Extended abstract No. 10

REWETTING OF DRAINED INDONESIAN PEATLANDS TO MITIGATE CARBON DIOXIDE EMISSIONS

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SUMMARY

Extensive degradation of Indonesian peatlands by deforestation, drainage and recurrent fires causes release of huge amounts of peat soil carbon to the atmosphere. A lowering of the groundwater level leads to an increase in oxidation and subsidence of peat. Therefore, the groundwater level is the main control on carbon dioxide emissions from peatlands. Restoring the peatland hydrology is the only way to prevent peat oxidation and mitigate CO2 emissions. In this study we present a strategy for improved planning of rewetting measures by dam construction. The study area is a vast peatland with limited accessibility in Central Kalimantan, Indonesia. Field inventory and remote sensing data are used to generate a detailed 3D model of the peat dome and a hydrological model predicts the rise in groundwater levels once dams have been constructed. Successful rewetting of a 590 km^2 large area of drained peat swamp forest could result in mitigated emissions of 1.4–1.6 Mt CO2 yearly. The proposed methodology allows a detailed planning of hydrological restoration of peatlands with interesting impacts on carbon trading for the voluntary carbon market.

KEY WORDS: dam construction, drainage canal, groundwater level rise, hydrological modelling, illegal logging

INREODUCTION

Problem statement

Extensive degradation of Indonesian peatlands by deforestation, drainage and recurrent fires causes release of huge amounts of peat soil carbon to the atmosphere. Construction of drainage canals is associated with conversion to other land uses, especially plantations of oil palm and pulpwood trees, and with widespread illegal logging to facilitate timber transport. Because groundwater levels control carbon dioxide emissions from peatlands, restoring the peatland hydrology is the only way to mitigate CO_2 emissions. An efficient and cost-effective methodology is presented to plan rewetting of disturbed tropical peatlands thereby aiming to meet the Voluntary Carbon Standard (VCS) regulations which allow selling carbon credits once registered. The VCS does not want to provide potential perverse incentives for the clearing and/or draining of native ecosystems in order to generate carbon credits. Therefore, in order to be eligible for crediting under VCS it must be demonstrated that the project area was not drained of native ecosystems such as peatlands. The study was conducted in the Sabangau catchment in Central Kalimantan (Fig. 1) under supervision of the World Wildlife Fund (WWF) and comprised of: 1) planning: selection of locations best suited for effective restoration measures and dam construction, 2) hydrological modeling: predicting the effect of dams, 3) implementation: dam construction, 4) monitoring: monitoring the performance of dams in time.

