Monitoring restoration measures in tropical peatlands using radar satellite imagery

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Summary

In the context of the ongoing climate change discussions the importance of peatlands as carbon stores is increasingly recognized in the public domain. Deforestation, drainage and peat fires are the main reasons for the release of huge amounts of carbon. Successful restoration of degraded tropical peatlands is of high interest owing to their huge carbon store and massive sequestration potential. The blocking of drainage canals by dam building has become one of the most important measures to restore the hydrology and the ecological function of peat domes. This study investigates the feasibility of using multitemporal radar remote sensing imagery for monitoring the hydrological effects of these measures. The study site is the former Mega Rice Project area in Central Kalimantan, Indonesia, where the peat drainage and forest degradation are especially intensive. First results of more than 40 ENVISAT ASAR and ALOS PALSAR images show that high frequency multitemporal radar satellite imagery can be used to detect an increase in soil moisture in the peat soil after dam construction.

Key index words: tropical peat, restoration, canal blocking, soil moisture, radar satellite

Introduction

In the past decade large areas of the Indonesian peatlands have experienced serious damage as a result of human activities such as logging and drainage. Peatland site development is often associated with the construction of drainage canals in order to make the land usable for agriculture or, more often, for oil palm and pulp wood plantations. Canals and ditches are not only built to control and lower the water level but also to facilitate access to the peat swamp forest and for transportation of timber logs. Once the peat swamp forest has been removed and the peat drained, the exposed peat oxidises owing to bacterial activity and emits carbon into the atmosphere (Rieley and Page, 2005). Furthermore, oxidation is leading to the irreversible process of peatland subsidence (PS KONSULTANT and LAWOO, 2001). Another severe consequence of drainage construction is that the peat surface becomes dry and thus susceptible to fire during the dry season. Fires in degraded peatlands can result in a quick release of huge amounts of the greenhouse gas CO_2 (Page *et al.*, 2002). These processes, which convert peatlands from being a carbon sink to a source, can only be halted by complete re-saturation of the peat with water. Owing to its very high permeability peat acts like a sponge. Therefore, one of the most important peatland restoration measures is the blocking of drainage canals by dams, which is now widely implemented by various projects in Central Kalimantan.

The objective of this study was to investigate the feasibility of using remote sensing data for monitoring the effects of tropical peatland restoration by canal blocking. Radar imagery was selected because it is available at high temporal frequency and it is sensitive to changes in soil moisture. In general, vegetation or soil with a high moisture content returns more energy back to the radar sensor, i.e. higher ^{0} value, than if it is dry (Lillesand and Kiefer, 1994). Several studies have demonstrated the relationship between ^{0} and surface soil moisture content under varying terrain conditions (e.g. Ulaby *et al.*, 1982; Hashim et al., 2002; Paloscia *et al.*, 2005). Study site was the former Mega Rice Project area (Ex-MRP) in Central Kalimantan, Indonesia, where with the presence of about 4,500 km drainage canals peat drainage and forest degradation is especially intensive (Fig. 1).

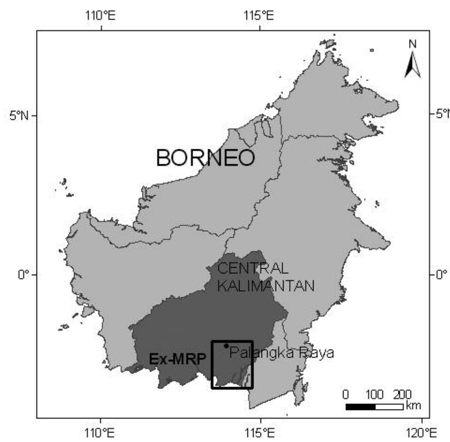

Figure 1.The former Mega Rice Project area (Ex-MRP), located in the Indonesian province of Central Kalimantan, is the study site.

