Government of Central Kalimantan

Government of Indonesia

Government of the Netherlands

Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan

FLOOD ANALYSIS OF THE EX-MEGA RICE PROJECT AREA IN CENTRAL KALIMANTAN

Technical Review / Analysis No. 6

OCTOBER 2008

Euroconsult Mott MacDonald and Deltares | Delft Hydraulics
in association with
DHV, Wageningen UR, Witteveen+Bos, PT MLD and PT INDEC

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SarVision Netherlands

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1 Summary

This draft report presents a series of flood event maps for the CKPP area for the period December 2006 until December 2007. The approach is based on analysis of radar echo modulation caused by flooding and soil moisture changes. Use is made of systematic and frequent observation by PALSAR radar and the previously produced LULC map. A final map and legend with accuracy assessment will be prepared after receiving input from the Palangkaraya May 2008 workshop.

2 Objectives

2.1 Assignment Objective(s)

A.1. To spatial-temporally analyze and map flood events occurring in Blocks A, B, C, D, encompassing the rising, peak and subsiding stages of the flood events and describing the timing, source, location, area and spread of each of the flood stages

A.3. To spatially analyze and map open water extent and soil moisture conditions in the dry season.

3 Project area

The project area is located in the south of Central Kalimantan province (Kalimantan Tengah), Indonesia and consists of the EMRP area as a whole including the so-called blocks A, B, C, D and E, as well as Sebangau National Park (SNP). The provincial capital (Palankaraya) is located to the northeast of the project area (see *figure 1*). The total mapped area mapped covers approximately 1°30'S – 3°25'S and 113°15'E – 115°E.

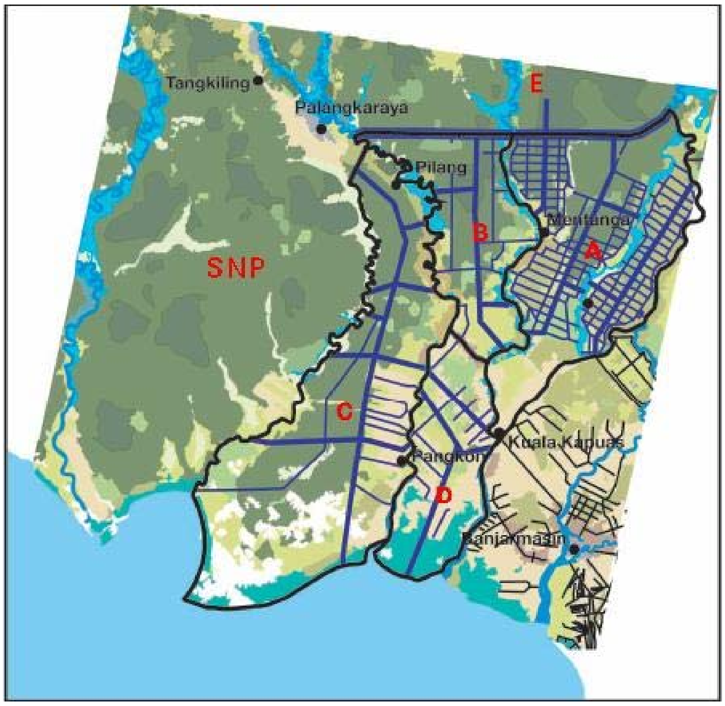

Figure 1. Project area including Sebangau National Park and blocks A-E, canal system and land cover for May 1997 (pre-fire). Dark green: low pole peat swamp forest (PSF); Green: tall PSF; Beige: agriculture and fallow land; Bright green: fragmented PSF and PSF mosaics; Brown green: grass and bushland; Blue green: mangrove forests; Light blue green: pristine swamp forest (periodically inundated); Pale green: dry and swampy grasslands; White: clouds; Blue: rivers. (Source: modified from Page et al., 2002).

The area is predominantly flat and characterized by a humid tropical climate with mean daily temperatures varying from 25 to 33°C at sea level, high humidity (85-90%) and a mean annual precipitation of approximately 2,400 mm. Normal dry seasons last from May/June to September. During El Niño-Southern Oscillation (ENSO) years such as 1997 however, the dry season may begin as early as March and last until December.

Land use / cover is dominated by (peat) swamp forest, secondary forests, bushland and grass- and cropland. Most forest has been extensively logged. Shifting cultivation and plantations (e.g. *Jelutung*, *Acacia*) prevail close to the rivers and canals, while large scale paddy rice cultivation is found in block A. Low growing grasses and wild ferns are widely found, the latter particularly in recurrently burnt areas.

Large rivers including the Katingan, Kahayan, Barito and Kapuas rivers and streams provide the main transportation routes and few roads exist. People live in small settlements located along the rivers and a small number of transmigration areas.

The following dynamics strongly influence land cover / use characteristics and their signature in satellite imagery:

- Seasonality - peatland covers most of the project area. During the wet season the peatsoil can be largely waterlogged with water levels rising above the soil surface.

Contrast in satellite imagery between vegetation types is stronger in the dry season.

- Fire influence - much of the project area (blocks A – D in particular) is known to be severely affected by fires on an annual basis during the dry season, resulting in a complex landscape including various stages of post-fire recovery.

4 Material and methods

4.1 PALSAR radar

Because of its unique suitability to observe soil moisture variation and flooding, even under a closed vegetation layer (though in the latter case some sensitivity is lost), the decision was made to use PALSAR L-band radar data as a basis for flood monitoring. Moreover, observation by radar systems is unimpeded by cloud cover, another necessary requirement for any operational monitoring system in the humid tropics.

Within the framework of the ALOS Kyoto and Carbon Initiative, a mosaic of Fine beam dual polarization (FB DP) HH and HV (dry period July 2007) and Wide Beam (WB) single polarization HH (period November 2006 - December 2007), with 50m spatial resolution, were obtained and used. HV polarization is well known to be sensitive to standing biomass and HH polarization is sensitive to flooding and soil moisture conditions. The combination of this type of information into a multidimensional classification allows the differentiation of different vegetation types associated to biomass levels and flooding conditions (see also revised LULC map report; SarVision, 2008).

The main system characteristics of the PALSAR are summarised in Table 1.

Table 1. ALOS PALSAR Wide Beam 1 (ScanSAR) characteristics*

	PALSAR WB	PALSAR FB DP
Centre frequency	1.27 GHz / 23.5 cm	1.27 GHz / 23.5 cm
Image mode	Single polarisation HH (default) or VV	Dual polarisation HH and HV
Incidence angle	24.6 - 27.1°	
Spatial resolution	100 m	50m
Swath width	250 km	70 km

**This mode is suited for direct downlink by international ground stations, enabling the current mapping approach to be implemented, in principle, for tropical peat swamp monitoring worldwide.*

A certain level of understanding of the physical interaction between the radar wave and the terrain is necessary to allow for an accurate interpretation of these PALSAR images. Biomass and flooding are the two main terrain parameters and polarisation is an important radar wave parameter. The effect of biomass is an increase of the radar echo (or backscatter) intensity with increasing biomass up to a level of around 100 ton/ha. Above this biomass level the radar image intensity saturates and the radar wave does not penetrate the vegetation well. Below this biomass level, or in open canopies, the effect of flooding is noticeable. In this case the interaction mechanism is somewhat different. The radar instrument is side-looking and the water surface acts as a mirror. Hence, smooth open water surfaces yield no radar return, i.e. these areas appear black in the image. However, when vegetation is present it causes a second reflection (mainly by tree trunks) in the direction of the radar. This effect is particularly strong for the so-called HH-polarisation used for the current assignment.

The combined effect of flooding and biomass is a variation in the image intensity for which the range of variation is mainly determined by the biomass level (i.e. low biomass areas show large variations in time; high biomass areas small variations) and for which the relative brightness is mainly determined by the intensity of flooding (i.e. dry terrain shows a relatively low intensity; flooded terrain a relatively high intensity).

The effect of high soil moisture content is somewhat similar to flooding. A wetter soil gives more backscatter; however, since the surface does not become flat, the surface does not start to behave like a mirror. Wetter soils, therefore, also generate increased reflections (as compared to dry soil) in the absence of vegetation.

A special case is the soil surface of the peat swamp forest. The presence of trees generates an extremely rough surface. Thus, depending on the ground water level, a patchy type of flooding occurs. With increasing ground water level tiny pools grow in aerial extent and get more and more interconnected. At the same time, after reaching a certain level (or flooding percentage), surface run-off increases dramatically.

In Hoekman (2007) several examples of the effects of fire damage, drought and flooding in peat forests in L-band radar images are discussed in more depth. Figure 2 illustrates a case of peat forest soil surface roughness. It shows the increase of water level at one point for a period of 4 months in the wet season, at an hourly sampling rate. The increase is almost a half meter and this is comparable to the soil surface height variation. This roughness is shown as a horizontal transect of 20 m, with the position of the water level logger in the centre. As a result the percentage terrain flooding can be estimated from the combined roughness and water table measurements (Hoekman, 2007).

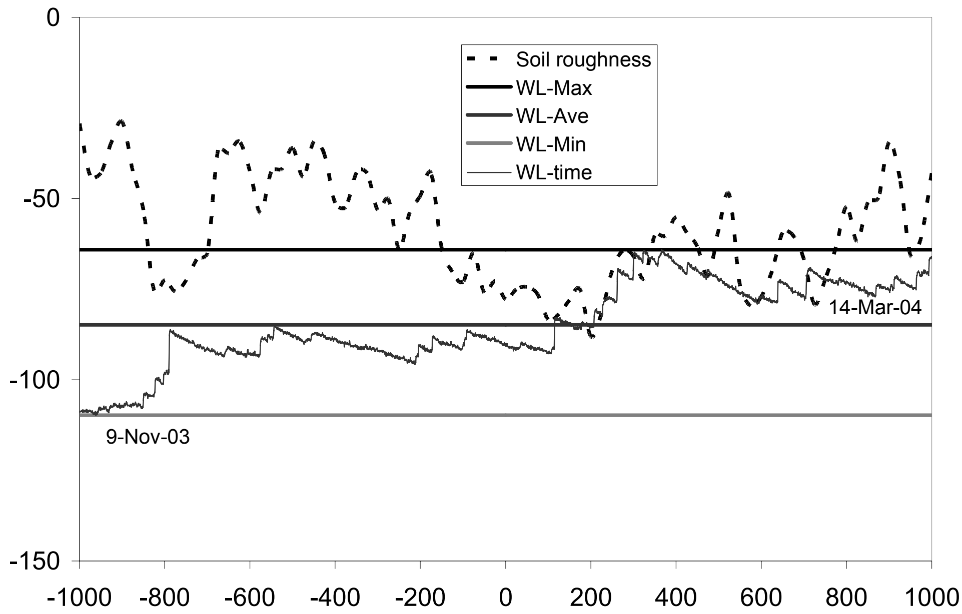

Figure 2. Water table variation WL-time (solid curve) and peat soil surface roughness (dashed curve). The vertical axis shows water level and soil surface height (both in cm). The horizontal axis shows horizontal distance (in cm) along the soil surface roughness profile (i.e. from -1000 to 1000 cm) as well as time (i.e. from 9-Nov-03 to 14 Mar-04). The position of the water table measurement is at the centre of this profile. These measurements are made every hour. The results for the period 9 Nov2003 until 14 March 2004 are shown (also along the horizontal axis). The three horizontal lines show the maximum (WL-Max), average WL-Ave) and minimum (WL-Min) water level. The percentage terrain flooding, thus, can be deduced from the combined roughness and water table measurements. (Source: Hoekman, 2007).

