Greenhouse gas flux monitoring

- an overview of applied methods and data, and considerations for data collection

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Content

Peatlands and peat resources of the world

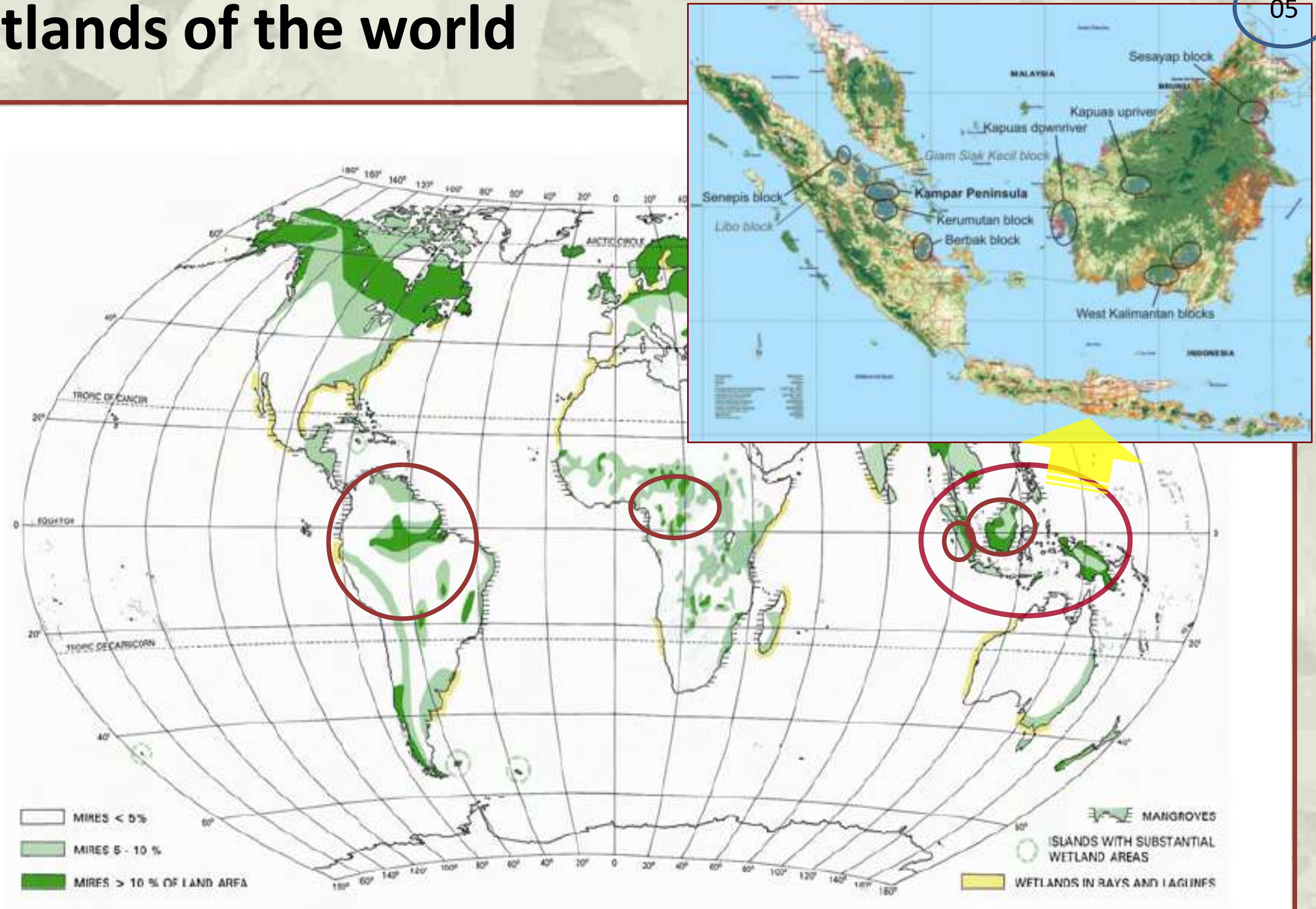
Peat

- Peat deposits can be found in every climatic zone, including the tropics
- Peat is accumulation of partially decomposed organic matter, mostly of plant origin, at the deposition location
- Decomposition may be inhibited by a combination of:

(a) Waterlogging
(b) Oxygen deficiency
(c) Acidity
(d) Nutrient deficiency
(e) Low temperatures

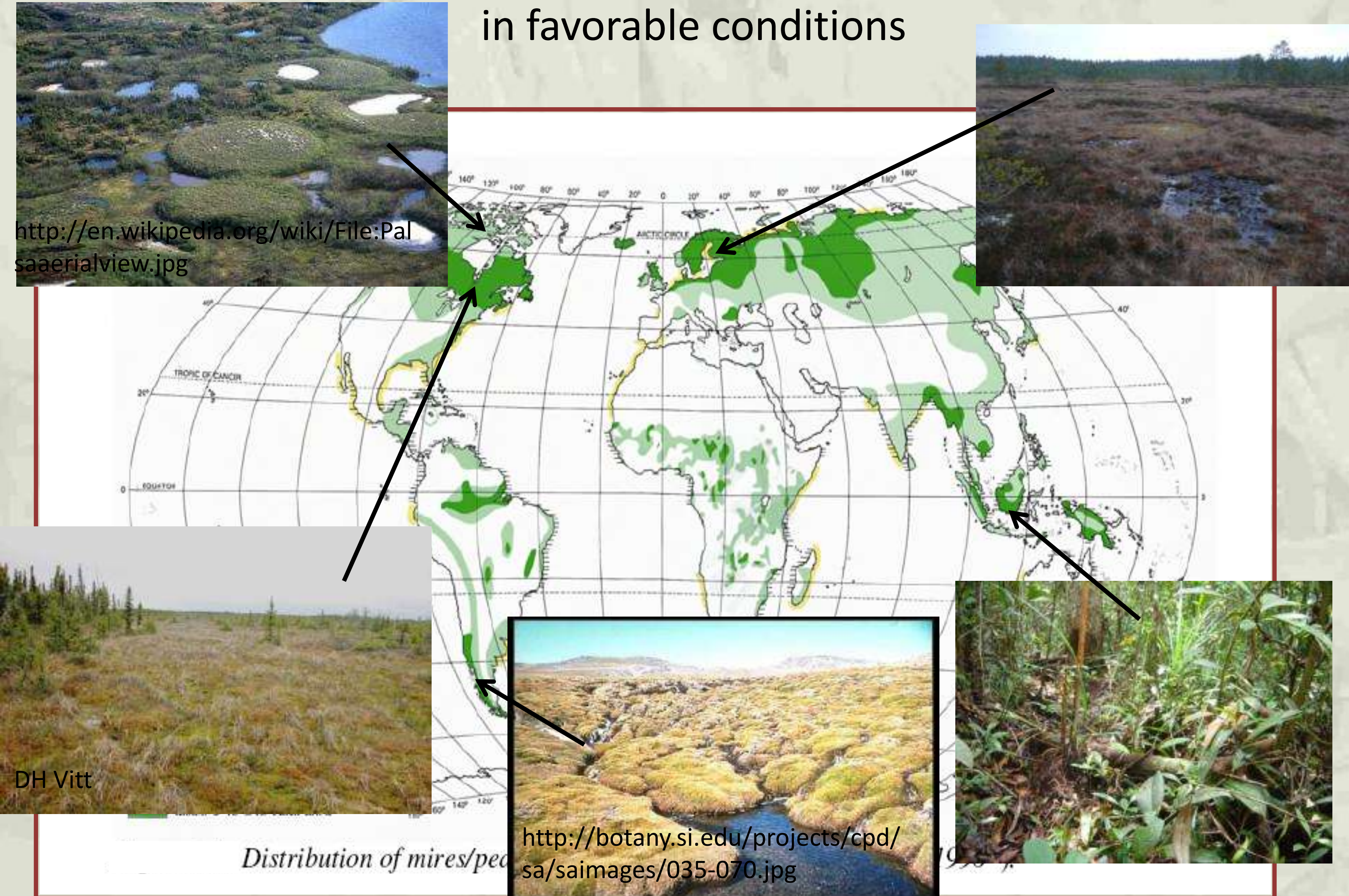
Non-tropical	Tropical
×	×
×	×
×	×
×	×
×	

Peatlands of the world



Distribution of mires/peatlands in the world (After Lappalainen 1996).

