REMOTE SENSING APPLICATIONS BASED ON SATELLITE OPEN DATA (LANDSAT8 AND SENTINEL-2)

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Resumo: A Deteção Remota tem evoluído bastante com o lançamento de vários satélites de Observação da Terra, cada vez com melhores imagens em termos de resolução radiométrica, temporal, espacial e espectral. Apesar dos múltiplos operadores internacionais, que vão desde os EUA à Europa e Ásia, a política de distribuição gratuita de dados deve, no entanto, ser o principal catalisador do desenvolvimento de serviços de deteção remota, em particular com o lançamento do Landsat-8 e o Sentinel-2. O estudo efetuado teve por objetivo fazer uma análise dos novos produtos abertos, identificando potenciais novas aplicações de deteção remota, assim como avaliar a viabilidade de implementar uma cadeia de produção rápida de mapas temáticos, como por exemplo mapas de uso e ocupação de solo. Esta avaliação centrou-se em Portugal Continental. A análise de Landsat-8 foi realizada com duas estações do ano dado que existem imagens adquiridas desde 2013. A análise do Sentinel-2 foi efetuada comparativamente com os resultados do Landsat-8 dado que as primeiras imagens só deverão estar disponíveis em 2015 existindo apenas dados simulados de algumas regiões específicas. Os resultados da avaliação apontam para a viabilidade de obter mapas rápidos de ocupação de solo, com base na automatização do processo de produção e usando dados de treino pré-definidos. A qualidade final dos produtos poderá ainda ser analisada com maior detalhe. O Sentinel-2 deverá introduzir algumas melhorias relativamente ao Landsat-8, com mais bandas nos red-edge e infravermelhos, para além de uma maior resolução temporal (5 dias de revisita) e espacial (10 metros). Considerando que ambos os programas têm a visão de garantir continuidade das suas missões, a implementação de um serviço de cartografia rápida baseado em dados abertos poderá fazer sentido como sistema de apoio à geodecisão em domínios aplicacionais específicos.

Palavras-chave: Landsat-8, Sentinel-2, deteção remota, ocupação de solo, dados abertos

Abstract: Remote Sensing has greatly evolved with the launch of several Earth Observation satellites from multiple international operators from U.S. to Europe and Asia. More images are available with better temporal, spatial and spectral resolution. Despite increasing number of images, the free data policy should be one of the main catalyst for the development of remote sensing services in particular with Landsat and Sentinel programs. The analysis conducted aimed to make an assessment of the new EO open data from optical domain, identifying the potential new remote sensing services and also to investigate the feasibility to produce rapid mapping from Landsat-8 and Sentinel-2, such as land use and land cover maps. This assessment targets in Portugal Continental. The evaluation of Landsat8 data was performed using images from two seasons since this satellite is making acquisitions since 2013. The evaluation of Sentinel-2 was performed comparatively with Landsat-8 since for the time being data is not yet available and only simulated data exists from specific regions. The analysis of the results indicate that it is feasible to quickly obtain land cover maps, based on the automation of the production process and using pre-defined training data. The quality of products has to be analysed. Sentinel-2 will introduce some improvements, with more bands in the red edge and infrared frequency range, in addition to better spatial 10 meters resolution. Whereas both programs have the vision to ensure continuity of its missions, the implementation of a rapid mapping service based on open data can make sense to support geo-decision systems in specific application domains.

Keywords: Landsat-8, Sentinel-2, remote sensing, land cover, open data.

1. INTRODUCTION

Remote sensing has greatly evolved with the launch of several satellites for Earth Observation (EO), from multiple international operators from U.S. to Europe and Asia. More images are now available with better temporal, spatial, radiometric and spectral resolution.

However, the free policy of the data distribution should be one of the main catalyst for the development of remote sensing services, particularly Landsat and Sentinel programs. Other open-data government initiatives, such as *open-data.europa.eu*, *Data.gov* and *Data.gov.uk*, will also encourage the production of new services resulting from the fusion of EO data with these open datasets.

In addition, the data continuity strategy of these open data programs assure the sustainability of services developed by the researchers and industry. Landsat is now the longest continuous Earth imaging program, starting with the launch of Landsat-1 in 1972 through Landsat-8 in March 2013 and Sentinels program will also provide enhanced continuity to Envisat and Landsat data. Considering this panorama there is also a need to know the span of the new available products and which of them best fit the evolution of existing services.

