MONITORING RESPONSIBLE RESOURCE DEVELOPMENT AND COMMUNITY LAND-USE USING MULTI-DATE RAPIDEYE DATA

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KEY WORDS: mining, environment, risk management, multi-temporal

ABSTRACT: Responsible resource development in Lao PDR faces several challenges, including communities living in close proximity to mining areas and competition for land resources. Resource developers have a responsibility to manage their land resources and associated risks throughout the life of a project. Monitoring of land use is a dynamic and continuous process that can be supported through the use of remote sensing by providing information across a large area to help manage environmental and social risks. Hatfield has developed www.landmonitoring.com to give users consistent and regular information about their land resources through the use of Earth observation (EO) data.

This applied research shows that the use of multi-spectral sensors can improve situational awareness and is effective for regular monitoring of land use in Lao PDR. Images from the RapidEye constellation were acquired over a four-year period to provide land cover information and track incremental changes in land use within a resource developer's operational area. Changes in land cover/use are visualized and tracked through an online web portal - www.landmonitoring.com.

Initial baseline land cover classification was established using object-based segmentation. Subsequently, changes in land cover were identified through RapidEye image-to-image differencing. The accuracy was assessed using Quickbird, GeoEye-1, and ground validation data. The change detection method proved successful and reliable, with the major factor causing mis-classification being seasonal changes between wet and dry season. The accuracy of land cover change detection can be improved by enhancing the knowledge base and rules related to actual change versus seasonal change.

Monitoring land cover and land use change using EO data can be integrated into an environmental and social management system to assist resource developers improve situational awareness of their land and natural resources and subsequently help in their decision-making about the development, health, and safety of their operations and surrounding communities.

1. INTRODUCTION

Mine development in Southeast Asia face several challenges, including the management of land resources. Responsible mining aims to reduce and minimize potential competition and conflict with local communities living close to mining areas, and to effectively manage land use change. Resource developers have a responsibility to manage their land resources and associated risks throughout the life of a project.

Monitoring of land use change is important for new developers as well as operating mines. Current approaches may involve obtaining land cover and land use information through aerial photography or satellite images every few years, especially for areas of persistent cloud cover. This approach limits understanding of land use change, particularly in areas where community growth and migration is highly dynamic. Furthermore, resource developers may not be aware of potential land speculators developing agriculture or small-scale mining in the same area. Both companies and the governmental require improved situational awareness and monitoring. New satellite remote sensing systems can provide more frequent, consistent, high resolution data to address this important information need.

The objective of the research was to develop and demonstrate that multi-date satellite data can improve situational awareness and be an effective tool for land monitoring, even in regions where cloud cover can be challenging. Images from the RapidEye constellation were acquired over a four-year period to provide baseline land cover information and for detecting changes in land cover (e.g. vegetation clearing).

2. DATA AND STUDY AREA

2.1 Data

RapidEye data were acquired over a four year period (November 2010 to March 2014) in order to develop a land cover baseline and demonstrate change detection techniques. This dataset provided roughly an annual temporal frequency. The Level-3A data from RapidEye were already orthorectified therefore pre-processing involved atmospheric correction, co-registration, and mosaicking of individual images to create a seamless mosaic of the study area. Atmospheric correction was completed on all the RapidEye data using PCI Geomatica v2013 to provide consistent spectral information between the scenes. Co-registration of all images to a common base image, in this case the 2010 image, was necessary to ensure correct and accurate detection of land cover changes. Following co-registration, all images within the same year were mosaicked to create a three seamless dataset covering the study area.

Available high resolution images included GeoEye (4-band, 50 cm pan sharpened from 2013), WorldView-2 (3-band, 50 cm pan sharpened from 2011) and Ikonos (3-band, geo-referenced, 1 m pan sharpened from 2008)

2.2 Study Area

The study area is approximately 400 sq. km with complex land use patterns surrounding the mining area. The landscape of the study area is typical of many areas of Southeast Asia. The topography is varied, including large flat plains, hills, and several steeply sloped mountains and ridges. Land cover and land use includes natural forest, swidden and permanent agriculture, and settlements in a patchwork associated to local communities.

