PROJECT DESIGN DOCUMENT
REDD-plus Center of Excellence in Central Kalimantan
(REDD-plus COE)

-APPENDIX-

A joint initiative of:
JST-JICA Project of Hokkaido University
(Center for Sustainability Science, CENSUS), Japan and
The University of Palangka Raya (UNPAR), Indonesia

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Palangka Raya, Indonesia
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Letters of Support for the REDD-plus COE in Central Kalimantan

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APPENDIX 2.
Methods of Measurement, Monitoring and Sensing

2.1. The obtaining of ground based/in situ data:

Appendix Figure 2.1. Conceptual illustration of sensing elements at ground based/in situ

2.1.1. Vegetation Census

a) Vegetation: In situ vegetation data obtaining commonly includes data about forest species, density, height, chest-height diameter, etc. For example, a special measuring type can be used to measure the diameter of trees that converts the circumference of a tree to a diameter. Using this tape, foresters can quickly find the diameter of a tree. The diameter at chest height (DBH) is roughly 4.5 feet from the ground, but can vary with the investigator. A common procedure for tree diameter measurement includes: a) record the location and plot type; b) for each tree in the plot, write down the label and species. If a tree is more than halfway in the plot, count the tree, otherwise don’t; c) mark whether the tree is dead or alive; d) measure the diameter (DBH) of
each tree; e) calculate the average diameter for each species and each stand condition.

Regarding forest species in the peat land of central Kalimantan, on shallow peat around the margins of the peat dome, the peat swamp forest is a “mixed” peat swamp with up to 240 tree species per hectare; in the center of the peat dome, the forest is less diverse, has low canopy and the tree species number declines to 30-55 species per hectare (Page et al., 1999). This continuum of forest types may represent an ecological succession over time as shown by Pollen analyses from peat cores in Central Kalimantan (Morley 1981). Along a 25 km transect due west from Sebangau River to the peatland dome, Page et al. (1999) identified about 7 forest types, and those forest types are: Riverine forest, Transition forest (riverine – mixed swamp forest), Mixed swamp forest, Transition forest (mixed swamp – low pole forest), Low pole forest, Tall interior forest, and very low canopy forest.

b) Plant Growth and Biomass: Vegetation biomass refers to the weight of all organic matter comprising vegetation within a specific area. Above ground biomass refers to the weight of all organic matter comprising vegetation above the soil surface (Drake et al. 2003). Below ground biomass refers to the weight of the organic matter comprising vegetation below the soil surface within a specific area. Wet biomass includes moisture in the weight while dry biomass does not include moisture in the weight.

Between peat swamp forest subtypes, there are differences in above and below ground biomass. The total above ground forest biomass of peat swamp forests in Central Kalimantan varies from 314 t ha\(^{-1}\) for mixed swamp forests to 14t ha\(^{-1}\) for low pole forests. With the increase of peat thickness, the root biomass decreases (Sulistiyanto, 2004). Tree roots are believed to be the principal source of organic matter in an accumulating tropical peat deposit (Brady, 1997a).

For more details of Biomass Estimation and the carbon content of trees, refer to APPENDIX 8 and 9.

2.1.2. Geo Census

a) Topography: To measure field topography and geometry requires placing a simple reference grid on the field, usually by staking, and then surveying the elevations of the field surface at the grid points to establish slope and slope variations. Usually one to three lines of stakes placed 20-30 meters apart or such that 5-10 points are measured along the expected flow line will be
sufficient. For example, a border or basin would require at most three stake lines, a furrow system as little as one, depending on the uniformity of the topography. The survey should establish the distance of each grid point from the field inlet as well as the field dimensions (length of the field in the primary direction of water movement as well as field width). There are important items of information that should be available from the survey: (1) the field slope and its uniformity in the direction of flow and what is normal to it; (2) the slope and area of the field; and (3) a reference system in the field establishing distance and elevation changes.

**b) Peat depth:** To measure peat depth, usually a peat sampler or a cone penetrometer can be used. A peat sampler, for example the Eijkelkamp Peat Sampler, is usually made of stainless steel designed to sample soft, saturated soils. It uses a plate fin and a rotating half-circular sampler with a cutting edge along one side. Having reached the desired sample depth, the user turns the entire sampler 180 degrees clockwise. During turning, the fin remains in position as the sampler completes the circle, thereby forming an enclosed core sample. The action of the Peat Sampler makes it suitable for only saturated or very soft soils.

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**Appendix Figure 2.1.** Some equipment to measure peat depth

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**PDD of REDD-plus COE in Kalteng**
c) **Subsidence of peat:** In the ground measurement, the subsidence of peat can be measured by using an iron pole which is fixed to the mineral soil below the peat layer. To avoid the influence of the variation of the ground water level during the dry and wet seasons, frequent observation data covering both dry and wet seasons is needed.

Except for in situ measurement, the use of airborne LiDAR sensors is becoming an increasingly common and effective tool essential for peat subsidence measurement. Airborne LiDAR systems consist of a laser mounted beneath an airplane or helicopter that follows a predefined path. The ground is then scanned by means of tens of thousands of pulses per second emitted from the laser. In order to obtain measurements for the horizontal coordinates (X, Y) and elevation (Z) of the objects scanned, the position of the aircraft is determined using accurate differential GPS measurements and the distance from the aircraft to the ground calculated (Zhang et al. 2002). These measurements generate a 3-dimensional cloud of points with irregular spacing. The non-ground features can be removed to produce a bare earth digital elevation model (DEM). The algorithms to eliminate non-ground objects include Kraus & Pfeifer 1997, Pfeifer et al., 2001, and Vosselman 2000. The same with the in situ measurement, by the remote sensing method, multiple time series Lidar data covering both the dry and wet seasons, are needed in order to obtain accurate information.

Interferometry SAR (InSAR) is the most effective technique for measuring ground deformation from space. The principle of this technique has been well described and its algorithm and detailed parameters have been discussed by many researchers (see Appendix 2.2.1 b)).

### 2.1.2. Vegetation Census

*a) Water Table Level:* Mainly around the Sebangau and Kahayan River, the ground water level is measured every 10km or 1km, the hydrographs for which are installed in the vicinity of the abovementioned CO₂ sensor. This level is the water surface measured in the hole dug at the peatland. *(Appendix Figure 2.3)*

The control and measured data of sensors are stored in the field server, and periodically transferred to the villages via Adhoc networks. These measurements are made every day.
Appendix Figure 2.3. Measurement of Groundwater Level

b) Soil moisture: There are numerous techniques for evaluating soil moisture. Here we introduce briefly the gravimetric sampling method, the neutron probe and the touch-and-feel method.

Gravimetric sampling: it involves collecting a soil sample from each 15-30cm of the soil profile to a depth at least that of the root penetration. The soil sample of approximately 100-200 grams is placed in an air tight container of known weight (tare) and then weighed. The sample is then placed in an oven heated to 105 degrees for 24 hours with the container cover removed. After drying, the soil and the container are again weighed and the weight of the water determined by the before and after readings. The dry weight fraction of each sample can be calculated using Eq. 1. Knowing the bulk density, one can determine moisture content from Eq. 2 and soil moisture depletion from Eq. 3.

\[
W = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}}
\]  
(Eq. 1)

In Eq. 1, \( w \) is soil moisture reported as a dry weight fraction.

PDD of REDD-plus COE in Kalteng
\[ \theta = \frac{\gamma_b w}{\gamma_w} \quad \text{(Eq. 2)} \]

To convert a dry weight soil moisture fraction into volumetric moisture content, the dry weight fraction is multiplied by the bulk density and divided by the specific weight of water which can be assumed to have a value unit.

\[ \text{SMD} = (\theta_{fc} - \theta_i) \times \text{RD} \quad \text{(Eq. 3)} \]

Eq. 3 describes the calculation of the soil moisture deficit (SMD), which is a measure of soil moisture between field capacity and existing moisture content, multiplied by the root depth (RD).

*The neutron Probe:* This is another way to measure soil moisture. By this method, the neutron probe is inserted at various depths into an access tube and the count rate is read from the scaler. The manufacturers of neutron probe equipment furnish a calibration relating the count rate to volumetric soil moisture content. Field experience suggests that these calibrations are not always accurate under a broad range of conditions so it is advisable for the investigator to develop an individual calibration for each field or soil type. Most calibration curves are linear, best fit line of gravimetric data and scaler readings but may in some cases be slightly curvilinear (van Baaval *et al.*, 1963). The volume of soil actually monitored in readings by the neutron probe depends on the moisture content of the soil, increasing as the soil moisture decreases. The accuracy of soil moisture determinations near the ground surface is affected by a loss of neutrons into the atmosphere and soil moisture measurements with a neutron probe are usually unreliable within 10-30 cm of the ground surface.

*Touch and fill:* This is a means of developing a rough estimate of soil moisture. A handful of soil is squeezed into a ball. Then the appearance of the squeezed soil can be compared subjectively to the descriptions of table x to estimate the depletion level. However, the accuracy of this method depends on the experience of the sampler.

**Appendix Table 2.1. Guidelines for evaluating soil moisture by feel and touch (FAO)**

<table>
<thead>
<tr>
<th>Percent depletion</th>
<th>Feel or Appearance of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loamy sands to fine sandy loams</td>
</tr>
<tr>
<td>0 (field capacity)</td>
<td>No free water on ball</td>
</tr>
</tbody>
</table>

*PDD of REDD-plus COE in Kalteng*
<table>
<thead>
<tr>
<th>Range</th>
<th>Characteristics</th>
<th>Notes</th>
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<tbody>
<tr>
<td>0-25</td>
<td>Makes ball* but breaks easily and does not feel slick</td>
<td>Makes tight ball, ribbons easily, slightly sticky and slick</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Easily ribbons slick feeling</td>
</tr>
<tr>
<td>25-50</td>
<td>Balls with pressure but easily breaks</td>
<td>Pliable ball, not sticky or slick, ribbons and feel damp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pliable ball, ribbons easily slightly slick</td>
</tr>
<tr>
<td>50-75</td>
<td>Will not ball, feels dry</td>
<td>Balls under pressure but is powdery and easily breaks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slightly balls still pliable</td>
</tr>
<tr>
<td>75-100</td>
<td>Dry, loose, flows through fingers</td>
<td>Powdery, dry, crumbles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard, baked, cracked, crust</td>
</tr>
</tbody>
</table>

* a Ball is formed by squeezing a soil sample firmly in one’s hand

A Ribbon is formed by squeezing soil between one’s thumb and forefinger

c) Soluble carbon content: Most of the organic matter in the water column of lakes is generally in the dissolved form. The dissolved organic matter (DOM) in lakes or peat river streams consists to a large degree of colored humic substances, which are mainly imported from the terrestrial surroundings to the lakes. Because this complex organic matter is highly colored, the concentration of colored DOM generally correlates closely with the total concentration of dissolved organic carbon (DOC) (Kutser et al., 2005). In situ and laboratory soluble carbon content measurements (DOC/CDOM analysis) consist of the following steps.

**In situ sample collection:** Before sample collection, water sample bottles (HDPE) are cleaned using HCL 10% and left to dry; usually for each sampling point, more than 1 sample bottle is prepared. A water quality checker (Horiba multi checker) examines parameters of water samples including PH, TDS, Conductivity, DO, ORP, and temperature, etc. Before measurement, the water quality checker is calibrated. At each sampling point, write the sample code on label and fill to full the sample bottles with sample water and cover the bottles with lids. After this, put the filled sample bottles into an ice box immediately. After this, water quality can be measured with the water quality checker and the water depth at sampling point can be measured with a (laser) sensor.

**Preparation at Laboratory:** At the Laboratory, prepare the aspirator and filtration unit, membrane filters 0.5um, 0.2um, and distilled water.
**Water sample filtration procedure at laboratory:**

For the filtration of water samples, first insert the 0.5um membrane filter on the filtration apparatus, clamp it, and then pour a water sample from the bottle into the filtration apparatus, apply vacuum, collect the filtrated water, transfer it to the beaker glass, after this, rinse the filtration apparatus with distilled water three times, put it on tissue paper, wait for a while for it to dry, and then set the filtration apparatus up again. After this, insert the 0.2um membrane filter on the filtration apparatus and clamp it. Pour the filtrated water from the beaker into the filtration apparatus, apply vacuum, collect the filtrated water, transfer it to a new bottle, and write the sample code on the label. Put the bottles with filtered samples into the refrigerator/ice box. After this, rinse the filtration apparatus with distilled water 3 times. Follow a similar process for each water sample.

