Research on Remote Sensing Applications in Malta

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Abstract—**This paper aims to investigate the range of potential applications of remote sensing in Malta by using data readily and freely available from the Sentinel-2 Mission. Remote sensing is expected to fill in the gaps where conventional methods fail. Currently in Malta, remote sensing technologies has seen very limited applications. Prior the Sentinel Missions,remote sensing satellites available had band resolutions that where too big for any application viable on the tiny island of Malta. While drones and other applications such as satellite imagery from Google has seen a varied degree of success in being implemented, these methods lack the efficiency and advantages that bear the potential of exploring the full range of spatial, temporal and spectral properties remote sensing can offer.**

Index Terms—**MCAST, IICT, LaTeX, Project, Paper, Remote Sensing, Sentinel-2, Malta**

I. Introduction

Theme: From the humble beginnings of small satellite renaissance in the 1980's, technology has advanced to support an ever more accurate sensory reading and data provided. Prior to the recent economic boom Malta has experienced in the last few years of writing this paper, its governing people never found the need to seek the potential uses of remote sensing. Although Malta is a small island of roughly 316km², with the recent shift in the economy and a diversification of influence from foreign investments, there is an ever growing need of keeping up and expanding potential applications suitable to accurately monitor and surveil its territory.

Motivation: This Paper aims to provide an answer to the problem by providing evidence and use case scenarios of how remote sensing is of benefit to this island. Prior to the Sentinel Missions, readily available remote sensing satellites where not accurate and precise enough to be considered a viable option for Malta. With the launch of the Sentinel 2 mission, band resolutions now vary between 10m to 60m, making the 10m and 20m extremely enticing for future applications in Malta.

Aim: By making use of the spectral range Sentinel 2 has to offer, three different scenarios relevant to the local population, are to be presented and analysed as proof of concept.

Hypothesis: While Remote sensing has come a long way from its infancy, there are still some major hurdles one can face when monitoring a small island compared to vast lands and features commonly found elsewhere in the world. However, certain techniques and features can still be resourceful such as monitoring and assessing fires in forested areas, monitoring urban development and keeping tabs on water bodies in the Maltese islands.

Research questions: Is remote sensing a viable option for Malta? What are the applications of remote sensing best suited for Malta? Are these options reliable?

II. Literature Review

High Resolution land cover is an important key data required by policy makers around the world to better understand existing development while protecting natural resources in countries, cities and towns. Until now, Malta has used very limited methods in order to cater for this problem, with varying results of success, mostly being bound by the limitations of conventional methods.

Developed and operated by the European Space Agency, while manufactured by a team led by Airbus Defense And Space, the Sentinel-2 mission is a twin-satellite, Earth observing mission by the Copernicus Programme. It systematically gathers images at high spatial resolution (ranging from 10m to 60m), covering land and coastal waters, revisiting once every 10 days under the same viewing angles. Sentinel-2A and Sentinel 2-B operate together and are phased at 180 degrees from each other on the same orbit trajectory. This is done to achieve a tandem of 5-day revisits instead of 10 days. Both satellites carry a single multi-spectral instrument, MSI, with a range of 13 spectral bands ranging in the visible and near infrared(VNIR) to the short wave infrared spectral range(SWIR). Table I highlights and describes the bands found on Sentinel-2[1].

With the aid provided by the Sentinel-2 mission, it is now possible to prepare an accurate land cover map and present the study as a viable option in this regard.This was proven in a research conducted by Warsaw University of Life Sciences [1], Faculty of Civil and Environmental Engineering, where relevant data was gathered from Sentinel-2 by combining the Google Earth HR imagery and Open Street Map to present a visual representation of the results. Computed data showed an example of a high-resolution image of a built up area in a part of the city of Warsaw. This image was mapped by combining specific bands available from Sentinel-2 called NDVI, which is computed with [Formula 1].

