# Report on landscape context of field sites

# Deliverable 1.2

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**PoshBee**

**Pan-european assessment, monitoring, and mitigation of stressors on the health of bees**

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## Preface

As a site network across eight European countries was established in WP1, considering Europe's main biogeographic zones, basic and complex landscape data were recorded and quantified to assess context dependencies or potential confounding effects for subsequent analyses to identify and quantify drivers of agrochemical exposure of wild and managed bees, their interactions with pathogens, parasites and nutritional status, and their combined effects on bee health. Both apples (perennial) and oilseed rape (annual) are important foraging crops for managed and wild bees but are also regularly treated with agrochemicals. Sites located in both of these crop types were selected along an intensity gradient, using the proportion of arable land in the landscape as a proxy, and sentinel bee hives and nests (one honeybee, bumblebee and solitary bees species) were deployed. The complex landscape data were quantified to best describe the composition and spatial configuration of agricultural and semi-natural habitats, potentially identifying available and alternative resources for managed and wild bees. In addition, basic landscape data were recorded at each focal field boundary and adjacent fields surrounding the sites to allow meaningful comparison of habitat availability across the field and landscape scales.

## Summary

Using a trans-disciplinary approach, by integrating laboratory, semi-field, field and landscape studies, PoshBee will provide the first pan-European quantification of the exposure hazard of chemicals to managed and wild bees to support and enhance healthy bee populations and sustainable pollination across Europe. The site network across eight European countries established in WP1 incorporates Europe's main biogeographic zones. Therefore, the characterisation of the structure of the landscape for each specific country is needed to better understand how agrochemicals affect bees, not only at the field scale, but also at the landscape level. Landscapes surrounding the field sites (up to 1km radius around the centre of the focal field, which includes the majority of the foraging distances of studied taxa) were characterized using GIS tools. The amount of each land-cover type was calculated to compare the proportions of arable land and semi-natural habitats between sites, countries and crop types. The heterogeneity of the landscape in oilseed rape and apple sites was highly dissimilar, suggesting that future analyses should focus on each crop type separately. At the landscape scale, oilseed rape sites tend to display a lower landscape diversity than the apple sites. This trend is particularly true for Spain, Germany, and Sweden. However, aside for the apple sites in the Trentino region of Italy, no clusters were identified by a PCA, suggesting that the cofounding effect of the countries is rather low for the landscape analyses. Finally, the data recorded at each boundary and adjacent field showed that half of the boundaries and adjacent fields are characterized by improved grasslands, hedgerows, and other semi-natural habitats that potentially provide additional resources to pollinators. This report details the methods used to create the habitat maps and calculate the metrics that describe the heterogeneity of the landscape in each site. As a key result, we conclude that the PoshBee site network covers a wide range in landscape characteristics and is representative for European agricultural landscapes. Further, the strong within-country gradients together with sufficient overlap of these gradients among countries allows for reliable further statistical analyses of agrochemical exposure of wild and managed bees, their interactions with pathogens, parasites and nutritional status, and their combined effects on bee health without country-specific confounding effects.

# 1. General methodology

## 1.1. Study sites of the PoshBee project

### 1.1.1. Experimental design and selection of the sites

Within each of the eight European countries, 16 sites were selected according to a gradient of land-use intensity (using percentage of arable land as a proxy), resulting in a total of 128 sites. The project focuses on two different crop types, i.e. oilseed rape fields (OSR) and apple orchards (APP). Thus, out of the 16 sites chosen in each country, half of them (8 sites) were selected in landscapes constituted mostly of OSR and the remaining half (8 sites) to landscapes containing APP. The mean distance between two sites was at least 5 km to best avoid overlapping landscape buffers and violation of statistical assumption of spatial independence for subsequent analyses.

### 1.1.2. Research regions and countries

To allow comparison of agro-ecosystems with different landscape structures and landscape intensity across Europe, eight countries were selected covering the main biogeographic regions in Europe (see Figure 1). The eight selected countries were Switzerland (CHE), Spain (ESP), Estonia (EST), England (GBR), Germany (GER), Ireland (IRE), Italy (ITA) and Sweden (SWE).

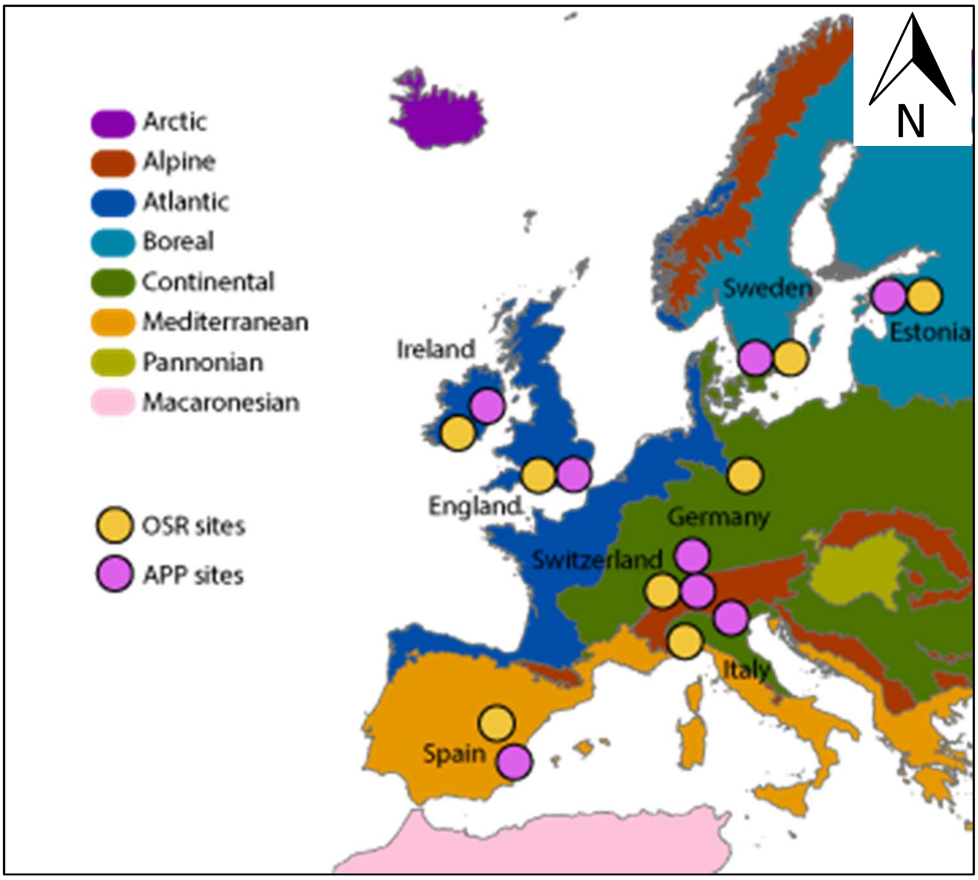


**Figure 1: European map with a bioclimatic stratification showing the approximate locations of the OSR and APP sites within PoshBee.**

All sites in Switzerland were located in the canton of Zürich, in the north-eastern part of the country. Shallow river valleys and lakes characterize the landscape where the elevation ranges from 392m to 871m. While a third of the area is covered by woodlands, more than 40% of the land is used for agricultural purposes.

In the southeast part of Spain, the OSR sites were distributed in the province of Albacete, while the APP sites were located in the province of Murcia. Both provinces, especially Murcia, are major producers of fruits, vegetables and flowers for the rest of Spain, despite the high temperatures and low precipitation levels. Mountainous reliefs, depressions and running valleys, as well as plateaux characterize the landscapes of these Spanish provinces.

The Estonia sites were located in the Tartu and Viljandi counties, in the vicinity of the lake Võrtsjärv. These regions are characterized by wavy plains, wetlands and the presence of numerous lakes. Up to one third of the region is covered with forests, while a third is dedicated to agricultural land.

The South East England region, where all 16 sites were selected, is renowned for its countryside, gardens and national parks.

In Germany, OSR fields were selected in the region of Saxony-Anhalt (East Germany), while APP fields were chosen in the region of Baden (South-west of Germany). In Saxony-Anhalt, the landscapes are dominated by flat agricultural plains. In contrast, the region of Baden shares its border with Switzerland and its mountainous region.

Both OSR and APP sites in Ireland were spread from Cork Kerry South-East and the region of Midland East. These landscapes comprise a mix of rolling hills, woodlands, valleys, and farmlands along a craggy coastline.

The mountainous region of Trentino in Italy was an ideal choice for the APP sites, known for its apple production in Europe. While the elevation can reach 3900m, the whole region is covered by forests, especially coniferous woodlands, and meadows. The OSR fields were selected in the northern region of Piedmont. While the region is famous for its rocky chains, the sites were located in the green rolling hills, where a mix of vineyards, orchards and cereals are grown.

Finally, the APP and OSR sites of Sweden were selected in the plains of Scania. Its landscapes consist mainly of coniferous forests, boreal taiga and alpine tundra. This region represents an important resource for the rest of Sweden since 25-95% of the total production of cereals and rape comes from it.

## 1.2. Complex landscape data

The compositional and configurational heterogeneity of the landscape are the two main components of landscape heterogeneity, which defines the complexity of the landscape. They can be described and quantified by means of landscape metrics, using Geographic Information Systems (GIS).

### 1.2.1. Creating habitat maps

All landscape features were identified and mapped within a 1-km radius, centred at the location of the sentinel bee hives and nests, using heads-up digitizing in a geographic information system (ArcGIS Pro 2.4.1, ESRI) based on high resolution images provided by World Imagery (ESRI). World Imagery provides one meter satellite and aerial imagery, typically within 3-5 years of currency, using a combination of imagery sources such as 2.5m SPOT imagery and 0.5m resolution imagery from DigitalGlobe.

Using EUNIS habitat classification as a guideline, land cover features were classified at a consistent scale of 1:2500 into eleven final categories: Surface running waters, Waterbodies, Wetlands, Grasslands, Woodlands and heathland, Bare areas, Apple orchards, Crop, Roads, Train tracks and

Urban areas (see Figure 2 for an example and Appendix Figures 12-27 for all habitat maps). While the EUNIS system offers a detailed classification of each land-cover that best defines ecological habitats (from natural to artificial and from terrestrial to freshwater and marine), the land cover features in the PoshBee project were harmonized and reclassified in accordance to the habitat requirements of pollinators. Therefore, woodlands and hedgerows were identified under the same land cover, under the assumption that they both positively benefit pollinators, by providing potential additional nectar, pollen or nesting resources. In contrast, artificial areas were grouped within the same land use type, as they may be an impediment to the survival of pollinators.

