Sustainable Management of Peatland Ecosystems in Mekong Countries

Training Module 3
FIELD VERIFICATION AND MAPPING OF PEATLANDS

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1. Introduction

The Global Environment Centre (GEC) has developed a training module on field verification and mapping of peatlands in Mekong region, which links closely with the training module on the application of remote sensing (RS) and geographic information systems (GIS) for peatlands mapping. It has been prepared for the Project on Sustainable Management of Peatland Ecosystems in Mekong Countries (Mekong Peatlands Project) and it comprises training notes, two PowerPoint presentations and survey forms.

2. Preparation for field survey

Training Module 3 on Field Verification and Mapping of Peatlands will take us through the planning of a field survey programme and the fieldwork required to verify and map peatlands within a particular project scope. As a first step, it is important that field survey objectives and plans are developed that align to the needs of the overall project. It is assumed that stakeholders using these training tools will already be interested in peatlands and peat soils, will already be engaged with other stakeholders in the assessment, conservation or development of these areas, and will have overarching project objectives that relate directly to the need for verification and mapping of the peatlands. In the case of the surveys related to the Mekong Peatlands Project, the main focus of the peatland surveys is to help develop an indicative national map of peatland distribution in Cambodia, Lao PDR and Myanmar. However, the resources are not sufficient for country-wide surveys and will focus on certain target sub-regions. The focus in these areas will be to undertake rapid assessments to verify the presence of peatlands and validate the nation-wide potential peatland maps. The priority will be to identify as many different peatland sites and peatland types in the targeted regions of the respective countries. The project will however look in more detail at one selected “pilot site” in each country, namely Inle Lake peatlands in Myanmar, Peam Krasop Wildlife Sanctuary/Koh Kapik Ramsar Site in Cambodia and the Beung Kiat Ngong Landscape in Lao PDR. Some of the approaches described in this module – can be used to document more clearly and identify management issues related to these target sites.

2.1 Preparation of a preliminary map of potential peatland areas and survey plan

Prior to planning and starting fieldwork, it is essential that a preliminary map outlining potential peatland areas has been prepared. Preliminary maps will provide a basis for:

a) Planning and managing field work activities to maximize efficiency and effectiveness of ground surveys and sampling,
b) validation or ground-truthing of the mapped information and/or mapped predictions, and
c) verification of the presence or absence of peat soils and characterization of the peat types and vegetation types.

In addition, the preliminary maps will form the foundation for more detailed maps of peatland distribution and character following input of the newly acquired field data.

Training Module 2 in this series provided the basis for preparing such maps, and the details will not be repeated here. However, a summary overview of the required steps is provided below:

Preliminary maps of potential peatland areas should be as comprehensive as possible. Obviously, this will relate to several factors, such as budget resources available; capacity, skill and numbers of staff to do the mapping; and, amount of digital information already available. However, as a general rule the following information should be included on a preliminary map for ground truthing:

a) Available information of site topography, hydrology (natural drainage) and canal (built drainage) systems,
b) Base map of infrastructure (e.g. roads, settlements, etc.),
c) Available information on the boundaries and extent of existing wetlands or natural features (especially freshwater swamps and marshes, peat swamp forests, floodplain wetlands, etc.),
d) Available information on existing or potential peatlands (from previous project maps, reports, etc.), and

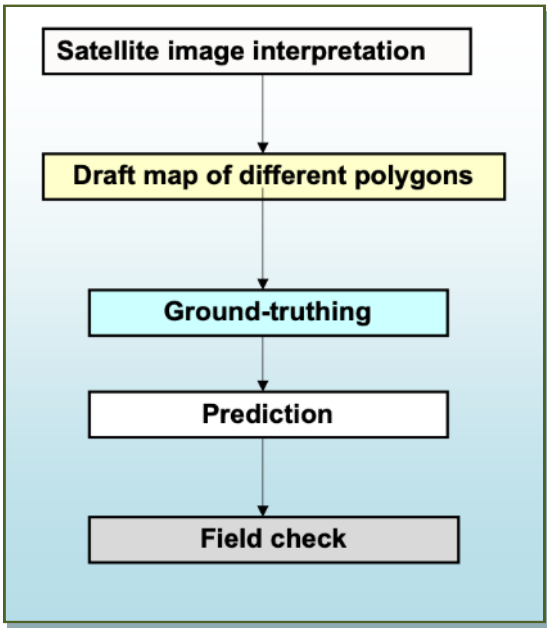
e) Planned survey access and routes to follow during field work.

The preliminary peatland map will provide the basis for planning the field itinerary. The extent of the potential peatlands mapped, points of access to these areas, potential routes through these areas, and the numbers and frequency of sampling required to verify the existence and extent of peatlands can all be determined from the map.

As a minimum, the field team should discuss these issues and plan survey access, routes and sampling locations based upon the preliminary peatlands map. Peatland ecosystems are often more difficult to access that other terrestrial ecosystems, and, it should be stressed that additional time requirements may be necessary to survey comprehensively. Always build contingency time into the field itinerary to allow for these circumstances.

The preliminary map will form the basis of a detailed map of results following the ground truthing and field surveys, so a more detailed and comprehensive preliminary map will provide a solid foundation for this analysis.

As such, if resources permit, prior to field surveys it is efficient to compile all available data on peatlands for the potential peatland areas and include in a GIS at the same map scale. This will include detailed information derived from sources such as a) satellite imagery, b) historical aerial or drone imagery, and c) landmarks, roads and rivers.



These vector layers should be generated and analyzed by spatial database technology. Universal Transverse Mercator (UTM) projection - WGS 84 datum should be applied to digitize the base map of the potential area.

The use of remote sensing platforms and ground-truthing practices are some of the techniques by which one develops the data to permit the classification. Satellite imagery should be interpreted to detect generally the distribution of wetland/peatlands.

2.2 Rapid Assessment of Peatland Ecosystems

This module includes a detailed methodology for comprehensive analysis of the presence of peatlands and peat soils based upon some quite sophisticated methodology (using satellite imagery, drones and soil sampling). In some cases, it may be necessary to undertake a "rapid assessment" to determine the presence or absence, extent, or type of peatland at a particular site. In other cases, sophisticated equipment may not be available, and the need to rely on simple techniques of field observation, sampling and recording will be necessary. These techniques can also be used as basic field data for each sampling point in a more sophisticated sampling and assessment programme. This section therefore outlines simplified techniques for the rapid assessment of peatland ecosystems.

Collect basic data at each proposed sampling point on the preliminary map to include information on date, location (GPS coordinates and marked on map), name of surveyor, and the natural features as outlined below. This data / information will be collected using a Rapid Assessment Field Description Form – as outlined in Annex 1.

The surveyor(s) will make an initial assessment of the sampling point based upon observation of soils, vegetation, hydrology, etc., before the use of more sophisticated sampling techniques (such as use of soil auger). Important field description parameters will be:

A. **Topography** – is the area flat, undulating or steeply sloped? Peat soils are more likely to occur in flat topography such as lake basins, floodplains (but may also form peat domes or sloping peat under some conditions). Take a photo of the landscape, note down the digital image number or any distinguishing features of the landscape in the photo.

B. **Soil type** – describe the soil on the surface – is it dark, light, smooth, lumpy? Dig down to 10cm and re-assess the soil – is it of the same type? If possible, dig further 30cm, 50cm to assess the same. If possible, try to view a deeper (1 to 2m depth) “soil profile” along a road cutting or channel edge as this will reveal the soil type without the need to dig down. Peat soils are dark brown / black in colour and consist of varying amounts of poorly decomposed organic matter (woody materials, leaf fragments, etc.). Smell the soil, decomposing organic matter will have a distinctive aroma. In some cases, taste the soil, peat soils have a distinctive earthy taste!

   Soils that are not dark brown/ black in colour are NOT peat soils – they can be classified or described by the amount of clay, silt or sand content they have. This can be easily assessed - take some soil and roll it into a sausage in the palm of your hand (you may need to wet it slightly to do this), soils with a high clay content will roll into long and thin sausages without cracking or breaking up; soils with a lot of sand content will easily break up and crack when a thick sausage is rolled. The more times you do this, you will start to understand where a soil type lies along the fine clay to fine silt or course sand continuum. Peat soils can sometimes contain quite a lot of silt or clay, so it’s important to determine how pure the peat soil is. It is also important to record any changes in soil types at the different depths (from a profile), and it will always be important to record how deep (cm from the surface) any peat soil layer is [note for the peat definition used in the Mekong region – the organic layer must make up at least 40cm out of the upper 80cm of the soil]. Take photographs of any natural soil profiles (sides of ditches, road cuttings, etc.) and take photos of soil samples from different depths if possible. A quick soil profile drawing can also be made to support your observations. A more detailed Peat Soil Profile Description is given in section 3.2 below, and a data collection form is provided in Annex 2.