[1]https://earth.esa.int/web/eoportal/satellite-missions/c-missions/copernicus-sentinel-2

TABLE I
SENTINEL-2 BANDS

Bands	Wavelength	Res	Description
B1	443nm	60m	Ultra blue (Coastal and Aerosol)
B2	490nm	10m	Blue
B3	560nm	10m	Green
B4	665nm	10m	Red
B5	705nm	20m	Visible and Near Infrared (VNIR)
B6	740nm	20m	Visible and Near Infrared (VNIR)
B7	783nm	20m	Visible and Near Infrared (VNIR)
B8	842nm	10m	Visible and Near Infrared (VNIR)
B8A	865nm	20m	Visible and Near Infrared (VNIR)
B9	940nm	60m	Short Wave Infrared (SWIR)
B10	1375nm	60m	Short Wave Infrared (SWIR)
B11	1610nm	20m	Short Wave Infrared (SWIR)
B12	2190nm	20m	Short Wave Infrared (SWIR)

$$NDVI = \frac{NIR(B8) - Red(B4)}{NIR(B8) + Red(B4)} \tag{1}$$

As mentioned in this research, the NDVI ratio was calculated by combining the visible wavelengths and near-infra-red wavelengths. Since clouds may impact the results of NDVI, a cloud mask was used to remove any clouds from the imagery.

However, it is cited that NDVI can be altered further to produce a cleared mapping of built-up areas. This was achieved by using the Normalized Difference Build-up Index or NDBI as it highlights urban areas with a higher reflectance in the shortwave-infrared spectral range (SWIR). This was computed by using Formula 2

$$NDBI = \frac{SWIR(B11) - NIR(B8)}{SWIR(B11) + NIR(B8)} \tag{2}$$

The calculated indices produced where found to be suitable for the detection of built-up areas. Both NDVI and NDBI proved to be a reliable source of information defining impervious surfaces in urban areas. However it was noted that NDVI (Fig1) was more accurate and matched up closer to the mapped area in Open Street Map than the same analysis produced by NDBI (Fig2). It was speculated that this is due to the fact that NDBI uses Band 11, which as a lower resolution of 20m compared to the 10m resolution Band 8 and Band 4 can offer.

NDVI can be modified even further, as shown in an article by the United Nations University Institute for the Advanced Study of Sustainability [2], where variants of NDVI were used in order to to map the severity of the burned area over Uttarakhand districts. The variants used in this study were the Differenced Normalized Burn Ratio (dNBR) and Relativized Burn Ratio (RBR) which were then calculated and cross referenced with active fire points. A cloud mask was used to remove any cloud pixels which might interfere with the NBR values computed at the end.

Sentinel-2 Bands 3, 8 and 12 were used to assess and map the severity of area that was burnt. This comes at a cost, since band 3 and 8 have a spatial resolution of 10m while band 12 has a spatial resolution of 20m, the data had to be resampled to 20m, hence losing the quality and detail of the 10m bands.

Fig. 1. Comparison of mapped impervious surface based on NDBI with Open street map

Fig. 2. Comparison of mapped impervious surface based on NDVI with Open street map.

After resampling the bands, NBR for post and pre fire event were computed and the burnt areas were in turn highlighted post-processing Formula 3.

$$dNBR = NBR_{prefire} - NBR_{postfire} \tag{3}$$

NBR index varies from -1 to +1, with healthy vegetation showing high reflectance in NIR regions while burnt areas show low reflectance. By contrast, areas that are burnt will show a higher reflectance in the SWIR region while health vegetation will show lower reflectance. Hence the higher the NBR value, the healthier the vegetation while a lower NBR Formula 4 value will indicate burnt areas.

$$NBR = \frac{NIR(B8) - SWIR(B12)}{NIR(B8) + SWIR(B12)} \tag{4}$$

It was also noted that water bodies will show up as false-positive since it is picked up in a similar spectral reflectance as burnt areas. Therefore prior computing NBR, water bodies have to be masked out both in pre and post fire events. To facilitate the process NDWI was used to highlight water bodies.

