COMPARATIVE STUDY ON C AND L BAND SAR FOR FIRE SCAR MONITORING

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ABSTRACT: During the drought caused by El-Nino in 1997 to 1998, Indonesia has experienced one of the greatest fire disaster ever observed in a tropical rainforest environment in SE-Asia. Following this event ESA and NASDA decided to set up a co-operation project to compare and combine the capabilities of the two SAR satellite sensors systems ERS-1/2 and JERS-1 aiming at an in depth analysis of this disaster. It was investigated whether these SAR systems can provide high resolution data on the pre-fire vegetation cover, the extent of the fire affected area and the damage to the vegetation. The results of the evaluation were quantitatively compared to a Landsat TM scene acquired during the fires and extensive field and aerial surveys.

1. INTRODUCTION

In the years 1997/98 fires started by men and driven by the exceptional El- Niño event evolved into uncontrolled wildfires which destroyed huge areas of rainforest and bush land in Indonesia. Fires raged on all major islands, Borneo, Sumatra and Irain Jaya. The total burnt area was estimated 9.7 Million hectares, economic costs of fire impact exceeded 10 billion USD (Asian Development Bank, 1999). These figures have to be taken with caution, since another study showed that fires destroyed more than 5 Million ha in East Kalimantan (Borneo) alone (Hoffmann, et. al., 1999). The extent and impacts of the forest fires have to be analysed in great detail to be able to prevent a similar disaster in the future and to adapt current land use practices, which are supposed to be a major cause of the fires (Schweithelm, 1998). Burnt areas have to be exactly located, the fire affected vegetation type and the degree of damage have to be known. Since the fire affected areas are vast and highly inaccessible the use of spaceborne remote sensing imagery is the tool of choice for such an investigation. Several studies were based either on visual interpretation of multitemporal Spot quick-look mosaics, Landsat TM images or the evaluation of NOAA-AVHRR and ATSR hot spot data (Liew, et. al., 1998; Fang and Huang, 1998). These investigations had the drawback of cloud cover and/or low spatial resolution to assess fire impact in the required detail. Active microwave SAR satellites like ERS-1/2 and JERS have the capability to penetrate clouds and to deliver images also during active burning when haze and smog hamper optical satellites. At the same time they provide a sufficiently high ground resolution for an fire impact assessment. ERS SAR coherence images were used successfully to assess burnt scars in Indonesia (Antikidis, et. al., 1998).

The joint ESA-NASDA cooperation on Indonesian forest fires aimed to compare the capabilities of the European ERS-1/2 C-band and the Japanese JERS SAR L-band satellites for vegetation and burnt scar mapping. Different processing techniques were applied to SAR images: 1.) Monotemporal approach: Deploying texture analysis techniques several land use classes and vegetation types could be identified in single ERS-2 and JERS SAR images. 2.) Multitemporal approach: ERS and JERS SAR PCA images were produced from multitemporal processing of images acquired before and after the fire event. 3.) Tandem missions: ERS SAR coherence images were produced from ERS-1 and ERS-2 tandem data to detect burnt scars.

2. METHODS

The study area (10.000 km^2) was located in the center of the province East Kalimantan on the island of Borneo in Indonesia. All major vegetation and land use types typical for Kalimantan are in this area: lowland *Dipterocarp* forest, heath forest, peat swamp forests and degraded forms of these. A significant proportion of formerly forested land has been invaded by the fire resistant grass *alang-alang*. 8 ERS-2 SAR Precision Images (PRI) acquired between August

1997 and November 1998 over the study site were calibrated, co-registrated, undersampled (pixel size 25x25m), geocoded (UTM Zone 50 S, WGS-84) and speckle filtered before further processing. For two time points, before and after the fires, JERS images were evaluated. To cover the study site 4 adjacent JERS images had to be mosaicked. Each image was calibrated, undersampled (pixel size 25x25m), geocoded, and speckle filtered before further processing.

Vegetation mapping. Unprocessed ERS and JERS SAR images show little thematic information (**Fig 1A**). In flat terrain ERS SAR texture images were successfully used to discriminate several different vegetation classes based on the structure of the canopy and water content of the leaves (Siegert and Kuntz, 1999). To compare both SAR sensors for vegetation mapping SAR color texture images were made by deploying a Lee speckle filter and two different texture filters (15 x 15 and 31 x 31 variance filter) to ERS-2 and JERS images. The results of three filter operations were combined into a single RGB color image by assigning each filter product a different RGB color channel (**Fig 1C+D**).