4.2 Reference data

Reference land use / cover maps

In a previous study a land use / land cover (LULC) map was made, which was revised in a parallel study (SarVision; 2007, 2008).

Ground survey data

Automated water table measurements are made by WUR (Hoekman, 2007) for the Mawas transect and by Delft Hydraulics at other locations of the EMRP area. Neither of these data sets have become available for this project. Fortunately, qualitative observations could be made by field teams providing valuable feedback on the quality of the tentative flood map produced early March 2008.

MODIS fire hotspot data

Fire occurrence for the dry seasons of 2006 and 2007 were checked using a previously developed dataset of daily moderate resolution fire hotspot data detected by the

MODIS sensor[1]. Each hotspot detection represents the centre of a pixel of approximately 1 km^2 containing one or more active fires within that pixel. It is important to note that not all actual fires are detected by these sensors due to cloud and smoke cover and intense fires burning when there is no satellite overpass. For example, vegetation fires occurring in dry grass or shrub cover in particular may spread fast and burn only briefly and hence go undetected, while peatland fires may burn for several days and have a higher chance of being detected.

See *table 2* for a full list of data satellite and reference used.

Table 2. Overview of satellite and reference maps used for the current assignment

Data source	(image) date	Remarks
PALSAR WB HH	11-11-2006 27-12-2006 11-02-2007 29-03-2007 14-05-2007 14-08-2007 29-09-2007 14-11-2007 30-12-2007	Used for flood monitoring
PALSAR FB HH-HV	06-11-2006	Used for Figure xx
PALSAR FB HH-HV	July 2007 SEA mosaic	Used for classification
Reference LULC map	SarVision 2007 LULC map	Used for classification (SarVision, 2007)
Reference LULC map	SarVision 2007 refined LULC map	Used for classification (SarVision, 2008)
Fire hotspot data	Database NASA/ University of Maryland MODIS hotspots; January 2004 – December 2007	

4.3 Image processing

Pre-processing

All image processing and post-processing was performed using ENVI 4.3 and IDL 6.3 software, including IDL programs and algorithms developed in-house.

PALSAR images were first radiometrically calibrated. As data was received in slant range each individual image was converted to ground range by means of registration to the SRTM elevation data set at 90 m resolution using an ortho-rectification software package developed by Gamma GmbH. Though speckle levels were low gamma-MAP speckle filtering was applied to improve flood mapping results.

1 MODIS active fire detection data courtesy of NASA/University of Maryland, 2002. MODIS Hotspot / Active Fire Detections. Data set. MODIS Rapid Response Project, NASA/GSFC [producer], University of Maryland, Fire Information for Resource Management System [distributors]. Data processed by SarVision.

Some pre-processed radar data are shown in Figures 3-6. Figure 3 is a colour composite based on all 9 WB images (using all 9 images maximises speckle reduction and enhances spatial details), in full swath. The project area is smaller and shown in Figure 4. In Figure 5 All 9 single date PALSAR Wide Beam sub-images of the project area are shown clearly revealing the temporal dynamics in radar backscatter. Figure 6 shows the changes in backscatter between the 8 image pairs, which is another way of depicting the temporal dynamics in radar backscatter.

Preliminary flooding detection

As explained in section 4.1 flooding or soil moisture increase may have an effect on the radar backscatter. Depending on the soil roughness and vegetation structure this may be a more or less strong increase or decrease. Using the previously produced LULC map (Figure 7a and 7b; SarVision, 2007) this dependence can be retrieved from the series of 9 WB radar images. This is illustrated in Figure 8, which shows the averaged temporal radar signature for each of the LULC classes. At the first date (i.e. 11-11-2006), the whole EMRP area just went through a severe dry season. (This can also be concluded from MODIS fire hot spot data, to be discussed later!). Therefore this date can be used as a baseline for dry conditions. Figure 8 shows that the LULC classes cover a small range of radar backscatter variation. In the following wet season the backscatter increases for certain classes and decreases for other classes. In the short dry season of 2007 (July-September) these signatures converge and in November 2007 these diverge again.

Of course these signatures are averages for a class. Within class variation can be calculated for each date (not reported) and this measure can be used as indication for temporal within class variation, which may be indicative for partial flooding (within a certain class, for a certain moment). To detect flooding these backscatter signatures can be tentatively thresholded (i.e. minimum increase/decrease with respect to the baseline date of 11-11-2007) to produce a series of flooding maps. For example, for the class “Forest Mosaics Degraded”, an increase of 2 dB may indicate flooding, while for the class ”Cropland/Rice Paddy Fields”, a decrease of 1.5 dB may indicate flooding. This preliminary result is shown in Figure 9. As yet no distinction is made between waterlogged and flooded. The map unit ’undeterminable’ indicates closed forest areas under a tentative flooding threshold. All thresholds have been refined after feedback from the EMRP field teams.

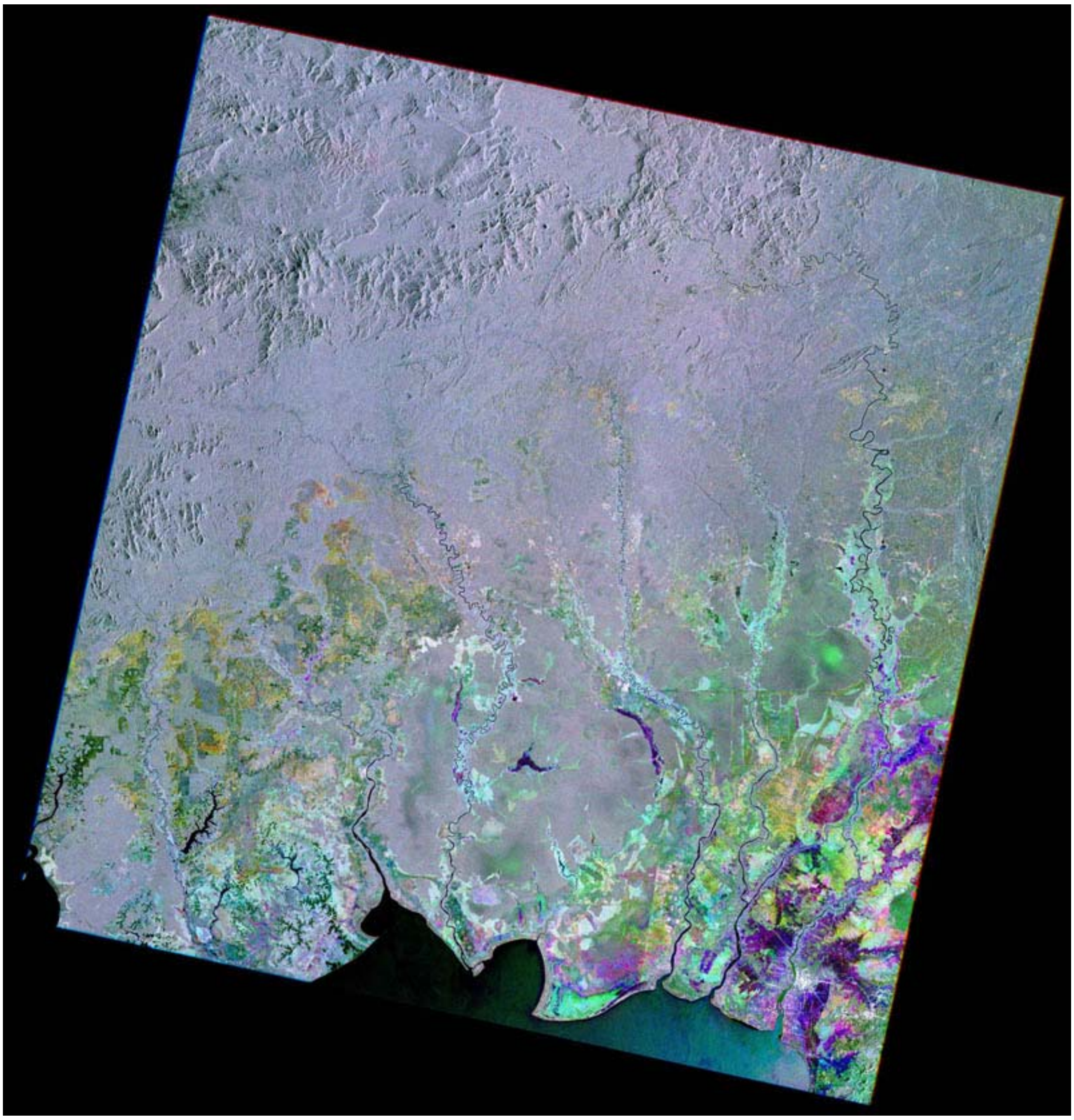

Figure 3. Colour composite of PALSAR WB HH images showing the full swath of the WB image (Red: average of first 3 images; Green: average of next 3 images; Green: average of last 3 images).