3. METHODS

3.1 Baseline Land Cover

Baseline land cover classification was created using 2010 RapidEye and an object-based segmentation and rule-set. The minimum mapping unit (MMU) was 0.25 ha with the mapping scale at 1:25,000. Image classification was conducted using Definiens eCognition v8 (Baatz et al., 2004). The focus on monitoring land use change meant that the classification schema was relatively simple (Figure 1).

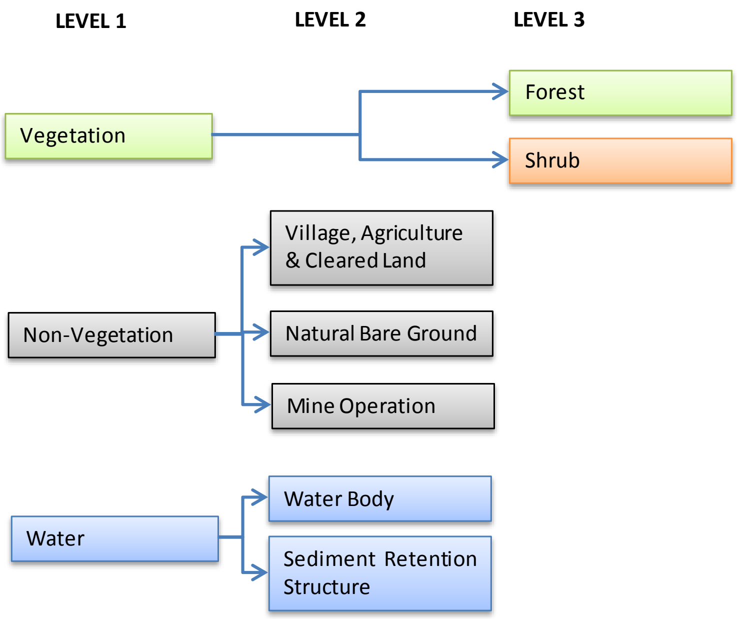

Figure 1. Baseline classification schema.

Multi-resolution image segmentation and class allocation rule-sets were developed incorporating the spectral channels, derived information from the spectral channels including enhanced vegetation index (Jiang et al., 2008), texture, and the spatial relationship between lower level land cover types from previous processing steps (e.g. distance between two land cover polygons). The strength of using multi-resolution segmentation is the ability to create image objects where the average heterogeneity is minimized and the homogeneity of the image objects are maximized. The rule-set was developed using a subset from two field surveys (Figure 2) conducted in May 2013 and November 2013, as well using the high resolution satellite images.

Figure 2. Field survey: shifting cultivation adjacent to mining area (left); permanent agriculture (right).

Manual class allocation was necessary to assign segmented ‘objects’ to certain land use classes, e.g., Mine Operations and Sediment Retention Structure. This was completed through expert local knowledge and the collected field data. All post-processing of the classification was completed in ArcGIS v10.1.

3.2 Change Detection

New land disturbances for subsequent years were identified and extracted through object re-segmentation using RapidEye image-to-image differencing and the thematic vector dataset from the previous land cover/ land use classification. Therefore, land changes between 2010 and 2011 were identified through RapidEye image-to-image differencing and the use of the 2012 baseline classification. RapidEye’s spatial resolution of 5m provides a suitable mapping scale to detect subtle vegetation disturbances and identify small land cover and land use changes. To smooth the final classification a MMU of 0.25 ha was applied to all datasets.

4. RESULTS

Accuracy of the change detection was assessed using high resolution images. Overall accuracy of the baseline was assessed at 80.3%, while the March 2011 change detection was assessed at 78.4%, and the overall accuracy of the December 2012 change detection was determined to be 79.6%. Identification of cleared areas (i.e., from forest to bare ground) was highly accurate while the boundaries between less stark land changes, such as re-vegetated areas were more challenging. The methodology applied was successful in detecting and identifying larger land changes while there were errors of commission and omission for subtle changes. Another factor causing mis-classification was seasonal change between wet and dry season. The accuracy of land cover change detection can be improved by enhancing the knowledge base and rules related to actual change versus seasonal change. An example of the effectiveness of the change detection procedure and result is shown in Figure 3.