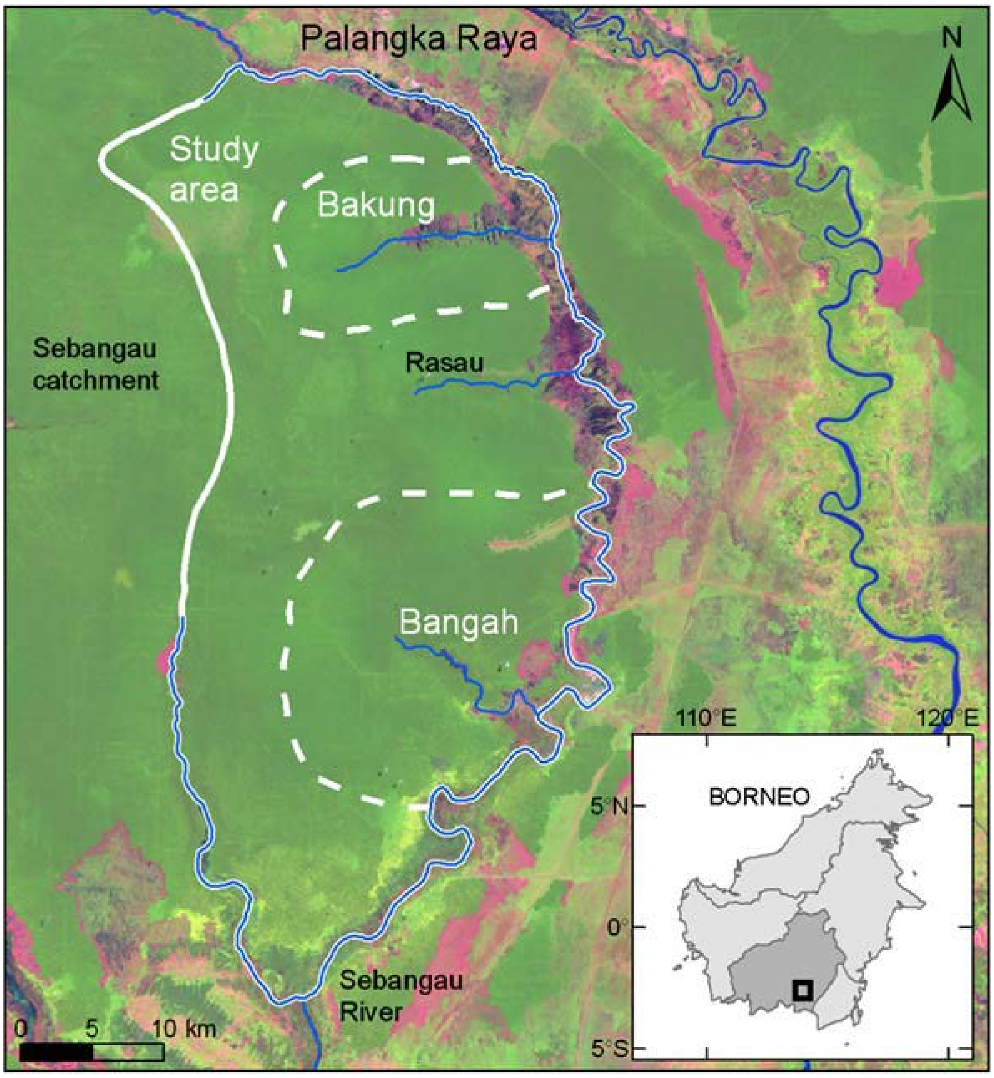

Fig. 1 Landsat ETM+ satellite image from August 2007 showing the study area located in Central Kalimantan on the island of Borneo, Indonesia. Dark green: peat swamp forest, red: fire scars in the year 2006.

MATERIAL AND METHODS

Remote sensing and hydrological modeling

Difficult access of tropical peat swamp forests and limited project funds, require the use of remote sensing data and modeling techniques in combination with field surveys of canal attributes. Optical satellite imagery from Landsat ETM+, SPOT HRVIR and ALOS AVNIR sensors, radar satellite data from the Shuttle Radar Topography Mission (SRTM) and high resolution airborne laser scanning data (LIDAR) were used to: 1) generate a Digital Terrain Model (DTM) of the peat surface and determine peat thickness, and 2) localize drainage canals for hydrological modeling of groundwater levels (Jaenicke *et al.*, 2010). Field surveys were used to validate the remote sensing results. Hydrological modeling with the physically-based SIMGRO (SIMulation of GROundwater flow and surface water levels) model (Querner and Povilaitis, 2009), allows identification of areas with good restoration potential and helps to optimize the number and location of dams required for rewetting a specific area. Canal location, length, width, depth and slope as well as peat bulk density, hydraulic conductivity and the stratification by peat thickness are required input parameters for the modeling. Calculations were made of water flow in the saturated zone, unsaturated zone, river channels and over the peat surface. Groundwater levels calculated are calibrated and validated using measured levels at an undisturbed test site.

Dam construction

Dams act as flow barriers but they cannot store water for long periods as water will eventually seep through the surrounding peat. As dams restrict water flow rather than stop all water movement, they do not have to be watertight and thus construction can be relatively simple. To determine the optimal number and location of dams required for efficient drainage reduction, the surface slope was determined along each canal selected to be closed. Hydrological model simulations revealed that a cascade of closely spaced dams is most effective for water control. The steeper the slope, the more dams are needed to reduce drainage. Figure 2 shows the slope of a medium priority canal in the Bangah catchment (length 10 km, width 3 m, depth 1 m). The absolute elevation difference of the canal from its origin at the top of the peat dome to its outlet into Bangah river is 3.1 m. Because the slope of the canal is not constant over its total length it was subdivided into two sections: an upper, relatively flat section (Fig. 2, Slope1) and a lower, steep section (Fig. 2, Slope2). The distance between dams required to reduce drainage is determined by the hydraulic head difference, i.e. difference between upstream and downstream canal water level across a dam. Field experiments showed that for small canals the water level over each dam should be limited to about 25 cm to reduce seepage and to prevent erosion. Thus, the canal in figure 2 requires a series of 13 dams to overcome the 3.1 m elevation difference. In the upper section of the canal a spacing of 975 m between dams is sufficient to keep water level differences low, while in the steeper section the spacing needs to be reduced to 320 m. Figure 3 shows an example of a relatively simple dam in the Bangah catchment mainly made of locally available material.