**CDOM analysis with Spectrophotometer SP-300:** The steps to measure CDOM with Spectrophotometer SP-300 (Appendix Figure 2.4) include the following: Filtrate the sample water with a 0.2 um membrane filter; turn ON the spectrophotometer, and allow the instrument to warm up for at least 20 minutes; select the wavelength by turning the wavelength knob to 420 nm; select the desired operating mode as “absorbance” (A) by pressing the Mode selector; fill a cuvette with distilled water for blank and set the cuvette into a cuvette holder; open the sample compartment cover, and insert the cuvette holder with distilled water into the sample compartment; close the sample compartment cover, set blank by pressing the 100% T/0-abs key until the displays show 100% T or 0.000A; remove the cuvette from the sample compartment; place the cuvette holder with the prepared water sample to be measured into the sample compartment, then read the absorbance value of the sample, and write the values in prepared data form. After this, remove the cuvette from sample compartment.

Appendix Figure 2.4. Spectrophotometer (SP-300) for measuring colored DOM in filtered water samples
**Dissolved Organic Carbon (DOC) measurement with a TOC analyzer:** Peat water contains about 1/3 of the carbon of the total carbon flux cycle in a peatland ecosystem. A peat water sample is analyzed with a TOC analyzer (Appendix Figure 2.5) to measure dissolved organic carbon (DOC). To analyze DOC, the water sample is filtered through Whatman GF/F (glass fiber/fiber) filters; after filtering, the sample is analyzed for the concentration of chlorophyll a (C<sub>chl</sub>) content with the ISO standard method based on measuring the chlorophyll absorption in ethanol at a wavelength of 665 and 750nm. To remove the suspended particulate inorganic matter, the water sample is filtered through pre-weighted GF/F filters. To remove the organic particles, the filters are combusted at 550 degrees for 3 hours. The amount of CDOM is expressed by the coefficient a<sub>CDOM(420)</sub> obtained from spectrophotometric measurements of filtered water (pore size 0.2um) in a 10-cm cuvette relative to a reference of distilled water. Samples for DOC are passed through 0.2um filters using acid-rinsed equipment and measured on a Shimadzu TOC-5000 total carbon analyzer after acidification and purging of inorganic carbon. Samples are stored under dark and cool (4 degrees) conditions in sterile polypropylene centrifuge vials (Falcon).

![TOC analyzer](image)

Appendix Figure 2.5. TOC analyzer for measuring DOC in filtered sample water

### 2.1.4. Atmospheric Census

**a) CO<sub>2</sub> Flux by Microclimate method:** As long-term monitoring is underway near Palangka Raya of Central Kalimantan, a Model Area for Intensive Study needs to be established in Central Kalimantan. A sensing network has been installed in the western part of the peatland of Central Kalimantan, where the town of Palangka Raya is located. The eddy covariance technique is now widely applied to monitor CO<sub>2</sub> flux above terrestrial ecosystems, because it provides net CO<sub>2</sub> exchange (NEE) between the atmosphere and the ecosystems at 30-min intervals from fluctuations of wind and CO<sub>2</sub> concentration measured on a tower. Using
empirical models, we can partition NEE into two biologically meaningful CO₂ fluxes: ecosystem photosynthesis (GPP) and ecosystem respiration (RE). Although the technique requires expensive instruments and a tower, it has its advantages, such as automated measurement and high-temporal resolution. Monitoring data is effective when using parameterization and validation of terrestrial biosphere models.

To investigate the effects of disturbances due to drainage, fires and El Nino events on the CO₂ balance of tropical peatlands, we have measured CO₂ flux using the eddy covariance technique at three different land-use types: an undrained swamp forest (UDF site) as a control, a drained forest (DF site) and a burnt forest after drainage (BD site) (Hirano et al., 2007 and 2009). The study area was located near Palangka Raya. Appendix Figure 2.13 shows an inter-site comparison of the annual sum of NEE from May 2004 to May 2005. During this period, no El Niño event occurred. NEE was positive at all sites. This means that all ecosystems functioned as a net CO₂ source including the undrained forest. The strength of the CO₂ source was the greatest at the burnt forest and the second greatest at the drained forest. In this area, farmers make fires for farmland management every year. Thus, even if no large-scale fires occur, a tropical peat swamp forest will be a CO₂ source to the atmosphere because of solar attenuation due to smoke.

From a 30m height tower, CO₂, temperature and vertical wind velocity are measured, and the quantity of CO₂ transmitted between the atmosphere and the vegetation is calculated. Measurement is made in the daytime and also in the night. For this measurement, anemometers, thermometers, and CO₂ sensors are utilized (Appendix Figure 2.6). Three towers are already installed in the burned, transient, and natural forest vegetated areas and CO₂ is measured by this method at each spot. These measured data and the in-and-out of carbon in the forest ecosystem measured by remote sensing as mentioned later are combined to estimate the quantity of CO₂ in the wider area.

The measurement is performed every hour and its data is stored up in the sensor control server, which is periodically transmitted by Adhoc NW to the villages covered by the wireless telecommunication networks.
Appendix Figure 2.6. CO₂ Measurement

b) Fourier Transform Spectroscopy (FTS): Fourier Transform Spectroscopy (FTS, Appendix Figure 2.7) is a measurement technique whereby spectra are collected based on measurements of the coherence of a radioactive source, using time-domain or space-domain measurements of the electromagnetic radiation or other type of radiation. It can be applied to a variety of types of spectroscopy including optical spectroscopy, infrared spectroscopy (FT IR, FT-NIRS), Fourier transform (FT) nuclear magnetic resonance, mass spectrometry and electron spin resonance spectroscopy. There are several methods for measuring the temporal coherence of the light, including the continuous wave Michelson or Fourier transform spectrometer and the pulsed Fourier transform spectrograph (which is more sensitive and has a much shorter sampling time than conventional spectroscopic techniques, but is only applicable in a laboratory environment).

The goal of any absorption spectroscopy (FTIR, Ultraviolet-visible ("UV-Vis") spectroscopy, etc.) is to measure how well a sample absorbs or transmits light at each different wavelength. The most straightforward way to do this is to shine a monochromatic light beam through a sample, measure how much of the light is absorbed, and repeat for each different wavelength. In absorption or emission mode, the system can resolve highly complex spectra into discrete lines for recognition and spectral assignment.

- Outstanding resolution across the entire spectrum
- Resolved linewidths of < 0.001 cm⁻¹
- Broad spectral range: from 5 cm⁻¹ in the far-IR to >50,000 cm⁻¹ in the UV
• Double-sided interferogram acquisition (option)
• Symmetric line shapes - due to high precision optics
• Easy range change - every experiment can access different sources and detectors without breaking vacuum.

An FTS system can be applied not only on the ground but can be airborne or employed in an airship. The system performance of airborne FTS is almost same as FTS on a satellite.

2.2. Satellite/Airborne Sensing

2.2.1. Satellite based sensing data obtaining and processing
One of the capabilities of the airborne/satellite sensors is to detect and measure, in multiple spectral regions of the electromagnetic spectrum, land cover and land use on the Earth’s surface. With the available sensors for this project, landcover maps at different spatial and temporal scales can be produced. For example with LANDSAT imagery, it is possible to produce land cover maps in scales up to 1:125,000, from dates as far back as the mid 70’s, for areas of considerable extension. To produce land cover maps with greater detail, there are other sensors available such as the ASTER and SPOT satellites, which allow producing maps in finer scales, up to 1:60,000 with ASTER images and up to 1:10,000 using the SPOT pan sharpened products (2.5 m of ground resolution). There are sensors such as IKONOS with 4m spatial resolution in multispectral bands and 1m resolution in the panchromatic band, with which land cover maps with higher spatial details can be produced.

Although the above mentioned sensors have the advantages of high spatial resolutions, they often have a limited number of spectral bands (spectral resolution), which cover in a coarse way.
different spectral regions in the electromagnetic spectrum, and do not allow discriminating earth objects in detail. For example, for land cover classification purposes, the above mentioned multispectral sensors allow producing generally broad land cover classes such as forest, grassland, bareland, waterbody, etc, but do not have the capacity to discriminate species of land cover in finer details. This can be solved by using hyper spectral sensors, which acquire information in many narrow, continuous, and contiguous spectral regions of the electromagnetic spectrum, allowing distinguishing many more objects with very specific spectral signatures, for example vegetation species and mineral components.

Other sensors, such as MODIS’s Aqua and Terra sensors have a much lower spatial resolution, but a very high temporal resolution (about 12/24 hours for revisit), and they are becoming ideal for the study of very dynamics processes (ex. thermal anomalies due to forest fires). With the availability of many diverse sensors mentioned above, it is possible to perform time series analysis to detect changes from one date to another (ex. deforestation, degradation, etc.).

**a) Remote Sensing by GOSAT satellite:** GOAST is equipped with two kinds of sensors: TANSO-FTS and TANSO-CAI. TANSO-FTS is designed for the observation of CO$_2$ and CH$_4$, etc., by Fourier Spectrometer. TANSO-FTS cannot make accurate observation in case of it being cloudy, but TANSO-CAI is used for the evaluation of the validity of the data of TANSO-FTS by observing cloud and aerosol conditions in the sky. The Density of CO$_2$ is measured using the absorption band of 1.57μm, and the influence of atmospheric pressure is proofread by the absorption of O$_2$ and the influence of temperature is proofread by thermal infrared *(Appendix Figure 2.8)* TANSO-FTS Observation Band and Atmospheric Absorption Curve Source:
TANSO-FTS space resolution is as low as 10km, but its spectrum wave resolution is very high, as much as 0.2cm⁻¹, which is suitable to monitor the density of CO₂ in a wide area. (The observation precision of CO₂ density has been confirmed.)

Bands 1 to 3 of FTS will provide the spectra of sunlight reflected from the earth's surface in the daytime and band 4 will observe light emitted from the atmosphere and the earth's surface throughout the day and night. The characteristics of sunlight reflection differ greatly between land and water surfaces. Seawater and freshwater absorb light which makes detection of the reflection difficult. However, in certain directions, sunlight is reflected as specular reflection and glitters brightly, so the sensor will target such points for observation over large water surfaces.

Appendix Table 2.2. Specifications of the Fourier Transform Spectrometer (FTS) sensor

<table>
<thead>
<tr>
<th></th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral coverage (μm)</td>
<td>0.758–0.775</td>
<td>1.56–1.72</td>
<td>1.02–2.08</td>
<td>5.56–14.3</td>
</tr>
<tr>
<td>Spectral resolution (cm⁻¹)</td>
<td>0.5</td>
<td>0.27</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td>Target species</td>
<td>O₂</td>
<td>CO₂ – CH₄</td>
<td>CO₂ – CH₄</td>
<td>CO₂ – CH₄</td>
</tr>
<tr>
<td>Instantaneous Field of View/Field</td>
<td>Instantaneous Field of View: 15.8 mrad</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of observation view at nadir | Field of view for observation (footprint): diameter of app. 10.5 km
---|---
Single-scan data acquisition time | 1.1, 2.0, 4.0 seconds
*) 1μm = 1/1000 mm

Source: [http://www.gosat.nies.go.jp/jp/gosat/page2.htm](http://www.gosat.nies.go.jp/jp/gosat/page2.htm)

TANSO-CAI will observe the state of the atmosphere and the ground surface during the daytime in image form. The imagery data from TANSO-CAI will be used to determine the existence of clouds over a wide area including the field of view of FTS. When aerosols or clouds are detected, the characteristics of the clouds and the aerosol amounts are identified. This information is used to correct for the effects of clouds and aerosols on the spectra obtained by FTS.

**Appendix Table 2.3. Specifications of the Cloud and Aerosol Imager (CAI) sensor**

<table>
<thead>
<tr>
<th></th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral coverage (μm)</td>
<td>0.370–0.390 (0.380)</td>
<td>0.668–0.688 (0.678)</td>
<td>0.860–0.880 (0.870)</td>
<td>1.56–1.68 (1.62)</td>
</tr>
<tr>
<td>Target substance</td>
<td>Cloud, aerosol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swath (km)</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>Spectral resolution (cm⁻¹)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: [http://www.gosat.nies.go.jp/jp/gosat/page2.htm](http://www.gosat.nies.go.jp/jp/gosat/page2.htm)

The data taken by the FTS and CAI sensors will be processed as shown in Appendix Figure 2.9. FTS-observed values provide spectra while CAI-based data will be used to generate cloud and aerosol information. These data will be combined together to calculate the CO₂ and CH₄ column abundances at observation points with no or only thin clouds and aerosol layer present. Furthermore, an atmospheric transport model will be used with the obtained distribution of column abundance of CO₂ to estimate the global distribution of CO₂ flux as well as the three-dimensional distribution of CO₂ concentrations.
Among spectra obtained with FTS, only those spectra with no clouds in the field of view of the FTS will be identified with the use of images from CAI. This is possible because the spatial resolution of CAI is high enough to detect cloud contamination in the field of view of FTS. The spectra with no clouds will then be analyzed using a numeric calculation method called the retrieval method based on the characteristics of absorption by gas, and the column abundances of CO$_2$ and CH$_4$ will be derived. The CO$_2$ absorption bands near 1.6μm and 2.0μm are quite important because they provide us with a large amount of information near the earth's surface where the changes in CO$_2$ concentrations are most apparent. The absorption band near 14μm is used for obtaining information mainly at altitudes of 2km and above.