Peatlands may look different – but the basic functions are similar. Peatlands have potential to sequester and store carbon in favorable conditions

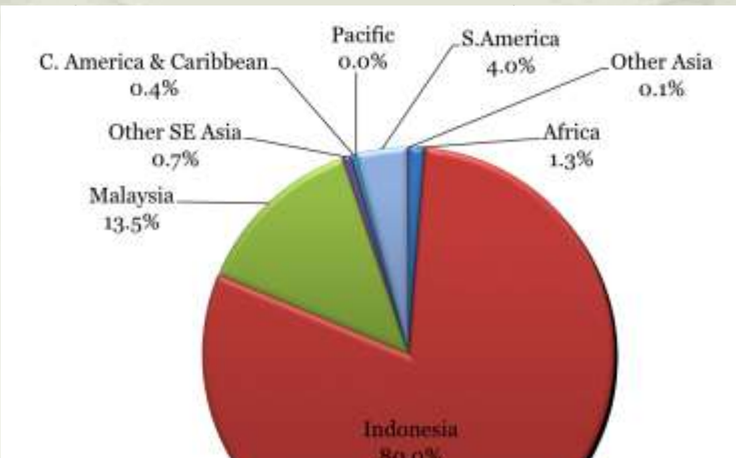


Why tropical peatlands interest so much?

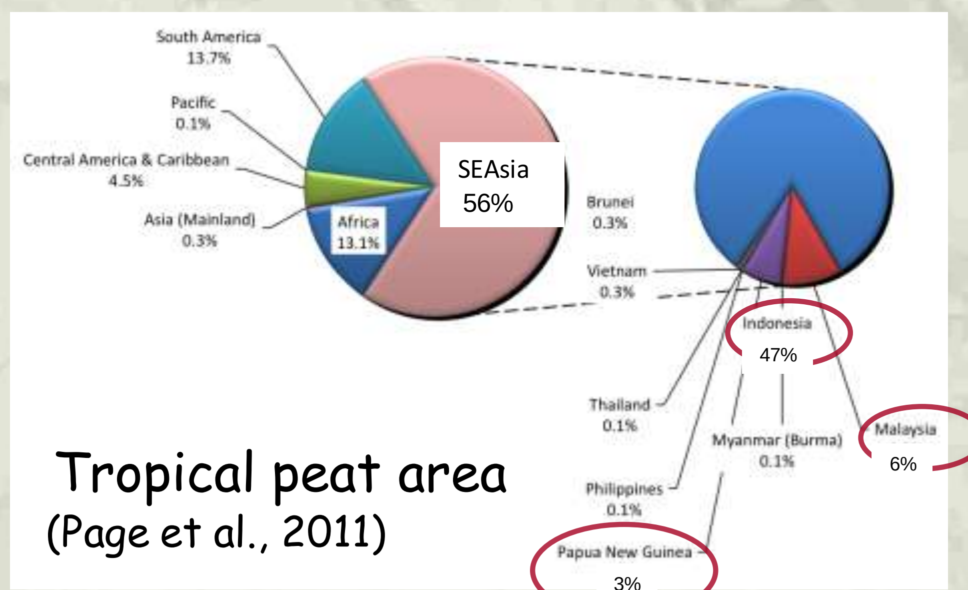
- Only a few peatlands in SE Asia have been investigated for peat structure, age, development, and rates of peat and carbon accumulation
- These ecosystems have functioned as a large net sink for atmospheric carbon at millennial timescales
- Deforestation, drainage, land regular fires (anthropogenic land use change) have all resulted in increased carbon transfer to the environment and loss of carbon sequestration function.
- Current carbon emissions from drained and fire-affected peatlands in Southeast Asia have been estimated to be of the order ~360 Mt C yr^{-1}
  - ~170 Mt C yr^{-1} from drainage-related peat decomposition (Hooijer *et al*., 2006)
  - 190 Mt C yr^{-1} from peat fires (Page *et al*., 2002; van der Werf *et al*., 2008)
- Losses contribute significantly to atmospheric carbon loading and contemporary climate change

Lowland peatlands in Southeast Asia

- Cover 24.78 Million hectares (Mha)
  - 56% of the tropical peat area
  - 6% of the global peat area
- Peat carbon store is 68.5 Giga tonnes (Page *et al*. 2011)
  - 94% the tropical peat C pool
  - 11-14% of global peat C pool
- Only 10% of the peatlands of Peninsular Malaysia, Borneo and Sumatra in an intact or slightly degraded condition by 2008



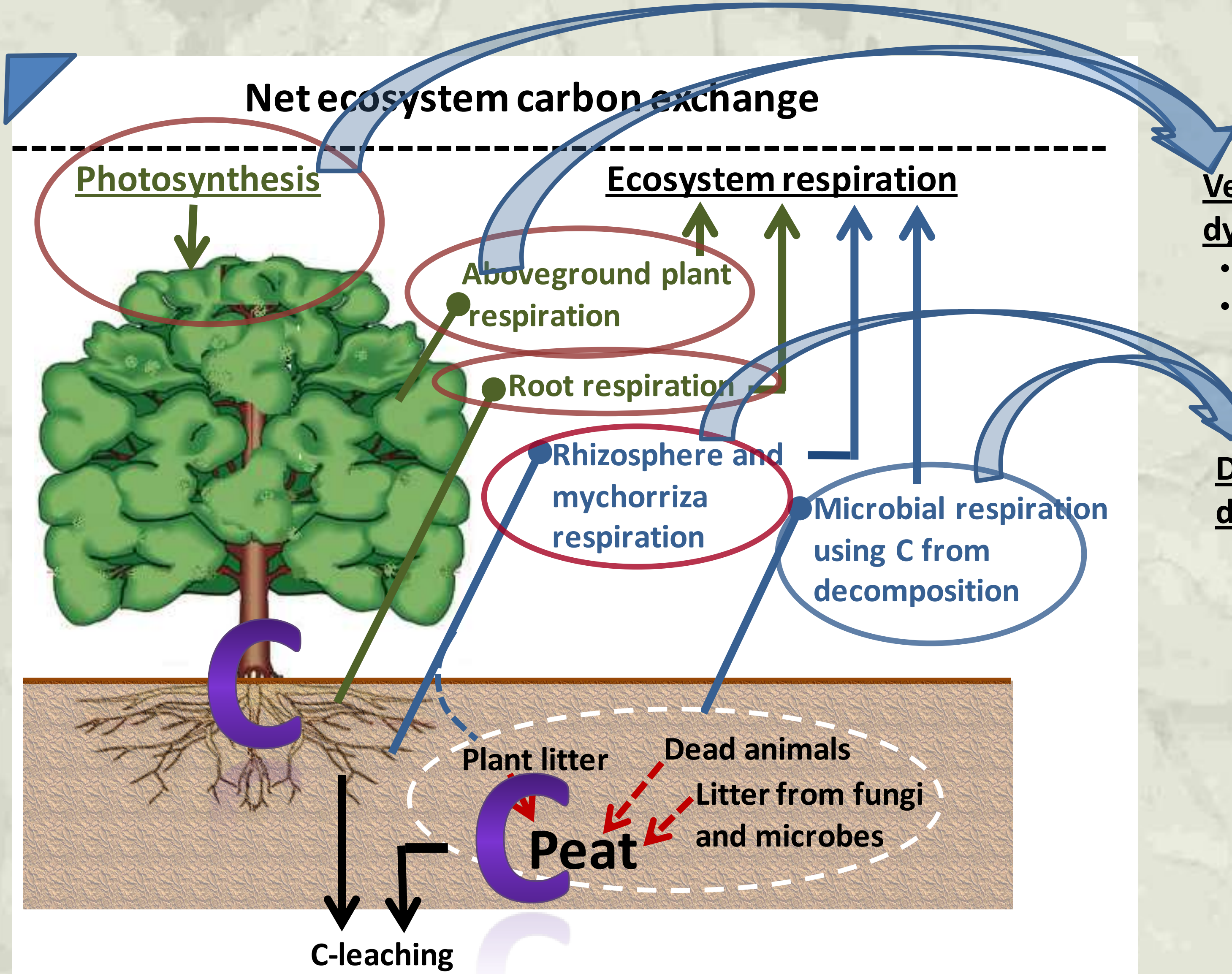
Tropical peat C store
(Page et al., 2011)



