Expert-Based Approach on Assessing Ecosystem Services Supply and Demand Surrounding a Protected Area

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The Ecosystem Services Concept

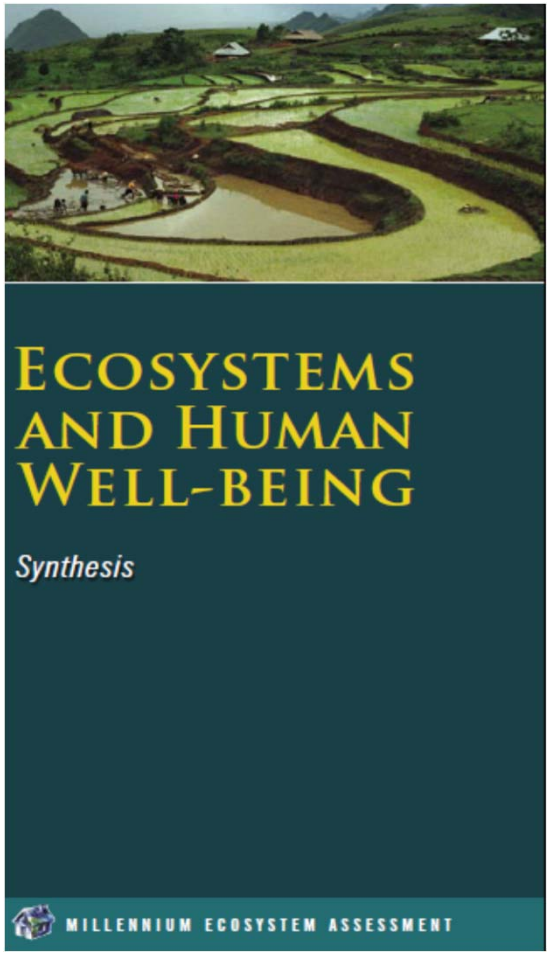
Global assessment of the state of ecosystems

- 2001 scientific work programme, commissioned by the United Nations
- 2001 - 2005 elaborated by more than 1300 experts from 95 countries
- Integrating scientific publications, available data, models
- Considering private, practical as well as local & traditional knowledge

Major Goals

- Illustrate the importance / relevance of ecosystems and biodiversity for human well-being & quality of life
- Awareness raising for the reliance of humans on nature & for the benefits of safeguarding / sustainable use
- Provide political guidance and advise for decision makers

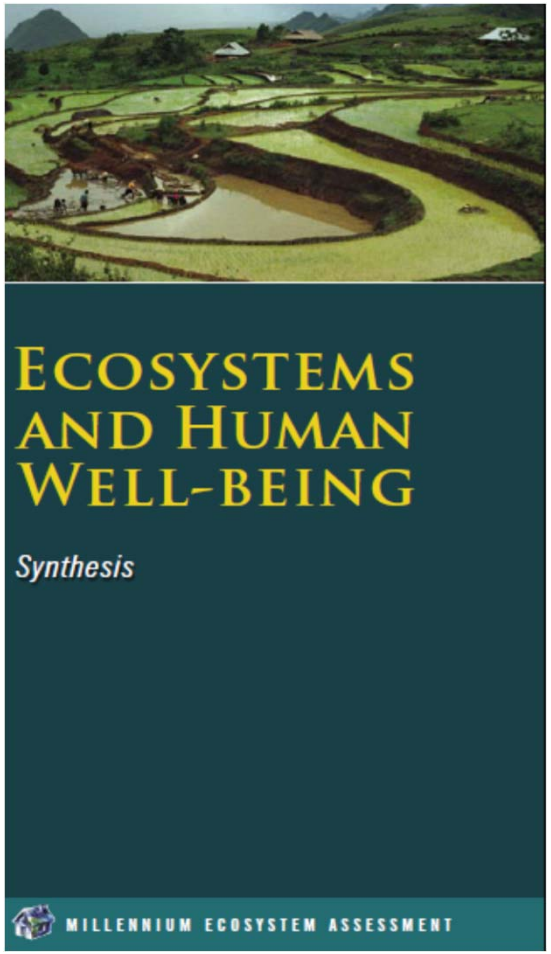
2005 Synthesis Report (Millennium Ecosystem Assessment 2005: Ecosystems and Human Well-being: Synthesis.- Island Press, Washington)



The Ecosystem Services Concept

Issues

- No detail guideline on how to use the concepts and framework that were developed (Seppelt & Dormann, 2011).
- Scientific argument regarding scarcity of the MEA framework (Fisher et al., 2009; Schröter et al., 2014).
- Challenges to establish standardized, comprehensible, and practicable approaches to be used by scientists and policy makers (Crossman et al., 2013; Elliff and Kikuchi, 2015).



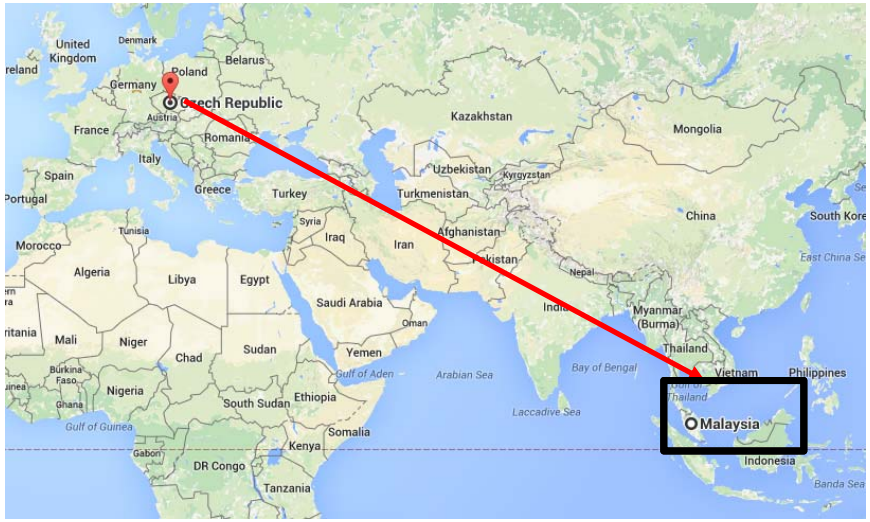
Background

- Growing attention ➡ measurement of non-monetary of ecosystem services (ES) & consequence of land use change (Camacho-Valdez et al. 2014;Vandewalle et al. 2009)
- Holistic appraisal of ES for bundles of landscape must be taken into account (Müller, 2005; Burkhard et al., 2010)
- There is a need to transfer the ES concept to landscape planning, integrated and easily applicable assessment (De Groot, 2006)
- **'Matrix Model'** using expert judgments in assessing landscapes' capacities to provide ES (Burkhard et al.; 2009, 2012a, 2012b and 2014a, 2014b)

