SPATIAL VARIABILITY OF FOREST SOIL PROPERTIES FOR C MANAGEMENT IN TROPICAL FOREST

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CLIMATE CHANGE IS REAL

- CO_2 increase to 391 ppm in 2011 compared to 280 ppm in 1800s (IPCC, 2013)

- IPCC – Increase in Earth's temperature by 0.6 & 1.1 ° C over the period of 1880 till 2012

- Global warming- Result in floods, droughts and tropical cyclones in South East Asia

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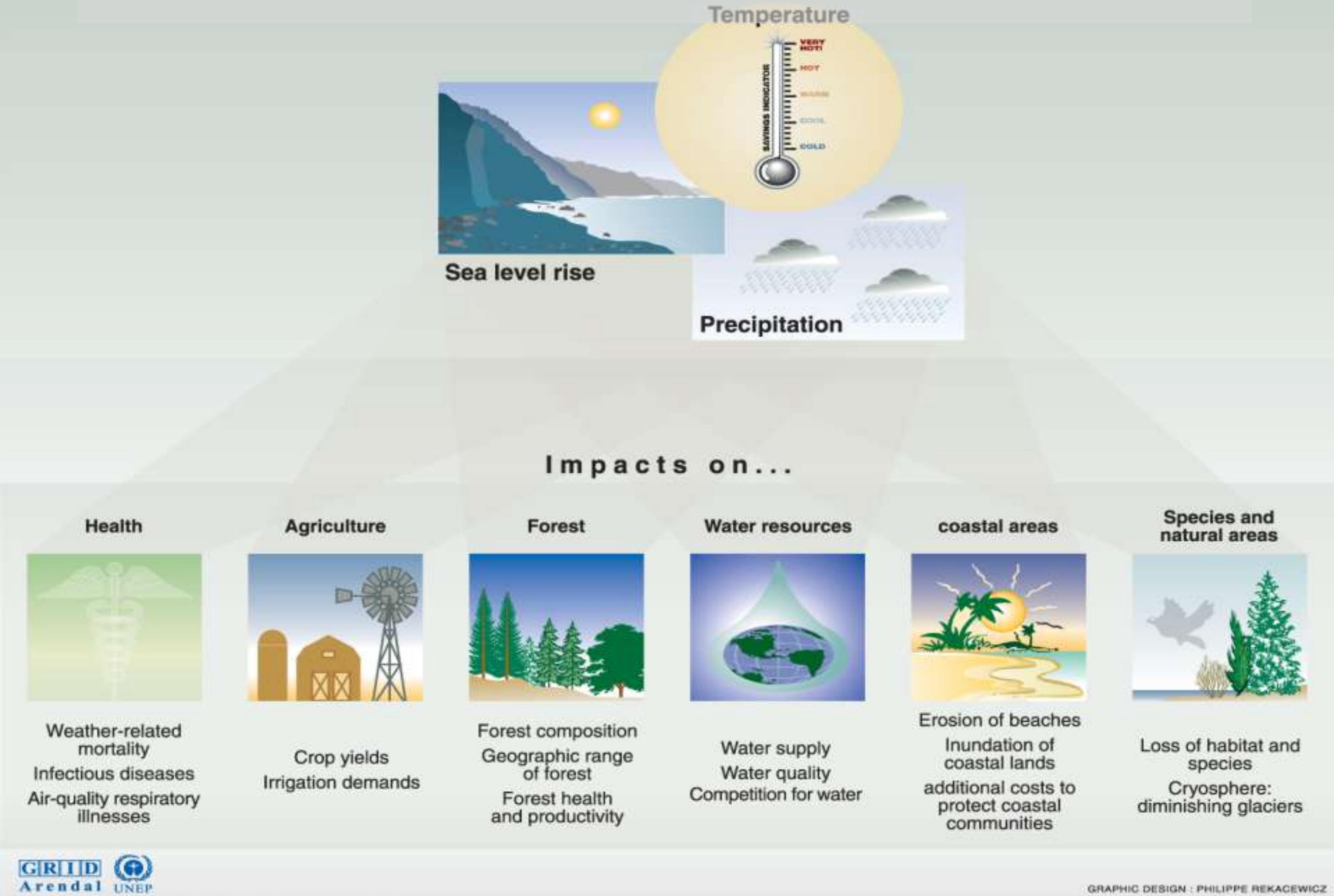
WRATH OF CLIMATE CHANGE



Source: United States environmental protection agency (EPA).

THE MALAYSIAN SCENARIO

- Kyoto Protocol-Malaysia pledged to reduce CO_2 emissions , increase carbon sinks and promote research in carbon cycling

- The Malaysian Prime Minister had delivered a proposal to reduce CO_2 emissions by 40% in terms of GDP by the year 2020 compared to 2005.

- 40% reduction of carbon intensity is equivalent to about 10% reduction of GHG emission from business-as-usual.

THE MALAYSIAN SCENARIO

- Malaysia's GHG emission was 293 Mt CO_2 e in 2007. (NRE, 2011)
- GHG removal was 247 Mt CO_2 e in Land Use , Land Use Change & Forestry (LULUCF) sector. (NRE, 2011)
- General default of soil C contents are provided by region and local values are incomplete.
- Most values in LULUCF is for lowland forest and montane forests are not included.