Tropical peat area
(Page et al., 2011)

Carbon dynamics in tropical peat ecosystem

Main carbon components in peat ecosystem



Vegetatiton carbon dynamics

- uptake in photosynthesis
- losses in canopy and root respiration

Decomposition carbon dynamics

- losses in soil processes

Controls of decomposition – (I) litter quality and quantity

Peat forming material, e.g. litter, quality and deposited amount both vary by land use types. Amount of litter on the peat surface (leaves, wood) and into peat (coarse and fine roots) is high in forest when compared to condition at degraded peatland or typical agricultural soils. Litter organic composition (relative amount of cellulosic, hemicelluloses and ligneous components) may also differ.

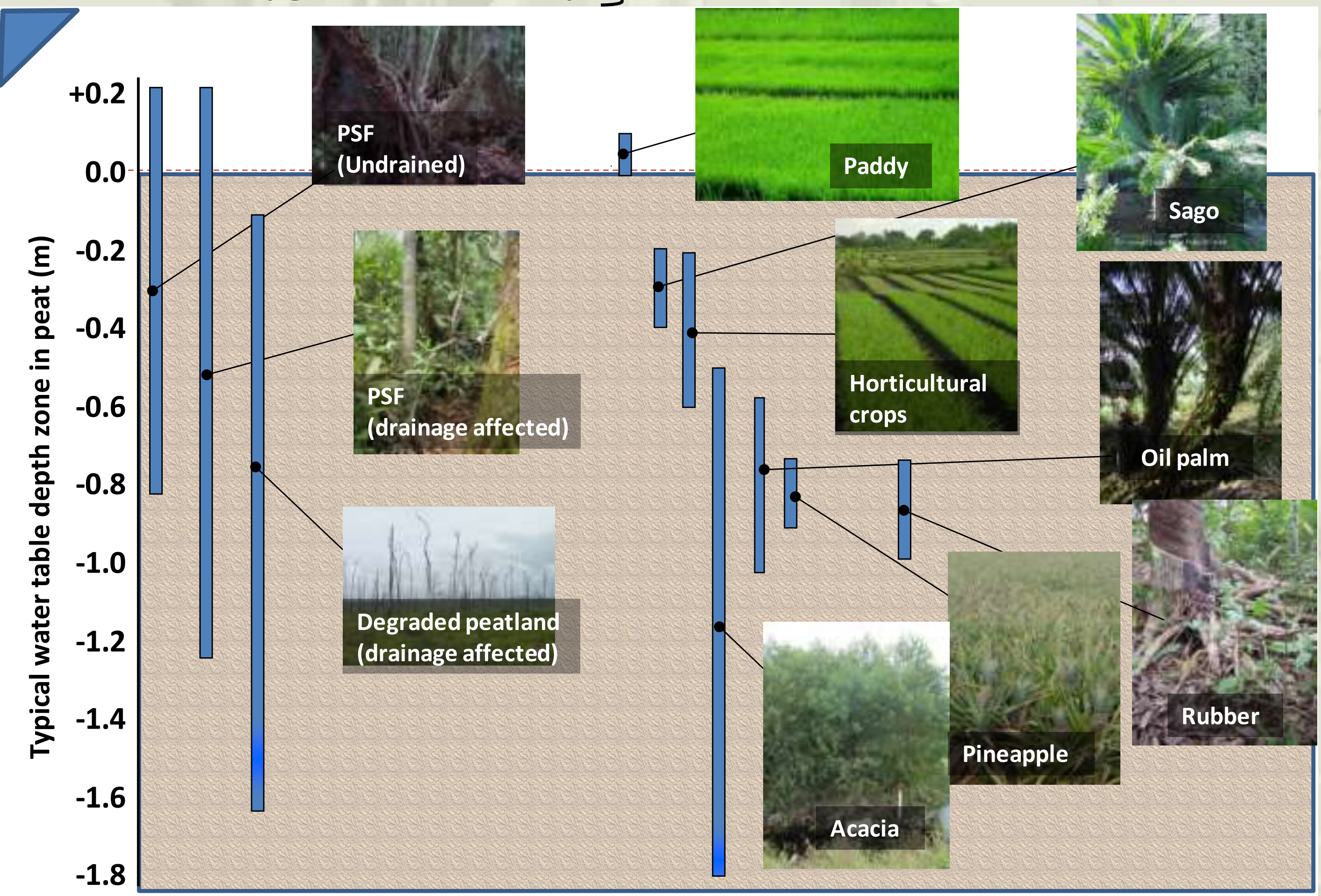
Surface peat in forest floor

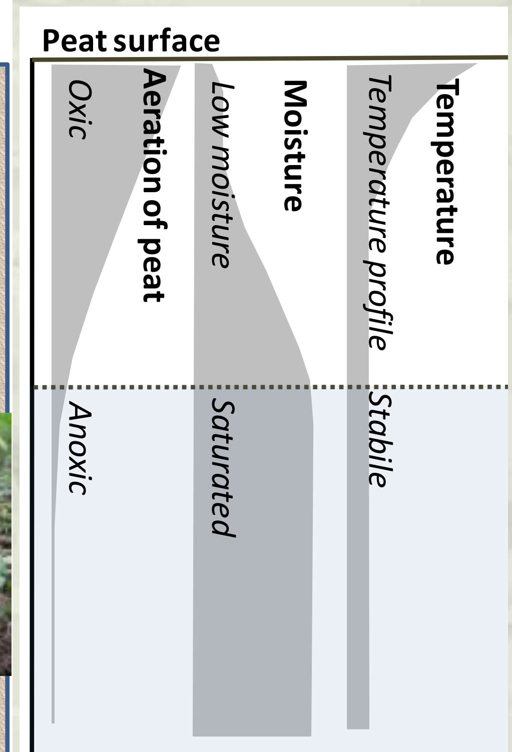
Peat surface in degraded peatland

Controls of decomposition – (II) environment controls

- Abiotic environment in peat differ by land uses
  - Temperatures (due to shadowing)
  - Moisture
  - Oxygen availability

