Satellite Imagery Interpretation Guide

Maker Abior, Abyei Region
Photo Credit: DigitalGlobe

Intentional Burning of Tukuls

Harvard
Humanitarian
Initative

Signal Program on Human Security and Technology

Authors

All research, analysis, writing, editing and layout for *Satellite Imagery Interpretation Guide: Intentional Burning of Tukuls* was completed by the Signal Program on Human Security and Technology at the Harvard Humanitarian Initiative.

Ziad Al Achkar, Researcher
Isaac L. Baker, Imagery Analysis Manager
Brittany L. Card, Program Coordinator
Nathaniel A. Raymond, Director

About The Signal Program on Human Security and Technology

The Signal Program on Human Security and Technology (Signal Program) was founded by the Harvard Humanitarian Initiative in 2012. Signal Program staff, fellows, and partners work to advance the safe, ethical, and effective use of information technologies by communities of practice during humanitarian and human rights emergencies.

The program addresses critical gaps in research and practice HHI encountered while designing and manging the pilot phase of the Satellite Sentinel Project (SSP) from December 2010 to the summer of 2012. Through the analysis of satellite imagery and open source reports from Sudan, SSP was a watershed moment in the use of remote sensing to monitor the human security of civilians during and armed conflict.

The program's ongoing research and scholarship focuses on the following three areas:

Tools and Methods
Design and scientifically test tools and methods that remotely collect and analyze data about humanitarian emergencies;

Standards and Ethics
Help lead the development of technical standards and professional ethics for the responsible use of technology to assist disaster-affected populations;

Mass Atrocity Remote Sensing
And conduct retrospective analysis of satellite imagery and other related data to identify remotely observable forensic evidence of alleged mass atrocities.

About the Harvard Humanitarian Initiative

The Harvard Humanitarian Initiative (HHI) is a university-wide center involving multiple entities within the Harvard community that provide expertise in public health, medicine, social science, management, and other disciplines to promote evidence-based approaches to humanitarian assistance. The mission of HHI is to relieve human suffering in war and disaster by advancing the science and practice of humanitarian response worldwide.

HHI fosters interdisciplinary collaboration in order to:

- Improve the effectiveness of humanitarian strategies for relief, protection and prevention;
- Instill human rights principles and practices in these strategies; and
- Educate and train the next generation of humanitarian leaders.

Table of Contents

Foreword

It is my pleasure to introduce this invaluable guide by the Harvard Humanitarian Initiative's Signal Program on Human Security & Technology on the use of satellite imagery to remotely assess and document the deliberate burning of traditional family housing or tukuls in East and Central Africa--a method of warfare against civilians that is tragically commonplace across the region.

At a time when the commercial availability of satellite data is at an all-time high, the Signal Program has identified the critical need for practical and authoritative guidance to professionals and interested volunteer communities alike to meet the growing demand for satellite-derived information relevant to the work of human rights and humanitarian organizations.

The Satellite Imagery Interpretation Guide: Intentional Burning of Tukuls draws upon years of practical experience and lessons learned from the author's ground-breaking work on conflict monitoring in Sudan as well as the work of many other academics, aid workers and researchers in the same field. It provides clear and detailed guidance on the technical requirements, methods and challenges commonly faced by practitioners to accurately identify and assess the deliberate burning of tukuls with satellite imagery.

This guide represents a significant contribution to the growing body of research on the role of new technology in human rights and humanitarian work, and is an essential educational resource for those new to this exciting and dynamic field. Most importantly, this guide is only the second in a series of innovative and timely research products by the Signal Program that hopefully will continue in the years to come.

Josh Lyons
Satellite Imagery Analyst
Human Rights Watch
Geneva, Switzerland
.

Acronym List

AOI	Areas of interest
HR	High resolution
HRW	Human Rights Watch
HHI	Harvard Humanitarian Initiative
IDP	Internally displaced persons
UNITAR-UNOSAT	United Nations Institute for Training and Research-Operational Satellite Applications Programme
VHR	Very high resolution
VTO	Voluntary technical organizations

Chapter 1: Uses and Methodology

1A. Need for an Interpretation Guide

The intentional targeting and razing of apparent civilian structures is a well-documented phenomena that routinely occurs during armed conflict throughout Africa, notably in East and Central Africa. Buildings that may often be targeted include civilian dwellings, humanitarian aid facilities, religious buildings, and schools. One of the most common and defining tactics of this violence is the widespread burning of traditional civilian dwellings, known generally as tukuls.

The intentional destruction of these dwellings, given their prevalence in these regions, is often one of the only available indicators of the intentional targeting of civilians observable in satellite imagery. It must be noted that damage analysis is often performed on other types of structures and infrastructure present in the same area and at the same time as the analysis of apparently destroyed tukuls.

This guide focuses on tukuls because they are a uniquely valuable metric for both documenting attacks on civilians during armed conflicts and assessing potential mass displacement that can result from these incidents. Future satellite imagery interpretation guides from the Signal Program may focus on other, related phenomena and structures present in similar operational contexts.

Tukuls and Armed Conflict in Africa
Tukuls are traditional civilian dwellings common in many areas of Africa. Built largely from organic, locally found material, tukuls are primarily circular mud and grass-thatch structures.[1] In some instances, tukuls may also be square or rectangular-shaped. Sometimes tukuls can be built from materials other than mud, including brick, stone, or concrete. Often, the roofs of tukuls are cone shaped.[2] However, the roofs can sometimes be pitched[3] or pyramidal as well.[4]

Tukuls are primarily found throughout countries in East and Central Africa, including the Central African Republic[5], Sudan,[6] and South Sudan,[7] where tukuls are burned as part of these ongoing armed conflicts. The destruction of tukuls as part of attacks on villages often result in the mass displacement of the civilians who live in these dwellings. For example, recent systematic attacks against civilian populations, including the burning of homes, in Unity state, South Sudan were reportedly undertaken with the intent to displace civilians.[8]

In many cases, civilian communities in these conflict zones are located in remote, insecure environments that cover large geographic areas. As a result, it may be difficult or impossible to collect first-hand information about attacks committed against communities living in these non-permissive environments. However, the interpretation of satellite imagery can provide organizations a means for more quickly and safely documenting and corroborating events that may have occurred in these difficult to access areas.

Role of Tukuls in Corroborating Reported Attacks
In these contexts, several major humanitarian agencies, human rights organizations, and researchers are increasingly employing high-resolution satellite imagery to capture information about these alleged attacks. As part of this work, satellite imagery is often collected of a location after an attack occurs to determine if civilian structures, such as tukuls, appear visibly damaged or destroyed.

For example, Human Rights Watch (HRW) used remote sensing to confirm the reported destruction of over 2,800 buildings, including tukuls, in the village of Abu Jeradil, Central Darfur, Sudan, as well as in surrounding villages nearby. HRW concluded, based on imagery analysis, that these structures were most likely burned down. This destruction occurred during an alleged April 2013 attack on the area by Sudanese government forces.[9]

Additionally, the United Nations Institute for Training and Research-Operational Satellite Applications Programme (UNITAR-UNOSAT) analyzed satellite imagery collected in February 2014 of Leer, South Sudan. Based on its

analysis, UNITAR-UNOSAT concluded that 1,556 burned or destroyed structures, including tukuls and other civilian structures, appear present in the town. Active fires and smoke plumes are also visible.[10]
Voluntary technical organizations (VTOs) are also increasingly being utilized to assist in the interpretation of remote sensing data related to these types of phenomena. This work is being done both to support humanitarian agencies assisting affected populations and human rights organizations seeking to collect evidence of alleged crimes.