Burnt scar and fire impact mapping. The analysis of multitemporal processed ERS-2 images acquired before and during the fire season allow for the detection of burned scars due to a significant reduction in the backscatter signal after burning (Siegert and Rücker G, 2000). To highlight the differences in backscatter in a multitemporal set of two ERS-2 and JERS SAR images acquired before and after the fires a Principal Component Analysis (PCA) of the two images was calculated. An artificial color image product (SAR PCA image) was made in which channel two of the PCA was combined with the two original speckle filtered SAR images. Burnt scars (decrease in backscatter) show up in orange to red colors, while unburnt vegetation appears in blue colors (**Fig 1E**). Burnt scars can also be detected from SAR images in ERS-1/2 SAR tandem mission data. In particular phase coherence calculated from tandem ERS image pairs (one day apart) were used to discriminate forested areas from non-forested areas, i.e. burnt scars. Interferometric Land Use images (ILU image) were produced by ESRIN, Italy, were evaluated. In this artificial color image orange colors indicate burnt areas or open land (e.g. grasslands), while green colors indicate alive vegetation and forests (**Fig 1F**). A Landsat TM scene acquired in August 1992 served as reference for vegetation mapping (provided by GTZ, German technical co-operation), another Landsat TM scene acquired end of March 1998 served as reference for burnt scar mapping (provided by TRESS). The TM images were contrast enhanced and geocoded, for visual interpretation bands 5,4,3 (RGB) were selected (**Fig 1B**). All satellite images were imported into Arcview GIS and visually interpreted for vegetation types before the fire and burnt scars and fire impact. Mapping scale was 1:200,000. Validation of the interpretation results was done during four ground surveys conducted between April 1998 and September 1999 and three aerial surveys. All travel routes were recorded by GPS. Red tracks in **Fig 1A** indicate ground surveys, yellow tracks aerial surveys.

3. RESULTS

3.1 Vegetation classification

In processed ERS SAR texture image images six basic vegetation and land use types could be identified in the study site: closed *Dipterocarp* and heath forests, wetlands, degraded forest types (by logging, shifting cultivation), grasslands (*alang-alang*) and land clearance. **Fig 1C+D** show the ERS and JERS SAR texture image respectively. With field knowledge a classification key was established: dark green represents areas covered with low vegetation, green/purple (disturbed) lowland *Dipterocarp* forest, pink strongly disturbed forests in hilly areas, black represents water surfaces or flooded wetlands.. **Fig 2A** shows the vegetation classification derived from a pre-fire ERS SAR texture image. A comparison with the Landsat TM scene (**Fig 1B**) shows that these basic vegetation types are readily recognized in ERS/JERS SAR texture images. In the TM image dark green indicates peat swamp forest, green Dipterocarp forest, light green degraded vegetation and red grasslands and clearings. **Fig 2B** shows the JERS SAR texture image vegetation map. The same types were identified in ERS and JERS images with more than 80% agreement between the two sensors (**Fig 3**).

3.2 Burnt scar detection and fire impact.

Ground surveys during and after the fires suggested that depending on the type of vegetation and fire impact it was possible to discriminate 4 different damage levels in SAR PCA images: 25–50%, 50–80% and >80% (in grasslands or peat swamp forests) damage to the vegetation (Hoffmann, et. al., 1999). The first two were found in logged over *Dipterocarp* forests, the third class was typical for strongly degraded forests and *alang-alang* grasslands. A fourth class (>80%) was found in peat swamp forests where almost 100% of the trees have been killed but most of the above ground biomass was left unburnt. **Fig 2C+D** show burnt scar maps based on the evaluation of multitemporal ERS-2 and JERS PCA images made from two orbits before and after the fires. Colors indicate damage levels: yellow: 25-50%, orange 50-80%, red and brown (peat swamp forest): >80% damage. 90% of the study site has been affected by fire. **Fig 2F** shows the corresponding Landsat TM image acquired during the fire disaster. Red indicates burnt surfaces, green unburnt vegetation, huge clouds of haze originate from peat swamp fires. The total burnt area was underestimated in the JERS PCA image (71% as compared to 90%). 36% in JERS were classified as 25-50% damage as compared to 8% in ERS. More worse was the result of the ERS ILU image: the burnt surface was underestimated by a factor of three as compared to the ERS PCA image product (**Fig 2E,** blue: water, green: unburnt vegetation, yellow: 25-50%, red: >80% damage. Compared to Landsat TM the total burnt area was overestimated in the ERS image (110%) and underestimated in the JERS (88%) and ERS ILU image (30%). Since the TM image does not show the final stage of fire damage (fires continued till end of April 1998) the ERS PCA result represents the most accurate figure on the total burnt area (note the large block of peat swamp forest -upper left in TM image- which was destroyed by fire afterwards).

