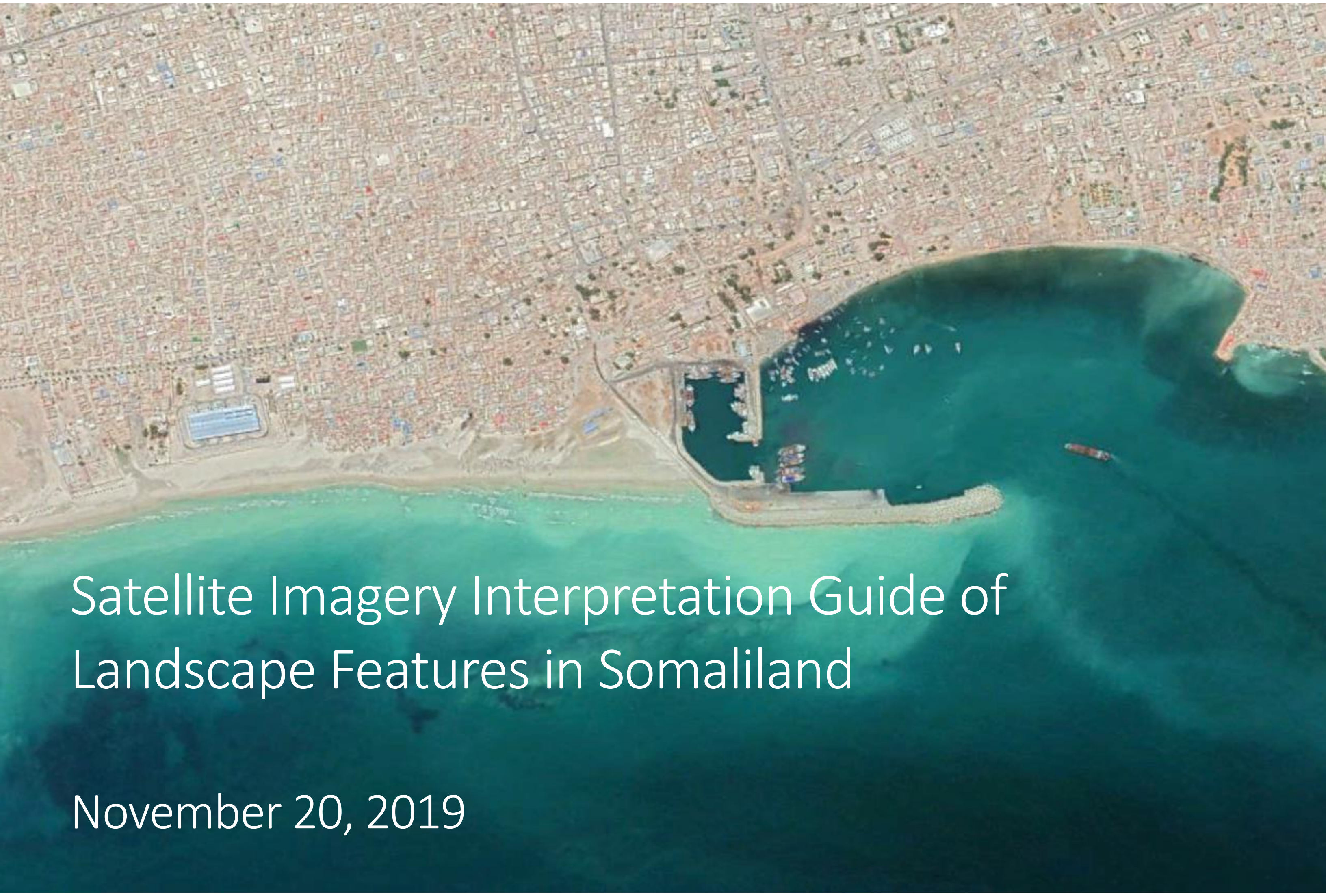

Satellite Imagery Interpretation Guide of Landscape Features in Somaliland

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GOVLAB

unicef

HARVARD HUMANITARIAN INITIATIVE

This project, "Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas", was submitted in response to the 2017 call for proposals by the World Bank's Development Data Group (DECDG) and the Global Partnership for Sustainable Development Data (GPSDD), is supported by the World Bank's Trust Fund for Statistical Capacity Building (TFSCB) with financing from the United Kingdom's Department for International Development (DFID), the Government of Korea, and the Department of Foreign Affairs and Trade of Ireland.

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INTRODUCTION

In September 2018, the Governance Lab at New York University, UNICEF, and the Signal Program on Human Security and Technology at the Harvard Humanitarian Initiative conducted research on population monitoring in Somalia (figure 1). Titled "Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas", the project used satellite imagery to develop a standardized methodology for identifying and monitoring vulnerable populations on the move in the Somalia.

Figure 1. Map of Somalia

Population migration is not a newly occurring phenomenon in Somalia or in the Horn of Africa. In fact, historical patterns of seasonal and economic migration within and across international borders are deeply engrained into the region's fabric. Unfortunately, the Horn of Africa is also no stranger to forced migration: ongoing political instability, conflict, and extreme weather events have aggravated forced displacement in the region, though the impact of these circumstances is unevenly distributed. Arguably, Somalia has taken on much of the hardship associated with these difficulties.

Over half of Somalia's population is composed of pastoralists, meaning that livestock rearing is directly linked to the livelihoods of many people.[1] The health and wellbeing of livestock is deeply dependent on the condition of the landscape, because livestock require adequate water and vegetation to survive.[2] The increasingly frequent and prolonged droughts in Somalia have substantially diminished the availability of water and vegetative cover, contributing to the widespread deaths of livestock in recent years. Additionally, environmental degradation is pervasive, and the lack of necessary resources at times leads to contention and resource conflict.[3] These conditions, among others, require pastoralists to travel beyond familiar territory, make deals, or take loans from friends and families to sustain themselves, while others must abandon their pastoral practices all together. In search of alternate livelihoods, many pastoralists become internally displaced and migrate to urban areas, where they frequently settle in ever-expanding internally displaced peoples (IDP) camps.

Patterns of movement generated by forced migration are incredibly complex. Somalia has several commonly used points of entry and exit along its shared borders and coastline. While the

[1] Avis, W., & Herbert, S. (2016). Rapid fragility and migration assessment for Somalia. *Birmingham: GSDRC University of Birmingham*.
[2] Ginnetti, J., & Franck, T. (2014). Assessing drought displacement risk for Kenyan, Ethiopian and Somali pastoralists. *Technical Paper. Norwegian Refugee Council (NRC)/Internal Displacement Monitoring Centre*
[3] Avis, W., & Herbert, S. (2016). Rapid fragility and migration assessment for Somalia. *Birmingham: GSDRC University of Birmingham*.

movement of migrants and refugees across borders is generally captured by organizations such as the International Organization for Migration (IOM), these data often do not reflect the large numbers of people that are voluntarily or forcibly on the move *within* countries.

While we live in the age of Big Data, publicly available population data from Somalia is limited, and often outdated. According to UNFPA, the most recent publicly available population census data is from 1975.[4] Since then, Somalia has undergone many changes and developments that have changed population dynamics, including a bloody civil war between 1981 and 1991. The country's population no longer resembles the population facts and figures captured during the 1975 census. Since then, UN agencies and other organizations have collected population data in pockets throughout the country, but capturing populations on the move, including pastoralists, is incredibly difficult given their mobile nature in remote areas.

WHY SATELLITE IMAGERY?

Population enumeration and data collection is time intensive and costly, especially when the populations of interest are dispersed and in hard-to-reach areas. To supplement more traditional means of population data collection, Signal analysts considered the use of very high resolution (VHR) satellite imagery (< 1 m) to capture movements of mobile populations. The use of satellite imagery as an observational and analytical tool allows for the near-continuous monitoring of remote and/or non-permissive environments. Analysts can capture large swaths of land in a matter of minutes to highlight change and/or anomalies in the landscape. Imagery analysis is a highly effective way of gaining an understanding of landscapes in a remote capacity. VHR imagery, however, is usually too coarse to spot individual people. Instead, natural and artificial features are analyzed as proxy indicators for human activity.

