Techno-Socio Approaches in Peatland Fire Control in Indonesia

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Abstract. Peatland fire has been the most prominent cause of transboundary haze problem in the ASEAN region since 1997/1998. The impacts are not locally but also globally identified. The paper aims to elaborate on how peatland fire occurred and techno-socio approaches for fire control. The study was based on a Focus Group Discussion of relevant stakeholders and literature review conducted using descriptive and content analyses. The study found that peatland fire occurred mostly caused by human activities in land preparation. Efforts on peatland fire control have been conducted by various agencies with various approaches. Technological approaches have been developed for peatland fire control in terms of fire prevention stage on early warning system, early detection system, and fire suppression stage on early suppression as well as of post-fire activities on burned area estimation. On the other hand, social approaches have also been developed and implemented in terms of community empowerment and incentives scheme for zero burning implementation. No doubt, synergy between socio-economic approaches and technological approaches have to be prioritized in peatland fire control in Indonesia with multi/transdisciplinary manners.

1. Introduction

The large fire occurrences in Indonesia are noted in 1982/1983, 1987, 1991, 1994, 1997/1998, 2002, 2006, 2012/2013, and 2015 [1]. Millions of hectares of forest and land burned out and caused great impacts on ecological, economical, and social aspects [2]. Indonesia experienced extraordinary fire occurrence in 1997/1998 when extensive fires ravaged large areas of Indonesia, particularly the islands of Sumatra and Kalimantan. The burned area has been estimated between 10 and 11.7 million ha, the number of people affected by smoke haze and fire was 75 million, and the total economic cost to the region was as much as US$ 3.5 – 9.7 billion [2]. The fires were mostly peat fire, which dominated by the smoldering process.

The impacts of fires in Indonesia are not merely local issues but also regional and global issues and become a regional disaster [3]. Smoke haze concentration dispersion did not only affect at fire location areas, but also extended to other neighboring countries of the ASEAN region, such as Singapore, Malaysia and Brunei Darussalam. The most pronounced impacts are the decrease of visibility, disturbing...
air and land transportation networks, increasing acute breath infection victims, and creating socio-economic problem of community. Smoke and haze come from the fires have blanketed some of regional ASEAN countries, of which transboundary haze pollution issue has appeared since 1997/1998 [4], [5], [6]. Peatland fire has been an important phenomenon since then. The fires were dominated by smoldering process contribute to haze and carbon emission in form of carbon dioxide, carbon monoxide, hydrocarbon, particulate matters, and other materials with decreasing content, which is dangerous to human health [7], [2].

Since the 1997/1998, fire occurrences in Indonesia was dominated by peatland fire, which has greater impacts compared to non-peatland fire [8]. The fires become an important threat to the peatland area covering about 14.9 ha [14] which plays very important role in global environmental balance as well as adjacent ecosystem and local community livelihood. Peatland fire has continuously occurred every year due to degraded peatland conditions caused by other human-induced disasters such as over drainage and overexploitation [8].

The Government of Indonesia realizes that forest and land fires is an important environmental issue to be solved. In 2014, the Government has merged the Ministry of Forestry and Ministry of Environment to become the Ministry of Environment and Forestry (MoEF) [19]. With this regard, the management of forest and land fires is expected to be more efficient and effective as it is under one main institution compared to the previous conditions when forest and land fires under separate ministries. In the policy aspect, the Government has released laws and regulations on forest and land fires from the central level and regional or local level as well.

Having the use of fire for centuries, traditional farmers in Indonesia have their own local wisdom in preparing their agricultural land which environmentally friendly. Studies show that traditional farmers implement controlled burning techniques to prepare the land, which consider: weather factor, dryness of fuel, safety, and impacts. Controlled burning practices are still implemented by Dayak community in Kalimantan, Baduy community in West Java, local community near National Parks in Jambi, the local community in Sulawesi, the local community in Papua, and the local community in Nusa Tenggara [3].

