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ACCURACY ASSESSMENT OF A 122 CLASSES LAND COVER MAP BASED ON SENTINEL-2. LANDSAT 8 AND DEIMOS-1 IMAGES AND ANCILLARY DATA

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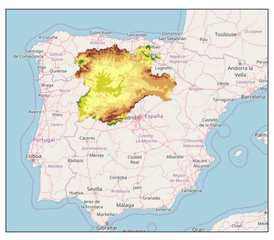
Summary

The main aim of this work is to produce a highly detailed land cover map for 2016 that represents the distribution of annual arable crops as well as permanent crops and the areas of natural vegetation.

Combining satellite images from several sensors between October 2015 and the end of 2016, this land-cover classification map shows different land cover classes across a country-size region in Spain. Over 1.3 TB of data were used to generate a 20m GSD map, which distinguishes between 122 land cover classes and includes 50 specific crop types, being 35 of them arable crops, 7 are irrigated crops and 8 for permanent crops.

Site description

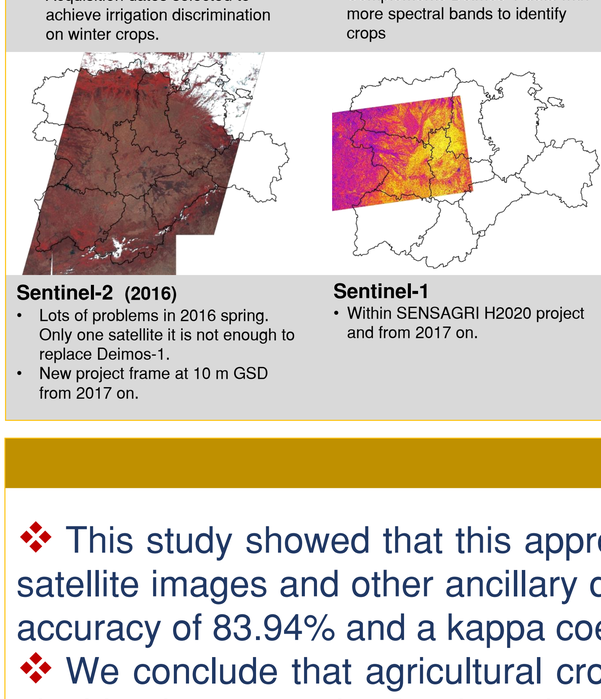


The study area covers the whole region of Castile and León, the largest region in Spain (94.223 km^2) with an average altitude of 800m, surrounded by mountains.

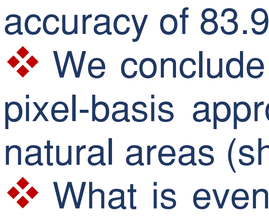
It is composed mainly of extensive herbaceous crops and natural vegetation. Most of the arable land (55.000 km^2) is located in the centre of the plateau where rain averages 500 mm. Dryland farming is based in winter crops such as cereals, namely wheat and barley, and also forage. the most important.

Ten percent of the arable land is irrigated in summer. The main irrigated crops are maize, barley, wheat, sugar beet, alfalfa and potato. Among permanent crops, vineyards are the most important.

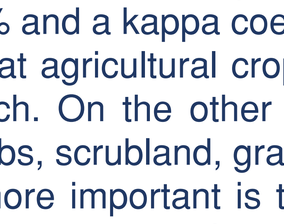
Data sources and methodology



SATELLITE DATA

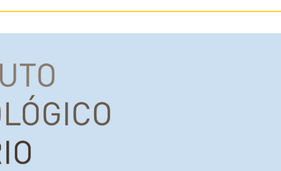


Deimos-1 (2011-2016)
- 8-10 coverages per season.
- Resampled to 20 m GSD
- Acquisition dates selected to achieve irrigation discrimination on winter crops.