Once enough points of data are accumulated, the acquired column abundances of CO$_2$ and CH$_4$ can be averaged on a monthly and quarterly basis, and mapped out globally. The next step in data processing is the estimation of the flux of CO$_2$ using the acquired column abundances of
CO₂. We effectively "reverse" the atmospheric transport model to trace the origins of the CO₂ detected by GOSAT, and estimate the flux of CO₂ on a sub-continental scale. The current method of estimating flux of CO₂ depends solely on ground-based observation data, which results in significant errors in estimations for regions such as Africa and South America, where observation points are scarce. GOSAT is capable of acquiring observation data almost uniformly around the globe and hence is expected to reduce errors in estimated CO₂ flux. Furthermore, using the distribution of CO₂ flux obtained in this manner and the atmospheric transport model, it will be possible to simulate the global distribution of CO₂ in three dimensions.

Over a three-day period, TANSO-FTS will take spectra from several tens of thousands of points distributed uniformly over the surface of the earth. Since analysis can only be done on cloud-free areas, only approximately 10 percent of the total number of observation points can be used for calculating the column abundances of CO₂ and CH₄. Even so, the number of data points significantly surpasses the current number of ground measuring points (currently under 200), and will serve to fill in areas where measurement has not been conducted to date.
The GOSAT operational path is shown above. Each color shows a neighbor path. Each path consists of 5 points as a global standard mesh point. Each color path recurs every 3 days. The left figure shows the down path from north to south, and the right figure shows the upcoming path from south to north at the same day.

Appendix Figure 2.10. GOSAT path calendar around Indonesia Kalimantan

b) Remote Sensing utilizing ALOS satellite: For the monitoring of the forests and peatlands of the cause of CO₂ emissions, ALOS and Aqua are utilized, in which the sensors fit for the observation of vegetation and the quantity of water in soil are mounted. The monitoring of the destruction of the forest is done by NDVI obtained from 22 visible and near infra range. As for CO₂ emissions from peatland, since it is believed to be caused by the dehydration of soil, its measurement is made by the monitoring of water quantity in soil. The estimation of soil water quantity applies the method of soil thermal inertia estimation obtained from the thermal infrared range, in addition the method using L-Band of PALSAL, too. (Appendix Figure 2.11).
These figures are one example of the public SAR picture. Red, green, and blue were allotted to the difference between the horizontally-polarized wave and the vertically-polarized wave, which is measured by PALSAR, and this image was made a color. It is shown that it is deforestation ground or not a forest seeing purple and a forest seeing green in a whole.

Appendix Figure 2.11. 50-meter mosaic image in Southeast Asia

Water level measurement of peaty soil could be measured by PALSAR. ALOS PALSAR is L band, and the vertical interval can be measured by using the characteristic that reflects in the surface of the water. The microwave scattered in it can be observed when there are algae and grass in the surface of the water though a complete surface of the water cannot be measured because it doesn't scatter.

The interferometer is processed to request an accurate vertical interval. It interferes with two observational data observed from the position where the satellite on the orbit equipped with SAR is extremely near, and it is the one to analyze the difference of phase information, and interferometry processing is looked upon as a technique for measuring and producing altitude data and the transition of geographical features. Aircraft equipped with SAR uses the same principle, too (Appendix Figure 2.12). It is thought that it is possible to measure it by the accuracy of several cm in the examination. It is preferable to be able to put the reflector with all sides of several meters on the surface of the water to measure it more accurately. However, it is a relative measurement in the interferometry processing, the data of a place that doesn't move
somewhere is needed, and a relative difference there can be measured.

![Interferometric processing result](http://www.palsar.ersdac.or.jp/e/data/interf.html)

**Appendix Figure 2.12. Interferometric processing result**

Source: [http://www.palsar.ersdac.or.jp/e/data/interf.html](http://www.palsar.ersdac.or.jp/e/data/interf.html)

The InSAR technique is divided into single pass method and repeat passes methods. The single pass method acquires two pulses scattered from different positions. The repeat pass method is generally subdivided into two passes and more than three passes. The two pass method requires a Digital Elevation Model (DEM) to remove the topographic component. The three methods require DEM which can be generated from SAR data. The Shuttle Radar Topographic Mission (SRTM) generated DEM globally in 2001, and 90m mesh DEM has been used in various research fields presently.

Excessive groundwater exploitation has caused serious land subsidence in many urban cities in the world. The InSAR technique has been introduced to detect land subsidence and identify the strong influence points, and good results were obtained (Massonnet and Feigl, 1998; Hirose *et al.*, 2001). Tropical peatland subsidence has occurred due to drainage development and peat forest fire. Although peatland subsidence has been reported by many researchers (Wosten *et al.*, 1997; Couwenberg *et al.*, 2010), there is no report using InSAR. ALOS/PALSAR is thought to be a powerful tool for peatland subsidence detection because of its high coherency. On the other hand, the conventional measurement method is important for subsidence detection. Differential GPS (DGPS) measurement enables us to provide accurate elevation data at a specific position. Thus, combining with the results of InSAR analysis and DGPS, the measurement is ensured of monitoring peatland subsidence.

*PDD of REDD-plus COE in Kalteng*
2.2.2. UAV Sensor/ Dropsonde

a) UAV (Unmanned Aerial Vehicle): The aims and operation of the UAV are described here, which enables the observation of ground surface topology, the state of fire, ground topology after the fire and other micro-points that cannot be obtained by the satellite system. This aerial vehicle is also set up to collect data from ground sensors through the wireless network system (APPENDIX 3).

Purpose and Observation Items of the UAV Sensor Networks are as follows.
i) Mere data obtained by the satellite system cannot reconstruct three dimensional information of the ground surface of the designated area; regular observation shall be done in order to obtain information on the whole area.

ii) In order to obtain the effect of wild fire in an inaccessible forest, the UAV sensor system shall be distributed such the difficult condition. Also, observation of the status of the ground surface after being burnt shall be measured for the study of counter-measures.

iii) In the near future, an ultra small passive type microwave sensor or absorption type sensor will be mounted on the UAV. The new UAV will be installed for the operation in order to measure the dissolved and exposed CO$_2$ on the ground or in the atmosphere.

iv) The UAV will correspond with ground sensors through a wireless telecommunication system and collect the data from ground sensors.

The System Structure is as follows.
i) Airframe : 1.5m wing span (Weight : approx. 4kg)

ii) Ground Station : Digital Map Display functions (2D, 3D), UAV’s Position, Track, Photo image, Flight Plan, Flight Monitor, Replay Display

iii) Camera: Day/Night Camera, Frame rate (for memory, transmit) selectable

iv) Battery: Rechargeable lithium battery (approx. 1 hour (Flying Range: approx. 50km as the crow flies)

b) Dropsonde: Dropsonde is a measuring instrument for observing the weather of the troposphere in the sky (Appendix Figure 2.13). The dropsonde is in contrast to the radiosonde which carries the observational sensors in a balloon from the ground to the sky. The dropsonde can choose the start points to drop while the radiosonde continues being able to choose the takeoff point on the ground. It is difficult to choose the points to observe in the radiosonde because the wind affects the elevation of the balloon. This is the most striking feature of the
The dropsonde is dropped usually with it deploying its parachute, and can be observed at constant intervals. Its frequency band used for wireless telecommunications is almost the same band as the radiosonde. Its observed metrological element also has no big difference from the radiosonde such as the temperature, humidity, the atmospheric pressure, the wind direction, and the velocity of the wind, etc.

Appendix Figure 2.13. Dropsonde


c) LIDAR: A LIDAR system can observe the atmosphere of the following items by setting up on the ground, and observing the perpendicular sky.

- Perpendicular distribution of clouds
- Perpendicular distribution of aerosol
- Perpendicular distribution of perpendicular distribution (Doppler lidar)
- Temperature of perpendicular distribution (DIAL)
- Velocity of the wind’s gas element density in a perpendicular distribution (Raman lidar)
- Atmosphere of steam (high spectral resolving power lidar)

A Difference Absorption RIDAR (DIAL, Appendix Figure 2.14) is effective for the
measurement of the atmospheric component. SO$_2$ (300 nm), O$_3$ (290 nm), and NO (227 nm), etc. are measured by using the dye laser and using the higher harmonics wave of NO$_2$ (The measurement wave length: 450 nm). Moreover, O$_3$ was measured by using the carbon dioxide gas laser. The measurement sensitivity at the ppb level necessary for the watch of a city atmospheric environment is obtained for these molecules by the DIAL measurement with the range discrimination. Recently, the DIAL system for air pollution measurement using the Ti sapphire laser and an optical parametric oscillator (OPO) are developed.

Appendix Figure 2.14. DIAL system (left) and MIE scattering LIDAR (right)

2.2.3. Geographic Information System (GIS)

The development of an MRV system requires the use of spatially referenced information, or *geoinformation*, such as satellite images (Appendix Table 2.4), digital maps, aerial photos, attribute tables, information collected from GPS field-surveys, among others. To be able to acquire, store, manage, query, analyze and produce new information based on the inputs, it is necessary to use the Geography Information System (GIS). The principle of GIS is to manage geoinformation based on its spatial reference, which allows identifying other datasets related to the same location on Earth. With GIS, datasets from diverse sources, scales, formats, dates and types can be integrated using spatial reference and processes such as re-projection, transformation and format exchange. GIS also facilitates sharing of all the datasets through desktop, mobile and Web mapping applications.
Appendix Table 2.4. Specifications of multispectral satellite images

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Resolution</th>
<th>Scene cover (km)</th>
<th>Launch date (Year)</th>
<th>Example of application for peatland management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High spatial resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUICKBIRD</td>
<td>450-900 (4 bands)</td>
<td>2.44</td>
<td>11.3*11.3</td>
<td>2001, Tree groups distinguish, limited area (Wang et al. 2004)</td>
</tr>
<tr>
<td>IKONOS</td>
<td>455-850 (4 bands)</td>
<td>4</td>
<td>11.3*11.3</td>
<td>1999, limited area (Wang et al. 2004)</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>500-1750 (4 bands)</td>
<td>20</td>
<td>60*60</td>
<td>1998, limited area (Wang et al. 2004)</td>
</tr>
<tr>
<td>SPOT 5</td>
<td>500-1750 (4 bands)</td>
<td>10</td>
<td>60*60</td>
<td>2002, limited area (Wang et al. 2004)</td>
</tr>
<tr>
<td><strong>Mid spatial resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTER</td>
<td>520-11650 (14 bands)</td>
<td>15, 30, 90</td>
<td>63* 74.7</td>
<td>2000, Middle -large area deforestation detection (Olander et al. 2008)</td>
</tr>
<tr>
<td>Landsat 5 TM</td>
<td>450-12500 (7 bands)</td>
<td>15, 30, 60</td>
<td>180*198</td>
<td>1984, Medium -large area deforestation detection (Olander et al. 2008)</td>
</tr>
<tr>
<td>Landsat 7 ETM+*</td>
<td>450-12500 (7 bands)</td>
<td>15, 30, 60</td>
<td>180*198</td>
<td>1999, Medium -large area deforestation detection (Olander et al. 2008)</td>
</tr>
<tr>
<td><strong>Low spatial resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODIS</td>
<td>400-14400 (36 bands)</td>
<td>250, 500, 1000</td>
<td>1200*1200</td>
<td>2000, Large scale deforestation detection</td>
</tr>
<tr>
<td>AVHRR</td>
<td>580-11500 (36 bands)</td>
<td>1000</td>
<td>2600*2600</td>
<td>1992, Large scale deforestation detection</td>
</tr>
</tbody>
</table>

*since May 2003, there has been a failure in LANDSAT 7 ETM+ scene corrector.

**Digital Terrain Models:** A digital terrain model is a numerical representation of a continuous terrain variable such as elevation, temperature, and slope. Digital Elevation Model (DEM) is one of the most frequently used digital terrain models which represent the terrain elevation (usually using as a reference the mean sea level). We are planning to use three types of DEMs: 1) Shuttle Radar Topographic Mission (SRTM), 2) ASTER imagery DEM, and 3) Laser Imaging Detection and Ranging (LIDAR).

- The SRTM was conducted by NASA in an effort to measure the elevation on almost all the Earth's surface. SRTM has a pixel size of 30 meters for United States and 90 meters for non-United States areas. Some of the main advantages of SRTM are: 1) as it was obtained by radar technique, the value of each pixel was individually “measured”, which was more accurate than the interpolated pixel values, for example contour lines interpolation. This advantage is more pronounced in the low elevation areas where the interpolation of contour lines is hindered by the lack of detailed contour lines, producing a "steps-like" effect, while SRTM has sufficient details to distinguish features such as coastal ridges, low river levees,
dunes etc. 2) SRTM results in a continuous surface, avoiding the possible problems originated in processing steps like mosaic production. 3) It is free and some institutions, like King's College from UK, have produced improved versions (references).

