Land Cover Analysis Using Sentinel-2 For Humanitarian Mine Action And ERW Survey

Alaa AlZoubi[1] and Nasir Ibrahim[2]

Alaa AlZoubi[1] a.alzoubi@derby.ac.uk, Nasir Ibrahim[2] nasir.ibrahim@buckingham.ac.uk

[1] School of Computing and Engineering, University of Derby, Derby, DE22 3AW, United Kingdom
[2] School of Computing, the University of Buckingham, Buckingham, MK18 1EG, United Kingdom

Introduction

Unexploded landmines and other explosive devices (both anti-vehicle and anti-personnel) that are buried during conflict or war present effects that are felt long-term after the conflict or war – and the immediate inhabitants are hit harder by the devastation. This impact – by extension – to the government - presents many challenges as it hinders the social and economic development of the affected areas resulting in abandoning of lands. These weapons can be found on roads, footpaths, agricultural fields, deserts, forests, in and surrounding houses and school. They deny access to water, food and hinders the movement and other basic activities of people [1].

In 2021, Landmine monitoring [2] recorded at least 5,544 casualties of landmines and (ERW) - 2,182 people were killed and 3,355 were injured majorly from conflict facing countries such as: Syria, Libya, Afghanistan, Iraq, Pakistan, Nigeria, Myanmar and Yemen. Of the casualties, more than 75% were civilians, 50% were children and 19% were women and girls [2]. However, there has been large support by countries to ban the use, production and transfer of mines. A framework was established in 1997, The Mine Ban Treaty [3], which provides the framework for governments to alleviate the suffering of civilians living in affected areas. Governments that join the treaty must stop the use, production, stockpiling and transfer of mines immediately and must destroy all stockpiled mines within four years and clear all mines in mined areas within ten years.

Land release process consists of three main activities: Non-Technical Survey, Technical Survey and Clearance. Non-Technical Survey (NTS) is the first step in the land release process. It involves collecting information from difference sources such as speaking to the populations in suspected areas, reviewing maps and field inspections. It is an essential step before the technical survey and mine clearance processes to identify the locations (and boundaries) of hazardous areas and gather information about the land-cover usage. Different technical survey (TS) methods for landmine detection were proposed in the literature2 such as: manual methods (e.g., metal detector technologies); electromagnetic methods (ground-penetrating radar - GPR); acoustic/seismic methods (vibration from sound waves); mechanical methods (heavy machinery and autonomous robots) and biological methods (e.g., dogs and rats). Each of these techniques has its merits and challenges ranging from efficiency (time-consuming), labour intensive, error-prone (low accuracy) and risk exposure (danger).

Understanding the changes in the land-cover before deploying the technical survey provides valuable information on the land usage, the scale of the problem, the resources needed to clear the field, and estimate the clearance time. Such analysis can help identifying minefield related indicators such as changes in buildings, roads and vegetations. It also ensures that most hazardous areas are identified and prioritised. Usually, on-ground activities are undertaken to gather information to support the decision-making process. Teams are deployed in potential areas, and they conduct interviews asking residents about the land use. However, this process is time and effort-consuming and costly.

Remote sensing data have been used successfully in identifying objects and studying the changes in the land cover for different applications such as agriculture, vegetations, built up areas, rivers and wetlands. This extended abstract presents our recent published framework [4] to help with the non-technical survey process by identifying minefield related indicators using land-cover analysis. We use remote sensing images from sentinel-2 to estimate the changes in vegetation and non-vegetation in different suspected areas. The mount and number of changes during a period are estimated to provide recommendations on suspected hazardous areas in Cambodia qualified for clearance. Our analysis is the first which directly uses sentinel-2 to estimate the changes in vegetation and non-vegetation for non-technical survey.

Russia-Ukraine war may result in landmine and unexploded ordnance (UXO) killing people. Many of them are children. Participating in the UK-Ukraine Digital Theme Research Twinning Initiative can help developing our work in [4] to other cases study such as Ukraine.

