EFFECTS OF GEOSPATIAL DATA SOURCES ON THE IDENTIFICATION AND CHARACTERIZATION OF BURNT AREAS IN PORTUGAL

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ABSTRACT:

The work presented in this paper compares the burnt areas in continental Portugal in 2017 and 2018 mapped by three initiatives, namely the Portuguese Institute of Nature and Forests Conservation (ICNF), the Corine Land Cover (CLC) inventory of the Copernicus programme and the European Forest Fire Information System (EFFIS). Then, the Land Use Land Cover (LULC) classes affected by the 2017 burnt areas mapped by ICNF are analysed considering CLC 2018 and the 2018 LULC map produced by the Portuguese National Mapping Agency (Direção Geral do Território) - "Carta de Ocupação do Solo" (COS 2018). To enable a comparison between the classes of both LULC products, a nomenclature was selected and both CLC 2018 and COS 2018 were mapped into the chosen classes. The comparison of the burnt area's extent showed that there are large differences in both area and levels of detail between the analysed data sources. The results regarding the LULC classes affected by the 2017 fires mapped by ICNF show large differences in terms of burnt area in each class as well as the proportion of the burnt areas associated to the classes. This analysis shows that very different results may be reached if different products are used, and therefore a large level of uncertainty is associated with the conclusions achieved with these products.

1. INTRODUCTION

Fire is considered to be one of the main factors regarding forest change globally (van der Werf *et al*., 2006), and one of the main drivers of desertification (Vieira *et al*., 2015). The identification and characterization of burnt areas within a given time interval and location is central for several tasks, such as the accounting of greenhouse emissions (Prosperi *et al*., 2020), local, regional and international reporting frameworks which may guide future policy (Bowman *et al*., 2017) and its impact on, for example, soil quality (Kutiel and Inbar, 1993). Hence, both national and international institutions aim at identifying the burnt areas of a given region to be then used as input in these tasks.

Portugal, a Mediterranean country, with a forest coverage close to 38% (as in Corine Land Cover 2018 – CLC 2018), is greatly affected by seasonal forest fires where, for example, between January and October 2020 a total of 9394 fires were recorded and 65,887 ha burnt (ICNF, 2020). In Portugal, burnt area assessment is often performed with in-situ analysis (Decree-Law 124/2006, 28th June), which may then be completed recurring to remote sensing techniques using satellite imagery (ICNF, 2020). Parallel to the Portuguese efforts to report on the burnt area of a given year, the Copernicus programme also includes the burnt areas as one of the classes in the Corine Land Cover product. Moreover, the European Forest Fire Information System (EFFIS), which is a modular system consisting of web-based modules, data processing and spatial databases that process and store forest fire information regarding most of the European countries (San-Miguel-Ayanz *et al*., 2012), also maps burnt areas globally generating a burnt area map every 10 days for the whole globe. Remote sensing and geographic information systems are used by EFFIS to forecast fire danger, early detection of forest fires and damage assessment related to these same fires. However, the mapping of such areas, namely using remote sensing techniques, is still a research topic where several researchers have proposed different mapping methodologies (Grégoire *et al*., 2003; Simon, 2004; Verhegghen *et al*., 2016).

Several burnt area products are available for Portugal, from national or international agencies. Given that such products are often used as input for policy making, climate change models and forest fire mitigation; it is critical to understand how the use of a given burnt area product may affect the outcome of any decision making considering such data. This is especially relevant given that not only the total burnt areas might differ but also because the burnt area spatial extent of each of the datasets may be different. Consequently, the land cover affected by a given fire may differ from dataset to dataset, affecting, for example, the estimation of the burnt biomass.

The aim of this paper is to assess the extent to which the use of different data sources regarding burnt areas and Land Use Land Cover (LULC) data may influence the analysis performed for the characterization of the burnt areas. Specifically, the yearly burnt maps for Portugal, produced by the Portuguese Institute of Nature and Forests Conservation (Instituto de Conservação da Natureza e das Florestas- ICNF) are compared with other sources of burnt areas for the years 2017 and 2018, such as the EFFIS and the "Burnt Areas" class of Corine Land Cover (CLC). Moreover, it is assessed how the consideration of each of these maps influence the quantification of burnt area per LULC class for Portugal, and how the characterization of the burnt areas changes when considering two LULC maps, namely, the CLC 2018 and the Portuguese LULC map. The results show that the areas of the burnt areas are very different when comparing CLC 2018 data

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and the ICNF data, but also the characterization of the burnt areas identified by ICNF is very different when using both LULC products.

