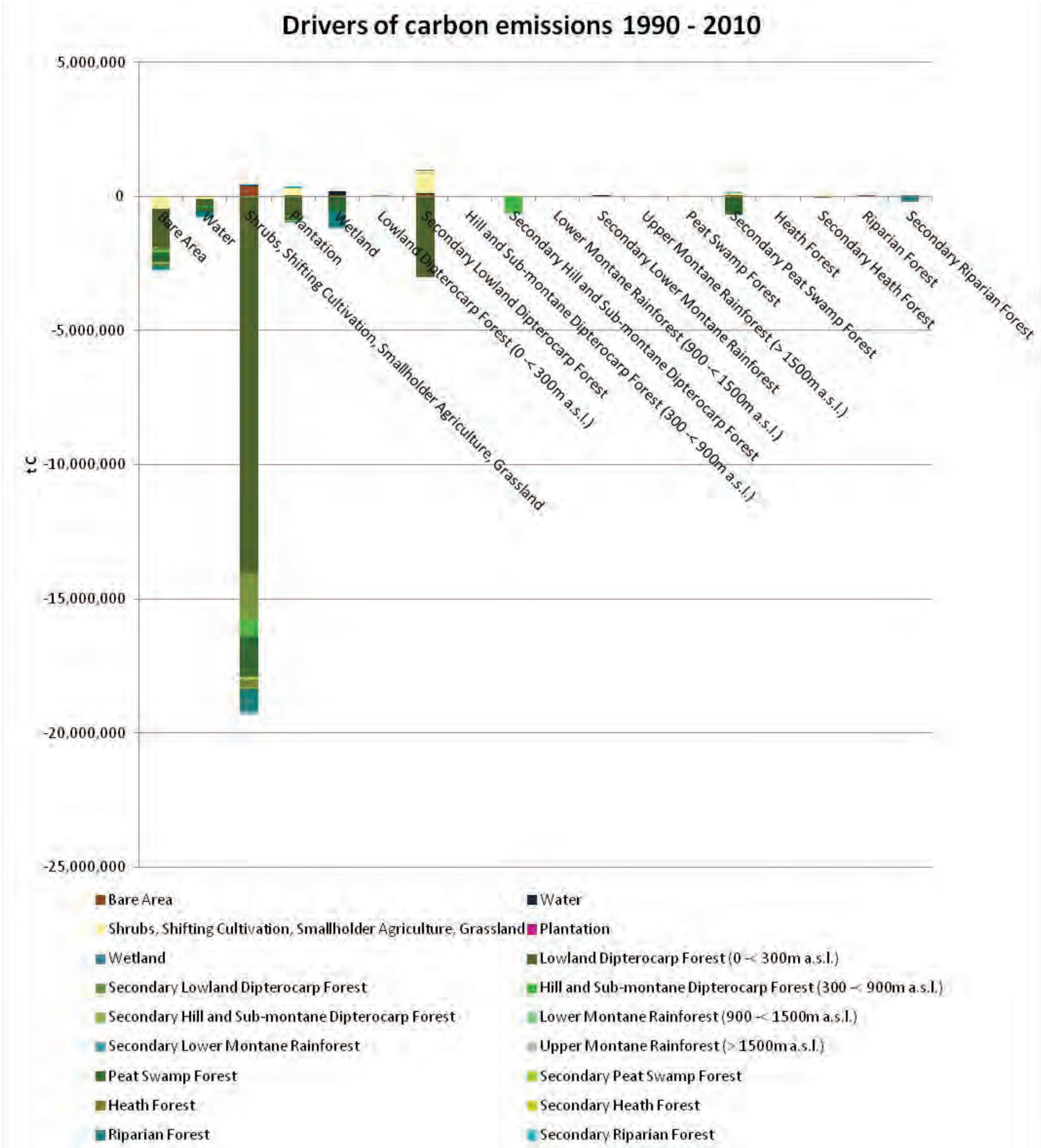


Figure 52. Drivers and source areas of carbon emissions in Kapuas Hulu district for the time period 1990-2010. The land cover classes on the x axis are the driver which caused the carbon emissions (i.e. the class at the later time step), while the color coding of the bars represents the source land cover from which the carbon was emitted.

Conversion into "Plantation" caused the sixth largest amount of net-emissions with 616,573 tC. The major part of these emissions comes from conversion of Primary "Lowland Forest" with 703,433 tC and "Peat Swamp Forest" with 108,374 tC. Other forest types contributed 128,969 tC altogether. However, these emissions were also offset significantly by carbon sequestration on areas which were converted from different land cover types, such as "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (254,184 tC), "Bare Area" (62,927 tC), "Wetland" (4,769 tC) and "Water" (2,324 tC).

The remaining drivers of emissions were **logging of "Hill and Submontane Forest" (614,817 tC)**, **logging of "Peat Swamp Forest"** (515,478 tC) **logging of "Riparian Forest"** (231,032 tC) and **logging of "Heath Forest"** (59,297 tC).

Table 35. The six most important drivers of carbon emissions in Kapuas Hulu district between 1990 and 2000, the land cover classes converted and the contributing carbon emissions and sequestration resulting from the conversion.

Contributor	Driver					
	Conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland"	Conversion into "Bare Area"	Logging of "Lowland Forest"	Conversion into "Wetland"	Conversion into "Water"	Conversion into "Plantation"
Bare Area	369,331	0	99,476	38,321	0	62,927
Water	54,151	0	4,929	167,033	0	2,324
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	0	-445,008	856,047	-23,337	-89,504	254,184
Plantation	-88	0	0	0	0	0
Wetland	8,707	-912	0	0	-7,462	4,769
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	-14,052,326	-1,448,429	-3,013,528	-4,956	-244,578	-703,433
Secondary Lowland Dipterocarp Forest	-1,733,924	-139,108	0	0	-17,949	-98,906
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	-577,683	-55,960	0	0	-19,366	0
Secondary Hill and Sub-montane Dipterocarp Forest	-6,087	-1,169	0	0	-157	0
Lower Montane Rainforest (900 -< 1500m a.s.l.)	-6,058	-287	0	0	-364	0
Secondary Lower Montane Rainforest	0	0	0	0	0	0
Upper Montane Rainforest (> 1500m a.s.l.)	0	0	0	0	0	0
Peat Swamp Forest	-1,540,549	-357,074	11	-491,662	-184,602	-108,374
Secondary Peat Swamp Forest	-97,269	-47,200	0	-12,789	-6,654	-3,497
Heath Forest	-304,645	-77,925	0	0	-4,142	-24,158
Secondary Heath Forest	-22,980	-3,362	0	0	-768	0
Riparian Forest	-885,509	-119,156	5	-624,219	-173,471	-2,482
Secondary Riparian Forest	-40,115	-13,750	0	-9,571	-7,424	74
Total	**-18,835,044**	**-2,709,339**	**-2,053,060**	**-961,181**	**-756,441**	**-616,573**

3.2.8 Status of protected areas

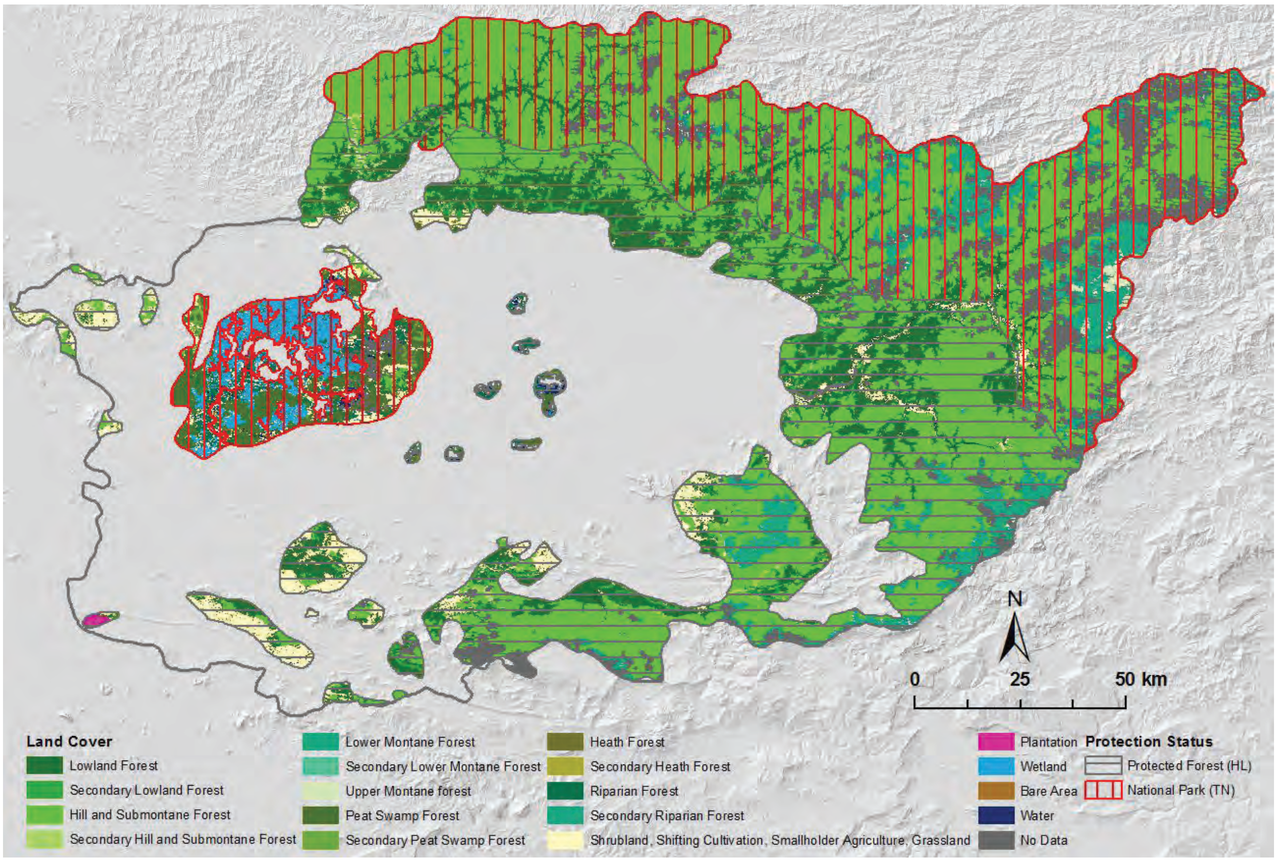


Figure 53. Land cover status of the protected areas in Kapuas Hulu district and their protection status.

Table 36. Land cover status of the protected areas in Kapuas Hulu district, their protection status and spatial extent.

Land Cover	Protected Forest (HL)	National Park (TN)			Total
		Total National Park	Betung Kerihun NP	Danau Sentarum NP	
	ha				
Lowland Forest	208,428	56,051	52,973	3,078	264,479
Secondary Lowland Forest	25,593	480	415	65	26,073
Hill and submontane forest	386,093	442,501	441,093	0	828,593
Secondary Hill and submontane forest	7,784	784	768	16	8,568
Lower montane forest	53,465	83,320	83,320	1,408	136,785
Secondary Lower montane forest	5	1	1	0	7
Upper montane forest	230	4,888	4,888	0	5,118
Peat swamp forest	2,533	41,595	0	41,595	44,127
Secondary Peat swamp forest	416	4,451	0	4,451	4,867
Riparian forest	3,177	15,715	0	15,715	18,892
Secondary Riparian forest	200	676	0	676	876
Non-Forest	65,961	16,598	2,039	14,560	82,559

Table 36. (Continued)

Land Cover	Protected Forest (HL)	National Park (TN)			Total
		Total National Park	Betung Kerihun NP	Danau Sentarum NP	
	ha				
Bare areas	1,939	1,693	113	1,580	3,632
Plantation	1,465	0	0	0	1,465
Wetland	278	46,140	0	46,140	46,418
Water	4,074	3,277	258	3,019	7,351
No Data	52,158	185,857	173,609	12,247	238,015
No Classification	1,506	3,094	1,415	1,679	4,600
Sum	**815,307**	**907,121**	**760,892**	**146,229**	**1,722,427**

4 Discussion

In order to facilitate ease of understanding for the reader, the discussion in this chapter is subdivided into the topics of the study.

Classification accuracy

The achieved accuracy of the land cover classifications was high throughout all time steps in both districts. In Malinau, the land cover maps had an overall accuracy of 88.8% (1990), 87.5% (2000), 84.6% (2005) and 79.6% (2010). Class-wise accuracy was high for the classes "Bare Area", "Water", "Plantation", "Primary Dryland Forest" and "Freshwater Swamp Forest". Mis-classifications were observed for the classes "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland", which was confused mainly with "Secondary Dryland Forest". "Secondary Dryland Forest" also produced a lower class-wise accuracy due to confusion of old "Secondary Dryland Forest" with Primary "Dryland Forest", and the confusion of young "Secondary Dryland Forest" with "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". "Secondary Freshwater Swamp Forest" was confused with Primary "Freshwater Swamp Forest" in the 1990 and 2000 map.

In Kapuas Hulu, overall accuracy of the land cover maps was 86.5% (1990), 87.5% (2000), 86.44% (2005) and 73% (2010). Class-wise accuracy of the land cover classes was high throughout. Confusions were observed for the classes "Heath Forest" with Primary "Peat Swamp Forest" due to low spectral separability of those classes, and for "Secondary Heath Forest" with "Secondary Peat Swamp Forest" and "Heath Forest" due to the same reason. "Secondary Riparian Forest" also featured a lower class-wise accuracy due to confusion with Primary "Riparian Forest", "Wetland" and "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland".

Land cover change

The land cover change assessment was carried out only in areas where all four land cover classifications contained actual data, and were not affected by No Data areas (due to residual cloud cover or SLC Gaps).

Land cover change dynamics in Malinau were low over all investigated time periods. From 1990-2000, 97.2% of the investigated featured "No Change", from 2000 to 2005, 96.6% of the area remained unchanged and from 2005 to 2010, 97.8% of the investigated area showed "No Change".

Land cover changes were dominated by "Forest degradation" throughout all investigated time periods with 1.5% (1990-2000), 1.9% (2000-2005) and 0.85% (2005-2010) of the investigated area affected. "Deforestation" was the second most dominant change process with 1.1% (1990-2000), 1% (2000-2005) and 0.74% (2005-2010) of the investigated area affected.

The largest losses in spatial extent were observed for the class Primary "Hill and Submontane Forest", which lost 122,228ha or 7.6% of its area between 1990 and 2010. The majority (80%) of these losses was due to "Forest Degradation" by commercial logging, which is reflected by an increase in area of the class "Secondary Hill and Submontane Forest" by 97,782 ha.

The largest percental loss in area was observed in the Primary "Lowland Forest" between 1990 and 2010, with 39.7% (82,076 ha) of the original area of this class being either degraded by logging (62% or 50,558 ha) or converted into other land uses (38%).

The montane forest classes were almost unaffected by land cover change. Largest increases in area between 1990 and 2010 were observed for the class "Shrubland, Shifting Cultivation, Smallholder Agriculuture, Grassland", which amounted to an increase by 54,448 ha from 42,791 ha in 1990, i.e. the spatial extent of areas in agricultural use more than doubled. The class "Bare area", which consists primarily of Mining Areas in Malinau expanded by 270% or 3,830 ha since 1990.

In Kapuas Hulu, change dynamics were significantly higher than in Malinau between 1990 and 2000, with only 92.4% of the investigated area featuring "No Change". Between 2000 and 2005, and later between 2005 and 2010, change dynamics significantly decreased, reflected by "No Change" areas of 97.5% and 98.3%, respectively. But in the overall investigation period 1990-2010, only 89.2% of the investigated area shown "No Change".

The most dominant change process over all investigation periods in Kapuas Hulu was "Deforestation", with 4.3% (1990-2000), 1.2% (2000-2005) and 1% (2005-2010) of the investigated area affected. In the overall observation period 1990-2010, 156,721 ha or 6.6% of the investigated area was changed by "Deforestation".

"Forest degradation" was the second most dominant change process. Between 1990 and 2000, 46,632 ha or 2% of the investigated area was affected, followed by another 20,101 ha or 0.8% between 2000 and 2005 and 3,598 ha 0.15% between 2005 and 2010. However, this shows a clear trend of decreasing forest degradation in Kapuas Hulu, due to reduced logging activity.

Primary "Lowland Forest" was the class which was most affected by land cover change, losing in total 108,477 ha of its area. Most of this loss in area was in fact due to deforestation, which is expressed by an area increase on "Secondary Lowland Forest" of only 22,114 between 1990 and 2010, i.e. approximately. 80% of the loss in area of "Primary Lowland Forest" was due to "Deforestation". The second largest losses in area were observed in the class Primary "Peat Swamp Forest" with 49,828 ha between 1990 and 2010. Meanwhile, "Secondary Peat Swamp Forest" experienced an increase in area by 19,384 ha, i.e. 62% of the Primary "Peat Swamp Forest" lost was due to deforestation and 38% due to forest degradation.

The largest increase in area in Kapuas Hulu was observed for the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland", which expanded by 89,401 ha or 21,8% between 1990 and 2010. This shows that expansion of agricultural areas is the most dominant driver of land cover change in Kapuas Hulu.

Deforestation

Deforestation processes were assessed by investigating the net forest loss and the deforestation rate in the two districts. Furthermore the causes/drivers were investigated by analyzing the gross deforestation areas and the land cover classes into which forest was converted.

Malinau showed only very low deforestation over all observation periods with a net forest loss of 32,351 ha or 0.96% between 1990 and 2000, 19,590 ha or 0.59% between 2000 and 2005 and 6,338 ha or 0.19% between 2005 and 2010. Overall, 58,279 ha of forest area were lost between 1990 and 2010.

Consequently, the observed annual deforestation rate in Malinau was very low over all observation periods. Between 1990 and 2000 it amounted to 0.096% yr^{-1}, followed by a light increase to 0.118% yr^{-1} between 2000 and 2005 and a sharp decrease to 0.04% yr^{-1} between 2005 and 2010. Over the whole observation period 1990 -2010 the annual deforestation rate was at 0.09% yr^{-1}.

The analysis of the drivers of deforestation revealed that conversion of forest into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" was clearly the most dominant, causing 91.6% of all deforestation between 1990 and 2010. Conversion into "Bare Area", i.e. coal mining, was the second most important driver of deforestation, amounting to 4% of all deforestation processes. 2.8% of all deforestation was due to conversion into "Water", which can be attributed to the intense meander erosion of the large rivers Malinau and Mentarang when leaving the enclosed meanders in the mountains into the free-swinging meanders of the lowlands.

Kapuas Hulu showed a much higher deforestation over all observation periods. Net forest loss amounted to 92,029 ha or 4.9% between 1990 and 2000, 28,840 ha or 1.6% between 2000 and 2005 and 24,673 ha or 1.4% between 2005 and 2010. Overall, 145,542 ha or 7.72% of the forest area in 1990 have been lost between 1990 and 2010.

Consequently, annual deforestation rates in Kapuas Hulu were also significantly higher than in Malinau. Between 1990 and 2000 it amounted to 0.49% yr^{-1}, but decreased from then on to 0.32% yr^{-1} between 2000 and 2005 and 0.28% yr^{-1} between 2005 and 2010. In the overall investigation period 1990-2010, annual deforestation was at 0.39% yr^{-1}.

Development of carbon stocks, carbon emissions and drivers of carbon emissions

The estimation of carbon emissions in this study was conducted by a stock difference approach of the carbon stock stored in the different land cover classes based on the land cover change layer.

Carbon stock in Malinau was and is mostly stored in "Lower Montane Forest" and "Hill and Submontane Forest" because these forest types occupy the largest area in the district. "Lower Montane Forest" only lost a small share of its carbon stock in the observation period 1990-2010 of 1,975,381 tC. The largest carbon losses were observed in the Primary "Hill and Submontane Forest" with a total of 20,435,362 tC between 1990 and 2010, mainly due to commercial logging activity. This equals to 7.6% of the original carbon stock in 1990.

The second highest carbon stock decreases were observed in Primary "Lowland Forest", with 19,291,189 tC between 1990 and 2010. Relative to the original carbon stock in this class, this equals to almost 40%. Primary "Freshwater Swamp Forest", even though small in area, also experienced severe losses in carbon stock, amounting to 50,546 tC between 1990 and 2010. Even though this absolute figure is comparably small, it equals to 9.1% of the original carbon stock in 1990.

The analysis of the drivers of carbon emissions revealed that the most dominant driver is Conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland", which accounts for net emissions of 10,017,551 tC or 44% of the overall emissions in Malinau district between 1990 and 2010. The largest contribution to these emissions came from conversion of "Lowland Forest" (5,416,233 tC) and Primary "Hill and Submontane Forest" with 3,590,934 tC. The reason for these conversions lies in the traditional land use pattern "Shifting cultivation".

The second highest emissions were caused by Logging of "Hill and Submontane Forest" which accounted for 6,618,312 tC or 29% of the overall emissions 1990-2010. "Logging of Lowland Forest" followed closely, with net total carbon emissions of 5,012,519 tC or 22% of the overall emissions in Malinau.

Annual carbon emissions in Malinau varied significantly between the three observation periods 1990-2000, 2000-2005 and 2005-2010. In the first observation period, 958,426 tC were emitted annually.

This was significantly increased in the second observation period to 1,989,191 tC yr^{-1} between 2000 and 2005, and then again reduced to 794,147 tC yr^{-1} between 2005 and 2010. The overall average annual carbon emission amounted to 1,144,124 tC yr^{-1} between 1990 and 2010.

The development of total carbon stock in Malinau showed a constant decline from 1990 to 2010. The total carbon stock at the beginning of the observation period in 1990 of 635,268,641 tC decreased by 9,584,260 tC to 625,684,381 tC until 2000, then by another 9,327,504 tC until 2005, followed by 3,970,734 tC until 2010. It is remarkable that between 2000 and 2005, almost the same amount of carbon was lost within 5 years as in the previous 10 year period. Carbon stock at the end of the observation period in 2010 amounted to 612,386,241 tC, which means that 22,882,478 tC or 3.6% of the original carbon stock have been lost.

A trend analysis was conducted by testing different regression models on the total carbon stock of the four investigated time steps 1990, 2000, 2005 and 2010. The highest model fit was achieved by a polynomial 2nd order regression with a R^2 of 0.982. The second best fit was achieved by a linear model with a R^2 of 0.9804, which is almost similar. A projection of the developed models to the year 2030 predicts a carbon stock of 582,180,500 tC (Polynomial) and 588,369,400 tC (Linear), i.e. additional carbon emissions of 30,205,741 tC (Polynomial) or 24,016,841 tC (Linear) until 2030. Due to almost similar model quality and the principle of conservativeness we recommend the adoption of the linear model for the projection of a business as usual scenario since the predicted emissions are smaller, and thus more conservative.

In Kapuas Hulu, the highest carbon stock was and is stored in the class "Hill and Submontane Forest" with 137,475,798 tC in 1990. Until 2010, carbon losses in "Hill and Submontane Forest" amounted to 2,281,863 tC or 1.7% of the original carbon stock. Primary "Lowland Forest" stores the second highest carbon stock in Kapuas Hulu, and also experienced by far the highest losses in the observation period 1990 to 2010. From the original 122,389,876 tC stored in 1990, 25,496,434 tC were lost until 2010, which equals to 20% of the original stock, leading to a carbon stock of 96,902,442 tC in 2010. Primary "Peat Swamp Forest" also lost significant amount of carbon between 1990 and 2010, with total losses of 5,346,488 tC or 19.7% of the original carbon stock of 27,120,718 tC. "Riparian Forest", while having only a comparably small carbon stock of 7,651,283 tC in 1990, experienced a decrease by 2,367,157 tC between 1990 and 2010, which equals to 31%. These losses were mainly due to deforestation and can be explained by the proximity of the Riparian Forest to the rivers, which still serve as the main traffic ways, and by the fertile alluvial soils in this forest type which makes it preferable for conversion into agricultural land uses.

Carbon stock increases were observed in the class "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" with 2,120,601 tC or 22% between 1990 and 2010. The class "Plantation", which had strong increases in area, consequently showed significant increases in carbon stock by 980,968 tC, which equals to a factor of 58 in comparison to the original carbon stock of this class in 1990.

The analysis of drivers of carbon emissions revealed that conversion into "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" produced by far the highest net emissions with 18,835,044 tC or 68% of the overall emissions of Kapuas Hulu in the observation period 1990-2010. The majority of these emissions came from the conversion of Primary "Lowland Forest" (14,052,326 tC), "Secondary Lowland Forest" (1,733,924 tC) and Primary "Peat Swamp Forest" (1,540,549 tC). Conversion into "Bare Area" amounted for the second highest net emissions of 2,709,339 tC in the observation period 1990-2010, with the majority of emitted carbon coming from "Lowland Forest" and "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland". Both of these land conversions can be attributed to the traditional land use pattern of shifting cultivation by smallholders. It remains to be analyzed whether these conversions follow a characteristic spatial pattern, e.g. along newly constructed roads.

Conversion into "Secondary Lowland Forest" ranked third in importance as a driver of carbon emissions with a total net emissions of 2,053,060 tC. Logging of "Lowland Forest" was the main contributor to those with gross emissions of 3,013,528 tC. The driving factor behind this development is logging. However, it was not further distinguished in this study whether the logging activity happened within forest concessions (which then could be classified as legal logging) or whether it was observed outside of concession areas (which would mean that it would be illegal logging). This analysis should be added in a follow up study.

These gross emissions by logging were off-set by carbon sequestration due to regeneration of "Secondary Lowland Forest", mainly on "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland" (856,047 tC) and "Bare Area" (99,476 tC).

Conversion into "Plantation" also caused an increasingly significant amount of emissions, with total net emission of 616,573 tC between 1990 and 2010. Even though "Plantations" also sequester carbon, which can be seen in the offset of emissions by conversion of "Shrubland, Shifting Cultivation, Smallholder Agriculture, Grassland (254,184 tC) or "Bare Area" (62,927 tC), the conversion of Primary "Lowland Forest" and "Peat Swamp Forest" into "Plantation" caused gross emissions of 703,433 tC and 108,374 tC in the observation period.

Annual carbon emissions showed a constant decrease from the first observation period 1990-2010 with 1,850,100 tC yr^{-1} , to 1,202,176 tC yr^{-1} between 2000 and 2005 and then to 564,312 tC yr^{-1} between 2005 and 2010. The overall average in the observation period 1990-2010 amounted to 1,366,672 tC yr^{-1} .

The development of total carbon stock in Kapuas Hulu reflects the development of the annual emissions. It showed a large decrease from 339,559,437 tC in 1990 by 18,500,999 tC until 2000, then by 6,010,879 tC until 2005 and another 2,821,560 tC until 2010, leaving a final carbon stock of 312,225,999 tC in 2010. This equals a total decrease by 27,333,437 tC in the 20 year observation period 1990-2010, or a loss of 8%.

The trend analysis on total carbon stock development showed that the best fitting model was a polynomial 2nd order regression with a R^2 of 0.9998. However, this model proved not suitable for a projection into the future, because it predicts large increases in carbon stock which is not realistic. The second and third best fitting models were the logarithmic regression and the potential regression, both with a R^2 of 0.998. A projection of these models to the year 2030 predicts a carbon stock of 301,765,765tC (Logarithmic) and 302,304,060tC (Potential model), which results in projected additional emissions of 10,460,234tC (logarithmic) or 9,921,940tC (Potential). Due to a similar model fit and reasons of conservativeness, we recommend to adopt the potential regression model for the projection of a business-as-usual scenario because the predicted emissions are smaller, and thus represent a more conservative estimate.

5 Summary and conclusions

The results of this study illustrate in a consistent manner the historic land cover and land cover change situation in the two districts Malinau and Kapuas Hulu. By applying the stock difference method based on biomass and carbon values from the published scientific literature and field data to the quantitative results of the change detection datasets of the time periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010, the historic trends in carbon emissions were calculated.

The study demonstrated the functionality of the chosen approach of object-based image classification techniques, post classification change detection and the stock difference method for calculating carbon emissions on sub-national (district) level.

The results reveal that the land cover, land cover change and associated carbon emissions in both districts show many similarities, however, also differ significantly many respects. While in Malinau, forest degradation is the most dominant change process leading to carbon emissions, and deforestation ranks second, the situation is vice-versa in Kapuas Hulu. Overall change rate and deforestation rate are much smaller in Malinau than in Kapuas Hulu, albeit net carbon emissions and also annual emissions are almost comparable. This shows the significant impact of emissions due to forest degradation on the overall carbon balance of a geographic entity. While in Malinau, the establishment of large scale estated plantation could not be observed by now, this process is already gaining pace in Kapuas Hulu. This development leads to increasing loss in forest area due to conversion and consequently produces increasing emissions. However, emissions due to logging show a declining trend in Kapuas Hulu.

The output of this study can serve is an important new information base on the general trend of land cover development and carbon stock changes in the past, and the data can be adopted as base data for the establishment of reference emission levels (REL) for the investigated districts.

6 Annex

6.1 Procured satellite data

Table 37. Full list of Landsat images procured for the project.

Malinau						Kapuas Hulu					
Path/Row	Sensor	Date	Path/Row	Sensor	Date	Path/Row	Sensor	Date	Path/Row	Sensor	Date
1990			2005			1990			2005		
117/057	LS5	20.04.1991	117/057	LS5	17.09.2005	119/059	LS5	18.04.1991	119/059	LS5	14.08.2005
117/057	LS5	07.06.1991	117/057	LS5	16.08.2005	119/059	LS4	25.05.1990	119/059	LS5	11.06.2005
117/058	LS5	20.04.1991	117/058	LS5	17.09.2005	119/059	LS5	11.12.1990	119/059	LS7	19.08.2004
117/058	LS5	07.06.1991	117/059	LS5	17.09.2005	119/060	LS5	18.04.1991	119/059	LS7	27.02.2005
117/059	LS5	20.04.1991	117/059	LS5	03.08.2006	119/060	LS5	21.06.1991	119/059	LS7	16.06.2004
117/059	LS4	16.01.1991	117/059	LS7	18.06.2004	120/059	LS5	17.06.1990	119/060	LS5	14.08.2005
118/057	LS5	30.06.1991	118/057	LS5	07.08.2005	120/059	LS5	25.04.1991	119/060	LS5	11.06.2005
118/058	LS5	30.06.1991	118/057	LS7	16.09.2005	120/060	LS5	30.07.1991	119/060	LS7	19.08.2004
118/058	LS5	14.06.1991	118/058	LS5	07.08.2005	120/060	LS5	25.04.1991	119/060	LS7	27.02.2005
118/058	LS4	19.06.1990	118/058	LS5	07.06.2006	2000			120/059	LS7	10.08.2004
118/059	LS4	28.12.1990	118/058	LS5	23.10.2004	119/059	LS7	28.11.2000	120/059	LS7	22.05.2004
	LS4	19.06.1990	118/058	LS5	16.05.2004	119/059	LS7	20.05.2000	120/059	LS7	06.03.2005
2000			118/058	LS7	25.06.2004	119/059	LS7	23.05.2001	120/059	LS7	16.08.2006
117/057	LS7	06.05.2000	118/058	LS7	16.09.2005	119/060	LS7	28.11.2000	120/060	LS5	25.09.2006
117/057	LS7	09.07.2000	118/059	LS5	07.06.2006	119/060	LS7	23.05.2001	120/060	LS7	26.08.2004
117/057	LS7	13.10.2000	118/059	LS5	16.05.2004	119/060	LS7	26.11.1999	120/060	LS7	10.08.2004
117/058	LS5	06.05.2000	118/059	LS5	23.10.2004	120/059	LS7	31.08.2000	2010		
117/058	LS7	13.10.2000	2010			120/059	LS7	11.05.2000	119/059	LS7	13.05.2009
117/058	LS7	09.09.1999	117/057	LS7	03.08.2009	120/059	LS7	01.07.2001	119/059	LS7	01.08.2009
117/059	LS7	26.08.2000	117/057	LS7	11.02.2010	120/060	LS7	28.06.2000	119/060	LS7	13.05.2009
117/059		10.13.2000	117/057	LS7	08.02.2009	120/060	LS7	11.05.2000	119/060	LS7	01.08.2009
118/057	LS7	25.02.2001	117/058	LS7	03.08.2009	120/060	LS7	01.07.2001	120/059	LS7	08.08.2009
118/057		17.06.2001	117/058	LS7	06.10.2009				120/059	LS7	05.06.2009
118/057		03.07.2001	117/058	LS7	03.10.2008				120/060	LS7	08.08.2009
118/058	LS7	05.11.2000	117/058	LS7	07.01.2009				120/060	LS7	05.08.2008
118/058	LS7	25.02.2001	117/058	LS7	15.03.2010				120/060	LS7	18.04.2009
118/058	LS7	03.07.2001	117/059	LS7	15.03.2010						
118/059	LS7	16.07.2000	117/059	LS7	07.11.2009						
118/059		02.09.2000	117/059	LS7	11.02.2010						
			117/059	LS7	18.05.2010						
			118/057	LS7	03.03.2009						
			118/057	LS7	12.07.2010						
			118/057	LS7	17.11.2010						
			118/058	LS7	03.03.2009						
			118/058	LS7	13.08.2010						
			118/058	LS7	12.07.2010						
			118/058	LS7	29.08.2010						
			118/059	LS7	18.02.2010						
			118/059	LS7	19.05.2008						

6.2 Accuracy assessment

6.2.1 Malinau district

Table 38. Confusion matrix of the 1990 land cover classification for Malinau district.

1990	Classification								
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Settlement	Dryland Forest	Secondary Dryland Forest	Freshwater Swamp Forest	Secondary Freshwater Swamp Forest	**Total**
Bare Area	40	9						1	**50**
Water	1	48			1				**50**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland			46						**46**
Settlement	1		10	36					**47**
Dryland Forest					85	7			**92**
Secondary Dryland Forest	1				3	65			**69**
Freshwater Swamp Forest			2				36	12	**50**
Secondary Freshwater Swamp Forest	1		1				1	47	**50**
Total	**44**	**57**	**59**	**36**	**89**	**72**	**37**	**60**	**454**

Table 39. Confusion matrix of the 2000 land cover classification for Malinau district.

2000	Classification									
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Settlement	Dryland Forest	Secondary Dryland Forest	Freshwater Swamp Forest	Secondary Freshwater Swamp Forest	Total
Bare Area	28	4	3			3	9			47
Water		49								49
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	1		41			1	7			50
Plantation				50						50
Settlement	2		9		39					50
Dryland Forest						43	2			45
Secondary Dryland Forest	1					3	40		1	45
Freshwater Swamp Forest								44	6	50
Secondary Freshwater Swamp Forest	1		5					1	43	50
Total	33	53	58	50	39	50	58	45	50	436

Table 40. Confusion matrix of the 2005 land cover classification for Malinau district.

2005	Classification									
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Settlement	Dryland Forest	Secondary Dryland Forest	Freshwater Swamp Forest	Secondary Freshwater Swamp Forest	**Total**
Bare Area	32	1	9	1	7					**50**
Water		45	1			1	1		1	**49**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland		3	47							**50**
Plantation				46			4			**50**
Settlement	5	1	7		37					**50**
Dryland Forest			1			34	9			**44**
Secondary Dryland Forest						1	47			**48**
Freshwater Swamp Forest		1	1			1	6	41		**50**
Secondary Freshwater Swamp Forest							1	5	44	**50**
Total	**37**	**51**	**66**	**47**	**44**	**37**	**68**	**46**	**45**	**441**

Table 41. Confusion matrix of the 2010 land cover classification for Malinau district.

2010	Classification district								
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Settlement	Dryland Forest	Secondary Dryland Forest	Freshwater Swamp Forest	**Total**
Bare Area	1		2	1	1		2		**7**
Water		4					1		**5**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland			56	2		5	23		**86**
Plantation							1		**1**
Settlement									
Dryland Forest			1			137	15	2	**155**
Secondary Dryland Forest			3			5	52		**60**
Freshwater Swamp Forest									
Total	**1**	**4**	**62**	**3**	**1**	**147**	**94**	**2**	**314**

6.2.2 Kapuas Hulu district

Table 42. Confusion matrix of the 1990 land cover classification for Kapuas Hulu district.