Data, Methods and Analysis

A dataset of 469 suspected hazardous areas (or polygons) in Cambodia were collected by landmine operators from the Mines Advisory Group (MAG) and the remote sensed images from Remote Sensing Images from Copernicus Sentinel-2 [5]. All polygons were stored in a Shapefile with their names, coordinates and other geographical information. The geometric location of each polygon was stored in longitude and latitude format. The polygons size ranges from 1,200m^2 to 519,267m^2, spanning over 5 communes and 29 villages in Cambodia. For this study, 66 polygons with large size were selected and analysed. Figure 1 shows example polygons overlaid on Google Earth and Sentinel-2.

Figure 1 Example Polygons Projected on Google Earth (left) and Sentinel-2 Tile (right)

We used Sentinel-2 which provides high-resolution multi-spectral images that cover the suspected hazardous areas (or polygons) in Cambodia defined by landmine operators. We collected 24 different observations (one observation every month) over two years (January 2019 - December 2020). However, due to the high cloud cover proportions on the observations, only 10 observations were appropriate and hence analysed. This includes Jan-2019, Feb-2019, Mar-2019, Nov-2019, Dec-2019, Jan-2020, Feb-2020, Mar-2020, Nov-2020, Dec-2020 observations.

Our proposed framework (Figure 2) comprises of three main components:

- **Segmentation**: The Sentinel images are segmented into different classes using the Scene Classification algorithm [6]. The algorithm provides pixel-classification for cloud, cloud shadow, snow, water, vegetation and non-vegetation – soils/desert. After the segmentation classes are grouped into vegetation, non-vegetation regions and other – only vegetation and non-vegetation classes were used in analysis. We identify both vegetation and non-vegetation regions in the suspected hazardous areas from each observation.
- **Change Detection**: The segmented outputs are used as an input for the change detection method. The algorithm outputs a binary change mask - which represents the change locations and the change type - which represents the corresponding change types that have occurred (e.g., from vegetation to non-vegetation and vice versa).
- **Change Description and Analysis**: For each suspected hazardous area (or polygon), we extract and estimate the amount and number of land cover changes by estimating the changes in every two

consecutive observations. The change detection method employed in this study allows different levels of granular information to be derived. With the pixel-based technique, the following descriptions were derived:

- From-To: The class change from one observation to the next observation.
- The amount of change (or no change) areas per class in m^2.
- The amount (in m^2) and proportion (in %) of the area lost per Class.
- The amount (in m^2) and proportion (in %) of the area gained per Class.
- The amount (in m^2) and proportion (in %) of the area without change per class.
- The amount (in m^2) and proportion (in %) of overall changes (in all classes) in the polygon.

The change description allows for polygon-based change analysis (analyses the amount of overall change in the polygon over a period) and polygon sub-area change analysis (analyses the number of changes inside of the polygon over a period - the polygon is split into sub-areas of 20m x 20m – single pixel- and the total change in each sub-area is estimated across the period of study and observations). The final recommendation of the area is decided based on the number of significant changes in the polygon over the period according to the NTS Threat Classification chart in Figure 3.