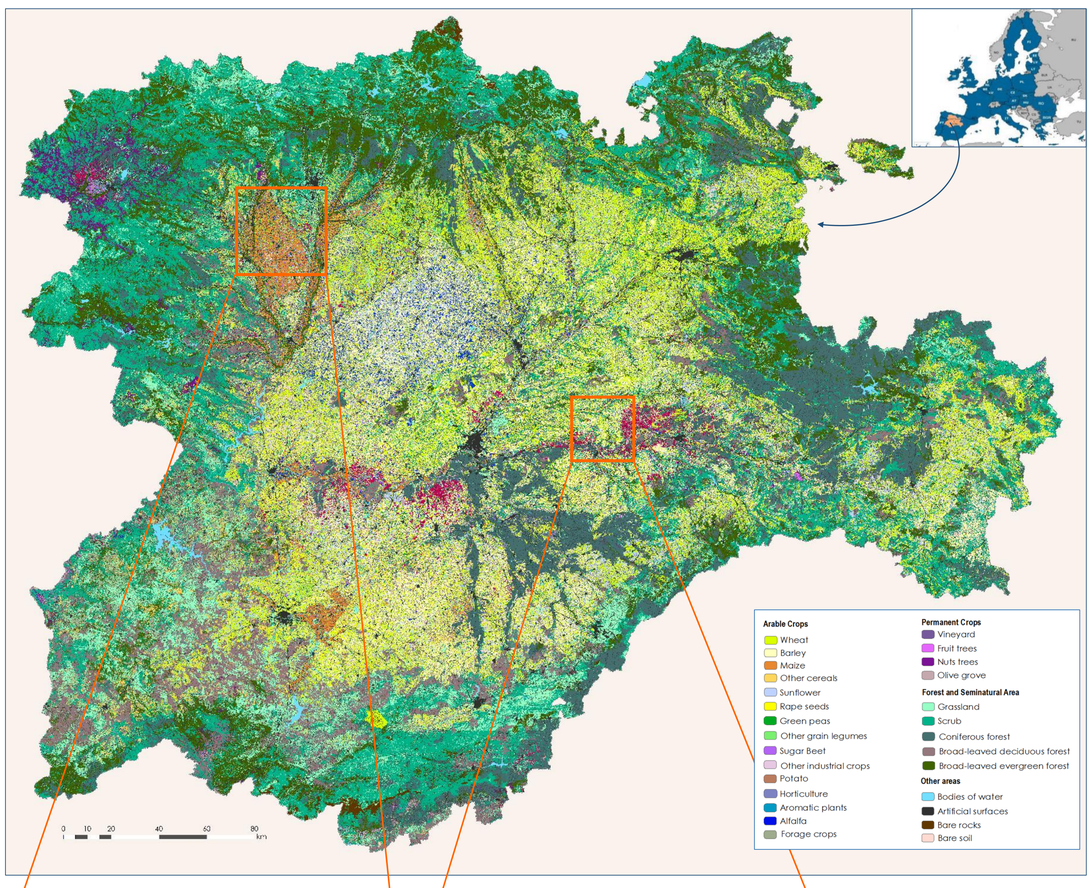
Landsat- 8 (2013-2016)
- Processed to be adapted to project frame (incl. pan-sharpening)
- Complements Deimos-1 data with more spectral bands to identify crops

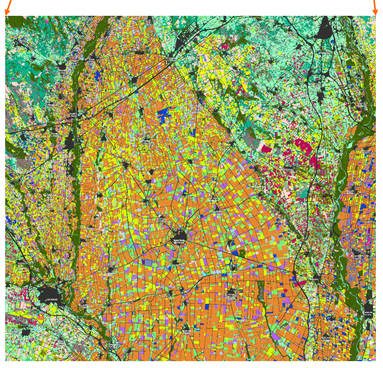
Sentinel-2 (2016)
- Lots of problems in 2016 spring. Only one satellite it is not enough to replace Deimos-1.
- New project frame at 10 m GSD from 2017 on.



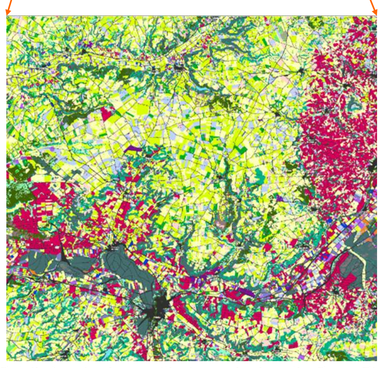
Sentinel-1
- Within SENSAGRI H2020 project and from 2017 on.

Results





Detail of a large irrigation area of maize in León province.



Detail of a mixed area with vineyards along the Duero River.

Figure 1. Castile and Leon Crops and Natural Land Map (MCSNCyL) in 2016 and two more detailed views.