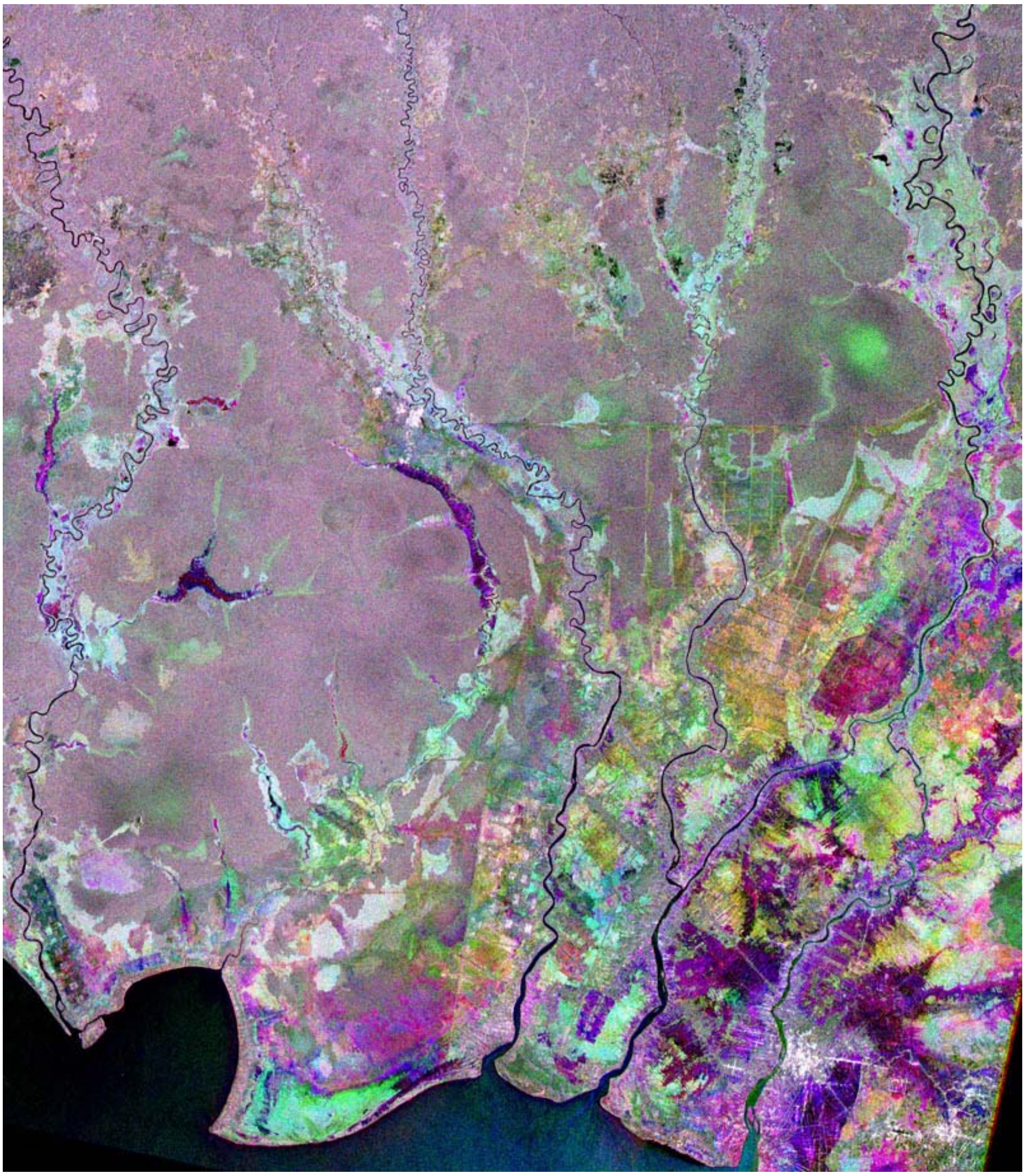

Figure 4. Colour composite: 20061111 – 20070329 – 20070929 of the project area (also shown on the cover of this report)

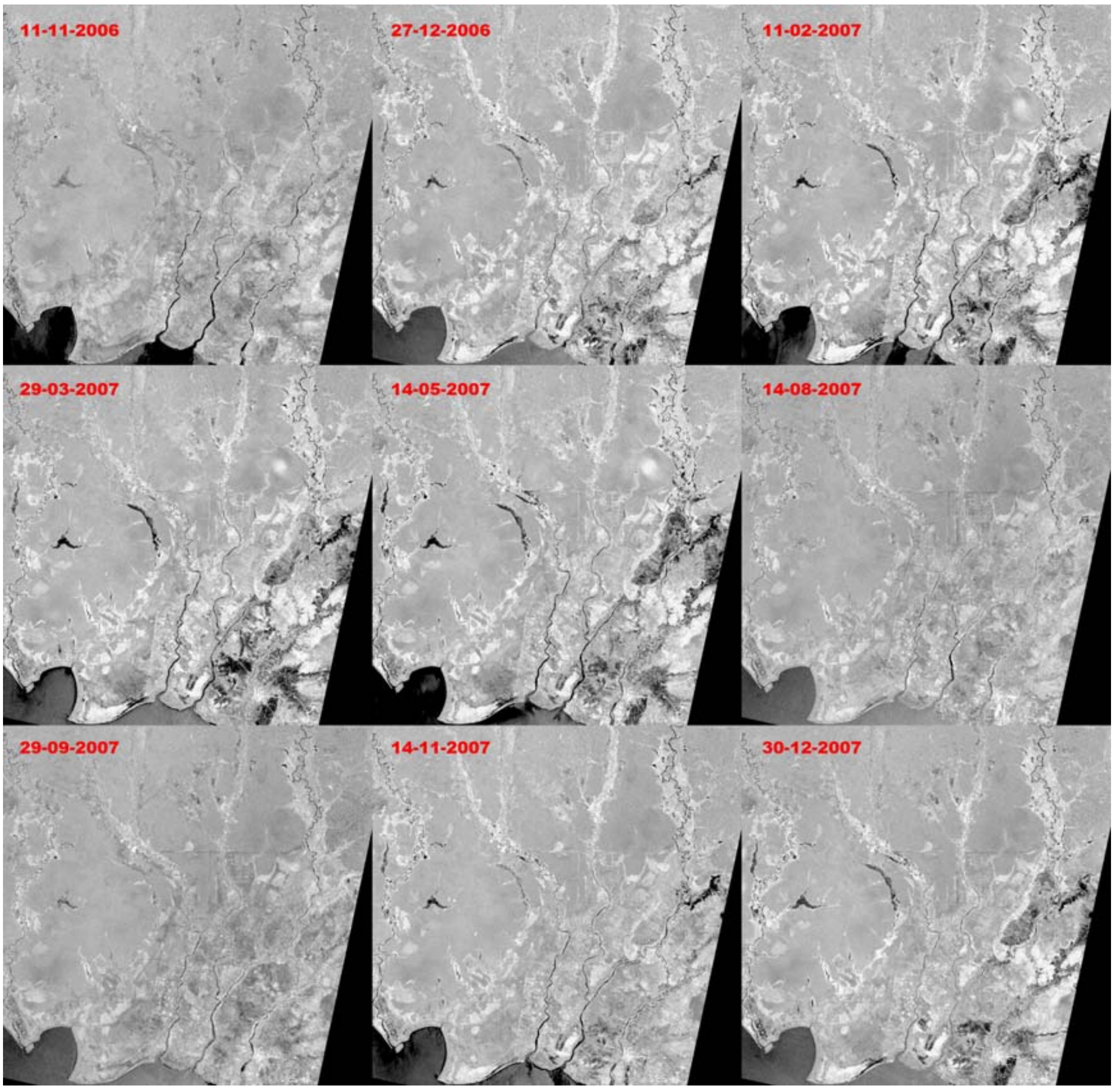

Figure 5. All 9 single date PALSAR Wide Beam sub-images of the project area showing temporal dynamics in radar backscatter.

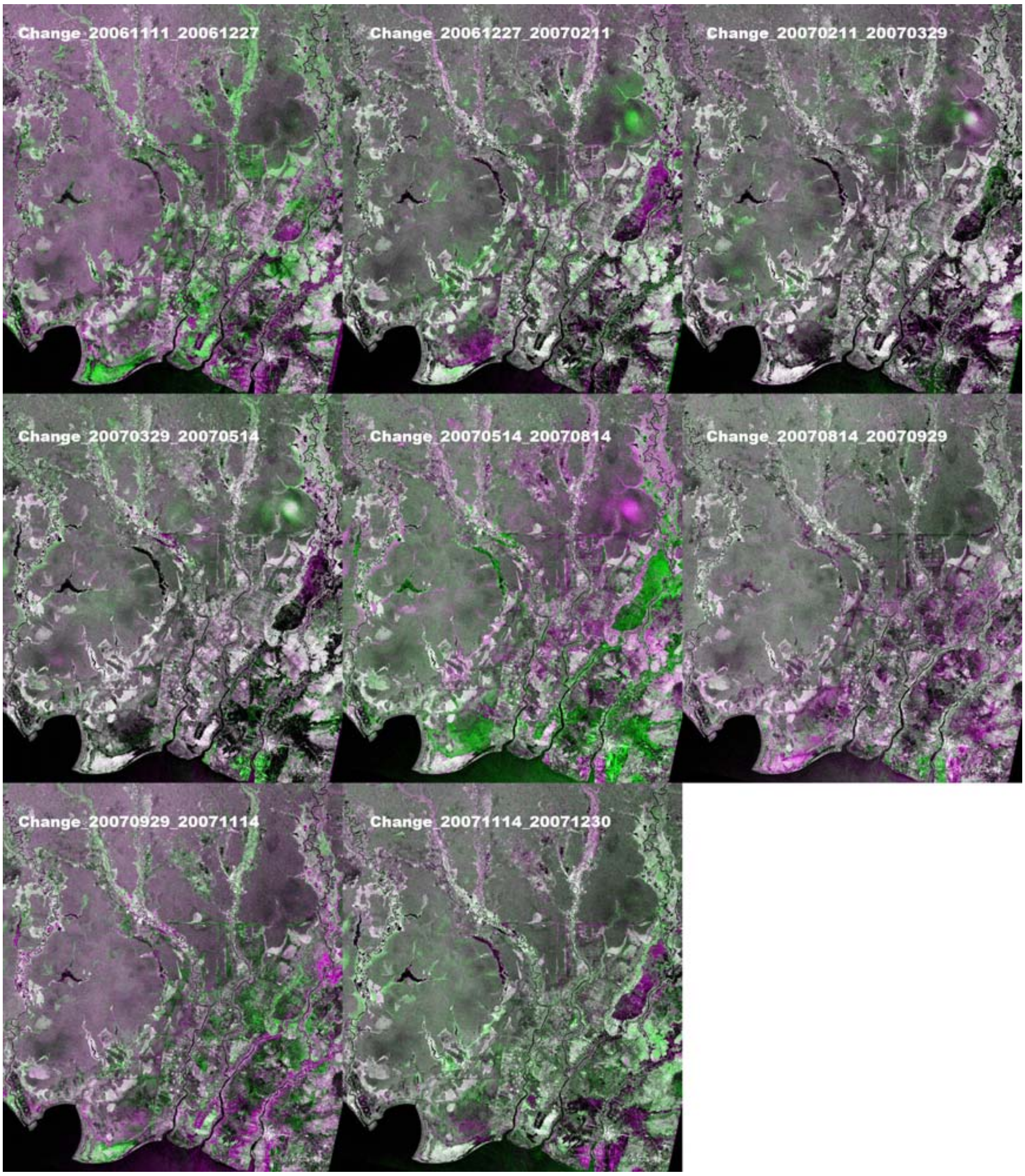

Figure 6. For the 9 single date PALSAR Wide Beam sub-images8 change images can be generated. The first change image is the change between the first and second image (of Figure 5), the second change image is change between the second and third image (of Figure 5). An increase in backscatter is shown in green and a decrease in purple. Grey indicates absence of significant change.