2. DATA

Two types of data were used for this analysis: 1) the LULC data to characterize the burnt areas and 2) the mapping of burnt areas in continental Portugal.

The LULC information was extracted from the CLC 2018 and the 2018 Portuguese "Carta de Ocupação do Solo" (COS 2018).

The CLC is a pan-European land cover product produced by the Land Monitoring Services of Copernicus European Earth observation programme (Buettner, 2014). CLC is available for the years 1990, 2000, 2006, 2012 and 2018 and the 2018 version has 44 LULC classes at the most detailed level (level 3). Table 1 shows the level 1 and level 2 classes of the nomenclature of CLC 2018. The Minimum Mapping Unit (MMU) of CLC is 25 ha for polygons and the minimum width for linear features is 100 m. The product has a positional accuracy of 100 m and the overall thematic accuracy is greater than 85%.

Level 1	Level 2
1. Artificial surfaces	1.1 Urban Fabric 1.2 Industrial, commercial and transport units 1.3 Mine, dump and construction sites 1.4 Artificial, non-agricultural vegetated areas
2. Agricultural areas	2.1 Arable land 2.2 Permanent crops 2.3 Pastures 2.4 Heterogeneous agricultural areas
3. Forest and semi natural areas	3.1 Forests 3.2 Scrub and/or herbaceous vegetation associations 3.3 Open spaces with little or no vegetation
4. Wetlands	4.1 Inland wetlands 4.2 Maritime wetlands
5. Water bodies	5.1 Inland waters 5.2 Marine waters

Table 1. CLC 2018 level 1 and level 2 nomenclature.

COS 2018 is produced by the portuguese national mapping agency (Direção Geral do Território – DGT). The nomenclature of COS 2018 for levels 1 and 2 is shown in Table 2. The MMU of COS is 1 ha for polygons. The minimum distance between lines and the smallest polygon width is 20 m. The overall thematic accuracy of COS 2018 is still under assessment. However, the accuracy of the previous products was reported to be greater than 85%, and for level 1, the accuracy was reported to be 97% for COS 2010 and 96% for COS 2015 (Caetano *et al.* 2018).

Three data sets with the burnt areas were analysed, namely:

1. CLC 2018, where the class "Burnt areas" is class 3.3.4 of level 3. CLC 2018 burnt areas consist of burnt natural woody plants and natural herbaceous plants, and bare soil or rock covered with ash.
2. The annual mapping of burnt areas generated by ICNF, as mentioned in section 1, for the years 2017 and 2018. This is based on field inspections by security forces and municipalities, which is then completed with classified satellite imagery. This is mapped regardless of the LULC present before the fire.
3. The burnt areas mapped by EFFIS for 2017 and 2018. Burnt areas are extracted from satellite imagery collected with the Advanced Wide Field Sensor. The final resolution of the product is 250m. This product does not consider both agricultural and urban burnt areas.

Level 1	Level 2
1. Artificial surfaces	1.1 Urban Fabric 1.2 Industrial, commercial and agriculture installations 1.3 Infrastructures 1.4 Transports 1.5 Mine, dump and construction sites 1.6 Equipment 1.7 Parks and gardens
2. Agriculture	2.1 Arable land 2.2 Permanent crops 2.3 Heterogeneous agricultural areas 2.4 Protected agricultural and plant nurseries
3. Pastures and semi natural areas	3.1 Forests 3.2 Scrub and/or herbaceous vegetation associations 3.3 Open spaces with little or no vegetation
4. Agroforestry surfaces	4.1 Agroforestry surfaces
5. Forests	5.1 Forests
6. Scrubs	6.1 Scrubs
7. Open spaces with little or no vegetation	7.1 Open spaces with little or no vegetation
8. Wetlands	8.1 Wetlands
9. Water bodies	9.1 Inland waters 9.2 Aquiculture 9.3 Transition and costal water areas

Table 2. COS 2018 level 1 and level 2 nomenclature.