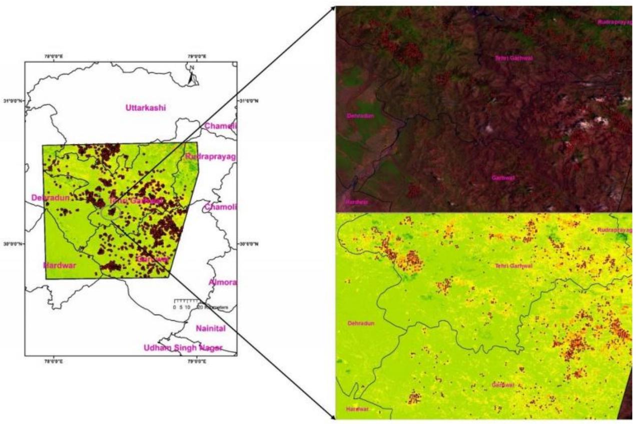

Fig. 3. Burn severity map and zoomed extent shows the active fire hotspots overlaid on the various severity levels.

Recent studies from the University of Debrecen in Hungary [3], determined that NDVI could also be used to map water bodies efficiently. In this research, the index was split into two sub indices, NDWI(Normalized Difference Water Index)Formula 5 and MNDWI (Modification of Normalized Difference Water Index)Formula 6. These indices are computed as follows:

$$NDWI = \frac{Green(B3) - NIR(B8)}{Green(B3) + NIR(B8)} \tag{5}$$

$$MNDWI = \frac{Green(B3) - SWIR(B11)}{Green(B3) + SWIR(B11)} \tag{6}$$

It was noted that all three indices more or less behaved similarly. However, some general discrepancy was found as NDVI and MNDWI was better at mapping visually water bodies and dense vegetation than NDWI and therefore was not appropriate to discriminate water itself. This was due to the fact that NDWI maps water pixels the same as forests and grasslands. What set MNDWI apart however was the fact that it enhanced water features such as ponds and rivers, which justified visual observations. Fig 4 is a comparison between NDVI, NDWI and MNDWI.

III. Research Methodology

This initial research will explore three different scenarios, by using the data gathered from Sentinel-2 MSI, available from the publicly available Copernicus database, of how remote-sensing can be a viable option for Malta. Each individual scenario chosen, have each a different time frame and study area which shall be individually discussed.

First, data was gathered from the Copernicus database by using the freely available SentinelApi. Data is retrieved from the servers by providing the platform name, its processing level and the accepted cloud coverage percentage for a given

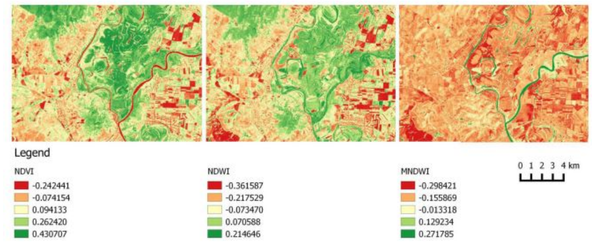

Fig. 4. NDVI, NDWI and MNDWI coverages of Bodrogköz (floodplain), Tokaj-hill (mountain), Tokaj-hegyalja (mountain) and a part of the Central-Zemplén (mountain).

sensing period. In all of the scenarios, the platform in use was Sentinel-2, with a Level-1C process and a varying cloud cover percentage, specific to the scenario.

Each study area was mapped using QGIS, an open-source geographic information application, which automatically assigns geospatial data into a geojson file. This geospatial data is used to focus on a specific area of the previously downloaded data from the Copernicus database.

For the next phase, a list of custom classes were made, using python and its open source libraries to compute and generate new material from the data fetched from the Copernicus database. Each of the scenarios will have an RGB image computed as a reference. This is done in bulk to save time by creating a class which goes through the contents of any given folder path. In this case, the contents would be the data gathered from the Copernicus Database for the specific scenario. The RGB images are then stored for the eventual evaluation.