As these and other examples show, remotely counting tukuls present in high resolution satellite imagery captured after a reported attack is becoming a widely accepted and reliable corroborative indicator of these alleged events having occurred. It should be expected that this type of analysis will likely become a more standard part of remotely determining the impact of armed conflicts on civilian populations in East and Central Africa.

Addressing the Pedagogy Gap in Tukul Analysis
The increasing adoption of remote sensing by humanitarian and human rights agencies for this purpose presents a critical operational challenge. Little formal, sector-specific research and pedagogy exist to guide the use of these methodologies in either a humanitarian or human rights context. The implications of this "pedagogy gap" may affect the accuracy, speed, and reproducibility of these types of analyses.

Understanding the history of the development and past use of remote sensing is helpful for addressing this gap. The earliest adopters of remote sensing were governments and militaries in the 1950's. By comparison, the application of remote sensing to humanitarian operations first began in the late 1980's and early 1990's. Initially, this technology was used primarily by large agencies, particularly UN and governmental organizations. Their adoption was a result of the growing commercialization of remote sensing.

However, the recent explosion in the volume of commercial satellite imagery collection has resulted in major growth in the number of humanitarian, human rights organizations, VTOs, and researchers accessing and employing this data as well. Additionally, the purposes for which it is being commonly used are expanding in breadth, depth and complexity.

Thus, rapid adoption and adaptation of this source of data has created a critical gap in accepted methodologies, examples of observable objects, and general best practices. Systematically and comprehensively addressing this gap will help ensure more accurate, actionable, and scientific data is generated by humanitarian and human rights analysts.

To help address this gap, *Satellite Imagery Interpretation Guide: Intentional Burning of Tukuls* provides an overview of the visual profile and characteristics of burned tukuls; common methodologies for this analysis; recommended best practices and operational considerations for analysts; and imagery examples of conflict-related burnings of traditional African dwellings.

This is the second publication in the Signal Program's *Satellite Imagery Interpretation Guide* series. The first was 2015's *Satellite Imagery Interpretation Guide: Displaced Population Camps*.[11]

1B. Intended Users and Potential Uses of the Guide

This interpretation guide is primarily intended as a reference and training resource for students studying humanitarian response and technology; volunteers supporting humanitarian operations; and general audiences interested in the application of these skills and technologies to humanitarian operations. While the guide may be of some utility to professional geospatial analysts, it is designed to serve primarily as an introduction to this work for those new to the field.

The goal of the guide is to provide suggested interpretation guidelines, tested techniques, and examples of data aggregated from case studies to develop skills in the following areas:

- Performing standardized counts of tukuls and other structures present in imagery;
- Identifying apparently burned tukuls versus apparently intact tukuls;
- Conducting basic forms of change detection using pre- and post-event imagery; and
- Assessing whether the burning of tukuls appears to be intentional.

Users will learn how these skills are applied to the interpretation of satellite imagery related to the alleged intentional destruction of tukuls in relevant regions and operational contexts. The guide will also provide reference examples of common, repeating scenarios to help standardize this type of interpretation and data set creation across communities of practice.

1C. Data and Methods

Imagery Selection

The guide includes case studies of 10 locations where standing and/or burned tukuls are present in Central and East Africa. The locations are Algheden, Eritrea; Bossangoa, Central African Republic; Gambella, Ethiopia; Mitwaba, Demoratic Republic of Congo; Kadugli, Sudan; Leer, South Sudan; and Maker Abior, Dungop, Tajalei, and Abyei Town, which are located in the contested region between Sudan and South Sudan known as the Abyei Area.[12] The case studies are based both on four new examples and images from past reporting by organizations who have engaged in this type of analysis.

These locations were selected for two reasons. First, tukuls are the primary traditional civilian dwelling type in these locations, including both rural and urban settings. Second, these areas provide examples of geographic regions where the intentional burning of tukuls is an ongoing and endemic part of armed conflict.

Imagery Data Sources and Analysis Methodologies

The following chart provides an overview of all sources of imagery discussed in this guide:

Figure Number	Location	Date	Source	Provider
3.1	Gambela, Ethiopia	20 January 2015	Google Earth	DigitalGlobe
3.1	Bossangoa, Central African Republic	03 November 2014	Google Earth	DigitalGlobe
3.1	Rumbek, South Sudan	14 January 2015	Google Earth	DigitalGlobe
3.2	Abyei Town, Abyei Region	28 January 2015	Google Earth	DigitalGlobe
3.3	Kadugli, Sudan	03 February 2015	Google Earth	DigitalGlobe
3.4	Abyei Town, Abyei Region	28 January 2015	Google Earth	DigitalGlobe
3.5	Maker Abior, Abyei Region	06 March 2011	DigitalGlobe	DigitalGlobe
3.6	Tajalei, Abyei Region	06 March 2011	DigitalGlobe	DigitalGlobe
3.7	Dungop, Abyei Region	03 February 2011	DigitalGlobe	DigitalGlobe
3.7	Dungop, Abyei Region	24 May 2011	DigitalGlobe	DigitalGlobe
3.7	Dungop, Abyei Region	26 May 2011	DigitalGlobe	DigitalGlobe
3.8	Leer, South Sudan	02 February 2014	UNITAR/UNOSAT	DigitalGlobe
3.9	Democratic Republic of Congo	20 July 2013	Google Earth	DigitalGlobe
4.1	Abyei Town, Abyei Region	15 February 2011	Google Earth	DigitalGlobe
4.1	Abyei Town, Abyei Region	26 May 2011	Google Earth	DigitalGlobe
4.1	Abyei Town, Abyei Region	28 February 2013	Google Earth	DigitalGlobe
4.1	Abyei Town, Abyei Region	03 September 2013	Google Earth	DigitalGlobe
4.2	Bossangoa, Central African Republic	15 December 2013	Google Earth	DigitalGlobe
4.2	Bossangoa, Central African Republic	07 January 2014	Google Earth	DigitalGlobe
4.2	Bossangoa, Central African Republic	03 November 2014	Google Earth	DigitalGlobe

All DigitalGlobe imagery dating from 2011 was previously acquired during the pilot phase of the Satellite Sentinel Project. The Google Earth imagery was downloaded directly through the platform's 'Save Image' function by analysts at the Signal Program.

The majority of imagery used in this guide was analyzed in ERDAS Imagine software, utilizing a dual-viewer function that allows analysis across temporal resolutions. Temporal resolution is the amount of time passed between shots collected over one area.[13] In ERDAS Imagine, imagery was analyzed at multiple different vectors. However, each are presented in this guide at a north-facing vector unless otherwise annotated with a directional marker.

Additionally, keeping count of destroyed and standing tukuls, was done using ERDAS Imagine's 'Count Feature' function. This tool allowed the analysts to perform counts of different objects with disambiguating symbols so that both standing and and burned tukuls could be accounted for, even if they are found within the same image. This function also allowed the analysts to save and store the results for future use.

Google Earth imagery was analyzed primarily within the Google Earth Pro platform by primarily utilizing the time-slider function to view archival imagery of an area. The directional tool was also employed when analyzing imagery at different angles. Additionally, imagery in Google Earth was compared with imagery analyzed in ERDAS Imagine through the 'Sync To Google Earth' function in the Imagine software.

Chapter 2: Interpreting Imagery of Razed Tukuls

2A: Operational Uses of Tukul-related Data

The use of satellite imagery as a corroborative indicator of an attack having occurred, and as a means of assessing the scope and impact of the event, can support different types of operations performed by a range of actors. These actors include governments, inter-governmental organizations, humanitarian organizations, human rights groups, and researchers.