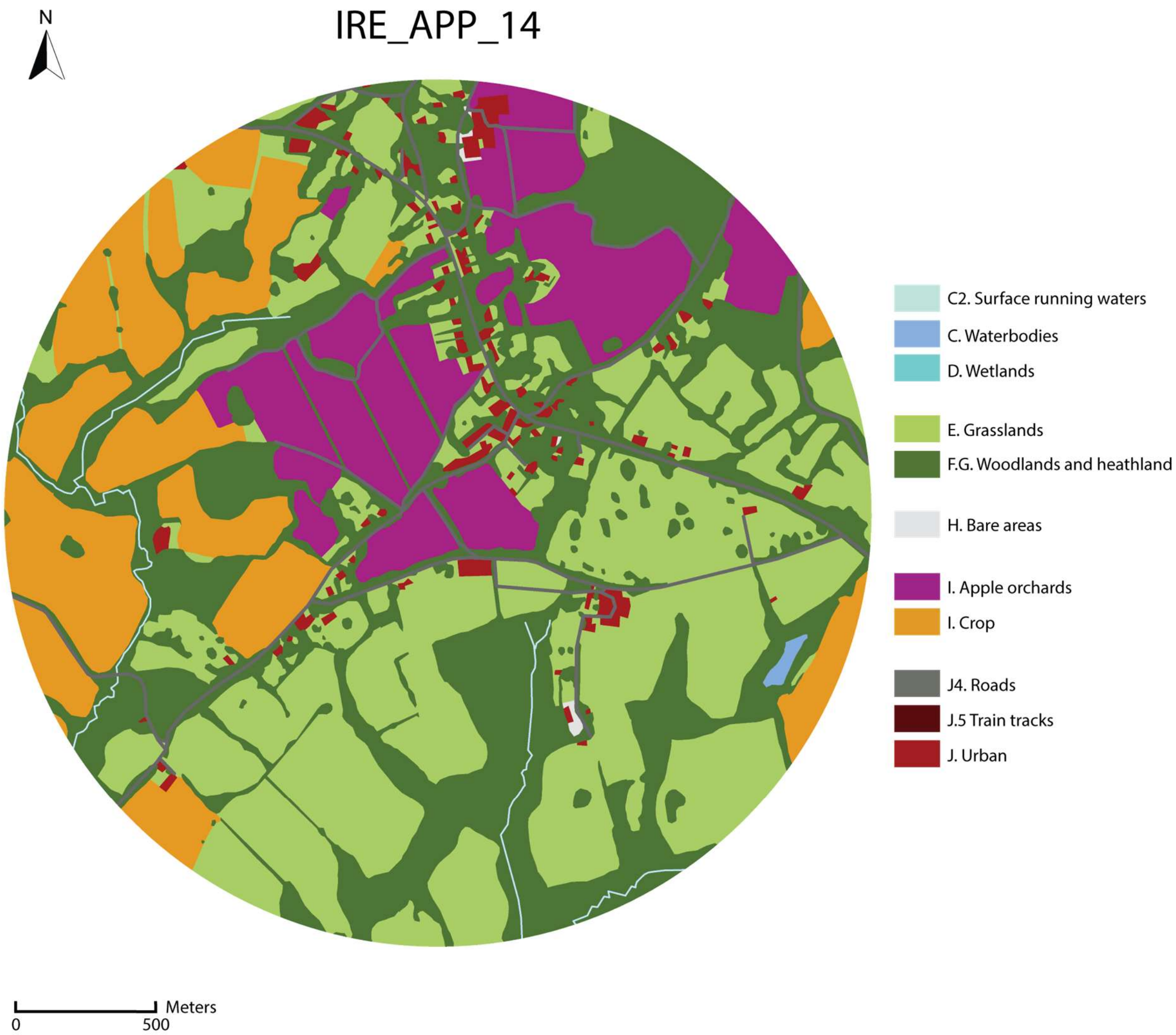


**Figure 2: Habitat map created at a 1-km radius from the location of the sentinel hives located in IRE_APP_14.**

### 1.2.2. Landscape metrics

Landscape metrics can be calculated at different levels to describe single landscape elements such as the size or shape of patches, or for entire landscapes by describing the arrangement of patches and composition of the landscape. Here, different metrics were selected and calculated to best describe the composition and configuration of the landscape using the software Fragstats 3.3 (Table 1).

| Landscape component | Description | Formula | Range | Graphical representation |
|---|---|---|---|---|
| Landscape composition | Shannon's diversity index (SHDI) | $SHDI = -\sum_{i=1}^{m} (P_i * \ln P_i)$ | SHDI ≥ 0, without limit |  |
| Landscape configuration | Number of rice patches (NP) | $NP = n_i$ | NP ≥ 1, without limit |  |
| | Physical connectedness of the rice bunds (COH) | $COHESION = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right]\left[1 - \frac{1}{\sqrt{A}}\right]^{-1} \cdot (100)$ | 0 ≤ COHESION < 100 |  |
| | Shape complexity of the rice patches (FRAC) | $FRAC = \frac{2 \ln (.25\, p_{ij})}{\ln a_{ij}}$ | 1 ≤ FRAC ≤ 2 |  |

**Table 1 Description of each landscape metric calculated in the thesis (from Dominik 2019).**

As measures of compositional landscape heterogeneity, the proportion of all eleven land cover types was calculated. In addition, the Shannon diversity index (SHDI) calculated at the landscape level with all eight land cover categories was used. Landscape diversity is generally perceived as a critical aspect of landscape heterogeneity, as many arthropods may be associated with a single land cover category (i.e. pollinators respond positively to semi-natural habitats).

The configurational landscape heterogeneity was measured exclusively for the arable land and orchards habitat. These habitats are usually composed of several fields that range from large monocultures (i.e. Spain and Germany) to highly fragmented landscapes of small fields. The numbers of crop patches (NP_Crop and NP_Apple) were calculated as a measure of fragmentation of the crop habitats. Specifically, the fragmentation of the crop habitat involved the subdivision of contiguous large crop patches into numerous smaller patches. To quantify the structural connectivity of woodland patches, the patch cohesion index (COH) was calculated. The crop fields located in the selected countries are comprised of a mosaic of crop patches (APP and OSR) that greatly differed in size and shape. For example, monocultures of OSR fields in Spain and Germany were often large and of rectangular shape to facilitate easy agricultural practice. Thus, the shape of habitat patches may affect arthropod communities via edge effects for example. A simple metric that described the geometric complexity of the crop patches (SHAPE_Crop, SHAPE_APP) was calculated.

## 1.3. Basic landscape data

General information of the landscape surrounding each site was assessed at the start of the field season in situ. More specifically, basic landscape data for each boundary and adjacent field at every site was recorded and classified into land types codes based on the simplified EUNIS system.

## 2. Main results

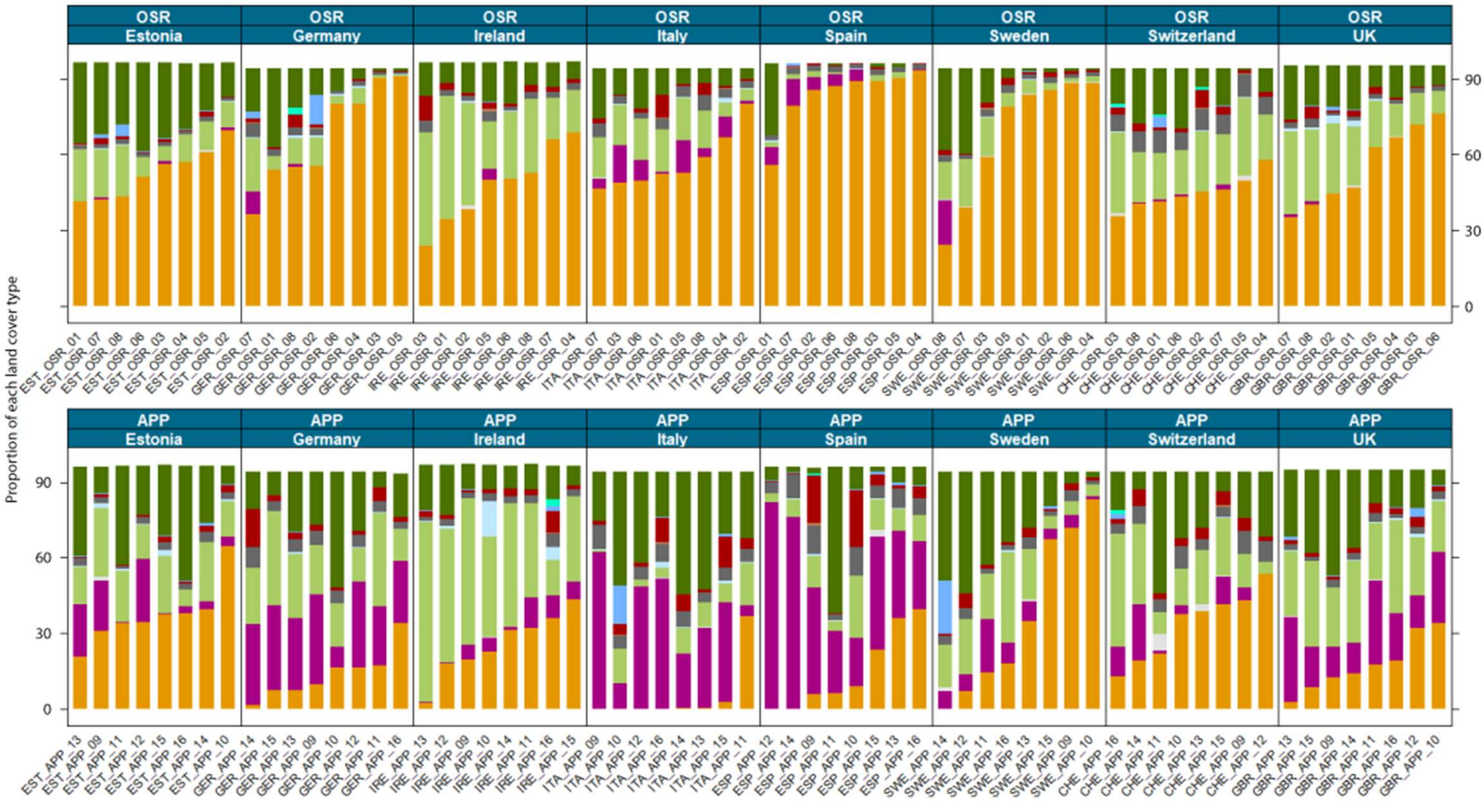


**Figure 3: The proportion of each land cover type for each site shown for each crop type and country. The colour codes are the same as in Figure 2. Orange: Crop; Purple: Apple orchards; Light green: Grasslands; Light grey: Bare areas; Dark grey: Roads; Red: Urban areas; Light blue: Surface running water; Blue: Waterbodies; Cyan: Wetlands; Dark green: Woodlands and heathland**

For both APP and OSR sites, the aim was to select sites representing a gradient of agrochemical use. At the field scale, the proportion of orchards and/or arable land was visually estimated by each country representative and used as a proxy for the agrochemical use gradient. A pool of candidate sites were then selected. In addition, coordinates were sent to UFZ to calculate the proportion of arable land within a 5-km radius on the basis of the Map of European Ecosystem Types (EEA) to help make the final decision for sites selection.

Using the methods described above in section 1.2, high resolution habitat maps were created to better capture the proper proportion of each land cover types within a 1-km radius. The total amount of each land cover for each site can be seen in Figure 3. A clear gradient of arable land (CA_Crop; orange color) can be observed in every country for both OSR and APP sites, with the exception of the APP sites in Italy. Indeed, the mountainous region of Trentino is known for its apple production and the lack of agricultural land in the area, and thus is the only outliner in this selection. However, this shows that despite the limited information extracted from the low resolution maps during the sites selection process, the intended gradient of agricultural intensity was respected in each site, when using arable land as a proxy. In Figure 4, the range in the proportion of arable land is shown for each country. While most of the sites in each country cover a wide range in the proportion of arable land (and thus a pronounced gradient), the sites located in Switzerland differed less. This could be explained by the high heterogeneity usually found in the Swiss sites, which results in more even proportion of the different land cover types in the landscape (see section 2.1).