1990	Classification													
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Wetland	Dryland Forest	Secondary Dryland Forest	Peat Swamp Forest	Secondary Peat Swamp Forest	Heath Forest	Secondary Heath Forest	Riparian Forest	Secondary Riparian Forest	**Total**
Bare Area	46	1		1					1					**49**
Water	3	49			3									**55**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland			47		3		6		4	3	5	2	6	**76**
Plantation				49										**49**
Wetland					44			1				6	3	**54**
Dryland Forest						46	6							**52**
Secondary Dryland Forest			3			3	38							**44**
Peat Swamp Forest								45	1	6	1			**53**
Secondary Peat Swamp Forest								3	43	1	3			**50**
Heath Forest										27				**27**
Secondary Heath Forest										1	27			**28**
Riparian Forest												41	7	**48**
Secondary Riparian Forest												1	34	**35**
Total	**49**	**50**	**50**	**50**	**50**	**49**	**50**	**49**	**49**	**38**	**36**	**50**	**50**	**620**

Table 43. Confusion matrix of the 2000 land cover classification for Kapuas Hulu district.

2000	Classification													
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Wetland	Dryland Forest	Secondary Dryland Forest	Peat Swamp Forest	Secondary Peat Swamp Forest	Heath Forest	Secondary Heath Forest	Riparian Forest	Secondary Riparian Forest	**Total**
Bare Area	47				1									48
Water		48			3									51
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	3		46	1	2	1			1	1	3		2	60
Plantation				49										49
Wetland		1			43							4	5	53
Dryland Forest						49	6							55
Secondary Dryland Forest			4				43							47
Peat Swamp Forest								39		5				44
Secondary Peat Swamp Forest								9	47	3	15			74
Heath Forest									1	34				35
Secondary Heath Forest										2	31			33
Riparian Forest								1		2		44	2	49
Secondary Riparian Forest												2	41	43
Total	50	49	50	50	49	50	49	49	49	47	49	50	50	641

Table 44. Confusion matrix of the 2005 land cover classification for Kapuas Hulu district.

2005	Classification													
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Wetland	Dryland Forest	Secondary Dryland Forest	Peat Swamp Forest	Secondary Peat Swamp Forest	Heath Forest	Secondary Heath Forest	Riparian Forest	Secondary Riparian Forest	**Total**
Bare Area	41		1											**42**
Water	1	43			2									**46**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	6	4	48	7	2		3		2		1		5	**78**
Plantation	1			43										**44**
Wetland	1	3			45			2	1			1	2	**55**
Dryland Forest						48			1					**49**
Secondary Dryland Forest			1			2	47							**50**
Peat Swamp Forest								42	1	5	1			**49**
Secondary Peat Swamp Forest								5	44		3			**52**
Heath Forest										39	3			**42**
Secondary Heath Forest										4	41			**45**
Riparian Forest					1			1	1	2	1	46	9	**61**
Secondary Riparian Forest												2	34	**36**
Total	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**649**

Table 45. Confusion matrix of the 2010 land cover classification for Kapuas Hulu district.

2010	Classification													
Validation	Bare Area	Water	Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	Plantation	Wetland	Dryland Forest	Secondary Dryland Forest	Peat Swamp Forest	Secondary Peat Swamp Forest	Heath Forest	Secondary Heath Forest	Riparian Forest	Secondary Riparian Forest	**Total**
Bare Area	37	1	1											**39**
Water	1	43	1											**45**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	18	4	82	4	1	1	3		2		2	4	10	**131**
Plantation	1		6	46										**53**
Wetland					46			1				3	5	**55**
Dryland Forest		1	3			52	10					3	1	**70**
Secondary Dryland Forest	2		10			6	41			1				**60**
Peat Swamp Forest					2	1		84	16	23	5	4	1	**136**
Secondary Peat Swamp Forest			3			2		14	47		9	1	1	**77**
Heath Forest			1					3		45	10			**59**
Secondary Heath Forest								1	2	2	27			**32**
Riparian Forest			3					1				36	11	**51**
Secondary Riparian Forest		1							1				19	**21**
Total	**59**	**50**	**110**	**50**	**49**	**62**	**54**	**104**	**68**	**71**	**53**	**51**	**48**	**829**

Table 46. Changecode matrix.

		Land cover time step 2																						
	Code	3	4	21	22	23	24	99	111	112	121	122	131	132	141	142	151	152	161	162	171	172	181	182
Land cover time step 1	3	No Change	Flooding	No Change	Plantation Expansion	No Change	Urbanisation	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	4	No Change	No Change	No Change	Plantation Expansion	No Change	Urbanisation	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	21	No Change	Flooding	No Change	Plantation Expansion	No Change	Urbanisation	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	22	No Change	Flooding	No Change	No Change	No Change	Urbanisation	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	23	No Change	Flooding	No Change	Plantation Expansion	No Change	Urbanisation	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	24	No Change	Flooding	No Change	Plantation Expansion	No Change	No Change	No Data	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation	Reforestation
	99	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	111	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	112	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	121	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	122	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	131	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	132	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	141	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	142	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	151	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	152	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	161	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	162	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	171	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	172	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change
	181	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation	No Change	Forest Degradation
	182	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	Deforestation	No Data	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change	Reforestation	No Change

6.3 Drivers of carbon emissions

6.3.1 Malinau distric

Table 47. Carbon change matrix Malinau district 1990-2000.

	Land Cover Carbon	2000															
Land Cover	1990	3	4	21	22	24	111	112	121	122	131	132	141	142	181	182	Sum
Bare area	3	0	0	25,266	0	0	0	7,642	0	5,958	0	761	0	104	0	798	40,529
Water	4	0	0	12,817	0	0	58,997	2,838	188,811	6,673	19,438	0	0	0	882	188	290,645
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-17,484	-18,914	0	455	-3,168	0	345,185	0	65,360	0	5,825	0	78	0	157	377,493
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settlement	24	0	0	139	0	0	0	0	0	0	0	0	0	0	0	0	139
Lowland Forest	111	-117,804	-107,077	-2,008,770	-137,879	0	0	-1,769,221	0	0	0	0	0	0	0	0	-4,140,751
Secondary Lowland forest	112	-7,082	-10,082	-381,232	0	0	0	0	0	0	0	0	0	0	0	0	-398,396
Hill and Submontane Forest	121	-348,551	-414,908	-2,292,144	0	-1,384	0	0	0	-2,089,913	0	0	0	0	0	0	-5,146,900
Secondary Hill and Submontane Forest	122	-2,713	-11,183	-43,850	0	-236	0	0	0	0	0	0	0	0	0	0	-57,981
Lower Montane Forest	131	-28,854	-37,345	-241,768	0	0	0	0	0	0	0	-217,845	0	0	0	0	-525,811
Secondary Lower Montane Forest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane Forest	141	-857	0	0	0	0	0	0	0	0	0	0	0	-4,561	0	0	-5,418
Secondary Upper Montane Forest	142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freshwater Swamp Forest	181	0	-4,240	-9,138	0	0	0	0	0	0	0	0	0	0	0	0	-13,379
Secondary Freshwater Swamp Forest	182	0	-404	-4,027	0	0	0	0	0	0	0	0	0	0	0	0	-4,430
Sum	Sum	-523,345	-604,153	-4,942,705	-137,424	-4,788	58,997	-1,413,556	188,811	-2,011,923	19,438	-211,259	0	-4,379	882	1,144	-9,584,260

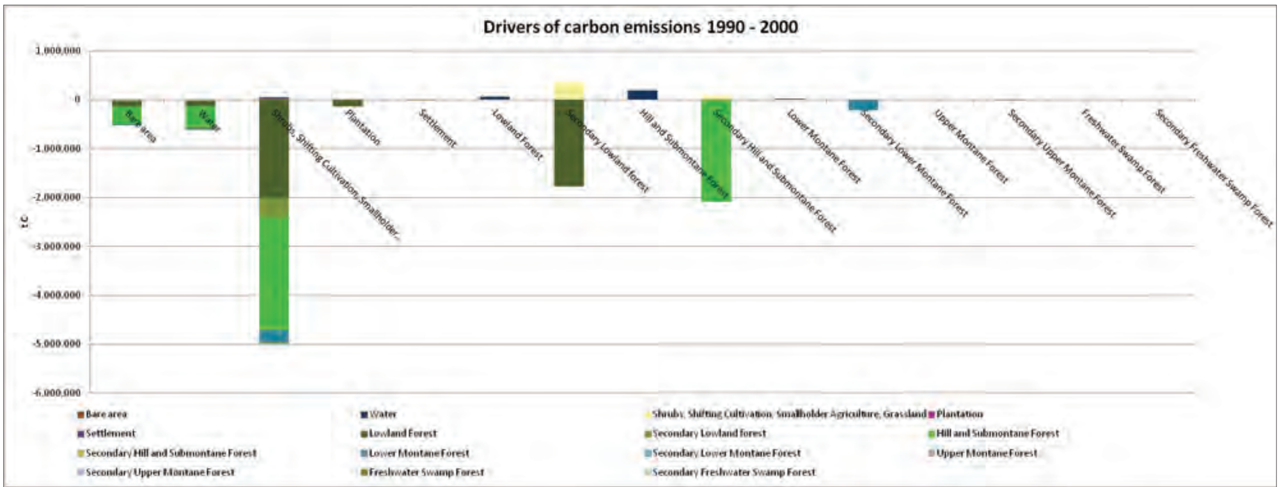


Figure 54. Drivers and source areas of carbon emissions in Malinau district 1990-2000.

Table 48. Carbon change matrix Malinau district 2000-2005.

	Land Cover Carbon	2005														
Land Cover	2000	3	4	21	22	24	111	112	121	122	131	132	141	142	181	Sum
Bare area	3	0	0	57,999	0	0	0	7,979	0	70,253	0	12,184	0	35	0	148,449
Water	4	0	0	39,122	0	0	144,476	17,762	338,861	3,315	17,389	0	0	0	0	560,925
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-58,448	-16,184	0	0	-4,137	18	364,298	0	625,616	0	51,094	0	0	0	962,256
Plantation	22	0	0	-14,289	0	0	0	914	0	0	0	0	0	0	0	-13,375
Settlement	24	0	0	751	0	0	0	12	0	131	0	0	0	0	0	895
Lowland Forest	111	-178,300	-50,790	-2,223,641	-14,697	0	0	-2,798,387	0	0	0	0	0	0	0	-5,265,815
Secondary Lowland forest	112	-56,385	-5,427	-793,354	-4	0	0	0	0	0	0	0	0	0	0	-855,169
Hill and Submontane Forest	121	-168,136	-182,356	-1,645,789	0	0	0	0	0	-2,451,626	0	0	0	0	0	-4,447,907
Secondary Hill and Submontane Forest	122	-13,163	-5,199	-113,136	0	0	0	0	0	0	0	0	0	0	0	-131,497
Lower Montane Forest	131	-13,099	0	-90,595	0	0	0	0	0	0	0	-117,542	0	0	0	-221,236
Secondary Lower Montane Forest	132	-954	0	-16,611	0	0	0	0	0	0	0	0	0	0	0	-17,565
Upper Montane Forest	141	0	0	-254	0	0	0	0	0	0	0	0	0	0	0	-254
Secondary Upper Montane Forest	142	0	0	-338	0	0	0	0	0	0	0	0	0	0	0	-338
Freshwater Swamp Forest	181	-1,201	-2,664	-13,602	0	0	0	0	0	0	0	0	0	0	0	-17,467
Sum	Sum	-489,686	-262,620	-4,813,736	-14,701	-4,137	144,494	-2,407,422	338,861	-1,752,310	17,389	-54,264	0	35	0	-9,298,098

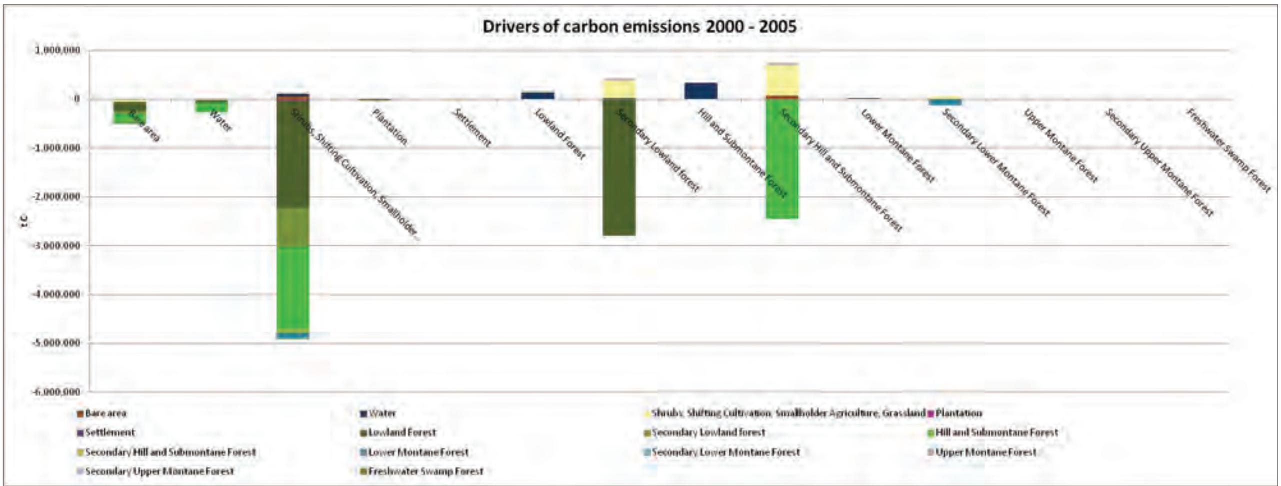


Figure 55. Drivers and source areas of carbon emissions in Malinau district 2000-2005.

Table 49. Carbon change matrix Malinau district 2005-2010.

	Land Cover Carbon	2010															
Land Cover	2005	3	4	21	22	24	111	112	121	122	131	132	141	142	181	182	Sum
Bare area	3	0	0	87,648	0	0	0	14,996	0	11,645	0	1,606	0	0	0	18	**115,913**
Water	4	0	0	22,347	0	0	89,205	7,082	186,674	5,591	19,400	0	0	0	0	0	**330,300**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-52,762	-15,616	0	8,831	-677	11,582	708,917	3,525	744,154	0	71,090	0	267	0	21	**1,479,331**
Plantation	22	0	0	0	0	0	0	2,437	0	0	0	0	0	0	0	0	**2,437**
Settlement	24	0	0	1,343	0	0	0	0	0	0	0	0	0	0	0	0	**1,343**
Lowland Forest	111	-117,904	-48,415	-990,283	-5,963	0	0	-740,928	0	0	0	0	0	0	0	0	**-1,903,494**
Secondary Lowland forest	112	-41,974	-5,937	-687,898	-1,063	0	0	0	0	0	0	0	0	0	0	0	**-736,872**
Hill and Submontane Forest	121	-56,878	-159,063	-1,107,227	0	0	0	0	0	-1,318,817	0	0	0	0	0	0	**-2,641,984**
Secondary Hill and Submontane Forest	122	-25,444	-3,882	-256,761	0	-9	0	0	0	0	0	0	0	0	0	0	**-286,095**
Lower Montane Forest	131	-18,746	0	-71,753	0	0	0	0	0	0	0	-210,976	0	0	0	0	**-301,475**
Secondary Lower Montane Forest	132	-145	0	-19,295	0	0	0	0	0	0	0	0	0	0	0	0	**-19,439**
Upper Montane Forest	141	0	0	-116	0	0	0	0	0	0	0	0	0	-5	0	0	**-121**
Secondary Upper Montane Forest	142	0	0	-553	0	0	0	0	0	0	0	0	0	0	0	0	**-553**
Freshwater Swamp Forest	181	0	-3,038	-6,674	0	0	0	0	0	0	0	0	0	0	0	-2	**-9,715**
Secondary Freshwater Swamp Forest	182	0	-36	-273	0	0	0	0	0	0	0	0	0	0	0	0	**-309**
Sum	**Sum**	**-313,855**	**-235,987**	**-3,029,494**	**1,805**	**-685**	**100,787**	**-7,495**	**190,199**	**-557,426**	**19,400**	**-138,280**	**0**	**262**	**0**	**36**	**-3,970,734**

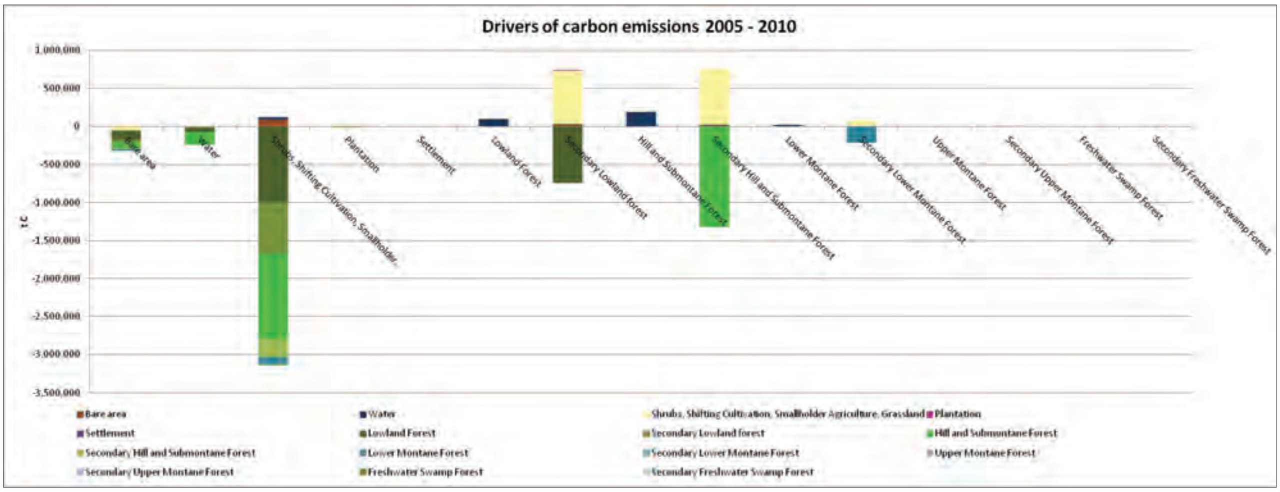


Figure 56. Drivers and source areas of carbon emissions in Malinau district 2005-2010.

Table 50. Carbon change matrix Malinau district 1990-2010.

	Land Cover Carbon	2010															
Land Cover	1990	3	4	21	22	24	111	112	121	122	131	132	141	142	181	182	Sum
Bare area	3	0	0	13,099	0	0	3,998	46,564	4,559	22,433	0	1,787	0	104	0	798	93,342
Water	4	0	0	28,931	0	0	99,527	10,655	223,028	17,341	19,438	0	0	0	657	332	399,908
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-55,189	-8,486	0	336	-5,837	2,814	217,815	3,538	130,001	0	7,306	0	78	0	157	292,534
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settlement	24	0	0	916	0	0	0	0	0	87	0	0	0	0	0	0	1,003
Lowland Forest	111	-256,834	-46,638	-5,416,233	-140,846	0	0	-5,273,556	-1,466	-41,954	0	0	0	0	0	0	-11,177,527
Secondary Lowland forest	112	-78,018	-6,323	-713,697	0	-249	0	0	0	-924	0	0	0	0	0	0	-799,210
Hill and Submontane Forest	121	-128,246	-236,555	-3,590,934	0	-451	16,958	-15,835	0	-6,713,417	0	-4,181	0	0	0	0	-10,672,662
Secondary Hill and Submontane Forest	122	-5,792	-7,903	-23,493	0	-244	0	1,709	2,682	0	0	0	0	0	0	0	-33,041
Lower Montane Forest	131	-18,976	-153	-251,564	0	0	0	0	-86	-31,879	0	-603,577	0	0	0	0	-906,236
Secondary Lower Montane Forest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane Forest	141	0	0	-2,123	0	0	0	0	0	0	0	-5	0	-4,100	0	0	-6,228
Secondary Upper Montane Forest	142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freshwater Swamp Forest	181	-19	-9,933	-29,842	0	0	12	129	0	0	0	0	0	0	0	-97	-39,751
Secondary Freshwater Swamp Forest	182	-1,830	-170	-32,610	0	0	0	0	0	0	0	0	0	0	0	0	-34,610
Sum	Sum	-544,904	-316,162	-10,017,551	-140,510	-6,781	123,308	-5,012,519	232,255	-6,618,312	19,438	-598,669	0	-3,919	657	1,191	-22,882,478

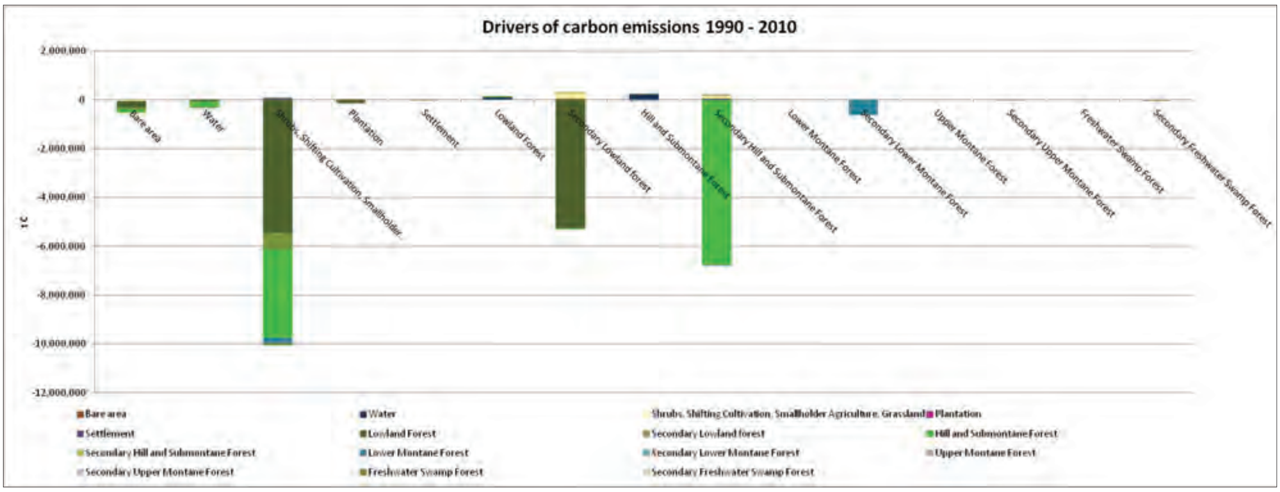


Figure 57. Drivers and source areas of carbon emissions in Malinau district 1990-2010.

6.3.2 Kapuas Hulu district

Table 51. Carbon change matrix Kapuas Hulu district 1990-2000.

		2000																		
Class	1990	3	4	21	22	23	111	112	121	122	131	132	141	151	152	161	162	171	172	Sum
Bare Area	3	0	0	343,190	34,419	2,544	0	102,165	0	11,148	0	314	0	0	43,337	0	1,425	0	713	539,255
Water	4	0	0	57,279	312	2,436	0	6,734	0	1,622	0	229	0	0	3,030	0	376	0	785	72,805
Shrubs, Agriculture etc.	21	-552,209	-96,677	0	73,493	-9,594	0	869,277	0	17,063	0	0	0	0	74,659	0	6,498	0	4,469	386,980
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wetland	23	-111	-45,750	4,465	0	0	0	0	0	0	0	0	0	0	3,839	0	0	0	265	-37,293
Lowland Forest	111	-1,292,612	-265,097	-8,795,491	-39,980	-41	0	-2,482,913	-714	0	0	0	0	0	0	0	0	0	0	-12,876,849
Secondary Lowland Forest	112	-138,722	-20,401	-1,419,629	-554	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1,579,306
Hill and Sub-montane Forest	121	-81,721	-18,869	-39,757	0	0	67	0	0	-401,865	0	0	0	0	0	0	0	0	0	-542,145
Secondary Hill and Sub-montane Forest	122	-1,204	-157	-191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1,552
Lower Montane Forest	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Lower Montane Forest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat Swamp Forest	151	-707,753	-434,385	-846,871	0	-1,064	0	0	0	0	0	0	0	0	-372,463	0	0	57	0	-2,362,478
Secondary Peat Swamp Forest	152	-33,093	-15,383	-76,056	-119	0	0	0	0	0	0	0	0	0	0	0	0	0	-343	-124,994
Heath Forest	161	-58,867	-3,759	-148,216	-21,925	0	0	0	0	0	0	0	0	0	0	0	-23,193	0	0	-255,960
Secondary Heath Forest	162	-1,873	-712	-16,570	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-19,156
Riparian Forest	171	-374,500	-518,656	-523,660	-8	-483	0	0	0	0	0	0	0	-36	0	0	0	0	-225,310	-1,642,654
Secondary Riparian Forest	172	-16,734	-14,518	-26,438	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-57,653
Total	Sum	-3,259,397	-1,434,365	-11,487,945	45,676	-6,202	67	-1,504,737	-714	-372,032	0	543	0	-36	-247,598	0	-14,894	57	-219,421	-18,500,999

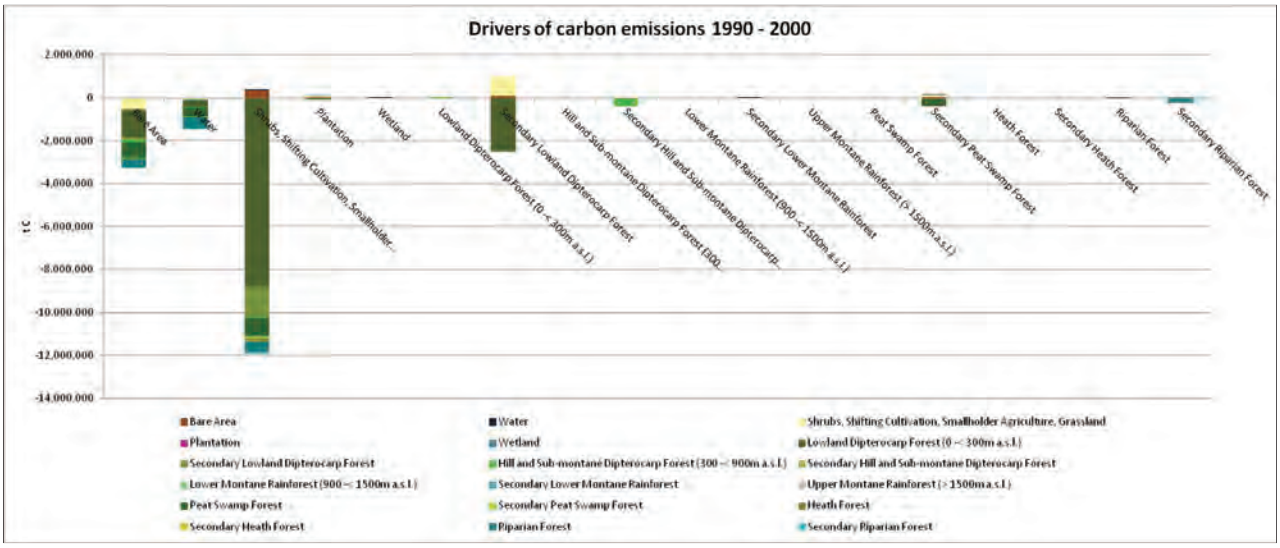


Figure 58. Drivers and source areas of carbon emissions in Kapuas Hulu district 1990-2000.

Table 52. Carbon change matrix Kapuas Hulu district 2000-2005.

	Land Cover Carbon	2005																		
Class	2000	3	4	21	22	23	111	112	121	122	131	132	141	151	152	161	162	171	172	Sum
Bare Area	3	0	0	275,923	61,330	288	0	149	0	0	0	0	0	0	6,443	0	0	0	0	344,133
Water	4	0	0	68,728	1,408	1,131	0	0	0	0	0	0	0	0	109	0	0	0	0	71,375
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-486,156	-27,039	0	61,434	-146	0	19,552	0	514	0	0	0	0	7,283	0	0	0	0	-424,558
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wetland	23	-11	-976	98	4,071	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,182
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	111	-814,054	-2,010	-2,269,913	-166,362	0	0	-744,841	0	0	0	0	0	0	0	0	0	-19	0	-3,997,198
Secondary Lowland Dipterocarp Forest	112	-121,022	-398	-361,824	-12,887	0	0	0	0	0	0	0	0	0	0	0	-4	0	0	-496,136
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	121	-76,439	-211	-208,818	0	0	0	0	0	-242,929	0	0	0	0	0	0	0	0	0	-528,397
Secondary Hill and Sub-montane Dipterocarp Forest	122	-2,469	0	-7,708	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-10,177
Lower Montane Rainforest (900 -< 1500m a.s.l.)	131	-4,692	-364	-306	0	0	0	0	0	0	0	-198	0	0	0	0	0	0	0	-5,560
Secondary Lower Montane Rainforest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane Rainforest (> 1500m a.s.l.)	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat Swamp Forest	151	-144,004	-1,424	-180,147	-13,348	-379	0	0	0	0	0	0	0	0	-220,204	0	0	0	0	-559,505
Secondary Peat Swamp Forest	152	-19,164	-191	-25,011	-40	0	72	0	0	0	0	0	0	0	0	0	0	0	0	-44,334
Heath Forest	161	-28,844	0	-53,030	-1,248	0	0	0	0	0	0	0	0	0	0	0	-36,247	0	0	-119,368
Secondary Heath Forest	162	-2,537	0	-6,028	-279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8,844
Riparian Forest	171	-67,341	-2,409	-114,674	-206	-580	0	0	0	0	0	0	0	0	0	0	0	0	-40,005	-225,213
Secondary Riparian Forest	172	-5,308	-367	-9,906	6	0	0	45	0	0	0	0	0	6	5,246	0	0	0	0	-10,277
Total	Sum	-1,772,040	-35,389	-2,892,616	-66,120	314	72	-725,095	0	-242,415	0	-198	0	6	-201,122	0	-36,251	-19	-40,005	-6,010,879

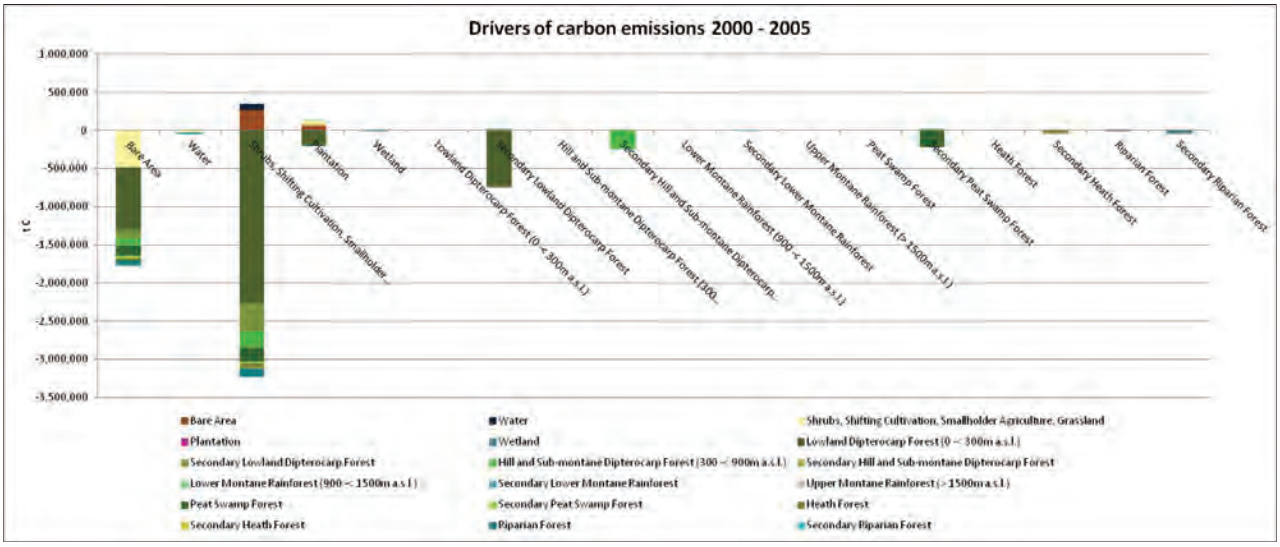


Figure 59. Drivers and source areas of carbon emissions in Kapuas Hulu district 2000-2005.

Table 53. Carbon change matrix Kapuas Hulu district 2005-2010.

		2010																		
Class	2005	3	4	21	22	23	111	112	121	122	131	132	141	151	152	161	162	171	172	Sum
Bare Area	3	0	0	793,539	52,134	39,682	0	0	0	0	0	0	0	1,424	0	0	0	0	0	886,780
Water	4	0	0	10,450	3,177	268,181	0	0	0	0	0	0	0	2,374	0	0	0	0	0	284,182
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-234,531	-37,634	0	126,804	-18,684	0	0	0	0	0	0	0	416	0	0	0	0	0	-163,629
Plantation	22	0	0	-2,526	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2,526
Wetland	23	-17	-182	864	448	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,113
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	111	-352,102	-3,110	-1,642,616	-284,274	0	0	-82,478	0	0	0	0	0	0	0	0	0	0	0	-2,364,578
Secondary Lowland Dipterocarp Forest	112	-48,381	-573	-258,001	-33,156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-340,111
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	121	-14,836	-542	-206,313	0	0	0	0	0	-11,188	0	0	0	0	0	0	0	0	0	-232,879
Secondary Hill and Sub-montane Dipterocarp Forest	122	-672	-105	-7,102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-7,878
Lower Montane Rainforest (900 -< 1500m a.s.l.)	131	0	0	-1,838	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1,838
Secondary Lower Montane Rainforest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane Rainforest (> 1500m a.s.l.)	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat Swamp Forest	151	-112,668	-3,314	-252,890	-32,343	-20,323	0	11	0	0	0	0	0	0	-66,206	0	0	0	0	-487,733
Secondary Peat Swamp Forest	152	-20,276	-396	-28,182	-3,789	-1,156	0	0	0	0	0	0	0	0	0	0	0	0	0	-53,799
Heath Forest	161	-23,170	-20	-65,819	-118	0	0	0	0	0	0	0	0	0	0	0	-11,027	0	0	-100,155
Secondary Heath Forest	162	-1,177	-16	-8,470	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-9,663
Riparian Forest	171	-29,213	-9,281	-124,391	0	-49,501	0	0	0	0	0	0	0	0	0	0	0	0	-2,436	-214,821
Secondary Riparian Forest	172	-3,354	-1,399	-6,428	8	-2,872	0	0	0	0	0	0	0	19	0	0	0	0	0	-14,025
Total	Sum	-840,396	-56,570	-1,799,722	-171,108	215,329	0	-82,467	0	-11,188	0	0	0	4,233	-66,206	0	-11,027	0	-2,436	-2,821,560

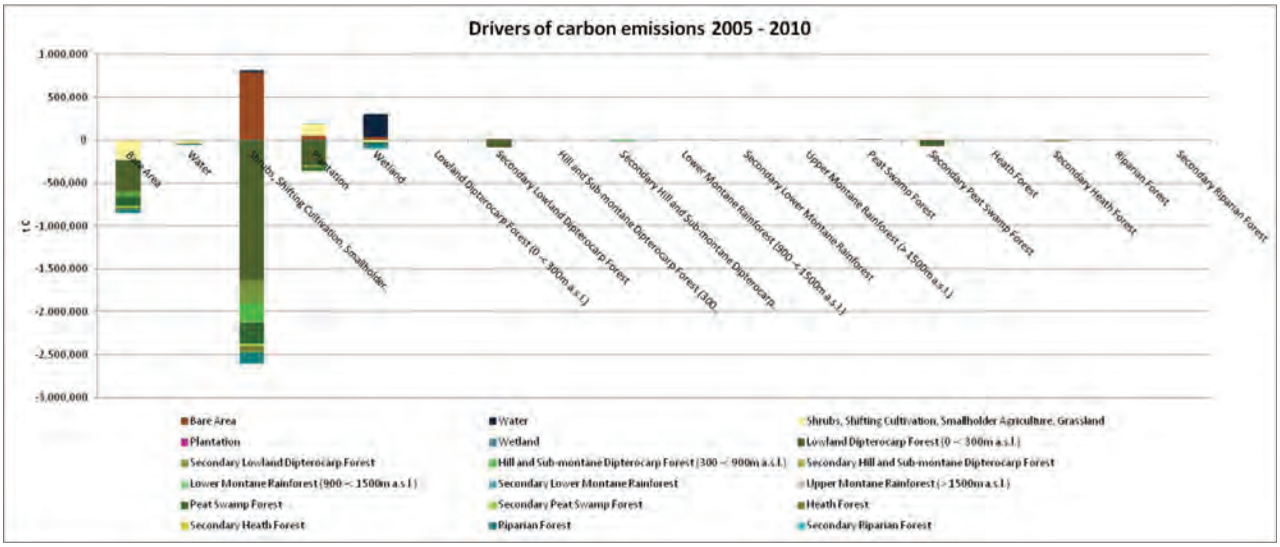


Figure 60. Drivers and source areas of carbon emissions in Kapuas Hulu district 2005-2010.