On the other hand, since social factors play more significant when compared to natural factors in fire causes, the government have developed strategy and programs to enhance the livelihood of the community and at the same time to force zero burning land preparation implementation. Incentive schemes for the community have been developed and implemented. This paper aims to elaborate on technological and social approaches in forest and land fires control in Indonesia.

2. Materials and Methods
This study was based on Focus Group Discussion conducted in August 2019 under Networked ASEAN Peat Swamp Forest Communities (NAPC) Project, which aims to deploy IoT-based solution for peat swamp forest monitoring, targeting the environmental and agricultural issues and at the same time engaging with the peat swamp forest communities for social innovation aspects. The FGD was attended by scientists/experts from Indonesia, Brunei Darussalam, Malaysia, and Japan. Our paper focused on materials prepared by Indonesia key stakeholders, namely: Ministry of Environment and Forestry (MoEF), Indonesia Peat Society (HGI), National of Aeronautics and Space Agency (LAPAN), Regional Fire Monitoring Center-SEA (RFMC-SEA), Agency for the Assessment and Application of Technology (BPPT), and IPB University (IPB). Besides, the study applied content analyses for peatland fire control research in Indonesia within national as well as international journals, which were selected from recognized journal searching engines by using “keywords” of forest fire causes, forest fire control AND Indonesia as the exclusive subjects of content analyses [9]. The content analysis enables the investigators to include large amounts of textual information and systematically identify its properties.
3. Results and Discussion

3.1. Causes of forest and land fires
Forest and land fires in Indonesia have been a regular phenomenon which cause great impacts to the environment, including Green House Gases emission and smoke haze transboundary haze pollution [4],[5],[6],[20]. The fires come from burning activities in land clearing for various purposes including land preparation for agriculture and forest plantation, settlement, and other development programs, burning due to land conflicts, unintentional spreading of fire and natural resources extraction activities, particularly in Sumatera and Kalimantan [8],[10],[11].

No doubt, the fires caused land use and land cover changes. Forest cover has been changed to other land use such as: agriculture, plantation, shrubs, and settlement. These changes contributed to carbon emission and global warming [10],[12],[13]. Jambi Province as one of fire-prone areas located in Sumatera having a large peatland area of 621,090 ha [14], which has both fire and conversion problems. The smoke haze that hit Jambi and several other regions in Indonesia in the middle of August until November of 2015 has impacts on the closing of Sulthan Thaha Saifuddin Airport in Jambi, school activities for about 2 months, and the increase of air pollution index at the end of October 2015 of 300-700 API level [15].

Conversion and expansion of agricultural land and plantation have contributed substantially to land-use and land-cover change (LULCC) in Sumatra and Kalimantan. The land expansion and intensification are expected to continue in Indonesia to meet the demands of a growing global population. Fire is a common tool for land conversion including for industrial agricultural plantations. Carlson et al [16], report that fire was the primary proximate cause of 1989–2008 deforestation (93%) and net carbon emissions (69%), and by 2007–2008, oil palm directly caused 27% of total and 40% of peatland deforestation. Studies have shown that there is a strong relation between LULCC and fire events in Sumatra and Kalimantan [17]. The role of land-use and land-cover change is important to be analyzed in determining the patterns of fire occurrences and emissions.

3.2. Technological approaches on peatland fire control
Ministry of Environment and Forestry of Indonesia divided forest and land fire control program into five categories, namely: Fire prevention, fire suppression, human resources development, and post-fire activities. Fire prevention including: Integrated prevention patrol, Routine patrol, Early warning and early detection, Campaign and education, Land preparation without burning/zero burning, Peatland Management, Fire Care Community, and Coordination meeting; Fire suppression covering: Ground suppression and aerial suppression; Human Resources Development consist of: Forest and Land Fire Brigades (Manggala Agni), Forest Fire Brigades in Forest Management Unit, Capacity building: training, Coaching clinic, and Equipment, and post-fire activities covering: Burn area calculation and Law enforcement.

