Formulating peatland fire prevention strategy in Bengkalis Regency: An application of analytical hierarchy process

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Abstract. Bengkalis has been widely known as one of the regencies in Riau Province that is dominated by peatland. Nevertheless, this regency is also known for its almost annually recurring peatland fires. Considering this issue, this study primarily aims to formulate peatland fire prevention strategy in Bengkalis Regency. This study was conducted through the Analytical Hierarchy Process (AHP) methodology. While having a high degree of consistency ratio among involved experts, the results of this study revealed that shrubs was the type of peatland cover that must be given priority attention. Meanwhile, the key criteria in implementing peatland fire prevention was budget availability. Besides, local governmental institution that should be prioritized to receive authority as the coordinator for peatland fires prevention was the Regional Disaster and Fire-Fighting Agency (BPBD-Damkar). In the meantime, sequentially, it seems that the best prevention alternative was to build and/or repair existing canal blocks; strengthened by the implementation of regional integrated security patrols; constructing and/or repairing of water reservoirs and boreholes; as well as the provision of zero-burning incentives to traditional cultivators. These findings are useful to support the local government in preparing a more proactive prevention approach in addressing peatland fires.

Keywords: AHP, Bengkalis, Peatland fires, prevention, proactive

1. Introduction
Bengkalis Regency is one of a second-level administrative areas in Riau Province that is dominated by peatlands. Based on the previous analysis regarding the distribution of peatlands, it is known that peatland in this regency is equivalent to about 65-67% of its area [1,2]. Naturally, such vast peatlands have a variety of very important functions, including preventing droughts and floods, conserving biodiversity, and playing an important role in mitigating climate change through its carbon storages [3]. Unfortunately, as the pressure of economic growth continues to increase, threats to peatland in this

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regency also continues to surge, especially as a result of unsustainable land conversion and use. In the meantime, along with the continuing trend of peatland clearing, it is not surprising that there are significant changes in the natural ecosystem of peat, which in turn raises more and more degraded areas with almost annually recurring peatland fires [4].

In order to overcome peatland fires that continue to occur, the government has issued a series of laws and regulations containing necessary fire control directives. Nevertheless, several previous studies [5, 6, 7] showed that the effectiveness of such policies and strategies applied in preventing peatland fires so as not to keep recurring were still low. In general, this may happen due to several drawbacks that were still prevailing, including the strategies implemented in the field were still relying on reactive efforts through monitoring hotspots to then be suppressed as soon as possible (detect-and-suppress) which in principle is a non-preventive measure. This kind of strategy was not effective if it continues to be applied to areas dominated by peatland. Besides, it seemed that the current fire control directives also tend to pay less attention to the recurring pattern of peatland fire itself. Considering these issues, this study was primarily aimed to formulate a strategy specifically designed to prevent the occurrence of peatland fires in Bengkalis Regency.

2. Method

2.1. Study location
This study was conducted in Bengkalis Regency, which is situated on the eastern coast of Sumatera Island. Meanwhile, geographically, this administrative area is located between 2°7’37.2”-0°55’33.6” North and 100°57’57.6’’-102°30’25.2” East, as illustrated in figure 1.

![Figure 1. Study location](source: [8])

2.2 Analytical approach
In this study, peatland fire prevention strategy is formulated using the Analytical Hierarchy Process (AHP) method. In principle, AHP is a method that can be used to formulate a complex and unstructured situation into several components in a hierarchical arrangement, by giving subjective values about the relative importance of each variable, and then determining which variable has the highest priority to influence results in a certain situation [9]. Concerning this notion, this study was initiated by arranging a multilevel functional hierarchy, as illustrated in figure 2. The overall process in this study was conducted with the help of Expert Choice 11 software that was not only able to integrate several experts’ judgement but also didn’t set limit to the number of hierarchical levels. This software also adopts the AHP comparison scale [10], as presented in table 1. The determination of variable weights in this study...
was obtained by interviewing three experts from the Forest and Land Fires Laboratory-IPB, Engineering Faculty of Pasir Pangaraian University, and Bengkalis Regency Local Government.

