Methodological report on resolving interoperability issues in reusing IACS data in LULUCF

H2020 Reusing spatial information of IACS. Case studies of interoperability

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Abbreviations

AAS - Areas associate with settlements

CAP – Common Agricultural Policy

DEM – Digital Elevation Model

EFA – Ecological Focus Area

EU – European Union

FMPs – Forest Management Plans

GHG – Greenhouse gas

GSAA – Geo-spatial Aid Application

IACS – Integrated Administration and Control System

INSPIRE - Infrastructure for Spatial Information in the European Community

IPCC – Intergovernmental Panel on Climate Change

JRC – Joint Research Centre

KP – Kyoto Protocol

LC – Land cover

LPIS – Land Parcel Identification System

LU – Land use

LUC – Land use change

LULUCF – Land use, land use change and forestry

NIR – Near infra-red

NDVI – Normalized difference vegetation index

OTSC – On the spot check

SFE – State Forest Enterprises

SFO – Sofia province

SHR – State Hunting Reserve

UNFCCC – United Nation Framework Convention on Climate Change

Executive summary

This report aims to present the results of the analysis on the interoperability of IACS and LULUCF regarding the geospatial tracking of land cover and land use changes. The report has been prepared in relation to the objectives and schedules of the pilot studies under the IACS65 project.

IACS data is considered as promising database to meet the LULUCF reporting obligations as it stores geo-referenced information on the land cover type of at least the broad categories of the agricultural lands, such as arable land, permanent pasture, grasslands etc. The LPIS data in Bulgaria covers the whole territory of the country, thus the information on the land cover type includes additional categories, which could be beneficial in terms of data sharing and reusing this information for other purposes such as LULUCF reporting.

Data sharing is the ability to access and use the same data resource with multiple applications or users. The pre-condition of data sharing is interoperability that allows users to interact with data without repetitive manual interventions in such way that the result is coherent. The interoperability issues of IACS and LULUCF refers mostly to the semantic mapping, spatial representation and encoding.

The reports discussed some technical and practical aspects of the following:

1. Semantic mapping and the appropriate level of disaggregation in data harmonization towards the IPCC categories.
2. Key technical aspects in data processing and geo-spatial analysis.
3. Methodology of merging information from IACS and national forest registry.
4. Accuracy of LC/LU change detection based on vector and raster data.

There is a high degree of semantic correspondence between the LPIS and the aggregated IPCC land use categories. However, at a more disaggregated level, there are several physical block (PhB) classes with one-to-many relationships which deserve to be further investigated. These are Courtyards, Areas associated to settlements, Areas with poor vegetation and Mixed land use. During the study it was noticed that many changes in land cover/use appear in these PhB, which is assumed to be because of improved mapping. Thus, a suitable approach to distinguish changes stemming from real changes of land-use from changes caused by an improved mapping has been proposed.

The issue with the data harmonization between the IACS and LULUCF in this report also addresses the allocation of the temporarily unmanaged lands. This is necessary under the LULUCF reporting as the legacy effects of past management can continue for extended periods and having these lands under unmanaged category could result in anthropogenic emissions and removals being unreported.

Another aspect of reusing the IACS data, which is covered by the pilot studies of IACS65 project, is to develop guidelines on merging other sources of information with IACS, such as the national forestry data, so to combine and complement the IACS data with other data as needed and to create additional information.

All changes in land cover and land use have been traced comparing all the polygons or parcels with the same geolocation during the study period. All the oscillating changes due to different area covered by the layer (as it is the case with the GSAA), or by changes in polygons in the LPIS data on physical blocks have been discarded.

Background

Introduction

The land use, land use change and forestry ("LULUCF") sector has the potential to provide long-term climate benefits in meeting the greenhouse gas emissions reduction targets of the EU under the Paris Agreement. The role of the land sector has been recognized and included into the EU 2030 climate policy framework with the adoption of the Regulation EU 841/2018. The Regulation sets a binding commitment for each Member State (MS) to ensure that accounted emissions from land use are compensated by an equivalent accounted removal of CO2 from the atmosphere through action in the sector. This is known as the "no debit" rule. The Regulation also improve the accounting methodology by simplifying the accounting system. It switches the accounting to a land-based approach in line with the United Nations Framework Convention on Climate Change (UNFCCC), rather than an activity-based approach as under the Kyoto Protocol (KP) and Decision 529/2013/EU. The Regulation also broadens the scope of accounting by covering all managed lands and impose some requirements for reporting which aim to improve the accuracy of the accounts. This imposes the use of more accurate data on land representation and land use changes which would enable the use of higher tier methods like models which in principle provide estimates of greater certainty.

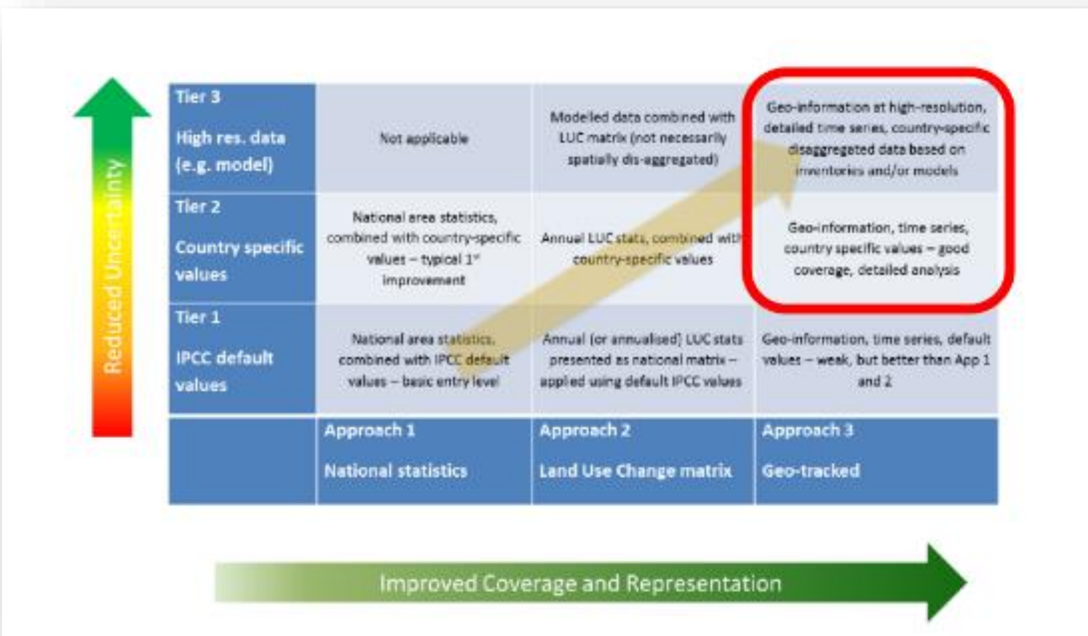


Figure 1 Improving accuracy and coverage in LULUCF sector, Source: European Commission

The demand for sharing spatial information residing in the Integrated Administrative and Control System (IACS) of the Member States has increased in many policy domains. The forthcoming horizontal regulation of CAP (COM(2018) 393 final) proposes concrete measures on data keeping and sharing, notably sharing the Land Parcel Identification System (LPIS) and the Geospatial Aid Applications (GSAA) for reusing in a number of domains, including the LULUCF sector.

In the frame of the Common Agricultural Policy (CAP) (Regulation (EU) No 1306/2013), each Member State shall set up and operate an Integrated Administration and Control System (Art. 67) and shall comprise (Art.68) different elements, i.e., an electronic database, an identification system for agricultural parcels and aid applications and payment claims. In this context, each Member State oversees collecting and storing EU CAP-relevant geospatial information.

IACS consists of several digital and interconnected databases, in particular:

- a system for the identification of all agricultural plots in EU countries, called the land parcel identification system;
- a system allowing farmers to graphically indicate the agricultural areas for which they apply for aid (the geospatial aid application);
- a computerized database for animals in EU countries where animal-based aid schemes apply;
- an integrated control system which ensures systematic checks of aid applications based on computerized cross checks and physical on-farm controls (on-the spot checks).

Relevant INSPIRE[1] themes for LULUCF are land cover, land use, soil type, habitats and biotopes, area management and information on management practices. The benefits of INSPIRE in terms of reporting are the improved transparency, harmonization of data and availability of relevant data sets. (Strange Olesen et al, 2016)

Data sharing is the ability to access/use the same data resource with multiple applications or users. The pre-condition of data sharing is interoperability that allows users to interact with data without repetitive manual interventions in such way that the result is coherent. Now the reuse of the datasets maintained under the CAP could be further enhanced through improvement of interoperability in terms of semantics, spatial representation and encoding. Interoperability can be achieved through spatial data services and/or data harmonization.
In order to facilitate sharing of IACS data and provide technical guidance to the Member States, JRC has launched pilot projects in 2019, targeting at the data discovery component of data sharing. The interoperability component of data sharing is to be addressed in period of 2020-2022, with pilot projects to be carried out in fields of LULUCF, crop classification, environment and agricultural statistics. The current report presents the results of the study on resolving the interoperability between IACS and IPCC land use categories as define in the 2006 IPCC Guidelines (LULUCF pilot).

Objective of the study

The main objective of the current study is to resolve the interoperability issues in terms of semantics, spatial representation and encoding in reusing IACS in LULUCF reporting and accounting framework.

[1] Infrastructure for Spatial Information in the European Community https://inspire.ec.europa.eu/

The study was structured in two main tasks:

1. Map land cover and land use change according to the LULUCF methodology (approach 3 – geospatial tracking) between two points of time (2018-2019; 2019-2020), using the data residing in the Bulgarian IACS implementation.
2. Deliver a Methodological report on resolving interoperability issues in reusing IACS data in LULUCF.

In meeting the main objectives of the current study, the following technical aspects have been considered:

1. Reporting requirements under the EU Regulation 841/2018;
2. Data harmonization towards IPCC concept and categories;
3. The possibility to merging information from IACS and national forest registry;
4. Exploring the possibilities of using Sentinel raster data via NDVI for monitoring of land-related changes.

Study area

Sofia Province is the second largest Province in Bulgaria and the one having the highest number of municipalities (22 in total) among the other provinces. It is in the central part of Western Bulgaria and embraces the area of town Sofia – the capital of the country. It covers an area of ~7060 km^2. The altitude in the Sofia Province varies from 350 to 2925 meters, which determines the wide variety of soils and climatic factors. The high valley fields presuppose good conditions for intensive agriculture. The climate is temperate, and it is characterized by relatively cold winters, cool springs, not very hot summers and mild autumns. Main agricultural activities are animal breeding and fodder production. In the vegetable sector, the largest share is occupied by the production of potatoes and cabbage.

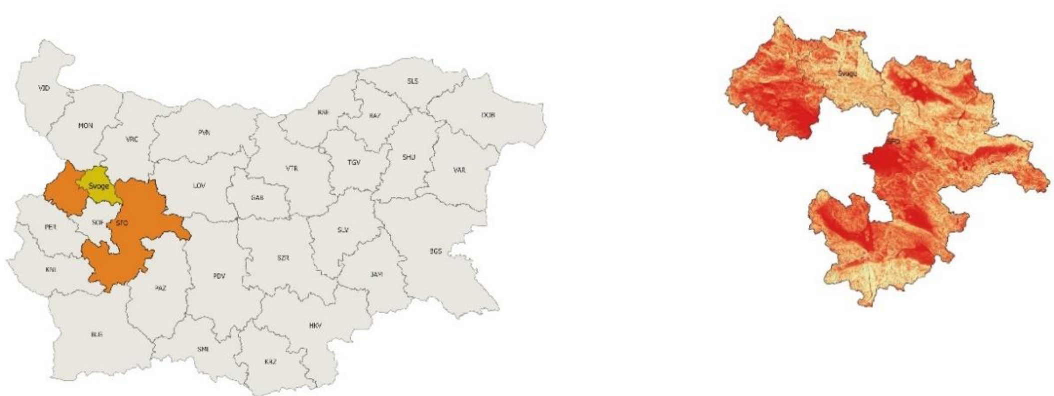


Figure 2 Left figure: Sofia Province (in orange color) and Svogue municipality (in yellow color); Right figure: DEM of Sofia Province

When defining the study area, the following considerations have been taken into account:

- Representation of the main IPCC land use categories;
- Many changes between croplands and grasslands have been detected during a preliminary study on changes in IACS of the whole territory of the country (Table 1);
- Possibility to merge the IACS data with FMP data. The available geo-spatial data on forest land within the boundaries of the study area (FMP of Svogue SFE, 2015).

The mapping of the land use and land-use changes has been performed on the district/province level. More detailed examination of the possibility to merge the forestry data with the IACS data have been done at a municipal level. For that purpose, Svogue municipality has been chosen. The area of the State forest enterprise falls completely within the boundaries of the municipal which facilitate the GIS operations.

Table 1 Results of the preliminary study on land use/cover changes within the totals of the LPIS classes

LC DESCRIPTION	BGS	BLG	DOB	GAB	HKV	JAM	KNL	KRZ	LOV	MON	PAZ	PDV	PER	PVN	RAZ	RSE	SFO	SHU	SLS	SLV	SML	SOF	SZR	TGV	VAR	VID	VRC	VTR
Arable Land	838,69	851,94	2541,18	647,84	3891,03	1002,79	3910,95	371,91	3425,23	1544,01	2813,03	6424,37	5044,64	670,18	159,21	933,98	4117,80	780,87	91,24	2223,57	0,98	1389,29	369,57	3842,66	325,71	2775,03	2072,97	2500,20
Permanent Crops	901,73	183,15	231,28	152,54	104,48	35,70	378,22	29,14	106,19	28,39	430,52	1620,46	13,37	126,64	285,98	161,42	67,10	368,71	294,35	295,45	2,91	20,67	19,96	236,97	106,03	27,40	120,12	416,57
Vineyards	163,13	50,21	5,29	2,71	216,51	183,79	14,28	1,19	25,79	131,08	75,10	245,42	0,00	282,48	87,43	51,02	0,00	202,66	37,10	266,37	0,00	0,00	148,53	11,85	150,75	69,99	189,50	71,00
Orchard	8,54	8,34	0,64	8,61	134,66	0,30	2,02	15,36	26,56	16,26	7,33	41,20	9,27	31,49	12,56	40,23	15,52	25,64	71,20	110,16	1,75	0,13	56,95	17,15	132,27	0,00	11,51	115,96
Other Perennials	130,06	0,50	2150,42	1,88	103,61	260,69	0,65	0,00	105,36	9,00	21,82	101,26	0,00	13,01	88,96	8,03	13,53	164,59	53,54	27,57	0,00	9,56	462,31	78,72	146,28	0,00	38,86	18,28
Settlements	0,00	0,00	0,00	4,35	0,00	0,00	0,00	0,00	2,68	0,00	0,00	0,00	0,02	0,00	0,00	0,00	4,40	0,35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Courtyards	69,37	143,01	11,72	129,30	265,62	46,93	54,16	33,40	106,94	591,02	26,75	27,61	150,10	217,14	21,51	0,59	1212,41	39,18	2,74	114,74	9,36	265,17	39,75	144,92	197,24	10,43	206,51	62,63
Areas Associate to Settlements	6,89	273,48	12,20	30,33	43,98	10,98	3,77	5,36	71,93	19,79	3,44	6,68	83,96	32,69	22,99	0,00	287,28	3,35	0,24	1,14	0,00	71,00	0,00	8,71	24,36	4,10	35,81	75,13
Pastures, Grasslands and Meadows/Pastures, Commonage and Meadows	566,01	1847,32	454,99	678,81	4133,76	193,28	1978,41	1866,44	2786,30	1484,18	827,36	1486,08	2236,17	475,43	4,81	64,16	3314,10	292,68	33,01	731,48	422,87	269,05	675,52	397,76	945,32	540,97	830,30	1195,34
Natural Pastures and Meadows	15,79	4,89	5,77	2,93	52,90	63,09	38,54	11,16	7,92	243,54	31,43	61,11	43,38	197,06	11,88	62,75	2132,51	0,09	0,02	43,62	78,95	0,00	154,16	218,82	6,13	8,36	19,88	204,79
Forest Meadows and Pastures	33,42	86,04	2,33	1,81	47,24	130,59	6176,56	0,42	11,48	139,45	14,27	10,97	8,06	58,95	0,67	1,20	379,23	0,30	1,07	25,37	7,91	20,68	0,00	1,24	4,01	0,09	11,38	19,24
Mixed Land Use	461,10	3856,56	88,92	1838,59	7393,85	1593,03	6203,97	1825,43	7243,17	3975,82	3751,05	8869,07	7133,77	1290,99	541,94	396,40	9611,90	1626,19	394,14	3041,01	249,60	1770,91	694,41	4671,92	1090,17	3699,93	4766,23	4535,89
Non-Treated Areas/Non-Arable Lands	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	80,23	0,00	0,00	0,15	0,00	4,68	0,00	0,00	0,98	0,00	0,00	0,00	0,00	4,80	17,68
Shrubs and Grasslands	665,54	360,46	70,76	476,43	1356,88	1194,16	349,66	321,90	229,43	509,37	278,14	358,67	311,15	487,62	42,43	130,90	453,24	119,29	42,79	75,96	53,73	122,08	245,46	354,28	533,68	110,74	1214,54	330,27
Gutters, Ravines and Washes	86,86	60,85	3,81	50,70	837,19	50,08	11,19	2,86	82,49	2,75	48,20	5,89	36,54	51,20	6,83	5,53	171,89	16,93	0,01	29,42	0,00	21,00	5,42	0,31	5,10	13,63	19,80	76,36
Field Roads, Clearings and Clearings	137,97	7,81	10,27	1,06	35,47	17,43	2,59	2,40	9,92	16,96	19,77	15,28	5,54	84,83	1,02	8,06	1,16	44,41	0,63	6,37	0,07	15,71	1,03	39,65	125,08	5,38	6,16	60,97
Forest Territories	671,41	1421,04	57,80	744,40	374,76	718,05	32,01	85,18	654,10	455,78	202,55	34,41	208,57	1545,68	37,39	35,04	2641,56	64,63	59,26	14,48	15,67	256,45	39,72	307,51	117,32	278,55	2393,39	1040,83
Urbanized Territories	0,00	0,00	0,00	0,00	5,54	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,00	0,00	0,00	0,58
Urban Structures	48,08	159,41	3,52	293,74	709,38	21,31	36,35	0,31	83,00	587,02	0,00	0,26	12,92	0,61	89,50	0,06	201,12	2,35	0,29	118,98	0,01	28,19	3,51	59,22	306,13	0,11	8,64	51,63
Sub Urban Territories	14,01	47,33	16,45	180,20	422,69	7,60	20,39	5,33	23,90	3,48	8,22	62,63	105,86	178,98	31,48	6,97	855,58	225,62	28,43	21,91	2,46	352,86	1,48	127,94	117,97	13,60	228,59	27,91
Sports and Relax Zones	21,50	0,00	0,10	1,38	3,14	9,29	0,02	0,08	5,59	3,82	0,68	13,56	0,00	4,63	1,84	0,01	15,19	23,35	1,23	1,27	0,00	146,29	3,09	6,18	8,26	0,00	9,18	4,65
Water Areas and Wet Zones	0,23	23,57	0,00	0,58	0,50	1,60	0,34	0,00	12,42	1,35	5,23	1,60	1,36	15,51	0,66	2,88	2,77	0,32	1,13	1,35	0,00	1,02	2,48	0,28	0,34	0,00	0,19	17,82
Rivers and Riverbeds	35,33	6,54	12,23	2,23	147,51	29,06	11,50	0,60	61,43	1,10	2,03	24,41	3,78	12,70	4,25	0,11	44,14	0,51	0,00	0,13	0,11	1,36	14,93	2,05	47,62	6,68	24,35	34,79
Lakes, Dams and Swamps	19,74	48,68	4,58	2,80	18,77	7,40	3,12	4,25	69,86	23,85	11,64	18,40	1,13	66,56	4,17	13,49	125,07	6,85	8,53	14,24	0,00	14,50	16,89	17,94	9,66	0,68	0,29	20,03
Channels	19,36	1,71	0,00	2,63	18,26	12,55	0,80	0,00	4,98	2,84	20,88	11,42	1,87	29,35	13,33	3,76	3,67	3,59	1,06	21,25	0,00	3,89	15,14	5,31	13,08	9,33	0,99	14,49
Boundary Water Areas	0,00	0,00	0,00	0,00	0,15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	5,66	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,35	0,00	0,00
Wetlands	17,97	32,07	6,56	0,01	0,29	16,73	1,43	0,00	30,85	2,43	7,47	11,23	1,39	193,60	11,35	1,94	39,75	0,51	0,15	60,96	0,00	8,07	3,41	2,96	42,80	0,65	20,40	61,59
Territory Dispared	1,08	6,16	0,00	1,67	1,70	5,10	8,40	0,00	19,82	0,30	0,00	0,21	9,76	7,31	6,00	0,00	699,26	0,00	0,34	0,00	0,00	3,60	3,02	1,22	22,25	0,00	1,11	0,00
Quarries, Open-Cast Mines, Extraction Sites	11,08	23,31	0,00	0,78	0,47	4,13	7,77	0,00	26,69	2,62	0,65	0,55	22,55	3,33	3,12	1,82	32,11	39,83	0,00	0,28	0,00	23,12	0,17	0,38	40,43	0,00	15,95	10,26
Landfills and Dump Sites	1,54	2,65	10,72	5,97	10,95	4,98	1,02	0,01	4,41	1,60	2,53	10,16	0,26	7,55	5,05	0,30	17,86	18,69	1,37	5,02	0,00	21,04	1,04	3,41	2,93	0,00	7,02	8,29
Transport Infrastructure	0,00	0,03	0,00	0,28	6,50	0,00	1,26	0,00	0,00	0,09	0,24	0,00	0,14	4,91	0,00	0,01	0,15	0,09	0,00	0,20	0,00	0,00	0,00	0,18	0,00	0,02	0,00	0,01
Roads with Permanent Pavement and Adjacent Territories	18,12	2,23	1,36	72,61	15,34	11,63	7,57	1,19	19,65	9,20	0,06	8,75	2,85	17,35	2,15	0,75	38,17	4,60	0,18	5,43	0,03	13,49	9,93	8,57	12,56	13,96	1,66	22,97
Railways and Adjacent Territories	0,92	0,11	0,00	0,00	11,85	0,21	0,25	0,01	5,22	0,58	0,03	1,85	0,32	0,93	0,70	0,00	1,82	0,87	0,02	5,97	0,00	1,27	2,79	1,83	80,64	4,67	0,72	0,30
Bare and Eroded Terrains	3,05	8,55	0,00	0,14	3,02	0,00	24,72	0,04	14,86	0,54	0,49	3,88	7,05	81,72	0,03	0,00	36,52	0,45	0,00	0,12	0,00	0,00	0,00	1,20	0,00	0,01	7,72	0,03
Sand, Gravel and Bare Rocks	4,44	337,10	0,00	3,92	11,98	0,52	3,99	14,08	1,26	0,48	5,48	0,05	6,45	48,97	0,50	0,23	30,84	21,73	0,00	0,84	0,00	28,62	77,09	6,75	31,27	0,10	46,10	14,31
Areas with Poor Vegetation	7,44	36,21	25,77	0,58	97,49	0,00	5981,47	4,93	113,06	167,30	36,73	50,16	44,15	420,07	0,00	0,35	2496,89	18,99	0,00	33,69	8,60	4,94	96,51	42,16	277,55	9,09	7,82	0,95
Other Territories	0,00	0,00	0,00	0,00	0,21	0,00	0,00	0,00	0,00	0,00	4,00	0,07	0,00	9,58	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,24
Ultra-Small Non-Agricultural Areas	1,43	0,42	0,21	1,29	2,06	1,37	1,26	0,04	7,67	0,01	1,55	4,21	2,11	3,31	0,51	0,05	8,12	0,87	0,31	0,59	0,08	0,40	0,27	1,04	4,48	0,17	7,43	7,85
Group Linear Objects (Ravine)	4,73	0,05	0,00	0,00	0,00	2,52	0,12	0,00	0,58	0,00	19,37	3,85	0,20	14,22	0,11	0,00	5,14	0,07	0,11	4,81	0,00	1,22	0,09	0,16	138,47	0,42	0,10	3,52
Area with Other (Non-Agricultural) Purpose	2,86	32,61	0,00	3,24	19,42	0,73	0,04	0,00	0,00	15,51	82,30	8,63	4,71	0,04	0,00	0,00	25,59	213,78	1,56	2,07	0,00	16,72	0,00	0,79	19,15	0,37	0,00	3,04
Total change (absolute value)	4989,43	9924,33	5728,89	5346,33	20499,18	5637,61	25268,80	4603,01	15400,83	9991,54	8760,36	19544,36	15513,37	6766,87	1500,36	1932,06	29109,23	4332,91	1130,72	7305,81	855,07	4903,34	3164,61	10622,06	5085,07	7604,82	12330,04	11046,43

LULUCF – overview, methodology and requirements

National greenhouse gas inventories for Land use, Land-Use Change and Forestry (LULUCF) cover greenhouse gas emissions and CO_2 removals resulting from land use and land use changes in predefined six land-use categories – **Forest land (FL), Cropland (CL), Grassland (GL), Wetland (WL), Settlements (SL), Other land (OL)**. The categories are broad enough to classify all land areas. In accordance with the 2006 IPCC Guidelines (IPCC 2006) emissions and removals are reported into two sub-categories – land remaining in the same category and land converted to another land-use category. Within each land use category and sub-category, carbon stock changes and emission/removal estimations comprise the overall carbon gains or losses in the relevant carbon pools – biomass, dead organic matter (dead wood and litter) and soils.

In the LULUCF sector, emissions and removals on managed land are taken as a proxy for anthropogenic emissions and removals. Thus, UNFCCC reporting covers all emissions by sources and removals by sinks from managed lands are considered to be anthropogenic, while emissions and removals for unmanaged lands are not reported. This approach was decided in the absence of a practicable methodology that would factor out direct human-induced effects from indirect human-induced and natural effects for any broad range of LULUCF activities and circumstances. (capreform.eu, Alan Matthews)

Land representation

Information, in terms of classification, **area data**, and sampling that represents various land-use categories, is needed for LULUCF inventory. It represents the **activity data** for the estimates of emissions and removals from the LULUCF sector.

The 2006 IPCC Guidelines (IPCC 2006) define **three Approaches** that may be used to represent areas of land-use. Approach 1 identifies the total change in area for each individual land-use category within a country but does not provide information on the nature and area of conversions between land-uses. Approach 2 introduces tracking of land-use conversions between categories, but it does not allow spatially explicit land-use conversions to be tracked through time. Approach 3 extends Approach 2 by allowing land-use conversions to be tracked through time on a spatially explicit basis. The Approaches are not presented as a hierarchical system and are not mutually exclusive. Mix of approaches is acceptable.

While the terms "land-use" and "land cover" are sometimes used interchangeably, they are not the same. Land cover refers to the bio-physical coverage of land (e.g., bare soil, rocks, forests, buildings and roads or lakes). Land-use refers to the socioeconomic use that is made of the land (e.g agriculture, commerce, residential use or recreation) (UNEP/FAO 1993). The definitions of land-use categories may incorporate management options and predominance over other land-uses when a land is subject to multiple uses. (Bertaglia et al., 2016)

Methodological choice

There are three methodological tiers for estimating greenhouse gas emissions and removals for each source. Tiers correspond to a progression from the use of simple equations with default data to country-specific data in more complex national systems. Tiers implicitly progress from least to greatest levels of certainty in estimates as a function of methodological complexity, regional specificity of model parameters, and spatial resolution and extent of activity data.

Tier 1 employs the basic method provided in the IPCC Guidelines and the default emission factors provided in the IPCC Guidelines (Workbook and Reference Manual).

Tier 2 can use the same methodological approach as Tier 1 but applies emission factors and activity data which are defined by the country for the most important land uses/activities. Tier 2 can also apply stock change methodologies based on country specific data. Country-defined emission factors/activity data are more appropriate for the climatic regions and land use systems in that country. Higher-resolution activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use categories.

At *Tier 3*, higher-order methods are used including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales. These higher order methods provide, at least in principle, estimates of greater certainty than lower tiers. Models should undergo quality checks, audits, and validations.

Information on IACS data in BG

The Integrated Administration and Control System (IACS) in Bulgaria is developed by following the main EU and EC regulations. In principle, IACS consists of several interconnected databases:

- a system for the identification of all agricultural parcels in EU countries, called the land parcel identification system;
- a system allowing farmers to graphically indicate the agricultural areas for which they apply for aid (the geospatial aid application);
- a computerised database for animals in EU countries where animal-based aid schemes apply;
- an integrated control system which ensures systematic checks of aid applications based on computerised cross checks and physical on-farm controls (on-the spot checks).

To map the land use and land-use changes in respect to LULUCF reporting, the most proper databases of IACS is the Land Parcel Identification Layers (LPIS) and the Geospatial aid application (GSAA) layers. The LPIS layers mostly cover the land cover concept, although in some cases the names of the PhB refer also to the land use. The information in the GSAA is more related to the land use concept expressed as farmers' intentions about the conduction of certain annual activity or intervention on the land. With the introduction of the mandatory geospatial aid application (GSAA) since 2017, both concepts – land cover and land use have explicit spatial representation in IACS (Bertaglia et al., 2016).

Land Parcel Identification System in BG

The Agricultural Land Parcel Identification System (LPIS) is a part of the Integrated Administration and Control System (IACS). The LPIS is built around a set of reference parcels that:

- Are measurable;
- Allow unique and unambiguous localisation of agricultural parcels (land used by the farmer);
- Record the eligible agricultural area they contain;
- Are stable over time.

Bulgaria has developed the system based on measurement of the visible physical boundaries on a digital orthophoto map of aerial/satellite photography and as a type of reference parcel – a physical block. The physical block is continuous land occupied by one or more crop groups within single agricultural land cover, declared by one or more farmers, limited most often by the natural boundaries. The Physical block (PhB) is stable (Semi-permanent) over time and, consequently, easy to update. This represents the production units as visible in a reference year by the administration without consulting the farmer.

In Bulgarian LPIS, the physical blocks are divided into two main classes – physical blocks of agricultural land and physical blocks of non-agricultural land. Agricultural areas are areas (parts) of the territory of the country that meet simultaneously the following conditions:

- suitable by their natural resources for potential agricultural use;
- authorized for agricultural use, under the legislation in force in the country (cadastre, prohibitions in some areas, etc.).

The LPIS in Bulgaria started as containing main elements, nomenclature, and definitions of Corine Land cover. They have undergone some changes and additions to reflect the specific nature of the objectives and objectives of the LPIS. Recently, the nomenclature has been revised again.

Each physical block has a unique identification code (identifier) within the country, formed as a position code of three parts: Uniform classifier of administrative-territorial and territorial units of the land in which most of their area falls, a dash and the serial number of the physical block in that land.

The most important characteristic of the Bulgarian LPIS design is that LPIS has a full coverage of the country's territory with PhB – agricultural and non-agricultural lands which give reliable information about the LC/LU and the data in PhB layer is updated annually.

Other important characteristics of the LPIS in Bulgaria that should be considered during the study are:

- The physical blocks – "Areas associate to settlements" and "Courtyards" do not consist only settlements features.
- Where there is more than one permanent use (arable land, grassland, or permanent crops land) which areas are too small (less than 0.2 ha) or not separated from a permanent topographic element, and the area of none exceeds 75% of the whole observable production block they are separated in the physical block of the agricultural area groups, but their permanent land use is defined as "Mixed Land Use". If the area with the same permanent use exceeds 75% from the reference parcel/physical block area, the reference parcel/physical block will be named after that use.
- Even if the "Shrub and area covered with grass" physical blocks are defined as non-agricultural physical blocks, they contain mostly areas with agricultural purpose in the cadastre data, so if any agricultural activities started on these lands, the area could change its category and defined as part of the agricultural physical blocks group after defining it as a different type Phb. It is the same with the physical blocks – "Field roads and clearings".
- The physical blocks named "Water areas and wet zones" do not represent the wetland defined by the Ramsar Wetland Conservation Convention.
- Agricultural lands occupied by trees with a short rotation cycle [2]– are defined as a part of the group – perennial crops under the GSAA. To be eligible for support, the areas with crops with a short rotation cycle should be agricultural areas managed as ecological focus areas from the farmer as part of the agricultural practices beneficial for the climate and the environment.

[2] https://ec.europa.eu/info/news/ecological-focus-areas-show-potential-helping-biodiversity-2017-mar-29_en

- The physical blocks defined as “Forest territories” are not equal with the forest territories according to the definition in the Forest law. As the physical blocks follow to a great extent the land cover concept when mapping the area, a deviation between the LPIS data and data from forestry administration could be expected. This is explained by the fact that the Forest law gives predominance to the forest definition and land designation when defining forest territories. Forest territories, according to the law, consist of wooded and non-wooded lands, suitable for silvicultural activities. Like this there could be non-wooded lands defined as forest territories in forestry data, but as agricultural in LPIS, or wooded lands which fully comply with the definition of forest in Bulgaria and are mapped as forests in LPIS but are under the agricultural designation of lands in practice. To define these lands as forest territory according to the Forest Law, a specific procedure to change the designation of that land to forest territory is required.

Another important part of the LPIS is the **Eligible layer** which contains all areas on which in the year of the LPIS update one of the follow activities was done according to the LPIS custodian:

- Ploughing;
- Shallow Ploughing/Second tillage;
- Mowing, cutting grass with or without hay production;
- Grazing;
- Herbicide treatment;

The Eligible layer itself lacks information on the accurate LU or LC unlike the PhB layer (although it is added in newer versions of Eligible layer). The lack of this information does not allow an accurate categorization of the area using only this layer. But it gives information about the amount of the whole area with yearly activity in the country according to the LPIS custodian. So, if we complement the Eligible layer data with the data from the GSAA layer, we could accomplish a full review of the LU by redistributing the ratio from GSAA to the extent of the Eligible layer.

The LPIS also contains layers such as: **Permanent pastures and grasslands** in which areas the ploughing is prohibited; **Ecological focus areas** – which currently contains data about the Landscape features only. We have not used these layers for that pilot, but the data have the potential to be useful, further study is needed.

Geospatial Aid Application in BG

All active farmers registered as farmers under the national law, who manage agricultural land and/or produce agricultural products on the land at their disposal for the campaign year, are eligible to apply for direct payments. The application[3] is made by submitting spatial and alphanumerical data. Bulgaria has 100 % GSAA for area-based schemes and measures since 2007, which could be considered as an advantage. The minimum area for a single parcel subject of an application is set to 0.1ha. The application serves as the basis for payment and is therefore carefully controlled by an elaborate system of administrative and on-the-spot checks (OTSC).

[3] Commission Implementing Regulation (EU) No 809/2014 of 17 July 2014 laying down rules for the application of Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system, rural development measures and cross compliance

The alphanumerical data in the application consists of data for the schemes and measures[4] for which the farmer applies for each of his parcels and the crop he will cultivate. The farmer also declares that he is aware of all the obligations to be fulfilled in these parcels so to be eligible for subsidy under the schemes and measures in question.

There are some mandatory obligations to all farmers related to Greening payment[5] , for example the ban on ploughing in sensitive permanent pastures, ban on application of plant protection products, crop diversification and maintenance of EFA. Other schemes and measures, such as for example the measure “Organic farmer”, are voluntary for the farmers, so when applying for subsidy under that measure, the farmer agrees by means to fulfil the specific requirements.