INTENDED PURPOSE & AUDIENCE

This guide will outline tools and techniques to establish a foundation for visual analysis and will discuss how these techniques can assist in identifying notable landscape features in Somalia. While it is not an exhaustive list, it attempts to holistically capture the indicators associated with population movement in Somalia. To the knowledge of the Signal Program analysts, there is no documentation of what frequently occurring natural and man-made features in Somalia look like and therefore this guide sheds light on how to identify and analyze these features. The information found in this document is intended to supplement research and is primarily for humanitarian analysts working on projects considering the region. If critically considered, the techniques and tools may also be extrapolated and applied in different humanitarian contexts.

[4] UNFPA. (2014). Population Estimation Survey 2014. *UNFPA Nairobi.*

AREAS OF INTEREST

The scope of analysis was intended to cover all of Somalia, however, the areas of interest (AOI) identified by the local partner, UNICEF Somalia, were concentrated in Somaliland. 24 AOIs were identified in the administrative regions of Awdal, Woqooyi Galbeed, Togdheer, Sanaag, Sool, Nugaal and Bari (Bari and Nugaal are the only region outside of Somaliland, in Puntland) (figure 2). While the AOIs are clustered in Somaliland, Signal analysts believe many features are comparable to those found in other parts of Somalia. According to the UNICEF Somalia team, the identified AOIs experienced high flows of movement and were therefore prioritized for analysis. With that in mind, Signal analysts examined the identified locations and the surrounding areas to detect proxy indicators of population movement.

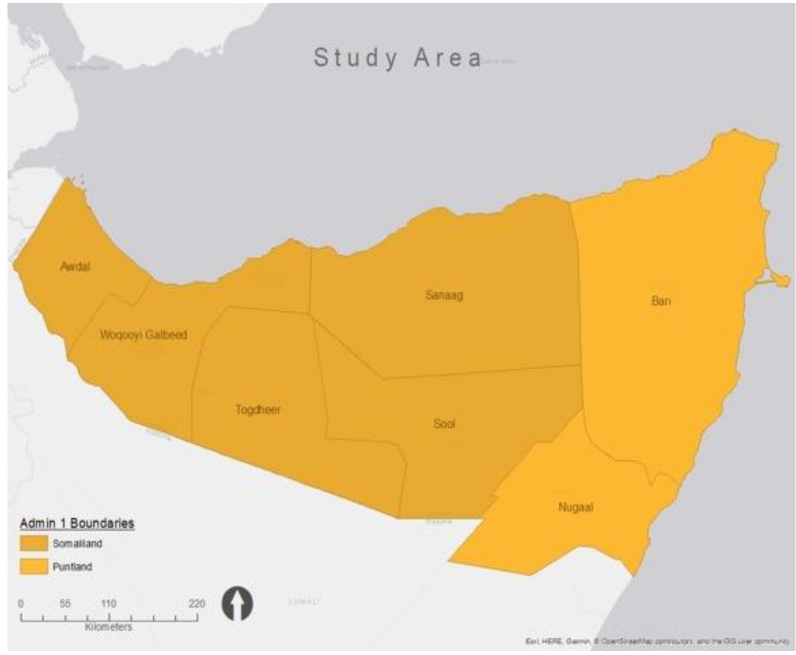

Figure 2. Administrative regions in Somaliland and Puntland

The examples that are used in this guide will be drawn from the listed administrative regions in Somaliland and Puntland. For reasons related to confidentiality and security, the exact geographic coordinates and the settlement names will not be included, but the date on which the image was captured will be denoted so that seasonal fluctuations are taken into consideration during visual analysis. All images examples are from Google Earth Pro and are North oriented, unless otherwise stated.

IMAGERY & SOFTWARE USED

Satellite imagery can be obtained, visualized, and analyzed in numerous platforms. When looking for imagery, it is important to establish project objectives beforehand to guide your imagery selection, rather than to obtain the imagery first and then develop a research question. When thinking about acquiring imagery, it is important to first consider the image characteristics listed below. It is highly likely that you will have to trade off one of the listed characteristics for another, so be sure to prioritize your needs prior to obtaining, purchasing, and/or downloading satellite imagery:

1) Spatial resolution
2) Temporal resolution
3) Spectral resolution
4) Radiometric resolution
5) Level of processing
6) Cost

When identifying software for processing satellite imagery there are additional prerequisites to consider including,

1) Cost
2) Licensing
3) Machine compatibility
4) Analysis functionality requirements

Figure 3. Google Earth Pro is compiled from multiple sources as indicated near the bottom of the image. Satellite images are of Hargeisa, Somaliland captured on 1/10/2019.

For this guide, we will use Google Earth Pro which is a free commercial software that is compatible with Windows, Mac, and Linux operating systems. If you are entirely unfamiliar with Google Earth Pro, there are many resources available online to orient you to the software. This guide will not explore Google Earth Pro in its entirety, but rather demonstrate how to effectively use a subset of the tools available for visual analysis.

Google Earth Pro is a platform that integrates imagery at various resolutions from a variety of sources and imagery providers (figure 3). Some of the imagery that is visualized in Google Earth Pro is freely and publically available via other platforms, such as satellite imagery captured through the Landsat constellation that can be downloaded through USGS' Earth Explorer, while other imagery, mostly at higher resolutions, are typically acquired at a cost. In Google Earth Pro, you can freely browse the imagery at different spatial scales. Please note, there may be platforms with equivalent capabilities that you may use to obtain, visualize, and explore satellite imagery.

GETTING STARTED

There are several steps you can take to strengthen the imagery analysis process and the subsequent results. By solely conducting visual analysis of satellite imagery, you will most likely not gain an in-depth understanding of what you are studying. This is primarily because you 1) may be unfamiliar with the context and/or 2) have not seen the AOI from above. Whatever the circumstances may be, you will likely be biased in what you are observing depending on how your own experiences have shaped you.

Take into consideration the following images (figure 4), what do you see? Remember that these are satellite images of Somaliland.

Figure 4. Manmade features captured via very high resolution satellite imagery in Somaliland. The imagery reveals the complexity of human landscapes and the need to understand a study area prior to drawing conclusions from imagery

In figure 4, Image A shows circular salt pits primarily in the eastern and southern parts of the image, bordering ocean waters to the northwest. Image B shows livestock holding pens, most likely at a livestock market, where animals can be seen congregating in areas throughout the scene while image C shows a densely settled internally displaced peoples (IDP) camp. Such phenomena can look different within a country and can especially vary between countries. These differences lie in the construction of a feature, the contrast between the feature of interest and the surrounding environment the quality of the image, and more.

To assist feature recognition through satellite imagery, it is strongly recommended that you conduct background research prior to and during analysis. If you are unfamiliar with salt mining or the livestock industry in Somaliland for example, image A and B will likely look unfamiliar, not allowing you to accurately categorize what you are seeing. Even if you've looked at urban areas, image C may appear quite different given that the structures are small, organized, and near one another with no paved road network visible between the structures. The contextual information gathered during the research process is invaluable to the interpretation of satellite imagery.

Background research can consist of diverse sources including news reports, academic articles, gray literature, white papers, blogs, photos and/or videos. These resources can be used to understand your study site better, i.e. what is the population of Hargeisa, Somaliland? Or, what does surface water collection look like in Somalia? There is no limit to the amount or subject of research. Understanding the economic, environmental, social, and political dynamics of an AOI will benefit imagery analysis in surprising ways and increases your general awareness of an AOI. Through the consideration of photos and videos, you are also likely to gain a better understanding of the appearance of landscape features from a ground angle. While the angle of capture is different to that of satellite imagery, the colors and shapes, for example, that are visibly documented in ground photos and videos may corroborate what can be seen from the remotely sensed data.

FEATURE CHARACTERISTICS

Before interpreting features, it is good practice to be aware of the image orientation and scale. Orientation, whether the top of the image is North, East, South, or West, may influences the way in which you understand the image (figure 5). For instance, if you are conducting analysis relative to other AOIs in the region, you will likely need to know how the locations relates to the other and will therefore need to know the image orientation. All the images in this guide are North oriented, unless otherwise stated. Scale is also an important consideration in addition to orientation, since features look distinctive at different spatial scales and could be misinterpreted if scale isn't considered.