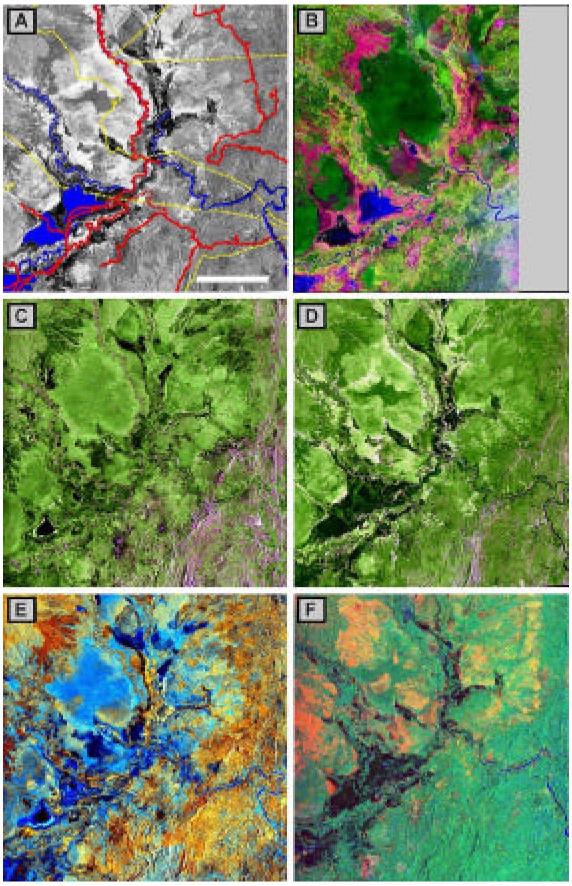

Fig 1: Different SAR image products. A. Calibrated, mosaicked speckle filtered JERS image. Bar: 25km. B. Landsat TM image (8-1992). C. ERS texture image (8-1997), D. JERS texture image (10-1998). E. Multitemporal ERS PCA image. F. ERS ILU image (D-E. see text for description).

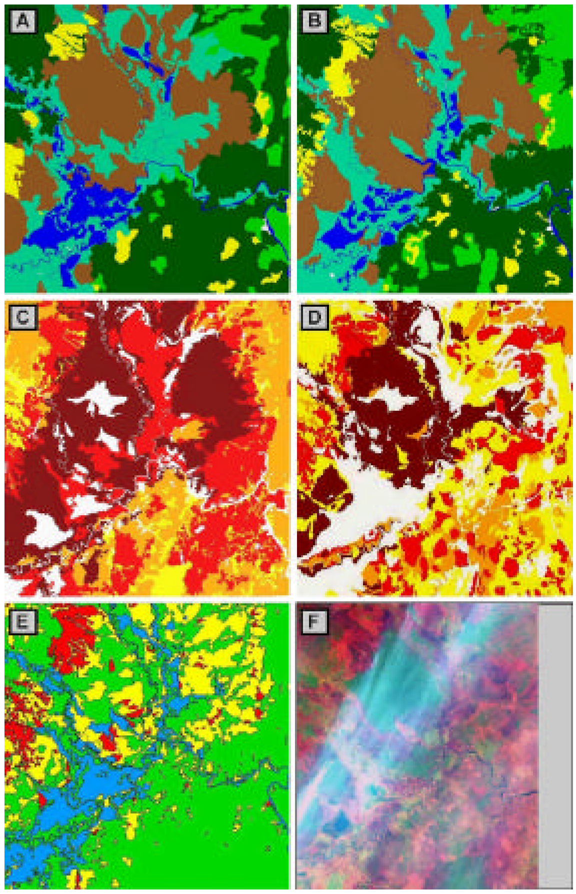

Fig 2: Classification results. A. ERS, B. JERS vegetation classification. C. ERS, D. JERS, E. ERS ILU burnt scar map. F. Landsat TM (March 1998); RGB: 5,4,3 (see text).