![Diagram of hierarchical structure for peatland fires prevention strategy formulation]

**Figure 2.** The hierarchical structure for peatland fires prevention strategy formulation

**Table 1. AHP comparative scale**

| Value | Remark                                      |
|-------|---------------------------------------------|
| 1     | Equally important                           |
| 3     | Moderately more important                   |
| 5     | Highly more important                       |
| 7     | Strongly more important                     |
| 9     | Absolutely more important                   |
| 2,4,6,8 | Should there be doubt between two adjacent comparative values |
| 1/(1-9) | Reverse value for importance level scale of 1-9 |

Source: Saaty (2008)

2.3 **Consistency evaluation**

Variables’ priority assessments through the AHP approach are in principle carried out according to subjective preferences from involved experts so that it is highly difficult to nullify overall inconsistencies in the final results of weighted hierarchies that have been compiled [12]. The overall level of inconsistency in which the analysis of the organized hierarchy can be carried out is about 0.10 or 10% [11]. The measurement of the level of inconsistency is conducted by taking into account the consistency ratio (CR), where CR is a comparison between the consistency index (CI) and the ratio index (RI) [11,12].
3. Result and discussion

3.1. Weighted Hierarchy and overall consistency

Results of weighting the hierarchy in the formulation of peatland fires prevention strategy in Bengkalis Regency along with the result of overall consistency evaluation are presented in figures 3 and 4. Based on those figures, it can be seen that the priority of target areas, institutional criteria that need to be considered, the institution in charge and alternative prevention strategies that need to be applied sequentially are shrubs, budget availability, concession holders, and canal blocks construction/renovation. Meanwhile, the result of inconsistency calculation from the overall hierarchy weighting process shows a very low number with only 2%. This indicates that the three experts involved in the priority weighting process gave preference assessments with a consistency level of 98%. Referring to the acceptable level of inconsistency through AHP approach which is 10%, as stated by Saaty (2012), it can be said that overall hierarchical weighting result in this study can be used as the basis for peatland fires prevention strategy formulation in Bengkalis Regency. The importance of such consistency evaluation has also been discussed by a previous study explaining that valid weighting results should have high consistency [13].

Figure 3. Weighted hierarchical structure for peatland fires prevention strategy formulation

Figure 4. Overall inconsistency evaluation result
3.2 Peatland fires prevention strategy in Bengkalis Regency

3.2.1. Priority of prevention area. Referring to the results presented in Figure 3, it can be seen that the area that needs to be prioritized in the prevention of peatland fires in Bengkalis Regency is areas covered by shrubs with a value weight of 0.335 (34%). This finding is in agreement with a previous study [14], who studied the typology of peatlands combustion behavior, where it has been reported that the main target area of burning is peatland covered by shrubs. According to experts involved in this study, the main motive in shrubs burning in Bengkalis Regency is to clear land that will be used for agricultural activities.

Meanwhile, the second to fifth positions are occupied by forest areas, plantations, bare land, and farming field, with a slight difference in weight between areas, namely 0.180, 0.165, 0.156 and 0.102. In terms of land use, it seems that those target areas are indeed closely related to peatland utilization activities for cultivation, including peatland use for annual crops, food crops, and horticulture crops, as reported previously [15]. Meanwhile, according to experts in this study, forest areas tend to have a higher priority because of the tendency that fires begin to emerge from ex-forest concessions which are often being the target of illegal land claims. Besides, along with the occurring decline in forest concession area's operational activities that is categorized as a peat ecosystem for protection function (FLEG), employees who previously also played a significant role in supervising the area will also be reduced. In other words, it means that there is a significant reduction of human resources needed to monitor massive infrastructures, especially road and canal networks, which have been built by concession holders who are now no longer in fully operational status. Eventually, this implies that new open access areas will emerge which increasingly enable intentional burning of peatlands [16]. In the meantime, it seems that the lowest priority ranking of target area for peatland fires prevention in Bengkalis Regency is the activities and residential areas with only about 0.063 points. This value indicates that there is a tendency that this type of area bears the lowest vulnerability level to the occurrence of peatland fires compared to the other five types of target areas.

3.2.2. Priority of institutional criteria required to prevent peatland fires. Based on the results of experts’ judgment, as presented in Figure 3, it seems that the highest priority of institutional criteria required in peatland fires prevention should be given to the availability of financial resources. The proportion of this variable contributes to about 25% of the total. This result is consistent with other studies [7,17,18], which report that there still a significant gap between current budget availability in preventing peatland fires and the need for sufficient financial sources to support a large number of parties involved in field operations.