Table 54. Carbon change matrix Kapuas Hulu district 1990-2010.

		2010																		
Class	1990	3	4	21	22	23	111	112	121	122	131	132	141	151	152	161	162	171	172	Sum
Bare Area	3	0	0	369,331	62,927	38,321	0	99,476	0	11,409	0	314	0	10	43,583	0	1,425	0	700	**627,496**
Water	4	0	0	54,151	2,324	167,033	0	4,929	0	1,622	0	229	0	0	2,798	0	376	0	604	**234,067**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-445,008	-89,504	0	254,184	-23,337	95	856,047	0	17,287	0	0	0	1,020	76,516	0	6,005	0	4,028	**657,332**
Plantation	22	0	0	-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-88**
Wetland	23	-912	-7,462	8,707	4,769	0	0	0	0	0	0	0	0	0	3,759	0	0	0	127	**8,987**
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	111	-1,448,429	-244,578	-14,052,326	-703,433	-4,956	0	-3,013,528	-714	0	0	0	0	0	-946	0	-13	-19	0	**-19,468,943**
Secondary Lowland Dipterocarp Forest	112	-139,108	-17,949	-1,733,924	-98,906	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-1,989,886**
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	121	-55,960	-19,366	-577,683	0	0	67	0	0	-645,136	0	0	0	0	0	0	0	0	0	**-1,298,078**
Secondary Hill and Sub-montane Dipterocarp Forest	122	-1,169	-157	-6,087	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-7,413**
Lower Montane Rainforest (900 -< 1500m a.s.l.)	131	-287	-364	-6,058	0	0	0	0	0	0	0	-198	0	0	0	0	0	0	0	**-6,907**
Secondary Lower Montane Rainforest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Upper Montane Rainforest (> 1500m a.s.l.)	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Peat Swamp Forest	151	-357,074	-184,602	-1,540,549	-108,374	-491,662	0	11	0	0	0	0	0	0	-635,591	0	0	57	0	**-3,317,785**
Secondary Peat Swamp Forest	152	-47,200	-6,654	-97,269	-3,497	-12,789	0	0	0	0	0	0	0	0	0	0	0	0	0	**-167,408**
Heath Forest	161	-77,925	-4,142	-304,645	-24,158	0	0	0	0	0	0	0	0	0	0	0	-67,089	0	0	**-477,959**
Secondary Heath Forest	162	-3,362	-768	-22,980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-27,111**
Riparian Forest	171	-119,156	-173,471	-885,509	-2,482	-624,219	0	5	0	0	0	0	0	-36	-6,120	0	0	0	-218,489	**-2,029,478**
Secondary Riparian Forest	172	-13,750	-7,424	-40,115	74	-9,571	0	0	0	0	0	0	0	0	523	0	0	0	0	**-70,263**
Total	Sum	**-2,709,339**	**-756,441**	**-18,835,044**	**-616,573**	**-961,181**	**162**	**-2,053,060**	**-714**	**-614,817**	**0**	**345**	**0**	**993**	**-515,478**	**0**	**-59,297**	**37**	**-213,032**	**-27,333,437**

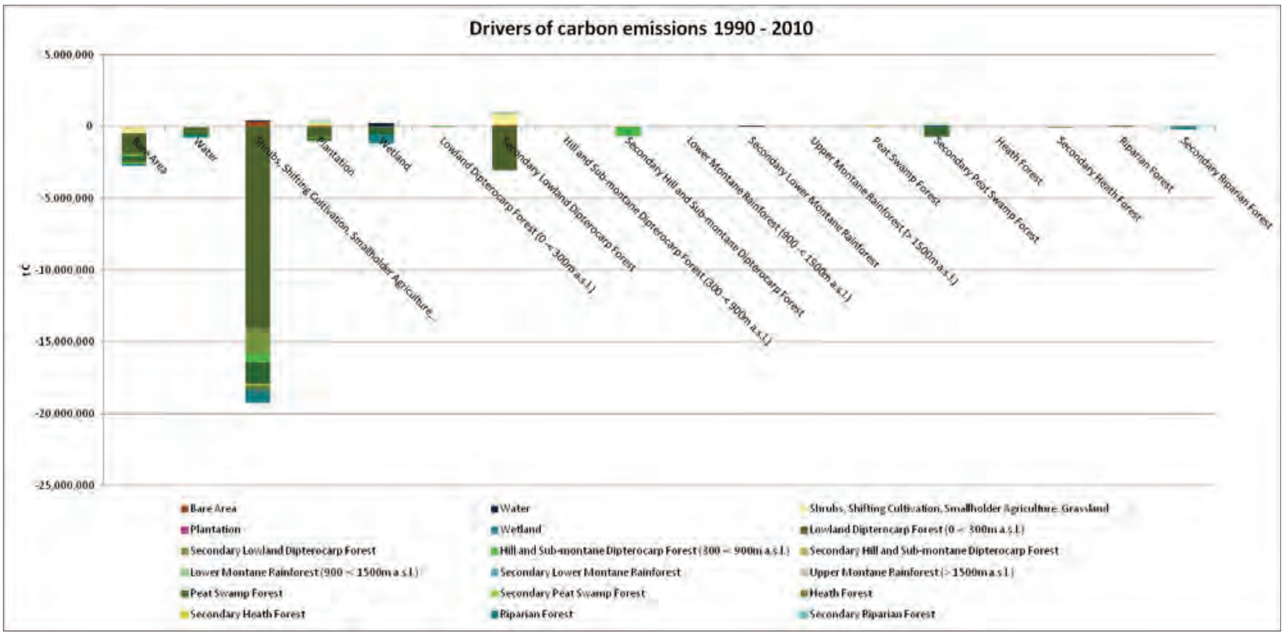


Figure 61. Drivers and source areas of carbon emissions in Kapuas Hulu district 1990-2010.

6.4 Results for the FMU areas

6.4.1 Malinau district

6.4.1.1 Land cover maps

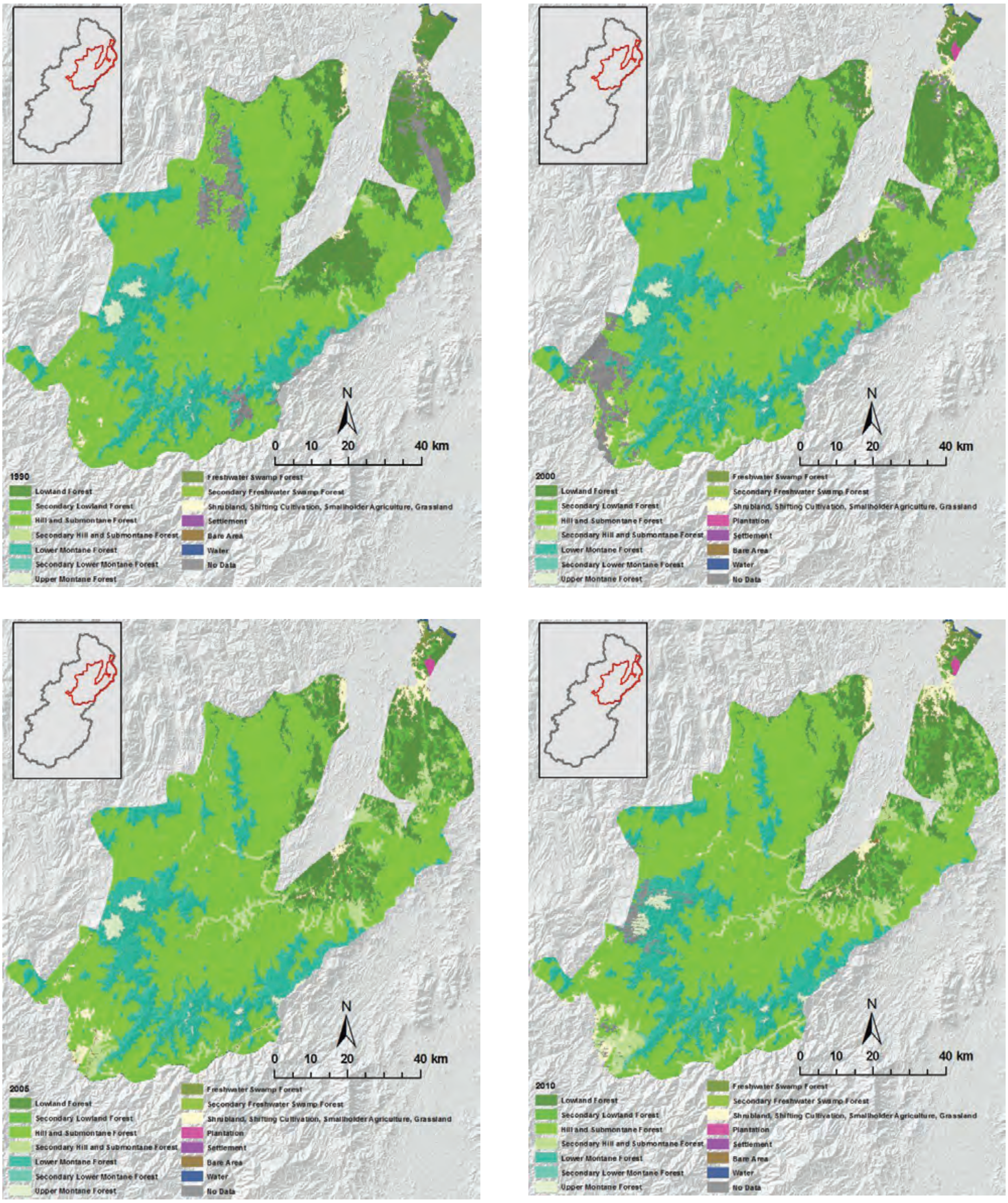


Figure 62. Land cover maps of the FMU in Malinau district.

Table 55. Spatial extent of the land cover classes in the Malinau FMU.

Land Cover Class	1990	2000	2005	2010
	ha			
Lowland Forest	102,973	90,320	78,013	73,227
Secondary Lowland Forest	6,885	18,396	33,420	37,086
Hill and Sub-montane Forest	419,049	393,315	393,101	382,968
Secondary Hill and Sub-montane Forest	3,779	15,676	37,947	46,427
Lower Montane Forest	121,362	129,037	129,199	122,840
Secondary Lower Montane Forest	23	433	785	1,243
Upper Montane Forest	5,393	6,037	6,139	5,102
Freshwater Swamp Forest	2,216	2,182	1,995	1,913
Secondary Freshwater Swamp Forest	68	64	76	77
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	6,739	12,074	20,866	22,878
Plantation	0	691	790	794
Settlement	12	12	17	8
Bare Area	505	489	1,825	936
Water	1,367	1,650	1,463	1,041
No Data	35,723	35,718	456	9,555
Total	**706,093**	**706,094**	**706,094**	**706,094**

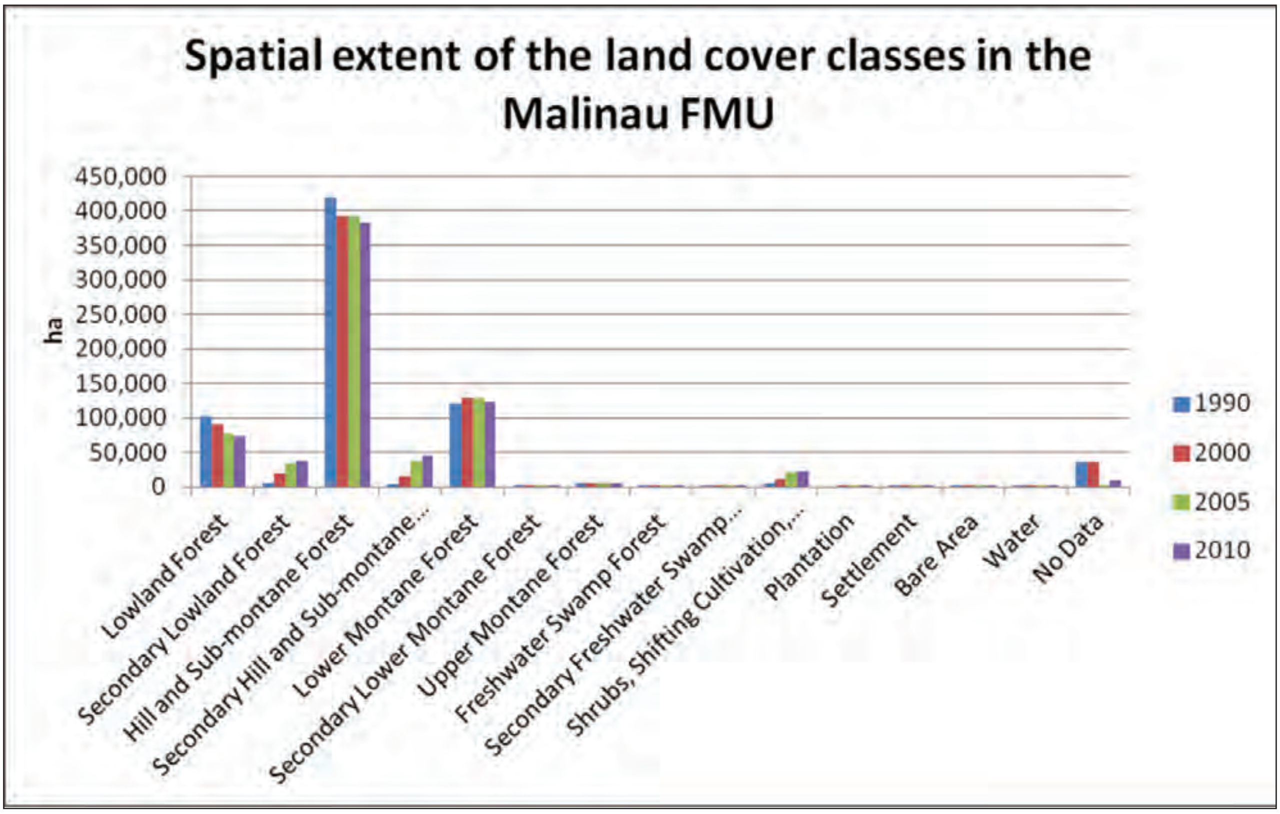


Figure 63. Spatial extent of the land cover classes in the Malinau FMU.

6.4.1.2 Land cover change maps

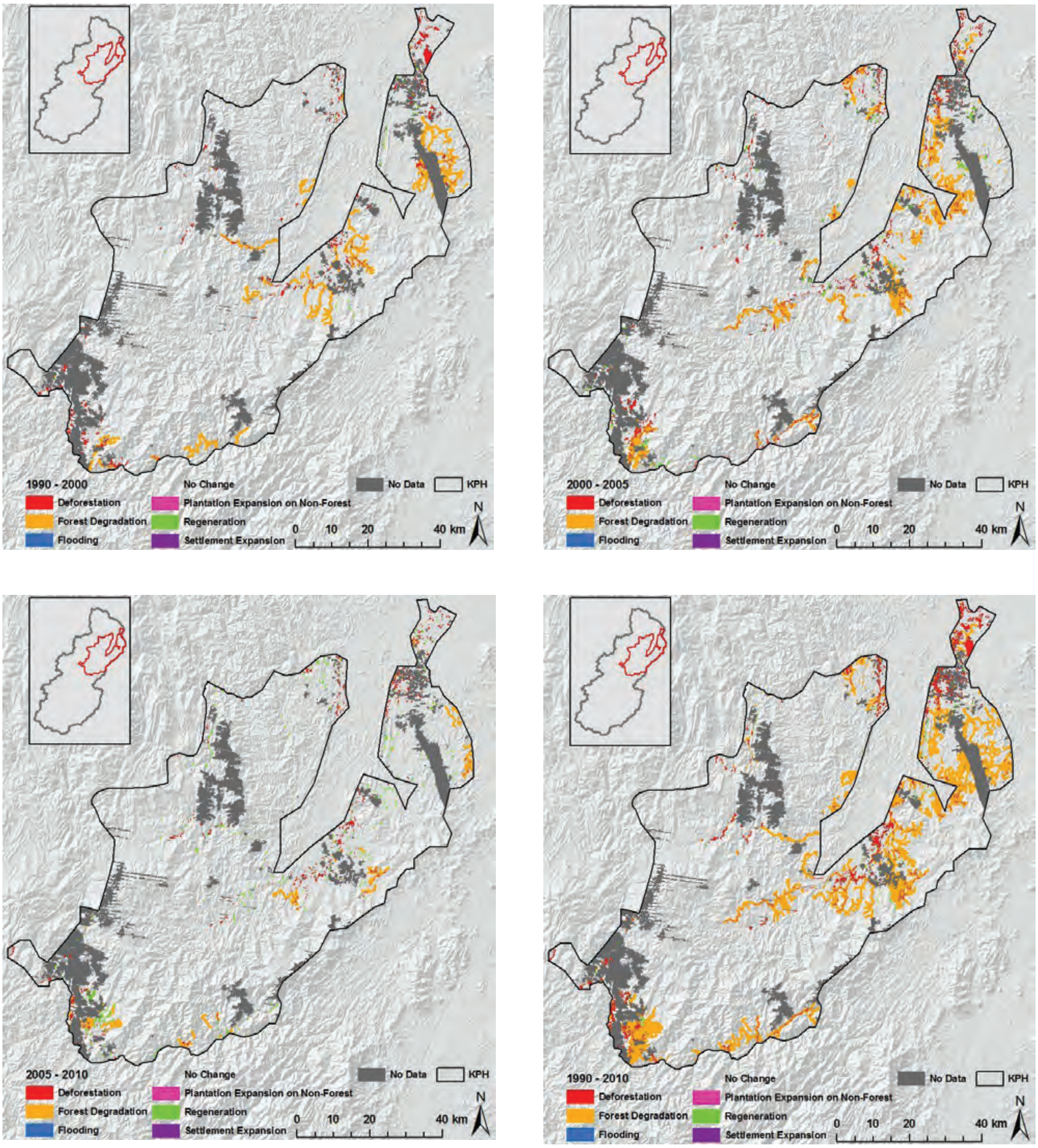


Figure 64. Land cover change maps of the FMU in Malinau district.

Table 56. Change processes in the Malinau FMU in the four observation periods.

Change process	1990-2000 ha %	2000-2005 ha %	2005-2010 ha %	1990-2010 ha %
Deforestation	6,823	9,060	5,176	13,316
	1.09%	1.44%	0.82%	2.12%
Flooding	99	101	63	46
	0.02%	0.02%	0.01%	0.01%
Forest Degradation	22,235	31,154	8,236	65,334
	3.54%	4.96%	1.31%	10.40%
No Change	598,213	584,850	609,667	548,194
	95.22%	93.09%	97.04%	87.26%
Plantation Expansion on Non-Forest	3	0	0	2
	0.00%	0.00%	0.00%	0.00%
Regeneration	891	3,100	5,124	1,372
	0.14%	0.49%	0.82%	0.22%
Settlement expansion	0	0	0	1
	0.00%	0.00%	0.00%	0.00%
Total	**628,265**	**628,265**	**628,264**	**628,265**

Table 57. Area change per class in the Malinau FMU for the four observation periods.

Class	1990-2000	2000-2005	2005-2010	1990-2010
	ha			
Bare Area	21	988	-620	390
Water	263	-218	-431	-386
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	4,957	5,106	1,102	11,165
Plantation	691	86	1	777
Settlement	0	-3	0	-3
Lowland Dipterocarp Forest (0 -< 300m a.s.l.)	-13,358	-15,468	-3,827	-32,653
Secondary Lowland Dipterocarp Forest	10,380	12,051	3,064	25,495
Hill and Sub-montane Dipterocarp Forest (300 -< 900m a.s.l.)	-14,316	-21,916	-6,617	-42,850
Secondary Hill and Sub-montane Dipterocarp Forest	11,411	19,610	7,375	38,396
Lower Montane Rainforest (900 -< 1500m a.s.l.)	-418	-385	-446	-1,248
Secondary Lower Montane Rainforest	407	323	481	1,211
Upper Montane Rainforest (> 1500m a.s.l.)	0	0	0	0
Freshwater Swamp Forest	-34	-187	-82	-303
Secondary Freshwater Swamp Forest	-4	12	0	8
Total	**0**	**0**	**0**	**0**

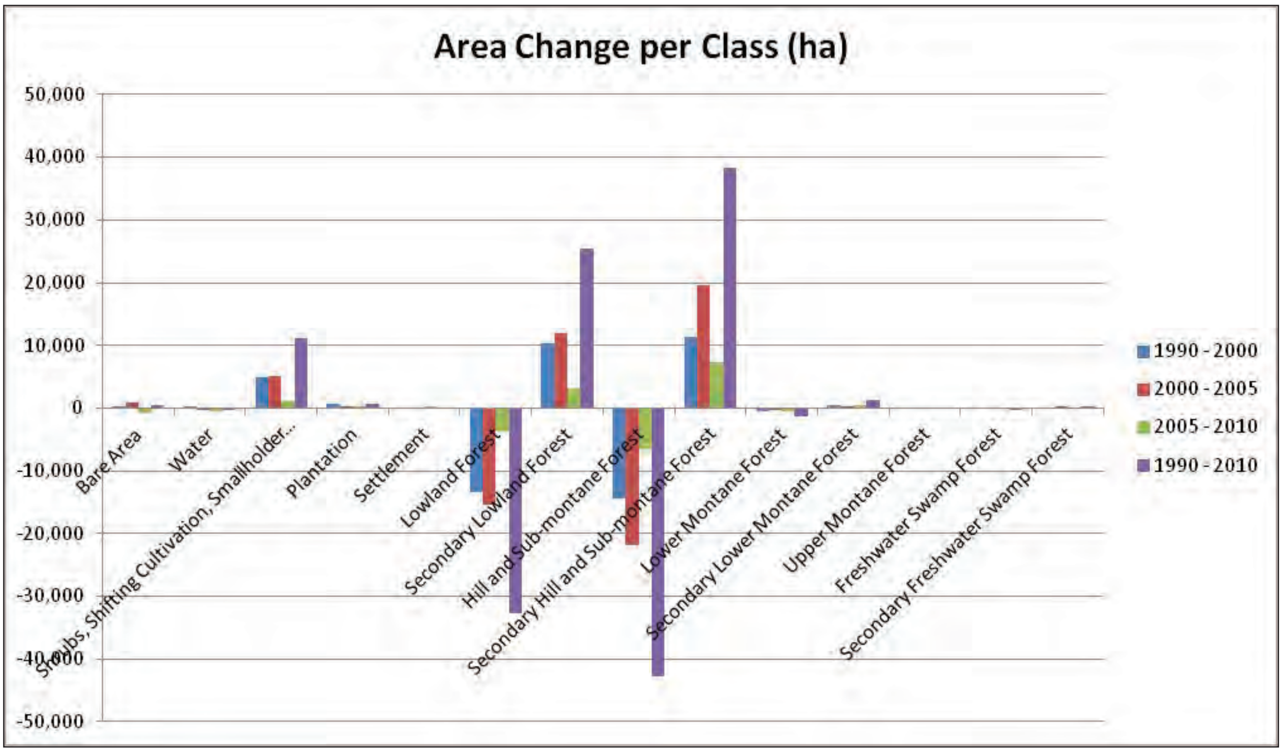


Figure 65. Area change per class in the Malinau FMU for the four observation periods.

6.4.1.3 Forest cover and deforestation maps

Table 58. Spatial extent of forest and non-forest areas in the Malinau FMU.

	1990	2000	2005	2010
Forest	621,040	615,108	609,148	609,096
Non-Forest	7,226	13,157	19,117	19,169
Sum	628,266	628,265	628,265	628,265

Table 59. Net forest loss in the Malinau FMU.

Net forest loss	1990-2000	2000-2005	2005-2010	1990-2010
ha	-5,932	-5,960	-52	-11,944
%	-0.96%	-0.97%	-0.01%	-1.92%

Table 60. Annual deforestation rate [% yr-1] in the Malinau FMU.

	1990-2000	2000-2005	2005-2010	1990-2010
Deforestation rate	0.10%	0.19%	0.00%	0.10%

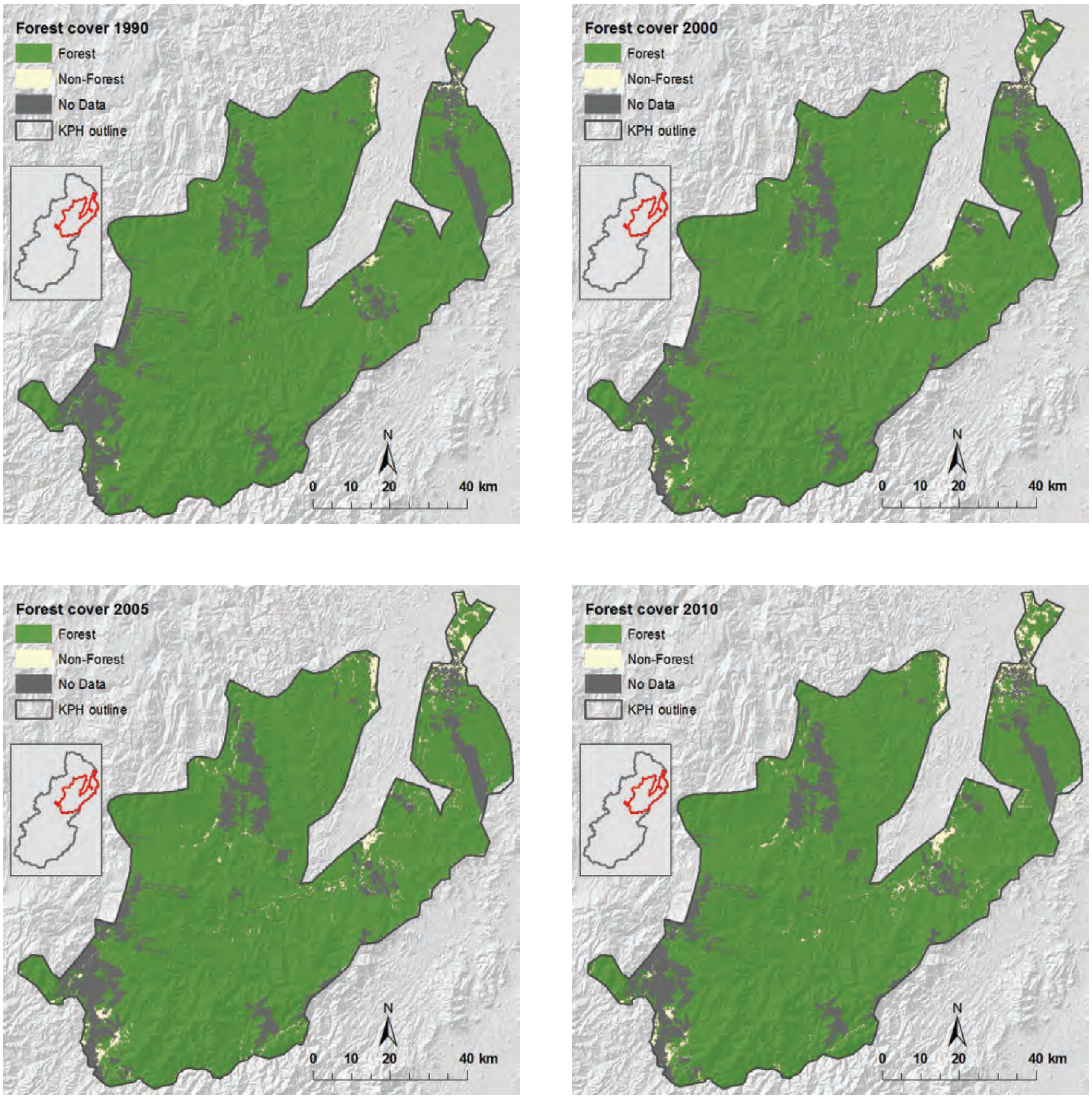


Figure 66. Forest cover maps of the FMU in Malinau district for the years 1990, 2000, 2005, 2010.

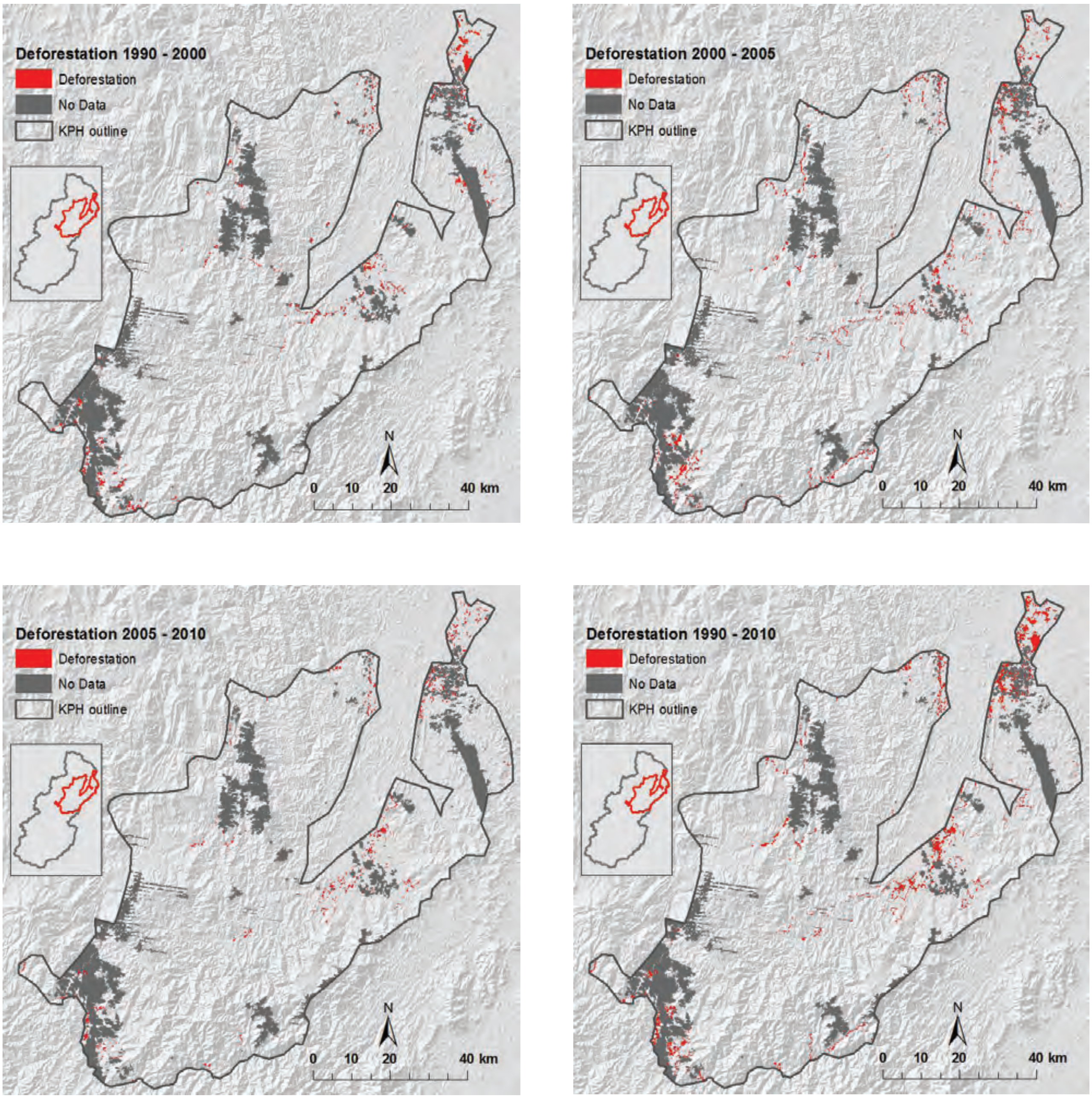


Figure 67. Deforestation maps of the FMU in Kapuas Hulu district for the time periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010.

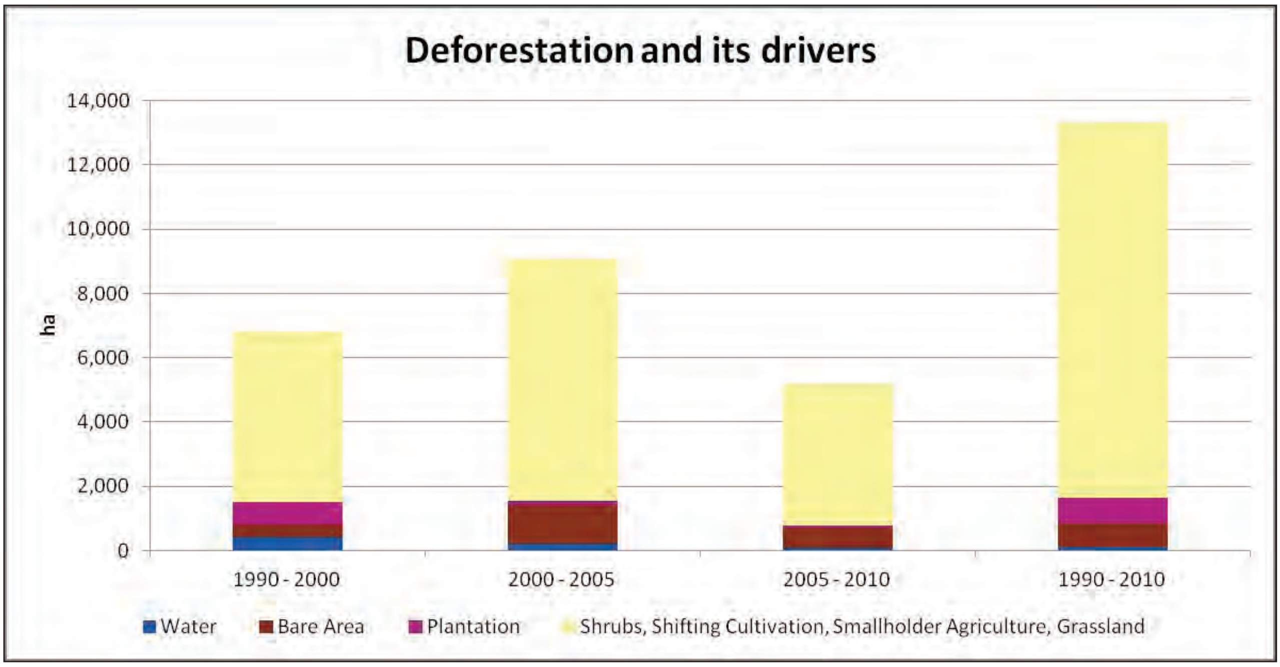


Figure 68. Deforestation and its drivers in the Malinau FMU.

Table 61. Deforestation and its drivers in the Malinau FMU.