Once the orientation and scale are acknowledged, you will be better equipped for visual analysis. While the captured features may be distinct in many ways, there are several traits to assist in the categorization of features. This includes the consideration of size, shape, color, tone, pattern, shadow, and the overall arrangement of features.

Figure 5. Port in Somaliland viewed using two different orientations. At this scale, the white features in the water could be misinterpreted, but at another scale the feature characteristics can be recognized as Somali fishing boats.

Shape & Size | Shape and size are often the most noticeable characteristics in satellite imagery (figure 6). Whether a feature is circular, round, triangular, elongated, or measures 1 x 1 m^2, the recognition of these characteristics adds meaning to ongoing research and helps further your understanding the AOI. For example, a structure that measures 1 x 1 m^2 is arguably too small to be a house while a structure that measure 3 x 3 m^2 could be interpreted as a livable size. This statement should be consistent with and supported by contextual research.

The diverse array of structures visible in figure 6A captures the heterogeneity of a single scene. The shape, size, and color of the elongated structure with the sand-colored roof in figure 6B, for example, looks substantially different from the surrounding buildings in the AOI. Contextual research suggests that there is a hospital at this exact location and therefore analysts assume this building is in fact, a hospital. The structures that appear more consistent in shape, size, and construction material in the AOI resembles the construction of homes in this area. You may speculate the intended function of a feature, but the interpretation must be made with caution because it is often difficult to confirm the features exact function. When possible, it is ideal to corroborate interpretations with ground validation and/or through eyewitness reports. Through repeated analysis an analyst will likely gain a better understanding of features' functions based on the observed physical characteristics.

Figure 6C shows a structure without a roof, where only the standing walls and room partitions are visible. To the right of the unfinished structure there is an outline of what likely demarcates the area upon which another structure will be erected. In summary, shape, size, and numerous other characteristics should be studied when conducting visual analysis, since these considerations assist and often simplify feature recognition.

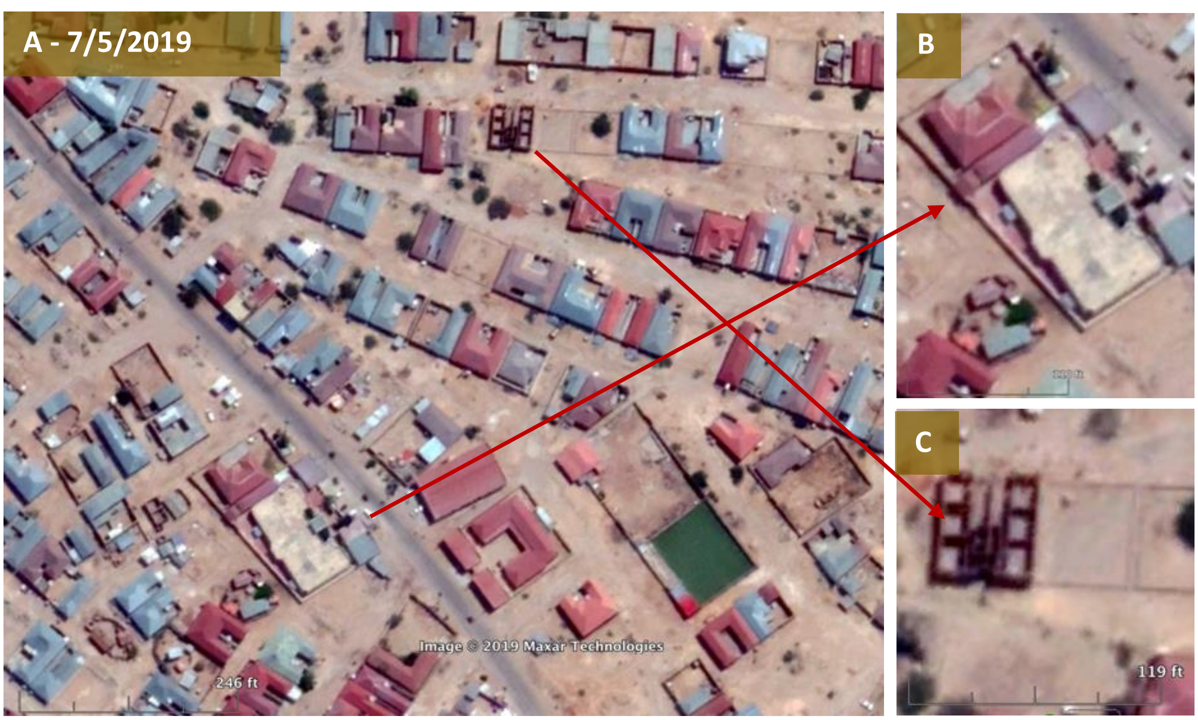

Figure 6. Shape and size of structures differ greatly between and within AOIs

Color, Tone, Pattern, & Texture | Color, tone, pattern, and texture are contextual pieces of information that can improve our understanding of landscape features. These characteristics may also provide some insight on the condition of the feature. For example, a brightly colored structure that appears next to a similar building with a dull-colored roof could suggest that the bright structure is newly constructed while the other structure is older or not well taken care of in comparison, though such conclusions should be carefully drawn.

These properties also speak to the material makeup of features to determine whether it is natural or artificial. For instance, exposed rock looks very different from sand or grass, while an aluminum roof looks different from tarps or wood. In figure 7, the pattern and bright color of the artificial turfs clearly set them apart from the natural and man-made features in the surrounding environment.

Figure 7. The color and texture of the artificial turf greatly contrasts the characteristics of the surrounding environment.

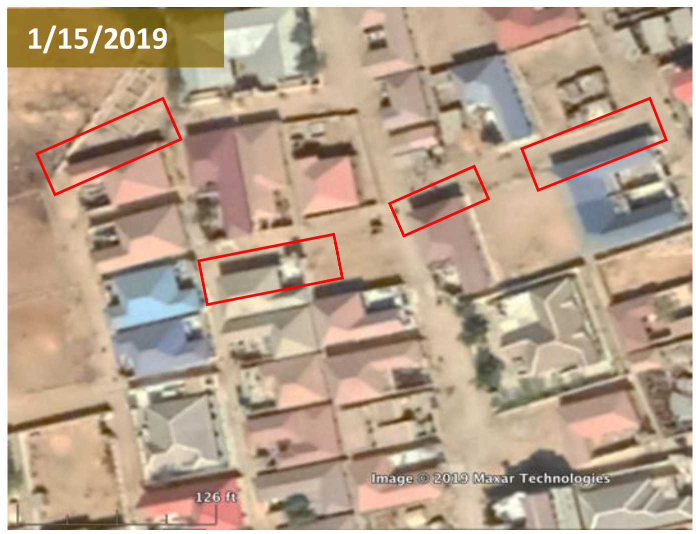

Figure 8. Closely arranged structures with different colored roofs cast shadows, encircled in red.

Shadow | Shadow may be used to understand what time of day the image was captured, given the length and direction of the shadow. Typically, this information is stored in the metadata, but Google Earth Pro only readily shows the date of capture, so in this case shadow can be used to determine time of day. Shadow can further provide an indication of how tall an object is, whether it is natural or artificial (figure 8). When taking vegetation into consideration, for example, a shadow cast by a tree will be longer than that cast by a bush. When comparing the shadow of the two features, it is evident which one is taller.

Arrangement | Are the features you are analyzing closely arranged or are they far apart? Is it organized or does it seem to be random? By asking questions about feature composition, you may be able to better understand what you are looking at. When considering human settlements for example, an organized refugee camp may look different from a newly-established, spontaneously developed IDP camp site. A variety of settlement examples are presented and discussed later in this document.

USING GOOGLE EARTH PRO TOOLS

For the purposes of the analysis discussed in this guide, the time slider, ruler, and “add placemark” features in Google Earth Pro will be discussed below. Please note that Google Earth Pro makes a plethora of tools and visualization techniques available for its users and that the discussed tools are not exhaustive.