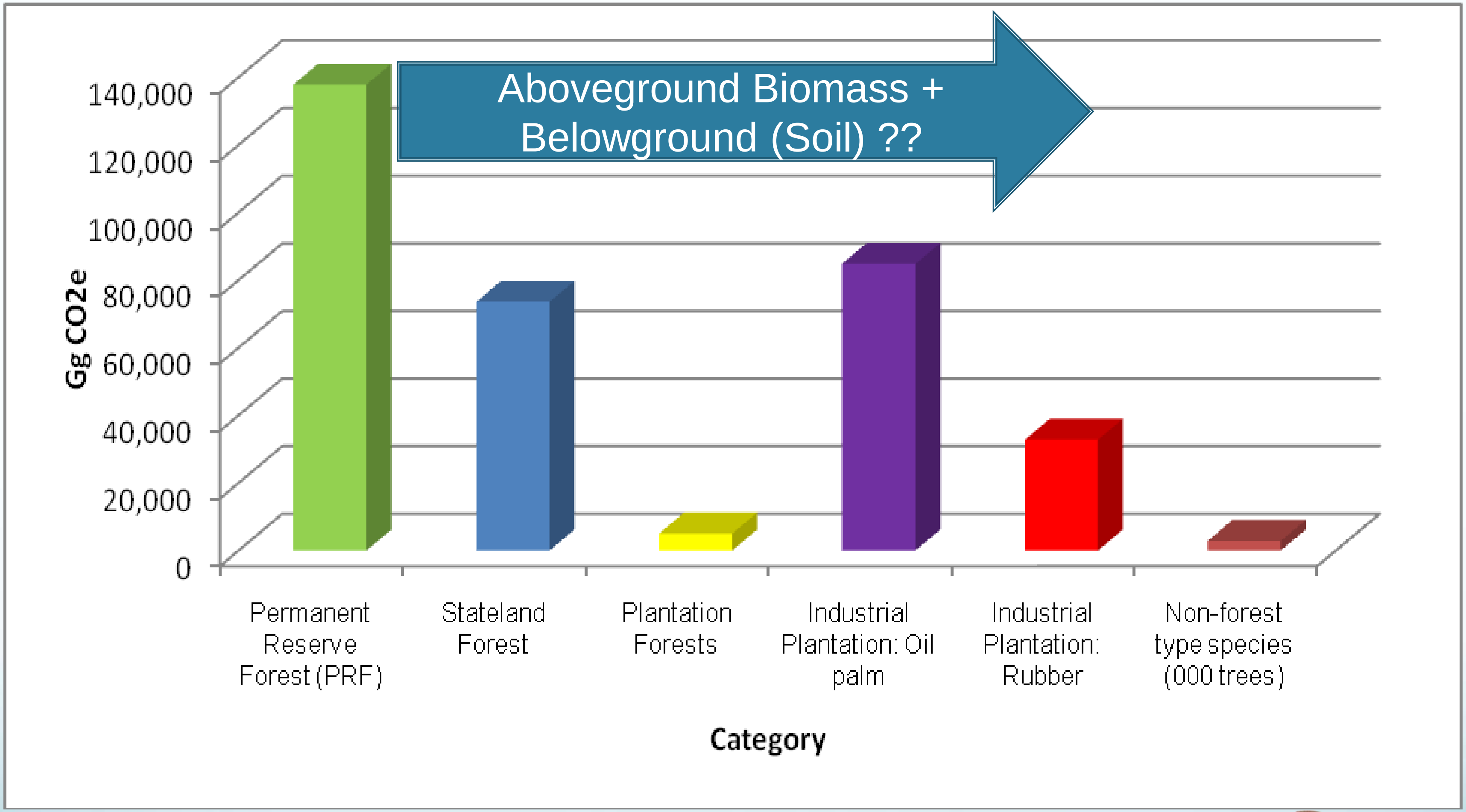


Fig. 2: Carbon removal by various forest and land use categories, 2000 (FRIM, 2009)

