# Geohydrological Conditions of the Developed Peatland in Central Kalimantan

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# Geohydrological Conditions of the Developed Peatland in Central Kalimantan

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**Abstract:** Mega Rice Project in Central Kalimantan was launched in 1996, covering about 7% of total peatland area in Indonesia. After four years, the project was closed and the land use has changed for various purposes such as forestry, agriculture, energy and horticulture. A field study was carried out in the former project area of 1.5 Mha during March 2001-June 2002. Land use change has resulted in general change of geohydrological conditions in the peatland area. Although there was no significant difference on the quantity, intensity and duration of the rainfall, the peatland capacity to store water was decreasing. The rainfall and vegetation of peatland affect significantly surface temperature as well as ground water table.

**Key words:** Peatland . rainfall . temperature . water table

## INTRODUCTION

Peatland is wetland ecosystem characterised by accumulation of organic matter that is produced and deposited at a faster rate than it can be decomposed [1]. Peat formation in the tropics commences under conditions of constant waterlogging or in wet coastal areas where organic matter is produced in abundance by an adapted vegetation of mangroves, grasses or swamp forest trees [2, 3]. Approximately 12% of the global peatland area occurs in humid tropical zones, mainly in mainland East Asia, Southeast Asia, the Caribbean and Central America, South and southern Africa [4]. Peatland in Indonesia covers about 16 to 27 Mha [4, 5]. These ecosystems are vitally linked to conservation issues such as carbon sequestration affecting global climate change and provision of key habitat for a diverse range of the world's flora and fauna. They also are the source of a significant portion of the freshwater and many economic resources vital to human survival. In addition, peatland ecosystems are important for water resources conservation since their ability to store water is very high and can be up to 8 times of the peat volume [6].

Tropical peatlands, however, are also the subject to land use pressures including forestry development and agriculture on them as well as extraction for energy and horticulture [7]. In 1996, 1.5 Mha of Peatland in Central Kalimantan was developed for rice production. This project failed and was closed down in 1999 but left on legacy of habitat destruction and fire occurrence. The land use has changed to be developed forest, regrowing forest and agriculture. Therefore, the purpose of this study was to describe geohydrological conditions of the developed peatland, particularly ground water table in supporting water conservation in the area.

## MATERIALS AND METHODS

**Area descriptions:** Research was carried out within the area of the former Mega Rice Project (MRP) in Central Kalimantan, Indonesia, that was launched through Presidential Decree No. 82/1995 on 26th December 1995. The purpose of MRP was to develop wetland, mostly peatland, for rice crop production. The MRP covers an area of 1.5 Mha that is bounded by S. Sebangau in the west, Java Sea in the south, S. Barito in the east and the Main Parent Channel in the north (Fig. 1).

**Hydrometeorology:** Information on fluctuations of the water table, incident rainfall and peat surface temperatures were obtained from monitoring instruments placed in the field. The location includes a forest area, regrowing forest as well as an agriculture area.

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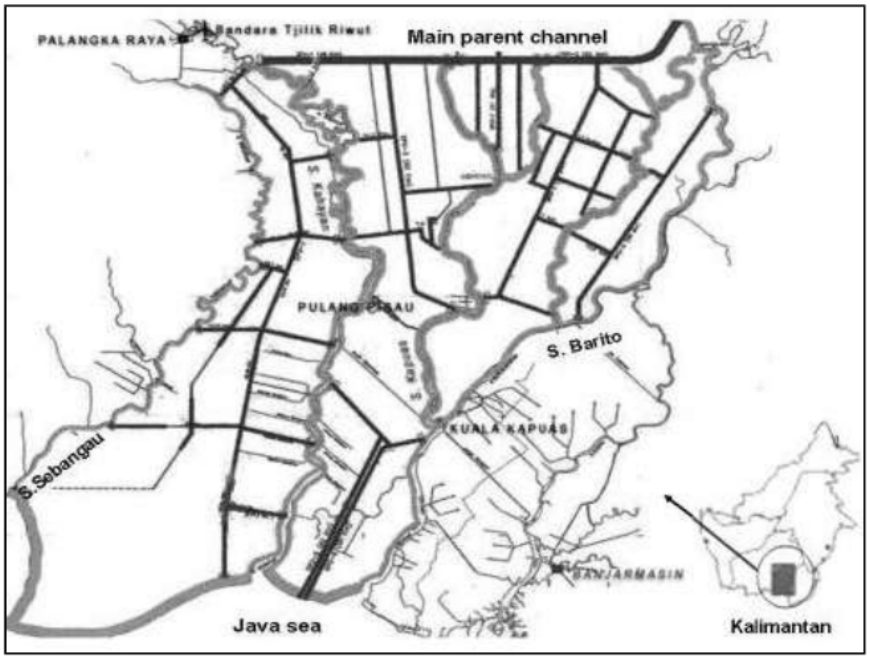


