High-Resolution Satellite Imagery and the Conflict in Ogaden, Ethiopia

Summary Report

June 10, 2008

This report was produced by the Geospatial Technologies and Human Rights project as part of the Science and Human Rights Program (SHRP; http://shr.aaas.org) of the American Association for the Advancement of Science (AAAS). SHRP brings scientists and scientific expertise to efforts to achieve human rights around the world. As a program of AAAS - the world's largest multidisciplinary scientific membership organization - SHRP engages individual scientists and scientific associations in human rights efforts; applies scientific tools and technologies to enhance human rights work; brings human rights standards to the conduct of science; and promotes the human right to enjoy the benefits of scientific progress.

Acknowledgment
Special thanks to Karen Douthwaite, Jonathan Drake, and Jonelle Gingrich for their invaluable geospatial labor. Primary support for this project was provided by the John D. and Catherine T. MacArthur Foundation through grant number 06-88407-000-GSS.

Disclaimer
The interpretations and conclusions contained in this report are those of the authors and do not represent the views of the AAAS Board of Directors, its Council, and membership, or the John D. and Catherine T. MacArthur Foundation.

American Association for the
Advancement of Science
Science and Human Rights Program
1200 New York Avenue, NW
Washington, DC 20005 USA

Table of Contents

Summary
In early 2008, the Science and Human Rights Program of the American Association for the Advancement of Science (AAAS) undertook a review of satellite imagery concerning the Ogaden region of Ethiopia. This review was done at the request of Human Rights Watch (HRW), which was barred from the region, and utilized witness reporting that described attacks on towns, villages, and individuals in the Ogaden region, primarily in 2007. AAAS staff sought to acquire commercial high-resolution satellite imagery that corroborated these witness reports, following a methodology developed during similar projects by AAAS concerning Darfur and eastern Burma. This work was funded by the John D. and Catherine T. MacArthur Foundation and seeks to refine applications and test new methods for non-governmental conflict assessment and monitoring using geospatial technologies.

Assessing reports of human rights violations in this instance relied on an initial set of witness statements provided by HRW in January, 2008. The draft final HRW report on this issue, entitled *Collective Punishment*[1], was then reviewed prior to release, drawing from the information gained from the initial reporting. Village names mentioned in the reporting were compiled and, where possible, their coordinates identified using a set of reference maps and geospatial data. These locations were then compared with existing archives of commercial, high-resolution satellite imagery, and in many cases new satellite imagery was ordered as well. Using these sets of satellite imagery, AAAS staff determined if visible evidence corroborating reports of attacks was found.

At present, AAAS has formally reviewed eight locations described in the final HRW *Collective Punishment* report as having been attacked and destroyed, largely by burning. An additional three locations are either still being analyzed or were discarded due to insufficient satellite imagery. Of the eight reviewed locations, all exhibited characteristics consistent with reporting, including significant removal of structures, in some cases possible evidence of burning, and new construction corresponding with forced relocation. These findings are detailed in the following pages.

AAAS welcomes comments and questions on its work to date, on any possible future image acquisitions, and input on past, present, and future attack locations in general. Please send such information, and any other comments, to Lars Bromley (lbromley@aaas.org; 202.326.6495).

[1] See http://www.hrw.org

Image Analysis in Ogaden

Satellite image analysis regarding the conflict in the Ogaden region of Ethiopia by the American Association for the Advancement of Science (AAAS) was undertaken at the request of Human Rights Watch (HRW). HRW was, in general, experiencing difficulties assessing events in the Ogaden region that took place in 2007, as they and other human rights organizations had been denied access to the area and few local sources of information were available. HRW had collected extensive witness reports from refugees in Somalia and Kenya, which provided the basis for the satellite imagery analysis. AAAS analyzed this information from HRW, and then – where possible – reviewed satellite imagery that might corroborate reported attacks on civilians and other human rights violations. AAAS undertook this work within its Geospatial Technologies and Human Rights project, which is part of the Science and Human Rights Program (SHRP) at AAAS. This project was funded by the John D. and Catherine T. MacArthur Foundation, and more information can be found at http://shr.aaas.org/geotech.

Reporting gathered by HRW from refugees in Somalia and Kenya summarized attacks on civilians throughout the Ogaden region, especially those which occurred in 2007. When possible, the precise locations of these attacks were identified by reviewing the reporting in accordance with geospatial data layers. These layers, assembled using ERDAS Imagine and the ArcView Geographic Information System (GIS), included:

- LandSat 7 GeoCover 2000 satellite imagery, acquired from the Global Land Cover Facility,[2] used to identify roads, seasonal and other waterways, land cover, and larger towns.
- Elevation data from the Shuttle Radar Topography Mission, acquired from the Global Land Cover Facility,[2] used to identify topographic characteristics such as valleys and seasonal waterways.
- Placenames compiled from the US National Geospatial Intelligence Agency[3] and from the University of Georgia Geographic Information Support Team[4].
- National and administrative unit borders compiled from the Digital Chart of the World[5] and the University of Georgia Geographic Information Support Team[4.]

In addition, a locally produced map of the area and local anecdotal information were often used to locate some of the villages mentioned by HRW. At times, high-resolution imagery available on GoogleEarth for portions of the region was also reviewed to precisely locate towns and villages. As with Darfur and Burma, the databases of village names were generally the most important information source given that most reported attacks referenced a village name. Searching for specific attacked villages was facilitated by a so-called 'fuzzy matcher' that utilized the Levenshtein Distance approximation algorithm implemented in PostgreSQL. This tool allowed comparison of reported placenames with similarly-spelled placenames referenced in the above mentioned sources. Such approximate comparison is essential for overcoming difficulties in recording witness statements, transliteration of reports, and the like.

