D.1 REPORT: DIFFERENT DATA SOURCES FOR THE FARM-LEVEL SUSTAINABILITY ASSESSMENTS AND HIGH-RESOLUTION GEOGRAPHICAL INFORMATION SYSTEM CREATION.

ACTION A.1

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Action 1 – Farms statistical and economic data and spatial information gathering

The report is the summary of the activities carried out in the Action 1 of C-Farms project which aim is (i) the characterization of the farms in Lombardy region on the bases of FADN data and (ii) the retrieving of the most suitable data sources to build the High-resolution geospatial information system of the regional territory.

The action is important to identify the extent to which available statistical and geospatial datasets are appropriate to build a solid knowledge to support decision-making carbon farming in the agricultural sector.

Two outputs have been obtained performing Action 1:

1. Selection and characterisation of a representative sample of farms dealing with agricultural production, cattle breeding, tree plantation and wood transformation
2. A report regarding different data sources for the farm-level sustainability assessment and high-resolution geographical information system creation.

The deliverable collects the results of three activities, performed by different working groups of C-Farms: (i) analysis of FADN data to identify the most representative farms for the regional crop and livestock farming; (ii) selection of the representative farms of tree plantation (poplar); (iii) gathering of geospatial data to build up the High-resolution geographical information system (GIS-FARMs), in the subsequent Action 4.

They will be presented separately in three chapters.

The partner involved in Action 1 are: CREA (also as coordinator), UNITUS, TS, CGAI, FLA.

1. Selection and characterisation of a representative sample of farms dealing with agricultural production and cattle breeding.

Marongiu Sonia, Luca Cesaro

1.1 Introduction

The main objective of this section is the description of a representative sample of farms in Lombardy, intended to be used to describe the most important type of farming in the region in terms of use of land, structure, physical inputs, outputs, economic, and financial aspects. The identification of the most relevant farming system and the association of some carbon farming practices allowed to perform a comparison between conventional and conservative farms. This work is preparatory to the Action A2 of C-Farm project providing for a specific questionnaire submitted to the sub-sample of farms operating with carbon farming practices to investigate in detail the sustainable management options for the main existing crop and livestock system in Lombardy.

The analysis of agriculture has been based on the Italian Farm Accountancy Data Network (FADN) as a primary source of microeconomic data. The result of this explorative analysis has permitted the definition of the most important general type of farming and livestock activities (according to the FADN classification). Their characteristics have been described in terms of size (hectares and economic dimension), economic aggregates (revenues and cost per hectare) and indicators (value added and net revenue per hectare). The FADN detail of the particular type of farming has permitted a further investigation on the most important crops and livestock activities while the specific information on the application of the Measure 10.1.4 of the regional Rural Development Plan 2014-2020 (no tillage and cover crops farming) has identified a group of beneficiaries, making possible an economic comparison between conservative and conventional farms. Confagricoltura (CGAI), a partner of the project, has actively participated in this stage of the analysis.

The tree plantations and wood transformation have been identified in the poplar cultivation, one of the most important of the whole region. In this case, the dataset is not FADN (it does not collect this information) but other sources of data coming from

CREA. Section 2 of the deliverable will explain the methodology followed to identify the sample.

1.2 The Italian Farm Accountancy Data Network (FADN)

The Farm Accountancy Data Network (FADN) is a sample survey that annually gathers information from more than 80,000 European farms representing around 90% of production. The sample of farms is set up on the basis of an official selection plan prepared by each Member State (Marongiu S., Turchetti L., 2021; Gastaldin et al., 2021). The selection plan sets out the number of farms to be selected by region, type of farming and economic-size class (three-way stratification). An individual weighting is applied to each farm in the sample. This weighting corresponds to the number of farms in the three-way stratification cell of the field of observation divided by the number of farms in the corresponding cell in the sample (or the FADN farms in a given cell).

Information is collected according to a questionnaire (Farm Return) and following legal requirements specified in the EU Regulation 1217/2009, supplemented by implementing legislation. FADN is one of the most important agricultural surveys deployed in the European Union: it is the only source of microeconomic data, based on harmonized bookkeeping principles, and it gathers structural and economic information of agricultural holdings comparable in space and time. The first aim of this survey is to provide data to the EU Commission for the assessment of farm profitability and for the evaluation of the Common Agricultural Policy (CAP) impacts. The Italian FADN (named RICA - *Rete Italiana di Contabilità Agricola*) provides data to the EU Commission (mandatory by regulation) but also for a broad category of stakeholders (public institutions, Universities, public and private research, individual researchers), serving as an important source of data for the national research system and meeting a wide range of informative needs. FADN dataset is produced, managed, and disseminated by the Policy and Bioeconomy Unit of the Council for Agricultural Research and Economics (CREA, the FADN Liaison Agency between Italy and the European Commission). Raw data are stored by CREA and most of the information is made available in an online database (BDR – Banca Dati RICA).

The Farm Return includes around 1,000 variables according to the EU Regulation. Information is divided in categories: (i) physical and structural data; (ii) economic data; (iii) financial data. The Italian FADN's information system is more articulate than the European one (it includes more than 2,500 variables, exceeding the core EU FADN) and it can meet the knowledge needs at farm and territorial level, allowing more detailed analysis going beyond the economic aspects (Marongiu S., Turchetti L., 2021) (Table 1).

Table 1: Quantitative assessment of informative contents in EU and IT FADN.

Categories	EU FADN	IT FADN
Accounting records (*divided into 80 transactions in IT FADN*)	<20	30
Accounts managed directly by user	0	80
Types of machinery and equipment	0	300
Types of farm buildings	0	70
Types of soil (*physical characteristics and fertility*)	0	20
Arable and permanent crops (*6,800 cultivars in IT FADN*)	<100	380
Animal species and categories	<30	100
Types of crop products (*main and processed*)	<50	54
Types of livestock products (*main and processed*)	<10	35
Categories of technical inputs (*fertilizers, seeds, etc.*)	<25	110
Subsidy types (EU, National, Regional)	<300	500
Total Variables (approximatively)	1,000	>2,500

According to the classification of agricultural holdings provided by the EC Regulation 1242/2008, each farm in FADN can be classified with a "general" type of farming (1-digit code), "principal (2-digit) and "particular" (3-digit). The type of farming of a holding is determined by the relative contribution of the standard output of the different characteristics of this holding to the total standard output of this one. Another classification is made considering the economic size, expressed in euro, and determined on the basis of the total standard output of the holding.

1.3 Description of agriculture in Lombardy according to FADN dataset

The selection and characterization of the representative sample of farms in Lombardy is based on the Italian FADN results, defined as an average of the period 2018-2020, stored in the BDR (Banca Dati RICA). This information is supported and integrated with further elaborations made on ISTAT data.

FADN sample of Lombardy in 2018-2020 includes on average 659 farms, representing 33,129 units of the field of observation (weighted data), distributed among all the provinces as shown in Table 2. Most of these farms (80.7%) operate in the flat areas (Pianura Padana); 11.5% are classified in hilly areas and 7.8% in mountains. 41.3% of farms in FADN are located in Mantova, followed by Cremona (12.4%), Pavia (11.6%) and Brescia (10.8%).

Table 2: Number of farms by Province in Lombardy (weighted; average 2018-2020; our elaboration on IT FADN data).

