A New Approach to Detecting Mass Human Rights Violations Using Satellite Imagery

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This report summarizes research conducted during a fellowship with the United States Holocaust Memorial Museum's (USHMM) Center for the Prevention of Genocide (CPG). This research tested a methodology for using free and publicly available moderate resolution satellite imagery to detect types of destruction that are consistent with mass human rights violations. The methodology was applied to images of Darfur acquired from the historical archive of a NASA earth observing satellite (Landsat ETM+) and succeeded in detecting, at up to two week intervals, where and when villages were burned in the Darfur conflict from 2002 to 2008. While the location of the burned villages is already known at approximately an annual basis, this study provided the first comprehensive documentation of when villages in the Darfur conflict were destroyed within as little as a two week period.

The study also demonstrates how data from moderate resolution satellites can be included in large-scale operational human rights monitoring campaigns, allowing monitoring campaigns to be more proactive, enabling them to cover larger areas more accurately, and making them more cost-effective.

Introduction

The international human rights community is increasingly using remote sensing to monitor regions where populations are at risk of suffering from human rights violations. These organizations, however, continue to rely on high resolution, commercial satellites and trained imagery analysts. Because of this, few organizations are able to conduct monitoring campaigns over large areas because of the expense involved (Marx & Goward, 2013). This research demonstrates a new way for organizations to monitor large areas for types of destruction consistent with mass human rights violations without incurring substantial costs or requiring the use of trained imagery analysts. It demonstrates this methodology using the Darfur Genocide.

Methodology

This approach uses data from the moderate resolution sensor Landsat ETM+. This sensor can cover a much larger area in a single image than high resolution satellites (Figure 1) but has a lower level of detail, or spatial resolution, than those satellites (Figure 2).

Recent research with moderate resolution images has shown that they are able to detect the burning of villages in arid environments with each new pass of the satellite with an accuracy of 84% (Marx and Loboda, 2013). This research detects a drop in the village's average reflectance in the near-infrared which is associated with the burning of the village. Near-infrared was most accurate in detecting when a village transitions from pre-burn materials (soil, dead wood, and dead twigs) to post-burn materials (soil, charred soil, charwood, and ash) (Figure 3) (US Geological Survey, 2011).

Work Summary

Approximately 650 Landsat ETM+ images were downloaded from the US Geological Survey and processed through a NASA developed code (LEDAPS) (Wolfe et al, 2004). LEDAPS made the images more accurate by reducing atmospheric noise such as aerosols as well as producing an automatic cloud mask. These images comprised all the available dry-season images from 2000 to 2008, covering all areas where villages were reported destroyed in the Darfur conflict. Years 2000 and 2001 were included to help build a spectral baseline for each village.

The methodology was applied to a reference database of 2,666 villages identified as destroyed between 2002 and 2008 (HIU, 2010). This database also provided a latitude and longitude for each village. These villages were then analyzed through an algorithm that identified if they were burned with each new image (Figure 4). This algorithm identifies when a village's reflectance in the near-infrared is significantly lower than all previous observations, and records that date as when the village is first detected as burned (Figure 5 and 6). This approach is shown to work even on small villages, producing a time-stamp as precise as two weeks.

The time-stamps were analyzed to detect if ceasefires were violated and to detect other patterns in the location and timings of village burnings. We worked with Palantir Technologies to produce movies that depicted the flow of the conflict over time (Figure 7).

Findings

Of the 2,666 villages analyzed, the methodology detected with high confidence 1,757 (66%) as having been burned and gave them a time-stamp of when they were last intact and first detected as burned. There are several reasons for the lower detection rate of 66%. First, only villages with a high confidence of being burned were recorded, improving precision but also increasing the omission rate. Second, eyewitness reports show that at some times and locations in the conflict, groups of villages were destroyed, but not burned. For example, eyewitnesses report that villages were "trashed" around Kutum, North Darfur in late 2003 and early 2004 were but not burned (Petersen & Tullin, 2006).

Results from this revealed new understandings about the conflict in Darfur, which suffers from poor data quality. The study showed that while rebels from the Sudanese Liberation Army (SLA) and the government claim that the other side violated the first ceasefire (September 2003 to early December 2003) (Totten & Markusen, 2006), results do not corroborate this. Detected village destructions during this time occurred only in areas where the Justice and Equality Movement (JEM) rebel group operated, which was not a signatory to the ceasefire (Figure 8) (Tanner et al., 2007).

Additionally, while the study also detected the destruction of 42 villages across Darfur during the second ceasefire (11 April to 26 May 2004), these were in an area where the National Movement for Reform and Development (NMRD) operated, another rebel group that did not sign the ceasefire (Figure 9).

This study also revealed that following a period of decreased village destruction (January 2006 to October 2006), there was an intense three month period of violence during which an average of four villages were detected as destroyed daily in southeast Darfur – the highest rate detected for the entire conflict. These attacks are not well-documented by human rights organizations and likely represent both increased government attacks on rebels who did not sign the Darfur Peace Agreement as well as an inter-tribal conflict between the Nur and Zaghawa in the region (Figure 10) (Flint & De Waal, 2008).

With the help of Palantir Technologies, we were able to produce visualizations of the data that show the progression of the conflict over time (Figure 7). These visualizations showed that the burning of villages was quite widespread in the beginning of the period and then, after the ceasefire, concentrated in areas where there were rebels operating who had not signed the ceasefire agreement.

Conclusion – Use of Moderate Resolution Satellite Sensors in Human Rights Monitoring

Remote sensing in human rights monitoring is on the cusp of a significant change. The growing constellation of moderate resolution satellites is now providing a constant stream of high-quality and, in some cases, free data. LDCM (Landsat Data Continuity Mission), which became operational 31 May 2013, is now staggered with Landsat ETM+ (used for this study), providing images every 8 days of the Earth's surface. Additionally, improvements to LDCM's processing reduce the lag between image acquisition to public availability to 6 to 24 hours, providing for near-real time monitoring of large areas.

