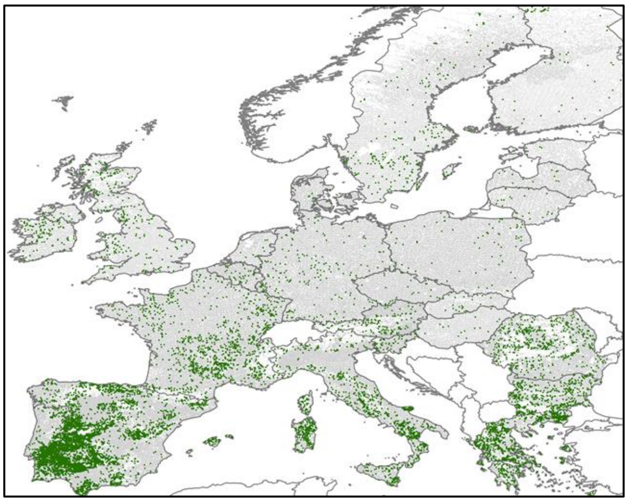
AGFORWARD
Agroforestry for Europe



Current extent and trends of agroforestry in the EU27

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Contents

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1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1) to understand the context and extent of agroforestry in Europe,
2) to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3) to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4) to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report describes a deliverable to address objective 1. The extent and recent changes of agroforestry systems in Europe will be assessed using existing EU27 land cover and land use databases.

2 Executive summary

An accurate and objective estimate on the extent of agroforestry in Europe is critical for the development of supporting policies. Despite the fact that agroforestry can be found almost everywhere it is hard to find reliable data on the extent of agroforestry, especially in Europe. However, databases that can be used to provide an estimate on the extent of agroforestry in Europe are available. The CORINE land cover classification (European Environment Agency, 1995) contains land cover data for Europe and includes the land cover class “agroforestry”. Nevertheless, it is obvious from previous studies that agroforestry is practiced on a much wider scale than estimated by the CORINE database. A recent literature study summarising the currently available data sources estimated that agroforestry is practiced in Europe at least on an area of 10.6 million hectares equivalent to 6.5% of the utilized agricultural area (den Herder et al. 2015) which is considerably more than the 3.3 million hectares as estimated by CORINE. However, even though literature studies are useful to understand the context, data obtained from literature studies are not collected in a comparable way which makes it difficult to give a reliable estimate. For this reason, a more harmonized and uniform pan-European estimate is needed. In this report we try to answer the question: How much agroforestry is there in Europe and where is it?

The agroforestry areas were mapped using three different approaches based on existing land cover and land use databases: LUCAS Land Use and Land Cover data, Copernicus Land Monitoring Survey (high resolution maps with tree cover density for seven countries) and a review of the literature and statistical inventories from some selected countries.

For the analysis of the LUCAS data in this report, agroforestry systems were grouped into three categories, similar as in the AGFORWARD project. These categories were chosen on the basis of the initial perspective of the farmer and comprise: i) high value tree agroforestry systems, ii) arable agroforestry systems, and iii) livestock agroforestry systems.

According to our estimate using the LUCAS database the total area under agroforestry in the EU 27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the utilised

agricultural area. This estimate is considerably larger than the previous estimate by den Herder et al. (2015) who suggested that agroforestry occupies at least 10.6 million ha representing about 6.5% of the utilised agricultural area in Europe. Of our studied systems, livestock agroforestry covers about 15.1 million ha which is by far the largest area. High value tree agroforestry and arable agroforestry cover 1.1 million and 358 thousand ha respectively. A cluster analysis revealed that a high abundance of areas under agroforestry can be found in south, central and north-east Portugal, south-west, central and parts of north Spain, south of France, Sardinia, south Italy, central and north-east Greece, south and central Bulgaria, and central Romania.

Spain (5.6 million ha), Greece (1.6 million ha), France (1.6 million ha), Italy (1.4 million ha) and Portugal (1.2 million ha) have the largest absolute extent of agroforestry. However, if we would look at the extent of agroforestry in relation to the utilised agricultural area (UAA), countries like Cyprus (40% of UAA), Portugal (32% of UAA) and Greece (31% of UAA) have the largest percentage of agroforestry cover.

LUCAS data were also used to estimate the extent of single trees and green linear elements such as hedgerows. Agroforestry involving single trees covers almost 300 thousand hectares corresponding to around 0.02% of the territorial area in the EU. The largest extent of agroforestry with single trees or single bushes can be found in France (55,900 ha) followed by Spain (44,300 ha) and the UK (35,900 ha). Agroforestry involving hedgerows cover about 1.78 million hectares representing around 0.42% of the territorial area in the EU. The largest extent of agroforestry with hedgerows can be found in France (598,000 ha) followed by the UK (240,000 ha) and Italy (168,000 ha).

The higher estimate for the agroforestry area using the LUCAS data (15.4 million ha) than the literature review (10.6 million ha) can be partly explained by the addition of data for Bulgaria (0.9 million ha), plus higher estimates for Spain (+1.7 million ha), France (+1.1 million ha), Romania (+708 thousand ha) and Italy (+437 thousand ha). When the LUCAS estimates for Spain and Portugal were compared with a more detailed analysis of national inventories, the higher estimate for agroforestry in Spain of about 5.6 million ha rather than 3.8 million ha seems valid. The higher estimate for Spain is primarily a result of including other silvopastoral systems in addition to the dehesa.

Remote sensing data were used to estimate tree cover on agricultural land. At the landscape scale (100 m x 100 m), tree cover density on agricultural land was surprisingly high and the seven investigated countries (Austria, Switzerland, Estonia, Latvia, Lithuania, Sweden and Norway) together have about 4.5 million hectares of agricultural land with more than 10% tree cover. At the landscape scale, Sweden has the largest extent of agricultural land with significant tree cover.

Considering the fact that agroforestry covers a considerable part of the agricultural land in the EU (up to about 8.8% of the UAA), agroforestry deserves a more prominent place in EU statistical reporting. This is not difficult to implement. Although this current estimate of the extent of agroforestry in Europe was difficult to undertake, statistical reporting could be improved. For example, identifying agroforestry areas using the Eurostat's LUCAS database could be made easier and more straightforward by introducing a few simple changes in data collection. Although analyses suggest that it was rare for LUCAS results from Spain to identify "agroforestry" at the interface of independently managed forest and agricultural land, this should still be checked for other regions.

Most likely there is still an error in the extent of agroforestry, but since the data were collected and analysed in a uniform manner it is now possible to make comparisons between countries and identify regions in Europe where agroforestry is already widely practiced and areas where there would be opportunities for practicing agroforestry at a larger scale. A more uniform reporting method makes it easier to give more precise estimates on the extent of agroforestry in Europe and changes in its extent. This would help to increase the role of agroforestry on policy agendas and provide decision makers with more reliable information on the extent of agroforestry and changes therein. Without reliable and up-to-date information on the extent agroforestry area, both now and changes over time, it will be very hard to plan and evaluate measures to promote this sustainable land use practice.

3 Introduction

In the AGFORWARD project agroforestry is defined as "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions" (Burgess et al. 2015). Based on this definition alone it would be very hard to estimate the extent of agroforestry in Europe and we would need some more information to frame the boundaries of what is and is not agroforestry. There are several categories of common agroforestry practices in Europe including wood pastures, hedgerows, windbreaks, riparian buffer strips, intercropped and grazed orchards, grazed forests, forest farming (Mosquera-Losada et al. 2009), and more novel silvoarable and silvopastoral systems such as alley cropping, woodland chicken, and food forestry. What each of these practices has in common is that they take advantage of the interactive benefits from combining trees and shrubs with crops and/or livestock to create an integrated and sustainable land-use system (Lundgren and Raintree 1982, Leakey 1996).

An accurate and objective estimate on the extent of agroforestry in Europe is critical for the development of supporting policies. Despite the fact that agroforestry can be found almost everywhere it has been hard to find reliable data on the global extent of agroforestry (Zomer et al. 2009) and especially in Europe. This lack of European data, and a narrow definition of agroforestry, has led in the past to the misconception that agroforestry is probably of little importance in a European context. This misunderstanding can lead to incorrect policy decisions and this problem can best be tackled by providing an objective estimate on the extent of agroforestry in Europe. This is especially important since recently agroforestry is gaining momentum in researcher, farmer and policy circles. In this report we try to answer the question: How much agroforestry is there in Europe and where is it?

Databases providing an estimate on the extent of agroforestry in Europe are already available. The CORINE land cover classification contains land cover data for Europe and includes the land cover class "agroforestry" (European Environment Agency 1995). According to the CORINE database, agroforestry covers about 3.3 million hectares in Europe, mainly in Spain, Portugal and Italy with some smaller areas in France and Austria. However other studies have demonstrated that agroforestry is practiced on a wider scale than this and that the CORINE database is underestimating the agroforestry area. The agroforestry system of wood pastures has the largest areal extent in Europe and they are found in all climatic zones ranging from the Mediterranean to boreal zones (Bergmeier et al. 2010, Plieninger et al. 2015). Oak tree systems in the Mediterranean and reindeer husbandry in northernmost Fennoscandia in particular cover large areas (Eichhorn et al. 2006, Jernsletten and Klokov 2002). There are also other systems. Fruit tree agroforestry systems are particularly found in the central (Herzog 1998) and Mediterranean regions of Europe, with large areas of olive agroforestry in the Mediterranean region (Eichhorn et al. 2006). A recent literature study summarising the currently available data sources estimated that agroforestry in Europe is practiced at least on an area of 10.6 million hectares equivalent to 6.5% of the utilized agricultural area in Europe (den Herder et al. 2015).

Zomer et al. (2009) report a first attempt to quantify the extent of agroforestry at the global level. One surprising result was the unexpectedly large extent of agroforestry worldwide. Globally, approximately 46% of all agricultural land had at least 10% tree cover. For Europe, the corresponding figure was that 40% of all agricultural land in Europe had at least 10% tree cover

(Zomer et al. 2009). A key result was that agroforestry is a significant feature of agriculture in all regions of the world. In the 2014 update on the global extent of agroforestry, Zomer et al. (2014) reported that even about 46% (i.e. about 113.5 million ha) of all agricultural land in Europe had at least 10% tree cover. Thus estimates on the extent of agroforestry depend a lot on the definition of agroforestry. In the current report, we adopt the same definition for agroforestry used by several authors (Lundgren and Raintree 1982, Leakey 1996, Zomer et al. 2009, Burgess et al. 2015); the deliberate integration of woody vegetation with crops and/or animals to benefit from the resulting ecological and economic interactions.

There are a range of methods for categorising agroforestry practices. This can be done on the basis of components, products, agro-ecological zones, and socio-economic groupings (McAdam et al. 2009). In the AGFORWARD project, agroforestry systems have been grouped into four categories on the basis of the initial perspective of the farmer. The main types of agroforestry systems provided by the AGFORWARD project are: high natural and cultural value agroforestry systems, high value tree agroforestry systems, arable agroforestry systems, and livestock agroforestry systems. A more detailed description of the four different systems is available on the AGFORWARD website (www.agforward.eu) and in the preliminary stratification of the systems by den Herder et al. (2015). In the current report we used the same stratification of European agroforestry into these four different systems. We were able to map and estimate the extent of three systems out of the four systems defined by the AGFORWARD project (high value tree, arable and livestock systems). The extent of the systems was estimated using uniform EU-wide statistics and databases. The results from these were then compared with the country reports made by experts from some selected agroforestry countries.

4 Material and methods

Agroforestry areas were mapped using three different approaches that are based on existing land cover and land use databases: LUCAS Land Use and Land Cover data, COPERNICUS Land Monitoring Survey (high resolution maps with tree cover density for seven countries) and a review of the literature and statistical inventories from some selected countries.

4.1 The Land Use/Cover Area frame Survey (LUCAS)

For the quantification of agroforestry in Europe, we used data collected in the Land Use/Cover Area frame Survey (LUCAS) which is a harmonised *in situ* land cover and land use data collection exercise that extends over the whole of the EU's territory (Eurostat 2015). The first survey was held in 2001. In 2006, the sampling methodology changed and its focus shifted from an agricultural land survey to a broader land cover, land use and landscape survey. In the same year, a three-yearly interval was introduced for carrying out the survey. In 2009, the geographical coverage of LUCAS was expanded to 23 of the then EU-27 Member States. For this report we used the data from the 2012 survey which covered all of the then EU-27 Member States. Croatia joined the EU in 2013 and was not yet included in the LUCAS 2012 data collection.

LUCAS is a two phase sample survey. The LUCAS first phase sample is a systematic sample with points spaced 2 km apart in the four cardinal directions covering the whole of the EU's territory; it therefore includes around 1.1 million different points. Each point of the first phase sample is photo-interpreted and assigned to one of the following seven pre-defined land cover strata: arable land, permanent crops, grassland, wooded areas and shrubland, bareland, artificial land, and water. From the stratified first phase sample, a second phase sample of points (the field sample) is drawn. During the LUCAS 2012 survey, a sample of 270,000 of first phase points was visited on the spot by field surveyors. The selection of the points is based on the stratification information producing a quasi-regular grid with on average a LUCAS sample point in every block of 4 km x 4 km. However, points above 1500 metres and far from the road network were considered inaccessible and were therefore not visited (Eurostat 2015).

Due to the intensive sampling effort that was used in LUCAS, the set of points can be viewed as representative of the land cover at EU and also for the larger countries at national scales. To estimate the extent of agroforestry practices in Europe, we divided the number of points defined as agroforestry in each country by the total number of LUCAS points in this country and multiplied this by the surface of the country.

It is important to note that LUCAS uses a double land cover classification system for land covers with multiple layers, such as for instance agroforestry systems where there is often in addition to a tree layer also a secondary layer which can be composed of shrubs, crops or grass. In LUCAS this is marked entered as the primary land cover (LC1) which is composed of trees when these are present, and the secondary land cover (LC2) which can be composed of e.g. shrubs, crops, grass or bare soil. In specific landscapes, such as agroforestry area and complex or heterogeneous areas these two separate land covers (LC1 and LC2) are used. For example, our database contains many points where for land cover 1 (LC1) is entered “apple trees (B71)” and land cover 2 (LC2) is “common wheat (B11)”. In the real world this means that on this particular point common wheat was growing under the apple trees. It is likely that points with this particular combination of primary and secondary land cover represent a silvoarable practice using a combination of apple trees and common wheat.

Another useful variable in the LUCAS database is land management, which contains information if there are signs of grazing. By identifying certain combinations of primary and secondary land cover and land management it is possible to identify agroforestry points and stratify them into different systems. Agroforestry systems were stratified according to the same classification described by den Herder et al. (2015) into systems or practices focussed on high value trees (e.g. olive and fruit trees), arable systems, and livestock systems. For each system, the criteria for the selection of LUCAS points belonging to a particular system were different. The selection procedure for stratifying agroforestry points into three discernible systems (high value trees, arable and livestock) is explained in more detail in the following sections.

4.1.1 Agroforestry with high value trees

As a first step in identifying agroforestry areas containing high value trees, we selected the following primary land cover classifications (LC1) indicating points with high value trees: B71 apple, B72 pear, B73 cherry, B74 nuts, B75 other fruit trees and berries, B76 oranges, B77 other citrus fruits, B81 olive groves, B82 vineyards, B83 nurseries and B84 industrial crops (only mulberry and carob were included). See Eurostat (2012) for more information on LUCAS land cover and land use classification codes.

As a next step, out of our selected points containing high value trees we identified those which can be described as grazed orchards. In LUCAS grazing is marked in the Land Management column (1 = signs of grazing, 2 = no signs of grazing). In LUCAS, grazed orchards can be identified by selecting points with high value trees as a primary land cover in combination with signs of grazing.

To identify arable high value tree systems, we have to find a combination of LC1 and LC2 which could indicate high value trees intercropped with arable crops. In combination with the selected primary land covers containing high value trees from above (LC1=B71-B84), the following secondary land cover classifications (LC2) could indicate intercropped high value trees: B11 common wheat, B12 durum wheat, B13 barley, B14 rye, B15 oats, B16 maize, B19 other cereals, B21 potatoes, B23 other root crops, B31 sunflower, B41 dry pulses, B42 tomatoes, B43 other fresh vegetables, B44 floriculture and ornamental plants, B45 strawberries, B50 fodder crops (mainly leguminous), B51 clovers, B52 lucerne, B53 other leguminous and mixtures for fodder and B54 mix of cereals.

4.1.2 Agroforestry for arable systems

To identify arable agroforestry systems, we selected combinations of LC1 and LC2 which could indicate intercropped permanent crops, woodlands or shrubland. To identify arable agroforestry systems, we select the same primary land cover (LC1) as under the high value trees (B71-B84; willow was now also added under B84), but now we also included the land cover classes indicating woodland (C10-C33). As a secondary land cover we selected B11-B54 indicating that there are crops grown under planted or forest trees.

4.1.3 Agroforestry for livestock systems

To identify livestock agroforestry systems, we selected the same primary land cover classes (LC1) as selected above under the arable systems (permanent crops B71-B84, woodland C10-C33 and shrublands with sparse tree cover D10. To this selection we added the grasslands with sparse tree cover (E10) as these areas are often used for livestock grazing. To identify those LUCAS points which show signs of grazing we used the same approach as under the grazed high value tree systems by selecting grazed points in the Land Management column (1 = signs of grazing, 2 = no signs of grazing). Agroforestry livestock systems were identified by selecting the grazed points from our selection of primary land covers.

4.1.4 Total extent of agroforestry area in Europe

The three main agroforestry categories are not mutually exclusive. Agroforestry with high value trees either belongs also to livestock agroforestry or arable agroforestry. Therefore, to estimate and map the total extent of agroforestry, we combined the two queries which were used to identify arable and livestock agroforestry. First, we selected the same primary land cover classes (LC1) as described above under the arable and livestock systems: permanent crops (B71 to B84), woodland (C10 to C33), shrublands with sparse tree cover (D10) and grasslands with sparse tree cover (E10). From this selection, we then selected all LUCAS points which had crops (classes B11-B54) as a secondary land cover or which had signs of grazing.

4.2 Cluster analysis

A cluster analysis was used to identify areas where agroforestry is a prevailing land use. The analysis was used to indicate in which areas agroforestry practices would occur in clusters. We can assume that in these areas there would be a high likelihood for high natural and cultural value agroforestry. Clusters of agroforestry points could indicate that for example wood pastures are relatively well-connected in a particular area or that they would cover larger areas. We can assume that large extents of wood pastures or wood pastures with a low level of fragmentation are more likely to have a high natural value compared to single isolated or fragmented patches (Larsson et al. 2001). In addition, many of the remaining high cultural value agroforestry practices are a legacy of past traditional land use. Clusters of agroforestry points would indicate areas where these mostly traditional practices possibly having a high natural and cultural value still exist. To estimate the abundance of wood pastures, we used the Kernel density tool in ArcMap 10 (ESRI 2015). The Kernel density tool calculates the density of a feature in a neighbourhood around the feature. In our case we used the tool to calculate the density of LUCAS agroforestry points around each agroforestry point and the results were visualised in a grid.

4.3 Estimating the extent of hedgerows and isolated trees

In order to estimate isolated trees and hedgerows cover in Europe, we used the transect data included in the LUCAS 2012 update for each LUCAS point. These transects describe all features found in a transect of 250 m east placed at each LUCAS point, using the same LUCAS cover codes but also new codes dealing with linear elements of the landscape. We focused on those features more likely related to agroforestry like isolated trees taken from “single trees, single shrub” with code 10 and tree lines defined as the code 11 (avenue trees: One line of trees, not clustered trees; two lines of trees (avenue trees) are separated by a road), and those with less than 3 m width as code 12 (Conifer hedges: the feature is coded when the width is less than 3 m), 13 (Bush/tree hedges/coppices, visibly managed, e.g. pollarded (generally < 5 m height). The feature is coded when the wide is less than 3 m) and 14 (Bush/tree hedges, not managed, with single trees, or shrubland deriving from abandonment - The feature is coded when the width is less than 3 m. Shrub or wood margins are found as field boundaries within agricultural land or alongside roads or water courses). Within each region, we identified each coded element within each transect. From the 1283 transects measured of total of 270,276 transects carried out in Europe we got a mean of the surface occupied by a tree at European level. We multiplied the number of coded elements per transect by the mean of the surface occupied by each tree and therefore we obtain the meters occupied by trees within a transect of 250 m. This value was later on divided by 250 m to provide the proportion of the length of an identified element with respect to the total length of the transects in a region. Hereafter, we multiplied this percentage by the total area of each region in Europe. The Microsoft Excel 10 program was used for these calculations. Maps were created with QGIS version 2.12 Lyon.

4.4 Tree cover density on agricultural land

The extent of agroforestry, if defined by tree cover on agricultural land of greater than 10%, can be estimated by analysing tree cover density. A first attempt on the quantification of the extent of agroforestry at the global level was made by Zomer et al. (2009) using the then-available remote sensing datasets. In their first attempt they used a 1 km^2 resolution tree-cover data set together with a global land-use layer to investigate the occurrence of agroforestry, which was defined as tree cover on agricultural land. Later, their assessment was updated using a dataset with improved resolution (250 m) and improved quality (Zomer et al. 2014).

For our European assessment in this report, tree cover density maps (% tree cover per pixel) at a 20 and 100 m resolution were available for Norway, Sweden, Estonia, Latvia, Lithuania, Switzerland and Austria (Figure 1)(Copernicus Land Monitoring Services 2015). The raster data were used to analyse tree cover density in agricultural land of these six countries for which we had data. An agricultural land vector layer was created by merging all CORINE land cover classes (CORINE class 2.1.1. to 2.4.4.) belonging to the first level category “agricultural areas”. The merged layer was used as a mask to map all agricultural land of the selected countries (Figure 2). Tree cover density data were analysed at different scales. The 20 m resolution raster data was used to assess tree cover density at the field scale and the 100 m resolution for the assessment of tree cover at the landscape scale. At the time of writing the report, we only analysed tree cover density for this limited set of countries. However, in the near future, tree cover density mosaic layers will be available for whole Europe at a 20 m and 100 m resolution.

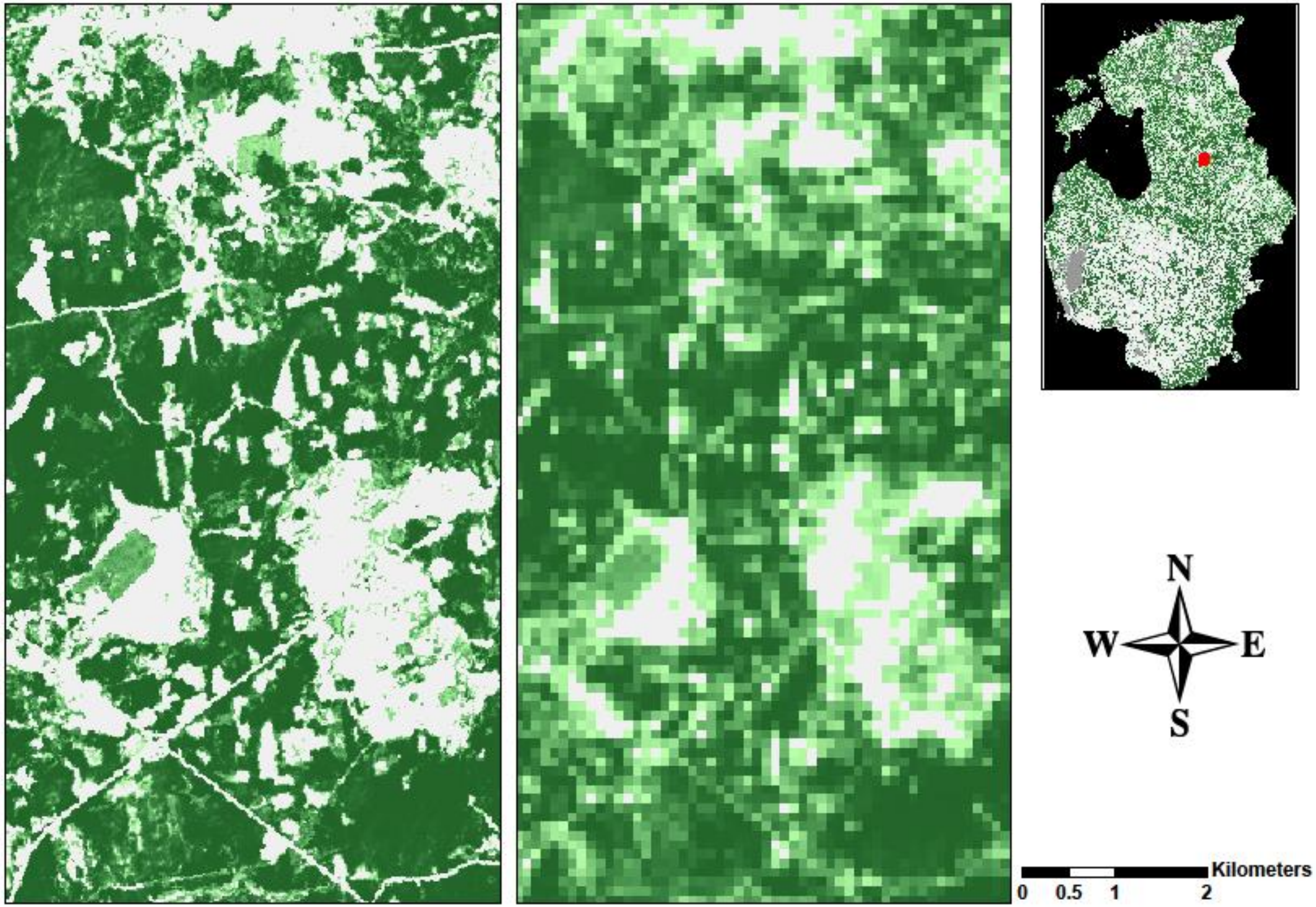


Figure 1. Tree cover density map at a) 20 m and b) 100 m resolution. The map depicts tree cover density in agricultural and forest areas.