1.1. Objectives

The paper aims to analyse the new open EO data from high-resolution optical domain and create awareness for its usage and application on other sectors rather than the traditional government sector. The analysis focus on Open Data from Landsat-8 and Sentinel-2 on the following two areas:

- Analysis of the new products, including spatial and spectral features, and identification of new potential applications
- Evaluation of the feasibility to produce rapid mapping from these open data sets (such as Land Cover mapping)

The analysis will not cover validation activities but only identify the potential indicators to be produced that will then require a proper validation.

2. COMPARISION ANALYSIS OF LANDSAT-8 AND SENTINEL-2

Landsat8 and Sentinel-2 will produce high-resolution optical imaging following their predecessors Landsat-7, Landsat-5 and Envisat. Therefore, this analysis not only compares Landsat-8 and Sentinel-2 but also Landsat-7 that was the latest reference on satellite's open data (see comparison table 1).

Table 1: Landsat-7, Landsat-8 and Sentinel-2 overview

	Launch	**Revisit Time (No. of Satellites)**	**Instrument (Spectral Bands)**	**Instrument (Thermal bands)**
Landsat-7	April, 1999	every 16 days (1 satellite)	ETM+ MS (6 bands)	ETM+ thermal (1 band)
Landsat-8	March, 2013	every 16 days (1 satellite)	OLI (8 bands)	TIRS (3 bands)
Sentinel-2	2014 (date to be confirmed)	every 5 days (2 satellites)	MSI (12 bands)	-

Landsat-8 and Sentinel-2 introduce new bands and provide narrowed bands. In addition, both Landsat8 and Sentinel-2 have radiometric quantization of 12-bits higher than the previous 8-bit from Landsat instruments and Sentinel-2 also provides better spatial resolution. A summary comparison is presented in Table 2.

Table 2: Comparison of Landsat and Sentinel-2 images specification

Parameter	Landsat-7 ETM+		Landsat-8 OLI		Sentinel-2 MSI	
Spectral bands	Band	Wavelength µm	Band	Wavelength µm	Band	Wavelength µm
	-		1 (coastal / aerosol)	0.43-0.45	B1 (blue)	0.43-0.45
	1 (blue)	0.45-0.52	2 (blue)	0.45–0.52	B2 (blue)	0.46–0.52
	2 (green)	0.52-0.60	3 (green)	0.52–0.60	B3 (green)	0.54–0.58
	3 (red)	0.63-0.69	4 (red)	0.63–0.68	B4 (red)	0.65-0.68
	-		-		B5 (red edge)	0.70-0.71
	-		-		B6 (red edge)	0.73-0.75
	4 (NIR)	0.77-0.90	-		B7 (red edge)	0.77-0.79
			-		B8 (NIR)	0.78-0.90
			5 (NIR)	0.84-0.88	B8a (NIR)	0.86-0.88
	-		-		B9 (water vapor)	0.93-0.95
	-		9 (cirrus)	1.36-1.39	B10 (cirrus)	1.37-1.39
	5 (SWIR1)	1.55-1.75	6 (SWIR1)	1.56-1.66	B11 (SWIR1)	1.57-1.66
	7 (SWIR2)	2.09-2.35	7 (SWIR2)	2.10-2.30	B12 (SWRIR2)	2.10-2.28
	8 (PAN)	0.52-0.90	8 (PAN)	0.50 - 0.68	-	
	L7 ETM+ thermal		**Landsat8 TIRS**		-	
	6 (TIR)	10.40-12.50	10 (TIR1)	10.3-11.3	-	
			11 (TIR2)	11.5-12.5	-	
GSD at nadir	30 m VNIR 15 m Pan 100 (30) m TIR		30 m VNIR 15 m Pan 100 (30) m TIR		10 m (B2, B3, B4, B8) 20 m (B5, B6, B7, B8a, B11, B12) 60 m (B1, B9, B10)	
Quantization	8 bit		12 bit		12 bit	
Onboard Calibration	Yes		Yes		Yes	
Off-axis viewing	Up to 7.5 deg off Nadir		Up to 7.5º off nadir		Up to 10.3º off nadir (w/o pointing)	
Orbit altitude	705 km		705 km		786 km	
Swath width	185km		185km		290km	

The target applications of Landsat-8 and Sentinel-2 are similar. Landsat-8 focus on natural processes (volcanic eruptions, glacial retreat, floods and forest fires) and human-induced processes such as urban expansion, crop irrigation and forest clear-cutting [Landsatnews, 2013]. Sentinel-2 preparatory activities are being supported by five European Space Agency (ESA) projects [Arino, 2013], each on a specific target sector, namely agriculture, wetlands, coastal zones, forest and food security. Each project included user consultation activities to gather product requirements from each user community.