Motivation & Objectives

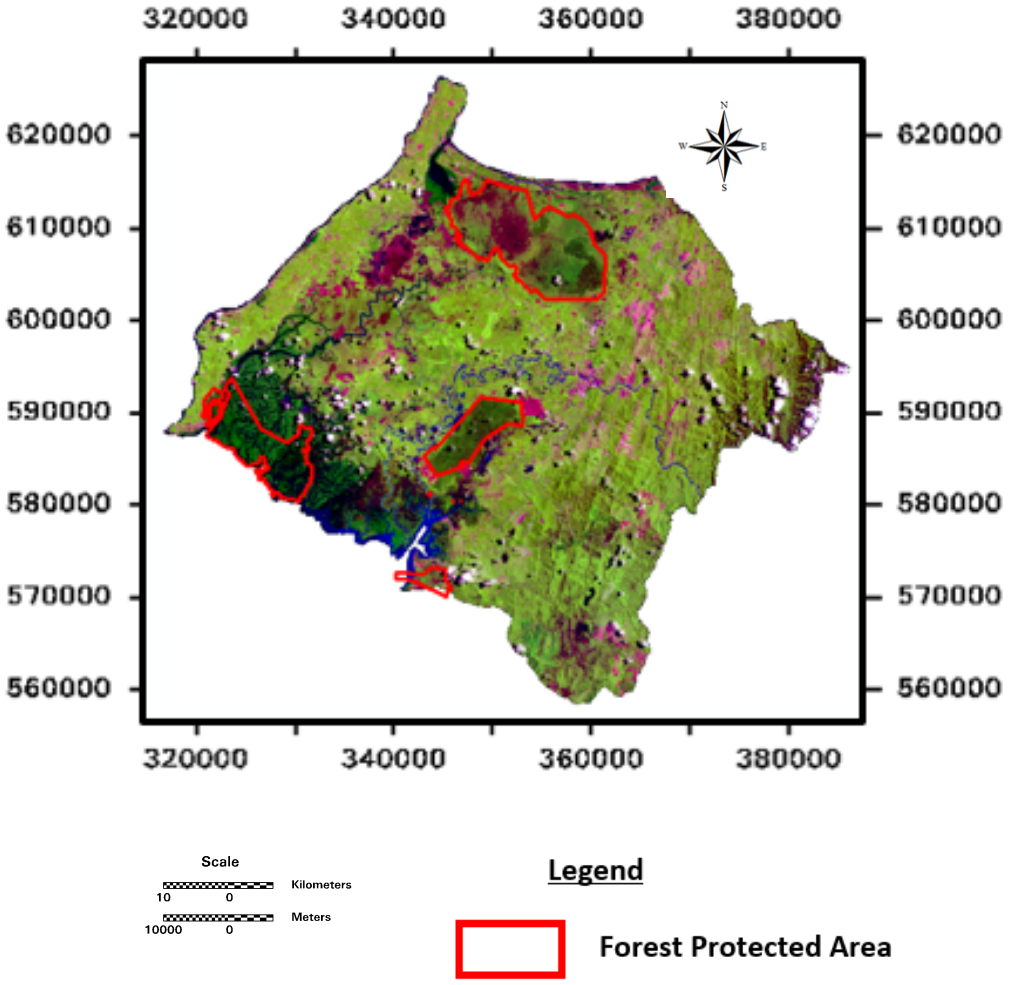
- Research is confronted with standard methodological evaluation problems.
- Lack methodological transparency make the matrix model a risky tool for actual decision support (Jacobs et al., 2015).
- Every uncertainty in the data translates to an increased risk for undesired outcomes for decision makers (Jacobs et al., 2015).
- Absence of comprehensive sets of data for ecosystem services (ES) mapping particularly on the local scale and in developing countries (Sumarga and Hein, 2014)
- Therefore this study was conducted:
  - To develop transparent analysis of ES bundles in tropical forest ecosystem
  - To identify potential landscape capacity to provide ES supply for protected area
  - To determine local community demand on various ES and relate to different land cover types
  - To quantify the potential supply-demand budget for various ES type

STUDY AREA: Southwestern Sabah, Malaysia



- Current population of Malaysia in total is **29,791,949**
- Total land area is 329,613 square kilometres (**127,260 sq mi**)
- Approximately **60%** covered by forest

Continue….



- Klias Peninsula (466,804 ha)
- Fire outbreak tremendously degraded the protected area during the El-Niño events
- Demands by the adjacent local communities to convert the area into agricultural use

Endemic Species

Local Community

Forest Fire During El-Nino

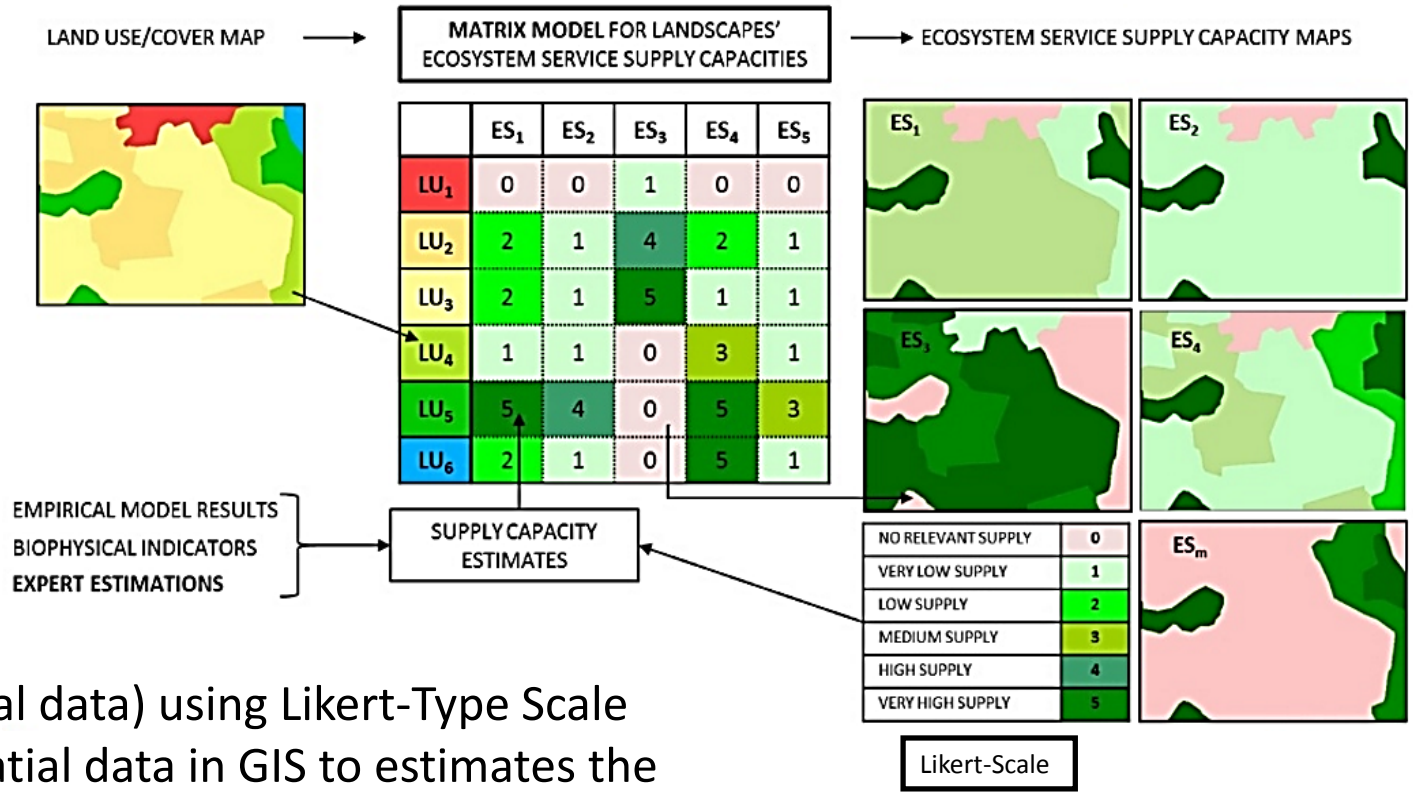
Land Clearing for Agriculture

Tourism/Recreation Activity

The “Matrix Model” Approach to Map Ecosystem Services

Assessment

- GIS and LU/LC map prepared to define different sense of ES
- ES (on the x-axis) and land cover types (on the y-axis)
- ES evaluations based on identification of appropriate indicators



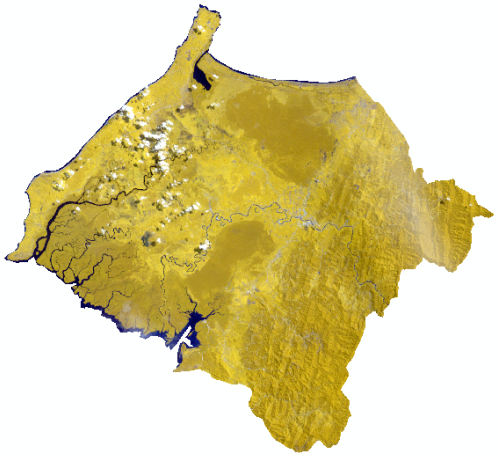
- Expert judgement (Empirical data) using Likert-Type Scale
- The Likert values link to spatial data in GIS to estimates the ES in spatially explicit units

after Burkhard et al. (2012, 2014)