Province	N° FADN Sample	N° FADN f. of obs.
Bergamo	48	3,722
Brescia	71	3,485
Como	9	395
Cremona	82	2,747
Lecco	3	358
Lodi	17	657
Mantova	272	14,087
Milano	30	1,557

Monza-Brianza	5	397
Pavia	76	2,522
Sondrio	41	2,991
Varese	5	209
Lombardy	659	33,129

On average, during the period 2018-2020, the FADN sample in Lombardy has covered 23,663 hectares of Utilized Agricultural Area (UAA; 81% irrigated), corresponding to 813,859 hectares, with an average farm size of 35.9 hectares.

Figure 1 shows the distribution of UAA among provinces and the average UAA per farms. UAA in FADN seems to be distributed mainly in 4 provinces (Mantova, Pavia, Cremona, and Brescia). Mantova is the most important in terms of farm number and acreage, but the average surface is very low if compared with other Provinces like Cremona, Pavia, Brescia, or Milano. Monza-Brianza, Lecco and Lodi are not representatives in terms of number, but they include big units in terms of surface.

Figure 1: Distribution and average UAA by farm and Provinces in Lombardy (ha; 2018-2020, our elaboration on IT FADN data).

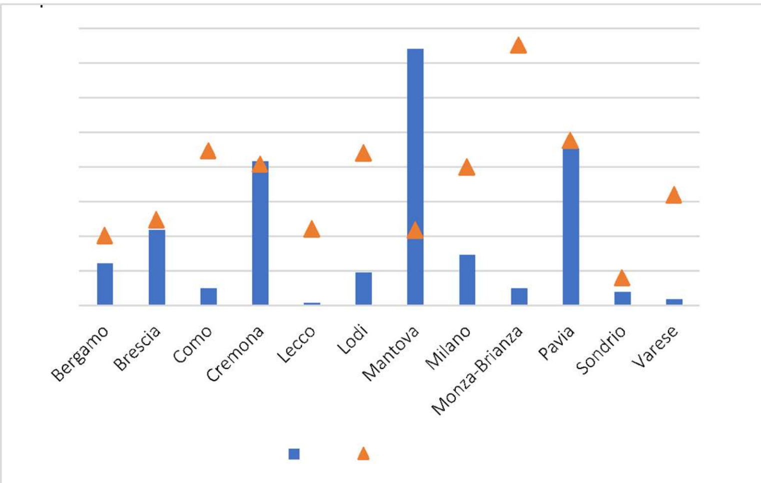
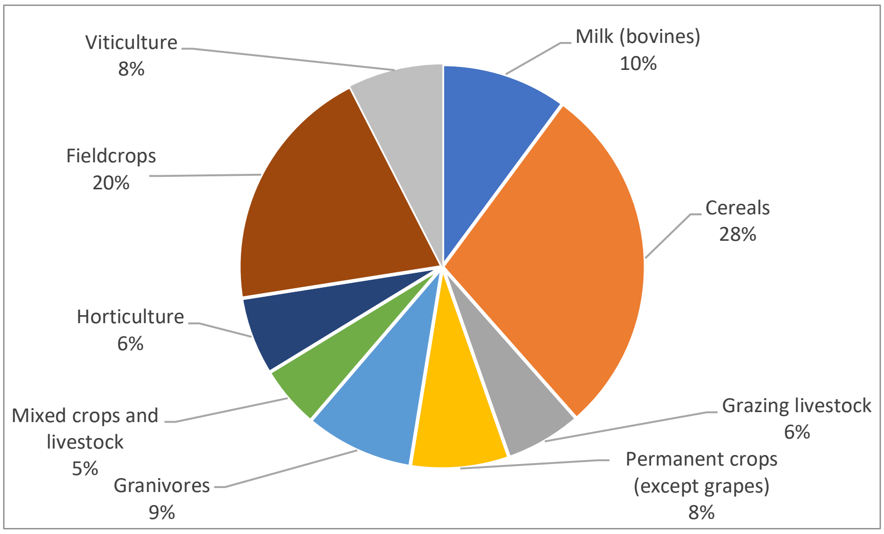


Figure 2 shows the distribution of the sample by general type of farming (according to the mentioned classification of agricultural holdings provided by the Regulation EC 1242/2008). The figure gives information about the type of agriculture in Lombardy. Field Crops and cereals are the most important land use in the region (48.4% of the sample includes farms with this type of farming). Among livestock, bovines breeding is the most important farming activity (10.1% of the sample) followed by granivores. Permanent crops are also relevant (15.4% globally).

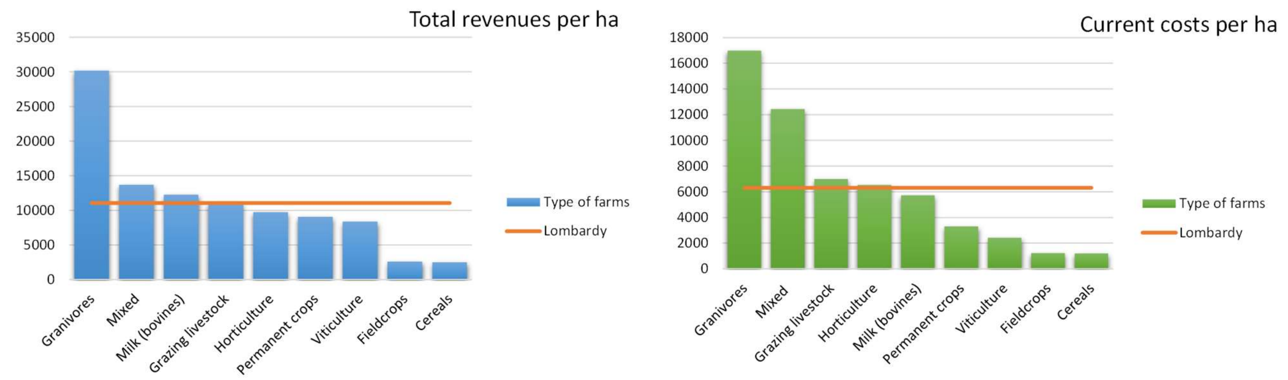
Figure 2: Distribution of FADN sample in Lombardy per general type of farming (%, 2018-2020, our elaboration on IT FADN data).



This general framework is confirmed by the information collected in the Register of Chambers of Commerce in Lombardy (Pretolani and Rama, 2021). In terms of number of units operating in 2019 (involved in activities of agricultural production), around 46% of holdings are classified in non-permanent crops activities (mainly cereals and field crops); 13% grows permanent crops (fruits and vineyards); 20% are livestock farming systems (bovines, ovines, pigs and others). The rest is represented by agricultural systems associated with livestock activities.

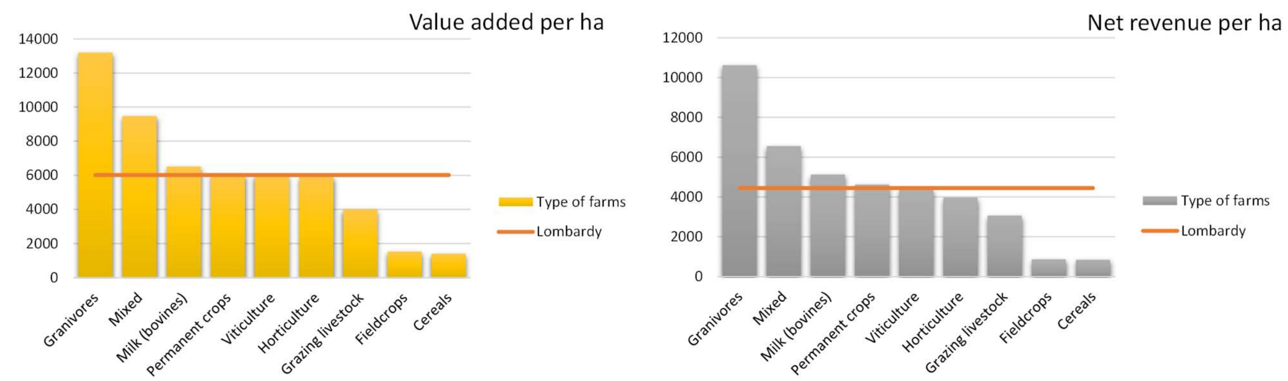
The economic size, defined on the basis of the total standard output of the holding, allows another important classification inside the FADN system. Figure 3 shows this distribution: there is not a big difference in terms of number among the economic size classes considered in the analysis. Small farms (8,000 – 25,000 euros) represent 15.2% of holdings while the medium-small ones (25,000 - 50,000 euros) reach 21.3%. The most represented is the medium-big class (100,000-500,000 euros) with 26.8%. The biggest farms (with a turnover of more than 500,000 euros) are also well represented (16.9%).