3. POTENTIAL REMOTE SENSING APPLICATIONS FOR PORTUGAL

3.1. Image Data Procurement for the Area of Interest

The area of interest under analysis focuses on Continental Portugal.

Landsat-8 has images available since 2013 and thus two complete acquisitions from a dry and a wet season were made constituting the analysis baseline. Additional historical Landsat images were used and new acquisitions were made in some of the analysis.

Sentinel-2 is planned to be launched shortly and, since only simulated data is available from specific regions, no data has been used. The analysis of Sentinel-2 was performed comparing the specifications with Landsat-8 analysis results.

3.2. Product Mosaic Portugal 2013/2014

Two full mosaics of Portugal from Landsat-8 were acquired for Dry Season 2013 (from 20th of June 2013 to 23rd of August 2013) and Wet Season 2014 (from 20th November 2013 to 23rd January 2014).

The spectral bands available and the radiometric capability allow multiple RGB band combinations. The common combinations have been defined over the years and mapped to Lansat-8 bands by [Butler, 2013]. The results applied to Portugal Mosaic have an impressive visual effect as presented in figure 1 and 2.

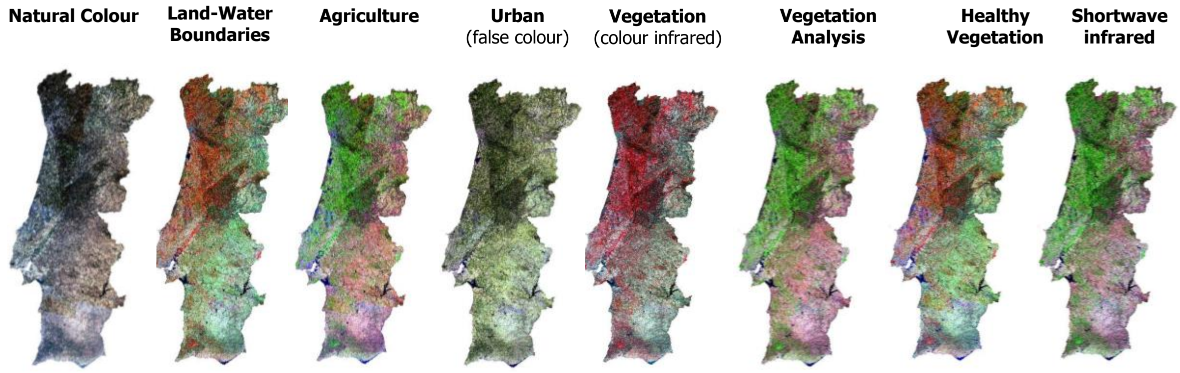


Figure 1- Portugal mosaic 2013 Dry Season band combinations.

