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ROLE OF WEATHER MODIFICATION TECHNOLOGY IN CLIMATE CHANGE ADAPTATION: INDONESIAN CASE

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Climate change has caused unexpected weather and extreme climate which induces increase both frequency and scale of intensity of hydro-meteorological disasters. As a maritime continent and lies at the equator, Indonesia became one of the most affected countries by climate change. The event of El Nino in 2015 which costed up to 0.2% of GDP became a very typical case related to extreme climates. Instead of farmers are blessed by fertility due to surroundings seasonal regular periodicity and ring-of-fire, the seasonal period shows a shift in rainfall and drought periods in the last 60 years. It thus affects the cropping pattern and damage the soil fertility. In an effort to handle prolonged drought and its effect on forest and land fire prevention, the so-called rain making of Weather Modification Technology (WMT) is conducted. Basically, the cloud atmospheric intervention is stimulated by sodium particles, the process of which is left naturally. The use of WMT for other purpose is to intervene in potentially heavy rain and water shed recharge. Activities of WMT are being introduced to accommodate the adaptation of climate change process. Several examples of WMT successful delivery are presented.

Keywords: climate change, hydro-meteorological disaster, prolonged drought, Weather Modification Technology.

Introduction

Climate change has caused unexpected weather and extreme climate which induces increase both frequency and scale of intensity of hydro-meteorological disasters. As a maritime continent and lies at the equator, Indonesia became one of the most affected countries by climate change. The event of El Nino in 2015 which cost up to 0.2% of GDP became a very typical case related to extreme climates.

Instead of farmers are blessed by fertility due to surroundings seasonal regular periodicity and ring-of-fire, the seasonal period shows a shift in rainfall and drought periods in the last 60 years. It thus affects the cropping pattern and damages the soil fertility. As it has also been widely expected, the dry season is getting longer and the rainy season is getting shorter. The average total rainfall has even an increasing trend in several areas. When it enters dry season, which is tend to be longer recently, it induces hot spot and caused a bigger forest fire.

In an effort to handle prolonged drought and its effect on forest and land fire prevention, the so-called rain making of Weather Modification Technology (WMT) is conducted. Basically, the cloud atmospheric intervention is stimulated by sodium particles, the process of which is left naturally. The use of WMT for other purpose is to intervene in potential heavy rain and water shed recharge. The purpose of the current work is to give an idea of WMT, and to present several examples of WMT success delivery.

Weather Modification Technology

For more than two decades, the frequent occurrence of disasters related to global climate change issues has placed Weather Modification Technology as one of the most reliable alternative solutions to anticipate losses due to climate and weather-related disasters, especially haze and smoke disaster due to forest fire. WMT for the first time began to be utilized by the Government of Indonesia as efforts to overcome the smoke hazard due to massive forest fire disaster in 1997. Frequency of WMT utilization for the effort to overcome the smoke disaster from forest fire increased dramatically in the last decade, along with the increasing frequency and intensity of incidence of smoke disaster from forest fire and the increasing of losses caused by the that disaster. From 2009 to 2017, the implementation of WMT for forest fire mitigation is routinely carried out every year in a number of provinces prone to forest fire disaster on the island of Sumatra and Borneo.

Weather Modification Technology is a human intervention in the process of rain formation in the cloud. The process of collision and coalescence of cloud drops with particles of cloud-seed material that

has changed from solid to liquid. As a result of this intervention, the process in the cloud will be more efficient than the natural. Intervention is done by injecting a material called seeding agent into the cloud. In the high layers, moisture in moist air condenses at the condensation core into very small cloud drops and the bundle is seen as a form of cloud. Naturally, core-condensation is present in the atmosphere. Through a process within the cloud and supported by the continuous entrainment of water vapour from the environment beneath the cloud base, the clouds grow into large clouds of rain and then produce rain.