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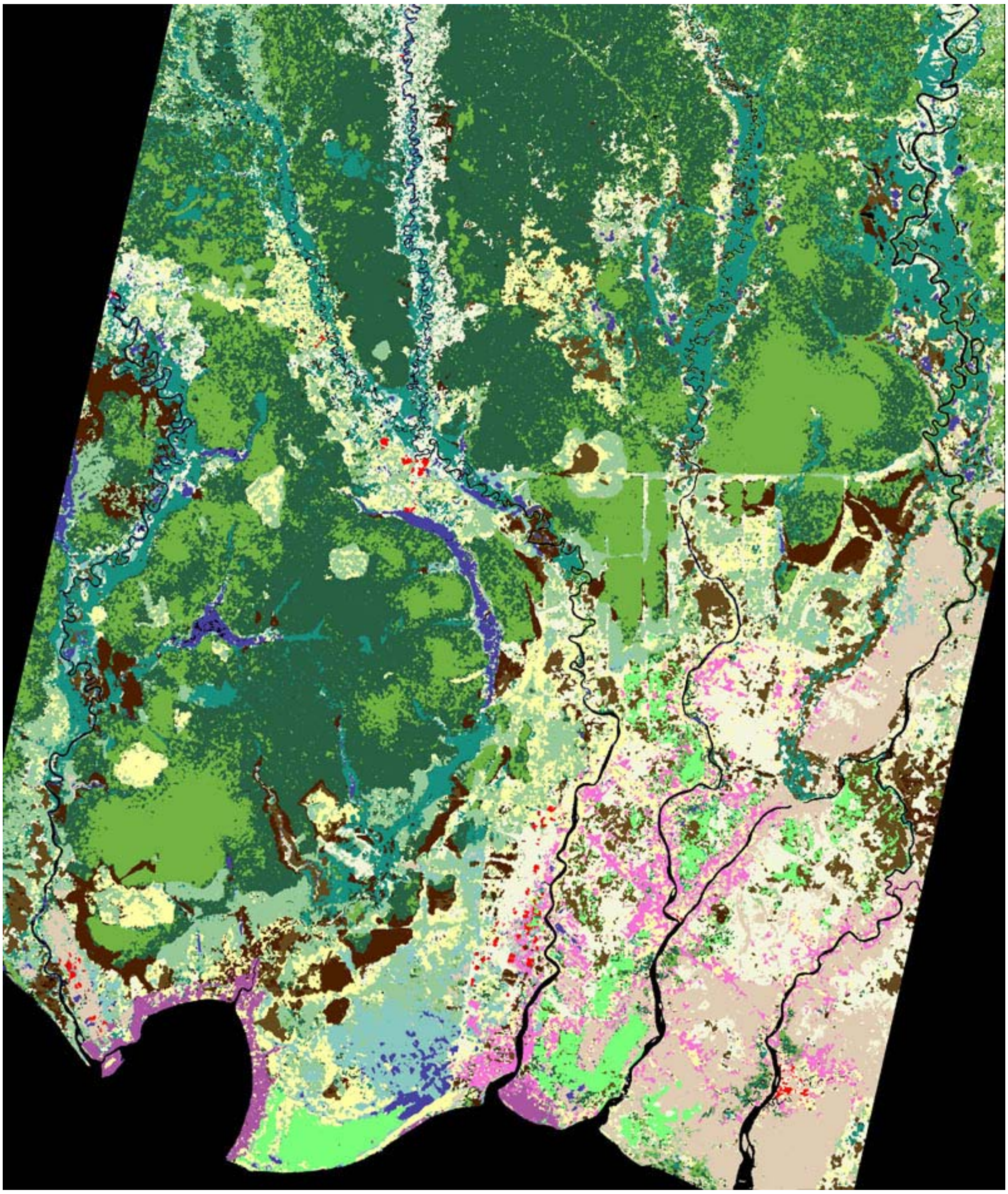


Figure 7a. SarVision LULC 2007 map (***Source: SarVision, 2007).***

Figure 7b. SarVision LULC 2007 map legend ***(Source: SarVision, 2007).***

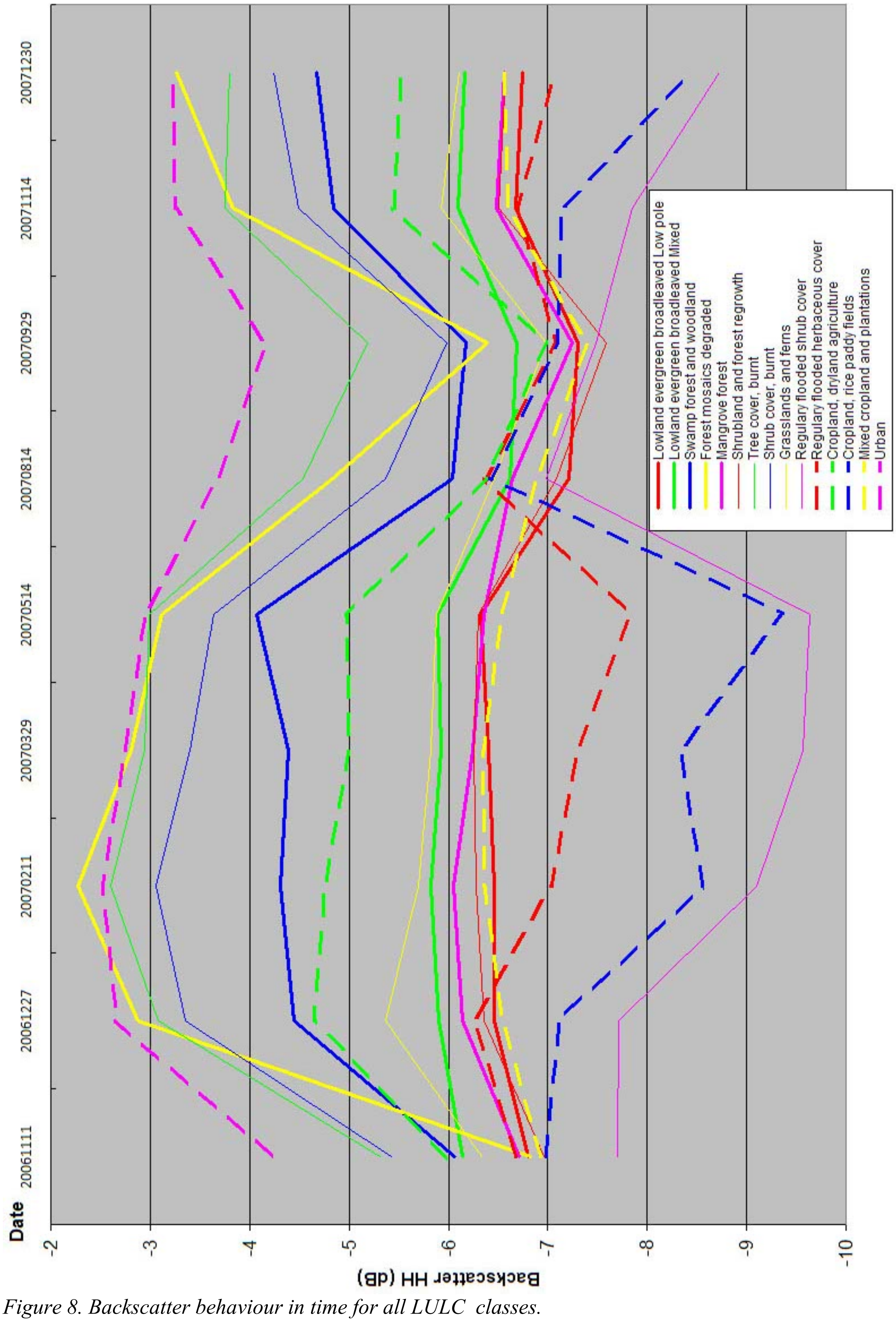


Figure 8. Backscatter behaviour in time for all LULC classes.

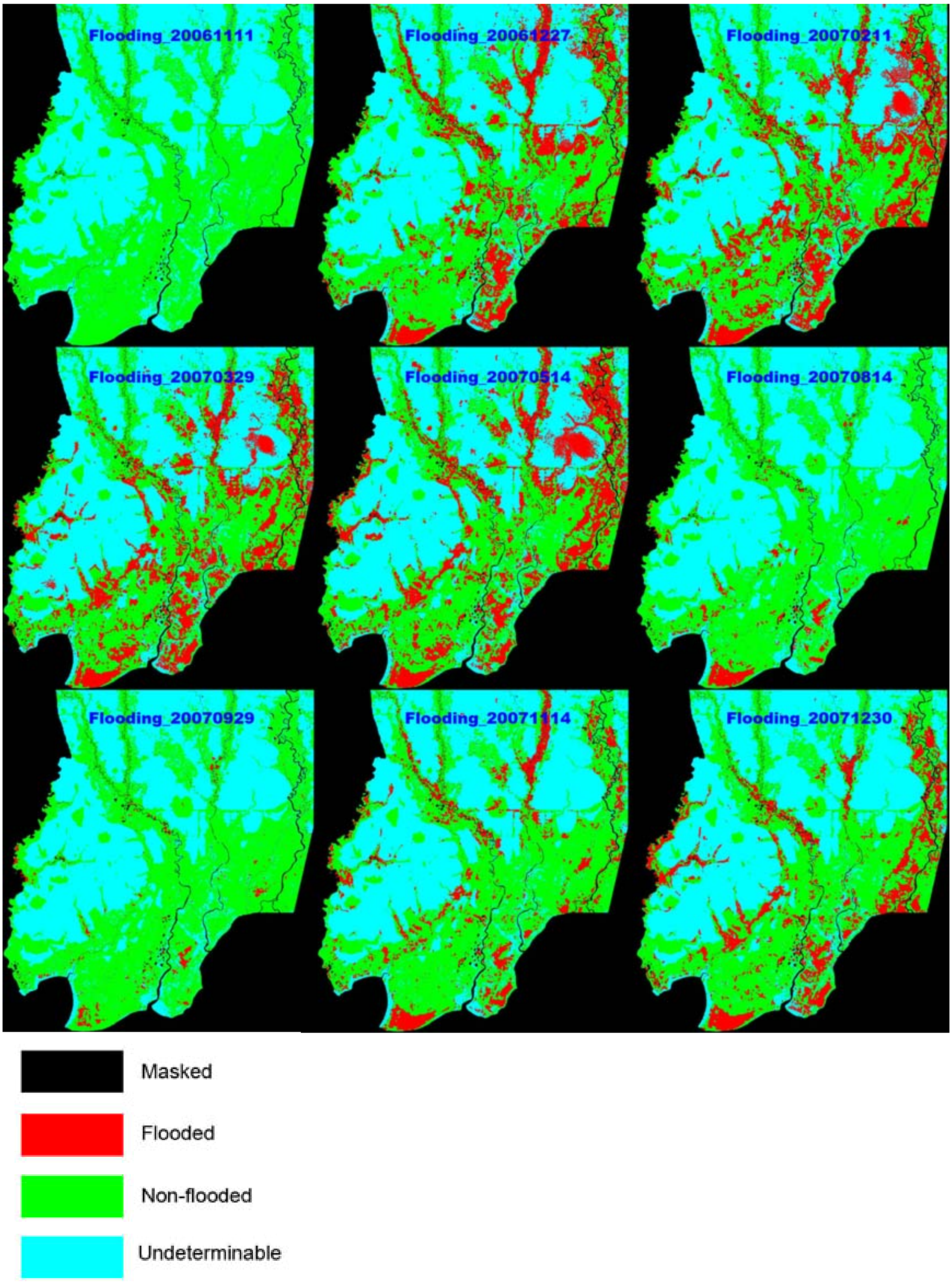


Figure 9. Tentative series of flooding maps. The map unit 'undeterminable' indicates closed forest areas under a tentative flooding threshold.