The layer discriminates between irrigated and rainfed crops. We obtained satisfactory results concerning the irrigated arable crops, expect for oats class, and also, for rye and triticale (not shown in the table), being the less extended one. This suggests that we might be able to discriminate only the main irrigated crops: wheat, barley, alfalfa and sunflower, being wheat the best classified by far. It is important to mention that reliability of ground truth for irrigated crop is under concern, especially for crops that are not first priority due to its productivity or market value (such as barley). The accuracy of the irrigation discrimination is much lower in winter crops.

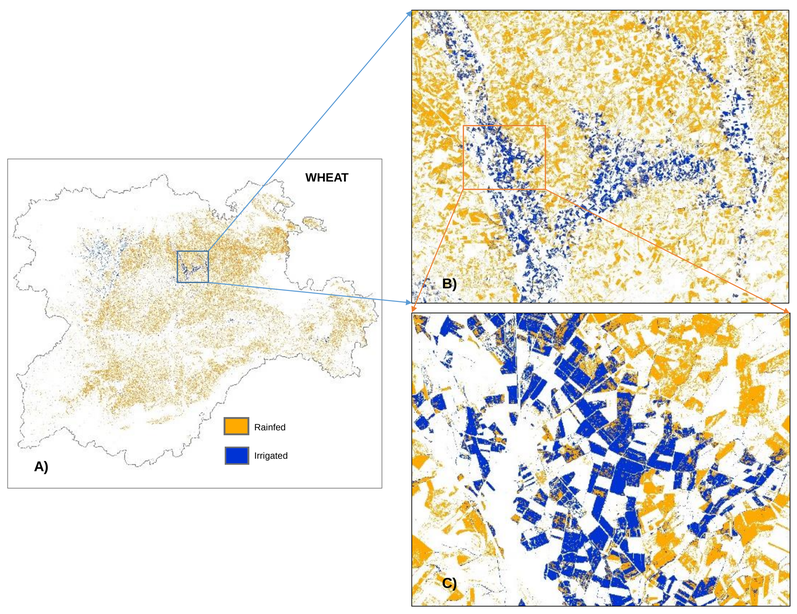


Figure 2. A) Rainfed wheat areas (orange) and irrigated wheat (blue) in the crop classification map; B,C) A more detailed view of the discrimination of rainfed and irrigated plots.

In general, the accuracy for each class is rather good, above 80% in the most classes. The two more representative crop classes within the region, wheat and barley, representing more than the half of the arable land of Castile and León, obtained high accuracy measures, F-Score of 87.1 and 89.2 respectively, even though both cereals are very similar botanically and have slight phenological differences.

The highest accuracies were achieved by crops and forest species resulting rather good accuracy indexes as shown in the table 1. In particular, maize class (F-Score 96.8), followed by sugar beet, sunflower, barley and wheat are the classes better classified among crops. The lowest accuracy measures among crops was obtained by triticale and forage classes (F-Score 38.22 and 38.36, respectively).

Regarding to seminatural and forest areas, most of them yielded very acceptable accuracy measures. In particular, among forest classes, the classification has turned out to be very useful to distinguish by species. Furthermore, it is very useful to discriminate some classes in terms of their forest canopy cover fraction (FCC), although the accuracy declines due to a postproccesing treatment of the final image.

Table. Accuracy measures for each crop type in the classification map 2016.