- ASTER DEM is created by the use of stereopairs of ASTER imagery (which bands), obtained in a slightly different point of view from the same study area, and by digital photogrammetric means, DEM is obtained. ASTER DEM has a spatial resolution of 30m.
- LIDAR is the most accurate DEM. It is acquired from an airborne platform using laser technology and high precision Differential Ground Position System (DGPS). A Lidar sensor scans the terrain using a laser beam with very high frequency pulses and measures the distance to the terrain in each pulse. Lidar obtains the elevation information not only from the terrain, but also the objects on it (vegetation, buildings, etc.). The result is known as Digital Surface Model (DSM) from which a very accurate DEM can be created by filtering the information using "last pulse". The DSM can be used to monitor land use change. Combined with DEM, LIDAR is often used to calculate forest biomass.
APPENDIX 3.
Sensor Network

The cause of many environmental and social problems in Central Kalimantan is derived from destruction of tropical peatland. Installation of a sensor network and satellite sensing will enable us to measure the quantity of CO₂ emissions and the ground water level accurately across a wide area. It will be a great help for planning how to effectively reduce the quantity of CO₂ emissions.

The ICT network is essential for the collection of data from sensors, and it will provide social benefits for the community in this rural area, as well. Delivery of a distance-learning network, information for industries (agriculture, fishery, forestry and so on), and a remote healthcare service through the network will provide immense benefits to the rural communities and improve people’s lives in this area (Appendix Figure 3.1).

Appendix Figure 3.1. Total management system of tropical peatland in Central Kalimantan
3.1. Sensors Network for Water Statue Monitoring

Sensors to measure water flow of the Sebangau and Kahayan rivers have been allocated from downriver to the upper stream of the rivers (Appendix Figure 3.2). The same sensors are set in the main canals that connect to these rivers (Appendix Figure 3.3). To research the effect of water flow from rivers and canals to the underground water levels of peatland, a lot of sensors that measure ground water levels have been allocated across a wide area of wet peat land, at 10-km intervals (Appendix Figure 3.4). For more accurate data, the same sensors are located at 1-km intervals at the southeastern area of Palangka Raya city (Appendix Figure 3.5).

These sensors provide GPS functions; therefore, the actual position of each sensor is easily located on a map. These position data of ground sensors will help to calibrate the location data that are collected by sensors mounted on airplanes and satellites. The sensors on airplane or satellite are able to observe the dynamics of greenhouse gasses and hotspots across large areas. The accuracy of these sensors is relatively rough; however, we can obtain accurate data set across large areas by calibrating these rough data with precise data from ground sensors. Greenhouse gasses and hotspots are observed with airplane or satellite sensors. The observation area covers the entire Central Kalimantan, including an area that is covered by a ground sensor network.

Appendix Figure 3.2. River sensor network
Appendix Figure 3.3. Canal sensor network

Appendix Figure 3.4. Broad range sensor network
Appendix Figure 3.5. Small range sensor network

3.2. UAV Sensor Networks

The aims and operation of the UAV (Unmanned Aerial Vehicle) are described here. The vehicle enables the observation of ground surface topology, the state of fires, ground topology after a fire and other micro-points that cannot be obtained by the satellite system. This aerial vehicle also handles data collection from ground sensors through the wireless network system (Appendix Figure 3.6).

3.2.1. Purpose and Observation of Items

i) Mere data obtained by satellite system cannot reconstruct three-dimensional information of the ground surface of a designated area. Consequently, regular observation shall be done in order to obtain the information of the whole area.

ii) In order to ascertain the effect of a wild fire in inaccessible forests, the UAV sensor system shall be deployed under such heavy conditions. Also, observation to determine the status of the ground surface after a fire shall be undertaken to study potential counter-measures.

iii) In the near future, ultra small passive type microwave sensors or absorption type sensors will be mounted on the UAV. The new UAV will be installed to measure any dissolved and
exposed CO$_2$ on the ground or in the atmosphere.

iv) The UAV will correspond with ground sensors via a wireless telecommunication system and collect data from the ground sensors.

### 3.2.2. Feature of the System

i) Data Collection with High Efficiency & Safety via the UAV
   - Eliminates the risk of human injury
   - In case of a crash, lowers the possibility of damage because it is small and light weight
   - Straightforward access to the area because it is an airplane, versus the difficulty of approaching on the ground

ii) Platform Appropriate for Sensing
   - No CO$_2$ emissions in comparison with a fuel engine because it is powered by electricity
   - Three-dimensional activity and operations from low ground level to high altitude in the sky

iii) Easy Operation
   - No special control skill required because of autonomous flight type
   - Easy flight plan; the route is input by clicking on the map on a PC display
   - Take-off & Landing require no special runway facility
   - Mobility (Transportability) ensured by only one vehicle because of the small scale of the system

iv) Robust functions for Sensing
   - Visual picture sensor (Day Camera) and thermal picture sensor (Night Camera) mountable
   - CO$_2$ sensor (small absorbing type) mountable
   - Data for flight position, altitude and shot point, time can be acquired
   - Data collected by the ground-installed type of environmental sensors can be collected in the vicinity of the sky above these sensors
   - Ground-installed type of environmental sensors and the UAV are capable of automatic wireless communication relay by Ad hoc Network technology
   - The real-time transmission of collected data (when wireless transmission is possible) and storage in the memory device mounted on the UAV

### 3.2.3. System Structure

PDD of REDD-plus COE in Kalteng
i) Airframe: 1.5m wingspan (Weight: approx. 4kg)

ii) Ground Station: Digital Map Display functions (2D, 3D), the UAV’s Position, Track, Photo image, Flight Plan, Flight Monitor, Replay Display

iii) Camera: Day/Night Camera, Frame rate (for memory, transmit) selectable

iv) Battery: Rechargeable lithium battery (approx. 1 hour Flying Range: approx.50km - as the crow flies)

As for the airframe, the most appropriate one will be selected from several kinds.

Appendix Figure 3.6. UAV Sensor Networks

3.3. ICT networks for the Solution of Social Problems

3.3.1 e-Agriculture

The most developed industries in the Central Kalimantan are the primary ones, such as agriculture, fishery, and forestry. These industries are deeply influenced by the natural environment, including climate, condition of soil, river, forest, and so on. We can collect basic information about nature through the sensor networks and make some adaptive plans based on the information. In such plans, trends of market prices will be combined as well. Then, producers in the rural communities can learn the adaptive plans that are delivered through the wireless network and they are able to earn a lot of money due to greater efficiency.

This system is adaptive for all kinds of primary industries. In this section, an ICT solution for
agriculture is explained (*Appendix Figure 3.7*).

For the development of agriculture in rural areas of the Central Kalimantan, it helps to understand what factors reduce the productivity of agriculture by monitoring weather, soil conditions, water conditions and quality, status of pest outbreak and many other factors. Then, appropriate plans to improve any inefficient production method can be proposed and presented to the farmers by simple “visualization”.

**a) Objective:**

i) To analyze the important factors that reduce agricultural productivity, such as weather, soil and water quality, an outbreak of pests, the growth of crops can be monitored by satellite and ground sensor webs and collected at the center on UNPAR.

ii) Developmental models for several crops can be created based on data from the sensor network. An optimum plan for cultivation can also be prepared including the price data collected in the market.

iii) The optimum cultivation plan and know-how for cultivation can be visualized and proposed to farmers through the computer terminal in each village.

**b) Operational Concept:**

i) Sampling of soil, water, chemical pollutants, pesky creatures, and environmental data in agricultural field and analyze them

ii) Mapping of the analyzed result on the map in the system

iii) To organize all data and create an integrated model to forecast crop production, outbreak of pests, and an optimal plan for crop cultivation

iv) To forecast the growth of agricultural products using meteorological data and to plan an optimal fertilizing schedule using analyzed data of soil and its nature

**c) Requirement for System:**

i) Installation of chemical analyzers for mercury, nitrogen, nitric acid, etc., (atomic optic absorber, chemical analyzer)

ii) The function of data imported from an analyzer (via RS232C, or LAN, etc.)

iii) Importing of environmental data

iv) Importing of satellite pictures

v) Display of various measurement data on the satellite picture

vi) The function of manually inputting observational data, such as insects and agricultural pest
d) System Configuration:
i) Analyzer for the quality of soil and water (analysis of mercury, nitrogen, nitric acid, etc.)
ii) PC (possible to import the data from an analyzer and to import the environmental data)

e) The Image of This System:

Appendix Figure 3.7. e-Agricultural System

3.3.2 e-Education
The major cause of the low frequency of educational opportunities in this area is due to the low literacy rate of the residents, which is caused by the location pattern of the villages: they are dispersed along the rivers. In a certain area, the number of villages almost corresponds to number of tribes, which requires the use of different languages. Therefore, delivery of an elementary language program of Indonesian to each village will build the basis of education and drastically improve the educational level of residents of the rural communities. An E-educational system also provides a higher and specialized educational program. Such a program will be provided for maintenance persons of the sensor network.
a) Objective:
i) To provide a basic education such as literacy in the Indonesian language and an elementary school program for rural inhabitants
ii) To equalize opportunities of education between urban and rural peoples by way of delivering school classes being held in urban areas to remote rural areas
iii) To realize the sustainability of a rural area, basic education for sustainability of the environment regarding the deleterious effects of illegal lumbering, mining, and burning forestry will be provided for all members of communities

b) Operational Concept:
i) 40 MB band (best case scenario) will be installed in small villages around Palangka Raya
ii) In each village, a thin client system “VirtualPCCenter” is placed as a terminal (Appendix Figure 3.7.)

c) Total Configuration: Single internet client is placed at the public organizations per 3 villages (e.g., Telecenter, Public Office, School), where the thin client system “VirtualPCCenter” is provided in a classroom style. Everyone can use the client system at their convenience for internet and e-learning. The necessary facilities (ex., server) are installed at the ICT Solution Center in UNPAR and are as concentrated as possible in order to assure the security and mitigate the burden of maintenance work on site. As for the individual contents, existing contents are utilized in principle, but it may become necessary to procure new contents to be produced depending on the situation on site.

d) Thin client system “VirtualPCCenter”: The Virtual PC Center thin client system, featuring disk-less thin client terminals and datacenter-consolidated virtual desktop environments, can reduce power consumption by up to 62% over conventional PC systems, as a system including the server. With a quiet, low-energy, low heat-emitting design, the US100/US110, the world’s smallest class thin client terminal, can also help reduce the power consumed by office air-conditioning systems.

In addition, network connection to virtual desktops from any location allows for secure use and this makes it easy to add to the client base. With Virtual PC Center it is possible to allocate applications according to the needs of each user and having a centralized location of Virtual PCs greatly simplifies maintenance and desktop management.
3.3.3 e-Human Health care (Appendix Figure 3.8)

a) **Objective:** To improve the healthcare/medical disparity in rural areas, we enhance health/medical services in the target area.

b) **Issues:** Opportunities to visit hospitals and healthcare centers are rare for the following reasons.
   - There are too few hospitals and healthcare centers.
   - Great distance and time are required.
   - Transportation and medical expenses are expensive. Lack of health/medical related knowledge
   - There are too few opportunities to access the information related to medical and health matters.

c) **Solutions and Services:** We provide the following services for people living in the target area by using ICT capability.
   - Remote Healthcare Consultation: Face to face consultation by video conference system
   - A regular Health Check Up: Monitoring and supervising Health conditions
   - An Integrated & Unified Healthcare Information Base: the basis for the establishment and provision of Healthcare Services from the local government
   - Healthcare information distribution and learning: Information on Health, Nutrition, and Disease Prevention

d) **Outcomes:**
   - Solving health disparity in rural area
   - Promoting prevention to disease
   - Improvement in health, improvement in QoL
   - Advancement of security and safety for patients and resident

d) **Outcomes:**
   - Solve health disparities in rural areas
   - Promote disease prevention
   - Improve health and Quality of Life
   - Improve the security and safety of patients and residents
e) Goals (Plan of a Target for Materialization):

- Increase the opportunity for health & medical checkups: Y times in X years
- Promote regular health checkups: introduce in M schools/L schools after N years

Appendix Figure 3.8. Overview of e-Healthcare Solutions and Services

f) Remote Healthcare Consultation:

- Objective: Increase the opportunities for residents to receive healthcare
- Service and Contents: 1) Consultation and guidance from doctors or healthcare staff to patients, 2) Inquiry from healthcare staff to doctor or healthcare staff in case of difficulty, and 3) Storing patient management data and consulting records into an Integrated Healthcare DB
APPENDIX 4.