C. **Hydrology** – describe (or measure) the depth of the water table (cm from surface) either by observation of natural water courses or channels / ditches, or by digging down (or inserting a rod or pole) into the soil until you find water (may not always be possible). Describe the direction and velocity of any water flows in natural streams or water ways or ditches and canals. Take a photograph of any natural water bodies.

D. **Water colour** – describe the colour and if possible, the transparency of the water found in any natural or man-made water features. Peatland water is usually high in humic acid due to the organic content and is rarely cloudy (usually a clear reddish-brown colour that resembles tea without milk). If the water if murky or cloudy this indicates a high clay or silt content. Take a photograph of any exposed water bodies.

E. **Existing Land Use** – make a note of current land use within the sampling area (100m radius). Is it under natural vegetation (disturbed or pristine)?; under an agricultural regime, if so which crops? Other land uses? Take a photograph of any dominant plants or crops.

F. **Natural Ecosystems** – if possible, make an assessment of the type of natural ecosystem the sampling point of located in. This may be described in general terms as forest, shrubland, grassland, wetlands (swamps, marshes, lakes, etc.). Describe levels of human disturbance – are parts being cleared for other land use, has the area been burnt? Has the top soil been disturbed by excavation, ploughing / tilling, etc.. Take photographs of any special features, plant species or disturbances.

G. **Biodiversity** – if possible, record any biodiversity encountered in the area. This is usually a specialist skill, but it may be possible to record the presence of larger water birds, larger mammals, characteristic or dominant plant species, etc., using photography, or local expertise (from local guides). Particular plant and animal species can be indicators of peatlands and peat soils, so its important to try and record / photograph such species. For instance, certain

Odonata (Dragonflies and Damselflies) species are restricted to peat swamp habitats in Southeast Asia, and their presence can be used as a strong indicator of peat soils.

2.3 Field equipment needs for peat survey

For a comprehensive site assessment, the following equipment is required:

i. Global Positioning Service (GPS) device – this is used to track and mark all sampling locations and other features that need to be mapped.
ii. Digital camera – a small digital camera allows reference photographs to be taken at each sampling location and to record other relevant features such as biodiversity, major vegetation species, etc.
iii. Soil auger set – this is necessary to make a detailed assessment of the depth and types of the soil within a deep soil profile. This is a large and heavy piece of equipment, and it requires at least two team members to transport and employ. If a soil auger set is not available, the field team should at least carry a heavy-duty spade or other digging tools to access below ground layers.
iv. Tape measure – to record soil profile depths, water table depths, etc., and for other general measurements.
v. Drone set with accessories – for aerial surveillance and photography.
vi. Mobile computers/ laptops – for data transfer, storage and field analysis.

2.3.1 Soil auger set

Soil auger sets generally have two different types of detachable “heads” – one for use in harder mineral soils and another specifically for softer peat soils (see Figures 1 and 2). Previous soil sampling surveys undertaken by the SEApeat project with the national teams in Cambodia, Lao PDR and Myanmar, showed that it is necessary for the field teams to carry both sets of soil auger “heads” into the field with them because sometimes peat soils are overlaid by mineral soils and vice versa and no single “head” is capable of sampling through all the layers.

It is therefore recommended to the relevant agencies to include a mineral soil auger head in addition to the peat sampler.

Figure 1: Peat sampler set

Figure 2: Mineral soil augers

2.3.2 Drone set and accessories

To support the field assessment, an unmanned aerial vehicle (UAV or more commonly a “Drone”) can be used to undertake aerial survey to enable the field team to cover a wider survey area (see Figure 3). Drones are useful in areas where access is difficult (which is often the case in peat swamp areas and wetlands), or where vegetation cover is dense (forested areas). Drones provide an instant aerial perspective on any site for the field survey team, and understanding and interpreting what can be seen through the Drone camera feed is an important skill to develop. Specific training in skilled drone operation for surveys is a prerequisite for the operation of these machines. Illustrations of different drone models are provided in Figure 3. Several key aspects in relation to preparing for and undertaking drone surveys are given in Annex 3.

(a) DJI Phantom

(b) DJI Mavic

(C) Fixed wing UAV

(d) Example of DJI Phantom 4 remote controller

Figure 3: Options of drone sets available to support field surveys (Source: internet)

3. Field survey

3.1 Field survey approaches and design

The design of any field survey programme is critical to its success. In most cases the field survey will have specific objectives and targets, relating to the overall goal of the project or initiative. The survey team should be asking themselves questions such as:

a) Where are the peat soils located in this area?
b) What is the extent (coverage) and depth of these peat soils?
c) What are the specific threats to peat soils in the area? Is drainage or burning a problem? Are peatlands in a natural or modified state? How have the peatland areas been used historically?
d) What are the key management scenarios for conserving the peat soils and their associated ecosystem(s) in the area?

These questions, will in turn determine the design approaches adopted during fieldwork. For the purposes of Training Module 3: Field Verification and Mapping of Peatlands we will assume that users will want to primarily answer the following two questions:

1. How to determine the extent of the peat soils?
2. How to determine the depth of the peat soils?

To determine the extent of the peat soils, it will be necessary to utilize existing digital maps and satellite imagery of the region to determine soil and land use types that may be indicative of peat soils (see methods used in section 3.1.1 below). In turn, these images can be used to design a series of transect surveys through the potential peat soil areas to determine their actual extent and condition (see section 3.1.2 below).

Likewise, to determine the depth of the peat it will be necessary to undertake a series of auger samples along these transects to determine the profile of the peat deposit and its relative depth throughout (see section 3.1.3 below).

3.1.1 Ground-truthing of satellite images

Satellite images provide a powerful and relatively easily available tool to detect the presence of peat soils and peatland ecosystems based upon the spectral reflectance of an image and the relevant topographical features of the land (Dirk et al, 2007, Alexandra et al, 2015). However, many factors on the ground may result in inaccuracies during image analysis (factors such as vegetation cover, standing water and soil types) and so it is always necessary to verify the analysis through ground-truthing.

Ground-truthing refers to the fieldwork needed to check the assessed regions of interest (ROIs) on the image, and to collect information from direct observations on the ground.

Ground-truthing enables calibration of remote sensing data, validates interpretation, and analysis of results and findings. The pixels associated with each ROI are assigned a uniquely colored polygon and overlaid onto the digital image. The soil type, vegetation type or other parameter under investigation for each specific polygon will then be checked in the field.

Figures 4 and 5 show examples of delineation of various polygons based upon the results of satellite image interpretation. Figure 6 shows data from satellite image interpretation in raster format to be converted to GIS in vector format. Design of field surveys must include the need to represent all different polygons and must be random within each polygon.