3. METHODOLOGY

The methodology used for this analysis includes two phases. The first phase aims to select the burnt areas that will be analysed and the second phase the identification of the LULC classes in the burnt areas, which may be used to characterize the areas affected by the fires.

3.1 Choice of the burnt areas for analysis

To identify which sources of data about burnt areas are comparable, an analysis was made to determine the correspondence between the CLC 2018 data with the other two sources of burnt areas. Figure 1 shows the burnt areas extracted from CLC 2018, from ICNF 2017, ICNF 2018 and EFFIS 2017. The comparison of the burnt areas between CLC 2018 and the data extracted from ICNF confirms that the burnt areas shown in CLC 2018 correspond to the burnt areas in 2017 and not in 2018. This is also supported by the data shown in Table 3, which shows

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the area of the burnt regions in CLC 2018, ICNF 2017 and 2018 data and the intersection between CLC 2018 and the two datasets from ICNF. Most of the burnt areas mapped in CLC 2018 are also included in the ICNF 2017 data and there is almost no overlap of those with the ICNF 2018 burnt areas. Therefore, for the remaining analysis, the burnt areas identified in CLC 2018 and ICNF 2017 were used. Figure 1 also shows the burnt areas available in EFFIS. It is clear that these regions have much less detail than the other two data sets, so no further analysis was made using the EFFIS areas.

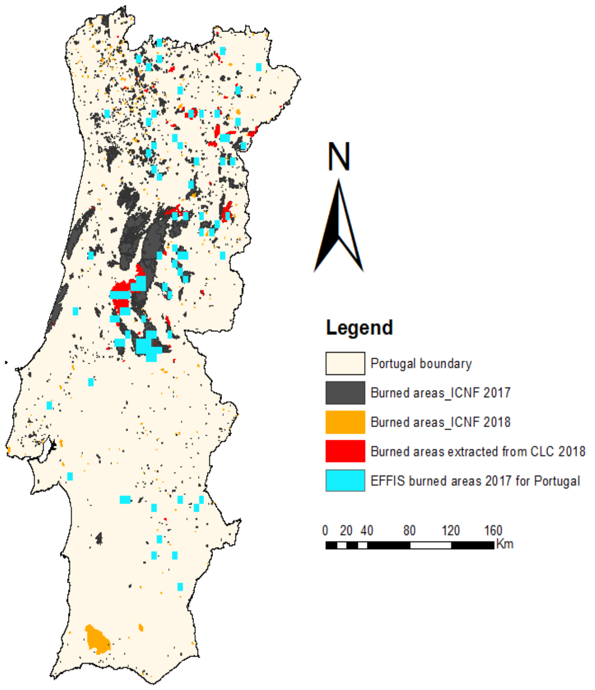

Figure 1. Burnt areas in Portugal available in CLC 2018, the mapping of burnt areas for 2017 and 2018 by ICNF and EFFIS 2017.

Data	Total area (ha)
Burnt areas in CLC 2018	69,666
Burnt areas in ICNF 2017	557,743
Burnt areas in ICNF 2018	40,279
Intersection between burnt areas in CLC 2018 and ICNF 2017	64,854
Intersection between burnt areas in CLC 2018 and ICNF 2018	35

Table 3. Area of the burnt areas according to the different data sources and their intersection.

3.2 Analysis of the LULC classes in the burnt areas

To assess the LULC classes that were affected by the burnt areas when using CLC 2018 and COS 2018, and be able to compare the results obtained with both data sets, it was necessary to define a nomenclature that could be mapped to classes of both products. Table 4 shows the selected classes and their mapping into the CLC 2018 and COS 2018 classes. The mapping with CLC 2018 considers in some cases level 1 classes and in other cases level 2 classes, while the mapping with COS 2018 considers only level 1 classes.