Materials and methods

Fig. 2 shows the location of eleven dams which were investigated to determine their peat rewetting effectiveness. The dams southeast of the town of Palangka Raya were constructed between July and September 2005 within the KEYTROP and RESTORPEAT project under the leadership of the University of Palangka Raya. The other dams, some of which are blocking the main canal going from west to east, were built between March 2004 and January 2005 within the CCFPI project mainly by Wetlands International (Suryadiputra *et al.*, 2005). Furthermore, water level data collected by automatic loggers since April 2004 at three locations in the Ex-MRP Block C were made available by the KEYTROP project (see Fig. 2). A time-series of 25 ENVISAT-ASAR radar images, acquired between July 2004 and October 2007, was investigated by change detection methods. In addition 18 PALSAR scenes, acquired by the ALOS satellite since July 2006 were analysed. All radar images were geocoded, calibrated to radar backscatter values (^{0}) and speckle filtered. When measuring changes in peat moisture it is important to consider the actual weather conditions during the time of radar image acquisition. Precipitation data collected by the Tropical Rainfall Measuring Mission (TRMM), which merges high quality microwave and infrared precipitation data, were used for this purpose. The data has a 3-hour temporal and a 0.25°x0.25° spatial resolution (see Fig. 2).

There are several advantages of satellite Synthetic Aperture Radar (SAR) data: (1) large scale data collection, (2) cloud penetration and (3) dependence on the dielectric constant which is dependent on the presence of moisture in soil and vegetation (Lillesand and Kiefer, 1994). However, SAR backscatter is also influenced by other surface parameters such as roughness which makes it often difficult to interpret. To assess SAR data quality, preliminary investigations on the sensitivity of the ASAR backscattering coefficient ^{0} to precipitation and *in situ* water level measurements were carried out. Test areas of the size 200 m x 400 m, located close to the dams, were analysed before and after dam construction as well as reference areas in undrained regions.

Results and discussion

A direct comparison of daily precipitation data with the ASAR backscatter coefficient ^{0} (VV polarization) shows a good correlation (Fig. 3), and demonstrates the relationship between the intensity of the SAR backscatter signal and the presence of moisture in tropical peat soil. As an example, figure 3 shows a SAR test area near the water level loggers and located on degraded peat. Within the ASAR time series of two years an increase of 0.8 dB occurs after completion of the dam construction, while there is only a very slight increase in precipitation data. On average backscatter values are higher after canal blocking than before. The annual precipitation in 2004 was with 1141 mm equal to the rainfall in 2007 (Jan.-Oct., 1143 mm), while 2005 was slightly drier (1036 mm). In 2006 El Niño caused significantly drier conditions with only 851 mm. This observation suggests that the increase in radar backscatter results from an increase in peat moisture after canal blocking. A similar trend and relationship exists with *in situ* water level data. The water level during the dry season of 2007 is clearly higher than in 2004 even though rainfall data of several months is directly comparable. Similar observations were made for other test areas and dams.

These preliminary results show the potential of multitemporal SAR imagery for monitoring the success of restoration measures in tropical peatlands. Further research will be conducted in order to confirm these first results. Especially a change detection analysis of ALOS-PALSAR imagery is of high interest. This sensor acquires data in the L-band wavelength, which is longer than the ASAR C-band, and thus generally better suited for monitoring soil moisture and surface wetness conditions (Schmullius and Furrer, 1992; Lillesand and Kiefer, 1994). Up to now too few PALSAR images are available for change detection. Unfortunately, there are no images available for the situation before dam construction, because ALOS imagery is available only since July 2006. However, in the near future the effectiveness of the latest dam constructions built by the Central Kalimantan