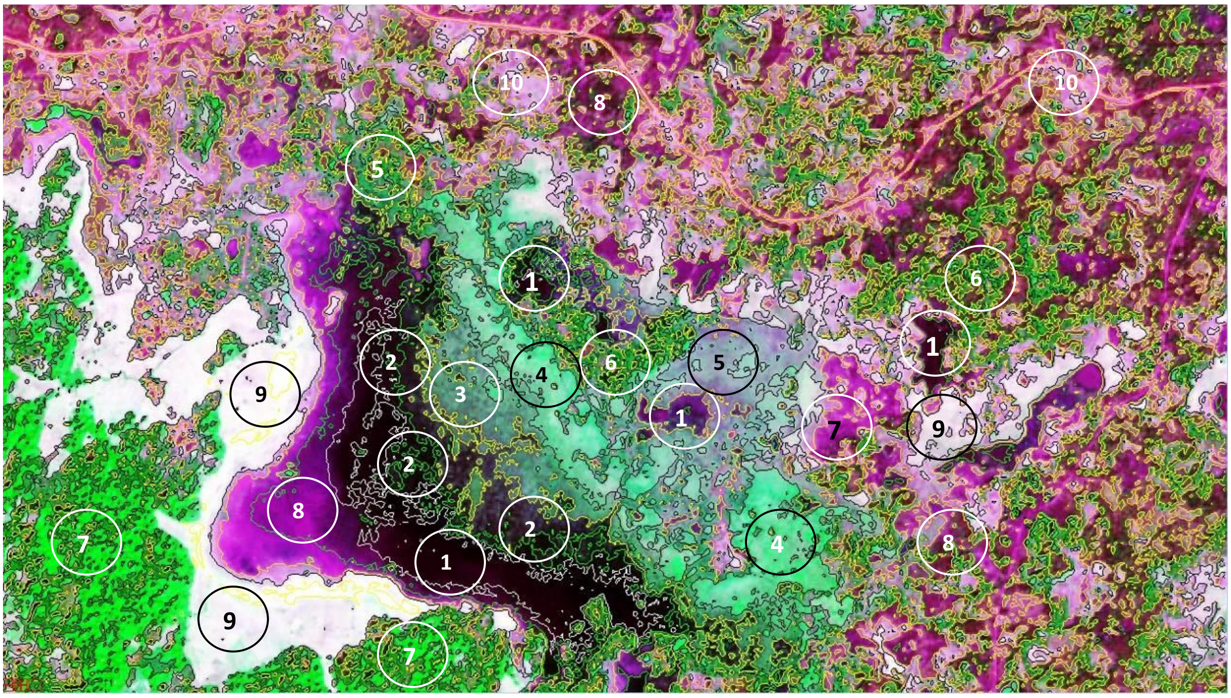
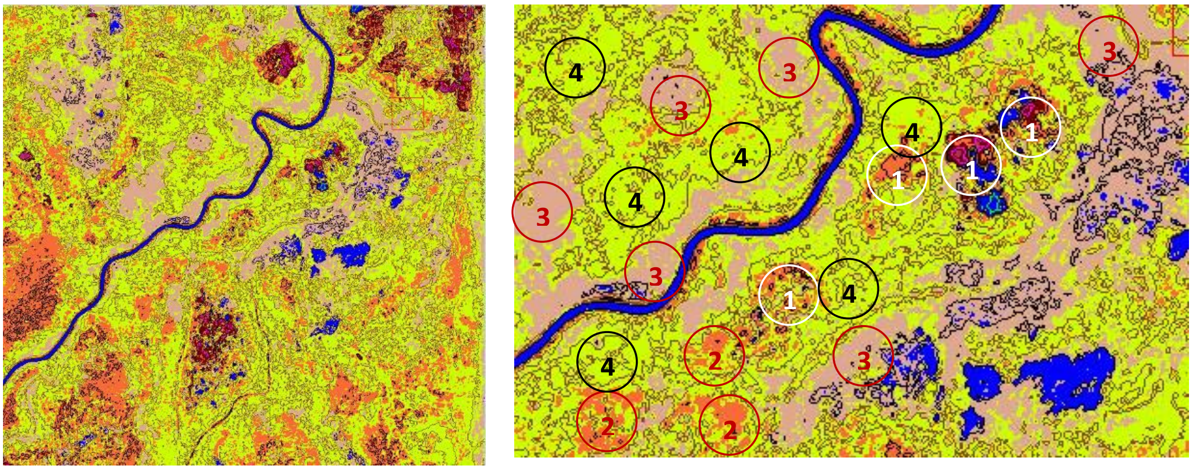


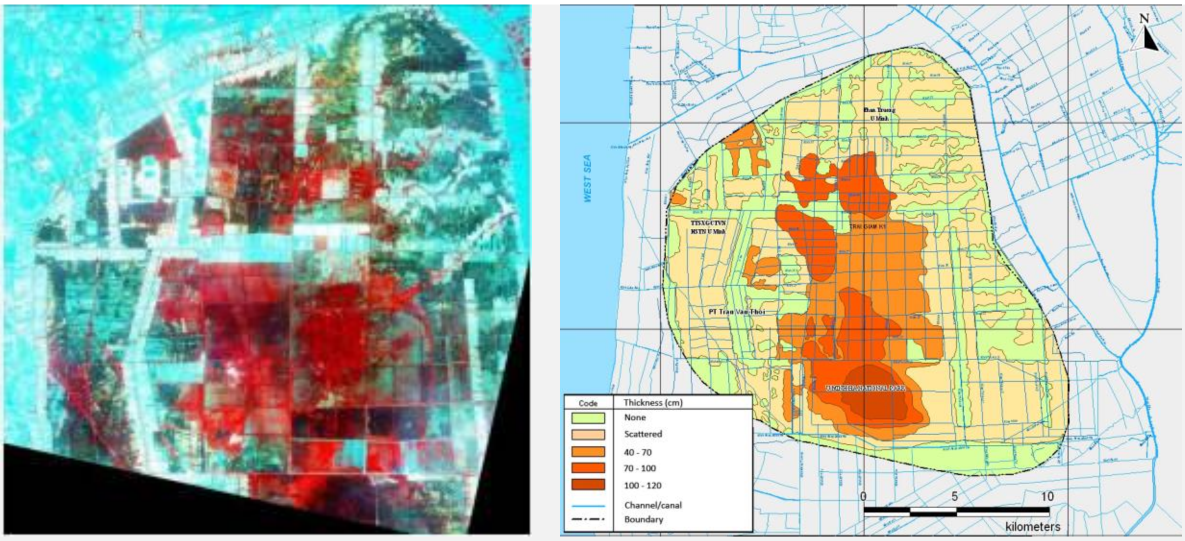
Figure 4: Delineation of various polygons of land-cover after classification in the Beung Kiat Ngong area (Pakse, Lao PDR). **Note:** (1) Peat marsh covered with aquatic plants, (2) Floating peat marsh covered with grass and aquatic plants, (3) Peatland covered with trees (peat-swamp forest), (4) Shrubs and grass, (5) Grass, (6) trees, (7) Forest in mountain, (8) Shallow water, (9) Bare land (sandy soil), and (10) Bare land (clay soil) (Quoi, 2019).



(a) (b)

Figure 5: (a) The satellite image is interpreted with different polygons contained various image elements. (b) Different polygons will be checked during ground-truthing. A part of Sentinel 2 satellite image downstream of Tonle Sap Lake (Cambodia).

The primary goal of ground-truthing is therefore to characterize and to identify soil characteristics, soil types, vegetation cover (plant communities) and habitats within the survey area. The collection of various data at each sampling point can vary, but we should always try to maximize our efficiency and collect more information than may be immediately necessary. Annexes 1 and 2 provide some specific guidance on what information can be collected in the field.



Raster image *Vector image*

Figure 6: Data from satellite image interpretation will be converted to GIS map (APFP, 2014)

3.1.2 Designing transect surveys

The techniques of ground-truthing data from specific polygons identified on the satellite image are an important first step in determining the presence of peat soils or peatland ecosystems. Once ground-truthing has verified the presence of peat, it will be necessary to undertake a more comprehensive field survey to determine the extent, condition and depth of the peat – these are achieved through a series of line transect surveys.

Line transect surveys can be time consuming and difficult (especially in peat swamp forests and wetlands), but a minimum of two perpendicular transect lines should be delineated through the main area of peat soil of peatland ecosystem identified on the satellite images. This arrangement is shown in Figure 7. With additional time and resources multiple line transects can be delineated through the peatland – this will improve the accuracy of the mapping of the extent and / or depth of the peat, but will not be necessary in most cases.

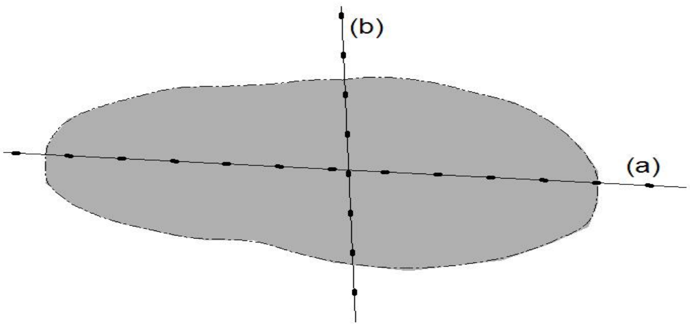


Figure 7: Illustration of two land transects crossing a peatland

Figure 7 is the ideal scenario, but it may not always be so easy to decide how to orientate the line transect.