Estimated Costs for an Integrated MRV-System

<table>
<thead>
<tr>
<th>Sensing</th>
<th>1st Phase (2012-2014) for Kalimantan: Landsat, SPOT, ASTER, Quickbird</th>
<th>2nd Phase (2015-2017) for whole Indonesia: PALSAR-2, GOSAT, HISUI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat</td>
<td>(Free)</td>
<td>(218US$/scene)</td>
</tr>
<tr>
<td>SPOT</td>
<td>(1143US$/scene)</td>
<td>(5US$/km²)</td>
</tr>
<tr>
<td>ASTER</td>
<td>(60US$/km²)</td>
<td>(2US$/km²)</td>
</tr>
<tr>
<td>Quickbird</td>
<td>(74US$/km²)</td>
<td>(1US$/km²)</td>
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<tr>
<td>PALSAR-2</td>
<td>(10US$/scene)</td>
<td>(10US$/scene)</td>
</tr>
<tr>
<td>GOSAT</td>
<td>(Free)</td>
<td>(Free)</td>
</tr>
<tr>
<td>HISUI</td>
<td>(5US$/scene)</td>
<td>(2US$/scene)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Area</th>
<th>Resolution</th>
<th>Scene Cost</th>
<th>US$</th>
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</thead>
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<td>23,667,000</td>
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<tr>
<td>Kalimantan</td>
<td>35</td>
<td>315</td>
<td>3,601,500</td>
</tr>
</tbody>
</table>

**Appendix Figure 4.1. Rough Cost for Sensing Kalimantan and Indonesia by Popular Sensors**

**Sensing**
- 1st Phase (2012-2014) for whole Kalimantan: >220,000 US$
- 2nd Phase (2015-2017) for whole Indonesia: >450,000 US$
- Total: >670,000 US$

**Monitoring**
- 6 Monitoring Sites (500,000 US$ / site for construction, and 100,000 US$ / site/year for maintenance): 3,600,000 US$
- 10 Monitoring Sites (300,000 US$ / site for construction, and 100,000 US$ / site/year): 4,600,000 US$
- Total: 7,200,000 US$

**Simulation**
- 2,000,000 US$
- Total: 4,000,000 US$

**After 2nd Phase (2017-) for whole Indonesia**
- 150,000 US$/year
- 800,000 US$/8 sites/ year

*high quality (to estimate CO₂ flux, Biodiversity & ecosystem, Water statue, Biomass), high resolution, and very low cost (comparing with other commercial sensors)*

**Appendix Figure 4.2. Estimated Rough Cost for Integrated MRV System**
APPENDIX 5.
Various Satellite Data Coverage Information

In tropical regions such as Indonesia, a major concern involving remote sensing is the cloud coverage problem of optical sensors such as LANDSAT, SPOT and ASTER. Following coverage maps show examples of areas that are difficult to observe by SPOT (left) and ASTER (right) in Kalimantan and West Papua regions in the case of less than 10% of cloud coverage in the image. Red circles show areas that were covered by ASTER instead of SPOT. Blue circles show areas that were not covered by either ASTER or SPOT. It is recommended to use mainly LANDSAT and ASTER supported by SPOT or High Resolution Sensors in terms of economic feasibility and wide ground coverage perspective.

Appendix Figure 5.1. SPOT(left) and ASTER (right) coverage maps in West/Central Kalimantan
Appendix Figure 5.2. SPOT(left) and ASTER (right) coverage maps in East Kalimantan

Appendix Figure 5.3. SPOT(left) and ASTER (right) coverage maps in West Papua
APPENDIX 6.
The Shimokawa town, Hokkaido (Japan) VER Example

1) The outline of Shimokawa-cho

Shimokawa-cho is located in the northern part of Hokkaido, and as of August 2009 it had a population of around 3,800 people, and there were around 1,850 households. The town is known as a “forest town” with an area of around 64,420 ha, of which 90%, or 58,277 ha, is dominated by forests. Shimokawa was first settled in 1901, at that time the main industry was forestry, but later a mining industry that mined in or near the town for 42 years, from 1941 to 1982, contributed to the development of the town. After the mine closed, the population also shrank and the current population is 25% of its peak. Against this background, the economy of the town has been supported by forestry and wood manufacturing, in particular the approximately 4,500 ha of municipal forest.

The Shimokawa’s basic forest management policy has been “sustainable cyclical forest management”, and where once in 1960 they were thinning and harvesting between 40 and 60 hectares annually, now they have established a sustainable forest management method.

Shimokawa has continued to consider ways of adding social and economic value to the volume of CO₂ capture by the forest since 2003. The four towns of Ashoro, Shimokawa, Takinoue and Bihoro established the “Association for the Promotion of Carbon Capture by Forest Biomass” (hereinafter, the “Association of towns”) in 2008.

The purpose of the Association of these towns was to improve the added economic value of CO₂ capture by enhancement of forest management and CO₂ emissions reduction by using biomass energy.

To set up the systems, a committee of seven experts including forest scientists, economists and lawyers was established, and in 2008 they held four meetings and set up a system plan for forest carbon sinks. In May 2009, they applied for the first registration of the J-VER forest management project system and on July 1, 2009 the registration was authorized. In addition, the Association of towns worked towards the inclusion of a biomass energy project under the J-VER registration.

According to an estimation by the Association of towns, registration of J-VER between the years of 2008-2012 can expect to yield about 38,000t - CO₂ by absorption credit (forest project) and about 4,100t - CO₂ emissions reduction credit.
The following is a representative definition of carbon-offset, and Figure 1 in ANNEX simply illustrates this definition: "a system whereby all members of society; citizens, businesses, NPOs/NGOs, local government, national government, etc., are aware of their own emissions of greenhouse gases and make an effort to reduce them autonomously by purchasing the reduction or capture of emissions occurring in another location to cover the portion which is difficult to reduce (known as credits) or, partially or wholly compensating for emissions by establishing activities or projects to reduce or absorb emissions in another location" (Ministry of the Environment of Japan, 2008).

Appendix Figure 6.1. Concept of carbon-offset
APPENDIX 7.
Research Proposal from LIPI

PEATLAND REFORESTATION AND REGENERATION IN TERMS OF REDD+ IMPLEMENTATION IN CENTRAL KALIMANTAN, INDONESIA

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INTRODUCTION

The estimation of the Intergovernmental Panel on Climate Change (IPCC) regarding the emissions from deforestation of tropical forest in the 1990’s is about 1.6 billion tons of carbon per year or as much as 20 % of total carbon emissions in total (Parker et al., 2009). Reduced Emissions from Deforestation and Forest Degradation (REDD) mechanisms are one of the best short-term alternatives for significantly reducing greenhouse emissions, thus contributing to minimizing the impact of global climate changes. REDD activities, or REDD+ when forest conservation and restoration are included, are geared to reducing the destruction of tropical forest in developing countries (Bonfante et al., 2010). REDD+ schemes offer economic incentives for conserving forests and associated carbon (C) stores in developing countries.

In Southeast Asia, including Indonesia, the conversion of peatland forest to oil palm and pulp wood plantations and the associated fires have been the main sources of greenhouse gas (GHG) emissions in the region during the past decades (Murdiyarso, et al., 2009). Total peatland in Indonesia is about 20.6 million hectares that are located on the 4 main islands, i.e. Sumatera (35 %), Kalimantan (32 %), Papua (30 %) and Sulawesi (4 %). Total carbon storage measurements in mangrove ecosystem including peat swamp in Indonesia is exceptionally high compared with most forest types, with a mean of 968 mg C/ha and a range of 863 – 1073 mg C/ha (Murdiyarso, et al. 2009). Besides its carbon stock function, peat swamp forest has other important functions; namely, hydrology and biodiversity. If the forest ecosystem is disturbed, then a greater intensity and frequency of natural disasters will be the outcome.

Based on Presidential Decree No 19/2010, as part of Partnership program between the governments of Indonesia and Norway, the REDD+ Task Force for Indonesia was established
on 20 September 2010. The president has selected Central Kalimantan province from the following eight other provinces as a pilot for testing the initial stage of REDD+ in Indonesia.

Katingan Botanical Garden is located in the Katingan Hilir Sub-district, Katingan District of Central Kalimantan province. The garden is one of the botanical gardens that were established under coordination among the Local Government (Katingan district), the Indonesian Institute of Science (in this case Bogor Botanical Gardens), and the Ministry of Public Works. The garden has an area of 127 hectares and is at an altitude of 40 m – 70 m above sea level and comprises 82 ha of dry land and 45 ha of peatland. The location is more or less level land with a slope between 0 % – 6 %. Starting from 2006, some important works have been done in developing the garden, i.e., completed and announced master plan, explored and collected plants, built the seedling shade house, built part of the main road (7 km), prepared, planted and grew the flora in the garden, made the garden map, and registered seedlings in the shade house and plants in the garden. At this time, as many as 985 collection plants and 818 roadside plants have been grown and recorded in the garden especially in the areas for Kalimantan fruit, medicinal timber and “dayak” traditional plants. Currently, the garden has 14 employees, who are managed by the Agriculture Service of Katingan District (Lestari and Widyatmoko, 2010).

As an ex situ plant conservation institution, a botanical garden can play important roles in preventing plant species from extinction and it has considerable potential in promoting research on the conservation, utilization, reintroduction/recovery/reforestation of tropical plant species, developing ex situ conservation areas and facilitating education/training activities (biology, agriculture, forestry and environmental); consequently, they provide material for the construction of policies concerning ex situ conservation of tropical plant species (Sari et al., 2005).

For lowland forests including peat forest in protected areas of Kalimantan, as much as 56 % from 1985 to 2001 has been logged and converted (Curran et al., 2004). In Central Kalimantan, deforestation rates of lowland forest including peat forest from 1985 to 2005 were 99,485 ha/year for production forest and 67,895 ha/year for conversion forest. To deal with deforestation of peat swamp forest, a program of reforestation and regeneration in terms of REDD+ implementation is very crucial. Up to now, the study of peat swamp reforestation and regeneration using selected tree species with high Carbon-sequestration and storage capacity has been very limited. The peat reforestation program needs many considerations including forest characteristics/types and floristic composition, limited data quantifying C-storage and C-sequestration at species level, the framework plant species method of the reforestation (selecting and testing plant species), types of degradation and time frame of the reforestation activities. A botanical garden has considerable capacity for research on those plant species’
reforestation and regeneration program. The proposed research that was carried out in the botanical garden was to answer the considerations in peat swamp reforestation program in terms of REDD+ implementation and strategy. The implications of the research will also provide materials for the construction of policies, for the surrounding community, for the researchers and their institutions, such as for scientific publications as well as to support the Katingan Botanical Garden in integrating its ex situ (through native plant collection) and in situ collection in terms of the adjacent peat swamp reforestation program.

The aims of the current study are (1) to recognize peat forest characteristics/types and their floristic composition, (2) to measure carbon stock and sequestration of each tree species in disturbed and undisturbed peat forests, (3) to select and test tree species for the reforestation based on their potential carbon stock and sequestration (4) to understand the regeneration of selected trees in a peat forest and (5) to determine the frame work and time frame of species’ method of reforestation in some types of peat swamp and degradation.

METHODOLOGY
1. Recognizing Floristic Composition and Peat Characteristics
   Determining Floristic Composition (species composition, stand structure) and Peat Characteristics (peatland type) will be done by conducting a vegetation survey and peat assessment.

   **Vegetation survey**
   The survey is going to be conducted on the natural peat swamp forest in Katingan Botanical Garden. This location is a representation of a natural peat swamp ecosystem in all of the areas in Central Kalimantan. Plots (20x20m²) will be placed systematically in the location. Then, determination of tree samples (diameter 20 cm up) and measurement of biotic factors (species name, diameter, and height) and abiotic factors (air temperature, air humidity and light intensity) will be carried out.

   **Peat assessment.**
   Peat swamps’ types will be characterized by peat depth, peat composition degree, and abiotic factors (like ground temperature, ground pH and moisture). Peat swamp types are going to be measured on the same plot as the vegetation survey.

2. Carbon Assessment and Tree Species Selection
   a. C-stock existing analysis
   
   C-stock existence is estimated using an indirect approach through the calculation of biomass in accordance with Brown (1997), where 50% of the
biomass is C. Biomass calculations are performed using the allometry equation (Hairiah & Rahayu, 2007; Ketterings *et al.*, 2001). The output of this phase is the value of C-stock of each tree species in tones/ha.

b. C-sink analysis

C-sink is a process whereby the leaves absorb CO\(_2\) in the air through the mechanism of photosynthesis. Measurement of inherent capacity of photosynthesis will be carried out on leaves that received direct solar radiation (lateral and overhead) by using a portable infrared gas exchange system (LICOR 6400XP). Measurements will be taken at the level of maturation of leaves young/moderate and open (fully expanded). The leaves will then be measured for their respiration. Then, extrapolation will be done by measuring foliage density per individual (with the Plant Canopy Analyzer) and nitrogen content in the leaves. The output of this phase is the value of the C-sink of each tree species in tones/ha/year.

c. Species for reforestation and regeneration will only be selected based on High C-stock and C-absorbent species using C-sequestration analysis as well as the survivorship of the species.

