Nutrient content of rainfall, water in canal and water at different depths in peatland in Central Kalimantan, Indonesia

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Summary

Rainfall and water in a peat swamp area in Kalampangan, Central Kalimantan, part of the former Mega Rice Project, Indonesia were sampled every four weeks from May 2004 to January 2007 and analysed for total content of Ca, Mg, K, Na, and Fe. The study area has been drained since 1997. Rainfall was collected at two sites in a deforested area. Water samples were collected at three sites in a canal and six sites in the adjacent peat area. At each peatland site water samples were obtained from depths of 50, 150 and 250 cm below the peat surface. Rainfall ranges from very acid to neutral (pH between 4.11 ± 0.01 and 6.60 ± 0.00 with average 5.12 ±0.55). Water in the canal is very acid (pH between 3.32 ± 0.04 and 4.22 ± 0.05 with average 3.71 ±0.19) with a predominance of Ca and K. pH of water sampled from the peat at 50, 150, and 250 cm depth in the deforested area has means of 3.98 ±0.60, 4.18 ± 0.36 and 4.31 ± 0.35, respectively. In contrast, pH of water sampled from the peat at 50, 150, and 250 cm depth in the forest area has means of 3.68 ±0.55, 3.70 ± 0.38 and 3.92 ± 0.46, respectively. Similarly to water in the canal, water sampled in the deforested and forest areas has a predominance of Ca and K.

Key index words: peat swamp, water sample, chemical analysis

Introduction

Several studies of tropical peat swamp forest have been carried out since the 1950s (Anderson, 1983; Rieley *et al.*, 2005) According to these, lowland tropical peatlands are usually dome-shaped (Rieley *et al.*, 1997) and the only input of water and nutrients to them is from precipitation. Furthermore, Sulistiyanto (2004) states that an understanding of the hydrological condition in peat swamp forest is important for revealing the nutrient dynamics, especially since precipitation is the only input of water to this ecosystem and surface water flow is the only major route for nutrient losses.

In the process of reclamation for agricultural purposes, extensive drainage networks were constructed across peat areas in Indonesia, including Central Kalimantan (former Mega Rice Project). Drainage may cause peat domes to collapse because, without water, and owing to the very low density of the peat (Rieley *et al.,* 1996), its low load-bearing capacity and high total porosity (Radjagukguk, 1992), peat cannot support tree vegetation or maintain the dome shape (Kool *et al.*, 2006). In addition, the continued growth of peat bog plants is made possible only by nutrient input from the atmosphere, coupled with various adaptive mechanisms of bog plants (Moore and Bellamy, 1974, Marcos and Lancho, 2002). Drainage and logging cause severe damage to ombrotrophic peat domes in the surroundings of Palangka Raya, Central Kalimantan.

The chemical properties of peat change upon oxidation, especially after burning. The following effects may be expected: (a) increase in acidity, owing to oxidation of pyrite in deeper mineral layers or leakage of organic acids from the peat; (b) increase in solute concentrations, resulting in release of nutrients following decomposition of the peat (Kool et al., 2006). This study evaluates changes in water chemical properties (nutrient content) at different depths in peat in both deforested and forested areas include rainfall and canal water.

Materials and methods

The study was carried out in the northern part of Block C of the former Mega Rice project near Kalampangan village in Central Kalimantan, Indonesia. Rainfall was collected in two fixed position rain gauges (constructed from wood and 35 litre capacity polyethylene containers fitted with 25 cm diameter plastic funnels) in a deforested area. Water samples were collected at three permanent sampling sites in a canal and six permanent sites in the adjacent peat area. The latter were established in (a) a deforested peat area (4 sites) and (b) peat swamp forest (2 sites). At each peatland site water samples were obtained from depths of 50, 150 and 250 cm below the surface. At each depth, a separate polyethylene pipe was inserted to sample each depth in the peat, making a total of 18 pipes from which water samples were taken by hand pump.