The data about the areas related to Natura 2000 network[6] is used in LPIS and GSAA as ancillary data. The data on Natura 2000 is designed and maintained by the Ministry of Environment and Waters, who is its custodian.

In conclusion, the LPIS thematic data in Bulgaria covers the whole territory which makes it suitable as a source of information on land cover and land cover changes. Using GSAA could be very useful for the examination of land use and land use changes within cropland and grassland areas. However, the original spatial and thematic data might be too detailed for a direct input in IPCC reporting requirements. Thus, a bottom-up approach for data aggregation, through semantic mapping and up-scaling of IACS data, should be implemented (Bertaglia et al., 2016).

Working approach and Methodology

Data access and data sharing

In respect to IACS data, in the last few years the availability of public accessible electronic data has constantly increased. The data about the Physical Blocks have been visible, but not downloadable till recently. It still has obstacles because the data which could be downloaded is only the current annual version.

The data on the Eligible layer and Permanent Grassland layer are publicly available and could be downloaded as the PhB layer[7].

The data from GSAA is also public but with limited access – only for the beneficiary as a spatial data. However, the data on declared cadaster parcels in table format as a reference could be found on the System for electronic services[7]. All above-mentioned layers could be seen on the map with the orthophoto as the background in this system.

[4] Commission Delegated Regulation (EU) No 640/2014 of 11 March 2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system and conditions for refusal or withdrawal of payments and administrative penalties applicable to direct payments, rural development support and cross compliance

[5] The Greening payment is part of agricultural practices beneficial for the climate and the environment. Commission Delegated Regulation (EU) No 640/2014 of 11 March 2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system and conditions for refusal or withdrawal of payments and administrative penalties applicable to direct payments, rural development support and cross compliance

[6] Natura2000

[7] System for electronic services: ftp://212.122.182.203/

Forestry data in Bulgaria is published on the internet site of the Executive Forest Agency[8]. The data is part of the Forest Management Plans, which are elaborated for each State Forest Enterprise (SFE) in the country for a duration of 10 years period. The Plans are elaborated after a forest inventory is conducted and the forest characteristics are updated. Although the Forest Management Plans are publicly available, they are stored in a specific format - *.ZEM file. To obtain the geographic information from these files there is a need to use a specific software, which is available against a paid service.

Overview of the working approach

In general, the approach consists of several steps aiming at the elaboration of maps of the land use and land use changes as well as the LUC matrices as required for the LULUCF reporting. The first and most important step was to resolve the interoperability of IACS with the LULUCF sector/reporting in terms of semantic. As a starting point, we used the results of the semantic mapping in the technical report delivered in 2019 by Ms. Ivanova-Stoyanova with a focus on LPIS and the so-called permanent use of the Physical Blocks. We complemented that work with further disaggregation of the IPCC categories to match the latest changes in the land representation in the LULUCF reporting of the Bulgarian GHG Inventory. In addition, we did a semantic mapping of the GSAA layer and of the Forest Management Plans. Once the semantic mapping was done, we moved to data processing and preparation of the layers for further geo-spatial analysis.

Combination of the different datasets has been used in the geo-spatial analysis. This refers to LPIS data on PhB layer, GSAA and the Forest Management Plans data. The geo-spatial analysis has started with intersection of the available layers in a time series aiming to extract the polygons with the same geolocation for each of the layers in the period 2018-2020. All changes in land cover and land use have been traced comparing all the polygons or parcels with the same geolocation during the study period.

The results from the geo-spatial analysis have been summarized in Excel. The LUC matrices have been elaborated using pivot tables.

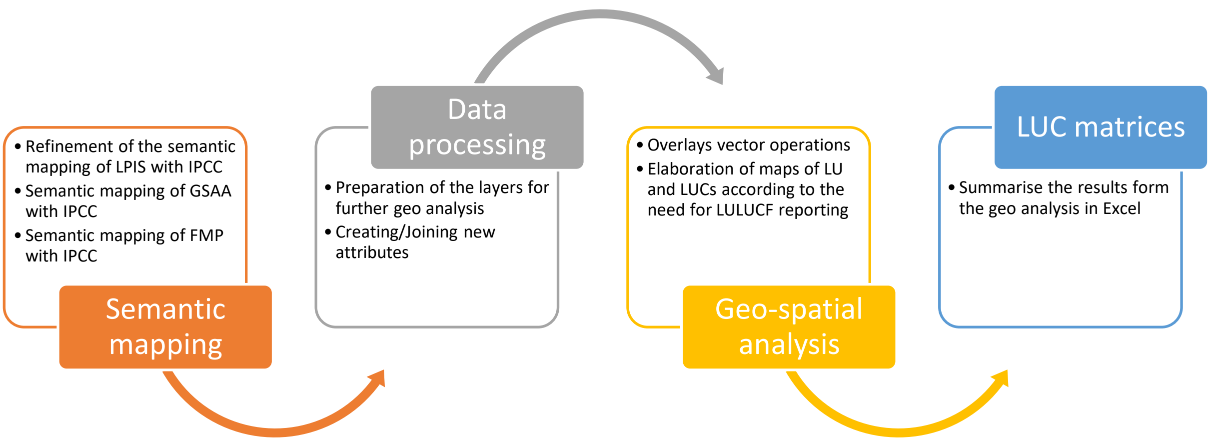


Figure 3 Summary of the working approach

[8] http://www.procurement.iag.bg:8080/cgi-bin/lup.cgi

Interoperability of IACS and LULUCF regarding the geospatial tracking of land cover and land use changes

Definitions

To resolve the interoperability issues of reusing the IACS data for the purpose of LULUCF reporting in terms of semantic mapping, good understanding of the definitions and reporting requirements are necessary. Thus, a short introduction on land use definitions and classification system used in the LULUCF reporting is presented here. In addition, the definitions of the accounting categories in accordance with EU Regulation 841/2018 are also provided. LPIS definitions and special characteristics are described above in subchapter Land Parcel Identification System in BG.

Land use categories reported from Bulgaria under the UNFCCC (National Inventory Report, 2020)

The land-use categories under the IPCC classification may be considered as top-level categories for representing all land-use areas, with sub-divisions describing specific circumstances significant to emissions estimation. The categories are broad enough to classify all land areas in most countries and to accommodate differences in national land-use classification systems. (IPCC, 2006). The definitions of the land categories reported under the GHGI of Bulgaria are as follow:

Forest land

For defining forest, Bulgaria uses the definition in the Bulgarian Forest Act:

"***Area over 0.1 ha, covered with forest tree species higher than 5 meters and tree crown cover over 10% or with trees which can reach these parameters in natural environment***".

Areas of natural forest regeneration outside urban areas with a size of more than 0.1 ha also represent "forest". City parks with trees, forest shelter belts, and single row trees do not fall under the category "forests".

According to their functions, forests are divided into: forests for timber production, protective and recreation forests and forests in protected areas.

Forests are also:

- areas which are in a process of recovering and are still under the parameters, but it is expected to reach forest crown cover over 10% and tree height 5 meters;
- areas, which as the result of anthropogenic factors or natural reasons are temporarily deforested, but will be reforested;
- protective forest belts, as well as tree lines with an area over 0.1 ha and width over 10 meters;
- cork oak stands.

All forests in Bulgaria are managed.

Cropland

Category Cropland consist of two subcategories – **annual and perennial crops**.

Under the subcategory "annual crops" we define arable lands, which are regularly ploughed and regularly cultivated. These lands are occupied by cereals and dry pulses, industrial crops, fodder and other field crops or vegetables. Arable lands, which are laying fallow, as well as cornfields and kitchen gardens are defined as annual croplands too.

Perennial crops include orchards, vineyards, fruit and berry plantation, other permanent crops, nurseries for wine, fruits, ornamental plants etc. The orchards are uniformly kept plantations (by annual pruning and regular treatment for protection from diseases and insects) of fruit trees (pip-trees, stone-trees and nut-trees).

Grassland

Grasslands are defined as herbaceous lands which are not classified as croplands. These lands are further stratified into two subcategories:

1) Pastures and Meadows
2) Shrubs and grasslands

The subcategory Pastures and Meadows includes lands, which are subject to grazing or mowing – permanent pastures, high mountain pastures and natural meadows.

The subcategory Shrubs and Grasslands includes low productive grasslands and secondary lawns, areas with scattered thorns and shrubs, abandoned arable land, naturally covered with thorns, grasses and herbs.

Wetlands

The Wetlands category includes lands covered with water or water saturated lands (throughout the year or partially in the year), which does not fall in the other categories. These are natural or artificial watercourses serving as water drainage channels, natural or artificial stretches of water, coastal lagoons, wetlands areas and peatbogs.

Settlements

The Settlements refer to all classes of urban formation – buildings, roads, streets and areas with artificial surfaces, roads and railways, their facilities and the appropriate area, mines, landfills and construction sites, city parks, gardens, cemeteries, sport facilities. These areas are functionally or administratively associated with public or private lands in cities, villages, or other settlement types.

Other land

Other land category includes bare lands, rock, sands, sparsely vegetated areas, and all area that do not fall into any of other five land-use categories.

Accounting categories according to Regulation 841/2019

As it was mentioned above with the adoption of the LULUCF Regulation the accounting approach of the land sector have been changed from activity-based accounting under the KP and Decision 529/2013 to a land-based accounting similarly with the reporting under the Convention. The LULUCF Regulation defines the following accounting categories:

Managed forest land: land use reported as forest land remaining forest land;

Afforested land: land use reported as cropland, grassland, wetlands, settlements or other land, converted to forest land;

Deforested land: land use reported as forest land converted to cropland, grassland, wetlands, settlements or other land;

Managed cropland: land use reported as: — cropland remaining cropland, — grassland, wetland, settlement or other land, converted to cropland, or — cropland converted to wetland, settlement or other land;

Managed grassland: land use reported as: — grassland remaining grassland, — cropland, wetland, settlement or other land, converted to grassland, or — grassland converted to wetland, settlement or other land;

Managed wetland: land use reported as: wetland remaining wetland, settlement or other land, converted to wetland, or wetland converted to settlement or other land.

Semantic mapping and update

Update of the semantic mapping of LPIS

As a starting point for the update, we used the results from the semantic mapping delivered in 2019 by Ms. Ivanova-Stoyanova. The update of the mapping was mostly in two directions:

1) to reflect the disaggregation of the IPCC categories to the adopted subcategories in Bulgaria in respect to Grassland category – since the last changes in land representation implemented in Submission 2020, and

2) to further investigate several physical block classes, where the semantic mapping to the IPCC categories is no straightforward. These blocks are the following:

- Courtyards
- Areas associated to settlements
- Areas with poor vegetation
- Mixed land use

The boundaries of these blocks are not updated annually in case there is a change in the land use unless there is a GSAA presented. For the LULUCF reporting and accounting it is important to know to which category is best to assign them. In our preliminary investigation of these physical blocks, we noticed that the instructions for the orthophoto interpretation are implemented differently by the various operators. Hence, some differences in determining the permanent usage of similar polygons under these physical blocks' categories have been detected. Examples for such differences:

Areas associated to settlements.

1. A case when we have buildings among other type of land

Figure 4 Physical blocks of Areas associated to settlements

2. A similar situation but different decision. The buildings are separated in a dedicated PhB – Sub-urban territories.

Figure 5 Physical blocks of Areas associated to settlements and Physical blocks of "Sub-urban territories" (buildings)

To solve this issue, we proceeded as follows. We extracted a 5% random sample for each of these categories and examined more carefully the polygons by using the Google Satellite. Then, we reinterpreted the sampled polygons according to their real permanent use and by treating similar polygons equally. Like this, we found out the average percentages of the real use for Courtyards: Pastures and meadows – 39%; Trees and shrubs -30%; Settlements – 25%; Arable land – 4%; Orchards– 1%. The analysis of the randomly extracted sample of polygons from a class "Areas associated to Settlements" showed that the real use of the land is: Pastures and meadows – 65%, Settlements – 24%, Trees and shrubs – 10%, Arable land – 1%. The examination of the polygons under the class Areas with poor vegetation proved that the real use of those polygons refers to Grassland category under the IPCC classes.

Another case which was examined was the class Mixed land-use, where the Grassland and Cropland categories have almost an equal distribution (46% Cropland, 45% Grassland). Referring to the class Mixed land use it should be noted that there is a clear trend in decreasing of this land cover class (by 48,69%) for the period of the study (2018-2020). This is related to improved mapping, because the responsible authority in Bulgaria dedicated special attention, resources, and human effort to resolve the issue with Mixed land use blocks by breaking down the polygons to smaller physical blocks and to determine more precisely the permanent usage of that land. The next screen shots are examples of this ongoing process of refinement in the mapping of physical blocks with more than one land use.

The polygon in 2018 is under Mixed land use block.

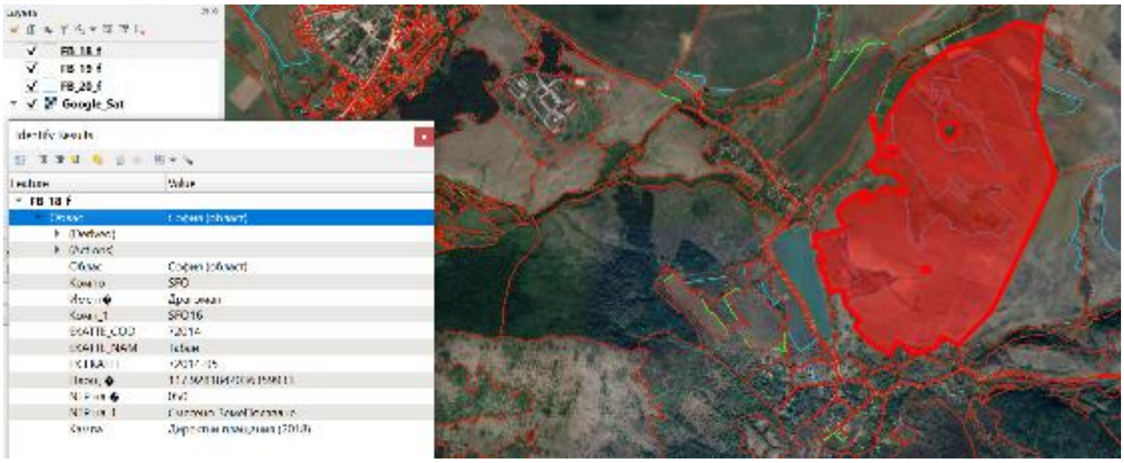


Figure 6 Physical block of Mixed land use class under LPIS in 2018

In 2020, the polygon is broken down to several polygons with disaggregation of the permanent use. In the first picture it is arable land whereas in the second one – pastures and meadows.

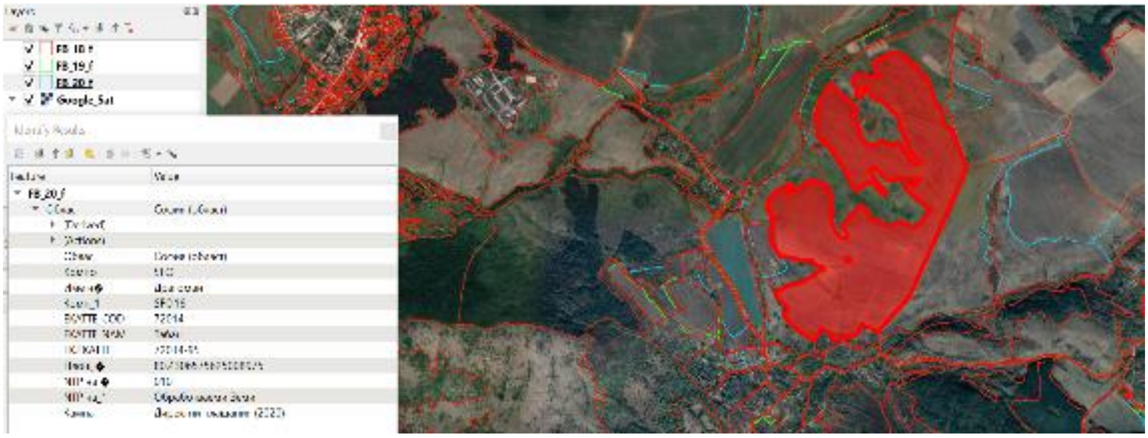


Figure 7 Physical block of Arable land class under LPIS in 2020

Figure 8 Physical block of Pasture and meadows class under LPIS in 2020

The results of the reinterpretation of the samples of the polygons of the abovementioned blocks have been confirmed later by the land use/cover, land use/cover change maps based on the GSAA layer (Table 6-Table 8).

Although, a distribution of the real use of such polygons have been derived, we decided to keep listed blocks separately for the geo-spatial operations and mapping, so to keep track on the changes. We followed this approach to make the assessment of land cover and land use changes more accurate. The changes stemming from real changes of land use and improved mapping should be unambiguously distinguished.

Taking into consideration the relatively small area (between 7.7 % in 2018 and 4.7% in 2020) covered by these types of blocks it could be considered possible to assign them to one or more land categories under the IPCC without introducing a significant error. In general, for the two blocks – Areas associated with settlements and Courtyards the best suitable IPCC category now appears to be the Grassland category. This could change in the near future, if more precise mapping is introduced, as it is currently ongoing for the Mixed land use blocks (reference parcels). We expect that in the near future all mapping issues would be resolved and thus these refined blocks (with grasslands and other land cover types, non-associated to built-up areas, excluded) could be assigned to Settlement's category under IPCC. The Settlements usually has complex land cover consisting of built-up, non-built-up artificial surfaces and associated, sometimes vegetated, areas. If we keep track of the changes in these lands by keeping them in separate category, this could allow us to refine the data in the past by using different splicing techniques. For the physical blocks "Mixed land use" outside of the declared data, currently the most appropriate IPCC category is "Shrubs and grasslands", which encompasses mainly secondary lawns and grasslands, but also all the area temporarily not extensively managed. Thus, they are not included in the area statistics under forestry or agricultural use, even though they are suitable for agricultural or silvicultural activities. This allocation of the temporarily unmanaged lands is necessary under the LULUCF reporting as the legacy effects of past management can continue for extended periods and having these lands under unmanaged category could result in anthropogenic emissions and removals being unreported.

The semantic mapping of the LPIS classes related to physical blocks (reference parcels) and IPCC categories and subcategories is provided in Table A: 1, Annex 1 Semantic mapping – tables

Semantic GSAA

The GSAA nomenclature follows the list of crops suitable for planting and cultivating. The nomenclature provides information on the crops and their type – cereals, oleaginous, etc. The semantic mapping on the GSAA with the IPCC categories have been done by disaggregating between annual and perennial crops regarding the Cropland category and pastures and meadows (as one subcategory) for the Grassland. As the nomenclature of the GSAA, regarding the crop type, is more detailed, we grouped them to make this information useful to combine it with different data source than IACS, considering that in general for the reporting there is a need to have a consistent and complete time series. In order to capture the legacy effect of carbon fluxes in the soils, there is a need for information on land use and land use changes for twenty years before the first year included in the time series, which for the Managed cropland and Managed grassland under the LULUCF Regulation is the year 2005.

The semantic mapping of the GSAA and IPCC classes is presented Table A: 2, Annex 1 Semantic mapping – tables

Semantic FMP

Forest territories in Bulgaria are managed by the Forest Law and its subordinated regulations and ordinances. The forest territories in Bulgaria consist of woodlands and non-woodlands.

The forests in Bulgaria are managed by Forest Management Plans (FMPs). FMPs provide the legal basis for pursuing economic activities and utilising forests. The forestry plans and programmes set the permissible level of use of forest resources and provide the guidelines for attainment of the forest area management objectives for a period of 10 years. The forest territories are covered by the scope of activities of the relevant State Forest Enterprises (SFE) and/or State Hunting Reserves (SHR). The forested areas within a SFE or a SHR are divided into compartments and sub-compartments. The sub-compartment is the smallest territorial unit which is the basis for inventory of resources and management. The area of one sub-compartment or forest management unit is between 1-25 ha, when forested. The area of the non-forested unit is 0,1 ha.

To merge the forestry data with the IACS database it was necessary to distinguish the wooded lands from the non-wooded to avoid any double counting of lands for the overlapping areas between the IACS/LPIS data and the forest management plans. This was done by classifying the forest territories by the attribute, which stores the information on the type of every sub-compartment within the area of the forest enterprises. So, a semantic mapping has been done between the defined type of sub-compartment as defined under the Forest Inventory and Planning Guidelines in Bulgaria (Ordinance №18/2015 Inventory and Planning of Forest Territories) and the predefined IPCC classes. The result of this mapping is presented in Table A: 3Annex 1 Semantic mapping – tables.

Databases and Spatial operations

The databases used for the LU and LUC mapping are: IACS data for the Sofia Province area – LPIS – Physical blocks layer, Eligible layer; GSAA. The merge of the IACS data with data from forest administration has been done for a single municipality within the study area – Svogue municipality. The Forest Management Plan of Svogue State Forest Enterprise has been obtained from a publicly available registry in *.ZEM format, which requires the use of a specific software to convert the file to a *.shp file. The FMP of Svogue SFE has been elaborated in 2015 and is valid for the period 2015-2025.

Table 2 Geo-spatial layers used for the pilot study. Area information is provided in ha.

Layers, ha	2018	2019	2020	Withstanding area
Physical Blocks, SFO	705,190.00	705,190.00	705,190.00	704,192.53
Eligible area, SFO	153,471.00	153,142.00	153,265.00	145,684.24
GSAA, SFO	186,494.00	180,545.00	175,921.00	120,267.89
FMP, Svogue Municipal	53,644.70	53,644.70	53,644.70	53,644.70

For the study period, the GSAA layer is by 20-15 % bigger than the Eligible layer, which is due to the uncertainty in the GSAA data pointed it out in the previous stage of the project. It is caused by: 1) Completely wrong geolocation delineated during declaration; 2) Declared activity/crop on the area which is bigger than the real area taken by the activity/crop; 3) Unfaithful declarations etc.

The area with the same geolocation in GSAA layer is ~83% of the unchanged areas within the Eligible layer. Using only that data we reduced most of the uncertainties described above, which is shown by the reversed proportion between GSAA and Eligible layer. The Eligible layer includes all the area

suitable for agricultural activity according to the judgement of the LPIS custodian. The GSAA, submitted by the farmer provides the most up to date information on the actual land use on annual basis. In case of an accurate representation of the GSAA layer we consider that this layer is a good data source to detect trends in land use changes in Managed cropland and Managed grassland.
The role of the Eligible layer in this study was restrained to the ancillary and verification data due to the fact, that the polygons in that layer do not have as an attribute the real land cover type which could be different from the appointed one for the physical block, where the eligible area is in for the studied period. After the responsible authority changed their approach, it will be possible to use the data in the Eligible layer as enough informative.

Spatial operations

In our approach we decided to work directly with the whole vector data as this was possible at regional level due to the size of the study area. However, this approach would not be feasible at national level, as it would require huge computation power. Thus, in the case of working with a larger area, it is advisable to use an approach, which is more suitable to work with Big data.

The geo-spatial analysis aiming at better representing the land use by using the GSAA and FMP data started with combining spatial data from GSAA and supplementing it with FMP and LPIS data for the rest of the region for the whole period. The result was one spatial layer with the attributes that represented the declared land use or defined land cover from FMP or LPIS for each year of the study period for the lands with same geolocation.

To extract the subsample of the area with the same geolocation for each of the layers, we firstly intersected the data for the whole period separately layer by layer. Then, the second step was to prioritize the datasets depending on the attributes they have. In that way we considered the data from the GSAA as the most accurate in respect to reporting of managed cropland and grassland areas, the FMP data - for the forest territories, and the PhB layer for the areas not covered by the GSAA and FMPs.

The final step was to unite the data from the subsample of the GSAA layer, the FMP layer and the PhB layer for the polygons outside the coverage of the previous two layers – GSAA and FMP. To accomplish the task, we extracted the polygons data for the GSAA and FMP from PhB data. The task could be done without such extraction but in that case, we would have worked with even bigger data and the prioritization of data would have been more complicated.

During all these operations it was important to consider that there is a risk of having “false” topologies of the polygons due to the application of spatial operations. This was avoided when the data were checked for validity after each step. If “false” geometries were found, they were removed very carefully, so that this would not trigger a loss of data.

In addition, a good practice is that the geometries with area less than a specified threshold are deleted. The area of the remaining polygons should be also recalculated regularly.

The accuracy of performing the geo-operation corresponded to the minimum mapping unit of the source data and the Sentinel spatial resolution data unit.

The minimum mapping unit in Bulgaria for agricultural parts of GSAA and LPIS is set to 0,1 ha. The same is the size for the FMP data. The minimum size for non-agricultural features found within parcels for GSAA and LPIS data is 0,01 ha, which is also the Sentinel pixel size. In an effort to perform better compatibility between the vector data and Sentinel, we decided to apply 0.01ha as minimum unit size for the GSAA data and LPIS non-agricultural features within the parcels and 0,1ha for FMP and the rest of the LPIS data.

The geo-spatial operations applied in these analyses consist mostly of vector geometry operations such as Vector selections; Select by location; Random selection. Vector overlay operations such as Crop; Differences; Intersections; Union; Detect dataset changes; Fix geometries; Join attributes; Join relationships; Data validation etc.

Optimal use of time series for consistent and reliable annual LULUCF reporting. Need of auxiliary data

The current study was performed for the years 2018-2020. However, in respect to reporting of LULUCF emissions and removals there is a need to have a complete and consistent time series of land use and land use changes. According to the IPCC methodology in order to capture the legacy effect of carbon fluxes in the different carbon pools, there is a need for information on land use and land use changes also for twenty years before the first year included in the time series. That means that for the accounting under the LULUCF Regulation the data on land representation and land use changes needed for accounting from categories Managed cropland and Managed grassland would be 1985 as under the Regulation the base year for the net-net accounting from these categories is an average of 2005-2009. Hence, if the IACS data in Bulgaria would be used for reporting there would be a need to combine the data with auxiliary sources. Such data could be the Bulgarian Survey of the Agricultural and Economic Conjuncture (BANSIK), The Farm structure/ Agricultural census, Cadaster map, Corine Land cover data etc. From that list the BANSIK statistics could meet the requirement for explicit land use information. BANSIK survey is based on the impartial technique of the sample excerpts of parts of territory since 1998. BANSIK survey studied the land use and cover over more than 111 000 points identified on the grounds of 3 123 square segments spread over 1 410 km of the country area and containing 36 points each, the distance between these points being 234 m. The physical nomenclature of the BANSIK survey is provided in Annex 3.

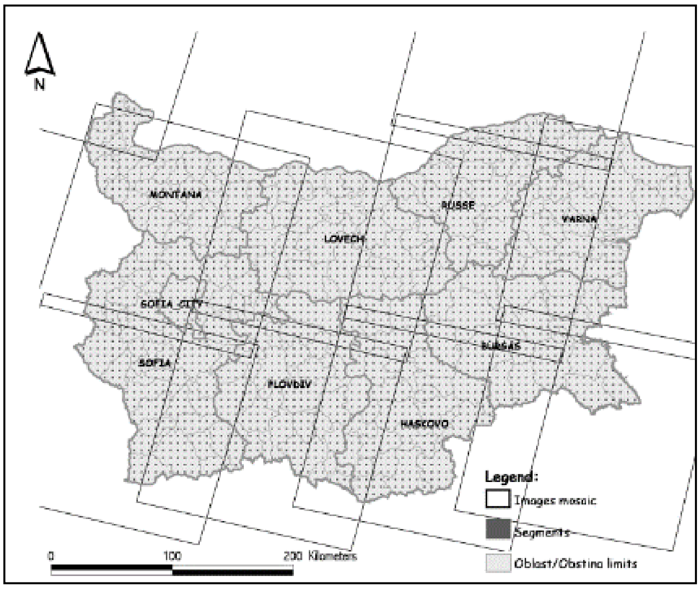


Figure 9 Sampling design of BANSIK

Another source of auxiliary spatially explicit data could be the Cadastre. However, most of the information in the Cadastre is based on the data from the Map of the restored rural property in Bulgaria, which is not updated and many changes in the land-use from the past are not considered.

Other sources of data which are not spatially explicit are: The National Statistics Yearbooks, which contain information on Cropland and Grassland areas for the years before 1998; and other agricultural census – farm surveys, etc.

Land representation and LUC matrices

As it was explained in more detail above, for the purpose of the elaboration of land use/cover and land use/cover change maps, we focused our work towards

1) Analysis of the practicability of the use of LPIS data to report on land representation and land use changes among all IPCC categories as the LPIS in Bulgaria covers the whole territory of the country;
2) Analysis of combining other IACS data or other spatially explicit data to improve the accuracy of the land cover/land use transitions detected from the analysis of the Physical block layer. In more details this consists of the following:
    a. Analysis the use of GSAA data to report on land use/cover and land use/cover changes from and to agricultural lands which could be useful for the accounting under the managed cropland and managed grassland.
    b. Analysis of the possibilities of merging the forestry data with the LPIS information on forest land.

LPIS data

As the LPIS data on physical block covers the whole territory of the country, the first step of our analysis was to extract the subsample of this layer which keep the same geolocation for the study period and to detect the changes. The physical block layer is rather stable; thus, the subsample is 99% of the total area of the layer for the study period. As it can be seen from the matrices below, the changes from the categories "Mixed land use" and "Courtyards" from 2018 till 2020 account for 45% of all land cover changes. As it was discussed above most of these changes are because of improved mapping and not real land use change. However, LPIS represent useful database in respect to LULUCF. Combining this data with other IACS information could improve the accuracy and correct the changes reported based on the improve mapping in LPIS. This could be done quite accurately for the cropland and grassland categories if the GSAA data is used.

Table 3 Land representation in SFO Province, based on the LPIS data on PhB, ha

	2018	2019	2020	Change, %
FL_IACS	377389.4	380047.6	380785.5	1%
ACL	57338.33	61443.6	65332.04	14%
PCL	2323.07	2285.1	2405.14	4%
PGM	115831.3	119959.6	124891.6	8%
SG	43606.37	43153.65	42430.26	-3%
WL	6710.86	6926.45	6864.23	2%
SM	29652.73	30047.08	31450.05	6%
OL	16884.5	16960.42	16954.74	0%
AAS	9476.62	9189.99	8605.85	-9%
CY	7234.19	6023.21	5100.02	-30%
MLU	37745.11	28155.92	19373.15	-49%
Total	704192.5	704192.5	704192.5	0%

Table 4 Land use change matrix for 2019, SFO Province, based on the LPIS data on PhB, ha

	FL_IACS	ACL	PCL	PGM	SG	WL	SM	OL	AAS	CY	MLU	Initial area, 2018
FL_IACS	376494.55	8.59	7.96	483.13	193.58	19.28	60.4	90.07	19.72	3.64	8.51	**377389.43**
ACL	75.75	54535.52	79.96	650.29	165.95	25.69	71.32	15.26	5.36	12.35	1700.88	**57338.33**
PCL	98.38	19.81	2037.06	45.53	37.79	0.31	1.44	1.2	6.61	4.25	70.69	**2323.07**
PGM	1010.06	609.39	56.6	110435.69	2484.66	40.34	194.6	114.66	36.89	28.99	819.44	**115831.32**
SG	1586.17	58.78	11.53	2392.23	39305.63	35.95	48.35	109.47	27.15	10.86	20.25	**43606.37**
WL	12.82	8.28	0.07	49.65	6.78	6619.5	6.61	0.23	0.53	1.64	4.75	**6710.86**
SM	99.43	22.57	2.48	402.54	290.64	152.34	28635.26	17.35	19.6	4.9	5.62	**29652.73**
OL	57.15	7.13		173.31	15.25	4.52	10.2	16605.55	6.72	0.12	4.55	**16884.5**
AAS	327.16	19.59	0.64	178.6	133.01	2.53	192.58	1.05	8581.28	34.81	5.37	**9476.62**
CY	62.92	4.88	0.84	63.03	103.65	0.36	759.93	0.08	382.38	5847.16	8.96	**7234.19**
MLU	223.16	6149.06	87.96	5085.56	416.71	25.63	66.39	5.5	103.75	74.49	25506.9	**37745.11**
Final area, 2019	**380047.55**	**61443.6**	**2285.1**	**119959.56**	**43153.65**	**6926.45**	**30047.08**	**16960.42**	**9189.99**	**6023.21**	**28155.92**	**704192.53**
Net change	***2658.12***	***4105.27***	***-37.97***	***4128.24***	***-452.72***	***215.59***	***394.35***	***75.92***	***-286.63***	***-1210.98***	***-9589.19***	***0***

Table 5 Land use matrix for 2020, SFO Province, based on LPIS data on PhB, ha

	FL_IACS	**ACL**	**PCL**	**PGM**	**MGL**	**WL**	**SM**	**OL**	**AAS**	**CY**	**MLU**	**Initial area, 2019**
FL_IACS	379550.23	9.69	3.59	152.44	240.63	7.93	23.38	45.91	3.82	3.73	6.2	**380047.55**
ACL	10.87	59660.69	53.98	967	74.04	8.34	65.2	11.66	0.15	15.8	575.87	**61443.6**
PCL	3.05	25.56	2225.2	15.1	5.1	0.03	0.71	0.13	0.55	0.19	9.48	**2285.1**
PGM	263.72	880.11	16.62	117235.87	816.35	13.12	165.16	27.38	4.31	10.14	526.78	**119959.56**
MGL	810.7	35.52	3.49	1246.94	40914.18	13.97	36.98	58.77	11.19	9.95	11.96	**43153.65**
WL	1.07	7.06	0.18	42.21	43.43	6805.68	14.31	7.36	0.24	2.66	2.25	**6926.45**
SM	61.03	21.76	0.36	97.24	45.36	0.63	29800.24	4.72	4.76	8.75	2.23	**30047.08**
OL	20.79	0.69	0.27	50.95	85.18	5.16	7.8	16788.15	0.01		1.42	**16960.42**
AAS	13.42	10.96	1.5	152.55	59.78	0.86	360.74	1.92	8558.19	29.94	0.13	**9189.99**
CY	5.48	2.18	0.64	51.17	26.8	0.31	947.22	1.81	6.4	4980.12	1.08	**6023.21**
MLU	45.09	4677.82	99.31	4880.13	119.41	8.2	28.31	6.93	16.23	38.74	18235.75	**28155.92**
Final area, 2020	**380785.45**	**65332.04**	**2405.14**	**124891.6**	**42430.26**	**6864.23**	**31450.05**	**16954.74**	**8605.85**	**5100.02**	**19373.15**	**704192.53**
Net change	***737.9***	***3888.44***	***120.04***	***4932.04***	***-723.39***	***-62.22***	***1402.97***	***-5.68***	***-584.14***	***-923.19***	***-8782.77***	

GSAA data

GSAA application layer could be useful tool for the purpose of the reporting and accounting of managed cropland and managed grassland in the LULUCF sector. It includes quantitative data on parcel area, boundaries and qualitative data on crop description. The layer store attributes on the permanent use of the physical blocks where the agricultural parcel is located, as well as information on the actual land use of the parcel according to the farmer's declaration. This provides good opportunity to check the representation of lands between the physical block classes mapped according to the IPCC categories and subcategories and the GSAA – annual, perennial crops, and pastures and meadows. As it could be seen from Table 6 – Table 8, the overlap between the defined physical block class and the real use is very good and it improves each year– 75% for annual crops, 76% for pastures and meadows and 67% for perennial crops for 2018 and 85% for annual crops, 84% for pastures and meadows and 80% for perennial crops in 2020. However, if the land representation from the GSAA layer is elaborated on the mapped categories according to IPCC on a parcel level (Table 9), the dynamic in the three categories is not so big. This confirms once again the process of the improved mapping in LPIS (physical blocks layer) discussed above. The results of the reinterpretation of the polygons of the LPIS classes – "Areas associated with settlements", "Courtyards", and "Mixed land use" have also been confirmed by this comparison (Table 6 – Table 8).

