Use of earth observation products to enhance humanitarian disaster response

A Case Study of KRCS Response to West Pokot Mudslides in 2019

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Inquire • Understand • Influence

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Abstract

Kenya is mostly affected by mudslides and floods during two rainfall seasons, namely March-April-May (MAM) and October-November-December (OND). These landslides, floods and mudslides more often than not lead to loss of human lives, destruction of houses, displacement of people, livestock deaths, loss of livelihoods among other impacts.

This paper highlights the use of earth observation satellite imageries from the Airbus foundation for post-disaster impact assessment during the 2019 OND rainfall season to support effective response. On the 23rd of November 2019 during the OND rainfall season, mudslides and floods occurred in West Pokot resulting in disruption of road accessibility, loss of human lives, loss of livelihoods, houses destruction and displacement of people.

Due to continuation of rainfall, roads were cut-off and hence it was difficult to access the area to determine the damage and the number of households affected. Through the partnership with Airbus foundation, International Center for Humanitarian Affairs (ICHA) at Kenya Red Cross Society (KRCS) tasked the Pleiades satellite to acquire imageries of the affected areas five days after the mudslide event.

A spot 6 imagery archive captured on the 15th of May 2019 (months before the mudslide event) was downloaded from the Airbus foundation archives. A comparison of these two imageries through change detection was done in order to extract mudslide and flooding hazard extents. A hazard exposure analysis was done in order to determine houses and roads affected by the mudslide and flood hazard. Results from exposure analysis revealed over 145 houses as being destroyed and over 2.1 kilometers of roads being cut-off. Further analysis was done to determine partially and completely destroyed houses. KRCS was able to use this information for post-disaster recovery interventions such as search and rescue as well as shelter initiation of re-construction houses that were completely damaged by floods and mudslides.

This study has demonstrated the valuable use of satellite imageries from the Airbus Foundation to KRCS through provision of timely and accurate information on impacts of mudslides and floods in remote and inaccessible areas in a cost-effective manner and further support effective and efficient response and recovery. It is highly recommended for KRCS and other Red Cross and Red Crescent National Societies to use earth observation satellites for post-disaster assessment especially in remote areas that are inaccessible. This by far would improve their humanitarian capacity in conducting post-disaster assessments in a cost-effective and timely manner.

Drone Photo: Landslides mapping at Tapach ward, West Pokot County

1.0 Introduction

1.1 Floods and Mudslides in Kenya

Floods usually occur in Kenya during the March-April-May (MAM) and October-November-December (OND) rainfalls more often than not leading to negative impacts such as loss of lives, disruption of people's livelihoods, infrastructure destruction and interruption of economic activities. An example of major floods in Kenya was during the 2018 MAM rainfall. These floods led to displacement of over 300,000 people and injuries in 12 counties namely Garissa, Isiolo, Kisumu, Mandera, Marsabit, Narok, Samburu, Taita-Taveta, Tana River, Turkana, Wajir and West-Pokot. This was according to the National Disaster Operational Centre (NDOC) and Kenya Red Cross Society (KRCS).

In the same year, numerous roads were cut-off following mudslides in Central Kenya. Houses were destroyed in Kangema sub-county by landslides resulting in displacement of over 250 people (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2018). Floods led to increased risk of health emergencies including cholera outbreaks in affected areas due to poor sanitation and lack of access of clean water. Cholera cases were reported in 8 counties including West Pokot, Turkana, Tharaka Nithi, Nairobi, Kiambu, Isiolo, Garissa and Elgeyo Marakwet (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2018).

1.2 Use of earth observation satellites in enhancing humanitarian response

With impacts arising whenever major flood and mudslide events occur, the uptake of earth observation satellites within the humanitarian sector has happened at an unprecedented rate over the last decade (Lang et al., 2018). Obtaining reliable information by gathering evidence on the ground is often limited in flood and mudslide situations due to limited accessibility and time criticality (Lang et al., 2019). In such a context, remote sensing can improve hazard assessment and management. Remote sensing is a cost-effective technology where one can accurately extract information about a disaster e.g. a flood, from an area using satellites without having direct contact to this location (Campbell & Wynne, 2011).

Kenya Red Cross Society in implementing its mandate of providing assistance to communities affected by disasters and alleviate human suffering has adopted the use of earth observation (EO) satellites in close collaboration with the Airbus foundation.

Remote sensing has proven to be a cost effective asset for humanitarian aid. This is as highlighted is table 1 below. The table from (Campbell & Wynne, 2011) and (Lang et al., 2018) highlights the benefits of remotely sensed data as compared to conventional ground mapping in enhancing humanitarian action during disaster events.

Drone Photo: Floods mapping at Rwambwa village, Budalang'i Busia County

Table 1: Benefits of remote sensing in humanitarian action

Characteristic	General asset	Specific assets	Challenges
Captures information from a distance	No direct access required	Overcomes safety and security issues as well as logistical difficulties in accessibility	Disconnectedness of "object of interest" may evoke ethical or privacy issues
Area-wide coverage	Global availability	For most areas of the globe, standard RS data can be obtained	The amount of data being available and the different options to obtain them may be overwhelming
	Cost-effective means of data collection	Cheaper and easier, less time-intensive than collecting field data	Data and product validation routines required
Level of detail	Variable spatial resolution	Information in several scales to be obtained from one single data source	Possible confusion at huge variety of different optical as well as radar sensor types, including remotely piloted aircraft systems (RPAS or "drones")
Spectral reflectance	Spectral profiles	Enable identification of dwellings for indication for population estimation and other relevant geographical features	Requires skills in interpreting false colour composites
Digital processing	Image analysis and classification	Algorithms for automatically detect (and count) relevant features exist such as knowledge-based, machine/ deep learning, object-based image analysis (OBIA)	Requires expert systems and respective training
Weather/ daylight independency	Using energy sources other than sunlight	For areas or timeslots with less favorable atmospheric or cloud conditions, active remote sensing can complement	Coverage interpretation more difficult, target classes different from optical imagery
Time series	Variable temporal resolution (coverage frequency)	Regular time intervals (monitoring) for detecting changes and dynamics	Finding suitable imagery in right interval and frequency rate for time-critical

Satellite imagery have been employed to guide humanitarian response to natural disasters including floods and mudslides. For example, in response to the Philippines landslides and the south east Asia tsunami (Voigt et al., 2007). Within the context of the south east Asia tsunami in 26th December 2004, two post-disaster and pre-disaster high spatial resolution satellite imageries allowed easy and quantitative damage assessment through visual change detection. The post-disaster imagery was a satellite archive captured in 30th January 2003 while the pre-disaster imagery was acquired in 29th December 2004 – 3 days after the disaster event. This enabled delineation of tsunami-affected areas and thus enabled disaster managers to assess the damage and to supply local logistic teams to affected areas. In 17th February 2006, a landslide triggered by heavy rains buried the village of Saint Bernard in the Philippines. Several satellite sensors were used to derive a landside extent layer that delineated areas affected by the mudslide. The landslide extent was derived by means of on-screen digitization (Voigt et al., 2007). The 2 global examples highlight how satellite imageries are applied in rapid mapping of disasters and thereby enhancing crisis management support in a timely and cost-effective manner.

1.3. West Pokot floods

West Pokot county (Figure 1) is located in north western side of Kenya whose economy is primarily driven by agriculture and livestock farming. It is inhabited by 621,241 people (KNBS, 2019). The main notable disasters experienced in West Pokot are floods and mudslides. These disasters are usually triggered by heavy rainfall in western Kenya. On the 23rd of November 2019, mudslides and floods occurred in West Pokot resulting in loss of human lives, houses destruction and displacement of people. According to local residents, the county experienced a heavy downpour that began at midnight and caused havoc in so many areas. The heavy downpour lasted almost 12 hours thereby making residents unable to get out their houses. These landslides led to at least 120 deaths, destruction of houses and displacement of over 10,000 people (FEWSNET, 2019). It also led to destruction of infrastructure of undetermined value including bridges and roads therefore hampering humanitarian response in affected areas in West Pokot (Floodlist, 2019).