In some cases, different types of organizations may perform these applications during either the same or different operational stages, depending on their mission and access to imagery data. For example, information about the number of civilian structures apparently destroyed may help inform the response planning of humanitarian organizations. A count of the number of apparent standing civilian structures present in imagery collected before an alleged attack may help inform a population estimate for a specific area.

The presence of destroyed tukuls or other structures in imagery captured after an alleged event can act as an indicator that humanitarian assistance for the affected community's population may be required. These attacks on civilian areas often result in widespread displacement, destruction of livelihoods, and casualties. Humanitarian organizations may use this information to inform rapid needs assessments of where operations should take place and the amount of relief goods that should be requisitioned, prepositioned, and delivered.

Satellite imagery can also be used to collect and document evidence of an event having occurred. Human rights organizations can employ this information as part of advocacy campaigns to protect vulnerable populations by corroborating and documenting alleged acts that may have been committed against them. This data is particularly valuable when corroborating eyewitness reports of gross human rights violations that these groups often collect.[14]

Sometimes imagery analysis of alleged attacks can also be a source of primary evidence in criminal cases, especially when witness reports are unavailable. However, it is critical to note that not all phenomena human rights groups work to document are visible in satellite imagery due to limitations of the technology. These limitations can include its spatial[15] and temporal resolutions.

Utilizing satellite imagery to document attacks against multiple communities over a period of time can also help individuals and agencies better understand, and in some cases anticipate, the attack patterns of certain armed actors.[16] If captured and analyzed in near-real time, this data can help support early warning activities by corroborating reports and providing otherwise unobtainable information from non-permissive environments.

In addition to having strong operational applications, satellite imagery can also be used by researchers to develop additional methods and tools for use by humanitarian and human rights organizations. Through this research, tools can be developed that may help standardize, enhance, and speed future civil society applications of satellite imagery analysis.

For example, algorithms may be developed to help analysts identify where observable objects, like burned tukuls or tents used by displaced populations, may be located.[17] The automation of this identification process is critical for the advancement of humanitarian applications of satellite imagery because, currently, images are manually interpreted by analysts - often a laborious and time consuming process.

2B: Operational Postures and Methods

There are two main operational postures for the use of satellite imagery analysis to capture and understand information about alleged attacks on communities. These postures - detection and documentation - are core to identifying and obtaining information about the disposition of, and changes to observable objects related to this phenomena over time.

Detection Posture
Detection is a two-step process. First, analysts must identify the areas of interest (AOIs) out of the total possible geographic scope that might be relevant. The identification of these locations can be accomplished in two ways. Public and/or confidential reports claiming that an attack has occurred can help inform what imagery should be obtained from which locations during what timeframes. Second, an analyst may visually discover evidence of intentionally burned tukuls while reviewing imagery of locations for evidence of destruction or other conflict-related phenomena.

Once the area of interest is identified and relevant imagery has been obtained, then the analyst can begin to identify specific structures that are present and ascertain the observable status of these objects. In the context of this guide, these structures could be apparently intact or apparently destroyed tukuls. In many cases, if an attack has occurred, a combination of standing and destroyed tukuls are often visible.

As part of this process, an analyst must be able to determine how both intact and destroyed tukuls can present in imagery across a variety of contexts. These commonly repeating visual properties are explained in detail in Chapter 3.

Documentation Posture
Following the identification of both standing and destroyed tukuls, documentation of data related to these observable objects and their ascertainable features can then be performed. Documentation is the process of ascertaining and capturing specific data about both objects and the surrounding physical characteristics of the AOI. In the case of burned tukuls, a numerical count of the destroyed, and, when applicable, the apparently intact structures is performed.

Documentation can be performed using two types of imagery sets. First, detection and documentation can only be performed if imagery captured after the reported event has allegedly occurred can be obtained. It is critical that any post-event imagery is captured as soon after the date when the reported event may have occurred as possible.

Capturing post-event imagery as close to the date of the event is critical to prevent or mitigate the impact of a variety of commonly occurring variable factors. These variable factors can include seasonal weather patterns, such as heavy rains; natural disaster-related events; conflict-related events; or population influxes and displacements that may impact the landscape or the size and disposition of a community's population.

If an image of the area before the attack can also be obtained, information from this pre-event imagery can then be used to build a baseline data set that better informs the analysis of any available post-event imagery. This baseline data allows an analyst to conduct what is referred to as "multi-temporal change detection".

Multi-temporal Change Detection
Multi-temporal change detection is the process of comparing two or more images of the same location from different times against one another to make probabilistic inferences about changes at that location over a specific time frame. [18] In most contexts of satellite imagery analysis, multi-temporal change detection is a core analysis methodology.

To engage in change detection, a differential change metric needs to be identified (e.g. number of burned tukuls versus intact tukuls). Once the change metric is identified, this pre-event imagery can be compared to post-event imagery, captured as close to the date of the event as possible.

By performing change detection, changes in the number of standing tukuls present before and after an attack can be more easily determined because the images can be compared in order to ascertain data about the structures. It also must be considered that some locations can be attacked multiple times, often in a relatively short timeframe. Repeated attacks on the same location can complicate assessing what apparent damage was caused by which attack and when.

If pre-event imagery is not available, an analyst can instead use post-event imagery only to count burned tukuls in the area. While this scenario is not optimal, it can still produce data sets that have both actionable and evidentiary value for responders and investigators.

2C: Key Practical and Operational Considerations

There are several key practical and operational considerations that an analyst should be aware of when interpreting satellite imagery of intentionally burned tukuls. Issues an analyst might encounter will likely vary from location to location. No matter what the primary goal of the project might be, some critical cross-cutting questions should always be discussed and answered prior to interpreting imagery. These include identifying the purpose of the project; deciding what objects will be identified; ascertaining the limitations of available imagery data; and determining how the data will be processed, recorded and stored.

What is the purpose of this project?

It is always essential for all stakeholders involved in a project to identify what are the purposes and goals of the project before it begins. Establishing the purpose will help identify for the team what information should be captured, what data is required, and at what tempo it should be collected. Additionally, this process can help determine how that data will be analyzed and presented, and how that data will be used and preserved.

Projects are usually initiated for multiple purposes. All potential applications of the project should be identified at it’s inception, if possible. Some of the types of purposes that can be identified at the start of a project include the following:

- **Evidence** of alleged gross human rights violations, including civilian displacement
- **Situational awareness** for use by affected populations and responding agencies
- **Advocacy** to promote improved responses and encourage political actions
- **Research** on dynamics of an armed conflict and its impact on civilians

What objects will be identified?

Before imagery interpretation begins, the objects required for identification must be determined. When working in large groups, which is often the case in VTO deployments, common imagery examples of key objects should be identified and shared with the group. Descriptions of notable visual characteristics should be provided as well. A system for reporting and recording any variances to these examples and descriptions should be established, including a process for agreeing changes to the basis for object identification.

What are the limitations of available imagery data?

The potential value of imagery interpretation for supporting humanitarian response often depends on what imagery can and cannot show. To identify the limitations of imagery interpretation in a specific scenario, two separate but related lines of inquiry are required.

First, general constraints of imagery interpretation must be addressed. Some questions that may help identify these constraints include, though are not limited to, the following:

- Are the objects of interest visible at the available resolution?
- If so, what characteristics of these objects can be seen and scientifically measured throughout the image?
- What inferences about these objects of value can be drawn from this data?
- Are these inferences based on identifying characteristics unique to these objects and their function, or can they also be drawn about different objects and for what reasons?