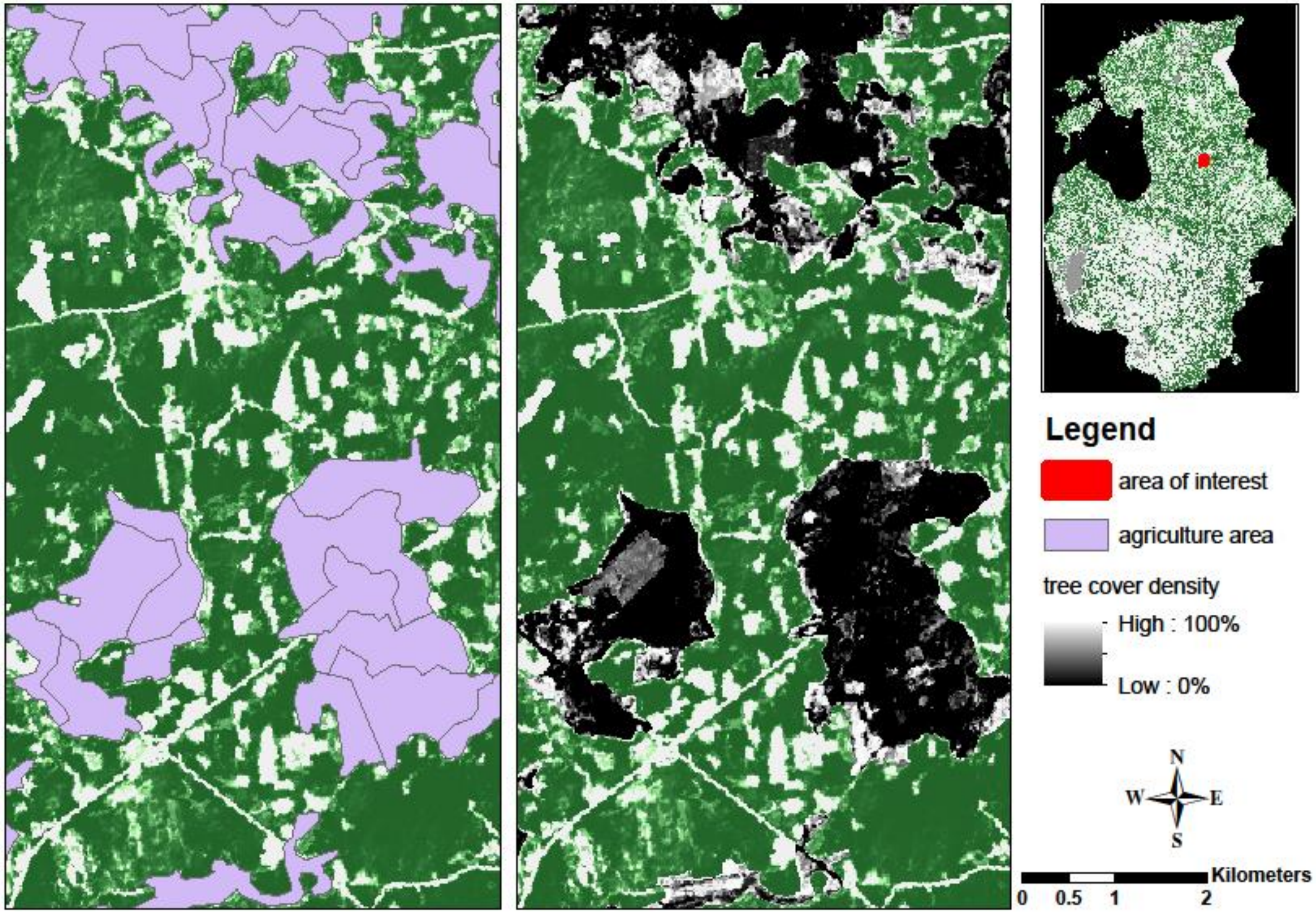


Figure 2. Tree cover density at a 20 m resolution: a) CORINE Land Cover classification was used to identify agricultural areas (in purple), and b) then we visualized and quantified tree cover density on agricultural land as indicated by the grey-scale gradient (black = 0% tree cover, white = 100% tree cover).

4.5 Verification of the LUCAS maps and area estimates

To verify if our LUCAS estimates on the area covered by agroforestry produced a reasonably reliable estimate, we included three chapters reviewing mapping exercises and examining national statistics in some selected agroforestry countries such as Greece, Portugal and Spain. Our LUCAS estimates were compared against the results from these national agroforestry reviews. Another way of verification method is handled in the discussion section. In this section the LUCAS results are compared with the results from the literature study on the preliminary stratification of agroforestry in Europe by den Herder et al. (2015).

5 Results

5.1 Extent of agroforestry based on LUCAS

5.1.1 High value tree agroforestry systems

Agroforestry involving high value trees cover about 1.1 million hectares corresponding only to about 0.2% of the territorial area in the EU (Table 1). The largest extent of agroforestry with high value trees can be found in Spain (261 thousand ha) followed by Italy (202 thousand ha) and Portugal (154 thousand ha) (Table 1, Figure 5). Greece also has a considerable area (137 thousand ha) under agroforestry with high value trees. The largest extent of intercropped high value trees is found in Italy (90 thousand ha) followed by Spain (52 thousand ha) and Portugal (36 thousand ha) (Table 1, Figure 3). The largest extent of grazed high value tree practices is found in Spain (217 thousand ha), Greece (123 thousand ha), Portugal (123 thousand ha) and Italy (116 thousand ha) (Table 1, Figure 4).

Table 1. Extent of intercropped, grazed and total extent of high value tree agroforestry practices in Europe based on LUCAS data

Country	Total territorial area[1]	Intercropped fruit, olive and nut tree area	Grazed fruit, olive and nut tree area	All high value tree agroforestry	
	1000 ha	1000 ha	1000 ha	1000 ha	%
Austria	8388	1.3	22.0	23.3	0.3
Belgium	3053	0.0	2.5	2.5	0.1
Bulgaria	11090	3.3	23.4	26.7	0.2
Cyprus	925	3.8	6.4	10.3	1.1
Czech Republic	7887	0.0	7.2	7.2	0.1
Denmark	4290	0.0	0.0	0.0	0.0
Estonia	4523	0.0	0.0	0.0	0.0
Finland	33843	0.0	0.0	0.0	0.0
France	54397	5.7	53.9	58.2	0.1
Germany	35713	0.0	35.8	35.8	0.1
Greece	13196	13.5	123.0	136.5	1.0
Hungary	9302	2.0	0.0	2.0	0.0
Ireland	6980	0.0	0.0	0.0	0.0
Italy	30134	90.3	116.2	202.2	0.7
Latvia	6456	0.0	0.0	0.0	0.0
Lithuania	6530	1.7	6.7	8.4	0.1
Luxembourg	259	0.0	2.4	2.4	0.9
Malta	32	0.0	0.0	0.0	0.0
Netherlands	4154	0.0	3.7	3.7	0.1
Poland	31268	2.9	11.5	14.3	0.0
Portugal	8909	36.4	122.7	154.2	1.7
Romania	23839	6.7	73.5	80.1	0.3
Slovakia	4904	2.0	0.0	2.0	0.0
Slovenia	2027	0.0	3.8	3.8	0.2
Spain	49851	52.1	217.0	260.7	0.5
Sweden	43858	0.0	2.0	2.0	0.0
United Kingdom	24853	0.0	14.2	14.2	0.1
EU-27 total	**430659**	**222**	**848**	**1050**	**0.2**

[1]Source: Eurostat Online data sources: Land cover overview, available online at: http://ec.europa.eu/eurostat/en/web/products-datasets/-/LAN_LCV_OV

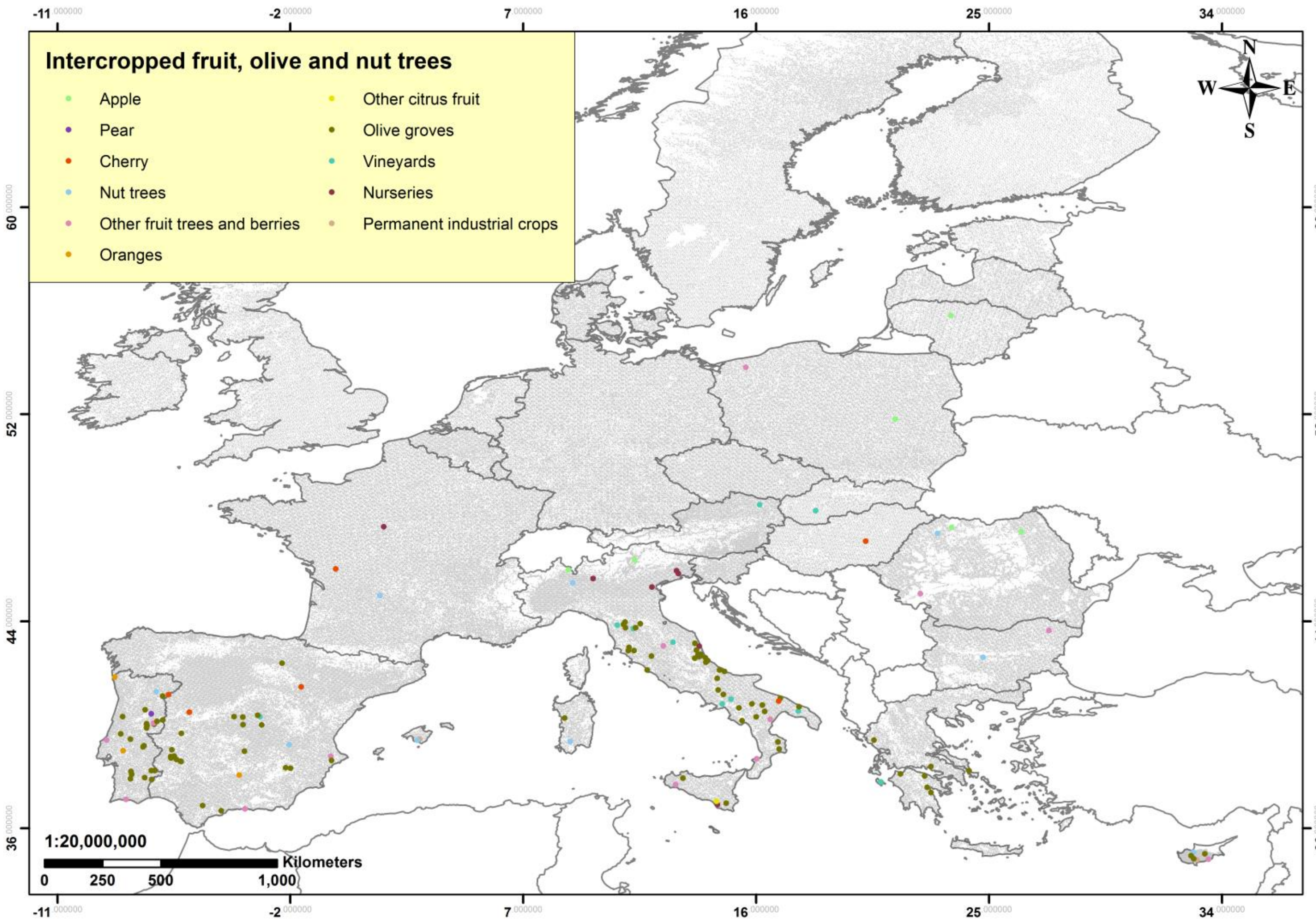


Figure 3. Intercropped fruit orchards, olive groves and nut tree plantations based on LUCAS data

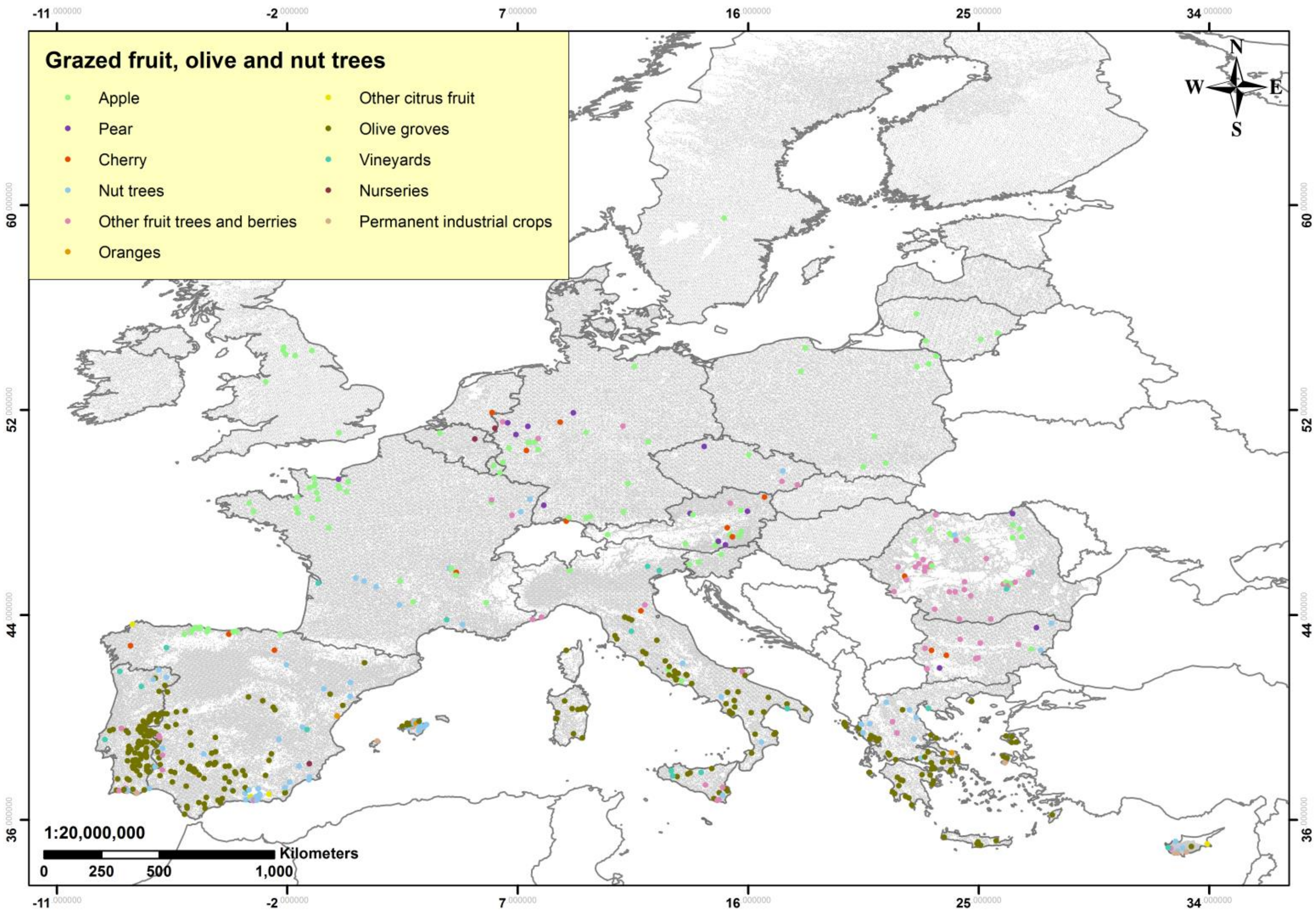


Figure 4. Distribution of grazed fruit orchards, grazed olive groves and grazed nut tree plantations based on LUCAS data.

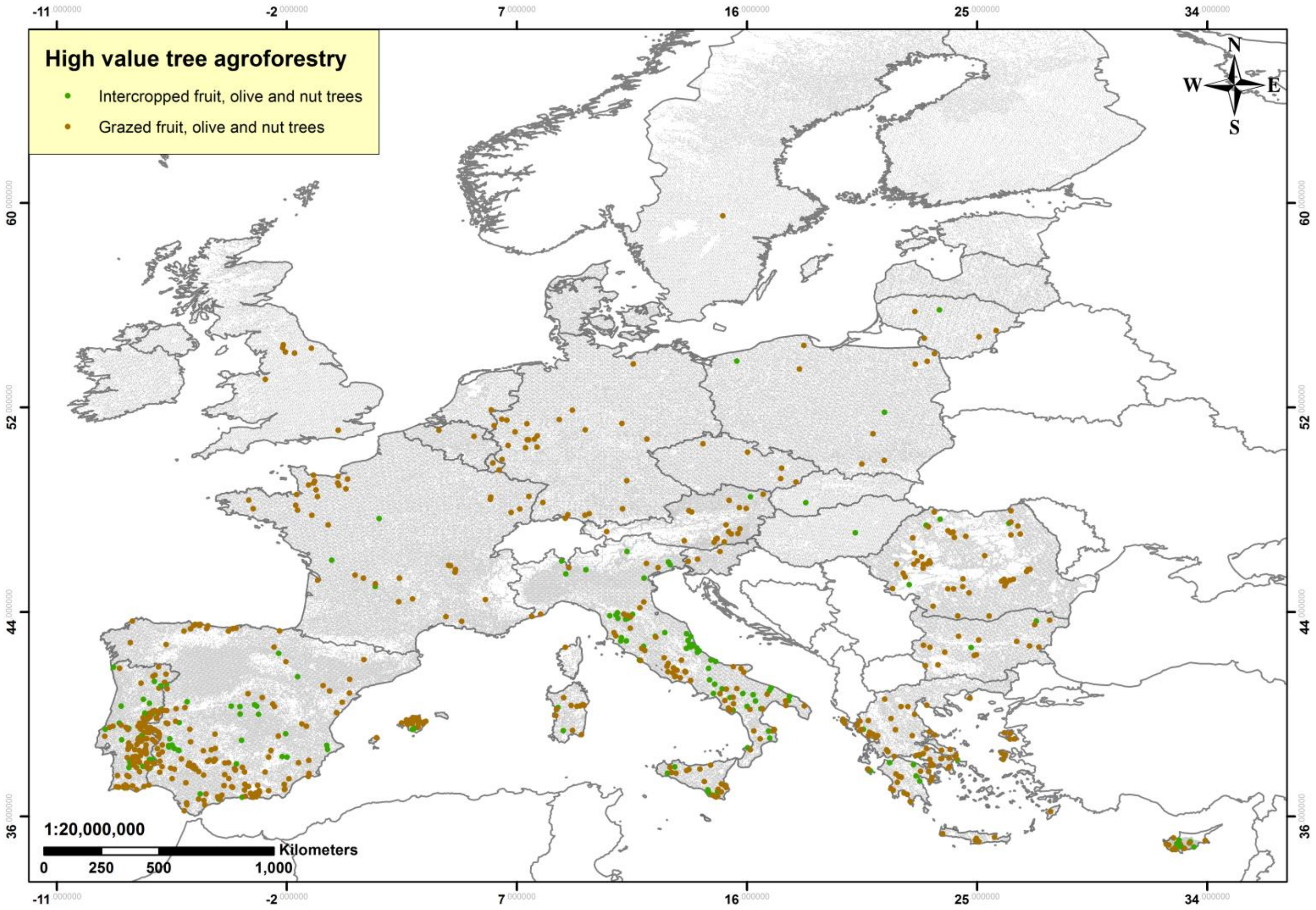


Figure 5. Distribution of two categories (intercropped and grazed) of high value tree agroforestry in EU27 based on LUCAS data.

5.1.2 Arable agroforestry systems

Silvoarable agroforestry covers about 358 thousand hectares corresponding only to about 0.1% of the territorial area in the EU (Table 2). The largest extent of silvoarable agroforestry can be found in Spain (117 thousand ha) followed by Italy (106 thousand ha) (Table 2, Figure 6). The largest extent of arable agroforestry with permanent crops (planted fruit, nut and olive trees) is found in Italy (90 thousand ha) followed by Spain (52 thousand ha) and Portugal (36 thousand ha) (Table 2, Figure 6). The largest extent of arable agroforestry in woodlands is found in Spain (65 thousand ha) and Portugal (40 thousand ha). These mainly oak-dominated woodlands often combine silvopastoral and silvoarable practices and are called dehesas and montados. Cereal cultivation is the most common arable agroforestry practise in these oak woodlands. Italy also had a considerable area (16 thousand ha) under arable agroforestry. There were almost no arable agroforestry systems linked with shrubland (tree height < 5 m) with sparse trees (Table 2).

Table 2. Extent of silvoarable agroforestry systems in Europe based on LUCAS data including agroforestry areas under permanent crops (fruit, nut and olive trees), woodlands and shrubland with sparse trees

Country	Total territorial area	Permanent crops	Woodland	Shrubland with sparse trees	All arable agroforestry	
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%
Austria	8388	1.3	0.0	0.0	1.3	0.0
Belgium	3053	0.0	0.0	0.0	0.0	0.0
Bulgaria	11090	3.3	0.0	0.0	3.3	0.0
Cyprus	925	3.8	0.0	0.0	3.8	0.4
Czech Republic	7887	0.0	0.0	0.0	0.0	0.0
Denmark	4290	0.0	1.2	0.0	1.2	0.0
Estonia	4523	0.0	0.0	0.0	0.0	0.0
Finland	33843	0.0	0.0	0.0	0.0	0.0
France	54397	5.7	0.0	0.0	5.7	0.0
Germany	35713	0.0	4.3	1.4	5.7	0.0
Greece	13196	13.5	1.7	0.0	15.2	0.1
Hungary	9302	2.0	0.0	0.0	2.0	0.0
Ireland	6980	0.0	0.0	0.0	0.0	0.0
Italy	30134	90.3	15.8	0.0	106.1	0.4
Latvia	6456	0.0	0.0	0.0	0.0	0.0
Lithuania	6530	1.7	0.0	0.0	1.7	0.0
Luxembourg	259	0.0	0.0	0.0	0.0	0.0
Malta	32	0.0	0.0	0.0	0.0	0.0
Netherlands	4154	0.0	0.0	0.0	0.0	0.0
Poland	31268	2.9	0.0	0.0	2.9	0.0
Portugal	8909	36.4	40.1	0.0	76.5	0.9
Romania	23839	6.7	1.7	1.7	10.0	0.0
Slovakia	4904	2.0	0.0	0.0	2.0	0.0
Slovenia	2027	0.0	0.0	0.0	0.0	0.0
Spain	49851	52.1	64.8	0.0	117.0	0.2
Sweden	43858	0.0	2.0	0.0	2.0	0.0
United Kingdom	24853	0.0	2.0	0.0	2.0	0.0
EU-27 total	**430659**	**222**	**134**	**3**	**358**	**0.1**

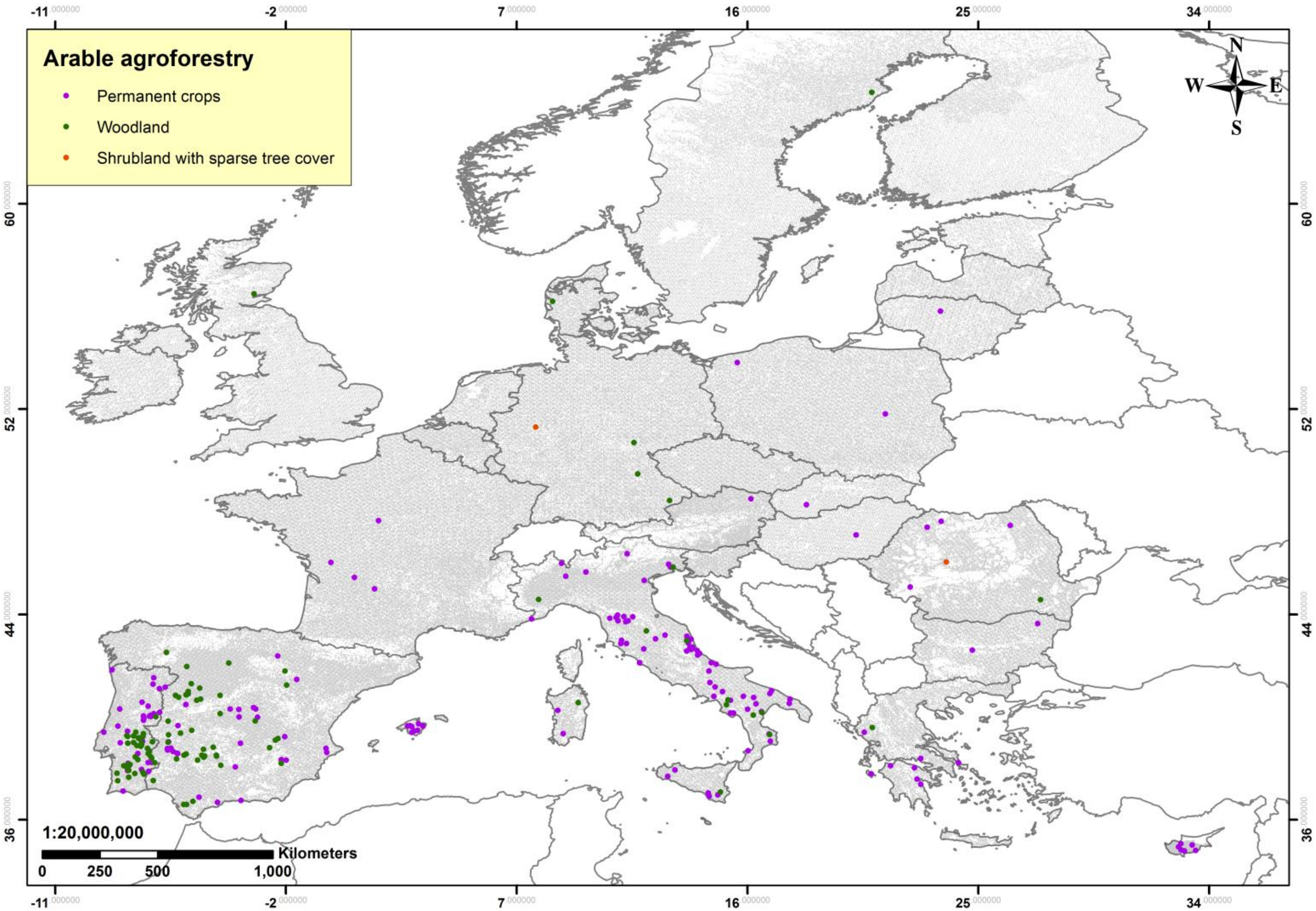


Figure 6. Distribution of silvoarable agroforestry practices. Included are intercropped permanent crops (fruits, olives and nuts), woodland (intercropped forest trees) and scrubland with sparse tree cover.