Figure 3: Total revenues and current cost per hectare by general type of farming in Lombardy (€/ha, 2018-2020, our elaboration on IT FADN data).



Looking at the most important economic indicators calculated in the FADN, the value added and the net revenue per hectare give an idea about the gross and net productivity of land. Granivores and mixed systems have the highest value for both indicators while the results are very similar to the regional average (6,014 €/ha of value added and 4,451 €/ha of net revenue) for bovines breeding farms permanent crops (other than grapes), viticulture and horticulture. Farms cultivating field crops and cereals have the lowest values of land productivity (these types of farming are the most representative of the agricultural region in terms of number and land use).

Figure 4: Value added and net revenue per hectare by general type of farming in Lombardy (€/ha, 2018-2020, our elaboration on IT FADN data).



A further detail on the specific crops can be performed considering the particular type of farming represented with a 3-digit code in FADN. This analysis is finalised to identify the most representative crops in Lombardy and, in a second step, the most important sustainable management options available for the common farming systems. The representativeness in the project does not refer to the profitability of farms but to the occupation of agricultural land. An explorative analysis on the UAA and number of farmers is resumed in the following tables. Table 4 and Table 5 shows the most relevant particular type of farming for crops and livestock per year as average during the period 2018-2020. According to the results of this more detailed analysis, the most representative farms in terms of surface and acreage in the FADN sample of Lombardy grow cereals (other than rice), oilseed and protein crops followed by farms with various field crops combined. This kind of farms are also relevant in terms of number in the sample so it should be selected as representatives for the further analysis on the farm practices.

Table 3: Most important particular type of farming in Lombardy – crops per year (IT BDR, average 2018-2020, our elaboration on IT FADN data).

Specialized TF	Description	n. farms	UAA	UAA/farm
151	Specialist cereals (other than rice), oilseeds and protein crops	149	4,697	32
166	Various fieldcrops combined	89	2,800	32

152	Specialist rice	29	2,779	95
163	Specialist field vegetables	32	2,347	74

The situation of agricultural area and productions in Lombardy in 2019 (Pretolani and Rama, 2021) confirms the importance of cereals (durum wheat, common wheat, barley, rice and maize represents around 11% of the total acreage in Italy and 17% of the national production), oilseeds and protein crops. Rice is one of the most relevant cultivations in the region, contributing to the national production for 39%).

Looking to the livestock farming systems, even if the most important in terms of livestock units (LU) is the pig fattening, the analysis will be focused on the specialist dairying systems because the management practices involve technical choices regarding the fodder crops and the use of manure as fertilizer (carbon farming practices are more suitable to be carried out on this context rather than in farms fattening pigs that often have not a relevant quota of agricultural area and do not cultivate fodder crops). In 2019, the milk production in Lombardy accounted for 41% of the national production.

Table 4: *Most important particular type of farming in Lombardy – livestock per year (average 2018-2020, our elaboration on IT FADN data).*

Specialized TF	Description	n. farms	LU	LU/farm
512	Specialist pig fattening	39	40,689	1,051
450	Specialist dairying	67	13,788	207
522	Specialist poultry-meat	12	7,264	597
460	Specialist cattle—rearing and fattening	27	3,288	122

Concluding, specialist cereals (other than rice), oilseeds and protein crops farming systems (151) and specialist dairying farms (450) are considered relevant for the agriculture in Lombardy, with a high representativeness according to FADN. The definition and selection of the list of farms on the field will be done considering the results of this explorative analysis.

1.4 Characteristics of the selected farms and related carbon farming practices

One important step in the selection of farms is the consideration of carbon farming practices in the most representative types of farming defined for Lombardy. The importance to manage FADN data in this step is not negligible because it allows the performance of economic comparison between conventional and conservative farming systems. So, a first step has been the identification of common carbon farming practices in farms specialized in cereals, oilseed, and protein crops and in specialist dairying farms. This activity has been done with the support of Confagricultura (CGAI), a partner of the project: around 31% of the farms recorded in the Italian FADN during the period 2018-2020 are associated with Confagricoltura.

Generally speaking, there are several kinds of practices that provoke a carbon loss in the agricultural soil. Soil carbon losses seem to be most common in conventional and integrated management strategies compared to organic farming, conservative agriculture, agro-ecological farming, etc. Agroforestry systems are recognized among the most promising carbon farming practices, storing carbon in high quantities. The most important carbon farming practices for arable crops and livestock farming systems are: cover crops, intercropping, green manure crops, manure, compost, biochar, no tillage (important to preserve the soil structure and in combination with other practices as it is not always clear whether no-till farming leads to a net carbon enrichment), arable rotation, crop residue maintenance on field. For livestock systems conducted in mountains, preserving permanent grasslands or converting cropland to permanent pastures are the most promising soil carbon storage techniques as they store higher amounts of carbon than tilled fields, along with silvopastoral agroforestry systems.

Conservative farms in the FADN sample have been identified on the basis of the application of Measure 10.1.4 for arable crops and on the use of manure as crop fertilizer in livestock farming systems in flat areas.

In the last programming period, Measure 10 of the EU Regulation 1305/2013 aimed "to preserve and promote the necessary changes to agricultural practices that make a positive contribution to the environment and climate." Several sub-measures have been applied to decline this compulsory requirement. Measure 10.1.4 in Lombardy provided a contribution for those farms practicing conservative agriculture through no tillage/strip-tillage/minimum tillage, mantainance of crop residues on fields and cover crops practices. The match of FADN dataset with the information of Confagricultura allowed the identification of this subsample of farms, classified with the particular type of farming 151 (Specialist cereals (other than rice), oilseeds and protein crops) and over 10 hectares of acreage (Table 6).

Table 5: Size of farms considered in the analysis of carbon farming practices (IT FADN and CGAI).

	Conventional	M 10.1.4
less than 10 ha	0	0
10-50 ha	240	12
more than 100 ha	47	9

Table 7 resumes a comparison of economic indicators between conventional and conservative farms (no tillage and cover crops) as average of the period 2018-2020. The Gross Saleable Production is lower in the case of conservative farms. In terms of EU subsidies, the difference of direct payments per hectare is not relevant between the two farm typologies but the support coming from Rural Development policies is relevant for conservative farms and important in the definition of the net revenue per hectare.

Table 6: Comparison of economic indicators between conventional and carbon-farming practices (€/ha; average 2018-2020, our elaboration on IT FADN data).