Assessing Available Imagery Data
Analysts will also need to determine whether the minimum pixel resolution of available satellite imagery is appropriate for identifying observable changes to objects consistent with tukuls. The minimum pixel resolution required is dependent on the objects or phenomena that an analyst needs to document.

Due to the small size of the objects discussed in this guide (e.g. tukuls), the imagery interpreted consists entirely of either high resolution (HR) or very high resolution (VHR) satellite imagery. HR imagery is characterized by having a resolution of approximately 1 to 5 meters per pixel, whereas VHR imagery has a resolution less than 1 meter per pixel. Currently, all satellite imagery is composed of pixels, and the resolution of an image is characterized by the size of the pixel that constitutes the image. For example, a VHR image with a resolution of .50 meters, would be an image entirely composed of .50 meter pixels. Taking this into account, the smaller a pixel is in measurement, the more pixels could constitute an image, thus making the resolution greater and smaller objects within the imagery better defined.[19]

Second, other key questions should be asked about the quality, volume, and temporality (e.g. how recently the imagery was collected) of the imagery data available for the project. These questions may include the following:

- How recently was available imagery collected?
- Are there large amounts of clouds, sun glare, or other factors that may corrupt the quality of the imagery available?
- How many images are available and over what time frame?
- What type of imagery was collected (e.g. panchromatic, high resolution, low resolution, near-infrared, etc.) and how does this imagery type affect completing the assigned task?

These questions are imperative to answer because the availability of imagery will determine its usability by the project. However, even if imagery is available, but its quality does not allow analysts to document the objects and phenomena they are interested in, then the imagery will not be useful to the project.

How will data be processed, recorded, and stored?

One of the first things that must be determined is what software will be used to process the imagery. For example, all raw imagery data for this guide was analyzed in ERDAS Imagine, with additional tasks performed with Google Earth Pro.

Once imagery interpretation begins, consistency and accuracy in how analysts record, categorize, and note who collected what data is essential. Decide before interpreting imagery what data will be recorded; how data will be entered into a database or logging system, with what specifications (e.g. to what precision will latitude and longitude be shown, etc.); and how activities performed by each analyst will be captured.

Also, a data storage plan should be developed and agreed upon. While data security is always crucial, it is especially important to ensure that data is secure and uncorrupted when dealing with information about the location and status of vulnerable populations, such as refugees and internally displaced persons (IDPs).

Collecting and Storing Data as Evidence
If the goal of imagery interpretation is to support accountability proceedings in a judicial venue, extra steps and precautions should be taken to ensure that potential evidence is not contaminated and the chain-of-custody is preserved.[12]

Some of these extra steps and precautions may potentially include the following:

- Storing potential evidence in a secure, encrypted offline server;
- Ensuring version and access control procedures, including an access log to preserve chain-of-custody; and
- the creation of corresponding time and date stamped narrative notes by each analyst documenting what they did with the data and how they processed it.

How will images be annotated and presented?

Analysts must determine how they will annotate and present images and findings in a way that clearly conveys the results of the analysis to both general and specialist audiences. Different icons including dots, chevrons, and lines can be used to indicate burned or intact tukuls, however, it is critical that minimal amounts of annotations are added to the image so that they do not distract from the image itself.

Chapter 3: Visual Characteristics of Tukuls and Their Intentional Destruction

3A: Identification of Intact, Undamaged Tukuls

In order to assess whether or not a tukul has apparently been intentionally damaged by fire, analysts must be able to first identify apparently intact, undamaged tukuls. To perform this identification, analysts should be aware that tukuls, as mentioned previously, are not uniform in shape and size. A circular tukul with a conical roof is the most common variation. Tukuls may also have pyramidal and pitched roofs. Additionally, they can be square or rectangular (Image 3.1). Being aware of these visual variations across regions, and sometimes even within regions, is crucial.

Analysts should be mindful to the sometimes subtle differences that exist amongst tukuls across different ethnic groups, and that sometimes exist even within the same tribe or cultural demographic. For example, in Unity state, South Sudan, the Nuer tribe, who are mostly located in the central and southern counties of the state, construct primarily square-shaped tukuls. However, the Dinka tribe, who mostly inhabit the northern counties, mainly construct circular tukuls.[20]

The walls of a tukul are most often constructed with a wattle framework that is supported by a daub filling.[21] Mud bricks and concrete bricks can also be used. The conical roofs on circular tukuls are usually constructed out of thatch or other organically occurring materials. In some cases, tarps have been observed as being present on-top of a roof or integrated as part of it.

The square and rectangular tukuls, whose roofs can be sloped or pyramidal, can also be constructed out of thatch. However, depending on the region and its cultural demographics, other materials, such as metal, are used. It is important to note that the shape of a roof, especially a conical roof, can be difficult to identify in satellite imagery unless a shadow is cast to reveal the profile of the structure.

Shadows Cast by Different Tukul Types
The analyst should note the different types of shadows that can be cast by a tukul that may be relevant to identifying its shape and proportions. The importance of noting specific patterns of shadows on individual structures and groups of structures can help an analyst determine if an object is consistent with a tukul. Shadows can help an analyst disambiguate a tukul from other objects, such as trees or rocks. Tukuls can cast three types of shadows: “peak” shadow, “body” shadow, and “overhang” shadow.

An additional visual indicator that often accompanies these shadow types is the reflection, or glare, from the sun on the tukul roofs. On the surface of conical roofs, this glare can often be identified as a white mark directly opposite the side of the peak shadow, or on the side where the sunlight hits the roof. Similarly, on pyramidal and pitched roofs, this glare can be present on the angular edges of the roofs sunlit side.

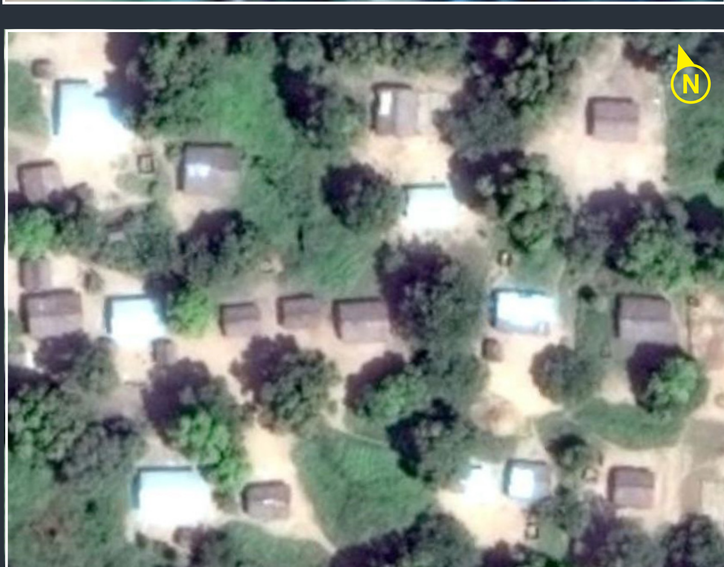
The first type of shadow that may be present is peak shadow, which is often visible on the conical roofs of circular tukuls. When sunlight falls on the tukul, the peak of the conical roof can cast a shadow on the roof of the tukul itself. The peak shadow emphasizes the conical shape of the roof.

Thus, the peak shadow assists in disambiguating tukuls with conical roofs from objects with potentially similar visual characteristics. Without a peak shadow, a conical tukul can sometimes appear as a circular object, with little to no other disambiguating visual indicators.

