REDD FAST LOGGING ASSESSMENT & MONITORING ENVIRONMENT (REDD-FLAME): EARLY DETECTION OF DEFORESTATION USING SAR

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ABSTRACT

This paper presents the outcome of the REDD-FLAME project: a system capable of monitoring tropical and sub-tropical forests using high-resolution, cloud-penetrating radar data (and optical imagery), acquired by Earth Observation satellites. By focussing on early detection of logging activities, the system provides the means to quickly identify the first signs of deforestation and thus contribute to the objectives of the UN-REDD (Reducing Emissions from Deforestation and Forest Degradation) Programme by facilitating timely intervention and thus reducing unauthorised tree loss in the context of carbon accounting.

The main results of the project are presented. REDD-FLAME has proven to be a reliable means of identifying small-scale deforestation events, complementing MRV actions with a continuously proactive tool for reducing carbon emissions. The system is ready to exploit Sentinel data as soon as they become available.

1. INTRODUCTION

On signing up to the UN-REDD (Reducing Emissions from Deforestation and Forest Degradation) Programme, a country commits to reducing its rate of deforestation in order to limit associated carbon emissions. This is defined by determining a baseline rate of tree loss, which can be projected into the future as the *business as usual* scenario, and then setting a target that is some lower rate, to be achieved by some specified point in the future. For example, Mozambique seeks to reduce its rate of deforestation from 0.58% per annum in the period 1990-2004 to 0.21% by 2025 [1]. Progress towards this target can be assessed periodically by the well-known MRV (Monitoring, Reporting and Verification) process.

Small-scale forest disturbance is a precursor for widespread deforestation, since it advances the frontier of human encroachment and facilitates access for larger plant, and its early detection would allow the relevant authorities to make timely interventions, thereby improving sustainable control of forest resources and helping limit tree loss. Forest saved through such interventions would contribute to the improvement over the *business as us ual* scenario for carbon emissions required to achieve commitments under REDD and thus secure carbon payments.

The REDD Fast Logging Assessment & Monitoring Environment (REDD-FLAME) is a system to identify small areas of new activity within forest areas as early as possible. As such, it has the potential to operate continuously as part of a national forest monitoring process, proactively helping to reduce the overall volume of forest lost.

The system uses repeat acquisitions of high and very high resolution (VHR) SAR data, whose cloud-penetrating properties are of major benefit in the tropics and sub-tropics, as well as optical data, for change detection. It can be seen as an add-on to (semi-)operational low- to mid-resolution systems, for monitoring ‘hot-spots’ (or REDD project areas) considered at highest risk of deforestation. It is not a wall-to-wall mapping system. Typical targets of change detection are shifting cultivation, selective logging, airstrip construction and illegal mining.

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2. SERVICE CONCEPT

Based on the findings of a User Consultation, the REDD-FLAME Service Concept was developed as shown in Fig. 1. This is based on three Service Options, which are selected according to user requirements.

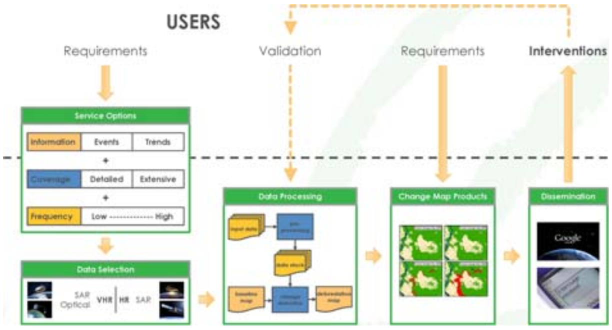

Figure 1. REDD-FLAME Service Concept

Events Information provides the location of suspected deforestation phenomena occurring during the most recent interval between acquired images and represents the core service offered by REDD-FLAME. Trends Information shows patterns of cumulative land cover change over extended periods, a service possible as a consequence of repeatedly providing Events Information: the output is a refinement of the earlier 'preliminary' information.

Coverage options represent trade-offs between data resolution, areal extent and cost, whilst the selected Frequency of observation will depend on the temporal nature of the phenomena to be detected.

Choice of appropriate satellite data is determined by the selected Service Options, and these are then processed into change map products for dissemination by means appropriate to individual users. Feedback is a critical element of the system that enables continuous improvement of the change detection parameters.