[2] see Global Land Cover Facility: http://glcf.umiacs.umd.edu/portal/geocover/
[3] see National Geospatial Intelligence Agency: http://www.nga.mil
[4] see Geographic Information Support Team: http://gist.itos.uga.edu/
[5] see University of Pennsylvania Digital Chart of the World Server: http://www.maproom.psu.edu/dcw/

Using the HRW reporting together with the geospatial data layers, AAAS was able to precisely map many of the reported attacks. For those reports which described the burning or wholesale destruction of a town or village, AAAS then attempted to acquire satellite imagery from both before and after the reported attack. By comparing such imagery, certain changes – for example, the razing or burning of a village – can be identified and analyzed. Specifically, by visually comparing more recent imagery with images collected prior to reported attacks, features such as villages and structures that have been removed in the intervening years are relatively easy to identify. Likewise, new construction, such as recently added or expanded villages, is also relatively easy to identify. Some other features, such as settlement abandonment and burn scars, can be tentatively identified, though confirming this assessment may require a deeper level of analysis which is not always feasible. Visual inspection of the imagery was the primary methodology employed for damage assessments, and damage assessments sought only to corroborate reporting received from HRW. In no cases were judgments regarding the possible causes or perpetrators of destruction inferred from the satellite imagery.

About the Imagery

Since 2000, high-resolution commercial satellite operators have acquired imagery with their respective satellites, largely for areas where customers request images. Once imagery is acquired from a satellite, it is then added to the companies' archives and generally made available for resale. In the case of the Ogaden region, this has resulted in a sparse archive of imagery for portions of the region, and non-existent coverage for others. Based on the locations of attacks reported by HRW, AAAS searched these archives for available imagery covering these attack locations. Imagery bracketing a reported attack, in that one image was acquired before the attack and one image after the attack, can sometimes be found entirely in the archives. More often, only a 'before' image can be found in the archive, and an 'after' image needs to be newly acquired, in which case AAAS places an order for such an image. Unfortunately, there is frequently no available archive imagery whatsoever for the locations of interest, making comparison of 'before' and 'after' images impossible. While in other regions effective analysis can be occasionally done with only 'after' imagery, this method was quickly discounted for the Ogaden region given the difficulties involved.

AAAS used several types of commercial satellite imagery in this analysis, each with one meter or better spatial resolution. Spatial resolution refers to the degree of detail the satellite sensor can 'see,' and thus the finer the resolution, the more information on conflict effects the sensor can provide. In a region such as the Ogaden, where home sizes are relatively small, AAAS always seeks the finest resolution satellite imagery possible. While resolution continues to improve, imagery with fine enough resolution is currently available from four different operational satellites[6], three of which were used in this project.

One source was the Ikonos satellite, operated by the GeoEye (http://www.geoeye.com) company. Ikonos is a multispectral (color) satellite with one meter panchromatic (black and white) resolution that has been in operation since 2000, giving it relatively deep archives. The other satellites utilized were WorldView and QuickBird, operated by DigitalGlobe (http://www.digitalglobe.com), which have panchromatic 60 centimeter spatial resolution and 50

[6] A fifth satellite, Orbview, operated by GeoEye, operated from 2003 until 2007 until experiencing a hardware malfunction.

centimeter[7] resolution, respectively. QuickBird became operational in 2002, while WorldView began delivering imagery in late 2007. QuickBird also has multispectral capabilities, while WorldView is solely panchromatic.

Of special note, the general public cannot request WorldView to acquire images of specific locations, but the public can purchase such images if they are in the DigitalGlobe archives. Only the US Government can direct WorldView to acquire new imagery. While QuickBird and WorldView provide the greatest level of detail and are thus preferred for new image acquisitions, Ikonos has been in orbit longer and has a more extensive archive of imagery for the Ogaden region.

Challenges

As with previous efforts in Darfur and eastern Burma, AAAS encountered numerous challenges over the course of this project. The process of precisely locating attacks based on reporting remained relatively laborious and difficult given the necessary translations and transliterations between local languages into the Latin (English) alphabet. In addition, the Ogaden region is perhaps one of most poorly mapped areas in the world, and in general terms locating specific villages based on reporting can be extremely difficult and often impossible. Unlike other AAAS work on Burma and Darfur, in no cases were GPS coordinates provided with the reporting, though considerable local knowledge was provided. For example, villages were sometimes identified as being along a specific road between other known towns, allowing a search for that village using high-resolution imagery. Though this was a relatively difficult method for locating villages, it was employed successfully in this project.

A unique and important circumstance of the Ogaden analysis is the nomadic nature of much of the population in the region. Nomadic settlements present a particular difficulty for the type of analysis performed for this project as a result of their frequent migration. While some towns are considered permanent, they can grow and shrink over the course of a year due to fluctuations in nomadic populations, and many smaller villages will relocate altogether. Migration schedules and patterns are relatively undocumented given available information sources. Likewise, nomadic home sizes are especially small and can be difficult to document in even the best commercially available satellite imagery. A more rigorous scholarly review of nomadic populations in the Ogaden region might be possible[8], but was not attempted as part of this analysis.

---

[7] While WorldView has 40 centimeter capability, it is degraded to 50 centimeter resolution for non-US Government (USG) client as required by US law.