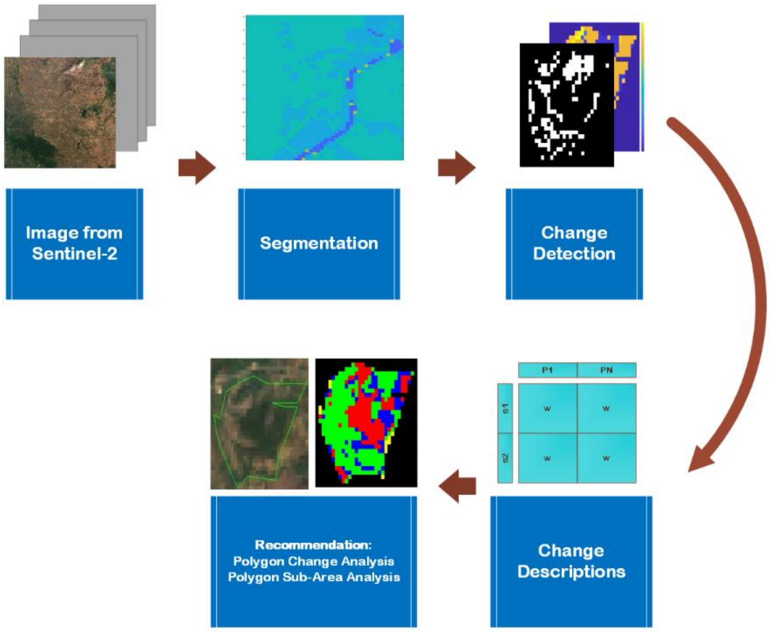

Figure 2: Our framework for polygons analysis using the land-cover change detection [4].

Conclusions and Future Work

Remote sensing data analysis to identify Suspected Hazardous Area has attracted interest from both landmine operators and computer vision researchers as it provides information about the physical changes and circumstances of the land cover to help with the technical survey. So far, work has been limited to small scale studies: no general method to analysis several observations have been investigated. In this paper, we have presented a new framework for land-cover analysis to help identifying Suspected Hazardous Area. We analyse the existing publicly available image dataset (sentinel 2) to estimate the changes in vegetation and non-vegetation to identify different suspected areas. The amount, and the number of changes in the land cover during a period of two years were used to provide recommendations on areas qualified for clearance. Our method is capable of processing two years observations (10 sentinel-2 images), predicting the Suspected Hazardous Area in less than 15 seconds.

The Sentinel-2 data suffers from cloud and shadow occlusion which made us limit the classes of interest (to just vegetation and non-vegetation) and regions of interest (to areas with vegetation and non-vegetation cover of more than 90%). Hence, pre-processing (cloud and shadow correction) needs to be applied for more precise analysis. Further, segmenting and analysing sentinel-2 with resolution 20m

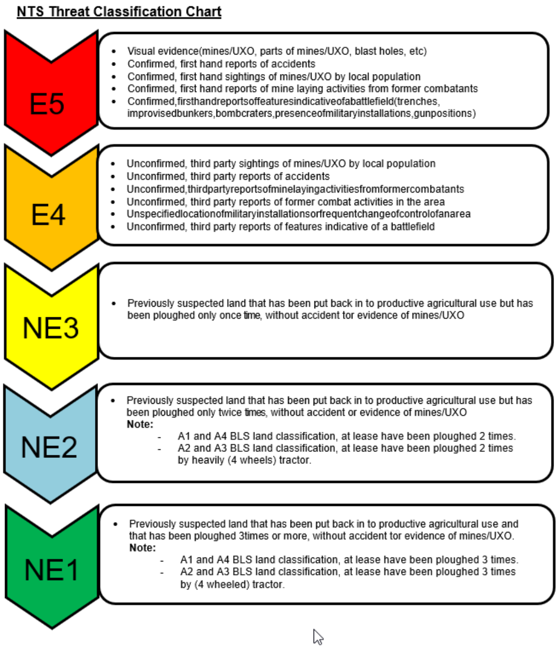

Figure 3: NTS Threat Classification Chart.

showed potential in detecting vegetation and non-vegetation areas as indicators of mines presence and absence. However, to create adequate land cover segmentations map and identify small objects, high-resolution images are needed.

Encouraged by our results, we plan to extend our work in a number of ways. Firstly, we wish to further support ongoing research into land cover change analysis by analysing other indicators such as changes in roads, buildings and water. We also wish to further evaluate our framework on remote sensing images with high resolution. Finally, we plan to extend our work by evaluating other image segmentation techniques such as UNet and Fully Convolutional Networks for accurate Semantic Segmentation.

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