Time slider | The time slider enables users to toggle through Google’s historical imagery archive, which is particularly valuable when conducting multi-temporal analysis. Comparing and contrasting imagery over time is typically referred to as change detection, which allows for the detection and documentation of landscape features across time. Through change detection for example, you can capture what a landscape looked like before and after flooding, before and after an earthquake, or generally observe changes across days, weeks, months, or years. It is a powerful way to capture historical changes and events and may even assist in anticipating future changes.

It is important to note that the distribution of available imagery is not perfectly uniform worldwide, and this is particularly true for VHR imagery. As you zoom in and out of landscapes at different scales, you will notice that the number of images available and their characteristics change. This is because Google mosaics imagery from a variety of sources that capture remotely sensed data across different spatial and temporal scales. So, while some AOIs have a heavily populated historical archive going back decades, others may only have two available images in the entire database (figure 9). Additionally, the quality of the images is not guaranteed. Haze, cloud cover, and low contrast are some elements that can obscure the features of interest and at times render an image useless. These limitations will be discussed in a later section.

Figure 9. Historical image availability of Boston, USA (top) and Gondar, Ethiopia (bottom) shows the difference in image availability in Google Earth Pro. The light blue lines indicate an image was captured on that date.

Ruler | The ruler is an incredibly useful tool when analyzing a feature or multiple features (figure 10). The Satellite Sentinel Project, for example, used the ruler tool to measure the dimensions of vehicles to identify if they were consistent to specific models of military use in the area of interest. The ruler could also be used to determine the height of a building by measuring its shadow, as well as calculate the distance on the ground between two structures. There are many ways to use the ruler tool and it can provide very valuable insights for visual analysis.

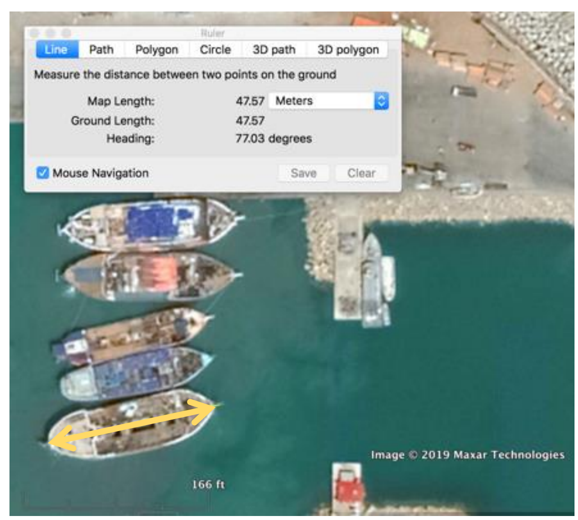

Figure 10. Ship measures 47.57 m. This measurement can be compared to known ships to identify the make and model

 Add Placemark | The "add placemark" feature functions similarly to "add polygon" and "add line". These tools can be used to save a latitude and longitude of a location/feature of interest by navigating to the place of interest and dropping a placemark at that location. The appearance of the placemark can be customized in a variety of ways but most importantly, the tool can be used to document an item of interest. Documenting a location of interest is valuable when conducting change detection and/or when collecting a database of evidence for analysis.

In addition to adding placemarks or denoting a location, it is also possible to import external data files. Existing data files may include imagery files and shapefiles that can be displayed and overlaid on the imagery in Google Earth Pro. By overlaying external information, you may be able to extract new information. Similarly, any placemarks generated in Google Earth Pro can also be exported for further analysis in another platform.

SOMALILAND FEATURES

Considering and understanding the feature characteristics described in the previous section will greatly support visual analysis. However, the manifestation of feature characteristics varies within and between countries. The following descriptions correspond to features identified in and around the AOIs analyzed in Somaliland. Consider Tobler's first law of geography, which applies to imagery analysis and states that "everything is related to everything else, but near things are more related than distant things". The examples outlined below are, of course, directly relevant to the AOI in which they were identified. Often, the same features or variation of the features can be found throughout other parts of Somaliland, Somalia, and even neighboring countries in the Horn of Africa and beyond. Careful analysis and contextual considerations will assist in the identification of features. The following examples are consistent with known ground features but have not been validated using ground data. The features described below are categorized as 1) agriculture and livestock, 2) water collection, and 3) settlements. The categories do not capture all analyzed features, but they are the most relevant to pastoral movement, which was the central focus of this project.

Agriculture and Livestock | Approximately 60% of Somalia's population practices nomadic pastoralism while another quarter of the population practices agro-pastoralism. While nomadic pastoralists primarily rely on livestock as a source of livelihood, agro-pastoralism integrates both livestock and agricultural practices to support livelihoods.[5] Given that livestock and agriculture are deeply interconnected with the lives of many Somalis, the presence of livestock and/or agricultural fields often suggest that people reside nearby. The identification of livestock in VHR satellite imagery, however, is challenging. In comparison to

[5] Carr-Hill, R. A., & Ondijo, D. (2012). Assessment of the Education, Livelihoods, Living Conditions and Welfare of Somali Pastoralists: A Representative, Multi-Sectoral Survey Conducted to Provide a Baseline for Programming.

structures, cars, or even large trees, the small size of livestock combined with their color (shades of brown, white, black) makes them harder to differentiate from their surroundings.

Pastoral migration is largely driven by the availability of vegetation and water. While there are very few limitations regarding where livestock can roam, it is recommended to begin scanning landscapes near greener pastures and surface water assuming these are the areas in which they congregate (figure 11).

In figure 12 we see a livestock market, captured in December 2018 and January 2019. The side-by-side comparison of the AOI shows a shift among the elongated shapes across space and time. The shift in movement between the images, combined with contextual research about the region's livestock markets, supports the rational that the visible features are consistent with livestock.

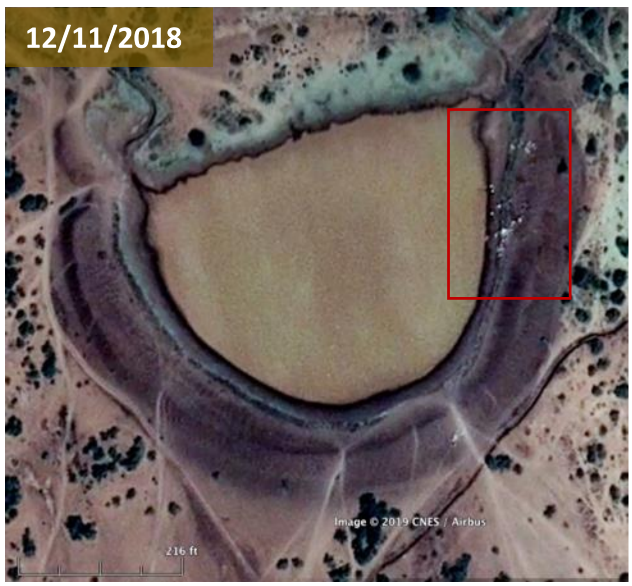

Figure 11. Livestock on the edge of a waterbody.

Figure 12. Livestock market where animals can be seen roaming and congregating in different areas

A very subtle yet noticeable characteristic that assists in the identification of livestock is shadow. The elongated body of an animal often casts a shadow that can provide information about the height and shape of the animal. The shadow cast by camels are particularly unique because of the hump on its back. While it is difficult to distinguish in figure 12, the small shadow visible support the theory that these are animals.

Livestock, as any other object of interest, can be mistaken with other features in an AOI. Figure 13 captures an agricultural field, that is lined with white-colored circular features. At first glance, it could appear to be livestock, but when considering the straight line in which the features appear, combined with the fact that they remain stationary at earlier dates, suggests that these features are not consistent with livestock.