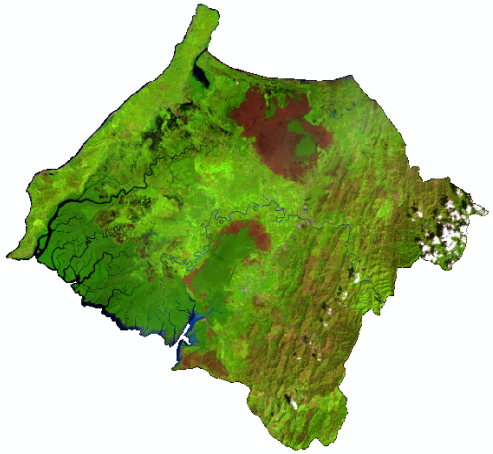
Multi-Temporal Satellite Images as an Available Database

- Landsat imagery and other remote sensing data area currently available for public access and download

- United State Geology Survey (USGS) & Global Land Cover Facility (GLCF), are the largest **FREE** source of **Landsat** data



Landsat MSS 1985



Landsat7- ETM+ 1998

Landsat7- ETM+ 2004

Landsat 8 OLI/TIRS 2013

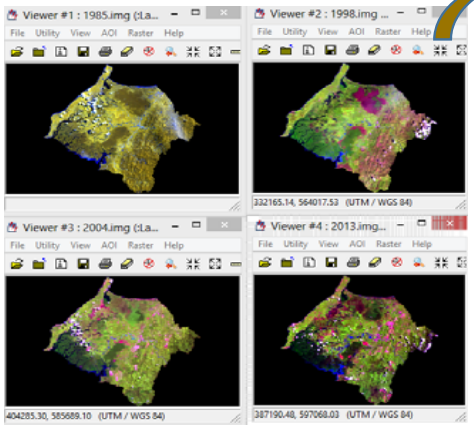
http://earthexplorer.usgs.gov/

Multi-Temporal Satellite Images Processing

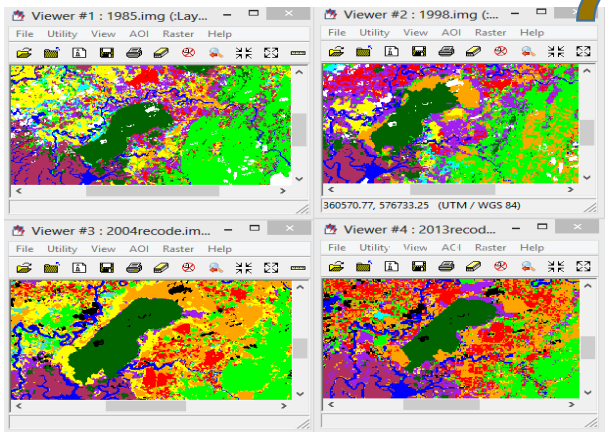
- Numerous analysts of multispectral Landsat data attempt to identify vegetation change in tropical wetlands (Cardoso et al., 2014; Kamlun & Phua, 2010; Ibrahim and Jussof, 2009)
- Digital image classification the most effective image analysis for mapping wetland vegetation (Churches et al., 2014; Ozesmi & Bauer, 2002; Tsuyuki et al., 2011)

Supervised Classification Process

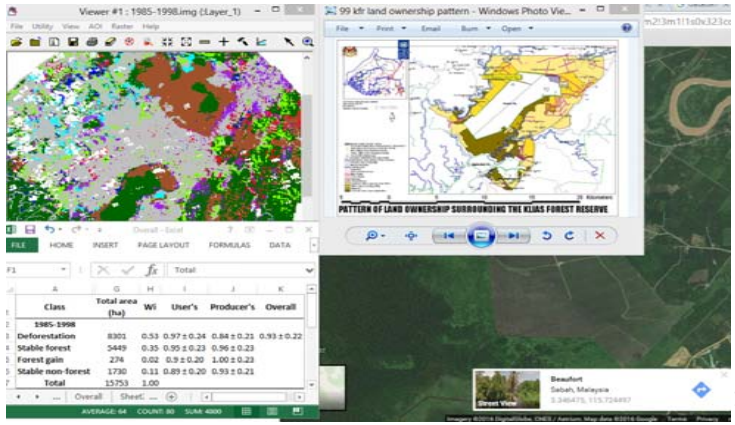
Band Combination



Pixel Based Maximum Likelihood

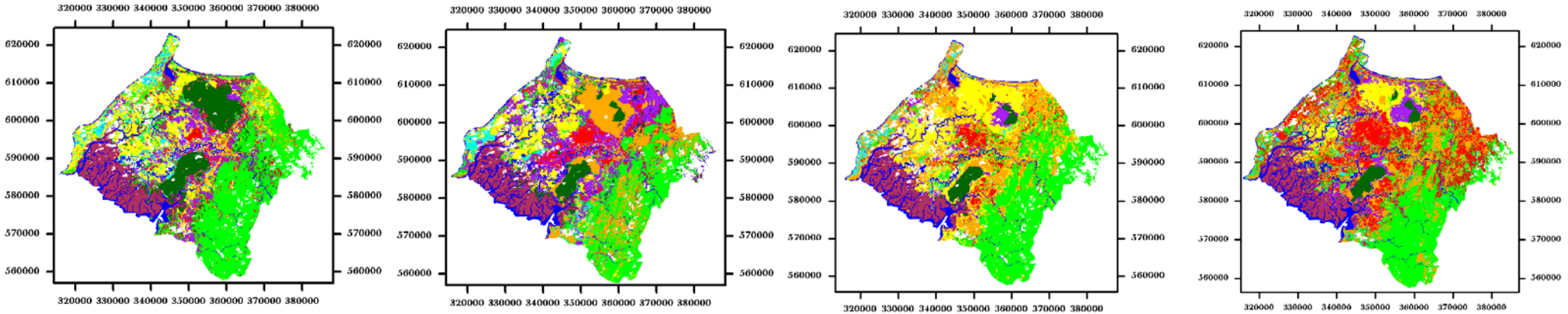


Accuracy Assessment: Error Matrix

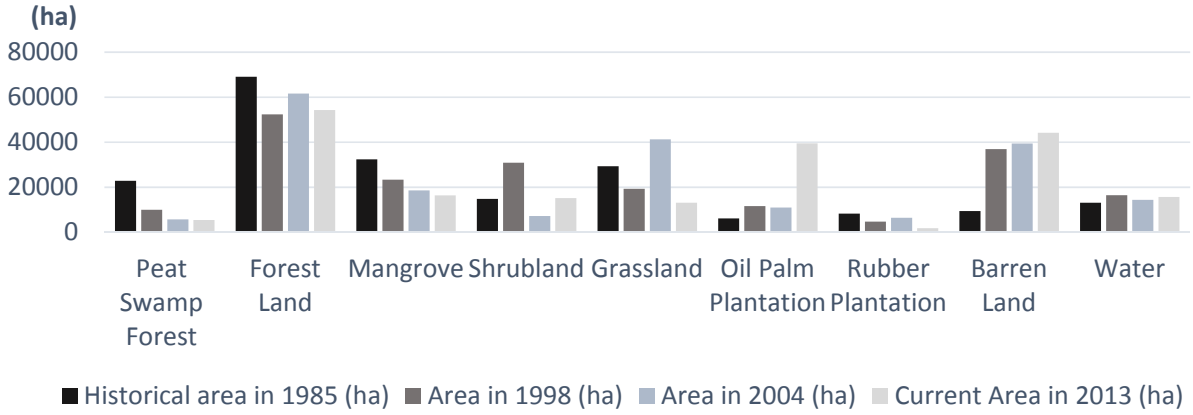


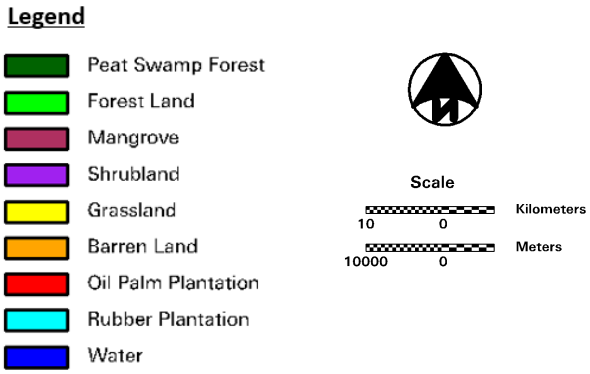
after U.K.Kamlun et al. (Under Review)

Multi-Temporal Visual Interpretation of Land Cover Map



LC 1985 LC 1998 LC 2004 LC 2013





after U.K. Kamlun et al. (Under Review)

IDENTIFICATION OF RELEVANT SUBSERVICES

- A wide range of subservices identified and used by various researchers for the categories of; provisioning services, regulating services, and cultural services (UNEP-WCMC, 2009; Burkhard et al., 2012; Crossman et al., 2013; Krasny et al., 2013; BIP, 2014).