Prior to delineating the alignment and length of a line transect, it will be necessary to consider the following factors:

a) Spatial distribution and landform characteristics of the peatlands to be surveyed:

   Not all peatlands will form a contiguous or homogenous area as shown in Figure 7. For example, in the Mekong region, there are various types of peatland which may each require a different line transect arrangement. These include, peatlands with a “peat dome” (U Minh Ha peatland, Viet Nam); peat swamp wetlands (Inle Lake, Myanmar and Beung Kiat Ngong, Lao PDR); and, coastal peatlands within mangrove forest (Botum Sakor, Cambodia).

b) Orientation of line transects:

Line transects should cross through areas where the thickness of the peat soil varies from thinnest to thickest layers.

For example, a line transect through a “peat dome” should cut through the edges and the maximum depth of the peat at the centre (as per Figure 7). A line transect through a riverine peatland (as per Botum Sakor peatland) should be oriented perpendicular to the river channel and cut through the peatland from the edge of the riverbank to the interior (see Figure 8), and a line transect for a peat swamp wetland along a lake shore (Inle Lake) will have a similar orientation (see Figure 9).

c) Sampling or observation points:

Depending on the length of the transect, a series of sampling or observation points will be established along the transect.

The number of sampling points depends on the length of the transect and the variation in the thickness of the peat layer and plant community. It may also be dependent on the time and resources available for survey. Sampling should at minimum follow vegetation changes along a transect – so if there are three obvious vegetation types there should be a minimum of three sampling sites. For relatively small peatlands- with a 500m transect line there may be three or four sampling sites (i.e. 125-160m). For a larger peatland with a 2km transect – there may be five or six sampling points (i.e. about every 500m). For very large relatively systems sampling could be every 1 km).

At each sampling point, a soil auger will be used to sample the soil (peat) composition and depth; and notes and photographs of the dominant vegetation type and plant communities, hydrology, water colour, and other observations must also be made.

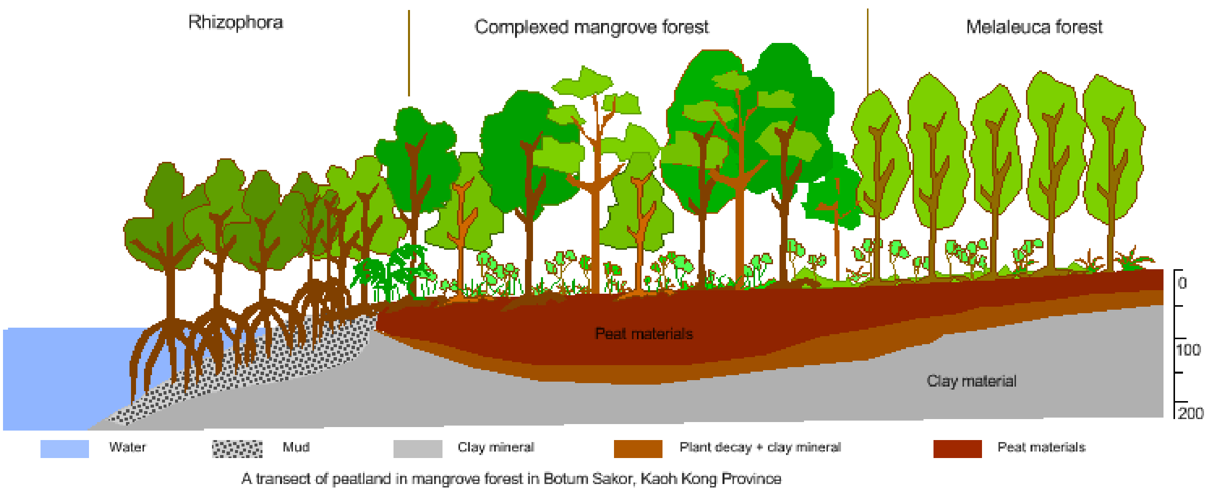


Figure 8: A land transect of peatland in Botum Sakor coastal mangroves (SEApeat, 2015).

(a) Tree in lakeshore peatland

(b) Grass and crop beds on floating peat mat.

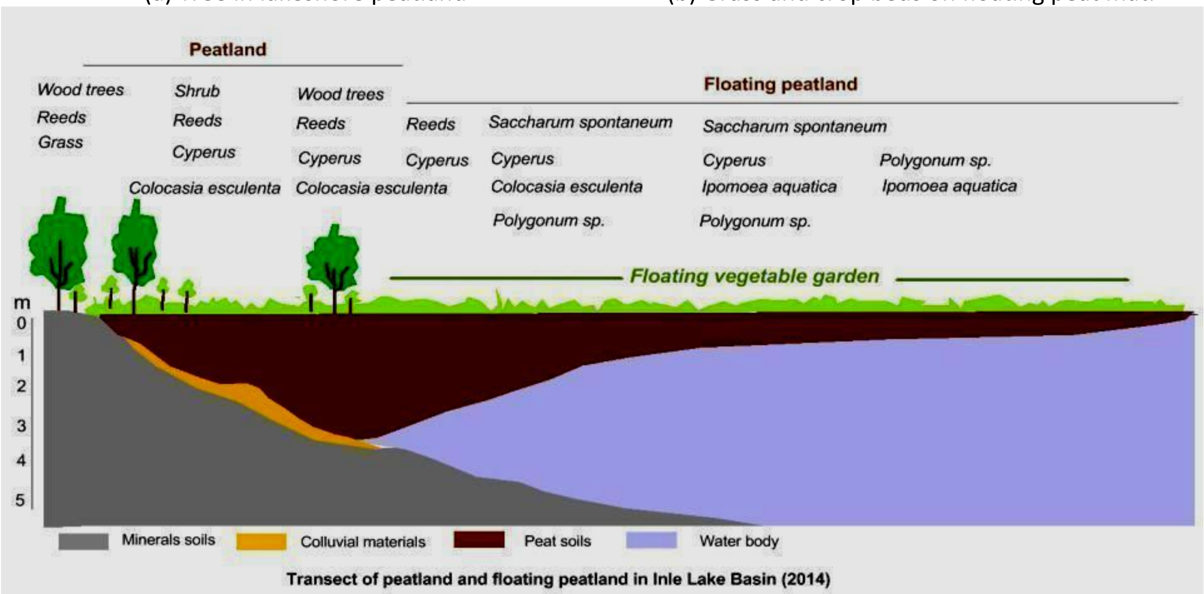


Figure 9: A transect illustrating the change of vegetation on floating peat mat and peatland in Inle Lake (SEApeat, 2014).

3.1.3 Soil sampling using a peat auger

A peat auger is used to check the depth of the peat soil and to extract samples from different depths for visual assessment and laboratory analysis. Figure 10 shows a complete peat auger set, consisting of a series of metal extension rods with a detachable handle and peat soil auger "head", and various tools for setting up and breaking down the auger. There are two types of detachable auger head, and it is important to have both a mineral soil head and a peat soil head in the field kit. The main section (sampler) of a peat auger consists of a hooked blade (fin) and a half-cylindrical tube (gouge) that has one sharp edge to cut the peat. The sampler can be easily connected to the extension rods and auger handle.