The peak shadow is also evident in both pyramidal and pitched roofs. However, their shadowing effect is different in size and shape than that of the shadowing effect of conical roofs. The peak shadowing on these types of roofs will likely cover more surface area compared to the narrow peaks of conical tukuls. This phenomenon is caused by the larger, angular face of pyramidal and pitched roofs obstructing more sunlight than the conical roof.

Image 3.1

Circular Tukuls With Conical Roofs
20 January 2015
Gambela, Ethiopia



Rectangular Tukuls With Pitched Roofs
03 November 2014
Bossangoa, Central African Republic

Square Tukuls With Pyramidal Roofs
14 January 2015
Rumbek, South Sudan

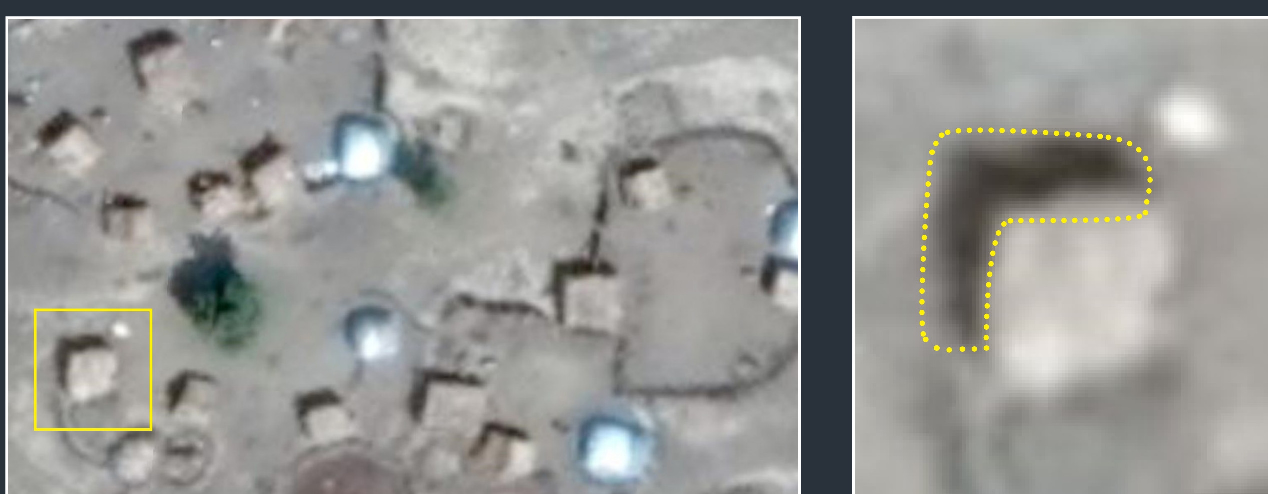
In Image 3.2, peak shadows are visible on circular and pyramidal tukuls present in the Abyei area, a disputed region between Sudan and South Sudan. On the circular tukul, a peak shadow is located on the northwest side of the roof, just below the peak. A peak shadow is also present on the northwest side of the pyramidal tukul.

Image 3.2

Pitch Shadow
28 January 2015
Abyei Town, Abyei Region

The second type of shadow that can be created by a tukul is body shadow. The body shadow can often be more evident in square or rectangular tukuls constructed with roofs that do not significantly extend beyond the walls of the tukul. Sunlight falling on the tukuls casts angular shadows. These shadows are visible in the direction opposite from which the sun is shining. In Image 3.3, this angular body shadow can be identified coming from the square-shaped tukuls found in the western outskirts of the town of Kadugli in Sudan.

Image 3.3



Body Shadow
03 February 2015
Kadugli, Sudan

The final type of shadow is overhang shadow. While this type of shadow can be observed on square or rectangular tukuls, overhang shadows are most often cast by the edge of the roof of circular tukuls. This shadow is more common in circular tukuls because the majority of these structures have roofs that overhang the walls of the structure. In Image 3.4, the overhang shadows cast by circular tukuls in this area of Abyei town can be identified coming from the circular-shaped tukuls.

Image 3.4

Overhang Shadow
28 January 2015
Abyei Town, Abyei Region

Factors that Affect Shadowing

A critical factor to consider when interpreting shadow types is that commercial satellites pass over areas on a relatively routine schedule. This operational factor results in imagery of areas being collected at roughly the same time of day each time when they are collected. Thus, the orbital patterns of satellites tend to regularly produce imagery of an area with the sunlight casting shadows in relatively the same direction and in relatively similar shapes in most every image.

One aspect of satellite imagery that analysts should consider is the angle at which satellites capture an image. The nadir, when referring to satellite imagery, is the point on the ground directly vertical from the center point of the satellite's sensor.[22] The off-nadir angle is the measurement of any point on the ground that is not at nadir. Thus, the off-nadir angle is point not directly vertically above from center point of the lens.[23]

The higher the degree of the off-nadir angle, the more the objects within the imagery may appear skewed, stretched, and distorted. Imagery collected at a high off-nadir angle can be useful in particularly urban settings, where the sides of larger structures can be better seen at an angle. However, when trying to interpret visual data, such as shape and size, a very high off-nadir could prove problematic by providing a less accurate representation of ground objects captured in the imagery. Many commercial satellite companies provide imagery with maximum off-nadir angles that range from 30 to 60 degrees.

3B: Identification of Recently Burned Tukuls

Burned tukuls, whether intentionally or unintentionally burned, have certain repeating visual characteristics that can be observed in satellite imagery. These characteristics relate to both how tukuls are usually ignited, what they are made out of, and the repeating patterns in which tukuls are often consumed by fires as they burn.

Seat of fire

Regardless of whether lit internally or externally, the roofs - because they are made from thatch or other dried, organic materials - are highly combustible and burn quickly. Thus, the roofs often appear as the origin point of the fire that destroys the tukul, a concept known in fire science as the "seat of fire."[24]

Villages that have been intentionally burned have multiple seats of fire because each structure has likely been burned individually. Sometimes structures can be burned by fires that originate from another structure that has been ignited nearby. However, analysts should first look for evidence of multiple individual structures being burned.

Four critical indicators of burned tukuls

Analysts should be aware of these four critical indicators when detecting evidence of apparently burned tukuls at any temporal resolution:

- **Charred walls:** Black in color and circular, rectangular, or square in shape depending on the type of tukul;
- **External ash**: An outline of ash caused by a roof that overhangs the exterior of the tukul being burned may be present around what remains of the tukul. This outline will likely be proportionate to what was the shape and size of the roof. Additionally, ash can be blown by wind in proximity to a burned structure, often scattering in a way consistent with the wind's direction;
- **Interior ash**: Ash resulting from the burning of the tukuls that may vary in color. The color of the ash is most often determined by the severity of the fire. Fires of medium severity often result in dark colored ash, whereas high severity fires result in grey or white ash.[25] Interior ash can be generated by the burning of the tukul's roof and walls, along with any objects inside that are combustible.
- **Ground scorching:** Lit tukuls can cause ground scorching by either the burning tukuls causing the ground vegetation to catch fire and/or the smoke, ash and heat of the tukul scorching the ground around it. Ground scorching is usually black in color.