Next will involve the computation of data, according to the specific scenario. All of these scenarios will only make use of the Sentinel-2 bands available.

The first scenario involves the monitoring of Hal Far through a span of 6 years, with data gathered between July and August once per year. Hal Far is one of the main industrial estates in Malta, situated in the southern extreme of the island. Monitoring of the area was done by creating another class which would handle the computation multiple band combinations in bulk of Hal Far throughout the 6 year span selected. All bands have been computed using the rasterio and numpy python libraries. The first band combination tested for this scenario was the short-wave infrared band combination Formula 7 which uses SWIR (B12), NIR (B8A), and red (B4). Combined, these bands will form darker shades of green, indicating denser vegetation, while brown will show an indication of bare soil and built-up areas.

$$ShortwaveIR = SWIR(B12), NIR(B8A), Red(B4) \tag{7}$$

The second band combination tested for this scenario was the Urban False Colour (UFC) (8) combination which makes use of two SWIR bands(B12 & B11) with red(B4). This combination tries to improve on the previous method by making urban features more pronounced, making changes to the landscape more easy to spot.

$$UFC = SWIR(B12), SWIR(B11), Red(B4) \quad (8)$$

The second scenario will focus on the Miżieb fire area which happened in the Summer of 2019. The Miżieb woodland was created in the early 1970's, located in the North of Malta. NBR or Normalized Burn Ratio is an index used to determine and highlight burnt areas in large fire zones. With the notion that healthy vegetation shows high reflectance in NIR while showing low reflectance in SWIR, it is easily assument that the very opposite is shown in areas devesated by fire. In order to map the burn severity, NIR (B8A) and SWIR (B12) are used, following Formula 9.

$$NBR = \frac{NIR(B8A) - SWIR(B12)}{NIR(B8A) + SWIR(B12)} \quad (9)$$

In this scenario, two data sets where collected, pre and post fire images. This is done so that the NBR can be calculated.

The third scenario will monitor the water flowing through the valley of Chadwick Lakes through a span of one year, with data gathered once a month. Chadwick Lakes are locally known as Wied il-Qlejgha and are a number of dams pouring into each other situated in the limits of Mtarfa and Rabat. For this scenario, NDWI or Normalized Difference Water Index Formula 10 was used to try and detect water objects and features in the valley area. This was tested by using the Green(B3) and NIR(B8A).

$$NDWI = \frac{Green(B3) - NIR(B8A)}{Green(B3) + NIR(B8)} \quad (10)$$

The second method for this scenario involves a modified version of the original NDWI which replaces the NIR band with a SWIR band as shown in Formula 6.

(Fig 5) represents the pipeline used throughout this research.

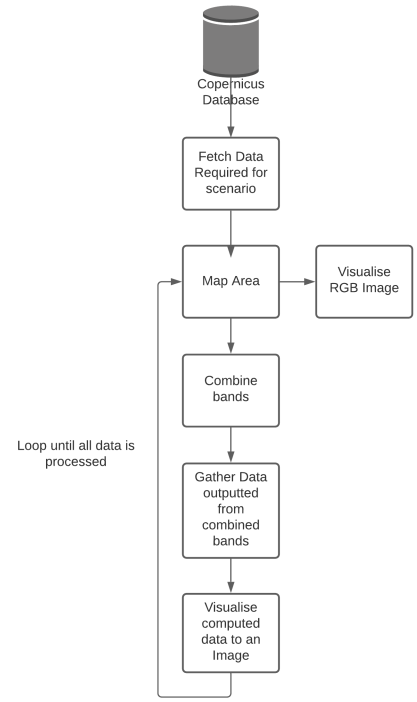

Fig. 5. Research Pipeline

IV. Findings & Discussion of Results

Since the main theme of discussion was about how sensible is remote sensing for Malta and in what way are they best suited for the small island, the current working model is just a mere prototype, showcasing the potential of the technology disposable to the common citizen. There are many ways of improving this concept with further research and work put into such projects, as shown in academic papers from around the world. Currently the working model provided works by going through ready made files and folders and will only output raw computed data with no real findings to talk about. However that was outside this research paper's scope and as such it will only focus on the results provided and the potential improvements and limitations challenging the idea.