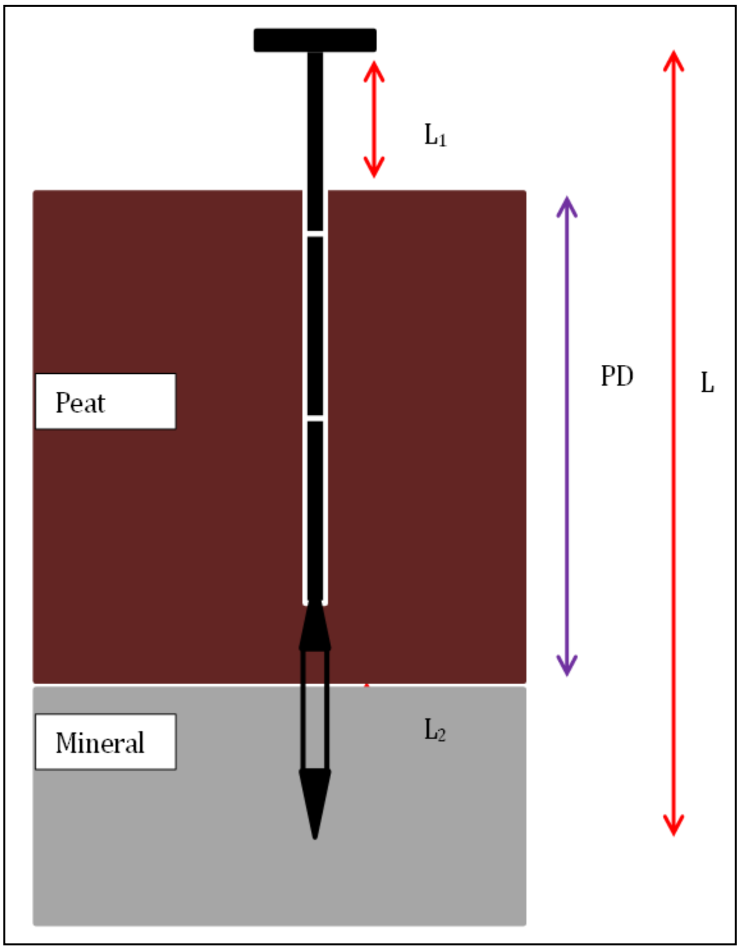
Figure 10: Peat auger set

A simple procedure for using the soil auger to measure peat depth is outlined below:

i. Attach the handle and the extension rods (remembering to add grease to the screw threads).
ii. Connect the main bottom section (gouge and fin) of the auger to the extension rods.
iii. Turn the fin so that the concave part is facing the outside of the tube.
iv. Drive the auger vertically into the peat without turning (until the sampler is fully under the surface).
v. Collect the sample by turning clockwise at least 180˚ (preferably a full 360˚ cycle) to ensure the gouge is filled with peat and the fin closes so that no additional peat enters the gouge as the auger is removed from the soil.
vi. Pull the auger slowly out vertically (without turning or twisting the auger) and lay it flat on ground to check the sample.
vii. Examine and take a photograph of the sample including a label with the site reference, sample number and depth (in cm).
viii. Remove a portion of the sample for further examination as needed.
ix. Clean the sampler.
x. Add an additional rod to the auger and reinsert the auger in the same hole and push it in a further distance equivalent to the length of the sampler.
xi. Collect the sample by turning clockwise at least 180˚ (preferably a full 360˚ cycle) to ensure the sampler is filled with peat and the fin closes so that no additional peat enters the sampler as the auger is removed from the soil.
xii. Pull the auger slowly out vertically (without turning or twisting the auger) and lay it flat on ground to check the sample.
xiii. Examine and take a photograph of the sample including a label with the site reference, sample number and depth (in cm).
xiv. Remove a portion of the sample for further examination as needed.
xv. Clean the sampler.
xvi. Repeat the process and extend length of the rods until reaching mineral layer.
xvii. Measure peat depth following the formula below.
xviii. After sampling disassemble and clean the rods and auger before storing.

IMPORTANT NOTE: As more extension rods are added to the auger, it is important to check that each tube is securely fastened to the adjoining tubes, failure to check may result in the auger head, or a section of it, detaching underground and being irretrievable.

Figure 11 shows how to calculate overall peat soil depth using the soil auger. Each extension tube has a set length and depending on the number of tubes fitted the depth can be calculated.



Peat depth = L – L1 – L2
where
L= Total length of the peat sampler used = Length of the handle + Length of the sampler + Length of extension rods
L1= length from the top of the handle to ground surface
L2= length of the sampler inside the mineral soil layer

Figure 11: Calculation of total peat depth based upon soil core measurements, number of extension tubes fitted and height of auger handle above ground surface.

3.2 Field Survey Data Collection

Previous sections in this Training Module have outlined how we identify potential peatlands using satellite imagery and ground-truthing; and how to establish a line transect to sample various points within the peatland for extent, characterization and depth of peat soil (if any), hydrology, vegetation cover, land use, ecosystems and biodiversity. This section provides an overview of field survey data collection.

The collection of peat samples (for later analysis) during the survey is quite important to assess the specific properties of the peat soils, as not all the properties can be determined by field observations. Depending on the study objectives, there are two methods to collect peat soil samples.

- *Use hand augers:* This method is used to determine soil type and depth of soil layers, including peat depth (Figure 12). Observing and describing soil profile based on soil layers stored in the auger tube. This method is also used for soil sampling for chemical analysis; however, it should be undertaken carefully to avoid disturbances that cause mixing soil materials between soil layers.
- *Typical soil profile (soil pedon):* In a detailed study of soil formation processes and properties as soil morphology and characteristics, a typical soil profile (soil pit) should be done. The general dimensions of the soil profile are as follows: horizontal 1.5 m, length 2.5 m, vertical 2.0 m (Figure 13). However, in peat soils with high water levels, it may be very difficult to dig a soil pit or it may require active use of a pump to remove the water from the pit.

A soil profile will be easy for the following assessments:

- Describe soil layers with basic soil components (peat soil profile description);
- Sampling to determine soil density values, especially for peat soils, water capacity assessment, and assessment of differential bulk density and characteristics of peat layers; and
- Minimise disturbance and mixing peat soil samples intended for analysis.

Figure 12: Peat profile in d-section of auger (Photo: Quoi, 2015)

Figure 13: Soil Pit (Photo: James Hutton Institute)

Sampling for soil bulk density analysis requires the use of a specialized sampling kit (See Figure 14). The soil sample used for analysis should be minimally disturbed.

Figure 14: A specialized sampling kit used for soil bulk density analysis (Photo: Quoi, 2018).

* Note: To assess the peatlands, a soil auger with 5 to 10 cm wide and 2 m or longer in length is used to determine the depth of the peat layer. If possible, typical sites will be chosen for soil sampling used to analyze soil bulk density and content of carbon and organic matter. Soil sampling depths from 0 to 200 cm, samples are to be taken from each peat layer interval of 20-50 cm (depending on the purpose of the sampling). For the purpose of the Mekong Peatlands Project, it is proposed that samples are taken at sub-surface (0-10cm); 50cm (45-55cm); 100cm (95-105cm), then 100cm increments, making sure that any distinctive peat layers are sampled.

3.2.1 Recording of samples

When conducting ground-truthing, some work needs to be prepared to carry out land information collection (soil and vegetation).

- site information sheets include a peatland description, natural conditions such as ground-water level, topography, landscape, ecosystem and vegetation communities, and land use status.

The soil sampling tools should include bags or containers to send samples to the laboratory for analysis. For example, plastic bags (e.g. zip-lock bags or normal plastic bags with ties) are used to store soil samples in case of chemical analysis or organic matter content e.g. Loss on Ignition (LOI). A soil bulk density sampling kit should be used when we want to take measured volumes to determine bulk density.

For field observations, all observed sites and soil samples that are gathered during the fieldwork should clearly be marked with a unique sampling reference number, geographical location, soil layer, and sampling date, as well as natural conditions in the sites. The precise locations of the observed sites have to be indicated on a site map and the GPS coordinates recorded; as it will later be very useful to refer to relevant data such as geological and topographical features, and other related information. For the recording of the soil samples, a soil samples log sheet should be prepared specifying the location of each of the samples and key conditions (See Annex 4)

3.2.2 Analysis of samples

Some preliminary analysis can be undertaken in the field such as:

a) pH (using a hand-held pH meter)
b) degree of decomposition (using the Von Post scale (see Training module 1)
c) Colour (using Munsell soil charts or other standard colour charts)

In order to define a peatland area and describe the main characteristics of the peat, some soil properties need to be determined through laboratory analysis.

- Percentage of organic matter (OM) in peat layers (through Loss-on-Ignition test)
- Percentage of organic carbon (C%)
- Composition of mineral fraction of the soil (i.e. if dominated by clay or sand)[1]
- Moisture content (%)
- Ash content (%)
- Values of soil bulk density of each peat layer (g/cm^3)

Analyzing the chemical and physical properties of peat soils will be expensive; therefore, depending on the purpose of the study, we must decide how many indicators will be analyzed. To define a peatland area, in addition to the minimum thickness of the peat layer required, the percentage of organic matter is the critical measure required for classifying peat soils.

After returning from the field, the samples should preferably be analysed promptly (within one week) although it will be possible to extend storage through refrigeration or freezing.