Driver	1990-2000 ha %	2000-2005 ha %	2005-2010 ha %	1990-2010 ha %
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	5,311	7,533	4,403	11,693
	77.84%	83.14%	85.08%	87.81%
Plantation	688	106	58	775
	10.08%	1.17%	1.12%	5.82%
Wetland	0	0	0	0
	0.00%	0.00%	0.00%	0.00%
Bare Area	410	1,198	629	722
	6.00%	13.22%	12.16%	5.42%
Water	414	223	85	126
	6.07%	2.46%	1.65%	0.95%
Total deforestation	**6,823**	**9,060**	**5,176**	**13,316**

6.4.1.4 Historic carbon change

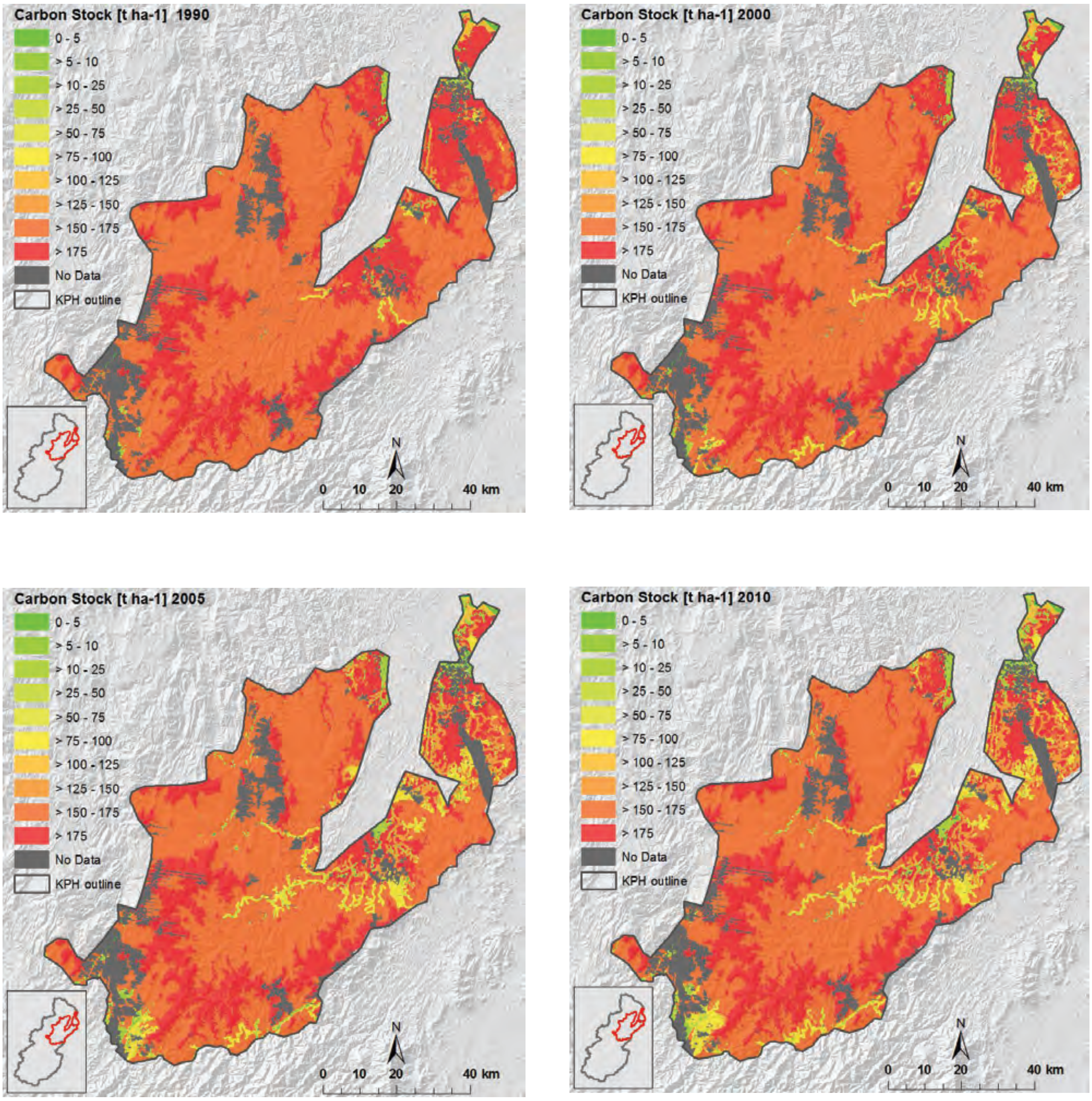


Figure 69. Carbon stock maps of the FMU in Malinau district for the years 1990, 2000, 2005 and 2010.

Table 62. Carbon stock of the different land cover classes in the Malinau FMU for the four time steps.

Class	1990	2000	2005	2010
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	128,793	246,377	367,491	393,638
Plantation		67,009	75,364	75,416
Settlement	0	0	0	0
Lowland Dipterocarp Forest (0 -< 300 m a.s.l.)	22,937,839	19,798,262	16,162,678	15,263,170
Secondary Lowland Dipterocarp Forest	804,784	2,240,330	3,906,967	4,330,685
Hill and Sub-montane Dipterocarp Forest (300 -< 900 m a.s.l.)	65,702,139	63,308,565	59,644,387	58,538,077
Secondary Hill and Sub-montane Dipterocarp Forest	307,390	1,413,381	3,313,956	4,028,759
Lower Montane Rainforest (900 -< 1500 m a.s.l.)	24,428,770	24,339,928	24,258,091	24,163,159
Secondary Lower Montane Rainforest	3,091	57,647	101,030	165,572
Upper Montane Rainforest (> 1500 m a.s.l.)	664,951	664,951	664,951	664,951
Freshwater Swamp Forest	230,959	227,418	207,965	199,380
Secondary Freshwater Swamp Forest	6,821	6,395	7,584	7,638
Total	**115,215,536**	**112,370,264**	**108,710,463**	**107,830,445**

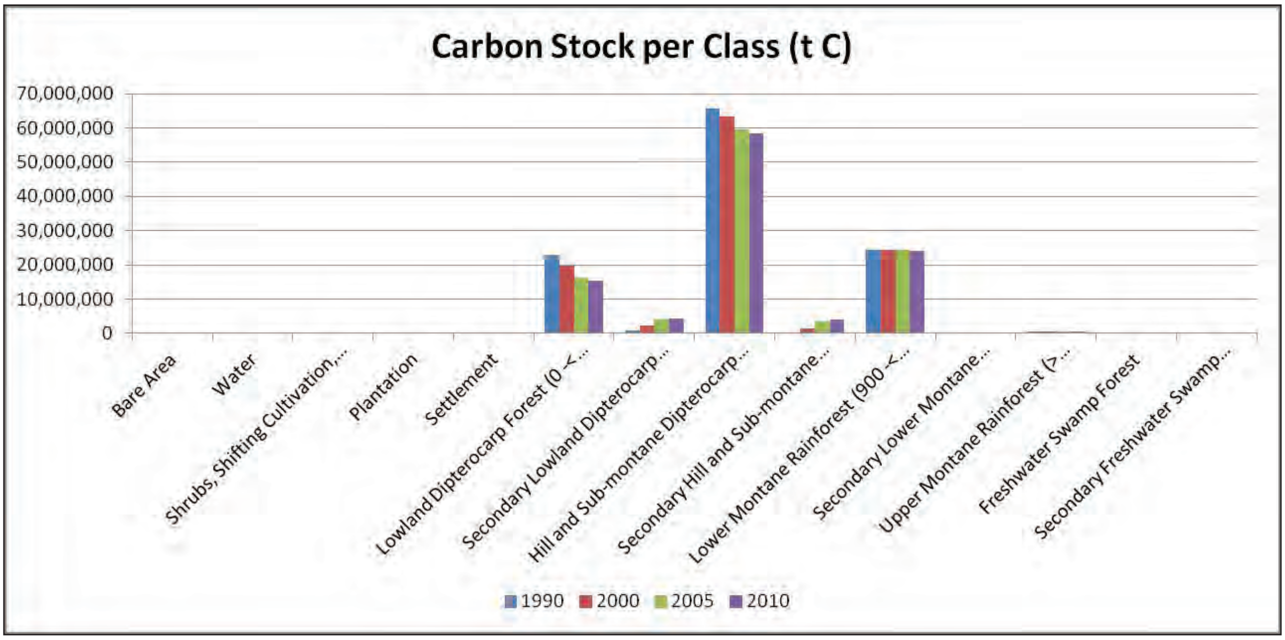


Figure 70. Carbon stock of the different land cover classes in the Malinau FMU for the four time steps.

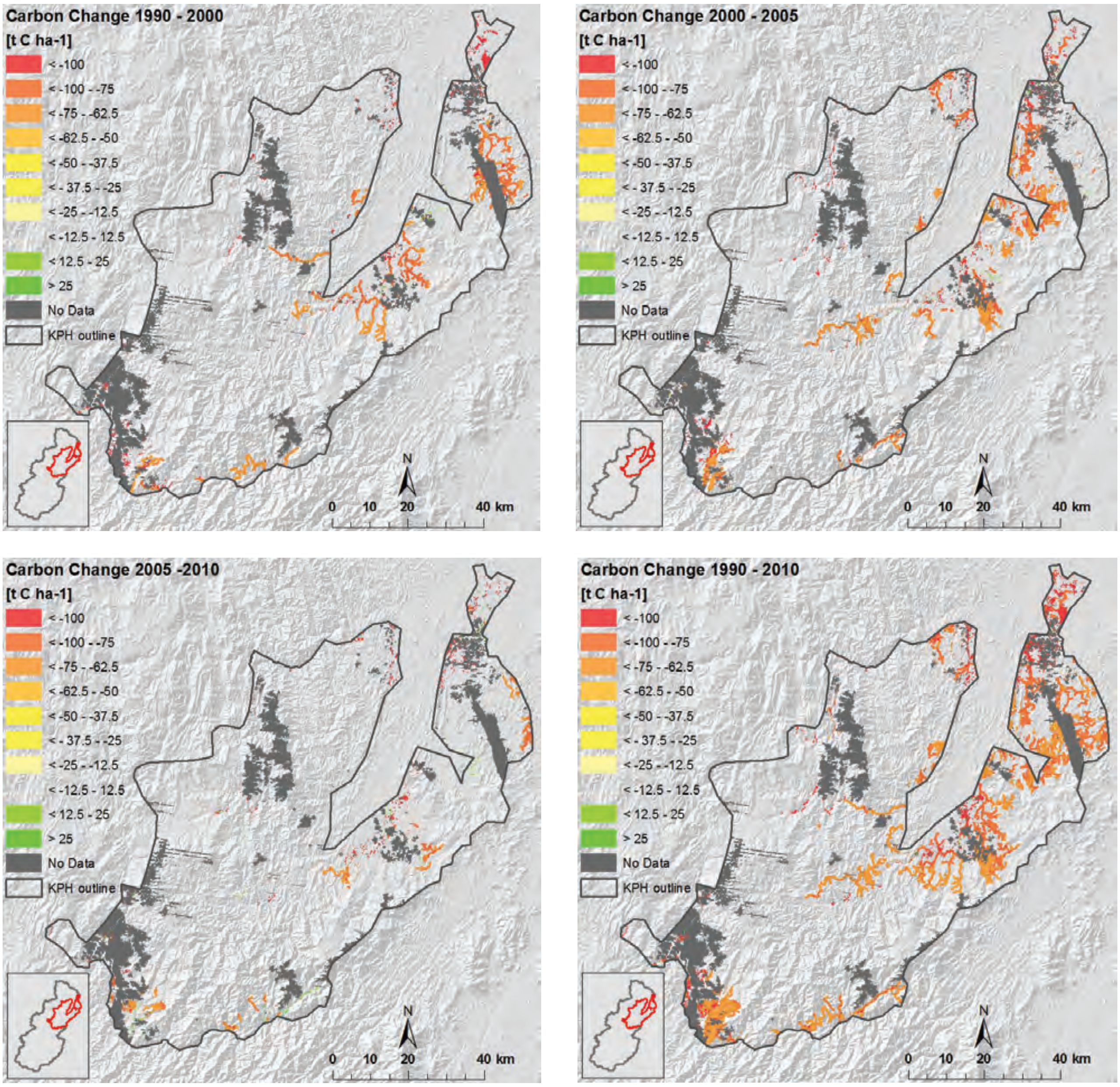


Figure 71. Carbon stock change maps of the FMU in Malinau district for the observation periods 1990-2000, 2000-2005, 2005-2010 and 1990-2010.

Table 63. Carbon stock change per class and time period in the Malinau FMU.

Class	1990-2000	2000-2005	2005-2010	1990-2010
	t C			
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	117,584	121,114	26,146	264,845
Plantation	67,009	8,355	52	75,416
Settlement	0	0	0	0
Lowland Forest	-3,139,577	-3,635,584	-899,508	-7,674,669
Secondary Lowland Forest	1,435,546	1,666,637	423,718	3,525,901
Hill and Sub-montane Forest	-2,393,574	-3,664,198	-1,106,310	-7,164,082
Secondary Hill and Sub-montane Forest	1,105,992	1,900,575	714,804	3,721,370
Lower Montane Forest	-88,842	-81,864	-94,932	-265,638
Secondary Lower Montane Forest	54,556	43,382	64,542	162,481
Upper Montane Forest	0	0	0	0
Freshwater Swamp Forest	-3,541	-19,453	-8,585	-31,578
Secondary Freshwater Swamp Forest	-425	1,189	54	818
Total	**-2,845,271**	**-3,659,848**	**-880,018**	**-7,385,137**

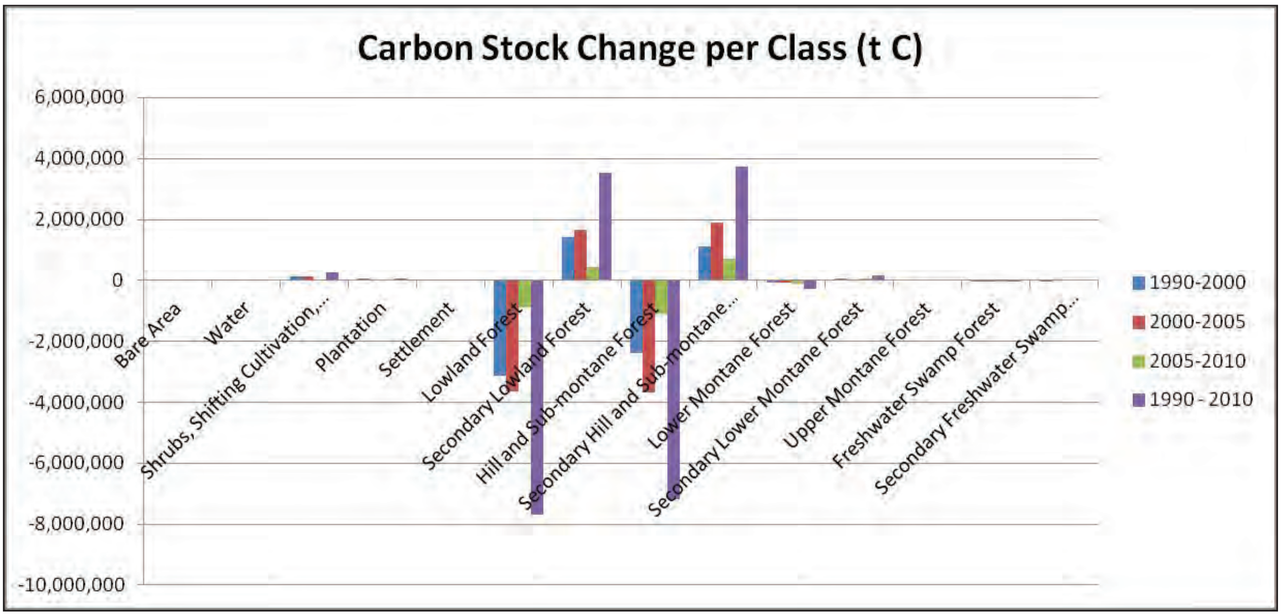


Figure 72. Carbon stock change per class and time period in the Malinau FMU.

6.4.1.5 Drivers of carbon emissions in the Malinau FMU

Table 64. Carbon change matrix of the Malinau FMU 1990-2000.

		2000														
Class	1990	3	4	21	22	24	111	112	121	122	131	132	141	181	182	Sum
Bare Area	3	0	0	7,966	0	0	0	4,864	0	401	0	0	0	0	658	13,889
Water	4	0	0	1,878	0	0	19,539	498	9,514	510	0	0	0	359	161	32,459
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-258	-1,515	0	209	0	0	56,505	0	14,168	0	298	0	0	157	69,564
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settlement	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lowland Forest	111	-75,500	-37,712	-412,084	-94,967	0	0	-998,461	0	0	0	0	0	0	0	-1,618,724
Secondary Lowland Forest	112	-2,701	-1,311	-50,877	0	0	0	0	0	0	0	0	0	0	0	-54,889
Hill and Sub-montane Forest	121	-10,756	-37,769	-369,129	0	0	0	0	0	-808,828	0	0	0	0	0	-1,226,482
Secondary Hill and Sub-montane Forest	122	0	0	-22,096	0	0	0	0	0	0	0	0	0	0	0	-22,096
Lower Montane Forest	131	-977	0	-1,702	0	0	0	0	0	0	0	-31,756	0	0	0	-34,435
Secondary Lower Montane Forest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Montane Forest	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freshwater Swamp Forest	181	0	-1,676	-1,717	0	0	0	0	0	0	0	0	0	0	0	-3,393
Secondary Freshwater Swamp Forest	182	0	-242	-922	0	0	0	0	0	0	0	0	0	0	0	-1,164
	Sum	-90,193	-80,226	-848,683	-94,758	0	19,539	-936,594	9,514	-793,749	0	-31,458	0	359	977	-2,845,271

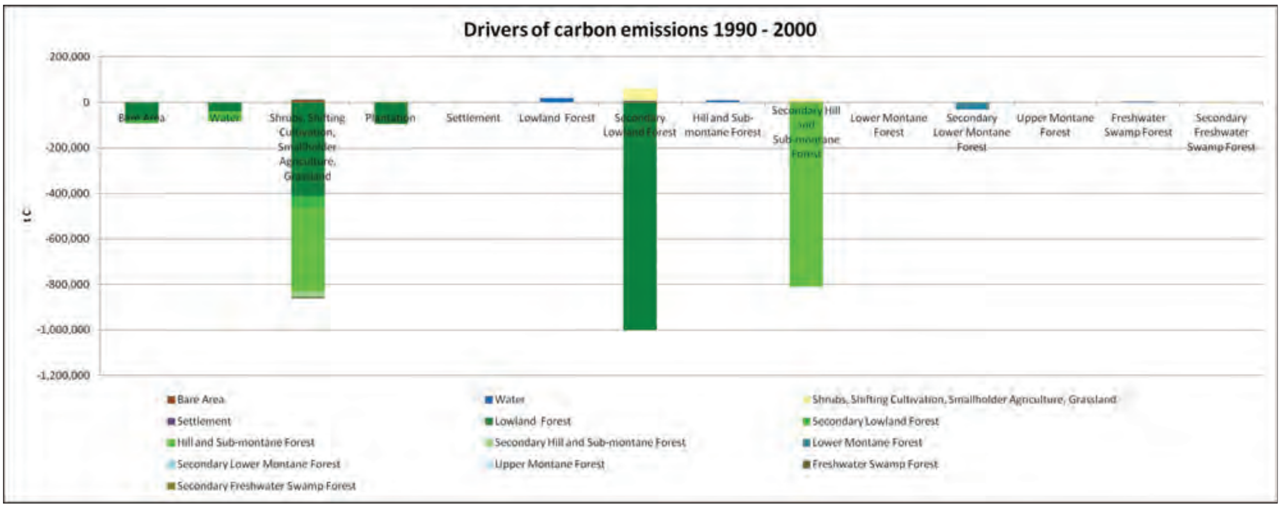


Figure 73. Drivers of carbon emissions in the Malinau FMU 1990-2000.

Table 65. Carbon change matrix of the Malinau FMU 2000-2005.

		2005														
Class	2000	3	4	21	22	24	111	112	121	122	131	132	141	181	182	Sum
Bare Area	3	0	0	8,940	0	0	0	5,387	0	1,465	0	0	0	0	0	15,792
Water	4	0	0	4,063	0	0	40,939	3,626	25,275	727	0	0	0	0	440	75,070
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-5,361	-2,104	0	0	0	0	110,140	0	124,552	0	0	0	0	0	227,228
Plantation	22	0	0	0	0	0	0	820	0	0	0	0	0	0	0	820
Settlement	24	0	0	62	0	0	0	0	0	0	0	0	0	0	0	62
Lowland Forest	111	-73,196	-13,657	-589,866	-14,623	0	0	-1,197,188	0	0	0	0	0	0	0	-1,888,531
Secondary Lowland Forest	112	-12,173	-846	-146,264	-2	0	0	0	0	0	0	0	0	0	0	-159,285
Hill and Sub-montane Forest	121	-108,911	-23,478	-411,566	0	0	0	0	0	-1,293,463	0	0	0	0	0	-1,837,419
Secondary Hill and Sub-montane Forest	122	-11,366	-1,189	-28,689	0	0	0	0	0	0	0	0	0	0	0	-41,244
Lower Montane Forest	131	-2,470	0	-4,101	0	0	0	0	0	0	0	-27,628	0	0	0	-34,200
Secondary Lower Montane Forest	132	-954	0	-2,316	0	0	0	0	0	0	0	0	0	0	0	-3,270
Upper Montane Forest	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Freshwater Swamp Forest	181	-1,177	-652	-11,991	0	0	0	0	0	0	0	0	0	0	-92	-13,911
Secondary Freshwater Swamp Forest	182	0	0	-960	0	0	0	0	0	0	0	0	0	0	0	-960
	Sum	-215,608	-41,926	-1,182,688	-14,625	0	40,939	-1,077,216	25,275	-1,166,718	0	-27,628	0	0	348	-3,659,848

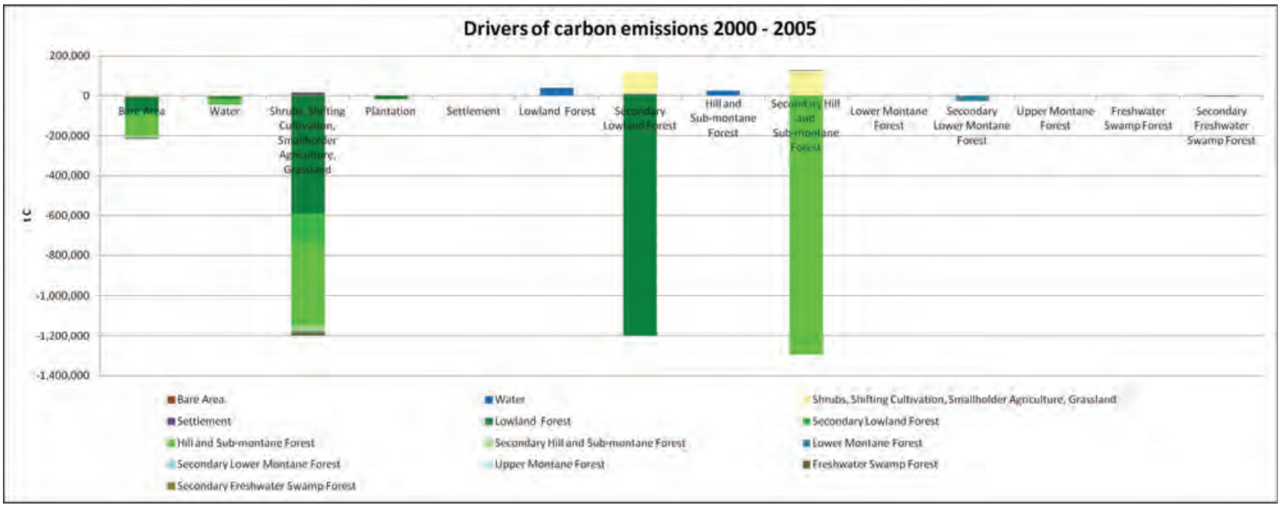


Figure 74. Drivers of carbon emissions in the Malinau FMU 2000-2005.

Table 66. Carbon change matrix of the Malinau FMU 2005-2010.

		2010														
Class	2005	3	4	21	22	24	111	112	121	122	131	132	141	181	182	Sum
Bare Area	3	0	0	31,166	0	0	0	5,368	0	5,042	0	0	0	0	0	**41,576**
Water	4	0	0	3,710	0	0	53,367	2,252	25,751	1,753	0	0	0	0	0	**86,834**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-3,663	-1,352	0	0	-14	7,569	228,016	0	182,679	0	4,225	0	0	21	**417,482**
Plantation	22	0	0	0	0	0	0	2,368	0	0	0	0	0	0	0	**2,368**
Settlement	24	0	0	13	0	0	0	0	0	0	0	0	0	0	0	**13**
Lowland Forest	111	-45,734	-5,909	-314,218	-4,535	0	0	-227,379	0	0	0	0	0	0	0	**-597,775**
Secondary Lowland Forest	112	-22,573	-747	-136,975	-1,033	0	0	0	0	0	0	0	0	0	0	**-161,329**
Hill and Sub-montane Forest	121	-25,515	-6,117	-163,551	0	0	0	0	0	-382,406	0	0	0	0	0	**-577,588**
Secondary Hill and Sub-montane Forest	122	-11,200	-653	-37,345	0	0	0	0	0	0	0	0	0	0	0	**-49,199**
Lower Montane Forest	131	-670	0	0	0	0	0	0	0	0	0	-34,827	0	0	0	**-35,497**
Secondary Lower Montane Forest	132	0	0	-20	0	0	0	0	0	0	0	0	0	0	0	**-20**
Upper Montane Forest	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Freshwater Swamp Forest	181	0	-1,190	-5,690	0	0	0	0	0	0	0	0	0	0	-1	**-6,882**
Secondary Freshwater Swamp Forest	182	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Sum	**-109,355**	**-15,969**	**-622,910**	**-5,568**	**-14**	**60,936**	**10,625**	**25,751**	**-192,931**	**0**	**-30,602**	**0**	**0**	**19**	**-880,018**

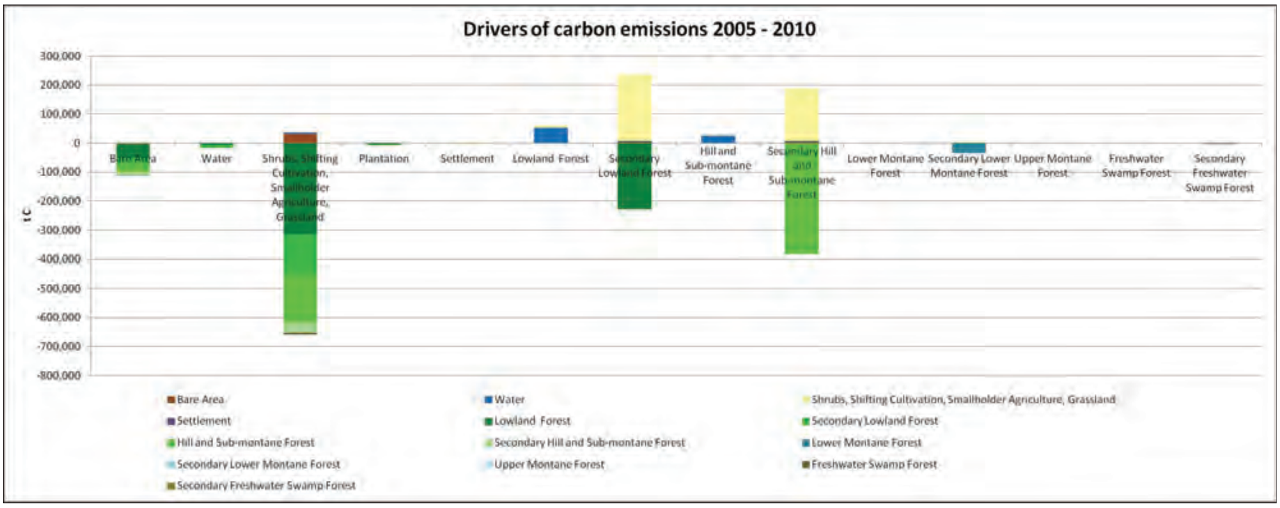


Figure 75. Drivers of carbon emissions in the Malinau FMU 2005-2010.

Table 67. Carbon change matrix of the Malinau FMU 1990-2010.

	Land Cover Carbon	2010														
Class	1990	3	4	21	22	24	111	112	121	122	131	132	141	181	182	Sum
Bare Area	3	0	0	2,827	0	0	2,813	33,301	226	2,582	0	0	0	0	658	**42,407**
Water	4	0	0	3,994	0	0	46,432	1,594	22,423	3,874	0	0	0	134	305	**78,756**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-1,934	-878	0	167	-14	361	45,902	39	21,160	0	298	0	0	157	**65,260**
Plantation	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Settlement	24	0	0	74	0	0	0	0	0	64	0	0	0	0	0	**138**
Lowland Forest	111	-96,286	-6,404	-1,262,951	-107,010	0	0	-2,481,676	-399	-18,559	0	0	0	0	0	**-3,973,284**
Secondary Lowland Forest	112	-5,506	-1,087	-120,283	0	0	0	0	0	-112	0	0	0	0	0	**-126,987**
Hill and Sub-montane Forest	121	-38,099	-10,019	-614,508	0	0	8,004	-7,583	0	-2,673,030	0	-24	0	0	0	**-3,335,259**
Secondary Hill and Sub-montane Forest	122	-3,960	0	-6,252	0	0	0	1,017	0	0	0	0	0	0	0	**-9,195**
Lower Montane Forest	131	-670	0	-4,407	0	0	0	0	0	-1,658	0	-94,940	0	0	0	**-101,676**
Secondary Lower Montane Forest	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Upper Montane Forest	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Freshwater Swamp Forest	181	-19	-3,218	-20,184	0	0	12	58	0	0	0	0	0	0	-94	**-23,445**
Secondary Freshwater Swamp Forest	182	0	-45	-1,807	0	0	0	0	0	0	0	0	0	0	0	**-1,851**
	Sum	**-146,474**	**-21,650**	**-2,023,497**	**-106,844**	**-14**	**57,623**	**-2,407,386**	**22,289**	**-2,665,678**	**0**	**-94,666**	**0**	**134**	**1,026**	**-7,385,137**

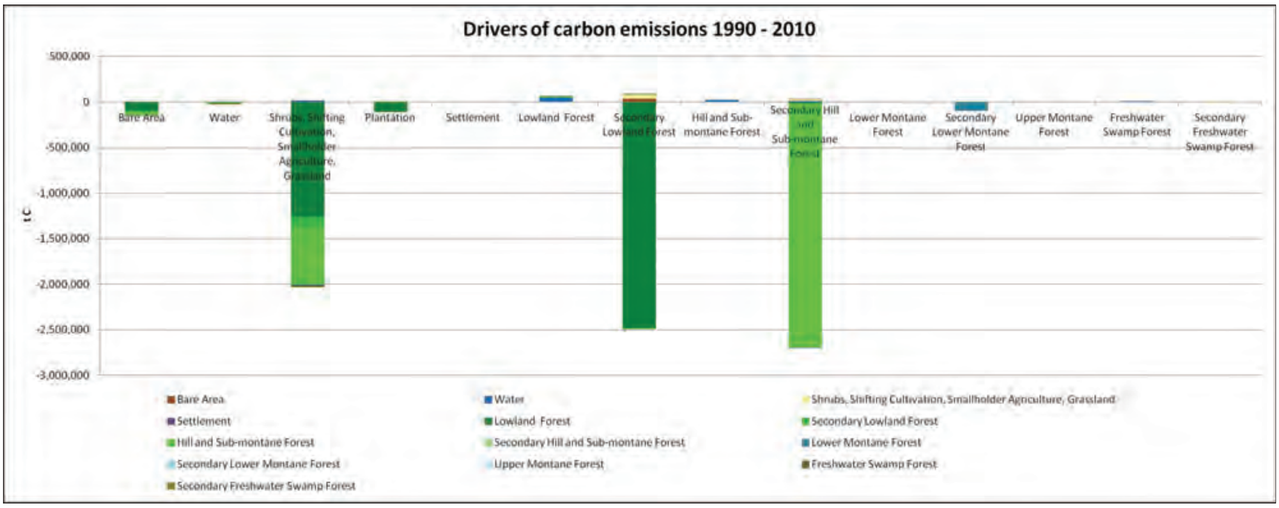
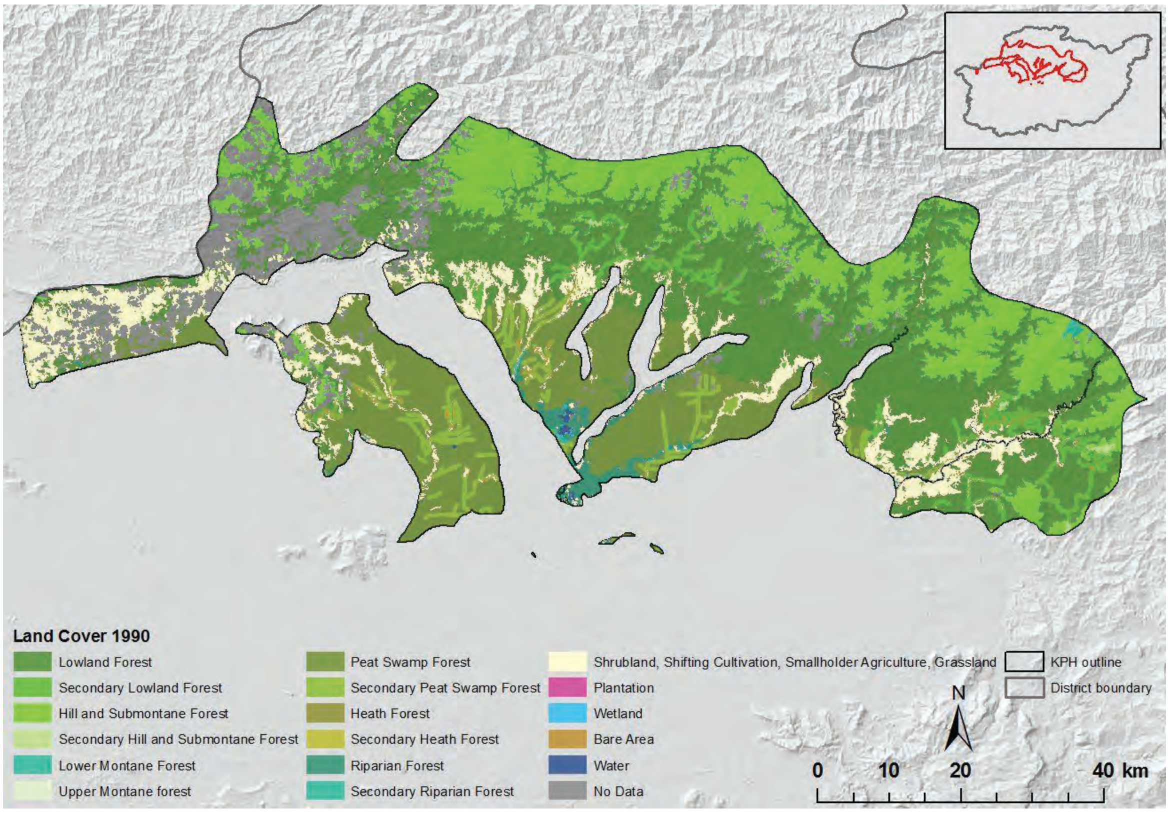


Figure 76. Drivers of carbon emissions in the Malinau FMU 1990-2010.

