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Review Article

Effects of Water Table Fluctuations on Peatland-A Review

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Abstract: The negative influence of global warming has really influenced the need for most of the studies on climate related studies today. Emission of carbon and some other greenhouse gases has been seen as the most factors influencing the global warming, and the task so far has been how to limit the emission of these gases in order to reduce the risk of global warming. Peatland has been identified as the largest source of these gases as it stores about 220 – 460 pg of carbon apart from other trace gases like CO₂, N₂O, and NO. With this knowledge, various studies are being carried out to study the potentials of peatlands regarding the budgeting of these gases and the factors responsible for their loss from the peatlands. One of the major factors that have been identified is the fluctuation in groundwater level among many others which has been given serious attention since discovery. This review paper then tends to look at various works that have earlier been done in this regard and look for the converging results of interest in all the studies and the solutions proffered to this menace so as to forestall the future occurrence.

Keywords: Groundwater table; peatland; peatland degradation; carbon; climate change.

INTRODUCTION

Peatlands, which stored about 220 – 460 pg of carbon can affect or influence atmospheric carbon dioxide, CO₂ concentrations[1]. Because of the roles played by the peatlands on the issues of global warming and the fact that most of the nutrients stored in these peatlands are major drivers of climate change, it then becomes necessary to ensure that these nutrients are kept safe and locked up in the peatlands. But, in the other hand, various practices have been reported to have exposed these nutrients to the atmosphere thereby increasing the risks of global warming. Intensive agricultural practices which led to the process of deforestation has been responsible for the reduction in the quality of land resources. According to Lubowski, *et al.*, [2] desertification, soil erosion, and salinization have reduced the quality of land resources and has affected the agricultural productivity. Anderson [3], and Moscrip and Montgomery, [4] had also reported that land-use change increases the runoff volume and also results in decrease in groundwater recharge and baseflow. Though the effects of all these mentioned practices have seriously affected the productivity of the peatland as a carbon sink, but yet little is being reported or known about the impacts of hydrology on our peatlands. Hydrology, water table position, in particular, has been identified as one of the most

significant controls of the carbon budget of peatlands[5]. Though there have been many reasons why there are changes in hydrological processes that define specific peatlands, nature of climate has also necessitated the changes in hydraulic parameters which govern the nature and magnitude of hydrological process [6]. The consequences of such climatic changes on our peatlands which are reputed to store large quantity of carbon and some other greenhouse gases GHGs are mind blowing. Apart from the environmental hazards as a result of the emission of these gases, farms are left destroyed and degraded as a result of forest fires which are induced due to the lowered water table. Due to the drop in groundwater level in most tropical peatlands below 40 cm from the surface as reported by Rieley and Page, [7] moisture content of the humified top layer decreases from 0.90 cm³ cm⁻³ to 0.50 cm³ cm⁻³ therefore making the peatlands vulnerable to fire[8]. In this review, we tend to look at various works that have been done in this topic and see areas where justice have been done to the issue and identify such areas where a lot has to be done so as to save our peatlands from degradation and our environment from the negative effects of climate change.

CHARACTERISTICS OF TROPICAL PEATLAND

Peatland comprises of highly organic and acidic soils which are formed from the degradation of plant materials under the conditions of both excess surface and ground waters. Peats are known to be water logged or nearly saturated most of the time, which are the conditions that favours peat formation. Peats are formed by either of the two methods known as terrestrialisation or paludification[9]. Terrestrialisation occurs when surface water bodies are taken over by organic matter leading to transformation of aquatic system to terrestrial peatland. And the latter is referred to as a condition where peat is formed over mineral strata in the absence of waterlogged conditions. Peatlands vary in properties from one area to another. Peatlands are characterized by their soil moisture

content, hydraulic conductivity, water tension and water yield. The peatland are also characterized based on the varying degree of decomposition as measured by bulk density and fibre content. Peat soils have been known to develop under conditions of both excess surface and ground waters and are known to be water logged or nearly saturated most of the time. Peat soils are porous and hold a sizeable amount of water when saturated. The soil moisture content of peat soil range from 155 to 350 %. Soil moisture is known to depend on many factors. Hydraulic conductivity of soil, which is the ease at which soil allows the movement of water through the soil, forms the basis by which water retention capacity is determined. Peatlands are mostly drained often times by inserting ditches by their sides as shown in Figure 1.0