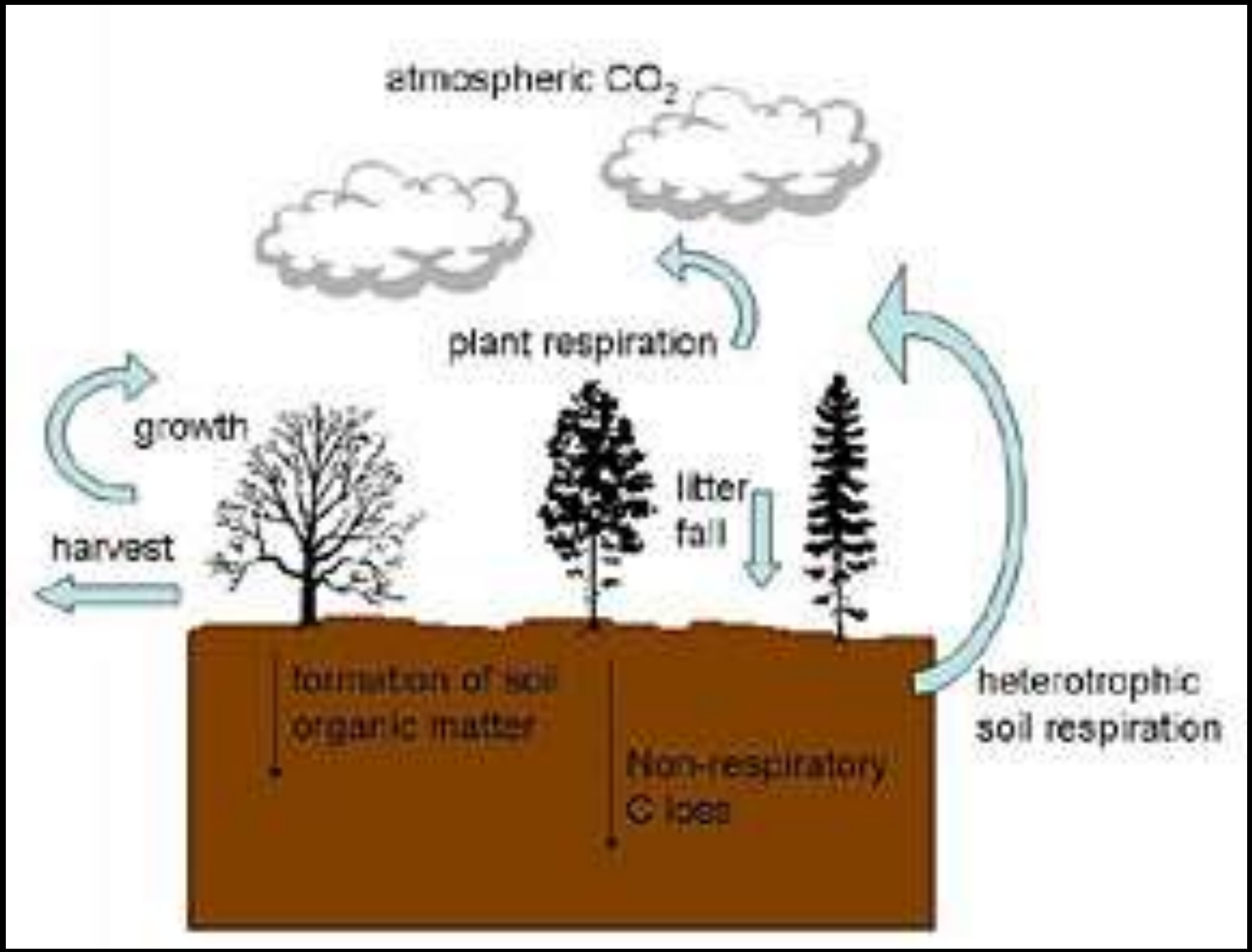


Fig. 3: Carbon sequestration in forest soils

LITERATURE REVIEW

- Tropical soils constitute 26% of SOC of the world **(Batjes 1996)**
- C:N ratio - increased with elevation at different slope aspects & vegetation types **(Yimer et al., 2006 ;Tang, 2006)**
- C:N ratio – 26% higher in uplands compared to lowlands **(Silveira, 2009)**
- 8% of carbon stocks are contributed by forest floor **(Chojnacky et al. 2009)**

LITERATURE REVIEW

- IPCC Good Practice Guidance: "*models and inventory measurement are tailored, repeated overtime and driven by high resolution activity data & disagregated to fine grid-scale*"
- Geostatistics can describe and predict spatial variation and carry out spatial interpolation **(Zhang & McGrath, 2004)**
- Spatial variability of SOC was evident in 3 operational areas in an oil palm plantation **(Lau *et al*., 2009)**
- Significant difference in spatial variability between SOC content of western and eastern part of Dehui County, Northeast of China **(Liu *et al*., 2006)**

JUSTIFICATION

- Determination of soil & litter C stocks in two different forest types in Malaysia as a standard for AFOLU reporting purposes
- Quantification of spatial variability in soil C and litter C with relation to forest vegetation type and slope position will be an important tool for forest management strategies for future.
- Information can assist in carbon crediting schemes and REDD+ efforts