	Medium Farms (10-50 ha)		Big farms (over 50 ha)	
	Conv.	10.1.4	Conv.	10.1.4
Total Revenues	2,279	2,804	2,560	2,245
GSP	2,205	1,824	2,326	2,219
Subsidies (direct payments)	395	314	401	332
Current Costs	1,002	1,380	1,054	1,161
Seeds	176	186	159	207
Fertilizers	159	182	186	182
Crop protection products	106	146	136	186
Mechanization	159	109	171	184
Insurance	25	16	26	18
Added Value	1,276	1,424	1,506	1,084
Pluriennal Costs	146	279	187	104
Net Product	1,131	1,145	1,319	980
Salaries and Wages	233	167	155	177
Operative Revenue	688	940	948	745
Other subsidies (RD measures)	18	158	16	181
Net Revenue	641	1,064	907	895

The cost for mechanization, as expected, is lower in medium farms and slightly higher in big farms. The cost per hectare of fertilizer and crop protection products is on average high in conservative farms compared with the conventional ones. This evidence is explained by the high use of herbicide in the conservative farming systems during several phases of the cultivation (including the seed bed preparation) with the aim to eliminate infesting plant. In conventional farming systems they are commonly managed with mechanical soil tillage. Moreover, sometimes the cover crops are concluded with herbicides and not with green manure.

A further investigation has been made looking at the gross margin at production process level comparing the beneficiaries and non-beneficiaries of M 10.1.4. The conventional farms have been selected considering the same structure of UAA of conservative farms (distribution of crops on total agricultural land):

- Common wheat (10-30% of total UAA)
- Hybrid corn (40-60% of total UAA)
- Barley (15-40% of total UAA)
- Soja (10-30% of total UAA).

Table 8 resumes the number of production processes.

Table 7: Number of production processes per crop in conventional and c-farms (average 2018-2020, our elaboration on IT FADN data).

	Conv.	M 10.1.4
Common wheat	84	8
Hybrid corn	83	25
Barley	16	12
Soja	48	16

Table 9 indicates the average acreage and the gross margin (GM) per hectare in the selected cereals, comparing the conventional and conservative farms. Only for common wheat, the gross margin per hectare is higher for conservative farms while in the other cases the profitability of the crops seems to be lower.

Table 8: Average acreage and gross margin per ha of crops (cereals) in conventional and carbon farming farms (€/ha; average 2018-2020, our elaboration on IT FADN data).

	Conventional		M 10.1.4	
	UAA	GM/HA	UAA	GM/HA
Common wheat	45	648	47	714
Hybrid corn	42	1,323	47	986
Barley	53	708	47	594
Soja	39	622	50	520

Table 10 shows in detail the calculation of gross margin per hectare by crop. Except for soja, yields seem very similar and not influenced in a relevant way by the carbon farming practices. Variable costs are also higher and conservative farms have in general higher expenses per hectare for fertilizers and crop protection products.

Table 9: Costs and gross margin per ha of crops (cereals) in conventional and carbon farming farms (€/ha; average 2018-2020, our elaboration on IT FADN data).

		Conv.	M 10.1.4
Common wheat	G.Saleable prod.	1,154	1,498
	Insurance	4	22
	Fertilizers	166	202
	Crop protection prod.	104	149
	Variable costs	519	784
	Gross margin	648	714
	Yield	58	61
Hybrid corn	G.Saleable prod.	2,080	2,135

	Insurance	7	12
	Fertilizers	228	270
	Crop protection prod.	133	227
	Variable costs	757	1,149
	Gross margin	1,323	986
	Yield	112	111
Barley	G.Saleable prod.	1,160	1,108
	Insurance	0	5
	Fertilizers	124	129
	Crop protection prod.	76	120
	Variable costs	452	515
	Gross margin	708	594
	Yield	55	57
Soja	G.Saleable prod.	1,308	1,097
	Insurance	3	3
	Fertilizers	140	142
	Crop protection prod.	147	148
	Variable costs	685	577
	Gross margin	622	520
	Yield	35	28

The analysis of carbon farming practices in livestock systems is based on the use of manure produced by the farm and used to fertilize the crops. Farms breeding bovines for milk production in Lombardy (farm type 450) have been selected inside the FADN sample.

The manure produced by animals in all the farms included in the sample is used as fertilizer for farm crops, making impossible a comparison with practices excluding the farm use of manure. Therefore, only the gross margin per hectare of the crops in livestock systems has been estimated (Table 11). Permanent grassland and corn are the crops with the highest values of farm uses per hectare. The expense for fertilizers is also high for corn cultivation while permanent grasslands have the lowest value.

Table 10: Costs and gross margin per hectare of crops in livestock farming systems (bovines) (€/ha; average 2018-2020; our elaboration on IT FADN data).

Alfa Alfa	G.Saleable prod.	160	*Hybrid corn*	G.Saleable prod.	1,037
	Insurance	0		Insurance	5
	Fertilizers	69		Fertilizers	220
	Farm uses	114		Farm uses	211
	Crop protection prod.	73		Crop protection prod.	169
	Variable costs	488		Variable costs	1,184
	Gross margin	777		Gross margin	928
	Yield	102		Yield	116
Common wheat	G.Saleable prod.	786	*Permanent grassland*	G.Saleable prod.	132
	Insurance	0		Insurance	0
	Fertilizers	126		Fertilizers	27
	Farm uses	79		Farm uses	146
	Crop protection prod.	113		Crop protection prod.	9
	Variable costs	624		Variable costs	288
	Gross margin	454		Gross margin	599
	Yield	58		Yield	89
	G.Saleable prod.	244			

Waxy corn	Insurance	2			
	Fertilizers	217			
	Farm uses	215			
	Crop protection prod.	144			
	Variable costs	1,048			
	Gross margin	744			
	Yield	551			

1.5 List of farms

A list of farms has been selected starting from the results of the FADN analysis and identified by the other partners for the further investigation through the targeted questionnaire (Table 12). The characteristics of carbon farming practices will be investigated deeply in the other actions of C-Farms project. A targeted questionnaire will be prepared in Action 2 in order to understand in detail the agronomic techniques carried out by the farms and the benefits for the carbon storage.

Table 11: List of farms selected in Action 1.

	Area	mis 10.1.04	Livestock	Biogas
Farm 1	Lodi	yes	no	no
Farm 2	Lodi	yes	no	no
Farm 3	Codogno	yes	no	no
Farm 4	Codogno	yes	yes (pigs)	no
Farm 5	Milano	no	yes (pigs and bovines)	no
Farm 6	Cremona	no	No	no
Farm 7	Cremona	no	yes (bovines)	no
Farm 8	Cremona	no	yes (bovines)	no

2. Selection and characterisation of a representative sample of farms dealing with tree plantation and wood transformation.

Pier Mario Chiarabaglio, Simone Cantamessa

CREA - Forest and Wood Research Center (ex - Poplar Research Institute) in Casale Monferrato has been monitoring poplar cultivation in the Po-Veneto Plain since 1980 with georeferenced point-based remote sensing inventories (Lapietra et al., 1980) and ground-based point-based inventories from 1989 to 1996.

In Italy, poplar cultivation involves more than 10,000 agricultural enterprises, almost all of which are direct-crop farmers (CGA, 2010). The latest statistics on wood plantations in Italy (Corona et al., 2018) estimate the area of intensive poplar cultivation at about 40,000 hectares. The market indications report a significant increase in the price of poplar wood: we can appreciate a recent renewed interest in poplar cultivation, especially in the areas of the Padano-Veneto plain. 40 % of Italian poplar plantations are located in Lombardy, mainly along rivers where poplars find suitable conditions for their growth. In Lombardy, 1,400 farms are involved in poplar cultivation (CGA, 2010), equal to 14 % of farms throughout Italy, mainly in the provinces of Pavia (5 % of the Italian total), Mantova (3 %), and Cremona (2 %) (Table 13).