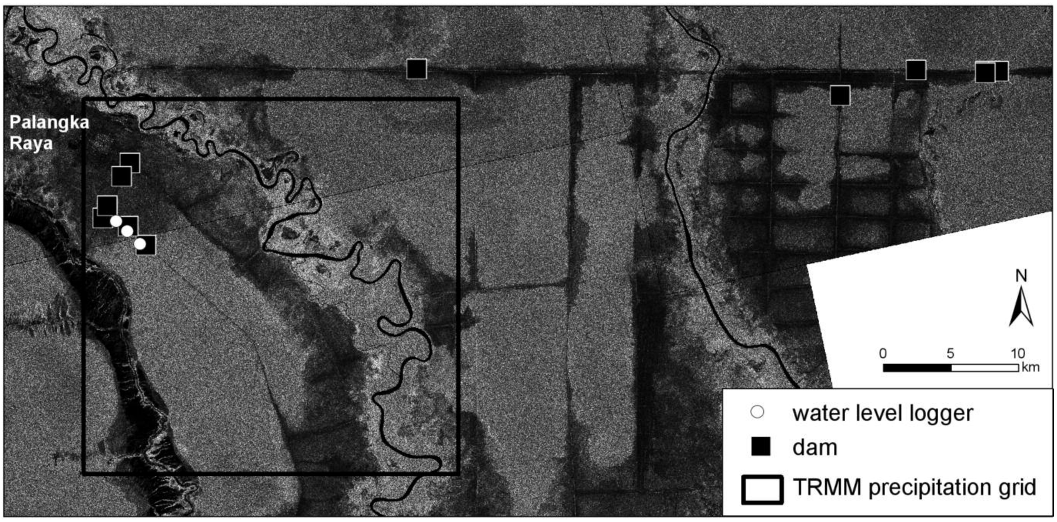

Figure 2. Shown is the location of eleven dams located in the Ex-MRP area, three water level loggers and the TRMM precipitation grid. ALOS-PALSAR dual polarized images from July 2007 clearly show burn scars and vegetation regrowth near the drainage canals (© JAXA).

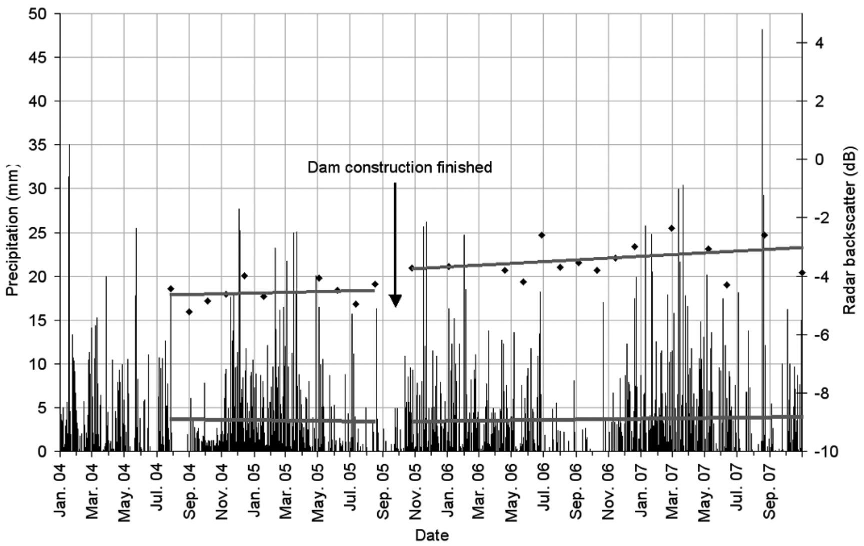

Figure 3. A direct correlation between TRMM precipitation (bar) and ASAR backscatter data (scatter) exists. There is an increase in radar backscatter after completion of dam construction. The backscatter values are means over a 200 m x 400 m large area southeast of Palangka Raya.

Peatland Project (CKPP) in 2007 can be investigated. In addition, PALSAR data have proved to be very useful for monitoring deforestation of peat swamp forest as well as regrowth. Figure 2, a dual polarized PALSAR image, clearly shows various conditions of vegetation regrowth after fire (mid to dark grey shades), which are mainly located near drainage canals. Monitoring of fire occurrence and impact as well as successful fire prevention are important components for peatland restoration. Rewetting of peat soil is an essential measure in order to stop peat oxidation and subsidence, support vegetation regrowth and to prevent fire ignition. On a regional scale peatland restoration will improve the quality of life for local people and is of global importance in order to stop the release of huge amounts of carbon to the atmosphere. With a functional hydrology tropical peatlands even have the potential to sequester significant amounts of CO_2.

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