Peatland conservation strategies and carbon pricing possibilities for climate change mitigation in Indonesia: a review

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Abstract. Humankind is digging to solve one of the world’s most complex issues at present, climate change. Many studies were conducted and initiatives were proposed as mitigation and adaptation strategies to date, such as restoration and preservation of carbon storage. Peatlands are widely recognized as the largest natural carbon storage of all terrestrial ecosystems. Peatlands can help mitigate climate change by its ability to sequestrate huge amounts of carbon and maintain water balance. This valuable yet vulnerable ecosystem needs to be managed properly to maintain the functions. This study aimed to critically review the peatland conservation strategies and possibility of carbon pricing for mitigation and adaptation of climate change, specifically for Indonesia. It was revealed that restoration strategies such as rewetting, revegetation, and revitalization could help with peatlands conservation and further reduction in emissions from land sectors. However, the funding for conservation activities would become a hindrance to the viability and sustainability. Carbon pricing could be a potentially effective approach to conservation of peatlands. Sequestrated carbon and potential additional value from ecosystem services could higher up the price that made the option for conservation more stunning. Therefore, to establish tradable carbon credits on peatland as a means to support the sustainability of Indonesia’s peatland conservation in the future, the action to well managing and standardizing the carbon credits should be started immediately. Though the process will take time and great willingness from all parties, this option could be used for long-term peatland conservation activities.

1. Introduction
The specter of climate change has been with us since the past decades. It has been recognized to have major impacts on the environments and humans, such as temperature waves and change of precipitation pattern and ecosystem services. Moreover, it can be worsened in the future [1,2]. Various research, activities, action plans are established to solve this catastrophe together. Climate change defines as the shifting condition of climate, determined by its properties change over time, whether due to natural variability or human activities [3]. Climate change has unfavorable impacts many aspects, including agriculture, biodiversity, water and marine resources. Moreover, it also effects on public health and energy [2]. Indonesia cannot escape from the negative impacts of climate change, whilst also acted as the third-to sixth-largest emitter in the world due to its large-scale deforestation and land use change...
Indonesia pledged to reduce the greenhouse gases (GHGs) by 26% unconditionally or 41% with the international support (additional 12% is conditional) for its NDC [6]. Various activities and policies have been designed and applied to achieve this goal, including policy on land use and forestry.

Peatland is part of wetlands which notorious for its largest carbon storage among other land ecosystems, but its management remains a challenge [7]. Most of Indonesian peatland conditions are prone to deteriorated. In 2011, an estimate of 3.74 million ha or about 25.6% of total peatlands in Indonesia was degraded. Furthermore, after the big catastrophic peat fire in Indonesia in 2015, peatlands burnt were estimated to be about 623 thousand ha in Sumatera, Kalimantan and Papua and have emitted about 2 million tons of carbon-equivalent (MtCeq) [8,9]. At this state, peatland conservation is needed so that the emission reduction from peatland can be reduced and do its job to sequester carbon and other GHGs from the atmosphere. Peatland restoration, such as rewetting and revegetation, is one of the conservation activities that can reduce emission nationally and globally [10,11]. If the water table is restored to pre-drainage levels, GHGs emission will reduce or stop, resulting in eventually switching direction from carbon source to carbon sink [12]. Revegetation will help the land cover peats ecosystem by planting native plant species or other types of crops that are adaptive to peat conditions and also have economic value [13].

The government of Indonesia has allocated some state budget for peatland restoration and conservation projects. However, as conservation needs continuity of the projects and activities, financial incentives for conserving forest and peatland are needed to achieve sustainable land management [14]. The World Bank has stated that putting carbon prices has been an increasingly popular approach to finance conservation activities. As part of climate policy, carbon price is used as an approach to charge parties who emitted the excessive emission of carbon dioxide by valuing the credits of carbon, which has implemented in many countries. Carbon credits defines as a market mechanism for minimization of GHGs emission which was introduced in Kyoto Protocol, while Paris Agreement validates the credits approach as a means to diminish emissions [15].