When forest fires happen, the atmosphere contains very little moisture (low amount in relative humidity). In addition, the burning of biomass causes the population or the amount of core-condensation in the atmosphere to increase by more than 300% [6]. This condition led to competition for water vapour which at that time was not very much in number. This situation makes it very difficult to form clouds. Even if there is a cloud, this cloud cannot grow bigger so it is difficult for the occurrence of rain. At the time of forest fires the weather conditions are usually stabilized and solar radiation to the earth is reduced. Because of the stable weather conditions, the smoke caused by forest fires and land is difficult to be wasted into the sky, causing longer distances to visibility and the air pollution increasingly disturbing respiration.

At the time of smoke conditions getting thicker like that, then the rainfall play vital role to clean up the air from the smoke layer to improve the radiation conditions. As the radiation improves, the weather becomes unstable so that the cloud formation process is running normally. For making that condition happen, Weather Modification Technology becomes very important to be able to convert the potential clouds into rain for making the area of forest fire become wetter. When the atmosphere above an area of forest fire becomes favourable with the entry of moist air periodically, the clouds in this area will grow and develop. It is in these conditions that WMT's role is very effective, that is accelerating rainfall process to increase rain intensity, expanding rainfall area and prolonging duration of rain.

Weather Modification Technology has some effectiveness compared to other technologies in fire extinguishment for haze and smoke disaster prevention due to forest and land fires. Firstly, no technology is capable of extinguishing forest and land fires in large escalations, except by rain. WMT provides an alternative way to accelerate the natural process of rain in several areas which are vulnerable to forest fire disaster in the dry season.

Secondly, under the conditions of concentrated smoke, smoke is not only harmful to humans. Concentrated smoke is also "unfriendly" to the occurrence of rain in 2 (two) terms:

a. Concentrated smoke blocks the radiation from entering the earth's surface. As a result the earth's surface temperature is not warm enough to create an unstable vertical profile of the air temperature. On the other hand, the vertical profile of the unstable air temperature is the medium for the formation of clouds due to convection activity or lifting the air period to occur condensation. Finally, the cloud becomes difficult to form and of course the rain does not happen.
b. When there are clouds in an area within dense smoke layer (generally the clouds on this area come from other areas carried by the wind, in meteorological terms called advection), the concentrated smoke will consume the water vapour and clouds so the cloud will always be in the first/initial phase. Clouds in the initial phase are marked with small clouds of grain. As a result, the rain process will be very difficult to happen. The concentrated smoke of forest and land fires is dominated by very small particles less than 2 microns of about 2000 particles cm^3.

Thirdly, WMT or artificial rain will play an important role in improving the efficiency of the rain process because it is able to change the clouds that are in the early phase entering the adult phase until mature. WMT is done by sowing large hygroscopic seeding materials (UGN: Ultra Giant Nuclei, 10-50 micron). Collisions and coalescence are always followed by a chain effect (known as the *Langmuir chain-reaction*) that causes droplet enlargement to expand rapidly and precede the occurrence of rain within a cloud [5].The presence of this seeding material will increase collision and coalescence efficiency, which is a key to the process of rain on warm clouds that often grow in the tropical area. For information, clouds in the early phases have collision efficiency below 10%. Meanwhile, cloud seeding can increase efficiency to about 80%.

Examples of WMT success delivery

From a number of WMT utilization experiences for forest fire mitigation purposes, there is still room to improve the effectiveness of these technologies in order to provide optimum results. Weather Modification Technology operations are often constrained if the atmospheric conditions around the affected areas have been very dry so that it is difficult

to meet the presence of potential clouds worthy for seeding. Moreover, several studies states if the smoke haze conditions are so thick, they block the radiation of sunlight from entering the surface which makes it difficult to convection process as an early stage of the cloud growth phase [3, 4]. This is why haze usually is associated with regions of large-scale stagnation. With both vertical and horizontal mixing at a minimum, whatever aerosols may be present will accumulate at first locally and then regionally over those areas experiencing minimal air flow, sunshine, and high relative humidity [2]. The thickness of the smoke haze also causes low visibility so it is not safe for flight. Under such conditions, the implementation of Weather Modification Technology operations is often constrained because the aircraft cannot fly to conduct cloud seeding activities.

