Impacts of Conflict on Land Cover, Land Use, Fire Dynamics and Biodiversity Potential in the Imatong Mountains of Southern Sudan

Virginia Gorsevski, The University of Maryland, Department of Geography

In roduc ion

Armed conflict negatively impacts biodiversity through habitat destruction and fragmentation, direct loss of animals from poaching or land mines, over-exploitation and degradation of natural resources, and increases in land and water pollution (Kanyamibwa 1998, Gleditsch 1998, Shambaugh 2001, McNeely 2003, Short 2003). In some cases, however, wars can have a positive impact on biodiversity, through the creation of "no go zones" that reduce pressure on the natural landscape due to the absence of exploitative human activity in the area (Martin 1999, McNeely 2003, Vanasselt 2003). In Sudan, where hostilities have been closely linked with competition over natural resources (Suliman 1993, Van Houven and Nimir 2004, UNEP 2007) and have historically been detrimental to wildlife (Cobb 1981, ElMahi 1996, Van Houven and Nimir 2004), satellite monitoring of land cover and fire activity can provide insight into the complex relationships between conflict, land cover/land use change (LCLUC) and biodiversity.

esearch oals

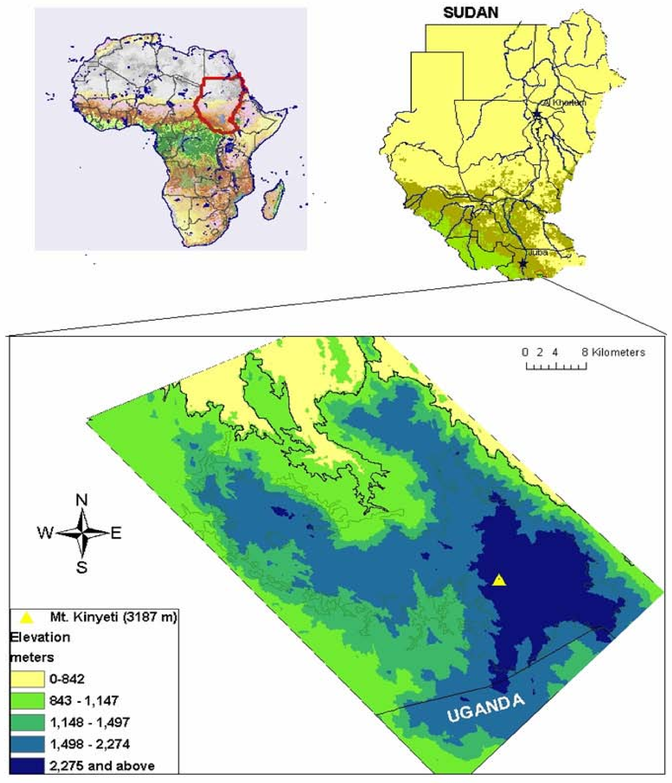
Focusing on the Imatong Mountains and surrounds, the primary goal of this project is to better understand how human activity drives changes in land cover/land use, both during and immediately following prolonged conflict; further, the research will seek to understand the implications of future changes in land cover for biodiversity. Specific research questions (RQs) in support of this goal, and their associated competing hypotheses are as follows:

Q1: How have human activities impacted forest cover found in the study region, both during and immediately following the most recent conflict?

Q2: How have demographic shifts during the conflict and post-conflict period affected the fire regime, and what do these changes reveal about human activity during this time?

Q3: How do observed changes in land cover and land use impact biodiversity and what are the implications for conservation?

Figure 1: Location of Study Area (Imatong Mountains, Sudan)



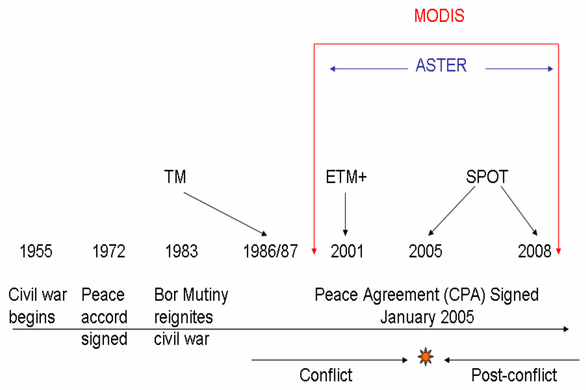
S udy egion

The Imatong mountains are located in southeast Sudan near the border with Uganda. They are considered part of the Eastern Afromontane Biodiversity Hotspot, due to the numerous endemic plant, bird, mammal, and amphibian species that are threatened by habitat loss, fire, and poaching. Experts believe that this area may be one of the most biodiverse areas in Sudan though no survey has been conducted due to the war. There is now widespread concern that returning populations are putting undue pressure on natural resources through logging of forests for timber and cutting of bamboo poles for fencing. Woodlands and pastures are also perceived to be under threat due to overgrazing, cutting of trees for firewood and fencing, and frequent use of burning during the dry season (Kanani 2006).