Code	Classes	CLC 2018 class code	COS 2018 class code
1	Artificial Surfaces	1	1
2	Agricultural areas	2.1 / 2.2 / 2.4	2 / 4
3	Pastures	2.3	3
4	Forest	3.1	5
5	Scrub	3.2	6
6	Open Spaces with little or no vegetation	3.3	7
7	Wetlands	4	8
8	Water bodies	5	9

Table 4. Considered classes and their mapping to the CLC 2018 and COS 2018 nomenclatures.

To identify the LULC classes that were affected by the fires, the following analyses were made:

1. The intersection of the LULC maps obtained with the CLC 2018 and COS 2018 with the ICNF 2017 burnt areas was made.
2. The regions identified in CLC 2018 as burnt do not have a pre-fire LULC class available. Therefore, to assess how these areas might influence the comparison of the areas affected by fires in each class considering both LULC data sources, the pre-fire class of the burnt areas in CLC 2018 was estimated with COS 2018 data, by intersecting this map with the CLC 2018 burnt areas.

4. RESULTS

Figure 2 and Figure 3 show the LULC maps resulting from the conversion of, respectively, COS 2018 and CLC 2018 into the considered classes, shown in Table 4.

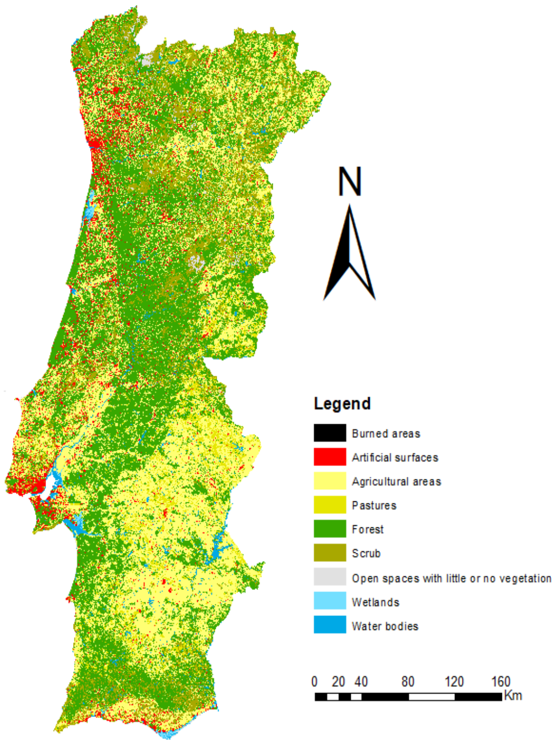

Figure 2. LULC map obtained from COS 2018.

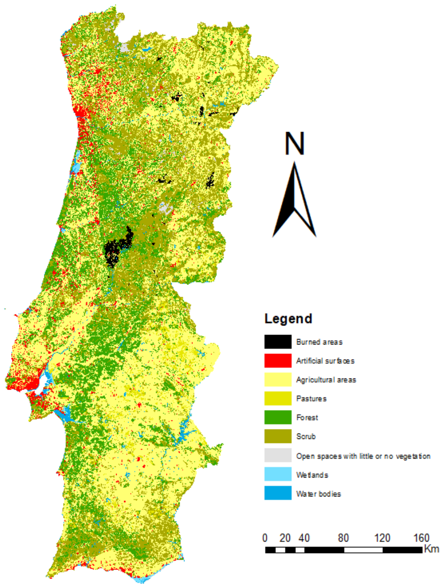

Figure 3. LULC map obtained from CLC 2018.

Table 5 shows the areas, in ha per class, of the LULC classes existing in the burnt areas mapped in the ICNF 2017 dataset, as well as the difference between the area obtained per class from each product, both in ha and percentage relative to the area obtained with CLC 2018 data. The results show that the differences of area obtained from both products is very large for some classes. The largest absolute difference obtained was for the class Forest, with a difference between the two datasets of 202,827 ha, which corresponds to an increase of 130% from CLC 2018 to COS 2018. The class with the second largest difference is the class Scrub, with an absolute value of 121,672 ha, which corresponds to a decrease of 50% from CLC 2018 to COS 2018. Two other classes show smaller absolute differences, as these classes occupy smaller regions, but even larger differences in percentage. The class Pastures shows a difference of 318% when comparing the data obtained from CLC 2018 and COS 2018, while the class Artificial Surfaces shows a difference of 148%, corresponding to an increase of 5,081 ha between the artificial areas mapped when using CLC 2018 and COS 2018. This shows that the difference between the areas mapped when using these datasets is larger than the whole artificial area mapped by CLC 2018 in the region under analysis.