3C: Visual Indicators of Intentionally Burned Tukuls

Determining whether tukuls have been intentionally burned through the analysis of satellite imagery alone is always based on a probabilistic assessment of available evidence. In the absence of ground confirmation, analysts must identify a few key indicators that are routinely consistent with the apparent intentional burning of tukuls. Three key visual indicators are critical for assessing evidence of apparent intentionality:

- **Spacing:** Observable unburnt spaces between burnt tukuls is the most critical visual indicator that an individual structure or group of structures has likely been intentionally burned. The unburnt ground between burnt structures indicates the deliberate targeting of individual structures;
- **Selection:** A related indicator to spacing is "selection" (e.g. some buildings or infrastructure being burnt when others are left untouched). When ground scorching obscures any visual evidence of spacing, selection becomes a key indicator of apparent intentionality. Evidence of selection may show intent to target certain types of structures (e.g. civilian dwellings) over others; and
- **Clustering:** Clusters of burnt structures, including entire villages, can be an indicator of intentionality. Clustering, a related manifestation of selection, is valuable for both showing apparent macro-patterns of perpetrators over time, as well as helping to rule out incidental, non-conflict related fires as the cause of combustion.

The properties of burned, and most importantly, intentionally burned tukuls are present in imagery of Maker Abior, Abyei Region, captured on 6 March 2011 (Image 3.5). This image was captured three days after a reported attack on the area. Approximately 20 circular tukuls of varying sizes appear to have been intentionally destroyed.[26]

Charred walls, circular and black in color, surround the perimeter of what used to be a standing, intact tukul. Inside the charred walls, white, black and grey interior ash is present. As stated previously, various ash colors indicate the intensity of the fire that previously burned. Additionally, exterior ash can be identified next to some of the burned structures. Ground scorching stemming from some of the structures is indicated by the black color and larger surface area, than compared to external ash.

Most critically, the unburnt spacing between the burned tukuls indicates that these structures were intentionally targeted. Standing, intact tukuls are also present nearby. The presence of these untouched structures, amongst clustered targeted structures, indicates these tukuls were individually selected by the perpetrator.

Image 3.5

Apparently Intentionally Burned Tukuls
06 March 2011
Maker Abior, Abyei Region

Additionally, in image 3.6 of Tajalei, Abyei Region captured on 6 March 2011, key characteristics are also demonstrated. Multiple burned structures, including both circular and rectangular tukuls, are present with the ground between them remaining unburnt. This pattern of destruction is consistent with that documented in Maker Abior. Black and white/grey ash are additionally present inside the remains of the burned tukuls. In some cases, ground scorching is also present next to the burned structures. Additionally, like in Maker Abior, trees throughout the attacked area remain intact.

Image 3.6

Multiple Burned Structures
06 March 2011
Tajalei, Abyei Region

Non-conflict Related Fires
In addition to the intentional burning of civilian dwellings during conflict, parts of Central and East Africa are prone to large-scale wildfires when vegetation becomes desiccated during the dry season. This seasonal phenomena often results in naturally occurring fires. These fires can spread over several square kilometers and have the ability to raze traditional structures when the fire is not quickly contained.[27]

Accidental fires, such as fires from cooking stoves, that damage structures and displace communities may occur. Further, the intentional burning of land for clearance or agricultural purposes, known as the slash-and-burn technique, is prevalent as well. During slash-and-burn, forests or wooded areas are cleared to to create fields for planting. Already cleared areas can also be lit prior to planting. The resulting ash is used to add nutrients to the soil for crop cultivation.[28] These fires often create large burned areas.

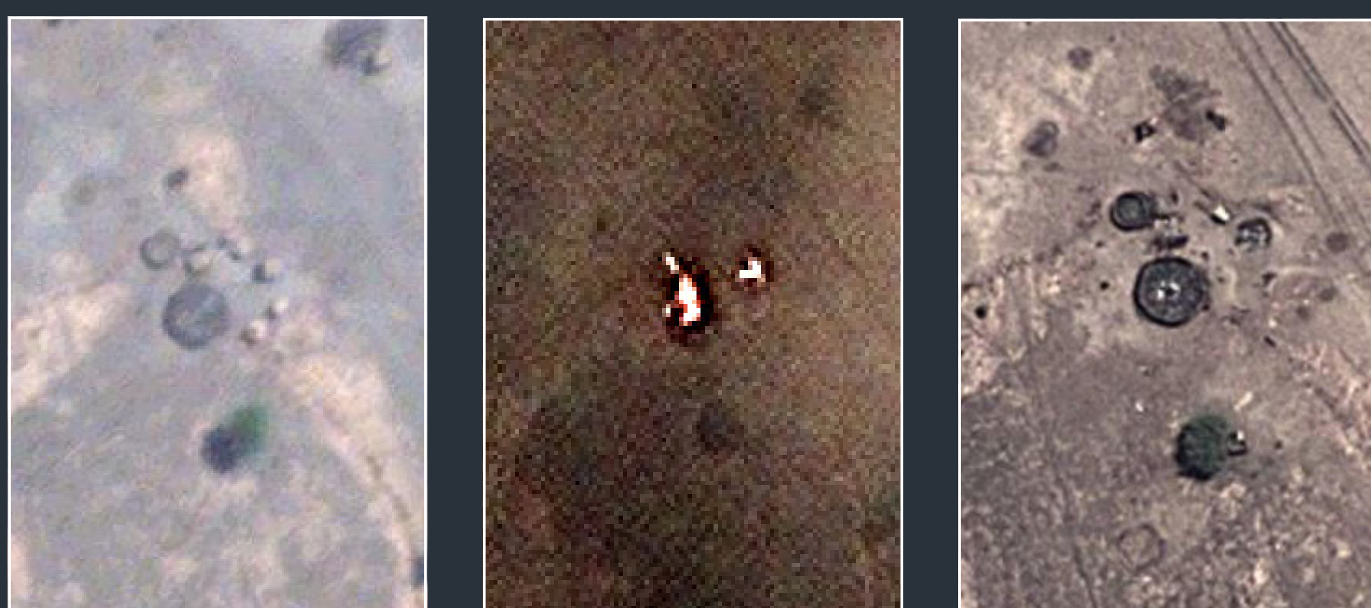
3D: Identification of Ongoing Burning and Smoke

In some instances, imagery can also reveal the presence of ongoing fires and smoke which can range in color from yellow to red and white to black, respectively. Factors that can affect the coloration of the fire and smoke include the materials being burned[29] and the level of moisture present in the environment.[30]

In the case of imagery collected of conflict areas, this active burning can occur during, or recently following, an attack, where tukuls or other objects are still burning. As seen in Image 3.7, a progression of three images reveals a standing tukul from 15 February 2011, fire burning in the location of the tukul during an attack on 24 May 2011,[31] and imagery of the destroyed tukul after the fire has subsided from 26 May 2011.

The burning tukul is partially obscured with smoke and clouds, however, the fire can be identified due to the stark contrast and luminosity of the flames. When comparing multiple georeferenced images of the same area, it can be determined that the coordinates of the fire are exactly the same location as the tukul identified in the other two images.

Image 3.7



Before, During, and After Images of a Burning Tukul
05 February 2011 | 24 May 2011 | 26 May 2011
Dungop, Abyei Region

Imagery analyzed by UNITAR-UNOSAT additionally reveals a structure still on fire and multiple clouds of smoke (See Image 3.8). This fire, in Leer, South Sudan, is burning in an area where approximately 1,500 structures, including tukuls, were destroyed and damaged over a large geographic area. UNITAR-UNOSAT notes that the majority of the destruction was caused by fire.

Image 3.8

Burning Tukul
02 February 2014
Leer, South Sudan

Most commonly, active burning is seen in imagery of agricultural fires or incidental wildfires during the dry seasons, as large amounts of forested or vegetative areas in these regions can often be subject to burning. Fires and the smoke extending upwards from the flames can be detected in the imagery.

