A SYSTEM TO SUPPORT DECISION MAKING FOR PEATLAND MANAGEMENT IN THE HUMID TROPICS

Published in: J. Päivänen (Ed). Wise use of peatlands. Proceedings 12th Int. Peat Congress, 6-11 June 2004, Tampere, Finland, Vol I: 720-725

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Abstract

To assist planners and managers in wise use of these tropical peatlands a decision support system (DSS) has been developed. This DSS, which is based on a GIS application, combines the Groundwater Modelling Computer Programme PMWIN with expert knowledge on subsidence, land use and water management. The DSS can be used to predict the long-term effects of different types of land use, e.g. peat swamp forest, sago or oil palm plantations, on the lifetime and associated CO_2 release of these tropical peatlands. The type of land use dictates the required depth of the groundwater table, which in turn has a significant effect on the sustainability of the peatland. The Decision Support System (DSS) helps to improve the decision-making process by showing the long-term consequences of selecting specific types of land use. To facilitate the communication between planners, farmers, plantation owners, decision-makers and other stakeholders the consequences of the proposed land use changes are visualized using various methods showing the effects of subsidence and CO_2 release over time. Data from Central Sarawak, Malaysia are used to test and refine these methods. This paper discusses possibilities and limitations for the visualisation process and demonstrates how visualisation can help to make better decisions on the implementation of sustainable management practices for tropical peatlands.

Keywords: Water Management, Tropical Peat, Management, Borneo, Planners, Decision-makers and Communication

Introduction

The majority of the world's tropical peatlands (11 million hectares) occur in South-east Asia, mainly in the coastal regions. Many of these coastal regions are identified as major regions for development with agriculture as its driving force. Agricultural development includes oil palm, sago and forest plantations, aquaculture, paddy and miscellaneous crops including pineapple and vegetables. Peatlands in these coastal regions have global ecological significance, being some of the largest remaining areas of lowland rainforest in SE Asia that provide the habitat of many endangered species. In addition, they are large stores of carbon and water and also play an important regional economic role, providing forest products and land for settlement. Owing to a lack of awareness and understanding about sustainable land management practices, however, many peatland development projects fail, resulting in serious environmental degradation and impoverishment of local communities (Diemont et al. 2002).

Peatlands are waterlogged most time of the year and need drainage to make them suitable from agriculture or other land use (Alan Tan and Ritzema 2003). Compared to mineral soils, peat has a much higher infiltration capacity, drainable pore space and hydraulic conductivity, but a lower capillary rise, bulk density and plant-available water (Wösten and Ritzema 2001). Another major difference is the subsidence behaviour of peat: it is never-ending and partly caused by oxidation. This oxidation leads to CO_2 emissions, which under Borneo conditions, is estimated to be in the order of 26 tonnes per hectare per year.

Beside the loss of peat by oxidation, the excessive subsidence rates result in a pronounced drop in the elevation of the land reducing the efficiency of the drainage system (Ritzema et al. 2001). To avoid flooding and waterlogging problems during the monsoon season, frequent deepening of the system is required. This never-ending process threatens the sustainable use of peat areas (Rieley et al. 2002). Controlled drainage can reduce subsidence but never arrest it (Ritzema and Wösten 2002a). The rate of subsidence depends on the design depth of the water table, which in its turn is prescribed by the type of agricultural use: e.g. oil palm requires a water table in the range of 0.60 to 0.80 m compare to sago which only needs a water table in the range of 0.20 to 0.40 m. Thus the type of agricultural development has a direct effect on the sustainability of the peat.

To assist planners, farmers, managers and other stakeholders in wise use of these tropical peatlands a decision support system (DSS) has been developed. This DSS, which is based on a GIS application, combines the Groundwater Modelling Computer Programme PMWIN with expert knowledge on subsidence, land use and water management. The DSS consists of three components:

- A groundwater model to simulate the impact of reclamation on groundwater levels;
- A model to calculate the corresponding soil subsidence, and
- A GIS component to visualise the results.