- It is important to establish a **clear** and **appropriate** classification system to assess ecosystem services for decision context.

- The definitions of each subservice adopted from various pioneer of ecosystem services expert (Costanza et al., 1997; Daily, 1999; MA, 2005; De Groot et al., 2010; Burkhard et al., 2012, Petter et al., 2013, Szücs et al, 2015)

- After thorough process certain subservices were excluded; **mismatched** of description, **double counting** of indicators, **not relevant** for local scale assessment

i.e:

Categories/ Sub-Categories	Description/ Rationales/ Functions	Potential Indicators/ State indicator (how much of the services is present) – Supply
Supporting Services		
Metabolic efficiency	Referring to the amount of energy necessary to maintain a specific biomass, also serving as a stress indicator for the system.	Respiration/biomass (metabolic quotient)
Energy Capture (Radiation)	The capability of ecosystems to enhance the input of usable energy.	Net primary production; Leaf area index LAI
Reduction of nutrient loss	Referring to the irreversible output of elements from the system, the nutrient budget and matter flows	Leaching of nutrients, e.g. N, P
Storage capacity (SOM)	Is referring to the nutrient, energy and water budgets of the system and the capacity of the system to store them when available and to release them when needed.	Solved organic matter; N, C org in the soil; N, C in biomass
Soil formation and regeneration	Role of natural processes in soil formation and regeneration. Soil formation is the facilitation of soil formation processes.	E.g. bio-turbation
Water cycling/ Biotic waterflows	Referring to the water cycling affected by plant processes in the system	Transpiration/total evapotranspiration
Biodiversity	The provision of suitable habitats for different species, for functional groups of species and for processes is essential for the functioning of ecosystems	Abiotic habitat components' diversity indices; Heterogeneity indices, e.g. humus contents in the soil; Number/area of habitats
Genepool protection (to maintain ecological balance/ evolutionary process)	Maintenance of a given ecological balance and evolutionary processes	Natural biodiversity (esp. Endemic species); Habitat integrity (irt min. critical size)

Qualitative Thematic Analysis Coding Catalogue

Categories/ Sub-Categories	Description/ Rationales/ Functions	Analytical Themes (Land Cover Type); (Scale)	Coding	Supply Indicator (How much is the Services present)	Data Reduction Process (For Mapping ES Supply)	*Peat Swamp Forest*	*Forest Land*	*Mangrove*	*Shrubland*	*Grassland*	*Oil Palm Plantation*	*Rubber Plantation*	*Barrenland*	*Water*
Ecological Integrity														
Reduction of nutrient loss	Referring to the irreversible output of elements from the system, the nutrient budget and matter flows	Reducing N/P leaching, nutrient runoff, loss of nutrient, AMF reduce nutrient loss	Reducing N/P leaching, nutrient runoff, loss of nutrient, AMF colonization %	Leaching of nutrients, e.g. N, P, No of AMF Species, AMF colonization %,	AMF colonization %	18-32% *(ScP), (S) (Turjaman et al., 2008)	59-71% *(ScP), (S) (Lakshmipathy et al., 2012)	9-25% *(ISI), (S) (Xie et al,2014)	50-60% *(ISI), (T) (Sánchez-Castro et al., 2012)	64-68% *(ScP), (S) (Lakshmipathy et al., 2012)	< 30% *(ScP),(R) (Nadarajah and Nawawi, 1993)	27-38% *(ScP), (G) (Omorusi et al., 2011)	0	0
Provisioning Services														
Timber	Biomass that use for other purposes other than food; Presence of trees or plants with potential use for timber.	Timber Production, Log production, Wood Production	Timber Production, log production, Wood Production (m3 /ha^{-1})	Wood/ha; kJ/ha; kg/ha	Wood Production, F7	30-60 m^3 /ha^{-1} *(TR), (R) , (Parlan and Harun, 2011)	150 -154 m^3/ ha^{-1} *(ISI), (L) (Berry et al, 2010)	164.03 m^3/ha^{-1} *(ISI), (T), (Tovilla-Hernández et al (2001)	0	0	0	45 m^3/ha^1 *(ScP), (R), (Ratnasingam et al. 2012)	0	0
Regulating Services														
Climate regulation	Influence of ecosystem on climate through land cover and biologically-mediated processes that regulate atmospheric processes and weather patterns which in turn create the microclimate; Ecosystems play an important role in climate by sequestering or emitting greenhouse gases	Climate, regulation,Carbon stock, Carbon sequestration	Climate, regulation,Carbon stock, Carbon sequestration, carbon/ha, MgC/ha, ton carbon/ha	Greenhouse gas-balance (esp. C-sequestration); land cover characteristics; Temperature, albedo, precipitation, wind; Temperature amplitudes; Evapotranspiration; ton carbon/ha; MgC/ha; ton carbon/ha	ton carbon/ha^{-1}	5800 ton carbon/ha *(GL), (L), (UNDP/GEF 2006)	500 ton carbon/ha^{-1} *(GL), (L) (UNDP/GEF 2006)	990 - 1074 ton carbon/ha^{-1} *(ScP), (T) (Donato et al. 2011)	2.8e^{-8}-3.0e^{-8} ton carbon/ha^{-1} *(ScP), (S) (Agus et al. 2013)	0.3e^{-8} ton carbon/ha^{-1} *(ScP), (S) (Agus et al. 2013)	3.0e^{-8}-4.0e^{-8} ton carbon/ha^{-1} *(ScP), (S) (Lucey et al, 2014)	5.8e^{-8}-2.8e^{-8} ton carbon/ha^{-1} *(ScP), (S), (Agus et al. 2013)	3.6e^{-8} ton carbon/ha^{-1} *(ScP), (S), (Agus et al. 2013)	0
Cultural Service														
Recreation and Ecotourism	Benefit People Obtain from nature by recreational activities; Refers specifically to landscape and visual qualities of the area; the sense of beauty people get from looking at the landscape and related recreational benefits.	Tourism Value, Natural Features and Attractio, Recreational Value	Tourism Value, Natural Features and Attractio, Recreational Value; Number of Elements and Features	Number/ area of landscape and wildlife features with stated recreational value; Number of visitors or facilities; Questionnaires on personal preferences;	Ecotourism/ Recreation Features	6 features (GL), (L) (Vaz, 1998)	10 features (ScP), (R), (Idris et al., 2013)	6 features (GL), (L) (Vaz, 1998)	0	0	1 Feature, (ScP), (G), (Turner et al., 2008)	0	0	3 Features (GL), (L) (Vaz, 1998)