This study demonstrates how these sensors can be used accurately in large-scale operational human rights monitoring campaigns. While this study focused on a specific conflict and violation (the burning of villages in Darfur), a single area at risk of human rights violations could be monitored for several different signals that are associated with possible human rights violations.

Use of satellite imagery for human rights monitoring has thus far been largely reactive: it is generally only after receiving eyewitness reports of a human rights violation that organizations obtain and analyze imagery to document the violation. This imagery, given its narrow range, is unlikely to capture similar violations in the same region. Moderate resolution sensors can provide organizations the ability to monitor large regions proactively, without eyewitness reporting. When these sensors alert of a possible violation, fine resolution imagery can then be purchased and analyzed, making large scale monitoring much more cost effective.

The increasing potential of data derived from the constellation of moderate resolution satellites may one day provide organizations with a low-cost and continual monitoring ability of very large regions at risk of a variety of human rights violations.

Works Cited

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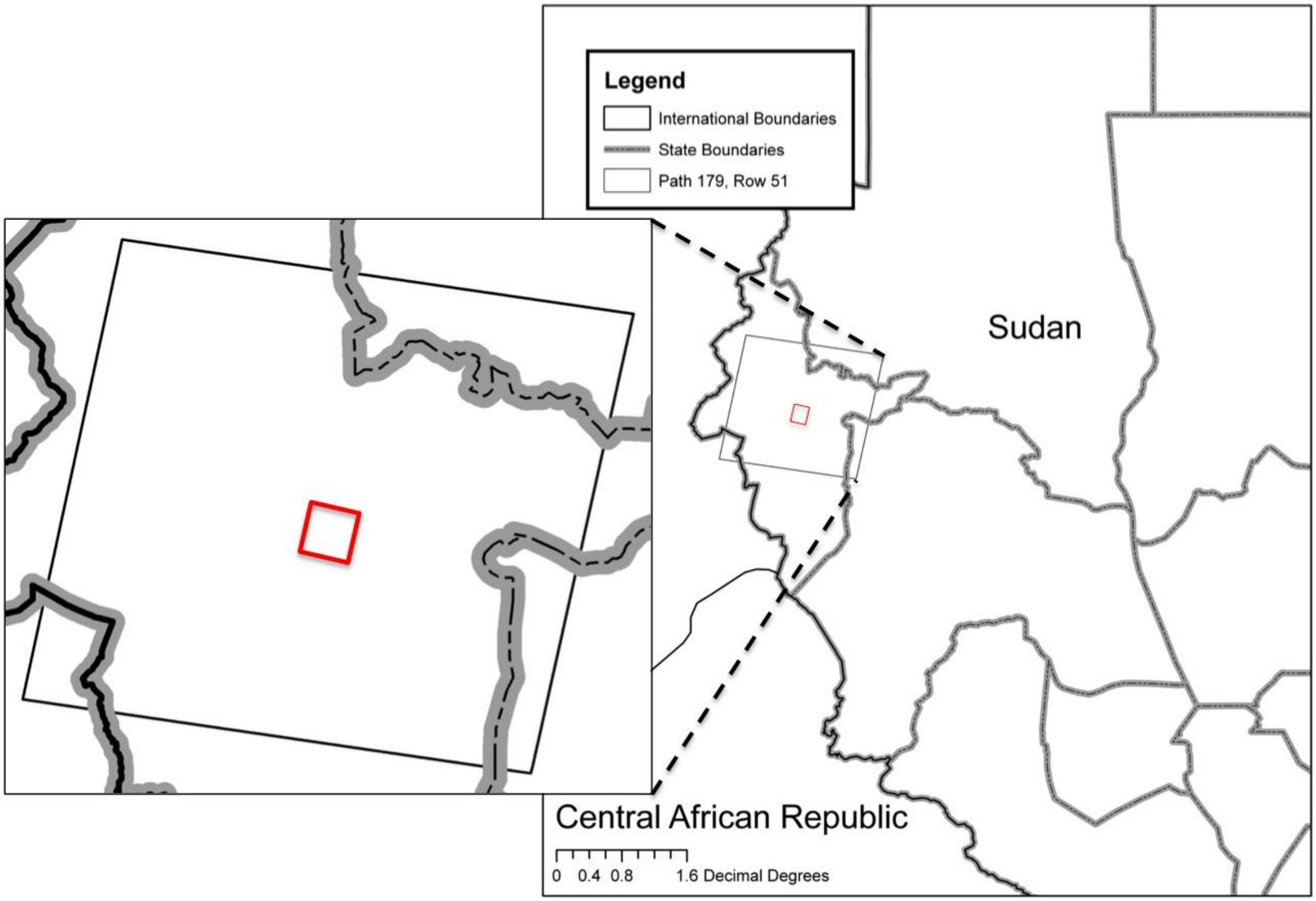

Figure 1: The high resolution satellite, DigitalGlobe has a footprint of 16km (shown in red) while Landsat ETM+'s footprint is 183km by 170km (shown in black).