Code	Classes	Area in ICNF 2017 burnt areas (ha)		Difference	
		CLC 2018	COS 2018	ha	% relative to CLC 2018
0	Burnt areas	64,854	0	-64,854	-100
1	Artificial Surfaces	3,442	8,523	5,081	148
2	Agricultural areas	84,272	56,888	-27,384	-32
3	Pastures	1,453	6,070	4,617	318
4	Forest	156,383	359,210	202,827	130
5	Scrub	242,004	120,332	-121,672	-50
6	Open Spaces with little or no vegetation	4,058	5,072	1,014	25
7	Wetlands	81	94	13	16
8	Water bodies	1,194	1,552	358	30
Sum		557,741	557,741		

Table 5. Considered classes and their mapping to the CLC 2018 and COS 2018 nomenclatures.

Figure 4 shows the percentage of the LULC classes included in the 2017 burnt areas mapped by ICNF, considering the classes extracted from CLC 2018 and from COS 2018. As in CLC 2018 for the areas classified as burnt there is no information about the existing class prior to the fire, to determine to what extent that may influence the percentage comparison shown in Figure 4, the COS 2018 LULC classes were assigned to the CLC 2018 burnt areas. The percentage of classes affected by the fires was then computed and are shown in Figure 4 with in middle (striped) columns. The results show that when using COS 2018 the burnt area mapped by ICNF in 2017 was mainly occupied by Forest (64.4%), while the second most affect LULC class was Scrub (21.6%). However, when CLC 2018 is used as the source of LULC classes, these proportions change drastically. Most of the burnt area was Scrub (43.4% if the burnt areas mapped by CLC 2018 are not considered and 45.9% if the COS 2018 classes are considered to occupy the burnt areas prior to the fires), and the second most affect class was Forest, with a percentage of only 28.0% if the burnt areas are not considered and 36.6% if the COS 2018 classes in these regions are accounted for.

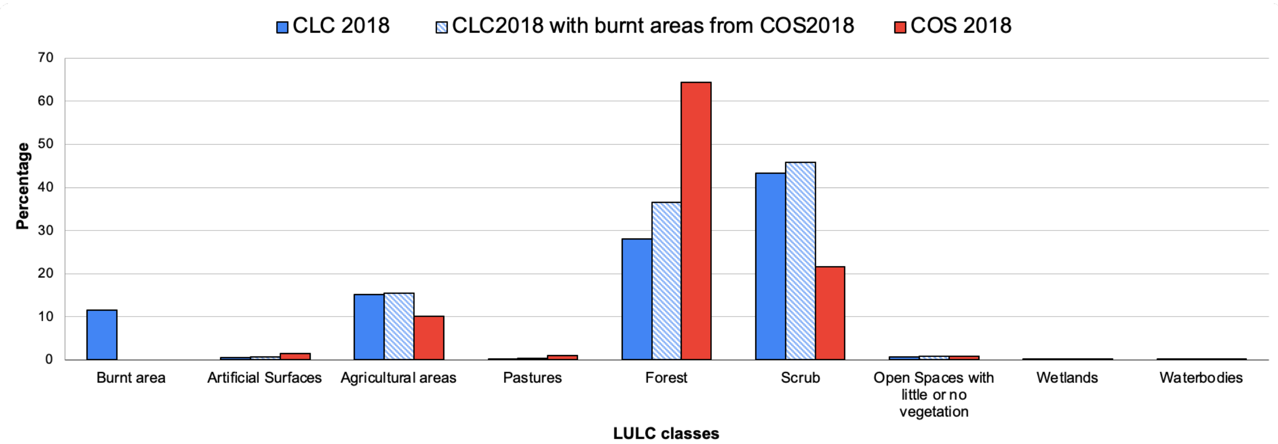

Figure 4. Percentage of the classes area in the burnt areas identified by ICNF in 2017 when considering the LULC data from 1) CLC 2018, 2) CLC 2018 retrieving the COS 2018 classes for the regions classified in CLC 2018 as burnt areas, and 3) COS 2018.