For determination of organic matter, the samples need to be weighted and then dried in an oven for at least 12 hours at a temperature of 105°C. The difference in weight between the wet sample and the dry sample (LOI_{105}) will give the moisture content. The sample should be homogenized (e.g. by passing through a 0.5mm sieve). The sample should then be burnt/ashed in an oven for 4 hours at 550°C which will burn off the organic matter. The difference in weight between the dry and the ashed sample (LOI_{550}) will give the percentage organic matter. The carbon content can be determined through other tests or calculated from the LOI_{550} by multiplying by a factor of 0.5 (given that approximately 50% of the organic matter can be considered as carbon)[2].

In sites which may have a significant content of calcium carbonate in the peat (such as calcareous mound springs), samples can be further ashed at 950°C which will burn off the carbonate and enable the carbonate content to be determined (LOI_{950}). However, this measurement would only be needed for more detailed assessments/research.

[1] The determination of the nature of the mineral fraction is only needed to confirm the presence of peat in cases where there is relatively low % organic matter (less than 30%).
[2] The actual carbon content may vary slightly between different peat types but for the purpose of the Mekong Peatlands Project 0.5 is adequate.

3.3 Drone survey

3.3.1 Mapping with drone

Drones are being used more and more frequently to support field surveys. Drones are particularly valuable when large areas need to be covered, and/or are not easily accessible. There are several types of drones available depending on functions and coverage range. Compact sets such as DJI Phantom and Mavic Drones are commonly used and have a flying range of 2-3km and 15-20 minutes flying time. There are also fixed winged unmanned automated vehicle (UAV) which can travel further (10-20km) with flying times of 1 hour or more. These can be used for large scale surveys and automatic mapping. For the field survey to verify peatland areas, a compact set drone is normally sufficient. As a drone battery may only last for 15-20 minutes flying time, it is highly recommended that the survey team bring several additional batteries to allow maximum usage of the drone set during the field survey day.

The drone can record video footage while flying through the survey locations, at the same time photographs can be manually captured by the drone pilot. It is recommended that an assistant be paired with the drone pilot to enable cross-checking of flight path, navigation, landscape features, etc., on a map (either a printed copy or viewed on another device).

In addition, a drone can be pre-programmed to auto-pilot. This function will allow the drone to fly at a consistent speed, at pre-set height, and over a pre-set route. The auto-pilot captured footage can later be uploaded to the DJI programme for auto-mosaic.

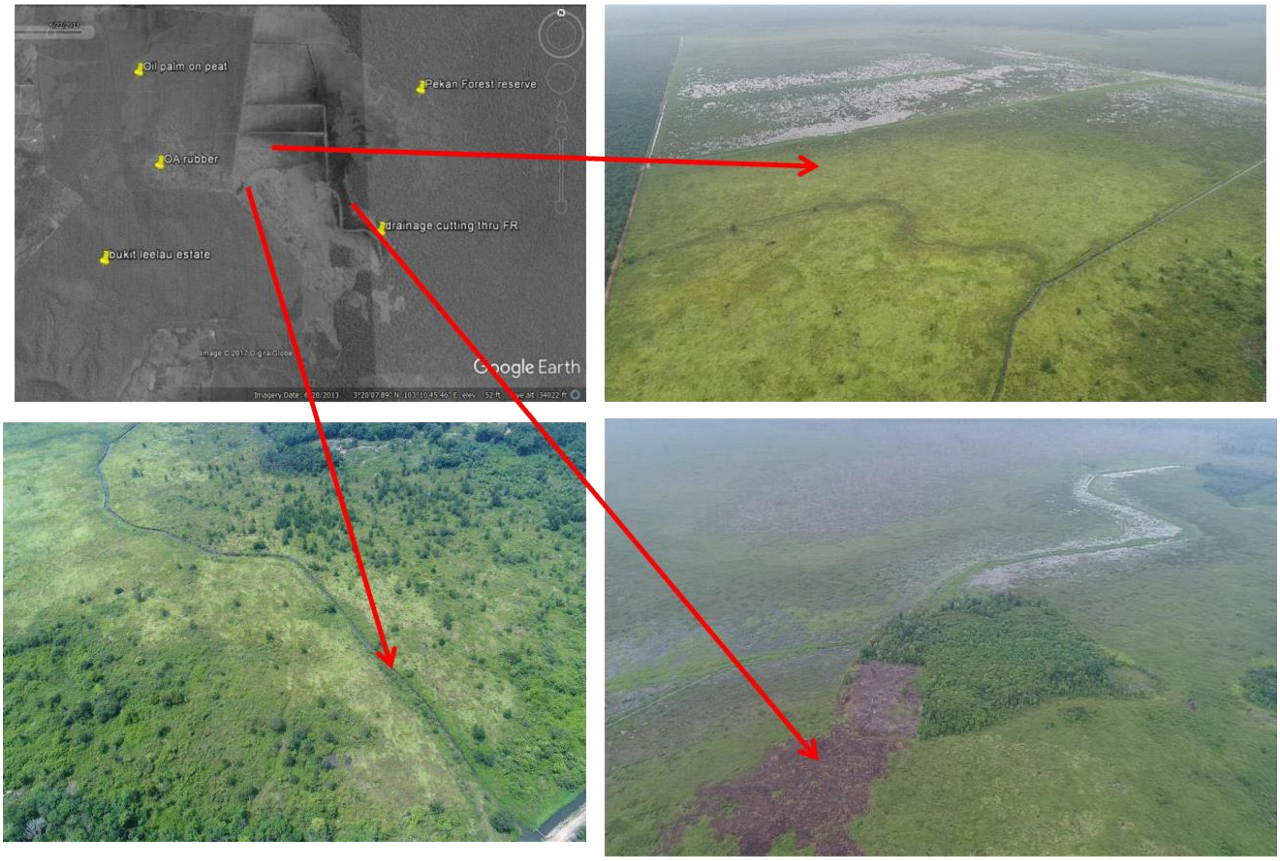


Figure 15: Photographs captured from drone survey being used to cross check satellite image (Source: GEC, 2019)

Figure 16: Mosaic combining from drone footages captured through auto-pilot (Source: GEC, unpublished)

4. Mapping

4.1. Combining the result of satellite image interpretation and ground-truthing

Field data will be used to determine the status of potential peatlands interpreted through remote sensing imagery.

Soils with an organic layer of more than 40 cm thickness are classified as peat soils, while soils with an organic layer less than 40 cm (excluding the leaf litter or vegetation on the soil surface) in the top 80cm may be considered organic soils.

Note that if the soil has a thin organic surface layer, that ranges from 20 to 40 cm along the edges or surrounding a peatland, it can be classified as soil with a thin or degraded peat layer (possibly affected by humans as in the case of U Minh Ha peat swamp, Viet Nam (APFP, 2014)). This thin or degraded peat layer can also be included in the defined area of the peatland if it is linked to contiguous deeper peat areas.

The boundaries of the peatland can be defined by typical topography, geomorphology or vegetation characteristics. For example, the low-geomorphology of peat swamps seen in southern Lao PDR; floating vegetation mats in Inle Lake, and some peat swamps in the North of Lao PDR (SEApeat, 2015).

The polygons identified as peat soil will be updated by reclassifying the satellite images and correcting the boundaries using GIS.

4.2. Converting interpretation image of raster map to vector

The results of remote sensing image interpretation for thematic mapping (for example, identifying potential peatland areas, or vegetation cover) are only the first step in the process of building thematic maps. The object attributes shown on the satellite image after classification are stored under raster images that can be used for reference, but are really difficult to use in correcting and especially managing spatial objects (the map units) later on.

Generally, the mapping process can be summarized as follows:

- The layer of potential peatland areas (or vegetative cover), pre-identified using remote sensing analysis, can be classified into various polygons. Each polygon is assigned and labeled to a unit of interest (e.g. a soil type or a vegetation type).

- Different polygonal layers (different units) from the classified image displayed on the image are automatically vectorized into vector layers (GIS) using specific software (e.g. ArcGIS, ENVI).

- Data from satellite image interpretation is converted to GIS aiming to support ground-truthing work and correction of thematic layers, and also management later on.