Fig. 1: Map of study area

Measurement of water table fluctuation was carried out using automatic water loggers type STS Module DL/N series 64 (http://www.sts-ag.ch/sw384.asp) produced by Sensor Technik Simach (STS) of Switzerland and, manually, from dip wells inserted into the peat surface. The automatic water loggers were established in the forest area, regrowing forest and the agriculture area and were set to record every hour. The data from automatic water logger were downloaded about every 3 or 4 months and in every download of the data, the existing water table depth was measured for calibration. Manual measurements of water table were conducted along a 400 metre transect in the same area every 3 months during dry and rainy seasons.

Rainfall was measured with tipping bucket rain gauges that were set up in the forest area (as for measuring throughfall) and an open area adjacent to it as well as in the agriculture area. Thermometers for measuring air and peat soil (20 cm depth) temperatures were established at the same locations as the automatic water loggers and these were also set to record at one-hour intervals.

## RESULTS AND DISCUSSION

**Rainfall:** Annual rainfall records at three areas (forest, regrowing forest and agriculture area) within the study area during March 2001 and June 2002 were in the range of 2,124 mm and 2,301 mm. These were lower than the average rainfall obtained in the natural peatswamp forest in the west of study area called Natural Laboratory (2,761 mm) and in the north at Palangka Raya (2,449 mm). The rainy season was in the period of October and April, while the dry season was May to September. The amount of rainfall in the rainy and dry season showed a significant difference, i.e. the amount of rainfall in the rainy season covers 82% of annual rainfall.

The total monthly rainfall in the agriculture area showed to be higher than in the forest and regrowing forest areas. However, there was no significant difference in daily rainfall, duration of rainfall and rain intensity among the three areas. The number of rainfall days ranged between 3 days to 26 days with an average of 14 days to 16 days.

For the whole peatland area of 1.5 Mha with an estimated evapotranspiration rate of 3.4 mm day$^{-1}$ [8], rain water adds 13-15 billion m$^3$ of water, amounting of water storage in the range of 8,859 m$^3$ and 10,634 m$^3$ of water per hectare per year. This huge amount of water will be absorbed by the peatland area and released slowly in the dry season.

**Peat surface temperature:** The peat and air temperatures at the three areas were summarised in Table 1. Peat surface temperature was higher than air

Table 1: Descriptive statistics of air and peat surface temperature within three land uses

| Area | Media | Number of measurement | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|---|---|
| Agriculture | Air | 27 | 25.13 | 29.66 | 27.25 | 1.03 |
| | Peat | 27 | 28.22 | 32.08 | 30.22 | 0.86 |
| Forest | Air | 137 | 23.27 | 29.35 | 25.84 | 0.85 |
| | Peat | 137 | 21.18 | 23.78 | 22.88 | 0.57 |
| Regrowing forest | Air | 136 | 23.28 | 27.26 | 25.62 | 0.83 |
| | Peat | 136 | 25.98 | 27.09 | 26.71 | 0.21 |

temperature in the agriculture area and regrowing forest while, in the forest, peat surface temperature is lower than air temperature. The highest average surface peat temperature of 30.22°C occurs in the agriculture area, following by regrowing forest (26.71°C) and forest (22.88°C). The analysis of means by using paired samples test resulted in a highly significant difference between the average air and peat surface temperatures within each and among all areas.