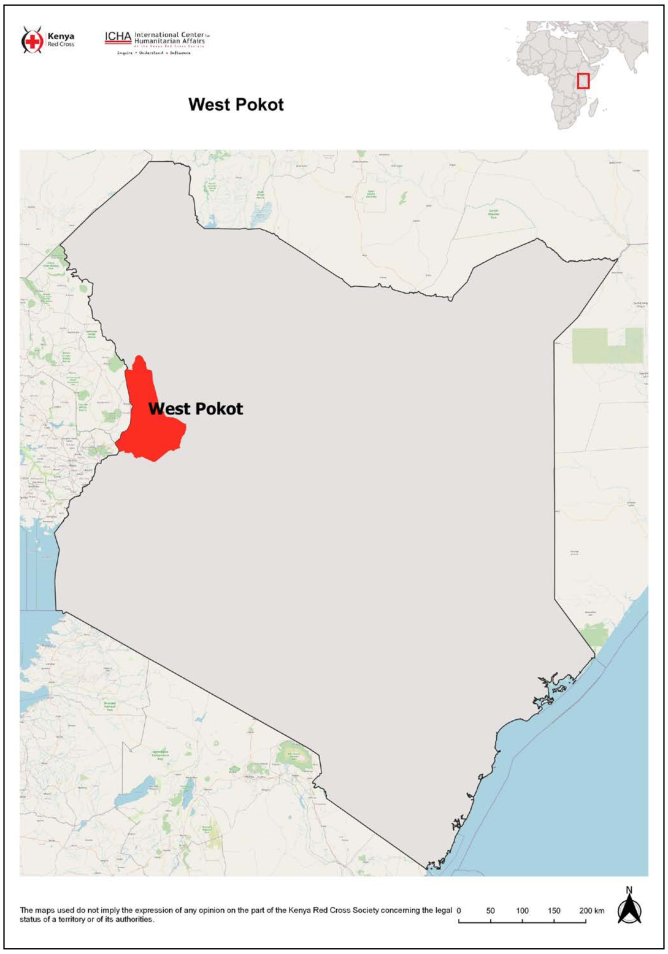

Figure 1: West Pokot study area

According to the county government of West Pokot, as of 24th November 2019, 54 people were killed by this hazard event. As a result of heavy rainfall, major rivers in West Pokot such as River Weiwei and River Muruny and other seasonal rivers burst their banks causing floods in low lying areas in the county (Figure 3).

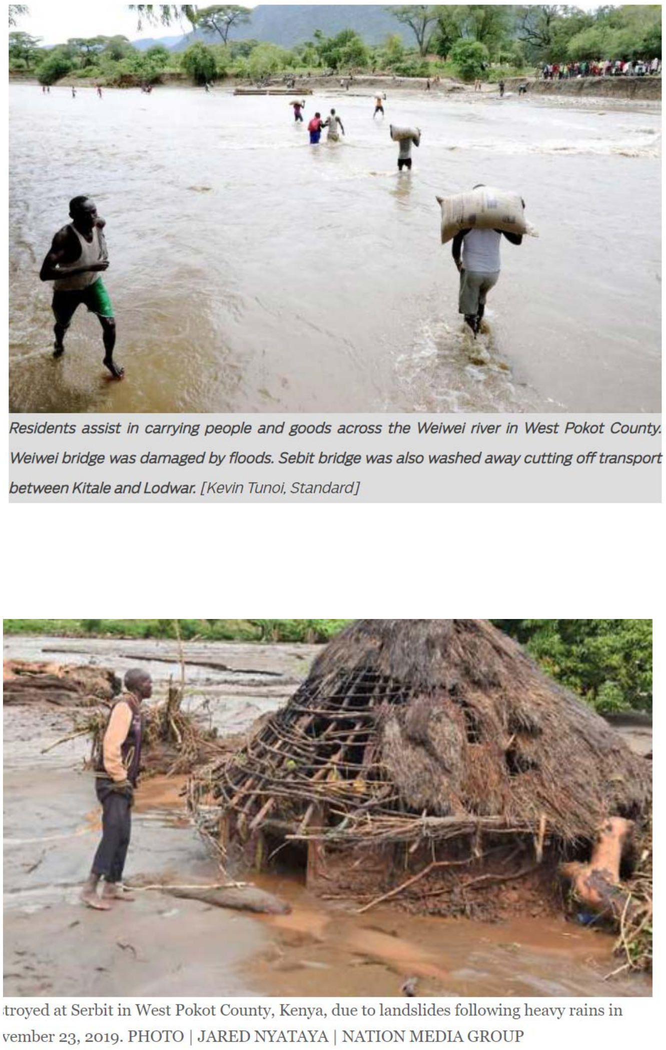

Figure 2: Weiwei River cut off by floods and houses destroyed at Serbit in West Pokot County. Image sources: The Standard (28th November 2019) and Nation Media Group (23rd November 2019)

The areas hardest hit by the landslide included Parua, Nyarkulian and Muino as shown in figure 5. This is due to their proximity to Weiwei river. The resulting floods and mudslides swept away 5 bridges and paralyzed road transport; according to the county government of West Pokot. As a result, aid efforts to deliver non-food items to affected families by KRCS were greatly hampered.

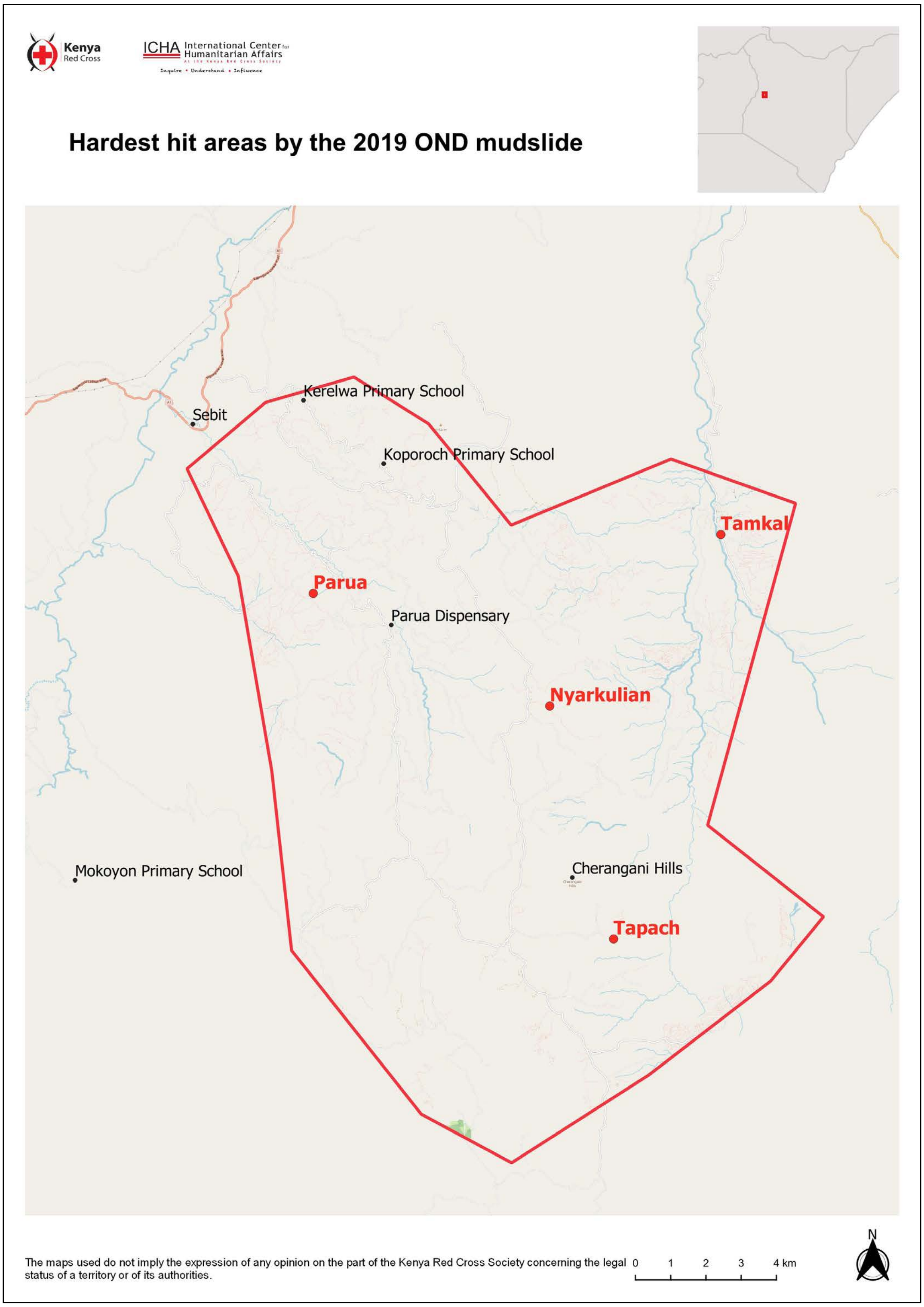

Figure 3: Hardest hit areas by the 2019 mudslide

Due to the massive destruction of property and infrastructure as result of the mudslide and flood event, the Government of Kenya ordered the deployment of rescue personnel from the National Police Service, Special Programs and the Kenya Defense Forces to the affected areas. The KRCS worked closely with these actors to ensure that citizens affected were urgently moved to safer grounds. The full assessment of the damage was greatly hampered by harsh weather conditions and impassable roads which called for the use of remote sensing solutions to acquire information of the damage extent without having physical contact of the affected areas.