5.1.3 Livestock agroforestry systems

Agroforestry systems with livestock cover about 15.1 million hectares in Europe corresponding to about 3.5% of the territorial area in the EU (Table 3). The largest extent of livestock agroforestry systems can be found in the Mediterranean countries in Spain (5.5 million ha), Greece (1.6 million ha), France (1.6 million ha), Italy (1.3 million ha) and Portugal (1.1 million ha) (Table 3, Figure 7). The largest extent of livestock systems associated with permanent crops is found in Spain (217 thousand ha), Greece (123 thousand ha) and Portugal (122 thousand ha). The largest areas of livestock systems on woodland are found in Spain (3.5 million ha), Portugal (799 thousand ha), Greece (656 thousand ha), France (648 thousand ha) and Italy (622 thousand ha). The largest extent of livestock agroforestry on shrublands with sparse tree cover is found in Spain (589 thousand ha) and Greece (534 thousand ha). The largest extent of livestock agroforestry on grassland with sparse tree cover is found in Spain (1.2 million ha), France (749 thousand ha) and Romania (670 thousand ha).

Table 3. Extent of agroforestry for livestock systems in Europe based on LUCAS data. Included are agroforestry areas under permanent crops (fruit, nut and olive trees), woodlands, shrubland and grassland with sparse tree cover, recreation areas, and (semi-) natural, unused and abandoned areas.

Country	Total territorial area	Permanent crops	Woodland	Shrubland with sparse tree cover	Grassland with sparse tree cover	All livestock agroforestry	
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%
Austria	8388	22.0	92.1	6.5	37.6	158.2	1.9
Belgium	3053	2.5	6.2	0.0	34.9	43.7	1.4
Bulgaria	11090	23.4	167.0	91.8	584.4	866.5	7.8
Cyprus	925	6.4	12.2	12.2	12.8	43.6	4.7
Czech Rep.	7887	7.2	31.5	0.0	7.2	45.8	0.6
Denmark	4290	0.0	8.7	1.2	5.0	14.9	0.3
Estonia	4523	0.0	8.2	0.0	6.2	14.4	0.3
Finland	33843	0.0	143.1	5.0	10.0	158.1	0.5
France	54397	53.9	648.4	106.4	749.2	1557.9	2.9
Germany	35713	35.8	116.0	10.0	95.9	257.7	0.7
Greece	13196	123.0	655.7	534.3	288.2	1601.2	12.1
Hungary	9302	0.0	12.0	2.0	22.1	36.1	0.4
Ireland	6980	0.0	94.2	24.0	106.2	224.4	3.2
Italy	30134	116.2	622.4	235.2	329.8	1303.6	4.3
Latvia	6456	0.0	13.1	0.0	10.2	23.4	0.4
Lithuania	6530	6.7	10.1	0.0	20.1	36.9	0.6
Luxembourg	259	2.4	2.4	0.0	2.4	7.2	2.8
Malta	32	0.0	0.0	0.4	0.0	0.4	1.3
Netherlands	4154	3.7	9.3	3.7	11.1	27.8	0.7
Poland	31268	11.5	37.3	1.4	47.3	97.5	0.3
Portugal	8909	122.7	799.1	43.7	139.7	1105.1	12.4
Romania	23839	73.5	93.5	41.7	669.5	878.2	3.7
Slovakia	4904	0.0	20.0	4.0	18.0	41.9	0.9
Slovenia	2027	3.8	17.5	7.5	27.5	56.3	2.8
Spain	49851	217.0	3520.0	589.0	1163.9	5490.0	11.0
Sweden	43858	2.0	279.7	9.8	172.1	463.6	1.1
United Kingdom	24853	14.2	243.4	50.7	239.3	547.6	2.2
EU-27 total	**430659**	**848**	**7663**	**1781**	**4811**	**15102**	**3.5**

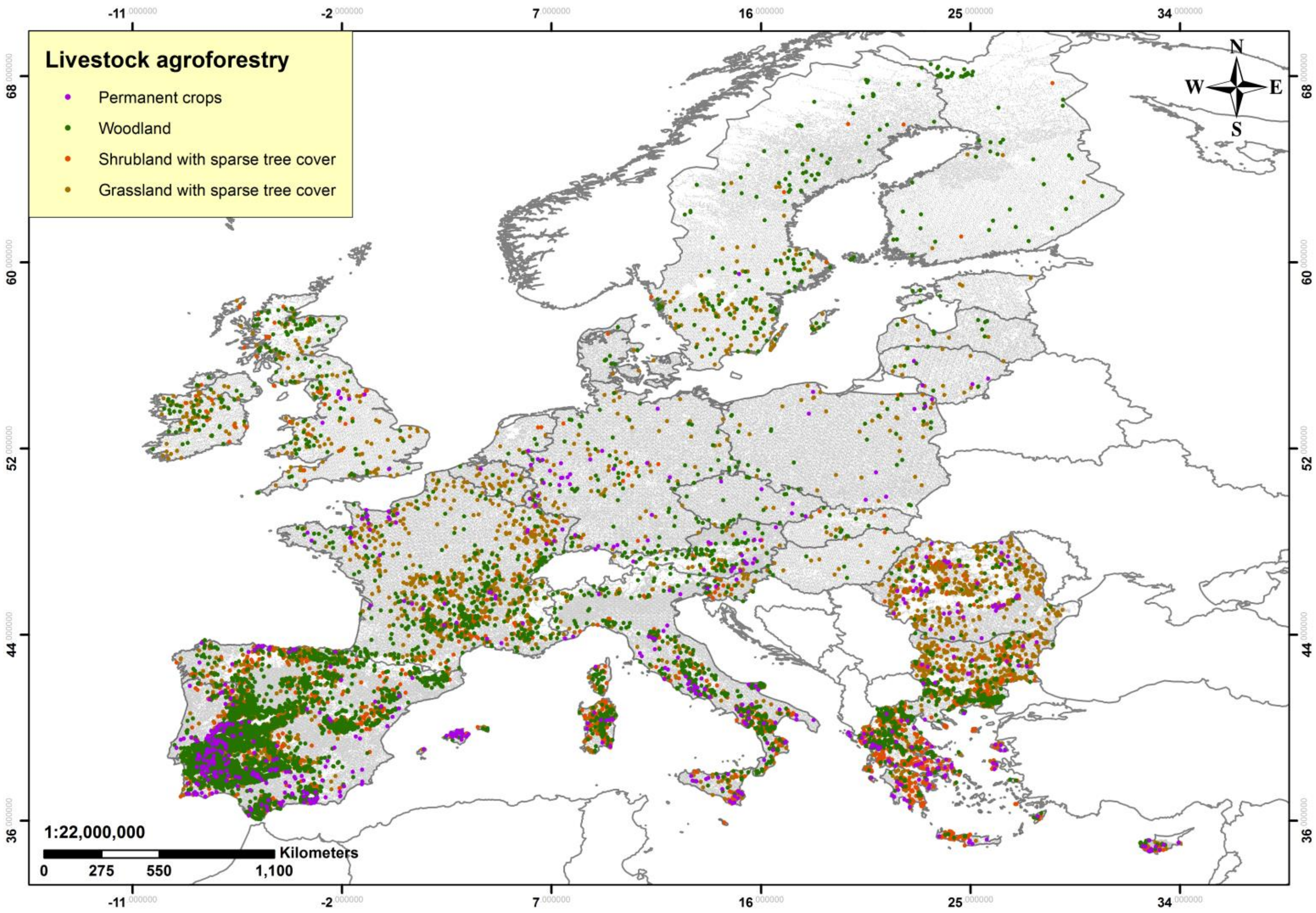


Figure 7. Distribution of agroforestry for livestock systems. Included are permanent crops (fruits, olives and nuts), woodland, shrubland and grassland with sparse tree cover.

5.1.4 Total extent of agroforestry area in Europe

According to our estimate using the LUCAS database the total area under agroforestry in the EU 27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the utilised agricultural area (Table 4, Figure 8). Of our three studied systems, by far the largest area (15.1 million ha) is covered by livestock agroforestry. High value tree agroforestry and arable agroforestry cover 1.1 million ha and 358 thousand ha respectively.

Spain (5.5 million ha), Greece (1.6 million ha), France (1.6 million ha), Italy (1.4 million ha), Portugal (1.2 million ha) and Romania (0.9 million ha) have the largest absolute extent of agroforestry (Table 4, Figure 10). However, if we look at the extent of agroforestry in relation to the utilised agricultural area (UAA), countries like Cyprus (40% of UAA), Portugal (32% of UAA) and Greece (31% of UAA) have the largest percentage of agroforestry cover (Table 4, Figure 11). Some countries have a very small agroforestry cover such as Malta, Luxembourg, Estonia and Denmark. This result is mainly due to their small size but is also an effect of a low percentage of the agricultural land covered by agroforestry. Some other countries do have some of their agricultural land under agroforestry in absolute numbers but the proportion of agroforestry area relative to the UAA is very low. This is the case in countries such as Poland, Germany and Czech Republic which have only 1% to 2% of their UAA under agroforestry.

A cluster analysis revealed that a high abundance of areas under agroforestry can be found in south, central and north-east Portugal, south-west, central and parts of north Spain, south of France, Sardinia, south Italy, central and north-east Greece, central and south Bulgaria, and central Romania (Figure 9). Large extents of agroforestry areas or areas with a low level of fragmentation are more likely to have a high natural value compared to single isolated or fragmented patches. The cluster analysis shows areas with a relatively high abundance of agroforestry points. It is likely that in these areas agroforestry covers larger areas and also high natural and cultural value agroforestry practices may be still relatively widespread in these areas.

Table 4. Total extent of agroforestry in Europe based on LUCAS data.

Country	Total territorial area	Utilised Agricultural area (UAA)[1]	High value tree agroforestry	Livestock agroforestry	Arable agroforestry	All agroforestry	Estimated proportion of total territorial area	Estimated proportion of UAA
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%	%
Austria	8388	2878	23.3	158.2	1.3	160.8	1.9	5.6
Belgium	3053	1358	2.5	43.7	0.0	43.7	1.4	3.2
Bulgaria	11090	4476	26.7	866.5	3.3	869.9	7.8	19.4
Cyprus	925	118	10.3	43.6	3.8	47.5	5.1	40.1
Czech Republic	7887	3484	7.2	45.8	0.0	45.8	0.6	1.3
Denmark	4290	2647	0.0	14.9	1.2	16.2	0.4	0.6
Estonia	4523	941	0.0	14.4	0.0	14.4	0.3	1.5
Finland	33843	2291	0.0	158.1	0.0	158.1	0.5	6.9
France	54397	27837	58.2	1557.9	5.7	1562.2	2.9	5.6
Germany	35713	16704	35.8	257.7	5.7	263.5	0.7	1.6
Greece	13196	5178	136.5	1601.2	15.2	1616.4	12.2	31.2
Hungary	9302	4686	2.0	36.1	2.0	38.1	0.4	0.8
Ireland	6980	4991	0.0	224.4	0.0	224.4	3.2	4.5
Italy	30134	12856	202.2	1303.6	106.1	1403.9	4.7	10.9
Latvia	6456	1796	0.0	23.4	0.0	23.4	0.4	1.3
Lithuania	6530	2743	8.4	36.9	1.7	38.6	0.6	1.4
Luxembourg	259	131	2.4	7.2	0.0	7.2	2.8	5.5
Malta	32	11	0.0	0.4	0.0	0.4	1.3	3.5
Netherlands	4154	1872	3.7	27.8	0.0	27.8	0.7	1.5
Poland	31268	14447	14.3	97.5	2.9	100.4	0.3	0.7
Portugal	8909	3668	154.2	1105.1	76.5	1168.3	13.1	31.8
Romania	23839	13306	80.1	878.2	10.0	888.2	3.7	6.7
Slovakia	4904	1896	2.0	41.9	2.0	43.9	0.9	2.3
Slovenia	2027	483	3.8	56.3	0.0	56.3	2.8	11.7
Spain	49851	23753	260.7	5490.0	117.0	5584.4	11.2	23.5
Sweden	43858	3066	2.0	463.6	2.0	465.5	1.1	15.2
United Kingdom	24853	16882	14.2	547.6	2.0	551.7	2.2	3.3
EU-27 total	**430659**	**174499**	**1050**	**15102**	**358**	**15421**	**3.6**	**8.8**

[1]Source: Eurostat online data sources: Farm structure statistics (2010). Available online: http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics

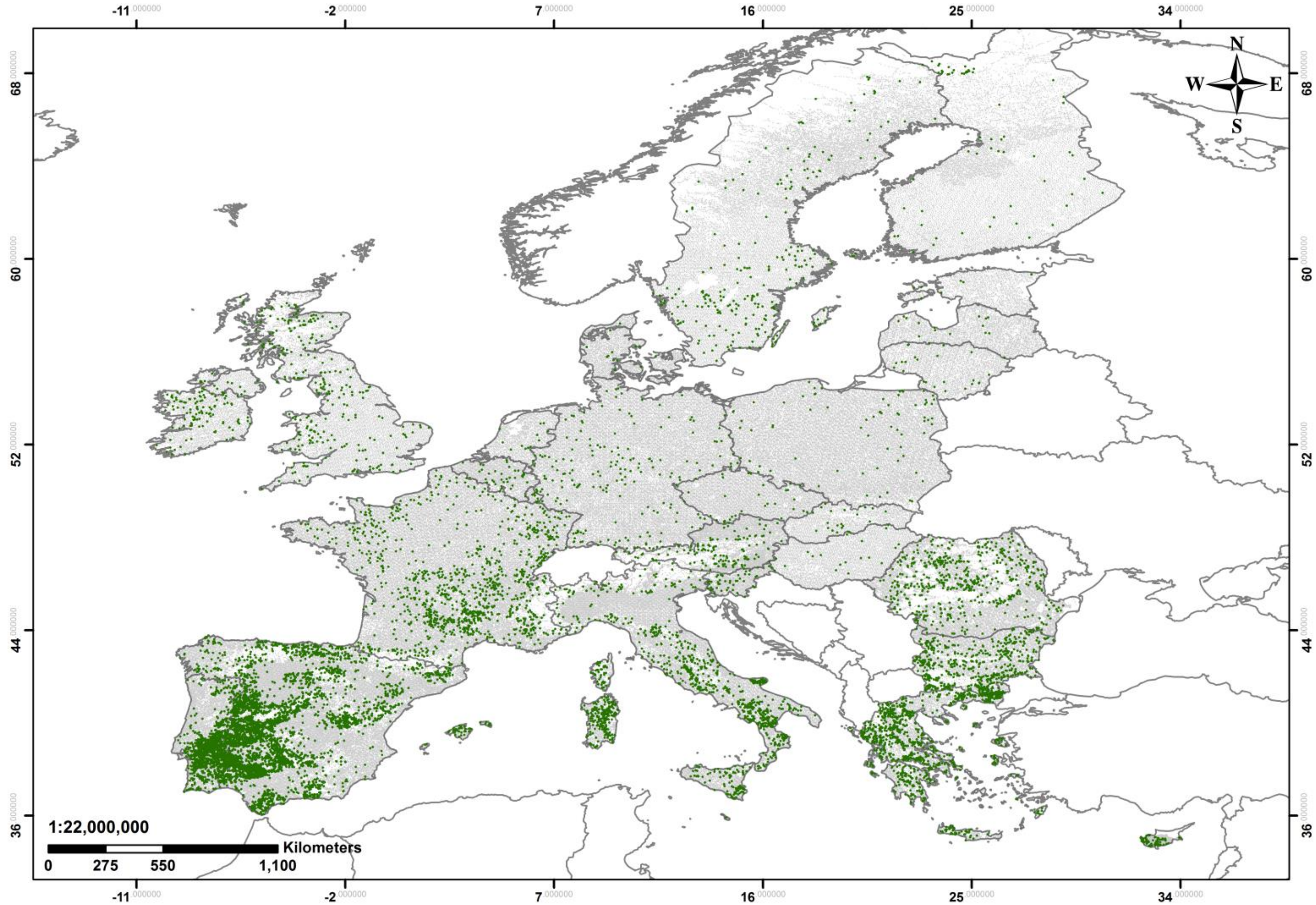


Figure 8. Total extent of agroforestry in Europe based on LUCAS data.

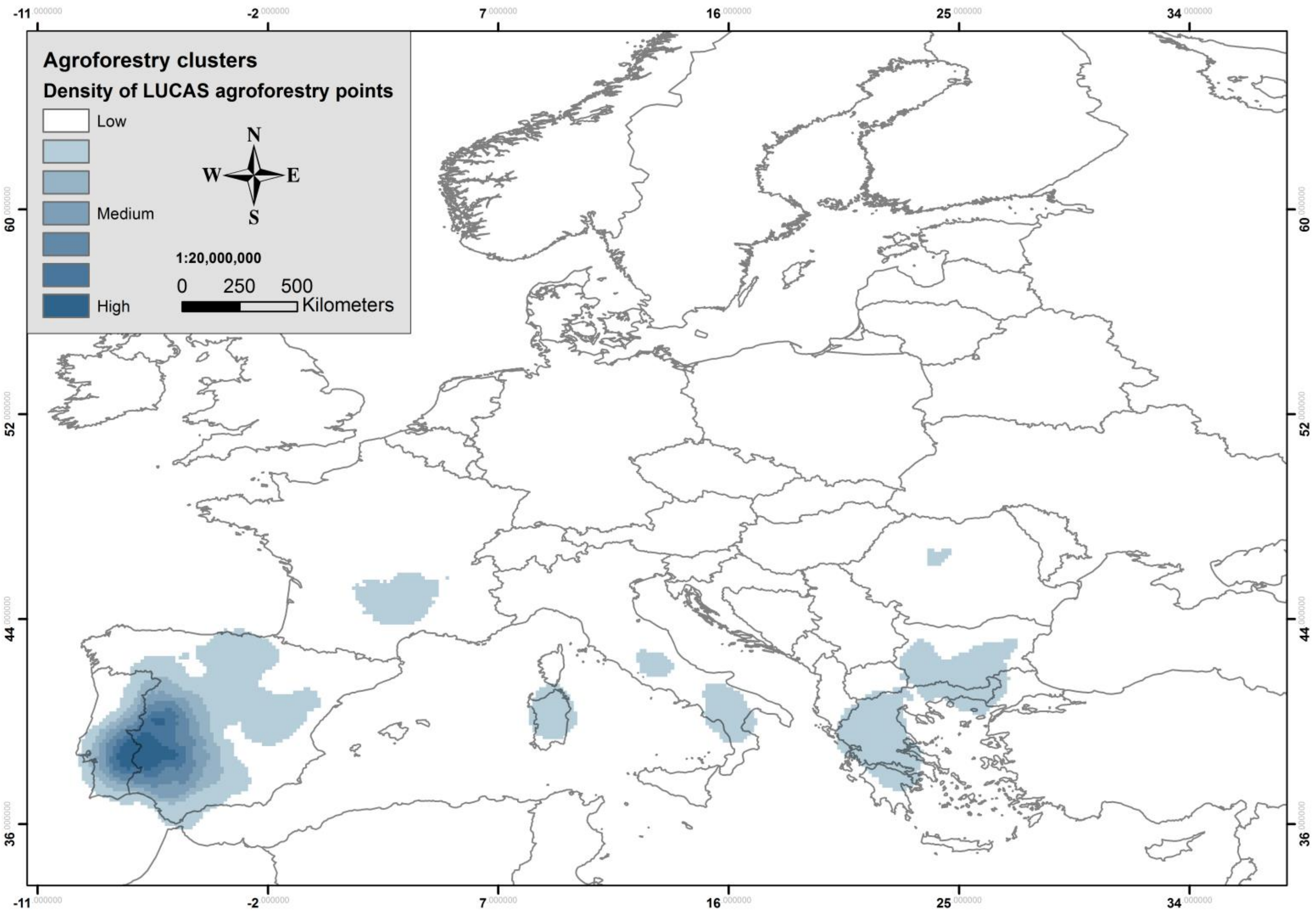


Figure 9. Agroforestry clusters in Europe. The dark blue areas indicate areas in Europe where agroforestry practices can be found in high densities.

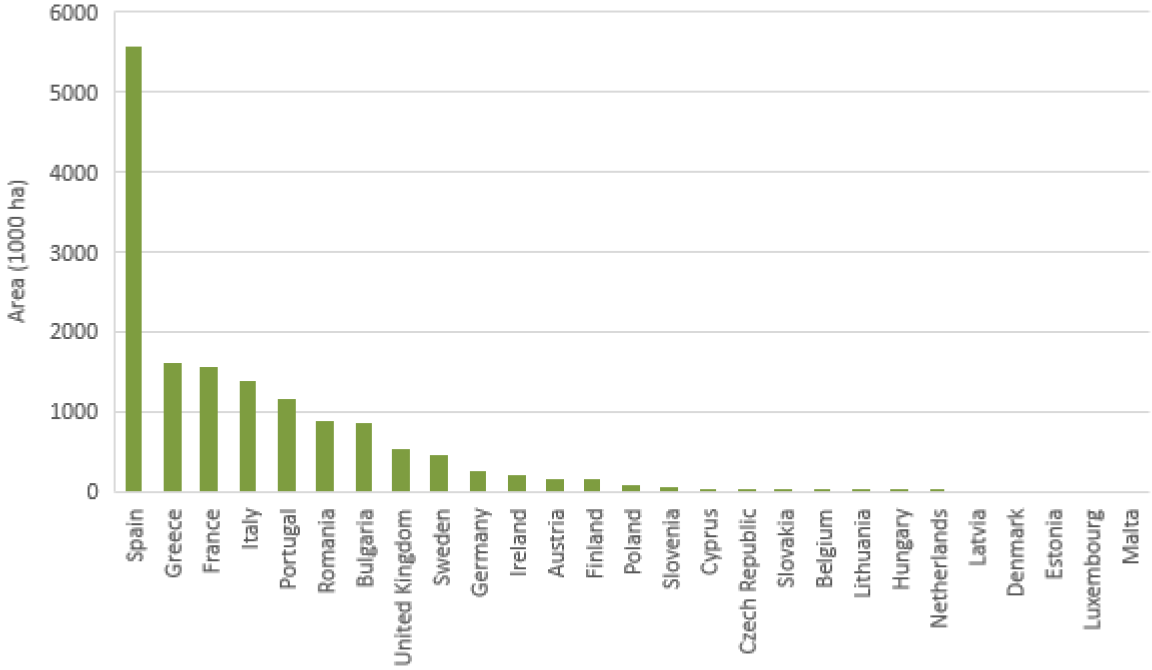


Figure 10. Estimated extent (x 1000 ha) of area covered by agroforestry in the EU27.

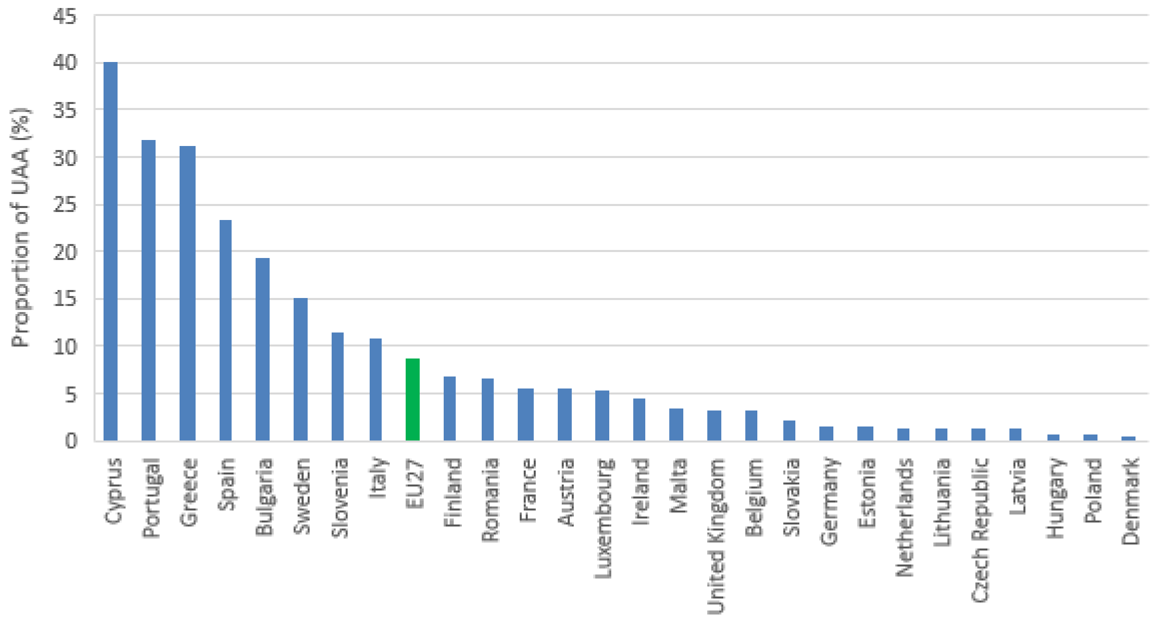


Figure 11. Estimated extent of agroforestry as a proportion of the Utilised Agricultural Area in the EU27.

5.2 Hedgerows and isolated trees

5.2.1 Single tree, single bushes agroforestry systems

Agroforestry involving single trees cover almost 300 thousand hectares corresponding only around 0.02% of the territorial area in the EU (Table 5, Figures 12 and 13). The largest extent of agroforestry with single trees, single bushes can be found in France (55.9 thousand ha)) followed by Spain (44.3 thousand ha) and UK (35.9 thousand ha). In terms percentage Malta (0.46%) and UK (0.15%), and Portugal (0.11%) are the countries with the highest density of single trees and single bushes.