Rainfall and water samples were collected every four weeks from the end of May 2004 to the beginning of January 2007 and stored in a refrigerator (4°C) after collection, in the Analytical Laboratory, University of Palangka Raya. Next day, rainfall and water samples were filtered. Chemical analyses were carried out on the filtered samples for Ca, Mg, K, Na, and Fe using atomic absorption spectrophotometry (AAS spectra 30). Acidity of the samples (pH) was determined using a Hanna pH meter 211.

Results

Rainfall

The pH of rainfall varied throughout the study period ranging from 4.11 ± 0.01 to 6.60 ± 0.00 and the mean during the study period was 5.12 ± 0.55. The highest value obtained was on 14 September 2006 (pH = 6.60 ± 0.00) in the dry season, followed by 12 November 2004 (pH 6.38 ± 0.03) in the dry season. In contrast, the lowest value occurred on 30 March 2006 in the wet season.

The major nutrients in rainfall are Ca and K. Calcium varied throughout the study period ranging from 0.09 ± 0.02 to 3.51 ± 0.09 mg l^{-1} and the mean during the study period was 0.72 ± 0.75 mg l^{-1}. Similarly to Ca, K of rainfall varied throughout the study period ranging from 0.04 ± 0.01 to 2.02 ± 0.02 mg l^{-1} and the mean during the study period was 0.71 ± 0.52 mg l^{-1}. The order of magnitude of chemical elements in canal water is calcium, potassium, sodium, magnesium and iron.

Canal

The pH of canal water varied throughout the study period ranging from 3.32 ± 0.04 to 4.22 ± 0.05 and the mean during the study period was 3.71 ± 0.19. The highest value obtained was on 18 August 2005 (pH = 4.22 ± 0.05) in the dry season, followed by 12 November 2004 (pH 4.05 ± 0.03) in dry season. In contrast, the lowest value occurred on 3 February 2005 in the wet season.

The principal nutrients in the canal water are Ca and K. Calcium varied throughout the study period ranging from 0.04 ± 0.06 to 2.91 ± 2.13 mg l^{-1} and the mean during the study period was 1.30 ± 0.67 mg l^{-1}. Similarly to Ca, K of canal water varied throughout the study period ranging from 0.18 ± 0.02 to 1.49 ± 0.15 mg l^{-1} and the mean during the study period was 0.75 ± 0.42 mg l^{-1}. Similarly to rainfall, the order of magnitude of chemical elements in canal water is calcium, potassium, sodium, magnesium and iron.

Deforested area

pH

Similarly to the pH of canal water, the pH of water in the deforested peatland at 50, 150, and 250 cm depth also varied throughout the study period. At 50 cm it ranged from pH 3.53 ± 0.08 to 5.93 ± 0.81 and the mean during the study period was 3.98 ± 0.60. The highest value obtained was on 15 September 2005 (pH = 5.93 ± 0.81) in the dry season, followed by 18 August 2005 (pH 5.69 ± 1.20) also in the dry season. In contrast, the lowest value occurred on 30 March 2006 in the wet season. The pH at 150 cm ranged from 3.69 ± 0.27 to 5.36 ± 0 (only one sample available) and the mean during the study period was 4.18 ± 0.36. The highest value obtained was on 12 November 2004 (pH = 5.36 ± 0) at the end of the dry season, followed by 14 September 2006 (pH 4.51 ± 0.93) in the dry season. In contrast, the lowest value occurred on 6 January 2006 in the wet season (pH 3.69 ± 0.27). For the 250 cm depth, pH ranged between 3.65 ± 0.16 and 5.27 ± 1.39 and the mean during the study period was 4.31 ± 0.35. The highest value obtained was on 12 October 2006 (pH = 5.27 ± 1.39) at the end of dry season, followed by 12 November 2004 (pH 4.82 ± 0.79) also at the end of dry season. In contrast, the lowest value occurred on 6 January 2006 in the wet season (pH 3.65 ± 0.16).