Integrate “Thematic Analysis” & “Matrix Model” Approach to Map ES Supply

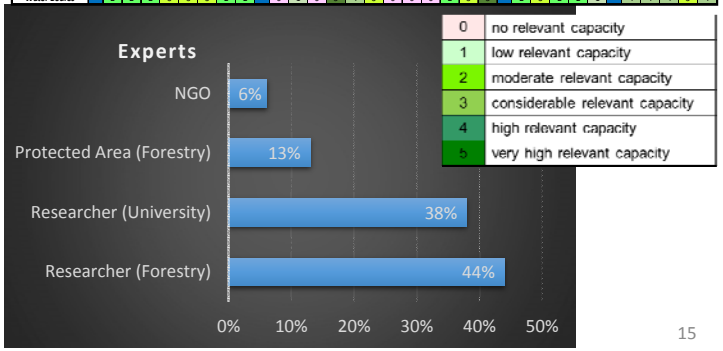
Validity and Reliability Assessment

- **17 Expert from various field of nature conservation, protected area, ecol... hydrologist, wildlife and etc. were interviewed**
- **Validation of the relevant indicators of sub-services and ecosystem type**
- **Merging the empirical and expert evaluation data**



ES Matrix Potential Supply Capacity

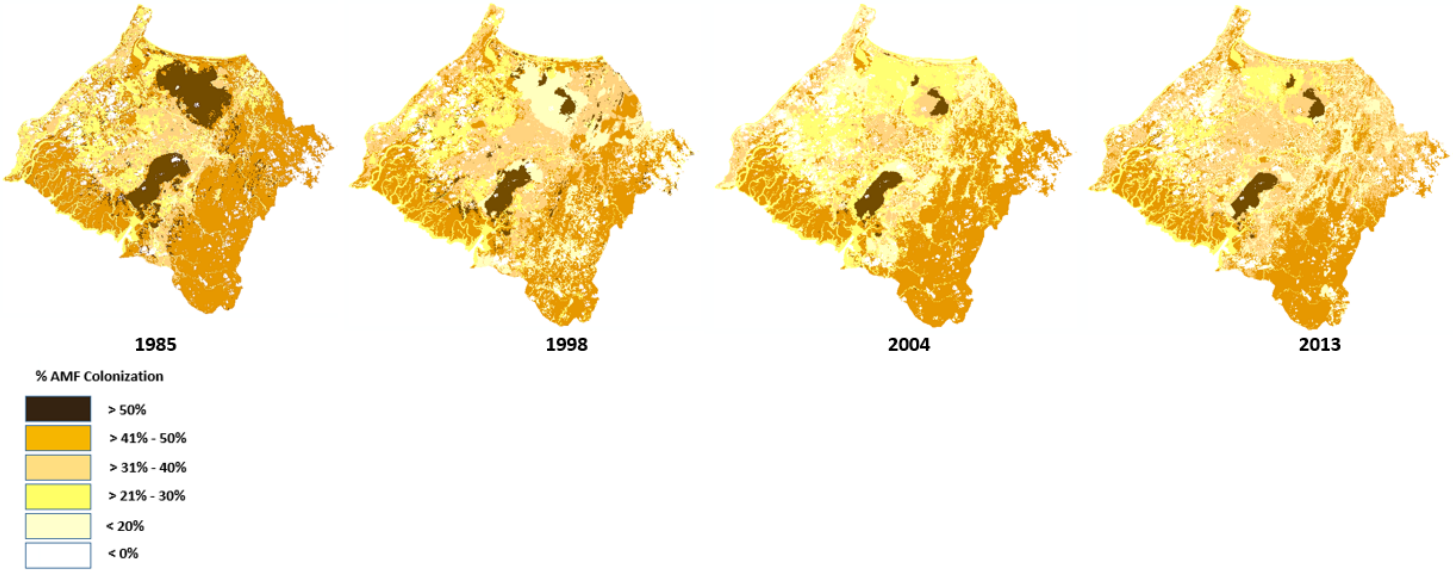
Land Cover Type	Σ Ecological integrity	Metabolic efficiency	Energy capture (radiation)	Reduction of nutrient loss	Storage capacity (SOM)	Abiotic heterogeneity	Biodiversity	Soil formation and regeneration	Biotic waterflows	Σ Provisioning services	Crops	Livestock	Fodder	Capture fisheries	Aquaculture products	Wild foods	Timber	Fuel Wood	Energy Resources	Medicinal resources	Genetic resources	Fresh Water Resources	Σ Regulating services	Climate regulation	Nutrient regulation	Flood protection	Water regulation	Erosion regulation	Σ Cultural services	Recreation and ecotourism	Cultural heritage	Inspiration for culture	Spiritual inspiration	Educational and scientific interes
Peat Swamp Forest	4	5	5	5	4	4	4	4	4	0	1	1	2	2	3	4	4	4	3	4	4	5	4	5	4	4	4	4	4	3	3	5	
Mangrove	4	4	4	4	4	4	4	4	4	0	0	0	4	4	4	4	4	4	3	4	2	4	4	4	3	5	5	4	4	3	5		
Forest Land	4	5	4	5	5	5	4	5	0	2	1	1	1	4	5	5	4	4	4	5	4	5	5	4	5	5	5	4	4	4	4	5		
Shrubland	3	3	3	3	3	3	3	3	0	3	2	1	1	2	2	3	3	2	3	3	3	3	3	3	3	3	2	2	2	2	3		
Grassland	2	2	2	2	2	2	3	2	0	3	3	1	1	2	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		
Oil Palm Plantation	3	3	3	2	2	2	3	5	3	2	1	0	3	1	1	3	2	1	1	3	3	2	2	3	2	2	3	2	1	1	1	3		
Rubber Plantation	3	4	3	3	2	2	2	3	4	3	1	1	0	2	4	3	3	1	1	2	4	3	2	3	3	2	1	2	1	3				
Barren Land	1	1	1	1	1	1	1	0	2	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	1	1	1	2			
Water Bodies	2	2	3	3	3	2	2	0	1	0	5	4	3	0	0	0	2	3	5	2	3	2	2	1	4	4	4	3	4					



after U.K.Kamlun & R. Bürger-Arndt (2015)

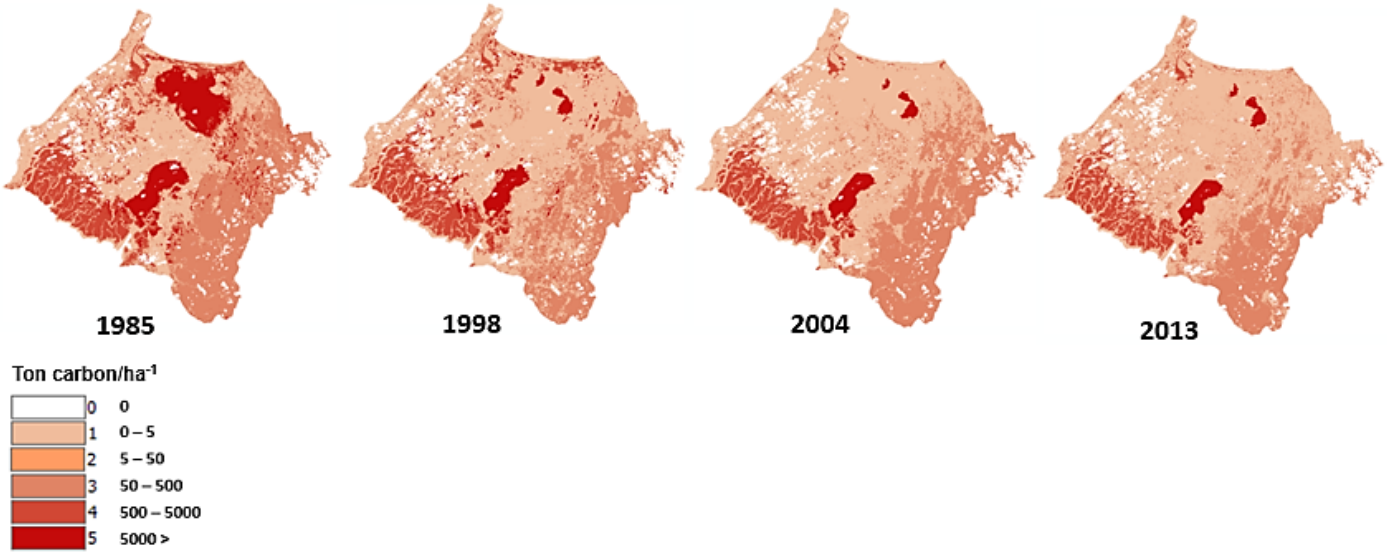
Mapping Ecological Integrity of Ecosystem (Reduction of Nutrient Loss)