Table 5. Extent of single tree and single bushes in Europe based on LUCAS data

Country	Total territorial area	Single tree, single bushes	
	1000 ha	1000 ha	%
Austria	8387	4.6	0.05
Belgium	3053	1.4	0.05
Bulgaria	11100	10.0	0.09
Cyprus	925	0.8	0.09
Czech Republic	7887	2.3	0.03
Denmark	4310	2.6	0.06
Estonia	4523	2.3	0.05
Finland	33842	10.3	0.03
France	63787	55.9	0.09
Germany	35713	14.7	0.04
Greece	13198	8.4	0.06
Hungary	9303	2.1	0.02
Ireland	7029	5.2	0.07
Italy	30132	33.7	0.11
Latvia	6456	1.4	0.02
Lithuania	6530	4.4	0.07
Luxembourg	259	0.1	0.03
Malta	32	0.1	0.46
Netherlands	3736	2.0	0.05
Poland	31268	15.7	0.05
Portugal	9191	13.3	0.14
Romania	23839	10.7	0.05
Slovakia	4904	1.9	0.04
Slovenia	2027	0.8	0.04
Spain	50537	44.3	0.09
Sweden	44742	8.6	0.02
United Kingdom	24410	35.8	0.15
EU-27 total	**441117**	**293.5**	**0.02**

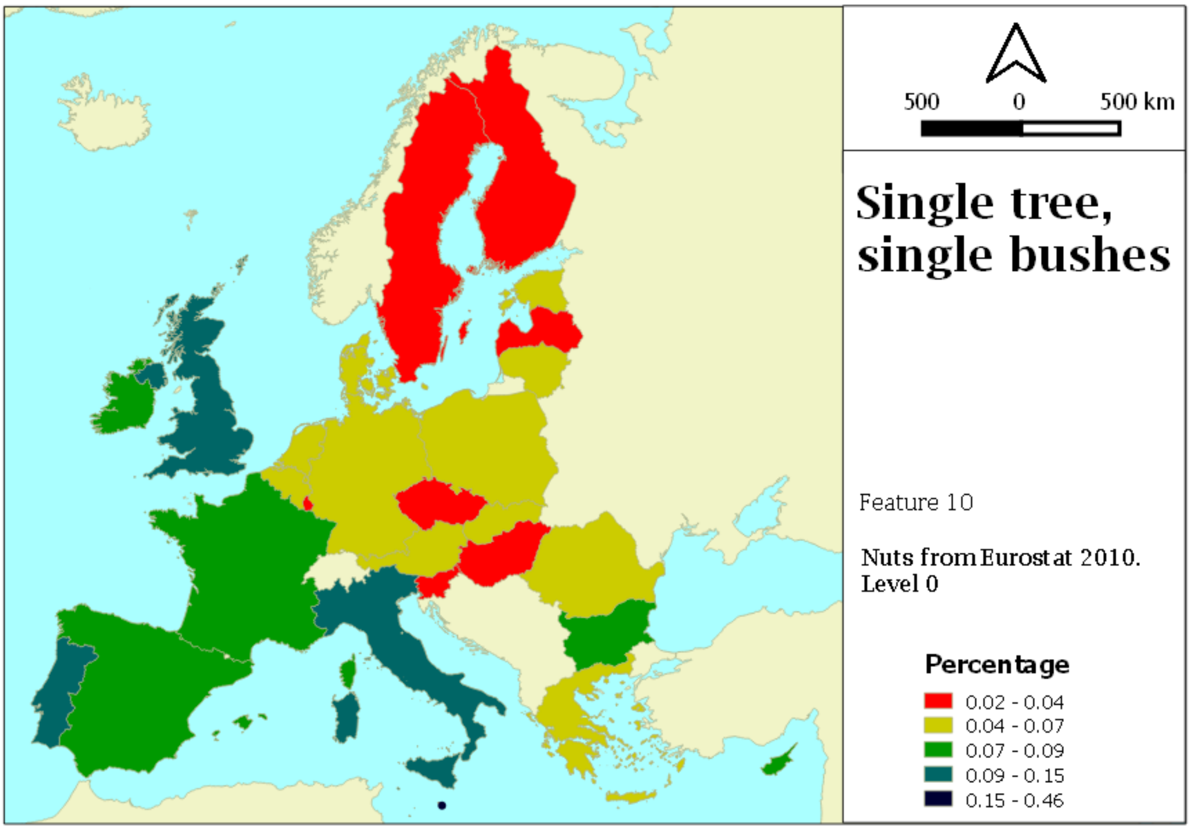


Figure 12. Single trees and single bushes cover (percentage)

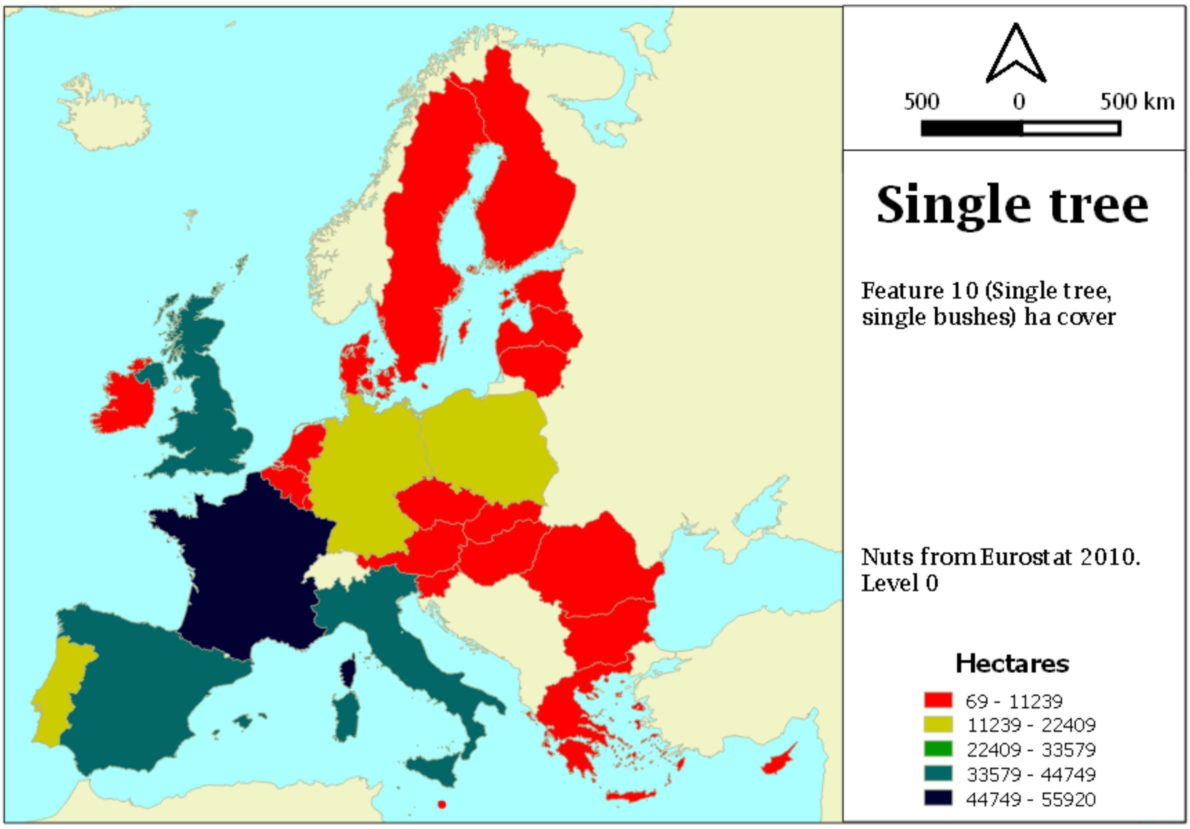


Figure 13. Single trees and single bushes cover (hectares).

Agroforestry involving hedgerows cover about 1.78 million hectares representing around 0.42% of the territorial area in the EU (Table 6, Figures 14 and 15). The largest extent of agroforestry with hedgerows can be found in France (598 thousand ha)) followed by UK (240 thousand ha) and Italy (168 thousand ha) (Table 6). In terms of percentage, Ireland (1.6%), UK and France (around 1%) are the countries with the highest hedgerows surface.

The hedgerows were split in four classes (*Avenue trees, Conifer hedgerows, hedgerows managed, and hedgerows deriving from abandonment*). The second (Conifer hedgerows) has the lower cover (only 11.7 thousand ha, the 0.002 % of the whole area) among the selected hedgerows features; having the rest a similar cover (from the 0.08 to 0.19 %) (Table 6).

Avenue trees cover around 769.7 thousand hectares corresponding to 0.19% of the territory of the EU (Table 6). The largest extent of avenue trees can be found in France (312.9 thousand ha) followed by Poland (78.2 thousand ha) and Italy (57.9 thousand ha) (Table 6). In terms of percentage, Belgium (0.64%), The Netherlands (0.59%), and France and Luxembourg (0.49%) are the countries with a highest density of avenue trees.

The largest extent of agroforestry with conifer hedges can be found in France (3.2 thousand ha)) followed by Spain (1.9 thousand ha) and Finland (1.7 thousand ha) (Table 6). Austria (0.008%), Belgium (0.006%), and France, Finland and Cyprus (0.005%) are the countries with the highest density of conifer hedges.

Managed hedgerows cover 421 thousand hectares representing around 0.08% of the territorial area in the EU (Table 6). The largest extent of agroforestry with managed hedgerows can be found in France (150.9 thousand ha), followed by UK (146.3 thousand ha) and Italy (35.6 thousand ha) (Table 6). The UK (0.6%), Ireland (0.37%), and France (0.24%) are the countries with the highest density of managed hedgerows.

Table 6 Extent of hedgerows in Europe based on LUCAS data

Country	Total territorial area	Total hedgerow area		Avenue trees		Conifer hedges < 3m		Bush/tree hedges/coppices, visibly managed (e.g. pollarded) <3 m		Bush/tree hedges, not managed, with single trees, or shrubland deriving from abandonment <3m	
	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%
Austria	8387	14.3	0.17	5.9	0.07	0.6	0.01	3.5	0.04	4.2	0.05
Belgium	3053	29.9	0.98	19.7	0.64	0.2	0.01	6.0	0.20	4.1	0.13
Bulgaria	11100	20.7	0.19	9.3	0.08	0.0	0.00	1.1	0.01	10.4	0.09
Cyprus	925	3.0	0.32	1.7	0.18	0.0	0.00	0.3	0.03	0.9	0.10
Czech Republic	7887	12.6	0.16	10.6	0.13	0.1	0.00	0.1	0.00	1.8	0.02
Denmark	4310	8.4	0.19	3.4	0.08	0.2	0.00	2.6	0.06	2.1	0.05
Estonia	4523	6.2	0.14	2.3	0.05	0.1	0.00	0.4	0.01	3.4	0.07
Finland	33842	57.8	0.17	22.6	0.07	1.7	0.00	5.1	0.02	28.4	0.08
France	63787	598.3	0.94	313.0	0.49	3.2	0.01	150.9	0.24	131.2	0.21
Germany	35713	72.9	0.20	51.4	0.14	0.6	0.00	7.4	0.02	13.6	0.04
Greece	13198	28.8	0.22	4.5	0.03	0.1	0.00	1.7	0.01	22.5	0.17
Hungary	9303	15.8	0.17	9.7	0.10	0.0	0.00	0.5	0.01	5.6	0.06
Ireland	7029	113.6	1.62	17.3	0.25	0.1	0.00	26.1	0.37	70.1	1.00
Italy	30132	167.6	0.56	58.0	0.19	0.8	0.00	35.6	0.12	73.2	0.24
Latvia	6456	12.6	0.20	1.9	0.03	0.1	0.00	0.3	0.00	10.3	0.16
Lithuania	6530	11.4	0.17	5.1	0.08	0.0	0.00	0.4	0.01	6.0	0.09
Luxembourg	259	1.8	0.71	1.3	0.49	0.0	0.00	0.4	0.14	0.2	0.08
Malta	32	0.3	0.90	0.2	0.48	0.0	0.00	0.1	0.18	0.1	0.23
Netherlands	3736	26.6	0.71	21.9	0.59	0.1	0.00	3.5	0.09	1.1	0.03
Poland	31268	113.7	0.36	78.2	0.25	0.4	0.00	3.3	0.01	31.9	0.10
Portugal	9191	41.1	0.45	34.8	0.38	0.0	0.00	1.0	0.01	5.3	0.06
Romania	23839	59.9	0.25	18.8	0.08	0.0	0.00	1.4	0.01	39.6	0.17
Slovakia	4904	3.8	0.08	1.4	0.03	0.0	0.00	0.3	0.01	2.2	0.04
Slovenia	2027	3.6	0.18	0.4	0.02	0.0	0.00	0.8	0.04	2.4	0.12
Spain	50537	89.0	0.18	30.9	0.06	2.0	0.00	14.5	0.03	41.6	0.08
Sweden	44742	26.5	0.06	6.0	0.01	0.2	0.00	7.6	0.02	12.7	0.03
United Kingdom	24410	239.8	0.98	39.6	0.16	1.0	0.00	146.4	0.60	52.8	0.22
EU-27 total	**441120**	**1780**	**0.42**	**770**	**0.19**	**12**	**0.00**	**421**	**0.08**	**578**	**0.14**

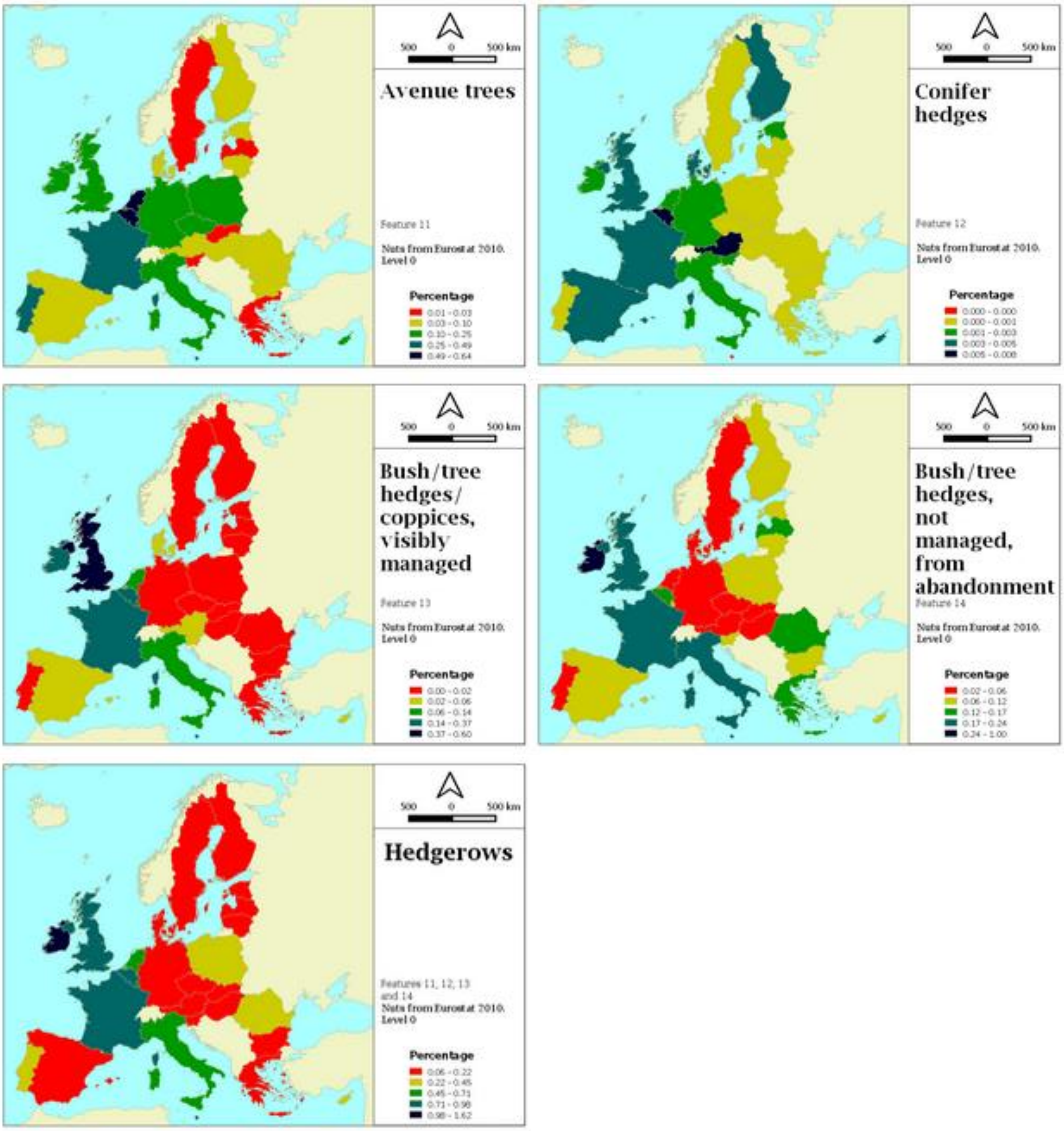


Figure 14 Hedgerows cover (percentage)

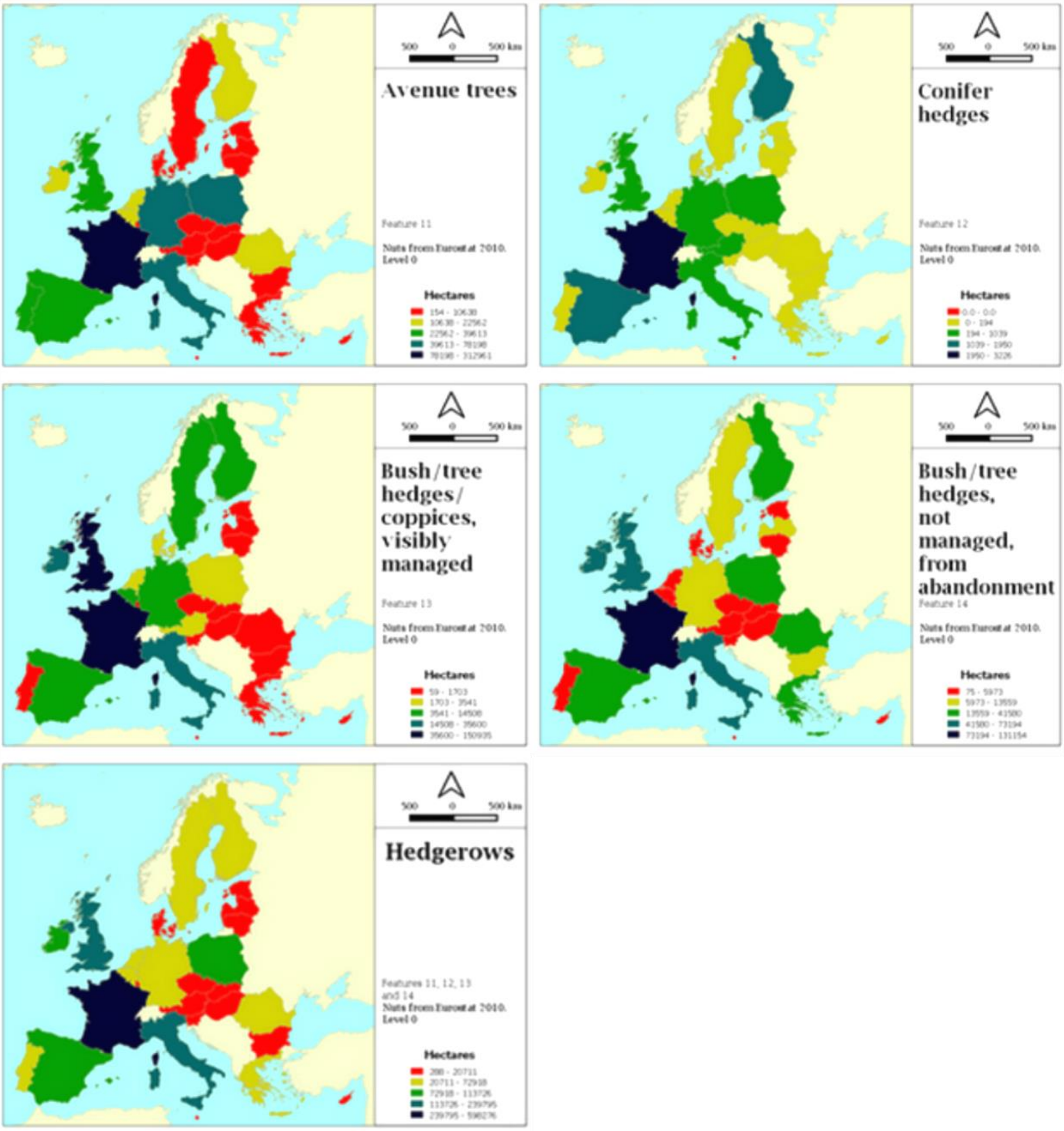


Figure 15 Hedgerows cover (hectares)

Hedgerows linked to abandonment cover 577.5 thousand hectares corresponding to about 0.14% of the territorial area in the EU (Table 6). The largest extent of hedgerows derived from abandonment can be found in France (131.2 thousand ha), followed by Italy (73.2 thousand ha) and Ireland (70.1 thousand ha) (Table 6). In relative terms, Ireland (1%), Italy (0.24%), and Malta (0.23%) are the countries with the highest density of managed hedgerows.

5.3 Tree cover on agricultural land

The tree cover analysis on agricultural land, using Copernicus data, was restricted to Norway, Sweden, Estonia, Latvia, Lithuania, Switzerland and Austria. At the field scale (20 m x 20 m), tree covers density on agricultural land was surprisingly high and Estonia, Lithuania and Latvia together have about 1.2 million hectares of agricultural land with more than 10% tree cover. Latvia has the largest extent of agricultural land with significant tree cover (Table 7). In Latvia, about 631 thousand hectares (22.4% of the agricultural area) of agricultural land has more than 10% tree cover and about 527 thousand hectares (18.7% of the agricultural area) has more than 20% tree cover. In Estonia and Lithuania, the extent of agricultural land with significant tree cover is considerably smaller compared to Latvia. For Norway, Sweden, Austria and Switzerland it was not possible to make calculations at the 20 m resolution due to errors in the raster data.

At the landscape scale (100 m x 100 m), tree cover density on agricultural land was even higher and the seven investigated countries together have about 4.5 million hectares of agricultural land with more than 10% tree cover. At the landscape scale, Sweden has the largest extent of agricultural land with significant tree cover (Table 7). In Sweden, about 982 thousand hectares (25.3% of the agricultural area) of agricultural land has more than 10% tree cover and about 667 thousand hectares (17.2% of the agricultural area) has more than 20% tree cover. Norway has the highest proportion of agricultural land with significant tree cover (Table 8). In Norway, about 43.9% of the agricultural land has a tree cover of more than 10% and about 31.6% of the agricultural land has more than 20% tree cover. Similar to the field scale, also at the landscape scale Lithuania has the lowest tree cover on agricultural land of the investigated countries. In Lithuania, 16% of the agricultural land had more than 10% tree cover and 11.8% of the agricultural land had more than 20% tree cover.

Table 7. Comparison of the amount of agricultural land (x 1000 ha) in the year 2012 with greater than 5%, 10% and 20% tree cover, showing the difference between tree cover at the field scale (20 x 20 m) and at the landscape scale (100 x 100 m).

Tree cover (%)	>5%		>10%		>20%		Agriculture (>0%)	
Pixel resolution (m)	20 x 20	100 x 100	20 x 20	100 x 100	20 x 20	100 x 100	20 x 20	100 x 100
Austria		736		591		392		3,309
Switzerland		362		288		194		1,616
Estonia	283	530	246	427	223	301	1,464	1,464
Lithuania	335	727	334	602	330	442	3,761	3,761
Latvia	659	1,092	631	896	527	643	2,813	2,813
Norway		813		680		490		1,550
Sweden		1,232		982		667		3,882
Total	1,277	5,493	1,211	4,466	1,080	3,129	8,038	18,394

The method is useful to compare tree cover density in agricultural land between different countries. In addition, the method can be used to assess changes in tree cover on agricultural land over time. However, the method cannot be used to assess agroforestry practices outside agricultural land, for example forest farming and woodland grazing.

Table 8. Comparison of the percentage of agricultural land in the year 2012 with greater than 5%, 10% and 20% tree cover, showing the difference between tree cover at the field scale (20 x 20 m) and at the landscape scale (100 x 100 m).

Tree cover (%)	>5%		> 10%		>20%	
Pixel resolution (m)	20 x 20	100 x 100	20 x 20	100 x 100	20 x 20	100 x 100
Austria		22.2		17.9		11.8
Switzerland		22.4		17.8		12.0
Estonia	19.4	36.2	16.8	29.2	15.3	20.6
Lithuania	8.9	19.3	8.9	16.0	8.8	11.8
Latvia	23.4	38.8	22.4	31.9	18.7	22.9
Norway		52.5		43.9		31.6
Sweden		31.7		25.3		17.2

6 Agroforestry inventories in Portugal, Spain and Greece

This section provides an agroforestry inventory for Portugal, Spain and Greece. It provides an introduction for each country, including maps and tables of the extent of agroforestry, a description of national statistics if available, and a discussion on how the national inventory results compare with the LUCAS results.

6.1 Portugal

6.1.1 Introduction

Portugal is a relatively small country but in Europe it has one of the highest diversity of wildlife and farming systems (Pereira et al. 2004). Climate is one of the major sources of variability and is described by Miranda (2002):

- Annual precipitation ranges from less than 400 mm in the Guadiana valleys (South of Portugal) to more than 3000 mm in the mountain range of Gerês (North of Portugal). The average number of rain days per year ranges from 15 to more than 90.
- Mean annual temperature ranges from 6-8°C in the mountains in the North and Centre to 18-20°C in the valleys of Algarve (South). Mean minimum temperatures ranges from -2°C in the mountains in the North, to 8-10°C in Algarve.
- Mean number of frost days per year range from less than 2 to 100. The number of days with tropical nights (nights with more than 20°C) ranges from less than 2 to 20.