6.4.2 Kapuas Hulu district

6.4.2.1 Land cover maps



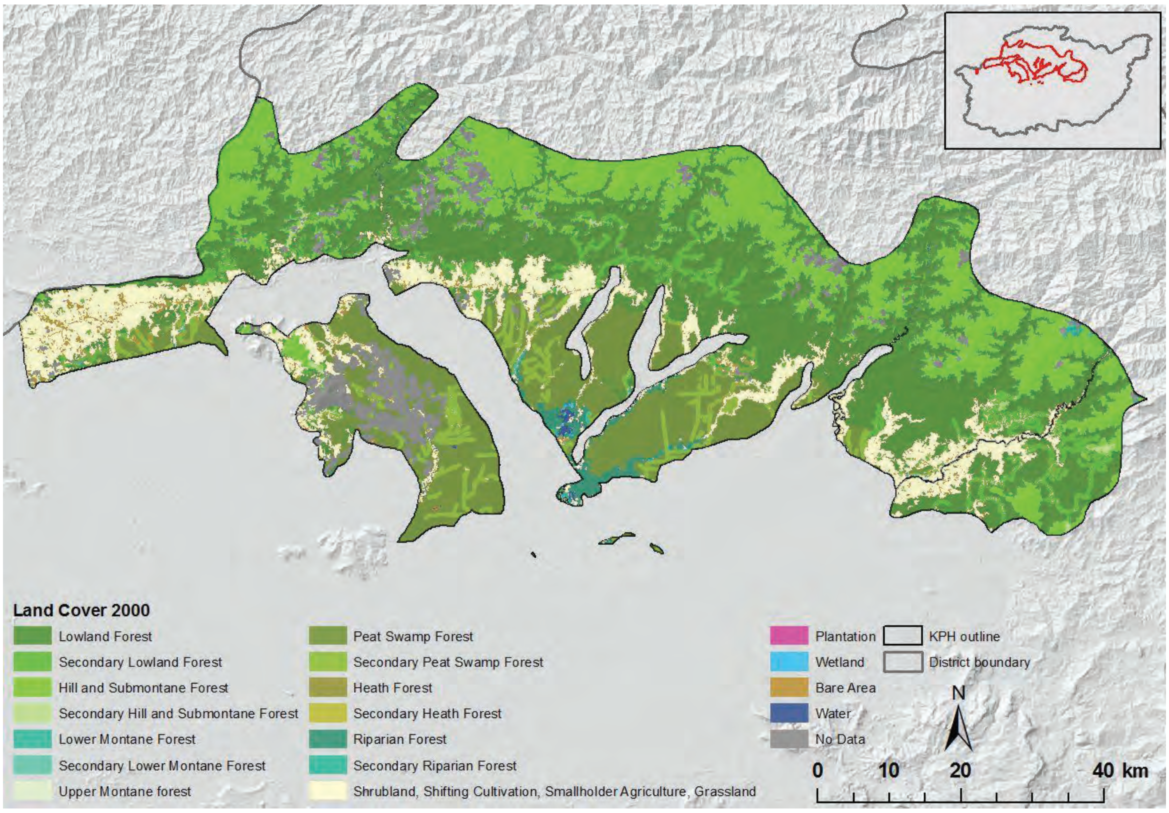
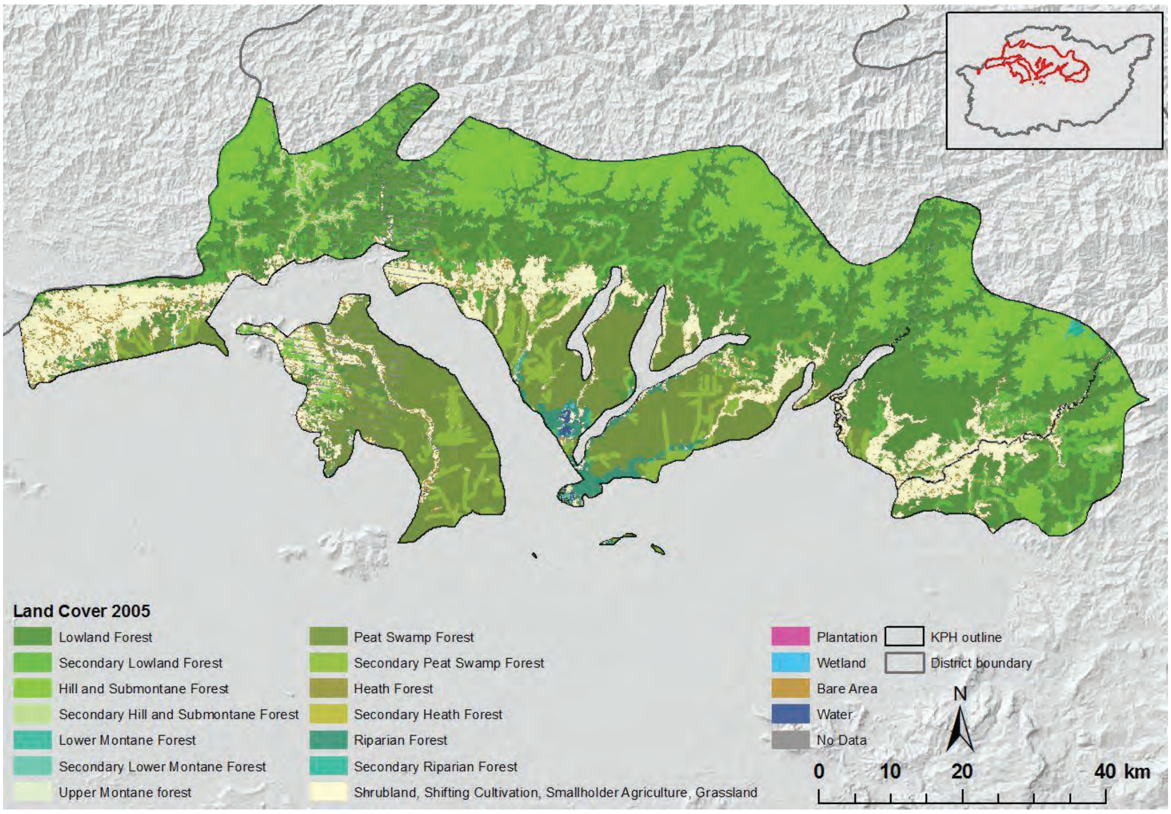


Figure 77. Land cover maps of the FMU in Kapuas Hulu district for the years 1990 and 2000.



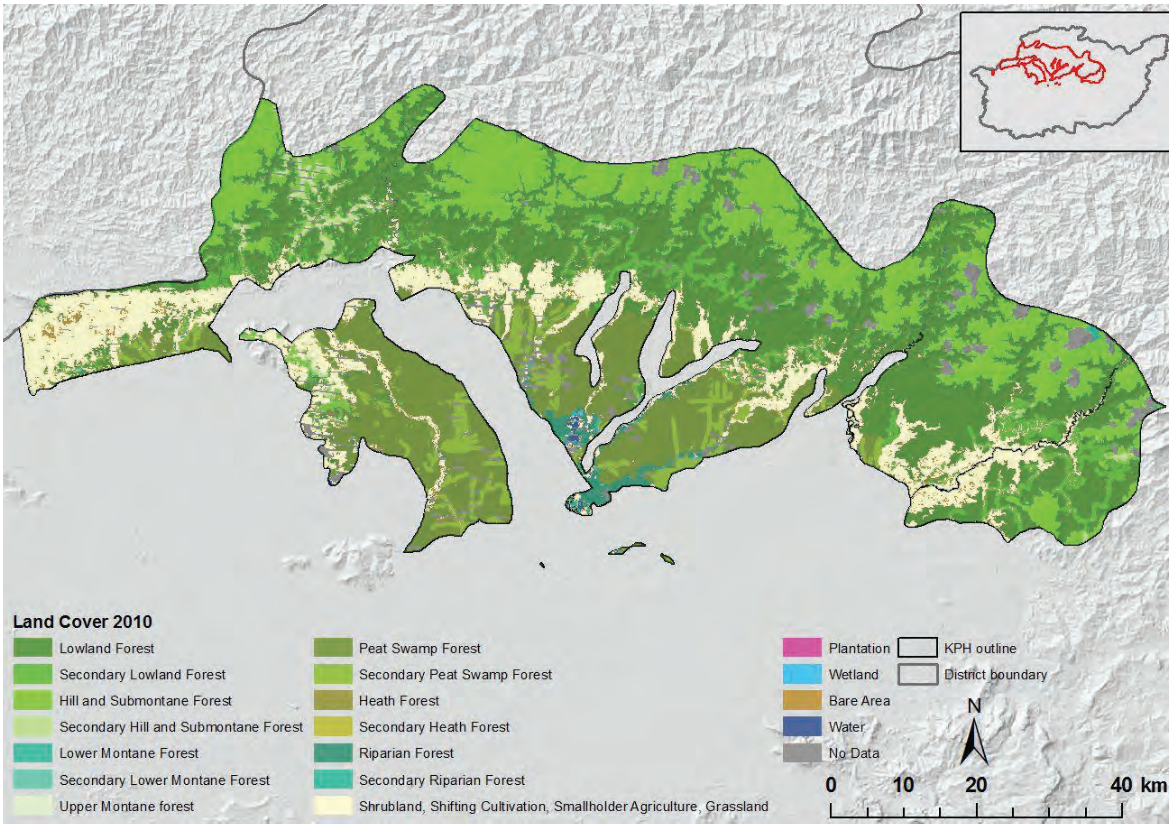


Figure 78. Land cover maps of the FMU in Kapuas Hulu district in the years 2005 and 2010.

Table 68. Spatial extent of the land cover classes in the Kapuas Hulu FMU.

Land Cover Class	1990	2000	2005	2010
	ha			
Lowland Forest	162,603	161,723	157,385	154,947
Secondary Lowland Forest	16,217	24,164	28,098	27,612
Hill and Submontane Forest	89,620	96,981	101,821	94,787
Secondary Hill and Submontane Forest	675	1,121	3,725	3,853
Lower Montane Forest	478	333	497	279
Peat Swamp Forest	76,694	65,286	70,228	68,512
Secondary Peat Swamp Forest	14,551	17,567	19,976	19,109
Heath Forest	12	12	12	12
Secondary Heath Forest	0	0	0	0
Riparian Forest	6,359	5,625	5,335	4,794
Secondary Riparian Forest	492	762	797	620
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	46,509	56,746	59,815	67,358
Wetland	175	147	147	141
Bare Area	2,677	5,865	9,004	3,833
Water	1,047	1,465	1,305	1,231
No Data	47,350	27,660	7,312	18,370
Total	**465,457**	**465,457**	**465,457**	**465,457**

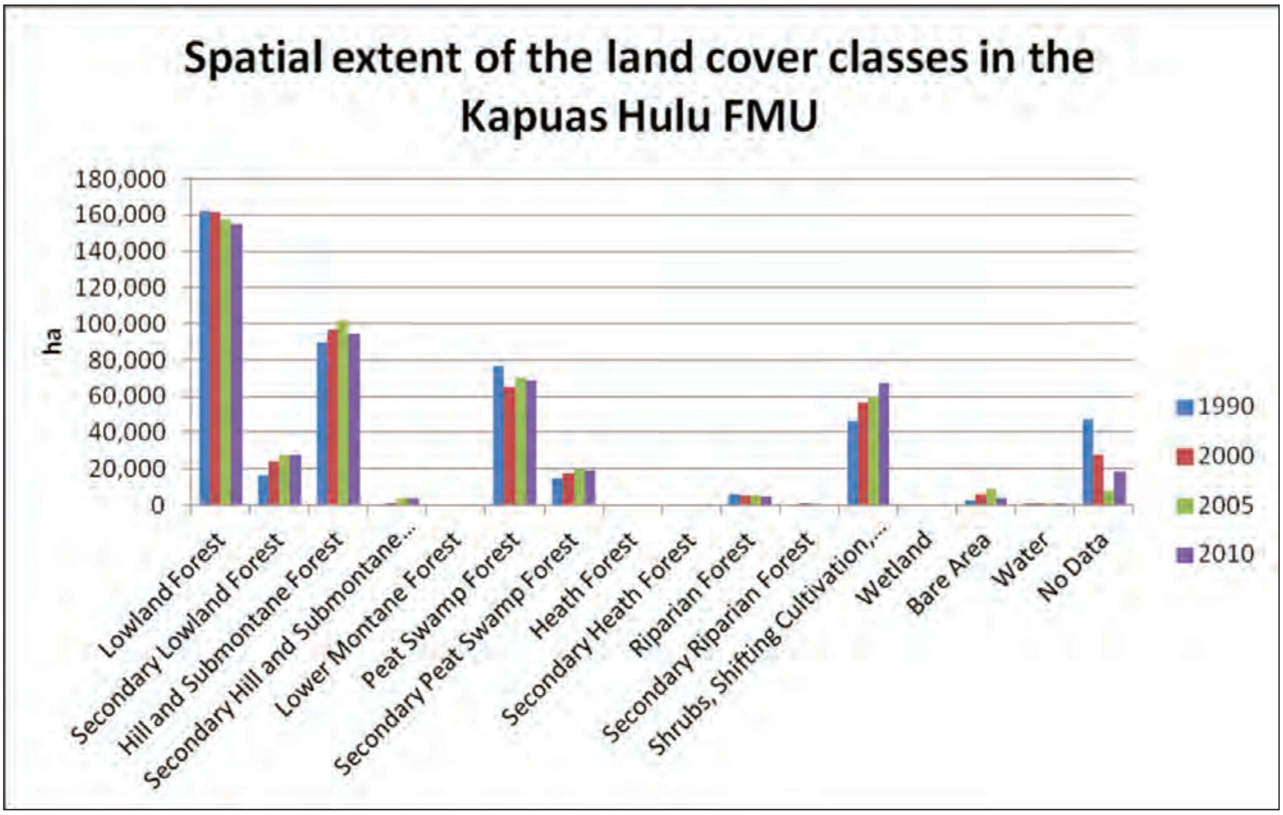
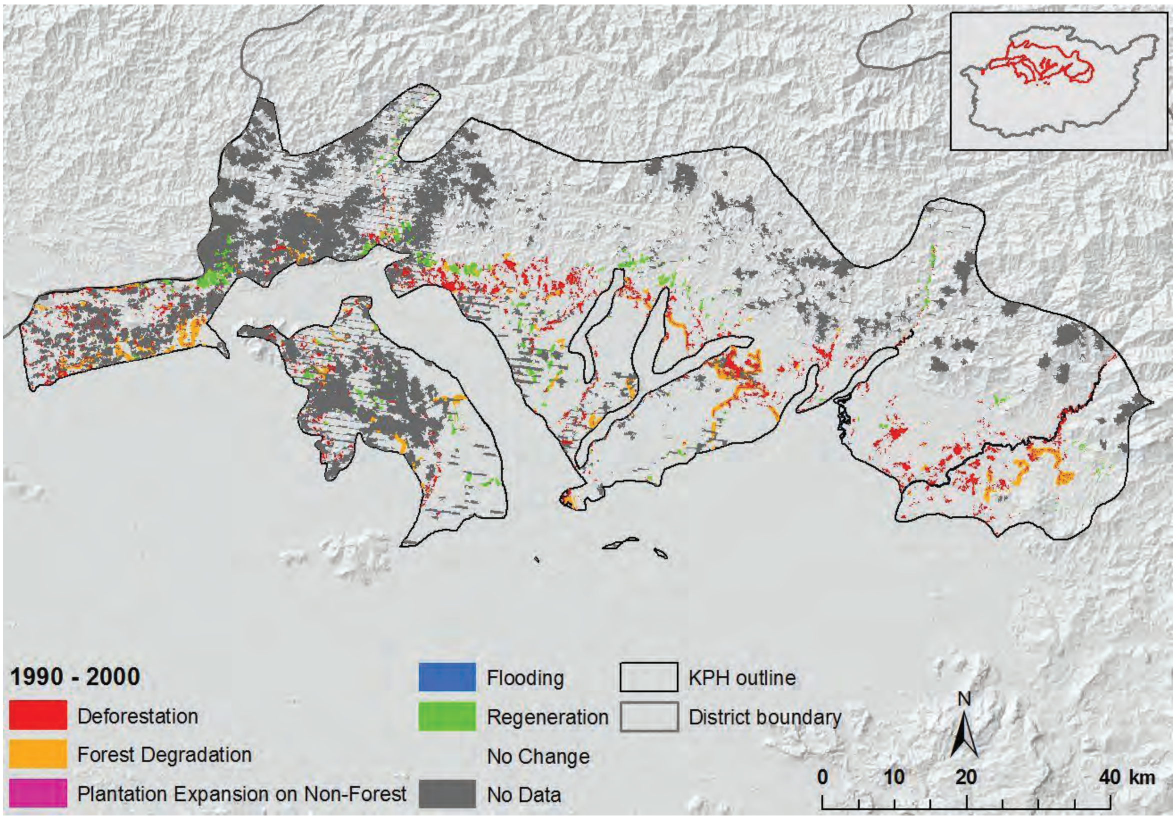


Figure 79. Spatial extent of the land cover classes in the Kapuas Hulu FMU.

6.4.2.2 *Land cover change maps*



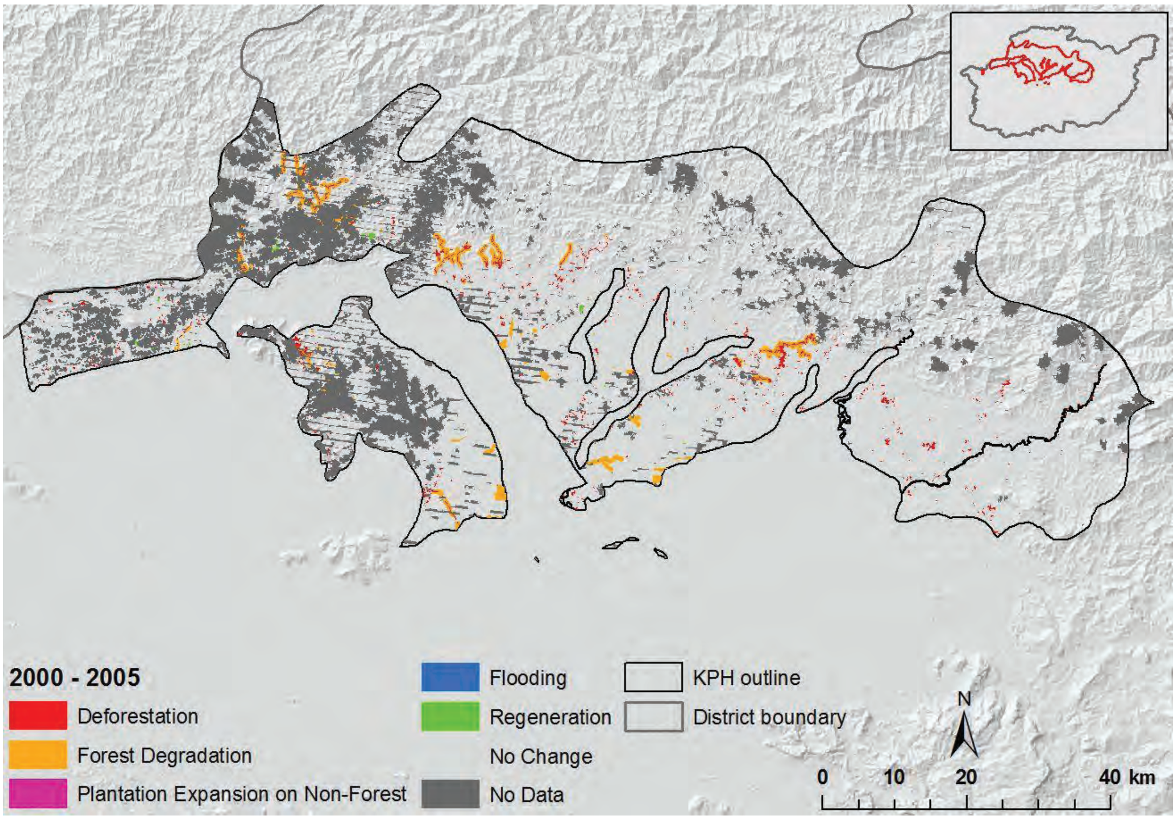
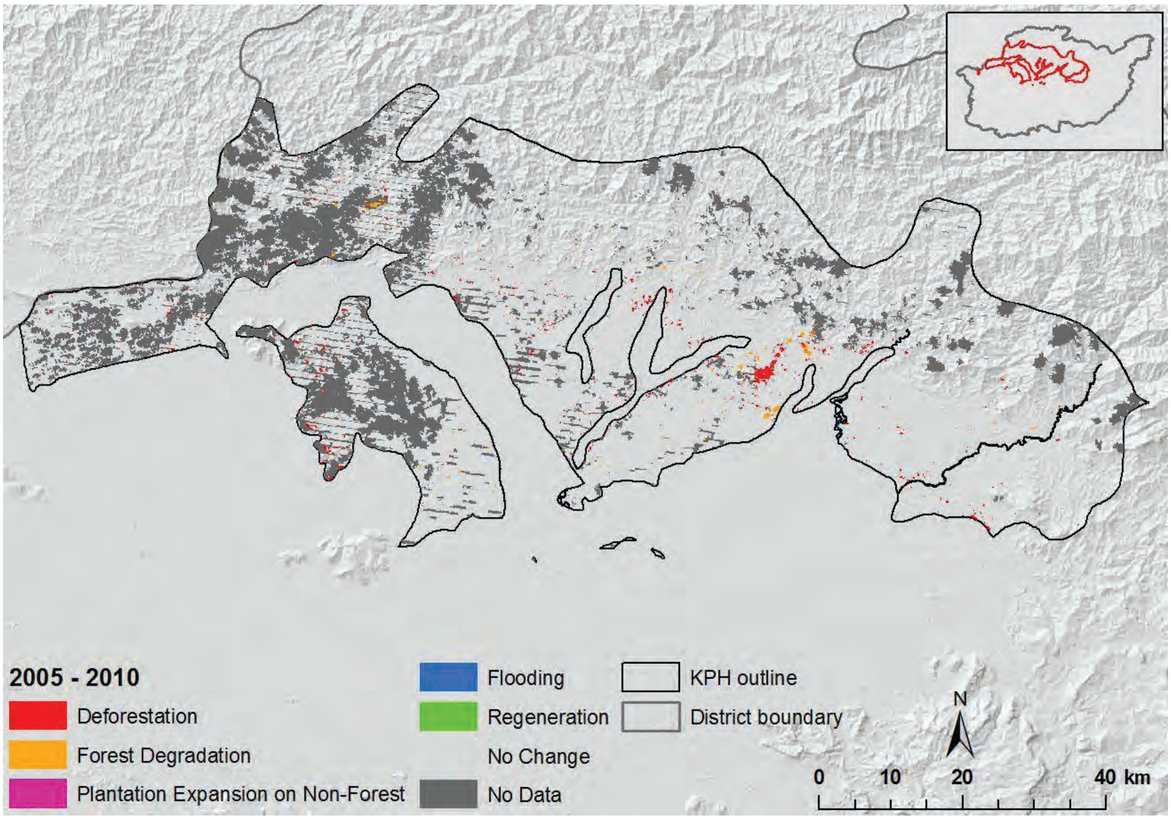


Figure 80. Land cover change maps of the FMU in Kapuas Hulu district for the time periods 1990-2000 and 2000-2005.



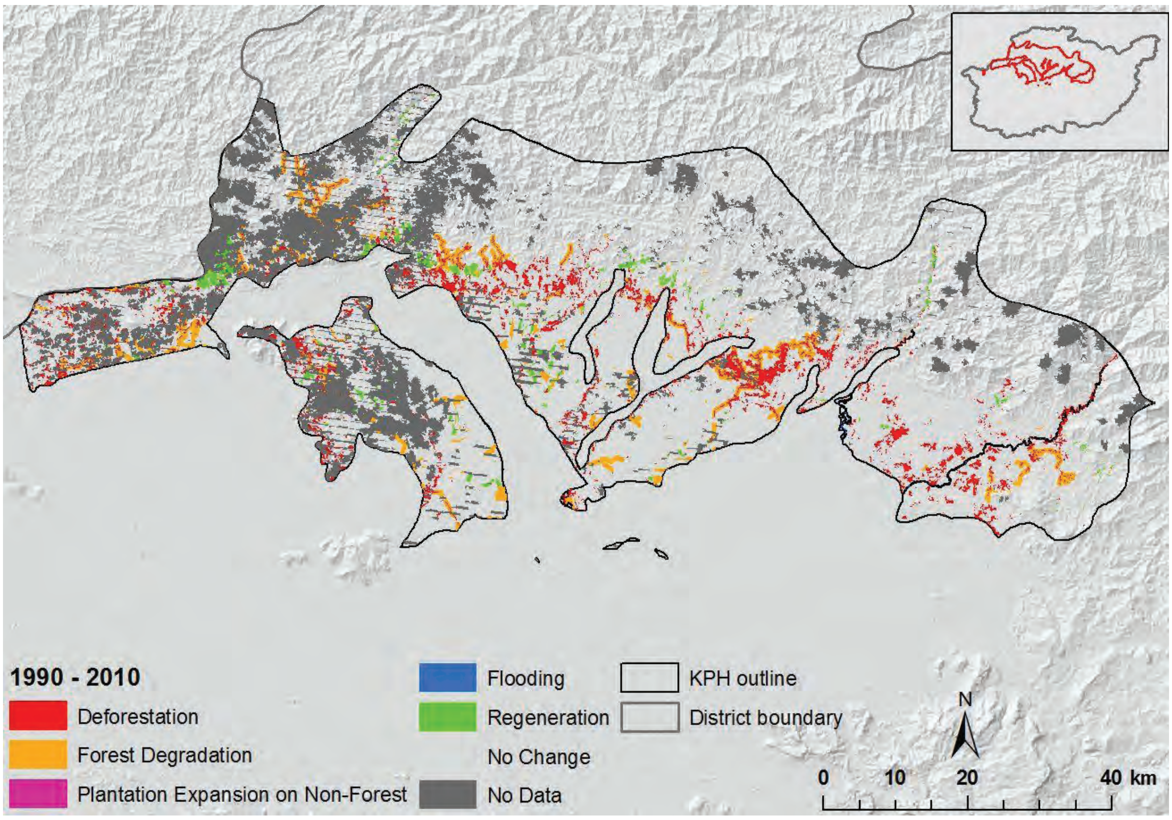


Figure 81. Land cover change maps of the FMU in Kapuas Hulu district for the time periods 2005-2010 and 1990-2010.

Table 69. Change processes in the Kapuas Hulu FMU in the four observation periods.

Change process	1990 - 2000	2000 - 2005	2005 - 2010	1990 - 2010
	ha %	ha %	ha %	ha %
Deforestation	11,775 3.16%	3,394 0.90%	2,436 0.65%	17,412 4.62%
Flooding	234 0.06%	17 0.00%	55 0.01%	217 0.06%
Forest Degradation	7,710 2.07%	6,434 1.71%	897 0.24%	14,436 3.83%
No Change	352,594 94.51%	366,612 97.33%	373,268 99.10%	340,239 90.33%
Plantation Expansion on Non-Forest	0 0.00%	0 0.00%	0 0.00%	0 0.00%
Regeneration	749 0.20%	200 0.05%	0 0.00%	4,352 1.16%
Total	**373,061**	**376,656**	**376,656**	**376,656**

Table 70. Area change per class in the Kapuas Hulu FMU for the four observation periods.

Land Cover	1990-2000	2000-2005	2005-2010	1990 - 2010
	ha			
Bare Area	1,990	2,347	-3,371	966
Water	346	-83	27	289
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	5,077	930	5,770	11,776
Wetland	18	0	10	28
Lowland Forest	-11,784	-5,308	-1,802	-18,895
Secondary Lowland Forest	5,870	3,048	118	9,035
Hill and Submontane Forest	-142	-1,192	-147	-1,482
Secondary Hill and Submontane Forest	115	869	47	1,030
Lower Montane Forest	0	0	0	0
Peat Swamp Forest	-4,869	-2,436	-689	-7,994
Secondary Peat Swamp Forest	3,843	2,041	178	6,062
Heath Forest	0	0	0	0
Secondary Heath Forest	0	0	0	0
Riparian Forest	-767	-221	-111	-1,099
Secondary Riparian Forest	304	6	-28	282
Total	**0**	**0**	**0**	**0**

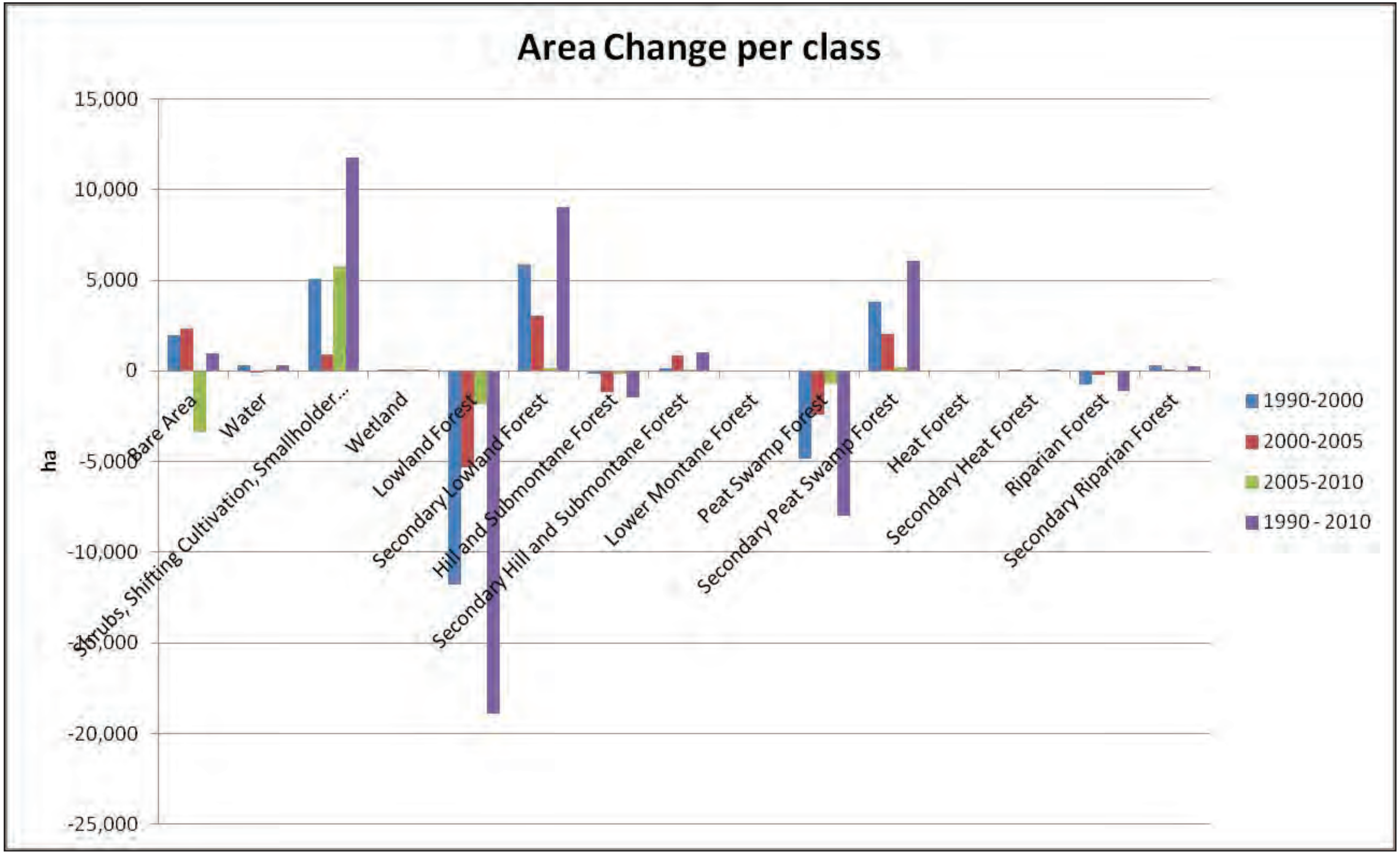
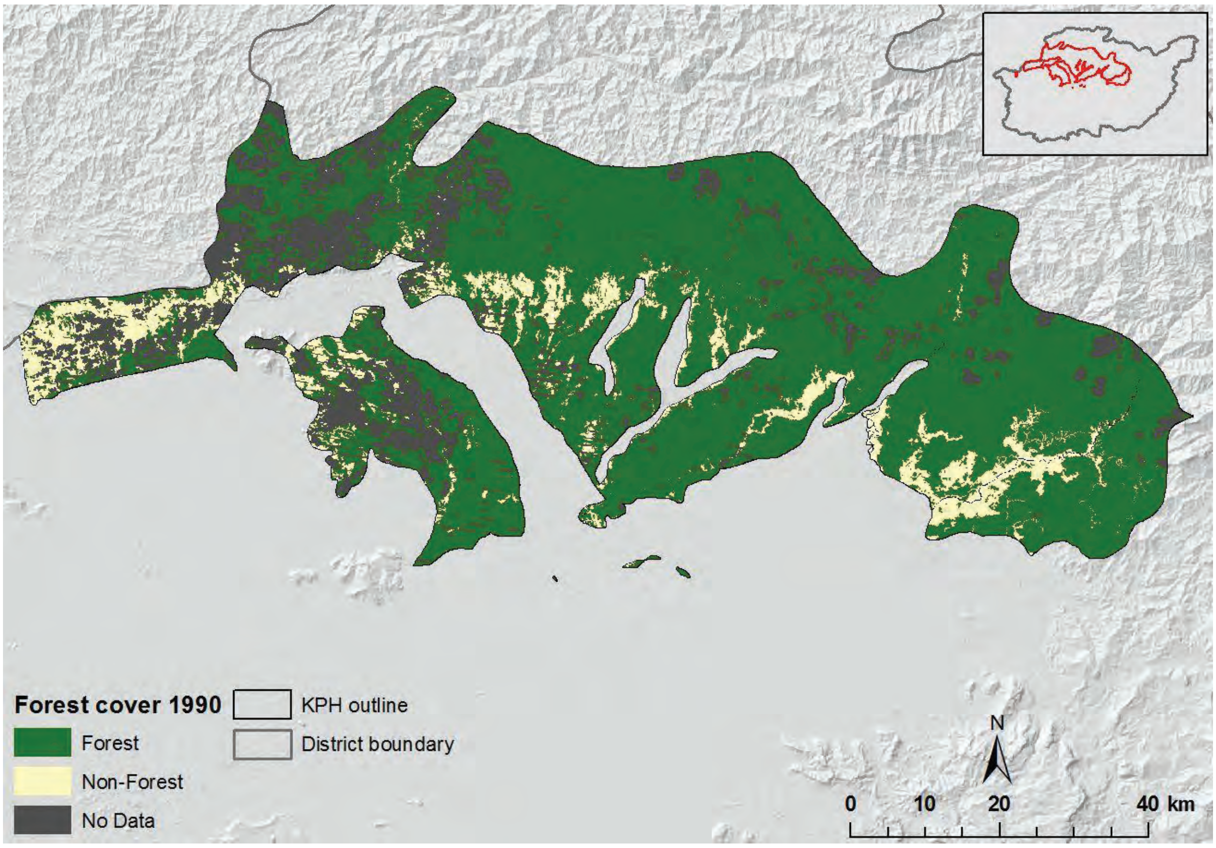


Figure 82. Area change per class in the Kapuas Hulu FMU for the four observation periods.