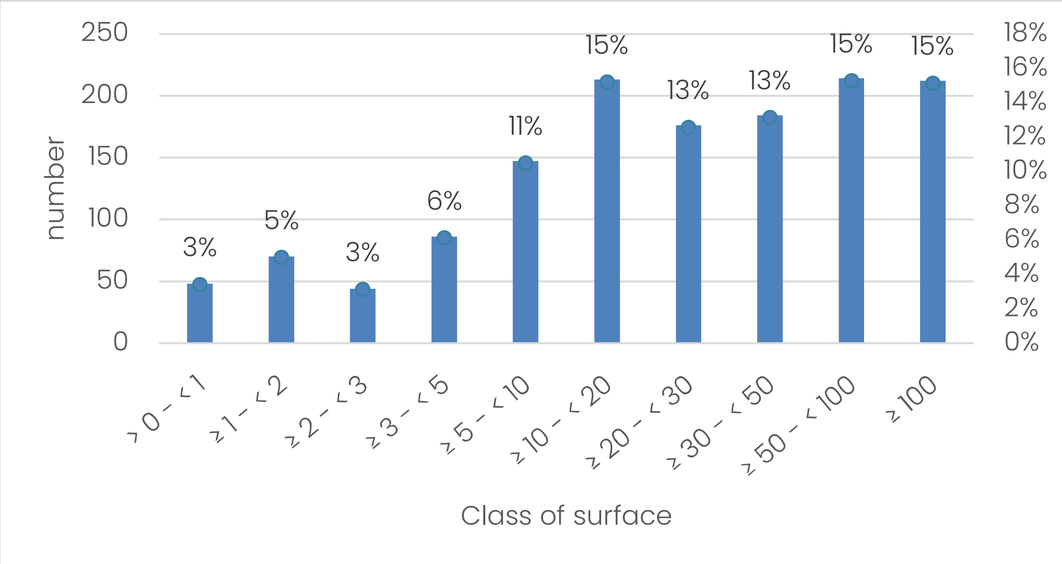
Table 12: *Farms number and area cultivated poplars in the Lombardy provinces and in total Italy.*

Provinces	Farms with poplars		Poplar cultivated area	
	number	*% on Italy*	*hectares*	*% on Italy*
Pavia	555	5%	5,202	13%
Mantova	331	3%	3,524	9%
Cremona	241	2%	1,974	5%
Lodi	144	1%	1,215	3%

Milano	74	1%	529	1%
Brescia	38	0%	116	0%
Varese	9	0%	45	0%
Bergamo	3	0%	7	0%
Como	1	0%	3	0%
Sondrio	3	0%	1	0%
Lecco	1	0%	0	0%
Monza e Brianza	0	0%	0	0%
Lombardia	**1,400**	**14%**	**12,615**	**32%**
Italy	**10174**	**100%**	**39308**	**100%**

71 % of farms with poplar plantations have a cultivated area greater than 10 hectares, and 30 % have a size greater than 50 hectares (Figure 6). These are therefore quite large farms specialized in poplar cultivation. Some farms also cultivate other crops in rotation with poplar, and a few also have cattle farms.

Figure 5: Number of farms with poplar plantations divided by class of surface with the percentage of the total number of farms.



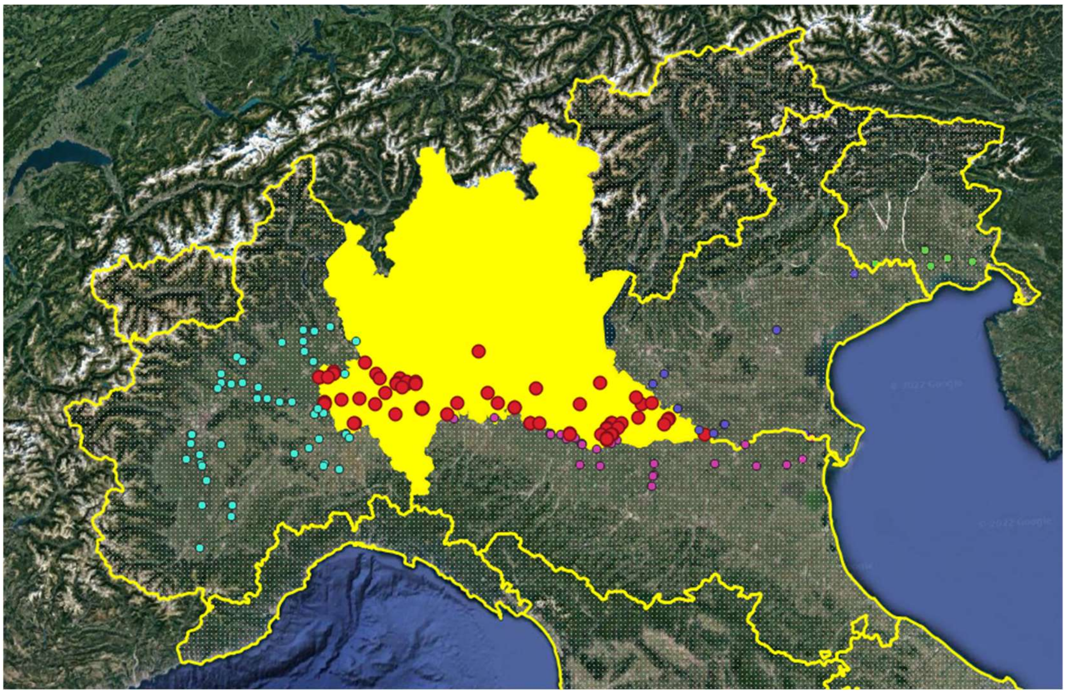
Standards for sustainable management of wood plantations existed in Italy for almost 20 years, thanks to the results of the Ecopioppo project (AA.VV., 2003). The cultivation systems developed in this project include appropriate cultural operations with minimum tillage and reduced phytoiatric interventions, even requiring polyclonality for poplar cultivation with a mosaic of clones. In the most recent revisions of these specifications, poplar clones resistant to major pests and diseases are being promoted. These cultivation techniques have been taken up in Italy by the Forest Stewardship Council® (FSC®) and Programme for Endorsement of Forest Certification schemes (PEFC) certification schemes, which produced, in the case of PEFC, an accurate cultivation specification that allows environmental enhancement and traceability of wood production. Through the reduction of cultivation practices, both certification schemes prevent the oxidation of the organic matter accumulated in the surface layers of the soil, favouring the maintenance of soil fertility. This aspect is relevant in the case of poplar and woody plantations-as well as natural forests; leaves are deposited and incorporated annually into the soil, while in the case of most crops these are generally removed, like the rest of the crop residues, thus depleting soils or making subsequent fertilizer inputs essential. Certification currently involves about 20 % of poplar planted areas in Italy. Traditional poplar cultivation, therefore, differs from certified cultivation, and the techniques promoted by the cultivation specifications are more favourable to the accumulation of carbon in the soil.

We started our analyses in according to Mari, 2020 by selecting a representative sample that meet the following conditions: 1) it must contain only and exclusively farms belonging to the field of observation; 2) the farms contained therein must present the same distribution presented by the farms in the field of observation.

The selection of farms has taken into account geographic distribution, soil type, and other farm characteristics according to the dictates of representative poplar farming. In addition, thanks to the European project Poplars For Farmers (AIR3-CT94-1753) concluded in 1996, pedological analyses had also been carried out regarding soil organic carbon content, and through the multitemporal study of land cover that can be carried out on the Google Earth platform (Chiarabaglio et al., 2018), it is possible to identify fields where poplar cultivation has been maintained or where conversions to agricultural crops have occurred.