[8] An initial review of nomads in Ogaden could include:
- E. Fratkin, K. A. Galvin, and E. A. Roth (Eds.), *African Pastoralist Systems: An Integrated Approach*. Boulder: Lynne Rienner Publishers.
- Lewis, I.M. 2002. *A modern history of the Somali : nation and state in the Horn of Africa*. Oxford: James Currey.
- Lewis, I.M. 1961. *A pastoral democracy: a study of pastoralism and politics among the northern Somali of the Horn of Africa*. New York, N.Y.: Oxford University Press for the International African Institute.
- Massey, G. 1987. *Subsistence and change: lessons of agropastoralism in Somalia*. Boulder: Westview Press.
- Zewde, B. 2001. *A history of modern Ethiopia, 1855-1991* (2nd ed.). Oxford: James Currey.
- World Food Program. *Estimating Population Size in Emergencies*. Rome, 26 September 2006. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp111670.pdf

Some effort was made by AAAS to assess nomadic population fluctuations. A survey done of nomadic settlements around the town of Labigah indicated the overall number of nomadic structures increased by about 10% between a 2005 satellite image and a 2008 image, despite evidence of near-total destruction of the town of Labigah itself in the intervening period. While the possibly burned remains of some nomadic settlements were seen in a 2008 satellite image, the generally itinerant nature of the settlements and the local soil characteristics make assessment of their actual status almost impossible. Overall, it is probably not possible to rapidly reach conclusions about the health of nomad settlements with the imagery used in this analysis.

To ensure the most accurate results, AAAS for the most part sought to review only permanent towns in the Ogaden, as indicated by their location along a well-defined road and by the presence of square structures with metal-sheet or brick roofing, and most often including a mosque. Nomadic villages were distinct in that their round structures are largely made of other materials, such as brush, tarps, and animal hides, and featured easily recognizable brush-fencing around their exterior. Also, they were not located along roads, though they often lie near roads and feature well-worn footpaths in the vicinity. Lastly, given that more permanent towns also feature significant nomadic population fluctuations, care was taken to differentiate between those fluctuations and wholesale destruction.

Regardless of their permanence, towns and villages in Ogaden generally feature small structures, with sizes down to a few square meters, challenging the limits of commercial satellite sensors. Further, the relative paucity of archival imagery for the Ogaden means that, often, no archival imagery exists for a given location and thus before-and-after comparisons are not possible. Trying to determine if a village was once present in a location based only on a single, newly collected image can be exceedingly difficult. While it is occasionally possible given ideal conditions, as sometimes seen in Burma and Darfur, no such attempts at single-image analysis were made in the Ogaden review.

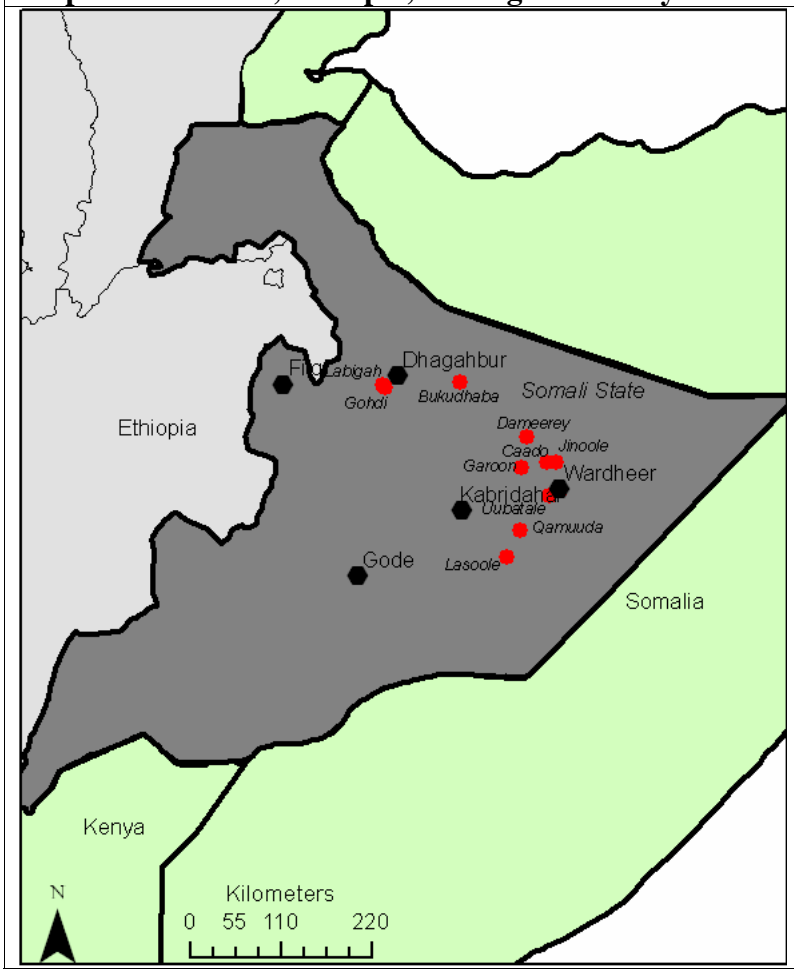
The military tactics reportedly in use are likewise an important factor in this analysis. Specifically, in the case of the Ogaden, towns and villages are often not wholly destroyed, but rather their residents are attacked and harassed, and structures sometimes damaged, as residents are forcibly driven out. In some cases this expulsion is short term, while in others it can go on indefinitely. Identifying a damaged or abandoned village is not quite possible with the imagery available, especially given the nomadic characteristics of the population. In addition, much of the reporting indicates that many attacks in the region are interpersonal in nature, including harassment or perhaps the killing of several people, and/or rapes and assaults on a similar scale. Commercial satellite imagery is of course not appropriate for analyzing such attacks.

Several other factors conspire to make imagery analysis in these circumstances quite difficult. For one, reporting itself is often quite uneven and incomplete. With no access to the original witnesses or inhabitants of the towns in question, it was often not possible to precisely understand what took place there. Given the stress of such violent, chaotic situations, this can perhaps result in fleeing civilians reporting a village burned when only limited burning took place, or other problematic reporting. In addition, in many cases imagery was acquired months, or longer, after the reported attack, and re-building or nomadic fluctuations can make simple visual interpretation of imagery more difficult in these cases. Lastly, given a reliance on geospatial databases, themselves gathered over long time periods by multiple entities and organizations, errors exist even in the underlying mapping resources.

