Indicator for peat natural recovery in Sebangau National Park in Central Kalimantan, Indonesia

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Abstract. Most of the existing peatland area in Indonesia is degraded mainly due to human activities. This, in association with the construction of drainage canals, resulted in a lower water table compared to its natural condition, causing many changes. Although the criteria for damage and recovery have already been articulated into several existing regulations, yet the indicators for recovery have not been widely studied. For effective restoration, managers need to have basic data related to the initial condition of damaged areas or at least have data on areas that are able to recover naturally without human assistance. Random sampling was used to collect field data on vegetation structure and composition, including direct interviews with the resource persons. Observations made in several locations within the Sebangau National Park indicated that some areas are recovering naturally and relatively fast, although some are not. During 2017 forest fires, only 98.03 ha or burned areas were recorded. This can be seen from the species composition and the vegetation structure covering the studied area. Conditions in the field indicate that all peat forests have been fragmented through the existence of canals which are used for various activities.

1. Introduction

Tropical peatland ecosystems are highly important for storing and cycling carbon and water, particularly for biodiversity. Presently, the Indonesian unique peat forest ecosystem has been threatened by a rapid national development program to improve the economic condition. It is well-known that this ecosystem provides significant benefits to people who live surrounding and the global community. However, these processes are highly dynamic due to climate change and human activity, leading to ecosystem damage. Recurrent widespread forest fires in combination with canalization and peatland conversion for crops production have caused considerable and irreversible environmental, social and economic damages [1, 2].

The peatland ecosystem has unique components consisting of abiotic and biotic, which influence each other. These interacting components will experience ecological changes and are generally known as ecological succession, which refers to successive changes in the structure and composition of an ecological community, specifically to peat characters. The changes can be predicted according to the biophysical conditions that change during the process [3, 4]. For peatland, the process of change in
ecological succession runs within an extended period. Often, along the way of the process, a sudden disturbance beyond prediction can cause conditions to reverse and require action to restore or restore to its original condition. Thus, a reference ecosystem of peatland is deemed crucial to return to its original state.

Peatland restoration comprises various stages that initiate and accelerate the recovery of a degraded peatland back to its origin. Restoration is constantly dealing with three main issues of i) What do you want to have back? ii) Is it possible to get that back? and iii) What action do you need to reach the restoration objective? [5]. Thus, people who want to do restoration shall understand and be aware that peatlands are a solid interaction and interconnection between "plants", "water", and "peat", and they are mutually interdependent. The plants shape the type of peat and hydraulic properties such as hydrological regime. The hydrology determines which plants will grow, whether peat will be stored and how decomposed the peat will be. The peat structure and the relief determine how the water will flow and fluctuate.

On the ground, the terms peatland restoration and rehabilitation are often used as mixed terms. In fact, there is a clear difference between the two, where rehabilitation refers to planting the degraded area aiming at improving the ecosystem process and is not necessary to return to its original state [6], while restoration refers to an effort to recover the degraded peatland back to its origin state. This covers activities such as hydrological improvement, canal blocking, native tree species planting to allow peatland species to return to the targeted site [7]. The recovery stages of the ecosystem run under the restoration process on the degraded, damaged, or disintegrated land by previous management [6]. Therefore, full recovery can be perceived as the state where the attribute of a particular degraded ecosystem can return to its original state or closely resemble the ecosystem reference.

2. Materials and Methods

2.1. Study sites

Based on Government Regulation No. 57 year 2016 [8], the target for restoration in 2017 is 400 thousand ha in three Peat Hydrological Units (Kesatuan Hidrologi Gambut/KHG), and one of them is KHG Kahayan-Sebangau in Pulang Pisau Regency, Central Kalimantan Province. Previously, the KHG Kahayan-Sebangau area was known as Blok C Peat Land Project (Proyek Lahan Gambut/PLG) One Million Hectares, which is located between the Kahayan and Sebangau Rivers. Based on the analysis results of [9], Pulang Pisau district is the most fire-prone area in Central Kalimantan with an average density of ~ three hotspots year\(^{-1}\). 10-3 in El Nino conditions, where around 50% is in Block C or KHG Kahayan-Sebangau. Significant loss of forest area occurred around domes in Paduran Sebangau and West Kanamit Villages due to severe fires in 2006 (thick boxes) and around domes in Paduran Sebangau, Tanjung Taruna, and Kalampangan Villages due to severe fires in 2009 (thin box). In 2015 and 2019, this area also experienced severe fires. Observation on vegetation was done in three sites: 1) Forest Area for Specific Purposes or Kawasan Hutan Dengan Tujuan Khusus/KHDTK Tumbang Nusa, 2) Dandang Barat Village, Sebangau Sub-district, and 3) Maliku Village, Maliku Sub-District.

