MONITORING INFORMAL SETTLEMENTS USING SAR POLARIMETRY

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ABSTRACT

The most pervasive form of land-cover change in South Africa is human settlement expansion. In many cases, new human settlements and settlement expansion are informal and occur in areas that were previously covered by natural vegetation. The spatial layout is often not planned, but informally developed by the inhabitants of the settlements themselves. The use of optical satellite data for the detection and mapping of new informal settlements has been an active research topic, but the use of SAR data for settlement mapping and detection has remained largely unexplored in Southern Africa. The objective of this study is to investigate the possible role that SAR polarimetry could play in the monitoring of informal settlements.

INTRODUCTION

The most pervasive form of land-cover change in South Africa is human settlement expansion. In many cases, new human settlements and settlement expansion are informal and occur in areas that were previously covered by natural vegetation. Informal or unplanned settlements usually evolve as people move closer to employment opportunities. These settlements can occur in various locations and are normally without basic services, which includes electricity, running-water, water-borne sewage and refuse removal. The spatial layout is often not planned, but informally developed by the inhabitants of the settlements themselves. Satellite data provide an effective way to monitor informal settlements and consequently, the detection and mapping of informal settlements using optical satellite data has been an active research topic (Salmon et.al. 2011a, Salmon et.al. 2011b, Salmon et.al. 2009, Kleynhans et.al. 2010, Kleynhans et.al. 2011). The use of SAR data for informal settlement mapping has been largely unexplored in Southern Africa even though SAR data has extensively been used in urban remote sensing (Ferro 2011) especially in the analysis of backscatter from buildings. The objective of this paper is to investigate the possible role that methods which make use of SAR polarimetry (adapted primarily from the urban remote sensing domain), could play in the monitoring of these informal settlements. In particular, Pauli decomposition was used and the single bounce, double bounce and volume components of the decomposition were used as discriminating features. In the study, two quad polarised RADARSAT-2 images were used to analyse the scattering mechanisms for both naturally vegetated and settlement areas. Results show that especially the double bounce component can effectively be used in the detection and mapping of informal settlements in the North-eastern South Africa.

DATA DESCRIPTION

Study Area

The study area is located in the north-eastern part of South Africa. The three dominant land tenure systems in the area are state-owned conservation, privately-owned conservation, and communal areas. The communal lands have a high human population density in the region of between 150 and 300 people/km^2. The study area covers an approximate 1260 km2 with a centre coordinate of (24◦51′02.63″S ; 31◦20′35.19″E) and is located on the border between the SabiSand private game reserve and the communal lands of Bushbuckridge.

Radar imagery

Two quad polarimetric RADARSAT-2 images where used in the study, one was inside (right) and the other outside (left) of the SabiSand private game reserve. Both images where acquired in August 2009 as to ensure that the local ground and climate conditions where similar. Figure 1 shows the location of the two RADARSAT-2 images.