The two farms selected are associated with Confagricoltura (CGAI), a project partner which manages the membership of the Italian poplar growers association (API).

Figure 6: Sample point in Poplar stands deriving from Poplars for Farmers project.



3. Gathering geospatial datasets to build up the High-resolution geographical information system

Anna Barbati, Olakinle Joshua, Giuliarelli Diego

3.1 Introduction

One of the main goals of LIFE C FARMs is the creation of the high-resolution demonstrative geospatial information system (GIS-FARMs) for estimating the carbon (C) sequestration potential of the agricultural sector in the Lombardy Region. In particular, LIFE C FARMs focuses on a well-defined area of C-farming practices, that is those farmland management practices capable to offset CO_2 emissions through soil carbon sequestration in the topsoil layer (0-30 cm). Accordingly, GIS-FARMs is designed to support informed decisions in the field of carbon farming by:

- selecting the best available information on current soil organic carbon (SOC) stocks and their spatial variation in the territory of Region Lombardy;

- assessing the maximum soil C storage potential in relation to local environmental conditions
- providing consistent scenarios in support of possible carbon sequestration policies, by assessing the effect of alternative C-farming practices on SOC accumulation compared to conventional farming.

Therefore, a data collection activity was undertaken under Action 1, in order to retrieve geospatial data sets suitable for being processed in a GIS environment to respond to the information needs identified above. SOC sequestration in the topsoil is mainly driven by potential decomposition rate, which is in turn primarily an effect of land use, in particular crop type, and farming methods. But when carbon farming scenarios are to be addressed across environmentally diverse territories, besides land use and management other drivers (climate, topography, parent material, soil properties) must be taken into account to explain spatial variation in SOC stocks and related maximum soil C storage potential.

Accordingly, geospatial data sets retrieved under Action 1 (Table 14) reflect the need to map, with a complete spatial coverage of Region Lombardy territory, both current SOC stocks and the key variables controlling the potential of carbon storage with the highest possible spatial resolution (environmental factors, soil properties, land use and crop type).

All geodatasets were transformed into the reference projection of the Territorial Information of Region Lombardy, that is WGS 84 UTM32 (EPSG: 32632).

Table 13: Overview of the geodatasets selected for building up the GIS-FARMs architecture.

Variable	Spatial Coverage	Type	MMU/pixel size	Period/ Reference Year	Source
Climatic stratification of the Environment of Europe	EU	Vector	1km^2	2018	https://datashare.ed.ac.uk/handle/10283/3091
Soil properties	Lombardy	Vector (Polygon),	120000 m^2	2008-2011	https://www.geoportale.regione.lombardia.it/en-GB/download-ricerca; (dataset name= “Basi

		1:250K			informative dei suoli", Carta Pedologica 250K)
Land Use	Lombardy	Vector (Polygon), 1:10K	1600 m^2	2018	https://www.geoportale.regione.lombardia.it/en-GB/download-ricerca; (dataset name= "Uso e copertura del suolo 2018")
SOC Topsoil	World	Raster	1km^2	1990-2013	http://54.229.242.119/GSOCmap/ (dataset name=GLOSIS - GSOCmap (v1.5.0)

In the following paragraphs the selected data sources are presented with the main goal of documenting the data sources and processing procedures adopted for the preparation of the input layers used in the architecture of the GIS-FARMs, under Action A4.

3.2 Environmental stratification

In order to identify areas that can be regarded relatively homogeneous in terms of climate conditions affecting on SOC dynamics, we used the Environmental Stratification of Europe (EnS), a statistically derived map, providing a spatial framework for the integration and analysis of ecological and environmental data in the European territory (Metzger et al., 2005). Based on an initial set of environmental variables (altitude, slope, latitude, monthly temperature and precipitation variables, monthly percentage of sunshine), the EnS map distinguishes 84 strata mainly according to variation in temperature gradient, oceanicity, precipitation pattern. These strata can be aggregated into 13 environmental zones (EnZ). We used this aggregated level for the environmental stratification of the Lombardy Region territory, thereby identifying three environmental zones (Table 15; Figure 8):

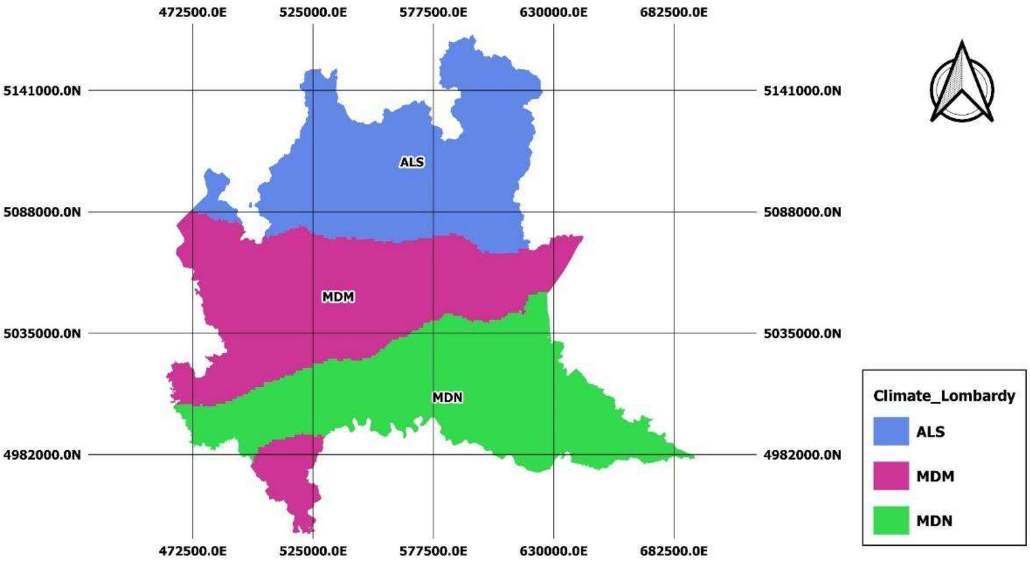
- Alpine South (ALS): The cool temperate climate is continental with a growing season lasting, in the different strata, between 173 and 214 days. There is considerable climatic variation, caused by aspect and altitude.
- Mediterranean Mountain (MDM): The climate, warm temperate to temperate, is Mediterranean with Continental and Alpine characteristics. The growing season is intermediate, variable in the different strata between 271 and 298 days.
- Mediterranean North (MDN): The warm temperate climate is Mediterranean, with an intermediate to long growing season, variable in the different strata between 290 and 336 days.

The different climatic conditions associated to the three zones are expected not only to affect net primary production (plant growth), but also the SOC decomposition rate (soil respiration) by regulating soil moisture and soil temperature regime.

Table 14: Environmental Strata based on area covered in hectares and percentage.

Environmental zone	Area (Ha)	Area (%)
ALS	740,787.03	31.05
MDM	868,915.63	36.41
MDN	776,464.07	32.54
Total	**2,386,166.73**	

Figure 7: Map showing the environmental stratification of the Lombardy region (EPSG32632 -WGS 84/UTM Zone 32N).



3.3 Soil texture

Among the soil properties, texture is considered the key variable controlling the potential of carbon storage in soils, because a fundamental mechanism of SOC stabilization is the formation of organomineral complexes between SOC and the fine fractions of silt and clay. In particular, the mass proportion of clay particles is positively correlated with the SOC content.