2.2. Sampling

Vegetation condition data were collected in order to have an idea of ecosystem restoration rate by analyzing vegetation in various characters of secondary peat forest, with natural and artificial succession regeneration patterns. There were seven land types investigated, i.e., (1) After fire area in 2015, secondary forest with natural succession; (2) After the fire area in 2015, secondary forest, planted in 2018; (3) After fire area in 1997, secondary forest with natural succession; (4) After fire area in 1997, secondary forest, planted 2003; (5) repeated fire areas, conversion land, thin peat, natural succession; (6) After fire area in 1998, secondary forest, natural succession; and (7) After fire area in 1998, secondary forest, Gerhan (Rehabilitation Movement) 2005. Vegetation analysis was made in one ha for each land unit. In the one-hectare land, three lines were made with a distance of 20 meters between the lines, each of which was made into three plots with a distance of 20 meters. A plot measuring 20 x 20 m is made to measure tree and pole levels; 5 x 5 m for sapling regeneration; and 1 x 1 m for seedlings.
The data collected were total species density $\text{ha}^{-1}$ and plant species dominant.

Socio-economic and regional development information was collected through direct interviews with community leaders and relevant government officers. The interviews included community activities related to the post-fire ecosystem restoration processes.

2.3. Data analysis

The vegetation observation data then calculated the total species density $\text{ha}^{-1}$ and plant species dominant at each land type's seedling, sapling, and tree levels. This information was used to evaluate vegetation communities’ development after a forest fire and also used as an indicator of post-fire ecosystem recovery. Standard criteria developed by [6] were further used to determine whether the recovery stages of degraded peatland approaching the ecosystem reference.

3. Results and Discussion

3.1. Indicators of peat recovery due to forest and land fires

The encroachment and logging of peat swamp forest accompanied by the construction of drainage canals resulted in a lower water table compared to its natural condition. The dryness of the peat causes the potential for fires to increase. Peat has a calorific value (or heating value) that ranges from 22 to 26 J kg$^{-1}$ [9]. This value tends to be higher than the lignite and sub-bituminous category of lignite coal in Central Kalimantan. This is one of the factors that causes peat to burn easily, especially in dry conditions. This drought condition can occur naturally during extreme drought. However, most of these are caused by human activity. Efforts to drain peat are often motivated by land conversion, both for development and for agricultural needs. Once the water is lost, small ignition fires on dry peatlands will burn the entire area in a relatively short period of time. In addition, the carbon in peatland organic compounds also has a low self-combustion temperature, so it can easily cause fires.

Based on observations and study results starting from the typology and depth distribution of the peat, the level of damage based on the degraded ecosystem, the character of damage due to fire, and natural regeneration conditions, there are a number of suggestions for recovery indicators for peatland in Sebangau National Park such as follows:

a. The availability of a restoration program strategy and direction (a program with clear objectives and targeted recovery action plan will facilitate recovery efforts)
b. Controlled water level and controlled hydrological system. The water level is not more than the water level
c. The presence of a canal system in terms of quantity and dimensions
d. The presence of natural peat ecosystems (reference)
e. The return of natural plant species (natural biodiversity, species richness, structure, and composition of plant species)
f. There is no land clearing due to fire and other disturbances (assessed in terms of frequency, intensity and area)
g. Participation of all parties, especially the community (people in and around the KHG area)
h. Structured governance of peat ecosystem restoration involving all stakeholders (local and national institutional structures, adequate human resources) and cross-sector synergy.

3.2. Species composition and vegetation structures after fires

Based on field observation, all sites were at peat depth of more than 3 meters excepts site located in Dandang Barat and Maliku villages which experienced recurrent fires and have been converted into agriculture and farmland. The following section describes the vegetation structure and species composition in the studied areas.