3. Understanding Regeneration of Selected Tree Species (Adopted from Forest Restoration Research Unit (2005))

Natural regeneration of tree species has been identified as understanding several factors that are directly or indirectly influential. Those factors are:

- Regeneration sources: Soil seed bank, stump or root re-growth
- Seed dispersal: Seed rain, seed dispersal agent, seed dispersion distance
- Seed predation
- Germination: seed dormancy
- Seedling establishment: seedling completion, weeds, seedling predatory
- Seedling survival: survival, re-sprouting ability

4. Propagating Selected/Targeted Tree Species

Propagation of selected species was conducted to determine the effectiveness of propagating these plants. These activities include: germination and seedling growth. Parameters measured in the germination are the water content of seeds, time of germination and percentage of germination. The growth parameters of seedlings measured were height, diameter, number of leaves and leaf area.
5. Initiating Reforestation by Outplanting Targeted/Selected Tree Species

Selected species are planted on two types of peatlands, i.e. disturbed and undisturbed peatland. Disturbed peat is peatland which has been degraded due to land clearing. Undisturbed peat is peatland which is still intact.

6. Monitoring and Evaluation

Monitoring is conducted while transplanting selected species in two types of peatlands. Parameters measured in the monitoring are:

c. Biomass measurement
d. C-sequestration
e. Plant growth and survival

PERSONNEL

Reni Lestari, Rosniati A. Risna, Yayan Wahyu C. Kusuma, Danang W. Purnomo, Didi Usmadi from Bogor Botanical Gardens (LIPI). Collaborators from Hokkaido University of Japan, Katingan Botanical Garden and Palangka Raya University will be designated later.

LOCATION AND TIMELINE

The primary project’s location is the Katingan peatland area, including the Katingan Botanic Garden, Central Kalimantan. The proposed project ideally will run from 2012 - 2022.

REFERENCES


Forest Restoration Research Unit. 2005. How to plant a forest: the principles and practice of restoring tropical forests. Biology Department, Science Faculty, Chiang Mai University, Thailand.


APPENDIX 8.
Research Proposal from LIPI

C stock and sequestration of the peat swamp forest and the role of biodiversity and species richness on REDD program in Central Kalimantan

Members:
Joeni S. Rahajoe, Marlina Ardiyani, Laode Alhamd, Bayu Aji Pratama, Fauzi Rahmat, Heru Hartantri, and Supardi Jaka Lelana

Indonesian Institute of Sciences

Introduction

Tropical peatlands are one of the largest near-surface reserves of terrestrial organic carbon, and hence their stability has important implications for climate change. In their natural state, lowland tropical peatlands support a luxuriant growth of peat swamp forest overlying peat deposits up to 20 metres thick. Tropical peat swamp forests may contain as much as 20% of the global soil carbon stock. They are threatened by large-scale deforestation, agricultural expansion (DeFries et al. 1999) and are susceptible to fire. An example was the conversion of peat swamp forest to rice fields in Central Kalimantan, in 1996. Called the One Million Hectare Mega Rice Project (MRP), it led to the establishment of big canals that resulted in the reduction of water levels in the peat swamp forest, and in the water from the peat swamp forest to Sebangau and Kahayan Rivers. This resulted in decreased primary production and lower water levels. As such, conditions are predisposed to fires; forest fires broke out frequently in Central Kalimantan (Boehm et al. 2005), and consequently decreased the biodiversity in the forest and attendant ecosystem services. Now, the MRP is a major fire “hot spot” region, especially in the dry season (Boehm 2004). There was also a rapid conversion of peat swamp forest primarily into un-used fallow land in 1999-2003. If the situation continues, it is very likely that most of the peat swamp forest resource in Central Kalimantan will be destroyed within a few years, which bodes for grave consequences for the local hydrology, climate, biodiversity and livelihood of the local people (Boehm 2004). As we mentioned earlier, forest fire is one of the factors of forest degradation in Kalimantan. At the end of the extreme dry season in 1997 (caused by ENSO), the biggest fires broke out over almost all forest types in Kalimantan and Sumatra Island. Forest fires have enormous impact on the tropical forest ecosystems and biodiversity (Barber and Schweithelm 2000; Page et al. 2002).
The estimated extent of spatial damage by fire during 1997-1998 in Kalimantan were 75,000 ha of peat swamp forest, 2,375,000 ha of lowland forest, 2,829,000 ha of land for agricultural, 116,000 ha of timber plantation, 55,000 ha of estate crops and 375,000 ha of dry scrub & grass land, or a total of 6,500,000 ha (Bapenas 1999). Forest fires occurred frequently during the past ten years, and repeated cycles of burning have completely transformed forests into grasslands or scrublands. In a study on the effect of forest fires on biodiversity loss carried out in the mixed dipterocarp forest in East Kalimantan, and undertaken after a forest fire, about 90% of 240 trees in a 1.6-ha permanent plot died (Whitmore 1984). Thus, the forest fires not only reduced the carbon stock but also lowered the biodiversity. Therefore, one important REDD component is also a biodiversity issue. To support this issue we have to prepare the biodiversity species richness data and also biodiversity mapping.

The peat swamp forest of Central Kalimantan is among the most extensive in Asia and contains an estimated total carbon store of 2.82–5.40 Gt (Page et al., 2002). Mitigation efforts such as avoided deforestation and fire suppression of peat swamp forest restoration should been identified as ways to reduce high carbon emissions from these ecosystems (Page et al., 2009) through estimating the tree biomass and its carbon. Several studies on standing-, dead-tree biomasses and their carbon had been carried out in Kahayan watershed with destructive sampling. The natural forest on peatland contained living plant biomass (600 t/ha) and carbon content (340 t/ha) that were about twice that of the other land uses (Ludang and Jaya, 2007). Dead plants on peatland have a biomass weight of circa 20 t/ha and carbon content of circa 11 t/ha.

Also, the aboveground biomass during the first 7 years since fire in unburned, once burned and twice burned forest in Sungai Wain, eastern Kalimantan was estimated by equation of Chave et al. (2005) for the trees with a DBH ≥ 5 cm and for smaller diameters using the biomass equation Chave et al. (2003). From our research in Bawan Village, above ground biomass estimation was recorded at 172.1 t/ha and carbon content was 81.15 t/ha in the low disturbance peat swamp forest (Rahajoe, unpublished data), and the above ground biomass almost double in the intact peat swamp forest (cir. 351.9 t/ha) with carbon content of circa 172.95 t/ha (Simbolon, unpublished data). This result was in line with the result of Ludang and Jaya (2007). Since 1997 up until the present, the estimation of biomass, C-stock and nutrient cycles was carried out in the peat swamp and heath forests in Lahei Village, Klampangan and Bawan Villages. Selected locations were intact and degraded peat swamp forests were mainly due to forest fire. From this research, the carbon sequestration of various ecosystems were recorded; therefore, we were able to estimate the Carbon sequestration and the reduction in CO₂ sequestration due to the land
conversion or forest degradation. In the forest ecosystem, not only the biomass, C stock and sequestration are important, but also the biodiversity loss.

As a component of the Copenhagen accord, REDD plus should be supported by all involved, such as researchers and stakeholders, as they prepare for the implementation of REDD by 2012 in Indonesia. This program is important to support reducing emissions by 26% in Indonesia, a formalized commitment of the Indonesian government. Therefore, we have to prepare for the monitoring, reporting and verification of the carbon initiative through the biomass and carbon stock estimation based on specific research approaches. In this context, this study seeks to achieve the following objectives: to estimate the biomass and carbon stock in the peat swamp forest including (above ground biomass, litter, dead wood, soil carbon, etc). And to determine the biodiversity, species richness and carry out biodiversity mapping (Collaboration with Hirose san) in selected locations. We, therefore, expect this study to offer policy-makers certain recommendations to support the REDD program through MRV (monitoring, reporting and verification) and to ensure the sustainable use and management of similar ecosystems.

**Methodology**

We will establish a plot in the intact and degraded peat swamp forest in Hampangan Forest (Palangka Raya University forest) based on a field survey. Two estimation methods will be used to estimate the biomass. The first is based on the Kauffman methodology for wetland area and a modification of the point-center quarter method (Muller Dumbois, 1974), and can be seen in the figure below.

Appendix Figure 8.1. Sample plots based on the Kauffman methodology for wetland area (minimal 5 – 10 transect for each ecosystem type)
(1) Soil samples will be collected by peat soil auger in 3 locations for each plot. The soil depth for C analyses will be separated into: 0 – 15, 15 – 30, 30- 50, 50- 100, 100-300 and >300 cm depth. Samples for bulk density/carbon concentration at least 50g – about 5 cm in depth, and a sample will be collected at the mid-point of the sample depth (e.g., 7.5 cm, 22.5 cm, 40 cm, 75 cm, 200 cm).

(2) Estimation biomass will be done by using a square plot with the modification models of Brown (1997) and Chave et al. (2003), based on tree height and diameter. To estimate above ground biomass, we will measure tree diameter at dbh by using diameter tape, tree height by using Haglof laser Vertex (1.6 Type).

**Establish Permanent Plots**

To estimate the species diversity and richness, we will establish permanent plots to study ecological aspects of the ecosystem. Three with diameter > 9.99 dbh will be recorded in a sub plot of 10 x 10 m². Three with diameter >4.99 - < 9.99 cm dbh will be recorded in a sub plot of 5 x 5 m², while a 2 x 2 m² sub plot will be used for seedling estimation. Important values will be calculated using Muller Dumbois method. Species richness will be estimated by ecological methods.

**Study Site**

Central Kalimantan is the biggest province on the island of Kalimantan. It is about 153,800 Km². It lies on the equator lines of 0°45 NL to 3° 30 SL, and 111° to 116° EL. The area is mostly covered by forest, about 67%, while swamps, rivers and lakes take up approximately 2% (Anonymous, 2001), and agricultural land about 7%, plantation land about 4.3 %, and settlement and building land about 0.81%. Palangka Raya is the capital city of this province, which is located in the upstream regions of Kahayan River. The town occupies an area of about 2,400 Km². Plantation area covers 3,139,000 hectares, and it contains plantation estates growing commodities such as palm-oil, rubber, rattan, coffee, cocoa and coconut. Food crops cover an area of 5,980,750 hectares. The topography of 32.97% of the area is flat, 9.83% of the area is hilly and 40% of the area has an extreme slope.

The biggest river in Central Kalimantan is the Kahayan River, which runs from North to South through Kualakulun and Palangka Raya. The upper stream and downstream are located in Kalukung Mountain and Pulangpisau, respectively. pH value in the Kahayan River was around
5.5 – 7.5 and 4.0 – 7.0 in the rainy and the dry season, respectively in the middle stream. Lower pH during the dry season is due to the strong effects of sulphuric acid discharge from pyrite-containing peat that appears during the rainy season (Haraguchi, 2005). One of the reasons for low water quality is gold mining activity. Nine hundred thirty-two gold mining machines were observed in 2003, and 999 machines in June 2004, from up to down stream of the Kahayan River. Hg (Mercury) content in the Kayahan River was 0.18, 0.39 and 0.23 ppb (part per billion) in the upper, middle and down stream regions, respectively (Kido 2009). A positive relationship between Hg content in the water or sediment and the number of the mining machines in Kahayan was observed, suggesting that Hg contamination was directly related to the gold mining activities (Yamada et al. 2005).

The annual precipitation in Palangka Raya was 2731 mm (average from 1989 to 2008). Monthly rainfall was in the range of 153.5 - 303.1 mm, and below 100 mm during a few months of the dry season. The annual mean temperature varies between 26.8 - 28.1°C. The lowest annual rainfall was recorded on 1996, 2001 and 2004, while the highest annual temperature was recorded in 1998, a year after the biggest forest fire broke out in Central Kalimantan.

Tropical peatlands are one of the largest near-surface reserves of terrestrial organic carbon, with 65% or more organic matter content (Mac Kinnon, et al. 1986), and they are ombrogenous (rain fed) (Mac Kinnon, et al. 1986). The peat deposits are usually at least 50 cm thick, but they can extend up to 20 m. Because peat swamps are not drained by flooding, they are nutrient deficient and acidic (pH usually is less than 4). pH was recorded around 3.4 in the natural peat swamp forest and between 3.5 – 4.1 in the agricultural land, while in the rice land pH was about 3.6.

