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VALUING AND MAPPING ECOSYSTEM SERVICES HOTSPOT AND TRADE-OFFS TO SUPPORT SUSTAINABLE PEATLAND MANAGEMENT

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SUMMARY

Indonesian tropical peatlands are rapidly degrading. Peatlands provide multiple services and therefore peatland conversion will affect society locally, regionally, nationally and internationally. Ecological and societal processes determine the impacts of such conversion and the medium-term and long-term effectiveness of different management options. The current drainage-based peatland uses in Indonesia have resulted in high peat soil subsidence rates (Wösten *et al.*, 2008;Hooijer *et al.*, 2010). In the future, this peat soil subsidence will lead to extensive flooding on Indonesian lowland peatland areas as the soil levels are lower than river or sea water levels (Hooijer *et al.*, 2012).

Indonesian tropical peatlands, mainly distributed in Sumatera (42%), Kalimantan (32%) and Papua (23%), cover about 10% of Indonesia's land area (Rintung *et al.*, 2011). Historically, all Indonesian peatlands were forested and have sequestered and stored carbon for thousands of years. Within the last decade, many Indonesian natural peatland areas have been continually converted for economic purposes into agricultural land, settlements, timber and pulp plantations, and oil palm plantations (Murdiyaso *et al.*, 2010; Law *et al.*, 2015). Some of those areas have been abandoned. These conditions will affect peat dynamics. The peat dynamics are complex and are influenced by a range of ecological mechanisms such non-linear interactions and feedbacks. For instance, conversion of peatland ecosystems involves reduced forest cover and drainage which lead to dryer top soils and enhanced fire risks. This causes further degradation. Spatial relations in peatlands are also important, since drainage in one part of a peat dome will also affect the others parts (Wösten *et al.*, 2008;Hooijer *et al.*, 2010). However, the good and services provided by ecosystem will be affected due to land use change (Sumarga and Hein, 2014). It means that peatland conversion and degradation will influence peatland ecosystem good and services supplies.

In the extensive domain of ecosystem assessment and land use planning, integrating the science of ecosystems and landscape functions and services to identify optimal allocation and management of land use options remains challenging (De Groot *et al.*, 2010). It is important to understand trend of ecosystem services and trade-off between different services when considering peatland uses and maintenance in order to support sustainable peatland management. This study focuses on the peatland area in Indonesia with specific case study on Riau province. This particular area is one of extensively forested peatlands, with a deforestation rate that has attracted global attention due to the high greenhouse emissions released in the process (Miettinen *et al.*, 2011). This research had aimed to measure and assign values to selected ecosystem services in peatland area through biophysical and monetary approaches in order to spatially map the distribution and “hotspot” ecosystem services. This research had analysed the synergy and conflict across ecosystem services with different land uses on peatland in order to explore policy options for sustainable land use planning and management.

The selected ecosystem services were assessed i.e. timber production, oil palm production, paddy production, carbon storage and carbon sequestration, and endangered species habitat. The research methodology adopted three main steps: (i) the analysing trends on peatland uses/cover change; (ii) the quantification and mapping of ecosystem services by assigning biophysical and monetary values; and (iii) the analysis of synergy and conflict that are present across ecosystem services on peatland areas. The case study will focus on Indonesian tropical peatland area, particularly inside the legalized forest area in Riau Province, Indonesia with a total coverage 32,579 km^2. The lookup table approach is applied for valuing and mapping of the seven selected ecosystem services (adopted from Sumarga *et al.*, 2014).