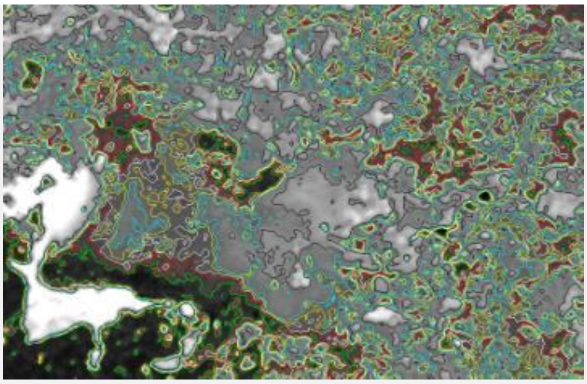
- The polygons in the GIS layer will be corrected from the field data and other related data (e.g. organic matter content to verify if the polygon is peatland or not).

- After completing the error correction, one or more thematic classes will be created containing two spatial and non-spatial attributes. These are GIS maps.

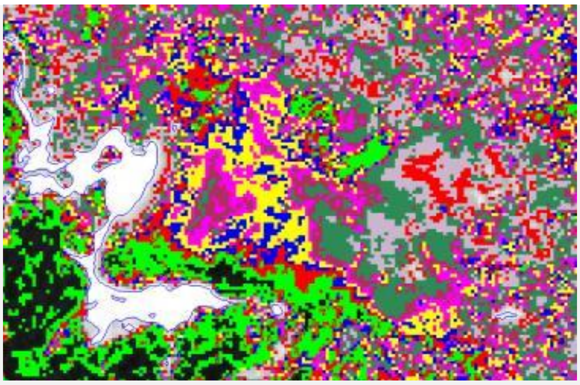
- Non-spatial attributes contain data required to provide complete information for objects (units) of the thematic GIS map.

Table 1: An example of the non-spatial attribute data of the vegetative layer

ID	Plant types	Category	Topography	Soil type	Area (ha)	District	Province	Latitude	Longitude
1	Forest	Dense	Medium	Acrisols	3,246.85	A	B	619756.65	1190164.16
2	Grass	Medium	Low	Fluvisols	824.57	A	B	-	-
...	.....								



The satellite imagery is roughly classified into areas with different natural features on the ground.



Satellite imagery is categorized (classified) and integrated with polygons that have the same features.

Figure 17: Satellite image including peat swamp area in Beung Kiat Ngong, Lao PDR.

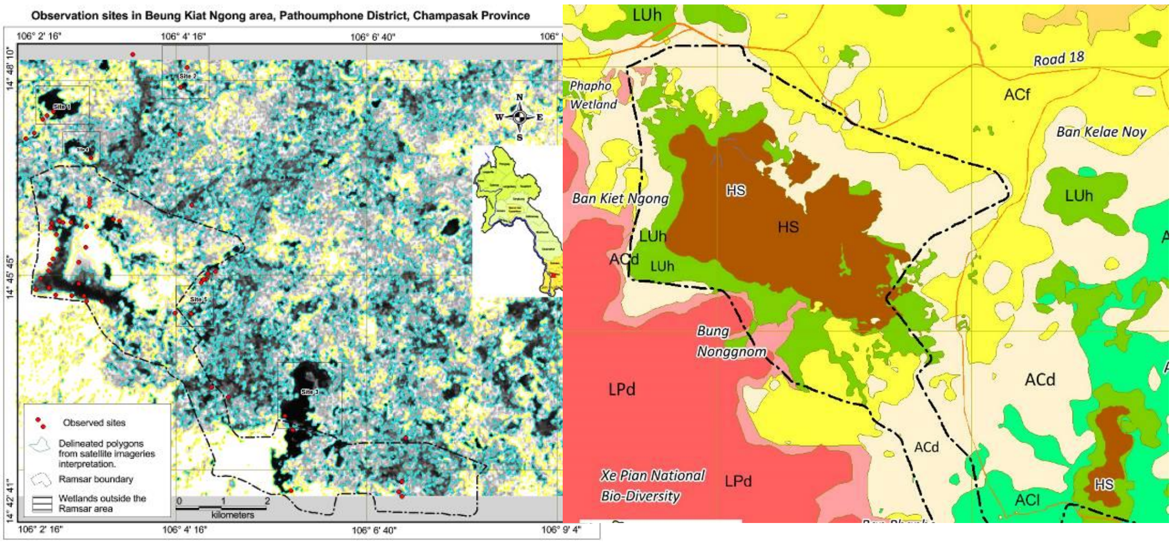


Figure 18: Different polygons denoting wetland/peatland units were initially detected and then automatically vectorized into a thematic layer with specific units of the map (Peat swamps in Beung Kiat Ngong – Lao PDR, Quoi, 2017).

4.3. Overlaying the thematic layers

An aggregate map is a combination of separate thematic data layers, for which all of the geographic data must be compatible with each other. To create a composite map, the technique of overlapping of different thematic layers must be applied.

Overlaying the map is done using a GIS tool. Therefore, all thematic layers must be converted to vectorized layers. The thematic classes required for map overlay are as follows:

- Administrative (boundary, administrative unit, etc.);
- River networks - hydrology (river, channel, canal);
- Transport networks (roads, paths);
- Topographic layers;
- Thematic classes (e.g. soil distribution, land cover, land-use).

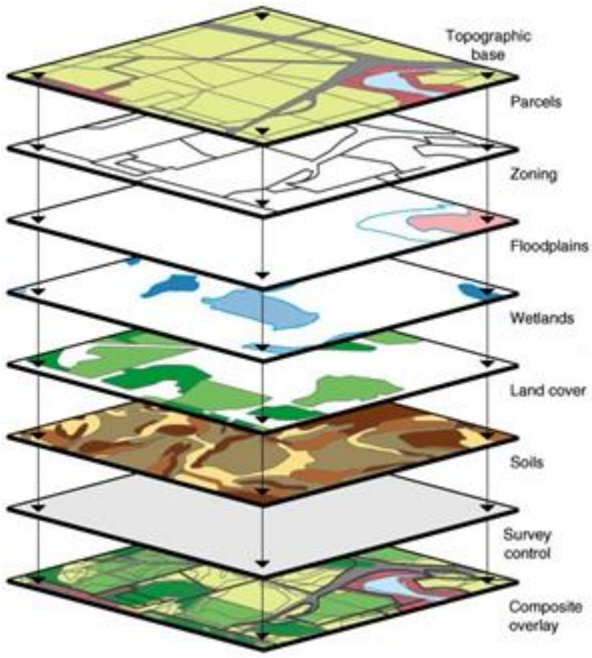


Figure 19: GIS overlay chart (Source: Forney, Texas)

4.4. Traditional maps

GIS maps are advantageous for research and management due to their ability to store large amounts of information and to manipulate the various information layers using computer technology. However, GIS maps are not easy to review at a large scale. In addition, it is not always possible to access computers with specialized software, or trained users, to upload and manipulate GIS maps.

It may therefore be necessary to convert GIS maps into raster maps that can be stored in bitmap formats (*.bmp, jpg, or tiff). The raster maps stored in the computer are also convenient for rapid data sharing, providing illustrations in reports, and especially printing on to paper.

When converting GIS map data into a raster format it is important to show the following elements on the final map: map scale, map grid, map projection, and map legend with full information of the map layer. An example of land cover map of Botum Sakor (Cambodia) is shown in Figure 20.