Some key notes about the database available is that this database only holds data from 2015 onward, as the first satellite was launched at that very same year. Another key note to keep in mind is that Sentinel-2 uses an orbital trajectory which revisits the same place at the same angle every 10 days. However, since it is in a twin-satellite constellation, revisit times were halved, hence data can be collected every 5 days. On this basis, the scenarios chosen had to be limited to the data available from 2015 with an interval of an approximated 5 day interval. Since orbital imagery are at the mercy of cloud coverage, cloud masks were used to enable and identify cloud-free pixels in order to commence and gather relevant data. The three scenarios have been selected specifically for showcasing Sentinel-2's capabilities.

For the sake of simplicity and scope of this research paper, results shown are limited for sole reason of comparing and analysing the methods used in this working model. Therefore

The first scenario looked at the possibilities of monitoring urban sprawling using remote sensing. Both SWIR and Urban False Colour rendering provided enough potential for further improvement and data collection as shown in (Fig 6).

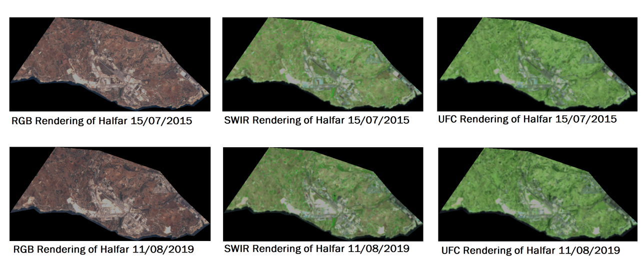

Fig. 6. RGB vs SWIR vs UrbanFalseColour

However it is to be noted that Urban False Colouring had a slight advantage on how it rendered data, which could mean less false positives and greater accuracy in the longer term.

Second Scenario looked at how remote sensing can be used as a way to assess fire damage in a given area using remote sensing. By processing the before and after fire data images, a clear indication of the damage can be done. This is proved by the RGB images in (fig 7 below of how misleading RGB images can be. Without context (A) and (C) do not look that much different. However with NBR, the pre-fire image (B) is easily recognisable from the post-fire image (D).

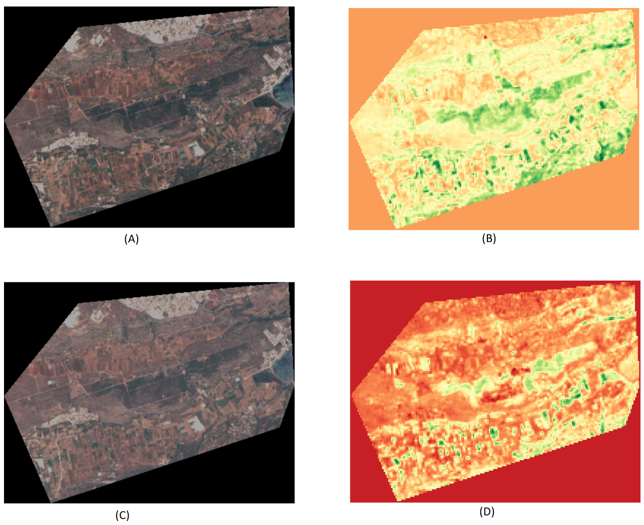

Fig. 7. A)Mizieb Pre Fire RGB B)Mizieb Pre Fire NBR C)Mizieb Post Fire RGB D)Mizieb Post Fire NBR

As an added bonus, dNBR Table II was calculated using Formula 3.

TABLE II
NBR

	Minimum NBR	Maximum NBR
Pre Fire	-0.2546	-0.2546
Post Fire	-0.0505	0.7062
dNBR	-0.2041	-0.9608

The third scenario looked into ways of detecting water objects. Although Chadwick Lakes are one of the largest naturally occurring flowing water bodies on the island, it was a challenge to map them using current remote sensing technologies. Both methods gave uninspiring results and mostly were not even reliable due to the fact that the water was too small to detect even with the 10m resolution bands. Data presented in [fig8] was from February 2020(A) and August 2020(B), representing rain season vs dry season.