2.0. Methodology

2.1. Acquisition of satellite imagery

The Airbus Foundation has enabled KRCS to task optical and radar satellites in inaccessible and remote areas that have been greatly affected by a disaster within a short timeframe without necessarily dispatching rescue teams on the ground to assess the extent of damage through conventional ground surveys. In so doing, KRCS has been able to accurately conduct disaster assessments to communities affected in a cost-effective and timely manner. This was the case during the Solai Dam burst in 2018 where timely acquisition of the Pleiades imagery from the Airbus foundation enabled extraction of 223 households that were affected by the dam burst. With this accurate figure, KRCS was able to disburse unconditional cash to the 223 affected households in Solai to access safe and dignified alternative housing.

With ground assessments to determine the magnitude of damage greatly hampered by harsh weather conditions and impassable roads, on the 28th of November 2019, KRCS once again resorted to the use of earth observation satellites from the Airbus Foundation. The aim of this was to acquire two post-disaster and pre-disaster satellite imageries to allow quantitative damage assessment through visual change detection thus enabling delineation of floods and mudslide affected areas by means of on-screen digitization. KRCS tasked the Pleiades satellite to capture imageries over affected areas. At a spatial resolution of 0.5 meters, the post-disaster Pleiades imagery was acquired on the 28th of November 2019 (Figure 4).

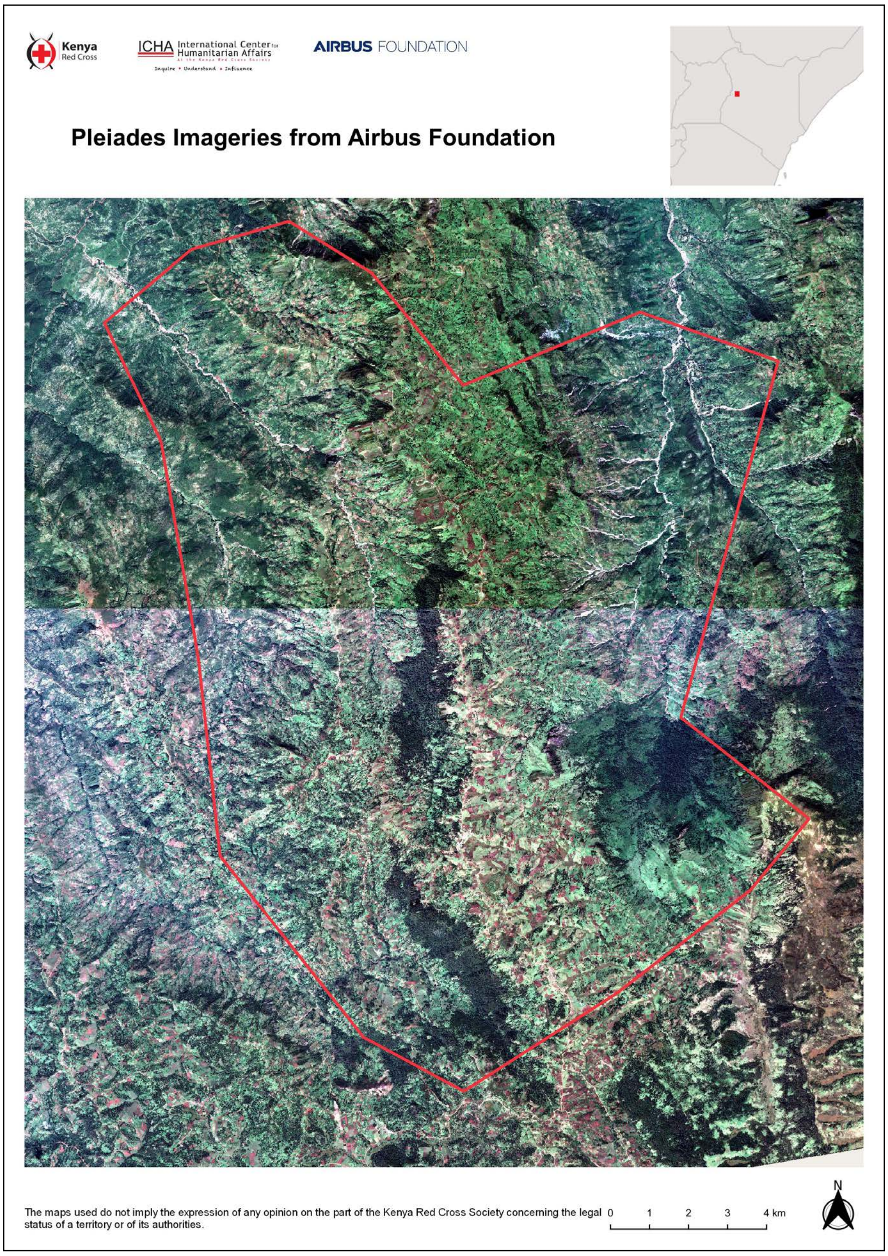

Figure 4: Post-disaster pleiades imagery acquired on the 28th of November 2019

At 1.5-meter spatial resolution, the spot 6 imagery was acquired on the 15th of May2019; months before the mudslide event (Figure 5).

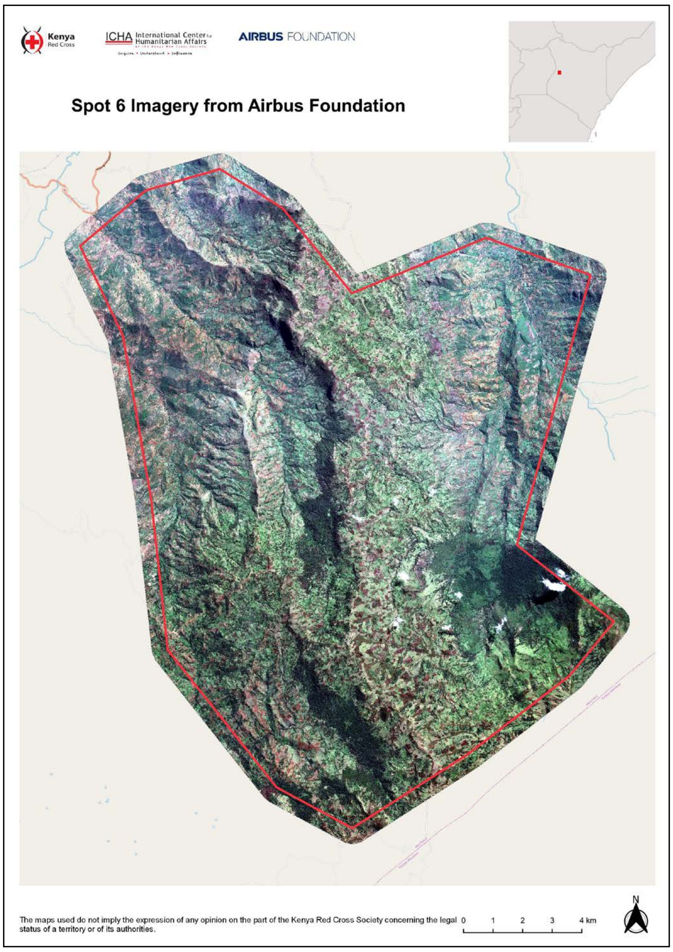

Figure 5: Pre-disaster spot 6 imagery from Airbus foundation

2.2 West Pokot Mapathon

In order to obtain updated spatial layers such as roads and buildings over West Pokot, KRCS together with the Netherlands Red Cross (NLRC) held a virtual Mapathon with the aim of digitizing from Humanitarian OpenStreetMap (HOT) these spatial layers. The latter were then to be used alongside the mudslide and flood hazard extent to derive hazard exposure maps. HOT is a crowd-mapping initiative that generates geospatial data such as roads, buildings which are critical to deliver in humanitarian operations. HOT follows the mission of creating maps for humanitarian response while strictly adhering to the principles of open source and open data sharing (Lang et al., 2019). Coetzee et al., (2018) describes a Mapathon as a collaborative initiative by the HOT that aims at collecting spatial layers through remote mapping where OSM data is scarce or non-existent. More often than not, Mapathons involve the use of knowledgeable volunteers who assist with geospatial data collection in areas that have been affected by disasters. Within 24 hours, Mapathoners who voluntary joined the task managed to digitize roads and buildings spatial layers which were uploaded onto OpenStreetMap for KRCS's consumption (Figure 8).