6.4.2.3 Forest cover and deforestation maps



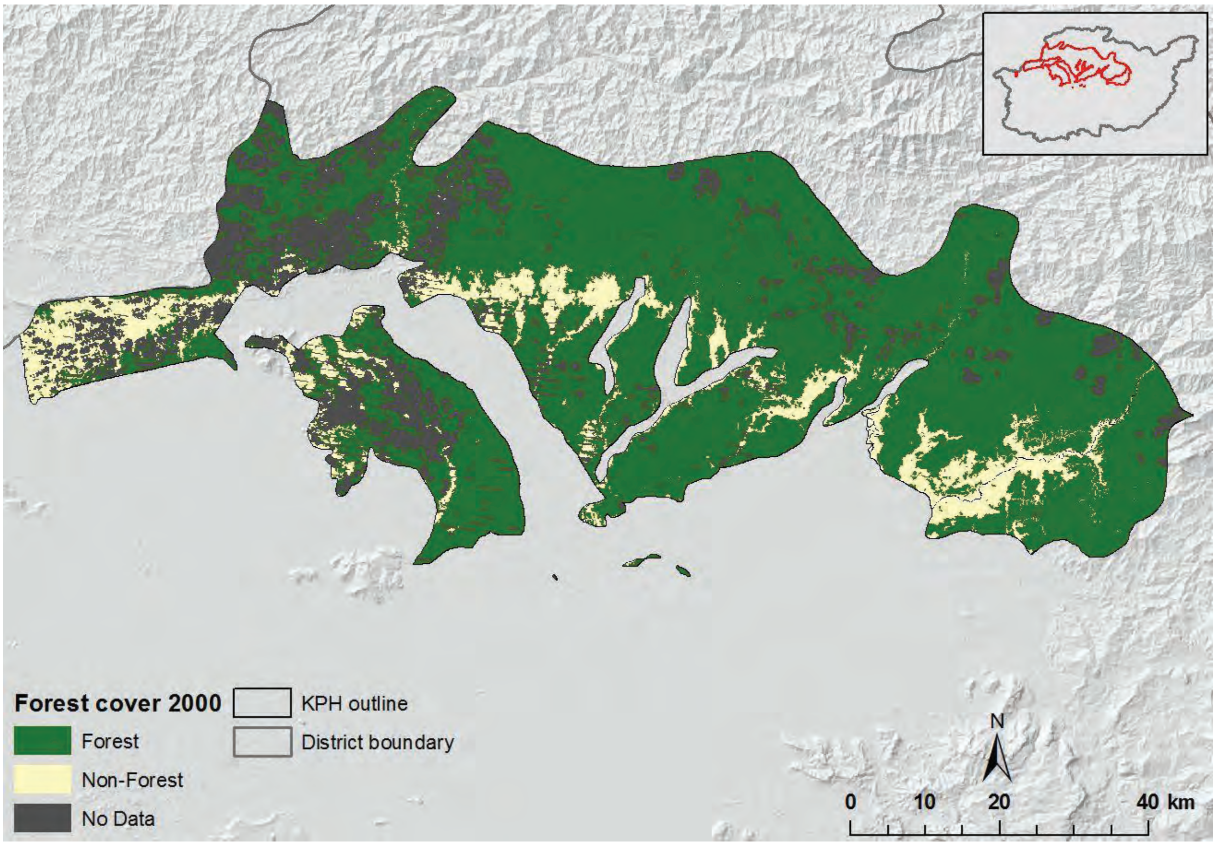
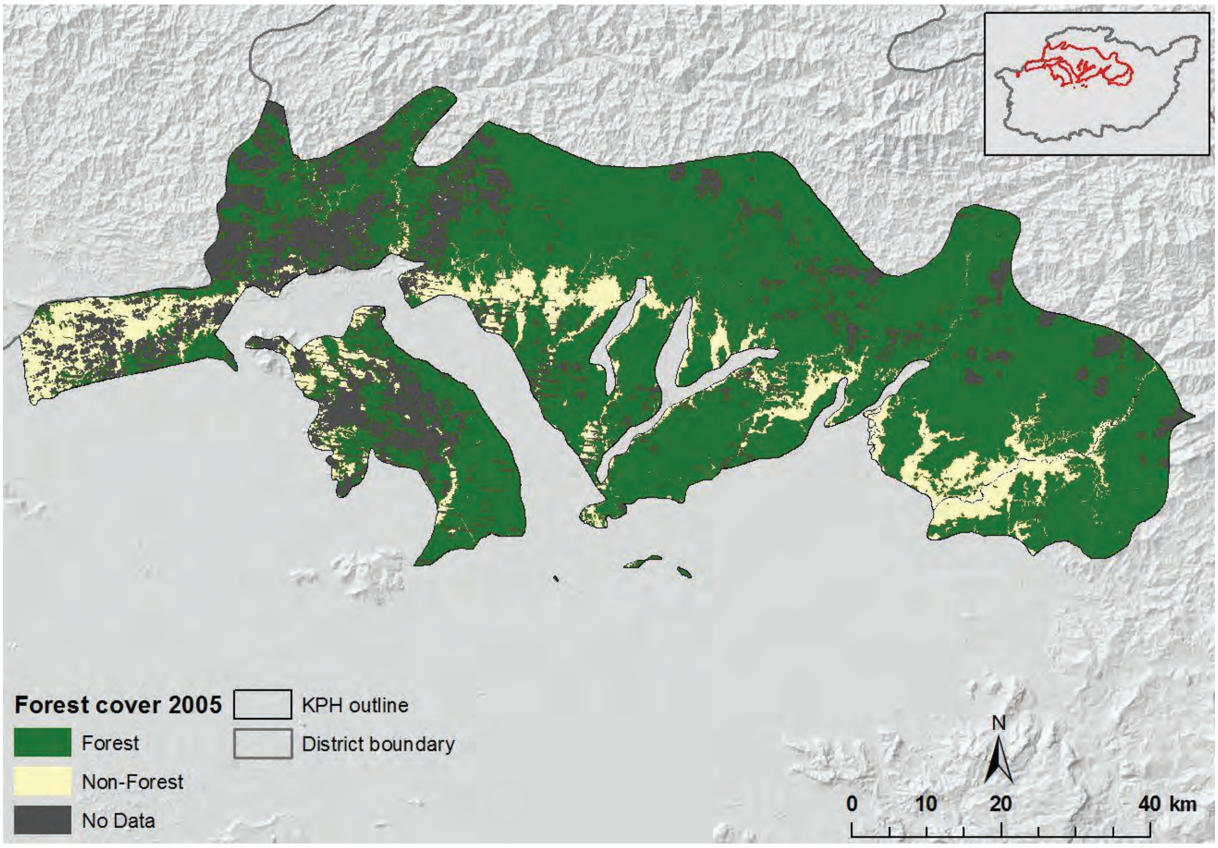


Figure 83. Forest cover maps of the FMU in Kapuas Hulu district for the years 1990 and 2000.



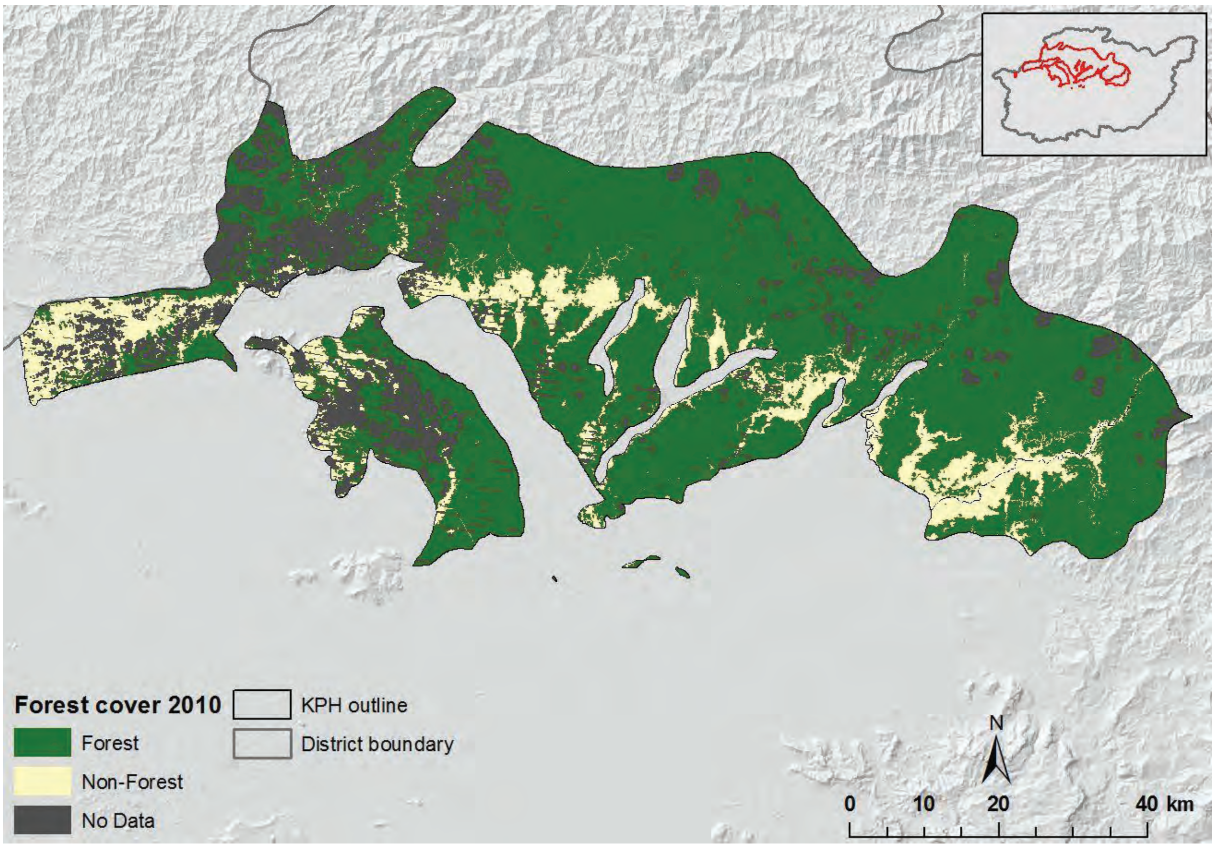
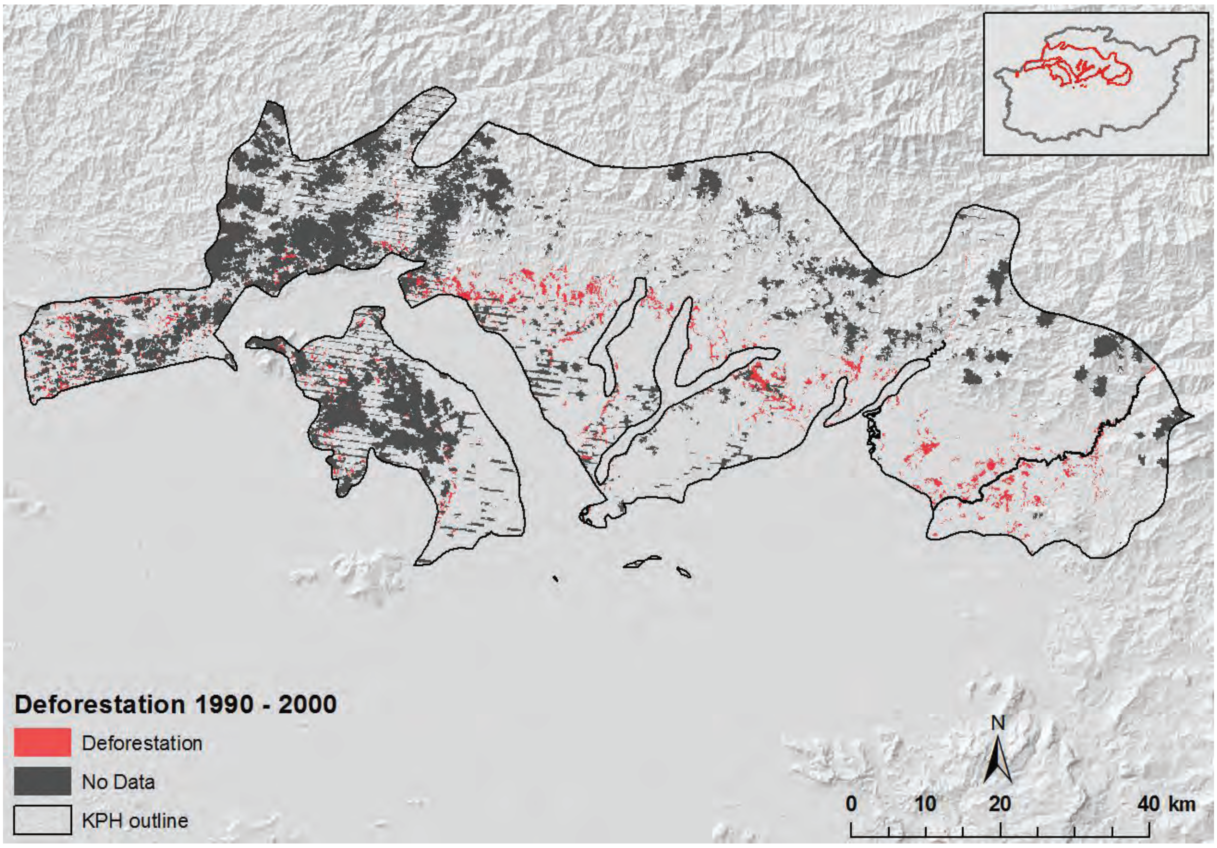


Figure 84. Forest cover maps of the FMU in Kapuas Hulu district for the years 2005 and 2010.



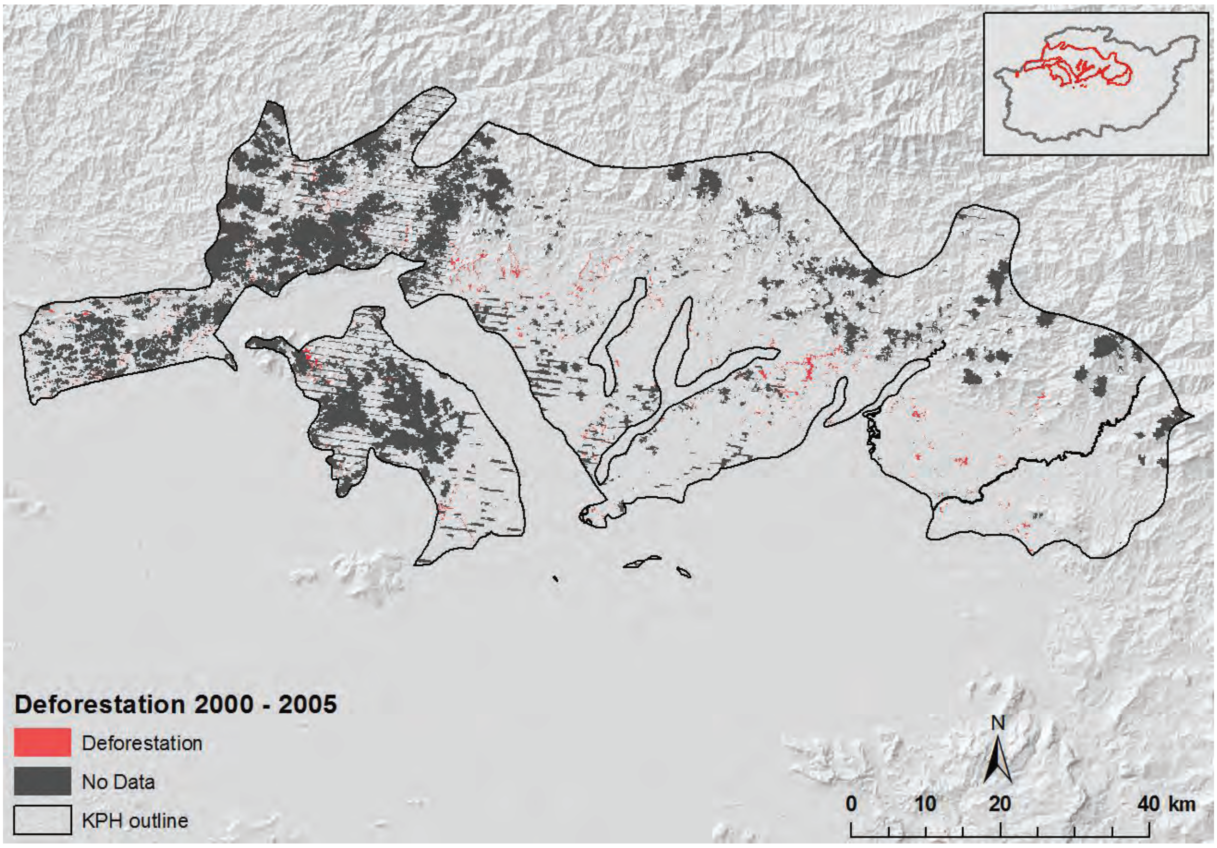
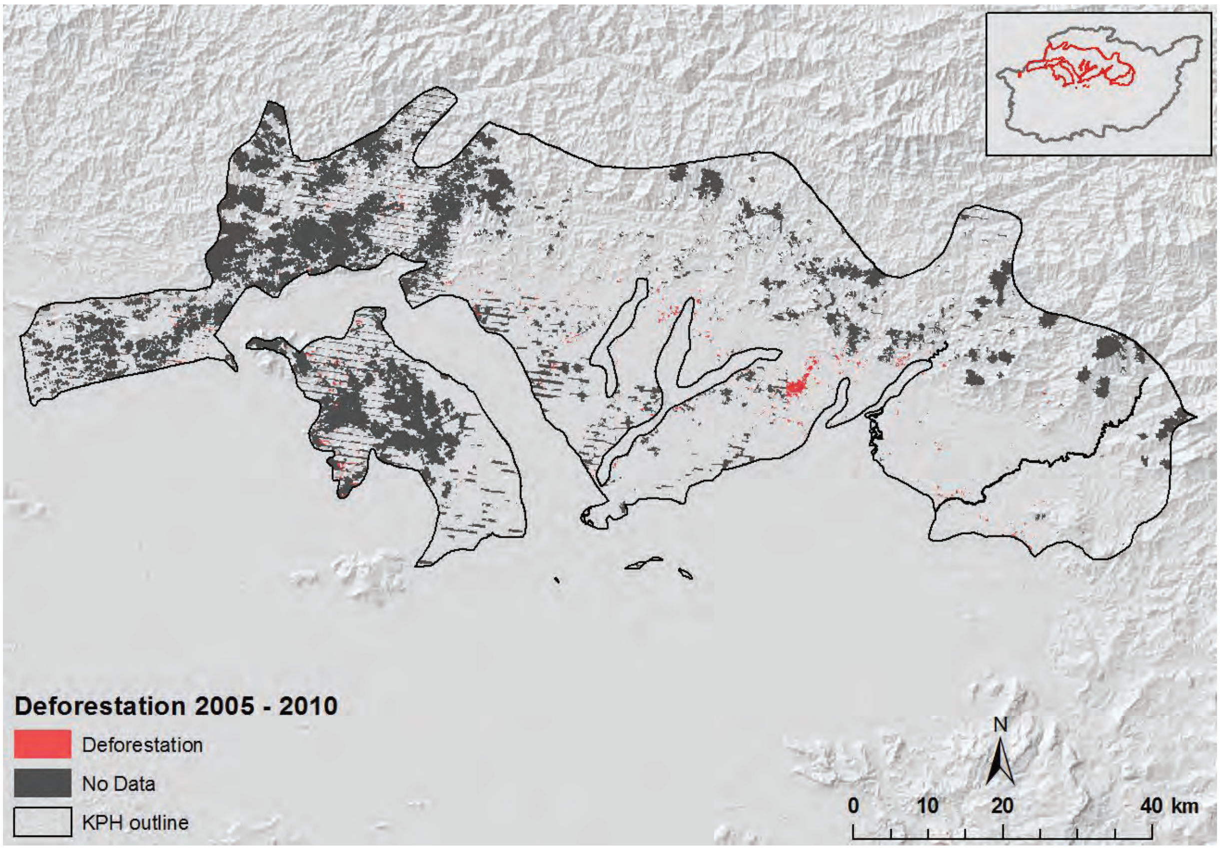


Figure 85. Deforestation maps of the FMU in Kapuas Hulu district for the time periods 1990-2000 and 2000-2005.



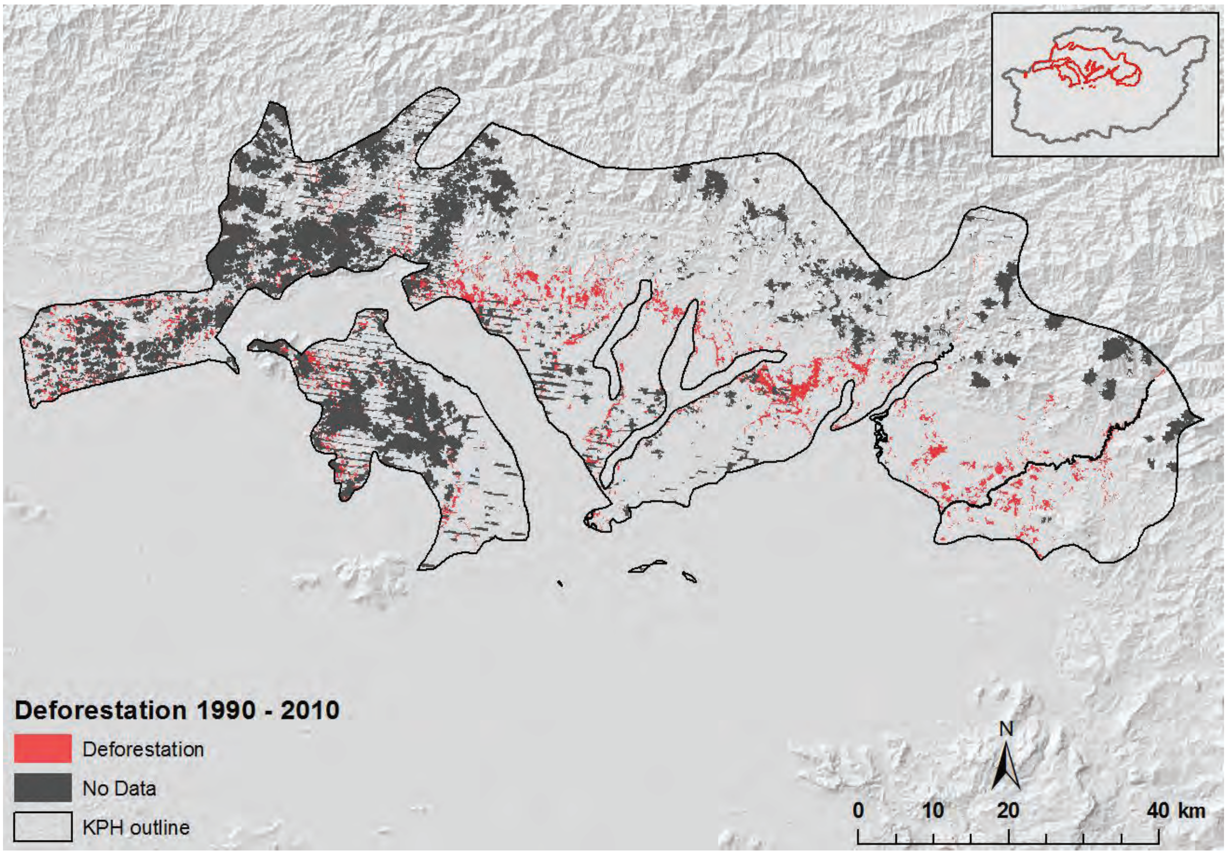


Figure 86. Deforestation maps of the FMU in Kapuas Hulu district for the time periods 2005 – 2010 and 1990 – 2010.

Table 71. Spatial extent of forest and non-forest areas in the Kapuas Hulu FMU.

	1990	2000	2005	2010
Non-Forest	420,064	412,634	409,440	407,004
Forest	45,393	52,824	56,018	58,453
Sum	45,393	52,824	56,018	58,453

Table 72. Net forest loss in the Kapuas Hulu FMU.

Net forest loss	1990-2000	2000-2005	2005-2010	1990-2010
ha	-7,430	-3,194	-2,436	-13,060
%	-1.77%	-0.77%	-0.59%	-3.11%

Table 73. Annual deforestation rate [% yr-1] in the Kapuas Hulu FMU.

	1990-2000	2000-2005	2005-2010	1990-2010
Deforestation rate	-0.18%	-0.15%	-0.12%	-0.16%

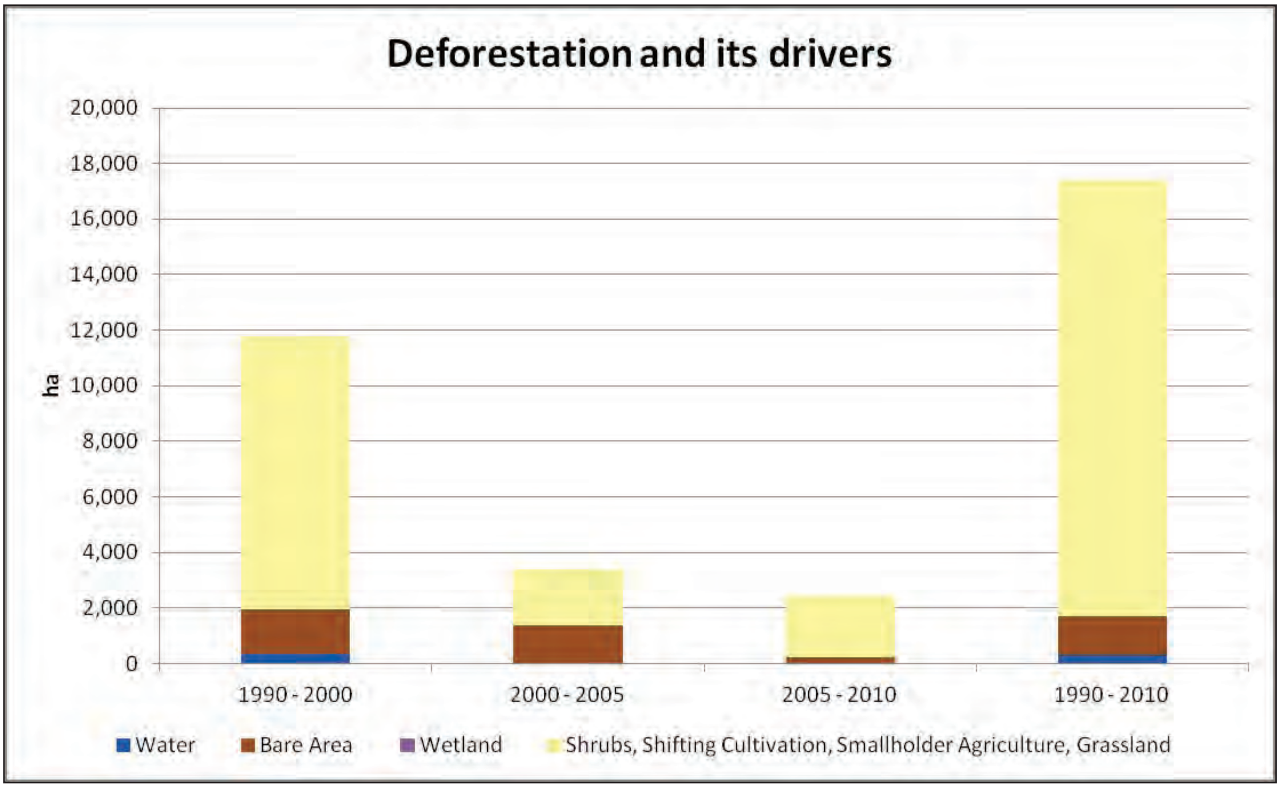
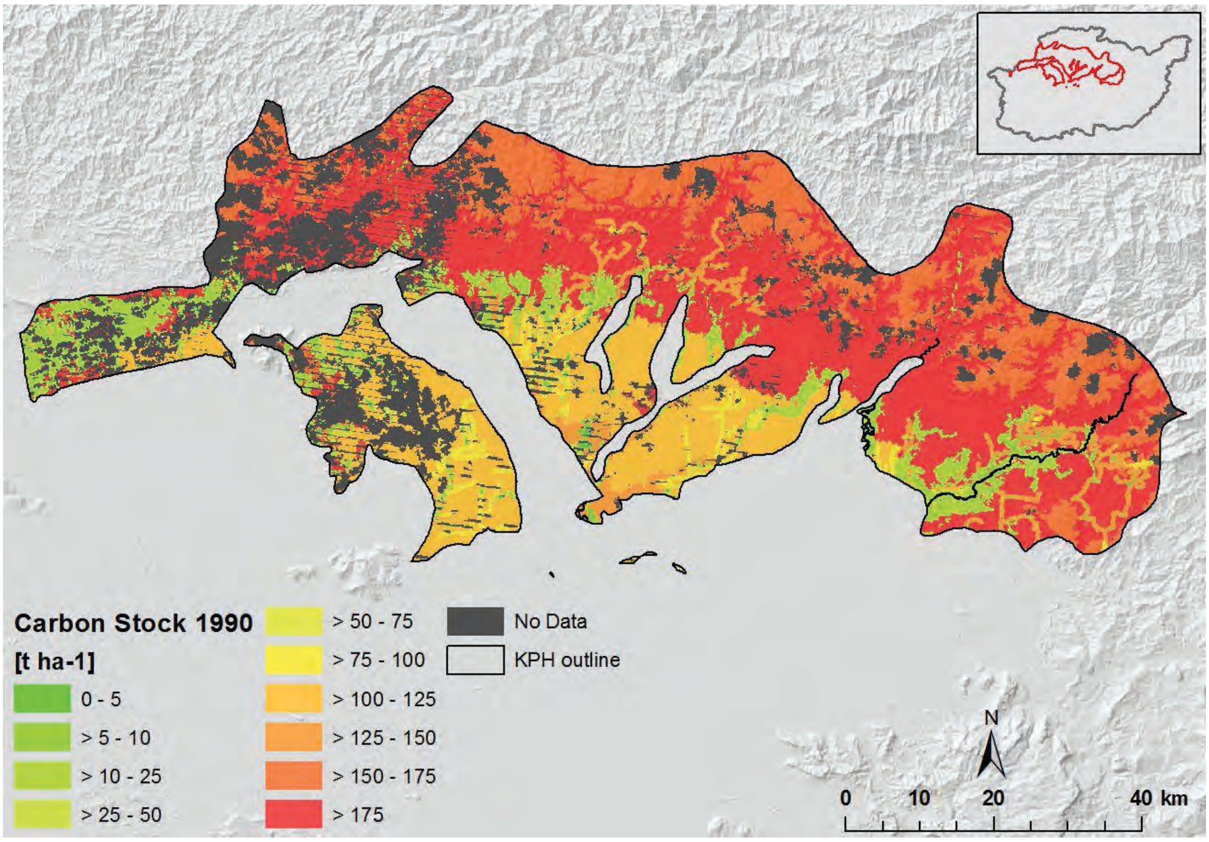


Figure 87. Deforestation and its drivers in the Kapuas Hulu FMU.

Table 74. Deforestation and its drivers in the Kapuas Hulu FMU.

Driver	1990-2000	2000- 2005	2005-2010	1990-2010
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	9,807	2,026	2,203	15,704
	83.29%	59.71%	90.46%	90.19%
Wetland	1	0	5	6
	0.01%	0.00%	0.21%	0.04%
Bare Area	1,624	1,365	224	1,378
	13.79%	40.22%	9.21%	7.92%
Water	343	3	3	323
	2.91%	0.07%	0.12%	1.86%
Total deforestation	**11,775**	**3,394**	**2,436**	**17,412**

6.4.2.4 Historic carbon change



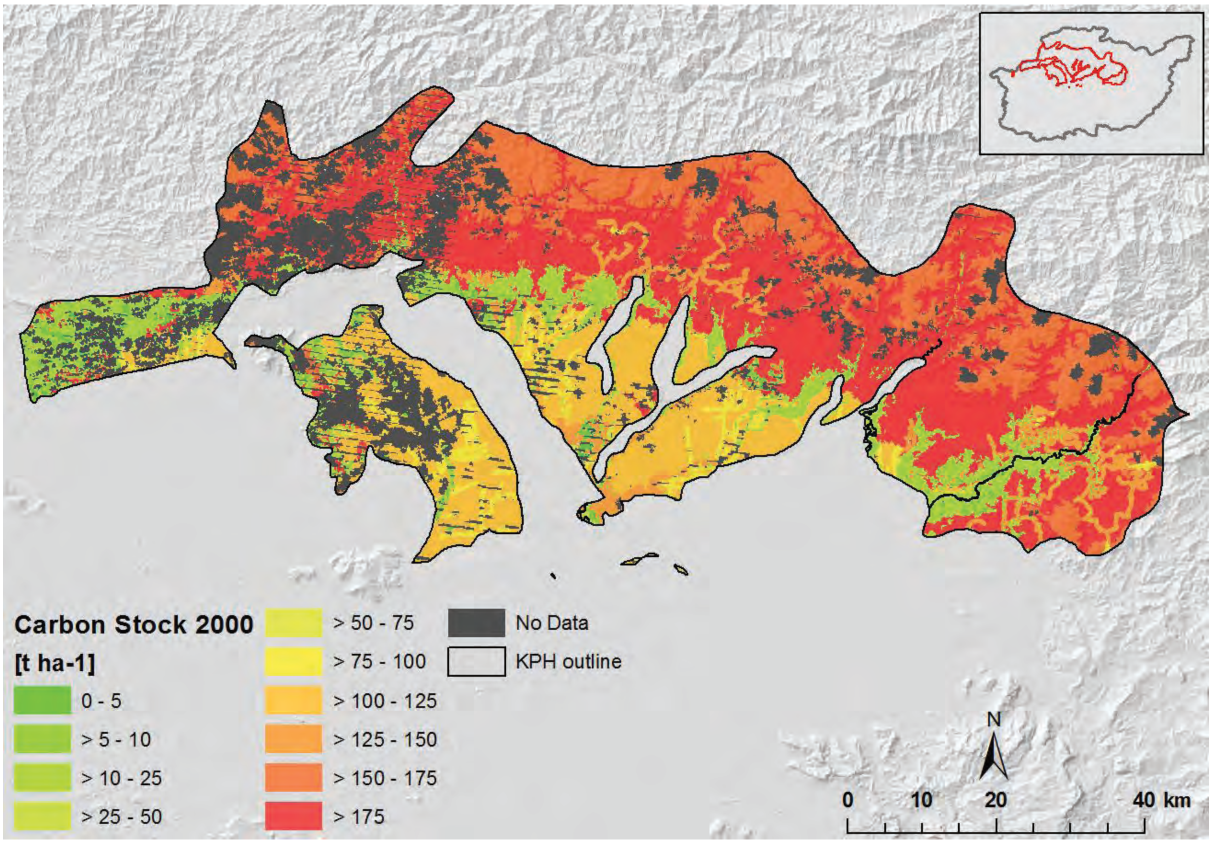
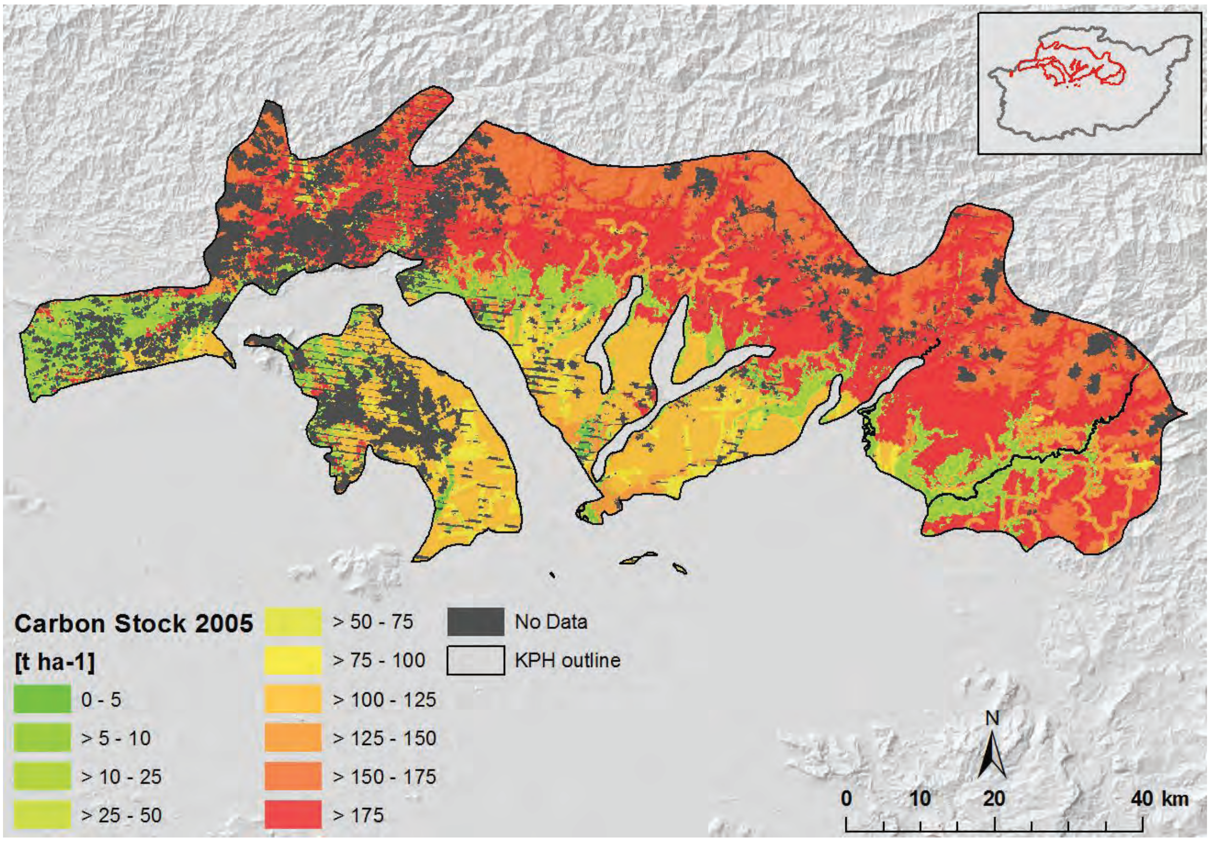


Figure 88. Carbon stock maps of the FMU in Kapuas Hulu district for the years 1990 and 2000.