References


APPENDIX 9.
Research Proposal from FORDA

CARBON MANAGEMENT IN TUMBANG NUSA PEAT FOREST
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Summary
Forest exploitation, forest conversion and forest fires all exacerbate global warming. Due to the high levels of carbon content in the peat swamp forest, it is vital that the forest be protected from deforestation and degradation. REDD is a scheme to reduce emissions from deforestation and degradation in Indonesia. The Forestry Research Institute (FOREI) of Banjarbaru is a research institute that conducts forestry research under the umbrella of the Forestry Research and Development Agency of the Indonesia Ministry of Forestry. To support the implementation of REDD in Central Kalimantan, FOREI Banjarbaru has a strategy to promote sustainable peat swamp forest management in the Tumbang Nusa forest research station (KHDTK).
This study consists of three outputs of integrated carbon management according to a JST-JICA project for wild fire and carbon management in peat forest in Indonesia. The objectives of each output are: (1) carbon assessment: by estimating the amount of carbon in biomass and peat; and by assessing peat decomposition and organic carbon loss; (2) carbon management: by estimating response and recovery of vegetation to climate change; (3) integrated peat management: by determining rehabilitation techniques in various succession stages of peat forest in KHDTK Tumbang Nusa.

I. MATERIAL AND METHODS

2.1 Study site
The study site is located in Central Kalimantan, at Tumbang Nusa Forest Area for Specific Purpose (KHDTK Tumbang Nusa), Banjarbaru Forestry Research Institute. The area of approximately 5000 Ha includes a large area of peat forest and shrubs. The KHDTK Tumbang Nusa lies on 0°8'48" - 3°2' 7" South Latitudes and 113°2' 36" - 114°44' 00" East longitudes. The elevation of this area is flat (slope 0 – 18%). The climate is tropical humid with a temperature range between 21°C - 23°C. The rainfall is between 200-3500 mm / year; wet months are October to March and dry months are June through August.
2.2. Carbon assessment

Classification based on imaging

The measurements of carbon in peatlands are conducted by classifying them based on:
- The dominant type: the area is classified based on site characteristics (shrub, secondary forest, after burn and bare land).

Definitions:
- Shrub: under storey vegetation, height < 2 m, non woody-plant,
- Secondary forest: log over area, unburned
- After burnt: after burnt forest vegetation
- Bare land: empty area, over- burned shrub < 20%

These vegetation characteristics is used to define carbon stock

Measurement of carbon stock on aboveground

Trees Species

The research project used various approaches in carbon stock estimation, such as biomass and carbon allometric model, Biomass Expansion Factor (BEF), and biomass allometric model with specific gravity. It used 100 trees of six different species. Species commonly found according to the forest inventory are: *Cratoxylon arborescens* Dyera spp, *Shorea teysmanniana* Xylopia spp *Quercus* sp *Combretocarpus rotundatus* Palaquium cochlearia H.J.L Knema mandarahan Warb *Neoscortechinia kingii* Pax.et.Hoffm *Diospyros*. The selected tree samples (100 trees) were used for carbon stock measurement.

The species were grouped as the type of growth (fast, medium and slow growing) on various sites (shrub, secondary forest, after burn and bare land).

Samples

Trees

Tree samples were selected by purposive sampling. Species and diameter distribution are considered when selecting the sample trees. Trees were selected proportionally per class diameter. DBH was measured using diameter tape on a standing tree. Biomass and carbon are measured from above and below ground biomass. Above ground biomass are branches, leaves, twigs, and stems, while below ground biomass is comprised of coarse roots. The total tree samples should consist of 40% small diameter and 60% large diameter (Brown 2002).
Litter
Litter was collected from permanent plots. Permanent 1 m x 1 m plots were established. In each of those plots, the litter was weighed to obtain the wet-weight. One hundred grams of litter is to calculate the dry weight. Laboratory analysis is then conducted to determine the carbon content of litter. This carbon content is used to convert the biomass into carbon-stock.

Deadwood
Dead wood data is collected by establishing 1 m x 1 m plots, using transects of 200 m for each stand, and 50 m sections between transects. The criteria for deadwood assessment is based on the remaining biomass and the level of decaying.

1. The remaining biomass
   A. 90% of the biomass remains; branch and a bit of canopy
   B. 80% of the biomass remains; only branches
   C. 70% of the biomass remains; small amount of branches

[Diagram of three trees, labeled A, B, C]
Source: Solichin

Appendix Figure 9.1. Type(s) of biomass remaining in the trees

2. Level of decay
   The level of decay is measured based on visual observation while hitting a dead tree with the back of a knife.
   1. Strong: hitting the wood with the back of knife, the knife will bounce back
   2. Medium: hitting the wood with the back of knife, part of knife (about half) embeds
   3. Decay: hitting wood with the back of knife, the entire knife embeds
   Ten samples are collected to analyze the solidity of each category.
Below ground

Soil
The soil sample is conducted on several land classifications. The sample pits are placed systematically at a distance of 100 m between pits. The soil sample is collected up to the depth of 100 cm with an assumption that soil depth is contributing to the emissions in the atmosphere regarding where the chemical process took place.

Appendix Figure 9.2. The sample pits

Sampling work procedure

Biomass
Tree samples were used to construct biomass and carbon content allometric models of peat swamp forest tree species. Briefly, the sampling procedures are using destructive tree as follows:
1. The dimensions of the sampled trees were recorded using stem diameter (DBH), height, and crown diameter.
2.a. Measurement of above ground biomass
   1. Harvesting the tree samples was done after each tree’s dimensions were recorded. A tree sample was divided into branches, twigs and leaves to reduce potential harvesting damage.
2. The fresh weight of each section was then measured. The stem section was divided into sortimens of 2 meters each. The total fresh weight of each tree is the sum of each section (branch, stem, twigs, and leaves).

3. Dry weight and moisture content of the tree sections were measured at the laboratory. A relationship between moisture content, fresh weight, and dry weight was used to determine the total dry weight of each tree. The relationship was calculated using the equation below (Haygreen dan Bowyer 1993):

\[ M_c \% = \frac{TDW - TDW}{TDW} \times 100 \% \] .................................(1)

The moisture content of each sample was used to determine the total dry weight of each tree, as depicted in the following equation (Haygreen dan Bowyer 1993):

\[ TDW = \frac{FW}{1 + \left(\frac{MC_c}{100}\right)} \] .................................(2)

Where: FW: the total fresh weight of the trees (kg); TDW: total dry weight of the trees (kg); KA_c: the moisture content of the sample (%); BB_c: the fresh weight of the sample (gr) and DW_c: the dry weight of the sample (gr)

Proportional samples of each section were as follows. 1) The stem was selected at three sections, top, bottom, and middle, with a sample length of 5 cm (plate) and the reason for this was that each section had a different moisture content (Einarsson et al 2005). 2) Branches and twigs were selected, as were (3) leaves; some leaf samples taken were as much as 300 gr. Dry weights were obtained after each sample was put in the oven at a temperature of 103 ± 2°C (Haygreen and Bowyer 1993) for 48 hours.

2.a. Measurement of below ground biomass

Coarse roots samples were excavated from the surface and then measured and weighed to obtain fresh weights of the roots. Using the same technique as the above ground biomass, determination of below ground biomass was made by measuring the dry weight and the moisture content.

**Determination of tree carbon content**

**Sample preparation at the laboratory**

Tree carbon content was used to determine carbon directly from each sample tree. Carbon content was measured for each section of the tree. The sample trees were used to measure the
carbon content and the moisture content as well. The total carbon was calculated from each section of the tree based on analysis per sample. The carbon content in each sample was used to determine the total carbon content of each tree; therefore, the carbon stock determination does not require a conversion factor (Brown, 1997; Heriansyah et al. 2002; Jepsen 2006; Samogyi et al. 2008; Nath et al, 2009). The common method used was pyrolysis/charcoal. Pyrolysis procedure is as follows:

1. Sample preparation
   - Samples of stems, branches, twigs, and leaves were meshed and 15 grams were used.
   - Each sample was dried out at a temperature of 103°C ± 2°C for 48 hours, after constant weight was reached, the moisture content was determined using a formula:

   \[ \text{MC} = \frac{a - b}{a} \times 100 \% \]

   *Where: MC: moisture content of sample (%); a: the initial weight of the sample; b: the final weight of the sample*

2. Pyrolysis phase:
   - At the initial phase, the samples were dried out at a temperature of 500°C for 3 hours.
   - Charcoal weight was obtained by weighing the burning result. Rendement charcoal from burning can be determined using this formula:

   \[ R\% = \frac{W_2}{W_1(1 - \%MC)} \times 100 \% \]

   *Where: R: rendement of charcoal; W_2: charcoal weight; W_1: initial weight; MC: moisture content of the sample at a temperature of 103°C±2°C*

3. Testing of the charcoal sample
   - Moisture content
   - Moisture content was determined by drying out 1 gram of sample at a temperature of 103°C±2°C for 48 hours. The water content is calculated as follows:

   \[ \text{MC} = \frac{a - b}{a} \times 100 \% \]

   *Where: MC: moisture content of sample (%); a: the initial weight of the sample; b: the final weight of the sample*
Where: MC: the moisture content of each sample (%); a: the initial weight of each sample; b: the final weight of each sample

- Volatile substance

Two grams of sample are dried out at a temperature of 600\(^0\)C for 3 hours. After the heating process was completed, the sample weight was measured and the weight loss determined. Determination of volatile substances was formulated as follows:

\[
K_{Zmm} = \frac{100 \times (a - d)}{a}
\]

\[
K_a = K_{Zmm} (\%) = Kb - Ka
\]

Where: a: the initial sample’s weight; d is the weight after heating; Kb: the weight loss; Ka: the moisture content; K\_Zmm: the volatile substance content

- Ash content

Ash content was determined by drying out 2 grams of each sample. Heating was carried out at a temperature of 600\(^0\)C for 4 hours on an open dish. Determination of ash content is expressed as follows:

\[
AC = \frac{100 \times (c - b)}{a}
\]

Where: AC: the ash content; c: the dish weight + ash weight; b: the dish weigh; a: the initial weight

- Determination of carbon fixed

Determination of carbon fixed was based on this process. Carbon fixed was formulated as follows:

\[
\text{fixed carbon}_i = \frac{\text{R}_i \times \% \text{carbon}_i}{\% \text{carbon}_i + \% K_{Zmm} + \% K_{abi}}
\]

Where: Ci: the carbon content of tree sections (stem, branch, twigs, leaves, and rots); R: charcoal rendement

Determination of tree carbon content

Carbon content of each section was determined by a relationship between charcoal rendement and carbon fix. Calculating carbon content was done as follows:

\[
C_i = B K_i \times \% R \times \% \text{carbon fixed}
\]

Where: Ci: the carbon content of tree sections (stem, branch, twigs, leaves, and rots); R: charcoal rendement
Data analysis

Carbon stock estimation on each tree

Allometric model based on biomass

Allometric modeling used regression analysis with the ordinary least squared method. The analysis established a relationship between biomass (tree sections) and dimensions of stands. The relationship was expressed by an allometric model of biomass estimation (*Appendix Table 9.1 and 9.2*).

**Appendix Table 9.1. Allometric model of biomass estimation**

<table>
<thead>
<tr>
<th>No.</th>
<th>Model Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$Y = a + bD$</td>
</tr>
<tr>
<td>2.</td>
<td>$Y = a + bD^2$</td>
</tr>
<tr>
<td>3.</td>
<td>$Y = a + bD^{-1}$</td>
</tr>
<tr>
<td>4.</td>
<td>$Y = a + b/D^2$</td>
</tr>
<tr>
<td>5.</td>
<td>$\ln Y = a + bD$</td>
</tr>
<tr>
<td>6.</td>
<td>$Y = a + b\ln D$</td>
</tr>
<tr>
<td>7.</td>
<td>$\ln Y = a + b\ln D$</td>
</tr>
<tr>
<td>8.</td>
<td>$\ln Y = a + b/\ln D$</td>
</tr>
<tr>
<td>9.</td>
<td>$Y = a + bD + cD^2$</td>
</tr>
<tr>
<td>10.</td>
<td>$\frac{YD^2}{D} = a + bD$</td>
</tr>
<tr>
<td>11.</td>
<td>$\frac{Y}{D} = a + b/D + cD$</td>
</tr>
<tr>
<td>12.</td>
<td>$Y = a + bD + cH$</td>
</tr>
<tr>
<td>13.</td>
<td>$Y = a + bD^{-1} + cH^{-1}$</td>
</tr>
<tr>
<td>14.</td>
<td>$\ln Y = a + bD + cH$</td>
</tr>
<tr>
<td>15.</td>
<td>$\ln Y = a + b\ln D + c\ln H$</td>
</tr>
<tr>
<td>16.</td>
<td>$Y = a + b\ln D + c\ln H$</td>
</tr>
<tr>
<td>17.</td>
<td>$Y = a + bD^2H$</td>
</tr>
<tr>
<td>18.</td>
<td>$Y = a + bD^2 + cH + dD^2H$</td>
</tr>
<tr>
<td>19.</td>
<td>$Y = a + bD^2 + cDH + bD^2H$</td>
</tr>
<tr>
<td>20.</td>
<td>$\frac{Y}{D^2} = a + bD^2 + bH^{-1}$</td>
</tr>
<tr>
<td>21.</td>
<td>$\frac{Y}{D^2H} = a + bD^2H^{-1}$</td>
</tr>
<tr>
<td>22.</td>
<td>$\frac{Y}{D^2H} = a + bD^{-2} + cD^2H + dH$</td>
</tr>
<tr>
<td>23.</td>
<td>$\frac{Y}{D^2} = a + bD^{-2} + cD^{-1}H + dH$</td>
</tr>
<tr>
<td>24.</td>
<td>$\frac{Y}{D^2H} = a + bD^{-2}H^{-1} + cH^{-1} + dD^{-1}$</td>
</tr>
<tr>
<td>25.</td>
<td>$Y = b_0D^{b_1}$</td>
</tr>
<tr>
<td>26.</td>
<td>$Y = b_0D^{b_1}H^{b_2}$</td>
</tr>
<tr>
<td>27.</td>
<td>$Y = b_0 + (D^2H)^{b_1}$</td>
</tr>
</tbody>
</table>


Where: $y$: Biomass estimation (kg/tree); $D$ is tree diameter (cm); $H$ is tree height (m) $a,b,c$ are the parameters of linear regression. Determination of carbon content involved multiplying with a biomass conversion factor by 50% (Brown, 1997; Heriansyah *et al.* 2002; Jepsen 2006; Nath *et al.* 2009).