Subsequently, second and third to budget availability, other criteria that also need to be prioritized are work authority and coordination capacity, with weights about 0.180 and 0.165 respectively. According to experts involved in this study, those two criteria are important to be considered to erode the tendency of sectoral ego or individualistic attitudes among regional organizations in implementing peatland fires prevention in Bengkalis Regency. Similarly, this notion was also conveyed previously [18,19,20], who states that each institution tends to prioritize its agenda, less able to coordinate with each other, and less support each other in handling a problem, especially if it is related to financial resources. The other three criteria that also need to be taken into account are including facility and infrastructure availability, human resources’ level of education, and the number of available human resources, with weights of 0.151, 0.127 and 0.113 respectively.

3.2.3. Priority of institution in charge. Results of weighting for the institution in charge (figure 3) reveal that the concession holder is the main actor that should be prioritized to take charge of peatland fire prevention in Bengkalis Regency. This is in line with current legislation’s mandate, where the implementation of peatland fires control in concession areas have become the responsibility of concession holders. Meanwhile, for peatland outside concession areas, it seems that involved experts agree that BPBD-Damkar is the most suitable institution to act as the coordinator of peatland fire
prevention in Bengkalis Regency, with a weight of about 0.143. This is because, the Local Disaster Mitigation and Fire Fighting Agency (BPBD-Damkar) is considered to be able to meet various institutional criteria needed in peatland fires prevention that have been determined previously in a balanced manner, including the availability of adequate budget, required work authority as set out in Bengkalis Regent Regulation No. 23/2015, long experience and good coordination capacity with various other local governmental services, as well as sufficient human resources both in terms of quantity and quality. Nevertheless, BPBD-Damkar certainly cannot work alone, therefore, other actors also need to be considered for their role in implementing peatland fires prevention in Bengkalis Regency, such as the local Agricultural Service and the Environmental Service, who bear weight proportions of about 0.118 and 0.105 respectively. The involvement of the Agricultural Service and the Environmental Service is highly essential, as stated by involved experts that those two local governmental institutions have been directly engaged in community development, particularly in land cultivation sector, so that they have emotional closeness with local communities.

Meanwhile, other actors, such as the National Military/Police units (TNI/Polri), the Local Public Works Services, Civil Service Police units (Satuan Polisi Pamong Praja), Community Fire Care Groups (Masyarakat Peduli Api/MPA), as well as Farmers Fire Care Group (Kelompok Tani Peduli Api/KTPA) have almost equal weights with about 0.072, 0.068, 0.061, 0.052 and 0.052. The involvement of the National Military/Police units and Civil Service Police units is highly necessary in the implementation of regional security patrols, because peatlands burnings are not only carried out by local communities, but also by opportunist parties who use fire as a tool in conflicts that do not rule out the possibility of being politically motivated [21,22]. On the other hand, the role of the Local Public Works Services is also needed, considering the fact that this local governmental institution has the required human resources with long experience and expertise in infrastructure design (e.g. construction / renovation of canal blocks, artesian wells and water reservoirs), as stated in previous studies [23,24]. Additionally, taking into account that Community Fire Groups and Farmers Fire Group are two actors who both come from the local community, it seems that involved experts in this study have given a balanced priority weight to them, although there is a basic technical difference in terms of coaching, where the MPA is fostered by the Environmental Service while the KTPA is by the Agricultural Service. This judgment is consistent with a previous study [25] concluding that both MPA and KTPA had an equally significant role in preventing peatland fires in Bengkalis Regency.