The results were integrated into a custom **Land Monitoring** web application (www.landmonitoring.com) to give users consistent and regular information about their land resources (Figure 4).

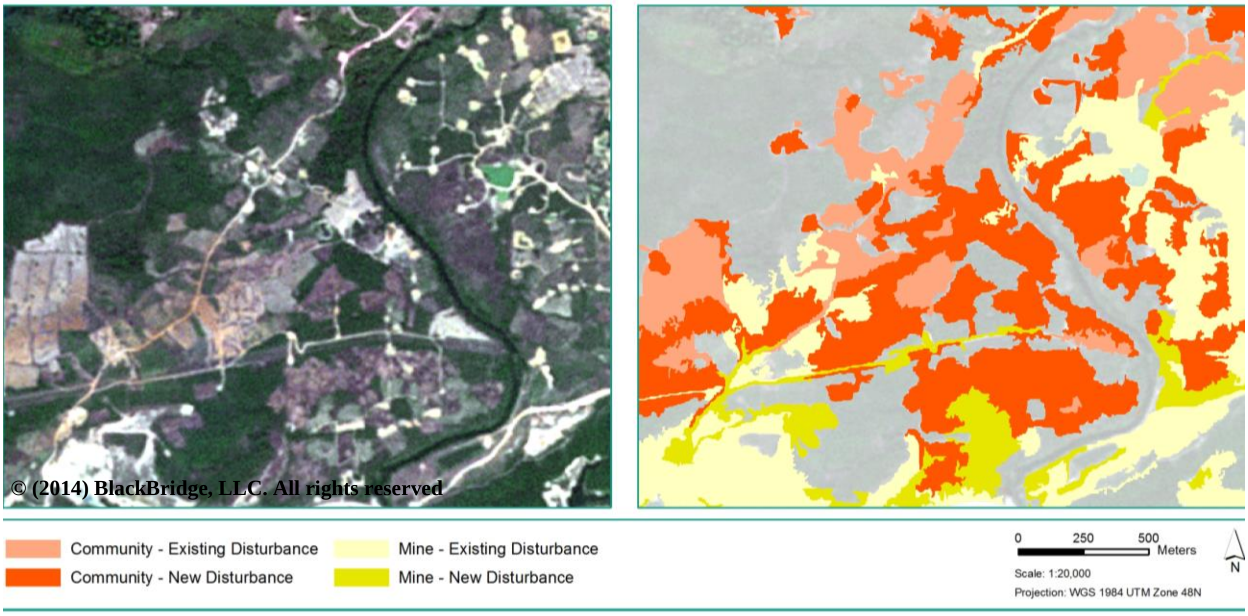

Figure 3. RapidEye images acquired December 11, 2012 and January 23, 2014 and the corresponding land changes.

Resource development typically requires land acquisition and compensation from local communities and local governments. The integration of baseline land cover and land use with compensation data can support this process. Furthermore, consistent and frequent monitoring of land changes can support management plans of the resource developer to identify areas of potential concerns, e.g., cultural heritage sites.