The SAR data processing chain, developed by SarVision and Wageningen University, is based on simultaneous spatio-temporal filtering of one or two polarisations, and was applied equally well to RADARSAT-2 and TerraSAR-X data. It can be easily adapted for future use with Sentinel-1 data. The optical data processing chain was developed by RSS for use with RapidEye data and involves segmentation and spectral mixture analysis [2]. A preliminary requirement of both chains is a forest/non-forest benchmark map: in the absence of pre-existing maps, these were produced from RapidEye mosaics, using a minimum mapping unit of 0.5ha (according to the FAO forest definition). Thereafter, once initial minimum time series of SAR data had been accumulated, maps showing the most recent changes were produced soon after new data were received (Fig. 2).

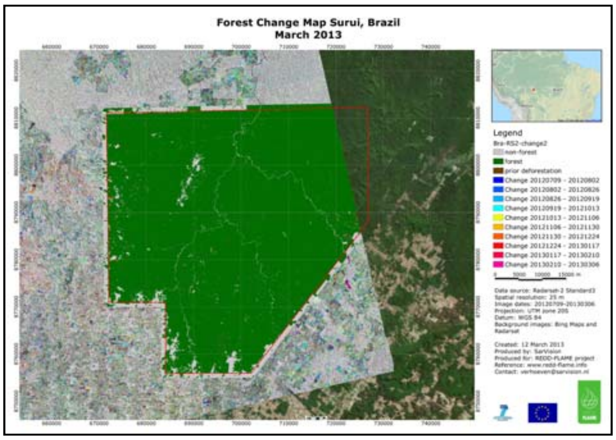

Figure 2. Example of REDD-FLAME Change Map Product for Sete de Setembro Indigenous Land, Brazil

3. CHANGE DETECTION EXAMPLE

The Mecuburi Forest Reserve in Nampula Province, Mozambique, was one of three sites at which the REDD-FLAME system was tested. The Reserve is at risk from agricultural conversion and harvesting of fuelwood, which result in damaging degradation of the sub-tropical Miombo forest. There are also threats from selective logging and wildfires. The distinction between forest and non-forest in Mecuburi is not clear, and some subjectivity is involved in setting thresholds: whilst wetlands are certainly non-forest, it is difficult to draw a line in the continuum between single-tier 'open' forest (including seasonal wetlands containing some woody biomass) and high, or 'closed', Miombo forest.

To illustrate the nature of REDD-FLAME outputs, an example is presented here from one of the locations selected for field evaluation in November 2012. A clearing of 1.4ha was masked out in the forest/non-forest benchmark map based on a RapidEye image from June 2012. Since older RapidEye imagery showed no evidence of the clearing, it was inferred that the area had been cleared recently. Both RADASAT-2 and TerraSAR-X change map products show new change dated at October 2012 in an area to the west of the original clearing (blue/cyan). A multi-temporal composite of TerraSAR-X images, and a RapidEye image from September 2012 both show larger homogenous areas than the originally masked clearing (Fig. 3).

On visiting the site, it was found that the whole area had been recently cleared of all but the largest standing trees and burnt ready for cultivation (Fig. 4). There was no visible distinction between the 'older' (masked) clearing and the new mapped area of change; the evidence suggests that clearing activity was actually on-going at the time of the benchmark map and was completed in the weeks before the field visit. The witnessed burning was very recent indeed: on the day of the field visit,