Moisture and Oxygen availability: Water table





Peat swap forest floor is flooded seasonally which slows down decomposition and thus helps to maintain the peat carbon store created from litter deposition from the vegetation. At other land uses both the lower amount of deposited litter and increase in aerobic conditions in peat reduce peat carbon storing functions.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Methods applied on studying tropical peat carbon dynamics – advantages and disadvantages

Eddy covariance

Peat subsidence

Chamber measurements

Eddy covariance (EC) method

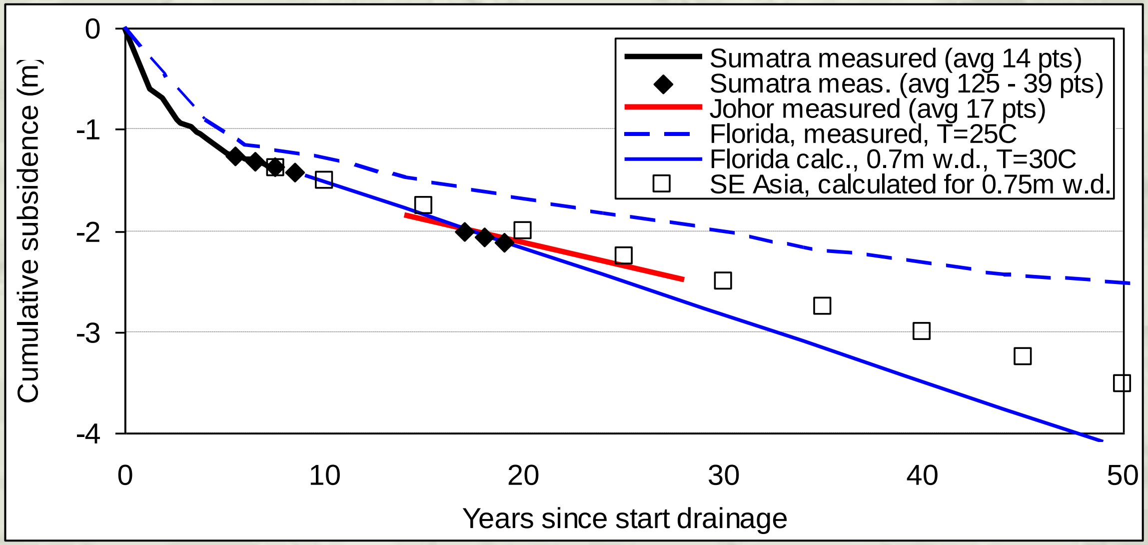
- Measures ecosystem level gaseous carbon balance. EC uses sensors mounted on a tower to sample the vertical component of atmospheric turbulence, and the concentration of greenhouse gas by automated gas flux monitoring
  - infrared gas analysis for CO_2
  - quantum cascade lasers for CH_4 and N_2O
- Challenges
  - Automated chambers are needed for measuring soil C emissions in vegetation growing areas
  - Highly technical and can be expensive
- Low amount published data from tropical peat
  - 3 forest sites in 2 studies (i.e. Suzuki et al. 1999; Hirano et al. 2007)





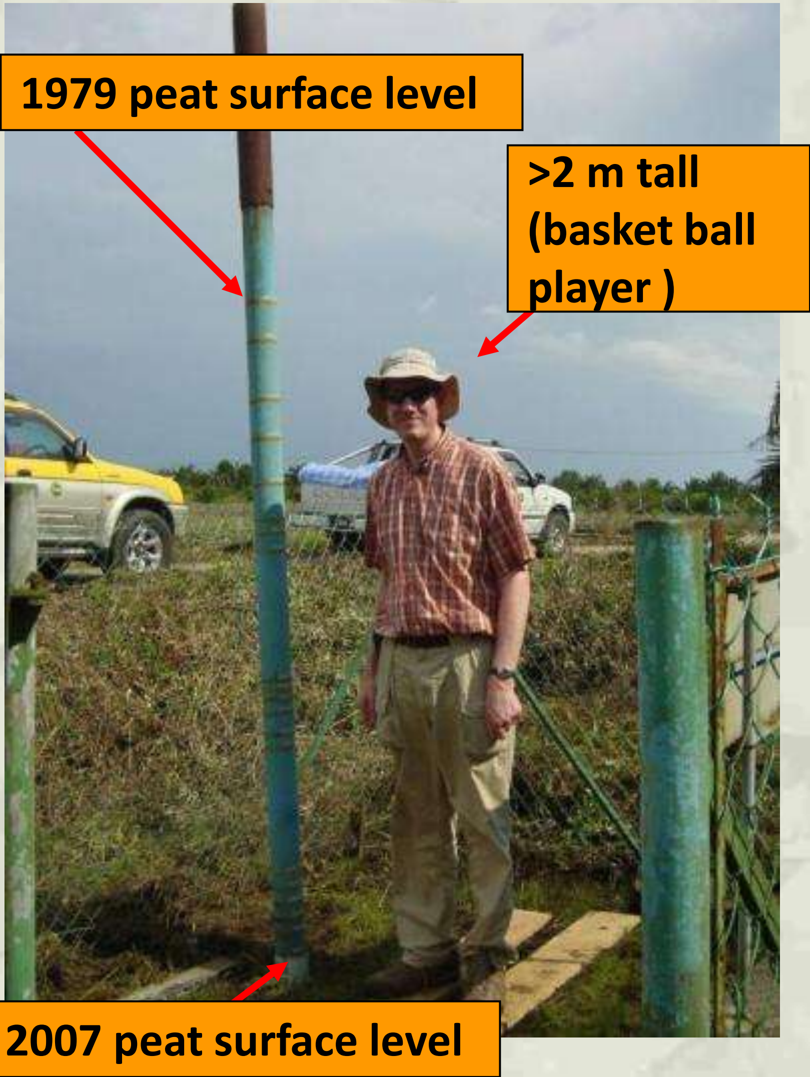
Peat subsidence method

- Measures peat carbon stock change rate over time by combining data from peat surface level change (subsidence) and peat physical characteristics (carbon content and bulk density)
- Results describe the net carbon stock change in peat (vegetation C-dynamics does not influence data)
- Challenges:
  - Subsidence data time series are usually short or records have gaps
  - Reference materials (bulk density, carbon content) are often missing (and theoretical values or general values may be misleading)
  - Detailed land management and drainage depth records often missing



Peat loss (subsidence) may lead for need of constant drainage system reconstruction in order to ensure sufficient water outflow

Peat subsidence pole showing peat loss between 1979 and 2007. Over 2 m tall man standing as a reference.



Chamber measurements

- Measures gas transfer between soil and the atmosphere over time from airtight chamber placed onto the peat surface for short period of time
- Gas concentration increase in chamber are quantified by collecting samples in syringes at specific intervals for subsequent laboratory analysis (static method), or by circulating air from the chamber headspace to a portable gas analyser (dynamic method)
- Separation of several gases (CO_2, CH_4, N_2O, ..) is possible from one sample
- Challenges;
    - small data base sizes in many studies
    - CO_2 emissions from decomposition processes and root respiration have not been separated
    - poor method description and data collection procedures

Summary of the tropical peat CO_2 emission studies (chamber data) peer reviewed by 2011

- About 10 studies are published in peer reviewed journals
- Studies are concentrated in very few locations
  - Central Kalimantan, East Sumatra, Sarawak
  - Sampling areas in various studies overlap
    - 2 areas in undrained forests total
    - 3 areas in degraded peatlands total
    - 1 area in plantations only