Results

AAAS attempted to review 11 of the locations identified as burned in the HRW *Collective Punishment* report (see Map). Imagery for three locations was inadequate for analysis as of the release of this report, and thus definitive reviews were conducted on eight of the locations. Of those, all bore signs consistent with events as described in the HRW reporting. These results are summarized below and in Table One. Definite damage to the villages of Dameerey, Lasoole, Labigah, Qamuuda, and Uubatale, was documented, while likely damage to the villages of Bukudhaba and Garoonka was also identified. Signs consistent with reports of forced relocation in the town of Wardheer were observed in imagery of that area.

Map: Somali State, Ethiopia, and Ogaden Study Sites



At present, AAAS is still awaiting new image collections for the village of Jinoole, which will conclude image acquisitions and analysis for this project. In addition, imagery for the towns of Caado and Gohdi was also acquired, though ultimately deemed insufficient for analytical purposes. In the case of Caado, pre-attack imagery only existed for a small portion of the town. For Gohdi, given its likely nomadic population status no final analysis was produced, though a small settlement in the proper location was removed between acquisition of the two images with some possible evidence of damage and burning. For these reasons, samples for Jinoole, Caado, and Gohdi are not provided in this report.

Note that image analysis was also done on numerous other villages first reported as attacked by HRW, with results helping to inform determination of their final status in the *Collective Punishment* report. Specifically, numerous towns initially identified as burned were reclassified as attacked or untouched based on satellite imagery showing no indication of structural removal on a scale consistent with wholesale burning. These towns included Qoriley, Birqod (also known as Birqodka), and Mudulka. Finally, analysis was attempted on several other towns in the Ogaden region, but difficulties determining their precise location and overall budget constraints forced AAAS to abandon that analysis. These towns included Dhabar-Dhalool and Sancaade.

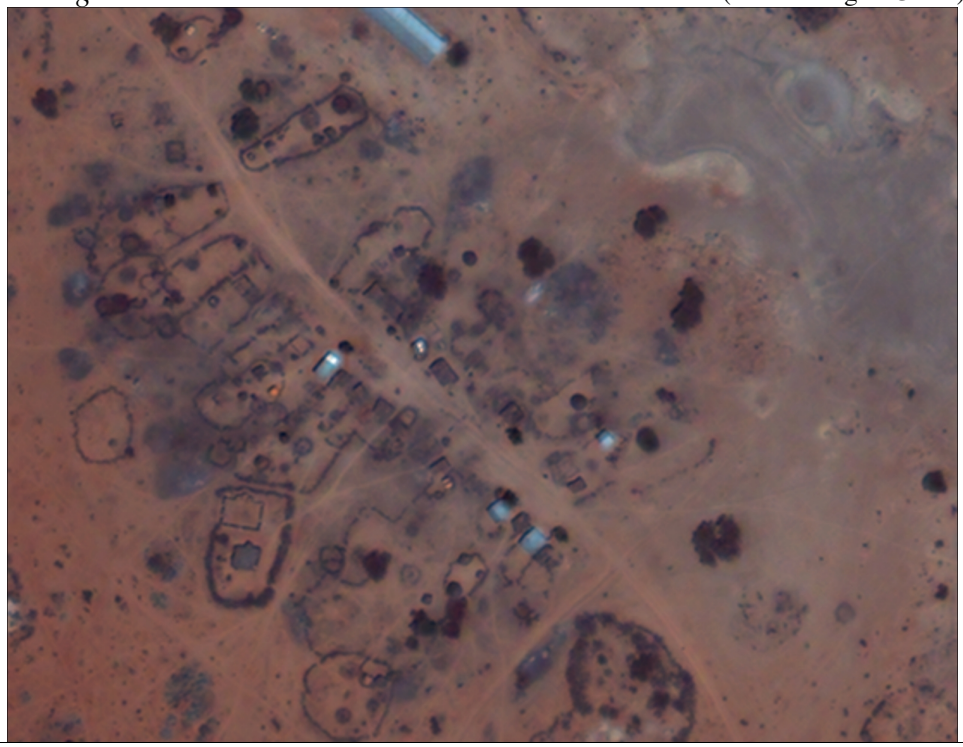
Table One: Summary of Imagery Analysis Findings

Location	Latitude	Longitude	Image Dates	Analysis Summary	Figure
Bukudhaba	8.16	44.24	12/2005, 12/2007, 5/2008	Moderate removal of structures documented. Possible rebuilding activity.	
Caado	7.27	45.20	2003 (partial) and 1/2008	Incomplete imagery coverage for town, no analysis possible.	
Dameerey	7.55	44.98	12/2006 and 3/2008	Approximately 65 structures removed, possible indications of burning.	1
Garoon (*aka* Garoonka)	7.22	44.92	12/2006 and 3/2008	Approximately 21 structures removed, possible indications of burning. Poor image quality a factor.	2
Gohdi	8.09	43.41	9/2005 and 2/2008	This village is proximate to Labigah and imagery indicates possible destruction. Unfortunately nomadic villages are problematic for satellite-based analysis. Sample deemed inconclusive.	
Jinoole	7.28	45.30	UNK	Image acquisition in-progress.	
Labigah	8.12	43.39	9/2005 and 2/2008	Approximately 40 structures removed, possible indications of burning.	3
Lasoole	6.23	44.75	3/2005 and 7/2007	Near-complete removal of the town, approximately 76 structures, and possible indications of burning.	4
Qamuuda	6.53	44.90	12/2006 and 3/2008	Approximately 85 structures removed and possible indications of burning.	5
Uubatale	6.90	45.22	8/2004 and 2/2008	Approximately 25 structures removed. Reduced image quality a factor.	6
Wardheer	6.97	45.34	2/2006 and 12/2007	Significant removal of structures and addition of new structures documented in accordance with forced relocation reports.	7