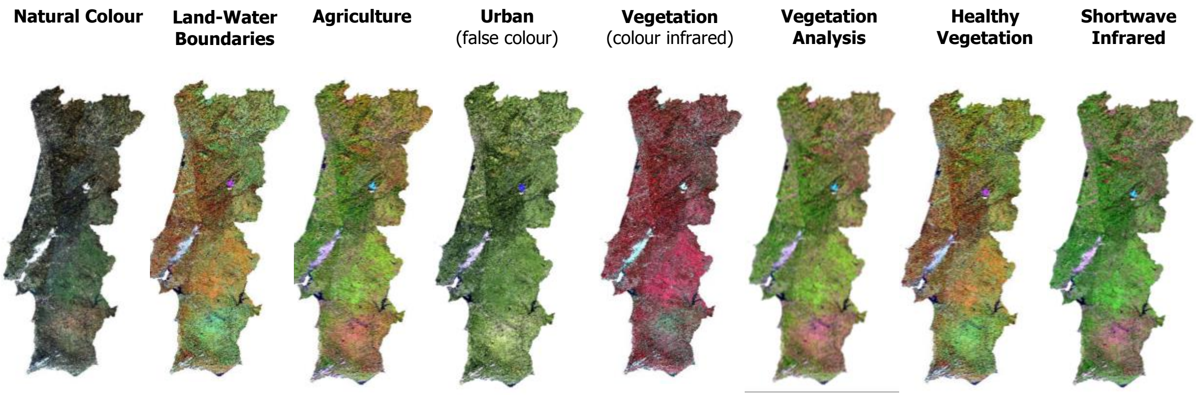


Figure 2- Portugal mosaic 2014 Wet Season band combinations.

3.3. Analysis of new spectral and spatial features

3.3.1. Land and Ocean

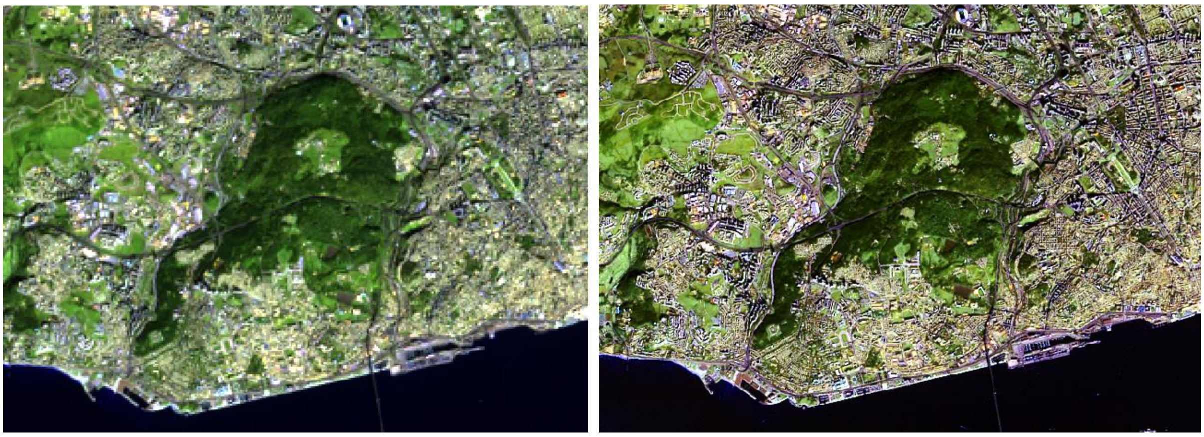
Although both satellites are more oriented to land than sea, Landsat-8 is providing an impressive picture of band combinations on coastal zones at regional scales mapping (Figure 3).

Figure 3 – Aveiro, Sagres and Alqueva band combinations from Portugal 2014 Wet Season.

Also the new band1, called coastal/aerosol band, will allow closer investigations of coastal waters and make imaging on shallow water.

3.3.2. Pan-sharpening

The pan-sharpening using panchromatic band is possible in Landsat-7 and it continues being supported in Landsat-8, allowing merging high-resolution panchromatic band of 15 meters and lower resolution multispectral imagery of 30 meters to create a single high-resolution colour image. An image detail of Lisbon is presented in figure 4.



Default 30 meters resolution | Pan sharpening to 15 meters resolution

Figure 4- Multispectral Urban band combination from Lisbon–Monsanto during 2014 Wet Season (2013-12-29).

The pan-sharpening with panchromatic band may be particularly useful to improve the classification accuracy, for instance for improving urban change detection rates (Forsythe, 2004).

3.4. Agriculture

Landsat is being used in agriculture for local and global decision-making, in particular North and South America, for monitoring and managing crops, forecasting crop production, managing water use and monitoring drought.

Landsat-8 continues to support these services. One of the services is computing vegetation indexes (such as Soil Adjusted Vegetation Index - SAVI or Normalized Difference Vegetation Index - NDVI) for making initial assessments of an area. These assessments allow highlighting possible problems derived by low vegetation areas cover and signs of possible stress (figure 5).