Within this variable climatic context, agroforestry is a widespread practice in Portugal. To provide a general overview of agroforestry in Portugal, Reis et al. (2014) tried to understand the spatial distribution of the agroforestry systems through a principal components analysis based on 26 land-socio-economic variables related to agroforestry. The authors reported three main components explaining 48% of the variability: 1) agriculture under montado (30%); 2) small scale agriculture, associated with oaks and cattle production, and 3) dried fruit production and small ruminants, oaks and honey production. The components 1, 2, 3 were spatially defined as South, North Atlantic and Northern Interior Mountains respectively (Figure 16).

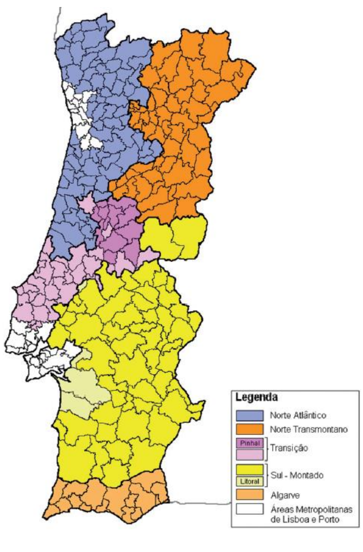


Figure 16. Portuguese agroforestry zones (adapted from Reis et al. 2014)

The traditional *Montado* system is the major agroforestry system and it is characterized by low density trees combined with agriculture or pastoral activities. The main tree species encountered in the *Montado* are cork oak (*Quercus suber* L) and/or holm oak (*Quercus rotundifolia* L). Mixed stands with a combination of these species are also common. Agriculture, typically for cereal production, was a common practice since the thirteenth century even in areas recognized for their low productivity. The incentives given by kings and politicians for this activity were based on the necessity of dealing with the increased population of this region at that time (Fonseca 2008). In the 20th century, during the 1980's, cereal production decreased and pastoral activities became dominant. Animal species include sheep, goats, pigs and cows, and the traditional breeds vary between regions and several are region specific. For example see Federação Nacional de Associações de Raças Autóctones (2015).

6.1.2 The statistics jigsaw

Although agroforestry has been practiced for a long time, there is currently no "agroforestry" class in the National Forest Inventory (NFI). The "Forest" class includes, among other land cover types, 1) "Montados" of cork oak and holm oak regardless of undercover and 2) stone pine, carob trees or chestnuts even when their management is focused for fruit production, but excludes orchards (ICNF 2013b).

Cork oak and holm oak forest area, occupies 736,775 ha and 331,179 ha respectively (Figure 17). However these values consider the class "forest" as a whole, including agroforestry. We have to go back to the previous NFI to access survey data on the understorey of these areas.

In 2005, 715,992 ha of cork oak were reported as the sum of pure, dominant and young plantations (AFN 2010). However these figures were updated (due to a new methodology) as being 795,489 ha (Figure 17). Because we can find more detailed data on the understorey in the previous NFI we report our analysis focusing on 2005 data (Table 9 and 10).

There are available data regarding whether the stand is pure, dominant, dominated or is pure/young. However when the stand is dominated for each species, information is lacking on which species is dominant for such cases. The analysis presented here is based on data from pure and dominant stands, excluding the dominated stands to avoid redundancy in the analysis. The exclusion of young pure plantations is related to the fact that these plantations were established under the Common Agricultural Policy (CAP), in particular afforestation measures under Rural Development Program, not considering agroforestry practices (agriculture or grazing in between trees), and therefore not accounting for agroforestry land use.

The following analysis is supported by Table 9 and Table 10:

Cork oak: An analysis for cork oak returns a total area of 659,751 ha, 53,324 ha (8%) was under silvoarable systems. However, "bare soil" could be considered the initial phase of arable management. But this class also includes ground covered by leaves, i.e. forest soil cover. If this area is considered, there are up to 60,015 ha (9%) of silvoarable systems. Silvopastoral systems, under a conservative perspective (considering understorey of natural and artificial pastures) yields 304,996 ha (46%). If we consider an additional understorey class of grass (herbaceous vegetation) we increase to a high end estimate of 386,853 ha (58%).

Holm oak: the same rationale applies to Holm oak (*Quercus ilex*). Holm oak is another important agroforestry species with a total area of 406,744 ha. The area under silvoarable systems ranges from 73,548 ha (18%) to a high end estimate of 77,187 ha (19% of the area). The conservative estimate for silvopastoral systems is 230,256 ha (57%) while the high end value is 266,237 ha (66%). Therefore the two classical agroforestry species would represent about 1,075,851 ha, where silvoarable systems would occur 126,872 ha - 144,551 ha (12-13%) and silvopastures would occur in about 535,222 - 653,090 ha (50-61%), totalling 662,094 - 797,641 ha (62-74%) of agroforestry systems with these two species.

Maritime pine (*Pinus pinaster*) *and eucalyptus*: although not being usually considered "agroforestry" tree species, maritime pine and eucalyptus interestingly yield conservative values of 969 ha and 1,014 ha respectively for silvoarable systems. The corresponding area of silvopastures would be 105,687 ha and 76,071 ha for maritime pine and eucalyptus respectively.

Other oaks (*Quercus faginea*, *Quercus pyrenaica* and *Quercus robur*): contribute to 1,917 ha - 5,605 ha to silvoarable, and 58,870 ha - 68,109 ha to silvopastoral systems.

Stone pine (*Pinus pinea*): this is an important species which can complement the income diversification of Montados (Coelho and Campos 2009). The species has increased more than 50% in area since 1995. The estimate of the area of silvoarable systems is 2,035 - 5,087 ha while the area of silvopastoral systems is 28,627 - 45,501 ha. The latter figures represent about 34-54% of the total area[1] of this species.

Chestnut: this high end estimate of the area of silvoarable systems with this species is 1,343 ha. However in this case, due to the tannins component of the leaves, the "bare soil" class could actually comprise fallen leaves and there may be no silvoarable systems with this species. In contrast, silvopastoral systems seems to occupy 8,552 - 13,163 ha based on conservative or optimistic assumptions. If we compare agricultural statistics from 2005 reporting 30,097 ha (GPP 2007a) and the 38,334 ha from the NFI (Figure 17), it is arguable that the additional 8,237 ha reported by the NFI could be considered as agroforestry systems, a similar area as the above conservative estimate.

Other species: Acacia is an invasive species, forbidden to plant, and is recorded to monitor its spread. It has residual area. Other broadleaves include *Alnus glutinosa*, *Betula* spp., *Populus* spp., *Fagus sylvatica*, *Fraxinus* spp., *Arbutus unedo*, *Salix* spp., and *Ulmus* spp. Other conifers included *Pinus halepensis*, *Pinus radiata*, *Pinus sylvestris*, *Cupressus* spp., and *Pseudotsuga menziesii*. Combining other broadleaves and other conifers could contribute about 4,282 – 6,523 ha as silvoarable systems while silvopastoral systems could exist on 26,549 – 50,860 ha.

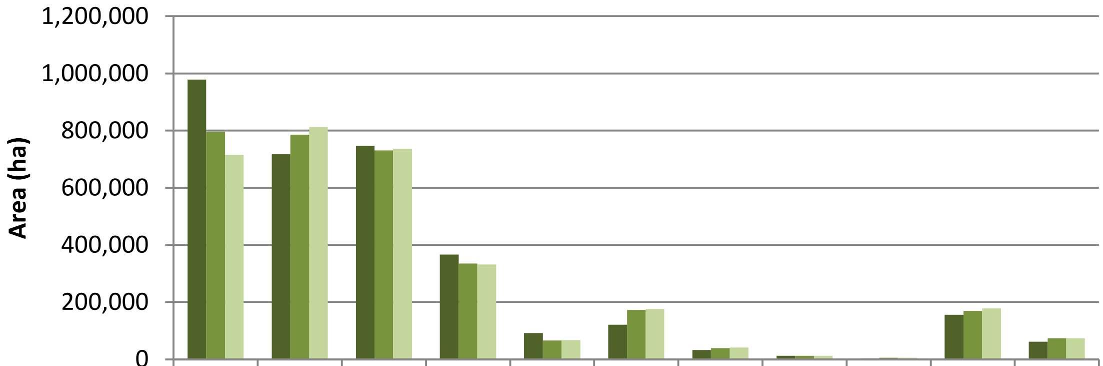
[1] Area of pure and dominant stands

Carob (*Ceratonia siliqua*)*:* this species is reported in the recent NFI as having 11,803 ha (Figure 17). However, a more detailed analysis by the Regional Directorate of Agriculture and Fisheries of the Algarve (Direção Regional de Agricultura e Pescas do Algarve (DRAPAlg 2000) in Reis et al. 2014) reports 85,000 ha of carob extension where about 60,000 ha are in a mixed system with almond, fig and olive trees, 13,000 ha dominated by shrubs (under abandonment) while 12,000 ha are related to recent plantations with the CAP support. The NFI statistics probably correspond to the CAP plantations because they are clearly identifiable through photo interpretation. Excluding the 13,000 ha of abandonment, there are potentially 60,000 ha that could embed agroforestry practices. Unfortunately there is no data on undercover management to stratify between silvoarable or silvopasture practices.

Almond is reported as having 38,049 ha with 60% of area (and 85% of the production) in the region of Trás-os-Montes (GPP 2006). This region, in the north also called "Terra quente" (warm land), along with Algarve in the south are the ecological areas for almond trees. If we consider that the remaining 40% (15,219 ha) are in Algarve region under the so called "traditional rain fed orchard system", and relate this with the above carob statistics, we could include this area under the 60,000 ha of mixed carob, almond, fig and olives.

Fig is reported as having 7,127 ha with 58% and 23% of area in the region of Algarve and Trás-os-Montes (GPP 2006). Again, if we consider as above that the 58% (4,133 ha) are in Algarve region we could hypothetically reach the distribution of the 60,000 ha as being 15,219 ha of almond, 4,133 ha of fig trees and the remaining area to carob and olive trees. Unfortunately we could not find data on olive trees under the traditional orchard system in Algarve.

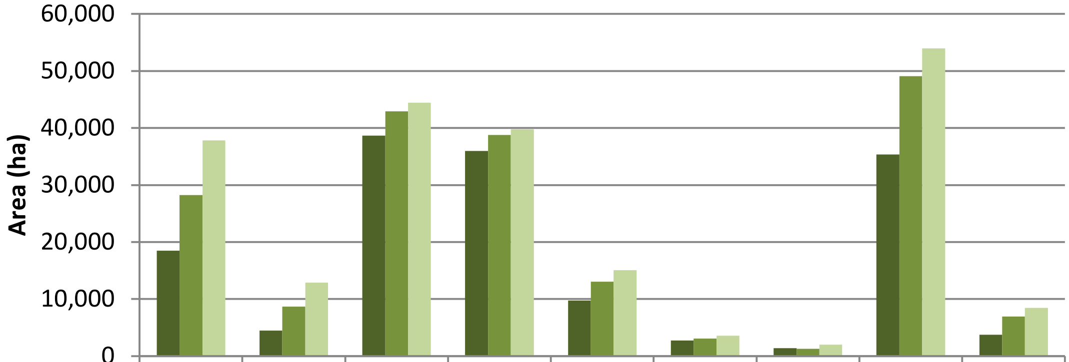
Cherry: in 1999, cherry trees were present in 4,576 ha where 1,961 ha are present in farms with less than 2 ha (GPP 2007b). Another 1,166 ha are present in farms up to 5 ha. If we consider these small holdings having additional agricultural activities in the undercover management, we could suggest 3,127 ha of agroforestry systems.



	Maritime pine	Eucalyptus	Cork oak	Holm oak	Oaks	Stone pine	chestnut	Carob	Acacia	Other broadleaves	Other conifers
1995	977883	717246	746828	366687	91897	120129	32633	12278	2701	155187	61340
2005	795489	785762	731099	334980	66016	172791	38334	12203	4726	169390	73442
2010	714445	811943	736775	331179	67116	175742	41410	11803	5351	177767	73217

Figure 17. Evolution of area cover per tree species in Portugal (adapted from ICNF 2013a)

However depending on the definition used for "agroforestry" we might consider additional figures from the NFI provides that provides areas for "Other tree covered land" representing areas where the tree cover is not enough to be classified as forest, having between 5-10% cover or where the shrubs, combined with the trees reach the 10% cover (Figure 18) . If we consider these areas as sparse agroforestry trees, an additional 217,924 ha could be considered to be under these land use systems. If we exclude maritime pine and eucalyptus, the area would be 167,240 ha.



	Maritime pine	Eucalyptus	Cork oak	Holm oak	Oaks	Stone pine	chestnut	Other broadleaves	Other conifers
1995	18479	4451	38634	35959	9752	2751	1400	35358	3726
2005	28257	8652	42935	38759	13053	3051	1275	49087	6927
2010	37809	12878	44461	39759	15054	3576	2000	53938	8452

Figure 18. Areas with 5-10% tree cover, not considered as forests in Portugal (adapted from ICNF 2013a)

Table 9. Areas (ha) of forest stand according to understorey cover with area estimates for silvoarable and silvopasture (conservative and optimist) in Portugal. Adapted from ICNF (2005)

Species	Stand	1	2	3	4	5	6	1	(4+5)	(1+6)	(2+4+5)
		Arable	Grass	Shrubs	Pasture (artificial)	Pasture (natural)	Bare soil	Silvoarable (conservative)	Silvopasture (conservative)	Silvoarable (optimist)	Silvopasture (optimist)
Maritime pine	Pure	450	95,413	483,368	1,350	74,260	26,554	450	75,610	27,004	171,023
	Dominant	519	26,447	85,044	1,556	28,521	2,593	519	30,077	3,112	56,524
	Sub-total	**969**	**121,860**	**568,412**	**2,906**	**102,781**	**29,147**	**969**	**105,687**	**30,116**	**227,547**
Eucalypt	Pure	1,014	117,070	326,884	2,027	62,843	56,761	1,014	64,870	57,775	181,940
	Dominant		20,723	58,808	1,120	10,081	2,240	0	11,201	2,240	31,924
	Sub-total	**1,014**	**137,793**	**385,692**	**3,147**	**72,924**	**59,001**	**1,014**	**76,071**	**60,015**	**213,864**
Cork oak	Pure	39,461	70,797	178,153	46,424	199,624	13,347	39,461	246,048	52,808	316,845
	Dominant	13,863	11,090	36,737	9,011	49,907	693	13,863	58,918	14,556	70,008
	Sub-total	**53,324**	**81,887**	**214,890**	**55,435**	**249,531**	**14,040**	**53,324**	**304,966**	**67,364**	**386,853**
Holm oak	Pure	66,075	32,245	54,446	22,730	181,839	3,172	66,075	204,569	69,247	236,814
	Dominant	7,473	3,736	8,874	1,868	23,819	467	7,473	25,687	7,940	29,423
	Sub-total	**73,548**	**35,981**	**63,320**	**24,598**	**205,658**	**3,639**	**73,548**	**230,256**	**77,187**	**266,237**
Oaks	Pure	1,917	4,218	51,767	767	41,030	2,684	1,917	41,797	4,601	46,015
	Dominant		5,021	21,090	1,004	16,069	1,004	0	17,073	1,004	22,094
	Sub-total	**1,917**	**9,239**	**72,857**	**1,771**	**57,099**	**3,688**	**1,917**	**58,870**	**5,605**	**68,109**
Stone pine	Pure	1,052	9,996	24,201	1,052	15,783	1,578	1,052	16,835	2,630	26,831
	Dominant	983	6,878	9,335	983	10,809	1,474	983	11,792	2,457	18,670
	Sub-total	**2,035**	**16,874**	**33,536**	**2,035**	**26,592**	**3,052**	**2,035**	**28,627**	**5,087**	**45,501**
Chestnut	Pure		4,028	11,414	1,343	6,043	1,343	0	7,386	1,343	11,414
	Dominant		583	2,332		1,166		0	1,166	0	1,749
	Sub-total	**0**	**4,611**	**13,746**	**1,343**	**7,209**	**1,343**	**0**	**8,552**	**1,343**	**13,163**
Acacia	Pure	88	528	1,056		176	176	88	176	264	704
	Dominant		277	1,659		138		0	138	0	415
	Sub-total	**88**	**805**	**2,715**	**0**	**314**	**176**	**88**	**314**	**264**	**1,119**
Other broadleaves	Pure	1,786	17,861	14,289	1,786	17,861	1,786	1,786	19,647	3,572	37,508
	Dominant	2,499	4,997	12,493		4,997		2,499	4,997	2,499	9,994
	Sub-total	**4,285**	**22,858**	**26,782**	**1,786**	**22,858**	**1,786**	**4,285**	**24,644**	**6,071**	**47,502**
Other conifers	Pure		905	9,276		1,357	452	0	1,357	452	2,262
	Dominant		548	1,095		548		0	548	0	1,096
	Sub-total	**0**	**1,453**	**10,371**	**0**	**1,905**	**452**	**0**	**1,905**	**452**	**3,358**
Total		**137,180**	**431,908**	**1,381,950**	**93,021**	**744,966**	**115,872**	**137,180**	**837,987**	**253,052**	**1,269,895**

Note: Oaks*: Quercus faginea*, *Quercus pyrenaica* and *Quercus robur*. Other broadleaves: *Alnus glutinosa*, *Betula* spp., *Populus* spp., *Fagus sylvatica*, *Fraxinus* spp., *Arbutus unedo*, *Salix* spp., *Ulmus* spp.. Other conifers: *Pinus halepensis*, *Pinus halepensis*, *Pinus radiate*, *Pinus sylvestris*, *Cupressus* spp., *Pseudotsuga menziesii*

Table 10. Summary of areas (ha) and correspondent percentage for each specie and its understorey cover with estimates for silvoarable and conservative and optimist estimates for silvopasture in Portugal. Adapted from ICNF (2005)

Species		1	2	3	4	5	6	1	4+5	1+6	2+4+5
	Total area	Arable	Grass	Shrubs	Pasture (artificial)	Pasture (natural)	Bare soil	Silvoarable (conservative)	Silvopasture (conservative)	Silvoarable (optimist)	Silvopasture (optimist)
Maritime pine	826,075	969	121,860	568,412	2,906	102,781	29,147	969	105,687	30,116	227,547
	28%	0.1%	15%	69%	0.4%	12%	4%	0.1%	13%	4%	28%
Eucalypt	659,571	1,014	137,793	385,692	3,147	72,924	59,001	1,014	76,071	60,015	213,864
	23%	0.2%	21%	59%	0.5%	11%	9%	0.2%	12%	9%	32%
Cork oak	669,107	53,324	81,887	214,890	55,435	249,531	14,040	53,324	304,966	67,364	386,853
	23%	8%	12%	32%	8%	37%	2%	8%	46%	10%	58%
Holm oak	406,744	73,548	35,981	63,320	24,598	205,658	3,639	73,548	230,256	77,187	266,237
	14%	18%	9%	16%	6%	51%	1%	18%	57%	19%	66%
Oaks	146,571	1,917	9,239	72,857	1,771	57,099	3,688	1,917	58,870	5,605	68,109
	5%	1%	6%	50%	1%	39%	3%	1%	40%	4%	47%
Stone pine	84,124	2,035	16,874	33,536	2,035	26,592	3,052	2,035	28,627	5,087	45,501
	3%	2%	20%	40%	2%	32%	4%	2%	34%	6%	54%
Chestnut	28,252	0	4,611	13,746	1,343	7,209	1,343	0	8,552	1,343	13,163
	1%	0%	16%	49%	5%	26%	5%	0%	30%	5%	47%
Acacia	4,098	88	805	2,715	0	314	176	88	314	264	1,119
	0.1%	2.1%	19.6%	66.3%	0.0%	7.7%	4.3%	2.1%	7.7%	6.4%	27.3%
Other broadleaves	80,355	4,285	22,858	26,782	1,786	22,858	1,786	4,285	24,644	6,071	47,502
	3%	5.3%	28.4%	33.3%	2.2%	28.4%	2.2%	5.3%	30.7%	7.6%	59.1%
Other conifers	14,181	0	1,453	10,371	0	1,905	452	0	1,905	452	3,358
	0.5%	0.0%	10.2%	73.1%	0.0%	13.4%	3.2%	0.0%	13.4%	3.2%	23.7%
Total	2,904,897	137,180	431,908	1,381,950	93,021	744,966	115,872	137,180	837,987	253,052	1,269,895
		4.7%	14.9%	47.6%	3.2%	25.6%	4.0%	4.7%	28.8%	8.7%	43.7%

Note: Total area is the sum of areas for pure and dominant (excludes the young pure plantations). Oaks: *Quercus faginea*, *Quercus pyrenaica* and *Quercus robur*. Other broadleaves*: Alnus glutinosa*, B*etula* spp., *Populus* spp., *Fagus sylvatica*, *Fraxinus* spp., *Arbutus unedo*, *Salix* spp., *Ulmus* spp.. Other conifers: *Pinus halepensis, Pinus halepensis*, *Pinus radiata*, *Pinus sylvestris*, *Cupressus* spp., *Pseudotsuga menziesii*

To resume the jigsaw between forest and agricultural statistics, we may synthesise the estimate as about 1,358,000 ha of agroforestry systems where silvoarable systems are represented on about 151,000 ha. Assuming that the remaining systems are under silvopasture system, this would represent a figure of about 1,207,000 ha (Table 11).

Table 11. Resume of the attempt to estimate agroforestry areas in Portugal according to forestry and agricultural statistics (x 1000 ha)

Species considered	Silvoarable	Silvopastoral	Agroforestry	Subtotal agroforestry	Supporting sources
Cork oak, Holm oak	127-145	535-653	662-798	730	(ICNF 2005)
Oaks	2-6	59-68	61-74	798	
Stone pine	2-5	29-46	31-51	839	
Chestnut	0	9-13	9-13	850	
Cherry		3?	3	853	(GPP 2007b)
Carob (mixed with olives)		41?	41	894	DRAPAlg (in Reis et al. 2014) and (GPP 2006)
Almond		15?	15	909	
Fig		4?	4	913	
Other broadleaves and conifers	4-7	27-51	31-58	957	(ICNF 2005)
Maritime pine	1	106	107	1064	
Eucalyptus	1	76	77	1141	
Other tree covered land excluding maritime pine and eucalyptus		167?	167	1308	(ICNF 2013a)
Other tree covered land by maritime pine and eucalyptus		50?	50	1358	
Total	151	927 (1207?)	1358	1358	

GPP (2013) provides an analysis of the agricultural systems with high natural value where silvopastoral systems represent 1,352,047 ha (Figure 19). In this report, additional figures are presented for extensive orchards (63,683 ha), extensive olive orchards (199,564 ha), extensive arable land (47,552 ha) and mosaic (39,981 ha). All these systems, except the extensive arable land, have trees to support the ecosystem. The sum of these tree based areas would correspond to **1,648,093** ha of agroforestry systems, where **303,228 ha** correspond to silvoarable and **1,352,047** ha correspond to silvopastoral systems.

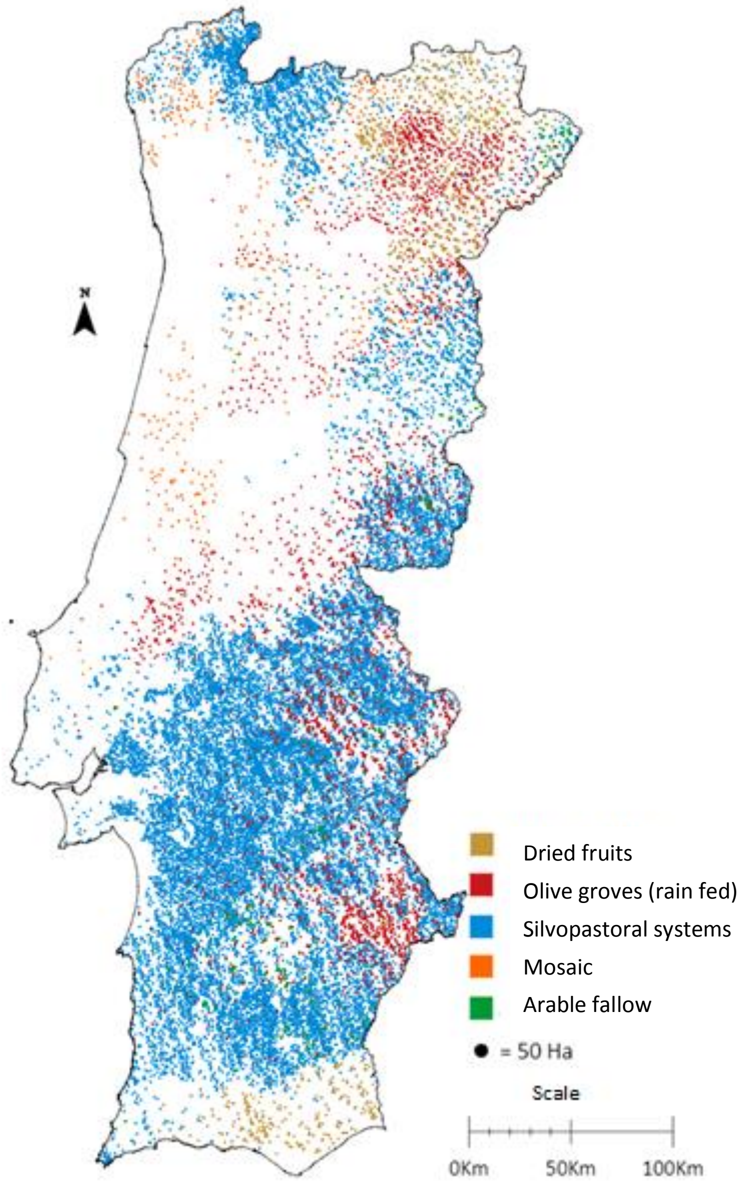


Figure 19. Distribution map of agricultural areas with high natural value in Portugal with silvopastoral systems representing 1,352,047 ha (Adapted from GPP 2013)

6.1.3 Area estimates based on animal statistics

Belo et al. (2014) provide an estimate of 14,000 browsing pigs, based on a 2011/2012 survey, corresponding to 4,200 Livestock Units (1 pig = 0.3 LU). If a carrying capacity between 0.15 and 0.74 LU ha^{-1} is considered (Belo et al. 2014; Goes 1991; Potes 2011), this would mean a holm oak silvopastoral system of between 28,000 ha and 5,676 ha (average = 16,838 ha). If the same exercise is done for 400,000 LU of cattle, 120,000 LU of sheep and 12,000 LU of goats (reported under agroforestry systems with utilizable agriculture area higher than 100 ha) with a carrying capacity of 0.4 LU ha^{-1} (Belo et al. 2014), this would mean 1,000,000 ha, 300,000 ha and 30,000 ha for cattle, sheep and goats respectively. The total area of cattle, sheep, goats and pigs would be about **1,346,838 ha** which is a close value to the analysis through LUCAS

(1,196,500 ha of silvopastoral systems) and to the silvopastoral extend of 1,352,047 ha under high natural value agricultural systems (GPP 2013).