Figure 13. Agricultural field with features resembling livestock

Agriculture is however, used to supplement livestock rearing. Agricultural fields in Somaliland are relatively small and are not uniform in their appearance. The fields captured in figure 14A and 14B are agricultural plots enclosed by fencing, suggesting these are privately owned. The landscape is consistent with agricultural characteristics given the organized, uniform patterns across the landscape, where berms and swales are visible. The swales are typically used to assist the distribution of rain-fed agriculture, which is a common agricultural practice in the region. When irrigated, the fields appear greener than the surrounding environment. The sharp color contrast usually allows for the rapid identification of fields, but it is important to consider seasonality and crop growing seasons to understand at what crop-cycle stage the field is in. The contrasting pattern of the fields and the surrounding area also help to further distinguish the agriculture: in figure 14E, the landscape surrounding the fields is dotted with trees while the texture of the fields themselves appear smoother in comparison. The texture of fields also varies depending on what is being produced. For example, an orchard will appear to be a series of dotted lines, representative of trees, while the fields in the images below are more uniform and smoother in their appearance. Through the integration of contextual research and the consideration of feature characteristics including color, texture, and shape, we advance our understanding of agricultural features as they appear in satellite imagery of Somaliland.

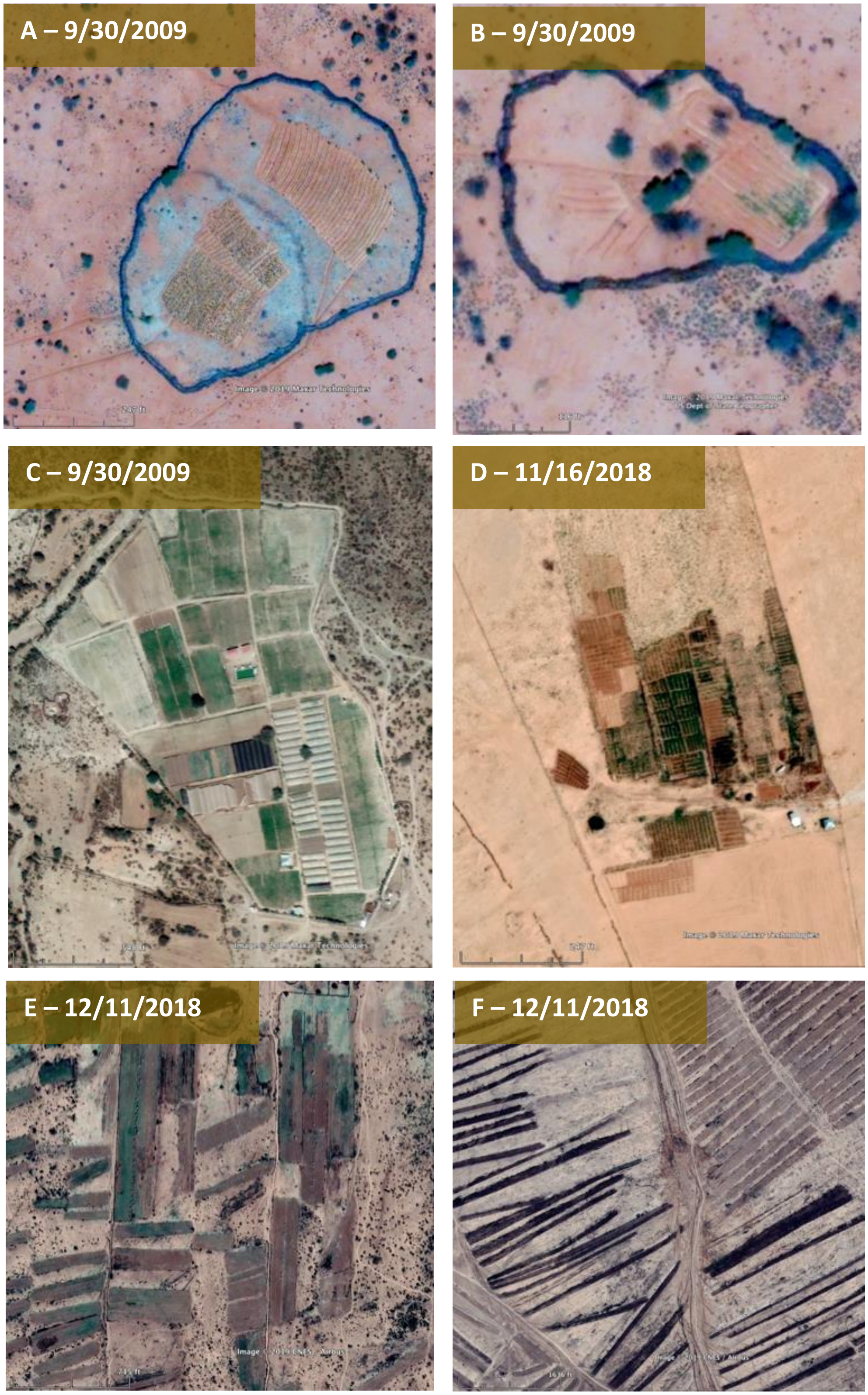

Figure 14. Agricultural fields in Somaliland

Water Collection | Somaliland has an arid climate and even though there are four distinct seasons (two wet, two dry), rainfall in recent years has been below average. In fact, since 2000 Somalia has experienced famine, numerous droughts, and seasons with below-average rainfall.[6] For these reasons, access to water throughout the year is challenging. There are no perennial rivers in this region, and seasonal rivers rely on unpredictable and sparse rainfall. The Somali people collect surface water via natural depressions, dams, or cisterns, while ground water is collected through wells and boreholes.[7] In recent years, as droughts have intensified, water is more frequently delivered to larger settlements via trucks while other organizations have set out to repair and maintain existing water collection sites.

Ground water collection points, including wells and boreholes, are generally not visible in satellite imagery. This is because ground water collection points take up very little surface area, likely less than 1 m^2, which is too small to capture in the imagery available in Google Earth Pro. VHR imagery is more suitable for identifying surface water collection mechanisms. Surface water collection is more widely practiced during the rainy season, while ground water collection or stored water becomes more favorable during the dry seasons.

Cisterns, referred to locally as berkads in the areas of analysis, are commonly used structures to collect and store surface water during the rainy season (figure 15A). While berkads are not always uniform in their appearance, they are generally elongated, have a rectangular shape, and are several meters deep. They are typically constructed with brick or cement and have a narrow inlet to allow water to travel through hand-dug trenches that lead into the berkad. Often, berkads are surrounded by fencing and can either be exposed or covered by a roof-like structure (figure 15C). Berkads are frequently clustered in the same area as shown in figure 15D. When full of water, the center of the berkad appears in the imagery as shades of dark green. When water levels are low, the color appears as light green and when there is no water in the structure, it blends into the surrounding environment (figure 15B). Berkads are used to support both livestock and humans, so when water is visible in the berkad, it is assumed that it is a pull-factor for pastoralists and people on the move.

Surface water is also collected through ponds that are either natural depressions or wide, hand-dug catchment areas (figure 16), many of which appear to be horseshoe shaped. Just like detecting water in berkads, water in ponds appears as dark shades of greens, blues, and browns. When empty, the pond's color looks like that of the surrounding environment. To prevent sedimentation and water drainage, tarps are draped over hand-dug holes. This portable water collection method is distinguishable in satellite imagery. When it holds water, the center of the tarp is darker than the edges (figure 17).