As seen in Image 3.9, a fire is visible in a forested region located in the Democratic Republic of Congo. The fire covers a long strip of ground, where vegetation is present, and light-colored smoke is extending from the flames. While this burn pattern can be consistent with that of slash-and-burn agriculture, it can’t be disambiguated from a natural wildfire without verification.

Image 3.9

Forest Fire
20 July 2013
Democratic Republic of Congo

Chapter 4: Techniques and Limitations

4A. Multi-temporal Change Detection and Its Limitations

One of the most frequently employed techniques in the analysis of imagery of damaged structures is multi-temporal change detection. To conduct change detection, the analyst compares a minimum of two images, once collected before the reported event and one collected after. By comparing the images, changes to the number and visual indicators of objects can be observed and a relative timeframe of when the destruction occurred can be assessed.

A major limitation of this technique is that the post-event imagery must be captured as close to after the reported event as possible. Depending on the length of time between the pre- and post-event imagery, characteristics will be observed to lesser and greater degrees due to seasonal weather and changes to the environment. For example, in the case of identifying burned tukuls, ash may be washed away if it rained soon after the tukul was razed. Whereas charred walls and any remaining structural components may be visible for sometime after the tukul was burned.

Visual indicators consistent with the intentional burning of tukuls may also become less apparent over time. Ground scorching and the dark charred remains of individual tukuls can fade over time due to natural factors, especially during rainy seasons when heavy rainfall can wash away traces of scorching that remain.

Vegetation can regrow in many areas, which can potentially obscure evidence of intentionally burned tukuls. This occurrence is especially prevalent following a rainy season, when grass and other vegetation regrows. This further emphasizes the critical need to acquire post-event imagery that is captured as close to the date of the attack as possible. Additionally, if structures are quickly rebuilt following an attack, before a post-event image can be captured, then evidence of damage may not be present.

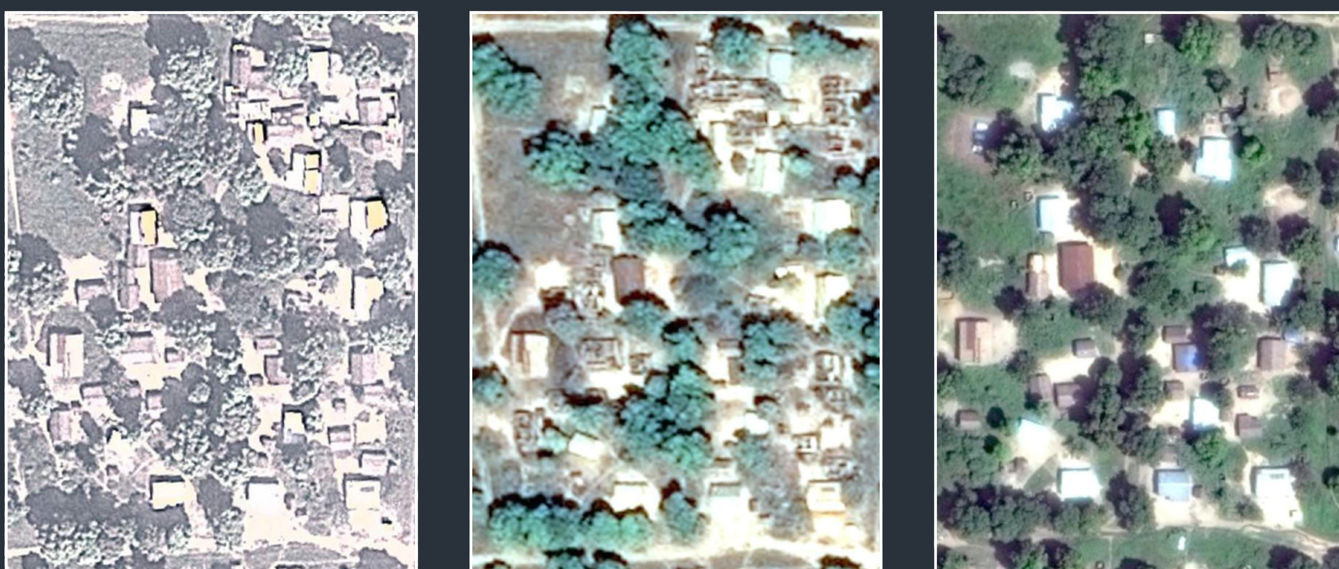
Image 4.1

Vegetation Regrowth Following Destruction
15 February 2011 | 26 May 2011 | 28 February 2013 | 03 September 2013
Abyei Town, Abyei Region

Following a large scale attack on Abyei Town on 24 May 2011[32], several structures, including a large number of circular and square tukuls, tents, and other buildings were destroyed and burned to the ground. Individually burned tukuls, yet no widespread ground scorching, are present in imagery captured after the event. However, subsequent imagery indicates that most of the destroyed structures were not rebuilt, and the area has since become overgrown with vegetation (See Image 4.1).

Additionally, in Image 4.2 , collected on 7 January 2014, just 5 days after an attack in the city of Bossangoa, the majority of the structures, primarily rectangular buildings of varying sizes, are seen without roofs.[33] Ground photos taken during the attack show that not only are these structures primarily composed of a type of mud brick with thatched roof, the roofs themselves were set on fire. While some ground scorching is present throughout the area, the majority of structures have no ground scorching between them. The absence of ground scorching indicates potential evidence that these structures were intentionally destroyed. However, subsequent imagery taken 10 months later reveals that some tukuls destroyed in the attack were rebuilt, while entirely new tukuls were also constructed in the vicinity.

Image 4.2



New and Rebuilt Tukuls Following Destruction
15 December 2013 | 07 January 2014 | 03 November 2014
Bossangoa, Central African Republic

Another major variable that can affect the temporal analysis of tukul destruction are cases when an area has been subjected to several attacks over a period of time. For areas that have been attacked repeatedly, it can prove difficult for an analyst to accurately assess what structures were damaged in which attack because remnants of razed structures from past attacks may still be visible.

4B. Limitations and Variables Affecting Analysis of Burned Tukuls

In addition to the limitation described in Chapter 3E relating to multi-temporal change detection, there are two additional limitations and variables that can affect the identification of visual characteristics of burned tukuls present in satellite imagery. These three categories of factors should always be taken into account when conducting an analysis and numerical count of apparently burned tukuls:

- Presence of apparently standing, intact structures; and
- Presence of objects that may resemble tukuls.

Presence of Apparently Standing, Intact Structures
The first variable that should be taken into account is the common occurrence of intact structures still present after an attack has taken place. This phenomena can be due to A) the structure not being targeted or B) the damage not being visible to the analyst.

In the latter case, it is likely that the tukul could become a “false negative” in any dataset created by the review of the imagery. This happens when a tukul is fire damaged internally but the roof is not ignited.

Depending on the size of the fire, or if the fire was extinguished before it could damage the roof, the tukul could suffer damage internally while still appearing intact externally. This is more likely to happen when tukul walls and roofs are built with less combustible materials, such as concrete and metal.

Presence of Objects that May Resemble Tukuls
Finally, the presence of objects similar to shape, size, and color to tukuls, both standing and destroyed, needs to be take into account. Especially when interpreting imagery of circular tukuls, there are several objects that the analyst needs to cognizant of that could be mistaken for both standing and destroyed tukuls. Trees and boulders, which can appear as similar to the circular shape and brown color of a standing tukul appear often in imagery, and objects such as wells and corrals can resemble a destroyed tukul’s circular base.