Capacity to Reduce Loss of Nutrient



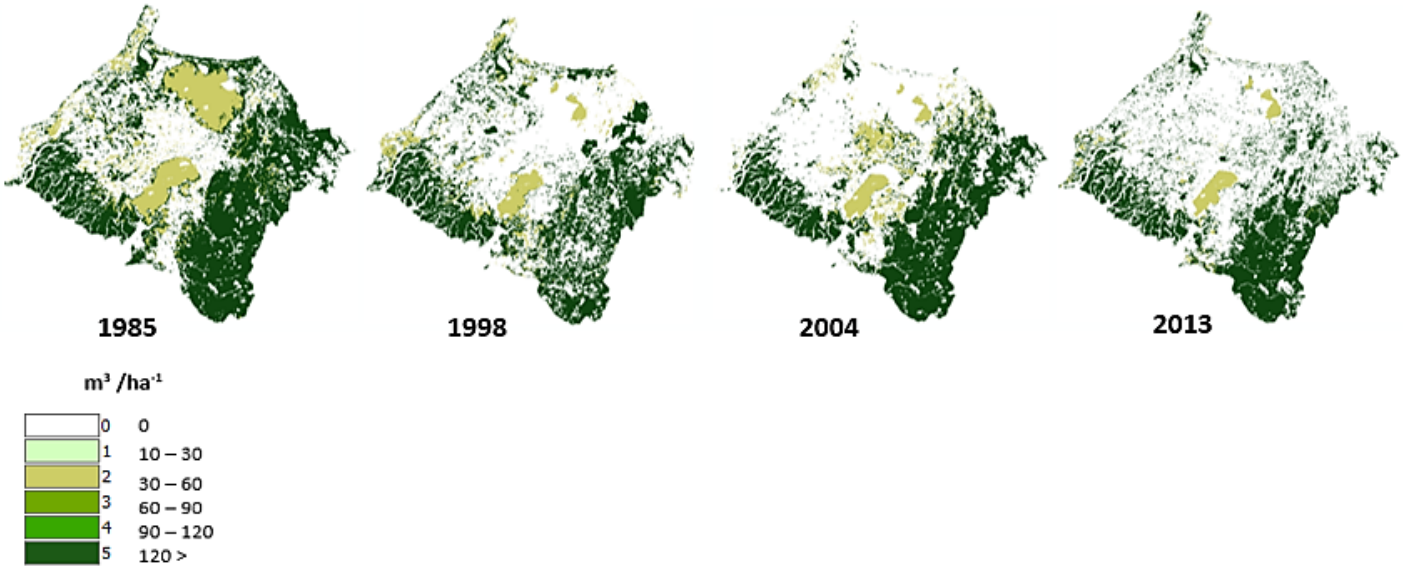
Mapping Ecosystem Services Potential Supply: Regulating (Climate Regulation)

Carbon Sequestration Capacity

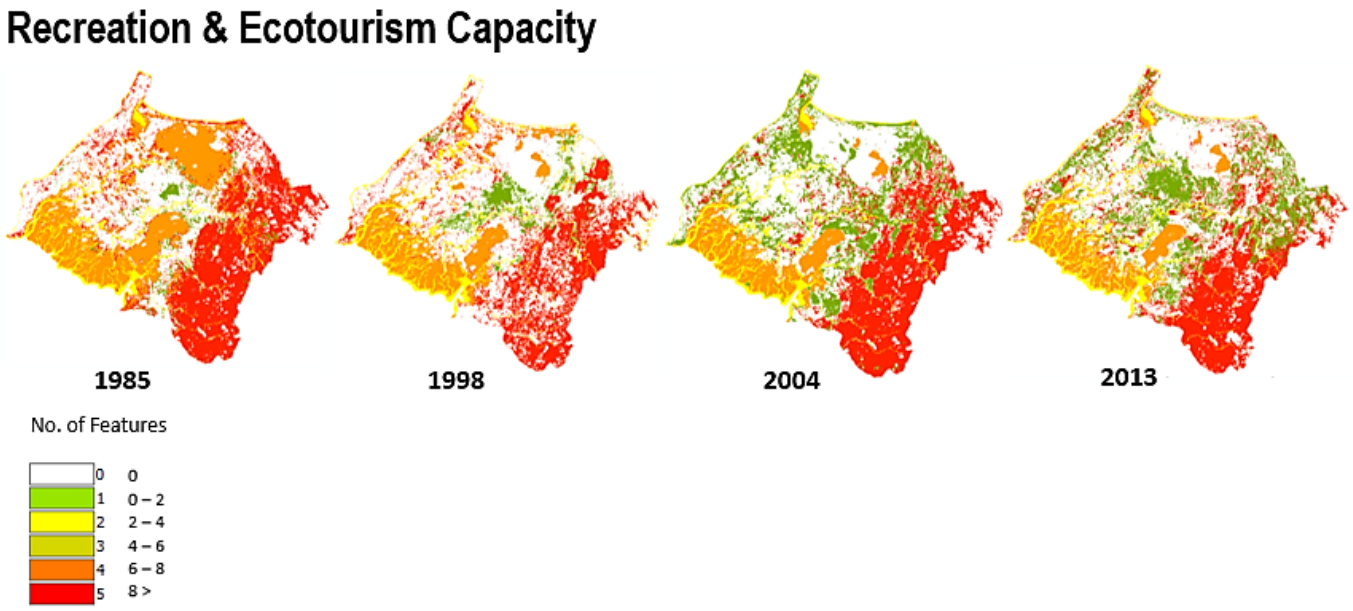


Mapping Ecosystem Services Potential Supply: Provisioning (Timber)

Timber Production Capacity

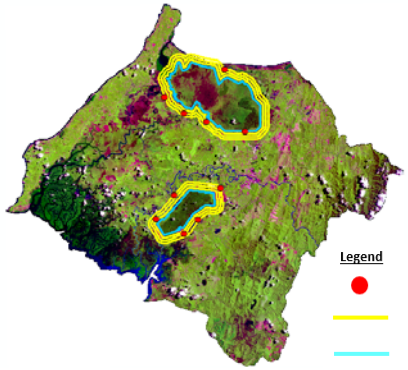


Mapping Ecosystem Services Potential Supply: Cultural (Recreation and Ecotourism)



Assessing Local Community Demand on Ecosystem Services

- Concentric circles sampling was used to select **10 villages** that proximately located near the protected area (Radius of 500 Meter, 1000 Meter, 1500 Meter)
- Likert-type scale questionnaire and interview (**281 respondents**)
- Local **people demand** for ES link with related land cover types