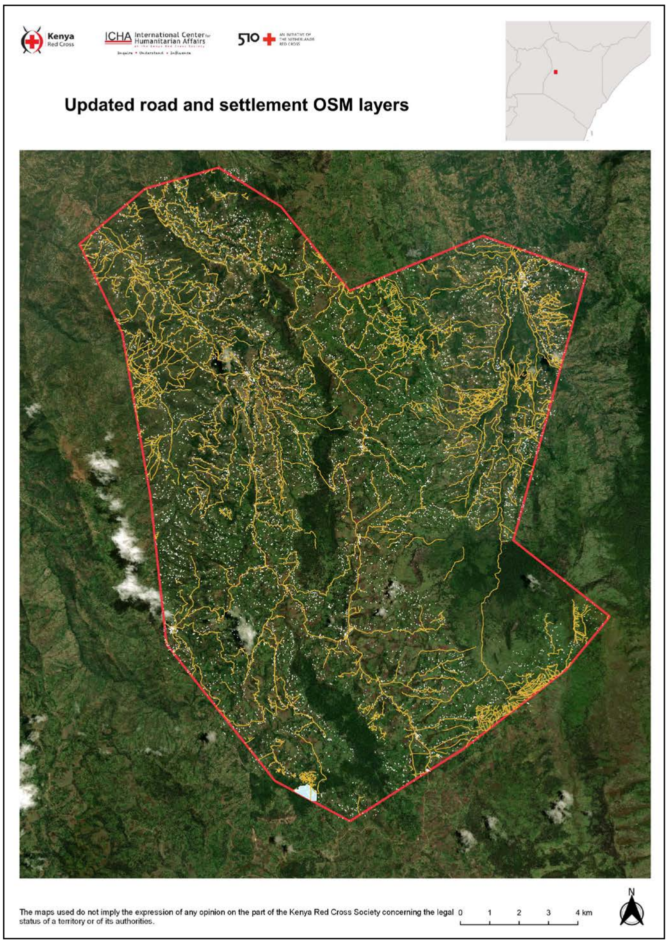

Figure 6: Updated building and road layers downloaded from OpenStreetMap (OSM)

https://www.hotosm.org

3.0. Findings

A comparison of the pre-disaster and post-disaster imageries was done in order to visually interpret mudslides and floods. Visual interpretation allowed extraction of mudslides and floods through onscreen manual digitization in order to quantify damage assessment thus enabling delineation of floods and mudslide affected areas in West Pokot.

3.1 Mudslide extraction through change detection

Onscreen digitization was conducted at large scale where the post-mudslide and pre-mudslide imageries were overlaid side-by-side in order to visually interpret mudslide scars. These scars were converted into vector data by tracing features through onscreen digitization. Figures 7 to 11 below illustrate the visual comparison of spot 6 and Pleiades imageries to determine landslide scars. The figures have been overlaid with rivers; in blue, houses; in black and roads; in yellow to visualize the situation before the mudslide event using the spot 6 imagery (at a coarser spatial resolution of 1.5 meters) while comparing it with the situation after the mudslide event using the Pleiades imagery (at a finer spatial resolution of 0.5 meters). The two images have been overlaid at the same map scale for visual comparative analyses.

Figure 7: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret landslide scars

The left image highlights farmlands as they were before the mudslide event. The image on the right shows farmlands that were destroyed by the mudslide. The affected farmlands were left bare as a result of the mudslide.

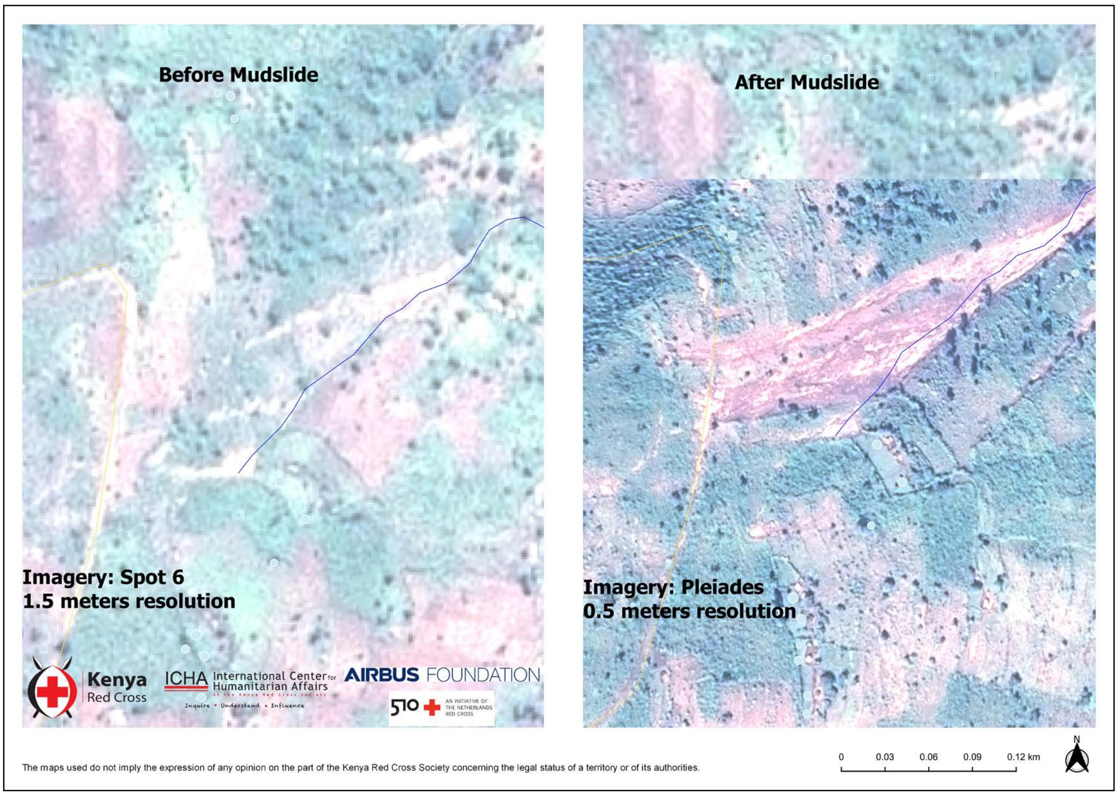

Figure 7: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret.