3.2.1. Ex Fire 2015, secondary forest with natural regeneration. This site was located at deep peat (>3 m) in Tumbang Nusa and experienced a fire in 2015. Currently, natural succession is ongoing. Our observation showed that only one tree of *Combretocarpus rotundatus* with a diameter of 37.3 cm has survived. There were no individuals at the pole level. The regeneration rate of saplings was quite
abundant, with 6000 seedlings per hectare, but only from two pioneer species of *C. rotundatus* and *Cratoxylon arborescens*. The regeneration rate of seedlings of both species was also abundant, which is 33,000 individuals per hectare. Based on the abundance of the natural regeneration at sapling and seedling stages, the peat ecosystem recovery in this area can run well without fire disturbance.

3.2.2. *Ex Fire 2015, secondary forest with planting in 2018*. This site was adjacent to the ex-burnt area in 2015 in Forest Area for Specific Purposes or *Kawasan Hutan Dengan Tujuan Khusus/KHDTK* Tumbang Nusa, but it was planted in 2018. Forest structure indicates a natural succession pattern as described in point 3.2.1. In this area, there are no individual tree and pole stages. Natural regeneration at the sapling level is relatively abundant, with 6,000 seedlings per hectare dominated by *C. rotundatus* and *Cratoxylon arborescens*. The natural regeneration rate of seedlings is also abundant, with 20,000 seedlings per hectare. Artificial regeneration was done in 2018 using *Shorea belangeran* and *Dyera polyphylla*. Planting is carried out at a density of 625 seedlings per hectare. The success rate two years after planting is 46.6%, so there is an additional regeneration resulting from the enrichment planting of 290 seedlings per hectare. If there is no fire disturbance, the peat ecosystem in this area will return to the condition before being disturbed by fires.

3.2.3. *Ex Fire 1997, secondary forest with natural regeneration*. Observations on secondary forest areas burned in 1997 in KHDTK Tumbang Nusa show that a natural regeneration process remains ongoing. Individuals at the tree and pole stages are quite dense, with a density of 775 individuals per hectare. There is sufficient natural regeneration at sapling stages with 7600 individuals per hectare. The natural regeneration rate for seedlings stages is 106,000 individuals per hectare. Based on the vegetation density at the tree, pole, sapling and seedling stages, the area has shown a remarkable recovery from fires that occurred 23 years ago, although there is no sign of restoration effort whatsoever. The total number of species recorded as a result of natural regeneration is 17 species: *S. belangeran*, *C. rotundatus*, *Eugenia* sp., *C. arborescens*, *Tetrameristra glabra*, *S.platycados*, *Dacrylocladus stenostachys*, *Myristica* sp., *Knema* sp., *Campnosperma* sp., *Dryobalanops* sp., *Luthocarpus spicatus*, *Artocarpus* sp., *Calophyllum* sp., and two unidentified species with the local name of *pentik* and *kopi-kopi*. In just 23 years after the fires, this area is almost close to a climax state of natural forest. Based on the interview with the forest ranger, this area was carefully guarded and prevented from any human disturbances.

3.2.4. *Ex Fire 1997, secondary forest with planting in 2003*. Observations on secondary forest in the ex-burnt area in 1997, which were planted in 2003, were carried out in the area adjacent to the plot in point 3.2.3. In this area, 825 individuals per hectare were recorded at the tree and pole stages. Natural regeneration at sapling stages was 7,200 individuals, and natural regeneration at the seedling stage is also abundant, with 76,000 individuals recorded per hectare. Some *S. belangeran* planted in 2003 was recorded along the road path inside the area. There are other 19 tree species (*Nothaphoebe coriacea*, *Melaleuca* sp., *S. belangeran*, *C. rotundatus*, *Eugenia* sp., *C. arborescens*, *Tetrameristra glabra*, *S.platycados*, *Myristica* sp., *Knema* sp., *Campnosperma* sp., *Dryobalanops* sp., *Xylopia fusca*, *Polyanthea hypoleuca*, *Luthocarpus spicatus*, *Artocarpus* sp., *Calophyllum* sp., and two unidentified species with the local name of *pentik* and *kopi-kopi.*) was recorded beside *S. belangeran* as a result of enrichment planting in 2003. This peat ecosystem has recovered close to previous forest conditions, which was 23 years ago. Enrichment planting adds to species diversity, showing that peat recovery in this area is almost similar to the ex-burnt in the same year but is enriched with some local species. There is no record of species composition before this area was burnt in 1997.