Vegetation cover on tropical peatland has a significant influence on the average daily air and peat surface temperature at the three study areas. Open peatland areas, such the agriculture area with an average of 27.62±1.38°C and destroyed forest with an average of 27.20±1.12°C have much higher temperatures and variation than those with a vegetation cover [4, 9] such as regrowing forest (26.04±0.81°C) and forest area (25.72±0.72°C). Similar ranges of temperature were also found by Hirano *et al*. [10] who obtained an air temperature of 26.5°C in a forested area at a height of 41.7 metres above the peat surface at the northern study area.

Within the forested area, the average peat surface temperature was 2.96°C lower than the average air temperature while, for the developed peatland area (e.g. the agriculture and re-growing forest areas), the average peat surface temperature was between 1.09-2.97°C higher than the average air temperature in the same locations. From these data, it was clear that the loss or changes of vegetation cover in peatlands is strongly influencing the peat surface temperature. The existence of plants that grow on the peat swamp alters the heat and water balance of the soil on which they grow. It has been found, for example, that peat swamp forest reduces the ground albedo significantly contributing to the frequency of rainfall that decreases when forest was cleared. With reference to radiation exchanges, there are marked differences between forested and deforested areas with respect to their solar radiation exchange [11].

Variations also occurred in both air and peat surface temperature under different land conditions. The highest variation was in the agriculture area, followed by regrowing forest and the forested area. This again supports the importance of vegetation cover in controlling temperature fluctuation. Compared to air temperature, however, peat surface temperature is higher than air temperature but shows a smaller variation for all areas.

**Water table:** Fluctuations in the ground water table obtained from an automatic water table measuring device and data logger showed that the ground water table only came above the peat surface between March and June 2001. The pattern of fluctuation in water table in the forest and regrowing forest area were quite similar and those were significantly different with the agriculture area (Fig. 2). The water table fluctuation might be influenced by temperature profile which was significantly different between agriculture area and forested areas.

The highest draw down of water table during the recording period occurred in the agriculture area (71.85 cm), followed by regrowing forest (67.04 cm) and forest area (48.48 cm), respectively. Thus the response of water table draw down due to rainfall changes in the agriculture area was faster than the forest areas. The lowest draw down was the forest area and this revealed the regrowing forest should be recovered in order to conserve water for agriculture area.

The drainage channels in the study area were affecting the draw down of water table. There was a tendency for the water draw down to be much greater closer to the drainage channel. The overall pattern of water table depth seemed almost to follow the peat surface contours. During rainy season, the water table depth in the regrowing forest area were in the range of 16 and 43.8 cm below the surface, while in the forest areas, it was much lower ranging from 19.9 and 69.0 cm. In dry season the ground water table under the regrowing forest was dropped lower (65.5-89.9 cm) than in forest area (64.6-135.7 cm) in the forest area. In the drought of August 2002 the water level under the regrowing forest dropped much lower (108.1-138.5 cm) than in the forest area (86.8-127.5 cm). These data revealed that during the rainy season there was no significant difference between the water table drawn down in regrowing forest and forest areas, however, the water table dropped considerably in the dry season.

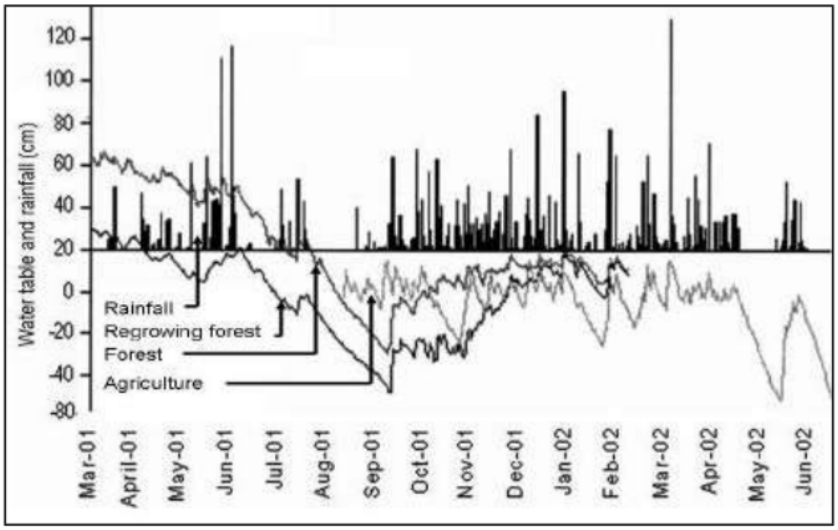


Fig. 2: Ground water table and rainfall in the agriculture area, forest and regrowing forest