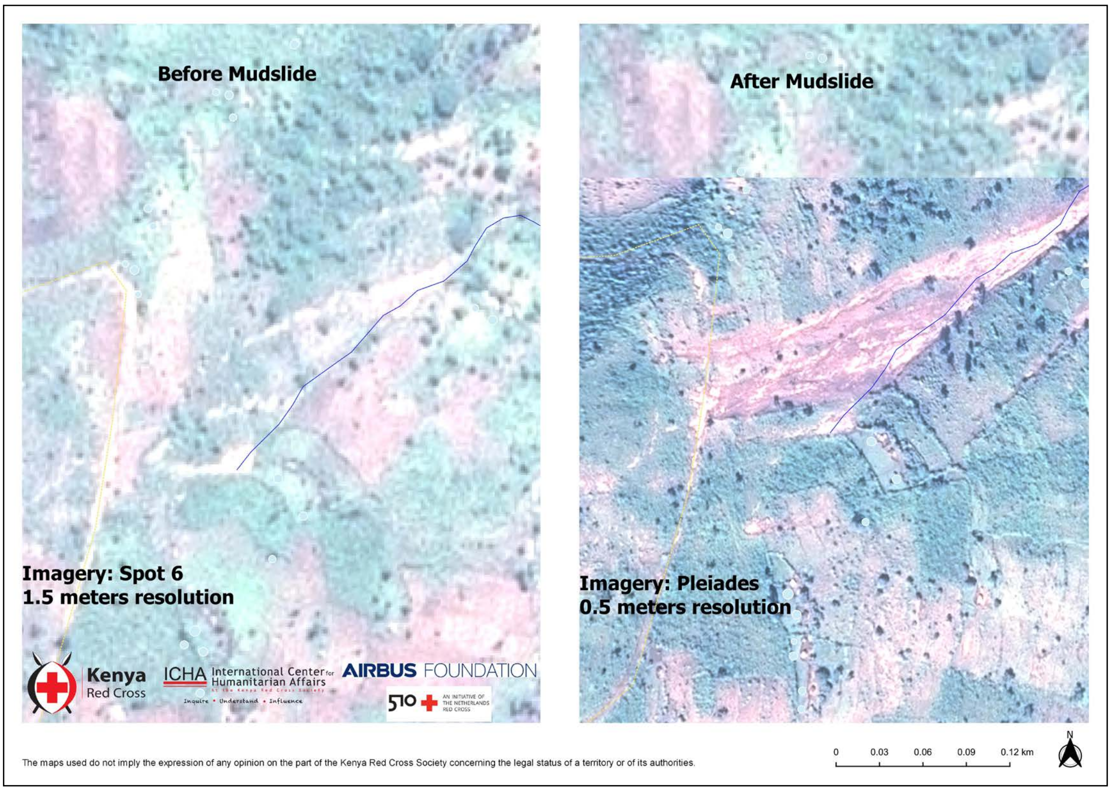

Figure 8: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret landslide scars

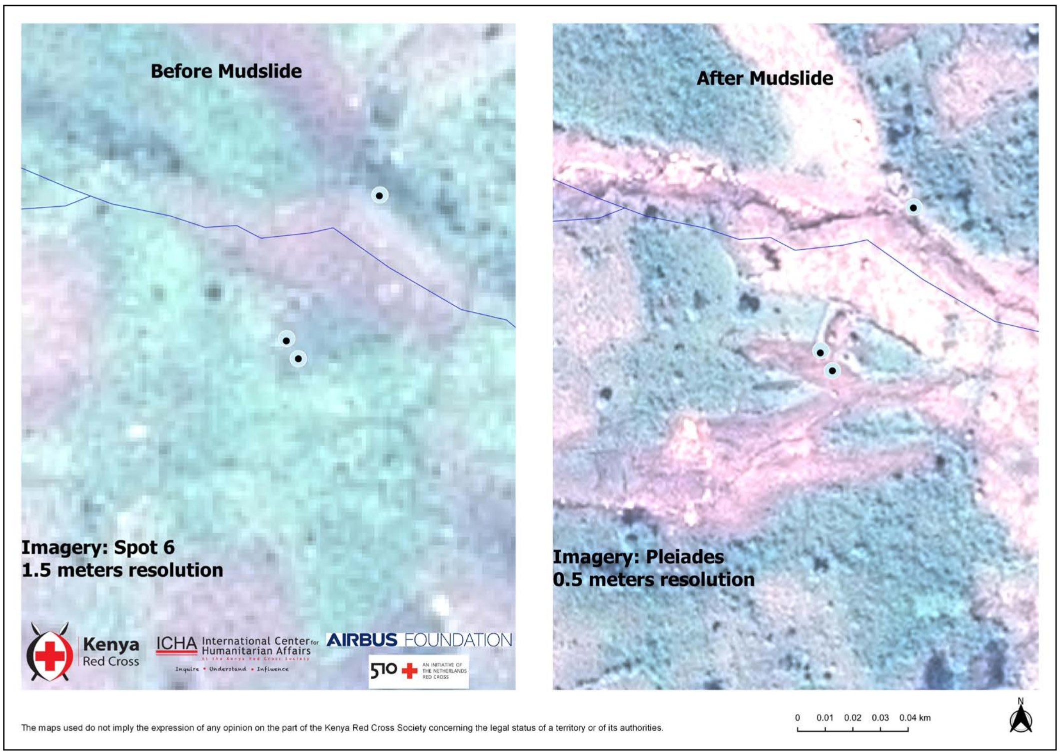

Figure 9: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret landslide scars.

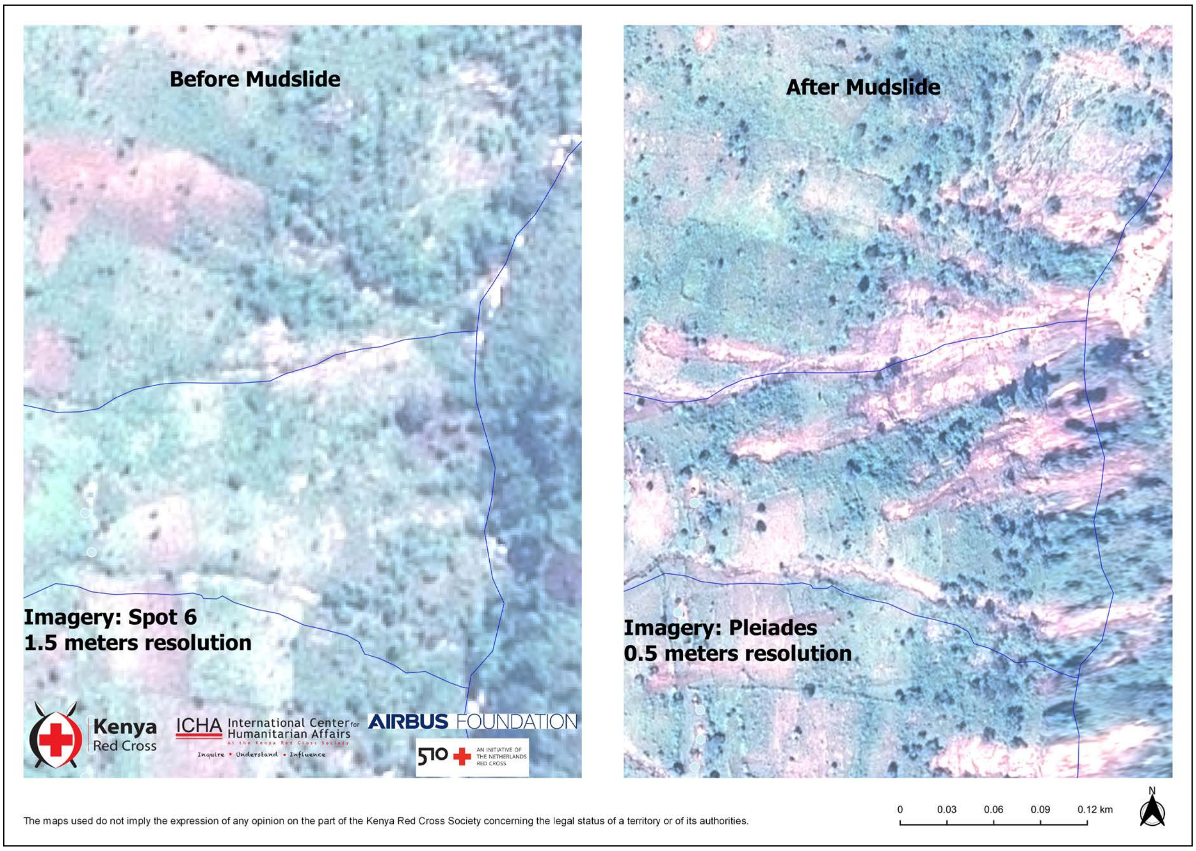

Figure 10: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret landslide scars.