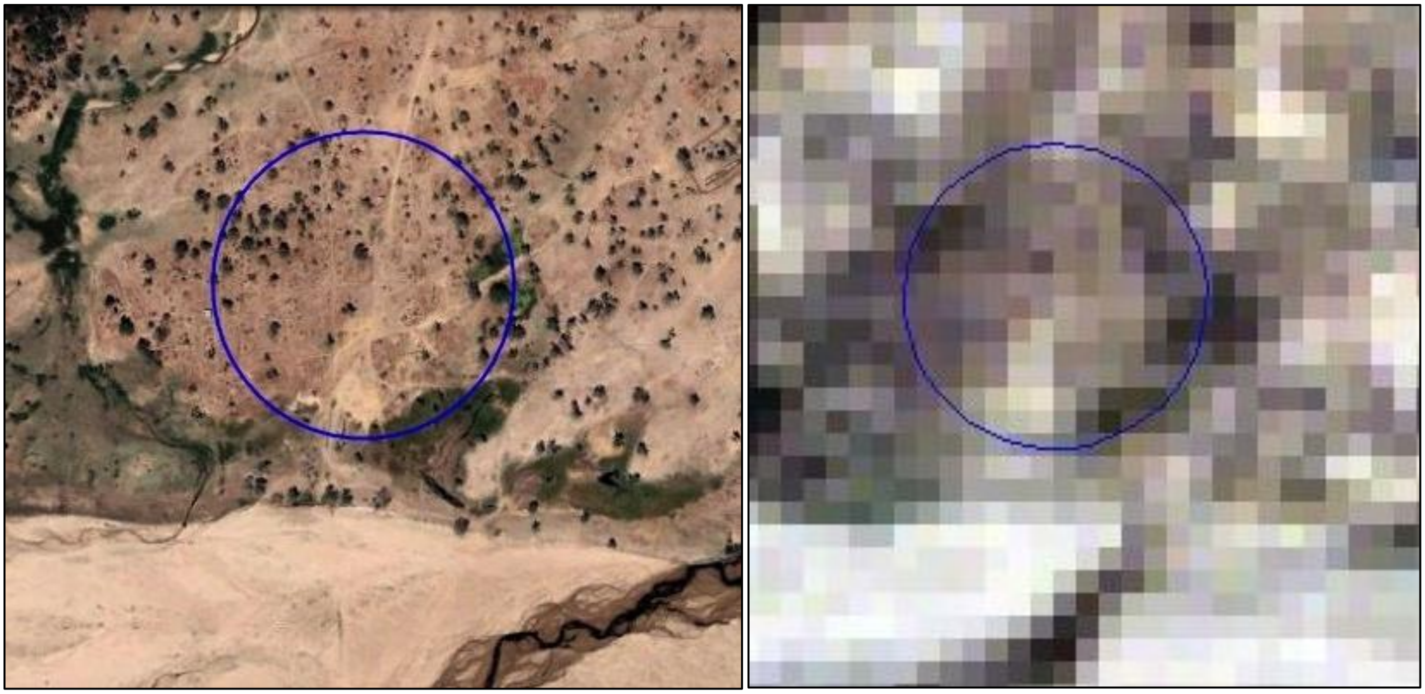

Figure 2: Right panel: An image from WorldView-2 showing a destroyed village in Darfur, Sudan in 2005. Left panel: The same destroyed village with Landsat ETM+ (RGB) 5 March, 2005. A 200 meter buffer around the destroyed village center is shown in blue in both panels.

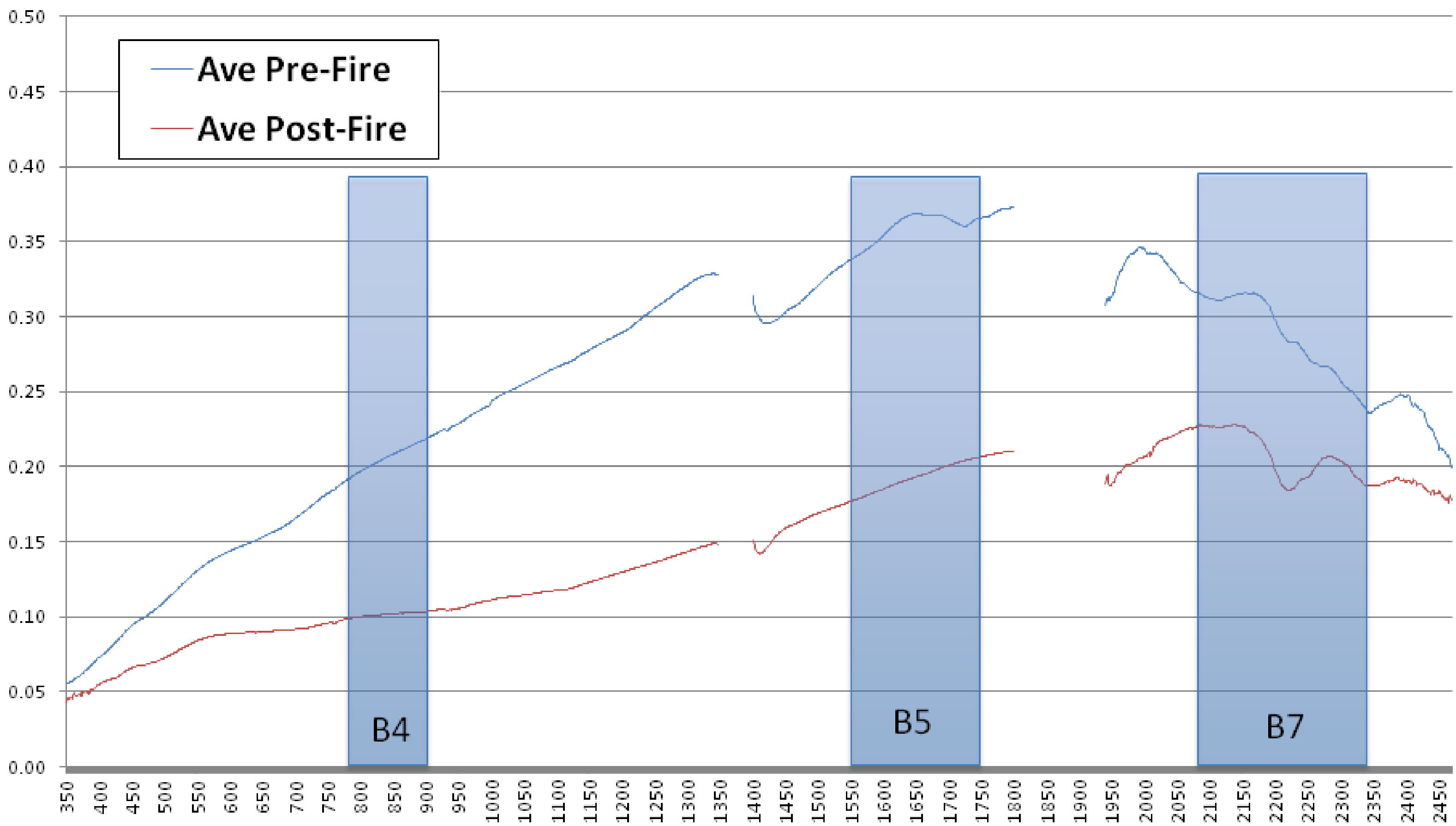

Figure 3: Pre- and Post-Fire average spectral profiles of an arid village. ETM+ bands 4, 5, and 7 are shown (US Geological Society, 2011). The water absorption bands from 1350um to 1400um and 1800um to 1900um are omitted.