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[6] Somalia: Drought 2015 – 2019. *Relief Web*. Accessed from https://reliefweb.int/disaster/dr-2015-000134-som

[7] Surface Water. *SWALIM*. Accessed from www.faoswalim.org/water/water-resources/surface-water

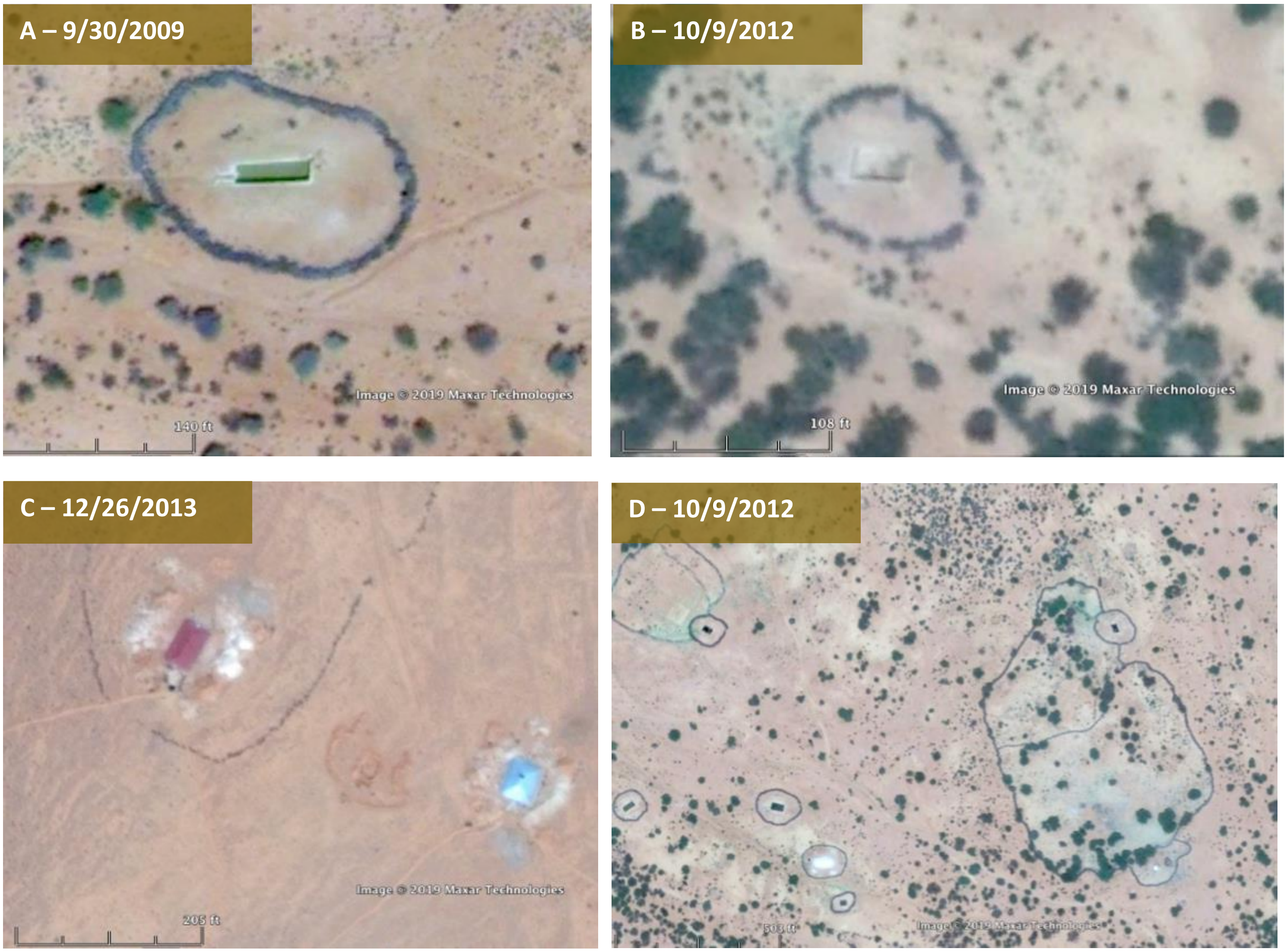

Figure 15. Berkads in Somaliland

Figure 16. Seasonal comparison of ponds highlights the appearance of ponds with and without water

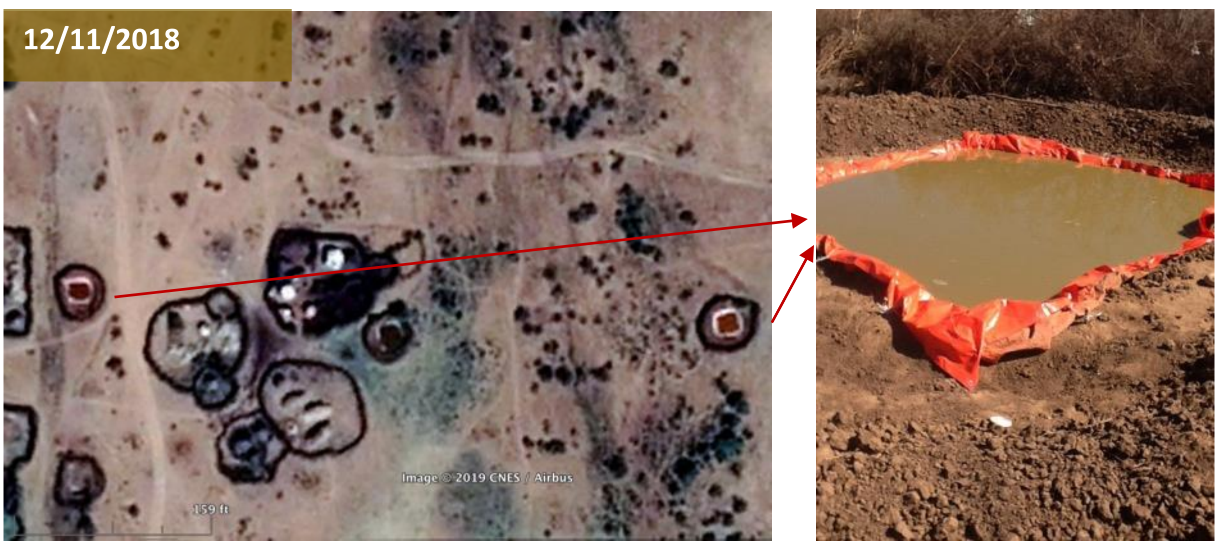

Figure 17. Tarps used for water catchment as seen through satellite imagery and ground information. Ground photo obtained from Medium.

Settlements | Perhaps the most direct indicator of human activity is the presence of structures. While analysts cannot confirm if the structures are in active use by a community, the condition of the structure's roof can often be analyzed to provide some insight on the matter.

There is endless variation in human settlements: spontaneous or organized, large or small, old or new. Their appearance can be modified due to physical arrangement, differing construction materials, and the variations of their local environments. When researching populations on the move in Somaliland, several assumptions come to mind: 1) individuals will reside in a single location for a limited time, 2) the structures people occupy are small and transportable and, 3) people in transit can be settled anywhere in a landscape and are not necessarily situated in existing settlements. Given the dispersal of people across the landscape, the focus should be placed on not only cities and smaller settlements, but also on the surrounding and unoccupied by structures close by.

The images displayed in figure 18 and 19 highlight many different types of settlements in Somaliland. Evidently, there is a lot of variation between the AOIs. Figure 18A shows a settlement enclosed in a fence with smaller properties within it. The image inset shows small, rectangular structures which are like the structures in figure 18C. The other images show more densely established settlements. While some are encompassed by fencing such as those shown in figure 18B, the structures in figure 18D resemble a city in which there is very little space to spare. The most organized settlement is captured in figure 19A and 19C, which are planned refugee camps. Figure 19D shows an extension of a refugee camp, that is consistent with the appearance of a spontaneously settled camp. Spontaneous settlements are often composed of very small informal structures near one another and are randomly arranged in a landscape. The image inset in figure 19D shows a series of temporary shelters composed of tarps and fabrics, locally known as buuls, lined up on the edge of an older settlement. Unlike the other fenced-in properties, the buuls don't introduce a sense of permanency, which suggests that people only recently settled here and/or did not intend to stay for an extended period. The change in the settlement characteristics can be monitored over time through available archival imagery (figure 20). The buuls visible on December 29th, 2017 cannot be seen on April 10th, 2017. We can conclude that the buuls were therefore set up here between April and December 2017, but more granular information cannot be obtained given the temporal gaps in available imagery in Google Earth Pro. The next image, captured on February 9th, 2018 still shows the buuls there but on September 28th, 2018 they are no longer visible.

Nomadic pastoralists settle in a location for a few days, weeks, or months. The short duration of their stay often requires their structures to be easily movable and therefore more temporary. These structures often resemble those captured in figure 19D. Nomadic pastoralists may also travel as a single-family unit or as smaller communities, meaning that single structures may exist in any part of the landscape, requiring thorough scanning of region.