Our study shows; (i) Trends on peatland uses/cover change in study area show several significant land cover changes from 1990 – 2013. For example, the identified estate crop area was recorded at 6% in 1990, increasing to 17% in 2013; there were no area detected containing plantation forest in 1990, yet it showed to be covered at 16% in 2013; secondary swamp forest in this area decreased from 70% in 1990 to 29% in 2013. From 1990 – 2013, the estate crop was increasing over time as well as the wet shrubland area. Most notably, the plantation

area increased drastically in 2013. Meanwhile, primary and secondary swamp forests shrank over time significantly. (ii) Biophysical quantification and monetary valuation of ecosystem services show that timber production area dominates the study area while oil palm and paddy rice productions are found in the area adjacent to the (legally) non-forest area. In terms of the habitat for Sumatran tiger habitat, almost half of the study area was detected as Sumatran tiger habitat. The carbon sequestration has the highest positive monetary value (€ 528 million) calculated taken from six land cover types out of 20 land cover classes. This trend is followed by pulpwood production (€ 455 million) from more than 1 million hectares of production forest with land cover of secondary swamp forest, open swamp, and plantation forest. The oil palm production covers more than 500 thousands hectares of area, and this is half the value of pulpwood production (€ 216 million). Meanwhile, the paddy rice production in the area was only worth € 33 million, as taken from more than 100 thousands hectares, and the non-pulpwood production contributed € 2 million from more than 40 thousands hectares. On the other hand, the carbon emissions caused a very high cost equal to more than € 2 billion, from nine land cover types out of two land cover classes for which the value is hardly comparable to the values from provisioning productions and carbon sequestration. (iii) Synergy between non-pulpwood timber production and carbon sequestration is possible in secondary dryland forests and primary swamp forests. This synergy is possible because non-pulpwood timber studied in this context is timber with a 35-year production cycle. In these types of land cover, maintaining carbon sequestration services while executing selective logging is possible. Not only is there synergy between non-pulpwood timber production and carbon sequestration, but these types of land cover can also support the Sumatran tiger habitat. In secondary swamp forests, a synergy between pulpwood production, carbon sequestration, and Sumatran tiger habitat are also found. The monetary value gained from the pulpwood production is less compared to that of plantation forests. However, this land cover is more favourable to maintaining carbon sequestration since the peatland is not massively drained. Other synergies are found between carbon sequestration services and Sumatran tiger habitats in secondary mangrove forests and open swamps. Conflicts or trade-offs between ecosystem services are present in several land covers. Among others, there are plantation forests, estate crops, settlement areas, agriculture activity, and mining areas. In plantation forests, conflict or trade-off are found between pulpwood production and carbon sequestration, as well as potential tiger-human conflict caused by frequent cultivation activities by humans. In the estate crop areas, the condition is similar to plantation forests, which are conflict or trade-off between oil palm production and carbon sequestration as well as potential tiger-human conflict. In settlement areas, there is no conflict between carbon sequestration and other types of ecosystem services because neither carbon sequestration nor emission is detected. The conflict has potentially arisen between human and the tiger since both are occupying the same area. In any type of agricultural area, most trade-offs occur between agriculture production and carbon sequestration. In addition to this, some potential tiger-human conflict are present in those areas also inhabited by Sumatran tigers. This kind of potential conflict is likewise possible in the mining areas. As a result, the other types of land use/cover do not show any synergy or conflict; instead, a neutral state is present. However, a favourable or unfavourable land use/cover for carbon sequestration could be found. The result of this analysis is therefore applied in providing a discussion space on the implications of spatial planning.

Based on the results of this study, there are several implications for spatial planning and decision making in order to conserve the Sumatran tiger habitat. If the extinction of Sumatran tiger takes place, the spatial planning should be part of the decision to support the current conservation effort to save Sumatran tigers by preventing their habitat landscapes from further damage. By restricting oil palm plantation and massive timber production on peatland areas, efforts to conserve the Sumatran tiger habitat can be complemented through less deforestation and forest fragmentation. Even though it will be difficult within the planning process if the governments still focus largely on economic development, ecosystem-based spatial planning still needs to be introduced objectively (Wibisono and Pusparini, 2010). The World Bank/Global Tiger Initiative has launched an approach of smart and green infrastructure as a main contributor to the vast and growing deforestation and fragmentation of the natural tiger habitat (Wibisono and Pusparini, 2010), a prominent example in how an integrated policy approach can maintain the ecosystem services as discussed in this study. Where synergy and conflict has not been evident, the policy approach should consider the likeliness of future potential benefits or costs according to the ecosystem services valuation based on trends of the land use changes.