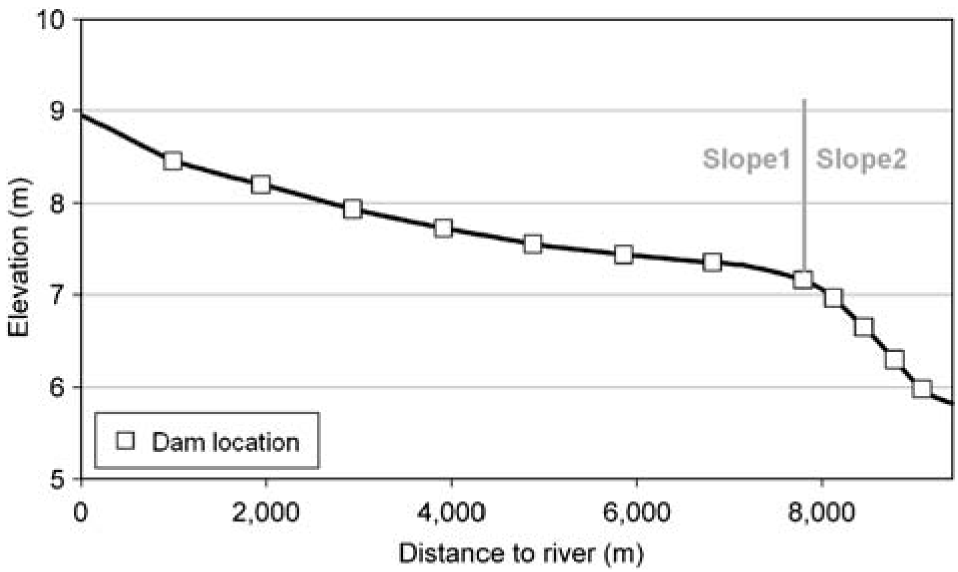

Fig. 2 Slope of the peat surface next to a canal in Bangah catchment as measured in the modeled DTM (0 marks the most upstream part of the canal). 13 dams are required to reduce large scale drainage.

Fig. 3 Simple dam in the Bangah catchment made of locally available material (3 m long, 1 m wide and 2.5 m deep).

RESULTS

Groundwater level rise

The effect of dams on groundwater levels is predicted by hydrological modeling comparing the situation before and after dam construction. In wet years calculated groundwater levels are at or close to land surface whereas in dry years they drop to about 1 m below land surface. On average the groundwater level at the undisturbed test site is -16 cm. This value provides an indication of the intended long-term average groundwater level after successful blocking of drainage canals in the Bakung catchment. The calibrated and validated hydrological model was applied to the whole of the Bakung and Bangah catchment for the 25 November 1997, an extremely dry period. Figure 4a shows that dams can raise groundwater levels up to 50-70 cm under these very dry weather and peat conditions. For larger areas the rise is approximately 10-30 cm. Rise in groundwater levels is presented in classes rather than as absolute values to reflect the uncertainty in the calculated results. The areas affected by rewetting are strongly influenced by the slope of the peatland area surrounding the canal as this determines the catchment area draining to the canal. Figure 4b shows surface water levels in a 12 km long canal. Compared to the situation without dams, the result is a rise of the canal water level of up to 35 cm in the upstream part of the canal. The resulting rewetting of the peatland area surrounding this canal is up to 50 cm. Hydrological modeling of the rise of groundwater levels on a daily base for the years 2006, 2007 and 2008 shows that on average this rise is 20 cm during the dry season.