As one can notice, both NDWI (C and D) and MNDWI (A and B) in fig 9 gave out different results, outlining different characteristics of the area, such as vegetation and soil conditions. However from the results shown, it is clear that with Sentinel-2 instruments, it is still not viable for monitoring water objects in Malta. It could be even argued that Malta is too dry for such applications.

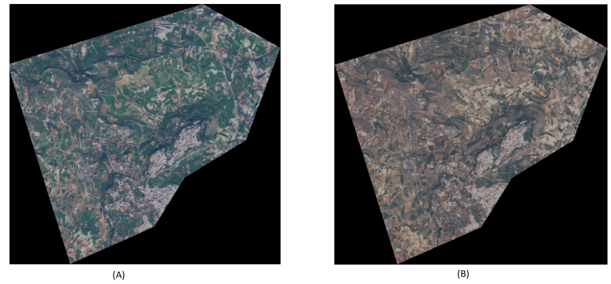

Fig. 8. RGB Render of Chadwick Lakes in February(A) and August(B)

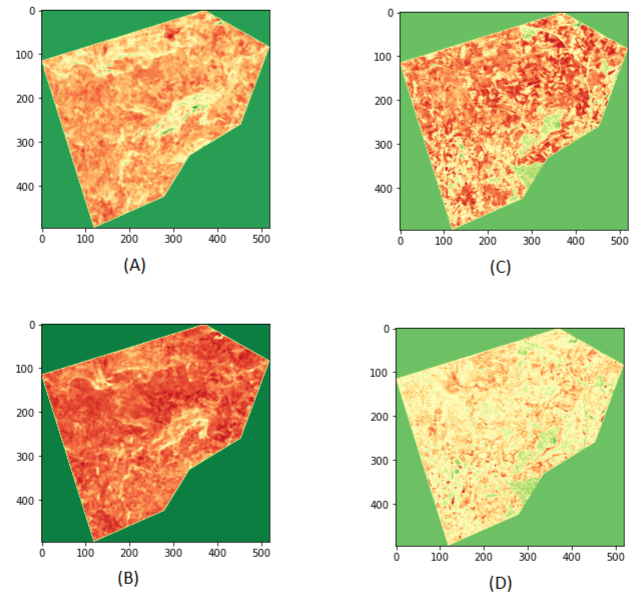

Fig. 9. NDWI (C February & D August) and MNDWI (A February and B August)

V. Conclusion

So in conclusion, this paper showed three potential scenarios in which remote sensing could be a viable solution instead of using conventional methods. All in all, two out three scenarios proved to have greater potential and could even be further improved to adhere to Malta's needs. Urban monitoring as it is could be automated and instructed to map and monitor urban sprawling around the country periodically, maybe keeping tabs on illegal constructions or to assess the impact of urbanisation on our country. Even assessing fire damages proved to be promising, even though there are very limited forested areas on the island as clearly shown in the scenario provided. However remote sensing lagged behind when it came to mapping water bodies. This could be due to a number of factors, such as an ever decrease in rainfall on the island, making it harder to detect or it could just be the case that as it stands, Malta does not have the capability of producing enough fresh water for Sentinel-2 to pick it up. Whatever the case, as it is, it is not a viable scenario to pursuit further. This research however does not look at all the capabilities of remote sensing. This paper only looked at three different scenarios from the data gathered off one satellite (Sentinel-2A and Sentinel-2B could be argued that they are the same satellite since they work in tandem and produce the same data), multiple satellites could be used together for a single scenario and get even more data than before. On top of that, this project relied heavily on image processing. Due to time limitation, not much effort went into allocating the processing of data to the GPU and instead relied on the processing power of the CPU which stretched the processing time required.

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