3.2.5. *Recurrent fires, converted land, and natural regeneration*. Observations on thin peat secondary forest areas, converted and burned repeatedly, were carried out in two locations, namely Dandang Barat village and Sebangau sub-district. The second location is in Maliku Village, Maliku sub-district. These sites are classified as areas that have suffered heavily from fires and other disturbances. In the first location in Dandang Barat Village, one unidentified species was recorded at tree stages with a density of 125 individuals per hectares and an average diameter of 11.6 cm. There is sufficient natural regeneration at the sapling level as many as 6400 individuals, and natural regeneration at the seedling
stage is also abundant as many as 170,000 individuals per hectare. There were only two types of regeneration at sapling stages, *Alstonia scholaris* and *Melaleuca* sp. Seedling stages were dominated by *A. scholaris*. There were no individuals at the tree stages in the second location in Maliku Village. However, natural regeneration at sapling and seedling stages was relatively abundant, 22,000 and 320,000 individuals per hectare, respectively. The second area is dominated by the *Melaleuca* sp., which is quite dense, followed by *A. scholaris*. The recovery process in these areas will continue unless there are no more fires and also better fire prevention actions. There is a need to carry out enrichment planting since no other seed sources were found except *Melaleuca* sp., which is well-known with its local name as 'gelam'. The bark is useful for the shipping industry, while the wood is often used in housing, boats, fences, or temporary poles.

3.2.6. *Ex Fire 1998, secondary forest with natural regeneration*. This site located at Sebangau National Park experienced forest fires in 1998 and then continues to have a natural succession process. This National Park was originally a production forest that was later declared a conservation area due to its ecosystem uniqueness and biodiversity richness. In this area, the individual density at the tree and pole stages are relatively high, with a density of 675 individuals per hectare comprising of 16 species (*Vatica resak*, *Litsea elliptica*, *Ganua motleyana*, *Knema mandarahan*, *Cratoxylon arborescens*, *Dyospiros areolata*, *Mezzetia parviflora*, *Xylopia* sp., *Tetramerista glabra*, *Terminalia catappa*, *Litsea firma*, *Calophyllum* sp., *Campnosperma* sp., *Eugenia* sp., *Shorea leprosula*). Sufficient natural regeneration at the sapling stage is available with 4,400 individuals per hectare. The natural regeneration rate for seedlings is also abundant, with 313,000 individuals per hectare. Based on the species diversity and its abundance, the recovery process of the peat ecosystem is considered sufficient as, after 22 years since the last fire, the vegetation structure and composition are similar to the undisturbed site.

3.2.7. *Ex Fire 1998, secondary with rehabilitation in 2005*. This site located at Sebangau National Park is a secondary forest that experienced forest fires in 1998. It was artificially enriched with *Shorea belangeran* and *Dyera* sp. through Gerhan (*Gerakan Rehabilitasi Lahan/Land Rehabilitation Movement*) Program in 2005. The success of this program was evaluated after 15 years of planting, and the result showed 92% of success. The individual density at the tree stage is adequate, with 250 individuals per hectare dominated by *S. belangeran*. At least 325 seedlings were recorded from planting and natural regeneration. However, regeneration at the seedling level was not observed because it was inundated with water after rainfall. In Sebangau National Park, *S. belangeran* has grown and forms a pure stand of trees of the same age. This indicates that *S. belangeran* is a pioneer species.