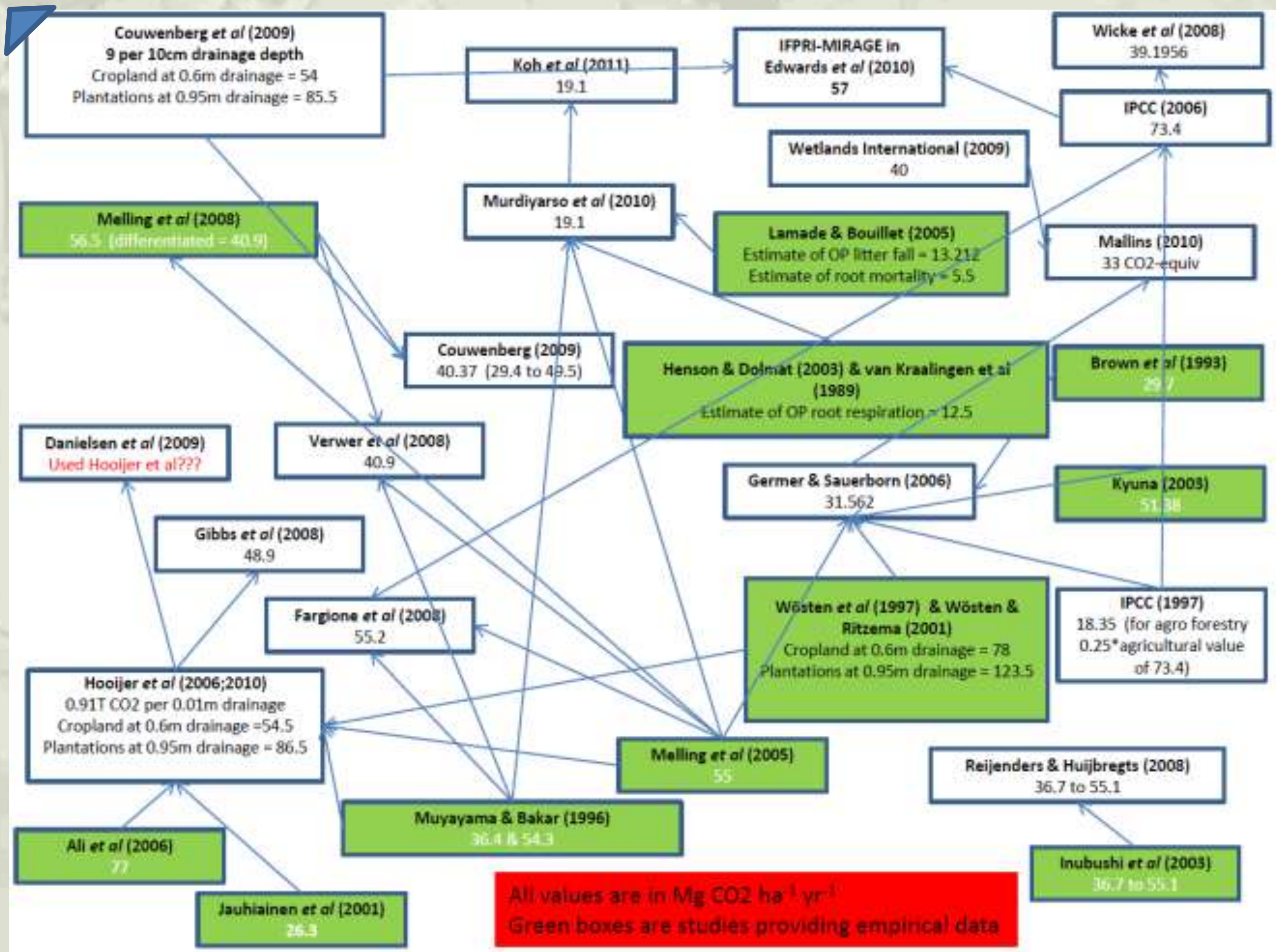
- Main reporting problems in the published studies
  - Land management history is poorly reported
  - Peat hydrology prior to and during the study is poorly described/quantified
  - Only the total emission from soil has been measured (emissions from decomposition and from root respiration <u>can not</u> be separated)
  - Data series are small
    - low number of replicates at sites and/or during each monitoring event
    - monitoring has been short-term only

Studies quantifying peat surface CO_2 flux and peat hydrology in Southeast Asia (peer reviewed by 2011)

FOREST	Time from the initial drainage	Burned once or more times	Location (number of studies)	Notes	Reference
Undrained		no, no no, no	East Sumatra(2) Central Kalimantan (2)	same area same area	1 ,4, 6, 9
Disturbed	5-10 5-10 and 20 5-10	no, no, no, yes ??, ?? ??	Central Kalimantan (4) South Kalimantan (2) Sarawak (1)	same area same area	3, 6, 8 5, 7 10
FALLOW & DEGRADED					
	<1 20 5-10	yes yes yes, yes	East Sumatra(1) South Kalimantan (1) Central Kalimantan (2)	 same area	1 7 3, 8
AGRICULTURE & PLANTATIONS					
Agriculture	<5 and >20 5-10 <5	yes, yes,??,??,??,?? yes, yes ??, ??, yes	East Sumatra (5) South Kalimantan (2) Central Kalimantan (3)	same area same area same area	1, 4 5 2, 5
Plantations	5-10	??	Sarawak (2)	same area	10

1. Ali et al., 2006 (Wetlands); **2.** Barchia & Sabiham, 2002 (Proceedings); **3.** Darung et al. 2005 (Proceedings); **4.** Furukava et al., 2005 (Nutrient Cycling in Agroecosystems); **5.** Hadi et al., 2005 (Nutrient Cycling in Agroecosystems); **6.** Hirano et al., 2009 (Ecosystems); **7.** Inubushi et al., 2003 (Chemosphere); **8.** Jauhiainen et al., 2009 (Ecology); **9.** Jauhiainen et al. 2005 (Global Change Biology); **10.** Melling et al., 2005 (Tellus)

Because low number of studies at field, possible data problems may become difficult to track-down from follow-up papers…