It should be noted that for each year two datasets for LPIS are available. One which is used in the declaration process, and one at the end of the year which includes the updated data within the year. In the study, we used the declaration dataset, so those percentages could look different using the LPIS dataset after the update in the year.

Table 6 Area from GSAA layer disaggregated by the mapped physical block attributes and the mapped GSAA nomenclature, 2018, ha

IPCC by Ph. bl.\ IPCC by GSAA	ACL	PCL	PGM	Total
FL_IACS	2.08	1.99	248.73	**252.8**
ACL	46111.03	98.28	1791.43	**48000.74**
PCL	200.59	740.92	41.97	**983.48**
PGM	1505.07	64.68	44068.39	**45638.14**
SG	24.75	1.91	340.46	**367.12**
WL	0.77	0.22	19.56	**20.55**
SM	2.78	0.48	5.61	**8.87**
OL	0.69	0.04	1092.55	**1093.28**
AAS	20.7	4.34	264.88	**289.92**
CY	19	5.94	100.07	**125.01**
MLU	13430.29	192.93	9864.76	**23487.98**
Total	**61317.75**	**1111.73**	**57838.41**	**120267.9**

Table 7 Area from GSAA layer disaggregated by the mapped physical block attributes and the mapped GSAA nomenclature, 2019, ha

IPCC by Ph. Bl.\IPCC by GSAA	ACL	PCL	PGM	Total
FL_IACS	0.57	0.85	179.60	**181.02**
ACL	49466.42	77.55	1765.12	**51309.09**
PCL	186.49	827.97	30.52	**1044.98**
PGM	1466.39	31.48	46268.52	**47766.39**
SG	2.72	0.64	52.14	**55.50**
WL	0.41	0.20	7.10	**7.71**
SM	1.25	0.55	2.88	**4.68**
OL	0.02	0.12	990.66	**990.80**
AAS	19.42	4.42	236.59	**260.43**
CY	18.42	7.27	96.93	**122.62**
MLU	9994.53	145.77	8384.37	**18524.67**
Total	**61156.64**	**1096.82**	**58014.43**	**120267.89**

Table 8 Area from GSAA layer disaggregated by the mapped physical block attributes and the mapped GSAA nomenclature, 2020, ha

IPCC by Ph. Bl.\IPCC by GSAA	ACL	PCL	PGM	Total
FL_IACS	0.83	0.82	176.86	**178.51**
ACL	52973.28	56.36	1823.9	**54853.54**
PCL	274.3	840.27	37.30	**1151.87**
PGM	1630.57	28.68	48509.15	**50168.4**
SG	2.31	0.63	22.20	**25.14**
WL	0.43	0.14	3.16	**3.73**
SM	0.17	0.52	1.85	**2.54**
OL	0.09	0.12	988.94	**989.15**
AAS	17.95	3.75	225.09	**246.79**
CY	20.19	6.21	103.17	**129.57**
MLU	6580.68	120.71	5817.26	**12518.65**
Total	**61500.8**	**1058.21**	**57708.88**	**120267.89**

Table 9 Area from GSAA layer distribution by IPCC categories for the study period, ha

IPCC	2018	2019	2020	Change, %
ACL	61317,23	61156,12	61500,28	0.30%
PCL	1111,73	1096,82	1058,21	-4.81%
PGM	57838,41	58014,43	57708,88	-0.22%
Grand Total	**120267,37**	**120267,37**	**120267,37**	

As it was described in the overview of the approach we used, the land representation and land use changes within the GSAA layer have been traced for a subsample of the layer which represents the lands with the same geolocation over the study period. With this almost all the fluctuation in the GSAA layers for the study period are discarded, enabling us to trace and map only conversions representing a real land use change. Again, we decided to present the land use matrices here in two variants – based on the information on the physical block of the land parcels and based on the land use of the parcels (Table 10 – Table 13).

Table 10 Land use change matrix 2019, GSAA data – attribute on physical blocks, ha

	FL_IACS	ACL	PCL	PGM	SG	WL	SM	OL	AAS	CY	MLU	Initial area, 2018
FL_IACS	177.58	0.86	1.65	69.87				0.01	0.25	0.17	2.41	**252.8**
ACL	0.44	46223	63.23	365.89	1.75	0.02	0.26	0.35		0.26	1345.4	**48000.74**
PCL	0.07	14.61	891.71	19.7	0.24		0.01	0.12	0.7	0.6	55.72	**983.48**
PGM	2.71	380.21	39.3	44668	14.81	0.33	0.44	0.79	3.15	9.26	519.32	**45638.14**
SG	0.21	21.14	0.26	301.16	37.48				0.05		6.82	**367.12**
WL		0.38	0.02	12.78		7.36					0.01	**20.55**
SM		0.79	0.3	3.61	0.01		3.17			0.01	0.98	**8.87**
OL		0.77		102.65				989.53			0.33	**1093.28**
AAS		3.76	0.34	31.15					249.75	4.8	0.12	**289.92**
CY		1.74	0.63	15.43					2.73	103.2	1.28	**125.01**
MLU	0.01	4661.7	47.54	2176.3	1.21		0.8		3.8	4.32	16592	**23487.98**
Final area, 2019	**181.02**	**51309**	**1045**	**47766**	**55.5**	**7.71**	**4.68**	**990.8**	**260.43**	**122.62**	**18525**	**120267.89**
Net change	***-71.78***	***3308.4***	***61.5***	***2128.3***	***-311.6***	***-12.84***	***-4.19***	***-102.5***	***-29.49***	***-2.39***	***-4963***	***0***

Table 11 Land use change matrix 2020, GSAA data – attribute on physical blocks, ha

	FL_IACS	ACL	PCL	PGM	MGL	WL	SM	OL	AAS	CY	MLU	Initial area, 2019
FL_IACS	176.99	0.18	0.05	3.67	0.05			0.01			0.07	**181.02**
ACL		50366	36.55	467.48	0.02	0.19	0.09			3.44	435.35	**51309.09**
PCL		13.87	1025	2.57							3.51	**1044.98**
PGM	1.29	625.28	12.15	46826	0.38		0.05	0.05	0.54	1.5	299.04	**47766.39**
MGL		0.39		30.34	24.69			0.07			0.01	**55.5**
WL			0.06	4.12		3.53						**7.71**
SM		1.9	0.06	0.33			2.38				0.01	**4.68**
OL				1.76			0.02	989.02				**990.8**
AAS		6.09	0.62	14.77					237.42	1.53		**260.43**
CY		1.05	0.31	4.84						116.3	0.12	**122.62**
MLU	0.23	3838.8	77.04	2812.4		0.01			8.83	6.8	11781	**18524.67**
Final area, 2020	**178.51**	**54854**	**1151.9**	**50168**	**25.14**	**3.73**	**2.54**	**989.15**	**246.79**	**129.57**	**12519**	**120267.89**
Net change	***-2.51***	***3544.5***	***106.89***	***2402***	***-30.36***	***-3.98***	***-2.14***	***-1.65***	***-13.64***	***6.95***	***-6006***	***0***

Table 12 Land use change matrix 2019, GSAA data – attribute on crop description, ha

	ACL	PGM	PCL	Initial area, 2018
ACL	59627.13	1649.13	41.49	**61317.75**
PGM	1487.91	56339.11	11.39	**57838.41**
PCL	41.6	26.19	1043.94	**1111.73**
Final area, 2019	**61156.64**	**58014.43**	**1096.82**	**120267.89**
Net change	***-161.11***	***176.02***	***-14.91***	***0***

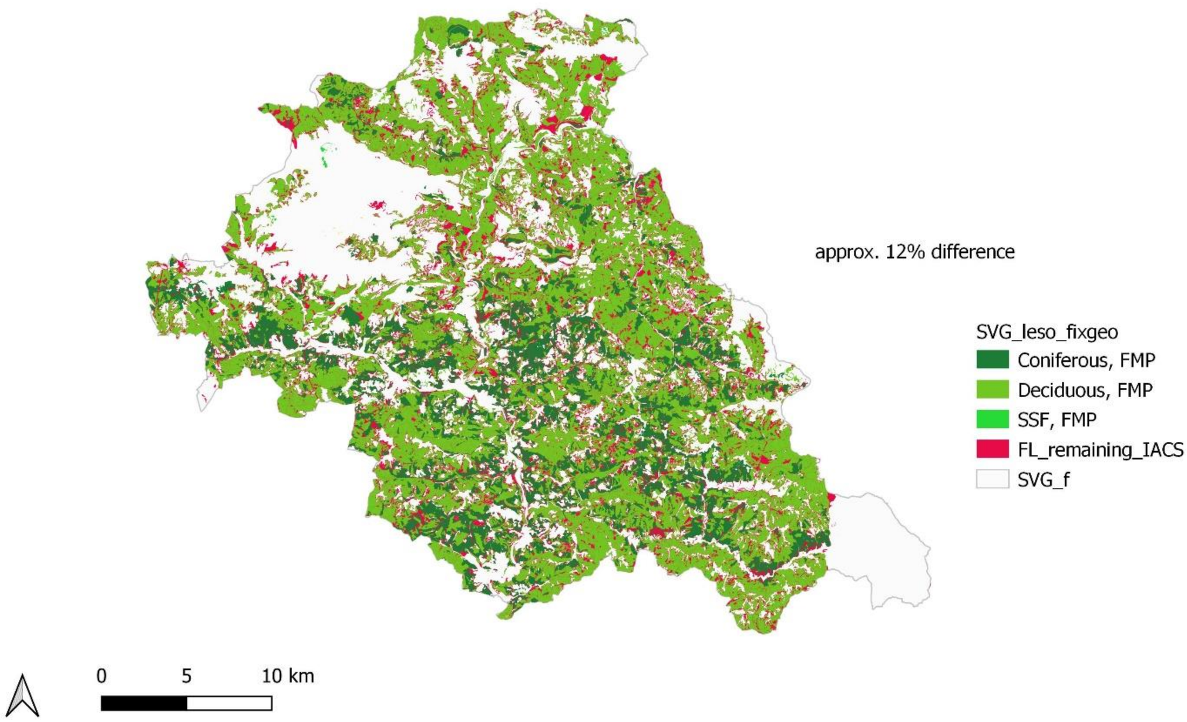
Table 13 Land use change matrix 2020, GSAA data – attribute on crop description, ha

	ACL	PGM	PCL	Initial area, 2019
ACL	59583.06	1548.1	25.48	**61156.64**
PGM	1866.17	56125.15	23.11	**58014.43**
PCL	51.57	35.63	1009.62	**1096.82**
Final area, 2020	**61500.8**	**57708.88**	**1058.21**	**120267.89**
Net change	***344.16***	***-305.55***	***-38.61***	***0***

The result of this analysis confirms that the GSAA layer has the potential to be used in reporting of Cropland and Grassland categories, assuming that the data is accurate and could be directly linked to these categories. However, the GSAA includes only the agricultural lands of farmers that receive payments under CAP, but we could consider that these lands include almost all agricultural lands with agricultural activities although some could be outside of GSAA if the farmer does not receive subsidy under CAP. As the GHGI in LULUCF aims at estimating the emissions and removals related to the land use and land use changes of particular importance is that the legacy effect of the land would be considered. Thus, in respect to the LULUCF reporting under the UNFCCC and Regulation 841/2018, it is also important to keep track on the croplands and grasslands that are temporarily not managed but have been managed in the past. This could be traced by using the LPIS data for the area outside the scope of the GSAA layer or by extrapolating the land representation and land use changes derived from the GSAA to the area of the Eligible layer. In that pilot we applied the first option.

Merging forestry data

In order to reduce the uncertainty for the land use transitions outside the agricultural area and most importantly in the forest territories, possible approach is to complement the IACS data with data from Forest Management Plans. As it was described, discrepancies between the LPIS data on Forest land (FL) and FMP could be expected as the LPIS is more related to the land cover whereas the FMP provide more accurate information on the forest management or managed forest lands. The analysis shows that the LPIS forest layer is bigger than the one from FMP. The difference is 12% as this refers to the area with the same geolocation of the forest polygons in LPIS, so in some years the difference is even bigger.



Map 1 Comparison of the forest land between the LPIS and FMP data

Merging the FMP data with IACS data could reduce the uncertainty in the land use changes as for Bulgaria, the forest territories account for almost 35% of the country's territory. By having also, the agricultural lands, which are well presented under IACS, this means that there is a possibility to cover almost 85% of the country with accurate databases, which meet the requirements for spatially explicit data. The figures below show that the differences between Forest territories by FMP and LPIS are in the periphery of the polygons which by itself is a confirmation that difference between the data refers to the difference between land cover and land use concepts. Examples of the overlaps and discrepancies between the FMP data (green polygons) and LPIS data (red contour) are presented below.

1. On the first image, the areas, outlined in red are recorded as forest in LPIS. Filled in green polygons are the forest lands according to FMP. As it could be seen, the areas delineated as forest in LPIS, but not included in the SFE and its FMP are indeed tree formations. However, in the example below these formations are within agricultural lands, thus their land's designation probably is under agricultural fund.

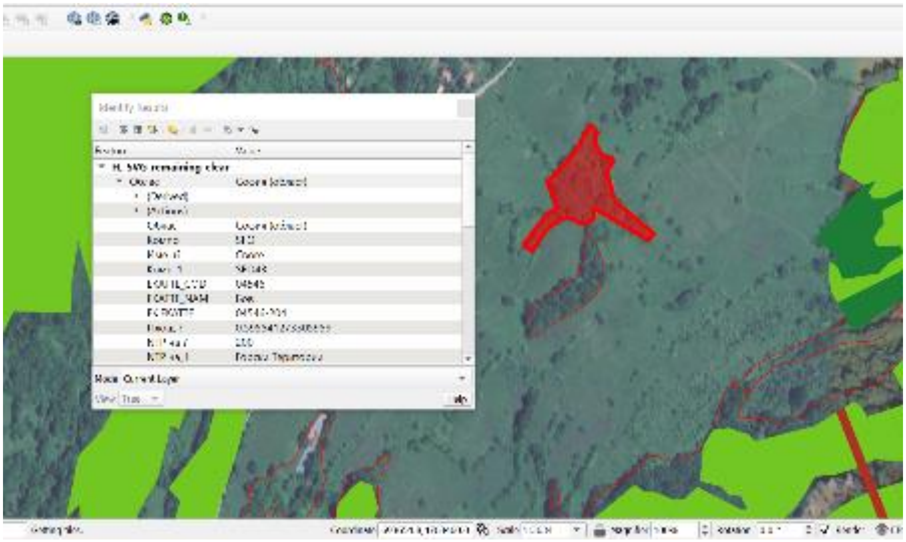


Figure 10 Overlaps and differences between the physical block of Forest in LPIS and the wooded lands according to FMP

2. On the second picture, it can be seen another example of the differences which have been detected. The example below shows that in LPIS the mapping is more aggregated in this case which could be explained also with the scale used for orthophoto interpretation under LPIS.

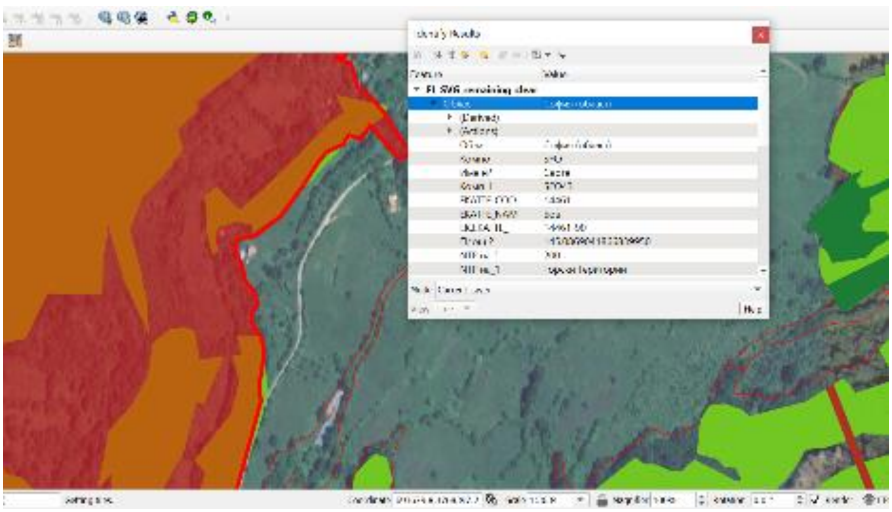


Figure 11 Overlaps and differences between the physical block of Forest in LPIS and the wooded lands according to FMP

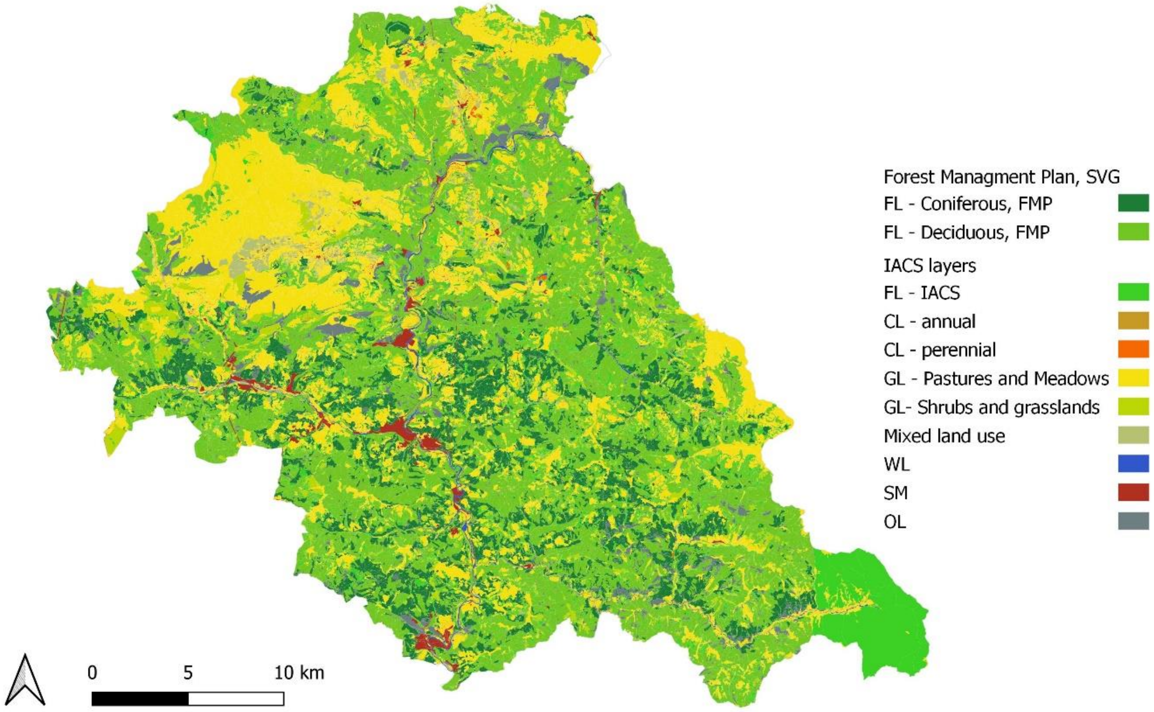
These differences appear primarily on the abandoned neighboring agricultural areas, which are conquered by the tree species. As it was explained already from the observational point of view, these lands meet the definitions of forests according to the Forest Law, but they are on lands under agricultural designation and not recorded in FMP. This requires an administrative procedure to change the designation of these lands to forest territory so to be mapped, to be included in the forest statistics and to be managed according to the Forest Law and its subordinated regulations. That is why it should be noted that the figures on land use changes according to the LPIS data from FL to other land use in most cases refer to lands which by their land cover characteristics are forests, but they are not managed as forest lands in the country as they are not part of the forest territories and thus are not subject to forest inventory and monitoring. This should be considered in case of direct use of the LPIS data for land representation and land use change reporting in Bulgaria. A possible solution here is to integrate the forestry data with the LPIS data or to use expert judgement for the better allocation of the lands subject to change from FL to agricultural lands as this by means refer to lands, which are not managed forestland. The update frequency of the non-agricultural (ex. Forest) data in the LPIS is the same as for the agricultural areas, according to national legislation.

In general, the merging of the forestry data could be done in a similar manner as with GSAA layer. However, the process is somehow jeopardized by the specifics of the spatially explicit data in the forestry sector in Bulgaria. This refers to the following:

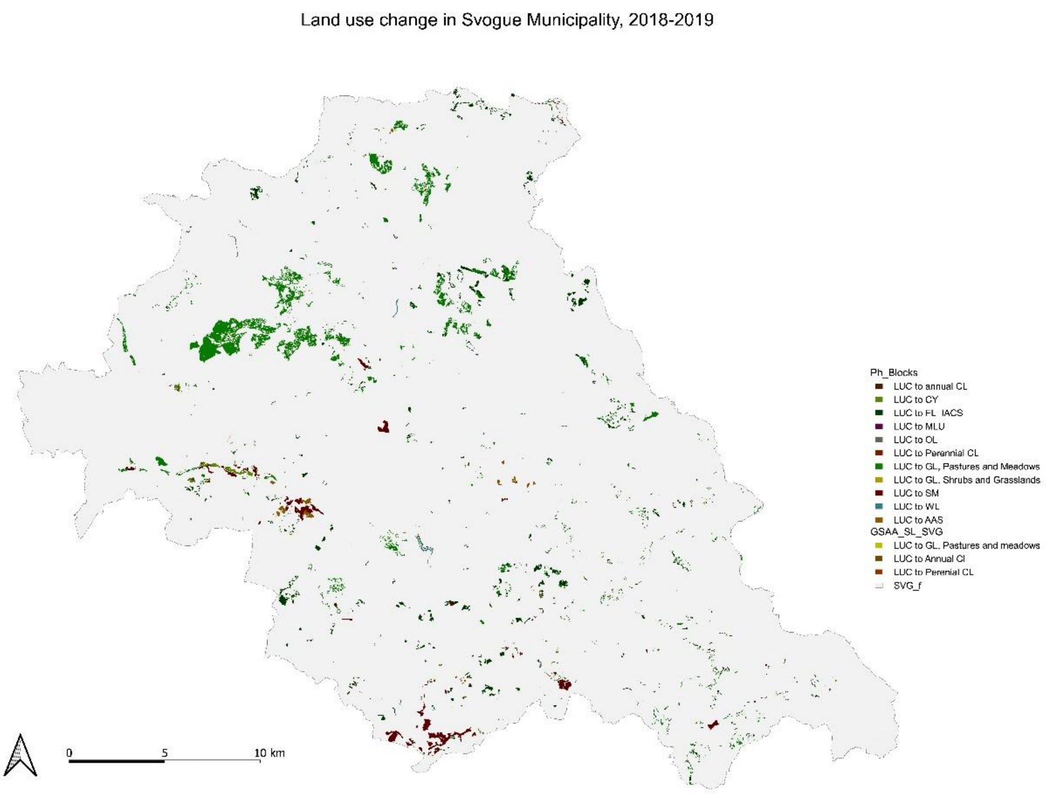
- The FMP plans are updated once in 10-12 years' period. Thus, if we merge all forestry data, the geo-spatial data on forest compartments and sub-compartments across the country would not represent the actual situation now, as for some State forest enterprises the spatial data could be 10 years old. This requires an additional workaround in order to get the area with the same geolocation. However, as the changes are not so dynamic as in agricultural land this approach is considered to deliver quite accurate results.
- There are many changes in the boundaries of the forest enterprises and/or sub-compartments which could interfere with the data processing and geo-analysis.
- The need of specific software to convert the *.zem files into *.shp format

Combining all data

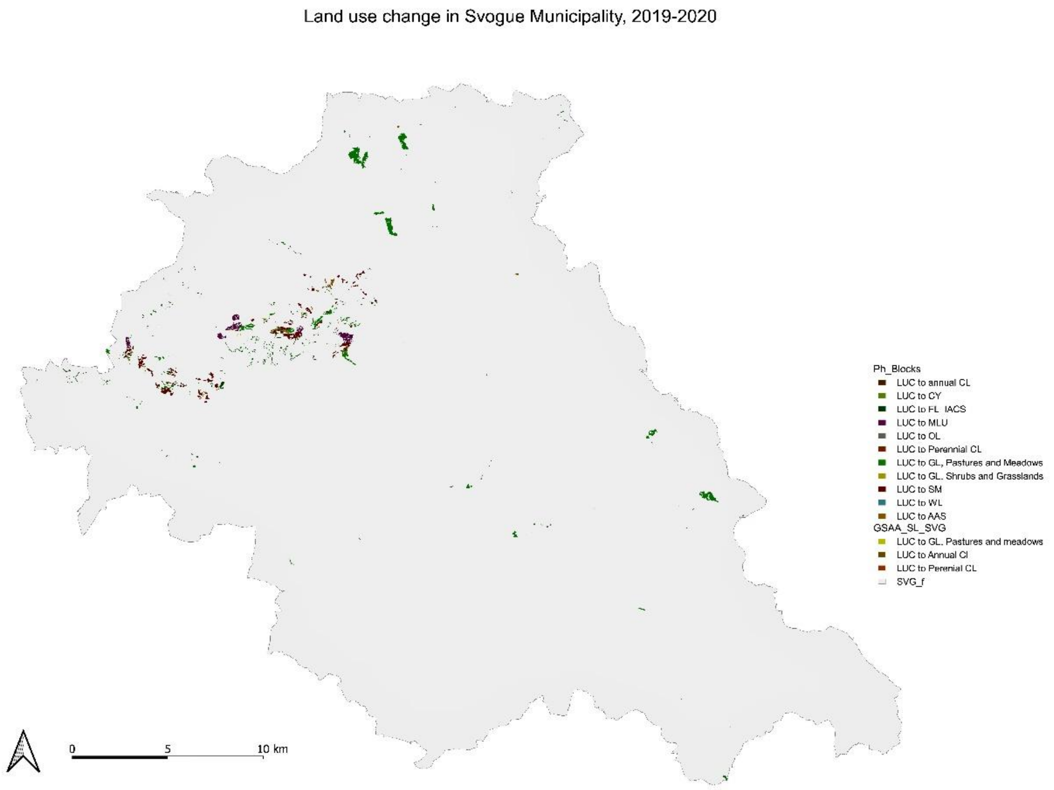
If the GSAA layer is used for CL and GL representation and the forestry data for FL, the land use changes in the area not covered by these data could be derived from the LPIS data which does not fall within the GSAA layer or FMP data. For this pilot study the merging of the forestry data has been done only for a single municipality as the forestry data is publicly available only at State forest enterprise level and combining that data for Sofia Province would require technical time for processing and analyzing the data. However, an example of the work on merging the IACS with FMP data is provided on the maps below. This approach could be in general implemented at regional or national level after considering the above-mentioned characteristics of the forestry data from the FMPs and allocation of time and human resources.



Map 2 Land representation of Svogue Municipality, 2018, combined data



Map 3 Land use change in Svogue Municipality in 2019



Map 4 Land use change in Svogue municipality in 2020

The mapping of land representation and land use changes at district level (Sofia Province) have been done after combining the data we have analyzed and described until now – GSAA and FMP and complemented with the LPIS data on PhB. Like this it should be noted that the representation of the FL area and land use changes from and to FL according to the land transition matrix is biased by the concept on land cover as most of the data on FL refer to the LPIS data.

Table 14 Area distribution of the PhB by IPCC categories for the study period (LPIS outside the data covered by GSAA and FMP), ha*

IPCC	2018	2019	2020	Change, %
FL_IACS	328436.26	331001.52	331693.22	1%
ACL	9713.18	10535.07	10919.39	12%
PCL	1343.92	1248.59	1261.35	-6%
PGM	69394.61	71232.88	73824.36	6%
SG	41561.23	41682.69	41028.99	-1%
WL	6636.73	6864.12	6805.87	3%
SM	29180.87	29558.47	30959.15	6%
OL	15530.21	15710.61	15706.67	1%
AAS	8755.62	8574.57	8010.82	-9%
CY	7060.48	5864.43	4936.46	-30%
MLU	14632.93	9973.09	7099.76	-51%
Total	**532246.04**	**532246.04**	**532246.04**	**0**

** The categories AAS, CY, MLU remain as in LPIS*

Table 15 LUC matrix for 2019, LPIS outside the data covered by GSAA and FMP, ha

	FL_IACS	ACL	PCL	PGM	SG	WL	SM	OL	AAS	CY	MLU	Initial area, 2018
FL_IACS	327858	7.65	6.31	218	155.43	18.67	56.16	88.98	17.68	3.4	6.09	**328436.26**
ACL	75.3	8665.2	18.07	286.46	164.06	25.67	70.69	14.91	5.36	12.09	375.37	**9713.18**
PCL	98.19	5.21	1148.1	26.16	37.55	0.31	1.37	1.08	5.92	3.65	16.37	**1343.92**
PGM	934.76	231.4	17.23	65099	2405.6	39.85	192.61	109.43	34.02	19.89	310.56	**69394.61**
SG	1320.9	37.66	11.26	1979.1	37969	35.52	47.27	109.46	26.61	10.84	13.44	**41561.23**
WL	12.64	7.91	0.05	36.87	6.69	6558.9	6.55	0.23	0.48	1.64	4.74	**6636.73**
SM	97.66	21.78	2.19	398.88	290.61	152.34	28173	16.97	17.94	4.89	4.63	**29180.87**
OL	52.08	6.21		68.48	15.02	4.52	9.88	15363	6.48	0.12	4.22	**15530.21**
AAS	270.23	15.85	0.3	141.66	121.41	2.32	185.06	0.79	7982.8	29.94	5.25	**8755.62**
CY	61.72	3.13	0.21	47.6	103.38	0.36	750.91	0.08	377.55	5707.9	7.68	**7060.48**
MLU	220.19	1533.1	44.86	2930.4	413.73	25.63	64.99	5.48	99.72	70.11	9224.7	**14632.93**
Final area, 2019	**331002**	**10535**	**1248.6**	**71233**	**41683**	**6864.1**	**29558**	**15711**	**8574.6**	**5864.4**	**9973.1**	**532246.04**
Net change	***2565.3***	***821.89***	***-95.33***	***1838.3***	***121.46***	***227.39***	***377.6***	***180.4***	***-181.1***	***-1196***	***-4660***	***0***

Table 16 LUC matrix 2020, LPIS outside the data covered by GSAA and FMP, ha

	FL_IACS	ACL	PCL	PGM	SG	WL	SM	OL	AAS	CY	MLU	Initial area, 2019
FL_IACS	330514	9.51	3.54	146.73	237.46	7.93	23.31	45.85	3.65	3.73	6.13	**331001.52**
ACL	10.87	9673.9	17.47	503.57	74.02	8.15	65.06	11.5	0.15	12.36	158.05	**10535.07**
PCL	3.05	13.12	1207.4	12.51	5.06	0.03	0.71	0.06	0.55	0.19	5.96	**1248.59**
PGM	251.25	267.78	4.4	69457	804.41	13.12	164.76	27.26	3.78	8.64	230.19	**71232.88**
SG	769.19	35.13	3.49	1201.8	39531	13.97	36.76	58.66	11.17	9.83	11.96	**41682.69**
WL	1.07	7.06	0.12	38.1	43.43	6747.5	14.31	7.36	0.24	2.66	2.25	**6864.12**
SM	60.96	19.85	0.32	96.84	45.11	0.63	29314	4.72	4.76	8.75	2.22	**29558.47**
OL	20.65	0.69	0.27	49.18	85.18	5.16	7.4	15541	0.01		1.42	**15710.61**
AAS	12.25	4.87	0.88	135.77	57.62	0.86	359.25	1.92	7972.7	28.29	0.13	**8574.57**
CY	5.43	1.13	0.34	46.12	26.65	0.31	945.22	1.79	6.4	4830.1	0.96	**5864.43**
MLU	44.82	886.38	23.17	2136.5	119.28	8.19	28.06	6.9	7.38	31.93	6680.5	**9973.09**
Final area, 2020	**331693**	**10919**	**1261.4**	**73824**	**41029**	**6805.9**	**30959**	**15707**	**8010.8**	**4936.5**	**7099.8**	**532246.04**
Net change	***691.7***	***384.32***	***12.76***	***2591.5***	***-653.7***	***-58.25***	***1400.7***	***-3.94***	***-563.7***	***-928***	***-2873***	

Although the area occupied by the PhB classes on Areas associated to settlements, Courtyards, and Mixed land use, represent between 6% in 2018 and 4% in 2020 from the area of LPIS layer outside the data covered by GSAA and FMP, these categories account for more than 43% of the changes in land use in that layer for the study period. That is why we have kept these categories separately in the analysis and in the mapping. However, in the tables below we allocated these categories under the Pastures and meadows (PGM) and Shrubs and grasslands (SG) and prepared the LUC matrices according to the IPCC land categories classification (Table 17, 18). The results of the land use change mapping and assessment for the study area are consistent with the trends in the land use changes reported under the GHGI. It should be stressed that some of the detected changes appear to be considered as not possible (for example OL converted to annual CL, Table 17), but the area of such changes is rather small. This could be further improved by ex-post work with the results without considering their geographical representation. This is considered as possible approach under the UNFCCC inventory preparation as according to the 2006 IPCC Guidelines, mix of approaches for land representation is possible when the inventory is prepared.

Table 17 Land use change matrix 2019, SFO Province, based on combined data, ha

	FL_IACS	ACL	PCL	PGM	SG	WL	SM	OL	Initial area, 2018
FL_IACS	381473.32	7.65	6.31	235.68	164.92	18.67	56.16	88.98	**382051.69**
ACL	75.30	67479.70	118.25	2699.17	551.52	25.67	70.69	14.91	**71035.21**
PCL	98.19	54.11	2176.59	66.43	57.57	0.31	1.37	1.08	**2455.65**
PGM	1204.99	1905.25	36.59	129423.54	2892.61	42.17	377.67	110.22	**135993.04**
SG	1602.77	1573.86	56.33	5460.95	53521.08	61.51	863.17	115.02	**63254.69**
WL	12.64	7.91	0.05	37.35	13.07	6558.93	6.55	0.23	**6636.73**
SM	97.66	21.78	2.19	416.82	300.13	152.34	28172.99	16.97	**29180.88**
OL	52.08	6.21		74.96	19.36	9.88	4.52	15363.20	**15530.21**
Final area, 2019	**384616.95**	**71056.47**	**2396.31**	**138414.90**	**57520.26**	**6869.48**	**29553.12**	**15710.61**	**706138.10**
Net change	***2565.26***	***21.26***	***-59.34***	***2421.86***	***-5734.43***	***232.75***	***372.24***	***180.40***	

Table 18 Land use change matrix 2020, SFO Province, based on combined data, ha

	FL_IACS*	ACL	PCL	PGM	SG	WL	SM	OL	Initial area, 2019
FL_IACS*	384129.11	9.51	3.54	150.38	247.32	7.93	23.31	45.85	**384616.95**
ACL	10.87	68047.92	58.01	2610.53	244.43	8.15	65.06	11.50	**71056.47**
PCL	3.05	72.46	2251.10	57.69	11.21	0.03	0.71	0.06	**2396.31**
PGM	263.50	2576.68	28.52	133849.75	1129.28	13.98	524.01	29.18	**138414.90**
SG	819.44	922.65	27.00	3409.32	51241.99	22.47	1010.04	67.35	**57520.26**
WL	1.07	7.06	0.12	38.34	48.34	6747.52	14.31	7.36	**6864.12**
SM	60.96	19.85	0.32	101.60	56.08	0.63	29314.32	4.72	**29558.48**
OL	20.65	0.69	0.27	49.19	86.60	5.16	7.40	15540.65	**15710.61**
Final area, 2020	**385308.65**	**71656.82**	**2368.88**	**140266.80**	**53065.25**	**6805.87**	**30959.16**	**15706.67**	**706138.10**
Net change	***691.70***	***600.35***	***-27.43***	***1851.90***	***-4455.01***	***-58.25***	***1400.68***	***-3.94***	***0***

Maps of LU/LUC

The maps on land representation and land use changes are provided in the Annex 2 Maps of Land use and land-use changes to this report.