Carbon price and carbon credits are part of the climate policy that has been applied for GHGs abatement option, that mainly sets from forest carbon. However, In Indonesia, the idea of carbon pricing is still uncommon in practice and lack of literature dealing with carbon credits for peatlands conservation in Indonesia could be a barrier for mitigation and development. With considering the peatland itself to acts as carbon storage [7] and carbon sink from land covers, it could be a great opportunity to helps mitigate climate change issue in Indonesia. This study was acted as a preliminary research on the potential of valuing the peatland ecosystem as a way of sustainable conservation option in the near future. This study aimed to review peatlands conservation strategies in Indonesia and establish the link on how said strategies contribute to climate change mitigation. This study has achieved by reviewing the characteristics and potential of peatland to mitigate climate change and possibilities of carbon pricing for sustainability of peatland conservation in Indonesia.

2. Materials and Methods

2.1. Materials

Data was arranged through literature review on characteristics and conservation of peatland and how the carbon sequestration from conservation would contribute in carbon pricing. Main data was collected from scientific journal articles from various sources at national and international levels, working paper, press release and other supporting information.

2.2. Methods

The analysis was done using comprehensive literature review (CLR) in this review study, particularly seven-step model with following three phases [16]:

1st phase : Exploration phase
   Step 1: Exploring the topics
   Step 2: Initiating the research
   Step 3: Organizing the information
Step 4: Selecting/deselecting information  
Step 5: Expanding the research  
2nd phase : Analyzing and synthesizing information  
3rd phase : Communication phase (Report)  
In this study, climate change mitigation from peatlands sector was explored with goal to enrich carbon sinks. Various possible strategies and activities are introduced to fasten the mitigation (as well as adaptation). Furthermore, carbon pricing seems could play role in reducing GHGs [17], as well as to support the continuity of peatlands conservation through carbon credits that is still not well explored in Indonesia. In this review, carbon-pricing possibilities explored to support the sustainable conservation of peatlands.

3. Results and Discussions  
3.1. Peatland characteristics and conservation  
Peatland ecosystems have provided many services, not only as carbon sinks from forests and peats, but also regulate water resources and preserve biodiversity. Peatland holds around 30% of the world soil carbon whilst only cover 3% of its terrestrial area [12,18,19]. Regardless of the climate zone, it spreads worldwide for about 40 million ha. As for tropical peatland, its predominance in The Southeast Asia with approximately 2 million ha of peatlands, distribute in the low altitude (less than 50 m MSL) and mostly covered by forest [19,20,21]. There are approaches that have been used to calculate carbon stocks on peatland, namely peat volume, carbon density, and time history approaches [22]. Rate of mean long-term carbon accumulation in tropical peat core areas have yielded over 50 g/m²/yr [23]. The global amount of carbon stocks in peatlands is estimated to be more than 600 Gt Carbon (GtC), distributed in northern, southern and tropical area with 550,15 and 100 of GtC, respectively [24].

Indonesia’s tropical peatland estimated to 14.904 million ha, spreading out in Sumatera (35%), Kalimantan (32%), and Papua (30%). It provides various significant tangible and intangible benefits at various level, local, national, and global, including the ecosystem services and as home for various endemic species [25]. Changes of large area of pristine peat swamp forests for other purpose are very susceptible to emit large amount of Carbon loss. Further study found out that land use change on peat swamp forest (PSF) triggered the oxidation and emitted carbon. A study examined the highest carbon emission produced from conversion for smallholder area and industrial plantation, then followed by open undeveloped area as stated on Table 1 [26]. It is expected the higher conversion rate will emit more carbon and other greenhouse gasses.