Figure 5 and Figure 6 show a detail of the LULC classes inside the 2017 ICNF burnt areas when using, respectively, CLC 2018 and COS 2018. The differences in the LULC products are visible both in terms of level of detail (due to the different MMU of the products), but also in terms of confusion in some regions regarding the classification as Forest or Scrub. Another aspect that can be pointed out is the difference between the urban areas (Artificial surfaces) affected but the fires when comparing the data extracted from both products. Many artificialized regions can be seen in COS 2018 that are absent from CLC 2018. This may also be due to the smaller size of these regions and the MMU of the products, but this difference has a large impact of the assessment of the artificial regions affected, which occupy an area three times larger in the burnt area when using COS 2018.

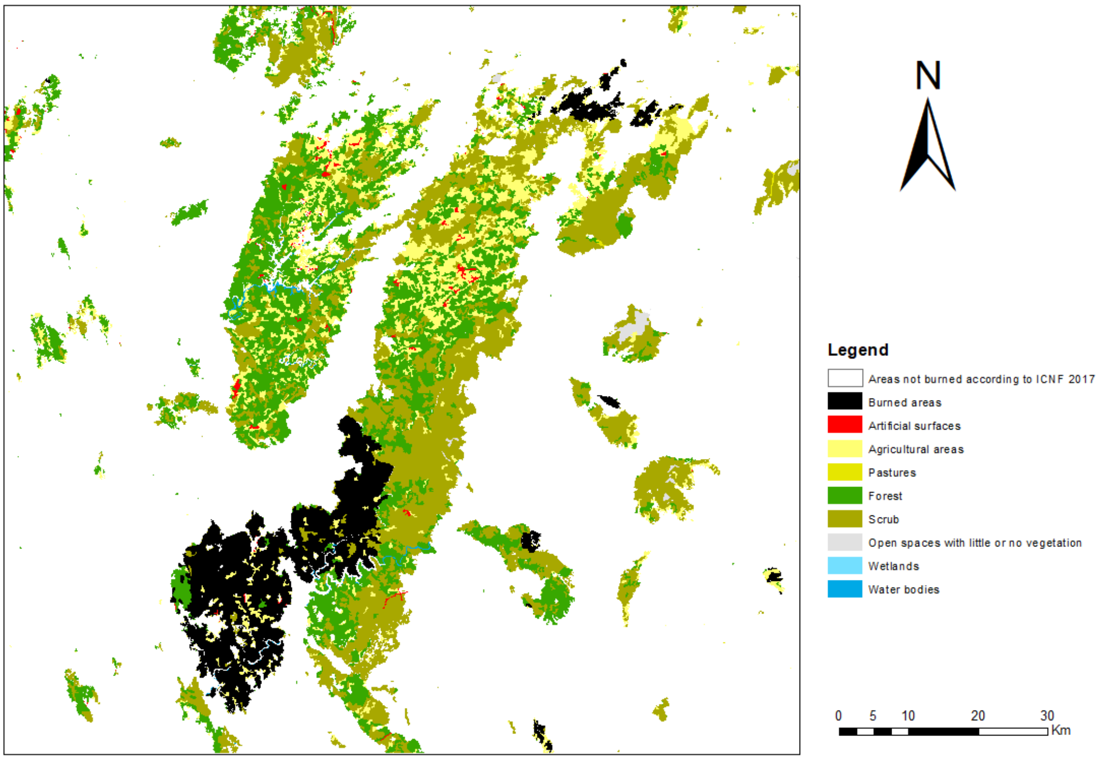

Figure 5. Example of the classes under analysis extracted from CLC 2018 for the ICNF burnt areas of 2017.