METHODOLOGY

- **SITE**

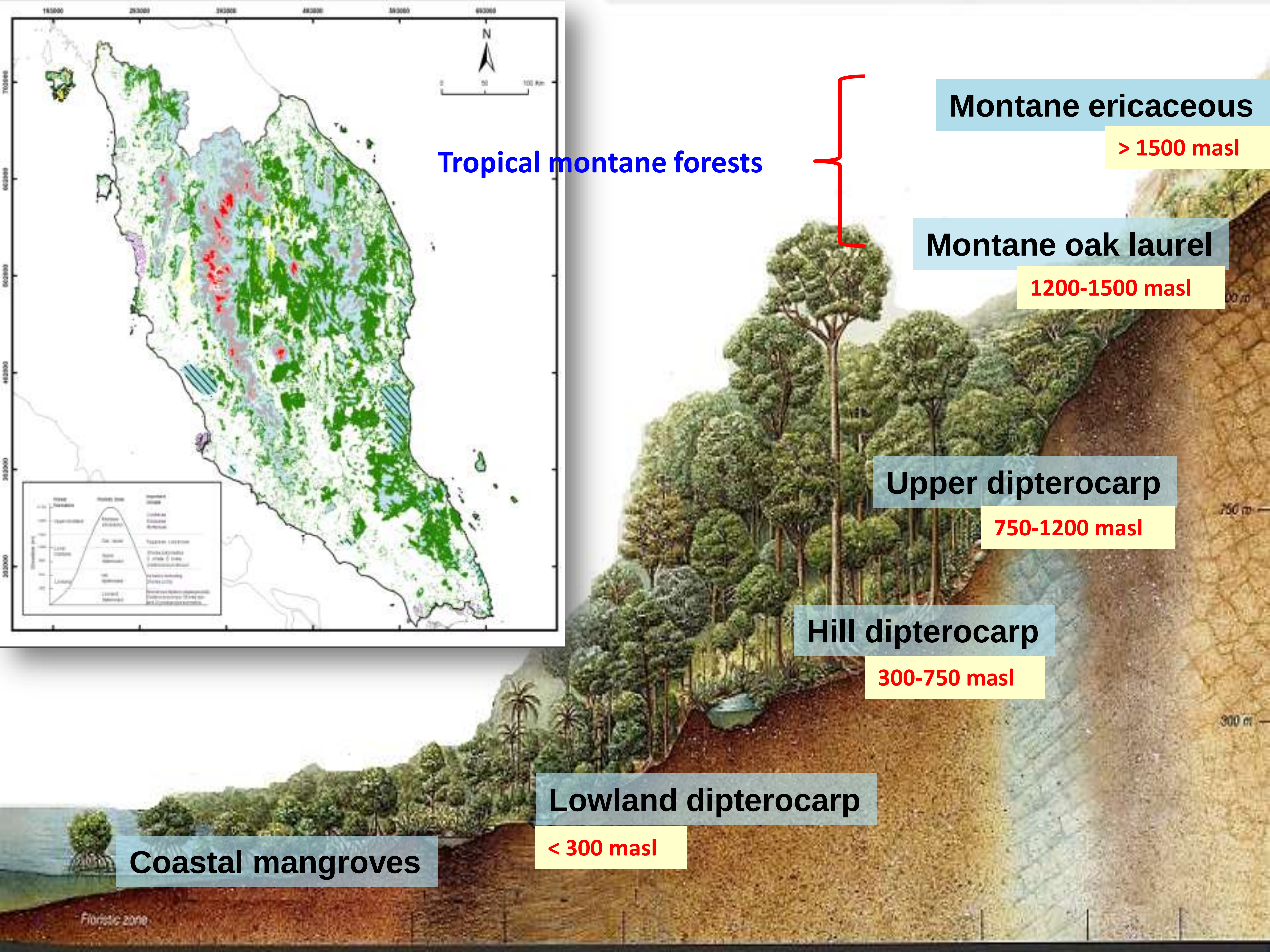
- Sungai Kial FR, Cameron Highlands (N 4˚ 31.17’ E 101˚ 25.92’, > 1500 masl), clay loam soil texture, annual rainfall 3325 mm, T: 17.8 ˚ C, Myrtaceae, Fagaceae

- VJR Jengka, Jengka, Pahang (N 3˚ 34.99’ E 102˚ 34.29’, 100 masl), silty clay loam soil texture, annual rainfall 2123 mm, T: 27.8 ˚ C, Euphorbiaceae, Dipterocarpaceae

METHODOLOGY

- **Plot preparation**

- Each forest type were segregated according to topography (summit, sideslope & toeslope)
- Forty quadrants measuring 10 x 10 m were established at each slope type
- Total of 120 quadrants/montane forest and 60 for lowland forest


Tropical montane forests
Montane ericaceous
> 1500 masl
Montane oak laurel
1200-1500 masl
Upper dipterocarp
750-1200 masl
Hill dipterocarp
300-750 masl
Lowland dipterocarp
< 300 masl
Coastal mangroves

Cameron Highlands, Pahang

Montane ericaceous forest
Location :N 04º 31’13.3” E 101º26’06.5”
Elevation : 1460 – 1700 m asl

Jengka, Pahang

Lowland Dipterocarp forest
Location : (N 3˚ 34.99’ E 102˚ 34.29’)
Elevation : 93 m asl

- **Litter and soil sampling**

- Litter samples collected using a 25 cm^2 frame where the litter depths and the C content were determined.
- Soil sampling:0-15 cm using a Jarret auger for geostatistics
- GPS receiver:GARMIN GPS CSx60
- 120 soil samples for montane and 60 for lowland forest
- Litter and soil samples were air dried, ground and analyzed for C and N.
- C, C:N and forest floor depth were explored further using geostatistics

Geospatial analysis

GPS coordinates and variable collected

Exploratory data analysis :Descriptive statistics, normality checks & non spatial outlier detection

Geostatistical analysis :Forest floor, soil C and soil C:N (0- 15 cm depth)

Spatial variability : variography & interpolation analysis (Balasundram, 2008)

Softwares : GS+ (variography & kriging) & Surfer (interpolation & mapping)