Allometric model based on carbon content

The allometric model establishment uses the same method as the biomass estimation model. The general models are in Table 1. Carbon content was determined by entering an independent variable on the best model estimation.
The best model criteria

The criteria used to select best model are: the maximum of determination coefficient ($R^2$ maximum), the minimum of standard deviation (s), and the maximum of corrected determination coefficient ($R^2_{adj}$ maximum) (Draper dan Smith, 1992). The best model should comply to accurate and precise criteria. The criteria are aggregation deviation < 1% (AD) and relative deviation < 8% (RD) (Husch 1963 in Herbagung and Suhaaran 1983). The formula is:

$$AD = \frac{\sum Ya - \sum Yt}{\sum Yt} \times 100\%$$ ...................................................(11)

$$RD = \frac{\sum \left| Ya - Yt \right|}{\sum Yt} \times 100\%$$ ...................................................(12)

Where: RD: relative deviation; AD is aggregation deviation; Yt: biomass and carbon estimation based on the equation; Ya: the actual carbon and biomass based on mensuration; N: the sum of the tree model

The other criteria are PRESS (Predicted Residual Sum of Square) where the best model is the smallest PRESS.

Biomass expansion factor (BEF)

The BEF uses a conversion from inventory (volume) to biomass (Brown 2002; Lehtonen et al 2004; Lehtonen et al 2007; Chaidez 2009). The BEF formula is:

$$B_i = \frac{W_i}{V}$$ ...................................................(13)

Where: $B_i$: BEFi (stems, branches, twigs, leaves, and roots); $W$ is dry weight of each section; $V$ is stem volume

Determination of carbon stock required using a conversion factor. Determination of total carbon (above and below ground carbon) based on the value of BEF is formulated as follows (Somogyi et al 2008):

$$C = V \times D \times ExpF \times (1 + R) \times CF$$ ...................................................(14)
Where: C: total carbon (below and above ground); V is tree volume (m$^3$); D: specific gravity (tonne m$^3$); ExpF: Biomass expansion factor; R: Root to shoot ratio; CF: carbon proportion of biomass

The equation above requires value of R (Root to shoot ratio), which is the ratio between below ground biomass and above ground biomass. So that it can be calculated as (Vande Well 2005):

$$R = \frac{B_{\text{root}}}{B_{\text{stem}}}$$

(15)

Where: R: Root to shoot ratio; B$_{\text{root}}$: root biomass (kg); B$_{\text{stem}}$: stem biomass (kg)

**Comparison among carbon estimation methods**

**t-Test**

The purpose is to find differences from various carbon estimation methods. t-Test is as follows: (Steel dan Torrie, 1995):

$$t_i = \frac{\bar{X}_i - \bar{X}_1}{S_{i0.01} \sqrt{\frac{1}{n_i} + \frac{1}{n_1}}}$$

(16)

Where: Xi: means carbon stock with methods i; X$_1$: means carbon stock with direct measurements; n: number of tree

**Deviation**

Deviation is systematic errors with positive and negative value. The sources of deviations are measurement errors, to select sampling technique, and parameters estimation (Van Laar and Akca 1997). Relative deviation is:

$$e = \left( \frac{\sum_{i=1}^{n} (C_{c} - C_{e})}{C_{c}} \right) \times 100\%$$

(17)

Where: e: mean of deviation; C$_{c}$: result of carbon fixed estimation with conversion factors; C$_{e}$: result of carbon fixed with direct measurement; n: number of tree

Negative deviation indicates that the carbon estimation methods used are underestimates.
**Precision**

Precision relates to repetition and describes the extent to which proximity measurement values express as mean values (Van Laar and Akca 1997). Accuracy indicated standard deviation from carbon stock estimation errors, and was expressed as follows:

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left( \frac{C_{b_i} - C_{c_i}}{C_{c_i}} \right)^2}{n-1}} \times 100\%
\]  

Where: \(s\): standard deviation; \(C_{b_i}\): result of carbon fixed estimation with conversion factors; \(C_{c_i}\): result of carbon fixed with direct measurement; \(n\): number of tree

A lower value of standard deviation indicates that the carbon estimation method is of a higher precision.

**Accuracy**

Accuracy is a combination of deviation and precision. Accuracy described the distance of observations and actual values (Van Laar and Akca, 1997). Model accuracy showed a RMSE (root means square errors) value. RMSE is expressed below:

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{n} \left( \frac{C_{b_i} - C_{c_i}}{C_{c_i}} \right)^2}{n}} \times 100\%
\]

Where: RMSE: Root mean square error; \(C_{b_i}\): result of carbon fixed estimation with conversion factors; \(C_{c_i}\): result of carbon fixed with direct measurement; \(n\): number of tree

A lower RMSE value indicates that the carbon estimation methods have a higher accuracy.

**Carbon stock inventory**

The principles of carbon stock inventory are the same as tree inventory; carbon measurement based on stand parameters (diameter, height). Carbon stock measurement applied sampling methods. Generally, plot size was 20 m x 20 m (Navar 2009; Chaidez 2009). In this study, the plot size was 50 m x 50 m (0.25 Ha). This plot size is due to the spatial resolution of an image that is used, since the data inventory will use the image application.
Sampling intensity was based on the variety of the coefficient in the preliminary study. Variation coefficient was expressed follows:

\[ CV = \frac{Sy}{\bar{y}} \times 100\% \] ..........................................................(20)

*Where:* CV: variation coefficient (%); Sy: means of standard deviation; \(\bar{y}\): Average

Number of sample plot adjusted by variation coefficient was formulated as follows: Shiver and Borders 1996)

\[ n = \frac{4N(CV)^2}{(AE)^2N + 4(CV)^2} \] ..........................................................(21)

*Where:* \(n\): number of sample plot; CV: variation coefficient; AE: maximum sampling errors permitted (5 %); N: number of population plot

Number of total plots was the basis to adjust the plots of each stratum (peat type). The method of carbon stock estimation uses a double sampling with stratification. Number of plot in each stratum was calculated as follows:

\[ n_h = \frac{L_h}{L_N} \times n = P_h \times n \] ..........................................................(22)

*Where:* \(n_h\): number of plot in each stratum; \(L_h\): area of each stratum; \(L_N\): total area; \(n\): number of total plot

\[ \bar{\bar{y}}_d = \frac{\sum_{n=1}^{N} \frac{\hat{N}_h \bar{y}_h}{N}}{\sum_{n=1}^{N}} = \sum_{n=1}^{N} \frac{P_h \bar{y}_h}{N} \] ..........................................................(23)

*Where:* \(\bar{\bar{y}}_d\): means of carbon stock from double sampling with stratification; \(P_h\): proportion of each stratum; \(\hat{N}_h\): population/area of each stratum; \(\bar{y}_h\): means of carbon stock at each stratum

Total of carbon stock estimation was formulated follows:

\(\hat{t}_{ds} = N\bar{\bar{y}}_d\)
\[
S^2_{\tau_{\text{dss}}} = \sum_{h=1}^{l} \left( p_h - \frac{p_h}{n} \right) S^2_{h} + \frac{1}{n} \left( \sum_{h=1}^{l} p_h \bar{Y}_h \right)^2 - \left( \bar{Y}_{\text{dss}} \right)^2 \]

\[
S_{\tau_{\text{dss}}} = \sqrt{S^2_{\tau_{\text{dss}}}} \]

\[
S_{\hat{Y}_{\text{dss}}} = NS_{\tau_{\text{dss}}} \]

\[
\bar{Y}_{\text{dss}} \pm 2S_{\tau_{\text{dss}}} \]

Where: \( \hat{T}_{\text{dss}} \): total of carbon stock; \( \bar{Y}_{\text{dss}} \): means of carbon stock from double sampling with stratification; \( p_h \): proportion of each stratum; \( \hat{N}_h \): population/area of each stratum; \( \bar{Y}_h \): means of carbon stock at each stratum; \( S_{\tau_{\text{dss}}} \): Standard deviation of double sampling methods.

**Total carbon = above ground + below ground**

**Remote sensing application on carbon stock estimation**

Remote sensing application was conducted after the image correction. The principles of image analysis are:

1. **Making the measurement plot**
   
   Size of measurement plot is 50 m x 50 m². This plot is used as inventory and the inventory results is used in preparation and validation of carbon stock estimation models. The model itself is based on the relationship between carbon stock and spectral parameters (backscatter value). The Validation model used 30% of inventory data.

2. **Image enhancements**
   
   An image enhancement was done by geometric correction. The geometric enhancement is determined by a number of ground checkpoints (GCP). GCP should be spread out throughout the image that will be corrected. The GCP is acceptable if the RMSE value is <0.5. However, if the RMSE value is more than 0.5, the GCP should be reduced until it reaches less than 0.5.
3. Spatial parameters extraction

Extraction was carried out on each plot measurement. The extract was used as an input in the statistical analysis. Spatial characteristics are backscatter values on each band. Backscatter values on each band were used in modeling. Radar images have only two layers; namely, band HV and HH. Interpretation is needed to add a synthetic band. Synthetic bands were added as below:

\[
R_{ab} = \frac{HH}{HV}
\]

The parameter was applied to the construct carbon stock estimation model. The models tested are:

1. Linear model: \( Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_iX_i \)
2. Power model: \( Y = b_0X_1^{b_1}X_2^{b_2} \ldots X_i^{b_i} \)
3. Exponential model: \( Y = e^{b_0 + b_1X_1 + b_2X_2 + \ldots + b_iX_i} \)

Where: \( b_0, b_1, b_2 \ldots b_i \): parameters of regression; \( X_1, X_2 \ldots X_i \): Backscatter values

The best model was selected based on certain criteria. The criteria were the maximum of determination coefficient (R\(^2\) maximum), the minimum of standard deviation (s), and the maximum of corrected determination coefficient (R\(^2\)\text{adj} maximum) (Draper dan Smith, 1992), PRESS, and residual analysis. The best model was applied to carbon stock estimation.

2.3. Carbon management

Estimate response and recovery of vegetation to climate change (by establishing permanent plots/ Plot Ukur Permanen/ PUP)

The observation of vegetation recovery is carried out by vegetation analysis; establishing PUP in each site characteristics: Shurb, secondary forest, after burnt, bareland. The observation is conducted periodically.

The method that is used is a mixture of line methods and square methods in PUP. The size of PUP for each level of plant growth is classified below:
- Seedlings; with the plot size of 2 x 2 m
- Saplings; with the plot size of 5 x 5 m
- Poles; with the plot size of 10 x 10 m
- Trees; with the plot size of 2- x 20 m.
The plots will be established to measure density, frequency and dominancy of the vegetation as follows:

**Remarks:**
- **T**: Trees
- **P**: Poles
- **Sp**: Sapling
- **Sd**: Seedling

Appendix Figure 9.3. Permanent sample plots for measuring tree density, frequency, and dominancy

**Integrated peat management**

- This research will also contribute to integrated peat management activity by giving recommendations for rehabilitation techniques in various sites of KHDTK Tumbang Nusa with different dominant vegetation.
- The rehabilitation techniques for KHDTK Tumbang Nusa are determined by using digital imaging and estimation of vegetation response in PUP.
- The strategy of secondary peat swamp forest management is enrichment planting with indigenous commercial peat swamp tree species while in over burnt degraded peat swamp forest with dominant fern vegetation is by rehabilitation (Yuwati and Tampubolon, 2004).

**2.4. Capacity building**

This research will not only contribute to the science of carbon management at the REDD Center of Excellence, but it will also enhance the capacity of FORDA researchers providing training or short courses of carbon measurement and valuation, laboratory data analysis and GIS.