3.3. *Restoration accomplishment based on recovery stages*

The guidelines developed by Society for Ecological Restoration (SER) International Science and Policy Working Group, Version 2 [6], were used to determine that the condition of restored peatlands is undergoing a recovery phase. This guide provides steps to determine whether such an ecosystem has recovered and is able to continue its development process without human intervention. The recovery that shows self-sustained in structural and functional ways should demonstrate the resilience of any ecosystem against stress and disturbance. This can be determined using nine attributes as guided under SER to determine restoration accomplishment. Table 1 shows stages of restoration accomplishment at different levels of disturbance and damage.
| No. | Attribute to determine restoration accomplishment [6] | Ex Fire 2015, secondary with natural regeneration | Ex Fire 2015, secondary with planting in 2018 | Ex Fire 1997, secondary with natural regeneration | Ex Fire 1997, secondary with planting in 2003 | Recurrent fires, converted land, thin peat and natural regeneration* | Ex Fire 1998, secondary with natural regeneration | Ex Fire 1998, secondary with rehabilitation in 2005 |
|-----|--------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 1   | The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure | Natural regeneration is dominated by two species of *Combretocarpus roundatus* and gerunggang (*Cratoxylum arborescens*). Both species dominated at seedling and sapling stages, meaning that the recovery process is good. These species are considered pioneer species in the peat ecosystem in the Kahayan Sebangau forest complex. | Abundant natural regeneration of native trees, namely *Combretocarpus roundatus* and gerunggang (*Cratoxylum arborescens*). Enrichment planting by two native trees, namely *Shorea belangeran* and *Dyera polyphylla*, was done in 2018 | N/A | N/A | N/A | N/A | N/A |
| 2   | The restored ecosystem consists of indigenous species to the greatest practicable extent. In restored cultural ecosystems, allowances can be made for exotic domesticated species and for non-invasive ruderal and segetal species that presumably co-evolved with them. Ruderals are plants that colonize disturbed sites, whereas segetal typically grow intermixed with crop species. | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 3   | All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| No. | Attribute to determine restoration accomplishment [6] | Ex Fire 2015, secondary with natural regeneration | Ex Fire 2015, secondary with planting in 2018 | Ex Fire 1997, secondary with natural regeneration | Ex Fire 1997, secondary with planting in 2003 | Recurrent fires, converted land, thin peat and natural regeneration* | Ex Fire 1998, secondary with natural regeneration | Ex Fire 1998, secondary with rehabilitation in 2005 |
|-----|-----------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 4   | The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory | N/A                                           | N/A                                           | 23 years after a fire, the area now consisted of 12 native trees of mature plants capable of producing natural regeneration | The area was burned down in 1998. Currently, the area consists of 12 native trees of mature plants capable of producing natural regeneration. Artificial planting enrich the area with another native tree, namely *Shorea belangeran* | N/A                                           | N/A                                           | N/A                                           |
| 5   | The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent. | N/A                                           | N/A                                           | N/A                                           | N/A                                           | The area was burned down in 1998. The restored ecosystem now functions normally and consist of 13 native mature trees with abundant natural regeneration | N/A                                           | N/A                                           |
| 6   | The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges. | N/A                                           | N/A                                           | N/A                                           | N/A                                           | N/A                                           | N/A                                           | N/A                                           |
| No. | Attribute to determine restoration accomplishment [6]                                                                                       | Ex Fire 2015, secondary with natural regeneration | Ex Fire 2015, secondary with planting in 2018 | Ex Fire 1997, secondary with natural regeneration | Ex Fire 1997, secondary with planting in 2003 | Recurrent fires, converted land, thin peat and natural regeneration*) | Ex Fire 1998, secondary with natural regeneration | Ex Fire 1998, secondary with rehabilitation in 2005 |
|-----|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 7   | Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible. | N/A                                             | N/A                                         | N/A                                             | N/A                                         | N/A                                             | N/A                                             | N/A                                             | N/A                                             |
| 8   | The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that maintain the ecosystem’s integrity. | N/A                                             | N/A                                         | N/A                                             | N/A                                         | N/A                                             | N/A                                             | N/A                                             | N/A                                             |
| 9   | The restored ecosystem is self-sustaining to the same degree as its reference ecosystem and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure, and functioning may change as part of normal ecosystem development and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change. | N/A                                             | N/A                                         | N/A                                             | N/A                                         | N/A                                             | N/A                                             | N/A                                             | N/A                                             |

Remark: *) The study area which severely degraded did not meet all nine criteria for ecosystem recovery
3.4. Management implication

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed, or entirely destroyed as the direct or indirect result of human activities [6]. The types of restoration based on different types of damage will have different management implications and even implications for the sustainability of their cost. There is no best single solution to recover degraded peatland, although restoration is promising. Yet, economic-social-environmental trade-offs often generate intense disagreement among stakeholders. Thus, peatland restoration achievement will rely on cross-sectors linkage and harmonization to implement their cross-cutting national program. Not to mention, improved governance and technical capacity building posed to the target community [1].

Figure 1 shows that a restoration process or stage is determined by the initial conditions and the form/type of damage caused so that recovery efforts require detailed information on the damage history. The restoration itself is an activity to restore an ecosystem or habitat from a condition that has changed from the condition where the community structure, natural features of the species, or its ecosystem function are at steady states to a later condition that has decreased [10, 11]. Thus, the indicator for the success of restoration will largely be determined by the ability of managers to identify the initial level of damage that occurred. It is very obvious here that any planned program shall take into consideration the structural components and composition of the native/local species. This can be done through a program with clear goals and objectives, including a clear decision-making structure, timeline, and a well-designed financing plan.