Feedback and response

From Figure 9 a flood frequency map was compiled by local EMRP staff. During a local workshop it was evaluated by local PU staff and field surveyors that have been in the field intensively in most of the area. Their comments are summarised in this flood frequency map shown here in Figure 10.

The main comment is that some waterlogged areas (i.e. wet soils but no standing water or only over a small part of the surface area), especially peatlands, are mapped as 'flooded'. A good example of this is the peatland in the NW part of Block A, which is mapped as being frequently flooded while water depth monitoring and modelling over the period (and common sense, as the area is dome-shaped and densely drained) indicates water levels are often high but flooding is rare.

Response: The physical interpretation of flooding detected by radar in peat land may be re-considered. As explained in Section 4.1 the flooding may be very patchy because of the extreme roughness of the soil surface. Patchy flooding can occur while the water level is still below the mean local soil surface height. An experiment to calibrate patchy flooding (or flooding percentage) is still ongoing in the Mawas area and may provide more insights in the future (Hoekman, 2007)

Other comments relate to Lake Manyun and the mangrove area.

Lake Manyun is a black water conservation area, characterised as a muddy lake covered with trees. This area is never flooded, which is an unexpected result.

Response: MODIS hot spot data over 2006 and 2007 show that at the indicated location no fires occurred, which makes sense. Even after fine-tuning of the algorithms and using the revised LULC map (see hereafter) flooding remains undetected. [Can the Lake Manyun location be double-checked by the EMRP team?]

Mangrove (no further remarks specified)

Response: The indicated areas of mangrove are too large. The mangrove is shown in grey (i.e. flooding frequency is unknown). The blue (frequently flooded) areas behind the mangroves have been identified by Leicester University as “strongly degraded heath forest”.

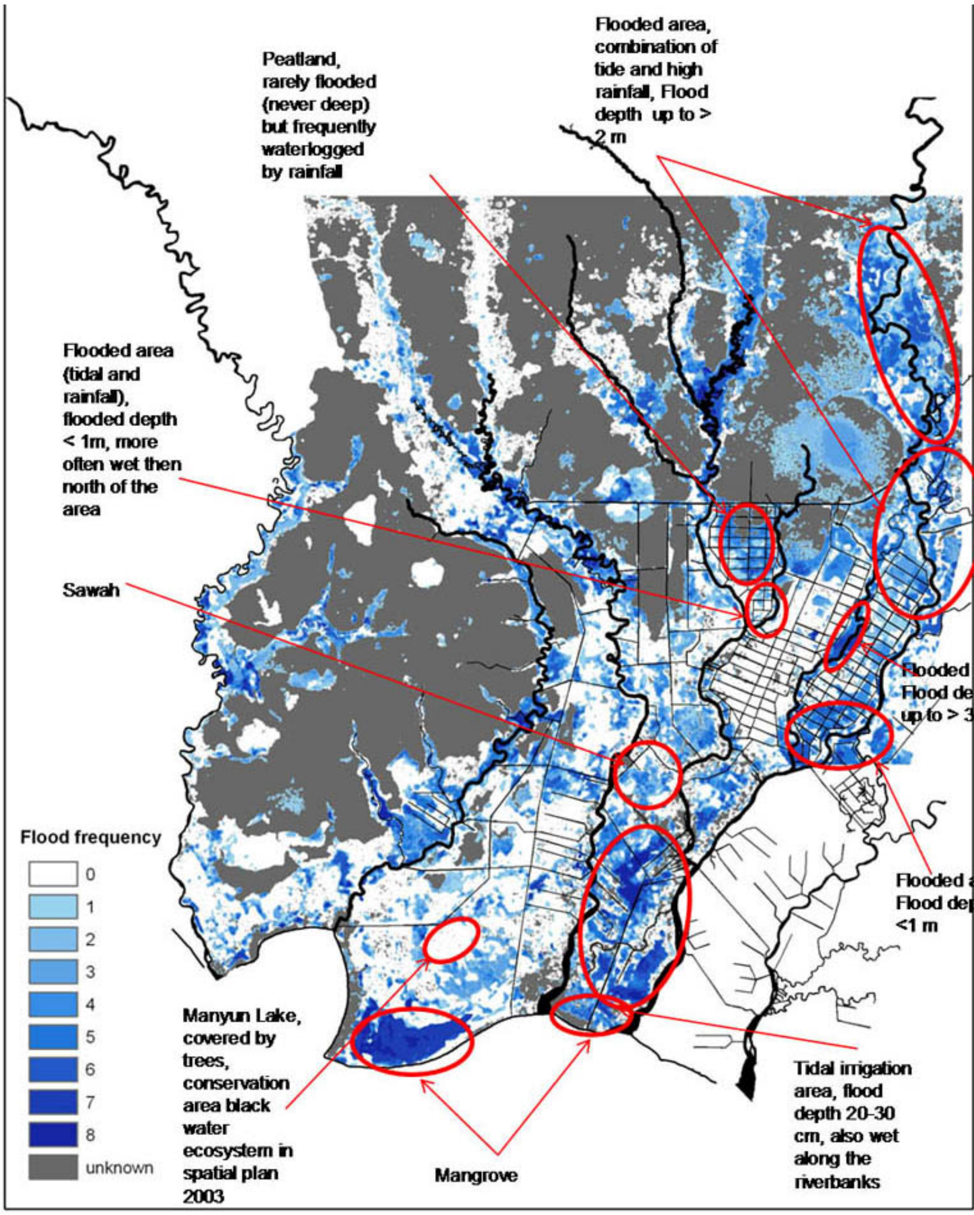


Figure 10. Tentative flood frequency map (produced by EMRP staff from Figure 9) with remark made by local PU staff and field surveyors.

5 Results

Draft flood monitoring maps

Using the revised LULC map (Figure 11a and 11b; SarVision, 2008) new averaged temporal radar signature for each of the LULC classes in the revised map (classes have been slightly re-defined). The resulting radar temporal signatures are shown in Figures 112a and 12b. Using the feedback comments fine-tuned values for the 'flooding' thresholds could be derived. Moreover the class "flooding unknown" is only applied to the mangrove area. For the peat swap forest flooding can be detected but should be interpreted as patchy flooding in hollows. Draft flooding and flood frequency maps are shown in Figures 13 and 14.

The year 2007 has been wetter than average and no severe drought conditions in the peat areas could be detected. The MODIS fire hot spot confirms this notion (Figure 15). In principle severe drought can be detected as was shown by previous research using 1997 JERS L-band radar images and the 6 November 2006 PALSAR FB image. An example is shown in Figure 16.

[Will be extended after May 2008 workshop Palangkaraya]

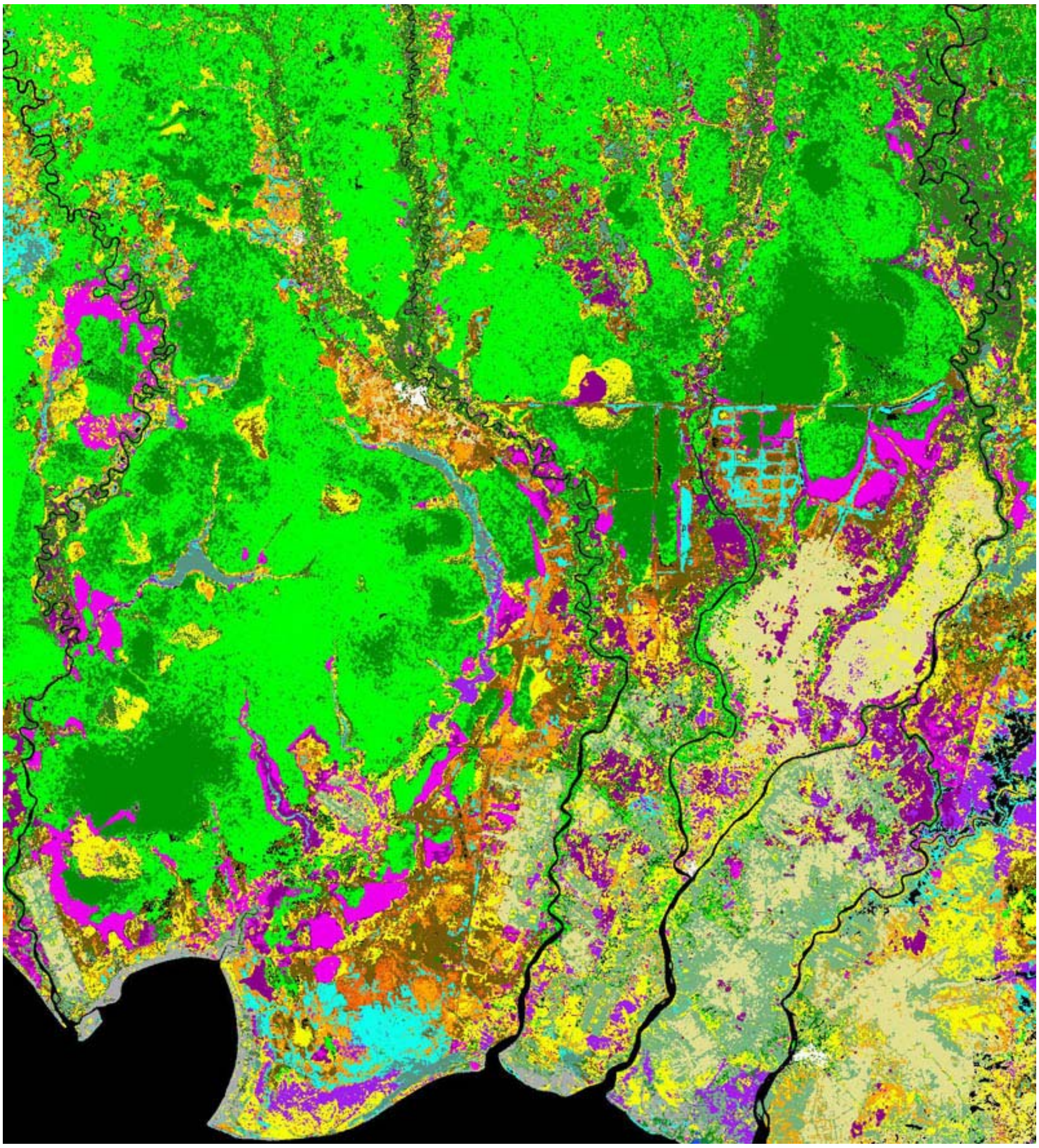


Figure 11a. Revised SarVision 2007 LULC map (Source: SarVision, 2008)