Nutrients

Similarly to the calcium of canal water, the calcium of water in the deforested area at 50, 150, and 250 cm depth also varied throughout the study period. The calcium concentration of water at 50 cm depth ranged from 0.07 ± 0.04 to 4.51 ± 0.57 mg l^{-1} and the mean during the study period was 1.93 ± 0.86 mg l^{-1}. Potassium content at 50 cm depth ranged from 0.06 ± 0.02 to 3.66 ± 1.08 mg l^{-1} and the mean during the study period was 1.27 ± 0.88 mg l^{-1}. Sodium content at 50 cm depth ranged from 0.13 ± 0.03 to 1.46 ± 1.12 mg l^{-1} and the mean during the study period was 0.51 ± 0.31 mg l^{-1}. Similarly to the order of magnitude of chemical elements in canal water, that at 50 cm depth in the deforested area is calcium, potassium, sodium, magnesium and iron.

At 150 cm depth, the highest nutrient content of water is calcium ranging from 0.48 ± 0.32 to 5.77 ± 1.74 mg l^{-1} and the mean during the study period was 2.24 ± 1.05 mg l^{-1}. This was followed by potassium with 0.05 ± 0.01 to 3.52 ± 3.32 mg l^{-1} and the mean during the study period was 0.96 ± 0.76 mg l^{-1}. Sodium ranged from 0.02 ± 0.01 to 1.23 ± 0.38 mg l^{-1} and the mean during the study period was 0.42 ± 0.30 mg l^{-1}. The lowest nutrient content is iron with a range from 0.03 ± 0.02 to 0.41 ± 0.02 mg l^{-1} and the mean during the study period was 0.22 ± 0.10 mg l^{-1}.

At 250 cm depth, the highest nutrient content of water is also calcium with a range from 0.70 ± 0.27 to 4.33 ± 2.82 mg l^{-1} and the mean during the study period was 2.06 ± 0.90 mg l^{-1}. This was followed by potassium with 0.09 ± 0.06 to 1.58 ± 1.10 mg l^{-1} and the mean during the study period was 0.77 ± 0.46 mg l^{-1}. Sodium ranged from 0.07 ± 0.06 to 1.58 ± 1.10 mg l^{-1} and the mean during the study period was 0.49 ± 0.42 mg l^{-1}. Magnesium ranged from 0.09 ± 0.02 to 0.96 ± 0.60 mg l^{-1} and the mean during the study period was 0.34 ± 0.21 mg l^{-1}. The lowest nutrient content was iron with only 0.057 ± 0.03 to 0.48 ± 0.01 mg l^{-1} and the mean during the study period was 0.24 ± 0.14 mg l^{-1}.

Forest area

pH

Similarly to the pH of canal water, the pH of water in forest area at 50, 150, and 250 cm depth also varied throughout the study period. The pH value of water in the forest at 50 cm depth ranged from pH 3.13 ± 0 to 5.54 ± 0 (one sample available) and the mean during the study period was 3.68 ± 0.55. The highest value obtained was on 9 December 2005 (pH = 5.54 ± 0) in the beginning wet season, followed by 31 March 2005 (pH 4.33 ± 0) in the wet season. In contrast, the lowest value occurred on 3 February 2005 also in the wet season. The pH of water in the forest area at 150 cm depth ranged from pH 3.04 ± 0.01 to 4.89 ± 1.73 and the mean during the study period was 3.70 ± 0.38. The highest value obtained was on 22 July 2004 (pH = 4.89 ± 1.73) in the dry season, followed by 31 March 2005 (pH 4.37 ± 0.93) in the wet season. In contrast, the lowest value occurred on 3 February 2005 in the wet season (pH 3.04 ± 0.01). For 250 cm depth in forest area, pH ranged between 3.37 ± 0.04 and 5.66 ± 1.97 and the mean during the study period was 3.92 ± 0.46. The highest value obtained was on 9 September 2006 (pH = 5.66 ± 1.97) at the end of dry season, followed by 7 December 2006 (pH 5.03 ± 1.37) in the wet season. In contrast, the lowest value occurred on 3 February 2005 in wet season (pH 3.37 ± 0.04).