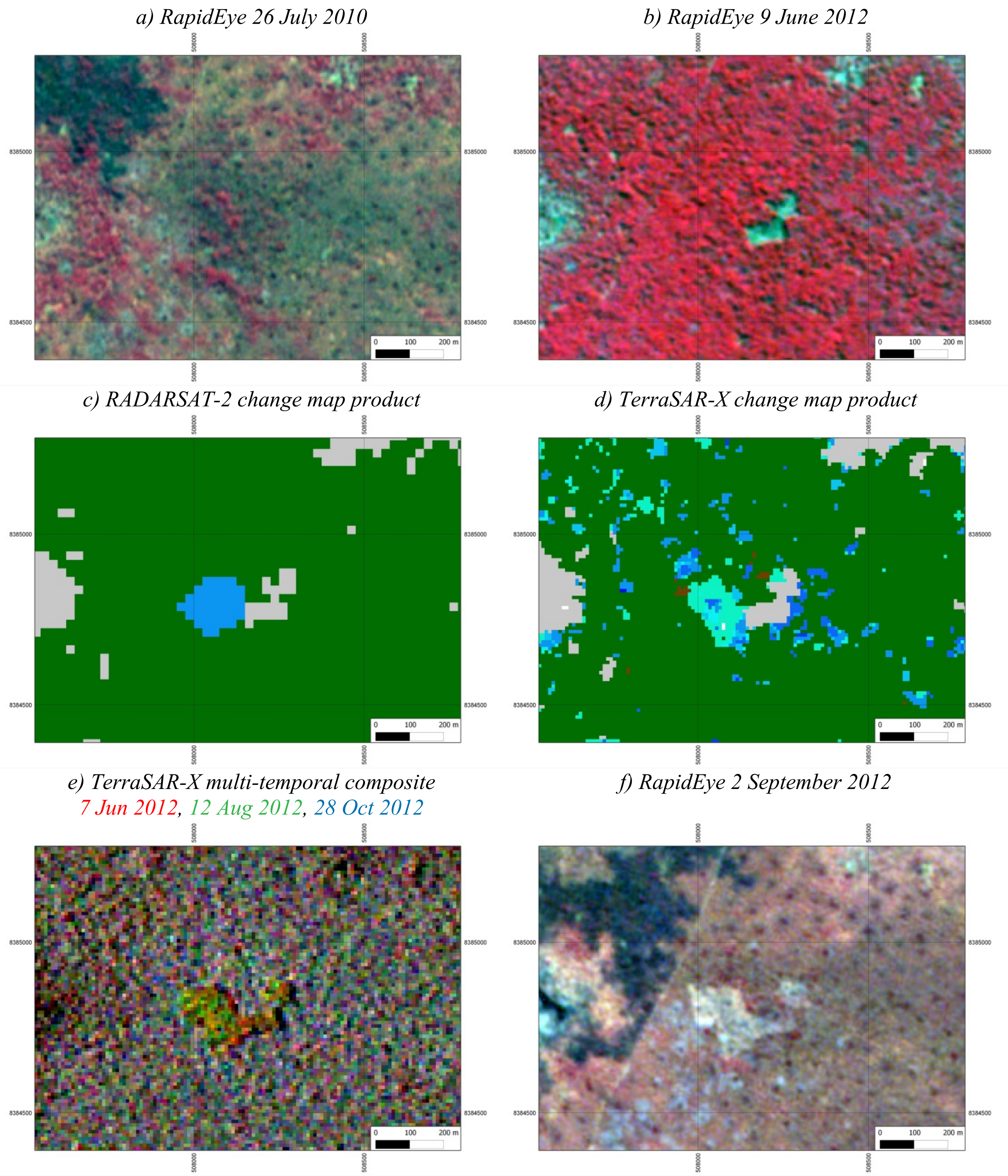

Figure 3. Maps and images of a very large clearing in Mecuburi Forest Reserve, Mozambique

larger logs were found still smouldering. If REDD-FLAME had been operational, this illegal clearance may very well have been stopped. The total area of the enlarged clearing is about 4.4ha. The deforestation is clearly detected by the radar data in this case of homogenous large-scale clearance.

Of all the field evaluation sites in Mozambique where change had been detected, only one yielded no conclusive evidence of disturbance (i.e. false alarm): six were confirmed as deforestation or forest degradation and four showed evidence of burning though no actual deforestation. New clearings visible in a later Worldview-2 image covering part of the Reserve were also checked against change maps, with up to 90% being detected. A statistical validation of a change map produced for Mawas Conservation Area, Central Kalimantan, Borneo, Indonesia (another of the test sites), compared to an optical image, yielded a classification accuracy of 97%.

Figure 4. Evidence of recent forest clearance and burning in Mecuburi Forest Reserve, Mozambique

At workshops held at the end of project, it was possible to demonstrate the system's ability to detect new forest disturbances previously unknown to the authorities, as well as some changes relating to loss of biomass in areas where the criteria for classification as forest are still met (i.e. forest degradation). REDD-FLAME products are proven to allow quick location of disturbances on the ground and it was concluded that they can facilitate interventions within the time it typically takes to complete a new clearing. Preliminary results across all sites seem to show that the high resolution change maps derived from RADARSAT-2 data are just as clean or cleaner, and possibly less prone to false alarms or over-detection, compared to VHR TerraSAR-X products: this augurs well for the introduction of Sentinel-1 data.