RESULTS

RESULTS

Statistical analysis results

Site	Total C (%)	C:N ratio	Forest floor depth (cm)
Sg. Kial FR			
Summit	**11.22**[a]	**120.02**[a]	7.54[b]
	(0.60)	(2.96)	(0.34)
Sideslope	6.73[b]	99.21[b]	4.56[c]
	(0.16)	(1.53)	(0.23)
Toeslope	5.31[c]	92.50[c]	**11.32**[a]
	(0.35)	(3.88)	(0.87)
Jengka VJR	1.05[d]	16.74[d]	1.85[d]
	(0.03)	(0.05)	(0.19)

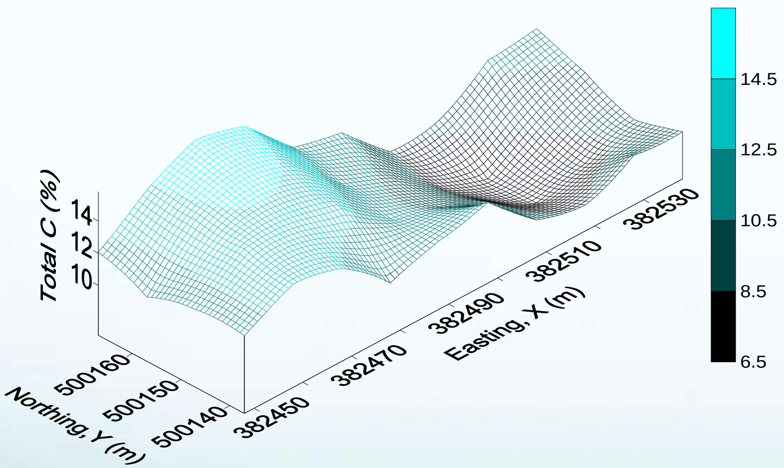
RESULTS

Geostatistical analysis

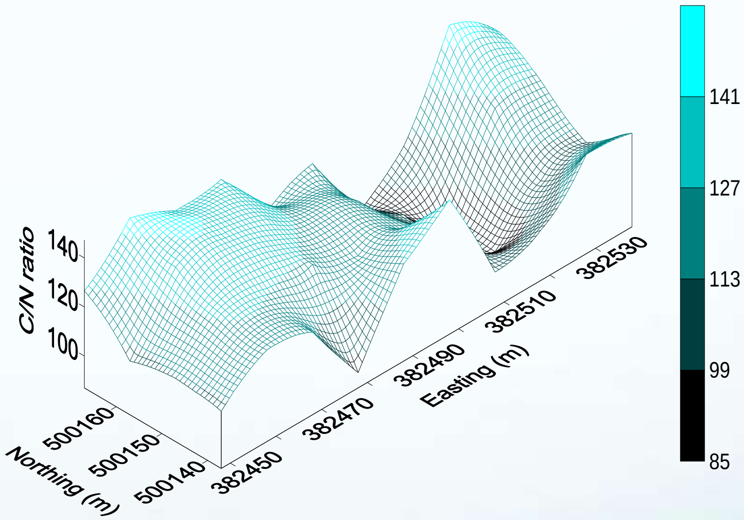
Site	Variable	model	Nugget (Co)	Sill (Co + C)	spatial dependence	effective range (m)
	total C%		5.560	23.640		107.3
summit	C:N	spherical	31.000	350.200	strong	26.7
	C:N		69.700	225.500	moderate	108.8
	total FF depth	gaussian	0.010	0.120		8.6
sideslope	Total C%		0.750	3.110		125.2
	total C%	exponential	0.020	0.170		8.1
	C:N		0.060	1.610		18.8
toeslope	total FF depth	spherical	0.001	0.730		18.2
	total C%		0.001	0.020	strong	8.9
	C:N		12.340	26.860		79.7
Jengka	total FF depth	exponential	0.570	3.150	moderate	44.6

RESULTS

- Spatial variability detected for **C, C:N, forest floor depth** for both sites for 0- 15 cm
- Semivariograms