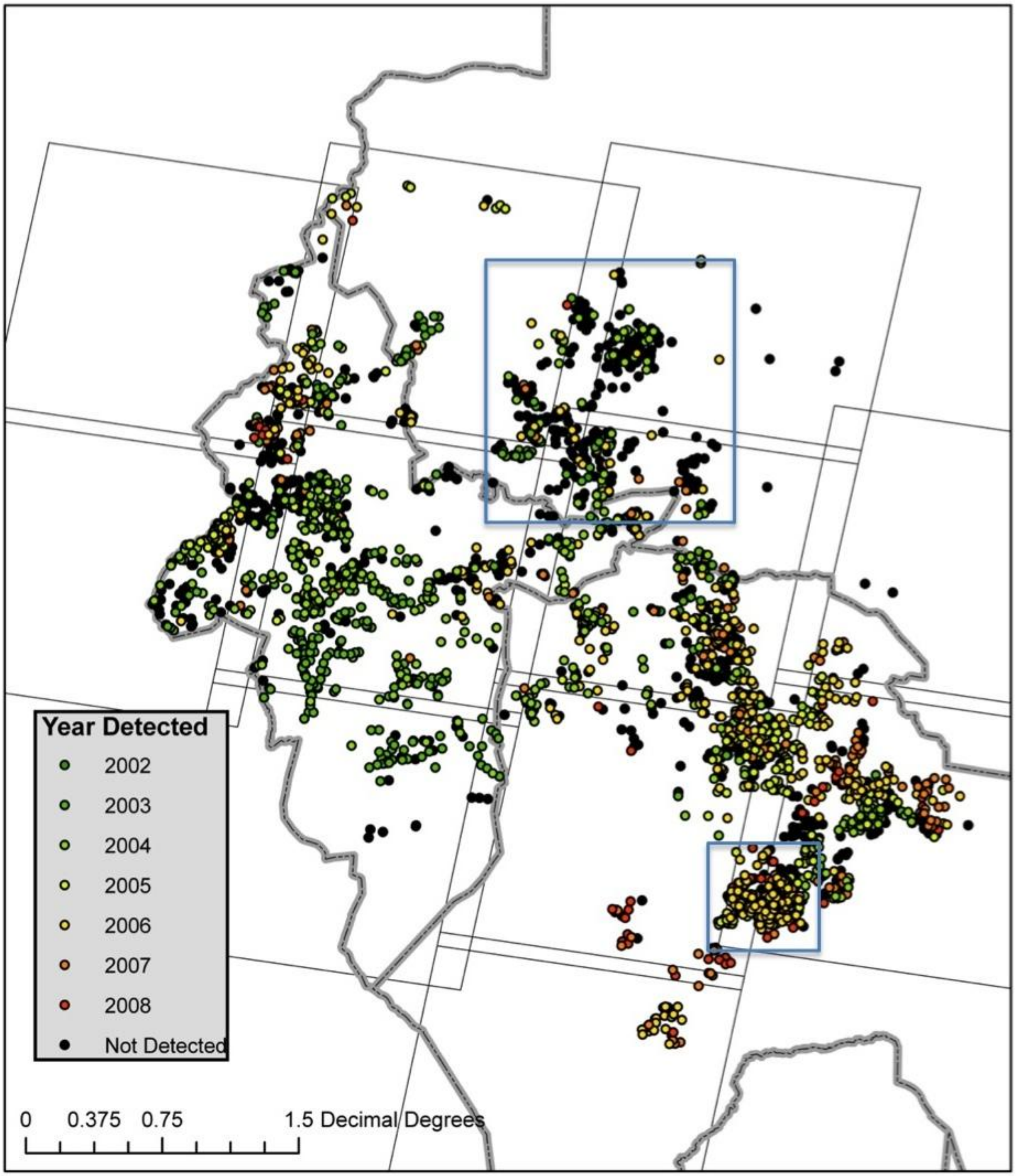

Figure 4: The study area in Darfur consists of 11 satellite footprints (black) and 2,666 destroyed villages (shown as colored dots). The area outlined in blue in the north had poor detection rates because the villages were often not burned as part of their destruction. Villages in the area outlined in blue in the south were nearly always burned as part of their destruction.