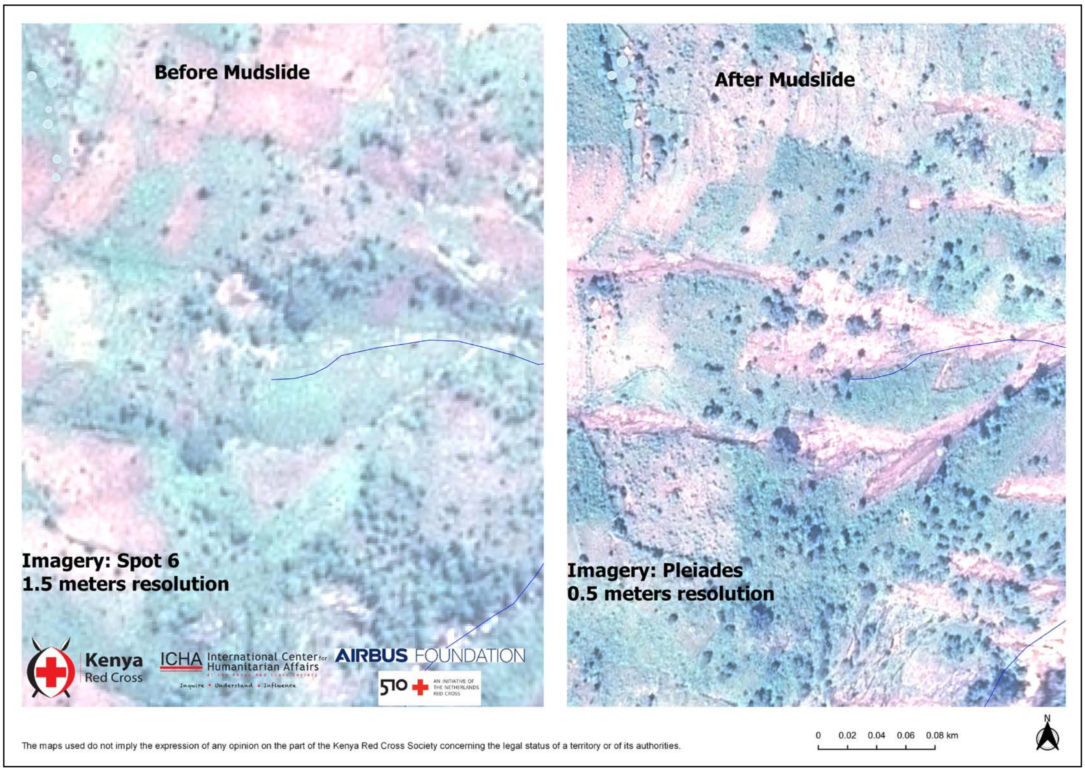

Figure 11: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to illustrate the escarpment of the landslide

3.2 Flood extraction through change detection

On screen digitization was conducted at large scale where the post-floods and pre-floods imageries were overlaid side-by-side in order to visually interpret flooding extents. These flood extents were converted into vector data by tracing features through onscreen digitization.

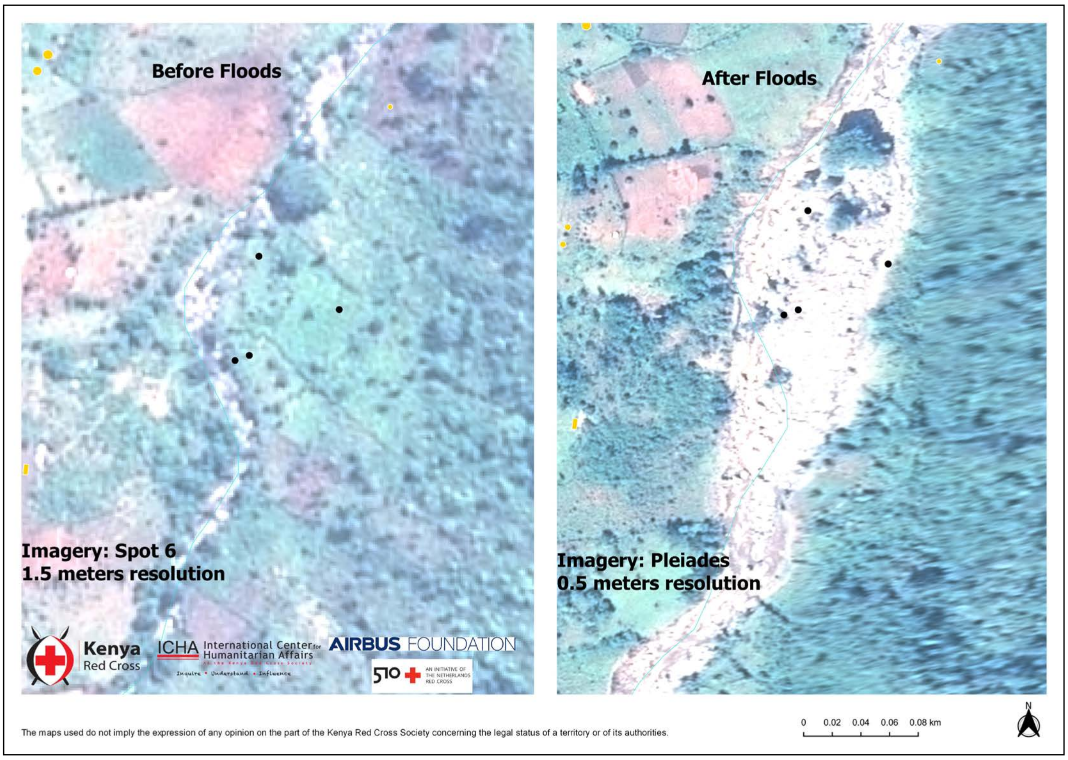

Figure 12: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret flooding extents

Figures 12 to 14 below illustrate the visual comparison of spot 6 and Pleiades imageries to determine flood extents. The imageries have been overlaid with rivers; in blue, houses: in black and roads; in yellow to visualize the situation before the flood event using the spot 6 imagery (at a coarser spatial resolution of 1.5 meters) while comparing it with the situation after the flood event using the Pleiades imagery (at a finer spatial resolution of 0.5 meters). The two images have been overlaid at the same map scale for visual comparative analyses.

The left image highlights the river as it was before the flood event. The image on the right shows the swollen river as a result of heavy rainfall. 4 houses (black dots) have been marooned by the swollen river.

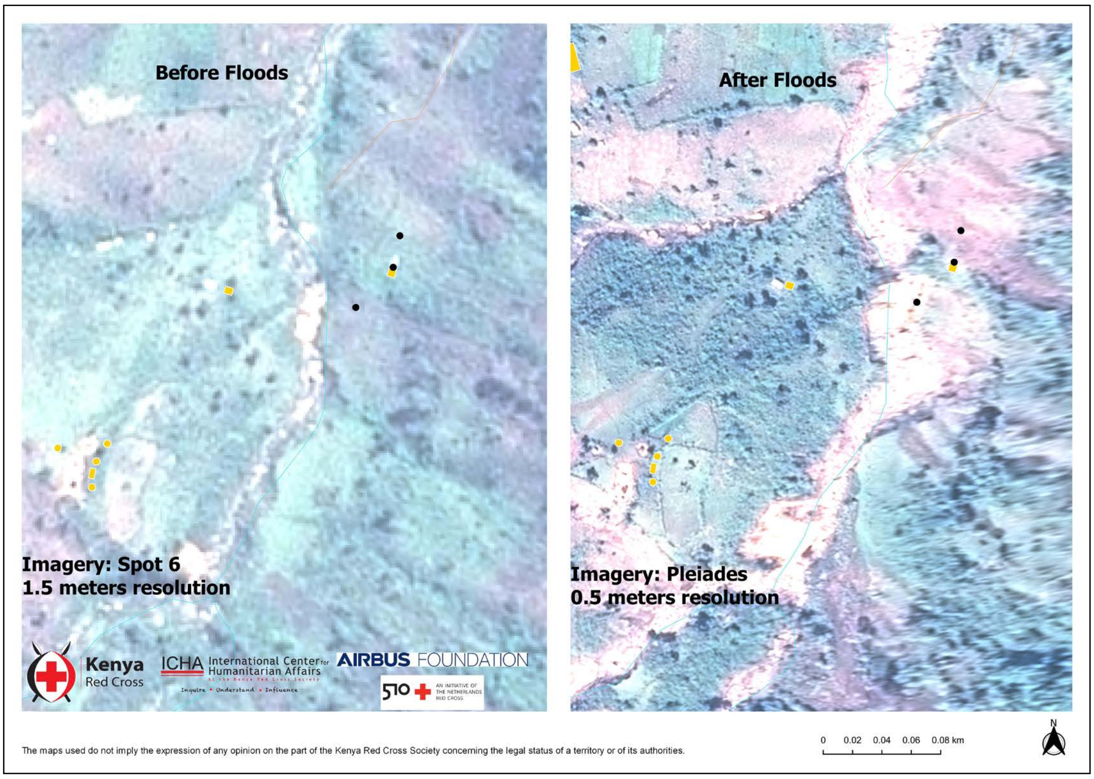

Figure 13: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret flooding extents

The left image highlights the river as it was before the flood event. The image on the right shows the swollen river as a result of heavy rainfall. 3 houses (black dots) have been marooned by the swollen river.