4. REDD-FLAME IN THE CONTEXT OF REDD

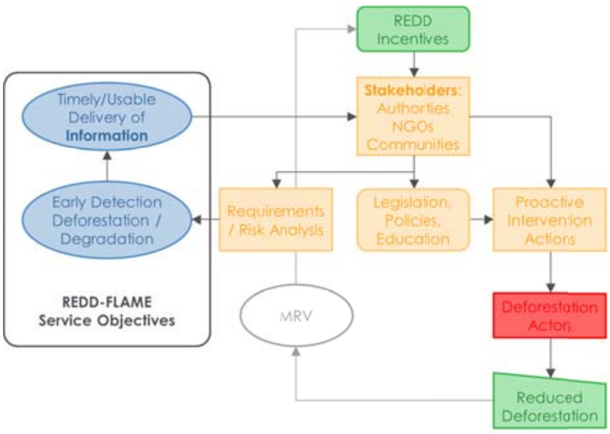

Figure 5. REDD-FLAME in context

In an operational REDD implementation, governments, civil society and local inhabitants will be motivated by the incentives offered through REDD to reduce carbon emissions from forests (Fig. 5). Reducing the rates of deforestation and forest degradation can be achieved by various stakeholders, for example, by adjusting governance, improving conservation practices and making lifestyle changes. Through user consultation, the requirements necessary to progress towards these objectives, and to measure such progress, have been determined; among such requirements, the need for early detection of deforestation and forest degradation is seen as important, both to facilitate control of carbon stocks and also as a means to assess risk of deforestation in a particular area for potential carbon investors. Thus, delivery to stakeholders of timely, usable information on new forest disturbances forms the central REDD-FLAME service objective.

The REDD Programme necessitates formulation of policies for emissions reduction and enactment of subsequent legislation to enforce them. REDD-FLAME products can inform these processes and contribute to education on deforestation matters, as well as facilitating proactive actions to reduce deforestation by enabling intervention directly at the site of encroachments that violate such new or other existing laws. Hence, the deforestation actors – loggers, farmers, charcoal producers – are reached and their activities interrupted so that deforestation and forest degradation, and consequently carbon emissions, can be reduced.

Traditionally, REDD remote sensing projects focus on MRV. This provides a means to periodically monitor progress towards reduced rates of carbon emission, providing the feedback loop to authorise the release of REDD incentives. However, a complete REDD approach also requires proactive measures to actively contribute to the reduction of deforestation on a continuous basis; REDD-FLAME demonstrates how remote sensing can also make an important contribution to this aspect of the programme.

Tab. 1 contrasts the characteristics of REDD-FLAME and MRV. The REDD-FLAME approach is an important tool to support REDD actions and is complementary to MRV: it is the combination of periodic wall-to-wall monitoring and focussed fast detection, plus effective intervention strategies responding to both, that will ultimately lead to successful reduction of deforestation rates.

Table 1. Comparison of REDD-FLAME and MRV systems

REDD-FLAME	MRV
Operational reporting	Intl. reporting requirement
Proactive	Reactive
Risk-based time interval	e.g. Biennial
Risk-based geography	National wall-to-wall

There is, perhaps, one way in which REDD-FLAME could help the MRV process. Current wall-to-wall mapping methodologies have inherent uncertainties, and the difficulties of consistently classifying forest and non-forest are well known. It is therefore doubtful whether MRV can reliably measure the small and diminishing incremental improvements on the *business as usual* rate of deforestation that are to be expected under REDD agreements (Fig. 6). REDD-FLAME could provide detailed information on the changes occurring in specific areas and during the periods between MRV exercises, which could also potentially be used to refine and validate wall-to-wall mapping.

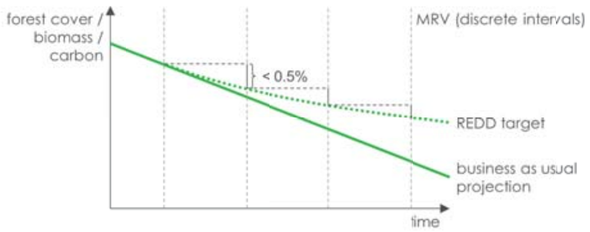

Figure 6. Incremental progress towards REDD target

5. CONCLUSIONS

The REDD-FLAME project has demonstrated a practical approach for the detection of recent small clearings in tropical and sub-tropical forests using optical imagery (given good weather conditions and data acquired at the correct time of year) or SAR data time series. Products can also provide information about the age of changes.

As a proactive measure in the context of REDD, the system offers a cost-effective solution to help reduce the rate of deforestation, with service costs representing no more (probably much less) than 50% of the carbon payments that could be due for saved units of forest. The advent of the Sentinel programme will maximise the potential economic benefits through free and open access to data, as well as assuring data continuity.

Of course, there is little sense in implementing a fast detection system if the capacity to respond with fast interventions is not also established. From the discussions held at the REDD-FLAME Final Workshops, it appears that there are significant concerns about current national capacities for intervention, so systems may need to be modified so that new information can be acted upon quickly enough for it to be effective. In the meantime, REDD-FLAME can help to focus limited intervention resources at sites most likely to represent on-going illegal forest clearances, thereby raising efficiency.

6. ACKNOWLEDGEMENTS

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Further information about the REDD-FLAME project can be found at http://redd-flame.info.

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