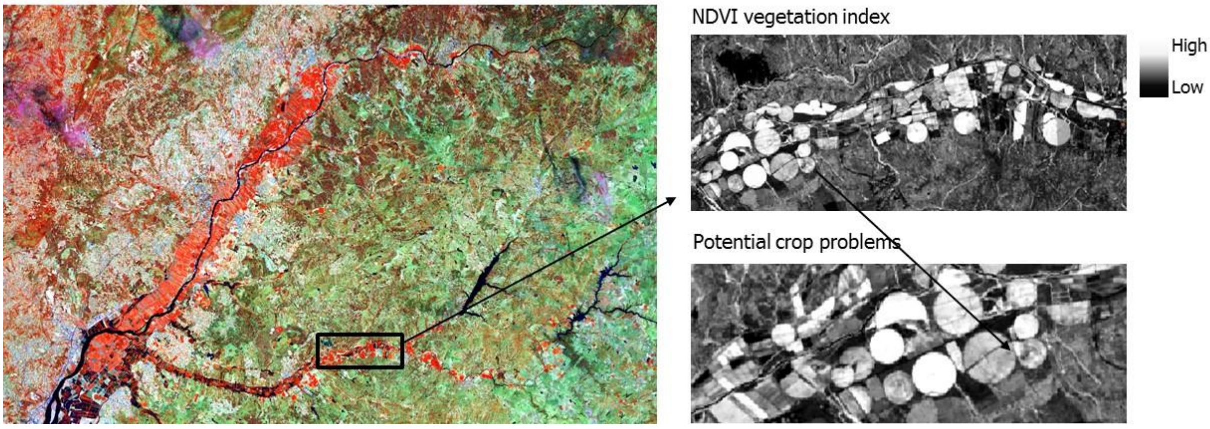


Figure 5- Irrigated fields of Tejo and Sorraia Valley using Agriculture band combination and NDVI calculation from 2013 Dry Season.

The possible problems can be then complemented with more detailed resolution images, such as Rapideye, or insitu visits.

3.5. Forest Clearcut

Forest clear cuts are visible in healthy vegetation combinations where bright blue areas represent recently clearcut areas as demonstrated on the assessment (see middle image from figure 6).

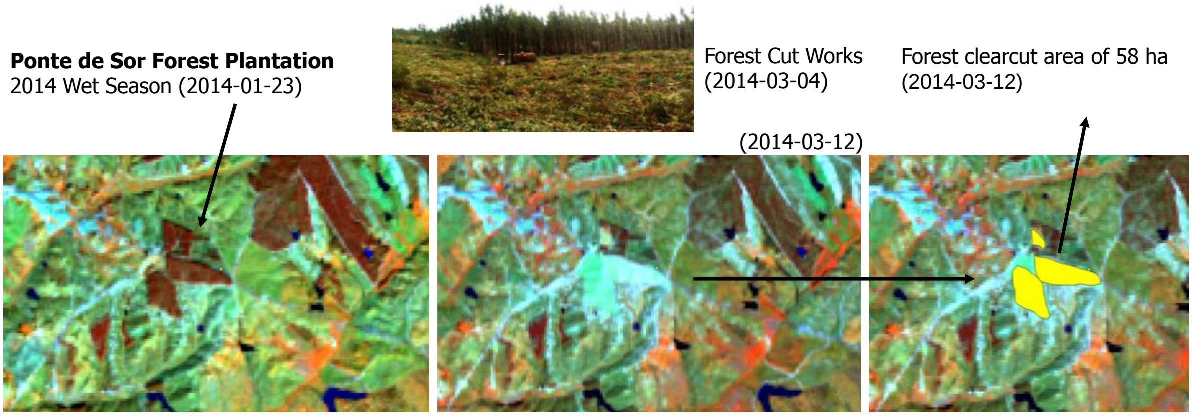


Figure 6- Clearcut at Ponte-de-Sor using healthy vegetation combination from 2014 Wet Season.

Change-detection techniques can be automated to make rapid detections not only of clearcuts but also burnt areas [Bastarrika, 2011].

3.6. Coastline changes

Due to both natural and anthropogenic causes the coastline, boundary between land and sea, keeps changing dynamically and continuously its shape and position over the time. Detection, extraction and monitoring the coastline is an important issue for Portugal where 85% of its GDP (Gross Domestic Product) is generated in the coastal zone in which more than 75% of its population lives there. Moreover, delineate automated procedures for detecting changes in coastline using free available remote sensing data sources and software is also an important issue nowadays.