4C. Limitations and Variables Affecting Assessment of Intentionality

There are also two additional major limitations and variables that must be taken into consideration when assessing the intentionality of the destruction of tukuls:

- Presence of ground scorching; and
- Areas subject to repeated attacks.

Presence of Ground Scorching
Analysts must be careful to note any ground scorching surrounding burned tukuls. Following a large-scale attack resulting in widespread fire, ground vegetation can be ignited and cause fire damage over a large area. Sometimes ground scorching and secondary fires can be evidence of intentionality or, in some cases, obscure indicators of intentionality.

As previously noted, the absence of ground scorching between destroyed structures is often the primary indicator of intentionality. However, it can also be the case that the presence of highly concentrated ground scorching around several structures can, itself, be an indicator of intentionality as well.

In some rare cases, intentionally attacked villages with large amounts of ground scorching may appear almost identical to a village affected by an unintentional incidental fire. Most often, though, tightly targeted clusters of ground scorching will generally present as an indicator of intentionality.

Endnotes

1. “Over 90% of houses in South Sudan are grass-thatched, mud huts.” Sudan Tribune, April 28, 2013, http://www.sudantribune.com/spip.php?article46395.

2. “Transplanting tukuls in the Somali desert.” UNHCR, March 31, 2005, http://www.unhcr.org/424bb41a4.html.

3. Mary McMahon,“What is a Pitched Roof.” WiseGEEK. July 20, 2015 http://www.wisegeek.com/what-is-a-pitched-roof

4. Odiaua, Ishanloasen. “Mission Report: Earthen architecture on the Lalibela World Heritage Site.” United Nations Educational, Scientific and Cultural Organization, July 2010, 9-11.

5. Raghavan, Sudarsan. “Tens of thousands of Muslims flee Christian militias in Central African Republic.” Washington Post, February 7, 2014, http://www.washingtonpost.com/world/africa/tens-of-thousands-of-muslims-flee-christian-militias-in-central-african-republic/2014/02/07/5a1adbb2-9032-11e3-84e1-27626c5ef5fb_story.html.

6. Gettleman, Jeffrey and Josh Kron. “Warnings of All-Out War in Fight Over Sudan Town.” New York Times, May 22, 2011, http://www.nytimes.com/2011/05/23/world/africa/23sudan.html?_r=0.

7. Kushkush, Isma’il and Nicholas Kulish. “Civilians Flee as Violence Worsens in South Sudan.” New York Times, February 26, 2014, http://www.nytimes.com/2014/02/27/world/africa/civilians-flee-as-violence-worsens-in-south-sudan.html?_r=0.

8. “They Burned it All.” Human Rights Watch, July 21, 2015, https://www.hrw.org/report/2015/07/21/they-burned-it-all/destruction-villages-killings-and-sexual-violence-unity-state.

9. “Sudan: Satellite Images Confirm Villages Destroyed.” Human Rights Watch, June 18, 2013, http://www.hrw.org/news/2013/06/18/sudan-satellite-images-confirm-villages-destroyed.

10. “Destruction in Leer, Unity State, South Sudan.” UNITAR / UNOSAT, February 7, 2014, http://www.unitar.org/unosat/node/44/1929.

11. Isaac L. Baker, Brittany L.Card and Nathaniel A. Raymond, “Satellite Imagery Interpretation Guide: Displaced Population Camps.” Harvard Humanitarian Initiative, Harvard University, April 2015. http://hhi.harvard.edu/publications/satellite-imagery-interpretation-guide-displaced-population-camps

12. Ziad Al Achkar, Isaac L. Baker, Brittany L. Card, et al., “Sudan: Anatomy of a Conflict,” Harvard Humanitarian Initiative, Harvard University, May 17, 2013,http://hhi.harvard.edu/sites/default/files/publications/Sudan%20Anatomy%20of%20a%20Conflict_Signal%20(1).pdf

13. “Temporal Resolution.” Government of Canada, April 22, 2014. http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9365

14. Card, Brittany and Isaac Baker. “GRID: A Methodology Integrating Witness Testimony and Satellite Imagery Analysis for Documenting Alleged Mass Atrocities.” Genocide Studies and Prevention: An International Journal: Vol. 8: Iss. 3 (2014), http://scholarcommons.usf.edu/gsp/vol8/iss3/7/.

15. http://micro.magnet.fsu.edu/primer/java/digitalimaging/processing/spatialresolution/

16. “Sudan: Anatomy of a Conflict,” 33.

17. “Tents and Tukuls: Lessons from the Development of AMALGAM.” The Tech Challenge for Atrocity Prevention, December 10, 2014. http://thetechchallenge.org/tents-and-tukuls-lessons-from-the-development-of-amalgam-3/.

18. Lorenzo Bruzzone, “Current Scenario and Challenges in the Analysis of Multitemporal Remote Sensing Images.” (Presentation, 4th Advanced Training Course in Land Remote Sensing, Athens, Greece, July 1-5 2013.) https://earth.esa.int/documents/10174/643004/D4T2b_bruzzone_LTC2013.pdf

19. Holli Riebeek, “How to Interpret a Satellite Image: Five Tips and Strategies.” Earth Observatory. November 18, 2013. http://earthobservatory.nasa.gov/Features/ColorImage/

20. Colin Cragg, “Long Duration Patrol.” June 30, 2013. https://colinsouthsudan.wordpress.com/2013/06/30/long-duration-patrol/

21. “Wattle and Daub.” Encyclopedia Britannica. http://www.britannica.com/technology/wattle-and-daub

22. “GIS Dictionary:Nadir.” ESRI http://support.esri.com/en/knowledgebase/GISDictionary/term/nadir

23. “GIS Dictionary:Off- Nadir.” ESRI http://support.esri.com/en/knowledgebase/GISDictionary/term/off-nadir

24. “Fire Investigation.” The Forensic Library. http://aboutforensics.co.uk/fire-investigation/

25. “Wildfire Burn Severity Classification.” United States Department of Agriculture. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mt/programs/planning/ewpp/?cid=nrcs144p2_056249

26. “Flashpoint: Abyei.” Satellite Sentinel Project, March 4, 2011. http://satsentinel.org/sites/default/files/SSP2-Final.pdf

27. Abdel Aziz M.S. Bayoumi. “Fire Situation in Sudan.” http://www.fao.org/docrep/006/ad653e/ad653e36.htm

28. Colin Stief “Slash and Burn Agriculture.” Geography http://geography.about.com/od/urbaneconomicgeography/a/slashburn.htm

29. “Fire Scene Investigation.” http://maiif.org/maiif2/images/stories/PDF/investigators/fire_chapter4.pdf

30. David W. Dodson “Where There’s Smoke.” Firefighter Nation. March 19, 2009. http://www.firefighternation.com/article/where-theres-smoke

31. “Abyei Invasion: Evidence of SAF Incursion Inside Abyei.” Satellite Sentinel Project, May 25, 2011. http://hhi.harvard.edu/publications/abyei-invasion-evidence-saf-incursion-abyei

32. “Abyei Invasion: Evidence of SAF Incursion Inside Abyei.” Satellite Sentinel Project, May 25, 2011. http://hhi.harvard.edu/publications/abyei-invasion-evidence-saf-incursion-abyei

33. “935,000 displaced in Central African Republic amid ‘unprecedented’ violence” RT, January 3, 2014. http://www.rt.com/news/car-displaced-violence-children-143/