This study combines three different dimensions of ecosystem services: biophysical, economic, and spatial, followed by a simple trade-off analysis to see the synergy and conflict across ecosystem services to explain the implication on the spatial planning processes. This study only focuses on the valuation of selected ecosystem services in the study area. The hydrological function of peatland areas were not carried out in this study due to its complexity and it should be done in a separate research. The hydrological function is part of the important ecosystem services on peatland in relation to soil subsidence and flooding risks due to peat drainage for cultivation purpose. Beside that fact, some other limitations and uncertainties of the study are present.

Future research on how ecosystem services supply in response to different future land use projections or scenarios is recommended using trade-off analyses for spatial planning purposes. The study should incorporate scenarios and further spatial mapping that likewise involves multi-layer analysis, stakeholder analysis, and future social demand analysis, among others. As such, these studies can help formulate the most appropriate land use strategies, management instruments, and financing mechanisms.

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Table 1: Synergy and conflict of selected Ecosystem services provided by Indonesian peatlands (Riau case study)

Land cover	Provisioning service				Regulating service	Sumatran tiger habitat	Synergy (↑↑); Conflict (↑↓); Neutral (→)
	Timber production (€/ha/year)		Oil palm production (€/ha/year)	Paddy production (€/ha/year)	Carbon sequestration (€/ha/year)	Tiger is present (+); Tiger is absent (-)	
	Non-pulpwood	Pulpwood					
Secondary dryland forest	66				421	+	↑↑ : Synergy between non-pulpwood production, carbon sequestration, and Sumatran tiger habitat
Primary mangrove forest					813	-	→ : No synergy or conflict exists, but favourable for carbon sequestration
Primary swamp forest	48				507	+	↑↑ : Synergy between non-pulpwood production, carbon sequestration, and Sumatran tiger habitat
Plantation forest		483			-1,913	+	↑↓ : Conflict between pulpwood production and carbon sequestration as well as potential tiger-human conflict
Dry shrubland					-392	+	→ : No synergy or conflict between carbon sequestration and Sumatran tiger habitat, but unfavourable for carbon sequestration
Estate crop			701		-2,219	+	↑↓ : Conflict between oil palm production, carbon sequestration, and Sumatran tiger habitat
Settlement area					0	+	↑↓ : Potential tiger-human conflict
Bare ground					-469	+	→ : No synergy or conflict between carbon sequestration and Sumatran tiger habitat, but unfavourable for carbon sequestration
Savanna and grasses					-469	-	→ : No synergy or conflict between carbon sequestration and Sumatran tiger habitat, but unfavourable for carbon sequestration
Open water					0	+	→ : No synergy or conflict between carbon sequestration and Sumatran tiger habitat
Secondary mangrove forest					813	+	↑↑ : Synergy between carbon sequestration and Sumatran tiger habitat
Secondary swamp forest		256			497	+	↑↑ : Synergy between pulpwood production, carbon sequestration, and Sumatran tiger habitat
Wet shrubland					0	+	→ : No synergy or conflict between carbon sequestration and Sumatran tiger habitat
Pure dryland agriculture				286	-899	-	↑↓ : Conflict between paddy production and carbon sequestration
Mixed dryland agriculture					-1,243	+	↑↓ : Potential tiger-human conflict
Paddy field				286	-899	+	↑↓ : Conflict between paddy production and carbon sequestration as well as potential tiger-human conflict
Fish pond/aquaculture					0	-	→ : No synergy or conflict exists
Port/harbour					0	-	→ : No synergy or conflict exists
Mining area					-469	+	↑↓ : Conflict between carbon sequestration and Sumatran tiger habitat as well as potential tiger-human conflict
Open swamp					497	+	↑↑ : Synergy between carbon sequestration and Sumatran tiger habitat