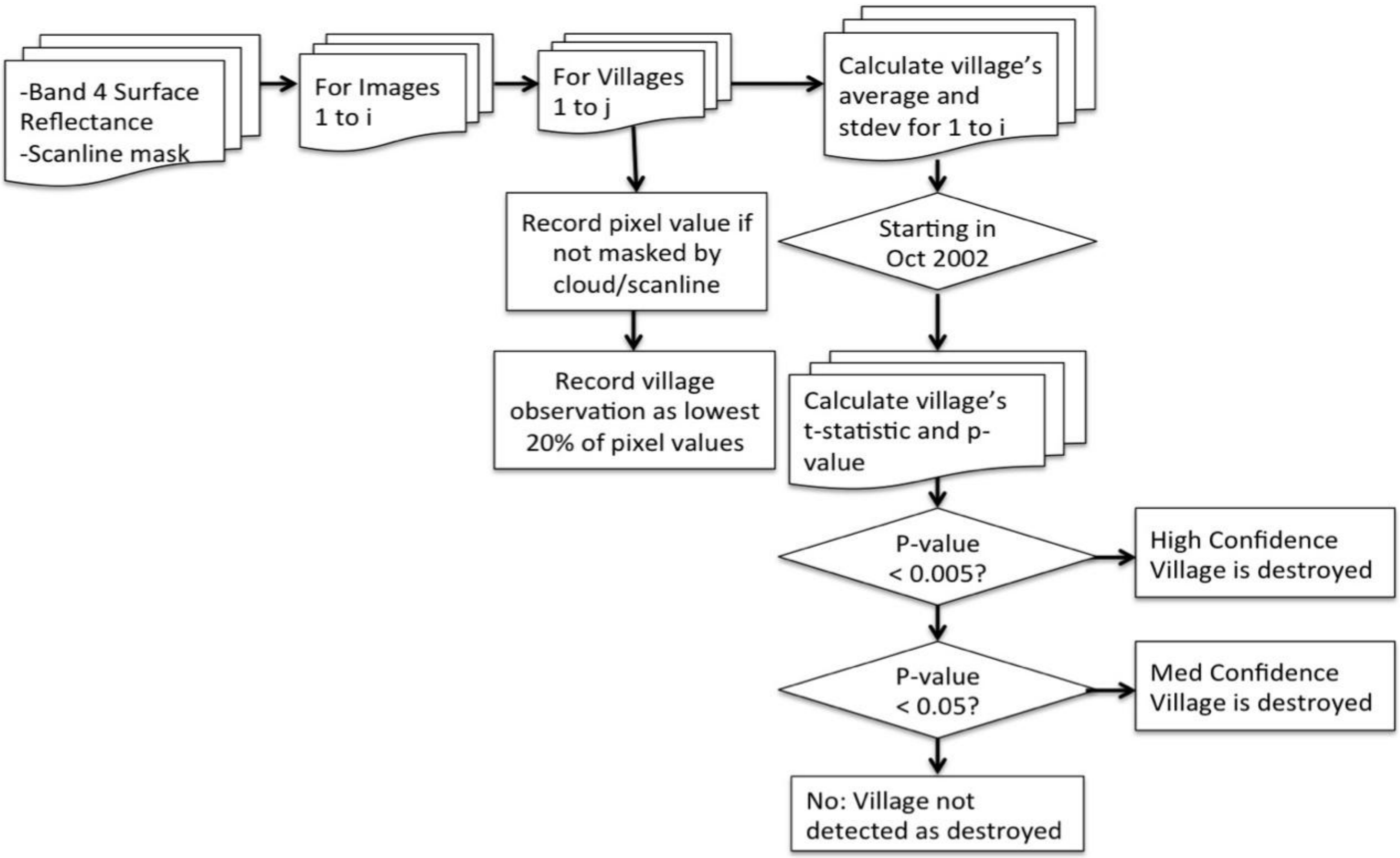

Figure 5: The study's destroyed village detection algorithm process stages. Programming was conducted in the Interactive Data Language (Marx & Loboda, 2013).