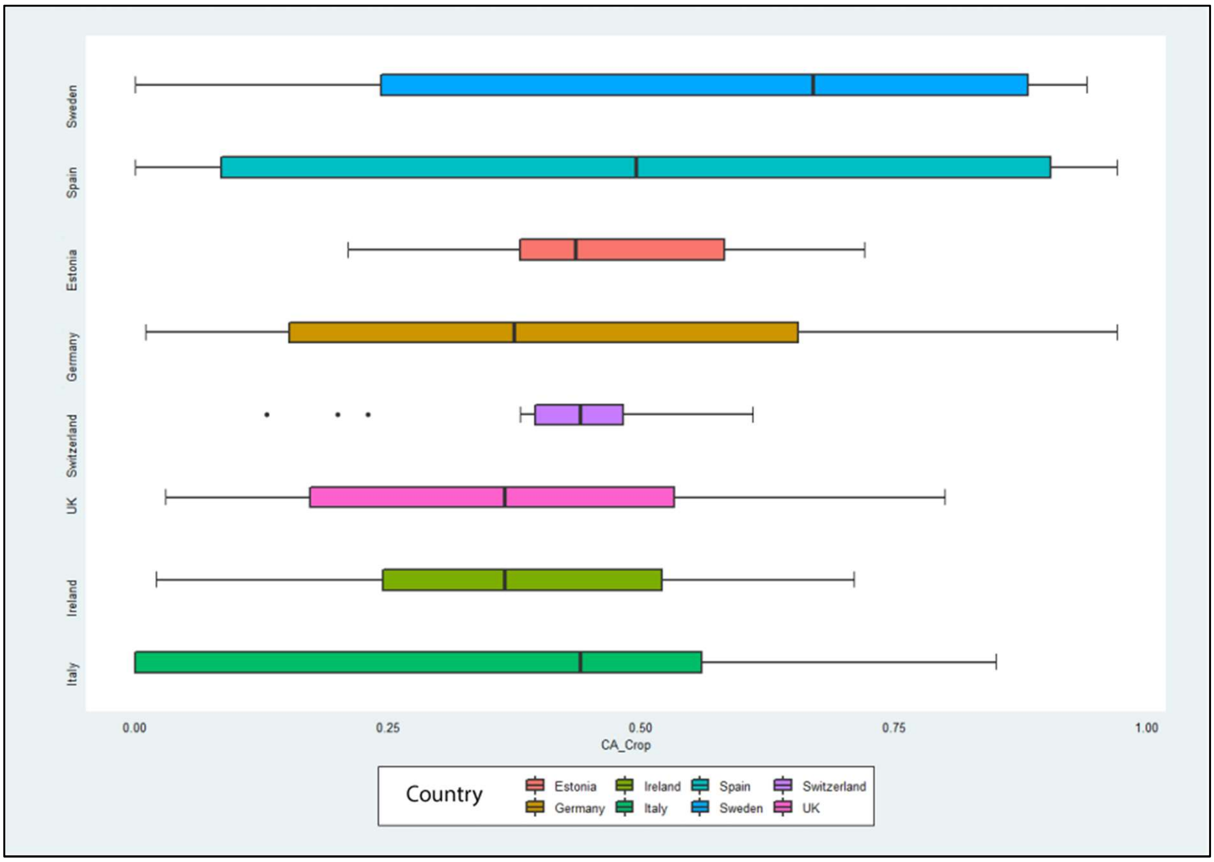


**Figure 4: Gradient of percentage of arable land for each country**

## 2.1. Complex landscape data

The total area for each land cover within a 1-km radius for each country is shown in Figure 5. In every country, the dominant land cover in the OSR sites was arable land (CA_Crop). Since the OSR sites in Spain were comprised of more than 80% of arable land, this suggests that the sites in Spain are the most intensive ones within PoshBee. On the other hand, the proportions of the different land covers in the OSR sites within Ireland, UK and Switzerland were more equally distributed across the countries.

For apple sites, apple orchards were the dominant crop for 3 countries only: Spain, Italy and Germany. Both in Ireland and England, the proportion of grasslands/pastures was greater than arable land or orchards. While the amount of apple orchards seemed rather low in Sweden, Switzerland and Estonia (in comparison to the three countries mentioned before), the proportion of woodlands, grasslands and arable land was evenly distributed.

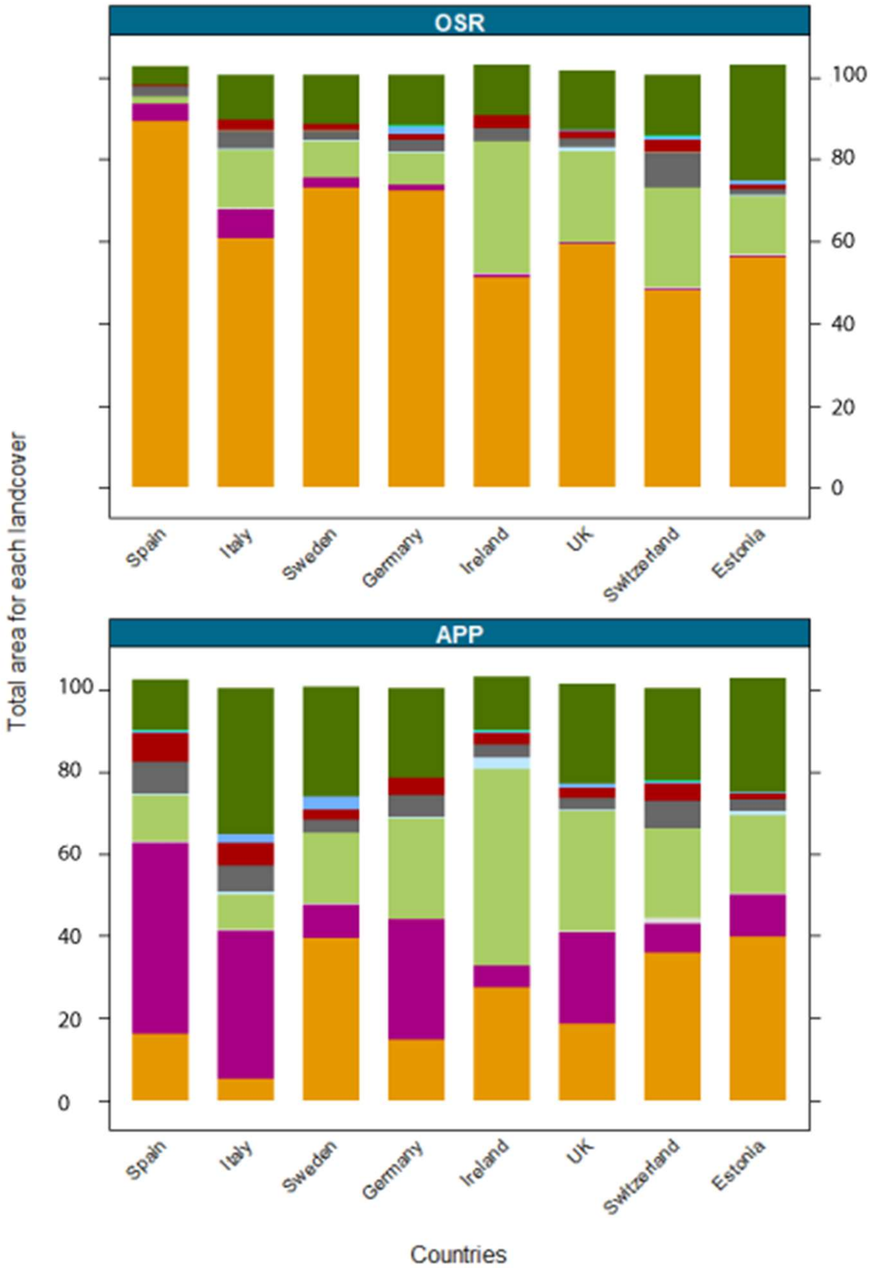


**Figure 5: Proportion of each land cover type within each country**

As a measure of compositional landscape heterogeneity, Shannon's diversity index (SHDI) was calculated at the landscape level with all eleven land cover categories (see Figure 6). Landscape diversity was overall higher in the APP sites than in the OSR sites (Figure 6a and b). The results are on par with the observations derived from Figure 4 and 5. First, the OSR sites of Spain were the ones displaying the lowest landscape diversity. In Figure 5, both OSR and APP sites in Spain were dominated by either arable land and apple orchards, which suggest that these sites are poorly heterogeneous. However, that does not necessarily mean that every site in Spain is characterized by poor landscape diversity, as seen by the wide interquartile ranges (IQR) in Figure 6a, where the landscapes of APP sites are among the most diverse, actually indicating a strong gradient within the country. Second, Switzerland displayed the highest landscape diversity in comparison to the other countries for both APP and OSR sites, but also the shortest gradient. For both crop types, the proportion of the other land cover categories were more evenly distributed in Switzerland than in other countries. In addition, the proportion of arable land was closer to 50% for each crop type (Figure 4) with a small IQR (Figure 6). Finally, the OSR sites of Germany and Sweden show a strong gradient of landscape diversity.