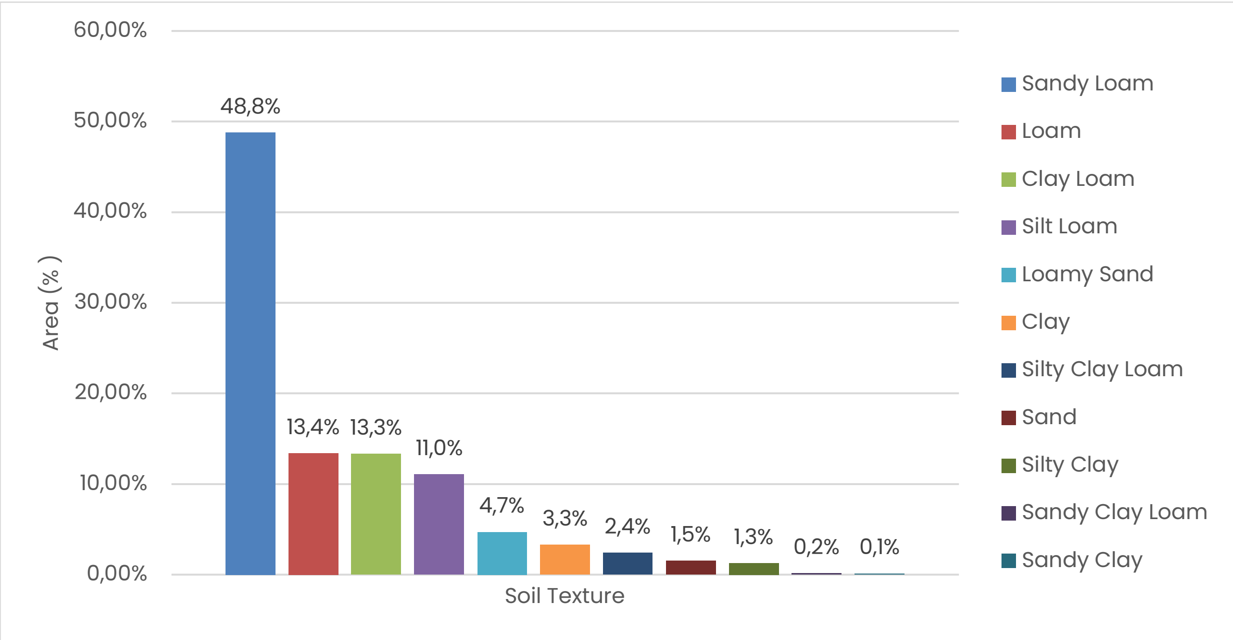
Information on soil texture for the Lombardy region was obtained from Carta Pedologica 1:250K (Table 14). The map provides for each soil unit the particle size distribution (% clay, silt and sand content) within 1-m depth soil profile and the relative classification. Soil texture classes are assigned to mapped soil units following the twelve (12) classes system defined by United States Department of Agriculture (USDA[1])

[1] https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167.

All soil texture classes, but silt, are represented in Lombardy Region (Figure 9). The original texture classes were then aggregated into four (4) macro-classes, resulting from the combination of the four most widespread USDA classes shown in Figure B associated with classes with similar size particle distribution:

1. Sandy loam (48.8%), including also the classes Sand (1.51%) and Loamy Sand (4.7%)
2. Loam (13.4%)
3. Clay Loam (13.3%), including also the classes Clay (3.3%), Sandy Clay Loam (0.2%), Sandy Clay (0.1%)
4. Silt Loam (11.0%), including the classes Silty Clay Loam (2.4%) and Silty Clay (1.26%).

Figure 8: *Relative share of USDA soil texture classes in Lombardy Region territory.*



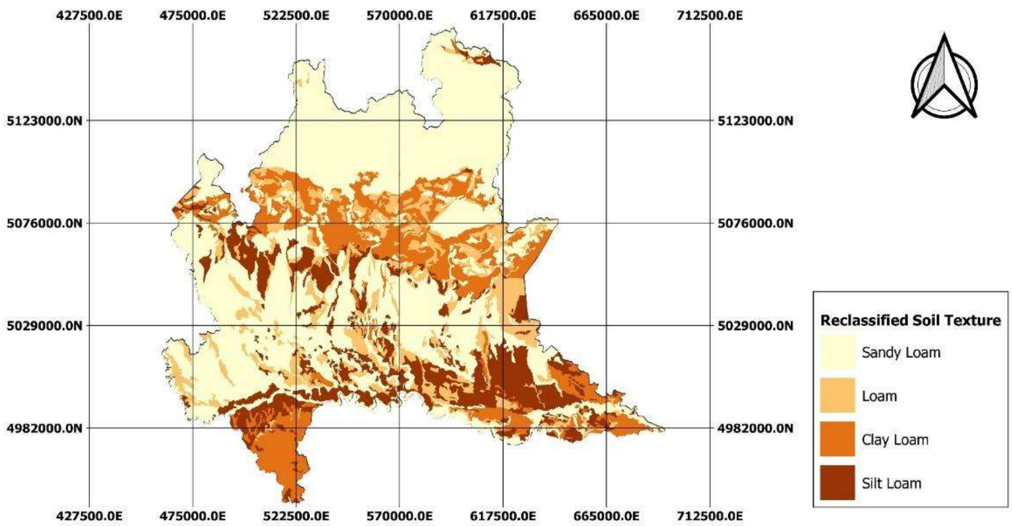
A dissolve of the polygons of the original vector map Carta Pedologica 1:250K was then carried out to produce a new map based on the four textural classes and statistics in terms of percentage for each new class was accordingly calculated (Table 16).

Coarse to moderately coarse textures (class 1) appear to be predominant in Lombardy territory (55%).

Table 15: Soil Texture classes based on area covered in hectares and percentage.

Reclassified Soil Texture	Area (Ha)	Area (%)
Sandy loam	1,312,866.42	55.00
Loam	319,918.96	13.40
Clay Loam	402,279.18	16.85
Silt Loam	351,816.56	14.74
Total	**2,386,881.12**	

Figure 9: Map of the aggregated soil texture classes (EPSG 32632- WGS 84/UTM Zone 32N).



3.4 Land use

The most updated vector file mapping land use classes in Lombardy region is dated 2018 and is shortly referred to as "DUSAF6" (*Destinazione d'Uso dei Suoli Agricoli e Forestali* - DUSAF). The map was produced by visual classification of very high and high resolution remote sensed imagery (orthophotos, aerial photographs and satellite imagery) with a pixel size between 0.2 and 1.5 m. As a result, the minimum mapping unit is extremely small (1600 m2). DUSAF6 was originally downloaded from the official geoportal of the region through the link shown in Table A. The classes considered are those relating to agriculture land, which are listed in the Table 17. Overall, the surface under agricultural land use in Lombardy covers the 42% of the territory, with an extent of ca 1 million of hectares.

Table 16: Agricultural Land Use classes based on area covered in hectares and percentage.

Class DUSAF6	Area (Ha)	Area (%)
221 - Vineyards	27,384	2.7
222 - Fruits	5,899	0.6
223 - Olive grooves	3,185	0.3
2241 - Poplar	29,703	3.0
2311 - Permanent lawns in the absence of tree and shrub species	119,445	11.9
2312 - Permanent meadows with the presence of scattered tree and shrub species	19,768	2.0
213 - Rice	99,136	9.9
2111 – Simple arable land	665,334	66.2
2112 – Arborated arable land	3,630	0.4
21131 – Open field horticultural crops	20,520	2.0
21132 – Protected horticultural crops	3,104	0.3
21141 – Open field nursery crops	5,040	0.5

21142 – Protected nursery crops	674	0.1
2115 – Family gardens	1,800	0.2
Total	**1,004,621**	

The original DUSAF classes were then reclassified into five (5) crop-type categories, as reported in Table 18.