6.1.4 Conclusion

Silvoarable systems: The analysis of LUCAS database yields **76,500 ha** of silvoarable systems in Portugal (see Table 2). The national forest inventory statistics does not support those estimates as the analysis estimated **151,000** ha (Table 9). Furthermore, NFI does not account for fruit trees nor olive trees. These systems are covered by the report on high natural value agricultural land (GPP 2013), with estimates of 63,683 ha for extensive orchards of dried fruits, an additional 199,564 ha of extensive olive orchards and a complex mosaic of 39,981 ha. All these figures sum about **303,228 ha,** which is about four times more compared to the LUCAS estimates.

Silvopastoral systems: LUCAS estimates an area of **1,105,100 ha** of silvopastoral systems in Portugal. This figure is acceptable but it appears to be an underestimate. The three estimates, based on national forest inventory, high natural value agriculture and estimation based on livestock carrying capacity, are **1,358,000 ha, 1,352,047 ha and 1,346,838 ha** respectively. Interestingly the silvopastoral system estimates from different sources have consistent results which could support the conclusion that LUCAS is under estimating the silvopastoral systems by about 20%. This seems a low percentage, but this error is larger compared to the whole extension for silvoarable land estimated by LUCAS.

6.2 Agroforestry in Spain

6.2.1 Methodological approach

The Spanish georeferenced database of land use SIOSE (2012)[2] is based on the interpretation of 2005 aerial orthoimages, updated with the 2009 orthoimages. SIOSE is built at 1.25000 scale and maps polygons ≥ 2 ha for farmed areas, forest and rangelands, ≥ 1 for urban areas, and ≥ 0.5 ha for water bodies and associated vegetation. The type of covers recorded are listed in Table 12, including both simple and combined covers.

Table 12. Main land covers recorded in the Spanish SIOSE database (grouped here for simplicity).

<table>
<tr><th colspan="2">Simple cover</th><th colspan="2">Combined covers</th></tr>
<tr><th>ID</th><th>COVER</th><th>ID</th><th>COVER</th></tr>
<tr><td>100 -131 and 800-922</td><td>Urban, Industry, transport and other artificial covers</td><td>600</td><td>Undefined Combinations</td></tr>
<tr><td>211-212</td><td>Arable lands</td><td>701</td><td>Dehesa[3]</td></tr>
<tr><td>222-223; 241</td><td>Fruit trees</td><td>702</td><td>Olive with vines</td></tr>
<tr><td>231</td><td>Vineyards</td><td>703</td><td>Farming settlement</td></tr>
<tr><td>232</td><td>Olive groves</td><td>704</td><td>Homegarden</td></tr>
<tr><td>290</td><td>Meadows</td><td colspan="2" rowspan="7">For polygons recorded as combined cover (defined or not), every simple cover with ≥ 5% of the surface is additionally recorded. For undefined combinations, three categories are defined:
A. Association (600A)
R. Regular mosaic (600R)
I. Irregular mosaic (600I)</td></tr>
<tr><td>300</td><td>Natural pastures</td></tr>
<tr><td>300-316</td><td>Forest trees</td></tr>
<tr><td>320</td><td>Shrublands</td></tr>
<tr><td>330-354</td><td>Bare soils</td></tr>
<tr><td>400-422</td><td>Wetlands</td></tr>
<tr><td>500-523</td><td>Water bodies</td></tr>
</table>

As the database only records Iberian dehesas and the combination of olive with vines as specific agroforestry systems, the rest of agroforestry system types have to be defined in relation to the combinations of single covers. The following categories of agroforestry systems were defined: intercropped forest trees, intercropped fruit trees, and wood pastures either with forest trees or with fruit trees. Table 13 shows the criteria used to define each agroforestry type. Regarding tree cover, polygons were classified into three categories: very open (< 5% tree cover) open (5-60% tree cover) and dense (> 60% tree cover). Although agroforestry could be limited to the polygons with 10-70% of tree cover, in this report data for the three categories are given.

[2] SIOSE: Land Cover and Use Information System of Spain (www.siose.es), coordinated by the IGN (National Geographic Institute of Spain). SIOSE record multidisciplinary spatial data infrastructure, is periodically updated and is designed according to the main INSPIRE principles and ISO TC/211 standards.

[3] Iberian dehesas are open oak woodlands devoted to livestock rearing and in more fertile soils periodically cultivated with cereal and/or fodder crops.

Table 13. Definition of different agroforestry types based on the covers recorded by SIOSE database.

Agroforestry type	Plot scale
Silvoarable (with fruit trees)	Arable lands (211-212) WITH Fruit trees OR olive groves OR vineyards (222-232)
Silvoarable (with forest trees)	Arable lands (211-212) WITH Forest trees (300-316)
Silvopasture (with fruit trees)	Meadows OR Natural Pastures (290-300) WITH Fruit trees OR olive groves OR vineyards (222-232)
Silvopasture (with forest trees)	Meadows OR Natural Pastures (290-300) WITH Forest trees (300-316)
Grazed dehesas	Natural Pastures (300) WITHIN Dehesas (701)
Intercropped dehesas	Arable lands (211-212) WITHIN Dehesas (701)
Dehesas	701
Olive_vines	702

When the combination of covers is recorded within undefined Regular or Irregular Mosaics (600R or 600I), agroforestry was defined at landscape scales. When the combination was already defined (701, 702, 703) or recorded within undefined Associations (600A), agroforestry was defined at plot scale. Any of the above mentioned agroforestry combinations recorded within Farming settlement (code 703) was defined as Artificial and reported separately. Images of agroforestry systems defined under these criteria are shown here below (Figures 20-23).

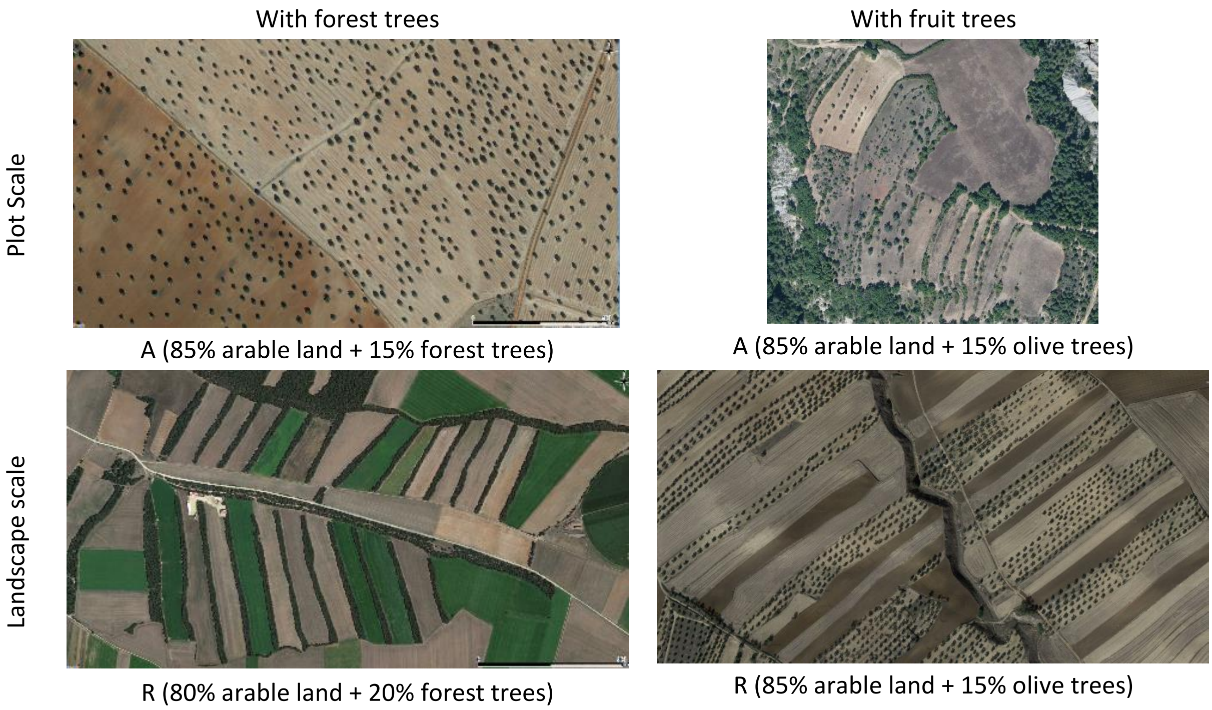


Figure 20. Examples of silvoarable agroforestry plots and landscapes, with forest and fruit trees.

With forest trees | With fruit trees

Plot Scale

A (85% pastures + 15% forest trees)

A (70% pastures + 30% fruit trees)

Landscape scale

I (80% pastures + 20% forest trees)

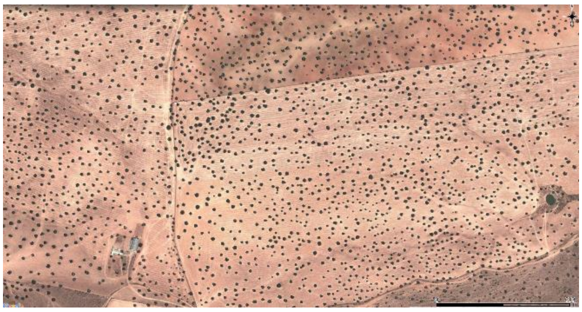
I (70% pastures + 30% fruit trees)

Figure 21. Examples of silvopastoral agroforestry plots and landscapes, with forest and fruit trees.

Grazed dehesas

DHS (70% pastures + 30% forest trees)

Cultivated dehesas



DHS (85% arable lands + 15% forest trees)

Figure 22. Examples of cultivated and grazed dehesas.

OVD (60% vines + 40% olive trees)

Figure 23. Examples of olive groves intercropped with vines.

6.2.2 Extent and location of agroforestry systems - Results from the SIOSE database

According to the criteria above commented, and taking the scenario more restrictive (agroforestry at plot level with tree cover ranging among 5 and 60%), in Spain there are about 1.1 million ha of silvoarable lands, 18 000 ha of olive intercropped with vines and above 4.5 million ha of silvopastures (Table 14). When very open (<5% tree cover) and dense (>60%) stands are included, silvoarable lands amount up to near 1.5 million ha and silvopastures up to > 6 million ha. These figures go above 4 and 9 million ha regarding agroforestry at landscape scale (Table 14).

At plot scale, most of the silvopastures (98%) are based on forest species. Dehesas account for more than one third of these silvopastures, with 2 million ha of dehesas out of the 4.5 million ha of silvopastures (these figures amount respectively up to 2.4 and 6.2 million ha when very open and dense stands are included). For silvoarable the presence of fruit trees is higher (15%), especially in dense stands (21%). In general, when viewed at landscape scale, the proportion of agroforestry lands based on fruit trees increase notably (mostly by the presence of olive trees in many rural areas of the Mediterranean regions and scattered fruit orchards in the northern and mountainous regions). For silvoarable landscapes, fruit trees are present in 43% of the cases while for silvopastoral landscapes, fruit trees are still minority (only 12%).

Part of the dehesas are annually cultivated, generally with cereal and fodder crops, following different rotational cycles. While in more fertile soils crops can be cultivated every 2-4 years, in less productive lands the rotation can be even over 10 years. Among the 2.4 million ha of the dehesas, around 234 000 ha are cultivated, near 1.8 million ha are grazed and about 380,000 ha are encroached by pioneer shrubs (*Cistus* spp., *Genista* spp., *Cytisus* spp., *Retama sphaeerocarpa*) (Table 15). Traditionally shrub encroached plots are cleared periodically and cultivated for 1-2 years and then grazed for the following years until shrubs come again abundant. Consequently, in dehesas silvoarable lands and silvopastures form part of the same management unit, and dehesas are frequently referred as an agro-silvo-pastoral farms.

Near 140,000 ha out of the 2.4 million ha of the dehesas are very open and near 110,000 ha are dense. These figures are indicative of the slow loss of the tree cover in the Iberian dehesas reported in the literature (e.g. Plieninger et al 2010). The excessive clearance of dehesas is more evident in cultivated dehesas (Table 15). While 6% of the dehesas has an excessively low tree cover (< 5%), for cultivated stands this percentage is as high as 15%.

Table 14. Summary of the data of extension of agroforestry systems in Spain, both at plot and landscape scale (the latter only for silvopastures and silvoarable lands). The extension of silvorable lands and silvopastures *sensu strictus* (crop or pasture integrated in close interactions with trees within the plot, and tree cover among 5-60% of the plot) is shown in bold. The proportion of the agroforestry formed with forest and fruit trees are given in brackets for silvoarable lands and silvopastures. More details are given in Annex B.

Type and tree cover[1]	**Silvoarable** Area (ha)	Fruit trees (%)	Forest trees (%)	**Silvopasture** Area (ha)	Fruit trees (%)	Forest trees (%)	**Dehesas**[2] Area (ha)	**Olive + grape-vines**[3] Area (ha)
Plot scale								
Very open	51,663	3	97	363,116	2	98	137,576	
Open	1,103,039	14	86	4,563,034	2	98	2,155,428	18,294
Dense	292,196	21	79	1,260,924	3	97	108,668	
Total	1,446,898	15	85	6,187,070	2	98	2,403,648	
Landscape scale[4]								
Very open	335,209	14	86	503,774	4	96	Not applicable	
Open	2,967,774	39	61	6,615,135	10	90		
Dense	985,963	64	36	2,161,918	21	79		
Total	4,288,946	43	57	9,280,822	12	88		

[1] Tree cover: Very open (< 5 %); Open (5-60%), Dense (>60%); Total (0-100%)
[2] Dehesas are already included in Silvopastures and has not to be summed.
[3] All the combinations of olives with grapes were pooled regardless of the tree density.
[4] Include agroforestry at plot scale, semi-urbanized areas (e.g. farm settlement with homegarden) and regular and irregular mosaics of crops and/o pastures with woodlots.

Table 15. Extension of Iberian dehesas, categorized by understory cover/use and tree cover.

Dehesa	**Very open (< 5 % tree cover)**	**Open (5-60 % tree cover)**	**Dense (>60 % tree cover)**	**Total**
Cultivated	23,216	192,125	4,672	233,897
Pasture	110,259	1,502,591	79,988	1,786,470
Shrubs	4,101	460,712	24,008	381,304
Total	137,576	2,155,428	108,668	2,401,671

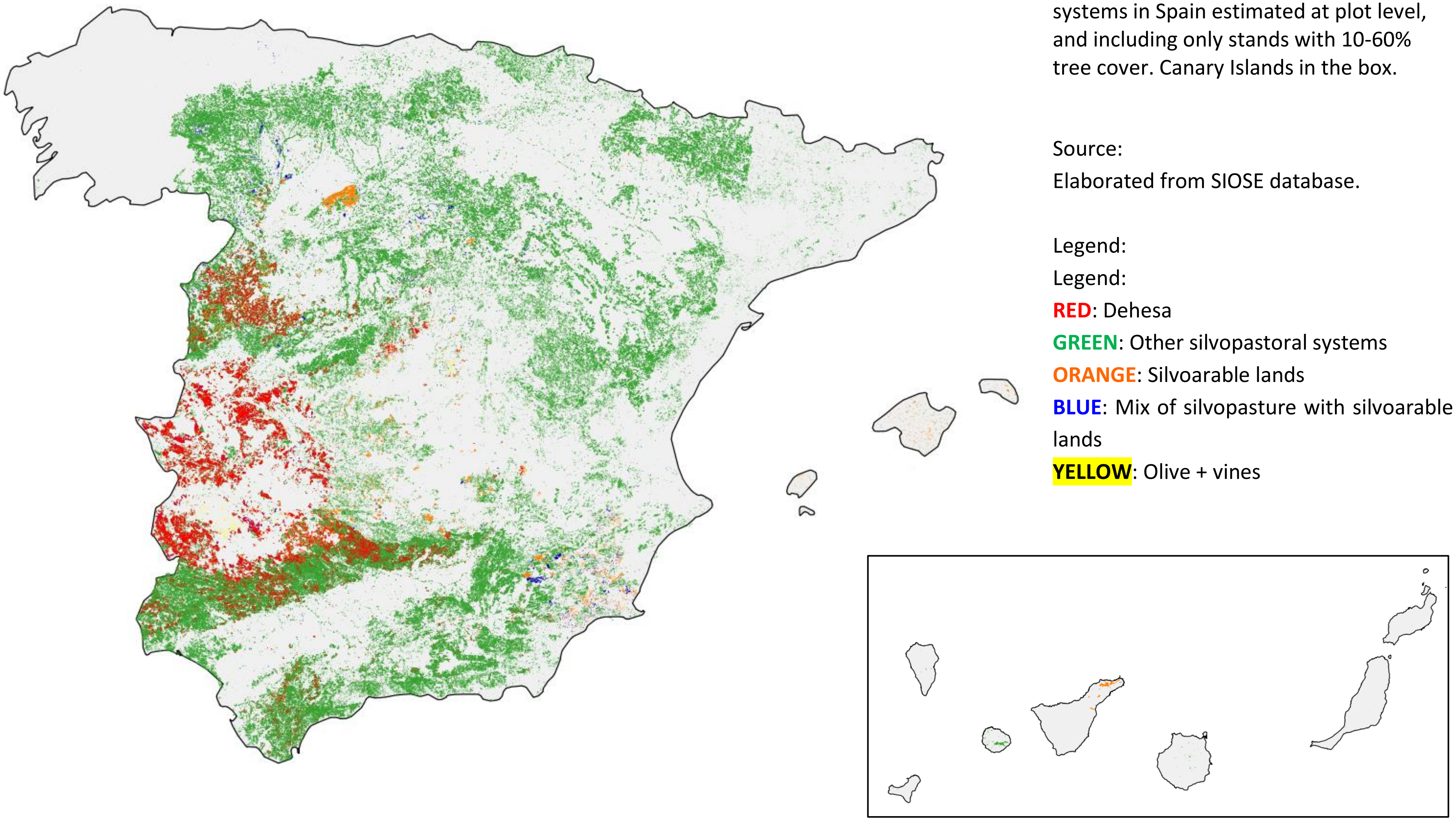


Figure 24. Distribution of the agroforestry systems in Spain estimated at plot level, and including only stands with 10-60% tree cover. Canary Islands in the box.

Source:
Elaborated from SIOSE database.

Legend:
Legend:
RED: Dehesa
GREEN: Other silvopastoral systems
ORANGE: Silvoarable lands
BLUE: Mix of silvopasture with silvoarable lands
YELLOW: Olive + vines

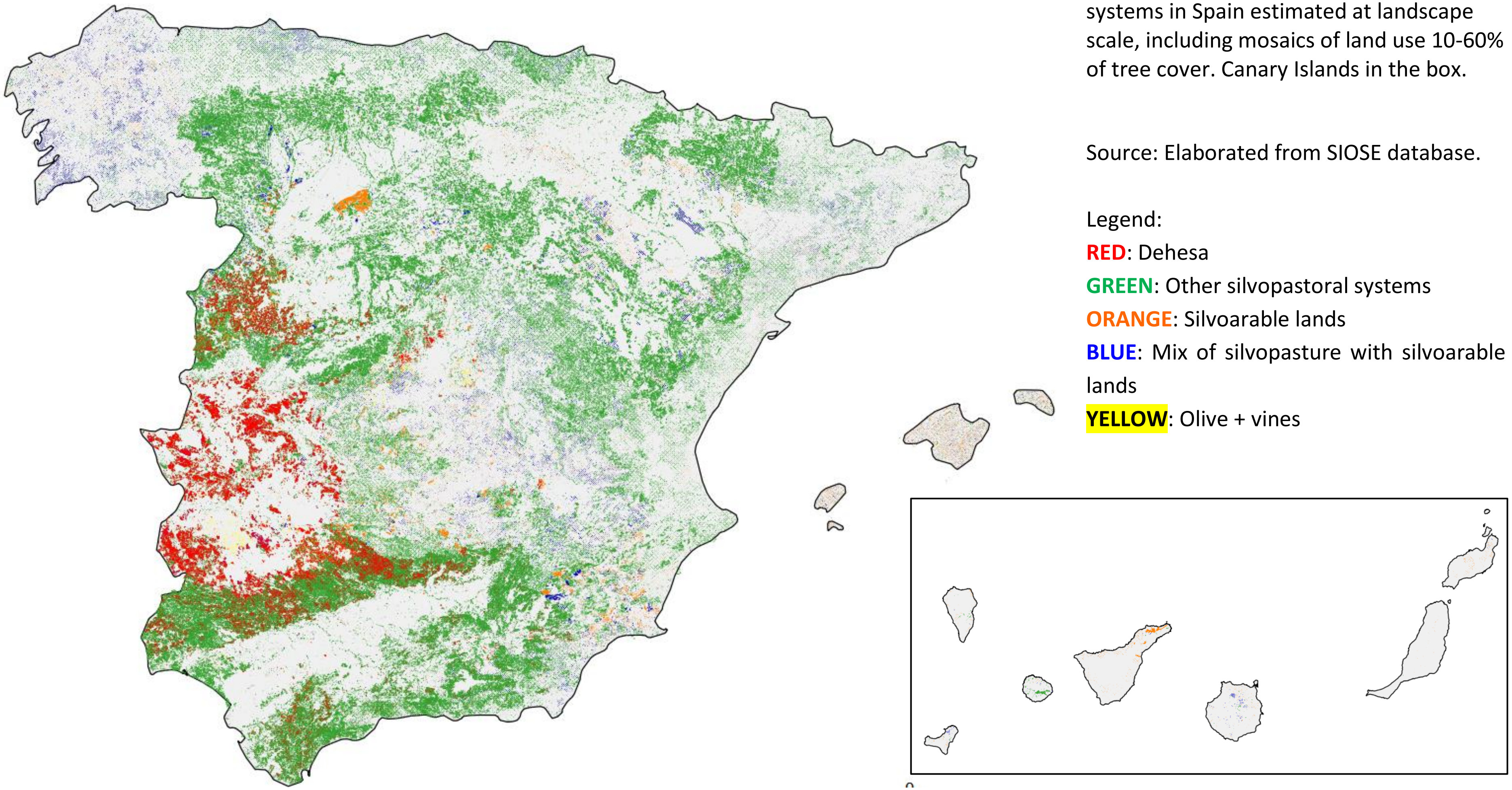


Figure 25. Distribution of the agroforestry systems in Spain estimated at landscape scale, including mosaics of land use 10-60% of tree cover. Canary Islands in the box.

Source: Elaborated from SIOSE database.