	Color	Indonesian legend	Revised map legend
12		Rawa	Sedges or Padag vegetation- regularly flooded
10		Wet pastures	Pastures- temporally flooded or wet
11		Pastures Dry- Savannas??	Pastures or ferns –non flooded
9		Bushes non flooded	Bushes non flooded
7		?	High bushes or secondary re-growths-woodlands dry
8		Belukar rawa-Swam bush	Bushes regularly flooded
19		Hutan Rawa sekunder or degraded ?	Low pole forest-high biomass seasonally water logged
4		?	Secondary or degraded peat swam forest regularly flooded or water logged
3		Hutan Rawa primer	Primary peat swamp forest
1		?	Riverine forest regularly flooded
13		Tanah Terbuka	Bare- burnt forest
14		Tanah Terbuka	Bare-burnt shrubs
15		Hutan Mangrove primer	Mangrove primary
16		Hutan Mangrove sekunder	Mangrove secondary
17		Pemukiman	Urban
18		Pertanian lahan kering- Perkebunan	Dry land agriculture
6		Sawah	Sawah or Irrigated agriculture
5		Water	Water
2		Tambak	Fish Ponds

Figure 11 b. Revised SarVision 2007 LULC map legend (Source: SarVision, 2008)

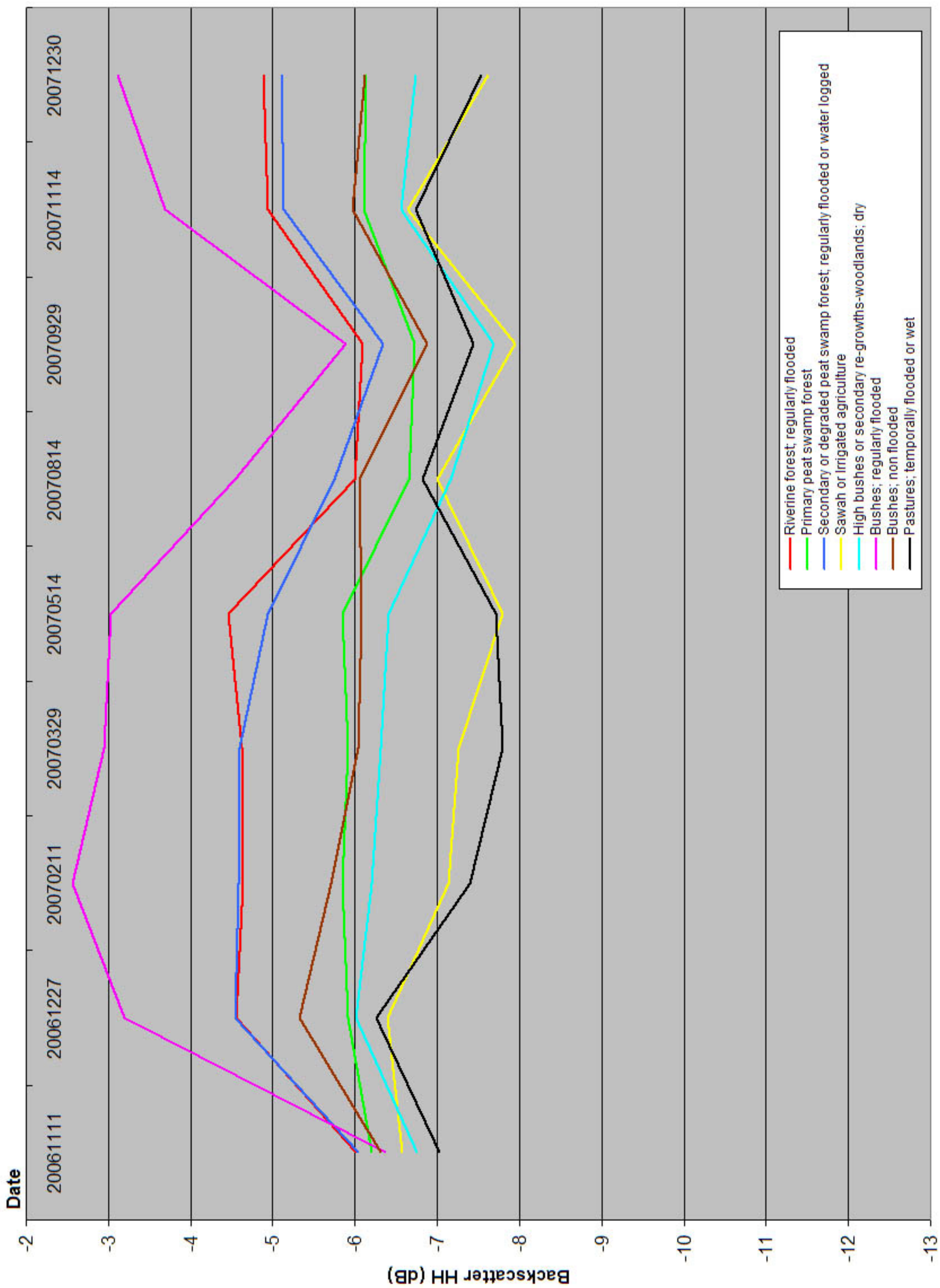


Figure 12a. Backscatter behaviour in time for several LULC classes of the revised map.

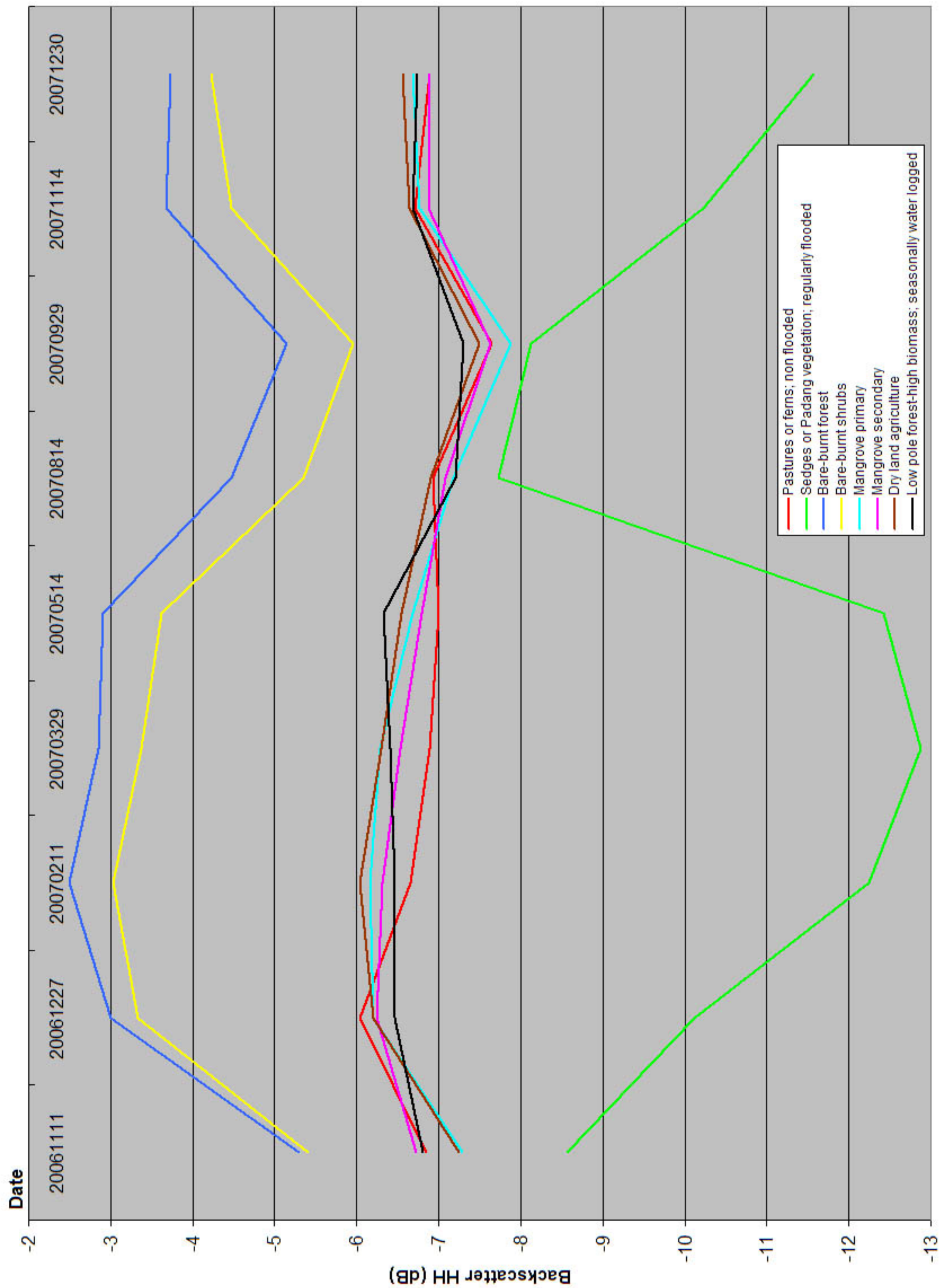


Figure 12b. Backscatter behaviour in time for the remaining LULC classes of the revised map.