The relative height of all the water tables is compared to the water table in the forest areas at a distance of 150 metres from the main channel as a reference point. The difference in height of groundwater table in the forest area is about 25 cm between distances of 150 m and 50 m from the main channel. The water table in the main channel is about 240 cm lower than at these two locations. Over a distance of 3 kilometres, the difference in height of the water table in the main channel is 150 cm. The ground water table pattern from March to July 2002 in the forest and destroyed forest is similar. The water tables in the main channel also have a similar pattern even at the distance of 3 km, but this pattern is different from the ground water table in the peatland, probably because the main channel was affected by fluctuations in water levels in the main river.

The depth of the water table in the peat on the study area during dry and rainy seasons were ranging from 0 to 137 cm below the surface, with an average of 43.24±3.37 cm. The lowest levels were reached in the dry season. For example, in August 2002, at the single measurement in forest area, the water table declined to more than 2 metres as a result of construction of the main channel and the small ditches parallel to it. A similar impact of channel construction on the water table has been reported by other researchers [12, 13]. However, it was very surprised that during the study periods the different height of the ground water table on the peatland area and in the main channel can be reaches of 2.20-3.03 metres, especially during the dry season. This revealed that peatland can still maintain the water, even in the dry season.

In general, there is a different pattern of ground water table fluctuations between rainy and dry seasons. During the rainy season, the ground water level especially on the forested area and regrowing forest showed a high water level that was close to the peat surface. In addition, in the rainy season the range of water table fluctuation was not more than 40 cm for areas covered by vegetation and agriculture areas [13]. On the other hand, during the dry season, the ground water level was much lower. In the research area, the ground water level dropped between May and October following the decreased amount of precipitation. During the periods of study the lowest water table obtained in the continuous measurement was 71.85 cm, while measurement after the study [13] showed that the ground water table dropped even lower to 2.0 and 1.4 m below the ground surface in the agriculture and forested areas, respectively.

The rate of water level decline was slightly higher in the agriculture area than in vegetated areas, confirming the effect of the drainage channels. The occurrence of frequent, heavy rain events maintains the water level high throughout the whole rainy season. During the dry season, the rate of ground water decline was much higher due to the small amount of rain, with the highest rates of decline occurring in the agriculture area.

There was a significant impact of land use change on ground water table fluctuation in peatland areas. On developed tropical peatlands, such as in this study area, the water table remains below the peat surface throughout the year while, in the natural peat swamp forest the water level was above the surface between

January and May in every year [8]. Under natural conditions, water from tropical peatlands drains out by small streams and rivers over a fairly long period of time. In developed peatlands, however, especially those used for agriculture, the existence of constructed drainage channels increases the rate of water loss leading to larger losses over a shorter time leading to shortened retention times for the incident rainfall. This, in turn, leads to markedly lowered water tables and water deficits that affect crop growth adversely. In the forest area, the groundwater levels have been affected by the main channel that was excavated as part of the drainage and irrigation system created for the former MRP. In contrast, the water table in the still natural Sungai Sebangau catchment, fell by one metre on only two occasions in the dry season of 1997 [14].

It was found that rainfall and evapotranspiration are the two factors that have most effect on the variability of ground water level in the peat swamp forest area [8]. Based on the transect measurements, it was evident that the water level in the forested area was lower than in regrowing forest and this was confirmed by [13] in addition to the maximum declining of depth and rates of water level. This probably relates to the higher rate of evapotranspiration on the forested area than in the regrowing forest.

## CONCLUSIONS

Result of this study confirmed that the average ground water table, in general, was lower in non-forested area than that of the forested one, while the ground water table fluctuation in non-forested area was found higher than that of the forested land, especially agriculture land. It was also found that there was a high fluctuation of ground water table in the non-forested land of the study area, where peak of ground water occurred immediately after rain and than gradually decline afterward. The existence of drainage channel as part of the former MRP was argued to have a profound effect in accelerating water movements from the peatland ecosystems.

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