Table 3: Tidal conditions during data acquisition

Images			Acq. Time	Tide max.	Tide min	Tide estim.
Date	Sensor	Im Numb.	GMT	GMT – H (m)	GMT – h (m)	h (m)
2000-06-24	ETM+	L7-2000	11:05:52	07:42 – 2.62	13:40 – 1.26	1.60
2002-06-30	ETM+	L7-2002	11:02:33	06:26 – 2.71	12:19 – 1.12	1.23
2013-06-20	OLI	L8-2013	11:16:02	12:01 – 3.11	05:41 – 0.94	1.05

Although the development of an automatic monitoring system is currently being developed by the authors, is worth to show how the multi-temporal and multi-resolution satellite images of Landsat archive can be used to detect changes in the coastline. In fact, using 3 satellites images whose characteristics are given in table 3 we can observe visually some significant coastline changes (see figure 7). First, an important accretion issue is revealed in Praia do Relógio beach (Area-1) between the years 2000 and 2013. Second, an erratic path can be observed in the pond ditch (Area-2).

Finally is worth to note that the planimetric position of the coastline derived from a satellite image depends on tidal height at the satellite overpass. Therefore, for monitoring the coastline with satellite images, they need to be acquired at similar tidal heights. In this study, the tidal heights for the 3 images at the time of satellite overpass are interpolated using a two-point cosine interpolator (table 3). Because the difference in tidal heights for the image differ by only 0.55m and take in consideration the pixel resolution (15m for pansharpenned images) and the slope for the beach areas we can conclude that the images are adequate for this analysis.

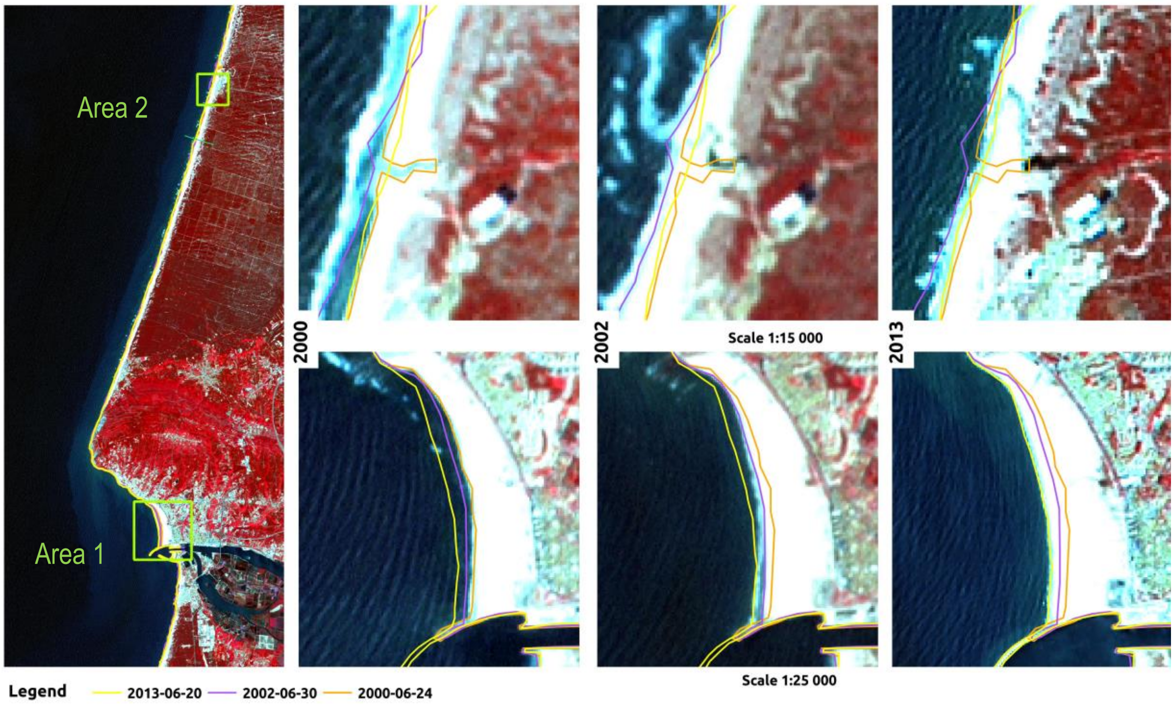


Figure 7- Detecting changes in coastline with Landsat-7 (archive) and Landsat-8 (2013 Dry Season).