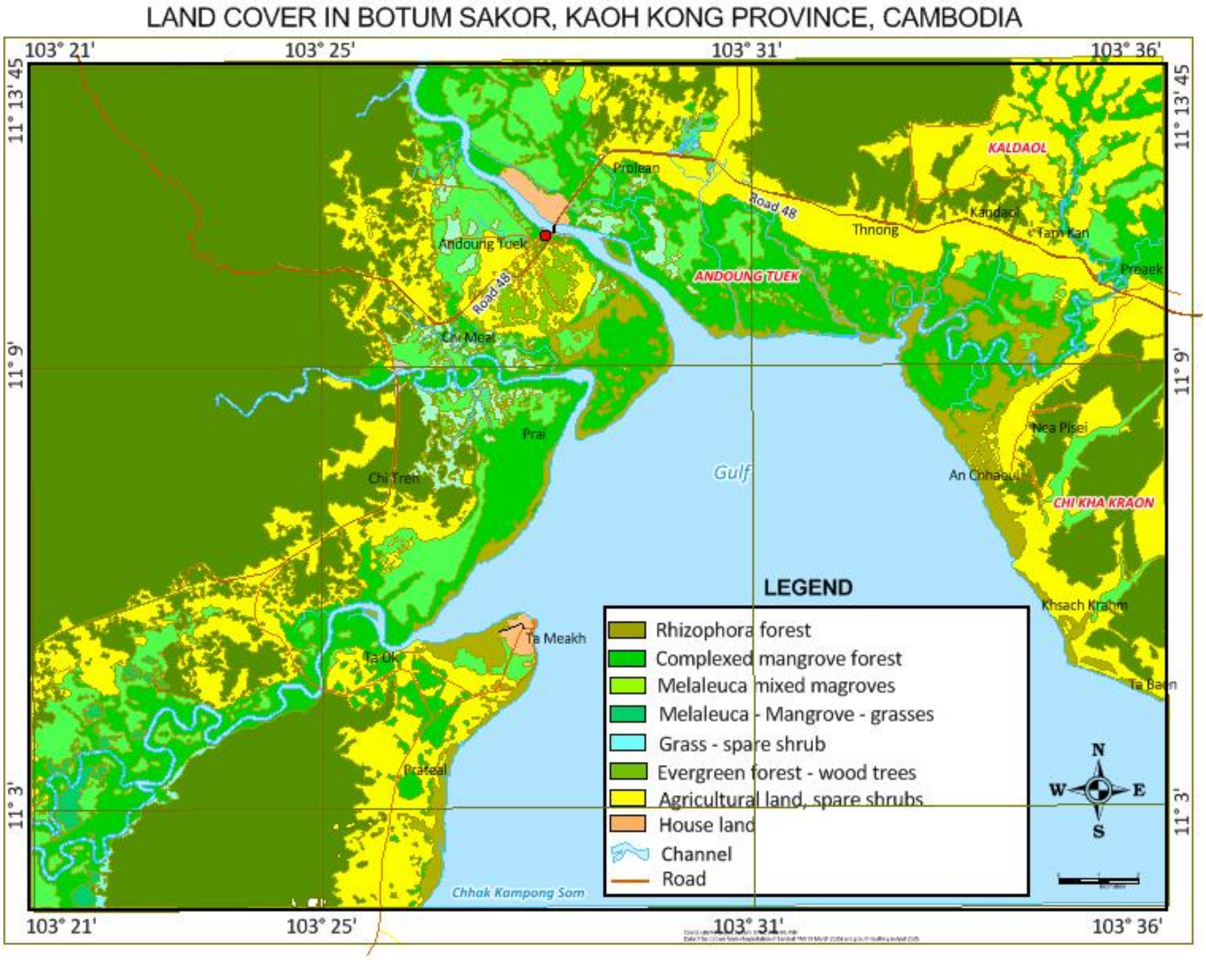


Figure 20: Land-cover in Botum Sakor, Koh Kong Province, Cambodia (SEApeat, 2015)

4.5 Drone Mapping

There are two main software or applications used for drone mapping:

i. Map Pilot for DJI; and
ii. Dronemapper

Further information of drone mapping software is given **as a Supplementary Material.**

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Annex 1: Rapid Assessment of Peatland Ecosystems – Data Collection Form

Peatland Ecosystem Rapid Assessment – Date Collection Form	
Name of the site (Name/country/ref number):	
GPS reference (Lat / Long)	
Sampling Point (Ref number)	
Date of survey:	
A - Topography	
Main topographical features:	Flat: Undulating: Steep:
Description of topographical features:	
Photographic record (topography):	YES / NO
B - Soil type	
Is the surface soil dark (brown/black)? Does it look like peat with significant organic matter?	YES / NO
Description of surface soil (colour, texture, friability): Try to describe clay, silt or sand content based on rolling samples in palm of hand:	Soil colour: Soil texture: Soil friability (clay/silt/sand content):
Description of soil at various depths (using auger or digging by hand):	10cm 20cm 30cm 50cm 1m+
Soil Profile sketch (profile along road cutting or drainage channel):	Soil profile description for each layer:
Photographic record (SOIL):	YES / NO

C - Hydrology	
Depth of water table:	Surface feature / XX cm below surface / No water Describe:
Water flows:	Describe direction and velocity of flow: Sketch map of water flow: YES / NO
Photographic record (HYDROLOGY):	YES / NO
D – Water colour	
Colour of water:	Peaty / Clear / Cloudy / others Describe:
Transparency (depth in cm below surface): Visual measurement / Secchi disk:	cm depth
E - Existing Land Use	
Land use within 100m radius:	Natural vegetation: Pristine / disturbed Agriculture: Crops: Others:
Photographic record (LAND USE):	YES / NO
F - Natural Ecosystems	
Ecosystem types:	Tick and describe type(s): a) Forest: b) Shrubland: c) Grassland: d) Wetlands: e) Others:
Human disturbance factors:	YES / NO, if YES describe type and levels: a) Land clearance: b) Burning: c) Excavation: d) Others:
Photographic record (ECOSYSTEMS):	YES / NO
G - Biodiversity	
Presence of any significant biodiversity: Dominant vegetation community:	Description of biodiversity: Description of dominant vegetation:

Peatland indicator Species	YES / NO, if YES which species:
Photographic record (BIODIVERSITY):	YES / NO
Additional Information on site:	
SKETCH MAP of SITE:	YES / NO
Prepared by: Name/Organization: Email: Tel: Date	

Annex 2: Peat soil profile description

Site:	Reference number:	Date:	Time:
Location:	Geographic coordinates (GPS)	Latitude:	Longitude:
Administrative location: (*village, district, province*)			
Ecosystem:			
Landscape position:			
Vegetation:			
Soil types:	Topography:	Slope:	Morphology:
Water level:	Inundated situation: (*seasonally, permanent*)		

Aspect description

Horizon (1)	Depth (cm) (2)	Texture (3)	Matrix colour (4)	Decomposition (5)	Mixture (6)	Consistency (moisture, stickiness, plastic) (7)		Other

Notes:

Notes:
(1) Soil horizon symbol used by capital letters O, H, A, B, C, etc.
(2) Soil depth, for example from 20 - 53 cm; (3) Soil texture examined by field testing (feeling test)
(4) Determine soil matrix color using the Munsell Soil Color Chart
(5) Determining the decomposition of organic matter by hand (feeling test)
(6) Identify the mixing of other materials in the peat soil profile; e.g. fresh wood chips or roots, clay or silt materials, etc.
(7) Determine soil moisture, sticky and plastic features of materials in the soil horizon. The feature is used by the feeling test method.

Annex 3: Peat site summary datasheet

Category: *Please tick where applicable* 1. Protected Area ( ) 2. Best Management Practices Sites (BMP) ( ) 3. High Conservation Value Area (HCVA) ( ) 4. others ( )	
Name of the site:	
Country:	
GPS point	
Location & Access: (Notes: Please attach the location map	
Total area (ha):	
Background of the Sites: (*e.g. Physical, Ecology, Social, Institutional Arrangement)*	
Significant values of the Sites: Biodiversity ( ) Hydrology ( ) Soil ( ) Cultural and Historical Value ( ) Socio-economic ( )	.
Designated use (status) : ( ) National Park/State Park ( ) International recognition (e.g. RAMSAR, MBR etc) ( ) HCVA ( ) Watershed/Water Catchment ( ) Wildlife Reserve/Forest Reserve ( ) Community Conservation Area/Forest ( ) Others	
Major issues:	
Site jurisdiction and administration (ownership):	
Peatland type:	( ) Upland ( ) Lowland ( ) Bog (rain-fed) ( ) Fen (groundwater fed) Vegetation type:
Management activities: a) Past b) Current c) Potential	
Facilities & Activities Available on Site:	
Institution responsible for the site: Name of organization: Postal Address of institution responsible: Phone: Fax: Website:	
Further information: (Please attach your file here)	
Prepared by: Name/Organization: Email: Tel: Date:	

Annex 4 : Mekong Peatlands Project - Soil Sample Log

Country:

No.	WAYPOINT	DATE / TIME (GMT)	LATITUDE (degrees)	LONGITUDE (degrees)	LOCATION	LANDUSE	Soil Sample ID	Depth of soil sample (m below ground surface)	Peat texture, moisture, colour, decomposition	Peat depth (m)	Water level (cm from ground surface)	Remarks/ Note
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
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