Image One: Dameerey

Before Image: 23-Dec-2006 (© 2008 DigitalGlobe)

After Image: 7-Mar-2008 (© 2008 DigitalGlobe)

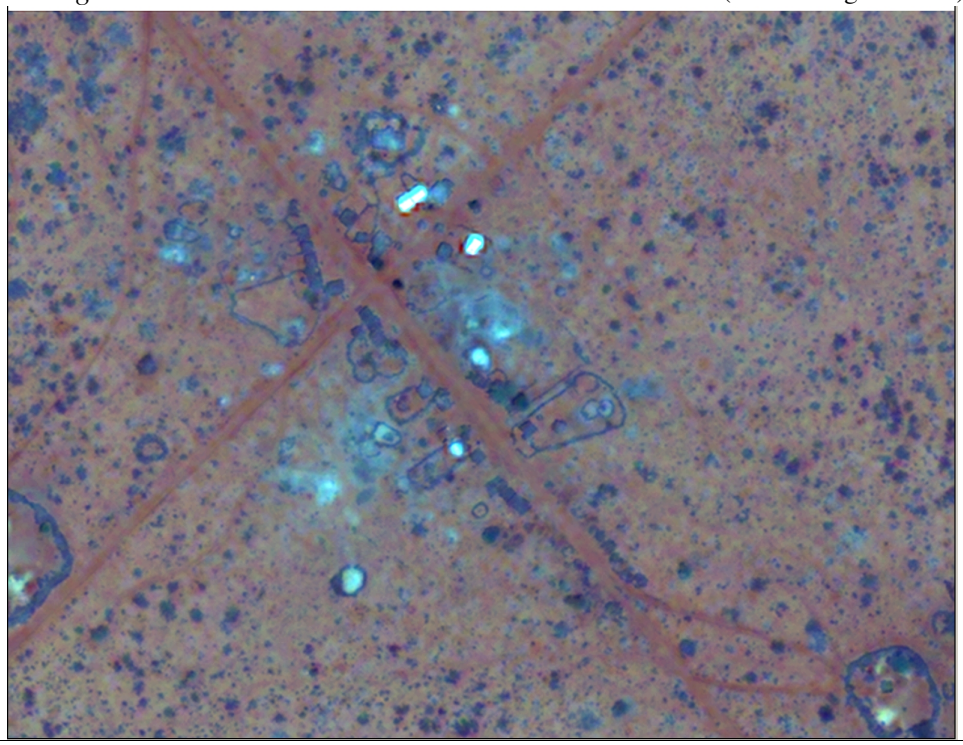


About 65 structures, almost the entire town, were removed (possibly burned), since the collection of the previous image. (Lat: 7.548; Long: 44.978)

Image Two: Garoon

Before Image: 23-Dec-2006 (© 2008 DigitalGlobe)

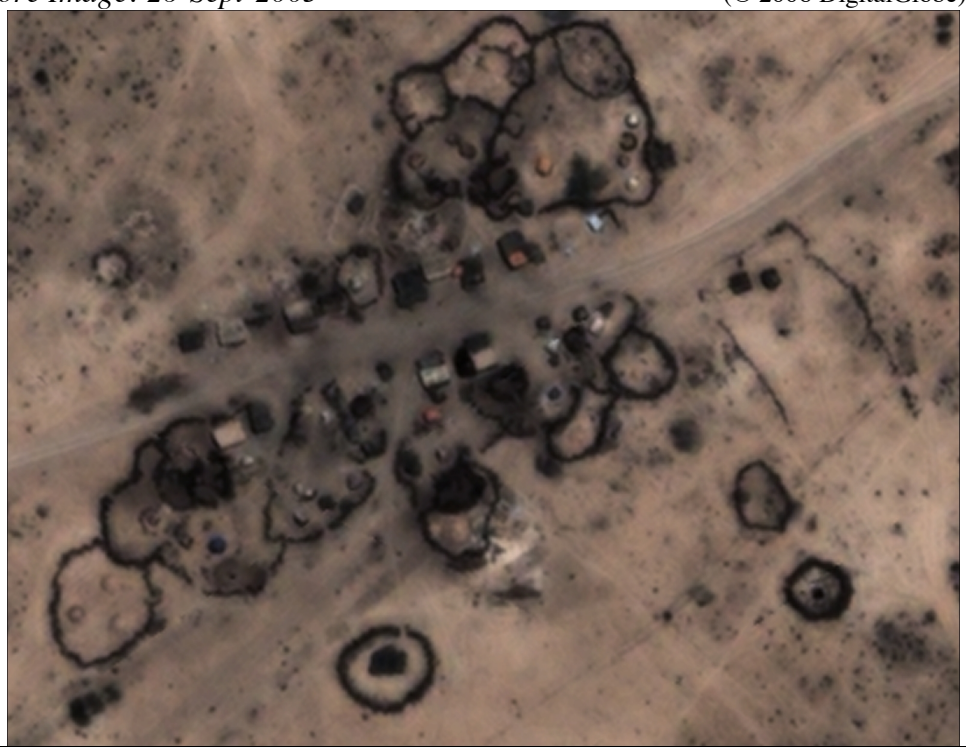
After Image: 7-Mar-2008 (© 2008 DigitalGlobe)



About 21 structures in this area were likely removed when compared in the period between the two images. In addition, the 2006 image shows signs of possible burning in the lower right quadrant along the road. Whitish areas in the 2008 image are most likely reflective sandy dirt, possibly trampled, though they are possibly ash. Note that the 2008 image quality was unfortunately poor due to a high off-nadir collection angle (Lat: 7.219; Long: 44.92).