![Stages of Peat Restoration/Recovery](image)

**Figure 1.** Peat restoration stages based on level of degradation.

Restoration of degraded peat ecosystems will definitely, go through a succession process to accelerate the recovery process of the ecosystem function. Therefore, the indicators of success during the accelerated process in manipulating the environment and resources must be measured and evaluated [11]. It is, therefore, indicators for the success of restoration must have: i) a reference for successful restoration, ii) a measurable “benchmark” of restoration efforts, iii) a decision-making structure, objectives, time limits, and regulatory compliance, iv) a level of achievement conditions different towards the reference ecosystem, and v) its own value of success for every progress towards success, and there will be a consequence of costs that must be borne.

In contrast to the above process, restoration indicators refer more to specific, observable, and measurable characteristics that can be used to show changes or progress achieved by the program to
achieve certain results [12]. There are three (3) types of indicators in restoration activities with different gauges, namely: i) to measure the process, ii) to measure the input/output, and iii) to measure the impact. As shown in Figure 1, the existing restoration/recovery indicators in the study area, namely the three (3) peat hydrological units that have a slight difference in peat depth distribution, will, indeed, have slightly different indicators.

Results of observation in the seven sites of peat ecosystem with various levels of fires disturbance and also other human intervention showed that efforts to restore peatlands had been proven to be carried out with good results if there are no recurring disturbances such as fires. However, peatlands that burn repeatedly will be more prone or vulnerable and difficult to restore directly without improving water management and the condition of the peat soil.

For this reason, comprehensive data and information are needed on typology, accurate distribution of peat depth and level of damage. This study will look for indicators of success in restoring degraded peatlands based on the level of damage. It is understandable that the recovery rate will depend largely on the condition of the land before it was disturbed and what activities took place and had a tangible impact on the ongoing restoration process.

When the result of observation was compared to recovery criteria set by [8] that has nine criteria to determine recovery stages, only a few conditions can meet the assigned criteria. Without adequate information on the ecosystem reference in particular degraded areas, the restoration process may take longer. Based on our field observation, we are proposing the following condition:

1. Recovery at seedling stages (available seedling density > 625 individual/ha)
2. Recovery at pole stage (available pole density > 625 individual/ha)
3. Continuing recovery at the pole (available pole density > 280 trees/ha)
4. Recover (minimal three of local/native plants > 280 trees/ha)
5. Climax (trees >4 local species > 280 trees/ha)

4. Conclusion

In general, restoration of the peat ecosystem in KHG Kahayan Sebangau, Central Kalimantan – under certain circumstances – is possible. However, several conditions should be met to consider that the recovery process can proceed as expected. With the limited data available and the insufficient observation time, some elements should be considered before and during the restoration.

Considering the unique typology of peat swamps and different levels of disturbances, the uttermost important thing that needs to be considered before starting to conduct or implement a restoration program is to have an ecosystem reference in the targeted site. So far, fires are a major factor in the failure of efforts to restore the peat ecosystem. Therefore, field officers or forest rangers are more aimed at preventing fires and interacting with local communities living in and around the forest area to build good partnerships.

Various silviculture measures and techniques can be adopted in Sebangau NP through enrichment or planting activities aimed at increasing species diversity, especially in heavily degraded areas where mother trees of local species are not available. A local tree species that are proven to be successful in artificial regeneration is Shorea belangeran. This species is a pioneer type of peatland and can form pure stands of the same age as it is found in this species population in Sebangau National Park. In areas where mother trees are still available, natural succession (without enrichment assistance) through natural regeneration can take place successfully, as shown in Sebangau National Park and KHDTK Tumbang Nusa.

Adequate time is also an important factor in determining the success of peat ecosystem restoration. During this recovery process, there should be no disturbance, especially fire, within a period of time (at least 20 years) until the target area can return to its climax condition. In addition to this, the impact of repeated fires on peatlands is relatively difficult to recover. Therefore the level of vulnerability or risk to fire can be used as a strong argument in formulating policies related to peatlands opening/clearance using fire. It is no doubt that restoration efforts on severely degraded peatlands require collaborative action from all stakeholders/parties.
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