echnical Approach

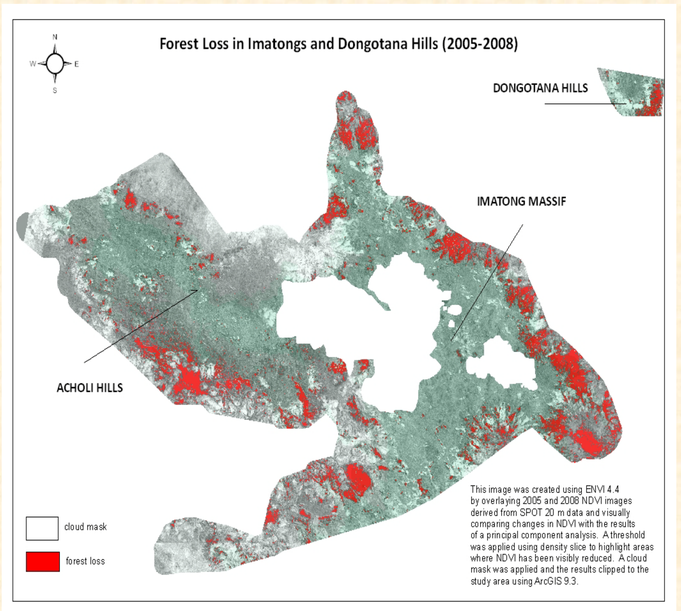
The data for this project will be acquired through remote sensing and field-based observations, and are based on the timeline depicted in Figure 2, indicating major milestones of the civil war in Sudan beginning with 1) the 1983 Bor Mutiny that set off the latest twenty year period of heavy fighting and 2) the 2005 CPA, which effectively ended the hostilities between government forces and the SPLA.

Figure 2: Timeline of key peace/conflict milestones in Southern Sudan conflict



To address RQ1, forest cover will be mapped using satellite imagery [1986/1987 (TM), 2001 (ETM+), 2005 (SPOT)] to determine change during the conflict period when the region was largely depopulated as a result of the war. Forest cover will then be mapped for the post-conflict period to show the impact of returning refugees and IDPs in 2008 (SPOT). To classify forest cover and forest cover change, the efficacy of both post classification comparison and direct change detection methods. The chosen approach will be applied to generate maps of intact and degraded forest that include changes between classes for the periods identified above. The results will be analyzed using GIS-overlay functions to develop transition matrices that describe how land cover has changed over both time periods. A visual comparison of the Imatongs and nearby Dongotana Hills corroborates anecdotal evidence that there has been increased human encroachment along the perimeters of the former forest reserve and around the Hills since 2005. See figure 2 below.

igure 2: 2005 – 2008 Change De ec ion using S O 20m sa elli e imagery



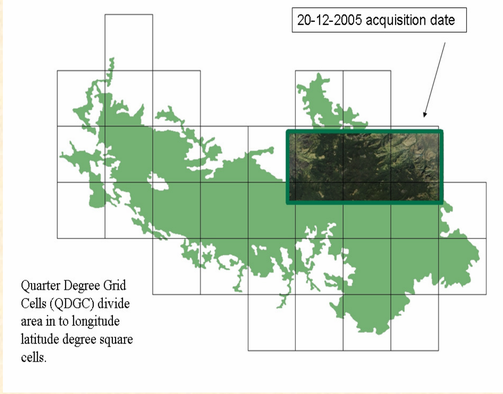
Recently acquired aerial photos reveal that natural *Podocarpus latifolius* forest found at higher altitudes in the Imatong Massif are largely intact, as are many of the cypress, pine and teak plantations developed by the Imatong Forestry Project prior to the restart of war in the 1980s. By contrast, the nearby Dongotana Hills appear to have been heavily logged.