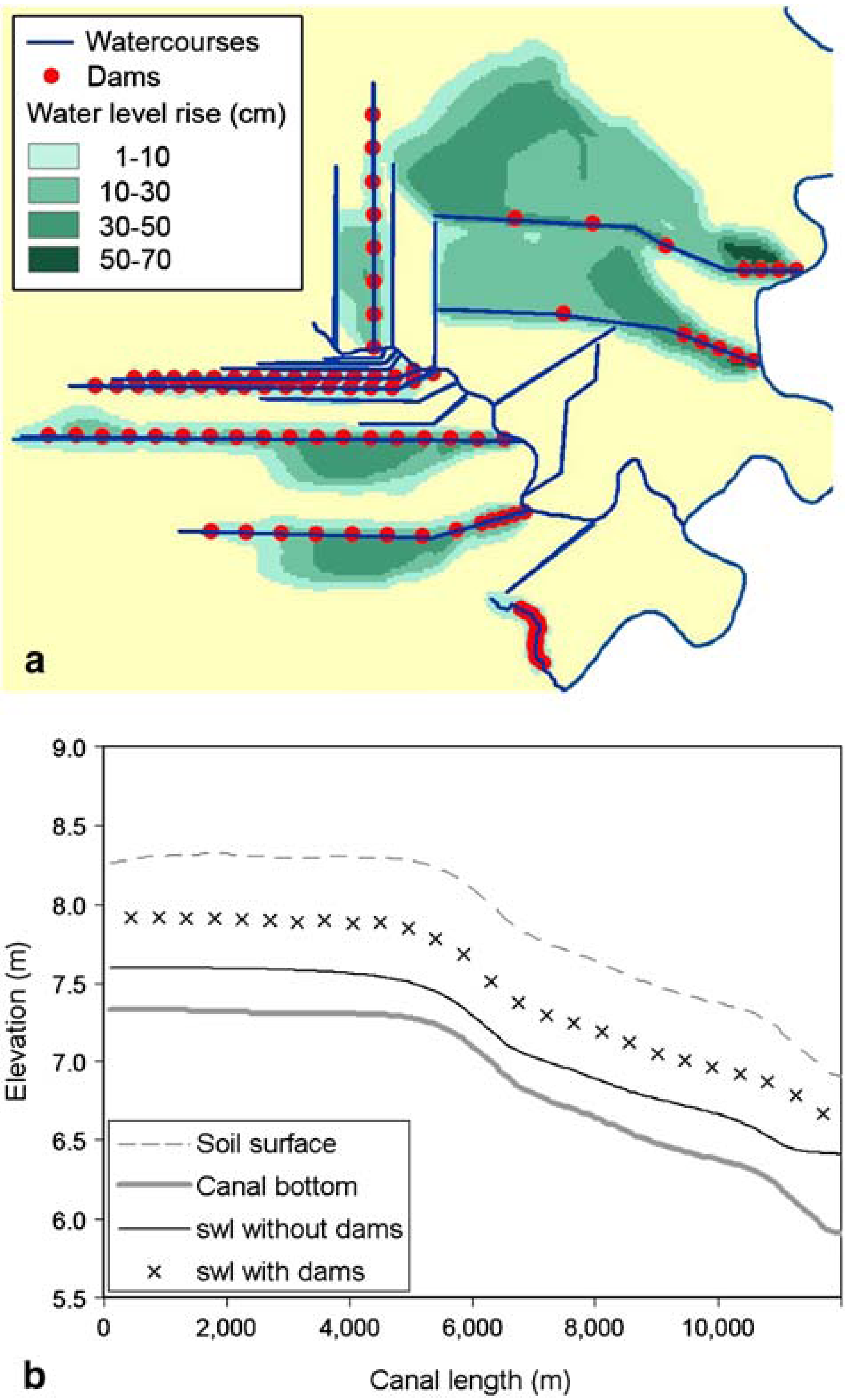

Fig. 4 Hydrological modelling applied to the Bangah catchment for very dry conditions on 25 November 1997. (a) Groundwater level rise in the whole area after construction of 114 small dams (b) Rise of the surface water level (swl) in a single canal after dam construction.

Mitigation of carbon dioxide emissions

Rewetting of drained tropical peatlands will potentially lead to large mitigations of carbon dioxide emissions. Quantifying the rise in groundwater levels of hydrological restoration projects in peatlands together with an estimation of the mitigation in CO_2 emissions caused by this rise, is important information to make greenhouse gas emission mitigations tradable under the Voluntary Carbon Standard regulations. Preliminary groundwater level measurements in the drainage affected Bangah catchment indicate an average level of -49 cm. Consequently, an average annual groundwater level of -50 cm was assumed to be a baseline level for the project area before hydrological restoration started. After construction of all dams, hydrological modeling indicates a rise of annual average groundwater levels of 20 cm. With a reported emission mitigation of approximately 0.8-0.9 t CO_2 $ha^{-1}a^{-1}$ per centimeter groundwater level rise (Couwenberg *et al.*, 2009), rewetting of the 590 km^2 area of the combined Bakung and Bangah catchments results in an estimated mitigated emission of 1.4-1.6 Million tons CO_2 annually.

CONCLUSION

The estimated emission mitigation will not be achieved in the first year after all dams have been constructed because only with time sedimentation of organic and mineral material upstream of the dams makes them fully effective. Higher emissions are expected during El Niño years, such as in 1997, 2002, 2006 and 2009 due to very low groundwater levels in addition to drainage. In the project area, long-term measurements of groundwater levels (before and after dam construction) as well as subsidence and gas flux emissions are needed to confirm these preliminary results. Results are reported as a class to reflect the uncertainty in the calculations. Other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are not taken into account because they are relatively unimportant in tropical peatlands.

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