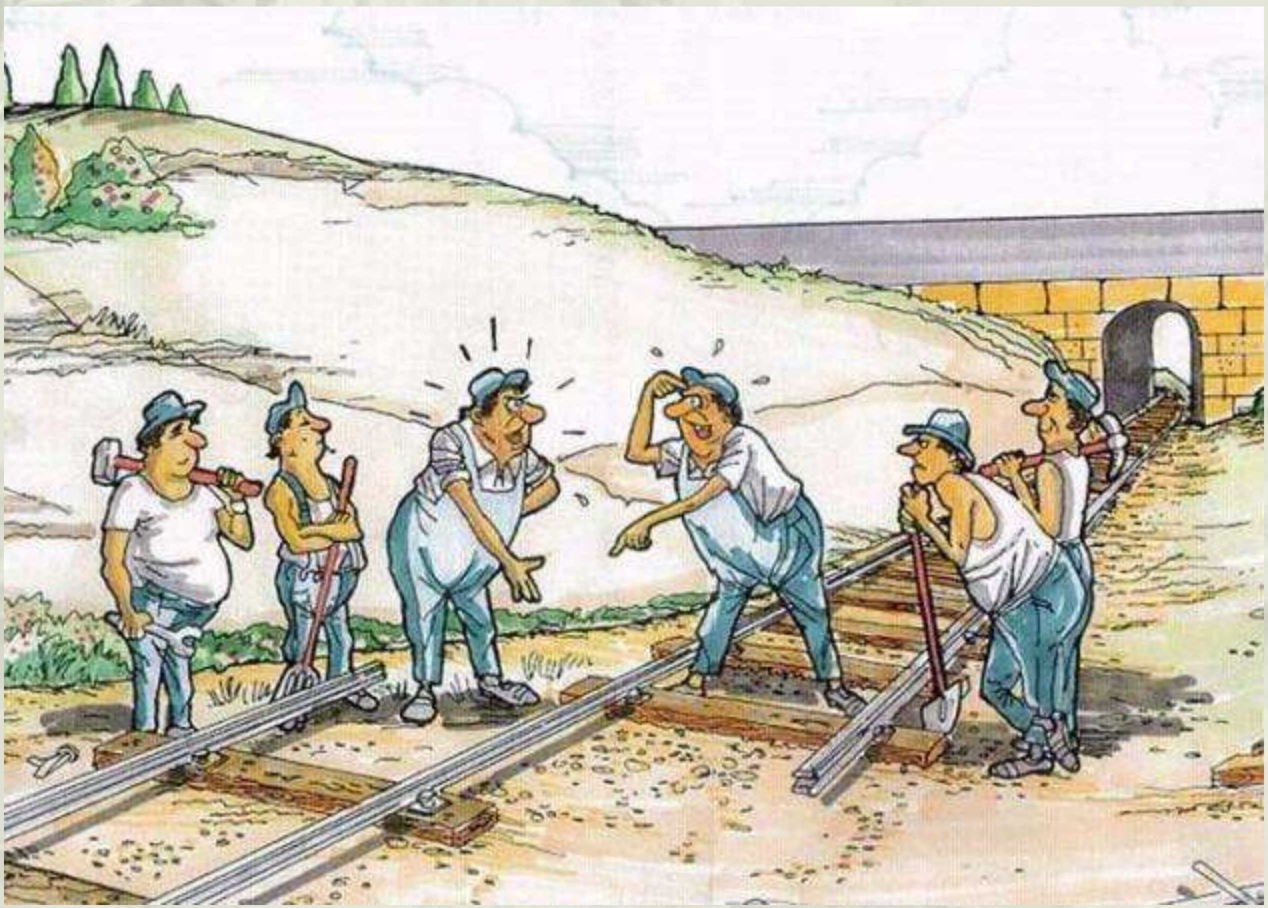
Flow chart showing the linkages between publications aiming to quantify emissions from oil palm plantations on tropical peatland. Green boxes indicate publications providing empirical estimates on data collected at field. CO_2 emissions values (Mg CO_2 ha^{-1} yr^{-1}).

What can be improved in tropical peat carbon dynamics data

- Perfect and simple method accounting all aspects of tropical peat carbon dynamics does not exist
- There is need for data bases which;
  - enable quantification of CO_2 emissions from decomposition and vegetation separately (instead of the total)
  - are sufficiently large for describing the studied phenomenon (on spatial and temporal scales)
  - Is collected from land uses formerly under-represented
  - Documents land management and drainage history in sufficient detail

=>There is a space for better data

Improving data quality
– matters to be considered



What to consider before starting a study

- **Objectives**
  - Is there a problem or general interest on a topic that seems to require action?
  - Do you have a "new" topic that needs clarification?

    -> **Formulate reasoning and goal of the study**

- **Hypotheses**
  - Is there a gap in previously published information? (review the literature)
  - How would you build upon the existing information?
    - Do you have an idea or a theory which is supported by the literature?
    - Do you have defined basis for challenging the existing beliefs?

    -> **Formulate what you expect from the study results and form of the evidences**

- **Methods**
  - Check generally agreed methods for studying such topic?
  - Consider best approach for the study (experimental or monitoring)?

    ->**Select the method and select the study scale**

(cont.) What to consider before starting a study

- **Target forum of the results**
  - Where is the potential study interest group?
  - What would be your result publication forum?

  -> **give consideration how the work will be organized in reporting and where it may be published in order to ensure that it will be noticed**

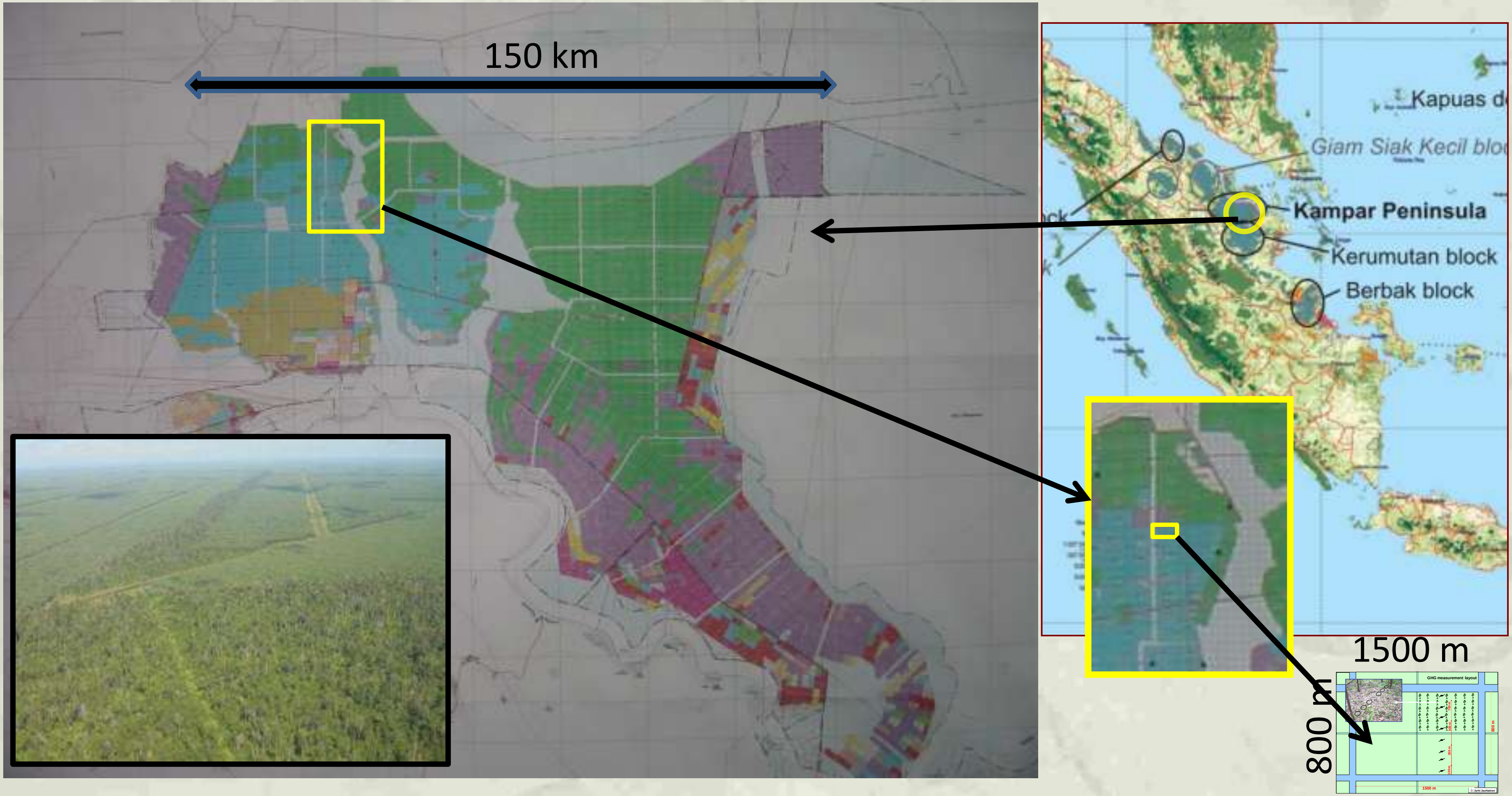
- **Recourses**
  - What are your recourses in..
    - expertise
    - manpower
    - time
    - applicable technology
    - funding
  - Can you do the work alone or would it be better to join forces with others?