Based on the above description, it can be concluded that the initial problem of smoke and haze hazard due to forest fire triggered by drought factors. The emergence of this disaster can actually be detected earlier when there is an indication of drought in the vulnerable area, especially peat land area. Thus, the forest fire disaster can be prevented/anticipated by trying to keep the water reserves on peat soil can be maintained so as not to experience drought. WMT operation will be more effective if it starts when the peatland shows a drought trend, characterized by an increased tendency of hotspots. WMT's target on the situation is not to extinguish the fire point in the field, but rather to maintain the level of wetness in the area of peatland (rewetting). With the maintenance of soil moisture in peatland areas, the potential for fire in peatland areas is also decreasing.

Since it was first implemented in 1979, until 2017 it has been recorded that 39 projects of WMT is used as one of the technology to reduce the smoke and haze hazard due to forest and land fire events in Indonesia. WMT operations are generally conducted during the transition season until the beginning of the rainy season, May to October, in some areas which are vulnerable to forest and land fire. In its implementation, WMT is focused to make forest and land fire vulnerable area become wet so that haze and smoke potential can be reduced. If the conditions have entered the peak of the dry season, by artificial rain that makes peat land become wetter WMT also serves as a technology to prevent the expanding area of forest fires.

The implementation of WMT is often operated in several provinces in Indonesia with considerable peat land cover, such as Riau, South Sumatra, Central Borneo and West Borneo. The peatlands in those provinces are potentially highly flammable. When it has entered the peak of the dry season, the potential of peat smouldering will be enormous. Until now forest and land fires in peat land are very difficult to be overcome. Fire under deep peat is difficult to be detected, so it is very difficult to know whether it is completely extinguished or not. For that, the role of WMT in modifying the weather by maximizing the potential for rainfall can provide very helpful influences in forest and land fire disaster prevention. By preserving the wetness of the peat land through rain, the potential for fire and its expansion will be reduced.

Some of the latest WMT operations such as in 2017 have a good effect in the context of forest and land fire mitigation. During 2017, WMT for disaster management of haze smoke caused by forest and land fires was carried out in Riau, South Sumatra, Central Borneo and West Borneo provinces. The results of Weather Modification Technology activities in some of these provinces succeeded in suppressing the number of hotspots, so as to prevent massive forest and land fire events in Indonesia. The success of WMT's operation could be evaluated by the number of hotspots. Recorded number of hotspots in Riau Province for example, during the implementation of WMT in 2017 can be pressed in the amount of 29 hotspots during August-September (MODIS hotspot data with confidence level $\geq$ 80%). The number has decreased significantly when compared to previous years. For comparison, the average number (2006-2016 historically) of hotspots in the same period in Riau Province reached more than 400 hotspots [1].

Another example of the success of WMT in disaster management of smoke caused by forest and land fires can be evaluated by increasing the value of rainfall during WMT period in weather modified areas. Each WMT activity by doing cloud seeding in the target area will be calculated. The calculated is done to find out how much rainfall that managed to fall to the surface. Another example in 2017, during WMT's operation in Riau Province, a total of 283 mm of rainfall during August-September, which is the peak of dry season in Riau area, is well calculated as the effect of Weather Modification Technology. By calculating the extent of the treated area of cloud seeding, the total rainfall of 283 mm is equivalent to 350 million m^3 of water produced through the weather modification process. Considering it is the peak of dry season, those numbers could be briefly describe as the effect of how Weather Modification Technology is one of the reliable technologies in forest and land fire disaster management.

Conclusion

In current work, activities of WMT are being introduced to accommodate the adaptation of climate change process. Several examples of WMT success delivery are briefly presented. At the next step assessment of the result on the economic benefit and socio-impact within the perspective of adaptation to climate change will be described.

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