Nutrients

Similarly to the nutrient content of water in deforested area at 50, 150, and 250 cm depth, the nutrient content of water in the forest area at 50, 150, and 250 cm depth also varied throughout the study period. At 50 cm depth, the calcium concentration of water ranged from 0.16 to 3.96 mg l^{-1} (one sample only) and the mean during the study period was 2.16 ± 1.08 mg l^{-1}. Potassium ranged from 0.17 to 1.92 mg l^{-1} (one sample only available) and the mean during the study period was 0.89 ± 0.51 mg l^{-1}. Sodium ranged from 0.27 to 1.3 mg l^{-1} (one sample available) and the mean during the study period was 0.63 ± 0.32 mg l^{-1}. Similarly to the order of magnitude of chemical elements in canal water, the magnitude of chemical elements at 50 cm depth in the forest area is calcium, potassium, sodium, magnesium and iron.

At 150 cm depth, the highest nutrient content of water is calcium, which ranged from 0.36 ± 0.32 to 5.43 ± 0.41 mg l^{-1} and the mean during the study period was 2.26 ± 1.15 mg l^{-1}. This was followed by potassium that ranged from 0.05 ± 0.01 to 1.45 ± 0.83 mg l^{-1} and the mean during the study period was 0.66 ± 0.47 mg l^{-1}. Sodium ranged from 0.3 ± 0.03 to 1.44 ± 0.83 mg l^{-1} and the mean during the study period was 0.52 ± 0.22 mg l^{-1}. The lowest nutrient content was iron that ranged from 0.16 ± 0.06 to 0.85 mg l^{-1} (one sample available) and the mean during the study period was 0.39 ± 0.16 mg l^{-1}.

At 250 cm depth, the highest nutrient content of water was also calcium with a range from 0.75 ± 0.15 to 4.08 ± 3.00 mg l^{-1} and the mean during the study period was 2.14 ± 0.96 mg l^{-1}. This was followed by potassium that ranged from 0.05 ± 0.00 to 1.94 ± 0.91 mg l^{-1} and the mean during the study period was 0.72 ± 0.52 mg l^{-1}. Sodium ranged from 0.23 ± 0.01 to 1.84 ± 0.21 mg l^{-1} and the mean during the study period was 0.53 ± 0.35 mg l^{-1}. Magnesium ranged from 0.11 ± 0.06 to 0.96 ± 0.06 mg l^{-1} and the mean during the study period was 0.39 ± 0.19 mg l^{-1}. The lowest nutrient content was iron with a range from 0.025 ± 0.02 to 0.755 ± 0.09 mg l^{-1} and the mean during the study period was 0.38 ± 0.15 mg l^{-1}.

Discussion

pH

The pH of rainfall during the study period was 5.12 ± 0.55; the pH of canal water was 3.71 ± 0.19; water pH in the deforested area at 50 cm depth (3.98 ± 0.60) was higher than in the forest area (3.68 ± 0.55). At 150 cm depth, the pH in the deforested area (4.18 ± 0.36) was higher than in the forest area (3.70 ± 0.38). Similarly to 50 and 150 cm depth, for 250 cm depth, the pH value in the deforested area (4.31 ± 0.35) was higher than the forest area (3.92 ± 0.46). These results indicate that the peat water was more acid near to the peat surface than far from the peat surface. One possible reason for this is that more organic acid is present at the top of the peat profile owing to the vegetation and decomposition process. The pH in the deforested area is higher than in the forest. The higher pH in the deforested area could be the result of the presence of ash and release of basic cations such as Ca, Mg, and K (Radojevic and Tan, 2000) from peat following burning.

Nutrients

In general, calcium, magnesium, potassium, and sodium concentrations in rainfall and canal water show higher values during the dry than the wet season. Iron does not show any distinct pattern between dry and wet seasons. These results agree with those of other workers who also found that the concentration of certain elements in rainfall was higher in the dry than the wet season, for example, magnesium and potassium (Liu *et al.*, 2002), calcium and sodium (Veneklaas *et al.*, 1990).

Several reasons have been suggested to explain why nutrient concentrations in rainfall and canal water are higher in dry than wet periods. The presence in the atmosphere of dust during the dry season, originating from peat burning may contain base cations (e.g. Ca, Mg, K) (Veneklaas *et al.,* 1990) that are deposited in canal water. Moreover, biomass burning, especially at the end of the dry season, may also contribute an increased amount of some cations to the canal water (Clark *et al.,* 1998).