3.7. Geoscience

The mineral composite index mapping is being performed by researchers using multispectral satellite images to support the identification of minerals, rocks and soils.

Landsat-7 has also been studied in articles such as [Dogan, 2009] by using ratios of spectral bands (Table 4). For example, iron oxide reflects more strongly in band 3 than in band 1, so that a Band-3/Band-1 ratio provides a mechanism for searching iron oxides. Other ferrous minerals can be found using a Band- 5/Band-4 ratio. Clay minerals reflect more strongly in band 5 than in band 7, so that a Band-5/Band-7 ratio is a means of separating them from other minerals.

Table 4: Mineral Indexes with Landsat

Feature	Band Ratio Landsat7	Band Ratio Landsat8
Clays	5/7	6/7
Ferrous oxides (goethite)	5/4	6/5
Iron oxide (hematite)	3/1	4/2

These ratios (Table 4) were applied to Portugal 2013 dry season and classified into 5 classes. The results are described in the figure 8.

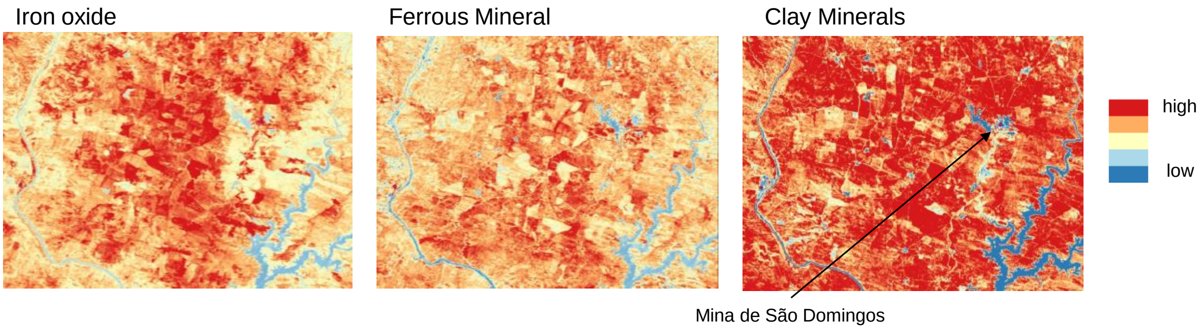


Figure 8- Mineral Index Mapping of São Domingos Mine during 2013 Dry Season.

Although the mineral index classification could have better results with more narrow spectral bands of Landsat-8, at this stage no conclusion can be achieved until scientific analysis are performed.

3.8. Land Cover

The analysis conducted aimed making a preliminary assessment of remote sensing services to quickly produce land use and land cover (LULC) maps from Landsat-8 open data. This assessment used existing open source processing chains from Landsat-5 and 7 (refer to figure 8). Acquisitions from dry and wet season are used by these processing chains in order to distinguish between rainfed and irrigated agriculture.

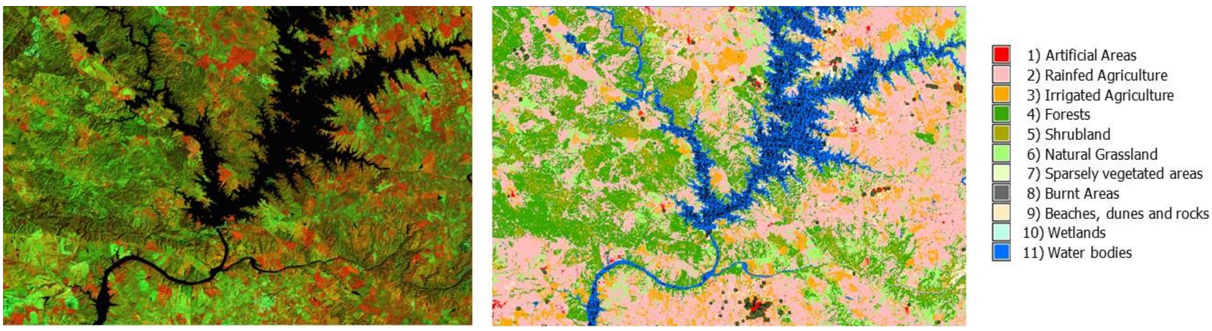


Figure 8 – Alqueva LULC exercise using supervised classification from Landsat-5/2011

The analysis results indicate that some adaption effort is needed to support the new features of Landsat-8 (e.g. 16bit images) but it is feasible to produce rapid land cover mapping based on an automated process and using pre-defined training data.