This paper discusses the possibilities and limitations for the visualisation process and demonstrates how visualisation can help to make better decisions on the implementation of sustainable management practices for tropical peatlands. Data from Balingian area, a tropical peat dome of about 10,000 ha in the Central Region of Sarawak, Malaysia (latitude 3^0 00' N, longitude 112^0 36' E) are used to test and refine these methods.

Input requirements for the visualization

Groundwater modelling

Each type of land use required a different type of water management. To visualize the long-term effects of these different types of land use the PWWIN 5.0-79 simulation package is used to simulate depth of the groundwater table (Grobbe 2003). PMWIN is based on Modflow: a public-domain, three-dimensional, finite-difference, saturated groundwater flow model (*www.modflow.com*). Modflow was selected because it offers good pre- and post-processing options, requires not too much input data, is well documented and can easily be extended with additional modules. In the model, the peat domes were schematized as a one-layered, unconfined aquifer with the mineral subsoil at mean sea level as the bottom boundary. The mineral subsoil was considered to be impervious. The top boundary was the soil elevation of the peat layer, which in the waterlogged peat soils, is also the elevation of the groundwater level.

Subsidence modelling

The outcome of the groundwater modelling was used to calculate the subsequent subsidence using the following relation:

Subsidence (m/year) = 0.1 x groundwater depth (m – ground level)

This relation is based on data of peat subsidence in Western Johore, Peninsular Malaysia, and (Wösten et al. 1997) and corrected for the conditions in Sarawak (Wösten and Ritzema 2001). To overcome local disturbances in the actual elevation of the ground level, the initial ground (water) level has been smoothened and made equal to the initial groundwater level.

Visualization of the outcome of the modelling process

The outcome of the modelling process, i.e. the change of the depth of the groundwater table and the corresponding subsidence, are normally presented in graphs and figures. The interpretation of this type of outcome is difficult for non-technical people. Therefore the geographic information system-based programme Arc View GIS 3.2 was used to visualize the effects. Three examples are discussed in this paper. These examples show for various types of land use, or the combination of various types of land use within a peat dome (basin) the effects of:

- Lowering the groundwater table in a part of the peat dome on the overall groundwater levels in the dome;
- The amount of peat loss due to oxidation;
- The rate of subsidence of ground levels over time, in the area itself and in the surrounding area.

The first two examples describe processes that are important for planners and decisions-makers at a regional or national level. The third example is more directed to managing the area after a certain type of water management has been introduced.

Lowering the groundwater table

The model was used to simulate the effect of the reclamation of part of the peat dome on the depth of the water table, subsequent subsidence and the elevation of the ground surface in the surrounding part of the dome (Grobbe 2003). Changes were calculated after 1, 2, 5, 10, 20 and 50 years. The simulations were done for two land use options, i.e. oil palm plantations with a required depth of the water table of 0.8 m below ground surface and sago plantations with a required depth of the water table of 0.4 m. The plantations were situated either on top of the peat dome or along the edges (Figure 1), resulting in the following scenarios:

- Deep drainage (0.8 m below ground surface) on the top of the peat dome;
- Shallow drainage (0.4 m below ground surface) on the top of the peat dome;
- Deep drainage (0.8 m below ground surface) along the edges of the peat dome;
- Shallow drainage (0.4 m below ground surface) along the edges of the peat dome.
- Combination of scenario 2 and 3.