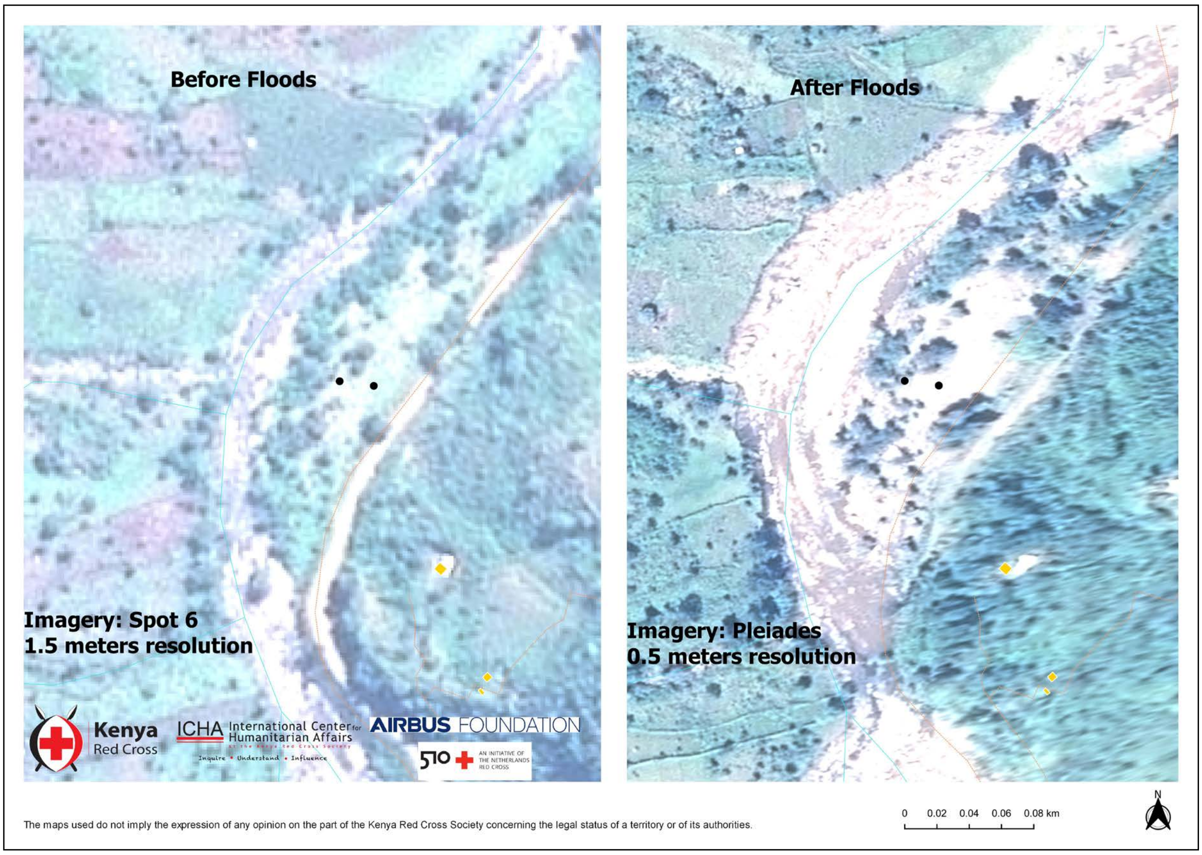

Figure 14: Change detection – visual comparison of spot 6 and Pleiades imageries was done in order to visually interpret flooding extents

The left image highlights the river as it was before the flood event. The image on the right shows the swollen river as a result of heavy rainfall. 2 houses (black dots) have been marooned by the swollen river.

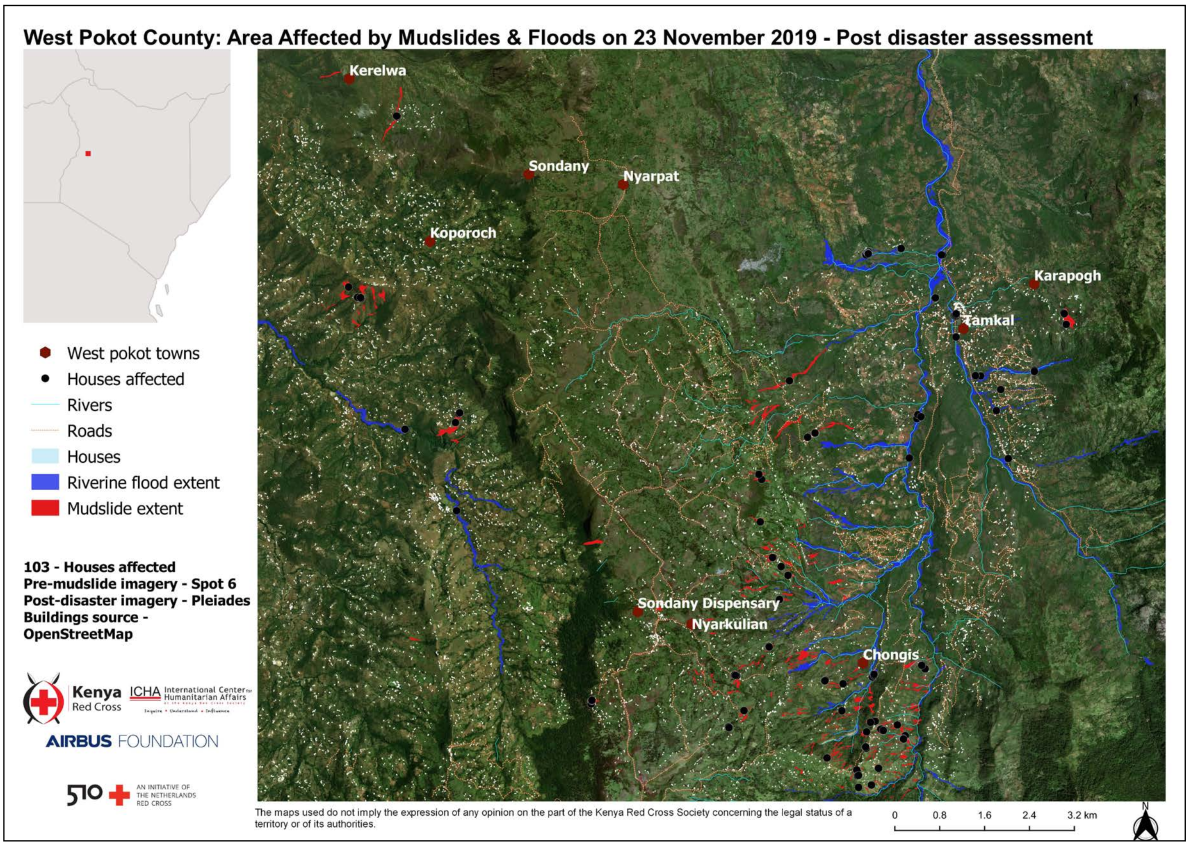

Figure 15: Extracted mudslides (in red) and floods (in blue) through on-screen digitization

Figure 15 shows the spatial extent of mudslide and flood hazard that were extracted through visual interpretation and onscreen digitization.

Using the digitized mudslide and flood extent layers (Figure 15), a spatial analysis was undertaken to derive hazard exposure elements such as cut-off roads, marooned dwelling and structures as shown in Figure 16. A count of these buildings within the hazard layer revealed that 105 hectares of farmlands and natural vegetation were flooded. Consequently180 houses were completely destroyed while 95 houses were partially destroyed by both floods and mudslide hazards. In addition, 2.1 kilometers of roads were cut-off. A total of 93 hectares of farmlands and natural vegetation was affected by the mudslide.