### Table 1. Carbon emission from peat oxidation (MtC/year) [26].

|                      | Riau M/C/yr | South Sumatera M/C/yr | Total Sumatera M/C/yr | West Kalimantan M/C/yr | Central Kalimantan M/C/yr | Total Kalimantan M/C/yr |
|----------------------|-------------|-----------------------|-----------------------|------------------------|--------------------------|------------------------|
| Degraded PSF         | 1.82        | 0.20                  | 2.53                  | 2.03                   | 2.80                     | 5.33                   |
| Tall shrub/ secondary forest | 0.46       | 1.67                  | 2.48                  | 0.82                   | 3.57                     | 5.47                   |
| Open undeveloped     | 2.44        | 1.44                  | 4.86                  | 1.97                   | 4.15                     | 7.61                   |
| Smallholder area     | 21.0        | 3.80                  | 25.80                 | 2.78                   | 4.26                     | 9.53                   |
| Industrial plantation| 18.10       | 9.27                  | 27.37                 | 5.28                   | 3.66                     | 12.2                   |
| Urban                | 0.03        | 0.00                  | 0.03                  | 0.02                   | 0.04                     | 0.04                   |
| Total                | 43.90       | 16.40                 | 59.50                 | 12.90                  | 18.50                    | 40.10                  |

Note: Adapted from Miettinen et al. (2017)  

Emission from peatlands in Indonesia reached the attention globally since the peat fire catastrophe in 2015, consequence in estimated 2 Mt GHGs emitted within three months [27]. The case had occurred during the strong El Nino, of which the heat temperature and long dry season hit drained and degraded peatlands area. However, it should be noted that the emission from peatland is continuously released even after fire is stopped and it gets accumulated in the atmosphere. Cumulative emission from peat fire were estimated 2.9 GtC and about 2 GtC from peat oxidation since 1997 [26]. As the benefits of
peatlands have been widely recognized, conservation, restoration, and protection of peatlands can help mitigate climate change and water balance disturbance [24]. The key management options for undegraded and degraded peatlands are: (1) Keep the wet peatland, (2) Rewet drained peatlands, and (3) Adapt the management for permanently drained peatland due to low water table [28,29].

Restoration is one of the conservation strategies implemented to revert back the peatlands to their original condition through rewetting, reforestation and revegetation of degraded peatlands and supported by community development. As a response to the degraded peatlands condition, the Government of Indonesia established a Peatland Restoration Agency (BRG) with the main objective to restore degraded peatlands [30]. It comes with conservation strategies, such as rewetting and revegetation. Rewetting is needed to create back its natural or pre-disturbed condition. Rewetting approaches may be different one to another, depend on the location and triggered factors. However, the basic technique, which also adapted in Indonesia is blocking waterways with peat dams [31,32]. Rewetting peatland and secondary PSFs could lower total CO2 fluxes by up to 75%, confirming that by increasing the water table from rewetting results in reduced emission that helps to mitigate climate change [11,33].

Revegetation is the next important step of peatland restoration after rewetting, to support the land condition [32]. Local and endemic species are the best option due to their suitability and adaptability; different species will be used on different region depend on the microclimate and other plants requirements. Moreover, design of planting also can be varied as the situation also may be different [34,35,36]. It will lower temperature, decrease chance of fire, and made significant changes for more stable water table and increase average peat cover. It also increases water chemistry and nutrient availability [37]. Revegetation after rewetting is claimed to improve the environmental condition and higher chance of carbon sequestration. Moreover, revitalization is the third conservation strategies after the rewetting and revegetation. It means to ensure local communities are imbued with improved livelihood from the restored condition of environment [32]. Revitalization of local people will be done through education and socialization, establishment of peat care villages in prioritize location, appoint restoration cadets, providing technical assistance and supervision [38]. This strategy will encourage the local people to take care of peatlands with better and sustainable management practices to keep peatlands condition well after physical restoration.

### 3.2. Conservation costs and possibilities of carbon pricing

To meet the country’s pledge, there are several activities has been done to eliminate the climate change catastrophe from degraded peatland, the main projects are led by Peatland Restoration Agency (BRG). The execution of programs of BRG will be finance in two schemes, firstly it will be funded by State budget of Republic of Indonesia. Moreover, BRG can also work and collaborate with other parties to carry out duties for restoring and conserving peatlands [30].