Image Three: Labigah

Before Image: 26-Sept-2005 (© 2008 DigitalGlobe)

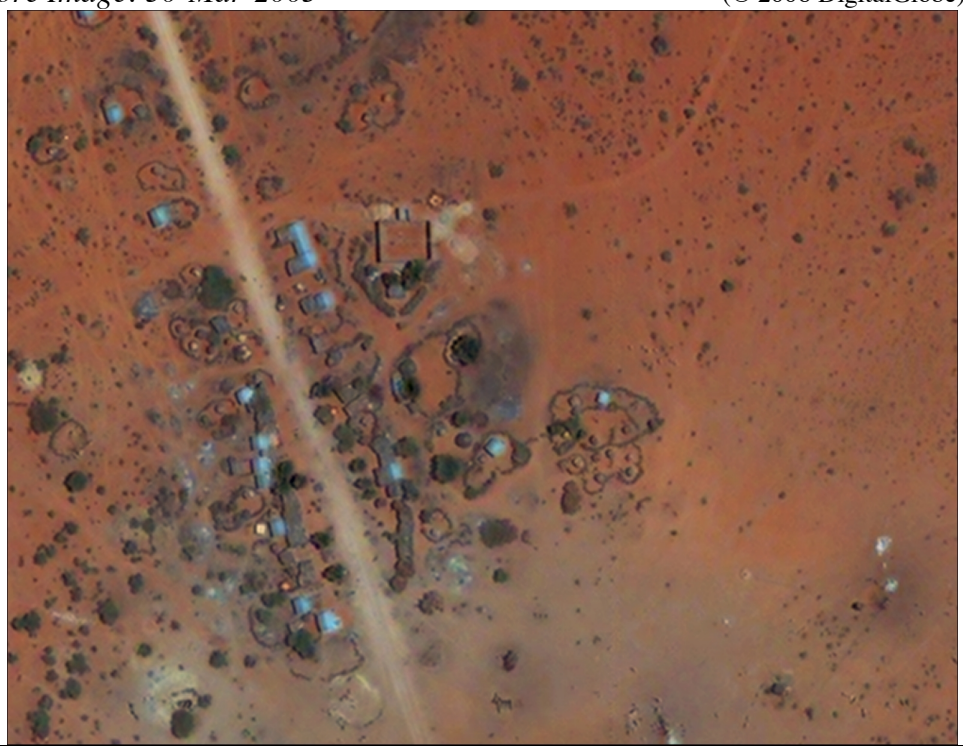


After Image: 28-Feb-2008 (© 2008 DigitalGlobe)

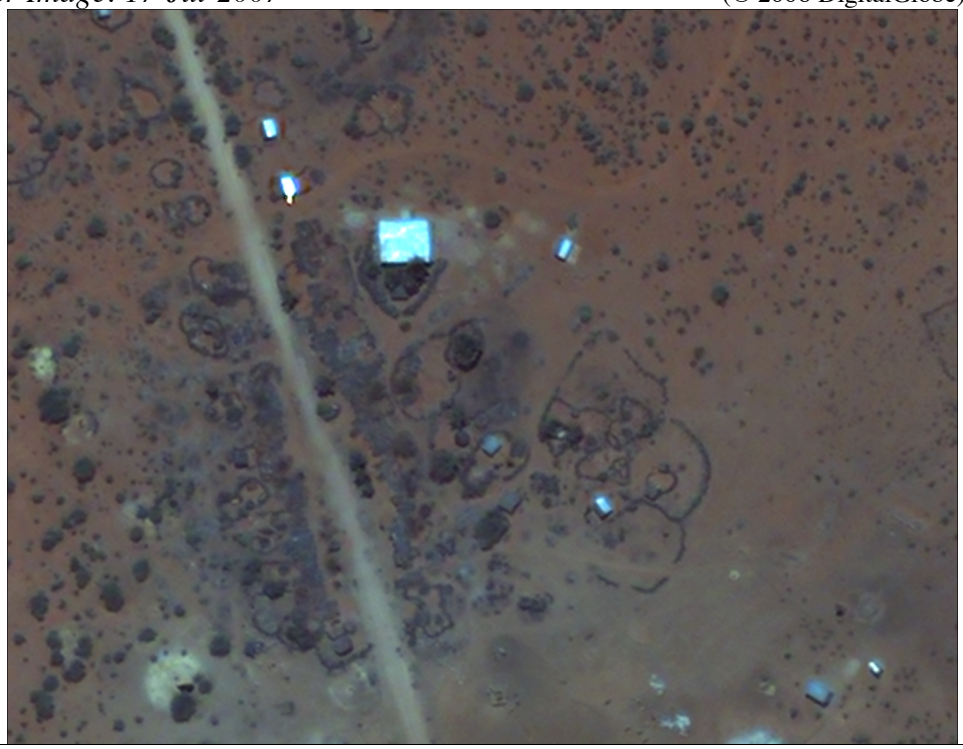
About 40 structures were likely removed or damaged when compared with the previous image, and the grey/white areas are possible evidence of burning. (Lat: 8.118; Long: 43.391)

Image Four: Lasoole

Before Image: 30-Mar-2005 (© 2008 DigitalGlobe)