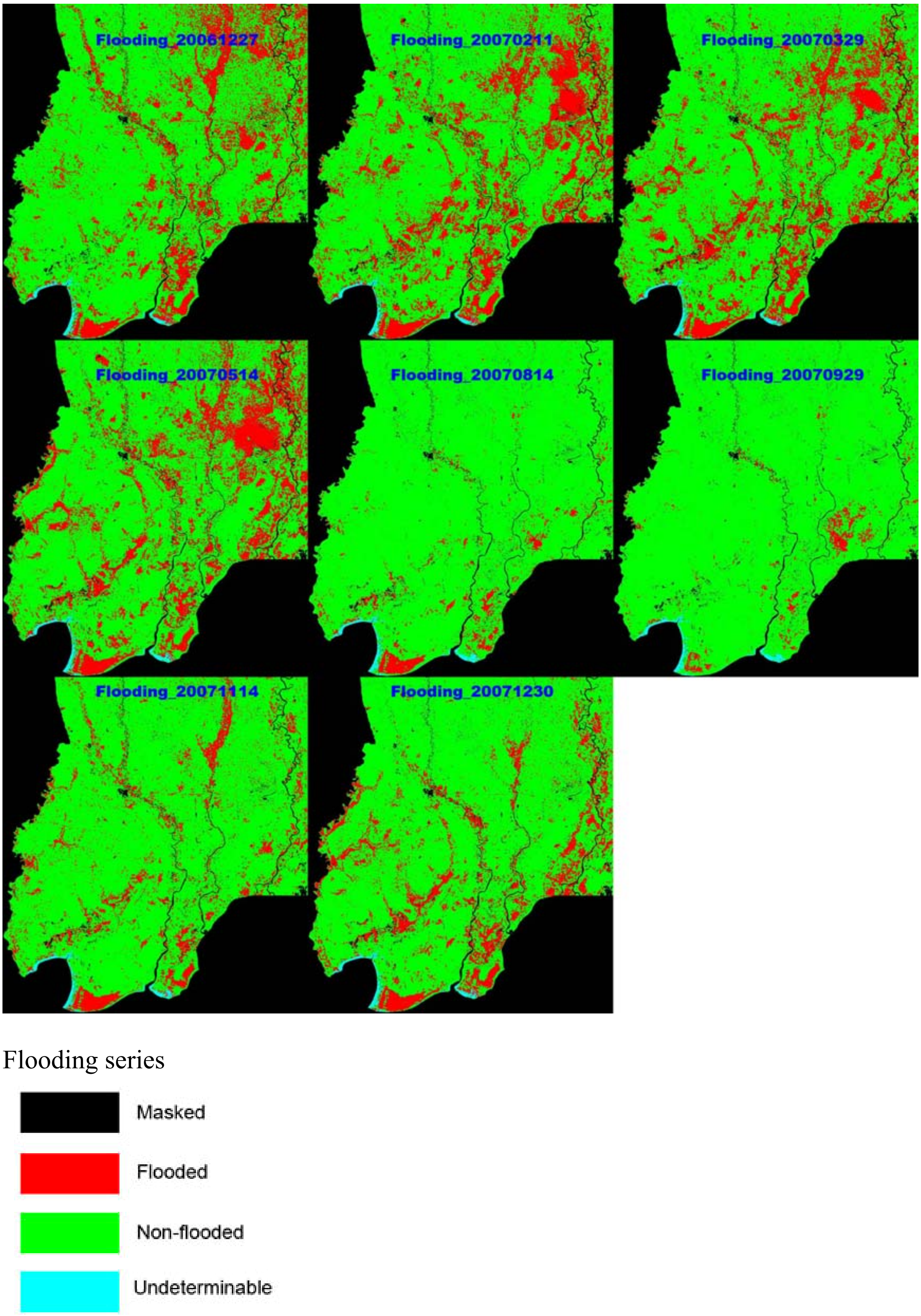


Figure 13. Draft series of flooding maps. Note that the map unit 'undeterminable' is now obsolete..

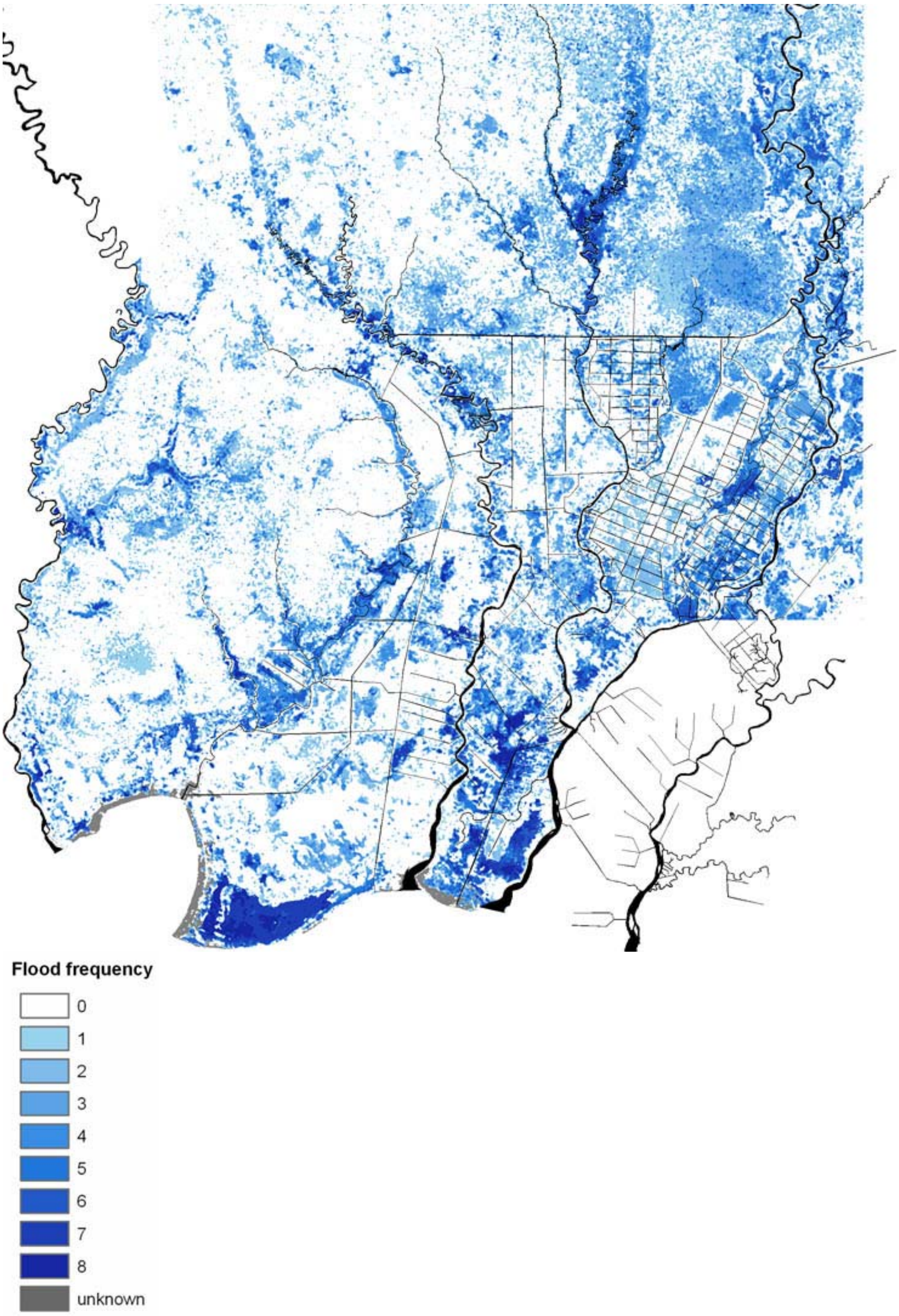


Figure 14. Draft flood frequency map (Produced from Figure 13).

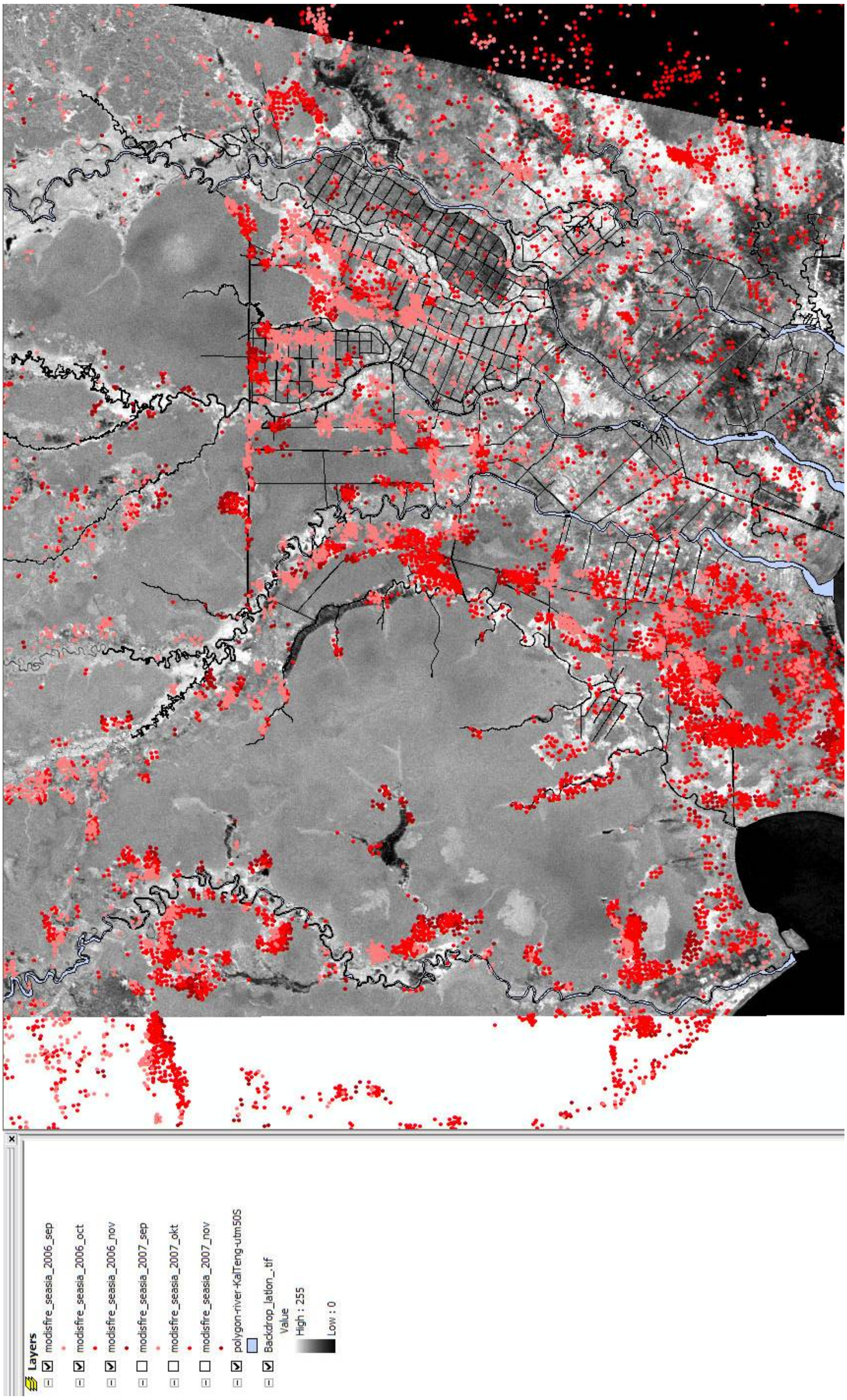


Figure 15a. MODIS hot spots for the 2006 dry season.