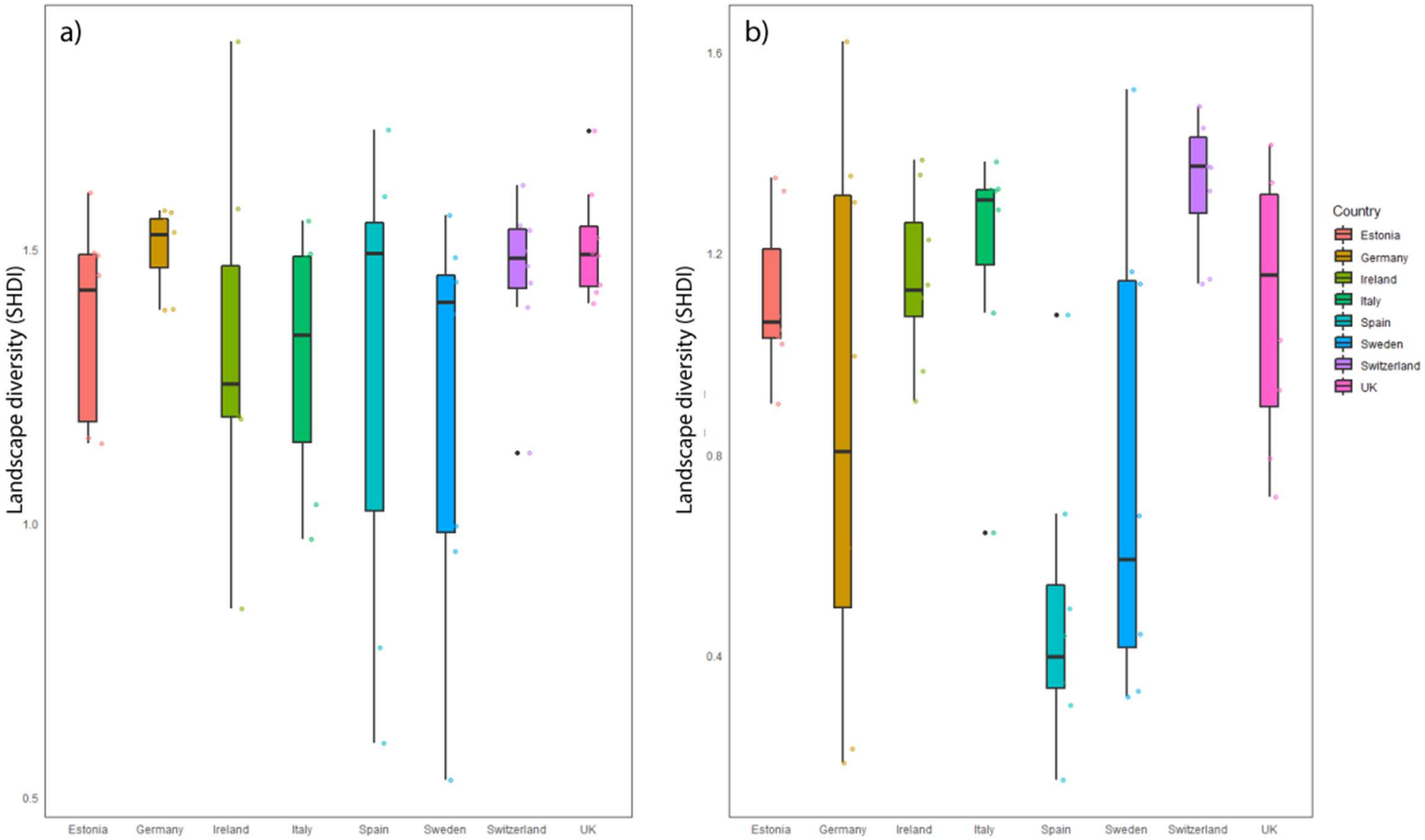


**Figure 6: Box plots showing variations in landscape diversity (SHDI) between the eight countries, with each core site represented as a dot in a) APP sites and b) OSR sites. Black horizontal line indicates the median, box shows the interquartile range (IQR) and the whiskers are 1.5× IQR.**

Finally, a PCA was performed to graphically represent the similarities or dissimilarities between each site based on the composition and the configuration of the landscape (Figure 7, but see section 1.2.2. for a description of the landscape metrics).

The first two axes of the PCA explained 59% of the total variation. The first component, which explained 35% of the variance, discriminated the sites with high landscape diversity (SHDI), high connectivity between woodlands patches (COH_Wood) and high number and complexed shaped apple or crop fields (NP_Apple, Shape_Apple) from the sites with low landscape diversity, low connectivity between the woodlands patches and fewer apple orchards. The second component, which explained 24% of the total variation showed an ecological gradient mostly dominated by the number of arable fields, separating the fields with highly fragmented arable landscapes (smaller patches (NP_Crop) with more irregular shapes (SHAPE_CROP) from the large monocultures of arable land. Finally an ecological gradient of landscape diversity (SHDI) can be observed from the bottom right to the top left of the PCA.

The PCA clearly separated the sites located in the APP crop from the ones located in the OSR crop at the European scale. More than half of the sites selected in OSR sites for Spain, Germany, and Sweden were characterized by low landscape diversity. On the other hand, some of the sites situated in the

APP crop for Spain showed the opposite trend, displaying high landscape diversity. These results observed in the Spanish sites can be explained by the overall proportion of arable land in OSR sites (see Figure 5) and the wide range of landscape diversity measured within the country (Figure 6). While the OSR sites of Albacete are characterized by poor landscape diversity and intensive monocultures, the APP sites of Murcia greatly differ in terms of composition of the landscape (see Figure 3). Another notable result is the clear characterization of the APP sites in Italy from the Trentino region that were dominated by highly fragmented orchard landscapes (NP_Apple) of irregular shapes (SHAPE_Apple). Finally, the sites located in Switzerland, independent from the crop type, were defined by high landscape diversity with smaller and more numerous arable land fields (NP_Crop) of irregular shape (SHAPE_Crop).

Additionally, two more PCA were performed to show the similarities between a) the sites located in OSR sites and b) the sites located in APP sites (See Appendix Figures 10 and 11).

As a key result for further analyses, this PCA shows that, although there is a certain level of clustering within some countries, the overlap among the countries is large enough covering a wide range of landscape characteristics, representative for agricultural landscape across Europe, which allows for reliable further statistical analyses, e.g. as planned in WP2. The larger within-country gradients combined with their larger overlap across countries means that such analyses will not be biased by country specificities or that a particular effect might vanish, e.g. when country is considered as a random effect in statistical models.

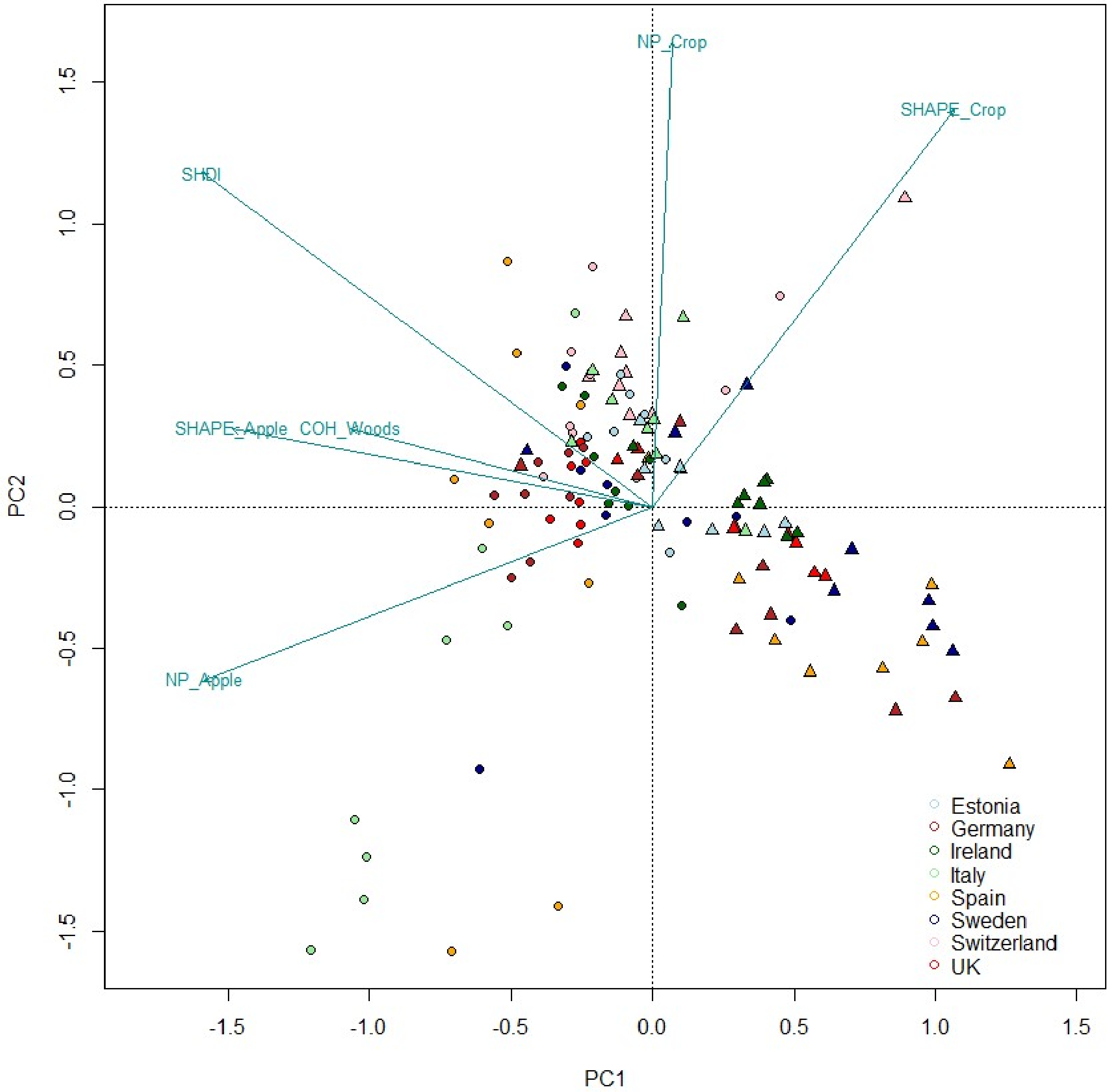


**Figure 7 Graphical interpretation of the PCA computed on all landscape metrics. Each dot represents a site, color based on the country they are located in. The OSR sites are represented by a circle and the APP sites are represented by a triangle.**

## 2.2. Basic landscape data

In addition to the complex data quantified by GIS tools, basic landscape data were recorded at each boundary and adjacent field of the sites. While further analyses are required to allow meaningful comparison between the resource availability at the field scale (basic landscape data) and the landscape scale (complex landscape data), an overview of the total proportion of each land cover types can be seen below.

### 2.2.1. Proportion of land types in the adjacent fields

The total proportion of land types measured in the adjacent fields across all countries can be seen in Figure 8. The most dominant land type was cereals or arable crops other than OSR (28.7%). Additionally, apple orchards (13.3%) and other types of orchards (7.63%) defined more than 20% of the surrounding fields. However, up to 25% of the adjacent fields were characterized by improved grasslands (17.1%) and semi-natural habitats (7.83%). These habitats are essential for pollinators by providing critical floral and nesting resources.