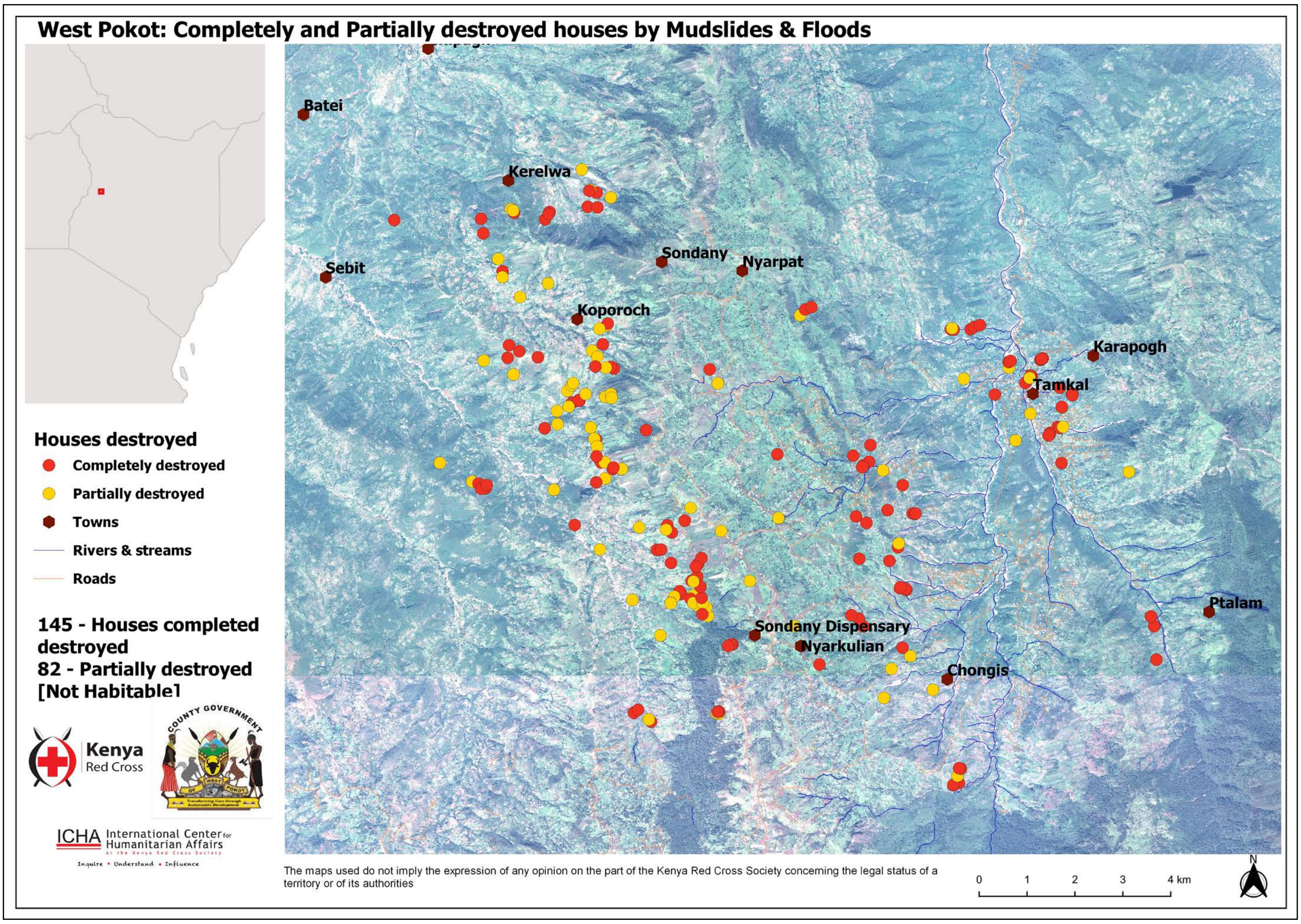

Figure 16: Completely and partially destroyed houses

4.0. Results and Discussions

Visual analysis and comparison of Spot 6 and high resolution (0.5m) Pleiades imageries allowed for the identification of landslide scars and flood extents. These were consequently used to determine areas affected by both hazards. At 0.5m resolution it was possible to create a detailed outline of freshly exposed soils, flood-movement, swollen rivers and concave structures identified as possible landslide scars in a number of locations, indicating potentially unstable slopes. Previous studies that have utilized high resolution satellite images to investigate similar events include (Gorum et al., 2011; Hervas et al., 2003; Jordan et al., 2015; Yang et al., 2019) and (Hunt et al., 2019).

From this study, about 105 hectares of land were affected by floods while 93 hectares were swamped by mudslides. Change detection analysis undertaken through image enhancement and visual interpretation revealed destruction of natural vegetation and farmlands such as uprooting of trees and shrubs and burying of crops. Other adverse impacts to the environment that were interpreted from the acquired earth observation satellites included waterlogging that compromised on surface and underground water systems. Such impacts have been reported in previous studies conducted by (Musoke et al., 2020) and (Ren et al., 2009). Indicative of the devastation to settlements, farmlands, natural vegetation and waterlogging as a result of mudslides and floods, maps generated from this study provided useful information on areas that need humanitarian support in terms of recovery and rehabilitation.

The spatial analysis results indicate that 180 houses were completely destroyed by both floods and mudslide hazards while 95 houses were partially damaged. In addition, 2.1 kilometers of roads were cut-off by the events. Therefore, the affected communities and infrastructure destroyed can be accurately detected within a short-timeframe and lead an effective response. The mudslide and flood hazard maps were used by KRCS to initiate shelter re-construction in the 275 houses that were destroyed by both floods and mudslide hazards. The results obtained using remote sensing appear very promising, especially since the technology allows mapping of flooded areas and hazard exposure analysis to identify residents marooned by flood waters, damaged structures and inaccessible roads due to the floods and mudslides. This study has demonstrated the valuable use of satellite imageries from the Airbus Foundation to KRCS through provision of timely and accurate information on impacts of mudslides and floods in remote and inaccessible areas in a cost-effective manner. This strongly concurs with the benefits of remote sensing in humanitarian action as alluded by (Lang et al., 2018). During disasters, such high resolution data can be used as reference maps suitable for early assessments and emergency response.

From this study

105
Hectares of land affected by floods

95
Houses were partially damaged

93
Hectares of land swamped by mudslides

2.1
Kilometers of roads were cut-off by the events.

270
No. of houses reconstructed by KRCS after floods and mudslide hazards

**The mudslide and flood hazard maps were used by KRCS to initiate shelter re-construction in the houses that were destroyed*

5.0. Conclusion and Recommendations

This case study focused on exploring the potential use of satellite imageries for identification of flooded areas, damage assessment and hazard response. The catastrophic floods and mudslide that occurred in West Pokot County, on November 23rd, 2019 due to incessant rains has been simulated and analyzed. Using digitization technique and visual interpretation of the pre and post mudslide satellite images (spot-6 pre-disaster imagery was captured on 15th of May 2019 while the Pleiades post-disaster imagery was acquired on 28th of November 2019 –five days after the event), a change map was obtained to show the extent of the flood and mudslide area. Therefore, it is evident that remote sensing tools can be effectively utilized for creation of flood extent maps,

Future assessments should explore use of higher resolution images such as drone imageries which have finer details for more accurate assessment. This would aid in detailed assessment of other variables such as type of crops and vegetation destroyed, condition of the landslide scars, water infrastructure such as communal water points and boreholes destroyed by floods and mudslides amongst other exposure elements. Additionally, the use of radar interferometric remote sensing techniques would enhance the analysis of the extent of the mudslide and gather additional parameters such as displacement measurements. Lastly, this study recommends the use of classification algorithms to complement onscreen digitization thereby enhancing extraction of mudslide scars and flood extents from the Pleiades and Spot 6 earth observation satellites.

Based on our study findings, we make the following recommendations: 1) stakeholders in West Pokot County should consider utilizing the flood hazard maps in implementing community driven tree planting and reforestation activities, to counter soil erosion reduce the reduce mudslide hazard; 2) KRCS and other national societies should utilize satellite products for post-disaster assessment since the affected areas may inaccessible due to the hazard. Whereas the interpretation of satellite imagery can provide a timely perspective on the extent of the hazard. This would improve their capacity to conducting post-disaster assessments in a cost-effective and timely manner. Additionally, it would strengthen humanitarian data preparedness through extraction of accurate information on hazard extent and accurate identification of affected households which is imperative for effective disaster response.

Recommendations

1. Stakeholders in West Pokot County should consider utilizing the flood hazard maps in implementing community driven tree planting and reforestation activities, to counter soil erosion reduce the reduce mudslide hazard.

2. KRCS and other national societies should utilize satellite products for post-disaster assessment since the affected areas may inaccessible due to the hazard.

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