In total, it is estimated the lowest gross financial cost to complete 2 million ha peatlands restoration and conservation in Indonesia are around USD 4.6 billion, which is currently more than the funds allocated for its purpose, and likely will cost more than the estimation (Table 2) [39]. Many countries appreciated the conservation strategies for climate mitigation and sustainable land use management by financing the conservation activities directly to BRG as legal institution for restoration and conservation of peatlands in Indonesia, or indirectly based on project funded by international organization. Government of Indonesia through BRG obtain conservation grant in total USD 92 million. Based on BRG finance calculation, financing needed for facilitate and coordinate peatland conservation estimated would reach USD 752 million (IDR 10.6 trillion$^1$), particularly in seven prioritized provinces. International support for peatland conservation currently can be divided into three schemes, such as grant, funding commitments and the benefit recipients [38]. However, there are uncertainty of sustainable funding of the projects in the future. Therefore, the presence of carbon pricing policy perhaps
could alert the seriousness of dealing climate change issues and secure the financial need of conservation. Many accomplished schemes of carbon pricing have been implemented. New Zealand and Kazakhstan are some of countries that illustrate the carbon pricing scheme from forestry and agriculture sectors. Forestry sectors in New Zealand are eligible to earn the credits with some conditions. Furthermore, revenue from carbon credits can affect the management of conservation area and harvesting decision as the lengthening rotation ages will influence carbon sequestration benefits and implies to the overall carbon stock balance [40,41].

**Table 2.** Estimated Financial Requirement for Restoration Peatland at BRG Priority Areas.

| Area classification | Restoration requirement                                                                 | Size of area (ha) | Lowest estimated cost per area (USD/ha) | Lowest estimated total cost (USD) |
|---------------------|----------------------------------------------------------------------------------------|-------------------|----------------------------------------|----------------------------------|
| Licensed production areas burnt post 2015 and drained production areas | Hydrological restoration on primary, secondary, or tertiary canals | 1,410,943         | 2,000                                  | 2,821,886,000                   |
| Non-licensed production areas burnt post 2015 | Hydrological restoration for primary, secondary, or tertiary canals with full revegetation | 396,945           | 3,225                                  | 1,280,147,625                   |
| Protection areas burnt post 2015 | Hydrological restoration of commodity to primary canal with potential full revegetation | 226,335           | 1,625                                  | 367,794,375                     |
| Protection areas with canals | Hydrological restoration of commodity to primary canal with potential enrichment planting | 201,457           | 400                                    | 80,582,800                      |
| Protection areas with shallow peat and canals | Hydrological restoration of commodity canal with potential enrichment planting | 256,846           | 400                                    | 102,738,400                     |
| Total                                                                  |                                                                       | 2,492,527         |                                        | 4,653,149,200                   |

Note: Adapted from Hansson and Dargusch (2018); Conversion rate USD 1 = IDR 14,000

A voluntary carbon market can be a solution for individuals and corporations who opt to reduce their carbon footprints but cannot accomplish it with internal reductions. By using carbon market, they can offset their emissions by retiring carbon credits generated somewhere else that has been standardized [42,43]. Carbon credits received from various carbon sequestration projects, including agriculture, forestry and others land use sectors. Many benefits have gained by protecting ecosystem and biodiversity in these sectors, including reducing poverty in rural area and supporting local communities. The trade of carbon credits started from the issuance (credits that verified by standard), to transaction, and retirement (represent offsets that cannot be resold anymore) [42].

### 3.3. Carbon pricing opportunities for peatlands conservation

Many conservation projects can be assessed for its carbon storage to be counted as carbon credits. However, we discovered that the landowners who want to put carbon price on their land must seriously commit to protecting their areas. Conservation of peatlands achieved by BRG until 2018 are 679.9 ha, which are differentiate on each province as shown in Table 3.