  -> **make strategic plan for the practical data collection and publication**

What to consider in data collection?

with an example based on a study made in plantation

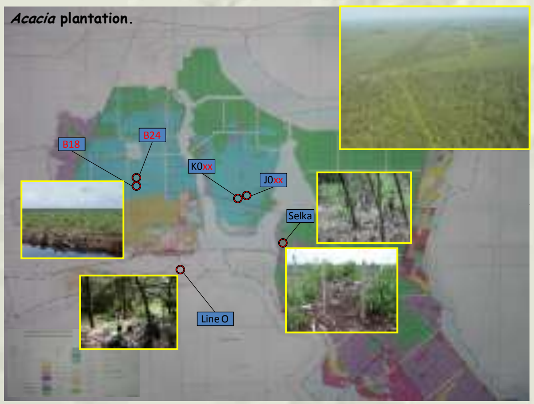
Given task in example: What is peat carbon loss rate from peat in *Acacia* plantation established on deep peat?

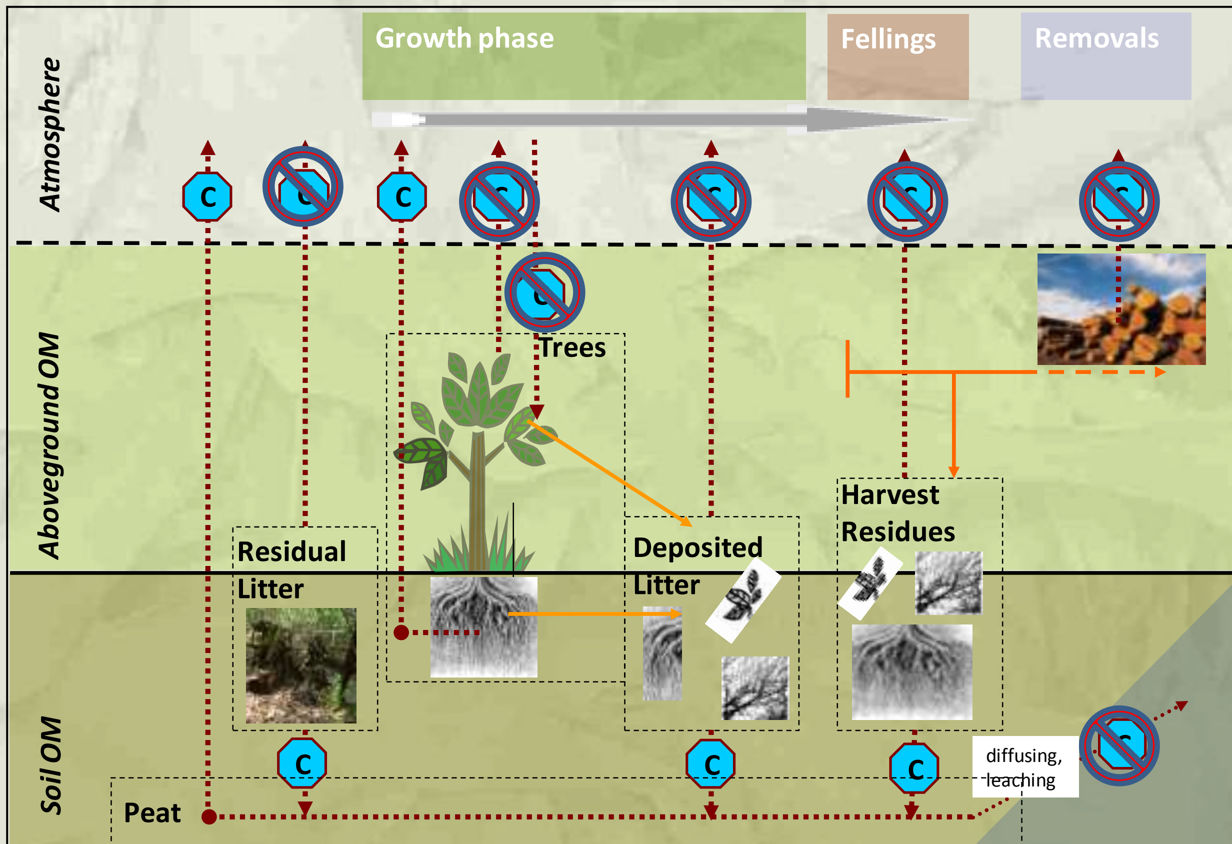


Site conditions varied a lot at the plantation area


Select the primary studied phenomenon and scale of measurements

Example study:		
Potential scaling	Potential topic	Selected
Spot (monitoring location) Site type Ecosystem Landscape ….	CO_2 total emission, CO_2 autotrophic respiration, CO_2 heterotrophic respiration, CO_2 ecosystem respiration, …	CO_2 root respiration, CO_2 decomposition respiration, (and total emission) on site and ecosystem scales





Plan potential (spatial) interpretation limits for your data.

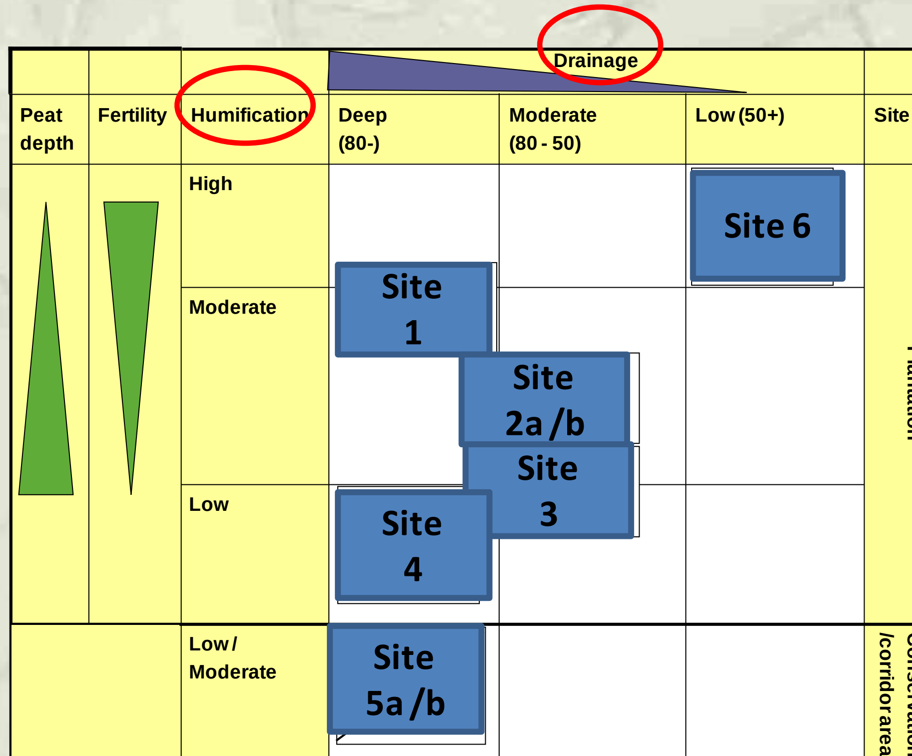
Which conditions differ or change slowly between monitoring sites or differ between experimental units during data collection?

Example study:

Possible variation	To be covered in data collection
Land management history	. (based on records)
Peat characteristics (depth, bulk density, nutrients, C & N content)	Peat characteristics (depth, bulk density, nutrients, C & N content)
Vegetation type	. (records and site selection)
Vegetation biomass	. (records for reporting)
Peat surface roughness in relation to water table	Peat surface in relation to water table (need leveling at each selected site)

Abiotic and biotic environment, and management vary at field and selection on conditions needs to be made. Later your conclusions from the study are based on data limited by this selection and actual conditions during data collection.