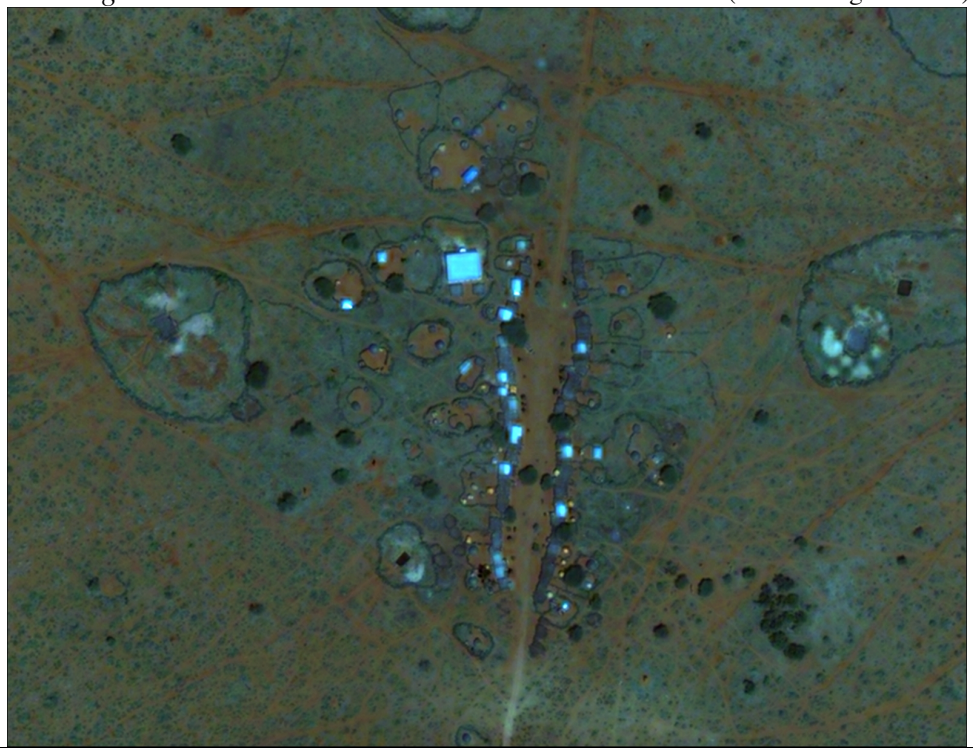
After Image: 17-Jul-2007 (© 2008 DigitalGlobe)



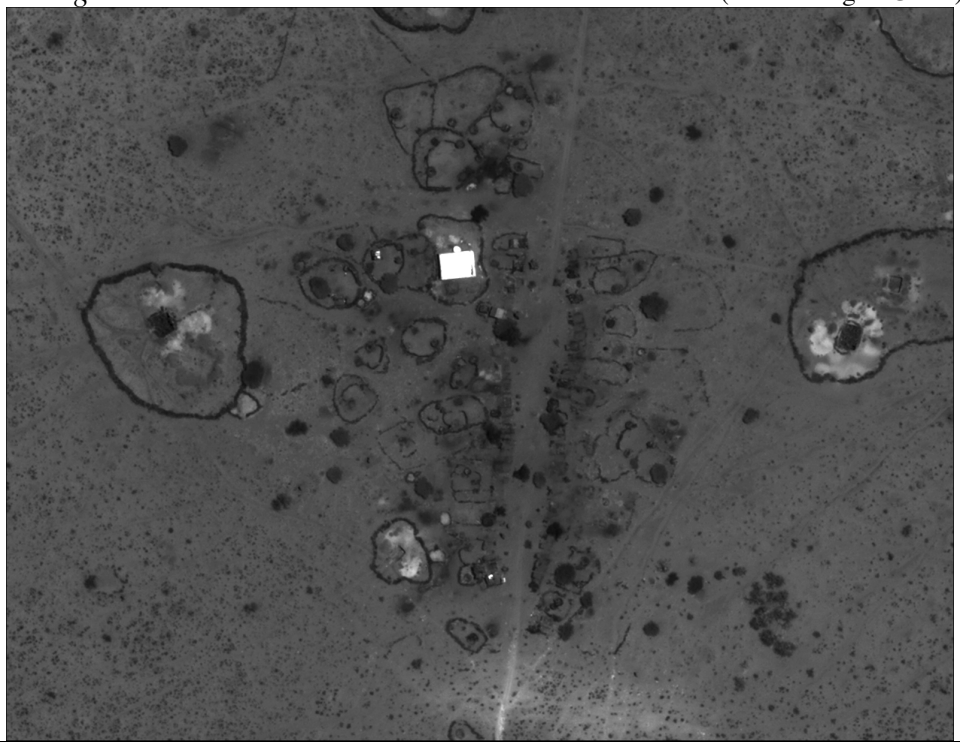
About 76 structures were likely removed or damaged when compared with the previous image, and burning is likely along the roadway. Note multiple new structures (not shown) also appeared in this area in the period between the two images. (Lat: 6.233; Long: 44.754)

Image Five: Qamuuda

Before Image: 23-Dec-2006 (© 2008 DigitalGlobe)