Accuracy

Minimum mapping unit

The minimum mapping unit for agricultural parts of GSAA, FMP and LPIS is set to 0.1 ha. The minimum size for non-agricultural features found within parcels for GSAA and LPIS data is 0.01 ha, which is also the Sentinel pixel size. In effort to perform better compatibility between the vector data and Sentinel we decided to apply 0.01ha as minimum unit size for the GSAA data and LPIS non-agricultural features within the parcels and 0.1ha for FMP and the rest of the LPIS data.

It should be noted that IACS vector data in Bulgaria is mostly delineated by using different sources of very high resolutions images (less than 0.5cm) and partially on measurements made by GNSS receivers with accuracy under 1m.

However, our recommendation is that the threshold of the mapping unit should be defined according to the minimal size of each of the data products (GSAA, LPIS, FMP) according to their specifications. As it can be observed in tables Land use change matrix, GSAA data – attribute on physical blocks (Table 10Table 11) "strange" transitions between the categories could appear when we do not apply the minimum unit size for the given data. For example, 0.01 ha defined as a change from Forest Land in 2018 to Other land in IACS in 2019. In these tables, the land-use change is spatially based on the GSAA data with 0.01 ha accuracy but represented with the attribute for land cover from LPIS data which accuracy is 0.1ha. To avoid that kind of mistakes, we should not represent one dataset with the attribute from another, or at least we should apply the appropriated accuracy. If we use the correct accuracy, we should exclude as a land cover change all areas less than 0.1ha.

Accuracy of land cover / land use change detection based on vector and raster data

In respect of the study, we tried to use data from Sentinel satellites for tracking land use/cover changes in a very simple method only to check the compatibility of the accuracy used with the vector data in respect to use the same accuracy with the Sentinel raster data. Sentinel data is with resolution 10x10m, which very well covers in theory our working minimum unit – 0.01ha for GSAA data. But having the Sentinel-2, pixel size as 10x10 meters, does not mean that we could map out features with MMU of 100m2. We might be able to detect a presence of something on the land with such size, but this feature should be much bigger in order that we could detect its nature and even estimate its area. More information could be found in JRC TG on Management of Layers in LPIS. The internal studies of

JRC done in the frame of the Checks by Monitoring, show that features should be at least 0.1ha – 0.2 ha in order to depict their size from Sentinel with sufficient reliability.

For that purpose, we used one tile of raster data from one and the same month of each year. We calculated the NDVI for that raster and the data change in the years, followed by calculating raster statistic for the polygons included in the united vector layer with the data from all years within.

The raster data used is tile T34TFN, product L2A (atmospherically corrected) form 08 June 2018, 13 June 2019, and 27 June 2020. The images have under 5% clouds and don't have no data in them. From that images, the NDVI was extracted and the change of NDVI between the years of the study calculated, and zonal statistics by IPCC categories defined in the vector data for GSAA and LPIS were made.

The formulas used for processing the raster are:

- For NDVI – (band 8(NIR) – band 4(RED)) / (band 8 (NIR)+ band 4(RED))
- For Data change in NDVI – (NDVI 2019 – NDVI 2018) and (NDVI 2020 – NDVI 2019)

Zonal statistic by IPCC categories based on LPIS and GSAA data per each of the studied years are shown in the tables below.

Table 19 Zonal statistic, 2018

IPCC_18	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM	5993995	599399500	-0,08990179	0,999395967	1,089297757	0,712841746	0,123172626	4272769,859
SG	1896004	189600400	-0,284276724	0,92268455	1,206961274	0,740857658	0,114098697	1404669,083
MLU	750106	75010600	-0,043732632	0,998881459	1,042614091	0,669468271	0,147769605	502172,1666
FL_IACS	6526140	652614000	-0,271739125	0,924805641	1,196544766	0,798313484	0,096875178	5209905,557
SM	1044301	104430100	-0,168803424	0,999557912	1,168361336	0,551412931	0,189334506	575841,0754
OL	173642	17364200	-0,071550258	0,896606922	0,96815718	0,616442346	0,171140548	107040,2819
ACL	2995567	299556700	-0,091669343	0,903471291	0,995140634	0,528088494	0,158628223	1581924,467
AAS	625714	62571400	-0,126110122	0,922403574	1,048513696	0,777037706	0,093101125	486203,3709
WL	188376	18837600	-0,288804084	0,901433349	1,190237433	0,640924725	0,21344265	120734,8361
CY	398600	39860000	-0,43695581	0,908272624	1,345228434	0,704411626	0,128501653	280778,4742
PCL	30369	3036900	0,124503314	0,901113927	0,776610613	0,650373088	0,155761252	19751,18031

Table 20 Zonal statistic, 2019

IPCC_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM	6155487	615548700	-0,089	0,999586 1	1,088582784	0,76923013	0,10389943 3	4734986,06 2
SG	1991616	199161600	-0,004	0,943738 2	0,947738163	0,80450884 9	0,08072306	1602272,69 5
MLU	419167	41916700	-0,0792	0,996377 8	1,075558446	0,75359070 5	0,12661042 3	315880,355 1
FL_IACS	6615420	661542000	-0,0354	0,999031	1,034429237	0,84768515 3	0,07070970 2	5607793,31 7
SM	1052146	105214600	-0,2593	0,999508 9	1,258812577	0,60064864 1	0,21377767 9	631970,064 9
OL	185662	18566200	-0,0497	0,929467 7	0,979152065	0,68973130 6	0,17583715 2	128056,893 7
ACL	3037419	303741900	-0,3241	0,999555 6	1,32367295	0,68245632 7	0,19199670 8	2072905,81 3

IPCC_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
AAS	590480	59048000	-0,1036	0,9995192	1,103153147	0,811951727	0,099144969	479441,2559
WL	207749	20774900	-0,335	0,9367276	1,271753013	0,671359423	0,226792558	139474,2487
CY	336026	33602600	-0,1209	0,9482698	1,069195189	0,767770889	0,124790106	257990,9808
PCL	31642	3164200	0,18385	0,9366531	0,75280717	0,747600807	0,134205418	23655,58472

Table 21 Zonal statistic, 2020

IPCC_20	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM	6326088	632608800	-0,090140492	0,96356374	1,053704232	0,726971746	0,135630101	4598887,242
MLU	249888	24988800	-0,002933189	0,932329297	0,935262486	0,692760645	0,152942641	173112,572
SG	1926596	192659600	-0,387186617	0,999207914	1,386394531	0,777956309	0,112883925	1498807,514
ACL	3062957	306295700	-0,051717006	0,999572039	1,051289044	0,613705211	0,176428499	1879752,673
FL_IACS	6666223	666622300	-0,279847175	0,999551594	1,279398769	0,826540667	0,101763451	5509904,402
SM	1174506	117450600	-0,455893248	0,999549627	1,455442876	0,57636601	0,213542412	676945,3365
WL	206746	20674600	-1	0,979044855	1,979044855	0,692893765	0,219864439	143253,0143
PCL	32515	3251500	0,168516651	0,927763283	0,759246632	0,703369413	0,138378952	22870,05648
AAS	544454	54445400	-0,213707283	0,999530613	1,213237897	0,804744107	0,101459707	438146,148
OL	177440	17744000	-1	0,930387676	1,930387676	0,64391417	0,19967095	114256,1304
CY	255397	25539700	0,023272468	0,999466836	0,976194369	0,758170977	0,125743961	193634,593

Table 22 Mean NDVI values per IPCC categories for 2018, 2019, 2020

IPCC categories	MEAN_18	MEAN_19	MEAN_20
PGM	0,7128417	0,76923013	0,726971746
MLU	0,7408577	0,804508849	0,692760645
SG	0,6694683	0,753590705	0,777956309
ACL	0,7983135	0,847685153	0,613705211
FL_IACS	0,5514129	0,600648641	0,826540667
SM	0,6164423	0,689731306	0,57636601
WL	0,5280885	0,682456327	0,692893765
PCL	0,7770377	0,811951727	0,703369413
AAS	0,6409247	0,671359423	0,804744107
OL	0,7044116	0,767770889	0,64391417
CY	0,6503731	0,747600807	0,758170977

For LULUCF it is really important to be known from which, to which category a certain area has changed. This cannot be determined only by using the change represented by the Mean, Min, or MAX of NDVI as the **Error! Reference source not found.** – **Error! Reference source not found.** shows.

Table 23 Zonal statistic based on the vector data for GSAA and LPIS and related with the data change value for NDVI from raster for 2018 – 2019

CH_18_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM	5638765	563876500	-0,743958235	0,848283648	1,592241883	0,05762728	0,073363215	324946,6888
SG	1738754	173875400	-0,651600361	0,886103392	1,537703753	0,064872837	0,075674792	112797,9057
MLU	386731	38673100	-0,680479527	0,718676567	1,399156094	0,078468909	0,133956661	30346,35968
FL_IACS	6491800	649180000	-0,72046423	1,006989479	1,727453709	0,049263749	0,072562358	319810,4065
SM	956674	95667400	-0,750982225	0,769443154	1,520425379	0,045911085	0,089675534	43921,94149

CH_18_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
OL	163612	16361200	-0,695456207	0,533063889	1,228520095	0,063926352	0,072283426	10459,11825
ACL	2826050	282605000	-0,685333908	0,825457573	1,510791481	0,156745065	0,239002297	442969,3916
SG to PGM	95685	9568500	-0,510730207	0,692878008	1,203608215	0,056063691	0,071098782	5364,454227
ACL to MLU	21343	2134300	-0,600157976	0,687770069	1,287928045	0,104766113	0,187011805	2236,023146
FL_IACS to PGM	11879	1187900	-0,330896974	0,556041598	0,886938572	0,043679175	0,05832358	518,8649192
MLU to PGM	217174	21717400	-0,538423121	0,655719995	1,194143116	0,067535301	0,080184658	14666,91137
AAS	565354	56535400	-0,725492656	0,743774533	1,46926719	0,039212411	0,052363822	22168,89315
SG to FL_IACS	44010	4401000	-0,406522423	0,69435817	1,100880593	0,0377069	0,037057002	1659,480665
WL	183712	18371200	-0,765375674	0,874503911	1,639879584	0,040603022	0,101014593	7459,262422
ACL to PGM	131008	13100800	-0,64721334	0,703915775	1,351129115	0,130514475	0,210659991	17098,4404
CY	325802	32580200	-0,686772168	1,101267576	1,788039744	0,055146069	0,068780776	17966,69952
PGM to MLU	9180	918000	-0,614442527	0,539751828	1,154194355	0,083038869	0,088272743	762,2968169
ACL to PCL	2097	209700	-0,453468412	0,602990746	1,056459159	0,044738594	0,231402504	93,81683233
SG to MLU	826	82600	-0,255948037	0,50352037	0,759468406	0,068907903	0,083264237	56,9179275
FL_IACS to AAS	920	92000	-0,273212016	0,246904135	0,52011615	0,019044146	0,046226865	17,52061418
FL_IACS to MLU	191	19100	-0,176673591	0,188868165	0,365541756	0,010272001	0,054755348	1,961952209
SM to PGM	38037	3803700	-0,397270501	0,456808329	0,854078829	0,137384254	0,057695617	5225,684876
FL_IACS to SM	2666	266600	-0,227318227	0,378543168	0,605861396	0,038822995	0,058188296	103,502105
OL to PGM	3785	378500	-0,093254119	0,486837238	0,580091357	0,113110578	0,063477747	428,1235383
PGM to FL_IACS	47992	4799200	-0,248298109	0,766289413	1,014587522	0,045877494	0,040008581	2201,752698
PCL	27030	2703000	-0,45998773	0,608355165	1,068342894	0,109423434	0,140233448	2957,715417
ACL to SM	4827	482700	-0,624958515	0,596792698	1,221751213	0,103718252	0,128183203	500,6480015
AAS to SM	16269	1626900	-0,563360751	0,456863999	1,02022475	0,036606641	0,052079225	595,5534474
AAS to FL_IACS	18868	1886800	-0,198055029	0,454612732	0,652667761	0,034914398	0,029911731	658,764866
SG to SM	2470	247000	-0,572174907	0,564021349	1,136196256	0,046761707	0,123946776	115,5014165
AAS to WL	179	17900	-0,066491246	0,273777217	0,340268463	0,081070879	0,066123177	14,5116873
FL_IACS to WL	1733	173300	-0,208386242	0,51140511	0,719791353	0,071526632	0,10232879	123,9556525
MLU to ACL	116627	11662700	-0,773359478	0,722585917	1,495945394	0,123952321	0,167183309	14456,18732
SG to AAS	2097	209700	-0,159240663	0,304535866	0,463776529	0,026687849	0,037240057	55,96442029
PGM to SG	182676	18267600	-0,354825675	0,656051576	1,010877252	0,061295276	0,051584861	11197,17585
PGM to SM	14271	1427100	-0,755610049	0,534934759	1,290544808	0,119175061	0,087928689	1700,747295
PGM to CY	756	75600	-0,594223738	0,384242207	0,978465945	0,039066235	0,160015182	29,53407362
MLU to SG	11646	1164600	-0,66455245	0,515232921	1,179785371	0,063883744	0,071145046	743,9900883
FL_IACS to SG	12199	1219900	-0,207220286	0,693997502	0,901217788	0,042969207	0,052457139	524,1813597
AAS to PGM	11992	1199200	-0,391532302	0,410158157	0,801690459	0,040735551	0,052022443	488,500723
AAS to OL	62	6200	-0,154095054	0,179847747	0,333942801	0,036069604	0,055141259	2,236315459
OL to AAS	55	5500	-0,100944161	0,172878861	0,273823023	0,007145121	0,035538951	0,392981678
WL to PGM	2858	285800	-0,550805688	0,559930682	1,11073637	0,036198252	0,144479867	103,4546048
WL to SM	285	28500	-0,405607104	0,479649901	0,885257006	0,126946005	0,155322792	36,17961155
SG to WL	2271	227100	-0,39340055	0,628188014	1,021588564	0,118634176	0,125698669	269,4182126
SM to CY	309	30900	-0,600575149	0,506448627	1,107023776	0,085916998	0,145128464	26,54835229
FL_IACS to OL	4254	425400	-0,108415544	0,273250848	0,381666392	0,045312032	0,025097925	192,7573831
SM to ACL	1485	148500	-0,334158659	0,65864116	0,992799819	0,108697262	0,157397206	161,4154345
SM to OL	74	7400	-0,108656198	0,234209299	0,342865497	0,01848759	0,050371446	1,368081659
SM to FL_IACS	2763	276300	-0,17835778	0,321413785	0,499771565	0,064081014	0,046393005	177,0558427
PGM to ACL	88219	8821900	-0,680581331	0,67015326	1,350734591	0,035771479	0,211265275	3155,724103
PGM to PCL	556	55600	-0,458924413	0,409930706	0,868855119	0,05166177	0,145015764	28,72394389

CH_18_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
CY to PGM	2694	269400	-0,18651402	0,512387991	0,698902011	0,129169628	0,105007812	347,9829775
WL to MLU	211	21100	-0,133035719	0,455158979	0,588194698	0,059401008	0,081535215	12,5336127
FL_IACS to CY	33	3300	-0,108166337	0,16012311	0,268289447	0,038245298	0,049451587	1,262094826
SM to SG	28469	2846900	-0,665818572	0,521611333	1,187429905	0,078649244	0,057730561	2239,06534
SM to AAS	1109	110900	-0,220837355	0,165255487	0,386092842	0,028591843	0,043570741	31,70835406
CY to SM	49795	4979500	-0,637770474	0,517983198	1,155753672	0,04234839	0,065773055	2108,738104
AAS to SG	9757	975700	-0,199033618	0,250263512	0,44929713	0,039456392	0,032880741	384,9760135
PCL to FL_IACS	272	27200	-0,057091415	0,142996669	0,200088084	0,033444236	0,027434164	9,096832156
SM to WL	15055	1505500	-0,299398184	0,46387437	0,763272554	0,023732888	0,144070181	357,2986268
MLU to FL_IACS	3011	301100	-0,096741557	0,36763823	0,464379787	0,046875308	0,041266539	141,1415527
FL_IACS to ACL	227	22700	-0,413155794	0,529814005	0,942969799	0,099196255	0,142177097	22,51754987
PGM to AAS	138	13800	-0,239619315	0,303575397	0,543194711	0,073811673	0,104192285	10,18601082
SM to MLU	202	20200	-0,500796854	0,39876616	0,899563015	0,05388334	0,110876411	10,88443466
OL to FL_IACS	4259	425900	-0,09542948	0,291968286	0,387397766	0,054552689	0,031119925	232,3399038
PGM to OL	9136	913600	-0,196063817	0,313658744	0,509722561	0,036943823	0,047611417	337,518763
CY to FL_IACS	1090	109000	-0,0633623	0,321157634	0,384519935	0,04828643	0,033876065	52,63220879
MLU to SM	4107	410700	-0,451575637	0,525892377	0,977468014	0,069221393	0,114100236	284,2922608
MLU to CY	5127	512700	-0,41776818	0,599417567	1,017185748	0,048192655	0,101653657	247,0837436
MLU to WL	1443	144300	-0,389703691	0,774977922	1,164681613	0,076232046	0,104930656	110,0028422
MLU to AAS	2313	231300	-0,407581657	0,425434917	0,833016574	0,020930814	0,067335989	48,41297212
SG to ACL	1430	143000	-0,288335234	0,582360983	0,870696217	0,110536348	0,1324423	158,0669779
WL to CY	153	15300	-0,19934231	0,460507721	0,659850031	0,049242763	0,060942388	7,534142733
WL to SG	616	61600	-0,176929951	0,259230852	0,436160803	0,085317842	0,051077974	52,55579045
AAS to CY	2106	210600	-0,143923759	0,37028262	0,51420638	0,066643084	0,066765763	140,350334
OL to SG	517	51700	-0,044958949	0,273531139	0,318490088	0,098218613	0,066968015	50,77902296
MLU to OL	355	35500	-0,620508671	0,314044416	0,934553087	0,104842693	0,120688202	37,21915606
WL to ACL	485	48500	-0,316236973	0,427717775	0,743954748	0,135441342	0,102574455	65,68905078
SG to CY	907	90700	-0,077671885	0,285936892	0,363608778	0,069441844	0,063370991	62,98375243
PGM to WL	2306	230600	-0,211919218	0,381417423	0,593336642	0,027771049	0,069863988	64,04003951
ACL to OL	621	62100	-0,184346199	0,298601151	0,48294735	0,103082771	0,0672417	64,01440093
ACL to WL	966	96600	-0,402679682	0,376964092	0,779643774	0,07575513	0,091268951	73,17945555
ACL to SG	5988	598800	-0,513460398	0,435614288	0,949074686	0,126623102	0,07767303	758,2191341
ACL to CY	832	83200	-0,183277518	0,289521515	0,472799033	0,071634871	0,061484238	59,60021228
AAS to ACL	946	94600	-0,213145673	0,350536168	0,563681841	0,091604215	0,064045012	86,65758725
SG to OL	7531	753100	-0,105355501	0,318743765	0,424099267	0,065534624	0,044905569	493,5412537
MLU to PCL	1572	157200	-0,180091977	0,573373199	0,753465176	0,149875336	0,14842934	235,6040277
WL to AAS	32	3200	-0,020460844	0,25662452	0,277085364	0,066158071	0,047174806	2,117058277
WL to FL_IACS	5	500	-0,001012027	0,033469856	0,034481883	0,011469591	0,014003181	0,057347953
CY to SG	946	94600	-0,159945905	0,144759536	0,304705441	0,029135296	0,030148605	27,5619899
ACL to FL_IACS	1350	135000	-0,238988221	0,720580339	0,95956856	0,070106935	0,088391384	94,644362
OL to ACL	356	35600	-0,195359945	0,574285805	0,769645751	0,323449276	0,202900976	115,1479422
SG to PCL	23	2300	0,046375453	0,307786107	0,261410654	0,125576587	0,05607887	2,888261497
CY to WL	28	2800	0,023416579	0,224788427	0,201371849	0,086890491	0,048809501	2,432933748
OL to SM	782	78200	-0,237000495	0,352499783	0,589500278	0,148776904	0,076345122	116,343539
OL to MLU	219	21900	0,033091903	0,588248253	0,55515635	0,39633748	0,155871512	86,79790804
CY to MLU	64	6400	-0,015955806	0,336867362	0,352823168	0,132942681	0,054856168	8,508331567
CY to AAS	17977	1797700	-0,629026473	0,54539907	1,174425542	0,043247886	0,080237352	777,4672505

CH_18_19	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
OL to WL	56	5600	-0,004885614	0,135880649	0,140766263	0,035155322	0,020967518	1,968698055
PCL to MLU	19	1900	0,027217329	0,1878016	0,160584271	0,094104478	0,038492003	1,787985086
AAS to MLU	181	18100	-0,15209496	0,521866679	0,673961639	0,12479553	0,12294887	22,58799094
CY to ACL	204	20400	-0,317566633	0,361717522	0,679284155	0,098171176	0,12617663	20,02691998
PCL to PGM	1610	161000	-0,203359723	0,565591156	0,76895088	0,181977551	0,108541173	292,9838564
SM to PCL	124	12400	-0,14410758	0,182797432	0,326905012	0,011167252	0,065128444	1,38473928
ACL to AAS	485	48500	-0,565274417	0,378100872	0,943375289	0,123833104	0,138024909	60,05905555
PCL to ACL	1390	139000	-0,510305762	0,40736562	0,917671382	-0,010373817	0,197259271	-14,41960624
PCL to SG	48	4800	-0,00356257	0,109888136	0,113450706	0,04380189	0,024336589	2,102490723
WL to PCL	2	200	0,089937508	0,095212638	0,00527513	0,092575073	0,002637565	0,185150146
FL_IACS to PCL	238	23800	-0,010881186	0,298746109	0,309627295	0,053002029	0,057197241	12,61448288
WL to OL	17	1700	-0,017781794	0,138682067	0,156463861	0,074286987	0,044032371	1,262878776
OL to CY	1	100	0,073526025	0,073526025	0	0,073526025	0	0,073526025

Table 24 Zonal statistic based on the vector data for GSAA and LPIS and related with the data change value for NDVI from raster for 2019 – 2020

CH_19_20	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM	5939909	593990900	-0,885654449	0,678261638	1,563916087	-0,043316158	0,093643463	-257294,0351
PGM to MLU	19249	1924900	-0,77043575	0,658401012	1,428836763	-0,041022199	0,096456209	-789,6363116
SG	1834707	183470700	-0,898625791	0,63787806	1,536503851	-0,027946259	0,078093277	-51273,1969
MLU to PGM	131839	13183900	-0,84528172	0,573682189	1,418963909	-0,045007762	0,094218078	-5933,778377
MLU to ACL	54243	5424300	-0,81097573	0,69097656	1,501952291	-0,014690751	0,191253151	-796,870429
FL_IACS	6588369	658836900	-0,938683867	0,741983771	1,680667639	-0,02097153	0,085019801	-138168,1777
MLU	217672	21767200	-0,818183005	0,636273742	1,454456747	-0,057619075	0,149949494	-12542,05934
SM	1037876	103787600	-0,84797442	0,800415695	1,648390114	-0,033436623	0,095710641	-34703,06805
FL_IACS to WL	479	47900	-0,130224586	0,182594538	0,312819123	0,013107977	0,03376352	6,278721094
FL_IACS to PGM	7222	722200	-0,613162398	0,423038751	1,036201149	-0,011646865	0,043252106	-84,11366072
FL_IACS to SG	16059	1605900	-0,546105623	0,31076628	0,856871903	-0,019269715	0,046624746	-309,4523546
SM to PGM	8011	801100	-0,683698177	0,399235278	1,082933456	-0,049487614	0,084456477	-396,445277
OL to PGM	4094	409400	-0,644683242	0,295470744	0,940153986	-0,031110509	0,064342281	-127,3664258
SG to PGM	92926	9292600	-0,744914174	0,459270567	1,204184741	-0,03228048	0,061045966	-2999,695895
OL to SM	541	54100	-0,721876323	0,264719307	0,986595631	-0,083084261	0,147757337	-44,9485851
MLU to SM	2207	220700	-0,718621731	0,492267519	1,21088925	-0,072099406	0,142940374	-159,1233893
PGM to SM	12721	1272100	-0,722266853	0,495515883	1,217782736	-0,054996134	0,128004585	-699,6058174
MLU to PCL	847	84700	-0,285578668	0,295538515	0,581117183	-0,001158296	0,061566332	-0,981076598
MLU to FL_IACS	1888	188800	-0,224432677	0,147017062	0,371449739	-0,004226241	0,030883528	-7,979142219
PGM to ACL	114015	11401500	-0,700008869	0,683394432	1,383403301	-0,093981012	0,22112697	-10715,24511
ACL	2890595	289059500	-0,948697448	0,954762995	1,903460443	-0,069072847	0,238694088	-199661,6263
ACL to PGM	121190	12119000	-0,813328624	0,676483214	1,489811838	-0,03464892	0,19965607	-4199,102611
ACL to PCL	1304	130400	-0,502994835	0,522173762	1,025168598	0,054050008	0,194815724	70,48121035
PGM to FL_IACS	17874	1787400	-0,815675139	0,248014867	1,063690007	-0,023679223	0,06657252	-423,242431
SG to FL_IACS	53562	5356200	-0,852933168	0,423889011	1,27682218	-0,026212629	0,082870906	-1404,000859
ACL to SG	4435	443500	-0,578422725	0,245595872	0,824018598	-0,062611062	0,085475152	-277,6800579
AAS	541203	54120300	-0,747196436	0,542611063	1,289807498	-0,010261785	0,047025185	-5553,708698
MLU to OL	364	36400	-0,561671913	0,122972563	0,684644476	-0,138301913	0,106477071	-50,34189633
MLU to SG	7110	711000	-0,621955156	0,315985799	0,937940955	-0,029158704	0,094157787	-207,3183837

CH_19_20	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
PGM to SG	47154	4715400	-0,781689525	0,393131852	1,174821377	-0,02503243	0,057501658	-1180,379225
SM to SG	3367	336700	-0,627844691	0,252054095	0,879898787	-0,015632259	0,06787971	-52,63381699
AAS to FL_IACS	1108	110800	-0,190828085	0,066345513	0,257173598	-0,007236975	0,019168875	-8,018568277
OL	170816	17081600	-1,513189435	0,599662721	2,112852156	-0,041930887	0,098724751	-7162,466475
SM to FL_IACS	513	51300	-0,331888586	0,379084229	0,710972816	-0,001788549	0,048035728	-0,917525381
SG to WL	1162	116200	-0,256039947	0,284375012	0,540414959	0,007095634	0,057823382	8,245126493
WL	202792	20279200	-1,323325634	0,785303116	2,10862875	0,019011077	0,126167358	3855,29441
WL to SM	883	88300	-0,655036867	0,494260132	1,149296999	-0,086601054	0,169695193	-76,46873109
ACL to MLU	11427	1142700	-0,600306273	0,581521988	1,18182826	-0,060028912	0,162322207	-685,9503792
CY	246549	24654900	-0,775493443	0,696581006	1,472074449	-0,021623208	0,067367882	-5331,180248
SG to OL	2078	207800	-0,724907279	0,115173727	0,840081006	-0,027775813	0,085113934	-57,71814012
WL to PGM	2757	275700	-0,5637483	0,423373073	0,987121373	0,084060101	0,137124596	231,753698
PGM to OL	1992	199200	-0,76453954	0,125904977	0,890444517	-0,047138672	0,143186992	-93,90023368
FL_IACS to ACL	312	31200	-0,260702014	0,472369611	0,733071625	0,073829515	0,165314485	23,03480875
CY to SM	81555	8155500	-0,731615901	0,53116411	1,262780011	-0,018576673	0,07321626	-1515,020586
CY to PGM	4331	433100	-0,597411811	0,313957989	0,911369801	-0,052932248	0,090166687	-229,2495652
ACL to SM	5392	539200	-0,770523429	0,531661749	1,302185178	-0,077179579	0,163603286	-416,1522906
SG to SM	2931	293100	-0,759436607	0,384254932	1,14369154	-0,023235364	0,101015275	-68,10285158
PGM to PCL	678	67800	-0,355400026	0,210026443	0,565426469	-0,119889802	0,092278949	-81,2852855
PCL	29361	2936100	-0,66069901	0,540028811	1,20072782	-0,044189662	0,130526047	-1297,452664
SG to ACL	1283	128300	-0,539904714	0,693771183	1,233675897	0,035400234	0,239119653	45,41849977
WL to ACL	235	23500	-0,3052845	0,38604188	0,69132638	0,009651382	0,134874961	2,268074751
SG to MLU	706	70600	-0,236098289	0,343603164	0,579701453	0,002301076	0,064011855	1,624559522
WL to MLU	203	20300	-0,416443169	0,462216705	0,878659874	0,073505463	0,169859481	14,92160901
AAS to SG	3755	375500	-0,138172626	0,163511157	0,301683784	-0,008903822	0,025180785	-33,43385187
AAS to PGM	12596	1259600	-0,741751075	0,254565537	0,996316612	-0,015660465	0,04569813	-197,2592178
SM to PCL	2	200	-0,010827959	0,031346858	0,042174816	0,010259449	0,021087408	0,020518899
ACL to FL_IACS	430	43000	-0,271638155	0,114100754	0,385738909	-0,027778339	0,049806521	-11,94468579
MLU to WL	313	31300	-0,156857669	0,248907804	0,405765474	0,00145015	0,06519188	0,45389694
OL to SG	7609	760900	-0,712989688	0,491387963	1,204377651	0,006498926	0,088765949	49,45033075
WL to SG	353	35300	-0,397580266	0,301724732	0,699304998	-0,002345113	0,085894207	-0,82782498
SM to AAS	458	45800	-0,252599299	0,08928597	0,341885269	-0,002027099	0,031440546	-0,928411216
SM to ACL	915	91500	-0,48567459	0,328805268	0,814479858	-0,027842167	0,15406998	-25,47558269
AAS to SM	29105	2910500	-0,826903462	0,450754672	1,277658135	-0,029288122	0,072493197	-852,4307955
FL_IACS to SM	1285	128500	-0,52323544	0,145346254	0,668581694	-0,017369616	0,054395569	-22,31995618
OL to WL	509	50900	-0,347948968	0,249931514	0,597880483	0,013864601	0,05448774	7,057081908
PGM to CY	787	78700	-0,245642006	0,135411918	0,381053925	-0,019189199	0,038146021	-15,10189992
FL_IACS to MLU	259	25900	-0,249608159	0,114543319	0,364151478	-0,008559294	0,054448069	-2,216857076
ACL to WL	448	44800	-0,419883251	0,235967845	0,655851096	-0,056209285	0,06848859	-25,18175948
SM to MLU	138	13800	-0,540991426	0,24266696	0,783658385	-0,057213535	0,117485735	-7,895467892
SG to AAS	983	98300	-0,28538835	0,087274671	0,372663021	-0,036032866	0,04387149	-35,42030731
AAS to OL	15	1500	-0,562184751	0,050397873	0,612582624	-0,05406849	0,145855112	-0,811027348
CY to MLU	95	9500	-0,152178496	0,099609077	0,251787573	-0,008502449	0,049257788	-0,807732671
SG to CY	975	97500	-0,292474121	0,607378483	0,899852604	0,003409135	0,113420877	3,323906839
OL to AAS	1	100	-0,047248423	-0,047248423	0	-0,047248423	0	-0,047248423

CH_19_20	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
OL to FL_IACS	1952	195200	-0,088899612	0,087180912	0,176080525	0,003617369	0,022374605	7,061104149
FL_IACS to AAS	296	29600	-0,210662723	0,099769533	0,310432255	-0,012094806	0,03130863	-3,580062628
CY to FL_IACS	507	50700	-0,244808227	0,126762271	0,371570498	-0,00884964	0,028441539	-4,486767471
FL_IACS to CY	374	37400	-0,260664761	0,123497963	0,384162724	-0,023624867	0,046710531	-8,835700125
PCL to PGM	1213	121300	-0,267546177	0,149739861	0,417286038	-0,012111964	0,049978899	-14,69181234
SM to CY	750	75000	-0,473029703	0,203343153	0,676372856	-0,056548114	0,073213332	-42,41108529
PGM to AAS	222	22200	-0,108117282	0,043014944	0,151132226	-0,001749536	0,022469326	-0,388397038
OL to ACL	15	1500	-0,235608697	0,099190176	0,334798872	-0,054881003	0,083666426	-0,823215038
ACL to OL	978	97800	-0,77655232	0,215228453	0,991780773	-0,205193139	0,241024148	-200,6788902
PGM to WL	886	88600	-0,20312947	0,153282642	0,356412113	0,006394263	0,039960426	5,665316775
MLU to AAS	556	55600	-0,445408136	0,336055905	0,78146404	-0,08796	0,105362323	-48,90576004
WL to FL_IACS	19	1900	-0,198782727	0,035966814	0,234749541	-0,03000742	0,065733203	-0,570140988
AAS to ACL	250	25000	-0,603438735	0,496248305	1,09968704	-0,007955772	0,263231643	-1,98894307
AAS to CY	2362	236200	-0,318334609	0,580090404	0,898425013	-0,012184029	0,094224354	-28,77867688
MLU to CY	2128	212800	-0,455133349	0,230484873	0,685618222	-0,054221316	0,077707596	-115,3829597
SM to OL	61	6100	-0,67901063	-0,048315644	0,630694985	-0,317623362	0,144412109	-19,37502506
PCL to AAS	58	5800	-0,046759725	0,056089997	0,102849722	0,011250707	0,017319458	0,652540982
CY to AAS	645	64500	-0,311717212	0,218974948	0,53069216	-0,032503585	0,058971424	-20,96481207
CY to SG	2047	204700	-0,358752549	0,205756307	0,564508855	-0,011980364	0,033522746	-24,52380472
CY to ACL	97	9700	-0,434389383	0,244295418	0,678684801	0,016707968	0,122673283	1,620672852
WL to AAS	15	1500	-0,173301101	0,02586025	0,199161351	-0,0287871	0,056403446	-0,431806505
WL to OL	223	22300	-0,671235323	0,017146349	0,688381672	-0,214570515	0,188150061	-47,84922481
ACL to CY	1203	120300	-0,427426308	0,337849259	0,765275568	-0,099981758	0,092353157	-120,278055
AAS to MLU	18	1800	-0,013969243	0,224855781	0,238825023	0,052471932	0,075480848	0,944494784
AAS to WL	68	6800	-0,129297674	0,093836248	0,223133922	-0,013349364	0,037565174	-0,907756746
SG to PCL	303	30300	-0,076490581	0,100832105	0,177322686	0,01152541	0,024161354	3,492199123
CY to WL	32	3200	-0,069128811	0,040898383	0,110027194	-0,016087461	0,028182166	-0,51479876
FL_IACS to OL	761	76100	-0,150722921	0,232368648	0,383091569	-0,006458012	0,022973802	-4,914547145
SM to WL	55	5500	-0,228259563	0,066566944	0,294826508	-0,0525423	0,063038355	-2,889826506
OL to MLU	121	12100	-0,407134622	0,044157177	0,4512918	-0,138576046	0,082126934	-16,76770154
PCL to WL	2	200	-0,020322382	0,040319443	0,060641825	0,00999853	0,030320913	0,01999706
PCL to ACL	997	99700	-0,617403805	0,430023819	1,047427624	-0,145171306	0,221640245	-144,7357916
PCL to SM	10	1000	-0,126315355	0,061063111	0,187378466	-0,053196186	0,058549457	-0,531961858
CY to PCL	16	1600	-0,095092297	0,078439891	0,173532188	0,001043785	0,046301415	0,016700566
FL_IACS to PCL	4	400	-0,136429071	0,012479603	0,148908675	-0,082420528	0,059463476	-0,329682112
WL to CY	269	26900	-0,178502172	0,260420084	0,438922256	-0,010036892	0,03891687	-2,699923873
CY to OL	152	15200	-0,070867836	0,055568576	0,126436412	-0,012177021	0,016108464	-1,850907117
ACL to AAS	17	1700	-0,215215415	0,08637473	0,301590145	-0,066075953	0,089215254	-1,123291194
PCL to FL_IACS	1	100	-0,011712909	-0,011712909	0	-0,011712909	0	-0,011712909

Another alarming tendency is shown in Table 25*,* where we could clearly see that the range on the NDVI for one crop type based on all pixel data within the declared area for that crop is too wide. The same distribution is observed in the 2019 and 2020.