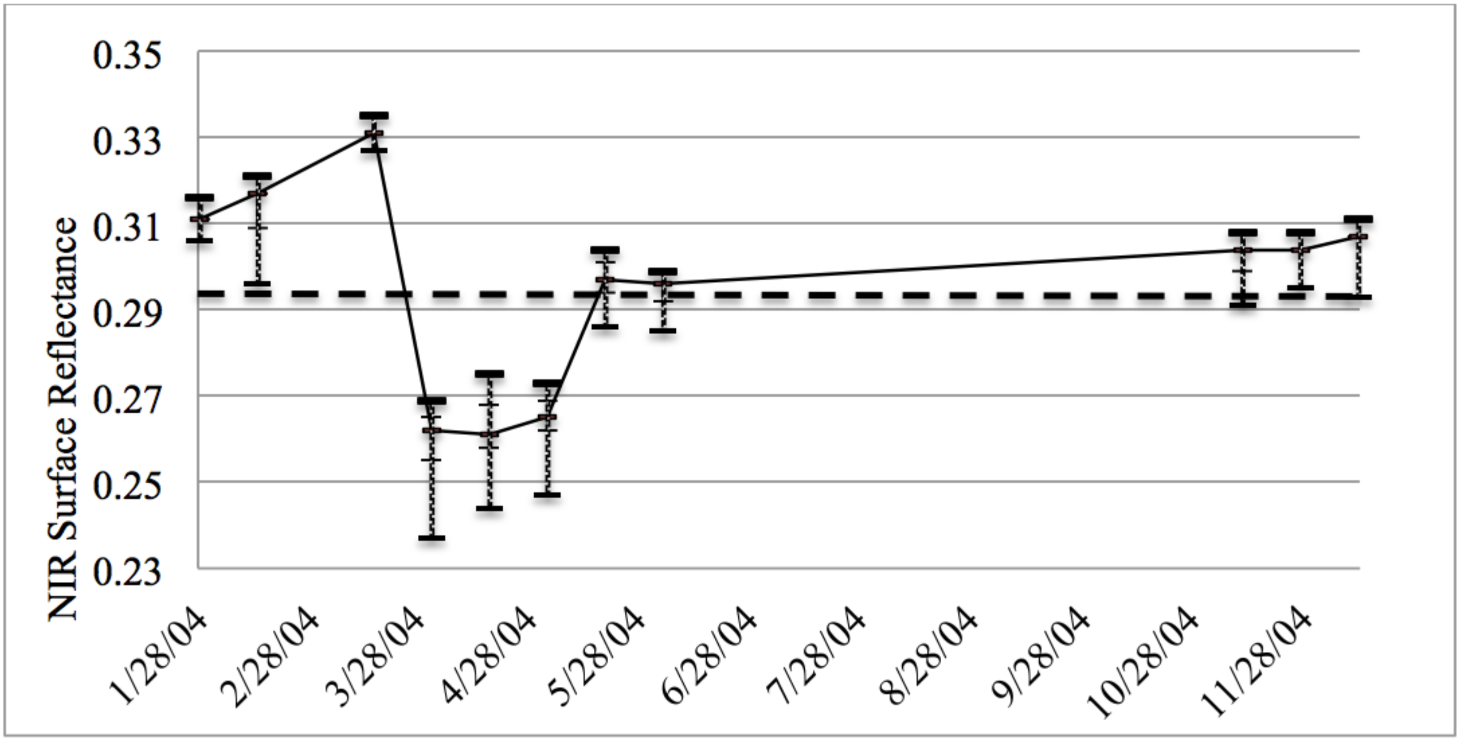

Figure 6: Year 2004 observations for a village in Sudan show the sensitivity of the near-infrared in the algorithm to detect a possible burning; between the third and fourth observations in this case. The village's average for baseline observations (0.294) is shown as a dashed line.

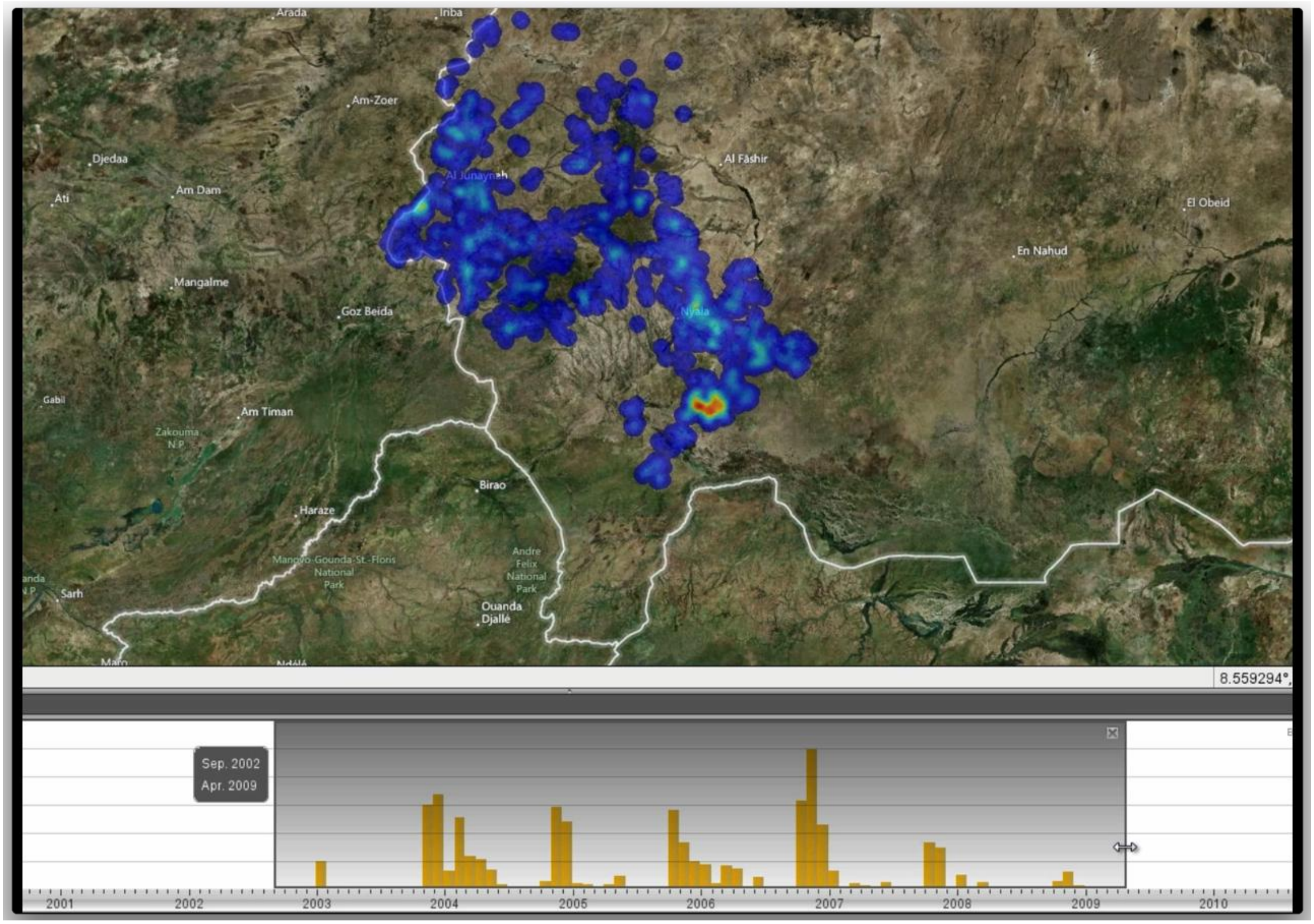

Figure 7: Screenshot from a movie showing a cumulative heatmap of all villages destroyed over time in Palantir's Gotham software. The bar chart shows how many villages were detected as destroyed per month.