***Podocarpus latifolius* a ilo**

elled ores near Dongo ana ills

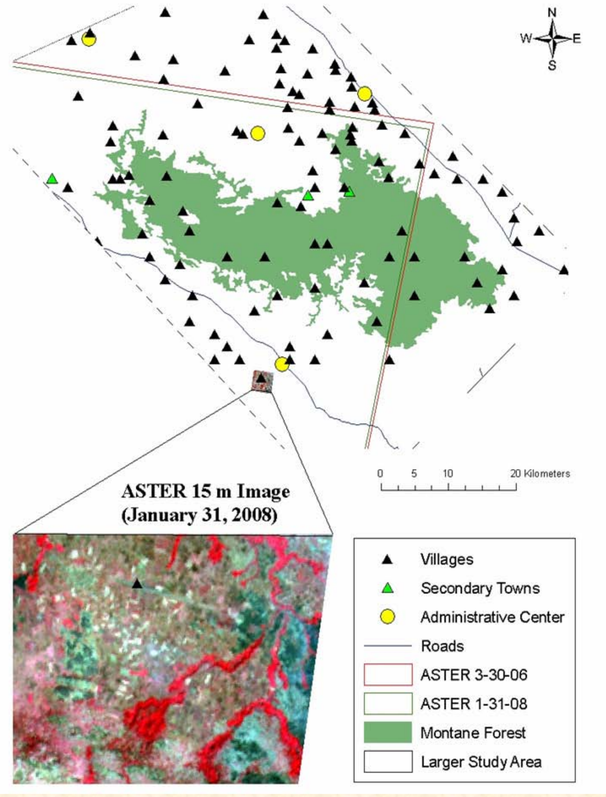
The accuracy of the land cover maps will be evaluated by comparing classification results with data derived from high resolution imagery and from ~2000 aerial photos acquired in January 2009 in collaboration with WCS Southern Sudan Program. High resolution (1m), cloud free IKONOS imagery have been obtained through the GeoEye Foundation for two adjacent scenes recorded in December 2005 and located in the middle of the Imatong massif (Figure 5). The information within these high resolution images will be used to validate land cover within the coarser-resolution Landsat, SPOT, and ASTER images.

Figure 5: 1 m IKONOS images acquired for Imatong massif



A similar approach will be taken to compare changes in the fire regime during the two periods. Burned areas will be detected using daily MODIS surface reflectance data at a spatial resolution of 250m for years 2000 - 2008. The resulting near-daily burned area maps will be used to construct a detailed fire chronology to separate out different ignitions. Mapping six pre and three post- return fire years will provide a controlled experiment to determine the effect of returning populations on fire activity through correlations with land cover and indicators of human pressure. The observed changes in forest cover and fire regime will be linked to people by developing robust, spatially explicit layers of key indicators of human activity. Specifically, the research will use ASTER 15m data to develop layers of villages, roads and fields - three different indicators of human pressure. These indicators will be developed during conflict and updated post- conflict to explore how the return of refugees and IDPs is altering human pressures and impacting forest cover (Figure 8). Using the Change Prediction tool in IDRISI Land Change Modeler (LCM), a soft prediction model will be developed showing vulnerability to change for the transitions described above.

Figure 8: Human settlements in and around Imatongs (2008)



Finally, various biodiversity metrics will be compared with each of the land cover types found throughout the region to determine which areas are more biologically diverse than others. Inputs to this assessment include species data to be collected by WCS in 2009 and converted to a spatial format compatible with a GIS, as well as detailed land cover maps developed for RQ1. The remaining analysis will focus on a single species to assess implications of future changes in habitat on conservation efforts. A habitat assessment will be performed using IDRISI LCM to designate land as belonging to five different categories: primary habitat, secondary habitat, primary potential corridor, secondary potential corridor, and unsuitable. The habitat suitability assessment will be further refined by converting presence data for the selected species into range polygons in a GIS and analyzed in concert with several key environmental variables using Mahalanobis typicalities embedded in IDRISI LCM. The results of this analysis will indicate potential distribution of the selected species currently and at a designated point in the future, assuming that the nature of development stays the same.

Expec ed Ou comes and Signi icance o esearch

The outcome of this study will provide a starting point from which to explore the complex relationship between conflict and land cover change in greater detail and in other geographic regions where war is ongoing and data are difficult to obtain from other conventional sources. Results may also contribute to the development of a National Park in an ecologically diverse and important region of the world, which is believed to be under mounting pressure from rapid human encroachment.

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