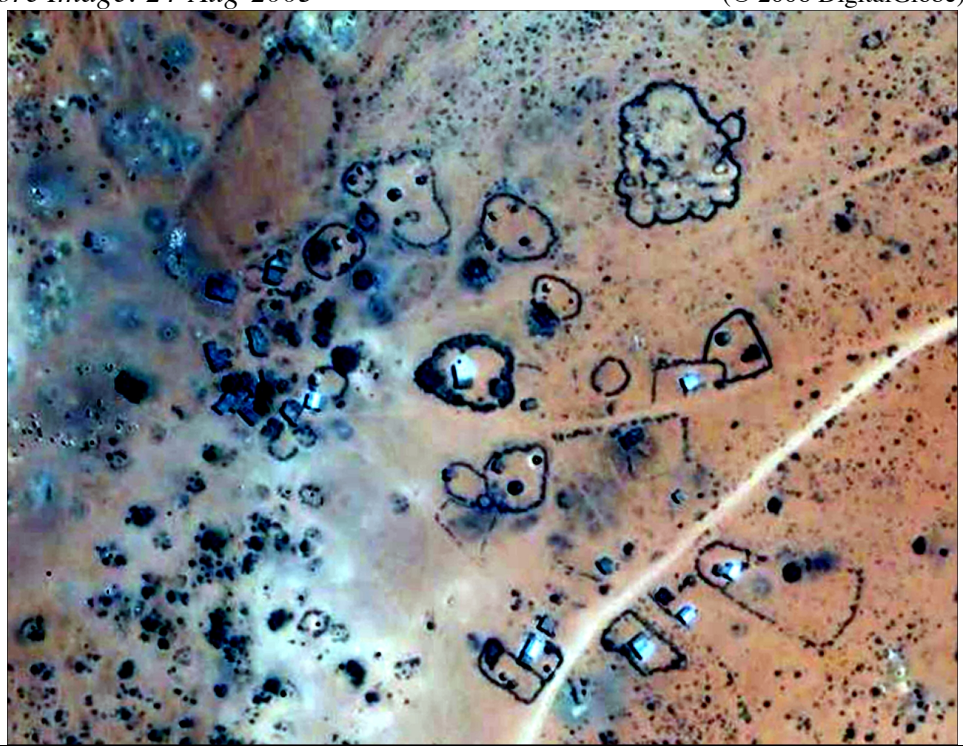
After Image: 24-Mar-2008 (© 2008 DigitalGlobe)



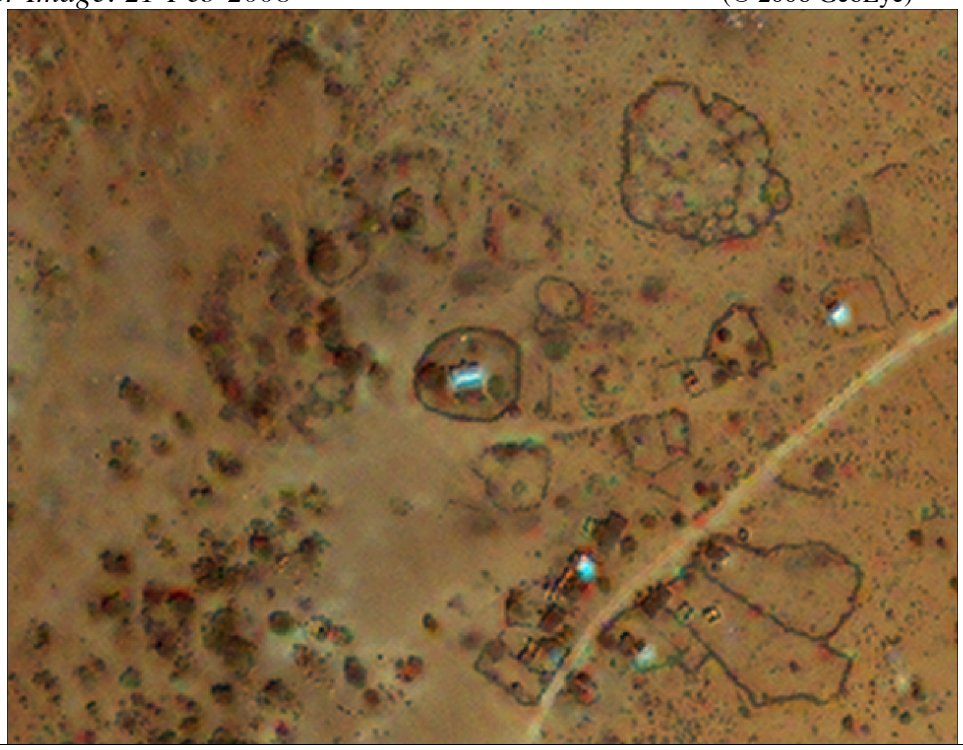
About 85 structures were likely removed or damaged when compared with the previous image. (Lat: 6.532; Long: 44.898)

Image Six: Uubatale

Before Image: 24-Aug-2003 (© 2008 DigitalGlobe)



After Image: 21-Feb-2008 (© 2008 GeoEye)



About 25 structures were likely removed or damaged when compared with the previous image. Note that the 2008 image is from the lower quality Ikonos satellite, accounting for the lower image resolution. (Lat: 6.903; Long: 45.218)

Image Seven: Wardheer

(© 2008 GeoEye)

In this image of the town of Wardheer, from December 30, 2007, yellow dots indicate structures removed since a previous image from February, 2006. Red dots indicate new structures added in that same period. The overall pattern is consistent with reports of forced relocations which indicated residents were compelled to leave outlying districts. (Lat: 6.974; Long 45.341)

Conclusion

The analysis of the Ogaden region of eastern Ethiopia in collaboration with Human Rights Watch allowed further methodological development for conflict assessment and monitoring in remote locations. Specifically, drawing from experiences mapping and imaging Darfur, Burma, Zimbabwe, and elsewhere, AAAS was able to refine its methods for rapidly locating villages in remote, poorly mapped conflict zones, utilizing information from a human rights organization. Analysis of reported attacks using a set of high-resolution commercial satellites has also been refined, the new WorldView satellite was used, and more cost-effective use of all satellites has been accomplished. Certain problems remain, related especially to the poor reference data for such areas and the difficulty rapidly compiling map-data and satellite imagery to inform analysis. Regardless, the process of informing investigations by a non-governmental organization such as Human Rights Watch with satellite imagery has proven quite effective.

AAAS has made significant progress in defining methods for remote conflict assessment and monitoring by human rights organizations using high-resolution satellite imagery. However, this progress has largely been on the assessment side, with actual monitoring of conflict regions as violence develops is more problematic. While based on the same principles, it of course requires vastly more funding to accomplish given the sharp increase in prices for new imagery. AAAS looks forward to further developing this near-real-time monitoring work in areas such as Ogaden, Darfur, and Burma.