Land cover type (treshold)	Class description	Class	Map area (%)	Reference data area (%)	Confidence Interval User's accuracy	Confidence Interval Producer's accuracy	F-Score	Est. Kappa
Arable Crops (>0,25% map area & >0,34% reference data)	Wheat	1	11,95	29,20	84,46±0,14	89,94±0,12	87,12	0,78
	Maize	4	1,29	3,20	99,01±0,12	94,7±0,26	96,81	0,99
	Barley	5	9,82	27,67	87,21±0,13	91,22±0,11	89,17	0,82
	Rye	6	0,71	2,94	83,31±0,67	39,44±0,6	53,54	0,83
	Other cereals	8	0,72	3,80	78,12±0,67	34,53±0,51	47,89	0,77
	Triticale	13	0,48	0,81	51,98±1,54	30,21±1,08	38,22	0,52
	Fallow	21	1,92	1,55	77,53±0,66	87,4±0,56	82,17	0,77
	Sunflower	33	3,87	8,96	92,42±0,19	92,22±0,19	92,32	0,92
	Rape	35	0,47	1,47	90,5±0,54	81,46±0,67	85,74	0,90
	Green peas	40	0,38	1,48	86,34±0,64	75,34±0,74	80,46	0,86
	Vicia sativa	52	1,11	4,57	87,33±0,36	70,45±0,45	77,99	0,87
	Alfalfa	60	0,74	3,34	92,34±0,34	74,24±0,5	82,3	0,92
	Forage	61	0,63	0,34	25,98±0,94	73,25±1,59	38,36	0,26
	Raygrass	69	1,15	0,48	42,68±1,14	74,08±1,33	54,16	0,42
	Sugar beet	82	0,27	0,38	92,69±0,87	97,22±0,57	94,9	0,93
	Potatoes	94	0,26	0,37	80,27±1,3	90,27±1,03	84,98	0,80
Irrigated Arable Crops (>0,15% map & >0,10% refer.)	Irrigated wheat	70	0,38	1,48	82,42±0,84	50,61±0,87	62,71	0,82
	Irrigated barley	71	0,16	0,55	61,14±1,59	46,39±1,42	52,75	0,61
	Irrigated alfalfa	72	0,44	0,72	70,27±1,02	86,44±0,85	77,52	0,70
	Irrigated sunflower	73	0,23	0,47	70,3±1,38	73,37±1,36	71,8	0,70
	Irrigated oats	76	0,17	0,12	37±1,94	81,34±2,32	50,86	0,37
Permanent crops (>0,14 & >0,08%)	Vineyard	100	0,96	1,14	98,28±0,26	96,86±0,34	97,56	0,98
	Olive groves	101	0,14	0,09	99,1±0,67	99,26±0,62	99,18	0,99
Seminatural Areas (>0,1% map area & >0,004% reference data)	Southwestern Mediterranean perennial pastures and Iberian summer pastures	86	4,70	0,03	39,31±3,76	99,44±0,91	56,34	0,39
	Weed and subnitrophilous grass and crucifer communities	88	1,35	0,01	20,96±3,68	99,96±0,4	34,66	0,21
	Subalpine cryoturbated-soils grasslands	98	0,20	0,00	96,55±5,54	98,92±3,18	97,72	0,97
	Atlantic and sub-Atlantic lowland and submontane hay meadows	99	1,15	0,01	43,63±7,25	99,95±0,5	60,74	0,44
	Grassy dwarf-shrub garrigues	165	0,69	0,01	73,19±7,22	99,44±1,42	84,32	0,73
	Scrubland Pulvinular Labiatae	166	0,55	0,01	56,78±8,89	99,94±0,58	72,42	0,57
	Hedgehog-heaths dominated by Genista hispanica	176	0,47	0,01	92,09±6,76	99,93±0,69	95,85	0,92
	Hedgehog-heaths dominated by Hedgehog broom (Erinacea anthyllis) or Genista pumila cushion	178	0,56	0,01	84,11±7,1	99,77±1,02	91,27	0,84
	Echinospartum dominated hedgehog-heaths and Genista and Astragalus cushion-heaths	180	1,33	0,01	76,2±9,46	99,87±0,93	86,44	0,76
	Gorse thickets of Ulex spp.	182	0,41	0,01	93,33±5,69	99,59±1,5	96,36	0,93
	Cytisus purgans piornal	201	0,55	0,02	99,2±1,41	99,92±0,44	99,56	0,99
	High mountain Genista piornal	202	1,45	0,01	90,39±5,63	99,37±1,58	94,67	0,90
	White-flowered broom fields (Cytisus multiflorus) and related	204	1,93	0,01	69,22±10	100±0	81,81	0,69
	Juniperus phoenicea scrub	231	0,36	0,01	90,78±8,17	99,91±0,9	95,13	0,91
	Juniperus scrub	232	0,55	0,00	77,65±11,39	99,9±0,98	87,38	0,78
	High thick heaths	234	1,88	0,05	97,35±1,49	99,29±0,79	98,31	0,97
	Low thick heaths	235	0,42	0,00	80,27±11,04	99,9±0,98	89,02	0,80
Forest Areas (>0,1% map area & ≥0,01% reference data)	Pinus sylvestris thick (>70% FCC)	120	2,50	0,09	91,36±1,99	91,36±1,99	91,36	0,91