Even alarming that tendency, can be expected, since within the GSAA geometry we have pixels from nearby non-agricultural land cover, such as roads, where NDVI will be low or pixels related to bare soil patches, associated with harvest, etc.

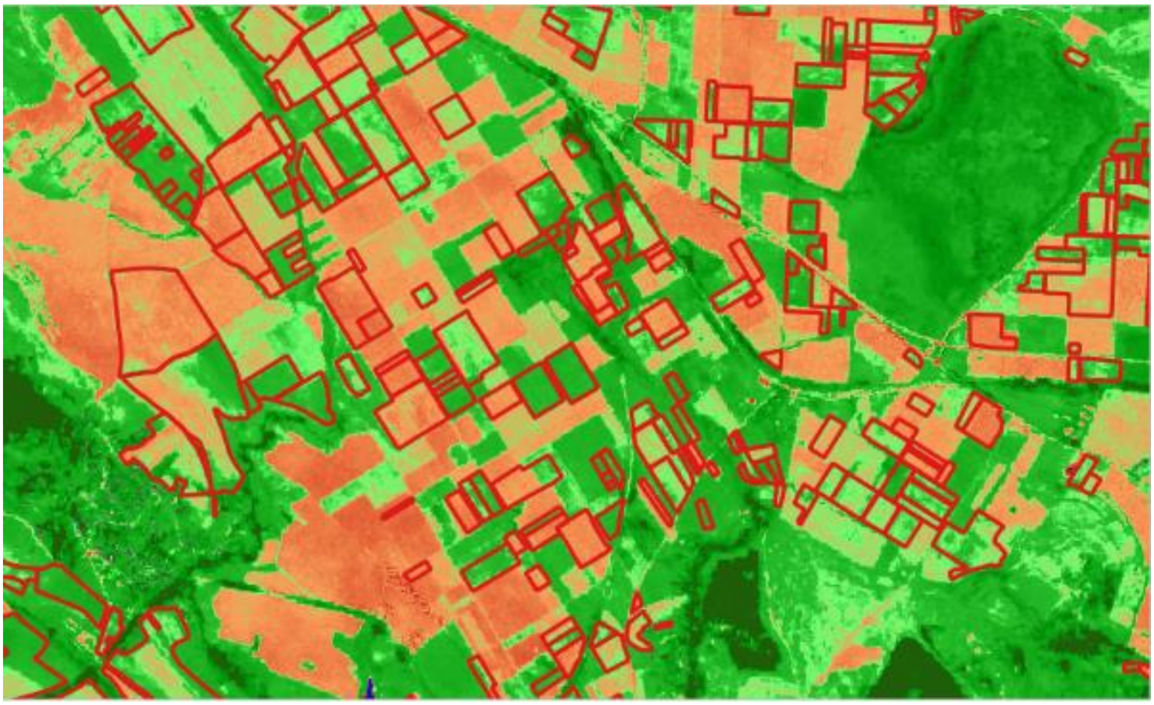
Table 25 Minimal and maximum value of the NVDI per crop type for 2018

CROP_CODE	CROP_NAME	Min NDVI_ 2018	Max NDVI_2018	AREA
111011	soft winter wheat	0,071801044	0,912429988	10227,76
111012	soft spring wheat	0,104712039	0,775696218	21,93
111013	annual einkorn	0,169980749	0,638368785	36,71
111014	two-grain einkorn	0,182252556	0,497725219	2,49
111020	durum wheat	0,176861703	0,661252916	6,75
111031	winter rye	0,107905366	0,787267923	204,34
111032	spring rye	0,199675977	0,705807567	9,96
111041	winter triticale	0,070328198	0,771784246	279,63
111050	maize grain	0,039324895	0,822546482	1707,49
111061	winter barley	0,077774704	0,753349721	811,09
111062	spring barley	0,105372764	0,726356208	166,25
111071	winter oats	0,145272061	0,668286741	25,38
111072	spring oats	0,094901375	0,769599199	500,97
111080	millet	0,242324039	0,476002246	2,72
111090	sorghum	0,152080908	0,714634895	316,89
112010	field beans	0,126056597	0,735106707	16,33
112020	chickpeas	0,148187637	0,5625	49,54
112041	winter grain peas	0,150027886	0,457181692	17,17
112042	spring grain peas	0,105207227	0,763804495	124,2
112050	grain fava beans	0,294844091	0,488696635	0,23
112060	lentils	0,263895839	0,610328615	0,98
122010	sunflowers	0,046996731	0,867656708	5699,58
122031	winter rapeseed	0,041060954	0,732298136	854,02
122040	soy	0,220255926	0,531395793	1,4
122070	other oil-seed plants	0,169868559	0,404986531	2,86
124020	coriander	0,098369874	0,793090165	5,28
124070	chamomile	0,188924149	0,275919735	0,2
131010	maize silage	0,089108914	0,712226748	375,4
131020	fodder beet	0,21017991	0,523926377	1,41
131030	annual cereals	0,131964803	0,657538056	27,22
131040	annual protein crops	0,115666181	0,70931977	44,63
131041	vetches	0,130645156	0,741100311	15,17
131050	mixed annuals	0,161434978	0,715484858	14,06
131080	other fodder crops	0,253629893	0,735550702	3,75
132010	artificial meadows-cereal	0,36663124	0,593929172	0,31
132021	alfalfa	0,122376241	0,912429988	579,32
132022	clover	0,36831969	0,74712646	1,72
132023	Birdsfoot trefoil	0,270316511	0,378943056	0,59
132024	sainfoin	0,198828265	0,749148667	23,01
132030	artificial meadows-mixed crops	0,189230382	0,811671078	184,34
141013	outdoor tomatoes	0,100909486	0,717282057	60,58
141023	outdoor pepper	0,203217164	0,755147874	3,36
141030	aubergine	0,376299381	0,539398015	0,46
141043	outdoor cucumbers	0,202304736	0,380249053	0,11
141045	outdoor gherkins	0,216570958	0,561932623	8,87
141050	courgettes	0,241972476	0,803008914	5,36
141060	pumpkins	0,130557522	0,843878806	11,18

CROP_CODE	CROP_NAME	Min NDVI_ 2018	Max NDVI_2018	AREA
141080	melons	0,226853564	0,347597599	0,53
141100	green peas	0,206230164	0,783213437	19,33
141120	okra	0,269652367	0,558639824	0,42
141130	sweet corn	0,189719304	0,73348999	10,65
141140	other fruit and vegetable crops	0,243549764	0,501517892	0,34
142010	cabbage	0,110734463	0,835588336	24,68
142020	cauliflower	0,280941188	0,784043729	2,83
142040	salad	0,286573142	0,547341108	0,39
142050	lettuce	0,173838213	0,481622308	0,45
142070	other deciduous crops	0,288467616	0,760946751	0,74
142080	dill	0,328608245	0,585122466	0,24
143010	carrots	0,125111714	0,710506976	108,07
143020	parsley	0,342281878	0,803008914	0,79
143030	celery	0,315535218	0,683820128	0,39
143040	salad beetroot	0,25	0,595811546	1,13
143050	radishes	0,335558027	0,585871696	0,15
144010	onion	0,311487764	0,576193571	0,15
144020	garlic	0,202581927	0,60225141	0,38
150000	POTATOES	0,087021381	0,863027275	2065,09
174000	Vegetables	0,317818195	0,655229449	0,56
175000	Berries	0,351785004	0,576400399	0,1
181030	greenhouse pepper	0,196324944	0,422351241	0,23
181040	greenhouse cucumbers	0,033707865	0,349016577	0,45
190000	FALLOW AREAS	0,055675443	0,803886533	2497,41
210000	VINEYARDS	0,236231223	0,54651922	0,23
212000	table grapes	0,306794792	0,422174841	0,18
220000	FRUIT SPECIES	0,406563342	0,794404268	0,42
221000	Pome fruits	0,392642826	0,716353118	0,18
221010	apples	0,187744066	0,846660078	11,84
221020	pears	0,290106535	0,484129637	1,01
221050	other pome fruits	0,433662117	0,672049701	0,17
222010	plums	0,150025085	0,800071895	16,91
222040	cherries	0,322055966	0,715010166	2,69
223010	walnuts	0,121798225	0,810744822	29,6
223030	hazelnuts	0,149622172	0,669322729	63,49
224010	strawberries	0,175550818	0,748627901	2,05
224020	raspberries	0,151977137	0,847047448	27,24
224030	blackberries	0,250243425	0,551432014	0,16
224040	redcurrant	0,18577981	0,276836157	0,16
224050	aronia	0,240610331	0,577130556	1,45
224060	blackcurrant	0,367050946	0,739654243	5,57
225000	Other orchard crops	0,307732761	0,381369025	0,8
231000	Medicinal and Aromatic crops	0,229078621	0,666238129	17,05
231010	damask rose	0,431170404	0,58605665	0,29
231020	lavender	0,169639468	0,362643838	4,49
231130	melissa	0,178343952	0,759412289	5,73
231210	sage	0,219544843	0,449075758	0,57
231230	rosehip	0,286326826	0,763824463	4,36
231240	other fragrant perennials	0,33609429	0,729441285	0,56
244000	Forest seedlings nurseries	0,298924744	0,91040659	4,08
314000	Permanent or temporary pastures for grazing animals (pastures and mountain pasture for grazing)	0,071038254	0,998506367	9794,7

CROP_CODE	CROP_NAME	Min NDVI_ 2018	Max NDVI_2018	AREA
315000	Hay meadows	0,090008259	0,996884763	14511,15
316000	Permanent grasslands maintained for grazing or mowing	0,131960332	0,99589324	3153,35
500000	CULTIVATED MUSHROOMS	0,415922612	0,638995111	0,17

The print screen below shows the NDVI in the parcels declared as soft winter wheat in 2018 on raster data from 2018, June. It shows clearly that the NDVI values are very different from group of parcels to group of parcels. The difference can be explained with harvesting started on some fields and not on others. This directs us to consider that when we use raster data, we should take the vegetation dynamic behaviors into consideration and use time series instead of a single image.



During observation of the raster data results, we found out that:

- It is important to apply some preliminary work to the images, such as preparing and using cloud mask, shadow of the clouds to be removed, etc. So, the results will not be influenced by the errors of artificially darkened pixels. Alternatively, only cloud free images should be used, which is possible because the LULUCF requires a more general data on phenology than the exact vegetation stage of the different crops.
- It is not enough to use only the data from one image, even when that image is taken in the most representative for most of the high vegetation present. Time series will do better. The periods when the vegetation development is at its highest are different from crop to crop or at least from crop group to crop group, so the time series data is needed.
- Using only NDVI values are not an option either, because the NDVI values for **water and settlement** are too similar to be easily separated. The same issue is observed between **deep ploughed lands and settlement features**. Another difficulty is the complicated separation between **forest lands and orchards**.
- The results suggest that when the polygons do not have complicated boundaries (curves) the accuracy in the area determination is higher.
- The results from calculated zonal statistic based on the NDVI value per one image in the year, show that it is not a good approach to be used to make truthful conclusions.
- The border pixels should be excluded, so they cannot influence the results.

Records on human efforts

The following table provides information on the time spent for each operation during the implementation of this study. The total hours spent amount to 166 hours or almost 21 man-days. In this record on human efforts, the time for preparation activities such as preliminary analysis, discussion on the approach, research activities and semantic mapping amounts to almost 25% of the time. Once the preparation work is done the subsequent technical work and analysis could be duplicated as much as needed. However, for the better planning of the human resources and time needed for such implementation, the study period should also be considered. The hours' distribution in the below table have been spent for work in three consecutive years. If the period used to derive the LU/LC changes is longer, more time for the technical work should be allocated.

Table 26 Records on human efforts in performing the technical steps

	Activity	Time, hours	Human resource	Total hours per activity
1	Gathering data	3	2	6
2	Preliminary analysis	8	1	8
3	Research	8	1	8
4	Discussion on the approach	4	2	8
5	Semantic	8	2	16
6	Preparing the data, new attributes	4	2	8
7	Geo-analysis IACS data	16	1	16
8	Geo-analysis IACS and Forest data	10	1	10
9	Raster data processing	10	1	10
10	Data processing	8	2	16
11	Land use representation statistics	10	2	20
12	Analysis	4	2	8
13	Maps	16	2	32
			Total	**166**

Recommendation and conclusions

This study proves once again that the IACS database is suitable to be used in other domains such as the LULUCF reporting and accounting. However, as the IACS is a system with specific goals, it could be expected that a direct use of the alphanumerical information is not appropriate and additional workaround with the data is required. This refers to a process of collecting the IACS database, selecting the appropriate information for the purpose of land representation and detecting of land use/cover changes, data harmonization in terms of semantic mapping, and combining this information with other geo-referenced data if needed. All this requires good understanding and knowledge of both IACS system and the LULUCF reporting requirements and methodologies. Thus, a collaboration between experts in these fields is recommended.

Considering the outcomes of the pilot study, LPIS data on PhB represents a great tool as a basis for land representation in Bulgaria as it covers the whole territory of the country. However, to improve the accuracy of the land representation and change detections within agricultural land, a combination with other IACS data is recommended. The results of the pilot study show that GSAA layer is a great tool for this purpose. Other IACS layers such as: Permanent pastures and grasslands, Ecological focus areas could also be useful databases, but further analysis in this perspective is needed.

IACS data stores information on annual activities or interventions on the agricultural lands, which could provide valuable input for calculation of the input and/or management factors needed for the soil organic carbon (SOC) estimates in agricultural lands.

IACS data could be merged with other geo-referenced data like forestry information from the forest management plans, which could improve the representation of forest lands. This will ensure that one and the same forest definition will be used in LULUCF reporting.

In resolving the interoperability issue in terms of semantic mapping, it is necessary to ensure good understanding of the land use categories under the IPCC and the adopted definitions on the land use categories and subcategories in the country. This will allow to define the appropriate level of disaggregation in data harmonization towards the IPCC land use categories. The pilot study proves that by keeping the IACS data more disaggregated, this could contribute to distinguishing the changes stemming from real land-use change from the changes, caused by improved mapping in IACS. During the semantic mapping between the IACS data and LULUCF needs, it is important to define a proper way to allocate the temporarily unmanaged lands. This is necessary under the LULUCF reporting as the legacy effects of past management can continue for extended periods and having these lands under unmanaged category could result in anthropogenic emissions and removals being unreported.

For the mapping of the land use/cover changes it is recommended to use only the data from areas which did not change their location during the investigated period. This will ensure that only real changes in land use/cover will be detected.

In case of using remote sensing data for verification purposes, such as Sentinel data, it is recommended to use more than one image per year. When deciding which spectral-based data to use, it is recommended to rely not only to NDVI.

References and resources

Alan Matthews blog, capreform.eu,

COMMISSION STAFF WORKING DOCUMENT - SWD/2016/0249 final - 2016/0230 (COD), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2016:0249:FIN

Guidelines on IACS spatial data sharing. Part 1. Data discovery (2020). https://marswiki.jrc.ec.europa.eu/wikicap/images/f/f8/DS-CDP-2019-04_REV2_TechnicalGuideline_IacsSpatialDataSharing_Part1_Final.pdf

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Ivanova, Rositsa (2019) Reusing Spatial Information of IACS In Land Use, Land Use Change and Forestry (LULUCF) in Bulgaria •

Lüker-Jans, N., Simmering, D. and Otte, A., 2016. Analysing data of the Integrated Administration and Control System (IACS) to detect patterns of agricultural land-use change at municipality level. *Landscape Online*, *48*, pp.1-24.

Marco Bertaglia, Pavel Milenov, Vincenzo Angileri, Wim Devos; Cropland and grassland management data needs from existing IACS sources; EUR 28036; doi:10.2788/132360

Regulation EU 2018/841

Strange Olesen, A., Lesschen, J. P., Rayment, M., Ebrahim, N., Weiss, P., Arets, E. J. M. M., Frelih-Larsen, A., Sikirica, N., Nabuurs, G. J., & Schelhaas, M. (2016). Agriculture and LULUCF in the 2030 Framework: Final report. European Union. https://doi.org/10.2834/818173

The INSPIRE data specifications (https://inspire.ec.europa.eu/dataspecifications/2892)

Tóth, K., 2018. Georeferenced agricultural data for statistical reuse. *Geosciences*, *8*(5), p.188. Technical

Annexes

Annex 1 Semantic mapping – tables

Table A: 1 Semantic mapping between LPIS, physical blocks and IPCC categories

Code	Physical block name	IPCC category	IPCC subcategory	Abbr
10	Arable Land	Cropland	Annual Cropland	ACL
20	Permanent Crops	Cropland	Perennial Cropland	PCL
21	Vineyards	Cropland	Perennial Cropland	PCL
22	Orchard	Cropland	Perennial Cropland	PCL
23	Other Perennials	Cropland	Perennial Cropland	PCL
30	Settlements	Settlements	Settlements	SM
31	Courtyards	Settlements/ Grassland	Courtyards	CY
32	Areas Associate to Settlements	Settlements/ Grassland	Areas associate to settlements	AAS
40	Pastures, Grasslands and Meadows/Pastures, Commonage and Meadows	Grassland	Pastures and Meadows	PGM
41	Natural Pastures and Meadows	Grassland	Pastures and Meadows	PGM
43	Forest Meadows and Pastures	Grassland	Pastures and Meadows	PGM
50	Mixed Land Use	Cropland/Grassland	Mixed land use	MLU
100	Non-Treated Areas/Non-Arable Lands	Grassland	Shrubs and grasslands	SGL
101	Shrubs and Grasslands	Grassland	Shrubs and grasslands	MGL
102	Gutters, Ravines and Washes	Other Land	Other land	OL
103	Field Roads, Clearings and Clearings	Settlements	Settlements	SM
200	Forest Territories	Forest Land	Forest land	FL_IACS
300	Urbanized Territories	Settlements	Settlements	SM
301	Urban Structures	Settlements	Settlements	SM
302	Sub Urban Territories	Settlements	Settlements	SM
303	Sports and Relax Zones	Settlements	Settlements	SM
400	Water Areas and Wet Zones	Wetlands	Wetlands	WL
401	Rivers and Riverbeds	Wetlands	Wetlands	WL
402	Lakes, Dams and Swamps	Wetlands	Wetlands	WL
403	Channels	Wetlands	Wetlands	WL
404	Boundary Water Areas	Wetlands	Wetlands	WL
405	Wetlands	Wetlands	Wetlands	WL
500	Territory Dispared	Settlements	Settlements	SM
501	Quarries, Open-Cast Mines, Extraction Sites	Settlements	Settlements	SM
502	Landfills and Dump Sites	Settlements	Settlements	SM
600	Transport Infrastructure	Settlements	Settlements	SM
601	Roads with Permanent Pavement and Adjacent Territories	Settlements	Settlements	SM
602	Railways and Adjacent Territories	Settlements	Settlements	SM
700	Bare and Eroded Terrains	Other Land	Other land	OL
701	Sand, Gravel and Bare Rocks	Other Land	Other land	OL
702	Areas with Poor Vegetation	Grassland	Pastures and Meadows	PGM
800	Other Territories	Other Land	Other land	OL
801	Ultra-Small Non-Agricultural Areas	Other Land	Other land	OL
802	Group Linear Objects (Ravine)	Other Land	Other land	OL
900	Area with Other (Non-Agricultural) Purpose	Other Land	Other land	OL

Table A: 2 Semantic mapping between GSAA, crop description and IPCC categories

№	CROP NAME	CROP TYPE	IPCC CATEGORY
1	Annual Einkorn	Cereals	Annual Cropland
2	Durum Wheat	Cereals	Annual Cropland
3	Maize Grain	Cereals	Annual Cropland
4	Millet	Cereals	Annual Cropland
5	Other Cereals	Cereals	Annual Cropland
6	Rice	Cereals	Annual Cropland
7	Soft Spring Wheat	Cereals	Annual Cropland
8	Soft Winter Wheat	Cereals	Annual Cropland
9	Sorghum	Cereals	Annual Cropland
10	Spring Barley	Cereals	Annual Cropland
11	Spring Oats	Cereals	Annual Cropland
12	Spring Rye	Cereals	Annual Cropland
13	Spring Triticale	Cereals	Annual Cropland
14	Two-Grain Einkorn	Cereals	Annual Cropland
15	Winter Barley	Cereals	Annual Cropland
16	Winter Oats	Cereals	Annual Cropland
17	Winter Rye	Cereals	Annual Cropland
18	Winter Triticale	Cereals	Annual Cropland
19	Fallow Areas	Fallow Lands	Annual Cropland
20	Alfalfa	Fodder	Annual Cropland
21	Annual Cereals	Fodder	Annual Cropland
22	Annual Fodder Vegetables	Fodder	Annual Cropland
23	Annual Protein Crops	Fodder	Annual Cropland
24	Artificial Meadows-Beans	Fodder	Annual Cropland
25	Artificial Meadows-Cereal	Fodder	Annual Cropland
26	Artificial Meadows-Mixed Crops	Fodder	Annual Cropland
27	Birdsfoot Trefoil	Fodder	Annual Cropland
28	Bitter Vetch	Fodder	Annual Cropland
29	Clover	Fodder	Annual Cropland
30	Fodder Beet	Fodder	Annual Cropland
31	Lupin	Fodder	Annual Cropland
32	Maize Silage	Fodder	Annual Cropland
33	Mixed Annuals	Fodder	Annual Cropland
34	Mustard	Fodder	Annual Cropland
35	Other Fodder Crops	Fodder	Annual Cropland
36	Other Fodder Vegetables	Fodder	Annual Cropland
37	Repco	Fodder	Annual Cropland
38	Sainfoin	Fodder	Annual Cropland
39	Vetches	Fodder	Annual Cropland
40	Bulb Vegetable Crops	Greenhouses	Annual Cropland
41	Cultivated Mushrooms	Greenhouses	Annual Cropland
42	Deciduous Vegetable Crops	Greenhouses	Annual Cropland
43	Flowers	Greenhouses	Annual Cropland
44	Flowers and Decorative Plants	Greenhouses	Annual Cropland
45	Greenhouse Cucumbers	Greenhouses	Annual Cropland

№	CROP NAME	CROP TYPE	IPCC CATEGORY
46	Greenhouse Pepper	Greenhouses	Annual Cropland
47	Greenhouse Tomatoes	Greenhouses	Annual Cropland
48	Other Vegetable Crops	Greenhouses	Annual Cropland
49	Root Vegetable Crops	Greenhouses	Annual Cropland
50	Anise	Industrial and Oleaginous	Annual Cropland
51	Artificial Meadows	Industrial and Oleaginous	Annual Cropland
52	Basil	Industrial and Oleaginous	Annual Cropland
53	Beebalm	Industrial and Oleaginous	Annual Cropland
54	Belladonna	Industrial and Oleaginous	Annual Cropland
55	Berries	Industrial and Oleaginous	Annual Cropland
56	Black Parsley	Industrial and Oleaginous	Annual Cropland
57	Catnip	Industrial and Oleaginous	Annual Cropland
58	Chamomile	Industrial and Oleaginous	Annual Cropland
59	Chicory	Industrial and Oleaginous	Annual Cropland
60	Coriander	Industrial and Oleaginous	Annual Cropland
61	Cotton	Industrial and Oleaginous	Annual Cropland
62	Cumin	Industrial and Oleaginous	Annual Cropland
63	Damask Rose	Industrial and Oleaginous	Annual Cropland
64	Echinacea	Industrial and Oleaginous	Annual Cropland
65	Fennel	Industrial and Oleaginous	Annual Cropland
66	Fibre Flax	Industrial and Oleaginous	Annual Cropland
67	Fibre Plants	Industrial and Oleaginous	Annual Cropland
68	Flowers	Industrial and Oleaginous	Annual Cropland
69	Fodder Beet	Industrial and Oleaginous	Annual Cropland
70	Good-King-Henry	Industrial and Oleaginous	Annual Cropland
71	Hemp	Industrial and Oleaginous	Annual Cropland
72	Henbane	Industrial and Oleaginous	Annual Cropland
73	Hops	Industrial and Oleaginous	Annual Cropland
74	Hops	Industrial and Oleaginous	Annual Cropland
75	Hyssop	Industrial and Oleaginous	Annual Cropland
76	Jimsonweed	Industrial and Oleaginous	Annual Cropland
77	Lavender	Industrial and Oleaginous	Annual Cropland
78	Leuzea	Industrial and Oleaginous	Annual Cropland
79	Marjoram	Industrial and Oleaginous	Annual Cropland
80	Marshmallow	Industrial and Oleaginous	Annual Cropland
81	Medicinal and Aromatic Crops	Industrial and Oleaginous	Annual Cropland
82	Medicinal and Aromatic Crops	Industrial and Oleaginous	Annual Cropland
83	Medicinal and Aromatic Perennials	Industrial and Oleaginous	Annual Cropland
84	Melissa	Industrial and Oleaginous	Annual Cropland
85	Milk Thistle	Industrial and Oleaginous	Annual Cropland
86	Mint	Industrial and Oleaginous	Annual Cropland
87	Oil Flax	Industrial and Oleaginous	Annual Cropland
88	Other Fibre Plants	Industrial and Oleaginous	Annual Cropland
89	Other Fragrant Perennials	Industrial and Oleaginous	Annual Cropland
90	Other Industrial Crops	Industrial and Oleaginous	Annual Cropland
91	Other Industrial Crops	Industrial and Oleaginous	Annual Cropland
92	Other Medicinal and Aromatic Plants	Industrial and Oleaginous	Annual Cropland

№	CROP NAME	CROP TYPE	IPCC CATEGORY
93	Other Oil-Seed Plants	Industrial and Oleaginous	Annual Cropland
94	Peanuts	Industrial and Oleaginous	Annual Cropland
95	Perennial Weeds	Industrial and Oleaginous	Annual Cropland
96	Periwinkle	Industrial and Oleaginous	Annual Cropland
97	Pumpkins for Seeds	Industrial and Oleaginous	Annual Cropland
98	Pyrethrum	Industrial and Oleaginous	Annual Cropland
99	Rosehip	Industrial and Oleaginous	Annual Cropland
100	Rosemarry	Industrial and Oleaginous	Annual Cropland
101	Sage	Industrial and Oleaginous	Annual Cropland
102	Sesame	Industrial and Oleaginous	Annual Cropland
103	Snowflake	Industrial and Oleaginous	Annual Cropland
104	Soy	Industrial and Oleaginous	Annual Cropland
105	Spring Rapeseed	Industrial and Oleaginous	Annual Cropland
106	Sugar Beet	Industrial and Oleaginous	Annual Cropland
107	Sugar Beet	Industrial and Oleaginous	Annual Cropland
108	Sunflowers	Industrial and Oleaginous	Annual Cropland
109	Thyme	Industrial and Oleaginous	Annual Cropland
110	Tobacco	Industrial and Oleaginous	Annual Cropland
111	Tobacco	Industrial and Oleaginous	Annual Cropland
112	Valerian	Industrial and Oleaginous	Annual Cropland
113	White Oregano	Industrial and Oleaginous	Annual Cropland
114	Winter Rapeseed	Industrial and Oleaginous	Annual Cropland
115	Wormwood	Industrial and Oleaginous	Annual Cropland
116	Yellow Poppy	Industrial and Oleaginous	Annual Cropland
117	Chickpeas	Legume	Annual Cropland
118	Field Beans	Legume	Annual Cropland
119	Grain Fava Beans	Legume	Annual Cropland
120	Lentils	Legume	Annual Cropland
121	Other Protein Crops	Legume	Annual Cropland
122	Spring Grain Peas	Legume	Annual Cropland
123	Vigna	Legume	Annual Cropland
124	Winter Grain Peas	Legume	Annual Cropland
125	Decorative Bushes	Nurseries	Annual Cropland
126	Decorative Plants Nurseries	Nurseries	Annual Cropland
127	Flowers Grown For Bulbs	Nurseries	Annual Cropland
128	Flowers Grown For Cut Flowers	Nurseries	Annual Cropland
129	Forest Seedlings Nurseries	Nurseries	Annual Cropland
130	Fruit Propagating Material	Nurseries	Annual Cropland
131	Graft Nurseries	Nurseries	Annual Cropland
132	Nurseries	Nurseries	Annual Cropland
133	Other Decorative Plants	Nurseries	Annual Cropland
134	Potted Plants	Nurseries	Annual Cropland
135	Potatoes	Potatoes	Annual Cropland
136	Artichoke	Vegetables	Annual Cropland
137	Asparagus	Vegetables	Annual Cropland
138	Aubergine	Vegetables	Annual Cropland
139	Broccoli	Vegetables	Annual Cropland

№	CROP NAME	CROP TYPE	IPCC CATEGORY
140	Cabbage	Vegetables	Annual Cropland
141	Carrots	Vegetables	Annual Cropland
142	Cauliflower	Vegetables	Annual Cropland
143	Celery	Vegetables	Annual Cropland
144	Courgettes	Vegetables	Annual Cropland
145	Dill	Vegetables	Annual Cropland
146	Garlic	Vegetables	Annual Cropland
147	Green Beans	Vegetables	Annual Cropland
148	Green Fava Beans	Vegetables	Annual Cropland
149	Green Peas	Vegetables	Annual Cropland
150	Leeks	Vegetables	Annual Cropland
151	Lettuce	Vegetables	Annual Cropland
152	Melons	Vegetables	Annual Cropland
153	Okra	Vegetables	Annual Cropland
154	Onion	Vegetables	Annual Cropland
155	Onion Set	Vegetables	Annual Cropland
156	Other Bulb Vegetable Crops	Vegetables	Annual Cropland
157	Other Deciduous Crops	Vegetables	Annual Cropland
158	Other Fruit and Vegetable Crops	Vegetables	Annual Cropland
159	Other Perennial Vegetable Plants	Vegetables	Annual Cropland
160	Other Root Crops	Vegetables	Annual Cropland
161	Outdoor Cucumbers	Vegetables	Annual Cropland
162	Outdoor Gherkins	Vegetables	Annual Cropland
163	Outdoor Pepper	Vegetables	Annual Cropland
164	Outdoor Tomatoes	Vegetables	Annual Cropland
165	Parsley	Vegetables	Annual Cropland
166	Pumpkins	Vegetables	Annual Cropland
167	Radishes	Vegetables	Annual Cropland
168	Salad	Vegetables	Annual Cropland
169	Salad Beetroot	Vegetables	Annual Cropland
170	Spinach	Vegetables	Annual Cropland
171	Sweet Corn	Vegetables	Annual Cropland
172	Turnip	Vegetables	Annual Cropland
173	Vegetables	Vegetables	Annual Cropland
174	Watermelons	Vegetables	Annual Cropland
175	Almond Willow	EFA	Perennial Cropland
176	Aspen	EFA	Perennial Cropland
177	Black Alder	EFA	Perennial Cropland
178	Black Mulberry	EFA	Perennial Cropland
179	Black Poplar	EFA	Perennial Cropland
180	Crack Willow	EFA	Perennial Cropland
181	Field Elm	EFA	Perennial Cropland
182	Goat Willow	EFA	Perennial Cropland
183	Hazel	EFA	Perennial Cropland
184	Mulberries	EFA	Perennial Cropland
185	Old World Sycamore	EFA	Perennial Cropland
186	Osier	EFA	Perennial Cropland

№	CROP NAME	CROP TYPE	IPCC CATEGORY
187	Poplars	EFA	Perennial Cropland
188	Short Rotation Coppice	EFA	Perennial Cropland
189	Silver Linden	EFA	Perennial Cropland
190	White Mulberry	EFA	Perennial Cropland
191	White Poplar	EFA	Perennial Cropland
192	White Willow Tree	EFA	Perennial Cropland
193	Willow Tree	EFA	Perennial Cropland
194	Almonds	Orchards	Perennial Cropland
195	Apples	Orchards	Perennial Cropland
196	Apricots/Umes	Orchards	Perennial Cropland
197	Cherries	Orchards	Perennial Cropland
198	Chestnuts	Orchards	Perennial Cropland
199	Dogwood	Orchards	Perennial Cropland
200	Fruit Species	Orchards	Perennial Cropland
201	Hazelnuts	Orchards	Perennial Cropland
202	Medlars	Orchards	Perennial Cropland
203	Nut Species	Orchards	Perennial Cropland
204	Other Nut Crops	Orchards	Perennial Cropland
205	Other Pome Fruits	Orchards	Perennial Cropland
206	Other Stone Fruit Species	Orchards	Perennial Cropland
207	Peaches/Nectarines	Orchards	Perennial Cropland
208	Pears	Orchards	Perennial Cropland
209	Pistachios	Orchards	Perennial Cropland
210	Plums	Orchards	Perennial Cropland
211	Pome Fruits	Orchards	Perennial Cropland
212	Quinces	Orchards	Perennial Cropland
213	Sour Cherries	Orchards	Perennial Cropland
214	Stone Fruit Orchards	Orchards	Perennial Cropland
215	Walnuts	Orchards	Perennial Cropland
216	Actinidia(Kiwifruit)	Other Perennials	Perennial Cropland
217	Aronia	Other Perennials	Perennial Cropland
218	Berry Species	Other Perennials	Perennial Cropland
219	Blackberries	Other Perennials	Perennial Cropland
220	Blackcurrant	Other Perennials	Perennial Cropland
221	Blueberries	Other Perennials	Perennial Cropland
222	Figs	Other Perennials	Perennial Cropland
223	Gooseberry	Other Perennials	Perennial Cropland
224	Other Berries	Other Perennials	Perennial Cropland
225	Other Orchard Crops	Other Perennials	Perennial Cropland
226	Other Permanent Crops	Other Perennials	Perennial Cropland
227	Raspberries	Other Perennials	Perennial Cropland
228	Redcurrant	Other Perennials	Perennial Cropland
229	Strawberries	Other Perennials	Perennial Cropland
230	Table Grapes	Vineyards	Perennial Cropland
231	Vineyards	Vineyards	Perennial Cropland
232	Vineyards	Vineyards	Perennial Cropland
233	Hay Meadows	Pastures and Meadows	Pastures and Meadows