Legend:

RED: Dehesa

GREEN: Other silvopastoral systems

ORANGE: Silvoarable lands

BLUE: Mix of silvopasture with silvoarable lands

YELLOW: Olive + vines

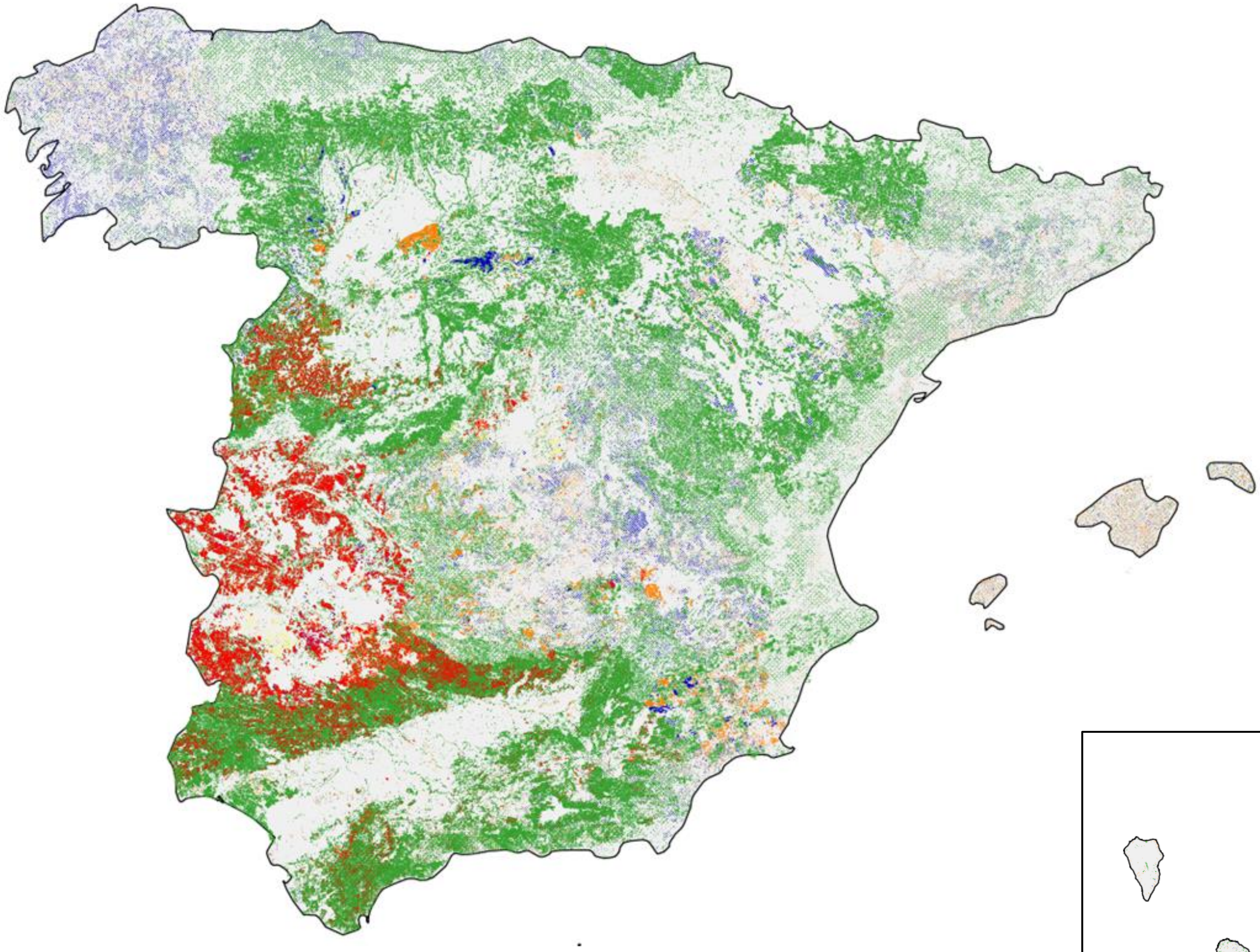
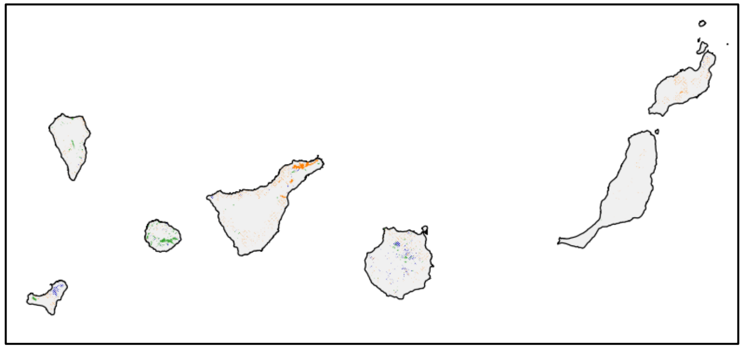


Figure 26. Distribution of the agroforestry systems in Spain estimated at landscape scale, including mosaics of land use with tree cover from 0 to **100 %**. Canary Islands in the box.

Source: Elaborated from SIOSE database

LEGEND:
RED: Dehesa
GREEN: Other silvopastoral systems
ORANGE: Silvoarable lands
BLUE: Mix of silvopasture with silvoarable lands
YELLOW: Olive + vines



6.2.3 Other national statistics in Spain

Grazing in forest and open woodland has extended over large areas for many centuries. Because of the long history of grazing in woodlands, there are many different structural configurations, and different criteria have been used to define or delimit them. In recent years, two independent studies based on the same source (the National Forest Map and Inventory) have estimated the surface occupied by dehesas and other wood pastures in Spain.

The first one produced by the Spanish Minister of Environment (MMA 2007) estimates the surface of wood pastures including stands with a tree cover between 5%-60% with a grass understory utilizable by livestock. The total area recorded as wood pastures was of 5,307,992 ha, which compares to 10.5% of the national territory and 19.3% of the forest area of the country (Table 16). Wood pastures are categorized in four groups: oak-dominated wood pastures (3,997,185 ha), other broadleaved wood pastures (793,198 ha), wood pastures dominated by *Juniperus* spp trees (188,007 ha), and wood pastures dominated by *Pinus* spp. trees (329,602 ha; restricted to stands with 5-40% tree cover as under *Pinus* spp. the grass understory grows worse than under other tree species).

The second study, produced by the Spanish Minister of Agriculture (MAPA 2008) focused only on the Spanish dehesas, which extend only in five regions in South West Spain. This study included open oak woodlands with 5-60% tree cover (in some cases included up to 80%) with grass and/or crop as understory. The values reported in this study are 3,515,920 ha of dehesa-type vegetation, of which 2,838,326 ha are managed as dehesa farms.

Table 16. Surface occupied by different types of wood pastures in Spanish regions. Source, MAPA (2008) and MMA (2007).

Region	**Dehesa (MAPA 2008)**		**Wood pastures (MMA 2007)**				
	Open oak woodland	**Dehesa**	**Evergreen broadleaves**	**Deciduous broadleaves**	***Juniperus* spp,**	***Pinus* spp.**	**Total**
Andalucía	946,482	483,460	959,724	63,377		173,700	**1,196,801**
Aragón			129,109	41,802	35,138	28,939	**234,988**
Asturias			400	6,584		1,285	**8,269**
Canarias				159			**159**
Cantabria			2,798	8,567		857	**12,222**
Castilla Mancha	751,554	675,726	851,800	72,657	80,993	31,642	**1,037,092**
Castilla-León	467,759	453,597	536,422	396,202	69,130	68,063	**1,069,817**
Cataluña			44,369	8,408		4,285	**57,062**
Extremadura	1,237,074	1,183,382	1,311,476	40,929		5,340	**1,357,745**
Galicia			1,199	115,886		6,229	**123,314**
Baleares			3,597				**3,597**
La Rioja			3,997	4,759		1,187	**9,943**
Madrid	113,051	42,161	107,125	19,275		4,285	**130,685**
Murcia			2,798			1,154	**3,952**
Navarra			5,596	6,822		1,154	**13,572**
Euskadi			3,597	6,346		956	**10,899**
Valencia			29,579	1,428	2,087	1,681	**34,775**
TOTAL	**3,515,920**	**2,838,326**	**3,997,185**	**793,198**	**188,007**	**329,602**	**5,307,992**

Until 2009 the annual of agricultural statistics recorded, for arable agroforestry land, the surface of annual crops cultivated in open woodlands. The area occupied by this land use was about 110,532 ha in 2009 (MAPA 2009). Until 1999, the National Agriculture Census also registered the surface occupied by fruit trees (included olive groves and grapevines), and this amounted to 36,873 ha and the combination of olives with grapevines amounted to 48,605 ha (INE 2002). As reported by Eichhorn et al (2006), all these agroforestry practices have declined in recent decades. For example the area of intercropped open woodlands is shown in Figure 27.

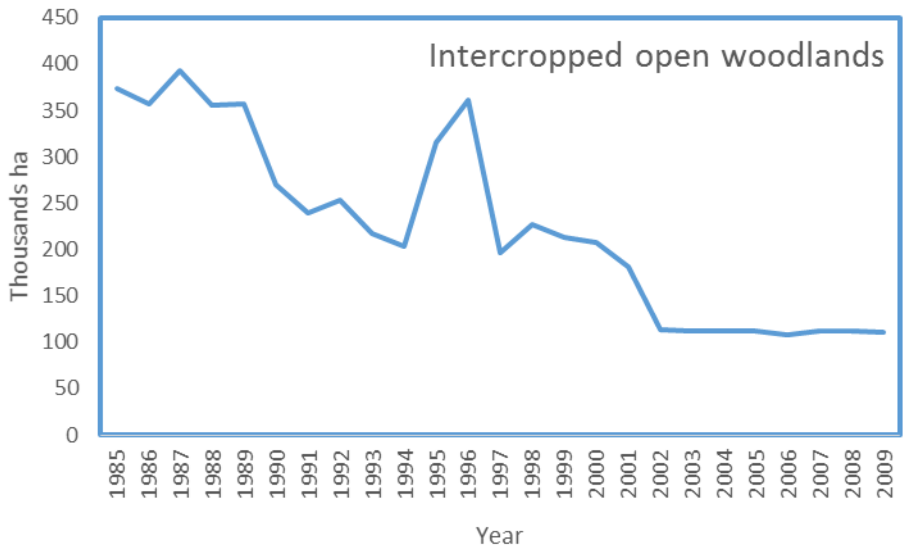


Figure 27. The area of open woodlands intercropped with annual crops (MAPA 1984, 2001, 2010)

6.2.4 Discussion

The decline of some agroforestry practices across Spain from 1980 to 2010 (Eichhorn et al. 2006), has been associated with a simplification of farming practices and increasing concentration on the most productive land. In contrast, land abandonment of less productive ones areas followed by subsequent woody encroachment has brought new agroforestry landscapes. However, these newly formed agroforestry landscapes rarely comprise the deliberate integration of the trees with the cultures and/or pastures.

The Spanish database used to determine agroforestry areas are primarily based on land cover records with no or poor information about the land use. Hence most of the calculations on the geographical distribution of agroforestry in Spain relate more to agroforestry landscapes than agroforestry practices. Consequently, the data presented here are only tentative and they could overestimate the current extent of active agroforestry practices in Spain. To start to address this, in this report, we have differentiated agroforestry at a plot scale and at a landscape scale.

As agroforestry landscapes frequently contain gradients from open fields to dense forest, any estimation of the extent of agroforestry will depend on the criteria of what is agroforestry and what is not. The use of different sources and criteria can help explain large differences in the area estimates in this report. An additional source of uncertainty is the regional organization of agriculture and environment administration in Spain. Comparing data presented in Table 16 and

Annex B it is clear that the estimate of wood pastures from the SIOSE database at a plot level is typically overestimated in some arid regions (e.g. Valencia, Murcia, and Aragón) and underestimated in some Northern regions (e.g. Galicia and Cataluña). In these two latter regions, estimates at landscape level seem more reliable. Also it is noteworthy that while estimates for wood pastures from SIOSE database at plot level roughly agree with other data sources, and also work well for arable agroforestry with cultivated trees, using the SIOSE database to estimate the area of arable agroforestry in presence of forest trees leads to large overestimates. This difference is because arable lands in Spain are frequently mixed with diverse semi-natural habitats that contain trees. These kinds of site are defined as agroforestry at a plot level when using SIOSE database.

Being cautious, and taking the more conservative figures here reported, it is clear that wood pastures are ubiquitous in most of the Spanish regions. Wood pastures occupy at least 4.5 million ha in Spain (viewed at plot scale and excluding very open and dense wood pastures), according to SIOSE database. Around 1.5 million ha out of these open wood pastures are typical Spanish dehesas devoted to extensive livestock rearing, with tree density ranging from 5 - 60% and with a grass overstorey. The area of the dehesa stands devoted to annual crop production is up to about 200,000 ha, but the area cultivated each year is roughly 100 000 ha. Although the area is smaller, olive groves with lines of grapevines (about 20,000 ha), and intercropped fruit trees (fruit orchards, olive groves and vineyards over about 40,000 ha) are also still important in Spain.

Overall the agroforestry data derived from the national Spanish sources agree to some extent with the data produced with LUCAS database for the three categories of agroforestry systems, pastures and arable lands with either permanent crops or forest trees (Table 17). In total, summing up these three categories, agroforestry amounts up to 6,137,820 ha according to Spanish sources here reviewed and up to 5,584,400 ha according to comparable LUCAS estimates reported in Table 4, which is a difference of about 10%.

Table 17. Extension of four categories of agroforestry systems estimated with the pan-European LUCAS database compared to the values estimated with Spanish data sources ([#]SIOSE 2012, [*]MAPA 2009).

Agroforestry type	Tree type	LUCAS (Table 2 and 3)	Spanish sources
Wood pastures	Permanent crop	217,700	134,424[#]
	Forest trees	3,520,000	5,680,321**
Arable agroforestry	Permanent crops	52,100	212,543[#]
	Forest trees	64,800	110,532*

** 5,680,321 ha comes from the average of the 5,307,992 ha estimated by MMA (2007; see Table 16) and of the 6,052,649 ha estimated with SIOSE database (see Table 16).

6.3 Agroforestry inventories for Greece

Agroforestry systems are widely distributed in Greece and constitute important elements of the rural landscape. The area covered by these systems is estimated to be more than 3 million hectares or 23% of the whole country (Papanastasis et al. 2009).

6.3.1 Silvoarable systems in North Greece

North Greece consists of two administrative regions, Macedonia and Thrace (Figure 28). Macedonia is the largest administrative region of North Greece with a total extent of about 33,500 km^2 and 13 prefectures. Thrace is the northeast administrative region of Greece with a total extent of about 8400 km^2 and three prefectures. The main land uses in Macedonia are rangelands (32.7%), arable lands (32.5%) and forests (26.2%). The main land uses in Thrace are arable lands (35.4%), forests (32.3%) and rangelands (25.8%) (NSSG 1995). The relief in Macedonia has been described as mountainous (36%), flat (34%) and hilly (30%) while the relief in Thrace is characterized as flat (48.8%), mountainous (27.8%) and hilly (23.4%) (NSSG 2009).

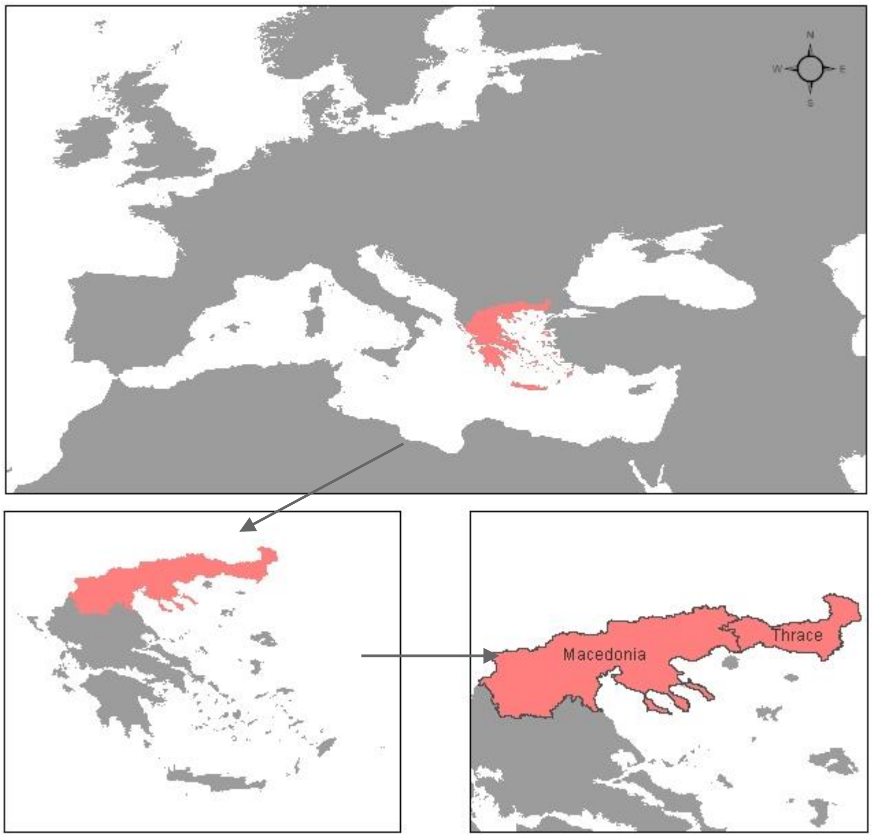


Figure 28. Location of the study area (Macedonia-Thrace).

It is estimated that there are about 685 silvoarable systems in North Greece that occupy more than 10 ha, covering a total area of 54,620 ha (Figure 29) with an average size of 79 ha. This area is currently incorporated in the arable land areas within the official state statistics (Sidiropoulou 2011).

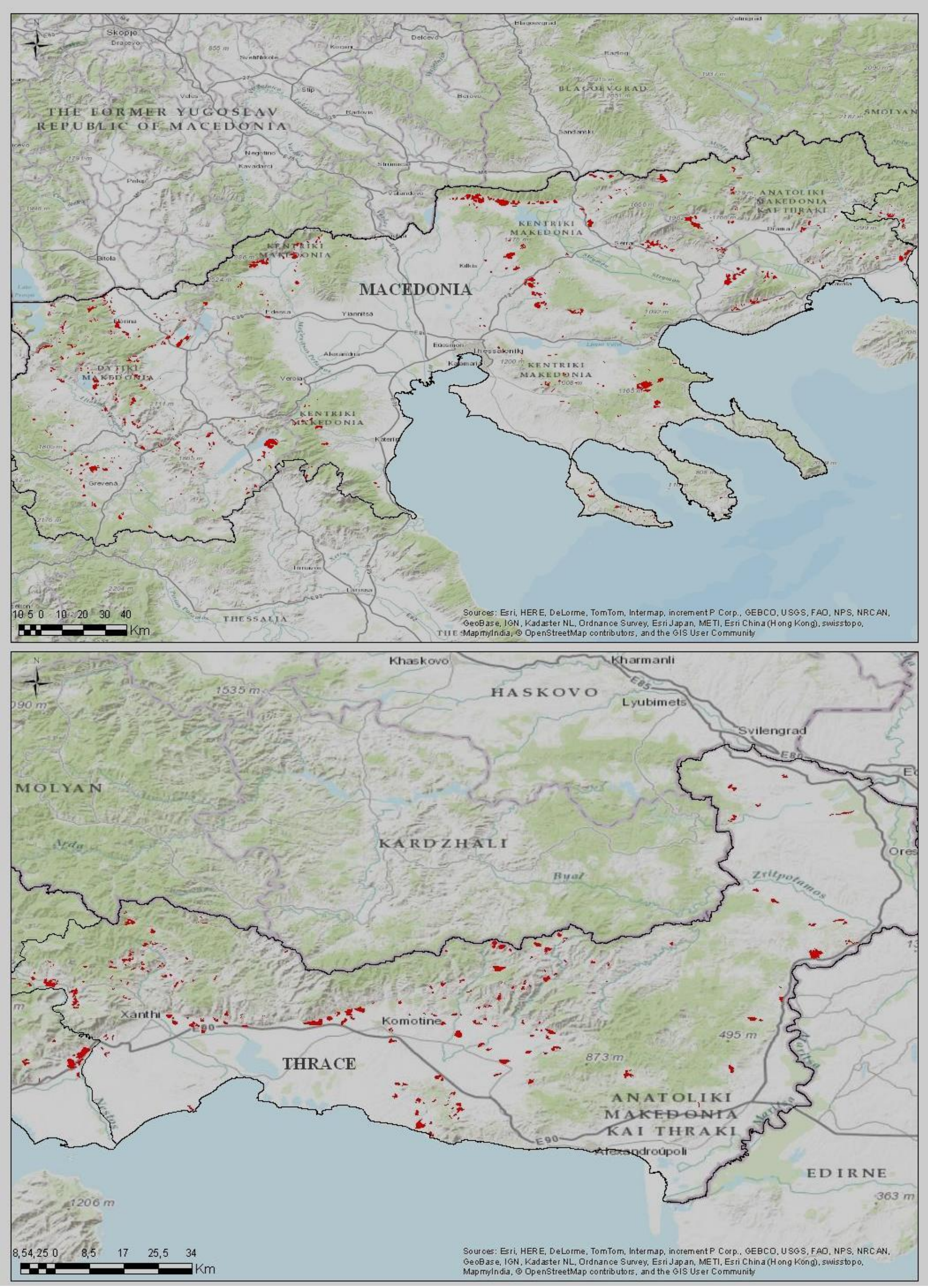


Figure 29. Distribution of silvoarable systems in North Greece

The prefecture with the largest extent of silvoarable systems is Serres (8,967 ha), followed by Kozani (5,907 ha) and Rodopi (5,411 ha) (Figure 30). By contrast, in Imathia, Pieria and Kilkis prefectures, silvoarable systems occupy less area (461 ha, 717 ha and 1,748 ha respectively).

Although Serres prefecture has the largest area with silvoarable systems, the prefecture with the highest number of silvoarable systems is Rodopi (98), followed by the prefecture of Kozani (78) and the prefecture of Florina (76). The smallest number of silvoarable systems is in Pieria (8). It is noteworthy that most of the silvoarable systems of North Greece appear at the foot of the mountains.

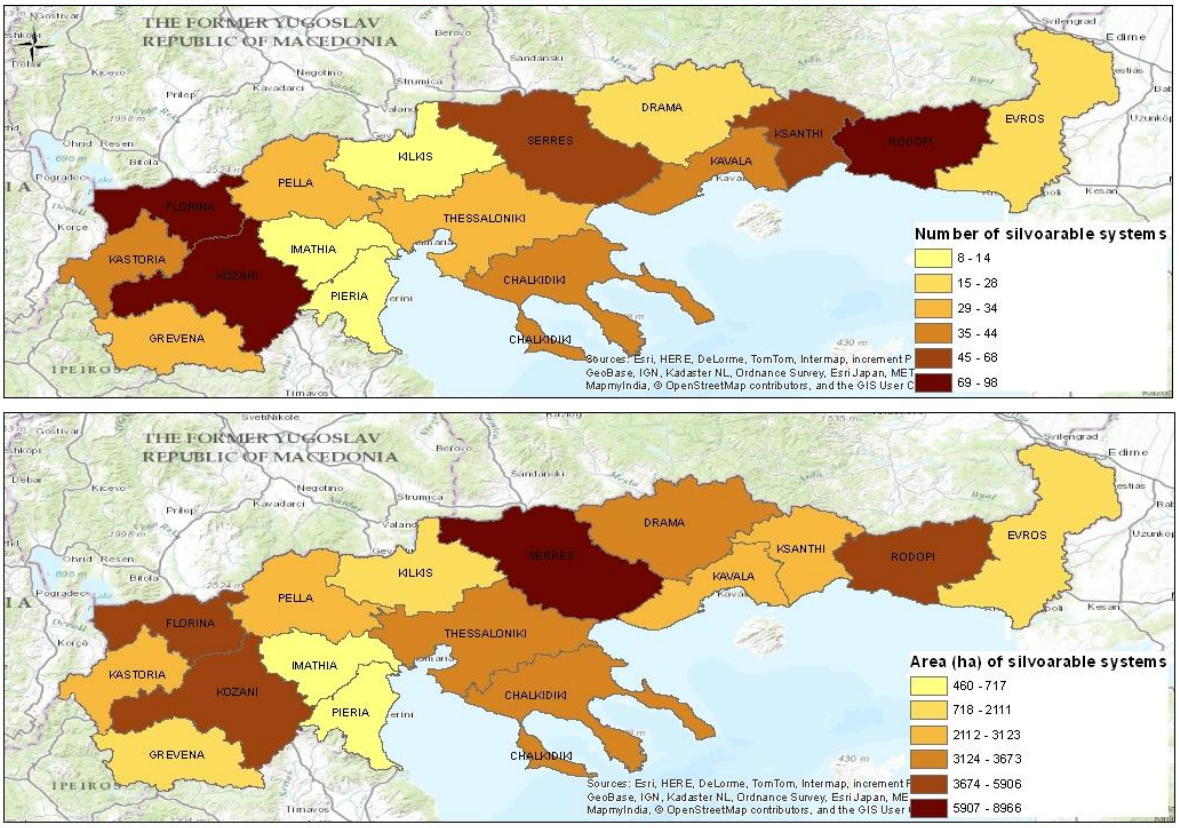


Figure 30. Number and area of silvoarable systems per prefecture in North Greece

Dominant tree species in the overstorey are oaks (*Quercus* sp.), olives (*Olea europea*), walnuts (*Juglans regia*) and poplars (*Populus* sp.) (Sidiropoulou 2011). Silvoarable systems with oaks are well distributed throughout North Greece. They include Macedonian oak (*Quercus trojana*), pubescent oak (*Quercus pubescens*), sessile oak (*Quercus petraea*), Italian oak (*Quercus frainetto*) and Turkey oak (*Quercus cerris*) (Papanastasis et al. 2009) either pure or mixed, with other oak species, or poplars, willows, walnuts, almond-leaved pears etc. (Sidiropoulou 2011). The trees are used primarily for timber or fuelwood, but also for the production of acorns and leaf fodder (Sidiropoulou and Ispikoudis 2009), shade to livestock during midday in the summer or as markers of property boundaries (Papanastasis et al. 2009). The main understory species are cereals, maize, alfalfa, dry pulses, and potatoes. The trees are found scattered within or in the boundaries of the fields.

Olive trees in silvoarable systems are found mainly in the Chalkidiki Peninsula, either within the arable fields or in their borders (Sidiropoulou 2011). Various crops are planted in the understorey such as vineyards, cereals or forages (Papanastasis et al. 2009). Agrosilvopastoral systems are formed when olive groves are grazed after the harvest of the crop. In all these cases, olive trees are mainly grown for the production of olives but the pruned branches are also used as fuel and for feeding animals either *in situ* or in the barn (Papanastasis et al. 2009).

Silvoarable systems with poplars are quite extensive in North Greece, both in the plains and in mountainous areas. Despite the fact that there are several species of native poplar, the most commonly used are clones of hybrids between native and American species (e.g. *P. thevestina*). Poplars are grown or planted in arable lands with good soils, irrigated or with access to water such as water canals and riverbanks. The most common pattern is the establishment of poplar hybrids around arable fields cultivated with vegetables or other summer crops (Papanastasis et al. 2009). Poplars are used for timber and fuelwood but also as windbreaks and boundary marking (Sidiropoulou 2011).

Walnut is a common cultivated tree in the sub-Mediterranean and mountainous Mediterranean zones of North Greece (Papanastasis et al. 2009). It is planted within arable fields or in their borders, alone or in mixture with other trees. It is usually combined with several crops, especially vineyards, cereals, maize, vegetables and alfalfa (Sidiropoulou 2011). Walnut trees are mainly grown for the production of walnuts for food, oil, and medicines as well as timber for furniture, guns and woodcrafts (Sidiropoulou and Ispikoudis 2009)

Other tree species used in silvoarable systems include willows (*Salix* sp.), nettle trees (*Celtis australis*), beech trees (*Fagus silvatica*), alders (*Alnus glutinosa*), chestnuts (*Castanea sativa*), pines (*Pinus* sp.), elms (*Ulmus* sp.), and mulberry trees (*Morus* sp.). The main understorey species are wheat, maize, alfalfa, barley, tobacco, rye, vines, cotton, sunflower, oat, dry pulses and vegetables.