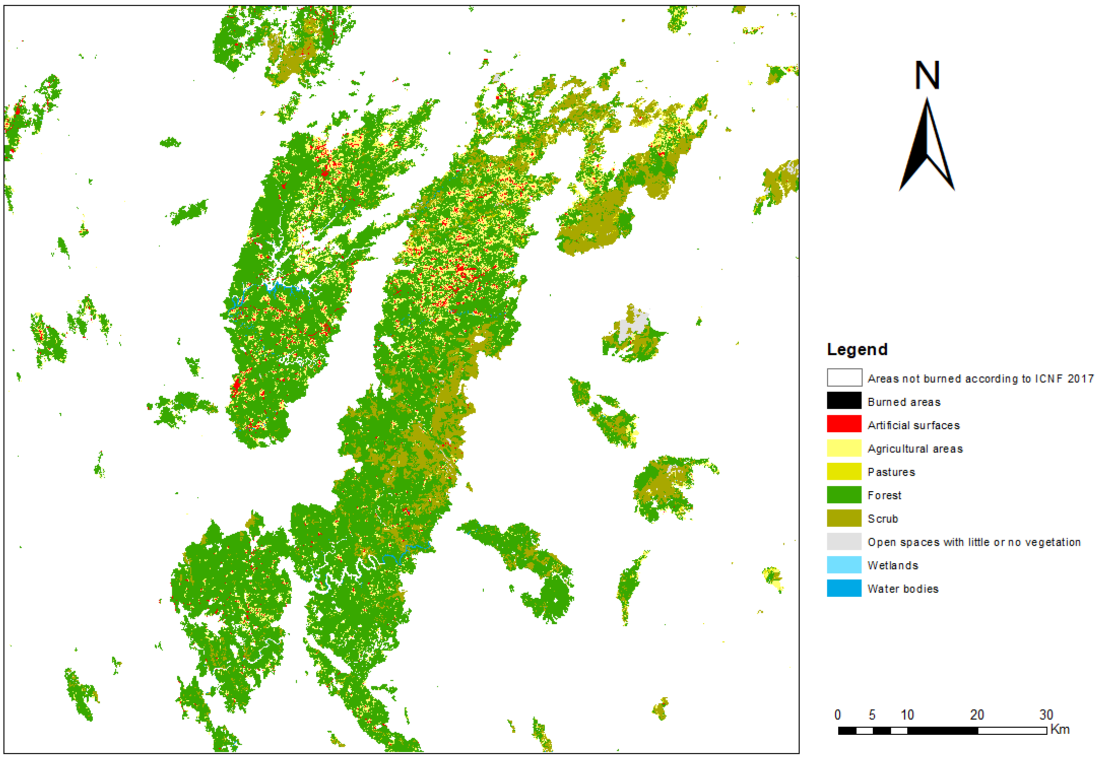

Figure 6. Example of the classes under analysis extracted from COS 2018 for the ICNF burnt areas of 2017.

5. CONCLUSIONS

The analysis presented in this paper shows the divergence between three datasets that report burnt areas for the years 2017 and 2018 in continental Portugal, and the effect that the LULC products used to characterize the burnt areas in 2017 may have over the characterization of these regions. The generation of LULC maps involves the definition of technical specifications, such as the choice of a MMU, but also several sources of uncertainty during production. Therefore, the resulting products may have differences. However, when the use of different products has a large effect over the conclusions obtained from the analysis, this may be a significative problem, as the data about the size, location and characteristics of burnt areas may have impacts over, for example, the assessment of the environmental effects of fires or decision-making regarding mitigation efforts.

The results presented in this paper raise the issue of LULC quality and the uncertainty associated to these products, as well as the impacts they may have over subsequent analyses. This is an important topic related to LULC data, which is usually generated and used as crisp data, where no uncertainty exists. However, in many cases this does not enable a reliable and accurate representation of reality, either due to the considered MMU, classification difficulties or the fact that the real LULC may not have perfect associations with the considered classes. Therefore, this is an area where further developments are necessary so that no drastically different conclusions are reached when using different products that report to have high overall quality.

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