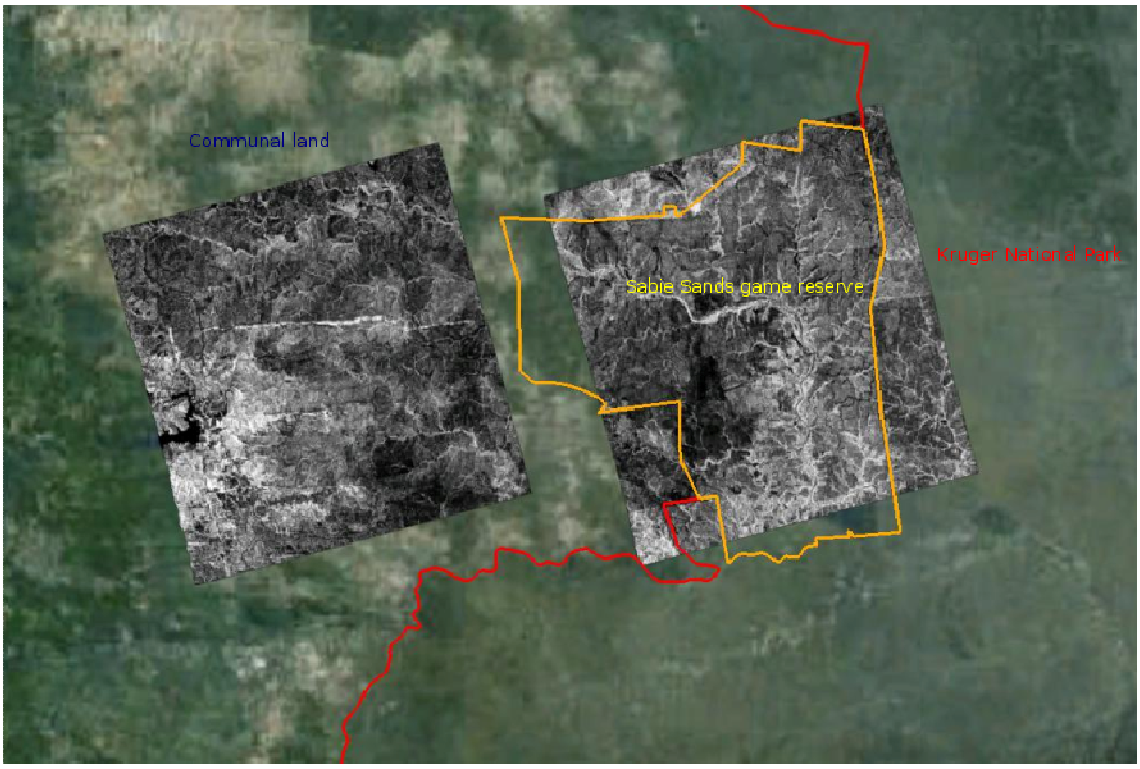

Figure 1. Study area showing the location of the Kruger National Park, SabiSands game reserve and communal areas. The footprint of the two RADARSAT-2 images is also shown.

METHODOLOLGY

The rationale of the experiment is as follows: The Kruger national park and SabiSands game reserve are protected environments and, as such, there are no unplanned informal settlements within the park boundaries. There are however areas adjacent to these protected areas (communal areas) where there are a number of informal settlements, as shown in figure 1. By utilizing two satellite images, one inside a protected area (in this study, the SabiSands game reserve) and the other, outside of the reserve, methods developed to enhance settlements could easily be tested by contrasting the two images which predominantly represents "settlements" and "natural vegetation" land cover areas respectively. Although optical imagery have been a more popular choice for settlement mapping and change detection applications in South Africa [cite], Synthetic Aperture Radar (SAR) technology offers the advantage of not being affected by cloud cover (in summer rainfall areas during the growing season) and haziness (during the dry season caused by bush fires), two conditions prevalent in Southern Africa. The objective was thus to make use of SAR technology to give an indication of the location of informal settlements and to process SAR imagery in such a way to enhance features that are able to distinguish informal settlements from natural vegetation. This is a first step in the bigger objective of determining the location of new informal settlements in naturally vegetated areas using SAR data. RADARSAT-2 data was used as it offers quad polarization and as such gives the potential to use full polarimetry information in an effort to enhance features that could then be used to better discriminate between human settlement and natural vegetation areas.

The double bounce effect, which is caused by a by the corner reflector assembled by the front wall of the building and its surrounding ground area have been widely studied and has been found to be particularly useful in urban SAR remote sensing for, among other application, the detection of buildings (Ferro, 2011). In this paper the double bounce, single bounce as well and the volumetric scattering components where analysed in an effort to distinguish human settlements form naturally vegetated areas using RADARSAT-2 imagery. The idea is that a RADARSAT-2 image processed in a specific way could provide an operator an effective manner to indicate the location of current human settlements in South Africa.

DATA PROCESSING

The processing of the Radarsat images was done using the Next ESA SAR Toolbox (NEST) software and the processing steps used in the generation of the final RGB image was as follows: First, a multi-look operation was performed on the SAR imagery, where-after a speckle filter was applied. A median filter with a 3x3 window size was used in the speckle filtering process. The Range Doppler orthorectification method for geocoding SAR images was then performed. The aforementioned processing steps were performed for each of the polarization modes (HH,VV and HV). A Pauli decomposition into the single bounce (|HH+VV|), double bounce (|HH-VV|) and volumetric scattering component (|HV|) was performed and the final RGB image was generated. The processing steps are shown in figure 2. The single bounce, double bounce and volume scattering represents the blue, red and green band respectively.