3.2.1. Forest and land fire information system. Forest and land fires related information system in Indonesia has been developed greatly since the last few years by several agencies. As the most significant progress on forest and land fire control is a strong coordination among agencies. It is shown by using one national hotspot data released by LAPAN. All ministries or agencies should refer to the hotspot data source, which can be accessed on the website of http://modis-catalog.lapan.go.id/mapping (Fig). The hotspot data can be extracted for the whole of Indonesia as well as for provinces in the form of excel data as well as map. It is derived from various satellites including: Aqua, Terra, SNPP, NOAA 20, and Landsat 8 with various confidence levels from < 29% to ≥ 80%. Ministry of Environment and Forestry developed forest and land fire monitoring system in a website of http://sipongi.menlhk.go.id/home/main (Fig. 1.), which shows important information on daily, monthly, and annual hotspots as fire indicators for the whole of Indonesia in the forms of data, graphs, and maps. The hotspot data is derived from LAPAN as the focal point for hotspot information. Besides, the website
also provides information on fire-related regulation nationally and regionally, fire control program, documentation in photos and video forms.

![Screen display of fire information system developed by LAPAN and MoEF.](image)

3.2.2. Early Warning System for forest and land fires. Since the last two decades, Indonesia has developed Early Warning System (EWS) for forest and land fires supported by the Canadian Government. The system is now improved and running by National Agency for Meteorology and Geophysics (BMKG), which covering: Fine Fuel Moisture Code (FFMC) and Fire Weather Index (FWI). New features of smoke dispersion and transboundary haze pollution have been developed (https://www.bmkg.go.id/sancakarla/) that show air quality elements such as PM10, SO2, and NO2. This Early Warning System also provides a long term prediction of forest and fires until the next 7 months as a result of high-resolution long term climatic data and hotspot historical data as a fire indicator.

3.2.3. Fire Monitoring. The use of hotspot data for fire detection at MoEF is equipped by real-time ground fire monitoring using Thermal CCTV Technology located in fire prone areas in six provinces. The technology was installed to conduct early detection and fire prevention by recording the area condition through CCTV thermal on look out towers located at fire prone areas at about 50 m high. The thermal CCTV will detect hot waves in 5-10 km radius, which is recorded, saved in a computer and indicate detail and real-time forest and land fires monitored. To support the fire brigade of ‘Manggala Agni’ operation, MoEF also operates drone to monitor and measuring burned areas.

3.2.4. Water level monitoring on the peatland area. As the awareness on peatland increased, the government of Indonesia has released the policy on peatland management in Government Regulation No. 71 Year 2014 on Peatland Ecosystem Protection and Management which was revised by the Government improved the Regulation by Government Regulation (PP) No. 57/2016 on Changing of the Government Regulation No. 71/2014 on Protection and Management of Peatland Ecosystem. There are three main important points in the regulation which indicate that the Government of Indonesia is seriously taking peatland into account in sector development and environmental management, namely: a) Using the word “peatland ecosystem” as the Government view not only to use peatland as an object but to use peatland as an ecosystem which influences each other in forming balance, stability, and productivity; b) Inclusion term of Peatland Hydrological Unit which means the peatland ecosystem located between two rivers, between river and sea, and/or in the swampy area; and c) Peatland ecosystem in Indonesia is classified in two functions, protection function and cultivation function. The implementation of the Laws is supported by the establishment of the National Board of Peatland Restoration-BRG [3].
One of the important points is maintaining the water level on peatland area. Therefore, BRG supported by BPPT developed peatland water level monitoring system as a platform real-time data monitoring from ground-water level (GWL) monitoring equipment, which includes measurement of peat soil moisture content, rainfall, temperature, relative humidity, and wind velocity.

As per December 2018, BRG has deployed GWL monitoring equipment as many as 142 units distributed in 7 restoration priority provinces (Riau-47 units, Jambi-13 units, South Sumatera-20 units, West Kalimantan -13 units, Central Kalimantan -42 units, South Kalimantan 5-units and Papua-2 units. Peatland GWL monitoring is very important to prevent forest and land fire and greenhouse gases emission. Monitoring of GWL may prevent uncontrolled water loss from peatland, which leads to negative impacts of GWL decrease, CO2 emission, fire occurrence, and irreversible drying. Peatland Ground Water Level Monitoring System (SIPALAGA) has a function from data recording of GWL to telemetry based real-time data publishing at the website. The system will record GWL, peat moisture content, and rainfall every 10 minutes daily. It is expected to support historical/series data and information of GWL and related parameters [21].