Total C (%), Summit,



C:N , Summit

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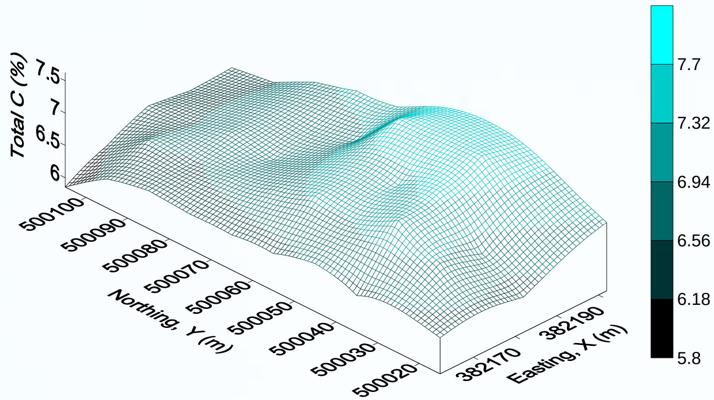
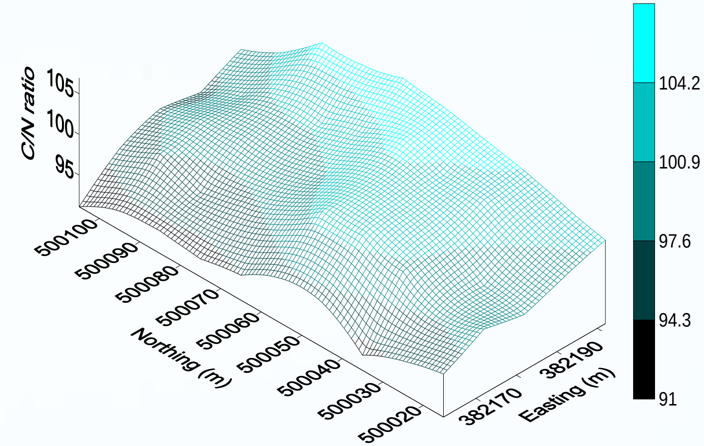
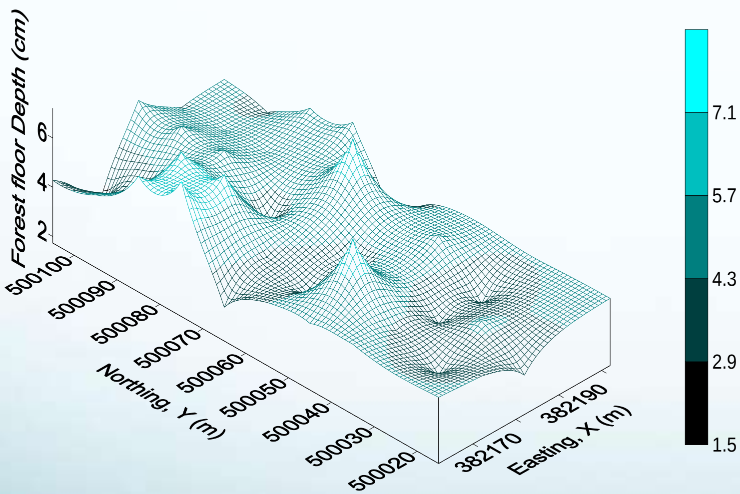