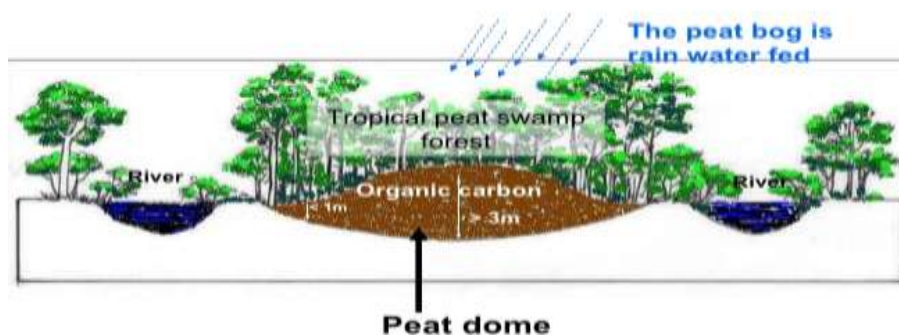


Fig-1: Schematic section of a typical peat dome drained at both sides.

According to Ayob and Ahmad Khairi, [10] peatland basins are found in many parts of the world, both in temperate and tropical regions. Out of 400 million hectares of the world area of peatland resources in the world, about 72 million hectares alone are found in the tropic, of which 23 million hectares are found in the Southeast Asia [11] and 24 million hectares (7% of the total land area) is located in Malaysia [12]. Out of this, the three regions that make up Malaysia share it as follows; 1 million ha. in Peninsula Malaysia, 1.6 million ha. in Sarawak, and about 0.8 million ha. in Sabah.

WATER TABLE IN TROPICAL PEATLAND

There is strong correlation between the nutrients locked up in the peats and the moisture content of the peat soil. According to Weiss *et al.*, [13] carbon stored in the ecosystem of Northern peatlands is sensitive to changes in land use and climate, through alternations in ecohydrology. Elements, like nitrogen, sulphur phosphorus found in these peatlands have direct bearing on the moisture content there in. According to Bubier [14] and Alm [15], the water table depth and peat temperature were two important variables that play a major role in the emission of carbon and methane from peatlands. It is an established fact that depth to water table determines the moisture content of the peat soils. In other words, the presence of moisture in the

root zones of the plants is an indication of nearness of water table to the soil surface. Hydrological characteristics of peatland regulate the nutrients regime, vegetation composition and structure and consequently peat formation and overall land form development [13]. In other words, it is the high water table of the peatland that encourages the gradual decomposition of organic matter, thereby promoting the peat formation. Therefore, understanding this hydrological mechanism driving the peatland response to changes in the climatic water budget is crucial to predicting potential feedback on the global carbon and nitrogen cycles [13]. Fraser, *et al.*, [16] and Pastor, *et al.*, [17] reported that influx of dissolved organic carbon, DOC, from the peatland is influenced by site hydrological process. This was further confirmed by Freeman, *et al.*, [18] which stressed that the export of DOC is generally greater from peatland with higher measured discharge. In other words, any hydrological factors affecting DOC production could potentially change the quality and chemistry of exported DOC [19]. This is where water table of the peatland comes in. Several attempts have been made to ensure that the peatland water table remains constant since drop in water table leads to flux of major nutrients present in the soil. But in the case of agricultural practices, high water table does not favour agricultural productivity, and to ensure greater

agricultural output, water table is being lowered in the process. Various attempts have been made to lower the water table of the peatland, especially where the peatland is being used for agricultural purposes like in oil palm plantation. Drainage systems within the peatland have helped in achieving this which helps in lowering the water table of the peatland [5]. According to Joosten and Clarke [6], many peatlands are drained for forestry, agriculture, and peat extraction. The process involves constructing ditches, where water is collected thereby draining the peatland and increasing the peatland discharge [21]. Though the extensive drainage in the various peatlands across the globe using open ditches has been attributed to the need to enhance agricultural productivity, this does not come without its adverse effects as most of the carbon and some other trace gases such as CO₂, N₂O and NO stored within the peatland escape with the water in dissolved form, as DOC [19] and GHGs [22]. Also, drainage does not just help to improve soil conditions for tree growth, it can also have negative effects on the environment [23]. According to Prevost, *et al.*, [24] when controlled to the control site, drainage clearly increased available nutrients in peat, and the concentration of nutrients at the drained site was generally higher than what was obtained at the control site. These results are emphasizing the roles of water table depth in the concentration of nutrients being fluxed out of the peatland. It has been established that drop in the depth of water table is attributed to the drainage systems in the peatland.