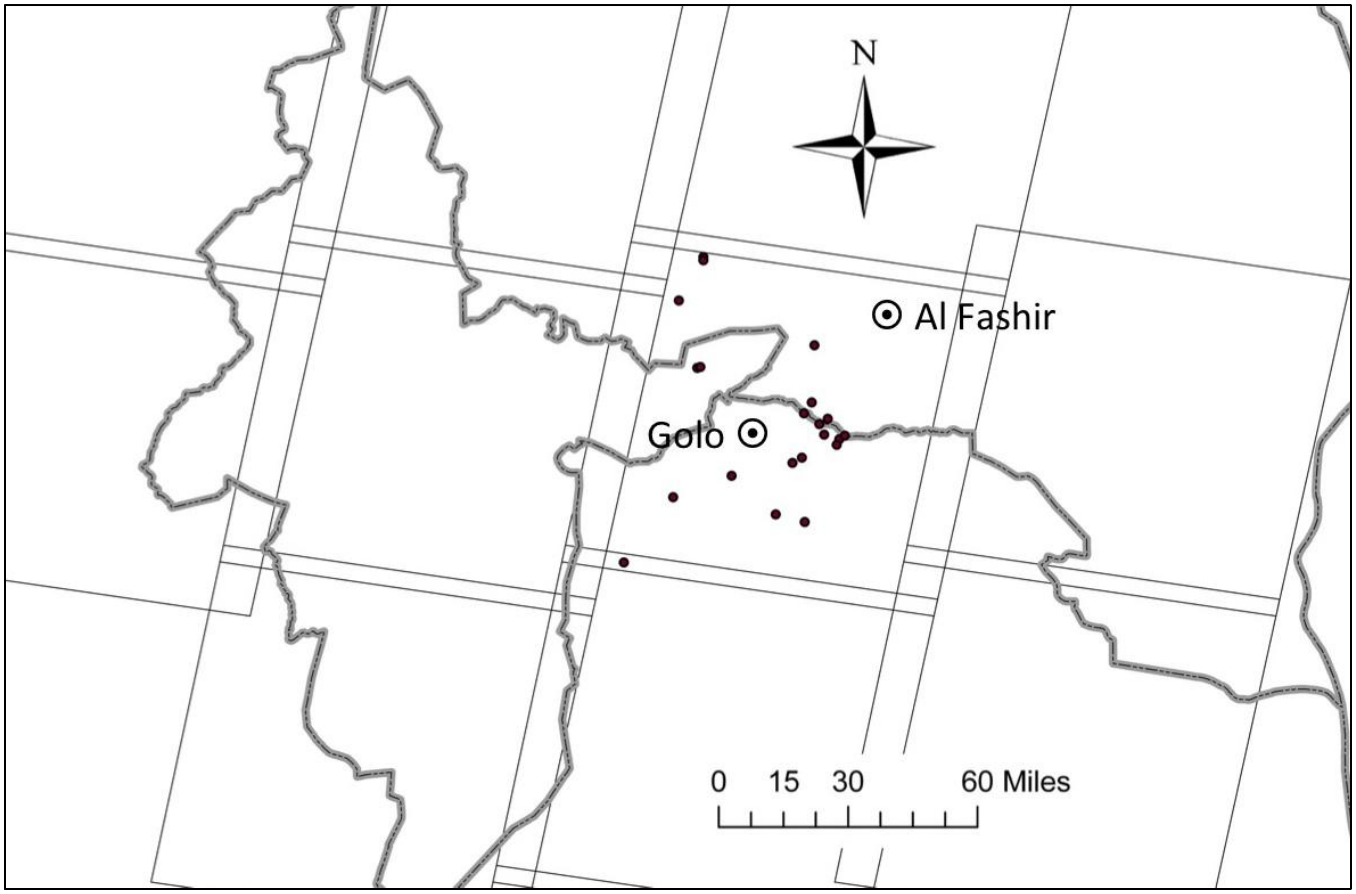

Figure 8: Villages detected as destroyed during the first ceasefire (September to early December 2003) only occurred in one path/row. These detections may not be violations to the ceasefire, but represent government operations against the JEM who were not signatories to the ceasefire and operated in this area in 2003.