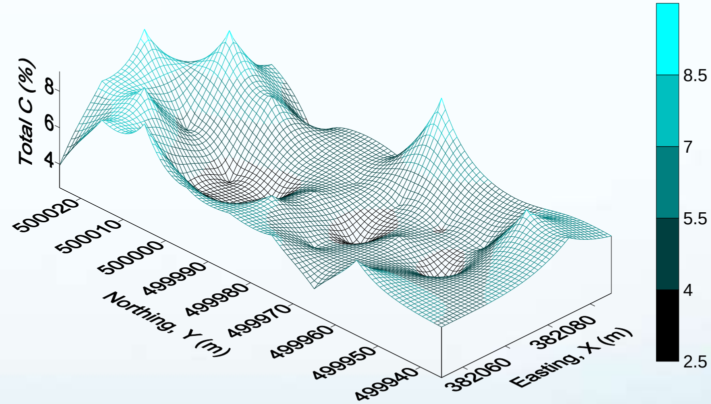
Total C (%), Sideslope



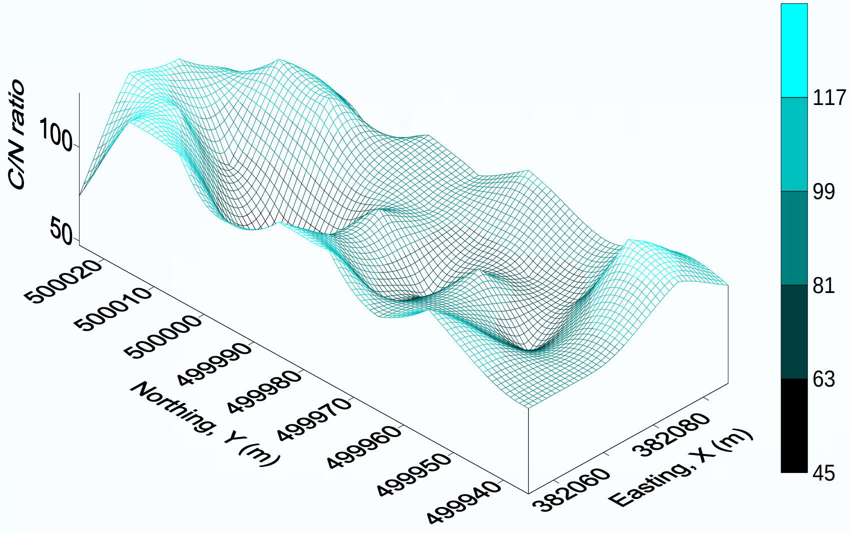
C:N , Sideslope



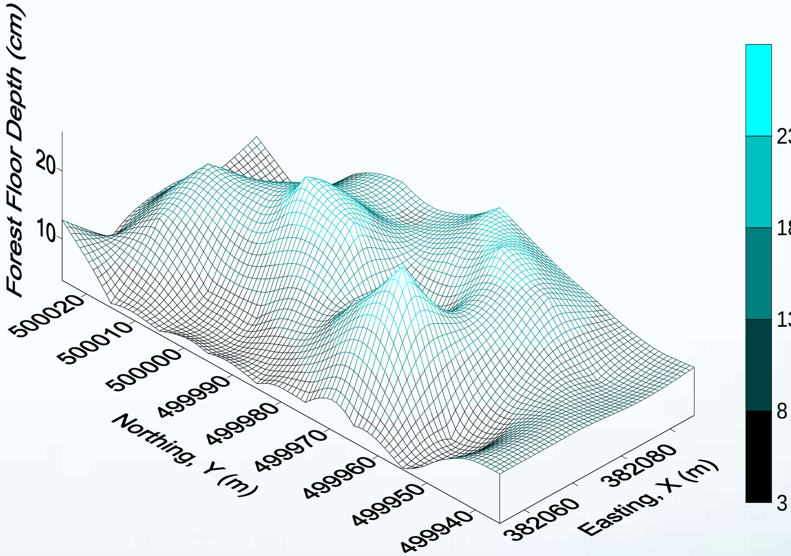
Forest floor depth (cm) , Sideslope



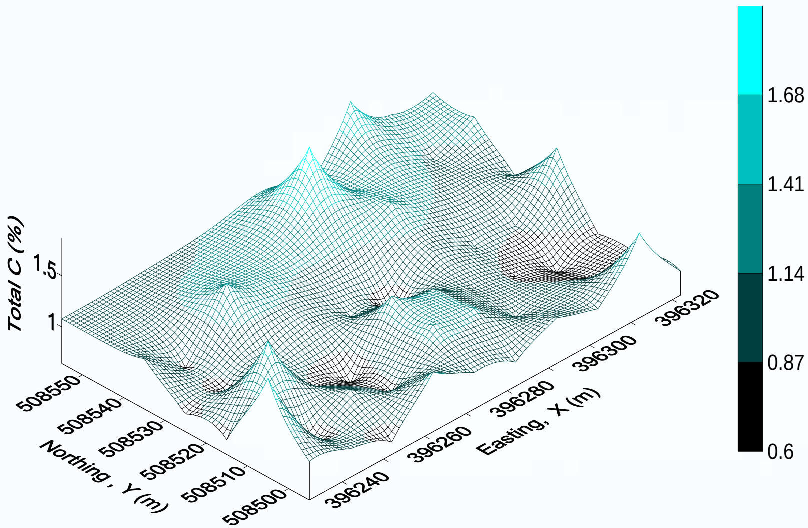
Total C (%), Toeslope



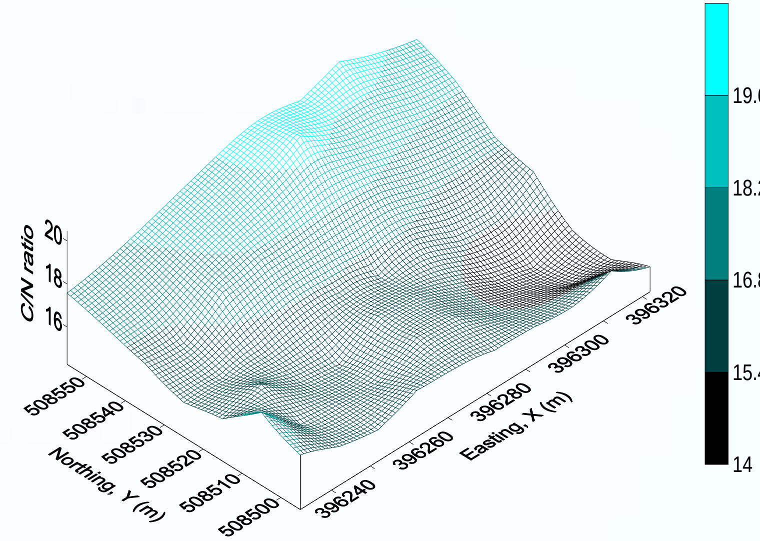
C:N , Toeslope



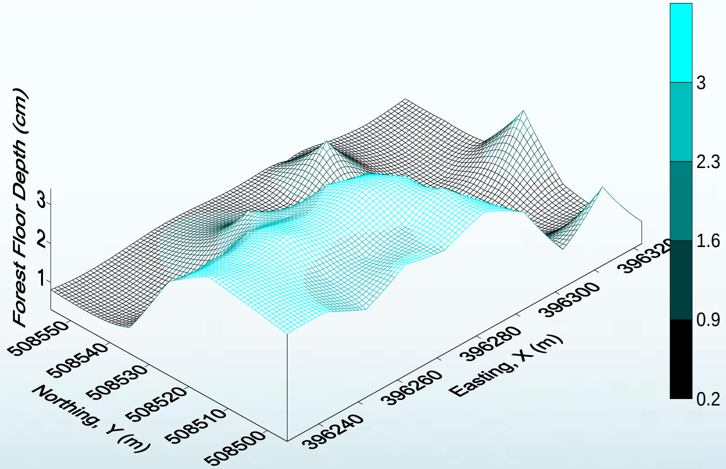
Forest floor depth (cm), Toeslope



Total C (%), Jengka VJR



C:N, Jengka VJR



Forest floor depth (cm) , Jengka VJR

DISCUSSION

- Soil total C is strongly influenced by topography and it increases with altitude (Garten & Hanson, 2006)
- High C:N in summit will hamper decomposition processes, data similar to Wagai (2008) in Mount Kinabalu
- Higher forest floor at toeslope due to mass wasting and water movement (Hugget & Cheeseman 2002)