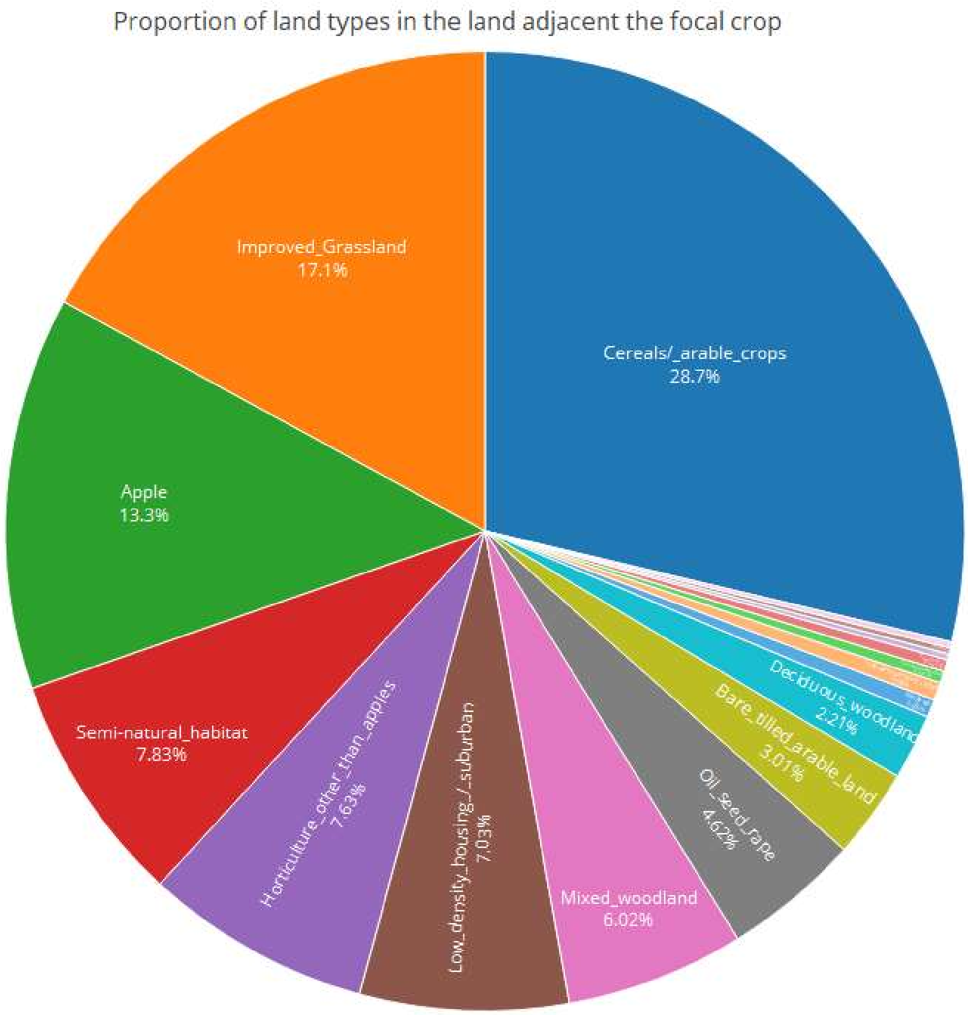


**Figure 8 Overall proportion of land types recorded in the adjacent fields of the sites across all countries**

### 2.2.2. Proportion of land types at the boundaries

Similarly, the land cover types present at each boundary surrounding the sites was recorded following the EUNIS classification system (Figure 9). The total proportion was characterized by 30% of hedgerows and 14.1% of improved grasslands, which can provide pollinators with additional resources. More than 41.8% of the boundaries were bare or non-existent, suggesting than almost half of the boundaries across all countries provided no additional resources.

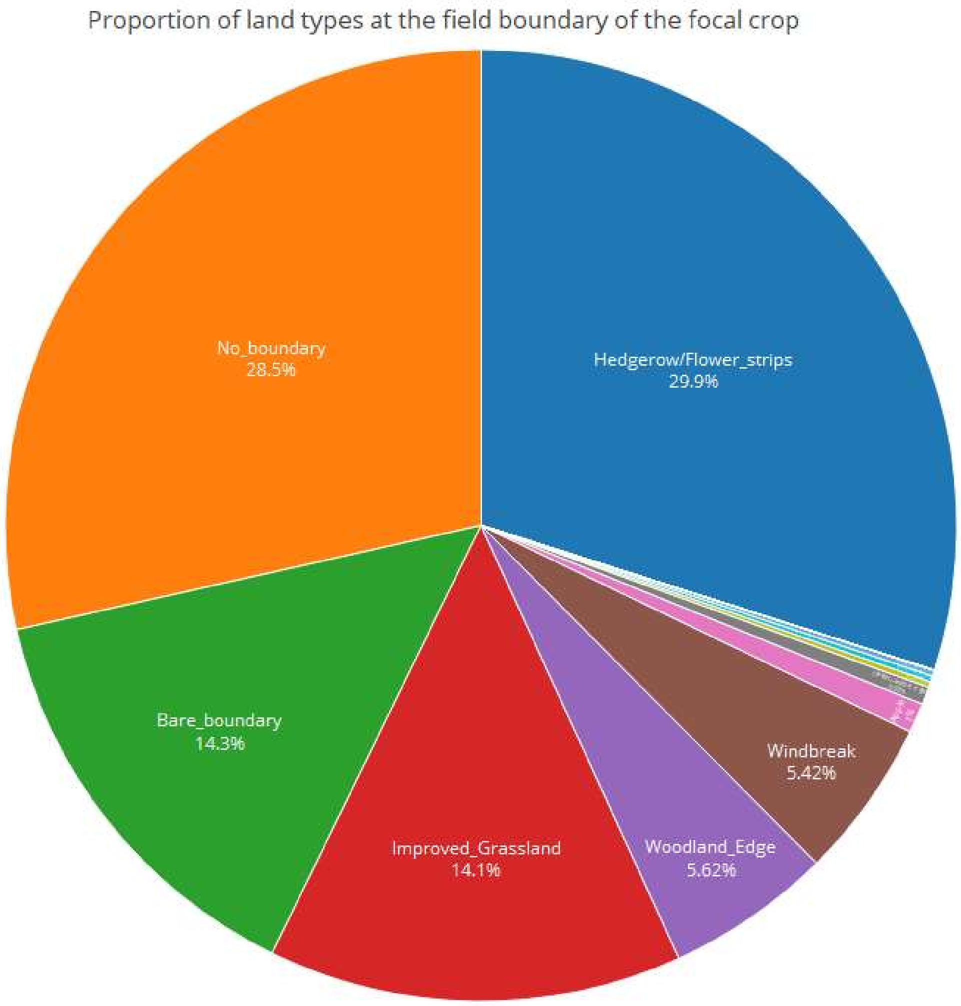


**Figure 9: Total proportion of land types recorded at each boundary of the sites across the eight countries**

## 3. Acknowledgements

We would like to thank all the farmers who participated in the PoshBee project and allowed us to use their sites for the sentinel pollinators. Additionally, we thank all the WP1 partners for collecting the basic landscape data and providing us the coordinates for the complex landscape data.

## 4. Appendix

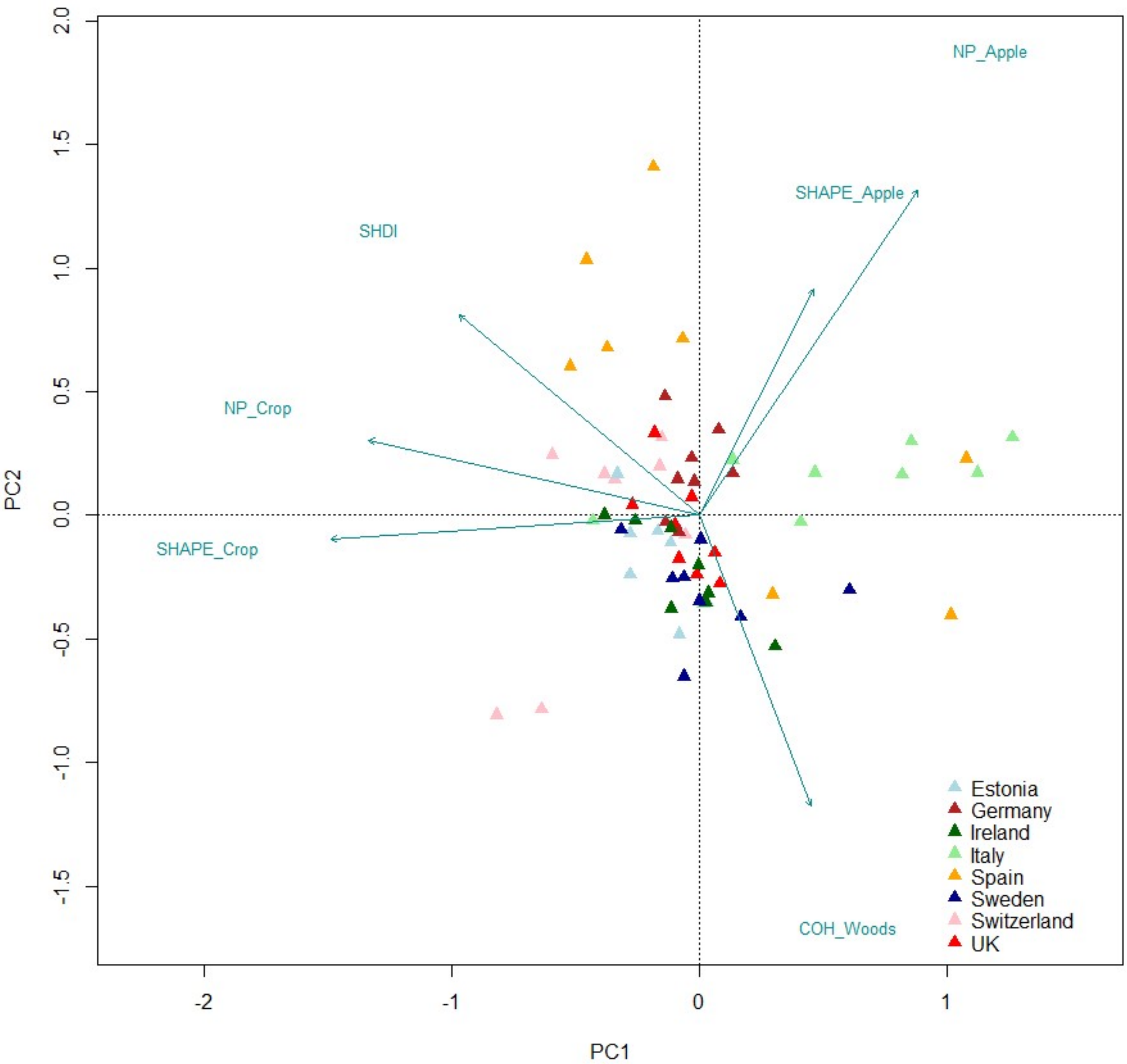


**Figure 10 Graphical interpretation of the PCA computed on all landscape metrics in the apple sites (APP). Each dot represents a site, color based on the country they are located in.**