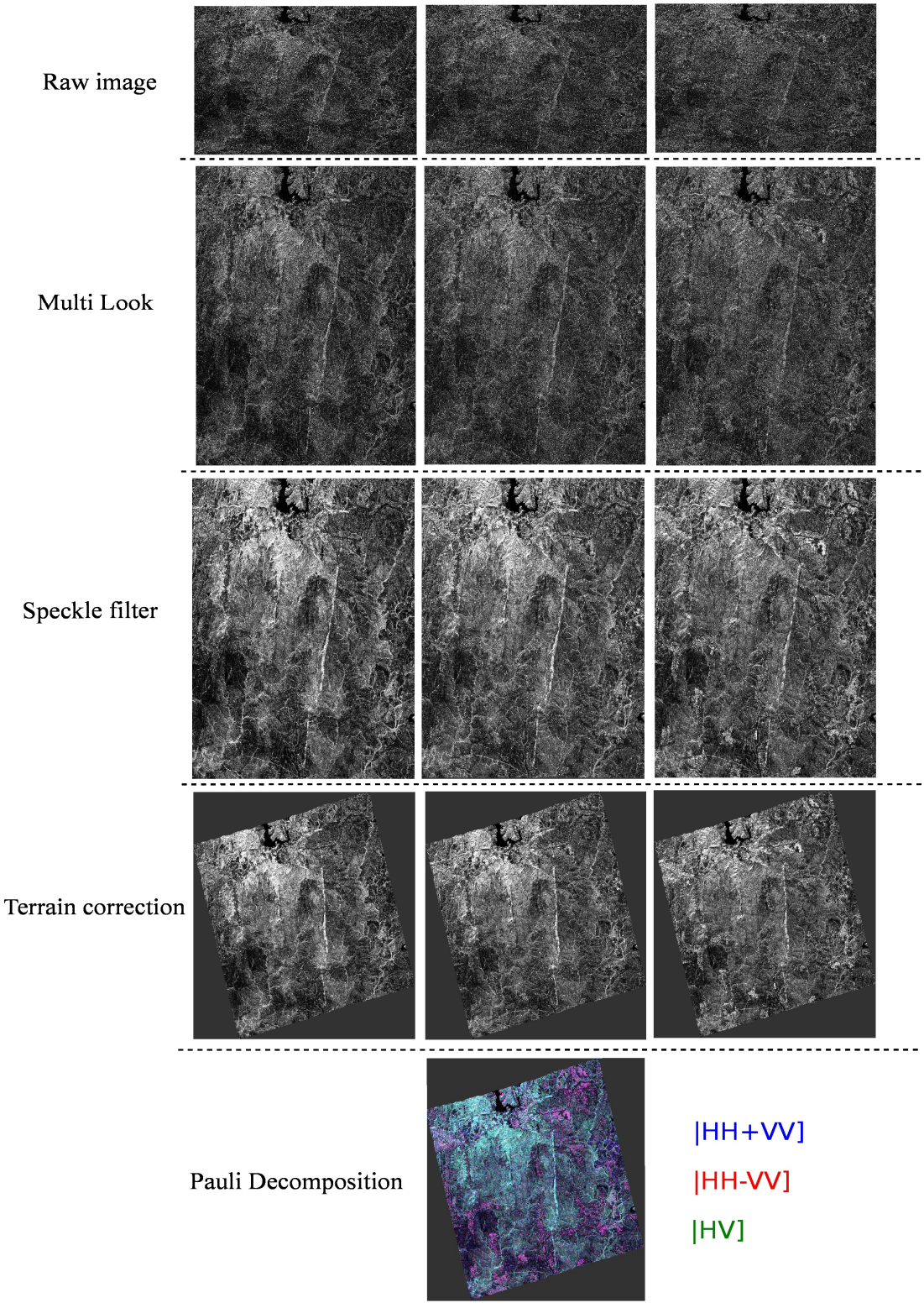

Figure 2. SAR processing steps used to create the final RGB image.