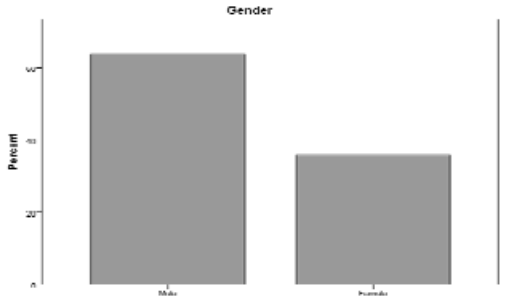
Village Sampling Zone

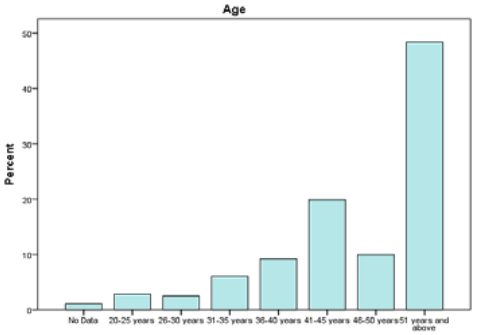
Public Opinion Pol

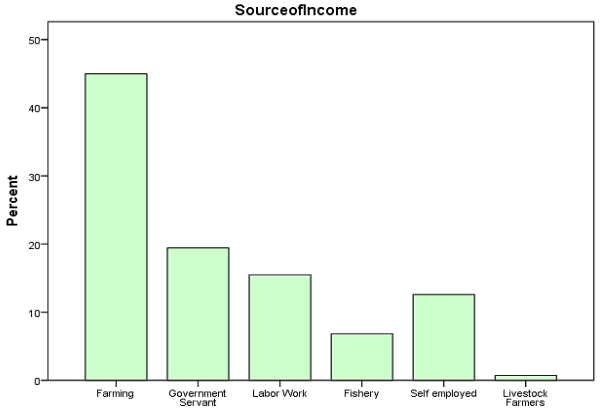


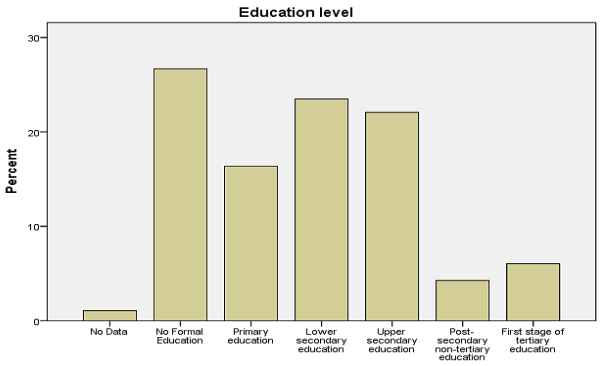



Local Community Demographic Information









Assessment Matrix Demands for Ecosystem Services of Local People

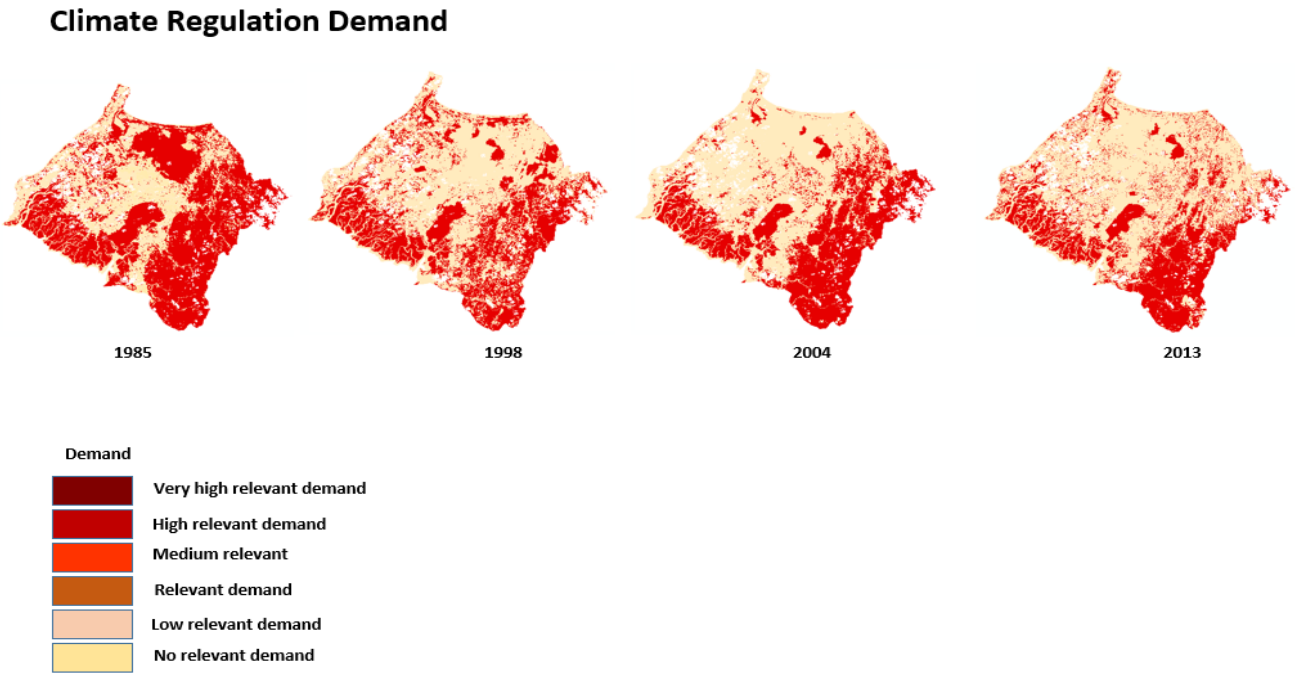
- Mean aggregated data from **Public Opinion Pol** ES demand assessment

Land Cover Type	Σ Provisioning services	Crops	Livestock	Fodder	Capture fisheries	Aquaculture products	Wild foods	**Timber**	Fuel Wood	Energy Resources	Medicinal resources	Genetic resources	Fresh Water Resources	Σ Regulating services	**Climate regulation**	Nutrient regulation	Flood protection	Water regulation	Erosion regulation	Σ Cultural services	**Recreation and ecotourism**	Cultural heritage	Inspiration for culture	Spiritual inspiration	Educational and scientific interes
Peat Swamp Forest		0	0	0	0	1	2	1	1	0	1	0	0		4	3	5	5	0		1	1	1	1	1
Mangrove		0	0	0	0	0	0	0	1	0	0	0	0		4	0	5	5	0		1	1	0	1	1
Forest Land		0	0	0	0	0	1	1	1	0	0	0	0		4	3	5	5	1		1	1	1	1	1
Shrubland		0	0	0	0	0	1	1	1	0	0	0	0		3	1	0	0	0		0	1	1	1	1
Grassland		1	1	0	0	0	0	0	0	0	0	0	0		0	1	0	0	0		1	1	0	1	0
Oil Palm Plantation		4	1	1	0	0	1	0	0	0	0	0	0		0	1	0	0	0		0	0	0	1	1
Rubber Plantation		2	0	0	0	0	1	1	1	0	0	0	0		0	0	0	0	0		0	0	0	1	1
Barren Land		0	1	0	0	1	0	0	0	5	0	0	0		0	0	0	0	0		1	1	0	1	1
Water Bodies		0	1	0	2	1	1	0	0	0	0	0	5		0	0	1	4	1		1	1	0	1	1

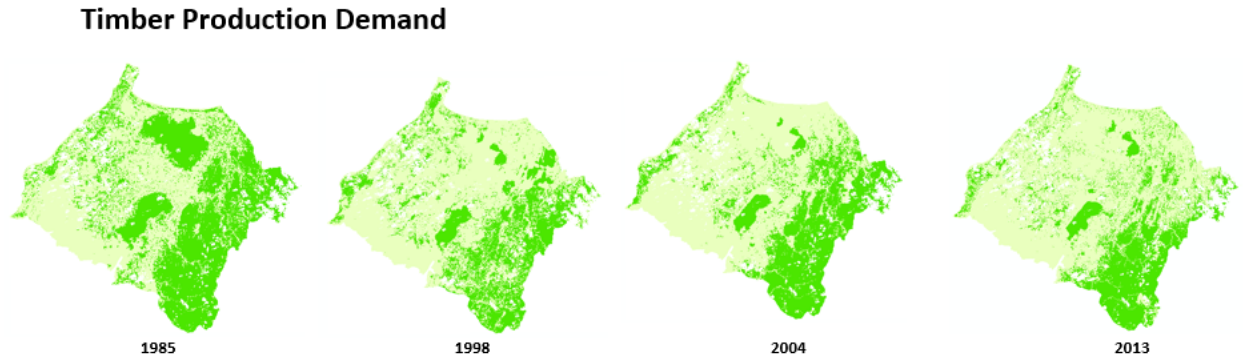
scale for assessing demands:

0 = no relevant demand
1 = low relevant demand
2 = relevant demand
3 = medium relevant demand
4 = high relevant demand
5 = very high relevant demand