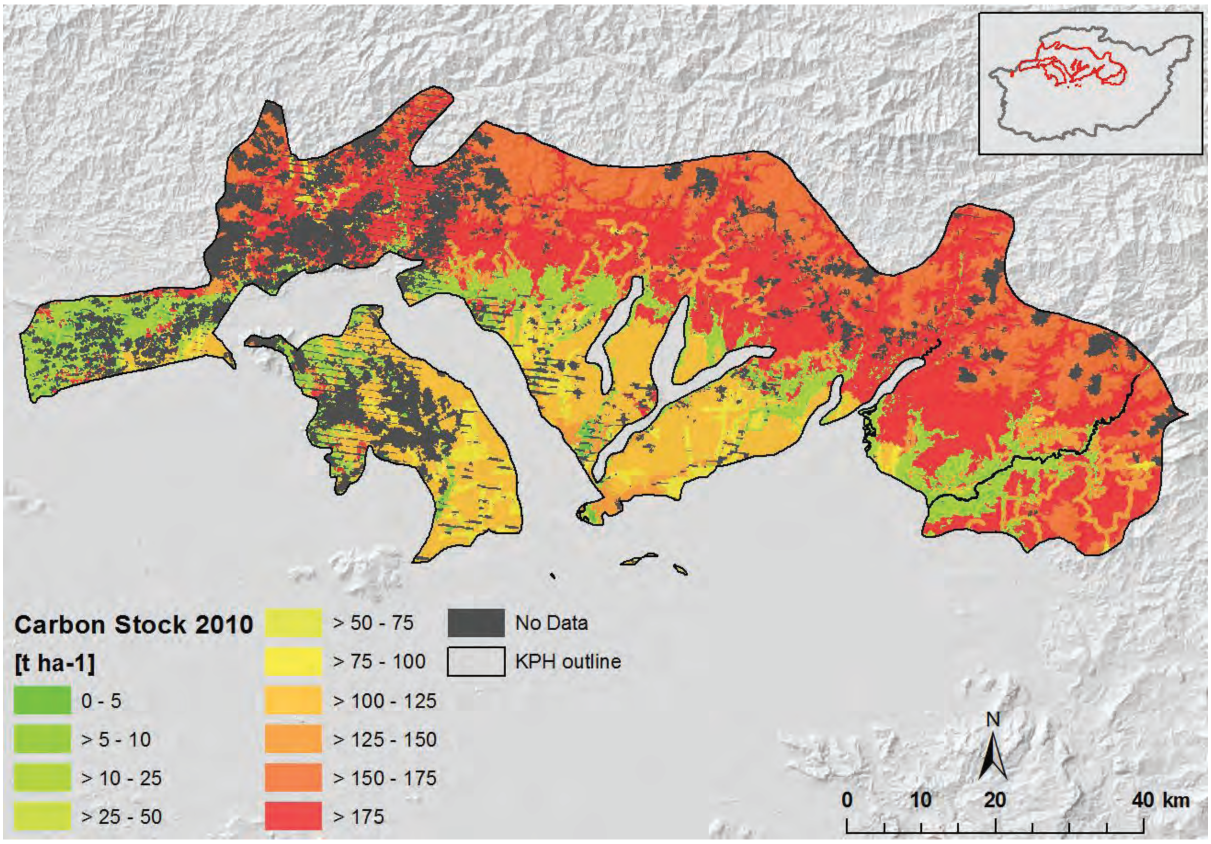


Figure 89. Carbon stock maps of the FMU in Kapuas Hulu district for the years 2005 and 2010.

Table 75. Carbon stock of the different land cover classes in the Kapuas Hulu FMU for the four time steps.

Land Cover	1990	2000	2005	2010
	t C			
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	999,722	1,120,146	1,142,199	1,279,058
Wetland	839	974	977	1,050
Lowland Forest	36,576,021	33,806,346	32,558,643	32,135,004
Secondary Lowland Forest	2,169,935	2,981,708	3,403,189	3,419,455
Hill and Submontane Forest	12,696,515	12,672,725	12,473,391	12,448,802
Secondary Hill and Submontane Forest	59,842	71,016	155,194	159,702
Lower Montane Forest	30,933	30,933	30,933	30,933
Peat Swamp Forest	7,015,128	6,490,950	6,228,727	6,154,511
Secondary Peat Swamp Forest	907,733	1,199,123	1,353,892	1,367,420
Heath Forest	1,299	1,299	1,299	1,299
Secondary Heath Forest	0	24	24	24
Riparian Forest	732,626	635,339	607,297	593,220
Secondary Riparian Forest	12,761	24,334	24,577	23,499
No Data	0	0	0	0
Sum	**61,203,354**	**59,034,915**	**57,980,340**	**57,613,976**

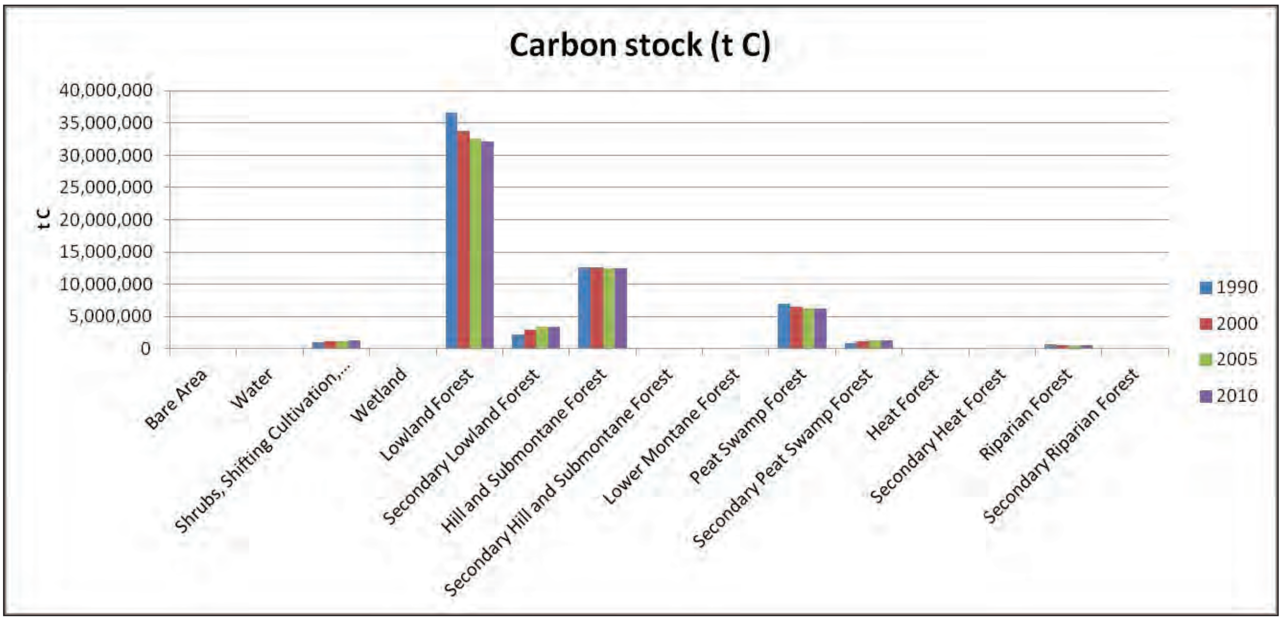


Figure 90. Carbon stock of the different land cover classes in the Kapuas Hulu FMU for the four time steps.

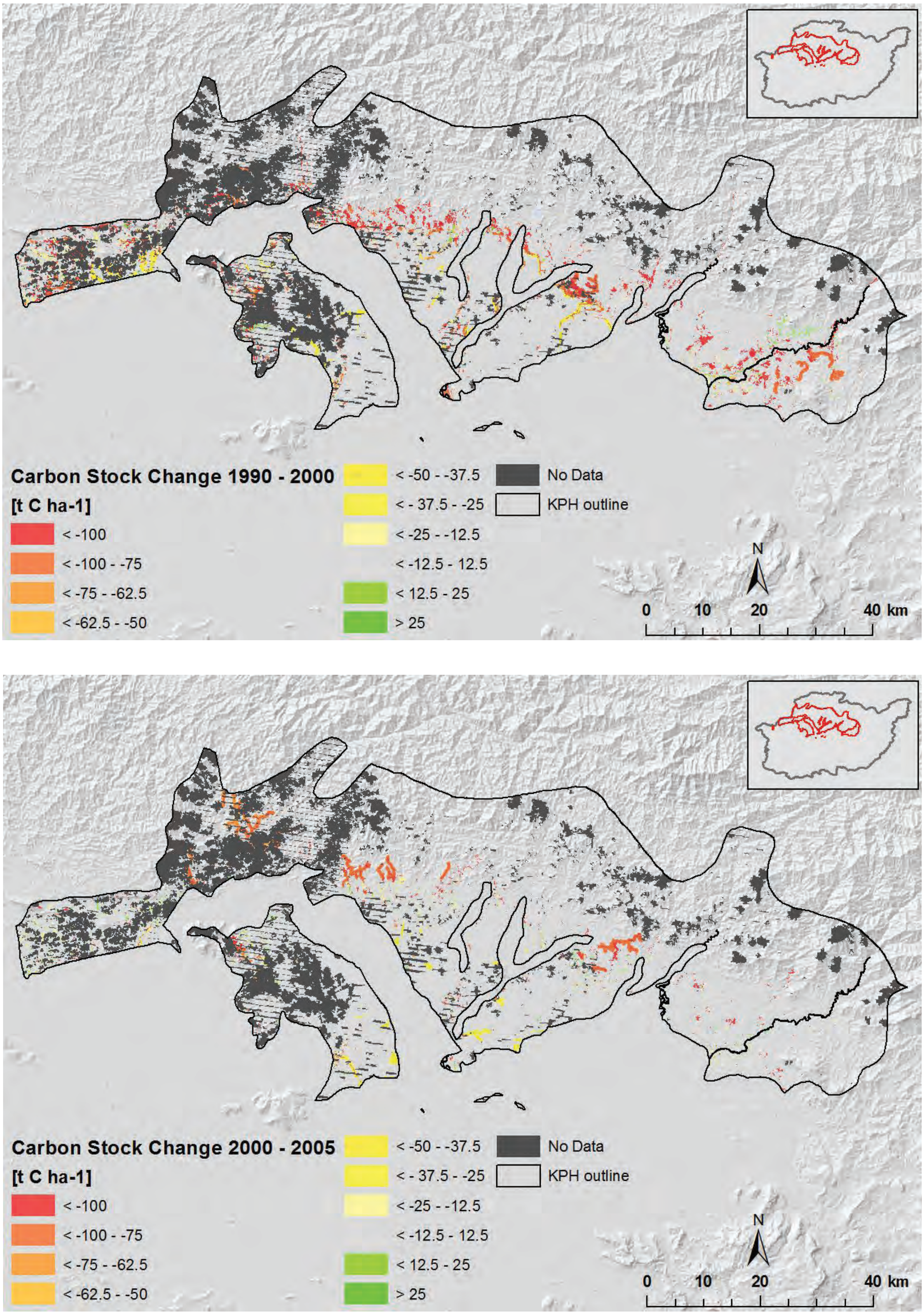
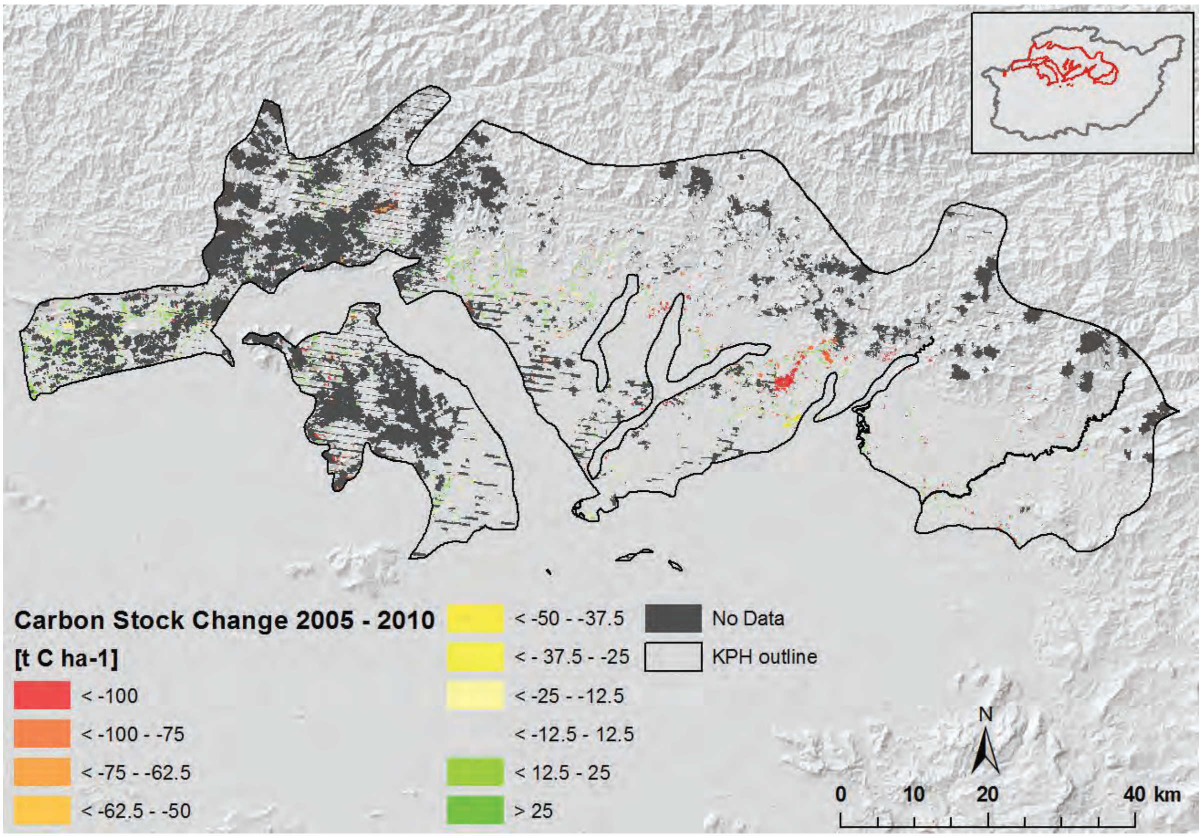


Figure 91. Carbon stock change maps of the FMU in Kapuas Hulu district for the time periods 1990-2000 and 2000-2005.



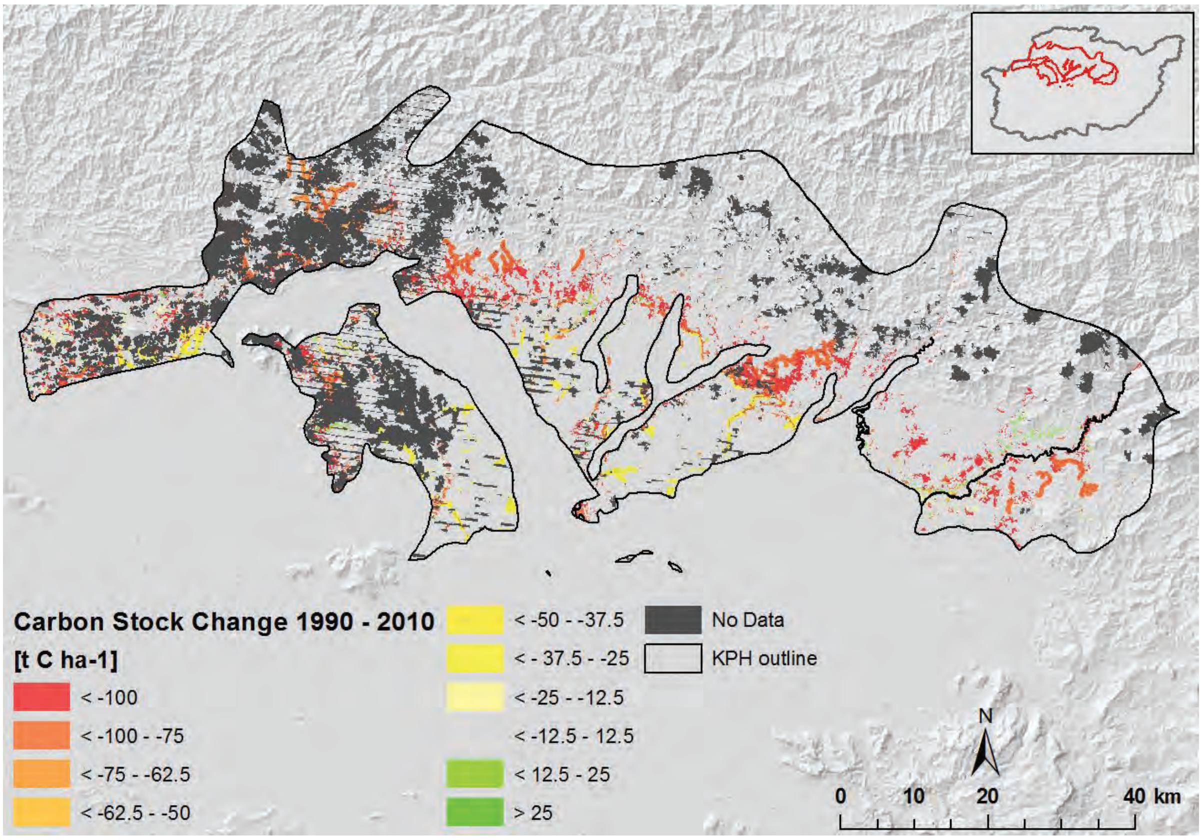


Figure 92. Carbon stock change maps of the FMU in Kapuas Hulu district for the time periods 2005-2010 and 1990-2010.

Table 76. Carbon stock change per class in the Kapuas Hulu FMU.

Land Cover	1990-2000	2000-2005	2005-2010	1990-2010
	t C			
Bare Area	0	0	0	0
Water	0	0	0	0
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	120,425	22,053	136,859	279,336
Wetland	134	3	73	211
Lowland Forest	-2,769,674	-1,247,703	-423,639	-4,441,017
Secondary Lowland Forest	811,773	421,481	16,266	1,249,520
Hill and Submontane Forest	-23,790	-199,335	-24,588	-247,713
Secondary Hill and Submontane Forest	11,174	84,178	4,508	99,860
Lower Montane Forest	0	0	0	0
Peat Swamp Forest	-524,179	-262,223	-74,216	-860,618
Secondary Peat Swamp Forest	291,390	154,769	13,528	459,687
Heath Forest	0	0	0	0
Secondary Heath Forest	24	0	0	24
Riparian Forest	-97,287	-28,042	-14,077	-139,406
Secondary Riparian Forest	11,572	243	-1,078	10,738
No Data	0	0	0	0
Total	**-2,168,439**	**-1,054,574**	**-366,365**	**-3,589,378**

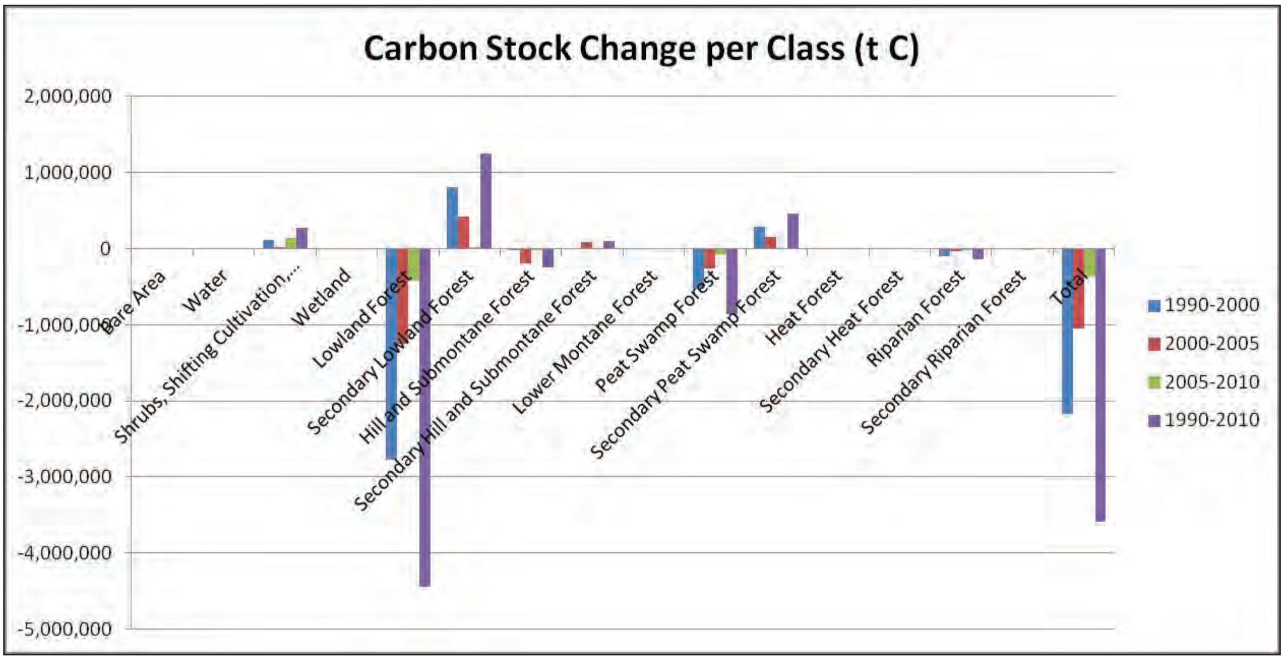


Figure 93. Carbon stock change per class in the Kapuas Hulu district FMU.

6.4.2.5 Drivers of carbon emissions in the Kapuas Hulu FMU

Table 77. Carbon change matrix of the Kapuas Hulu FMU 1990-2000.

		2000															
	1990	3	4	21	23	111	112	121	122	131	151	152	161	162	171	172	Sum
Bare Area	3	0	0	30,732	17	0	30,488	0	0	0	0	34,581	0	0	0	62	**95,879**
Water	4	0	0	3,641	0	0	716	0	0	0	0	215	0	0	0	75	**4,647**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-54,929	-4,180	0	-585	0	326,790	0	138	0	0	39,879	0	18	0	462	**307,593**
Wetland	23	0	-120	10	0	0	0	0	0	0	0	0	0	0	0	141	**31**
Lowland Forest	111	-252,092	-49,075	-1,332,266	0	0	-406,115	0	0	0	0	0	0	0	0	0	**-2,039,548**
Secondary Lowland Forest	112	-14,446	-634	-148,612	0	0	0	0	0	0	0	0	0	0	0	0	**-163,691**
Hill and Submontane Forest	121	-2,376	-604	-1,588	0	0	0	0	-7,969	0	0	0	0	0	0	0	**-12,537**
Secondary Hill and Submontane Forest	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Lower Montane Forest	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Peat Swamp Forest	151	-33,450	-4,700	-122,431	0	0	0	0	0	0	0	-97,270	0	0	0	0	**-257,851**
Secondary Peat Swamp Forest	152	-3,242	-1,001	-19,436	0	0	0	0	0	0	0	0	0	0	0	-319	**-23,998**
Heath Forest	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Secondary Heath Forest	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Riparian Forest	171	-5,525	-8,235	-32,527	-107	0	0	0	0	0	0	0	0	0	0	-30,366	**-76,761**
Secondary Riparian Forest	172	-1,372	-152	-679	0	0	0	0	0	0	0	0	0	0	0	0	**-2,203**
	Sum	**-367,431**	**-68,700**	**-1,623,156**	**-676**	**0**	**-48,121**	**0**	**-7,830**	**0**	**0**	**-22,596**	**0**	**18**	**0**	**-29,946**	**-2,168,439**

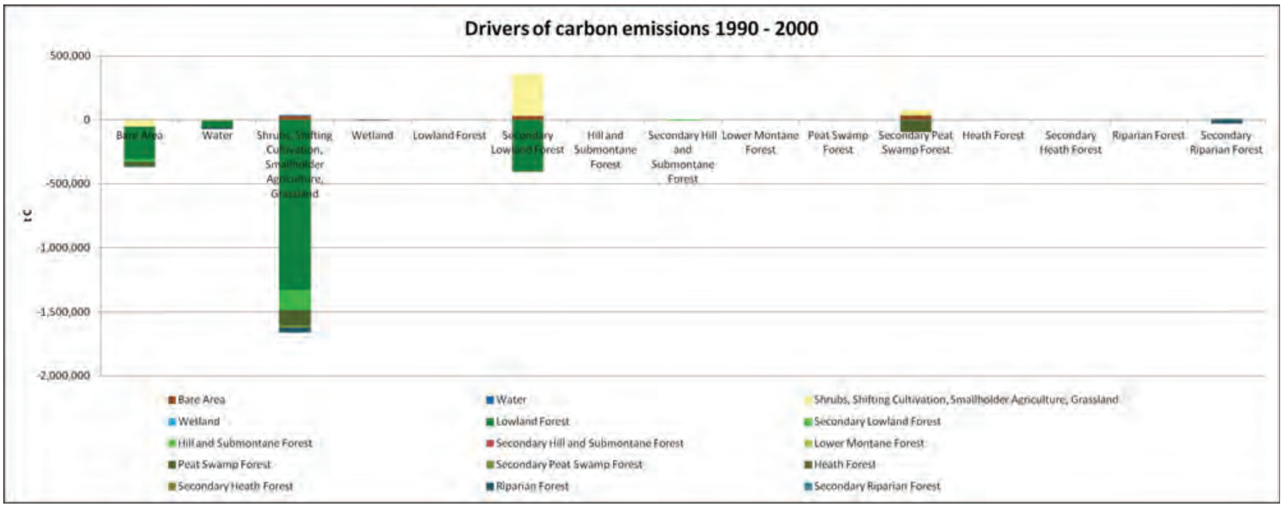


Figure 94. Drivers of carbon emissions in the Kapuas Hulu FMU 1990-2000.

Table 78. Carbon change matrix of the Kapuas Hulu FMU 2000-2005.

	Land Cover Carbon	2005															
	2000	3	4	21	23	111	112	121	122	131	151	152	161	162	171	172	Sum
Bare Area	3	0	0	21,544	3	0	149	0	0	0	0	2,593	0	0	0	0	24,290
Water	4	0	0	2,302	0	0	0	0	0	0	0	0	0	0	0	0	2,302
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-45,710	-245	0	0	0	12,581	0	0	0	0	2,842	0	0	0	0	-30,533
Wetland	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lowland Forest	111	-187,447	-295	-242,153	0	0	-325,457	0	0	0	0	0	0	0	0	0	-755,352
Secondary Lowland Forest	112	-23,711	0	-29,395	0	0	0	0	0	0	0	0	0	0	0	0	-53,106
Hill and Submontane Forest	121	-27,301	0	-20,810	0	0	0	0	-62,113	0	0	0	0	0	0	0	-110,224
Secondary Hill and Submontane Forest	122	-707	0	-593	0	0	0	0	0	0	0	0	0	0	0	0	-1,299
Lower Montane Forest	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat Swamp Forest	151	-12,384	0	-17,488	0	0	0	0	0	0	0	-67,237	0	0	0	0	-97,109
Secondary Peat Swamp Forest	152	-4,545	-68	-6,482	0	72	0	0	0	0	0	0	0	0	0	0	-11,024
Heath Forest	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Heath Forest	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Riparian Forest	171	-5,149	0	-11,058	0	0	0	0	0	0	0	0	0	0	0	-6,500	-22,708
Secondary Riparian Forest	172	-374	-14	-440	0	0	45	0	0	0	6	964	0	0	0	0	188
	Sum	-307,328	-623	-304,572	3	72	-312,682	0	-62,113	0	6	-60,837	0	0	0	-6,500	-1,054,574

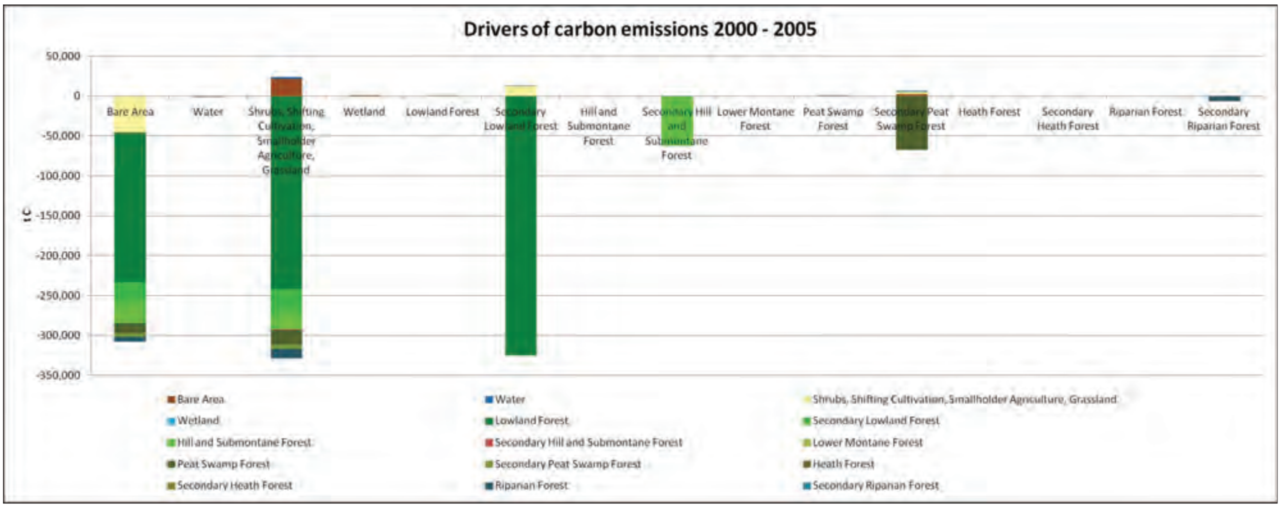


Figure 95. Drivers of carbon emissions in the Kapuas Hulu FMU 2000-2005.

Table 79. Carbon change matrix of the Kapuas Hulu FMU 2005-2010.

	Land Cover Carbon	2010															
	2005	3	4	21	23	111	112	121	122	131	151	152	161	162	171	172	Sum
Bare Area	3	0	0	102,669	19	0	0	0	0	0	0	0	0	0	0	0	102,688
Water	4	0	0	530	20	0	0	0	0	0	0	0	0	0	0	0	549
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-17,716	-896	0	-13	0	0	0	0	0	0	0	0	0	0	0	-18,624
Wetland	23	-1	0	20	0	0	0	0	0	0	0	0	0	0	0	0	20
Lowland Forest	111	-35,111	-42	-243,218	0	0	-48,554	0	0	0	0	0	0	0	0	0	-326,926
Secondary Lowland Forest	112	-2,405	0	-42,081	0	0	0	0	0	0	0	0	0	0	0	0	-44,486
Hill and Submontane Forest	121	0	0	-9,902	0	0	0	0	-5,485	0	0	0	0	0	0	0	-15,387
Secondary Hill and Submontane Forest	122	0	0	-2,309	0	0	0	0	0	0	0	0	0	0	0	0	-2,309
Lower Montane Forest	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peat Swamp Forest	151	-2,403	-10	-29,704	-243	0	11	0	0	0	0	-9,885	0	0	0	0	-42,234
Secondary Peat Swamp Forest	152	-1,908	0	-5,576	0	0	0	0	0	0	0	0	0	0	0	0	-7,484
Heath Forest	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Heath Forest	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Riparian Forest	171	-723	-11	-9,944	-333	0	0	0	0	0	0	0	0	0	0	-530	-11,541
Secondary Riparian Forest	172	-165	-96	-390	0	0	0	0	0	0	19	0	0	0	0	0	-632
	Sum	-60,430	-1,055	-239,905	-550	0	-48,543	0	-5,485	0	19	-9,885	0	0	0	-530	-366,365

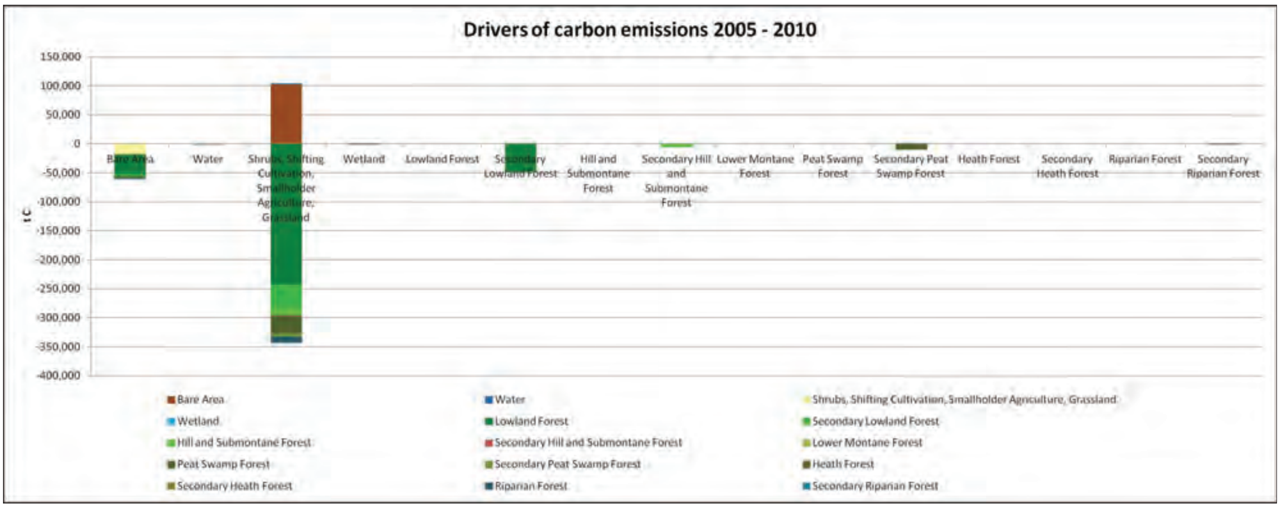


Figure 96. Drivers of carbon emissions in the Kapuas Hulu FMU 2005-2010.

Table 80. Carbon change matrix of the Kapuas Hulu FMU 1990-2010.