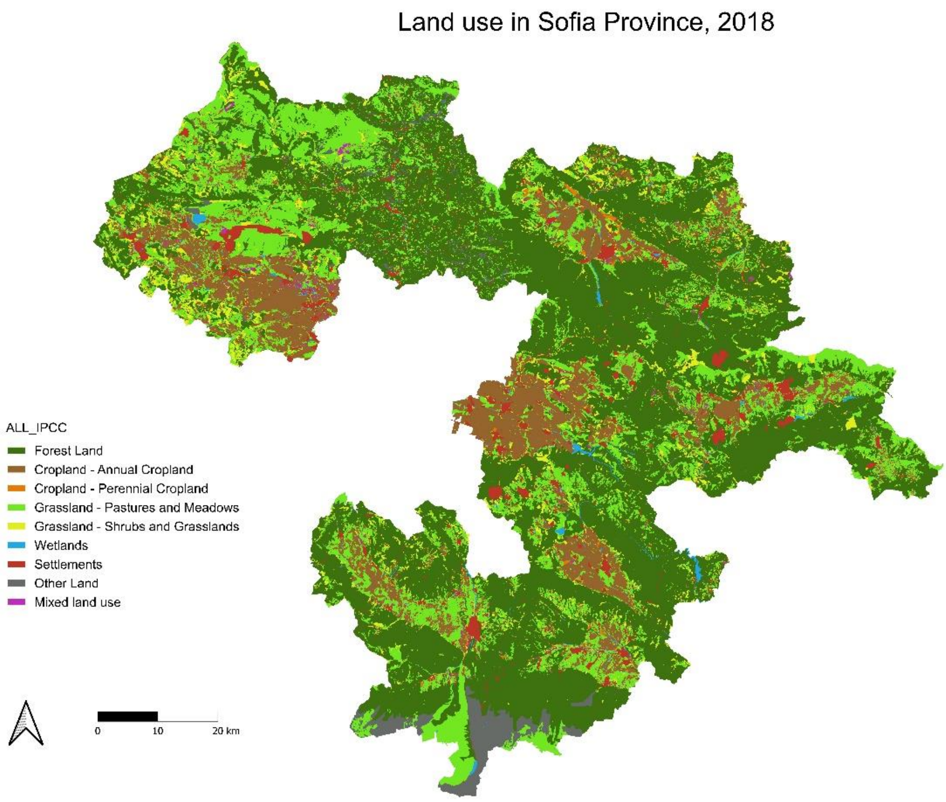
№	CROP NAME	CROP TYPE	IPCC CATEGORY
234	Permanent Grasslands maintained for Grazing or Mowing	Pastures and Meadows	Pastures and Meadows
235	Permanent or temporary pastures for Grazing animals (Pastures and Mountain Pasture for Grazing)	Pastures and Meadows	Pastures and Meadows

Table A: 3 Semantic mapping between FMP descriptions of sub-compartments and IPCC categories

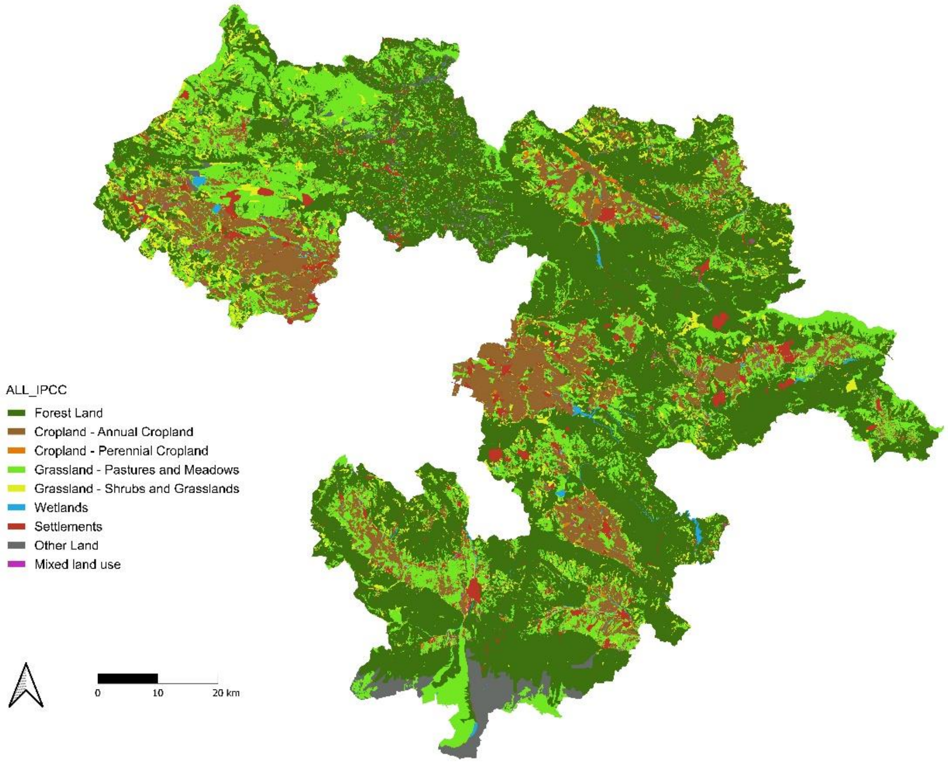
№	FMP areas	IPCC category/subcategory	IPCC Code
1	Dense forest	Forest land	FL
2	Coppices	Forest land	FL
3	Meadow	Grassland	PGM
4	Talus	Other land	OL
5	Barren Lands	Other land	OL
6	Forest Roads	Settlements	SM
7	Morains	Other land	OL
8	Felling site	Forest land	FL
9	Rocks	Other land	OL
10	Clearings	Settlements	SM
11	Courtyards	Grassland	CY
12	Road	Settlements	SM
13	Trench	Other land	OL
14	Spills	Wetlands	WL
15	Temporarily unstocked	Forest land	FL
16	Pothole	Other land	OL
17	Quarries	Settlements	SM
18	Dump site	Settlements	SM
19	Dike	Settlements	SM
20	Woodland with low density	Forest land	FL
21	Bog	Wetlands	WL
22	Burnt-out area	Forest land	FL
23	Pit site	Other land	OL
24	Hut	Settlements	SM
25	Arable land	Cropland	ACL

Annex 2 Maps of Land use and land-use changes

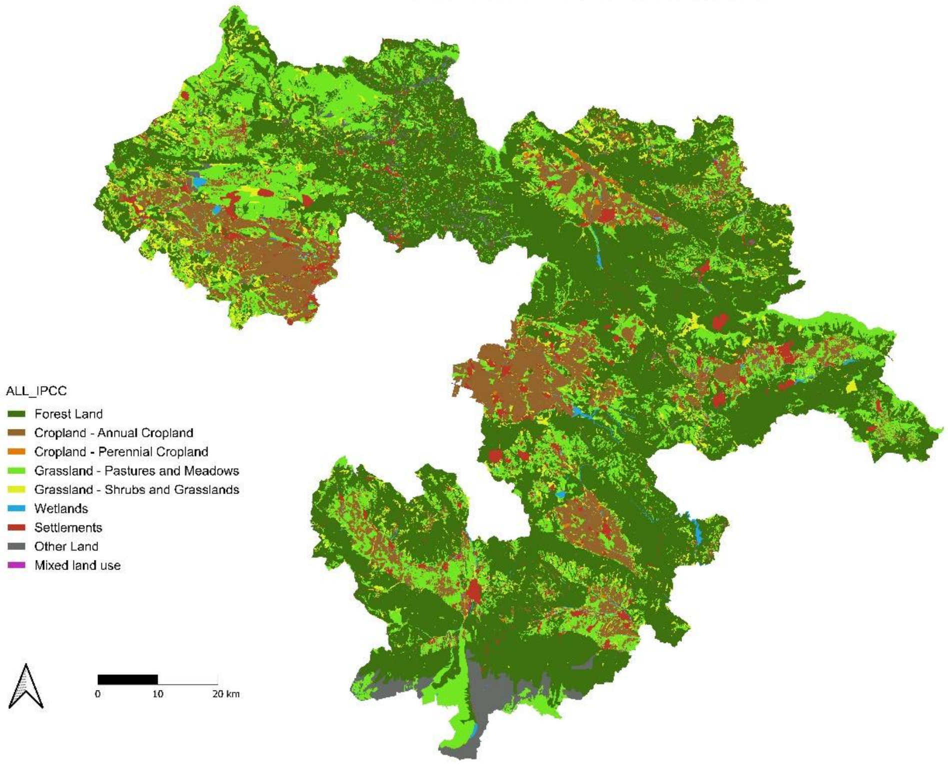
Vector

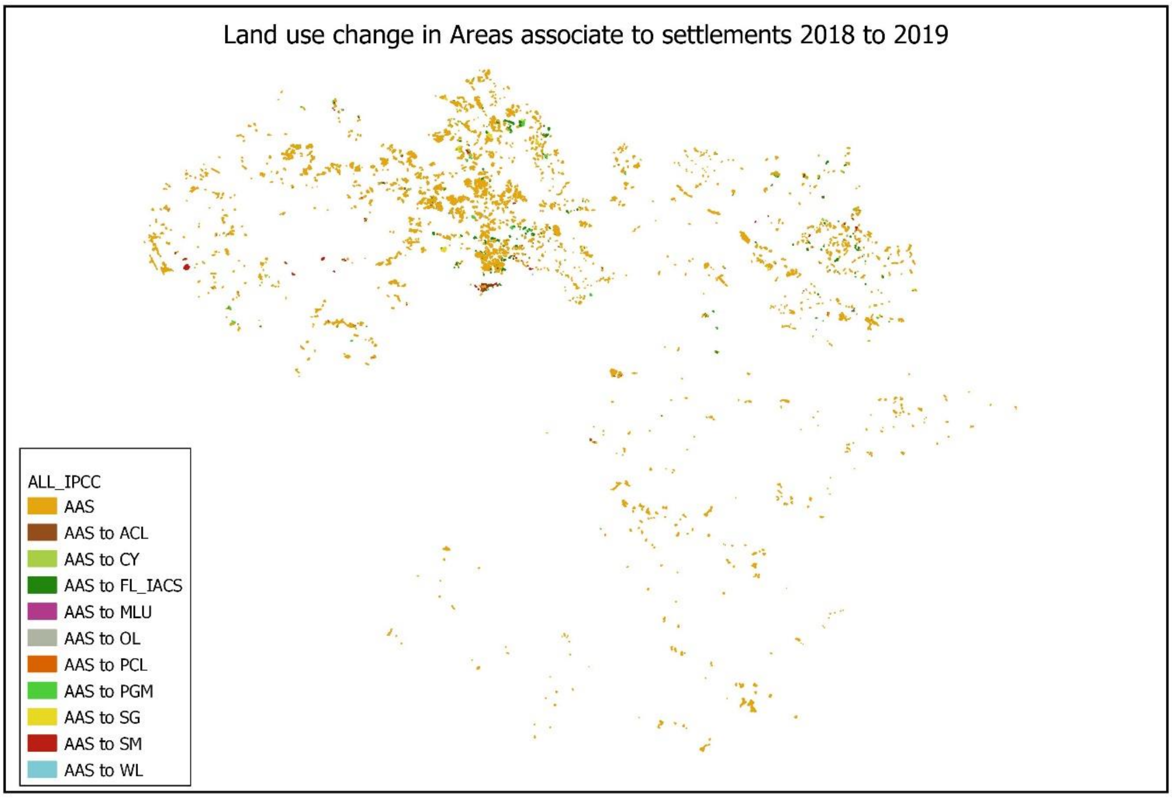


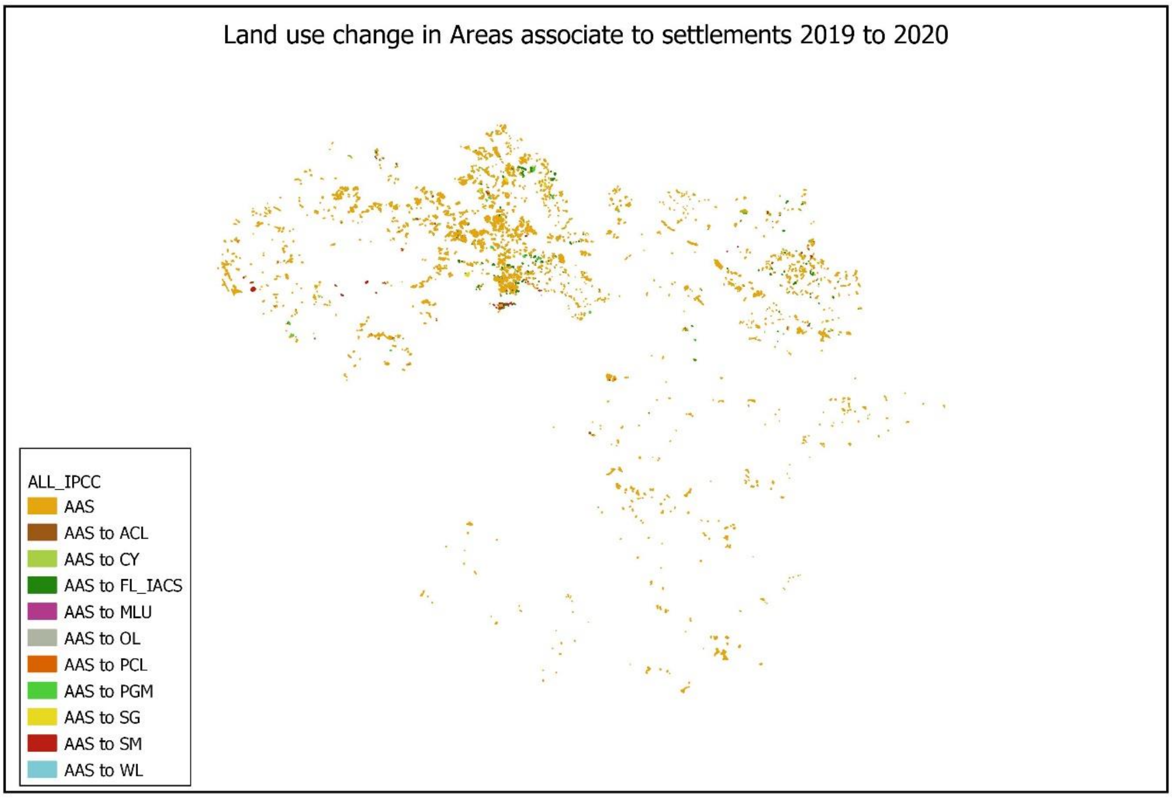
Land use in Sofia Province, 2019

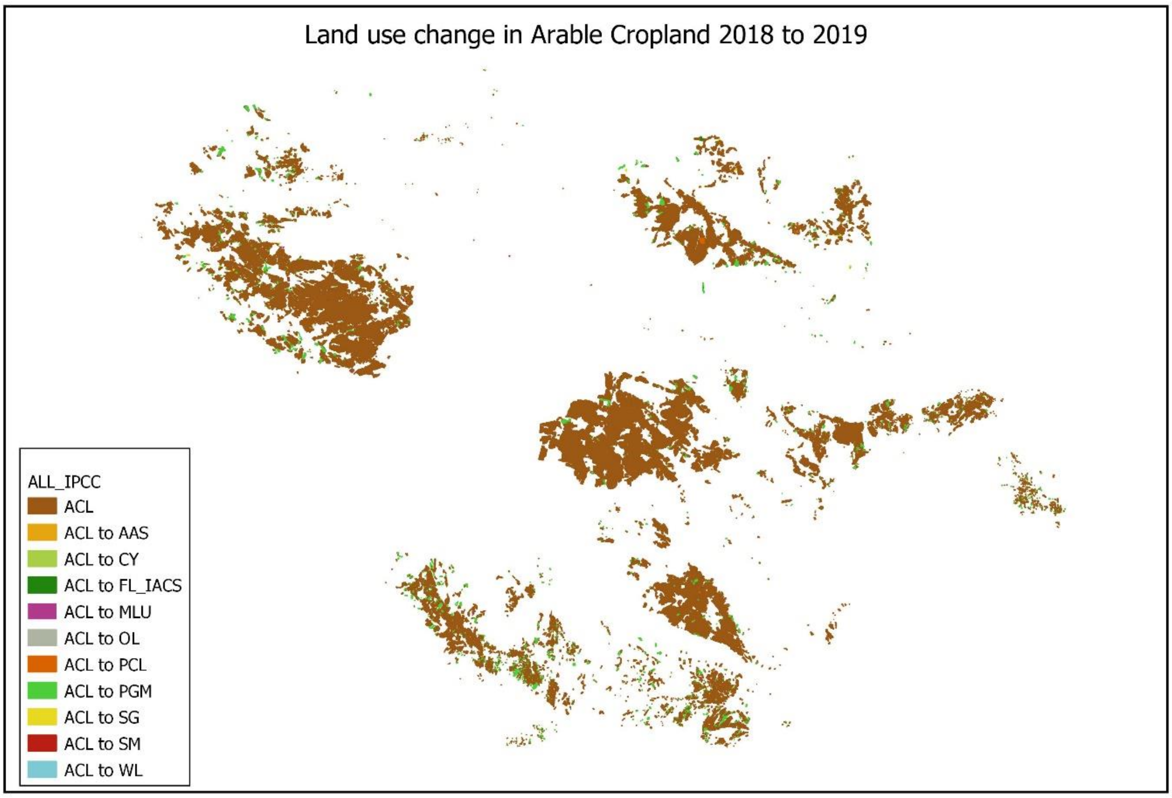


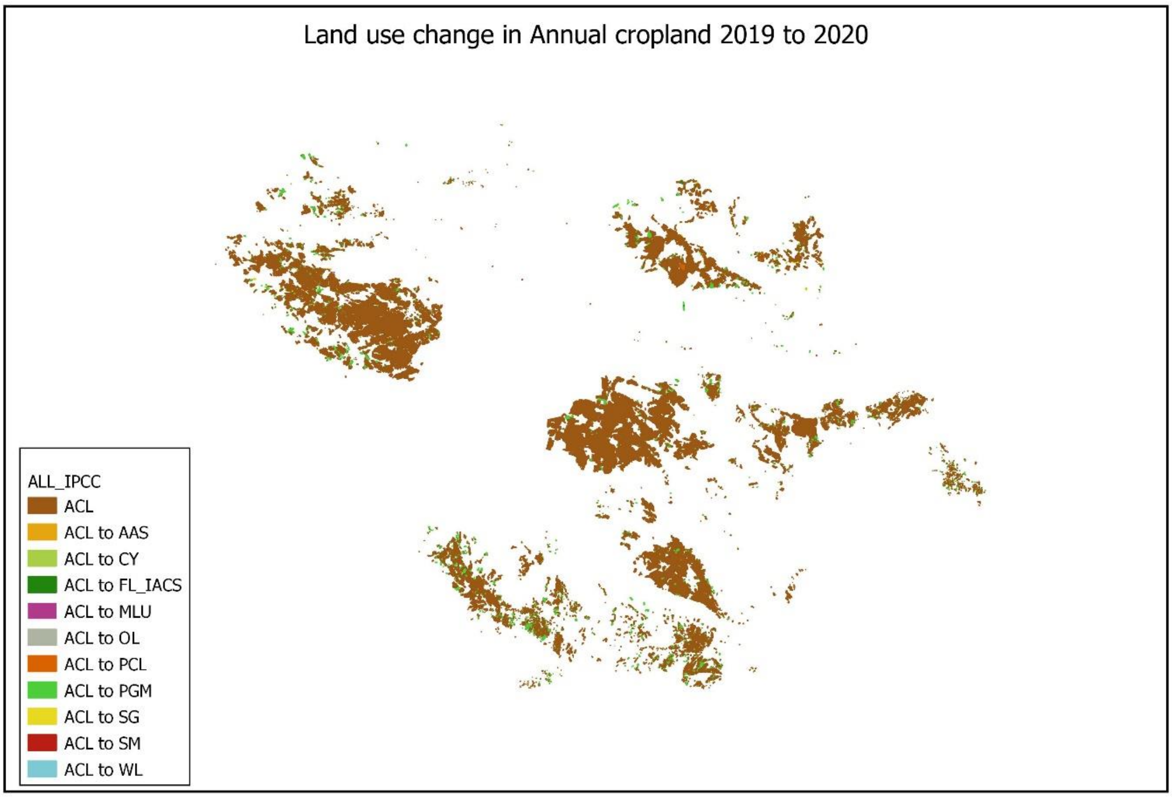
Land use in Sofia Province, 2020

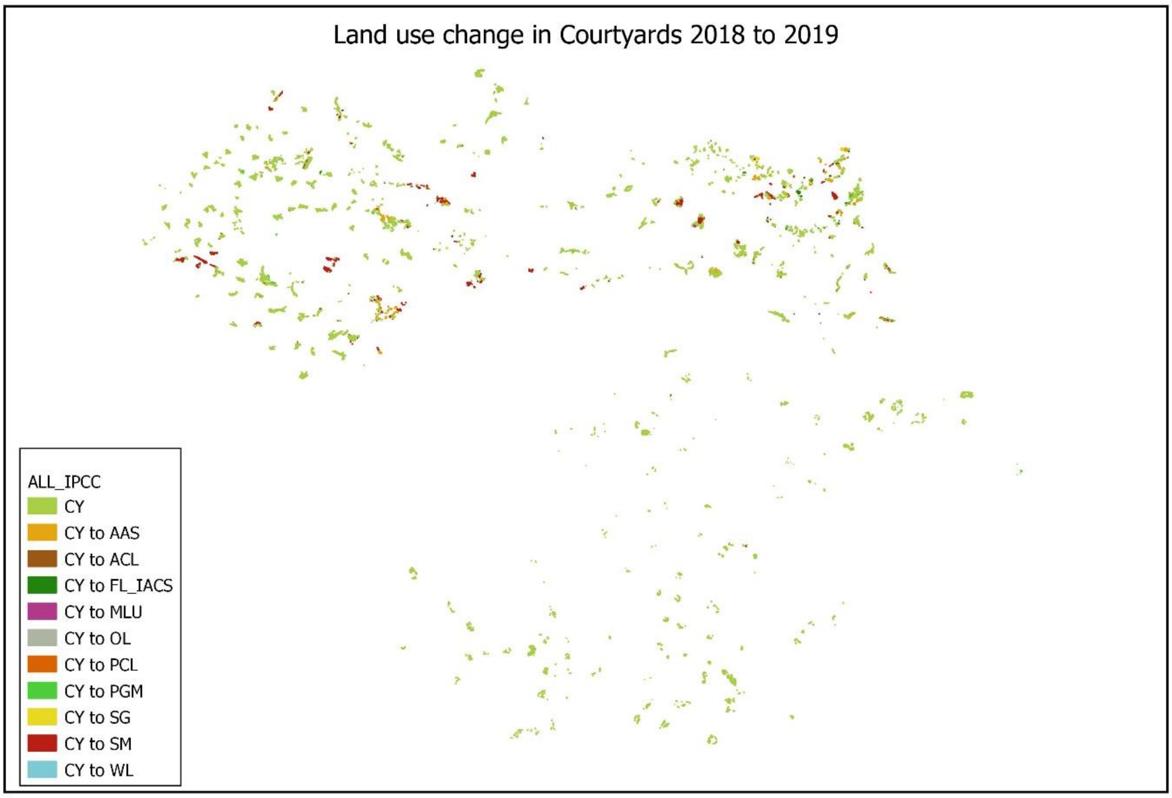


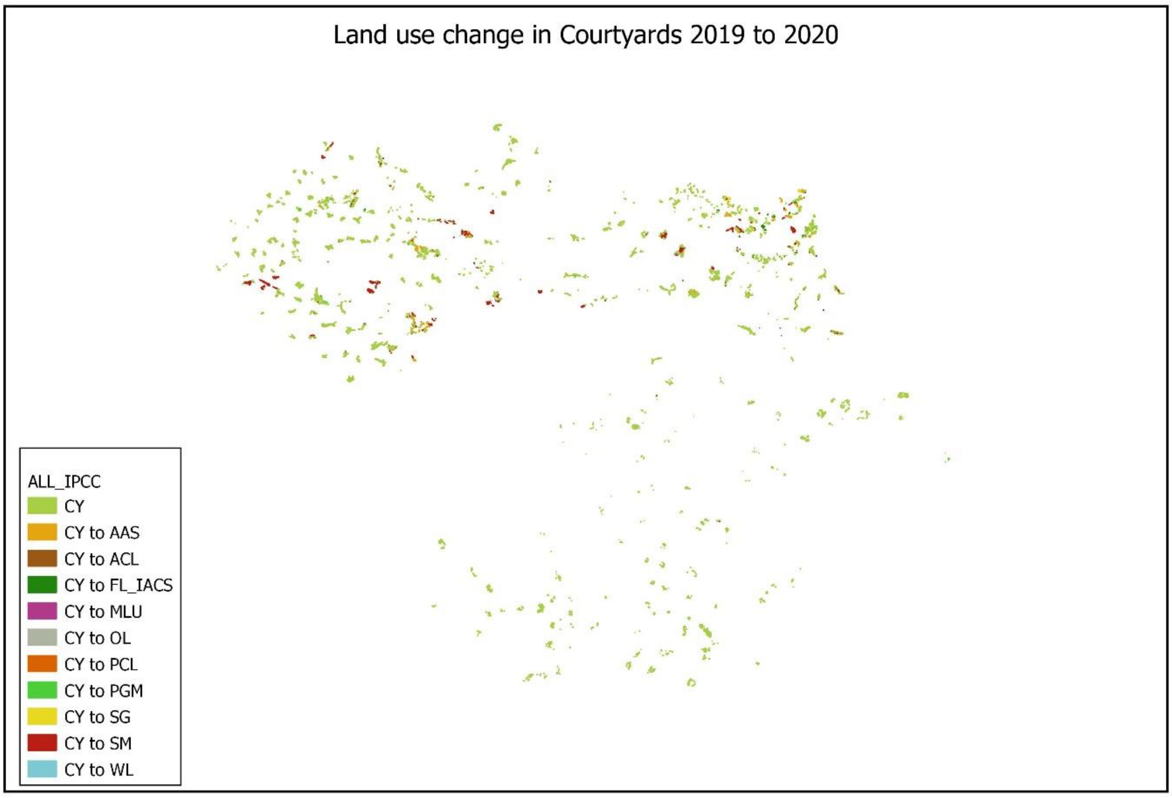

Land use change in Areas associate to settlements 2018 to 2019
ALL_IPCC
AAS
AAS to ACL
AAS to CY
AAS to FL_IACS
AAS to MLU
AAS to OL
AAS to PCL
AAS to PGM
AAS to SG
AAS to SM
AAS to WL

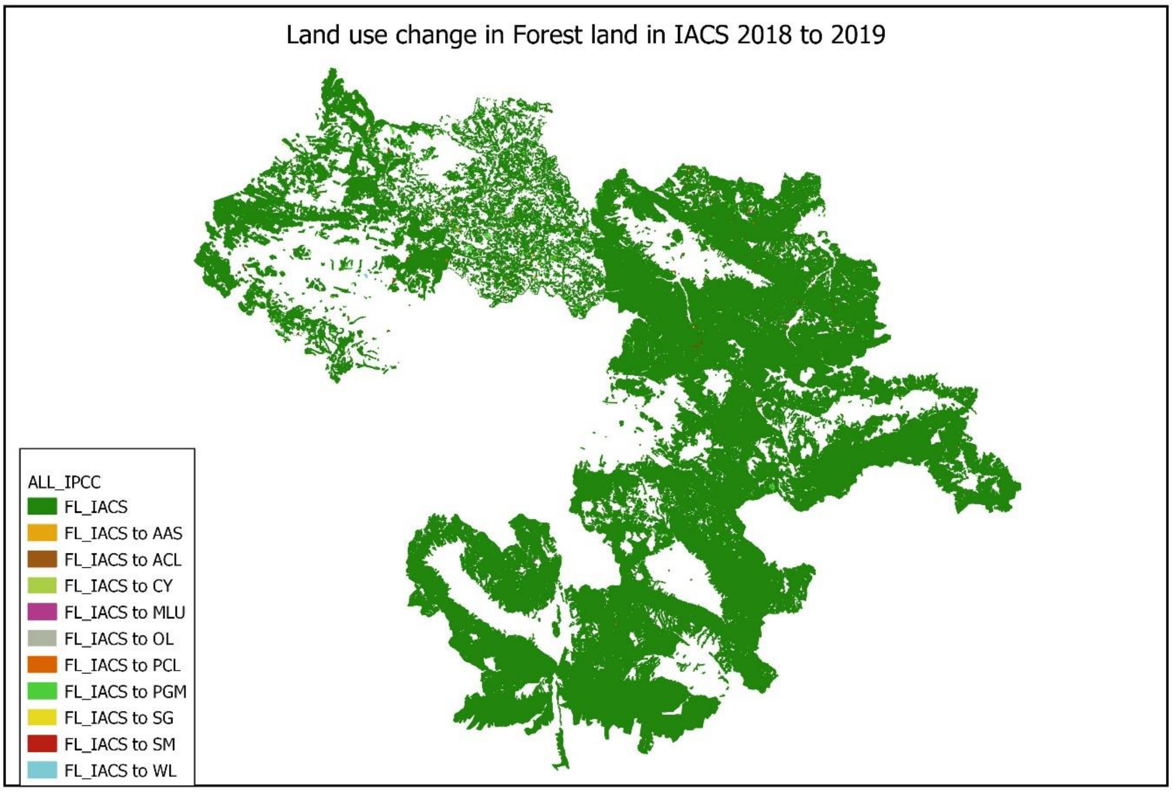

Land use change in Areas associate to settlements 2019 to 2020
ALL_IPCC
AAS
AAS to ACL
AAS to CY
AAS to FL_IACS
AAS to MLU
AAS to OL
AAS to PCL
AAS to PGM
AAS to SG
AAS to SM
AAS to WL

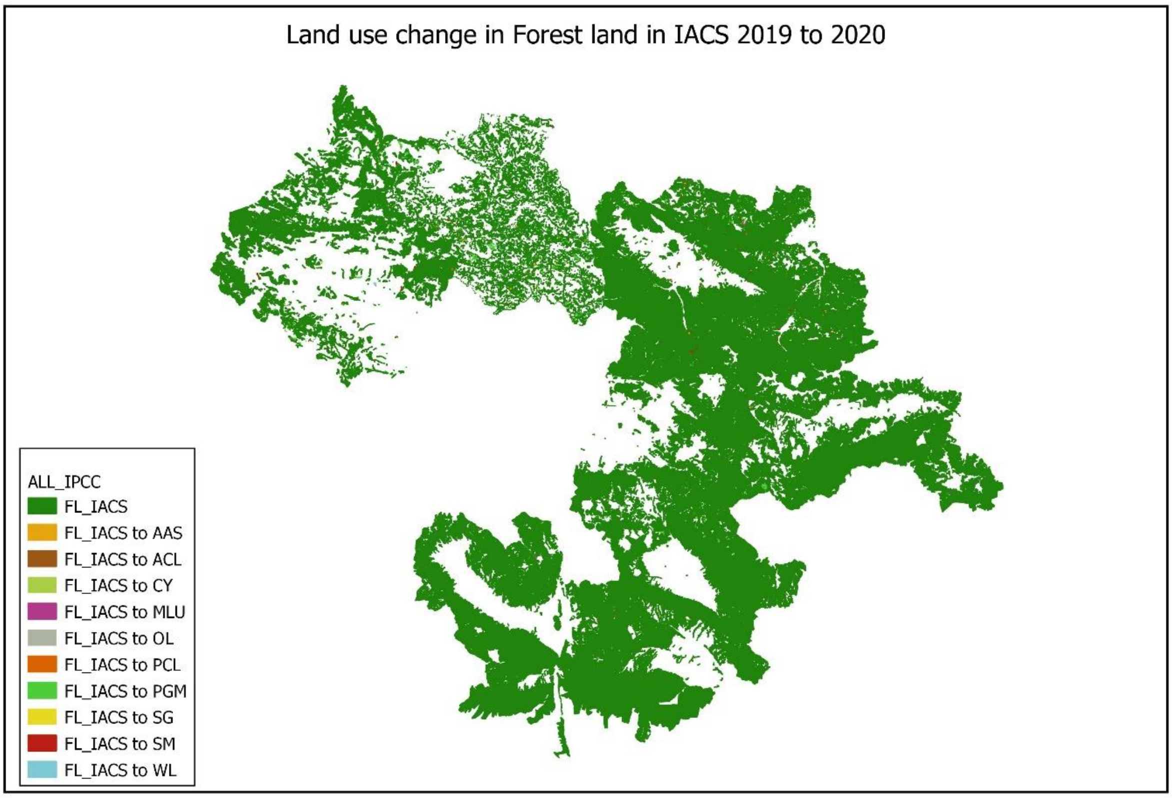

Land use change in Arable Cropland 2018 to 2019
ALL_IPCC
ACL
ACL to AAS
ACL to CY
ACL to FL_IACS
ACL to MLU
ACL to OL
ACL to PCL
ACL to PGM
ACL to SG
ACL to SM
ACL to WL

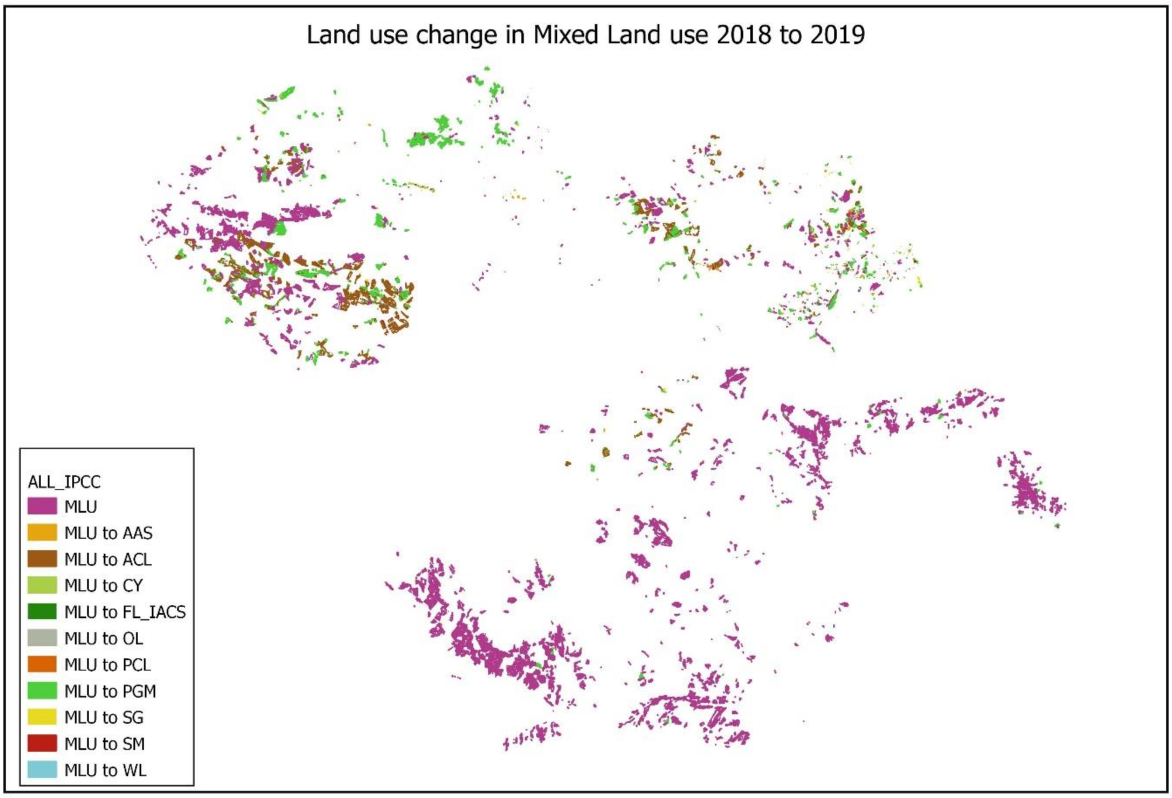

Land use change in Annual cropland 2019 to 2020
ALL_IPCC
ACL
ACL to AAS
ACL to CY
ACL to FL_IACS
ACL to MLU
ACL to OL
ACL to PCL
ACL to PGM
ACL to SG
ACL to SM
ACL to WL