Factor	Effect on GHG flux on relative scale	Effect on GHG flux over time
Peat property		
Nutrient status	poor – rich	Permanent
Humification status	low – high	Progressing
Peat depth	shallow – deep	Altering
Time from clearance/drainage	short – long	Progressing
Vegetation		
Status	bare land – maturing stand	Cyclic
Planting density	low – high	
Biomass	low – high	Cyclic
Litter	low – high	Cyclic
Management		
Drainage depth	low – deep	Variable
Fertilization	low – high	Cyclic
Harvesting disturbance	low – high	Cyclic
Weeding	no – yes ?	?



Apply sufficiently long monitoring period and data collection intensity

<u>and/or</u>

estimate sufficient database size on experimental work

Which conditions likely change at the monitoring locations (or experimental units) during the study or in shorter term?

This sets limits on what you can interpret from your data in temporal scale.

Use supporting data records, apply information existing literature, and learn from experiences – but be also critical

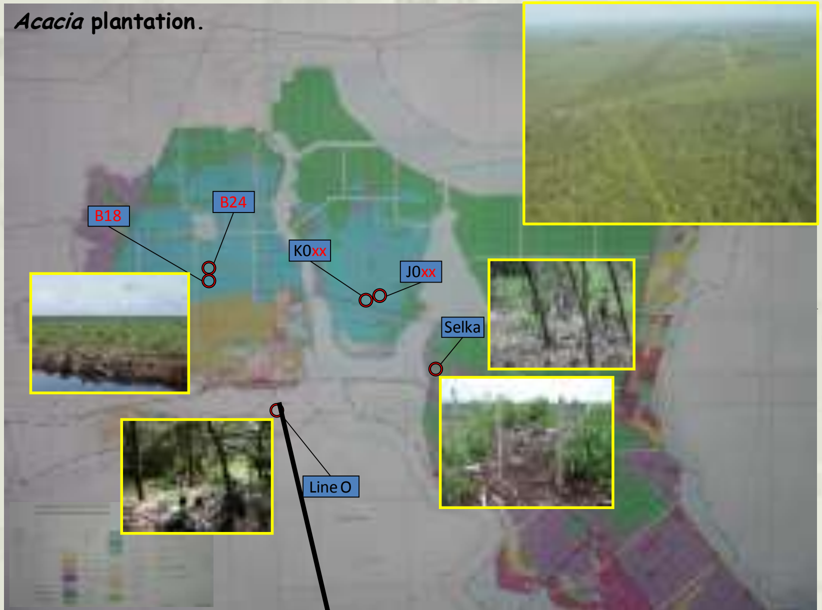
Example study:

Likely changing condition during monitoring or between sites	Selected in monitoring
Water table Peat temperature Soil moisture Precipitation Solar radiation ….	Water table Peat temperature . . (based on external records) . (not important here)
Possible monitoring intensity	**Selected monitoring intensity**
•One time •Frequent monitoring ○ Night and day ○ Daytime ▪ Daytime every day ▪ Daytime every week ▪ Daytime every month	. Frequent monitoring . Daytime (Night and day optimal but too difficult) . . Daytime every month
Potential monitoring periods	**Selected monitoring period**
1 time 1 month 1 season 1 year >1 year	2 years of monitoring to guarantee inter-annual differences and cover possible data losses

How many measurements provide sufficiently large database?

- Flaws in data are very difficult to fix after the data collection is over
- Each sub-category in data may cause need for additional data – collect enough data and a bit more (*.
- Unexpected conditions may make data collection challenging….

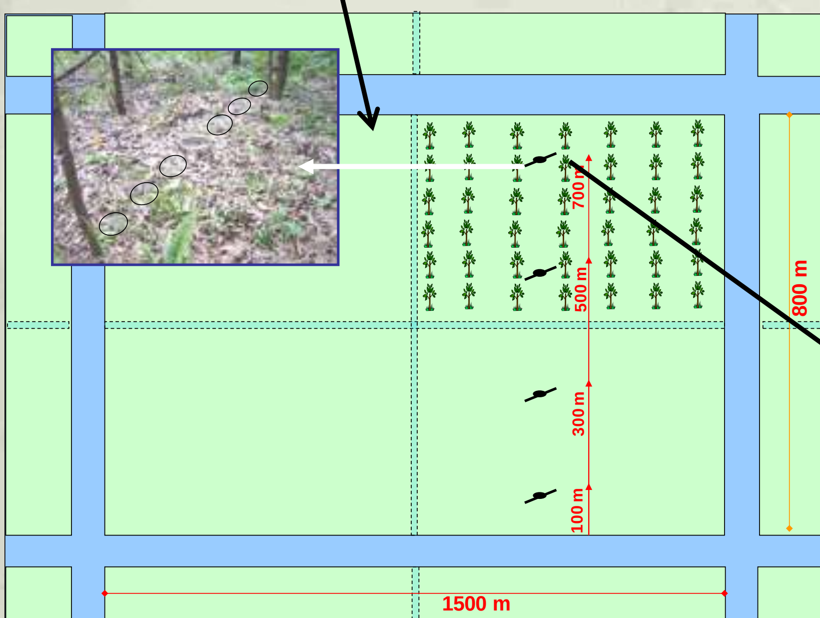
(*Other presentations and practical work during the course will help creating understanding on this subject

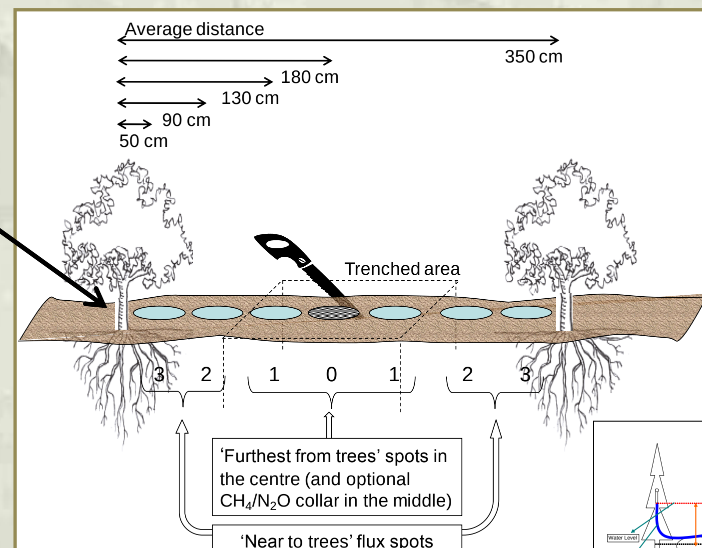


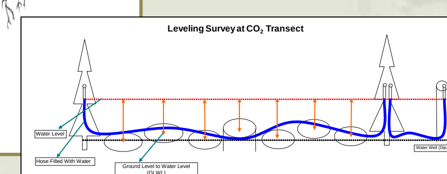
In the example study at plantation:

- 8 transects max. at 23 km distances at open and *Acacia* growing sites
    - 144 monitoring positions with levelled micro-topography
- Each monitoring location included both decomposition and (potential root respiration monitoring positions)
- Over 2 years monitoring on CO_2 emissions, peat temperatures and water depths
- Supporting data on peat characteristics, precipitation, vegetation status etc from other sources
- Over 2300 CO_2 emission numbers in the final database (from >3000 readouts taken at field)

Full paper Jauhiainen et al. 2012 is downloadable freely at: http://www.biogeosciences.net/9/617/2012/bg-9-617-2012.pdf







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