DISCUSSION

- Soil total C (Zhang & McGrath, 2004), C:N and forest floor depth exhibited spatial variability and acceptable accuracy of interpolated values along a toposequence and in an undulating lowland forest
- Most variables exhibited a strong spatial dependence (Cambardella et al., 1994)
- Short ER at the toeslope and Jengka FR: sampling spacing should be closer in the lowlands
- Moderate ER at the sideslope and summit: increased spacing between samples will promote cost savings
- CS monitoring in tropical forest should be based on a site specific strategy (i.e. topographic delineation)

CONCLUSIONS

- Soil C stock in different forest vegetation may be use as a standard for AFOLU
- Forest floor thickness may be used for estimation of C stock with regards to varying soil temperature at different forest types
- Prediction of soil C sequestration potential using C/N ratios and forest floor segregation as indicators
- Spatial variability maps of soil C, C:N, and forest floor can be used by forest managers for decision making and C management.
- Information can assist in carbon crediting schemes and REDD+ efforts

EMERGING TRENDS

- Assessment/ Changes of forest C stocks using remote sensing maps
- Spatial variability of C stocks using geostatistics (soil, litter, C:N)
- Sea level monitoring using GIS applications at mangroves
- Disaster risk management and weather patterns monitoring using GIS

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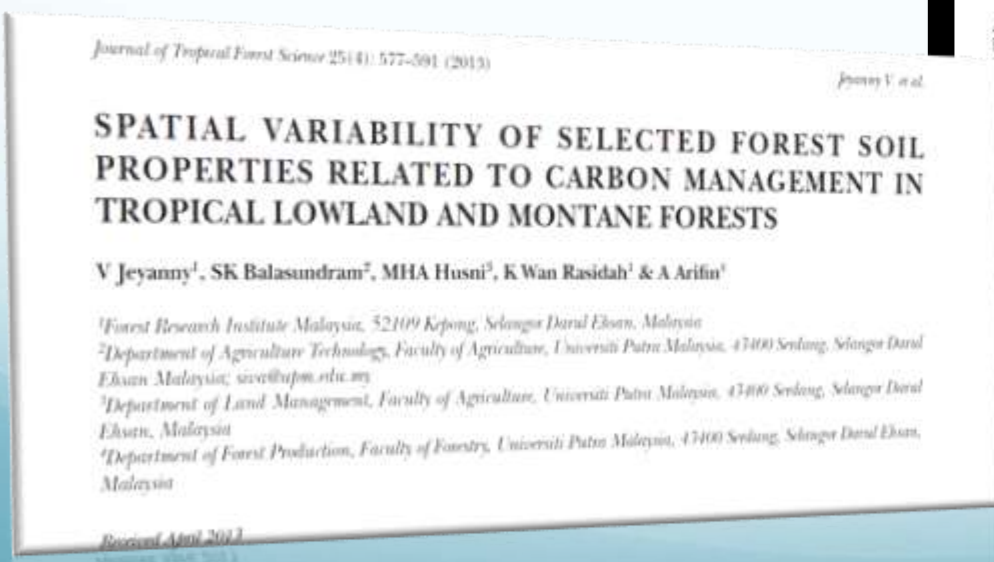
MMD

PUBLICATIONS

- **Jeyanny,V**.,S.K.,Balasundram and M.H.A Husni. 2011. Geo-spatial technologies for carbon sequestration monitoring and management. *American Journal of Environmental Sciences* 7(5): 456-462

- **Jeyanny, V.,** Balasundram, S.K., M.H.A, Husni, Wan Rasidah, K., and Ariffin. 2013. A. Spatial variability of selected forest soil properties related to carbon management in tropical lowland and montane forests *Journal of Tropical Forest Science* 25(4): 577-591



Journal of Tropical Forest Science 25(4): 577–591 (2013)

SPATIAL VARIABILITY OF SELECTED FOREST SOIL PROPERTIES RELATED TO CARBON MANAGEMENT IN TROPICAL LOWLAND AND MONTANE FORESTS

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Received April 2012

American Journal of Environmental Sciences 7 (5): 456-462, 2011
ISSN 1553-345X
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Geo-Spatial Technologies for Carbon Sequestration Monitoring and Management

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Abstract: Problem statement: Globally, the quantification of Carbon Sequestration (CS) potential of various ecosystems is a challenge. There is an urgent need for technologies that can quantify CS potential cost-efficiently in a repeated and organized manner. **Approach:** Remote Sensing (RS) and Geographic Information System (GIS) have great potential in current estimation, future prediction and

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ACKNOWLEDGEMENTS

- DG FRIM
- MOA Science Fund
- Pahang Forestry Department
- GeoSmartAsia Conference
- Soil Management Branch, FRIM
- Department of Soil Management, UPM

THANK YOU

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