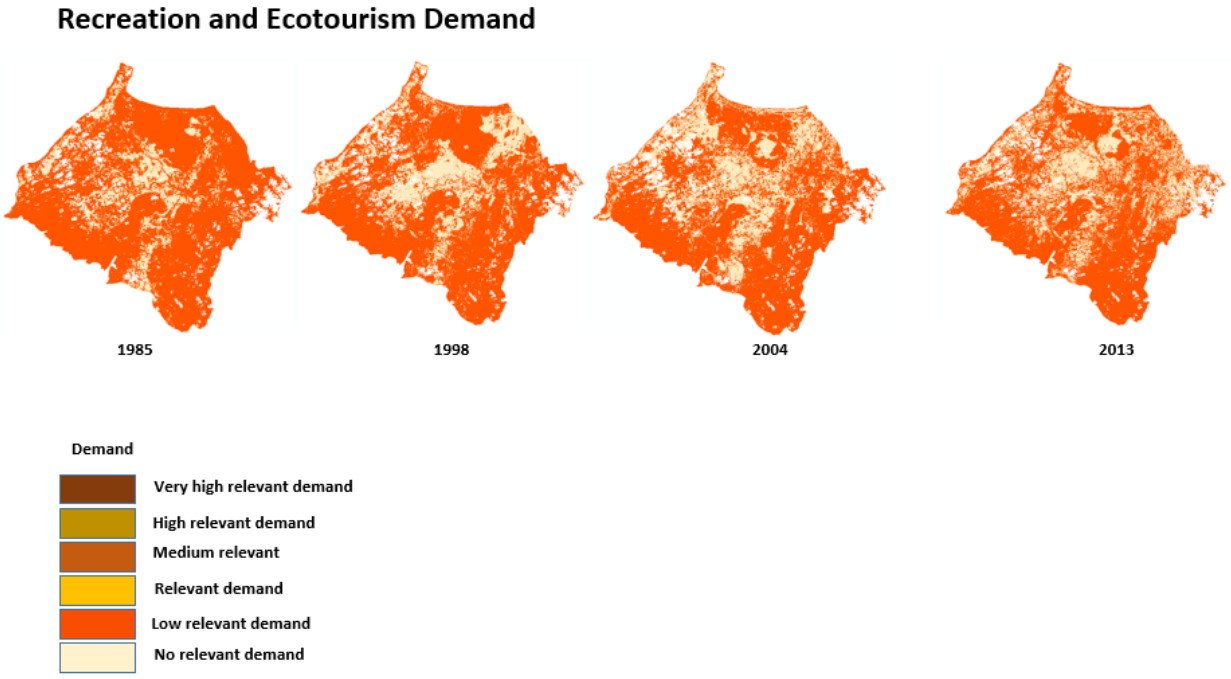
Mapping Ecosystem Services Demand: Regulating (Climate Regulation)



Mapping Ecosystem Services Demand: Provisioning (Timber)



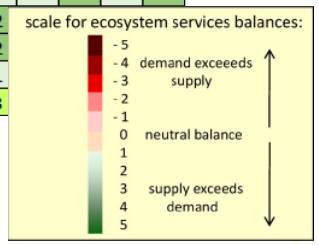
Mapping Ecosystem Services Demand: Cultural (Recreation and Ecotourism)



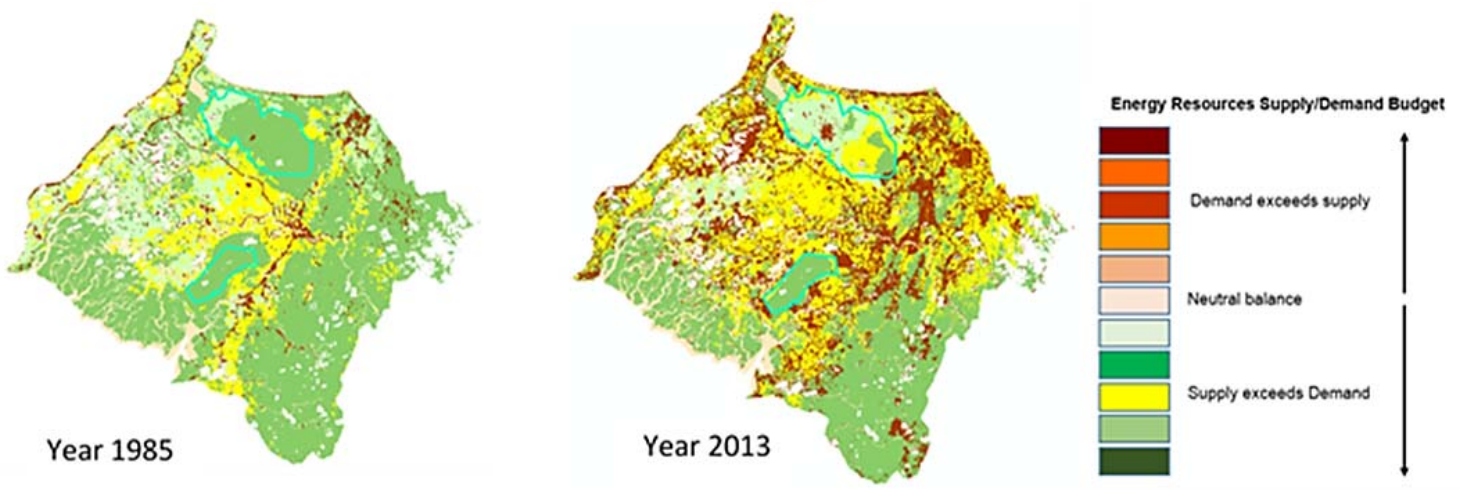
Assessment Matrix Potential Supply and Demands Budget

Potential Supply and Demand Budget

Land Cover Type	Σ Provisioning services	Crops	Livestock	Fodder	Capture fisheries	Aquaculture products	Wild foods	Timber	Fuel Wood	Energy Resources	Medicinal resources	Genetic resources	Fresh Water Resources	Σ Regulating services	Climate regulation	Nutrient regulation	Flood protection	Water regulation	Erosion regulation	Σ Cultural services	Recreation and ecotourism	Cultural heritage	Inspiration for culture	Spiritual inspiration	Educational and scientific interest
Peat Swamp Forest		0	1	1	2	1	1	3	3	4	2	4	4		1	1	0	-1	4		3	3	2	2	4
Mangrove		0	0	0	4	4	4	4	3	4	3	4	2		0	4	-1	-2	5		4	3	4	2	4
Forest Land		0	2	1	1	1	3	4	4	4	4	5	4		1	2	-1	0	4		3	3	3	3	4
Shrubland		0	3	2	1	1	1	1	2	3	2	3	3		0	2	3	3	3		2	1	1	1	2
Grassland		-1	2	3	1	1	2	0	0	1	2	2	2		2	1	2	2	2		1	1	2	1	2
Oil Palm Plantation		1	2	1	1	0	2	1	1	3	2	1	1		3	2	2	2	3		2				
Rubber Plantation		2	3	1	1	0	1	3	2	3	1	1	2		4	3	2	3	3		2				
Barren Land		0	1	0	0	0	1	0	0	-5	0	0	1		0	0	0	0	0		1				
Water Bodies		0	0	0	3	3	2	0	0	0	2	3	0		2	3	1	-2	0		3				



Mapping Ecosystem Services Potential Supply and Demand Budget: e.g. Energy Resources



Conclusion

- Integrating thematic analysis approach in matrix model assessment gave **systematic** & **transparent** process in collecting enormous amount of expert knowledge from literature extraction, expert interview validation and local people demand assessment
- The trends of ES **supply** for wetland protected forest and the surrounding area shows a **decline** over 28 years period
- The projections of **local people** represents variety of ES **demand** on different land cover type and exhibit a **decrease** in the demanded services of ecosystem
- Methodological approach provide a **clear visualization** of the ecosystem services **source-sink** in different landscape ecosystem

THANK YOU FOR YOUR ATTENTION....