EFFECTS OF WATER TABLE FLUCTUATION ON PEATLAND

Loss of greenhouse gases

Martikainen, *et al.*, [25] and Augustin, *et al.* [26], attributed the increase in the emission of nitrous oxide, N₂O from the peatland to drainage of minerotrophic peat soil. Also, according to Regina, *et al.*, [27] changes in water table level, caused by drainage systems for forestry may alter the nitrogen cycle of the peat soil, making them larger N₂O source. The drainage system employed for agricultural purposes in oil palm fields, especially have ways of contributing to the carbon loss. Fahmuddin *et al.*, [28] reported that oil palm requires drainage to about 80 cm depth which leads to below ground CO₂ emission of about 73 t ha⁻¹ yr⁻¹. He further stated that the net CO₂ emission from oil palm plantation is about 87 t ha⁻¹ yr⁻¹ taking into consideration the emission from forest clearing and sequestration in the crop biomass. If the draining of peatland is allowed to persist without proper monitoring, large quantity of the nutrients like carbon being emitted from the peatland and other trace gases being fluxed out of the peatland will consequently lead to degradation of peatland. Holden, *et al.* [29] reported that the presence of drainage system in the peatlands does not just cause potentially detrimental changes in the run-off response, but its presence has also led to

greater erosion of the peat soil. reported that The drainage systems in the peatlands is responsible for the increase in concentration of DOC in the run-off [30]. As peatlands being drained, the upper layer of the bog, known as *acrotelm*, where *Sphagnum* mosses, known as peat-forming community is contained is lost, this causes the bog itself to lose its peat-forming capacity. In other words, IPCC, [31] put it that once the peat soil is exposed to air as a result of drainage system, it begins to break down. This continuous draining of peatland will also lead to drying of the peatland and consequent shrinkage, if the peatland is not quickly restored. Due to the irreversible drying process of peats as a result of peatland over-drainage, under this condition, some peat soils find it hard to reabsorb water for peatland restoration. Blodau, *et al.*, [32] concluded that short-term disturbances such as water table draw-downs will lead to increase in aerobic and anaerobic carbon, C mineralization and emission. In other words, as more water is being drained away from the peatland, the rate of C emission and from such peatland and mineralization increases. Lohila, *et al.*, [33] while studying the responses of N₂O to temperature, water table and N deposition, observed the decreasing trend in the annual mean of N₂O flux which was related to both the decreasing N deposition and the rising trend in the water table. More intense fluctuation of water table levels in temperate minerotrophic fen alters the budget of the greenhouse gas N₂O. Goldberg, *et al.*, [22] also established that drought appears to increase N₂O emissions substantially from minerotrophic fens to levels already described for their long term drainage.

Loss of biodiversity

As peatlands get degraded as a result of over-drainage, loss in biodiversity has also been observed as one of the negative consequences. Most of the flora and fauna that thrive well in well watered bogs have escaped as a result of lowered water table. The drainage system in the peatlands has resulted into drying up of pools in the environments and thus encourages the susceptibility of peat to fire outbreak. Most of the soil in their natural state encourage the presence of habitats which due to indiscriminate destruction of the swamp has led to the escape of large variety of fauna and flora. According to Barber [34], peat bogs preserve past biodiversity in a way that is unique among ecosystem. According to Spitzer, *et al.*, [35] peatland possesses large qualities or characteristics that favours the existence of different species of insects, animal, and plant. He further stated that peatlands are abundant in the boreal zones of Europe, Asia, and North America, where there are favourable climate and relative high precipitation and limited evaporation coupled with poor drainage pattern. As a result of these conditions, these regions are characterized by large presence of biota, which is large presence of plants and animals in general. But the reported hydrological problem in these zones have caused a great damage to the ecosystems.

