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IRON ORE MINE WASTE FLOODWATER EXTENT MAPPING UTILIZING REMOTE SENSING DERIVED INDICES

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ABSTRACT

The collapse of two iron ore mine dams in south-eastern Brazil on 5 November 2015 is one of the recent environmental disasters. The clean-up and environment recovery would take several years and cost billions of dollars. Mapping the extent of the affected areas and monitoring the water quality deterioration is a challenge. In this study the new optical satellite SENTINEL 2 imagery along LANDSAT 8 were utilized to test the applicability of the Land Surface Water Index (LSWI) and Modified Normalized Difference Water Index (MNDWI) in the mapping process. The systematic coverage of the study area from the aforementioned satellites before and after the incident were studied and compared. The dynamics of LSWI, MNDWI were utilized in the delineation of the affected areas. Both quantitative and qualitative measures to assess the mine waste floodwater extent were developed. The high reflectance in both the 650-nm and 750-nm wavebands as an indication of Iron-Oxide precipitates occurrence was also tested. The study revealed that the mine tailings extended about 500 Km downstream. The affected areas and extent revealed from the study results were validated against the official figures from the Brazilian government. There was a good agreement between the study results and the published figures. The temporal variation in the Iron-Oxide precipitates occurrence was successfully mapped. In addition, visual interpretation go well with the study results. The findings of this study indicates that the proposed algorithm can be used in the timely mapping of the iron ore mine waste floodwater disaster.

Keywords: Mine waste, water indices, environmental disasters, remote sensing, Sentinel 2

1. INTRODUCTION

Iron ore is used for steel making and according to the United States Geological Survey (USGS), Brazil is the third largest iron ore mine production country in 2015 with 428 million metric tons. Brazil exports of iron ore accounts for one third of the world's total. The region responsible of the highest iron ore production in Brazil is the so-called Iron Quadrangle located in the state of Minas Gerias. Tailings dams are used to store mining by-products. In the case of failure of such dams, negative severe environmental consequences occurs. A recent tailings dam failure in Brazil caused what is described as the worst environmental disaster in Brazil's history.
On the 5th of November 2015, a collapse of the tailings dams at Bento-Rodrigues in south-eastern Brazil caused a severe environmental disaster by the flooding of iron waste into the Doce River even reaching the Atlantic Ocean more than 500 Km downstream the collapse location. The environmental recovery of this disaster would cost billions of dollars and last for years. The need to monitor and assess the extent of iron waste mudflows in such an incident is essential.

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2. METHODOLOGY

2.1. Data and Methods

Remote sensing is considered a time-cost efficient technology for environmental monitoring over large areas. A number of remote sensing based indices had been developed that make use of the different targets reflectance behaviour for different bands. A number of indices that are sensitive to the presence of water are the normalized difference water index NDWI (McFeeters 1996), the modified normalized difference water index MNDWI (XU2006), and the land surface water index LSWI (Chandrasekar 2010). Very high resolution imagery VHR were used for the Doce river course mapping. The archives of LANDSAT8, SENTINEL-2 and CBERS covering the Doce River area were searched. The cloud coverage of the incident area rendered many images in the respective archives unusable.

2.2. Algorithm

The satellite images were checked for any anomalies. The top of atmosphere TOA reflectance was calculated for each band. A simple threshold on the blue band was used for the cloud masking. The indices LSWI and MNDWI for a pre event image were calculated. The LSWI and MNDWI were also calculated for each available post event image. The dynamics of the pre and post event indices were utilized to map the flooded land. In addition the flooded areas Red and NIR reflectance in the pre and post images were compared. The whole steps were modelled into a semi-automated ERDAS model.

3. RESULTS AND DISCUSSION

The collapse affected the whole river course to the Atlantic Ocean stretching more than 500 km downstream the collapse location. The major affected area was near the vicinity of the collapse flooding Bento-Rodrigues, an area of about 3 km^2. Figure 1 shows the vicinity of the collapse and the affected areas while Figure 2 depicts the mouth of the river at the Atlantic Ocean. The presence of water quality samples analysis from the river could have helped to better investigate and understand the change in the red and near infra-red bands reflectance.

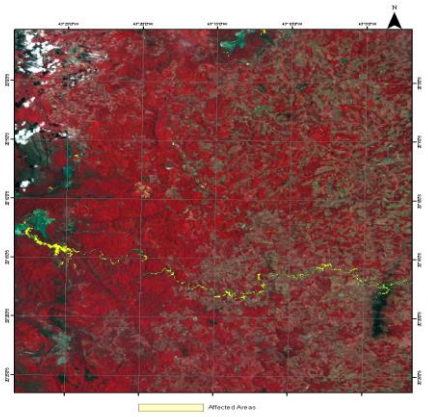

Figure 1: The vicinity of the collapse and affected areas

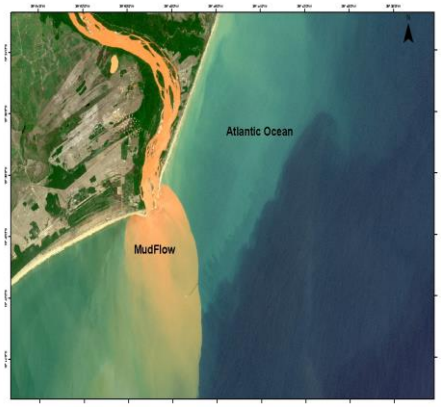

Figure 2: mouth of River (SEN-2 Dated 11 Feb 2016)

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