	Pinus nigra thick (>70% FCC)	124	0,83	0,01	63,44±7,63	94,99±4,23	76,07	0,63
	Pinus pinaster thick (>70% FCC)	126	2,29	0,10	83,31±2,53	83,83±2,51	83,57	0,83
	Pinus pinaster sparse (40-70% FCC)	127	0,56	0,03	71,68±6,73	50,75±6,28	59,42	0,72
	Pinus pinaster very sparse (10-40% FCC)	128	0,62	0,01	51,76±10,55	46,15±9,94	48,8	0,52
	Pinus pinea thick (>70% FCC)	130	0,47	0,01	54,22±8,08	91,88±5,77	68,19	0,54
	Pinus radiata thick (>70% FCC)	134	0,15	0,03	96,82±2,03	99,38±0,92	98,09	0,97
	Juniperus thurifera very sparse (10-40% FCC)	141	0,10	0,01	62,56±11,9	85,62±10,09	72,29	0,63
	Quercus ilex thick (>70% FCC)	143	1,39	0,02	52,48±6,38	69,62±6,76	59,85	0,52
	Quercus Ilex sparse (40-70% FCC)	144	1,87	0,04	38,99±4,25	61,08±5,32	47,6	0,39
	Quercus ilex very sparse (10-40% FCC)	145	2,37	0,04	42,64±4,45	59,67±5,23	49,74	0,43
	Quercus pyrenaica sparse (40-70% FCC)	186	0,92	0,02	52,85±9,27	43,7±8,37	47,84	0,53
	Quercus pyrenaica thick (>70% FCC)	187	3,36	0,06	72,99±3,57	86,7±2,98	79,25	0,73
	Quercus pyrenaica very sparse (10-40% FCC)	188	2,10	0,02	42,16±7,08	54,01±8,09	47,36	0,42
	Fagus sylvatica thick (>70% FCC)	191	0,20	0,01	76,18±8,94	99,16±2,18	86,17	0,76
	Populus plantations sparse (40-70% FCC)	192	1,15	0,04	87,56±3,4	81,92±3,83	84,65	0,88
	Populus plantations very sparse (10-40% FCC)	194	0,14	0,04	92,77±2,94	86,08±3,79	89,3	0,93
	Populus plantations thick (>70% FCC)	198	0,62	0,27	93,63±0,97	98,6±0,48	96,05	0,94
	Quercus robur thick (>70% FCC)	241	0,50	0,23	93,89±1,02	97,9±0,62	95,85	0,94
	Quercus robur sparse (40-70% FCC)	242	0,10	0,03	85,59±6,89	39,33±6,5	53,89	0,86
	Castanea sativa thick (>70% FCC)	243	0,45	0,17	93,83±1,2	97,64±0,77	95,7	0,94
	Castanea sativa sparse (40-70% FCC)	244	0,12	0,02	84,2±7,27	46,31±7,37	59,76	0,84
Other areas (>0,5% & >0,05%)	Rocky areas of bedrock, boulders and cobbles	9	0,79	0,06	98,35±1,11	98,11±1,18	98,23	0,98
	Artificial and urban areas	3	1,31	0,09	95,97±1,33	99,99±0,08	97,94	0,96
	Water cover	255	0,67	1,50	99,86±0,07	98,74±0,19	99,3	1,00
	Overall accuracy							**83,94**
	Kappa index							**0,80**

Conclusions

❖ This study showed that this approach is very useful to map crops and natural land cover from satellite images and other ancillary data, in a very large area (9.4 million ha), achieving an overall accuracy of 83.94% and a kappa coefficient of 0.80.

❖ We conclude that agricultural crops and many forests can be well classified by means of this pixel-basis approach. On the other hand, we have verified that open forests and non-forested natural areas (shrubs, scrubland, grassland, etc.) are not easily classified with this methodology.

❖ What is even more important is that it proved that crop discrimination in Castile and León is accurate enough to support the proposed monitoring approach within European Common Agriculture Policy.

Applications

The resulting product is a useful multipurpose tool that could be applied on administrative controls for agriculture and environmental monitoring.
These are some use case examples: Water use monitoring, LPIS update, CAP subsidies on-the-spot checks, Environmental monitoring (NATURA 2000), Market supply information, Agronomic statistics, and Crop modeling.

Acknowledgments

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