Silvoarable systems in North Greece are in danger of being abandoned or converted to intensive monocultures (Sidiropoulou 2011; Papanastasis et al. 2009). A relatively large proportion (38.6%) of the above systems exhibit some degree of abandonment (Sidiropoulou 2011). In areas with severe labour problems, the traditional silvoarable systems have been completely neglected (Papanastasis et al. 2009).

6.3.2 Silvoarable systems of North Greece in the framework of LUCAS 2012 and CORINE Land Cover 2000 classification schemes

For the comparison of LUCAS (2012) and CORINE Land Cover (2000) databases with the inventory of silvoarable systems of North Greece, a GIS environment was used (ArcMap 10.1). The three maps were joined, resulting in a polygon layer that preserved all the properties found in the original layers.

As far as LUCAS database is concerned, only 39 out of the total (695) silvoarable systems overlapped with LUCAS points. 33% of these systems are located on grasslands, 28% on woodlands, 23% on croplands, 8% on artificial land and 8% on shrublands (Table 18). The main land uses are agriculture (36%), semi-natural and natural areas not in use (18%), forestry (18%), roads (8%) and abandoned areas (5%) (Table 19).

Table 18. Silvoarable systems of North Greece recorded within LUCAS 2012 land cover categories

Land cover category	CODE	Number of systems
Grassland	E00	13
Woodland	C00	11
Cropland	B00	9
Artificial land	A00	3
Shrubland	D00	3

Table 19. Silvoarable systems of North Greece recorded within LUCAS 2012 land use categories

Land use category	CODE	Number of systems
Agriculture (excluding fallow land, kitchen garden)	U111	14
Semi-natural and natural areas not in use	U420	7
Forestry	U120	7
Fallow land	U112	6
Roads	U312	3
Abandoned areas	U410	2

According to the CORINE Land Cover data analysis, silvoarable systems of North Greece are located mainly on non-irrigated arable land (29%), land principally occupied by agriculture, with significant areas of natural vegetation (25%), broad-leaved forest (14%) and sclerophyllous vegetation (7%) (Table 20).

Table 20. Silvoarable systems of North Greece recorded within CORINE 2000 land use categories

Land use category	CODE	Number of systems
Non-irrigated arable land	211	198
Land principally occupied by agriculture, with significant areas of natural vegetation	243	177
Broad-leaved forest	311	97
Sclerophyllous vegetation	323	52
Complex cultivation patterns	242	44
Natural grasslands	321	37
Transitional woodland-shrub	324	32
Sparsely vegetated areas	333	20
Mixed forest	313	12
Olive groves	223	6
Fruit trees and berry plantations	222	5
Permanently irrigated land	212	5
Vineyards	221	3
Other	312, 112, 122, 511 etc.	7

The LUCAS data are insufficient to estimate the accuracy and potential use of this classification scheme. However, the above CORINE Land Cover codes can be used to indicate where silvoarable systems are, although field visits are essential to verify the presence of agroforestry and also to obtain data on their extent and characteristics.

Valonia oak silvopastoral systems

Pantera et al. (2008) explain that Valonia oak *(Quercus ithaburensis* ssp. *macrolepis)* is distributed in continental and insular Greece, mainly in lowlands and forested hills, as well as in arable and urban areas (Figure 31). It covers an area of 29,632 ha in the form of small (thickets) or larger stands and isolated individuals. Areas of greater distribution include western Greece (11,894 ha), the islands of Crete (5,500 ha) and Lesvos (5,000 ha), south Peloponnesus (3,484 ha) and the Cyclades islands (2,000 ha).

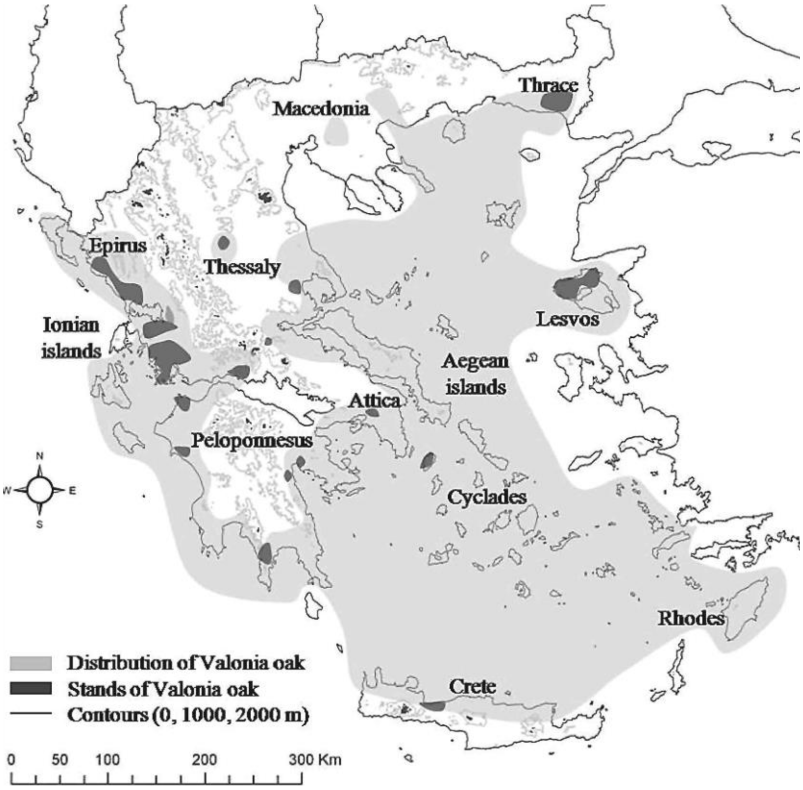


Figure 31. Distribution of *Quercus ithaburensis* ssp. *macrolepis* in Greece (Pantera et al. 2008)

Pantera et al (2008) explains that most of the valonia oak forests grow on limestone soils (76%) in various areas of continental Greece, the Ionian islands and Crete. Another 16.9% is found on volcanic soils in Lesvos and other Aegean islands and a 7.1% on fhlysch, schist, igneous and Neogene rocks in various Greek areas. Concerning soil depth, 41.9% is present on shallow to very shallow soils (0.15-0.30 m) and 53.5% on moderately deep soils (0.30- 0.60 m). Only a small part of forests (4.6%) grows on deep to very deep soils (>0.60 m) due to the extensive forest destruction and subsequent land use for agricultural purposes (Pantera and Papanastasis 2003; Pantera and Panagiotou 2003). The species expands in areas from sea level (0 m) up to 1100 m a.s.l., and in various aspects and slope inclinations.

The distribution of the species confines to areas with a mean annual precipitation ranging from 324 to 1085 mm. Regarding the mean minimum temperature of the coldest month (m), valonia oak occurs only in areas with it ranges from 0 to 9.4^{o}C. In respect to the mean maximum temperature of the warmest month (M), the species occurs in areas with a range between 26.8 and 34.5^{o}C.

According to the bioclimatic map of Greece (Mavrommatis 1980), the species grows in the following Mediterranean bioclimates:

a) Semi-arid, with cool winters in Macedonia, temperate winters in Attica and warm winters in the Cyclades islands,
b) Sub-humid, with cool winters in Thrace and Thessaly, temperate winters in Sterea Ellada (Central Greece), in north-western and south Peloponnesus and the north Aegean islands and warm winters in the south Aegean and south Ionian islands, and
c) Humid, with temperate winters in west Peloponnesus, Epirus and north Ionian islands.

It appears that valonia oak grows mainly in the mesomediterranean layer of the Quercetalia ilicis zone. Its presence decreases in the thermomediterranean layer where it mainly grows in the lowlands of southeastern Greece. Occasionally it is present in restricted areas of the supramediterranean layer in northern and northwestern Greece, in mixture with other deciduous oaks such as *Quercus frainetto, Q. cerris, Q. trojana* and *Q. pubescens*.

The valonia oak understorey differentiates according to the vegetation zone and consists mainly of:

1. Grasslands and shrubby vegetation in the supramediterranean layer (Thrace, Lesvos, south-eastern Thessaly, north-western Peloponnesus);
2. Phryganic and shrubby vegetation in the mesomediterranean and thermomediterranean layer (Cyclades, south Peloponnesus, Crete etc.).

In general, the understorey is mainly composed of unpalatable to grazing plant species such as *Phlomis fruticosa, Urginea maritima, Euphorbia dendroides* and other phryganic species. Additionally, evergreen broadleaved shrubs such as *Ceratonia siliqua, Acer sempervirens* etc. accompany the species in several areas whereas, in some of those, it grows in mixture with conifers such as *Pinus pinea* in northwestern Peloponnesus and *Juniperus excelsa* in Thrace.

To conclude, valonia oak has a wide ecological range in Greece, characterized by its adaptive capacity to various climatic and soil environments of the low and middle altitude zones. Its absence or low presence in many lowland areas of Greece may be attributed to the intense human interference applied to this zone for many years since ancient times. The species may be used in regeneration projects in xerothermic areas where phrygana and thermophilic conifers dominate and are presently threatened by desertification.

7 Discussion

7.1 Comparison of LUCAS data with the literature study

Our current estimate shows that the current total extent of agroforestry is about 15.4 million ha in the EU 27 and covers about 3.6% of the territorial area or 8.8% of the Utilised Agricultural Area (Table 4). This estimate is considerably larger than the previous estimate by den Herder et al. (2015) who suggested that agroforestry occupies at least 10.6 million ha representing about 6.5% of the utilised agricultural area in Europe. The higher estimate for the agroforestry area using the LUCAS data than the literature review can be explained by the addition of data from Bulgaria (0.9 million ha) and higher estimates for Spain (+1.7 million ha), France (+1.0 million ha), Romania (+0.7 million ha) and Italy (+0.4 million ha)(Table 21). By using LUCAS, we were also able to obtain additional data from several other countries (Estonia, Latvia, Lithuania, Luxembourg and Malta) with a small agroforestry cover.

Even though the total estimate may seem quite reasonable, the estimates for individual countries showed sometimes very large differences (Table 21). The LUCAS sampling grid may result in reasonably accurate estimates for the larger countries as these are covered by a higher number of sample points. Smaller countries are covered by a lower number of samples and it is quite logical that sampling error increases with lower numbers of samples. Furthermore, it is possible that some agroforestry systems are not well described in the literature which may have resulted in a lower estimate in the literature review. For example, in our LUCAS estimate, the higher estimate for Spain is primarily a result of including other silvopastoral systems in addition to the dehesas. For example, forest grazing is common in Spain also outside the dehesa area and this practice is very useful in forest fire control. On the one hand, it is likely that countries where agroforestry is traditionally practiced on a relatively large scale, have a rich source of agroforestry literature and that we were able to retrieve a good sample of the published literature. On the other hand, it is quite understandable that countries which do not have a history where agroforestry was widely-practiced (for example the Netherlands), do not have much literature describing agroforestry practices. This explains why for many countries the estimate from the literature review would be far from complete or is even totally lacking. By using the LUCAS database, we were now able to make a uniform estimate covering the whole EU 27.

Inconsistencies between the literature estimate and the LUCAS estimate may also have arisen from the fact that they are possibly based on a different understanding of the agroforestry concept. The published literature, may consider only formalized agroforestry systems, for example typical well-managed, dense orchard meadows in Germany or the well-known montados and dehesas in Portugal and Spain. By using LUCAS data, we would also include an isolated tree within a larger tree-less grassland. Neither of these two perspectives is wrong. It just depends on the underlying assumptions and understanding what is included in the agroforestry concept.

It should be noted that the LUCAS data should be interpreted with some caution. For example, mountainous and other remote areas may be under-represented in the LUCAS survey. For instance, reindeer husbandry in northernmost Fennoscandia is obviously underestimated. In northern Fennoscandia, very remote areas had lower sampling intensity and the evidence of grazing was probably too low to be noted by the surveyors and was therefore misinterpreted during the survey.

Furthermore, some LUCAS sites might be located at a local ecotone, for example at a forest edge between adjacent sites of grass land cover and tree land cover which are managed separately. In this analysis, such sites would be interpreted as agroforestry, even though the grassland and tree areas may be managed totally independently. However, although there may be some systematic errors, since the LUCAS data were collected and analysed in a uniform manner, it is possible to make uniform comparisons between countries and identify regions in Europe where agroforestry is widely practiced and where it is not.

Table 21. Total extent of agroforestry (total area x 1000 ha) in Europe according to the literature study (den Herder et al. 2015) and the LUCAS estimate.

Country	All agroforestry (literature estimate)	All agroforestry (LUCAS estimate)	Difference (LUCAS – literature)
	1000 ha	1000 ha	1000 ha
Austria	48.6	160.8	112.3
Belgium	12.4	43.7	31.3
Bulgaria		869.9	869.9
Croatia	64.5		
Cyprus		47.5	47.5
Czech Republic	9.2	45.8	36.5
Denmark	3.2	16.2	12.9
Estonia		14.4	14.4
Finland	7.3	158.1	150.8
France	510.1	1562.2	1052.0
Germany	480.5	263.5	-217.0
Greece	2096.7	1616.4	-480.3
Hungary	22.8	38.1	15.3
Ireland		224.4	224.4
Italy	967.0	1403.9	436.9
Latvia		23.4	23.4
Lithuania		38.6	38.6
Luxembourg		7.2	7.2
Malta		0.4	0.4
Netherlands	3.0	27.8	24.8
Poland	200.0	100.4	-99.6
Portugal	1842.3	1168.3	-674.1
Romania	180.1	888.2	708.1
Slovakia	92.0	43.9	-48.1
Slovenia	185.0	56.3	-128.7
Spain	3839.9	5584.4	1744.5
Sweden	100.0	465.5	365.5
Switzerland	97.3		
United Kingdom	157.5	551.7	394.2
EU-27 total	**10643**	**15421**	**4778**

In addition to the three agroforestry types described in this report, the AGFORWARD project also refers to “high natural and cultural value” agroforestry (Burgess et al., 2015). Currently there is no universal or officially accepted definition of the concept “high natural and cultural value” agroforestry systems (but see den Herder et al. 2015 for a preliminary stratification of agroforestry systems). The high nature value concept was proposed by the European Environment Agency

(Parachini et al. 2006). The concept recognizes that specific farming practices and systems support high biodiversity levels (Pointereau et al. 2007). For instance, the dehesas and montados agroforestry systems in Spain and Portugal are among the highly diverse high nature value systems in Europe. According to Paracchini et al. (2006) there exist three types of high nature value farmland: 1) farmland with a high proportion of semi-natural vegetation, 2) farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, stone walls, patches of woodland or scrub, small rivers, and 3) farmland supporting rare species or a high proportion of European or world populations. Plieninger et al (2015) made an estimate on the extent of wood pastures in Europe based on LUCAS data and their analysis would correspond with the "type 1" high nature value farmland with a high proportion of semi-natural vegetation. Plieninger et al. (2015) estimated that wood pastures cover approximately 20.3 million ha in the European Union. This estimate is considerably higher than our estimate on livestock agroforestry (15.1 million ha) which should be overlapping with wood pastures to a large extent. The main difference is due to the fact that Plieninger et al. (2015) also included ungrazed wood pastures in their estimate, whereas in the current estimate in this report LUCAS points were only interpreted as "livestock agroforestry" when there were clear signs of grazing.

Although LUCAS does not include information about the natural and/or cultural value of the surveyed points, the cluster map could be viewed as indicator of regions with agroforestry landscapes of high natural and cultural value. This would be based on the assumption that large extents of agroforestry areas or areas with a low level of fragmentation are more likely to have a high natural value compared to single isolated or fragmented patches. The cluster analysis shows areas with a relatively high abundance of agroforestry points indicating that agroforestry areas are situated at a relative close proximity to each other or that these practices would cover larger areas. Many of the remaining high natural and cultural value agroforestry practices are a legacy of traditional land uses and clusters of agroforestry points would indicate areas where these mostly traditional practices possibly still exist. The cluster analysis revealed that a high abundance of areas under agroforestry can be found in mainly in southern and south-eastern European countries and it is likely that high natural and cultural value agroforestry is still relatively widespread in these areas.

7.2 Comparison of LUCAS results with the national inventories

For some selected countries, a national inventory on the extent of agroforestry was carried out against which our LUCAS estimate could be compared. Comparison of the national inventories with the LUCAS results should give us an idea whether it would be possible to produce a reliable and realistic result at the national level result using LUCAS data.

For Portugal, the LUCAS estimate was slightly lower than a national estimate of the livestock agroforestry area. LUCAS estimated 1.1 million hectares versus 1.4 million hectares in three different national inventories. This relatively small difference of about 20% would be equivalent to the whole extent of silvoarable practices in Portugal. The arable agroforestry area estimated by LUCAS was only about 25% of the national estimate: the analysis of LUCAS database estimated about 77 thousand hectares of silvoarable systems against about 303 thousand hectares in the national inventory.

For Spain a straight comparison among LUCAS estimates and estimates based on different national surveys was done for four categories of agroforestry, wood pastures and silvoarable lands with either cultivated trees or forest trees, yielding comparable values for the three of the categories to some extent, and only certain overestimation with LUCAS for wood pastures under cultivated trees (Table 17). In summary, the area of agroforestry was about 6.1 million ha according to Spanish sources and about 5.6 million ha according to comparable LUCAS estimates reported in Table 4.

For Greece, a direct comparison between the LUCAS results and the inventory from northern Greece and the extent of silvopastoral systems with Valonia oak was not possible. However, the experts from Greece concluded that LUCAS had limitations in that only 39 out of the 695 known silvoarable sites, which were mapped in the national inventory, were visited during the LUCAS survey.

7.3 Comparison of LUCAS results with the tree cover density data

Tree cover density was surprisingly high in the investigated countries and ranged from 9 to 22% of agricultural land with more than 10% tree cover at the field scale (20 m x 20 m). In the six countries included in our assessment, at the landscape scale there was a range of 16-44% of the agricultural land with more than 10% tree cover (100 m x 100 m). According to our LUCAS estimate agroforestry would cover only about 1-15% of the Utilised Agricultural area which is considerably lower than the 16-44% as estimated using tree cover density. However, these two estimates are based on different methodologies. Nevertheless, our estimates using tree cover density are in line with those made by Zomer et al. (2009, 2014) who estimated in their global assessment (using a 1 km and a 250 m resolution) that in Europe about 40-46% of the agricultural land has more than 10 percent tree cover.

Analysing tree cover density on agricultural land using remote sensing data would be a very reliable method, if agroforestry was defined as agricultural land exceeding a certain percentage of tree cover. An advantage of determining the extent of agroforestry using tree cover density is that, similar to using LUCAS, the data are collected using a uniform and homogenised approach and they are available for whole Europe. Another advantage is that it is possible to make time series visualising possible changes over time in tree cover. However, by using remote sensing data such as tree cover density on agricultural land we would leave some agroforestry practices such as forest farming and forest grazing out of our consideration. Agroforestry practices linked with forests would not be possible to analyse using the tree cover density, as the approach does not provide us information if trees in forests are linked with crops or livestock. Therefore, the approach using tree cover density provides a useful estimate on the extent of agroforestry outside forests, but inside forest this would be very difficult.

There are some more basic differences between LUCAS and tree cover density remote sensing data which need highlighting: LUCAS includes – at least to some degree – land use / land management information, while the satellite data purely tell us about tree cover on agricultural land. As agroforestry is more a land management practice than a land cover, LUCAS data are actually more meaningful. For example, some of the sites with trees on agricultural land could be abandoned farmlands and not deliberate agroforestry systems. LUCAS offers better possibilities to exclude such situations from the analysis, for instance by considering evidence of grazing.

7.4 Recommendations for more harmonized reporting of agroforestry in Europe

It is very difficult to make a reliable and comparable estimate of the extent of agroforestry in Europe using the databases which are currently available. Zomer et al. (2009, 2014) noted similar difficulties in estimating the extent of agroforestry at the global level.

An important feature of this report is that we have made an estimate on the extent of agroforestry and there are indications that our estimate is reliable. For countries which have extensive literature on agroforestry, such as Spain, Portugal and Greece, the difference between the total extent of agroforestry as a result of our review and the LUCAS estimate were relatively small. For some countries, the difference between the numbers reported in the literature review and LUCAS were large, even up to a 20 or 30-fold difference. Nevertheless, the fact that the numbers from both studies were matching for some agroforestry countries with a rich amount of available literature, gives us an indication that our LUCAS estimate can be quite reliable and that the same reliability could apply in other countries as well.

Considering the fact that agroforestry most likely covers a considerable part of the agricultural land in the EU up to about 8.8% of the UAA, it is necessary that agroforestry gets a more prominent place in EU statistical reporting. This is not difficult to implement. For example, the LUCAS Land Use classes "*agriculture"* and "*forestry*" could get a secondary land use class "agroforestry" indication in case a silvoarable or silvopastoral agroforestry practice is observed during the field survey.

A more uniform reporting method would make it easier to give more precise estimates on the extent of agroforestry in Europe and changes in its extent. This would help to put agroforestry on the agenda of policy and decision makers who would need reliable information on the extent of agroforestry and changes therein. Without reliable information it would be very difficult to plan future policies and evaluate policy measures which may have an impact on agroforestry.

8 Conclusions

Making estimates on the current extent of European agroforestry is challenging but of key importance if we want to develop measures and policies to promote this sustainable land use practice. In addition, if we want to evaluate the impact on agroforestry of certain measures it is important to know how much agroforestry there is. In this report we used three different methods for estimating the extent of agroforestry. Two of the methods, using the LUCAS database and using tree cover density data, provide a comparable and uniform estimate on the extent of agroforestry in Europe. In addition, both approaches would enable us to evaluate changes over time. However, while LUCAS enables us to include most of the common agroforestry practices, remote sensing data such as tree cover density would leave some practices related to forests (e.g. forest farming and forest grazing) outside consideration.

According to our estimate, agroforestry covers about 15.4 million hectares in Europe which is equivalent to 3.6% of the territorial area or 8.8% of the Utilised Agricultural Area. The greatest area is covered by livestock agroforestry which extends over 15.1 million hectares. This system is found mainly in the Mediterranean and south east Europe, but examples occur across all of Europe including the boreal region. Agroforestry with high value trees covers about 1.1 million hectares and is mainly found in southern, eastern and central Europe. Arable agroforestry covers about 358 thousand hectares with again the largest areas found in the Mediterranean.

It proved quite challenging to make an estimate on the extent of agroforestry in Europe and statistical reporting could still be improved. For example, identifying agroforestry areas using the Eurostat's LUCAS database could be made easier and more straightforward by introducing a few simple changes in data collection. Improved reporting would be of key importance in placing agroforestry on the political map. Without reliable and up-to-date information on the extent agroforestry area and its changes over time it would be very hard to plan and evaluate measures to promote this sustainable land use practice.

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Annex A. Data sources

CORINE: CORINE land cover data available for the EU in raster and vector format.
http://land.copernicus.eu/pan-european/corine-land-cover/view and
http://www.eea.europa.eu/publications/COR0-landcover

Copernicus: Pan-European tree cover density raster data: http://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density
Some of the data were not available at the time of writing this report. For the report the intermediate unverified data where requested by e-mail and data for seven countries were used in the analysis in this report. When the report was finished (30.9.2015) 100 m resolution raster data were available for whole Europe but the 20 m were not verified yet.

LUCAS: Land Use and Land Cover Survey data for the EU-27: http://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey

Annex B. Spanish agroforestry systems by region

Plot level

Region	SA	SP	OVD	DHS	DHS_SP	DHS_SA
Andalucia	96,462	1,169,440	143	786,220	604,411	91,893
Aragon	589,008	589,671	44	104	53	49
Asturias	87	621	0	0	0	0
Balear	7,718	1,639	0	0	0	0
Canarias	509	2,858	0	0	0	0
Cantabria	118	12,467	0	0	0	0
Castilla Leon	275,575	1,731,867	4	262,137	209,570	4,926
Castilla Mancha	181,409	924,856	1,100	7,747	1,198	6,189
Cataluña	326	5,812	0	0	0	0
Ceuta Melilla	1	245	0	0	0	0
Euskadi	333	70,097	2	0	0	0
Extremadura	152,167	1,024,897	6,087	1,203,124	861,334	108,696
Galicia	25	185	0	0	0	0
Madrid	11,661	91,093	2,156	27,984	16,262	8,250
Murcia	127,224	371,871	74	0	0	0
Navarra	518	14,707	0	0	0	0
Rioja	3,386	1,433	0	0	0	0
Valencia	372	173,315	4	0	0	0

Landscape scale

Region	SA	SP	OVD	DHS	DHS_SP	DHS_SA
Andalucia	400,861	1,434,347	568	888,401	691,386	102,474
Aragon	1,059,512	986,005	54	104	53	49
Asturias	18,769	218,475	0	0	0	0
Balear	78,613	29,280	2	0	0	0
Canarias	15,369	20,087	0	0	0	0
Cantabria	5,731	103,450	0	0	0	0
Castilla Leon	299,611	1,754,152	4	262,137	209,570	4,926
Castilla Mancha	1,184,895	2,016,204	6,451	11,523	1,725	8,629
Cataluña	235,208	131,309	0	0	0	0
Ceuta Melilla	18	324	0	0	0	0
Euskadi	17,551	124,316	2	0	0	0
Extremadura	229,646	1,137,448	7,886	1,211,217	867,270	109,490
Galicia	407,761	235,989	0	0	0	0
Madrid	29,191	107,289	3,164	28,290	16,465	8,329
Murcia	174,496	391,527	125	0	0	0
Navarra	12,061	19,081	11	0	0	0
Rioja	35,237	6,004	0	0	0	0
Valencia	84,415	565,538	24	0	0	0

SA: Silvoarable land; SP: Silvopastures; OVD: Olive groves intercropped with vines.

DHS: Dehesa (Surface already included in SP); DHS_SP and DHS_SA: grazed and cultivated dehesas.