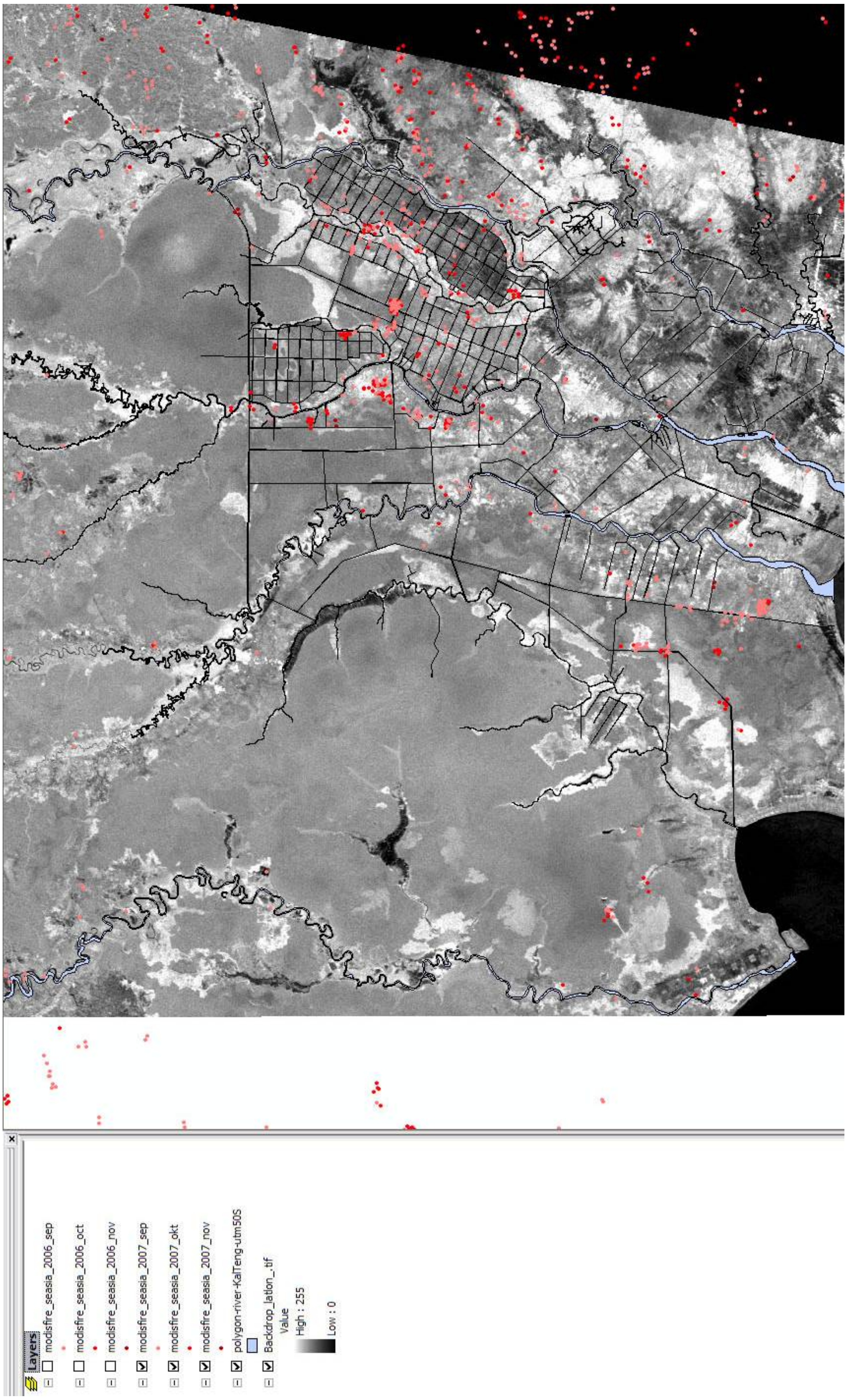
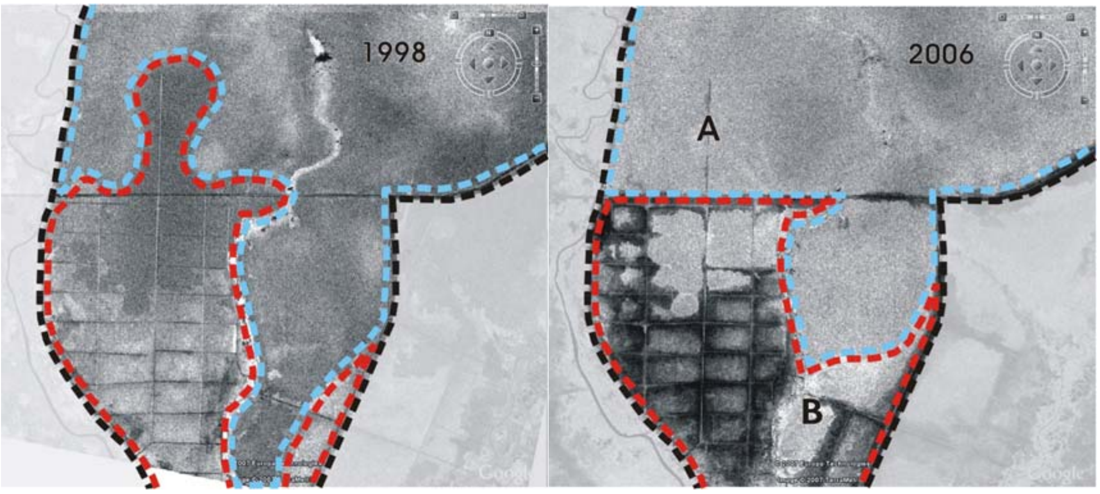


Figure 15b. MODIS hot spots for the 2007 dry season.



JERS 1998 **PALSAR FB HH polarisation; 6 Nov 2006**

Figure 16. Example peat swamp forest soil drought detection. Peat swamp forest degradation and restoration in Central Kalimantan in 1998 and 2006 is already perceivable from unprocessed L-band radar images. Within red dashed line: dark grey areas are excessively drained (canals are visible), light grey areas are forests degraded by fire. Inside blue dashed line: Intact and regenerating forest in light grey. Constructions of dams (A) resulted in restoration, while in (B) additional forest areas burned because of continued drainage.

6 Concluding remarks

[Will be finished after May 2008 workshop Palangkaraya]

Use of diver measurements as flood and drought mapping calibration points

Ground water level monitoring data in combination with soil surface height data can be used to evaluate and calibrate remote sensing derived flood and drought map series. The approach is based on the notion that any soil surface is more or less rough.

In practice the roughness is measured along transects using, for example, a water level device. In the example given in Figure X the height h(x) has been sampled every 20 cm along a 20 m transect centred at the location x=0 of the tube that contains the diver. The soil heights are measured relative to the top of the tube and, of course, the same applies to the ground water level measurements. Therefore, flooding (water height above soil height) can be inferred for every position along the transect. Because the soil surface is rough the percentage of flooding depends on ground water level and can be estimated.

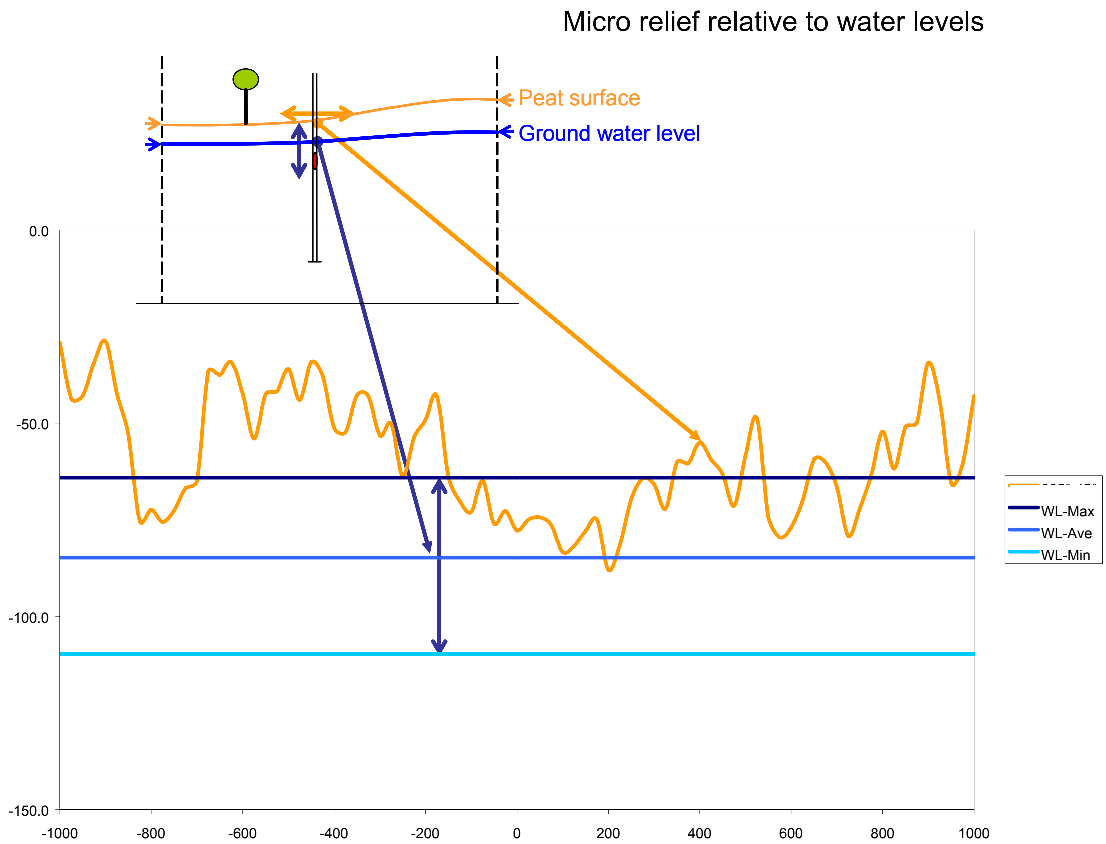


Figure 17. Measurement set up for ground water level measurements in rough soil characterised by patchy flooding (approach explained in text)

The Figure 10 shows a real measurement for a peat swamp forest. The soil surface height variation over 20 m is more then 50 cm. The ground water level measured over a period of 5 months shows a minimum with no flooding, an average with a very low flooding percentage and a maximum with approximately 40% flooding. Results from the ESA INDREX-2 field campaign (over the year 2004) in the Mawas peat swamp reserve generally show flooding percentages of 0% for the dry season and maxima of 20%-40% in the wet season.

In principle, empirical relationships between L-band radar data, vegetation cover, soil surface roughness and ground water level could be made. This is pursued in future research. For the time being an indirect approach is adopted where the temporal dynamics of radar backscatter (averaged over land cover types) is linked with wet and dry periods.

Irrespective which of the two methods is used, it is expected it will be hard for heterogeneous areas with complex vegetation structures to distinguish more than three moisture classes with L-band radar, viz. flooded, “normal” and severe drought. In the case of the very rough peat surfaces, flooding has to be understood as ground water level in excess of a certain flooding percentage. Severe drought did not occur in 2007 was its detection by L-band radar was demonstrated in earlier experiments for 2006 and, very dramatically, for 1997.

7 References

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SarVision, 2007, LULC

SarVision, 2008, revised LULC

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