Under the crop type 5 we aggregated various types of annual crops (e.g. cereals, forage crops, vegetable crops), except rice (crop type 4). These two classes represent the predominant crop types in Lombardy, covering nearly the 80% of the agricultural land, followed by permanent grassland (crop type 3).

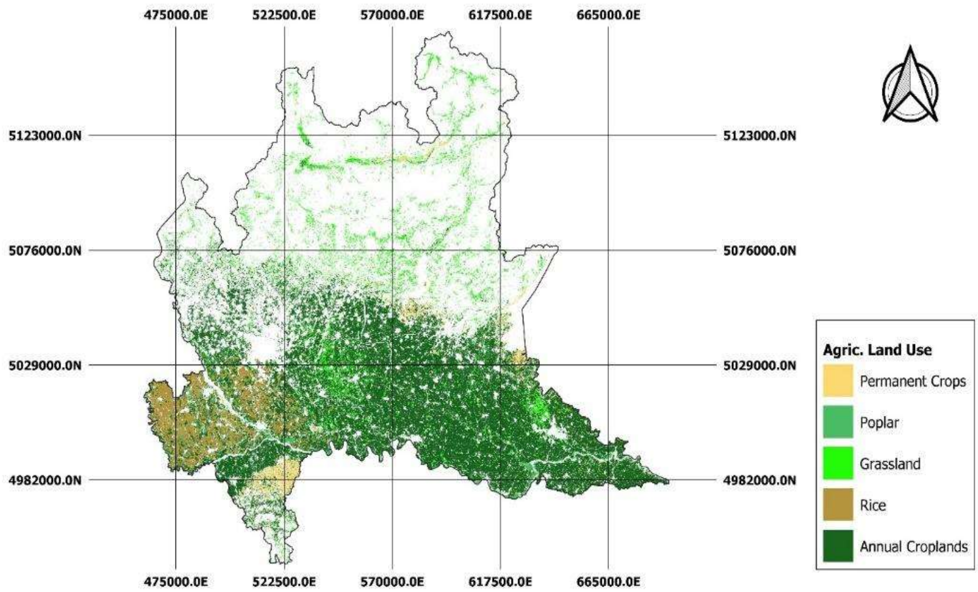
Table 17: Spatial extent of the agricultural Land Use classes and relative aggregation into the five crop-type categories.

Class DUSAF6	Area (Ha)	Crop type category	Area Covered in %
221 – Vineyards	27,384	1. Permanent Crops	3.6%
222 – Fruits	5,899		
223 – Olive	3,185		
2241 – Poplar	29,703	2. Poplar	3.0%
2311 - Permanent lawns in the absence of tree and shrub species	119,445	3. Grassland	13.9%
2312 - Permanent meadows with the presence of scattered tree and shrub species	19,768		
213 – Rice	99,136	4. Rice crops	9.9%
2111 – Simple arable land	665,334	5. Annual Croplands	69.7%
2112 – Arborated arable land	3,630		

21131 – Open field horticultural crops	20,520		
21132 – Protected horticultural crops	3,104		
21141 – Open field nursery crops	5,040		
21142 – Protected nursery crops	674		
2115 – Family gardens	1,800		
Total Agricultural Land Use	**1,004,621**		

Based on the five crop-type categories the original DUSAF 6 vector map was dissolved to produce a new map (Figure 11). Such a map is intended to stratify the agricultural land into areas that are expected to exhibit different SOC levels, as they are representative of conventional agricultural models characterized by management practices that have a different impact on SOC dynamics, also because of the different type, amount and timing of the net primary production that is allocated to SOC pools.

Figure 10: Crop type category map of Lombardy region (EPSG32632 - WGS 84/UTM Zone 32N).



3.5 Soil Organic Carbon

Despite the Soil Map of the Lombardy Region (Carta Pedologica, scale 1:250K) includes information on average carbon content (%) by soil type units (field=CO_1M), such information was not usable, being not referred to the topsoil, but to the 1-m depth soil profile.

The freely available EU geodataset LUCAS Topsoil Survey[2] provides SOC information, but its spatial structure does not meet GIS-Farms information needs, i.e. complete coverage of the Lombardy territory (120 sampling points, reference year 2015).

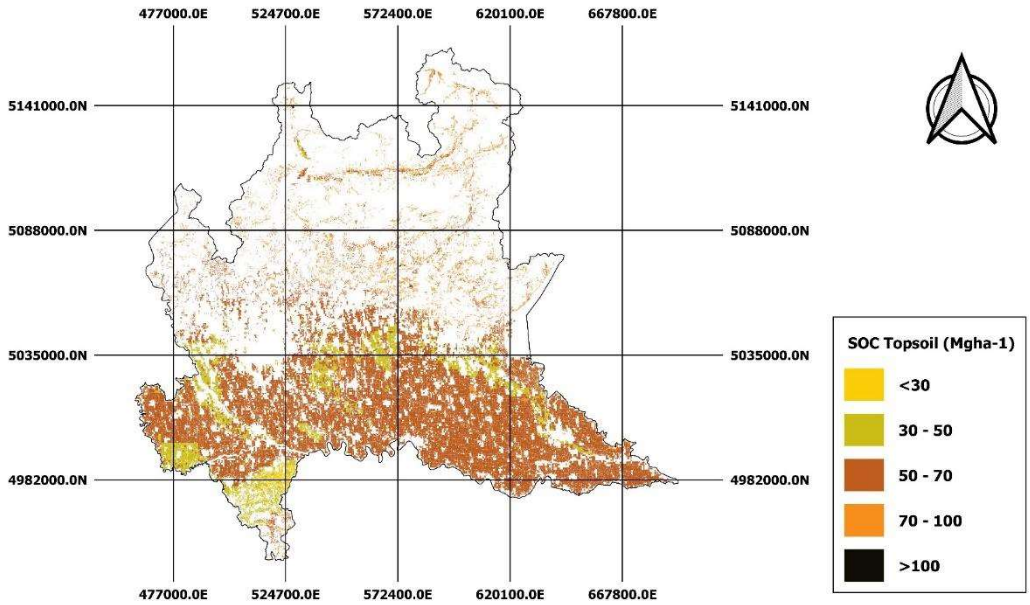
2 https://esdac.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR26102EN.pdf

The JRC has also produced a GIS map of organic carbon stock in European agricultural soils using a modelling approach[3]. For the Lombardy territory, the average size of mapped polygons is much larger (50.4 km^2) than the pixel size (1 km^2) of the Global Soil Organic Carbon (GSOC) raster map, produced by FAO and ITPS. 2018). For this reason, we resorted to the GSOC product to map current soil organic carbon (SOC) stocks in the topsoil in the territory of Region Lombardy. It is a global layer of harmonized national soil carbon stock maps, i.e. it results from the compilation of soil organic carbon stock maps produced by countries in accordance with the GSOCmap Guidelines (FAO - GSP, 2017).

The GSOC map has almost a complete spatial coverage for the areas under agricultural land use in Lombardy (Figure 12). In order to characterize the SOC content of the agricultural land, the GSOC raster map was first converted into vector format.

[3] https://esdac.jrc.ec.europa.eu/content/pan-european-soc-stock-agricultural-soils#tabs-0-description=1

Figure 11: SOC in the topsoil (0-30 cm) in Lombardy region (EPSG32632 - WGS 84/UTM Zone 32N).



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