3.2.5. Innovation on fire suppression tools. Forest and land fires suppression, especially on peatlands, has its challenges and levels of difficulty when compared to the suppression of forest and land fires on mineral soils. This is caused by the characteristic of peat fires which spread not only on the surface but also within the peat layer. Peat fires are difficult to extinguish and require very expensive costs. Based on experiences, innovation is needed to suppress peat fires. One of the innovations on peat fires suppression equipment is called Sambunesia Nozzle. This innovation is an answer in addressing the problem of peat fires suppression. Suppression can be carried out effectively, efficiently, and safely using Sambu Ponti Nozzle to suppress peat fires. Sambunesia Nozzle is a modified pipe to maximize the fire suppression in peatland. Sambunesia Nozzle consists of two types, namely the Primer types, and Branch types. Sambu Ponti Primer is equipped with a support rod so that when it is used, the position and movement of the Fire Fighting Team will be more comfortable, so that the Fire Fighter could save their energy during the peat fire suppression. Sambunesia Branch is equipped with three types of pipe mouths, namely Variable Nozzle, Spray Nozzle, and Peat nozzle. Variable Nozzle is used for extinguishing the main part of the burnt area and “backfire” area, where the power of water spay is faster and stronger. While the Spray Nozzle serves to keep the surface of the fire always wet with smaller spray power but it can spread and reach out to various directions (MoEF).

3.3. Social approaches on peatland fire control
Since the causes of forest and land fires in Indonesia mostly by human activities, social approaches play very important role to minimize the fire occurrences. Strengthening efforts to minimize human factor in burning activities through village community empowerment has been an important choice to be implemented [18]. Some lessons learned of social approaches are obtained from various stakeholders that might be replicated or upscaled to more broaden region and communities.

3.3.1. Fire Care Community (MPA). MPA or (Masyarakat Peduli Api) is a community that voluntarily cares about forest and land fire control, and have trained and given knowledge regarding forest and land fires control. MPA can be involved in forest and land fire control activities (prevention, suppression, and post-fire suppression). In 2018, MoEF has formed 704 MPA groups or about 10,569 personnel in 28 provinces of Indonesia. MPA is a “role model” of success in land preparation without burning/supporting zero burning policy. MPA takes a role in the dissemination of information related to forest and land fires control.
3.3.2. Integrated Patrol. A high commitment of the Government of Indonesia is also indicated by the implementation of Integrated Forest and Land Fire Prevention Patrols initiated by the Ministry of Environment and Forestry (MoEF) which was launched in 2016 in 8 fire prone provinces in Sumatera and Kalimantan. The patrol team consists of: fire brigade of MoEF, army, police, and villagers. The patrol is conducted daily in targetted village about 731 villages within the eight fire prone provinces, which prioritize on early detection, data updated, the presence of fire-guard on the site, and synergy among institutions and village community. The patrol team provide socialization on fire prevention to the community and do early detection of village-based fire risk assessment everyday. The patrol’s results are reported tierly to the village task force, district/province task forces to central government through the communication network of smartphone applications of WhatsApp in order to be monitored and followed up in a shorter period time especially when forest and land fires occur. It is expected, the patrol may support fire prevention and early fire suppression in site level effectively in order to minimize forest and land fires in Indonesia [3].

3.3.3. Techno-Socio innovation. This techno-socio innovation focused on the program to support the community for fuel management. In general, land preparation with burning is the most common causes of forest and land fires in Indonesia. Therefore, it is important to provide community good solution for not burning their land by fuel management, such as: wood vinegar, charcoal briquette, and composting. These kinds of fuel management has been implemented in project scale in fire prone areas in Sumatera and Kalimantan [18]. This innovation plays a role as incentives for communities in zero burning policy implementation.