The main drivers behind this biodiversity loss are; deforestation, industrialization, forest fires and population expansion. Parish and Looi,[36] revealed that clearing of peatlands as a result of agricultural development results in a loss of biodiversity and a loss of habitat for some indigenous flora and fauna. There is high level of presence of flora and fauna prior to the invasion of peatlands for logging purposes. Some environmental groups claim that the tropical peatlands have a large variety of fauna and flora endemic to these areas. But the total destruction that is related to decline in groundwater table and other physical activities being practiced on the swamp forest have caused a lot of damages to the ecosystem of the forest.

Fire outbreak

The risk of forest fire in peatland is very important thing to note. Peat lands are known to be the world's largest source of carbon. When the fire breaks out in the peat forest, this pool of carbon is exposed to atmospheric condition where organic carbon C is converted to carbon dioxide CO₂ which is released to atmosphere in large quantities thereby becoming GHGs as a fuel of global warming [37]. Tacconi reported that ENSO (El-Nino Southern Oscillation), a climate phenomenon associated with sea surface temperature anomalies in the waters of the pacific ocean, caused widespread forest fires in Indonesia between 1997-1998 which reached 9.75million ha [38]. The peatlands fires was reported to have released between 2.9 and 9.2 billion tonnes of CO₂ as a result of burning peat and vegetation, equivalent to 13-40 % of the average annual global emission during that period [39]. Studies have attributed the risk of fires in the peat forest to decline in groundwater level. Susilo, *et al.* [37], further reiterated that construction of drainage channels causes a drop in the groundwater in the peat soil and that the decline in groundwater as a result of constructed drainage will lead to increased risk of forests fire due to dry peat. In their studies of fires in undrained peatlands in Sumatra, Miettinen, *et al.* [40], reported that only 7 fibre/100 km² for 1996-2012 were in pristine or undrained peat swamp forests as against the concentration of fires in degraded areas with 140 fibres/100 km². Hooijer *et al.*, [41] further maintained that fires are found to be responsible for nearly half of the emissions from tropical peatlands.

Restoring water table-induced degraded peatlands

Monitoring groundwater levels by studying the behavior of groundwater in the peat in order to maintain a high water table and reduce the risk of forest fires has become one of the established remedy to the problem of forest fires in the swamp forest [37]. This will be achieved by installing monitoring wells so as to monitor the groundwater. Though this method has received lots of criticisms due to the huge amount of costs involved. In a situation where it has been observed that the peatlands are being degraded as a result of excessive

drainage, restoring the peat either by blocking the drains or finding means of controlling the quantity of water being lost to the drainage remain a better solution. IPCC, suggested a situation where the drain is being dammed so as to bring the water table on the peat up so as to limit it to 10 cm or more of peat surface. This practice will encourage the subsequent growth of peat forming plants that have been destroyed as a result of excessive lowering of peatlands water table. Wallage, *et al.* [42], and Worrall, *et al.*, [43] gave reports on benefits of blocking the drains as evidenced in ecosystem services such as inhabitants restoration and carbon sequestration. The financial implication attached to this practice if the entire length of the drain is to be blocked calls for caution. In order to reduce this associated cost, Armstrong, *et al.*, [44] suggested that drains could be blocked at intervals along their course. Armstrong, *et al.*, [44] further suggested many other associated methods, which include; using peat dams, plastic piling, ply wood, wooden planks, stones, or using the combination of these methods in order to achieve the objectives. The study further revealed that when the listed methods are effectively implemented, the dammed water behind the piles diffuses over the downslope peatlands surface and the lowered water table begins to rise thereby reducing the risk of peatlands fires and further degradation.

CONCLUSION

Effects of water table fluctuation on peatland has been reviewed and the impacts noticed. Peatland is believed to store large amount of major nutrients that are capable of influencing our environment negatively if exposed indiscriminately. Among the reported negative influence is the global warming that has now become associated with some practices within the peatland. Such practices have been identified has deforestation, fossil fuel burning, vegetation burning, and so on. For the purpose of agriculture, many swamp forests were deforested and in process large amount of these gases escaped in form of GHGs to the atmosphere thereby igniting the global warming. Little was mentioned about the impacts of hydrological processes in terms of groundwater fluctuations. The negative effects of this have been reported as forest fires, loss of biodiversity, degradation of peatland and many more. This review has been able to establish the fact that a water table-induced degraded peatland can still be restored if some certain steps that are highlighted here are practiced. Monitoring of groundwater and blocking of drainages at intervals where there is high risk of forest fires have been recommended to reduce the degradation of peatlands to a larger extent.

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