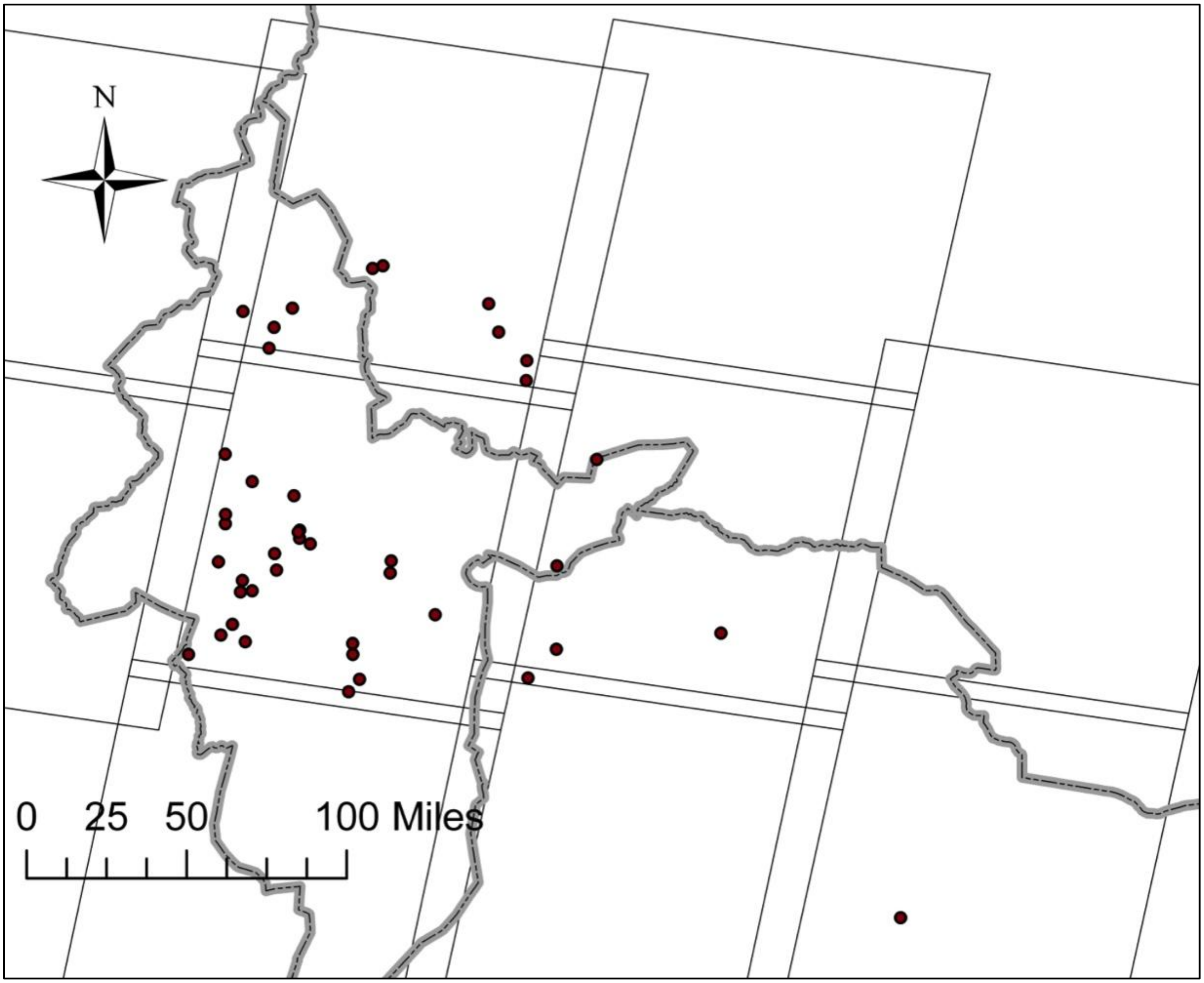

Figure 9: 42 villages detected as destroyed during the second ceasefire (11 April to 26 May 2004). These detections may not represent violations to the ceasefire, but continued operations against the NMRD who did not sign the agreement and operated in West Darfur.

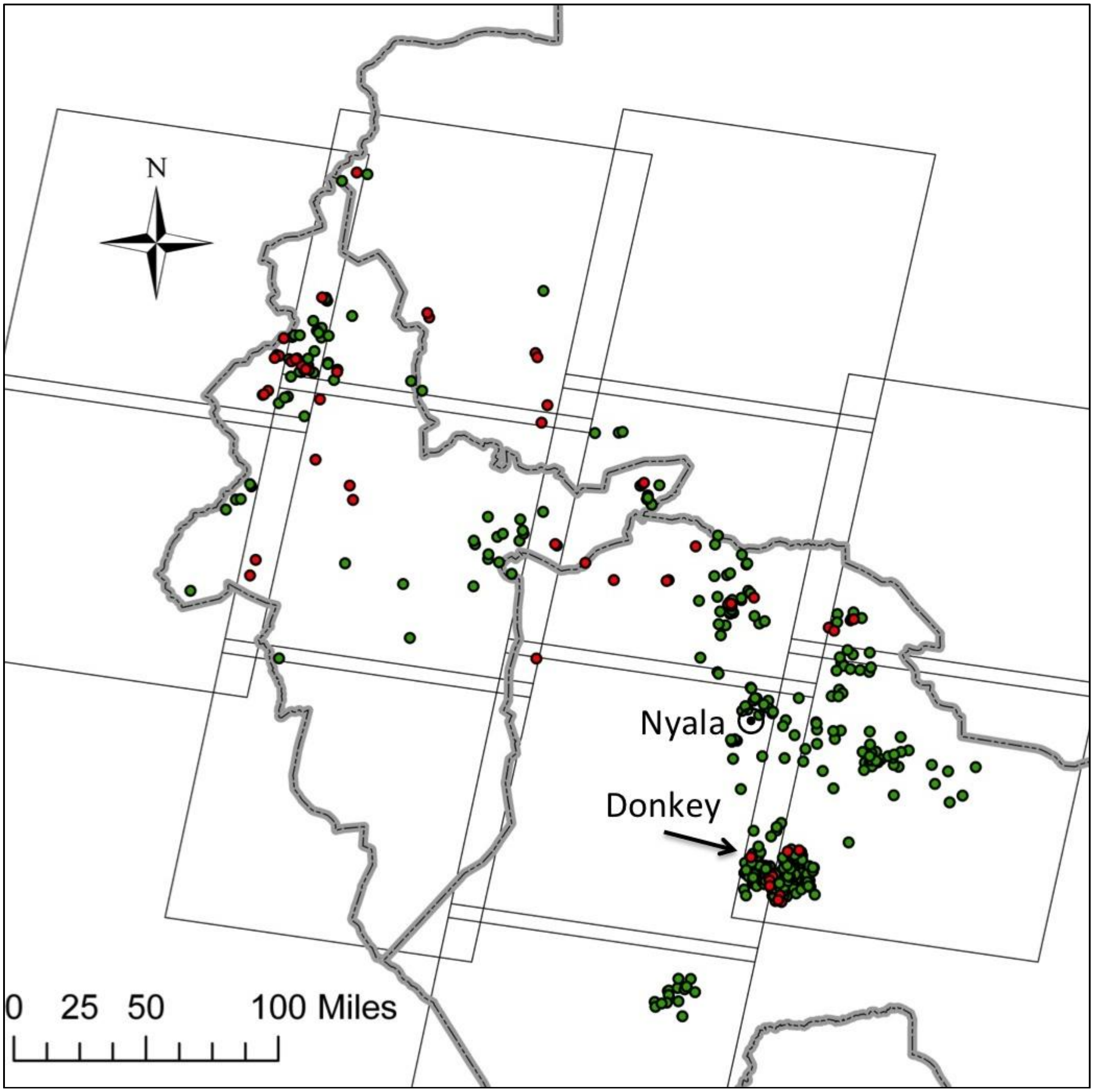

Figure 10: The highest rate of detections, 4.0 per day, occurred from October to December 2006 (green). The rest of the dry season (January to June 2007) only had 0.3 detections per day (red). These detections are consistent with press reporting of increased government attacks against rebel groups that did not sign the Darfur Peace Agreement, and of inter-tribal conflict between Zaghawa and Nur.

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