The findings of this present study accord with the conclusions of Clark *et al.* (1998) and Prasad *et al.* (2000) who suggest that the majority of elements in rainfall result from biomass burning carried out by farmers near to the study areas every year at the beginning of crop cultivation, mainly during the dry season.

Comparison between deforested and forest areas at 50 cm depth indicated that the mean calcium value in the deforested area (1.93 ± 0.86 mg l^{-1}) was lower than in the forest area (2.16 ± 1.08 mg l^{-1}). For magnesium, the value in the deforested area (0.41 ± 0.13 mg l^{-1}) was lower than in the forest area (0.63 ± 0.44 mg l^{-1}). Sodium in the deforested area (0.51 ± 0.31 mg l^{-1}) was lower than in the forest area (0.63 ± 0.32 mg l^{-1}). Iron in the deforested area (0.20 ± 0.11 mg l^{-1}) was lower than in the forest area (0.31 ± 0.16 mg l^{-1}). In contrast, potassium in the deforested area (1.27 ± 0.88 mg l^{-1}) was higher than in the forest area (0.89 ± 0.51 mg l^{-1}). Unfortunately, the above averages were obtained from only half the number of total samples owing to a lack of water during the dry season at that depth.

For 150 cm depth, calcium in the deforested area (2.24 ± 1.05 mg l^{-1}) was nearly the same as in the forest area (2.26 ± 1.15 mg l^{-1}). For magnesium, the value in the deforested area (0.35 ± 0.18 mg l^{-1}) was the same as the forest area (0.35 ± 0.22 mg l^{-1}). While for sodium, the value in the deforested area was (0.42 ± 0.30 mg l^{-1}) and, in the forest area, (0.52 ± 0.22 mg l^{-1}). For iron, the value in the deforested area (0.22 ± 0.10 mg l^{-1}) was lower than in the forest area (0.39 ± 0.16 mg l^{-1}). In contrast, the value in the deforested area (0.96 ± 0.76 mg l^{-1}) was higher than in the forest area (0.66 ± 0.47 mg l^{-1}).

At 250 cm depth, calcium in the deforested area (2.06 ± 0.90 mg l^{-1}) was nearly the same as in the forest area (2.14 ± 0.96 mg l^{-1}). Similarly to calcium, potassium in the deforested area (0.77 ± 0.46 mg l^{-1}) was nearly the same as in the forest area (0.72 ± 0.52 mg l^{-1}). For magnesium, the value in the deforested area (0.34 ± 0.21 mg l^{-1}) was also nearly the same as the forest area (0.39 ± 0.19 mg l^{-1}). In contrast, iron in the deforested area (0.24 ± 0.14 mg l^{-1}) was lower than in the forest area (0.38 ± 0.15 mg l^{-1}).

Various reasons have been suggested to explain the differences in the chemical composition of water in deforested and forest areas. Lower nutrient contents (Ca, Mg, Na, and Fe) in the deforested area at 50 cm depth (acrotelm area) may result from leaching over the more than 10 years since the canal was constructed. This agrees with Crowther (1987) who found that that nutrient (Ca and Mg) losses through runoff or leaching could occur from the ecosystem. Sulistiyanto (2004) reported that Ca, Mg, Na and K were leached from a peat ecosystem in the Sabangau catchment, Central Kalimantan. Meanwhile, at 250 cm depth, almost all nutrients studied (Ca, K, Mg, and Na) were nearly the same in both deforested and forest areas. It has been suggested that at that depth the water is quite stable (catotelm area) and has been unaffected by changes that have taken place on the surface. Water does not moving laterally in the catotelm.

Conclusion

This study provides information on the variation of nutrient content of rainfall, peat water at different depths in deforested, forest peatland and in a canal. During the three-year study period concentrations of all nutrients in the canal were lower than in forest and deforested area. Moreover, the results of this study highlight that nutrient concentrations in peat water at 250 cm depth were nearly the same on deforested and forest areas.

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