4. DISCUSSION

Recent vegetation and land use maps are not available for many tropical rainforest regions and images from optical satellite are difficult to obtain when needed. To asses fire impact it is necessary to have up-to-date information on the pre-fire vegetation cover. In this study both SAR sensors proved to be suitable for basic vegetation mapping in a tropical rainforest environment. Although ERS and JERS operate at different wavelengths it was not possible to discriminate more or different types in JERS than in ERS images. As a consequence no synergy between both sensors was found. Burnt areas were clearly visible in SAR PCA images due to a marked decrease in backscatter after the removal of the vegetation cover by fire and subsequently a higher contribution of backscatter from soil. Under dry weather conditions the backscatter signal was very stable over time (Siegert and Rücker, 2000) and it was possible discriminate different levels of fire impact, i.e. to estimate the amount of dead, unburnt biomass. This information is of significant importance to calculate greenhouse gas emissions and to assess of future fire risk. Classification errors included different weather conditions between successive orbits, other reasons for deforestation than fire and drought effects. Weather effects could be excluded for several ERS images, since 5 weather stations reported constant dry conditions from January to April 1998. The analysis of ERS images acquired during wet meteorological conditions showed that rain had a strong impact on radar backscatter and thus classification results.

Especially the discrimination of the fire impact classes became obsolete. Wet soil has a higher dielectric constant, leading to a higher radar reflectivity resulting in false class assignment in low vegetation types as grass-, wet and bushlands where soil contributes to the backscatter signal. In peat swamp forests fires caused vegetation death almost without altering vegetation canopy structure. No change in backscatter occurred in image pairs acquired under dry/wet conditions. Rainy weather conditions during image acquisition also explain the weak performance of JERS for burnt area assessment. While burnt-unburnt classification accuracy was 5% for ERS SAR PCA images calculated from two images acquired during dry conditions it was more than 20% for the JERS SAR PCA image calculated from one image acquired during dry (8-1997) and one during wet conditions (10-1998). A similar problem occurred with ILU images. A low interferometric correlation usually indicates dense vegetation since over forests the backscatter signal is dispersed by volume scattering and changes occur between the two dates of image acquisition due to e.g. leave motion. High correlation occurs on open soil (or burnt surfaces) because of surface backscattering. However if the soil is soaked with water during one time point and dry during the other or the vegetation was only in part consumed by the fires (e.g. peat swamp forest) this prediction becomes obsolete. Burnt area identification will be probably more reliable in JERS and ERS ILU images acquired under stable, dry weather conditions. However, this conjecture could not be verified since for the study site no suitable image pairs were available.

REFERENCES

Asian Development Bank, 1999, Planning for fire prevention and drought management project. Final Report: Asian Development Bank TA 2999-INO

Hoffmann A., Hinrichs A. & Siegert F., 1999, Fire damage in East-Kalimantan in 1997/1998 related to land use and vegetation classes: satellite radar inventory results and proposal for further actions. GTZ-IFFF/SFMP

Schweithelm J., 1998, The Fire this Time. An Overview of Indonesia's Forest Fires in 1997/98. WWF Discussion paper. WWF Indonesia

Liew S.C., Lim, O.K., Kwoh, L. K. & Lim, H., 1998, A Study of the 1997 Forest Fires in South East Asia using SPOT Quicklook Mosaics, CRISP, National University of Singapore. 1998 IGARRS Symposium, 6 - 10 July 1998, Seattle

Fang M. & W. Huang, 1998, Tracking the Indonesian Forest Fire using NOAA-AVHRR images, Int. J. Remote Sens. Vol. 19, No.3, 387-390

Antikidis E., Arino O., Laur H. & A. Arnaud, 1998, ERS SAR coherence and ATSR hot spots: a Synergy for Mapping Deforested Areas. The Special Case of the 1997 Fire Event in Indonesia,ESTEC Workshop, 21-23 October 1998 Nether-lands, ESA SP 441

Siegert F. & Kuntz S., 1999, Monitoring deforestation and land use in Indonesia with multitemporal ERS- Data. Int.J.Rem Sensing, Vol. 20, No.14, 2835-2853

Siegert F. & Rücker G., , 2000, Use of Multitemporal ERS-2 SAR Images for Identification of Burned Scars in South-East Asian Tropical Rainforest, Int.J.Rem.Sensing