Land use change in Courtyards 2018 to 2019
ALL_IPCC
CY
CY to AAS
CY to ACL
CY to FL_IACS
CY to MLU
CY to OL
CY to PCL
CY to PGM
CY to SG
CY to SM
CY to WL

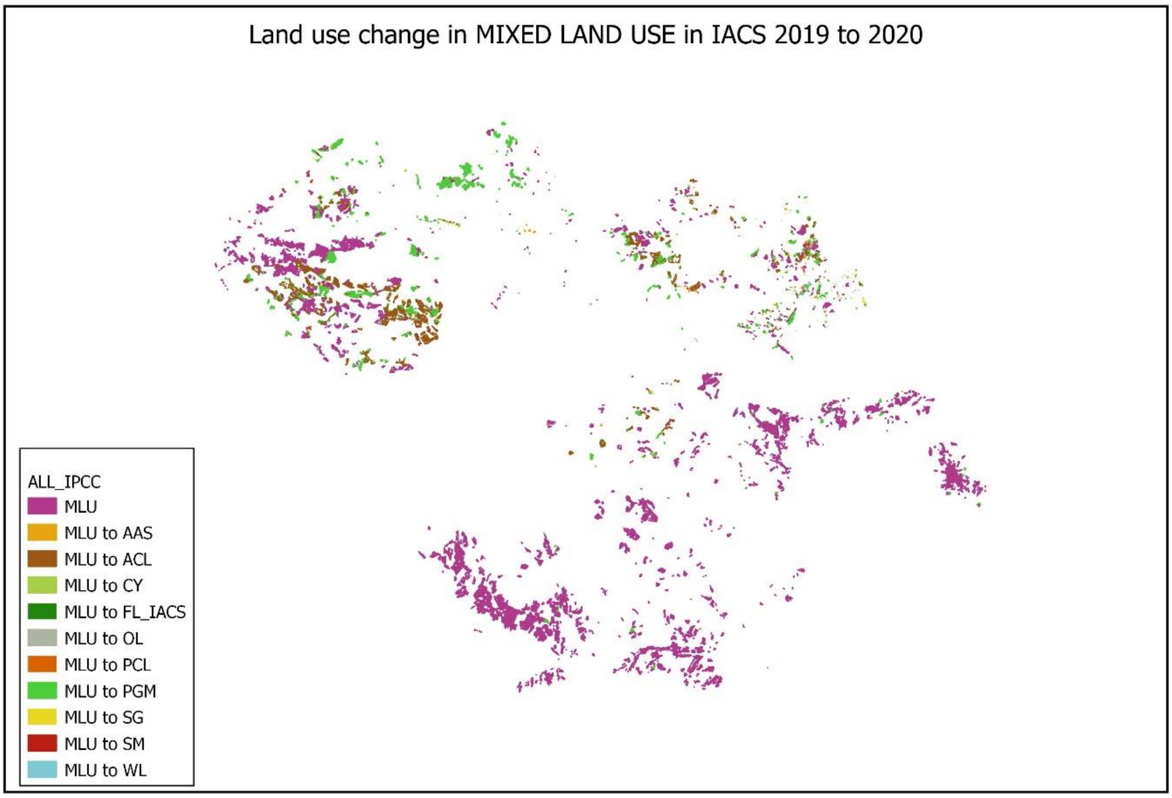

Land use change in Courtyards 2019 to 2020
ALL_IPCC
CY
CY to AAS
CY to ACL
CY to FL_IACS
CY to MLU
CY to OL
CY to PCL
CY to PGM
CY to SG
CY to SM
CY to WL


Land use change in Forest land in IACS 2018 to 2019
ALL_IPCC
FL_IACS
FL_IACS to AAS
FL_IACS to ACL
FL_IACS to CY
FL_IACS to MLU
FL_IACS to OL
FL_IACS to PCL
FL_IACS to PGM
FL_IACS to SG
FL_IACS to SM
FL_IACS to WL

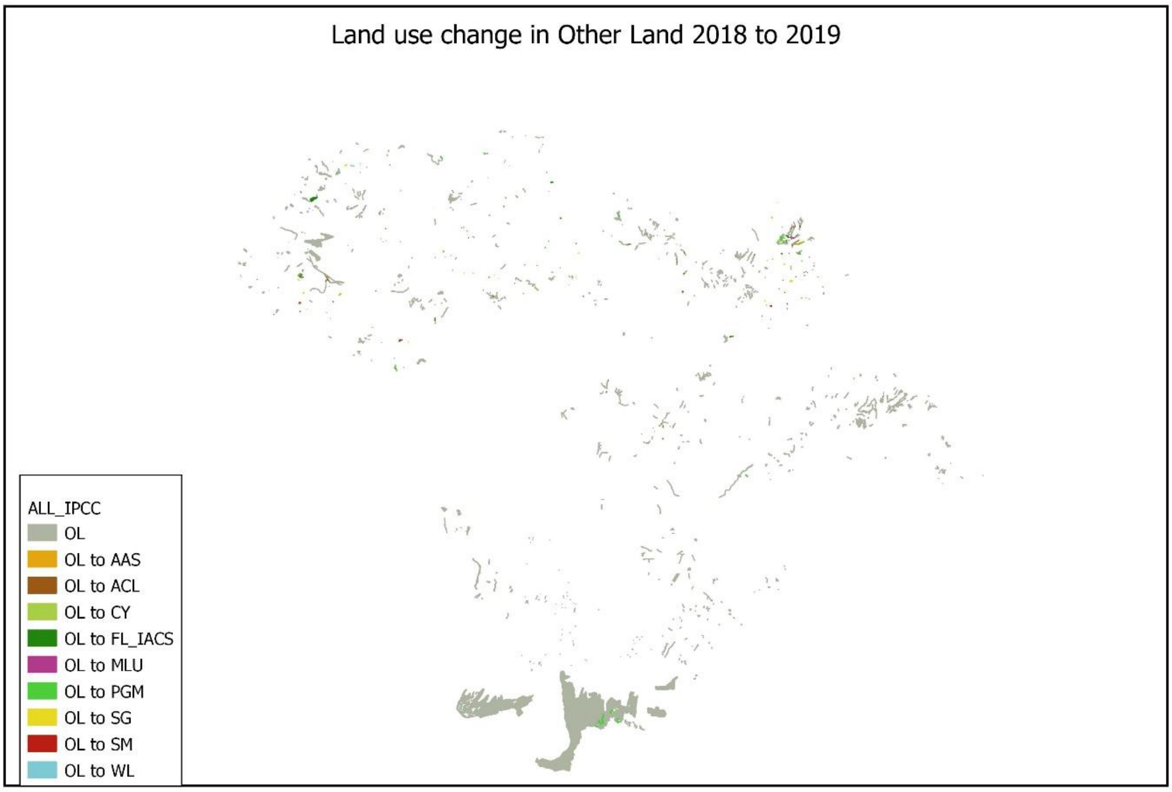

Land use change in Forest land in IACS 2019 to 2020
ALL_IPCC
FL_IACS
FL_IACS to AAS
FL_IACS to ACL
FL_IACS to CY
FL_IACS to MLU
FL_IACS to OL
FL_IACS to PCL
FL_IACS to PGM
FL_IACS to SG
FL_IACS to SM
FL_IACS to WL

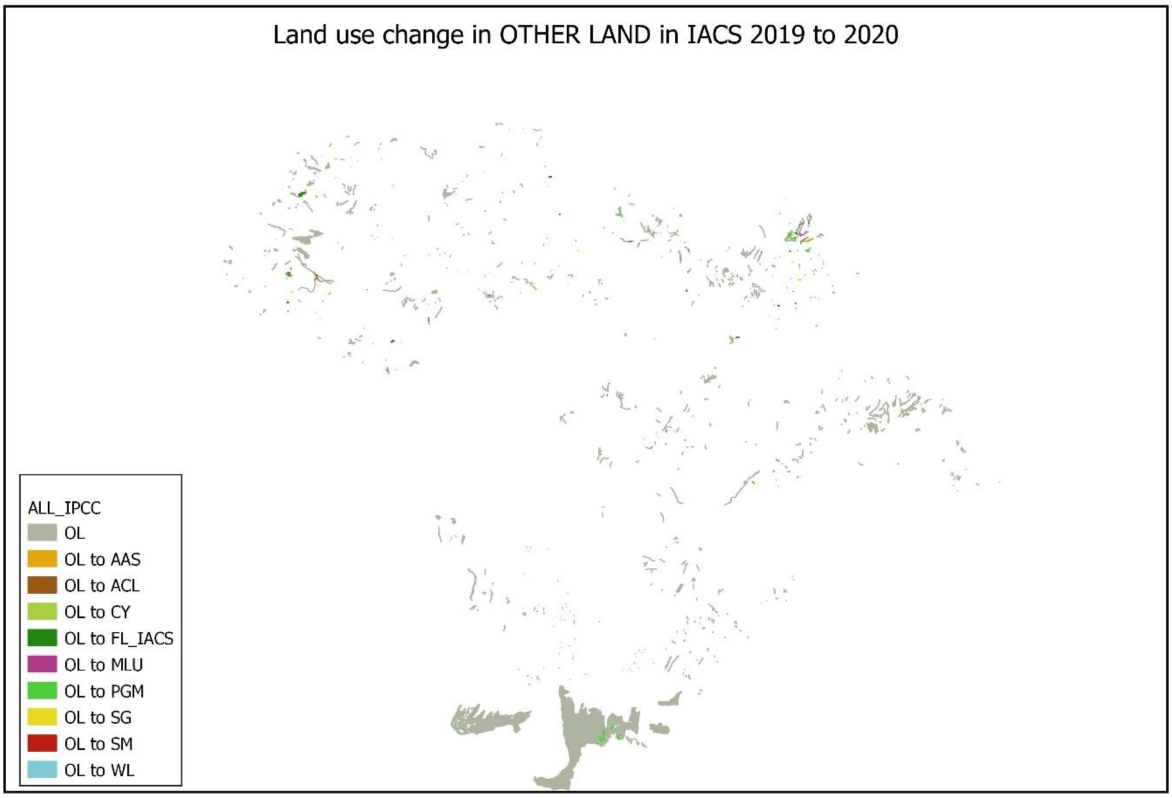


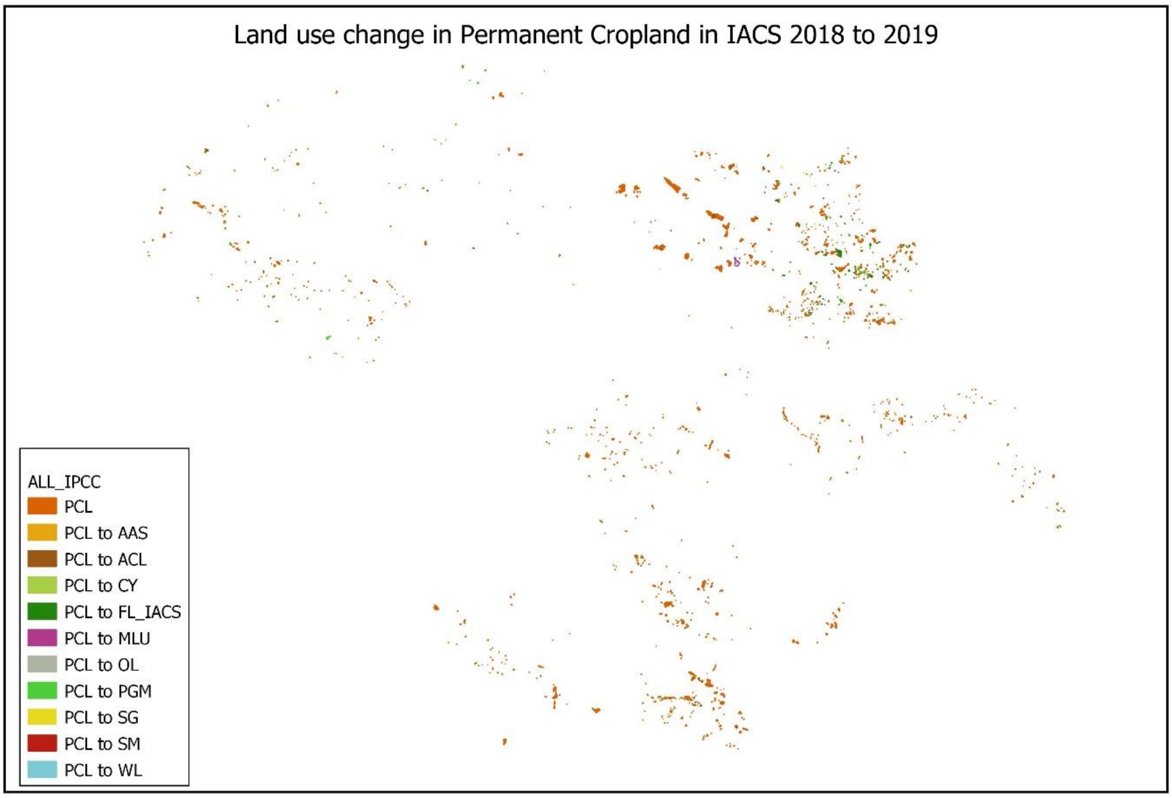
Land use change in Mixed Land use 2018 to 2019
ALL_IPCC
MLU
MLU to AAS
MLU to ACL
MLU to CY
MLU to FL_IACS
MLU to OL
MLU to PCL
MLU to PGM
MLU to SG
MLU to SM
MLU to WL



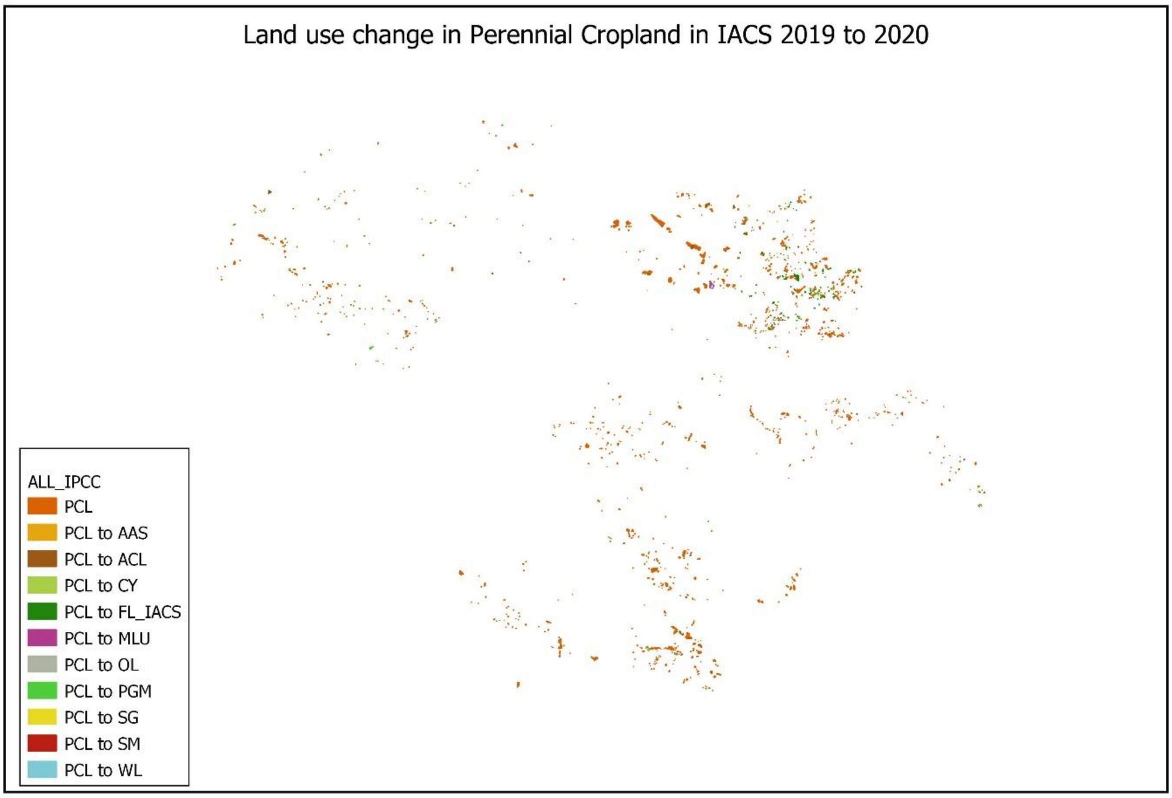
Land use change in MIXED LAND USE in IACS 2019 to 2020
ALL_IPCC
MLU
MLU to AAS
MLU to ACL
MLU to CY
MLU to FL_IACS
MLU to OL
MLU to PCL
MLU to PGM
MLU to SG
MLU to SM
MLU to WL


Land use change in Other Land 2018 to 2019
ALL_IPCC
OL
OL to AAS
OL to ACL
OL to CY
OL to FL_IACS
OL to MLU
OL to PGM
OL to SG
OL to SM
OL to WL

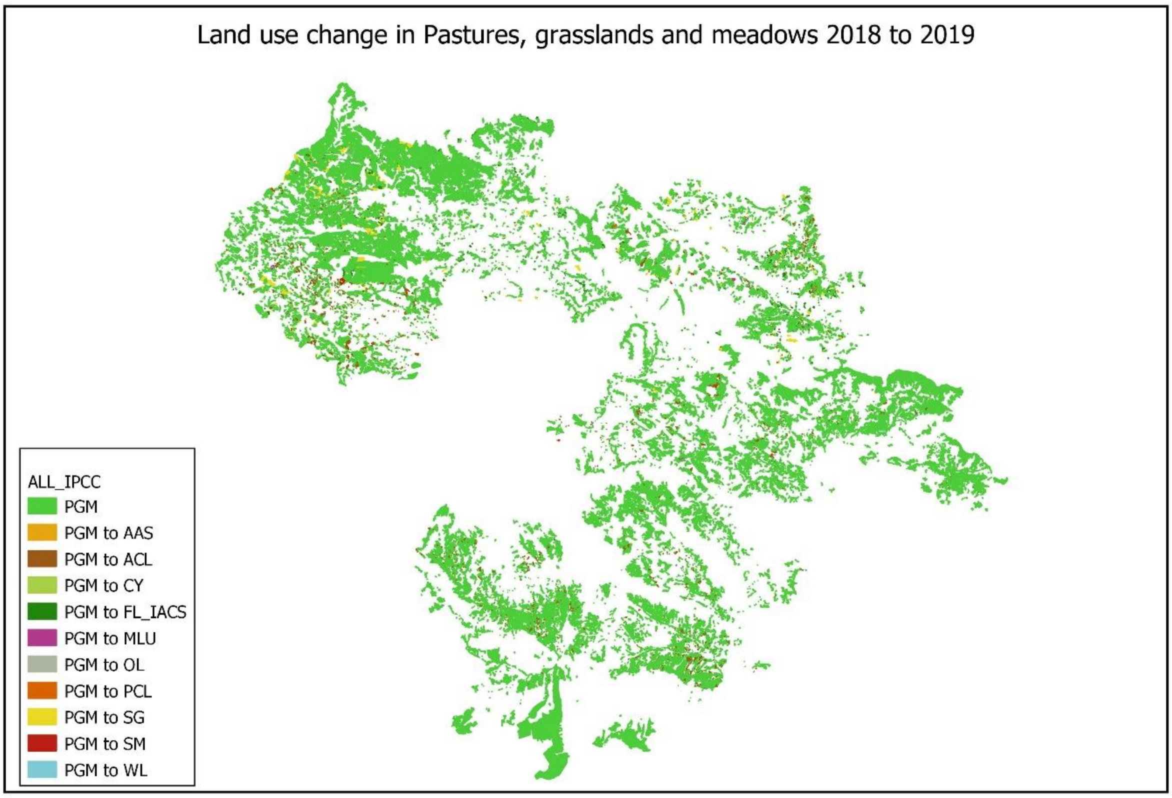

Land use change in OTHER LAND in IACS 2019 to 2020
ALL_IPCC
OL
OL to AAS
OL to ACL
OL to CY
OL to FL_IACS
OL to MLU
OL to PGM
OL to SG
OL to SM
OL to WL



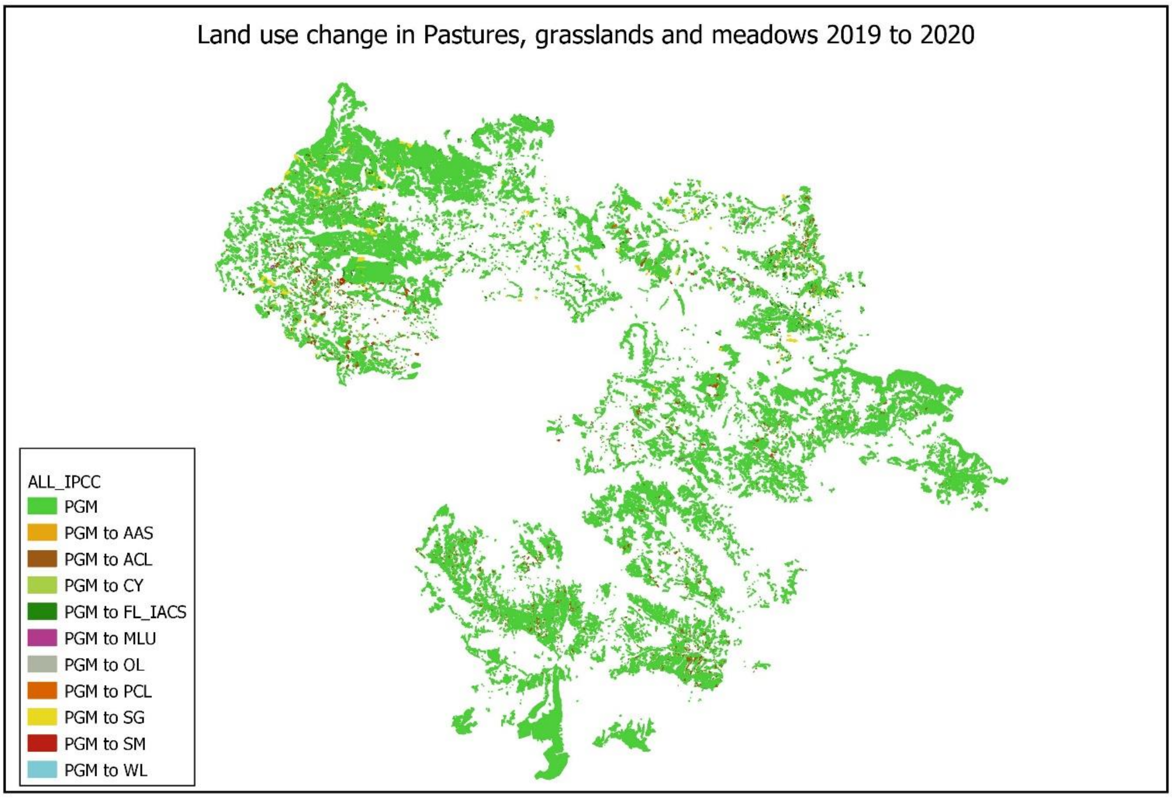
Land use change in Permanent Cropland in IACS 2018 to 2019
ALL_IPCC
PCL
PCL to AAS
PCL to ACL
PCL to CY
PCL to FL_IACS
PCL to MLU
PCL to OL
PCL to PGM
PCL to SG
PCL to SM
PCL to WL



Land use change in Perennial Cropland in IACS 2019 to 2020
ALL_IPCC
PCL
PCL to AAS
PCL to ACL
PCL to CY
PCL to FL_IACS
PCL to MLU
PCL to OL
PCL to PGM
PCL to SG
PCL to SM
PCL to WL

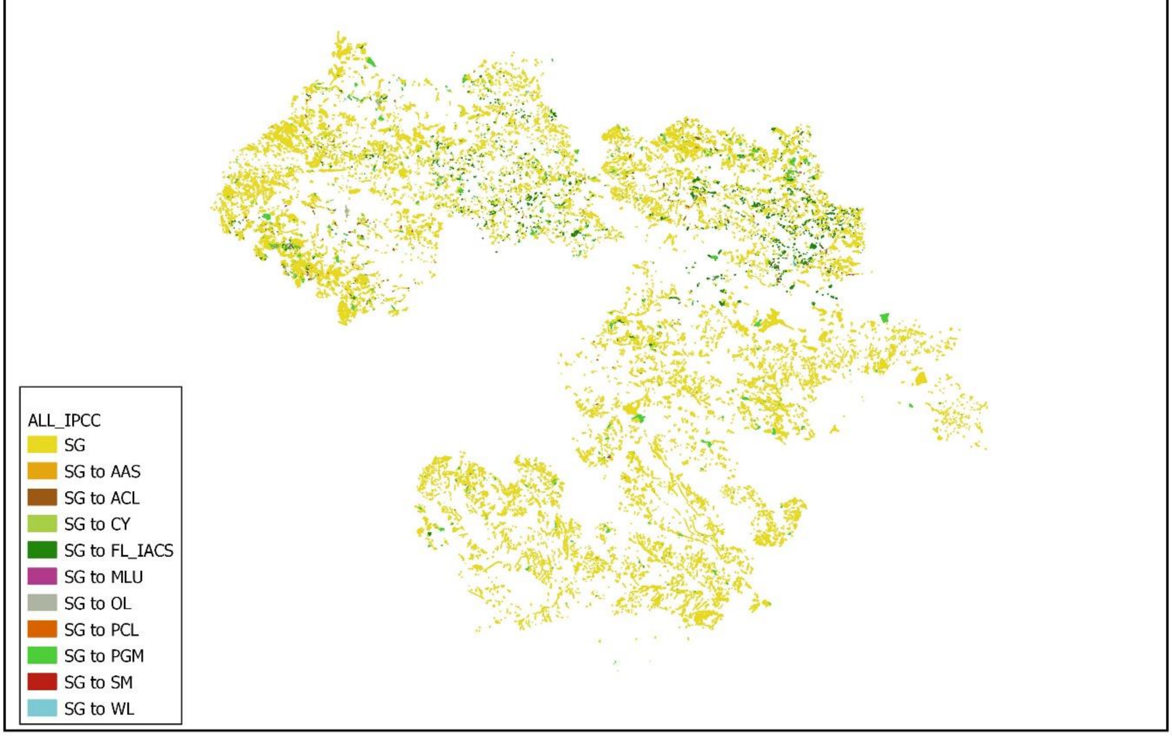


Land use change in Pastures, grasslands and meadows 2018 to 2019
ALL_IPCC
PGM
PGM to AAS
PGM to ACL
PGM to CY
PGM to FL_IACS
PGM to MLU
PGM to OL
PGM to PCL
PGM to SG
PGM to SM
PGM to WL

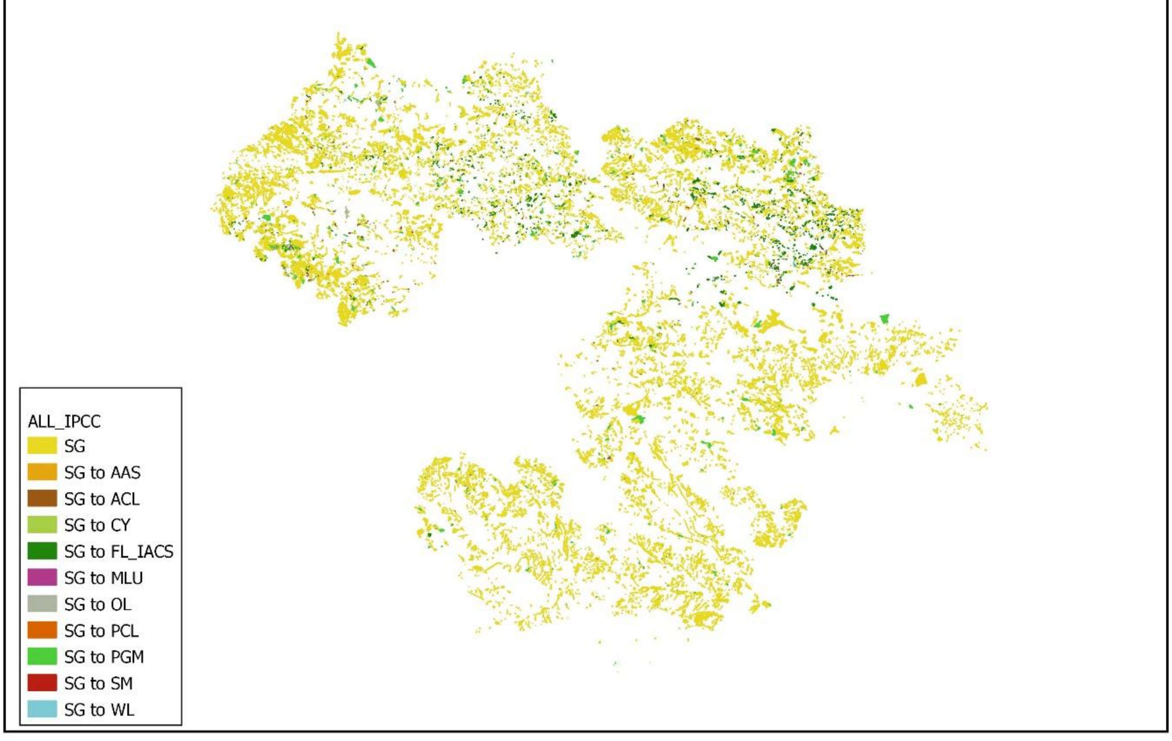


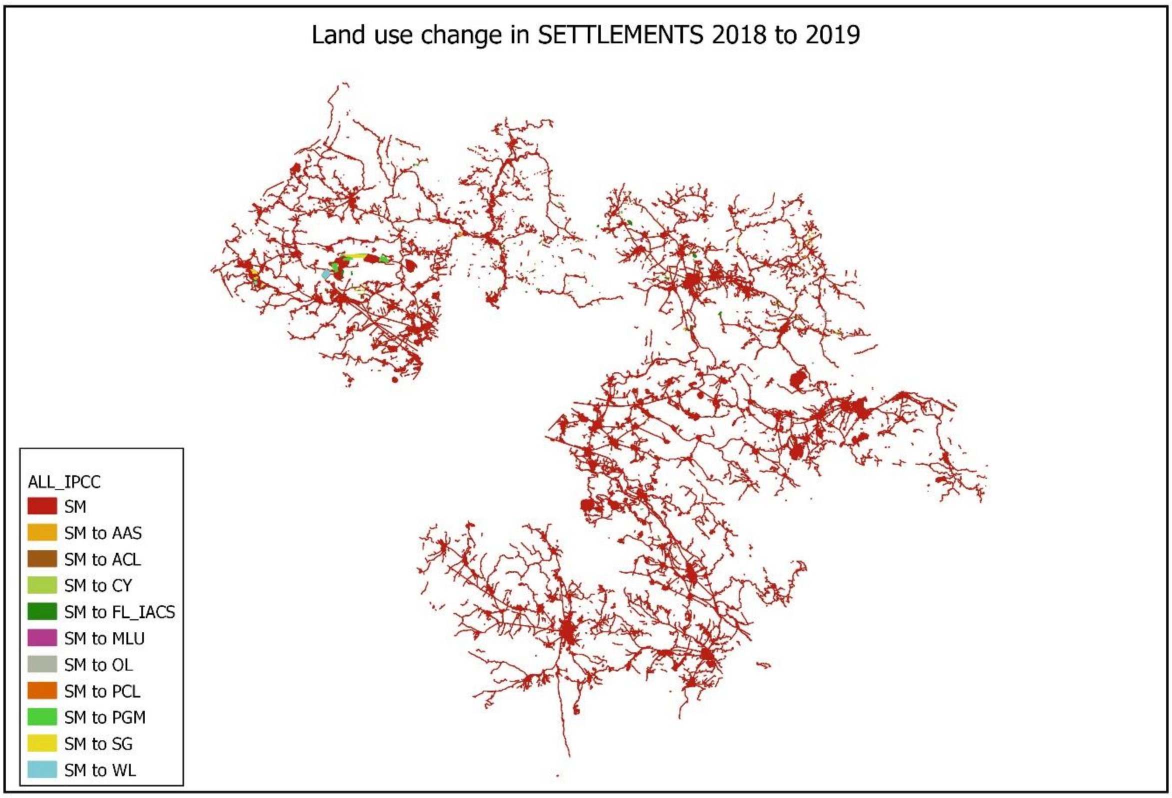
Land use change in Pastures, grasslands and meadows 2019 to 2020
ALL_IPCC
PGM
PGM to AAS
PGM to ACL
PGM to CY
PGM to FL_IACS
PGM to MLU
PGM to OL
PGM to PCL
PGM to SG
PGM to SM
PGM to WL