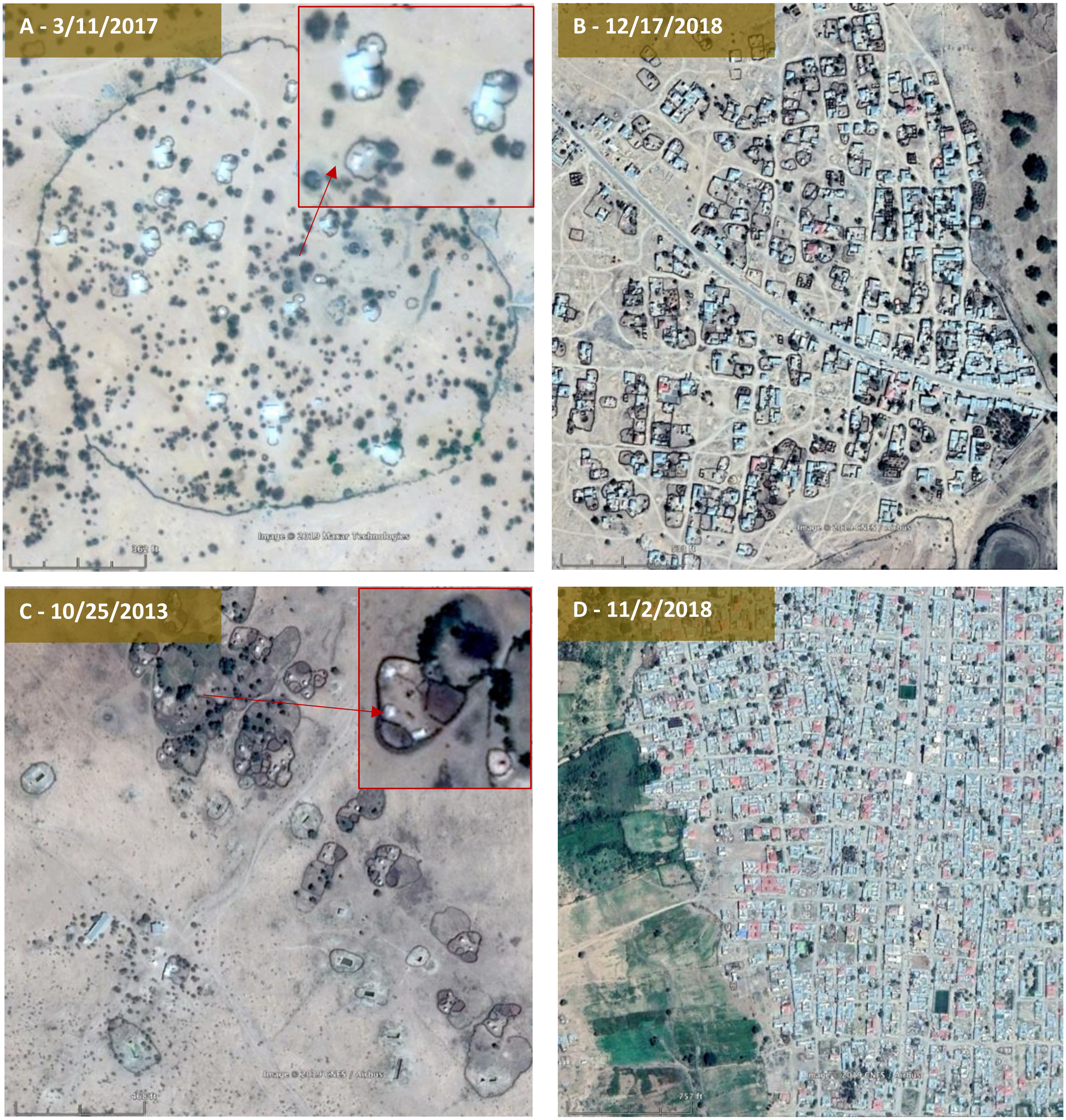

Figure 18. Settlements in Somaliland are heterogeneous. Structure density, type, size all vary