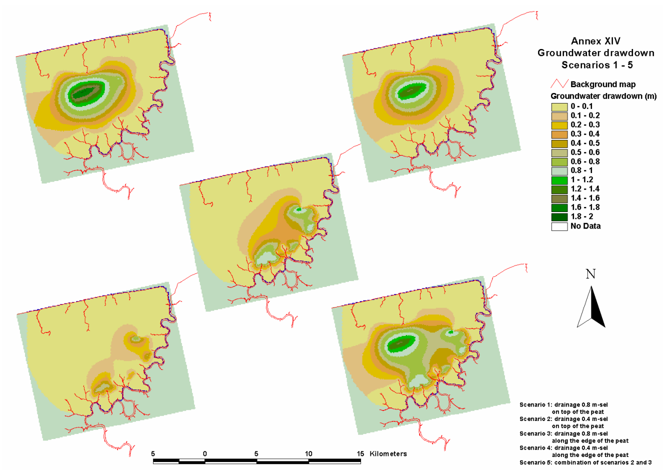
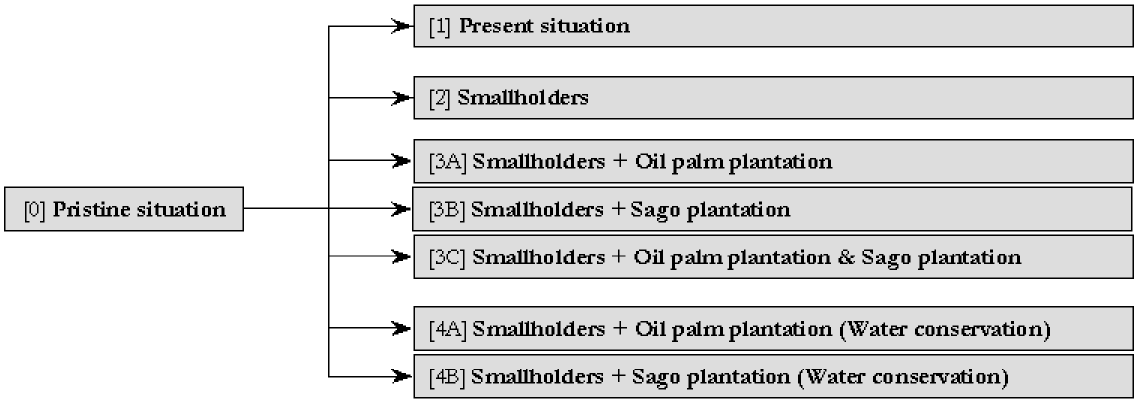


Figure 1 Effect of the installation of a drainage system on the groundwater levels surrounding the plantations (top left - scenario 1; top right – scenario 2; middle – scenario 3; bottom left – scenario 4 and bottom right – scenario 5).

The amount of peat loss due to oxidation
The second example shows the cumulative amount of peat loss for 8 different land use options (Veltman 2004):



Simulations indicate that CO_2 emission for the most intensive land use option (option 3A smallholders + oil palm plantations without water conservation) is four times higher than the smallholders options, i.e. 10.2 MT of option 3A compared to 2.8 MT for option 2 (Figure 2).

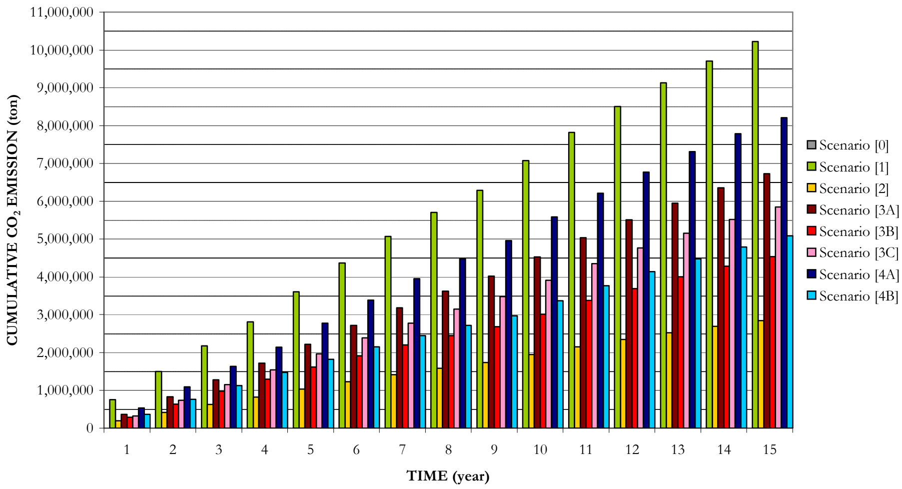


Figure 2 Cumulative amount of CO_2 emission in tons for eight different land use options