**Table 1.** Area restored after three years projects by BRG.

| Restored area | Facilitate by BRG (ha) | Coordinate by BRG (ha) |
|---------------|------------------------|------------------------|
|               | 2017                   | 2018                   | 2016       | 2017       | 2018       |
| Riau          | 26,395                 | 50,889                 | 630        | 0          | 535        |
| Jambi         | 6,448                  | 61,778                 | 0          | 3,410      | 5,892      |
| South Sumatera| 2,000                  | 100,060                | 0          | 32         |            |
| West Kalimantan| 3,114                  | 16,805                 | 0          | 0          | 25,950     |
| Central Kalimantan | 62,126               | 72,754                 | 1,924      | 91,809     | 138,133    |
| South Kalimantan| 3,193                  | 4,568                  | 157        | 0          | 0          |
| Papua         | 0                      | 1,100                  | 0          | 0          | 0          |
| Total         | 103,476                | 307,954                | 2,711      | 95,219     | 170,542    |
In total, almost 680,000 ha of peatlands had been restored. Therefore, by adopting carbon density of tropical peatlands from previous research [44], 60 kgCO$_2$/m$^3$ and average peat depth is 2 m, its calculated restored peatlands estimated can contain 815,882 MtCO$_2$. Carbon stored estimated will much higher than this numbers considering non-degraded peatlands already stored carbon for a long time and can be counted for carbon credits. Assuming peatlands restoration project wants to generate certified carbon credits, there are requirements that must be followed to certified the carbon [43]. As peatland is conserved and covered by vegetation, it can gain carbon credits and pricing from aboveground and below ground sequestration. Moreover, the characteristics of peatland with its ecosystem services could be added value. By valuing the unique ecosystem services from peatland, it could higher up the potential of pricing, thus make the peatland conservation projects more attractive. A study evaluates that under present condition, the carbon pricing value of peatland conservation are less than one USD/tCO$_2$. However, by adding the valuation of ecosystem services provided by peatland, the pricing value rising up to USD 26/tCO$_2$ [45].

In present, carbon pricing opportunities are possible for the sustainable practice of peatlands conservation, but it needs serious willingness from all the parties. Example of carbon credits from forestry in New Zealand Emission Trading Scheme gained carbon credits and priced after more than 20 years [41]. Therefore, to establish tradable carbon credits on peatland as a means to support the sustainability of Indonesia’s peatland conservation in the future, the action to standardize the carbon credits should be started immediately at the restored area so that the results could follows to support current funding scheme. After all, there are great opportunities for pricing carbon sequestration by voluntary carbon markets, though the process of verification takes time and great willingness by parties is required. In this regard, it does not seem to support the conservation cost immediately but can be used for long-term conservation activities.

4. Conclusions
Peatland management has great potential to mitigate climate change due to its characteristics. To achieve these important goals, mismanagement of peatlands should be solved in such a way that peatlands are rehabilitated to its pre-degradation condition. Conservation strategies have been applied through restoration projects and others throughout the world, including Indonesia. Rewetting and revegetation are well-known conservation strategies that prove peatlands can turn back to its natural condition. To do so, however, large amounts of funding are needed to cover the costs. The costs needed for peatlands conservation tend to reach larger than the grant and conservation budget that have been set by the government and international donors. Limited state budget and non-continuous external funding can become some barriers for the continuity and sustainability of peatland conservation. Therefore, another approach needs to be introduced for sustainable conservation in the future, such as incentive and carbon pricing. There is high potential in carbon pricing and incentive approaches from the peatland restoration activities that has been done to support the peatlands conservation in the future. By certifying the carbon while conserving the peatland, we could reduce national emission and possibly to trade rest of carbon for other parties’ carbon offset. The ability of peatland and its cover to sequestrate carbon under its optimal condition has been investigated, hence it is possible to be converted as carbon credits. Financial incentives from carbon sequestration should be provided at levels where sustainable management allows to compensate for conservation costs. From this point of view, carbon credits and pricing are really possible to be introduced and implemented to support the continuity of peatlands conservation in the future.

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