3.3.3.1 Wood vinegar. One of innovation which is currently developed by Manggala Agni (Forest and Land Fire Brigades-Ministry of Environment and Forestry) is biomass utilization through utilize crops or plantation or wood residue into wood vinegar, if the residue does not well managed, then those residues potentially become combustible fuel. Wood vinegar is a liquid product that produced from the condensation process of charcoal production. In the scale of field practice, the uses of wood vinegar are as follows: 1) additional fertilizer for agriculture and plantation; 2) coagulation material in the natural rubber industry, and 3) farm disinfectant [19].

3.3.3.2 Charcoal briquette. Charcoal briquettes are charcoal that has been modified in shape, size, and density, to be a more practical product in storage and used as fuel. Instead of burning land preparation biomass wastes or crop residues, the community can produce charcoal briquettes from biomass, which may reduce the possibility of people to burning organic wastes or crops residue that could trigger wider forest and land fires. In 2011, the Ministry of Forestry (currently Ministry of Environment and Forestry) through the Directorate of Forest Fire Management had published the Technical Guidelines for Making Charcoal Briquette and Compost [19].

3.3.3.3 Compost. Anther practical technology in fuel management is biomass composting. By composting, the community can implement zero burning land preparation as well as producing fertilizer for their crops. Compost is the result of decomposition from various materials derived from living things such as leaves, branches, twigs, animal feces and other organic litter. Naturally, compost can occur by itself but it requires a long time [19]. In some places, compost production has increased the livelihood of local community. Though, composting and charcoal briquette seems possible implemented in a small area of cultivation.

3.3.4. Agroforestry development. Degraded peatland rehabilitation has been a great challenge in Indonesia. Acidic soil, low nutrient content, irreversible drying peat characteristics, and water log are among serious problem of cultivation in degraded peatland. One of the peatland management technologies that can be applied to answer the challenges above is the local type-based agroforestry
system (indigenous tree species). The application of this system is expected to bridge the economic interests of local farmers with the interests of environmental conservation of peatlands. ‘Jelutung rawa’ (Dyera polyphylla Miq. Steenis or synonym as Dyera lowii Hook F.) is one of peatland endemic species with high economic value and only found in Indonesia (Sumatera and Kalimantan) and Malaysia. The wood is good for pencil production industry and the latex has been known as bubble gum raw material (Daryono, 2000). A study on Agroforestry development of jelutung on degraded peatland in Central Kalimantan shows technically and environmentally feasible [2].

3.3.5. Zero burning implementation support. The fire has been utilized as the simplest, the cheapest, the most efficient tool in land preparation as well as providing benefit to the soil by increasing soil pH and may enhance plant growth. Meanwhile, zero burning land preparation seems to be more expensive for the community. Therefore, a win-win solution needs to be identified to minimize fire occurrence. Our study suggests that all stakeholders need to be hand in hand to support the community in particular to implement zero burning policy. The central government as well as the local government and private sectors should provide equipments for zero burning land preparation for communities with different schemes or approaches.

In summary, the techno-socio approaches on peatland fire control in Indonesia is shown in Fig.2.

![Fig. 2. Techno-socio approaches for peatland fire control in Indonesia](image)

4. Conclusion
Forest and land fire in Indonesia is mainly caused by human activities (100% in peatland area), intentionally (land clearing) and unintentionally (fire spread from the adjacent burning area). Indonesia has developed technology in forest and land fires information system, early warning system, early detection and early suppression for fire control as well as social innovation including: wood vinegar, charcoal briquette, and compost production. Good practices of social approaches such as MPA (Fire Care Community) and Integrated Patrols have been identified and need to be replicated and enhanced. Multistakeholder approach and technosocio approaches need to be conducted integratively to minimize fire problems in Indonesia. Funding allocation as well as strong supports from all stakeholders, including the central government, local government, and private sectors on fire control need to be enhanced. Finally, incentives and disincentives system need to be enhanced if peatland fire control is a must.
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