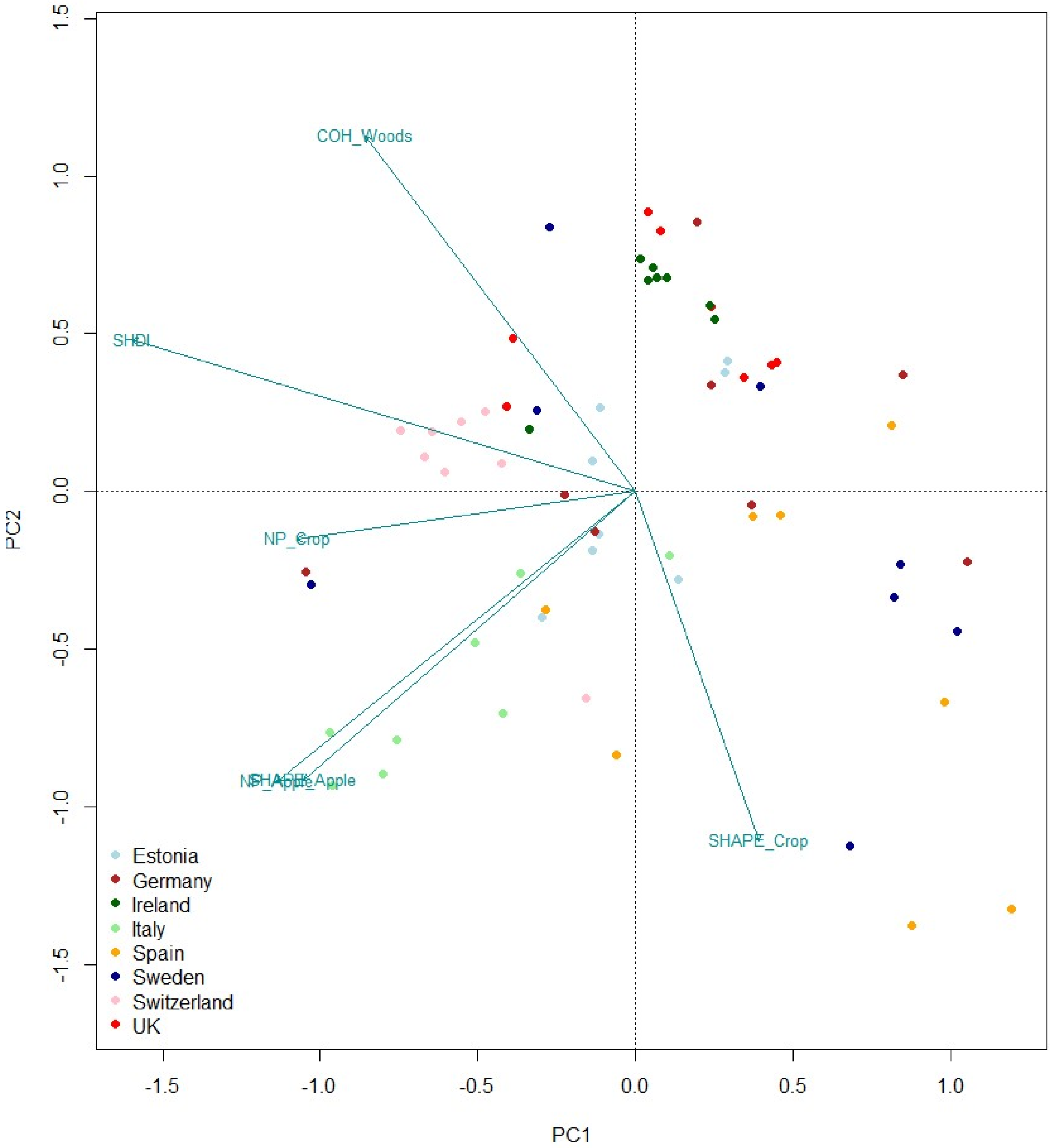


**Figure 11 Graphical interpretation of the PCA computed on all landscape metrics in the oilseed rape sites (OSR). Each dot represents a site, color based on the country they are located in.**