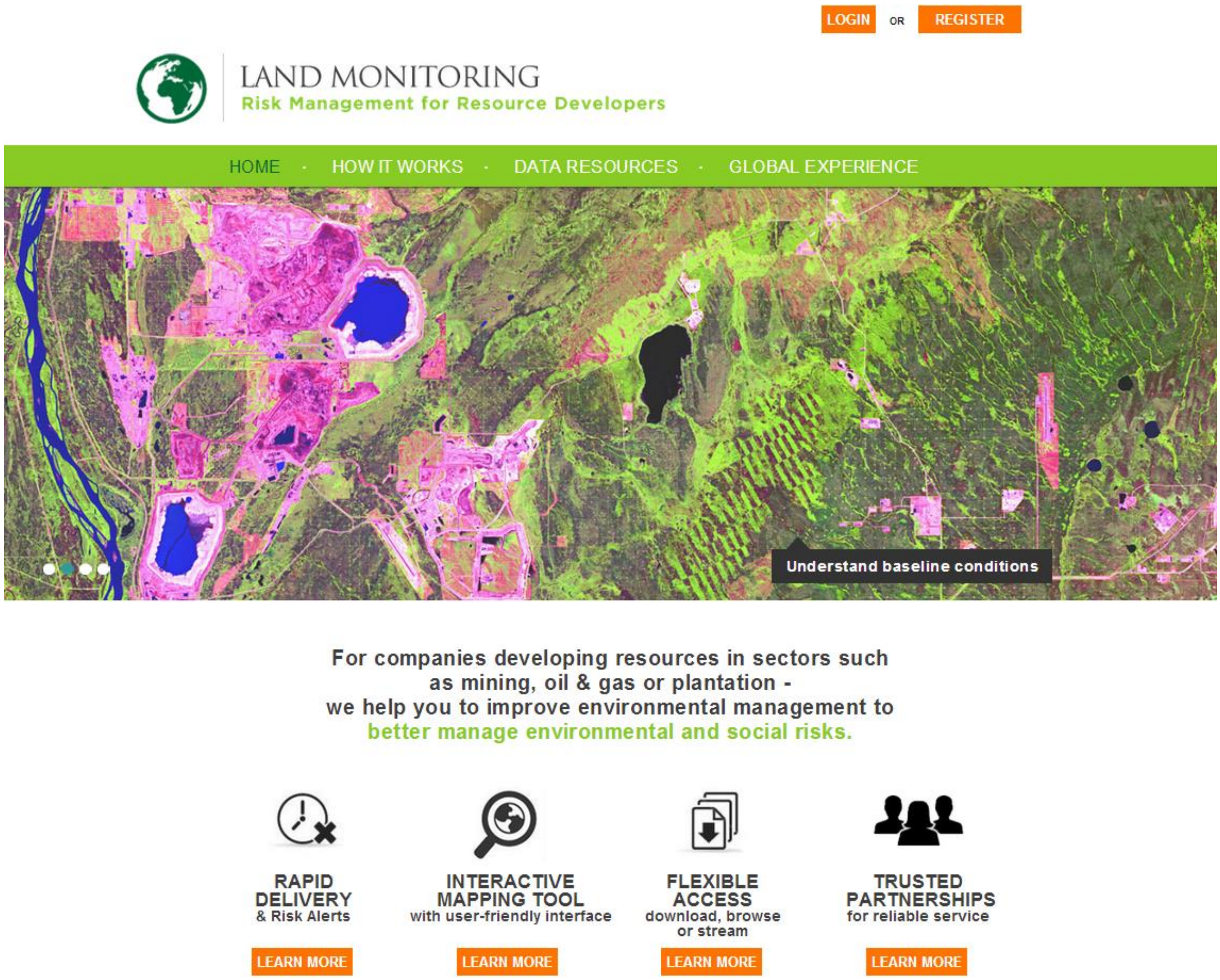

Figure 4. Land Monitoring web portal.

5. CONCLUSIONS

This applied research shows that the use of multi-spectral sensors can improve situational awareness and is effective for regular monitoring of land use in Lao PDR. Images from the RapidEye constellation were acquired over a four-year period to provide land cover information and track incremental changes in land use within a resource developer's operational area. Changes in land cover/use are visualized and tracked through www.landmonitoring.com. The developed application also integrates alerts based land use change that may indicate increased social and environmental risks. Improvements to Land Monitoring may be supported by the use of new data streams from sensors such as open access radar data from Sentinel-1 (Torres et al., 2012).

Monitoring of land use is a dynamic and continuous process that can be supported through the use of remote sensing providing information across a large area to help manage environmental and social risks. Baseline land cover and land use changes extracted from satellite images can be integrated into an environmental and social management system that can assist resource developers improve their understanding of their land and natural resources. Ongoing land use monitoring will subsequently help resource developers in their decision-making about the development, health, and safety of their operations and surrounding communities.

6. REFERENCES

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