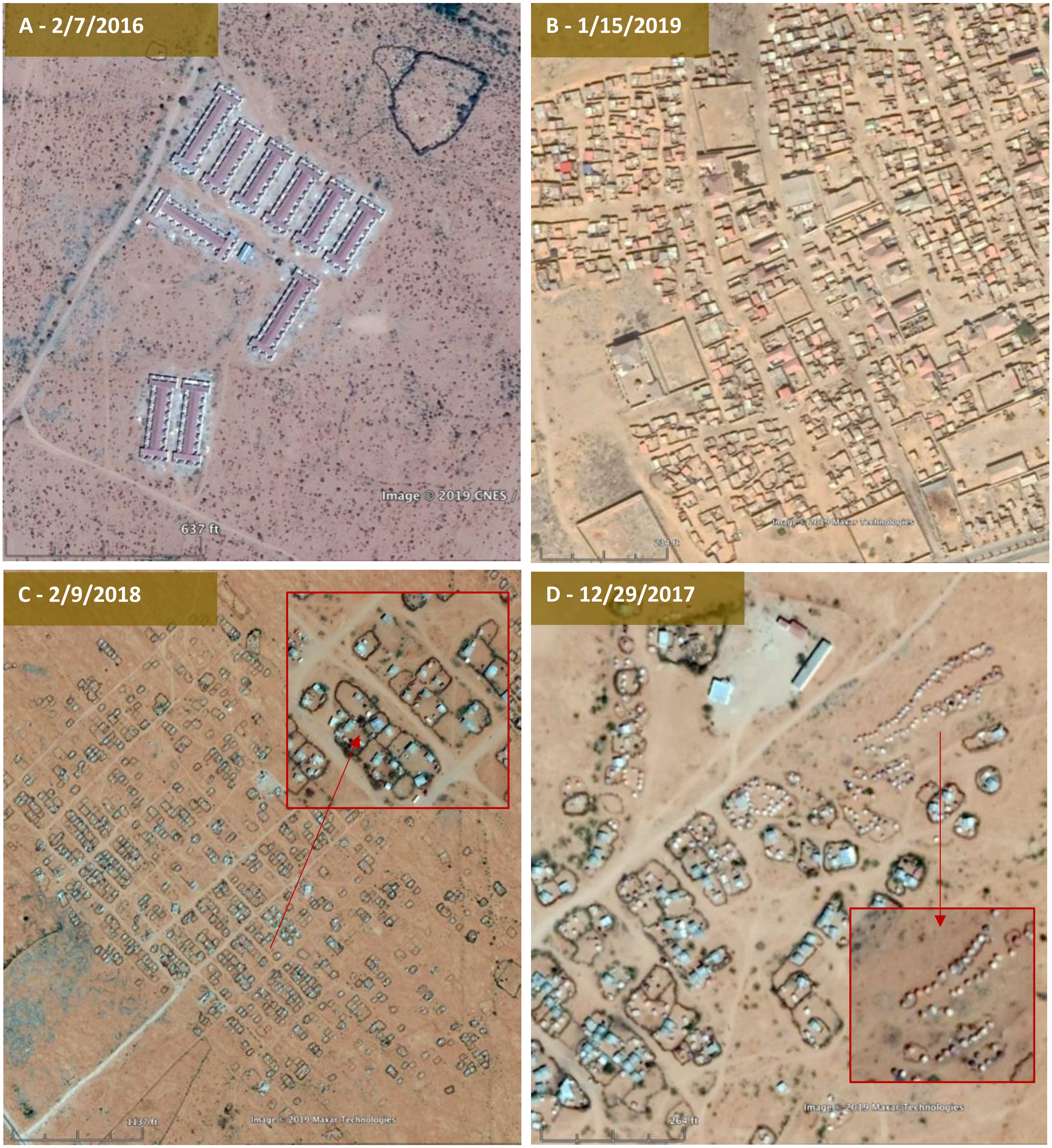

Figure 19. Refugee and IDP settlements

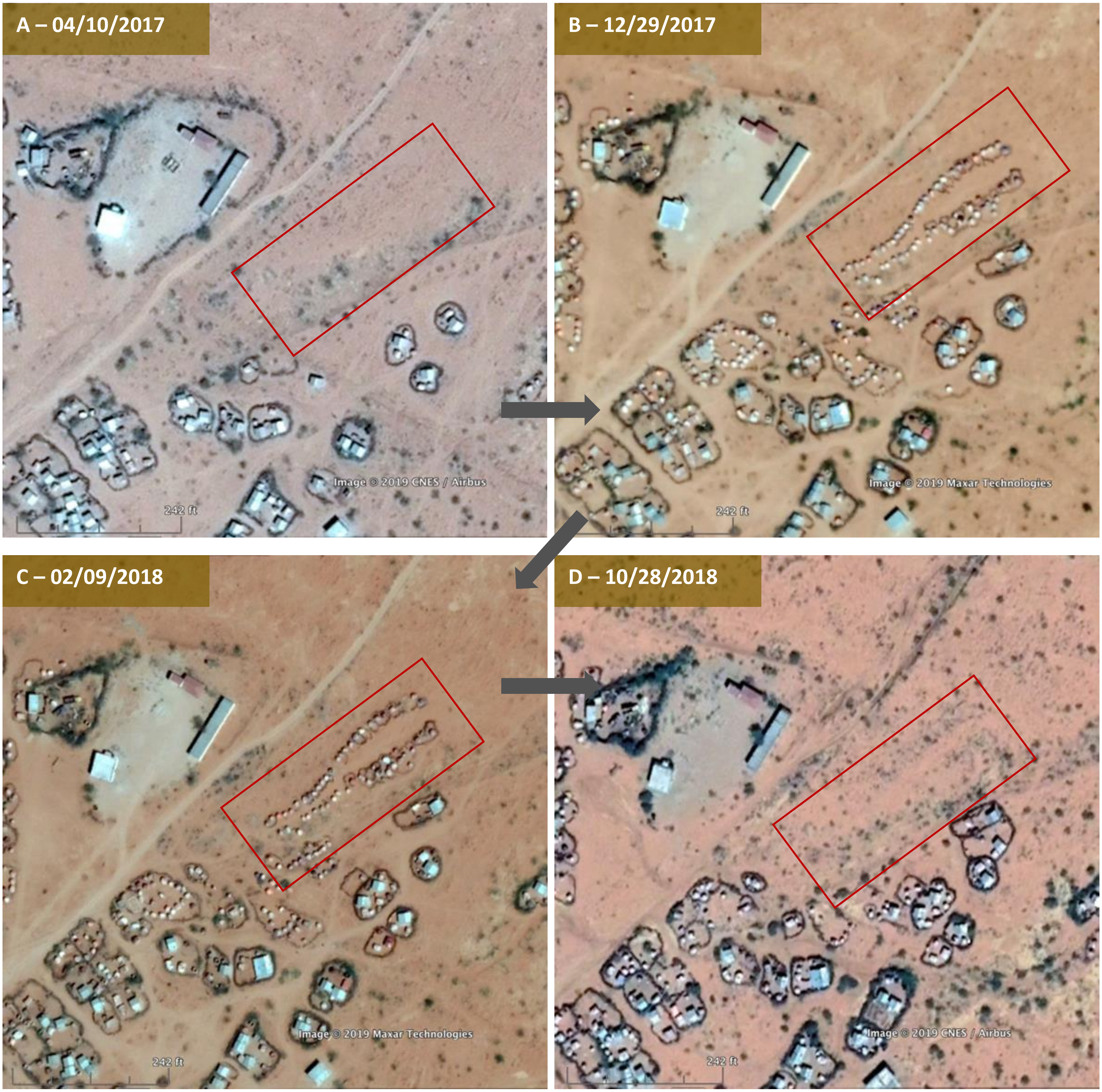

Figure 20. Change detection of spontaneous settlement site

L I M I T A T I O N S

Visual analysis tools available in Google Earth Pro enable humanitarian analysts to recognize, observe, and monitor landscape phenomena over time. The integration of remotely sensed data into ongoing research adds an additional layer of valuable open-source information to support our understanding of an AOI. With that said, satellite imagery does have limitations. While this is not an exhaustive list of limitations, the following limitations generally capture commonly identified restrictions.

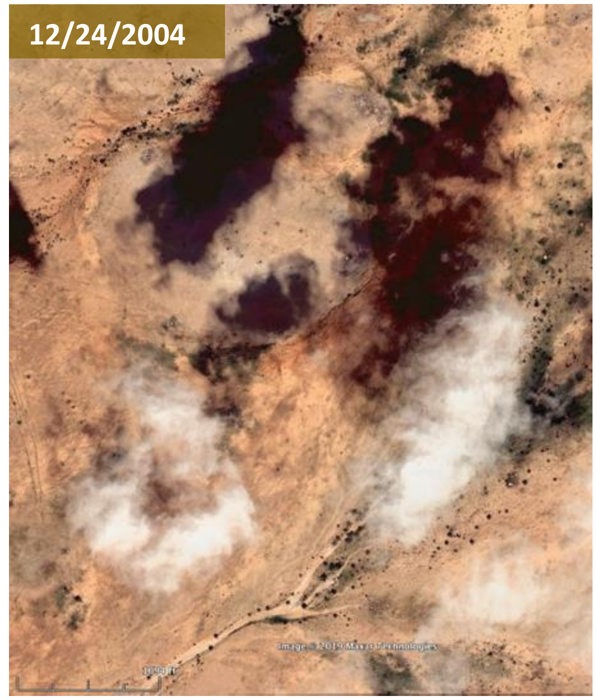

Figure 21. Cloud cover and cloud shadow obscure parts of the image

Cloud Cover and haze | Cloud cover can pose a major problem for imagery analysis (figure 21). The data sources integrated into Google Earth Pro do not have the capacity to penetrate cloud cover, which means that images can at times be partially or entirely obscured. It can therefore be very challenging to study AOIs during rainy seasons and limited availability of imagery can also inhibit analysis temporal analysis. The presence of clouds, dust, or smoke can also contribute to haze, reducing image quality.

Figure 22. Low image quality reduces contrast between the features of interest and the background

Low contrast can make it difficult to distinguish features from the background (figure 22). In the case of Somaliland, many man-made structures appear off-white, or as shades of gray, which can be difficult to spot when dealing with poor image quality and when the feature of interest situated in an area with light-colored land cover.

Temporal availability | VHR imagery is not constantly collected nor is it all available on Google Earth Pro. The unpredictable frequency of imagery can make temporal analysis over a short timeframe complicated. Moreover, Google Earth Pro archives historical imagery and does not provide real-time imagery. To analyze VHR imagery in near real-time that is not available in Google Earth Pro, you will likely have to purchase the image(s) through a commercial provider.

C O N C L U S I O N

Visual interpretation of satellite imagery is a valuable means of data extraction, particularly in data-scarce and/or non-permissive environments. This guide provides an overview of the general tools and techniques available to conduct basic imagery analysis through Google Earth Pro. The availability of Google Earth Pro and other free software enable humanitarian analysts to explore and analyze an unfamiliar data format, bridging the gap between technology and humanitarian work. Imagery analysis can be used in a variety of ways in humanitarian operations: identify areas accessible via road during a disaster, provide an overview of the number of tents in a refugee camp, validate ground information, gain insight to an inaccessible area where remote analysis is the only means of data capture, and more.

Identifying and recognizing the physical characteristics of features (shape, size, color, pattern etc) are important to developing an understanding of an AOI and the observed phenomenon. Prior to the development of this guide, there was little to no information available to assist in the identification of landscape features in Somaliland through imagery analysis. The analysts working on this project largely relied on their existing knowledge of regional feature characteristics to further their understanding of the features seen in Somaliland. Through using the techniques described in this guide as well as secondary data sources, analysts could identify landscape features associated to population settlements and people on the move. The described features include surface water, agriculture, groups of livestock, and presence of structures. The documentation of these features allows humanitarians to continue monitoring these features of interest to further understand their relationship to population movement. Unfortunately, extreme environmental changes and ongoing conflict that will continue to affect Somaliland and the surrounding regions in the years to come, likely displacing thousands of Somalis. To monitor populations on the move regularly on a country-wide scale, satellite imagery analysis and the techniques described in this guide can assist in humanitarian efforts in the years to come.