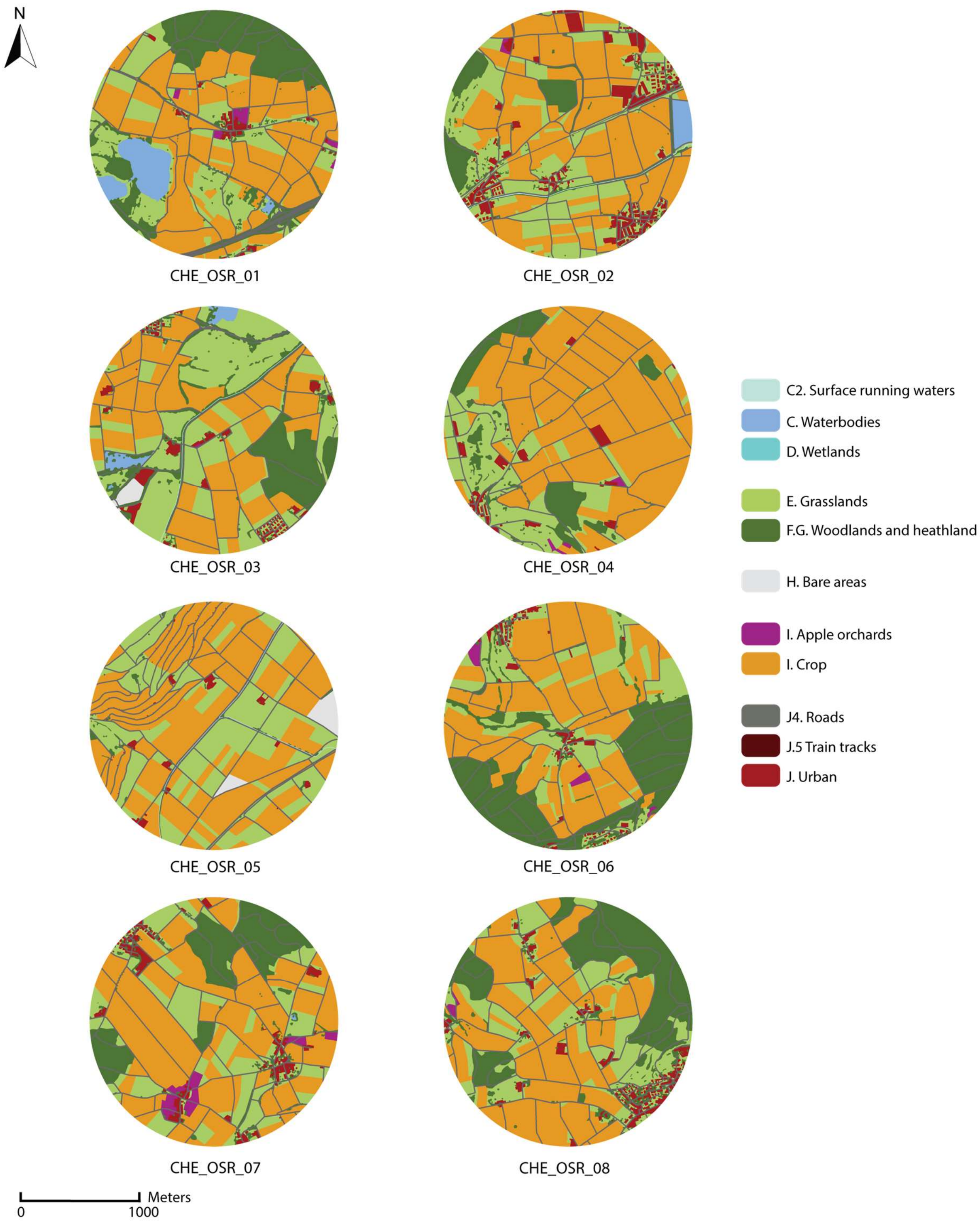


**Figure 12 Digitized habitat maps of the oilseed rape sites (OSR) located in Switzerland (CHE).**

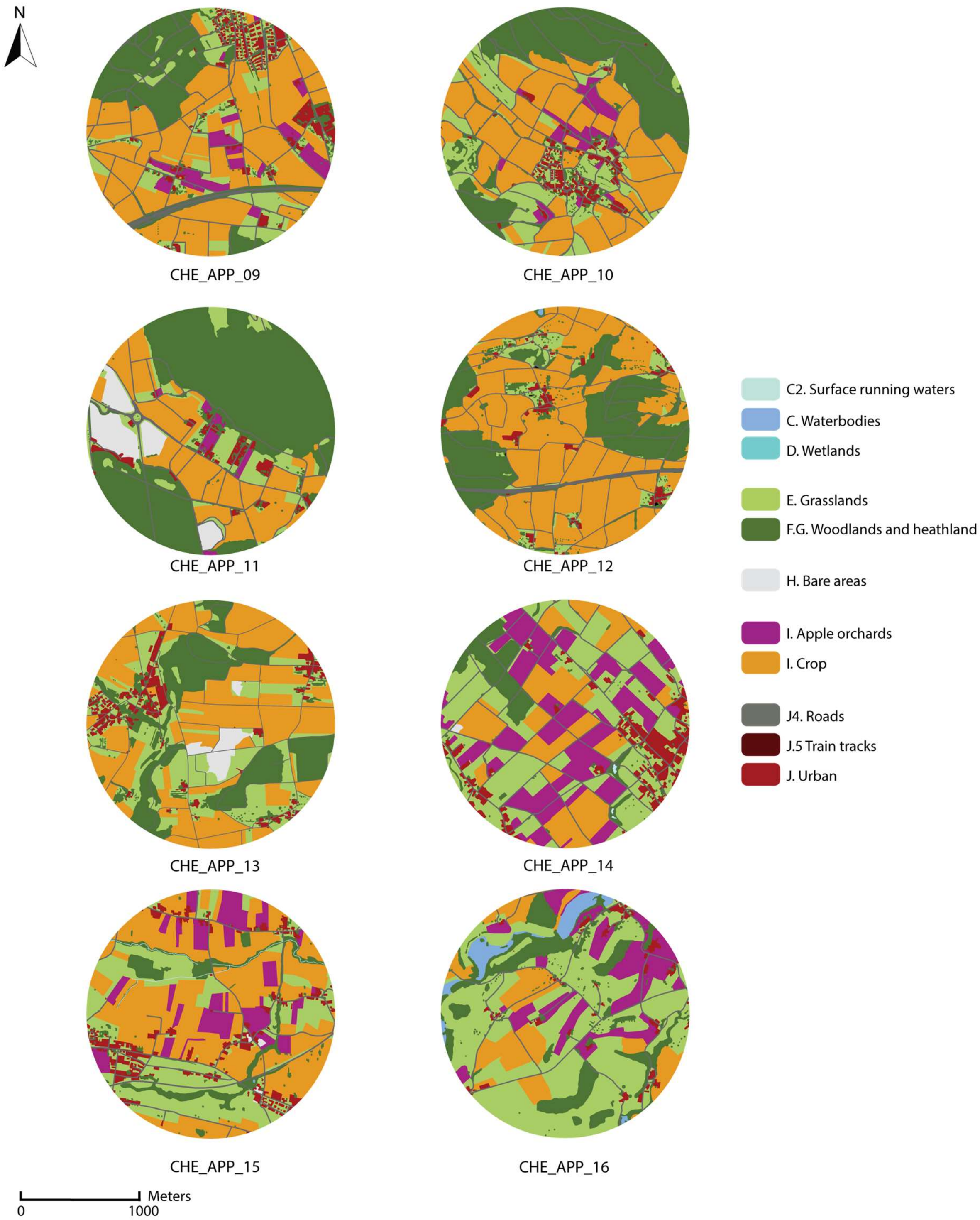


**Figure 13 Digitized habitat maps of the apple sites (APP) located in Switzerland (CHE).**


**Figure 14 Digitized habitat maps of the oilseed rape sites (OSR) located in Spain (SPA).**

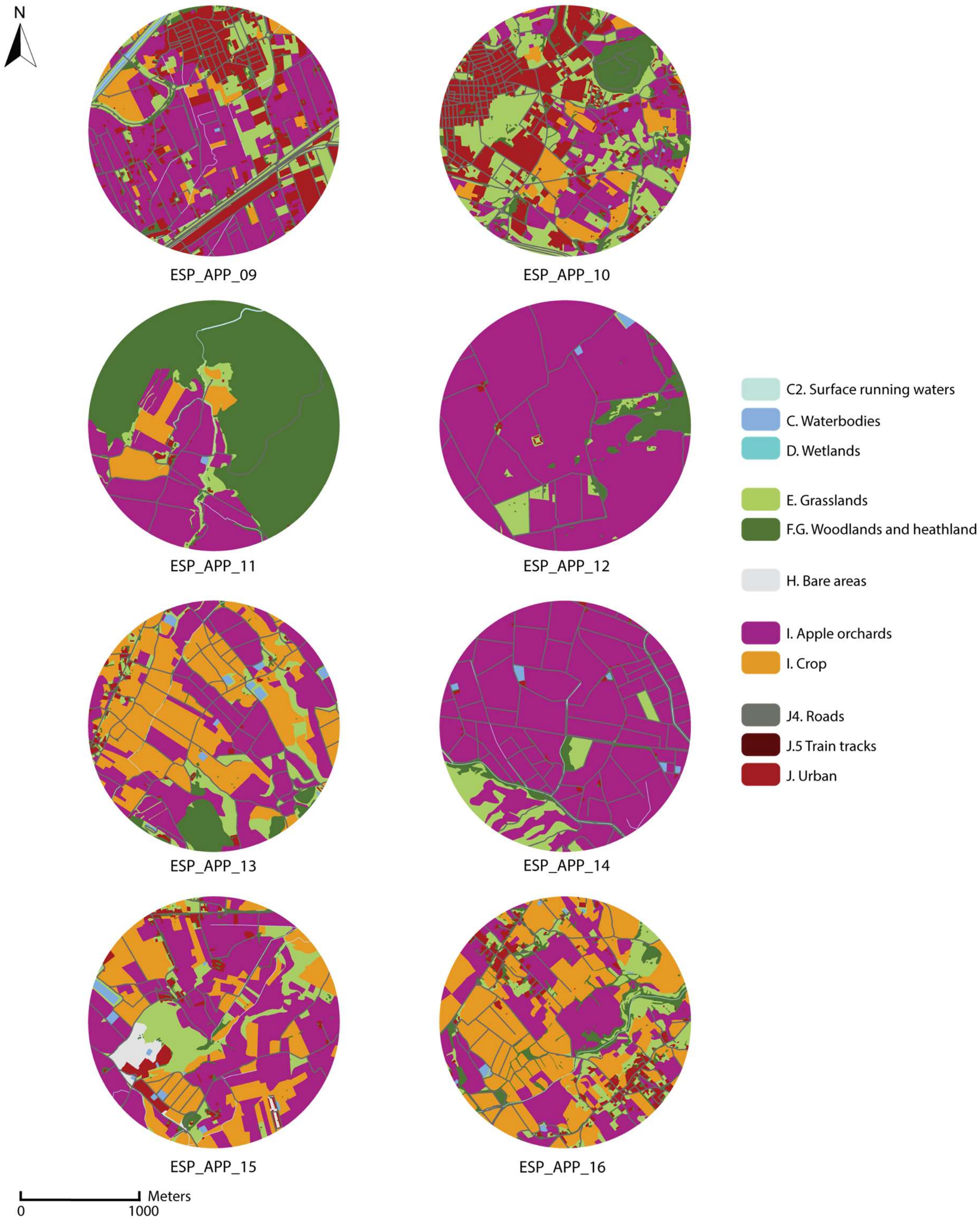


**Figure 15 Digitized habitat maps of the apple sites (APP) located in Spain (ESP).**

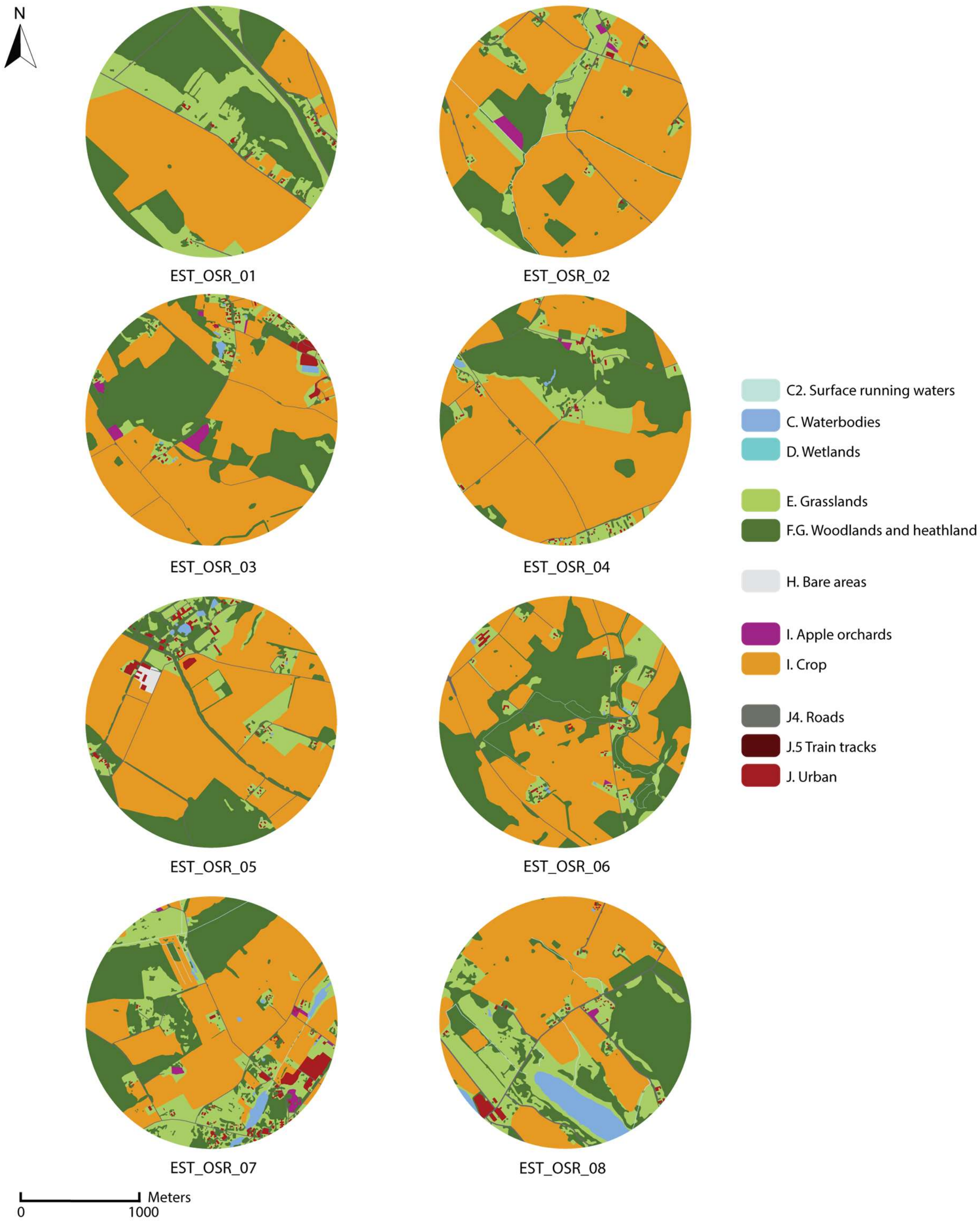