The quality of products has to be analysed but according to classification tests, conducted by Curtis Woodcock of Boston University, the classification results were 19.5 percent more accurate than those developed from Landsat-7 [Landsat News, 2014].

4. CONCLUSIONS

4.1. Applications in multiple sectors

The demonstration for Portugal used two open datasets from Landsat-8 providing valuable information to produce different information. These baseline datasets, complemented with historical or new acquisitions, were used for making different spatial, spectral, temporal analysis. The analysis results demonstrated that the two baseline datasets per year is technically feasible to acquire and to produce indicators that complemented with a validation process can be very useful to support geo-decisions in multiple sectors (see figure 9).

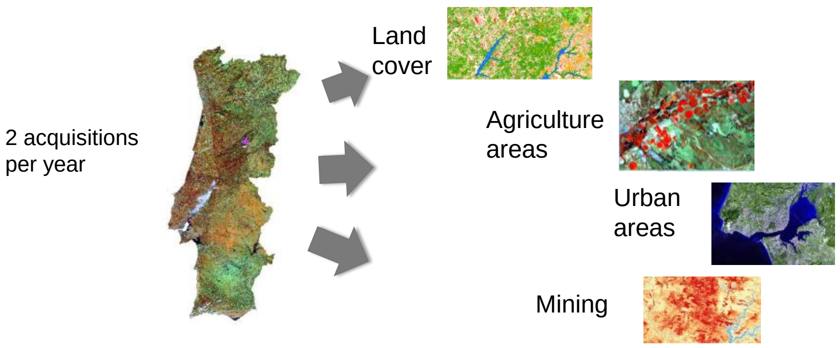


Figure 9 – Applications in multiple sectors to support geo-decisions.

At a first level the high resolution Landsat-like imagery is still driven by government entities since its specification is more adequate to public needs. But at a second level the same data can be exploited by other sectors, such as industry and energy that are more demanding in terms of spatial and temporal resolution but could be complemented with other sources (e.g. aerial data, very high resolution data).

The implementation of geo-decisions processes on each sector will required specific validations. The validation of thematic Landsat process chains has been developed over the years with various programs but it has not been the subject of this analysis. Nevertheless, the implementation of Landsat-8 validation processing with insitu and auxiliary data is possible and, in some cases, can be performed automatically.

Considering the Sentinel-2 specification, and based on the Landsat-8 results, it is expectable that Sentinel-2 will bring significant improvements to the users of open data. The three major improvements are: more narrow bands in the red edge and infrared frequency range, better spatial resolution (10meters) and better temporal resolution (5 days revisit). The better temporal resolution theoretically allows 3 times more acquisitions than Landsat that will allow to acquire more successfully baselines and/or perform more monitoring detections. The spatial resolution of 10 meters will get closer to the current commercial satellites while the narrow bands in the red-edge and infrared may provide better vegetation monitoring services. These three features enhancements makes Sentinel-2 more promising for usage in agriculture and forest sectors.

4.2. Rapid Prototyping feasibility

In addition of having good sensors, the satellite success depends on the existence of good tools and support of developers/providers to produce the final user applications.

Landsat8 has inherit most of the formats, techniques and applications from its predecessors with some features enhancements. Commercial and open source tools are gradually supporting the new features, in particular the 16 bits data images derived from 12-bits sensors. Commercial tools reacted more rapidly, such as ArcGIS (support Landsat-8 since v10.2, September 2013) and PCI Geomatics. Open Source tools support were not so straight forward, some difficulties were encountered in this work. Nevertheless, the automation is possible with OTB, QGIS and GRASS to produce rapid mapping.

With respect to Sentinel-2, ESA program is now developing a specific toolbox based on BEAM open-source toolbox to support S2 product analysis and processing.

As a final remark, it is the authors believe that open data and open source tools will create a wider development community that may boom the development of new applications and solutions.

5. OTHER INFORMATION

Bluecover Technologies is a start-up organization that is evaluating the market opportunities to produce a rapid mapping service from Open Datasets such as Landsat-8 and Sentinel-2.

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