	Land Cover Carbon	2010															
	1990	3	4	21	23	111	112	121	122	131	151	152	161	162	171	172	Sum
Bare Area	3	0	0	32,063	40	0	29,985	0	0	0	0	34,567	0	0	0	62	**96,718**
Water	4	0	0	4,672	7	0	697	0	0	0	0	317	0	0	0	75	**5,768**
Shrubs, Shifting Cultivation, Smallholder Agriculture, Grassland	21	-38,286	-4,063	0	-595	95	327,924	0	66	0	30	40,235	0	18	0	396	**325,821**
Wetland	23	-1	-66	153	0	0	0	0	0	0	0	0	0	0	0	80	**167**
Lowland Forest	111	-213,977	-44,632	-2,140,903	0	0	-740,822	0	0	0	0	-946	0	0	0	0	**-3,141,279**
Secondary Lowland Forest	112	-18,954	-621	-179,444	0	0	0	0	0	0	0	0	0	0	0	0	**-199,019**
Hill and Submontane Forest	121	-1,355	-604	-63,195	0	0	0	0	-72,338	0	0	0	0	0	0	0	**-137,492**
Secondary Hill and Submontane Forest	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Lower Montane Forest	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Peat Swamp Forest	151	-23,664	-4,204	-199,653	-243	0	11	0	0	0	0	-170,420	0	0	0	0	**-398,172**
Secondary Peat Swamp Forest	152	-3,513	-1,056	-25,575	0	0	0	0	0	0	0	0	0	0	0	0	**-30,144**
Heath Forest	161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Secondary Heath Forest	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Riparian Forest	171	-4,239	-8,689	-62,374	-440	0	5	0	0	0	0	-964	0	0	0	-32,767	**-109,467**
Secondary Riparian Forest	172	-881	-152	-1,323	0	0	0	0	0	0	0	78	0	0	0	0	**-2,277**
	Sum	**-304,869**	**-64,086**	**-2,635,577**	**-1,231**	**95**	**-382,200**	**0**	**-72,272**	**0**	**30**	**-97,132**	**0**	**18**	**0**	**-32,154**	**-3,589,378**

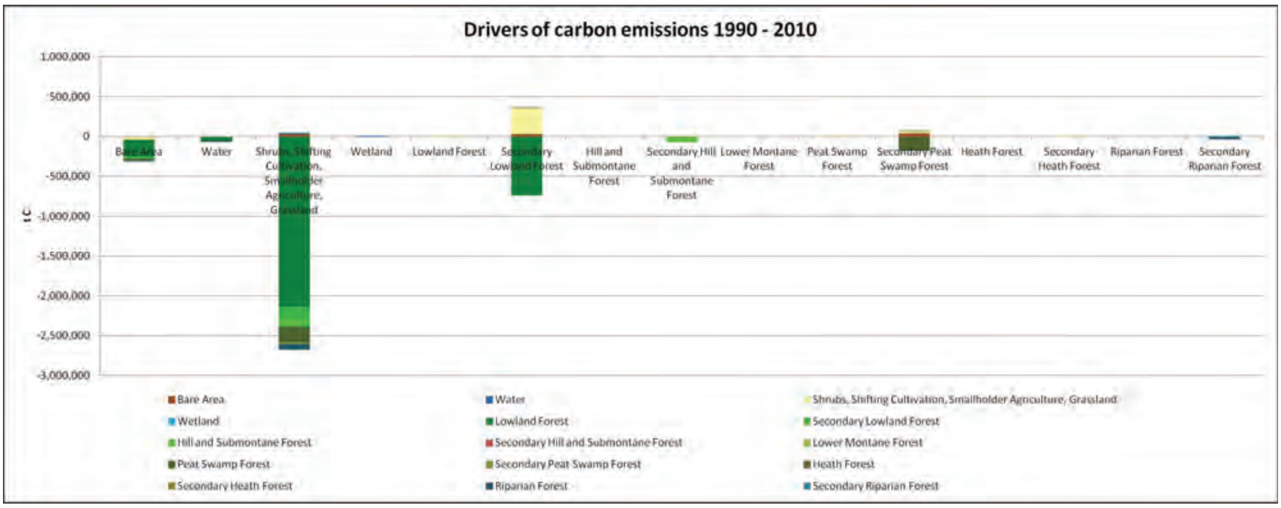


Figure 97. Drivers of carbon emissions in the Kapuas Hulu FMU 1990-2010.

6.5 Delivered Datasets

Topic	File name	Content	File type	Location	Remarks
Landcover district	KH_LandCover_1990.shp	Land cover Kapuas Hulu 1990	Shapefile	\Data\KapuasHulu\district\LandCover	
	KH_LandCover_2000.shp	Land cover Kapuas Hulu 2000	Shapefile	\Data\KapuasHulu\district\LandCover	
	KH_LandCover_2005.shp	Land cover Kapuas Hulu 2005	Shapefile	\Data\KapuasHulu\district\LandCover	
	KH_LandCover_2010.shp	Land cover Kapuas Hulu 2010	Shapefile	\Data\KapuasHulu\district\LandCover	
	KH_Landcover_Legend_Arc93.lyr	Land cover Legend Kapuas Hulu	ArcGIS 9.3 Layer file	\Data\KapuasHulu\district\LandCover	
	KH_Landcover_Legend_Arc10.lyr	Land cover Legend Kapuas Hulu	ArcGIS 10 Layer file	\Data\KapuasHulu\district\LandCover	
	KH_Landcover_Legend_Arc10_1.lyr	Land cover Legend Kapuas Hulu	ArcGIS 10.1 Layer file	\Data\KapuasHulu\district\LandCover	
	MN_LandCover_1990.shp	Land cover Malinau 1990	Shapefile	\Data\Malinau\district\LandCover	
	MN_LandCover_2000.shp	Land cover Malinau 2000	Shapefile	\Data\Malinau\district\LandCover	
	MN_LandCover_2005.shp	Land cover Malinau 2005	Shapefile	\Data\Malinau\district\LandCover	
	MN_LandCover_2010.shp	Land cover Malinau 2010	Shapefile	\Data\Malinau\district\LandCover	
	MN_Landcover_Legend_Arc93.lyr	Land cover Legend Malinau	ArcGIS 9.3 Layer file	\Data\Malinau\district\LandCover	
	MN_Landcover_Legend_Arc10.lyr	Land cover Legend Malinau	ArcGIS 10 Layer file	\Data\Malinau\district\LandCover	
	MN_Landcover_Legend_Arc10_1.lyr	Land cover Legend Malinau	ArcGIS 10.1 Layer file	\Data\Malinau\district\LandCover	
Land cover change district	KH_Change_1990_2000.shp	Land cover change Kapuas Hulu 1990 – 2000	Shapefile	\Data\KapuasHulu\district\Change	Based on datasets with ac- cumulated No Data mask of all time steps
	KH_Change_2000_2005.shp	Land cover change Kapuas Hulu 2000 – 2005	Shapefile	\Data\KapuasHulu\district\Change	Based on datasets with ac- cumulated No Data mask of all time steps
	KH_Change_2005_2010.shp	Land cover change Kapuas Hulu 2005 – 2010	Shapefile	\Data\KapuasHulu\district\Change	Based on datasets with ac- cumulated No Data mask of all time steps
	KH_Change_1990_2010.shp	Land cover change Kapuas Hulu 1990 – 2010	Shapefile	\Data\KapuasHulu\district\Change	Based on datasets with ac- cumulated No Data mask of all time steps
	KH_Change_Legend_Arc93.lyr	Land cover change legend (changecode)	ArcGIS 9.3 Layer file	\Data\KapuasHulu\district\Change	
	KH_Change_Legend_Arc10.lyr	Land cover change legend (changecode)	ArcGIS 10 Layer file	\Data\KapuasHulu\district\Change	
	KH_Change_Legend_Arc10_1.lyr	Land cover change legend (changecode)	ArcGIS 10.1 Layer file	\Data\KapuasHulu\district\Change	
	KH_NoData_complete.shp	Cumulative No Data Mask Kapuas Hulu	Shapefile	\Data\KapuasHulu\district\Change	
	KH_NoData_Legend_Arc93.lyr	NoData Legend Kapuas Hulu	ArcGIS 9.3 Layer file	\Data\KapuasHulu\district\Change	
	KH_NoData_Legend_Arc10.lyr	NoData Legend Kapuas Hulu	ArcGIS 10 Layer file	\Data\KapuasHulu\district\Change	
	KH_NoData_Legend_Arc10_1.lyr	NoData Legend Kapuas Hulu	ArcGIS 10.1 Layer file	\Data\KapuasHulu\district\Change	

Topic	File name	Content	File type	Location	Remarks
	KH_Change_1990_2000_analysis.xlsx	Land cover change Kapuas Hulu 1990 - 2000 analysis	Excel sheet	\Data\KapuasHulu\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	KH_Change_2000_2005_analysis.xlsx	Land cover change Kapuas Hulu 2000 - 2005 analysis	Excel sheet	\Data\KapuasHulu\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	KH_Change_2005_2010_analysis.xlsx	Land cover change Kapuas Hulu 2005 - 2010 analysis	Excel sheet	\Data\KapuasHulu\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	KH_Change_1990_2010_analysis.xlsx	Land cover change Kapuas Hulu 1990 - 2010 analysis	Excel sheet	\Data\KapuasHulu\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_1990_2000.shp	Land cover change Malinau 1990 - 2000	Shapefile	\Data\Malinau\district\Change	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_2000_2005.shp	Land cover change Malinau 2000 - 2005	Shapefile	\Data\Malinau\district\Change	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_2005_2010.shp	Land cover change Malinau 2005 - 2010	Shapefile	\Data\Malinau\district\Change	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_1990_2010.shp	Land cover change Malinau 1990 - 2010	Shapefile	\Data\Malinau\district\Change	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_Legend_Arc93.lyr	Land cover change legend (changecode)	ArcGIS 9.3 Layer file	\Data\Malinau\district\Change	
	MN_Change_Legend_Arc10.lyr	Land cover change legend (changecode)	ArcGIS 10 Layer file	\Data\Malinau\district\Change	
	MN_Change_Legend_Arc10_1.lyr	Land cover change legend (changecode)	ArcGIS 10.1 Layer file	\Data\Malinau\district\Change	
	MN_NoData_complete.shp	Cumulative No Data Mask Malinau	Shapefile	\Data\Malinau\district\Change	Based on datasets with accumulated No Data mask of all time steps
	MN_NoData_Legend_Arc93.lyr	NoData Legend Malinau	ArcGIS 9.3 Layer file	\Data\Malinau\district\Change	
	MN_NoData_Legend_Arc10.lyr	NoData Legend Malinau	ArcGIS 10 Layer file	\Data\Malinau\district\Change	
	MN_NoData_Legend_Arc10_1.lyr	NoData Legend Malinau	ArcGIS 10.1 Layer file	\Data\Malinau\district\Change	
	MN_Change_1990_2000_analysis.xlsx	Land cover change Malinau 1990 - 2000 analysis	Excel sheet	\Data\Malinau\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_2000_2005_analysis.xlsx	Land cover change Malinau 2000 - 2005 analysis	Excel sheet	\Data\Malinau\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
	MN_Change_2005_2010_analysis.xlsx	Land cover change Malinau 2005 - 2010 analysis	Excel sheet	\Data\Malinau\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps

Topic	File name	Content	File type	Location	Remarks
	MN_Change_1990_2010_analysis.xlsx	Land cover change Malinau 1990 – 2010 analysis	Excel sheet	\Data\Malinau\district\Change\Analysis	Based on datasets with accumulated No Data mask of all time steps
Forest Cover district	KH_ForestCover_1990.shp	Forest cover Kapuas Hulu 1990	Shapefile	\Data\KapuasHulu\district\ForestCover	
	KH_ForestCover_2000.shp	Forest cover Kapuas Hulu 2000	Shapefile	\Data\KapuasHulu\district\ForestCover	
	KH_ForestCover_2005.shp	Forest cover Kapuas Hulu 2005	Shapefile	\Data\KapuasHulu\district\ForestCover	
	KH_ForestCover_2010.shp	Forest cover Kapuas Hulu 2010	Shapefile	\Data\KapuasHulu\district\ForestCover	
	MN_ForestCover_1990.shp	Forest cover Malinau 1990	Shapefile	\Data\Malinau\district\ForestCover	
	MN_ForestCover_2000.shp	Forest cover Malinau 2000	Shapefile	\Data\Malinau\district\ForestCover	
	MN_ForestCover_2005.shp	Forest cover Malinau 2005	Shapefile	\Data\Malinau\district\ForestCover	
	MN_ForestCover_2010.shp	Forest cover Malinau 2010	Shapefile	\Data\Malinau\district\ForestCover	
Landcover KPH	KH_KPH_LandCover_1990.shp	Land cover KPH Kapuas Hulu 1990	Shapefile	\Data\KapuasHulu\KPH\LandCover	
	KH_KPH_LandCover_2000.shp	Land cover KPH Kapuas Hulu 2000	Shapefile	\Data\KapuasHulu\KPH\LandCover	
	KH_KPH_LandCover_2005.shp	Land cover KPH Kapuas Hulu 2005	Shapefile	\Data\KapuasHulu\KPH\LandCover	
	KH_KPH_LandCover_2010.shp	Land cover KPH Kapuas Hulu 2010	Shapefile	\Data\KapuasHulu\KPH\LandCover	
	MN_KPH_LandCover_1990.shp	Land cover KPH Malinau 1990	Shapefile	\Data\Malinau\KPH\LandCover	
	MN_KPH_LandCover_2000.shp	Land cover KPH Malinau 2000	Shapefile	\Data\Malinau\KPH\LandCover	
	MN_KPH_LandCover_2005.shp	Land cover KPH Malinau 2005	Shapefile	\Data\Malinau\KPH\LandCover	
	MN_KPH_LandCover_2010.shp	Land cover KPH Malinau 2010	Shapefile	\Data\Malinau\KPH\LandCover	
Land cover change KPH	KH_KPH_Change_1990_2000.shp	Land cover change KPH Kapuas Hulu 1990 – 2000	Shapefile	\Data\KapuasHulu\KPH\Change	
	KH_KPH_Change_2000_2005.shp	Land cover change KPH Kapuas Hulu 2000 – 2005	Shapefile	\Data\KapuasHulu\KPH\Change	
	KH_KPH_Change_2005_2010.shp	Land cover change KPH Kapuas Hulu 2005 – 2010	Shapefile	\Data\KapuasHulu\KPH\Change	
	KH_KPH_Change_1990_2010.shp	Land cover change KPH Kapuas Hulu 1990 – 2010	Shapefile	\Data\KapuasHulu\KPH\Change	
	KH_KPH_NoData_complete.shp	Cumulative No Data Mask KPH Kapuas Hulu	Shapefile	\Data\KapuasHulu\KPH\Change	
	KH_KPH_Change_1990_2000_analysis.xlsx	Land cover change KPH Kapuas Hulu 1990 – 2000 analysis	Excel sheet	\Data\KapuasHulu\KPH\Change\Analysis	
	KH_KPH_Change_2000_2005_analysis.xlsx	Land cover change KPH Kapuas Hulu 2000 – 2005 analysis	Excel sheet	\Data\KapuasHulu\KPH\Change\Analysis	
	KH_KPH_Change_2005_2010_analysis.xlsx	Land cover change KPH Kapuas Hulu 2005 – 2010 analysis	Excel sheet	\Data\KapuasHulu\KPH\Change\Analysis	
	KH_KPH_Change_1990_2010_analysis.xlsx	Land cover change KPH Kapuas Hulu 1990 – 2010 analysis	Excel sheet	\Data\KapuasHulu\KPH\Change\Analysis	
	MN_KPH_Change_1990_2000.shp	Land cover change KPH Malinau 1990 – 2000	Shapefile	\Data\Malinau\KPH\Change	

Topic	File name	Content	File type	Location	Remarks
	MN_KPH_Change_2000_2005.shp	Land cover change KPH Malinau 2000 - 2005	Shapefile	\Data\Malinau\KPH\Change	
	MN_KPH_Change_2005_2010.shp	Land cover change KPH Malinau 2005 - 2010	Shapefile	\Data\Malinau\KPH\Change	
	MN_KPH_Change_1990_2010.shp	Land cover change KPH Malinau 1990 - 2010	Shapefile	\Data\Malinau\KPH\Change	
	MN_KPH_NoData_complete.shp	Cumulative No Data Mask KPH Malinau	Shapefile	\Data\Malinau\KPH\Change	
	MN_KPH_Change_1990_2000_analysis.xlsx	Land cover change KPH Malinau 1990 - 2000 analysis	Excel sheet	\Data\Malinau\KPH\Change\Analysis	
	MN_KPH_Change_2000_2005_analysis.xlsx	Land cover change KPH Malinau 2000 - 2005 analysis	Excel sheet	\Data\Malinau\KPH\Change\Analysis	
	MN_KPH_Change_2005_2010_analysis.xlsx	Land cover change KPH Malinau 2005 - 2010 analysis	Excel sheet	\Data\Malinau\KPH\Change\Analysis	
	MN_KPH_Change_1990_2010_analysis.xlsx	Land cover change KPH Malinau 1990 - 2010 analysis	Excel sheet	\Data\Malinau\KPH\Change\Analysis	
	KH_KPH_ForestCover_1990.shp	Forest cover KPH Kapuas Hulu 1990	Shapefile	\Data\KapuasHulu\KPH\ForestCover	
	KH_KPH_ForestCover_2000.shp	Forest cover KPH Kapuas Hulu 2000	Shapefile	\Data\KapuasHulu\KPH\ForestCover	
	KH_KPH_ForestCover_2005.shp	Forest cover KPH Kapuas Hulu 2005	Shapefile	\Data\KapuasHulu\KPH\ForestCover	
	KH_KPH_ForestCover_2010.shp	Forest cover KPH Kapuas Hulu 2010	Shapefile	\Data\KapuasHulu\KPH\ForestCover	
	MN_KPH_ForestCover_1990.shp	Forest cover KPH Malinau 1990	Shapefile	\Data\Malinau\KPH\ForestCover	
	MN_KPH_ForestCover_2000.shp	Forest cover KPH Malinau 2000	Shapefile	\Data\Malinau\KPH\ForestCover	
	MN_KPH_ForestCover_2005.shp	Forest cover KPH Malinau 2005	Shapefile	\Data\Malinau\KPH\ForestCover	
	MN_KPH_ForestCover_2010.shp	Forest cover KPH Malinau 2010	Shapefile	\Data\Malinau\KPH\ForestCover	
Status of protected areas	KH_ProtectedAreas_Landcover_2010.shp	Current Status of Protected Areas in Kapuas Hulu	Shapefile	\Data\KapuasHulu\ProtectedAreas\	
	MN_ProtectedAreas_Landcover_2010.shp	Current Status of Protected Areas in Malinau	Shapefile	\Data\Malinau\ProtectedAreas\	
Carbon data	KH_Biomass Carbon Calculation_Report.pdf	Biomass report Kapuas Hulu	pdf	\Data\KapuasHulu\CarbonValues	
	MN_Biomass Carbon Calculation_Report.pdf	Biomass report Malinau	pdf	\Data\Malinau\CarbonValues	
	KH_carbon_LUT.dbf	Biomass and carbon LUT Kapuas Hulu	Dbase table	\Data\KapuasHulu\CarbonValues	
	MN_carbon_LUT.dbf	Biomass and carbon LUT Malinau	Dbase table	\Data\Malinau\CarbonValues	
Change matrices	KH_carbon_change_matrix.dbf	Change Matrix Kapuas Hulu	Dbase table	\Data\KapuasHulu\CarbonValues	
	MN_carbon_change_matrix.dbf	Change Matrix Malinau	Dbase table	\Data\Malinau\CarbonValues	
District Maps	KH_LandCover_1990_300dpi.pdf	Land cover Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\LandCover\300dpi	
	KH_LandCover_2000_300dpi.pdf	Land cover Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\LandCover\300dpi	
	KH_LandCover_2005_300dpi.pdf	Land cover Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\LandCover\300dpi	
	KH_LandCover_2010_300dpi.pdf	Land cover Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\LandCover\300dpi	
	KH_LandCover_1990_600dpi.pdf	Land cover Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\LandCover\600dpi	
	KH_LandCover_2000_600dpi.pdf	Land cover Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\LandCover\600dpi	

Topic	File name	Content	File type	Location	Remarks
	KH_LandCover_2005_600dpi.pdf	Land cover Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\LandCover\600dpi	
	KH_LandCover_2010_600dpi.pdf	Land cover Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\LandCover\600dpi	
	KH_Change_2000_2005_300dpi.pdf	Land cover change Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\district\Change\300dpi	
	KH_Change_2005_2010_300dpi.pdf	Land cover change Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\district\Change\300dpi	
	KH_Change_1990_2010_300dpi.pdf	Land cover change Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\district\Change\300dpi	
	KH_Change_1990_2000_600dpi.pdf	Land cover change Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\district\Change\600dpi	
	KH_Change_2000_2005_600dpi.pdf	Land cover change Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\district\Change\600dpi	
	KH_Change_2005_2010_600dpi.pdf	Land cover change Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\district\Change\600dpi	
	KH_Change_1990_2010_600dpi.pdf	Land cover change Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\district\Change\600dpi	
	KH_ForestCover_1990_300dpi.pdf	Forest cover Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\ForestCover\300dpi	
	KH_ForestCover_2000_300dpi.pdf	Forest cover Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\ForestCover\300dpi	
	KH_ForestCover_2005_300dpi.pdf	Forest cover Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\ForestCover\300dpi	
	KH_ForestCover_2010_300dpi.pdf	Forest cover Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\ForestCover\300dpi	
	KH_ForestCover_1990_600dpi.pdf	Forest cover Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\ForestCover\600dpi	
	KH_ForestCover_2000_600dpi.pdf	Forest cover Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\ForestCover\600dpi	
	KH_ForestCover_2005_600dpi.pdf	Forest cover Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\ForestCover\600dpi	
	KH_ForestCover_2010_600dpi.pdf	Forest cover Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\ForestCover\600dpi	
	KH_Change_1990_2000_300dpi.pdf	Land cover change Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\district\Change\300dpi	
	KH_Deforestation_1990_2000_300dpi.pdf	Deforestation map Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\district\Deforestation\300dpi	
	KH_Deforestation_2000_2005_300dpi.pdf	Deforestation map Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\district\Deforestation\300dpi	
	KH_Deforestation_2005_2010_300dpi.pdf	Deforestation map Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\district\Deforestation\300dpi	
	KH_Deforestation_1990_2010_300dpi.pdf	Deforestation map Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\district\Deforestation\300dpi	

Topic	File name	Content	File type	Location	Remarks
	KH_Deforestation_1990_2000_600dpi.pdf	Deforestation map Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\district\Deforestation\600dpi	
	KH_Deforestation_2000_2005_600dpi.pdf	Deforestation map Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\district\Deforestation\600dpi	
	KH_Deforestation_2005_2010_600dpi.pdf	Deforestation map Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\district\Deforestation\600dpi	
	KH_Deforestation_1990_2010_600dpi.pdf	Deforestation map Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\district\Deforestation\600dpi	
	KH_CarbonStock_1990_300dpi.pdf	Carbon Stock Map Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\CarbonStock\300dpi	
	KH_CarbonStock_2000_300dpi.pdf	Carbon Stock Map Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\CarbonStock\300dpi	
	KH_CarbonStock_2005_300dpi.pdf	Carbon Stock Map Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\CarbonStock\300dpi	
	KH_CarbonStock_2010_300dpi.pdf	Carbon Stock Map Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\CarbonStock\300dpi	
	KH_CarbonStock_1990_600dpi.pdf	Carbon Stock Map Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\district\CarbonStock\600dpi	
	KH_CarbonStock_2000_600dpi.pdf	Carbon Stock Map Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\district\CarbonStock\600dpi	
	KH_CarbonStock_2005_600dpi.pdf	Carbon Stock Map Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\district\CarbonStock\600dpi	
	KH_CarbonStock_2010_600dpi.pdf	Carbon Stock Map Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\district\CarbonStock\600dpi	
	KH_Carbon_Change_1990_2000_300dpi.pdf	Carbon Stock change Kapuas Hulu 1990 - 2000	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	KH_Carbon_Change_2000_2005_300dpi.pdf	Carbon Stock change Kapuas Hulu 2000 - 2005	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	KH_Carbon_Change_2005_2010_300dpi.pdf	Carbon Stock change Kapuas Hulu 2005 - 2010	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	KH_Carbon_Change_1990_2010_300dpi.pdf	Carbon Stock change Kapuas Hulu 1990 - 2010	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	KH_Carbon_Change_1990_2000_600dpi.pdf	Carbon Stock change Kapuas Hulu 1990 - 2000	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	KH_Carbon_Change_2000_2005_600dpi.pdf	Carbon Stock change Kapuas Hulu 2000 - 2005	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	KH_Carbon_Change_2005_2010_600dpi.pdf	Carbon Stock change Kapuas Hulu 2005 - 2010	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	KH_Carbon_Change_1990_2010_600dpi.pdf	Carbon Stock change Kapuas Hulu 1990 - 2010	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
Malinau District	MN_LandCover_1990_300dpi.pdf	Land cover Malinau 1990	PDF	\Maps\Malinau\district\LandCover\300dpi	
	MN_LandCover_2000_300dpi.pdf	Land cover Malinau 2000	PDF	\Maps\Malinau\district\LandCover\300dpi	

Topic	File name	Content	File type	Location	Remarks
	MN_LandCover_2005_300dpi.pdf	Land cover Malinau 2005	PDF	\Maps\Malinau\district\LandCover\300dpi	
	MN_LandCover_2010_300dpi.pdf	Land cover Malinau 2010	PDF	\Maps\Malinau\district\LandCover\300dpi	
	MN_LandCover_1990_600dpi.pdf	Forest cover Malinau 1990	PDF	\Maps\Malinau\district\LandCover\600dpi	
	MN_LandCover_2000_600dpi.pdf	Forest cover Malinau 2000	PDF	\Maps\Malinau\district\LandCover\600dpi	
	MN_LandCover_2005_600dpi.pdf	Forest cover Malinau 2005	PDF	\Maps\Malinau\district\LandCover\600dpi	
	MN_LandCover_2010_600dpi.pdf	Forest cover Malinau 2010	PDF	\Maps\Malinau\district\LandCover\600dpi	
	MN_Change_1990_2000_300dpi.pdf	Land cover change Malinau 1990 - 2000	PDF	\Maps\Malinau\district\Change\300dpi	
	MN_Change_2000_2005_300dpi.pdf	Land cover change Malinau 2000 - 2005	PDF	\Maps\Malinau\district\Change\300dpi	
	MN_Change_2005_2010_300dpi.pdf	Land cover change Malinau 2005 - 2010	PDF	\Maps\Malinau\district\Change\300dpi	
	MN_Change_1990_2010_300dpi.pdf	Land cover change Malinau 1990 - 2010	PDF	\Maps\Malinau\district\Change\300dpi	
	MN_Change_1990_2000_600dpi.pdf	Land cover change Malinau 1990 - 2000	PDF	\Maps\Malinau\district\Change\600dpi	
	MN_Change_2000_2005_600dpi.pdf	Land cover change Malinau 2000 - 2005	PDF	\Maps\Malinau\district\Change\600dpi	
	MN_Change_2005_2010_600dpi.pdf	Land cover change Malinau 2005 - 2010	PDF	\Maps\Malinau\district\Change\600dpi	
	MN_Change_1990_2010_600dpi.pdf	Land cover change Malinau 1990 - 2010	PDF	\Maps\Malinau\district\Change\600dpi	
	MN_ForestCover_1990_300dpi.pdf	Forest cover Malinau 1990	PDF	\Maps\Malinau\district\ForestCover\300dpi	
	MN_ForestCover_2000_300dpi.pdf	Forest cover Malinau 2000	PDF	\Maps\Malinau\district\ForestCover\300dpi	
	MN_ForestCover_2005_300dpi.pdf	Forest cover Malinau 2005	PDF	\Maps\Malinau\district\ForestCover\300dpi	
	MN_ForestCover_2010_300dpi.pdf	Forest cover Malinau 2010	PDF	\Maps\Malinau\district\ForestCover\300dpi	
	MN_ForestCover_1990_600dpi.pdf	Forest cover Malinau 1990	PDF	\Maps\Malinau\district\ForestCover\600dpi	
	MN_ForestCover_2000_600dpi.pdf	Forest cover Malinau 2000	PDF	\Maps\Malinau\district\ForestCover\600dpi	
	MN_ForestCover_2005_600dpi.pdf	Forest cover Malinau 2005	PDF	\Maps\Malinau\district\ForestCover\600dpi	
	MN_ForestCover_2010_600dpi.pdf	Forest cover Malinau 2010	PDF	\Maps\Malinau\district\ForestCover\600dpi	
	MN_Deforestation_1990_2000_300dpi.pdf	Deforestation map Malinau 1990 - 2000	PDF	\Maps\Malinau\district\Deforestation\300dpi	
	MN_Deforestation_2000_2005_300dpi.pdf	Deforestation map Malinau 2000 - 2005	PDF	\Maps\Malinau\district\Deforestation\300dpi	
	MN_Deforestation_2005_2010_300dpi.pdf	Deforestation map Malinau 2005 - 2010	PDF	\Maps\Malinau\district\Deforestation\300dpi	
	MN_Deforestation_1990_2010_300dpi.pdf	Deforestation map Malinau 1990 - 2010	PDF	\Maps\Malinau\district\Deforestation\300dpi	
	MN_Deforestation_1990_2000_600dpi.pdf	Deforestation map Malinau 1990 - 2000	PDF	\Maps\Malinau\district\Deforestation\600dpi	
	MN_Deforestation_2000_2005_600dpi.pdf	Deforestation map Malinau 2000 - 2005	PDF	\Maps\Malinau\district\Deforestation\600dpi	
	MN_Deforestation_2005_2010_600dpi.pdf	Deforestation map Malinau 2005 - 2010	PDF	\Maps\Malinau\district\Deforestation\600dpi	
	MN_Deforestation_1990_2010_600dpi.pdf	Deforestation map Malinau 1990 - 2010	PDF	\Maps\Malinau\district\Deforestation\600dpi	
	MN_CarbonStock_1990_300dpi.pdf	Carbon Stock Map Malinau 1990	PDF	\Maps\Malinau\district\CarbonStock\300dpi	
	MN_CarbonStock_2000_300dpi.pdf	Carbon Stock Map Malinau 2000	PDF	\Maps\Malinau\district\CarbonStock\300dpi	
	MN_CarbonStock_2005_300dpi.pdf	Carbon Stock Map Malinau 2005	PDF	\Maps\Malinau\district\CarbonStock\300dpi	
	MN_CarbonStock_2010_300dpi.pdf	Carbon Stock Map Malinau 2010	PDF	\Maps\Malinau\district\CarbonStock\300dpi	
	MN_CarbonStock_1990_600dpi.pdf	Carbon Stock Map Malinau 1990	PDF	\Maps\Malinau\district\CarbonStock\600dpi	
	MN_CarbonStock_2000_600dpi.pdf	Carbon Stock Map Malinau 2000	PDF	\Maps\Malinau\district\CarbonStock\600dpi	
	MN_CarbonStock_2005_600dpi.pdf	Carbon Stock Map Malinau 2005	PDF	\Maps\Malinau\district\CarbonStock\600dpi	

Topic	File name	Content	File type	Location	Remarks
	MN_CarbonStock_2010_600dpi.pdf	Carbon Stock Map Malinau 2010	PDF	\Maps\Malinau\district\CarbonStock\600dpi	
	MN_Carbon_Change_1990_2000_300dpi.pdf	Carbon Stock change Malinau 1990 - 2000	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	MN_Carbon_Change_2000_2005_300dpi.pdf	Carbon Stock change Malinau 2000 - 2005	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	MN_Carbon_Change_2005_2010_300dpi.pdf	Carbon Stock change Malinau 2005 - 2010	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	MN_Carbon_Change_1990_2010_300dpi.pdf	Carbon Stock change Malinau 1990 - 2010	PDF	\Maps\Malinau\district\CarbonChange\300dpi	
	MN_Carbon_Change_1990_2000_600dpi.pdf	Carbon Stock change Malinau 1990 - 2000	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	MN_Carbon_Change_2000_2005_600dpi.pdf	Carbon Stock change Malinau 2000 - 2005	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	MN_Carbon_Change_2005_2010_600dpi.pdf	Carbon Stock change Malinau 2005 - 2010	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
	MN_Carbon_Change_1990_2010_600dpi.pdf	Carbon Stock change Malinau 1990 - 2010	PDF	\Maps\Malinau\district\ChangeChange\600dpi	
FMU Maps	KH_KPH_LandCover_1990_300dpi.pdf	Land cover KPH Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\KPH\LandCover\300dpi	
	KH_KPH_LandCover_2000_300dpi.pdf	Land cover KPH Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\KPH\LandCover\300dpi	
	KH_KPH_LandCover_2005_300dpi.pdf	Land cover KPH Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\KPH\LandCover\300dpi	
	KH_KPH_LandCover_2010_300dpi.pdf	Land cover KPH Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\KPH\LandCover\300dpi	
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	KH_KPH_Change_1990_2000_300dpi.pdf	Land cover change KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\Change\300dpi	
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	KH_KPH_Change_2005_2010_300dpi.pdf	Land cover change KPH Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\KPH\Change\300dpi	
	KH_KPH_Change_1990_2010_300dpi.pdf	Land cover change KPH Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\KPH\Change\300dpi	
	KH_KPH_Change_1990_2000_600dpi.pdf	Land cover change KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\Change\600dpi	
	KH_KPH_Change_2000_2005_600dpi.pdf	Land cover change KPH Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\KPH\Change\600dpi	
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Topic	File name	Content	File type	Location	Remarks
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	KH_KPH_ForestCover_2000_300dpi.pdf	Forest cover KPH Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\KPH\ForestCover\300dpi	
	KH_KPH_ForestCover_2005_300dpi.pdf	Forest cover KPH Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\KPH\ForestCover\300dpi	
	KH_KPH_ForestCover_2010_300dpi.pdf	Forest cover KPH Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\KPH\ForestCover\300dpi	
	KH_KPH_ForestCover_1990_600dpi.pdf	Forest cover KPH Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\KPH\ForestCover\600dpi	
	KH_KPH_ForestCover_2000_600dpi.pdf	Forest cover KPH Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\KPH\ForestCover\600dpi	
	KH_KPH_ForestCover_2005_600dpi.pdf	Forest cover KPH Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\KPH\ForestCover\600dpi	
	KH_KPH_ForestCover_2010_600dpi.pdf	Forest cover KPH Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\KPH\ForestCover\600dpi	
	KH_KPH_Deforestation_1990_2000_300dpi.pdf	Deforestation KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\Deforestation\300dpi	
	KH_KPH_Deforestation_2000_2005_300dpi.pdf	Deforestation KPH Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\KPH\Deforestation\300dpi	
	KH_KPH_Deforestation_2005_2010_300dpi.pdf	Deforestation KPH Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\KPH\Deforestation\300dpi	
	KH_KPH_Deforestation_1990_2010_300dpi.pdf	Deforestation KPH Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\KPH\Deforestation\300dpi	
	KH_KPH_Deforestation_1990_2000_600dpi.pdf	Deforestation KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\Deforestation\600dpi	
	KH_KPH_Deforestation_2000_2005_600dpi.pdf	Deforestation KPH Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\KPH\Deforestation\600dpi	
	KH_KPH_Deforestation_2005_2010_600dpi.pdf	Deforestation KPH Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\KPH\Deforestation\600dpi	
	KH_KPH_Deforestation_1990_2010_600dpi.pdf	Deforestation KPH Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\KPH\Deforestation\600dpi	
	KH_KPH_CarbonStock_1990_300dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\KPH\CarbonStock\300dpi	
	KH_KPH_CarbonStock_2000_300dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\KPH\CarbonStock\300dpi	
	KH_KPH_CarbonStock_2005_300dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\KPH\CarbonStock\300dpi	
	KH_KPH_CarbonStock_2010_300dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\KPH\CarbonStock\300dpi	
	KH_KPH_CarbonStock_1990_600dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 1990	PDF	\Maps\KapuasHulu\KPH\CarbonStock\600dpi	
	KH_KPH_CarbonStock_2000_600dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2000	PDF	\Maps\KapuasHulu\KPH\CarbonStock\600dpi	
	KH_KPH_CarbonStock_2005_600dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2005	PDF	\Maps\KapuasHulu\KPH\CarbonStock\600dpi	
	KH_KPH_CarbonStock_2010_600dpi.pdf	Carbon Stock Map KPH Kapuas Hulu 2010	PDF	\Maps\KapuasHulu\KPH\CarbonStock\600dpi	
	KH_KPH_Carbon_Change_1990_2000_300dpi.pdf	Carbon Stock change KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\CarbonChange\300dpi	
	KH_KPH_Carbon_Change_2000_2005_300dpi.pdf	Carbon Stock change KPH Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\KPH\CarbonChange\300dpi	
	KH_KPH_Carbon_Change_2005_2010_300dpi.pdf	Carbon Stock change KPH Kapuas Hulu 2005 - 2010	PDF	\Maps\KapuasHulu\KPH\CarbonChange\300dpi	
	KH_KPH_Carbon_Change_1990_2010_300dpi.pdf	Carbon Stock change KPH Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\KPH\CarbonChange\300dpi	

Topic	File name	Content	File type	Location	Remarks
	KH_KPH_Carbon_ Change_1990_2000_600dpi.pdf	Carbon Stock change KPH Kapuas Hulu 1990 - 2000	PDF	\Maps\KapuasHulu\KPH\CarbonChange\600dpi	
	KH_KPH_Carbon_ Change_2000_2005_600dpi.pdf	Carbon Stock change KPH Kapuas Hulu 2000 - 2005	PDF	\Maps\KapuasHulu\KPH\CarbonChange\600dpi	
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	KH_KPH_Carbon_ Change_1990_2010_600dpi.pdf	Carbon Stock change KPH Kapuas Hulu 1990 - 2010	PDF	\Maps\KapuasHulu\KPH\CarbonChange\600dpi	
	MN_KPH_LandCover_1990_300dpi.pdf	Land cover KPH Malinau 1990	PDF	\Maps\Malinau\KPH\LandCover\300dpi	
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Topic	File name	Content	File type	Location	Remarks
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