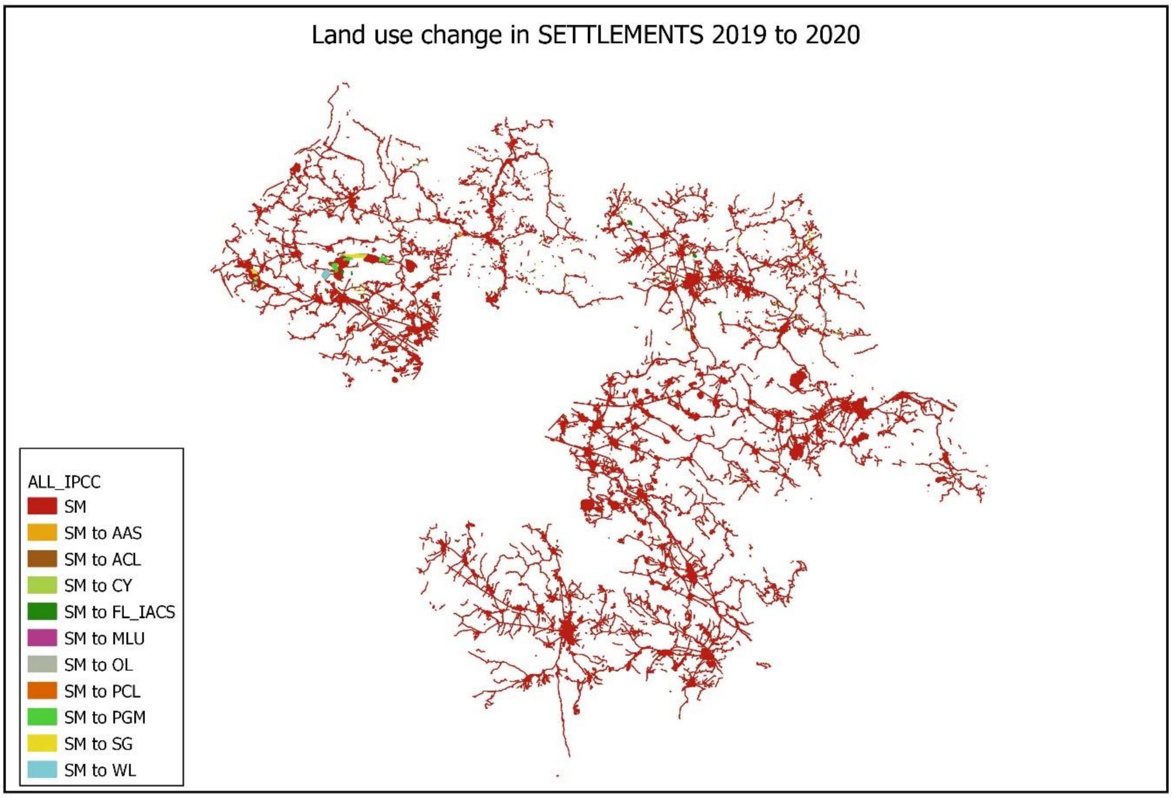
Land use change in Shrubs and grasslands 2018 to 2019

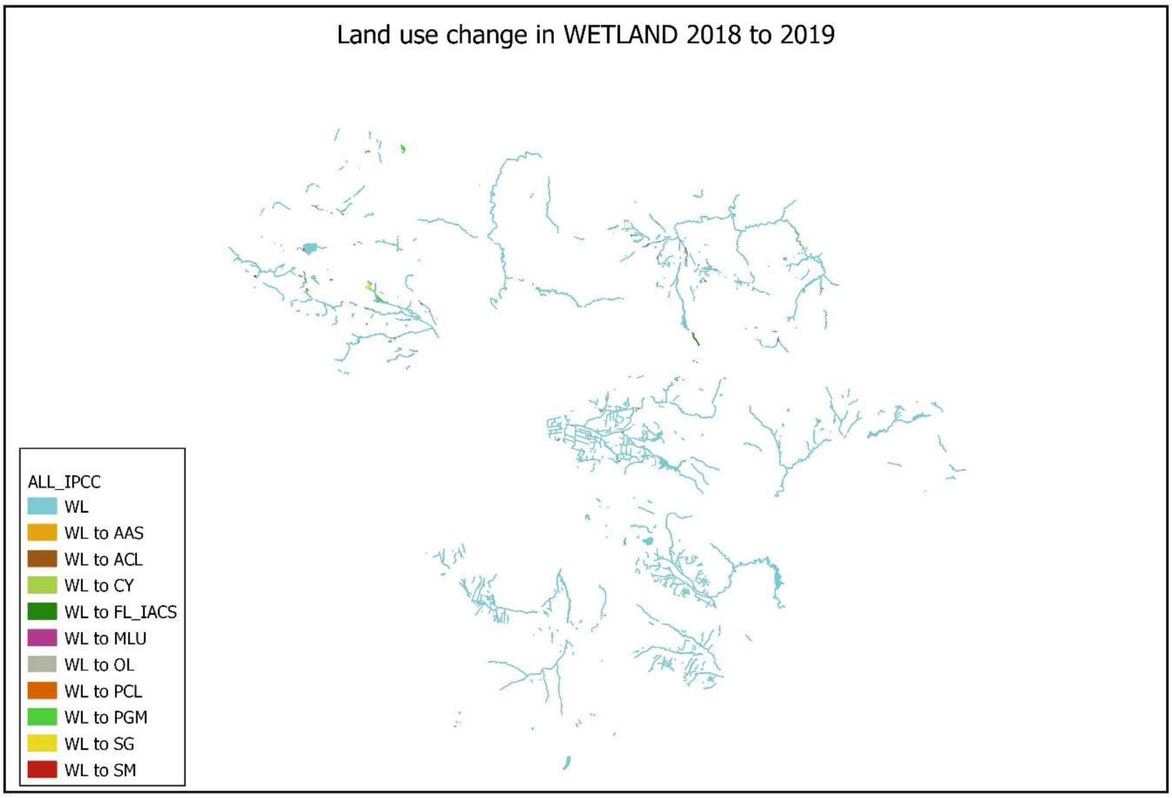


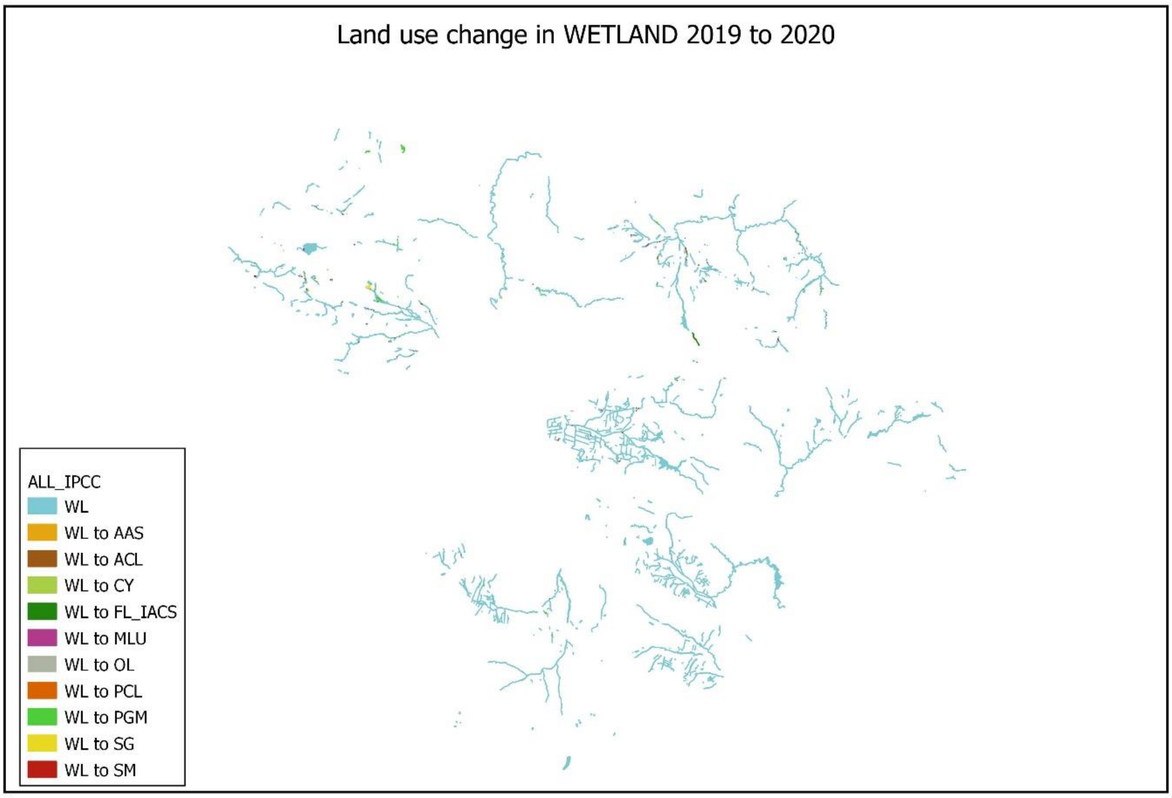
Land use change in Shrubs and grasslands 2019 to 2020

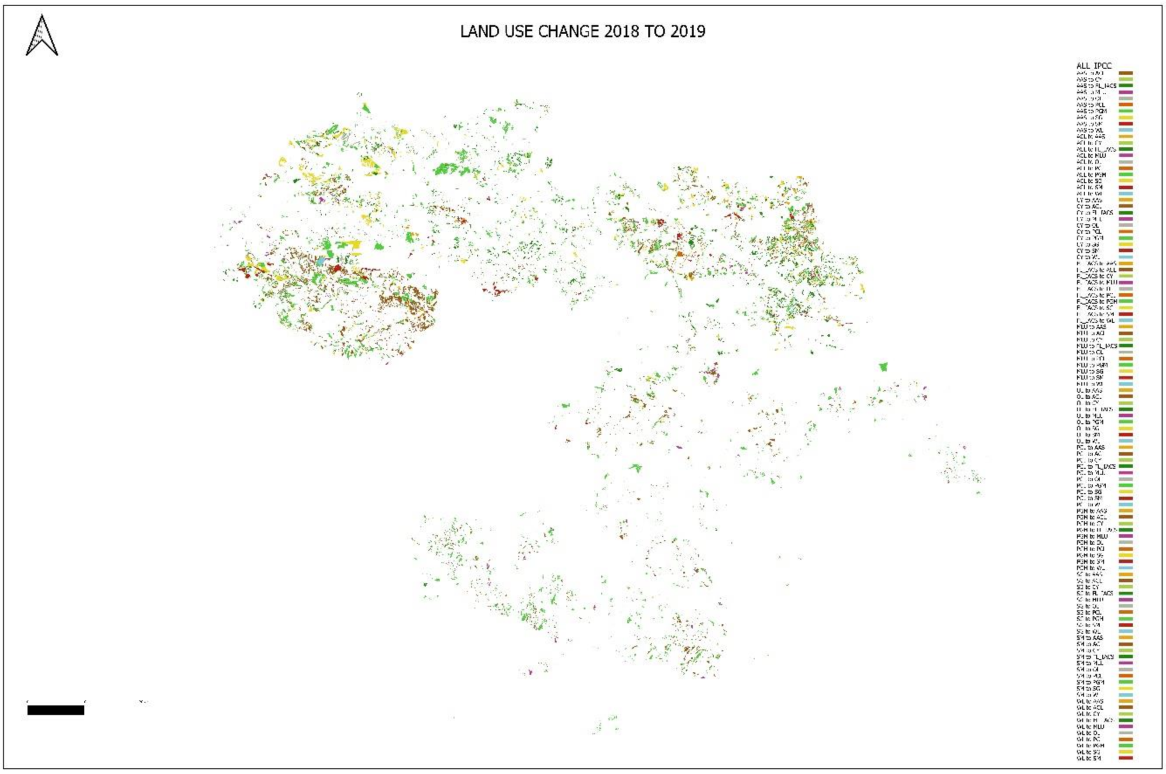


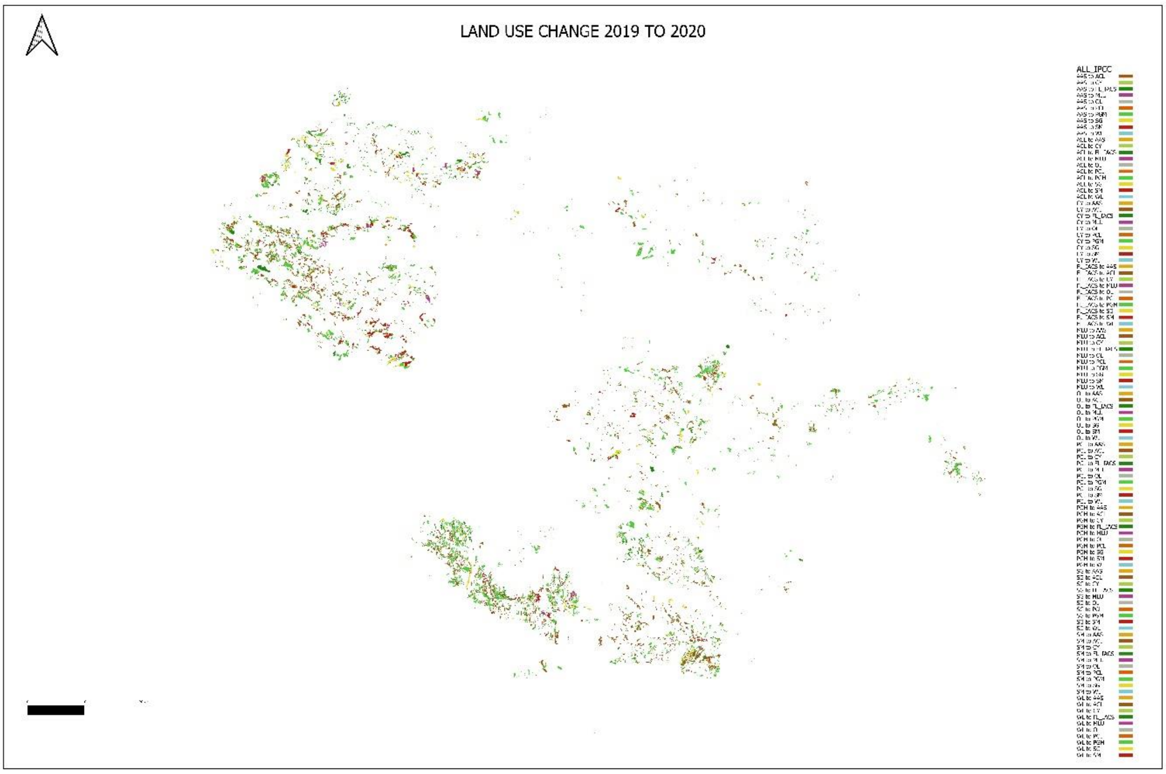

Land use change in SETTLEMENTS 2018 to 2019
ALL_IPCC
SM
SM to AAS
SM to ACL
SM to CY
SM to FL_IACS
SM to MLU
SM to OL
SM to PCL
SM to PGM
SM to SG
SM to WL


Land use change in SETTLEMENTS 2019 to 2020
ALL_IPCC
SM
SM to AAS
SM to ACL
SM to CY
SM to FL_IACS
SM to MLU
SM to OL
SM to PCL
SM to PGM
SM to SG
SM to WL

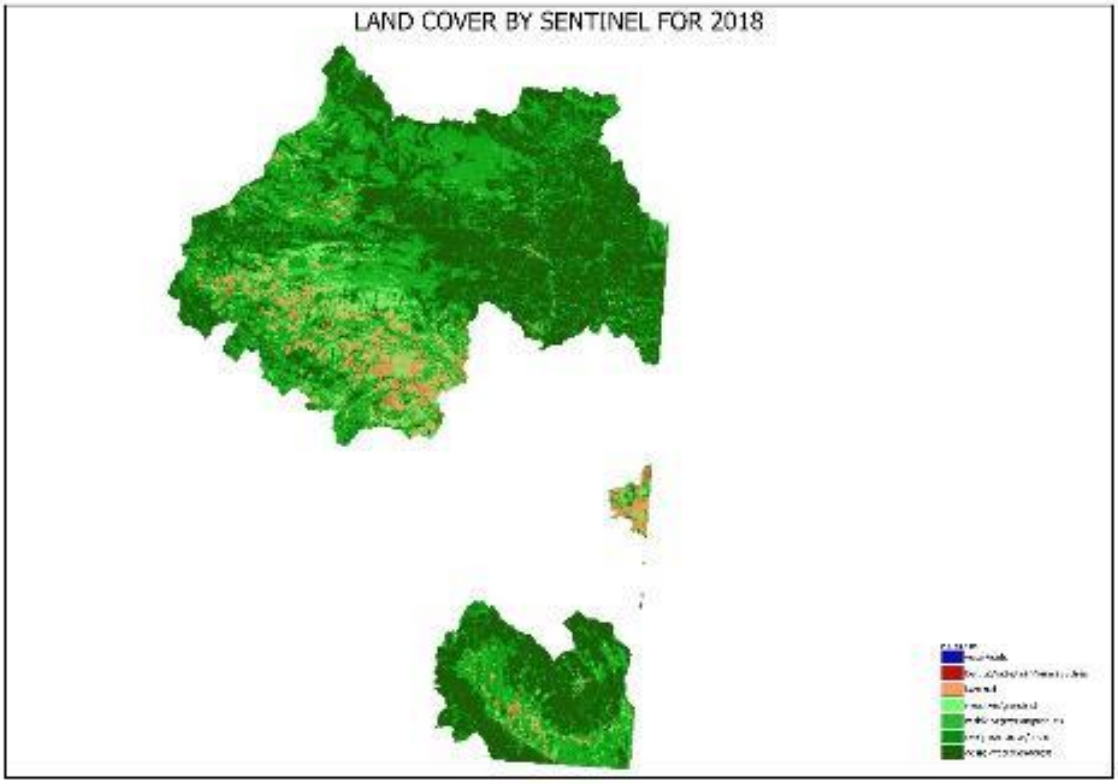

Land use change in WETLAND 2018 to 2019
ALL_IPCC
WL
WL to AAS
WL to ACL
WL to CY
WL to FL_IACS
WL to MLU
WL to OL
WL to PCL
WL to PGM
WL to SG
WL to SM

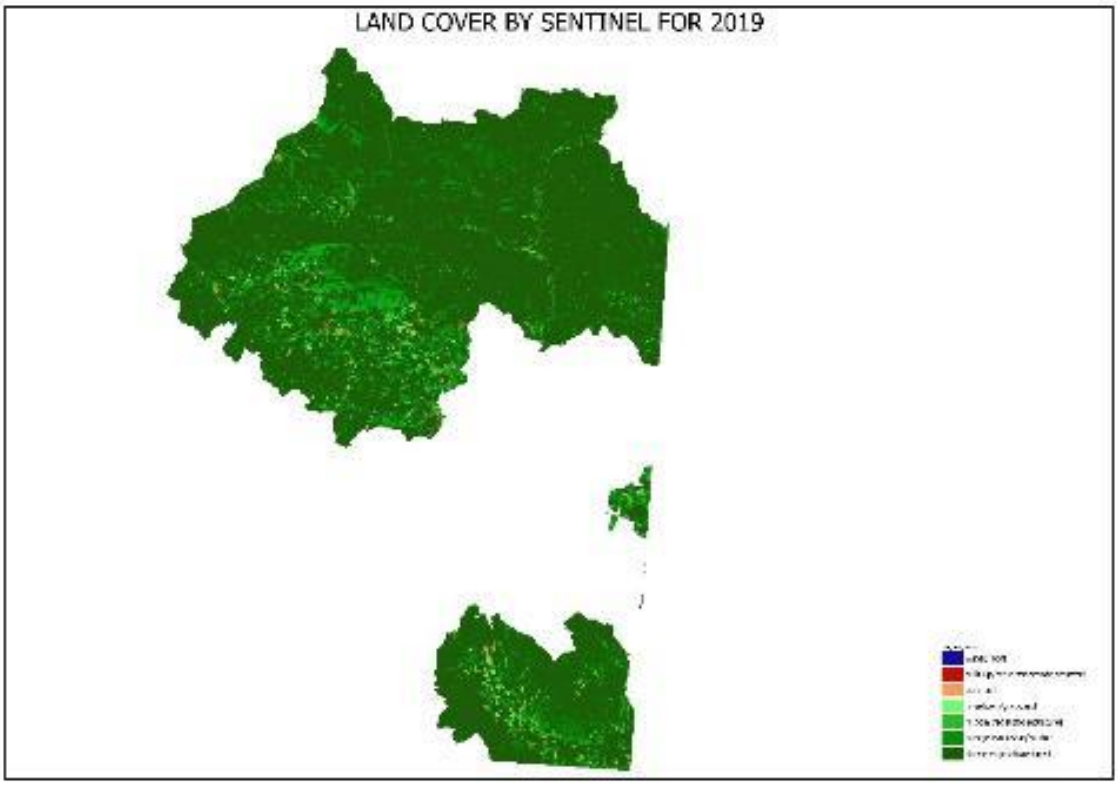

Land use change in WETLAND 2019 to 2020
ALL_IPCC
WL
WL to AAS
WL to ACL
WL to CY
WL to FL_IACS
WL to MLU
WL to OL
WL to PCL
WL to PGM
WL to SG
WL to SM

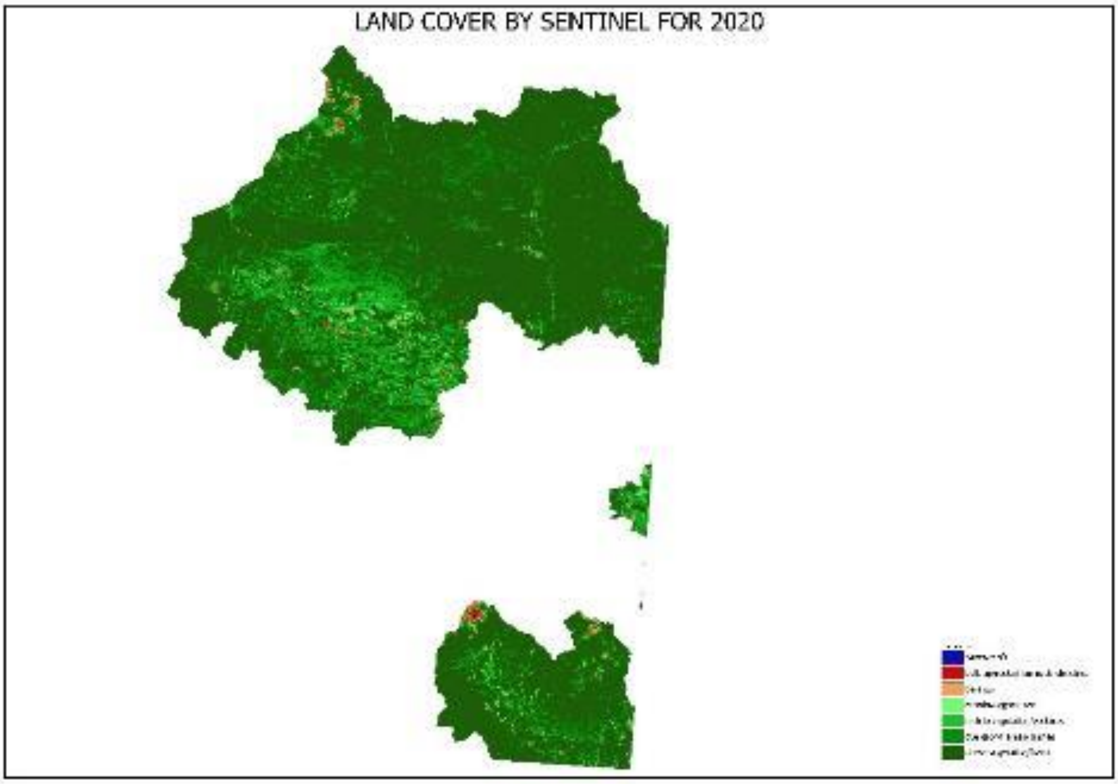

LAND USE CHANGE 2018 TO 2019
ALL_IPCC

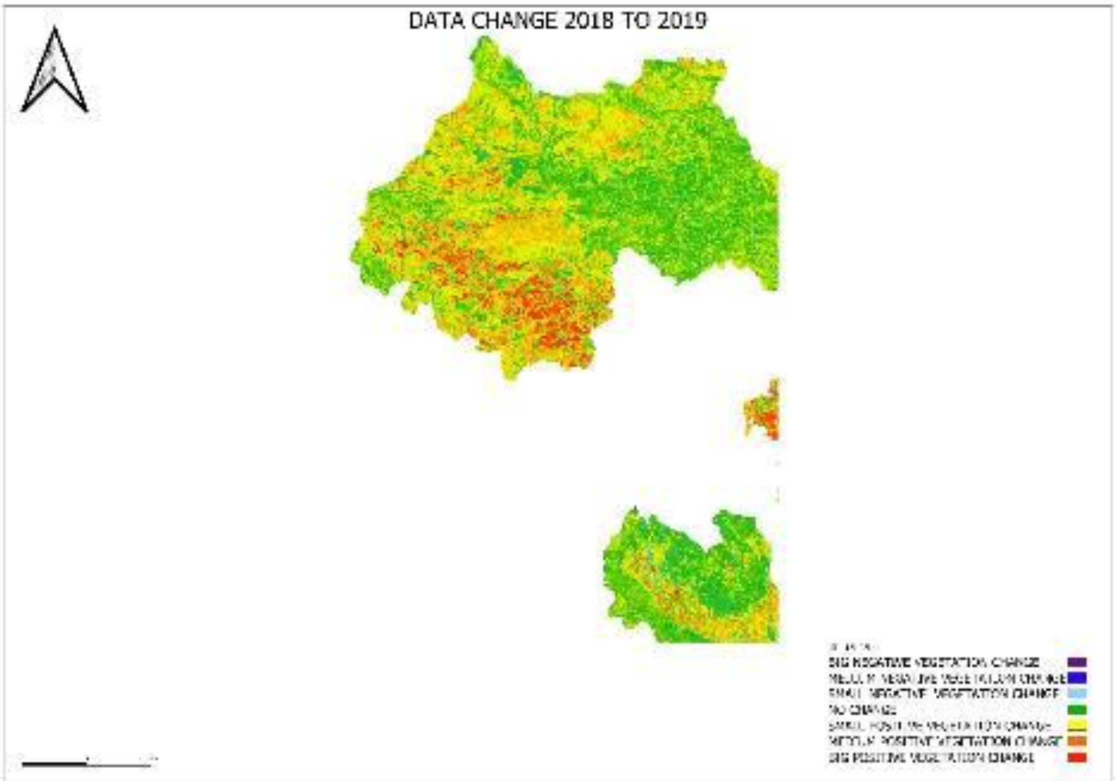

LAND USE CHANGE 2019 TO 2020
ALL_IPCC

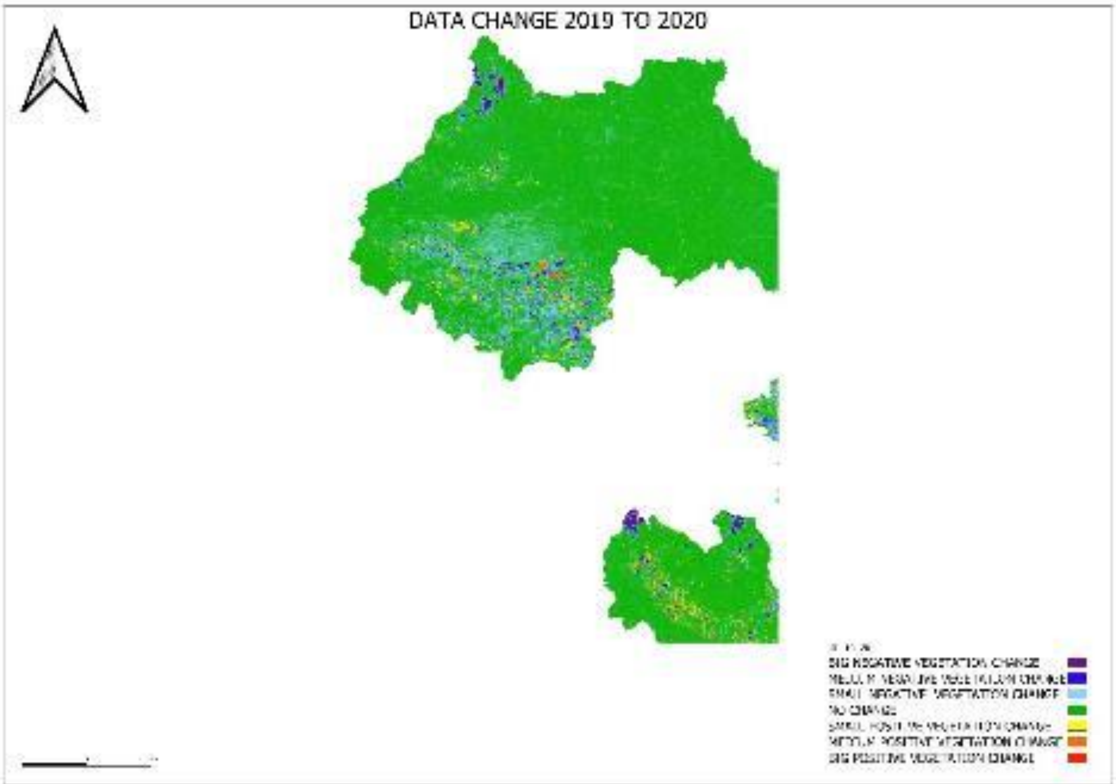
RASTER

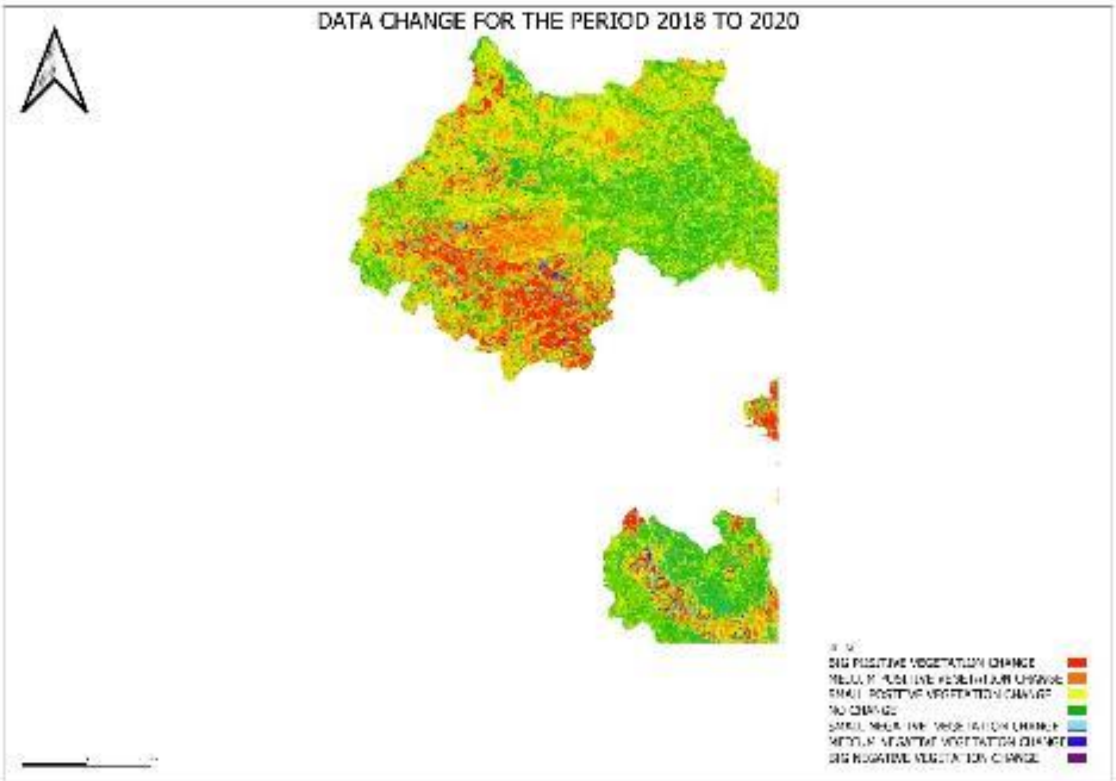

LAND COVER BY SENTINEL FOR 2018


LAND COVER BY SENTINEL FOR 2019


LAND COVER BY SENTINEL FOR 2020


DATA CHANGE 2018 TO 2019
BIG NEGATIVE VEGETATION CHANGE
MEDIUM NEGATIVE VEGETATION CHANGE
SMALL NEGATIVE VEGETATION CHANGE
NO CHANGE
SMALL POSITIVE VEGETATION CHANGE
MEDIUM POSITIVE VEGETATION CHANGE
BIG POSITIVE VEGETATION CHANGE


DATA CHANGE 2019 TO 2020
BIG NEGATIVE VEGETATION CHANGE
NO CHANGE
BIG POSITIVE VEGETATION CHANGE


DATA CHANGE FOR THE PERIOD 2018 TO 2020
BIG POSITIVE VEGETATION CHANGE
NO CHANGE
BIG NEGATIVE VEGETATION CHANGE

Annex 3 Physical Nomenclature of BANSIK statistics

Code Description
1 - Overseas
02 – Indefinite territory (can be used only at first crossing)
11 – Salt-pit, shallow mild salt-water lakes
12 – Lakes, basins, shallow fresh-water lakes
13 –Rivers, channels, gullies
14 – Wetland areas, swamps, (marshland and peateries included) free of permanent agricultural use
15 – Rocks
16 –Dunes, beaches – sandy or rocky
17 – Broadleaved forest areas
18 – Coniferous forest areas
19 – Sparse tree cover - wildwood
20 – Mixed – woodland (broadleaved and coniferous)
21 – Cluster of trees
22 – Isolated trees
23 – Wheat
24 - Barley
25 – Rye and triticale
26 - Oats
27 – Maize
28 – Rice
29 – Other cereals (sorghum, millet, buckwheat included), mixed cereals
30 – Sugar beet
31 – Industrial fiber crops (cotton, flax, hemp)
32 – Sunflower
33 – Tobacco
34 – Industrial oleaginous crops
35 – Other industrial crops (aromatic, medical and essential oils included)

36 – Potatoes
37 – Beans, peas, broad beans
38 – Lentils, chickpeas and other dry pulses
39 – Fresh vegetables apart from beans and peas (melons and water-melons included)
40 – Nurseries (forest trees, essential oils, aromatic and medical included); floriculture and ornamental plants
41 – Earthed-up fodder crops
42 – Other fodder annual crops
43 – Grassland under legumes
44 – Grassland under cereals
45 – Permanent productive grassland
46 – Alpine pastures
47 – Grassland with tree or shrub cover – rough grazing
48 –Meadow - orchards
49 – Fallow land
50 –Apricots (Prunus armeniaca)
51 – Cherry-trees and morello-trees
52 – Peach-trees
53 – Plum-trees
54 – Pear-trees
55 – Apple-trees
56 – Other fruit-bearing tree species
57 – Mixed fruit-bearing tree plantations
58 – Mixed – various fruit-bearing trees and other production
59 – Vineyards (plain crop)
60 – Mixed: vineyard - orchard
61 - Mixed: vineyard – other crops
62 – Small fruit and other various crops
63 – Kitchen gardens

64 – Lawns (in the broad sense)
65 – Unutilized agricultural land
66 – Infertile land, shrub land
67 – Hedge-rows
68 – Areas for temporary agricultural use
69 –Building site: buildings, public works
70 – Other terrains with changed relief due to extraction activities (stone-pits, sand-pits, mines, excavations)
71 – Other terrains with changed relief due to different depots (dumps, mine waste, slag, cinders, embankment)
72 – Cemetery
73 – Non-built-up areas within urban areas
74 – Farmyards and adjoining areas for different use
75 – Non-built-up area features with trees
76 – Non-built-up area features without trees
77 – Non-built-up linear features with trees
78 – Non-built-up linear features without trees
79 – Complex structure parks
80 – Buildings with 1 to 3 floors, roofed
81 – Buildings with more than 3 floors, roofed
82 – Greenhouses, shelters, high penthouses
83 – Roofed constructions without walls
84 – Temporary constructions - dismountable
85 – Other industrial and public works
86 – Abandoned constructions
87 – Urban zone, family gardens under 500 m^2 in populated areas included
88 – Industrial zone
99 – Forbidden zone

Annex 4 List of the tools used

QGIS

ArcMap

MS Excel – Pivot tables, Lookup and Reference Functions,

MKAD – Software to convert the .ZEM files to a .shp file

FAP – Forest Analysis and Planning software http://fap.ximaps.com/