The rate of subsidence
The third example (Figure 3) shows the effect of different management options to maintain the drainage system in an oil palm plantation. The design water table is 0.75 m and it is assumed that yield reduction will occur as soon as the water table is shallower than 0.60 m. After the drainage system has been installed to maintain the water table at 0.75m (year 1), subsidence will start and peat will be lost through oxidation. Over the years, if the drains are not deepened, the groundwater level will become shallower as the elevation of the ground surface will drop and consequently the oxidation will reduce as the oxidation only takes place in the peat layer above the water table. A shallower water table, however, results in a yield reduction, thus the manager has various options:

- Scenario I: deepening the drains as soon as yield reduction is likely to occur, for oil palm under the prevailing conditions in Central Sarawak this means every 2.1 years;
- Scenario II: accepting a slight yield reduction and only deepen the drains as the water table becomes shallower than 0.4 m, for oil palm under the prevailing conditions in Central Sarawak this means every 4.8 years;
- Scenario III: no deepening of the drains thus excepting yield reduction.

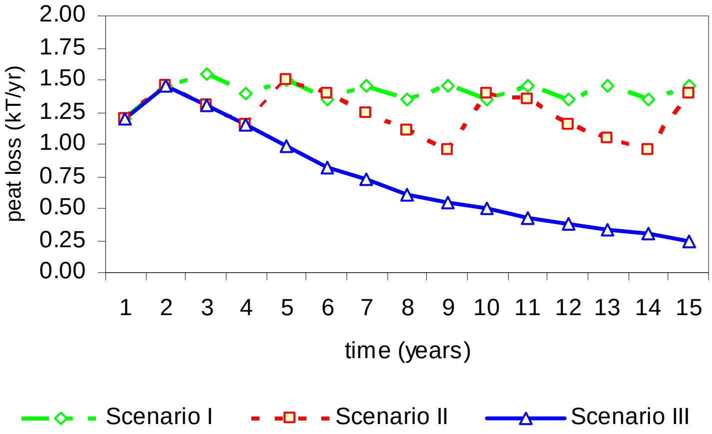


Figure 3 Scenarios for the maintenance of the drainage system: Scenario I: deepening the drains every 2.1 years; Scenario II: deepening the drains every 4.8 years and Scenario III: no deepening.

Conclusions

In this study a decision support system (DSS) for peatland management in the humid tropics was developed. This DSS, which is based on a GIS application, combines the Groundwater Modelling Computer Programme PMWIN with expert knowledge on subsidence, land use and water management. The DSS made it possible to visualize the effect caused by certain land uses options, e.g. the effect of reclaiming part of the peat dome for (oil palm or sago) plantation development on the groundwater levels, subsequent subsidence and loss of peat to the atmosphere. The GIS structure of the DSS allows the presentation of the simulation in parameters and formats that suit the user. This makes the DSS a useful tool for planners, farmers, designers and other stakeholders to discuss the effects of various land use options and in this way to optimize the sustainable use of these valuable peat domes.

Acknowledgements

The study presented in this paper is based on various research programmes conducted by LAWOO, the Land and Water Research Group of Wageningen University and Research Centre, Wageningen, The Netherlands, PS Konsultant, Kuching, Sarawak and research organisations and Universities in Malaysia and Indonesia for among others the Government of Sarawak (DID 2001), Malaysia, the Ministry of Agriculture, Fisheries and Nature of the Netherlands and EU-sponsored research projects.

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