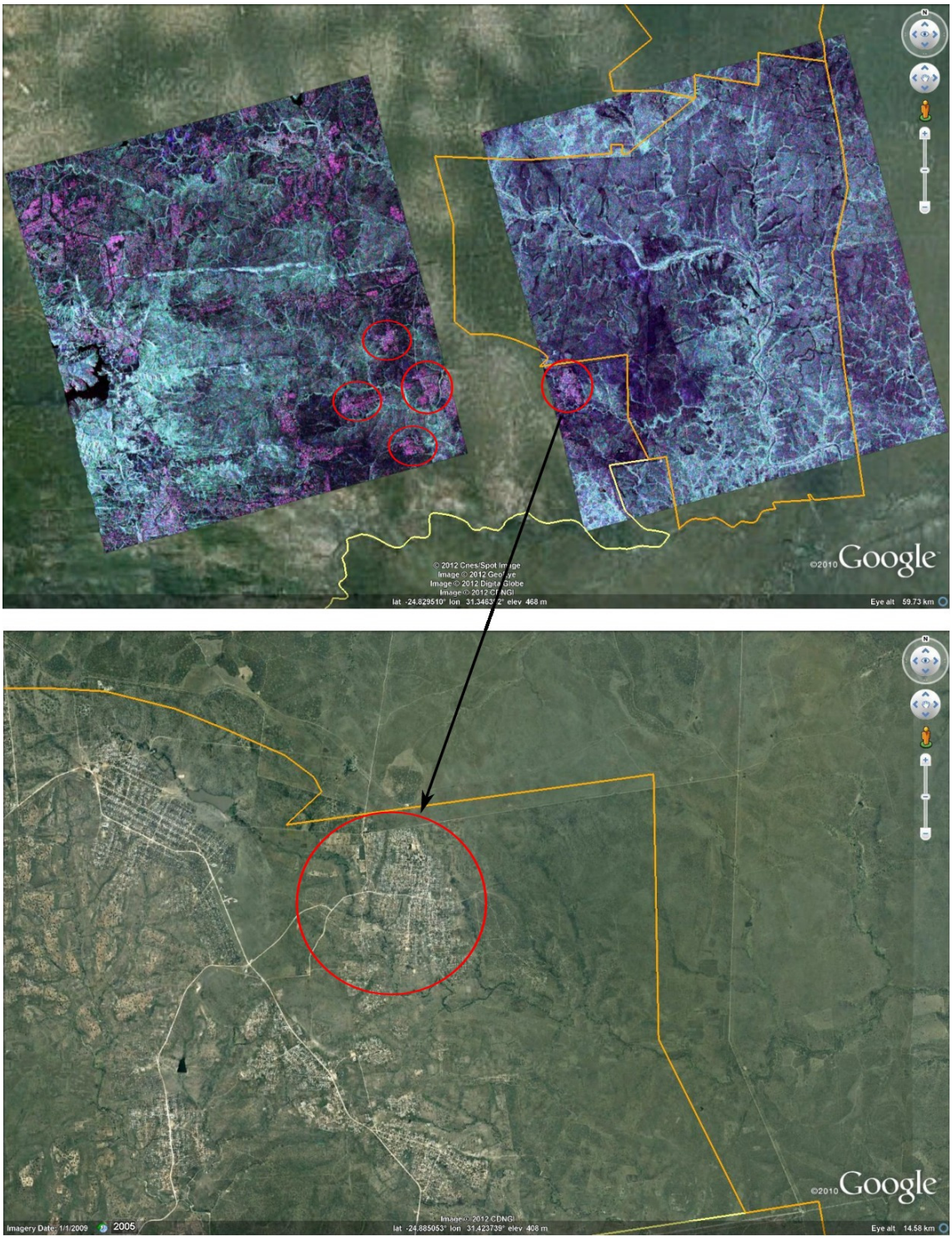

Figure 3. Top: Two RADARSAR-2 images, one on the left and the other on the right of the SabiSand game reserve boundary, examples of settlements are indicated by red circles. Bottom: Optical image of an informal settlement on the park boundary detected using the SAR image (courtesy of Google™Earth).

RESULTS AND DISCUSSION

The processing steps presented in the previous section where applied to both Radarsat-2 images in the study area and is shown in figure 3. It is clearly visible that the double bounce component (represented as red) is much more prevalent in the left image. This was to be expected as this image was taken exclusively over the communal land area having a high number of settlements. The image on the right on the other hand has a very small amount of double bounce. This is also expected as the image is primarily within the SabiSands game reserve having little to no anthropogenic activity. The image on the right clearly shows the location of an informal settlement on the fence line of SabiSand. This was investigated and found to be the Justica informal settlement (24°52'48.28"S, 31°24'39.83"E).

CONCLUSION

In this paper, the feasibility of using SAR as opposed to optical data in the mapping and detecting of informal settlements in South Africa is investigated. Preliminary results show that using polarimetric information and in particular Pauli decomposition to extract the double bounce, single bounce and volumetric scattering (well known scattering mechanisms which has been widely used in, for example, urban SAR remote sensing applications), it is possible to effectively distinguish informal settlements from natural vegetation. Two Radarsat-2 images where used in the study, each representing predominantly natural vegetation and settlement land cover types. It was found that by utelizing the full polarimetric information available in Radarsat-2 that settlement where able to be successfully distinguished from natural vegetation.

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