3.2.4. Priority of alternative approach to prevent peatland fires. Weighting results at the level of alternative approaches (Figure 3) show that canal blocks construction/renovation should be regarded as a top priority in preventing peatland fires in Bengkalis Regency. The implementation of this strategy can be accompanied by the implementation of regional security patrols, construction/renovation of water reservoirs and artesian wells with slightly different priority weights of about 0.166, 0.164 and 0.133 respectively. In general, the implementation of such strategies may support peat rewetting program [26], and also strengthen the technological aspect, especially in relation to peatland wetting infrastructure. Nevertheless, referring to the classification of peat functions as stipulated in Government Regulation No. 71/2014 Jo. Government Regulation No. 57/2016, in which that peatland is divided into two distinct categories for cultivation and protection, then there are also differences in the type of wetting infrastructure that can be applied in accordance with its objectives. On one hand, construction purposes of wetting infrastructure in peatland for cultivation function tend to focus on water management [27]. Therefore, the type of infrastructure constructed can be a canal block equipped with a water level control mechanism in the form of an excess water overflow. Technically, according to the provisions in Government Regulation No. 57/2016, canal block structures can be made of wood combined with fillers in the form of soil sacks, concrete and sluice gates, provided that elevation of the overflow should not be deeper than 0.4 meters from peatland’s surface. In order to strengthen this technological aspect, the institution in charge may implement sluice automation, either through a simple mechanism with water flow power, or a more complex electronic system. The existence of sluice automation in canal blocks can keep peatlands to remain wet because during rainy season/high tide, floodgates can be opened to
maximize water stocks that enter the land and fills existing canals; on the contrary, during the dry season/low tide, floodgates can be closed so that water remains stored in the canal so that water level can be maintained at a certain level [28,29].

On the other hand, construction purposes of wetting infrastructure on peatland dedicated for protection function are primarily aimed for water conservation, so that developed infrastructure can be in the form of canal blocks without a water level control system, and / or canal backfilling directly [27]. However, it should be kept in mind that although such rewetting infrastructure in protected areas does not require a water level control mechanism in the form of a spillway, the recommended elevation of that wetting infrastructure is not higher than the existing peatland’s surface, in order to avoid scouring to the right and left side of the bulkhead building, which can eventually cause leakage. In addition to that, the canal block and backfilling structures must also be peat-friendly, so that building materials that cannot be integrated with peat, such as concrete and the like, are not recommended [27].

Subsequently, another alternative that may also be considered further is the provision of incentives for traditional planters/cultivators to support zero-burning policy implementation, with about 0.130 (13%) points of preference. This kind of incentive may include financial support, mechanical tools, and technological assistance for peatland management. Provision of such incentives is expected to avoid, or at least reduce emerging situations in which that traditional cultivators/planters have no choice but to continue to apply a slash and burn method, due to the lack of support for alternative financial sources, mechanical tools, and new technology in peatland management, during the implementation of zero-burning policy. The legal basis for such incentives provision has been regulated in the Riau Governor Regulation No. 5/2015.

The last two priorities are construction/renovation of fuelbreaks and implementation of prescribed burning, with their respective weights of about 0.107 and 0.074. According to involved experts in this study, implementation of prescribed burning is the last resort in case that institutions in charge of peatland fire prevention in Bengkalis Regency do not have sufficient resources to implement other approaches that have been prioritized more. Legally, prescribed burning implementation for traditional planters / cultivators is still permitted, as stipulated in Riau Governor Regulation No. 11/2014.

4. Conclusion
This research has presented the formulation of peatland fire prevention strategy to be implemented in Bengkalis Regency covering aspects of the target area that need to be prioritized, institutional criteria that should be fulfilled, the institution in charge for on-site coordination, and the approaches that need to be implemented. Based on the Analytical Hierarchy Process (AHP) method, this study shows a high consistency among experts involved in the process of priority judgment determination among variables. Overall, experts’ assessment in this study suggests that shrubs covered peatland should be considered as the top priority in preventing peatland fires in Bengkalis Regency. Meanwhile, budget availability has been regarded as the key criteria for implementing peatland fire prevention. Apart from that, consistent with current laws and regulations, the main actor that should take a lead for peatland fires prevention is permit holder companies in their corresponding concession areas, while outside concession area, the Local Disaster Mitigation and Fire Fighting Agency (BPBD-Damkar) has been considered to be the most suitable governmental institutional to take in charge. Afterwards, it seems that the best prevention alternative to prevent the occurrences of peatland fires in Bengkalis Regency is to establish and/or renovate existing canal blocks, strengthened by the implementation of regional security patrols, construction/renovation of water reservoirs and artesian wells, and the provision of zero-burning incentives to traditional planters/cultivators. In addition to that, in certain circumstances where available resources do not support the implementation of those measures, especially the provision of zero-burning incentives, after ensuring the readiness of necessary fuelbreaks, the institution in charge of peatland fire prevention may also consider implementing prescribed burning as the last resort.

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