**Figure 16 Digitized habitat maps of the oilseed rape sites (OSR) located in Estonia (EST).**

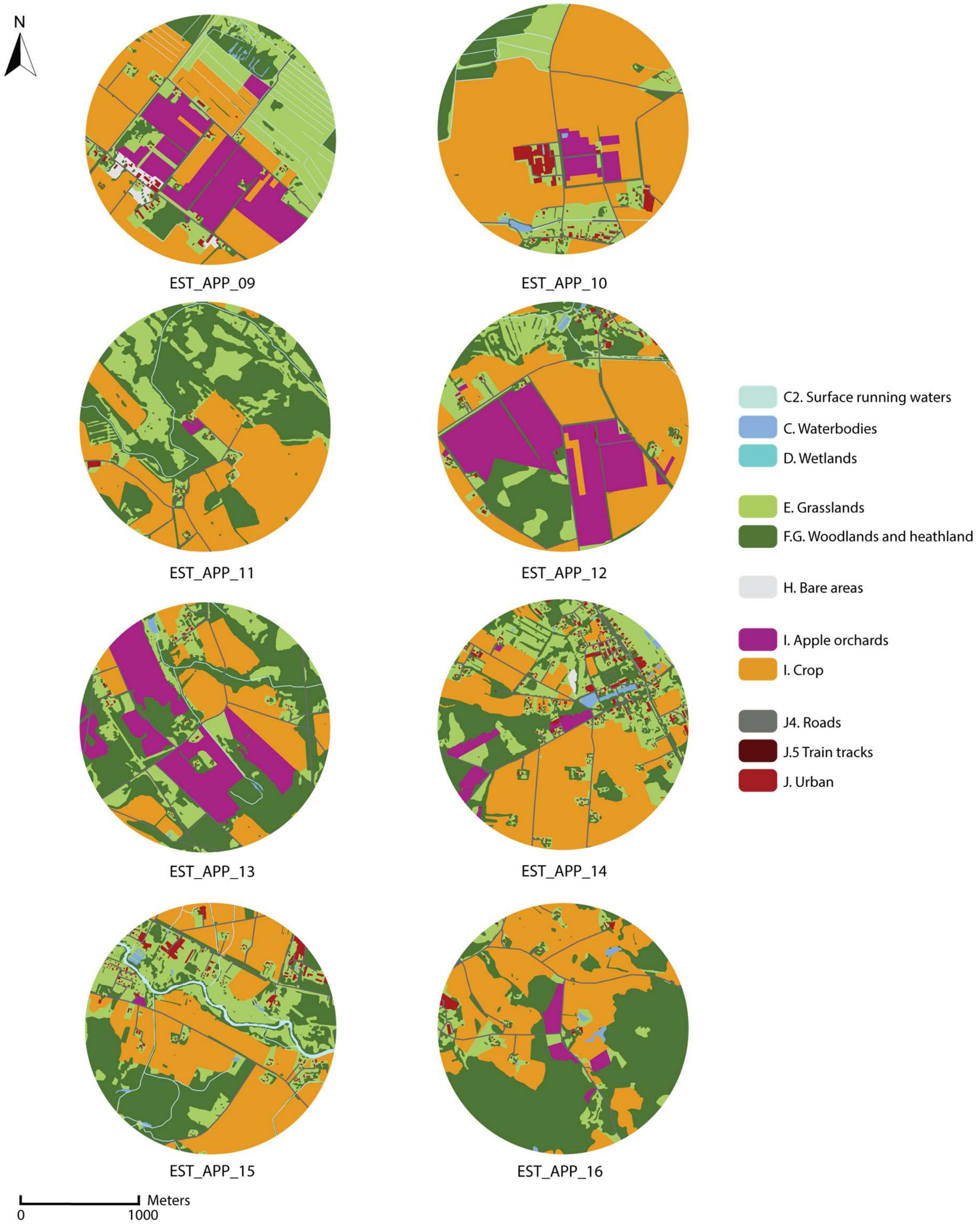


**Figure 17 Digitized habitat maps of the apple sites (APP) located in Estonia (EST).**

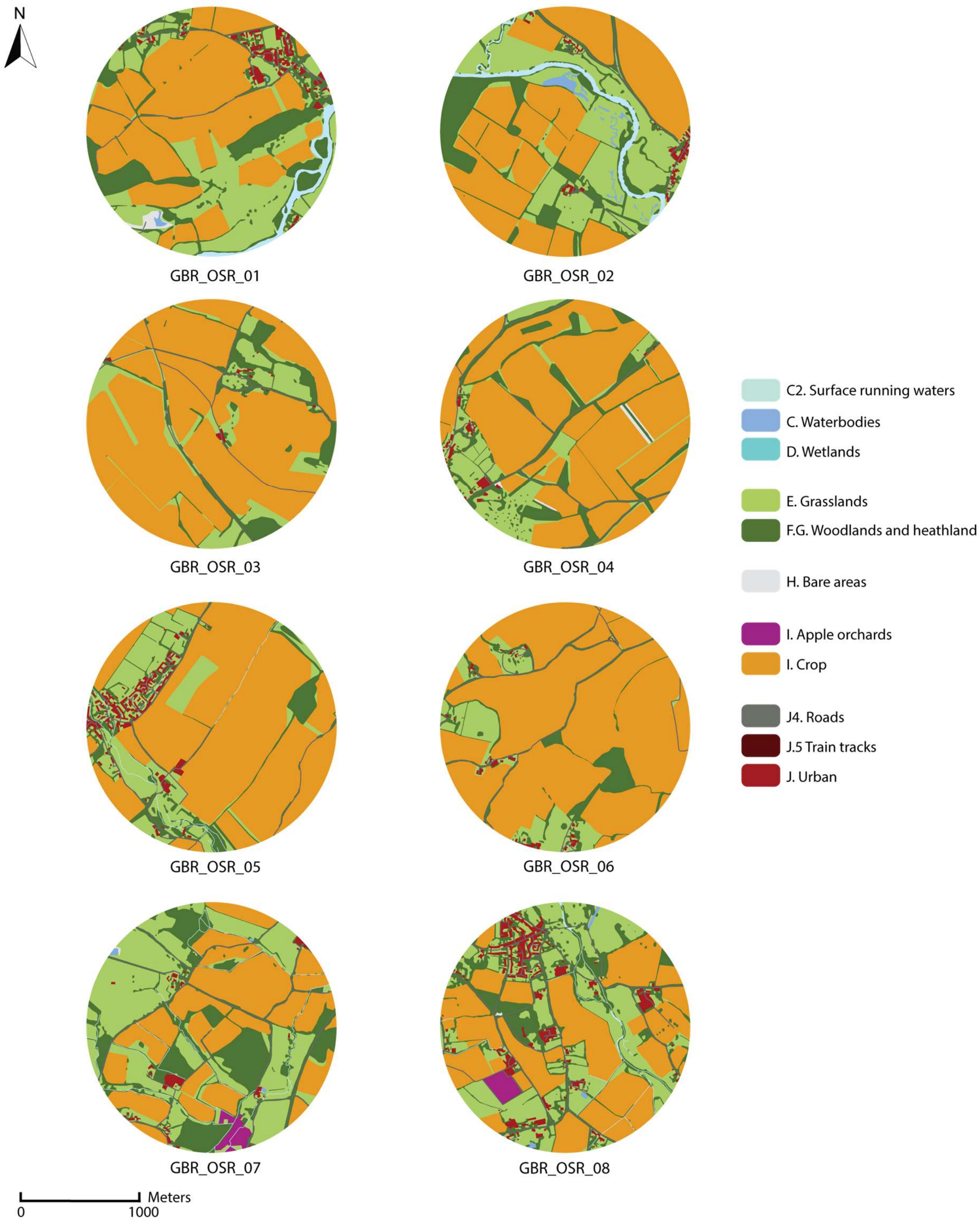


**Figure 18 Digitized habitat maps of the oilseed rape sites (OSR) located in England (GBR).**

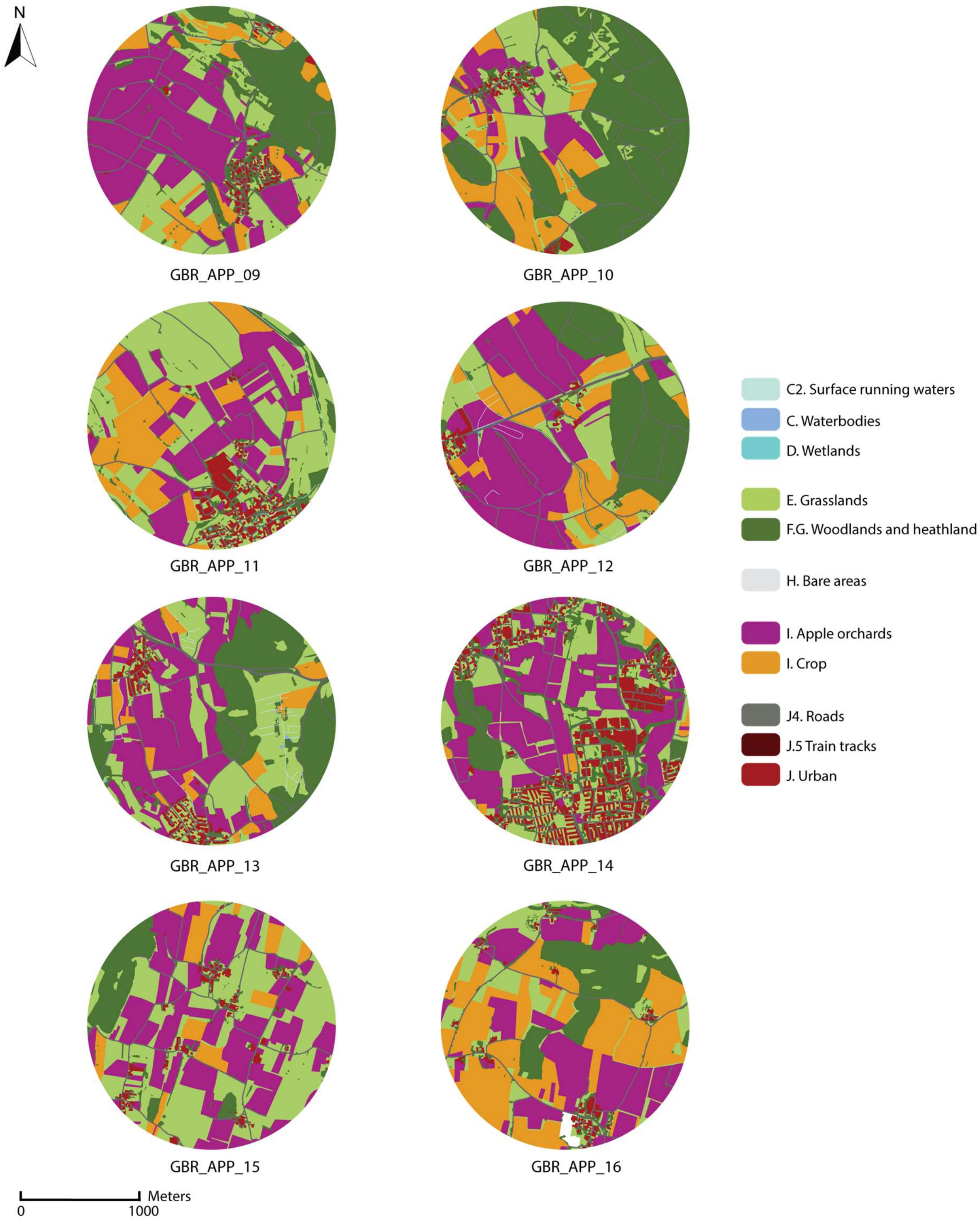


**Figure 19 Digitized habitat maps of the apple sites (APP) located in England (GBR).**

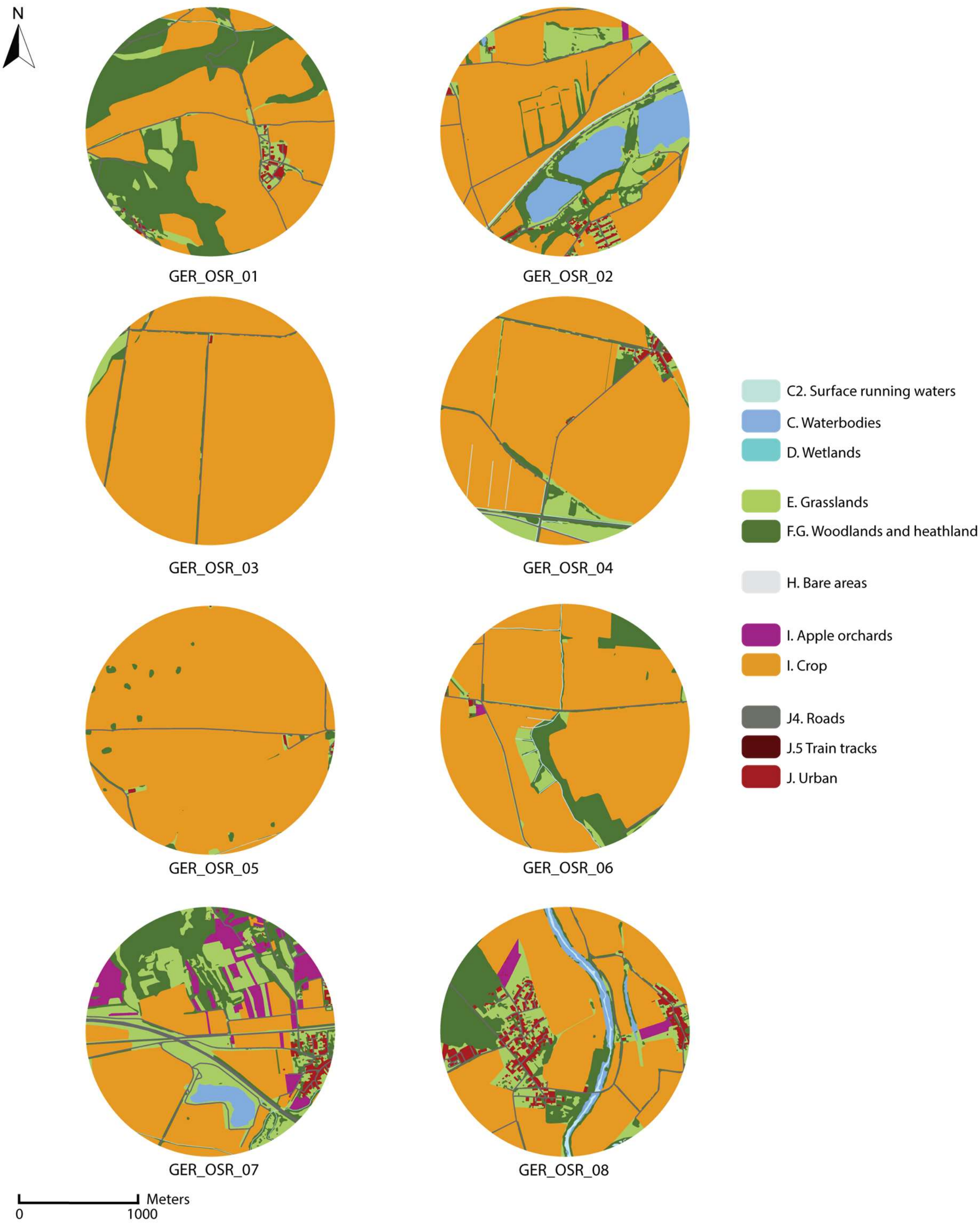


**Figure 20 Digitized habitat maps of the oilseed rape sites (OSR) located in Germany (GER).**

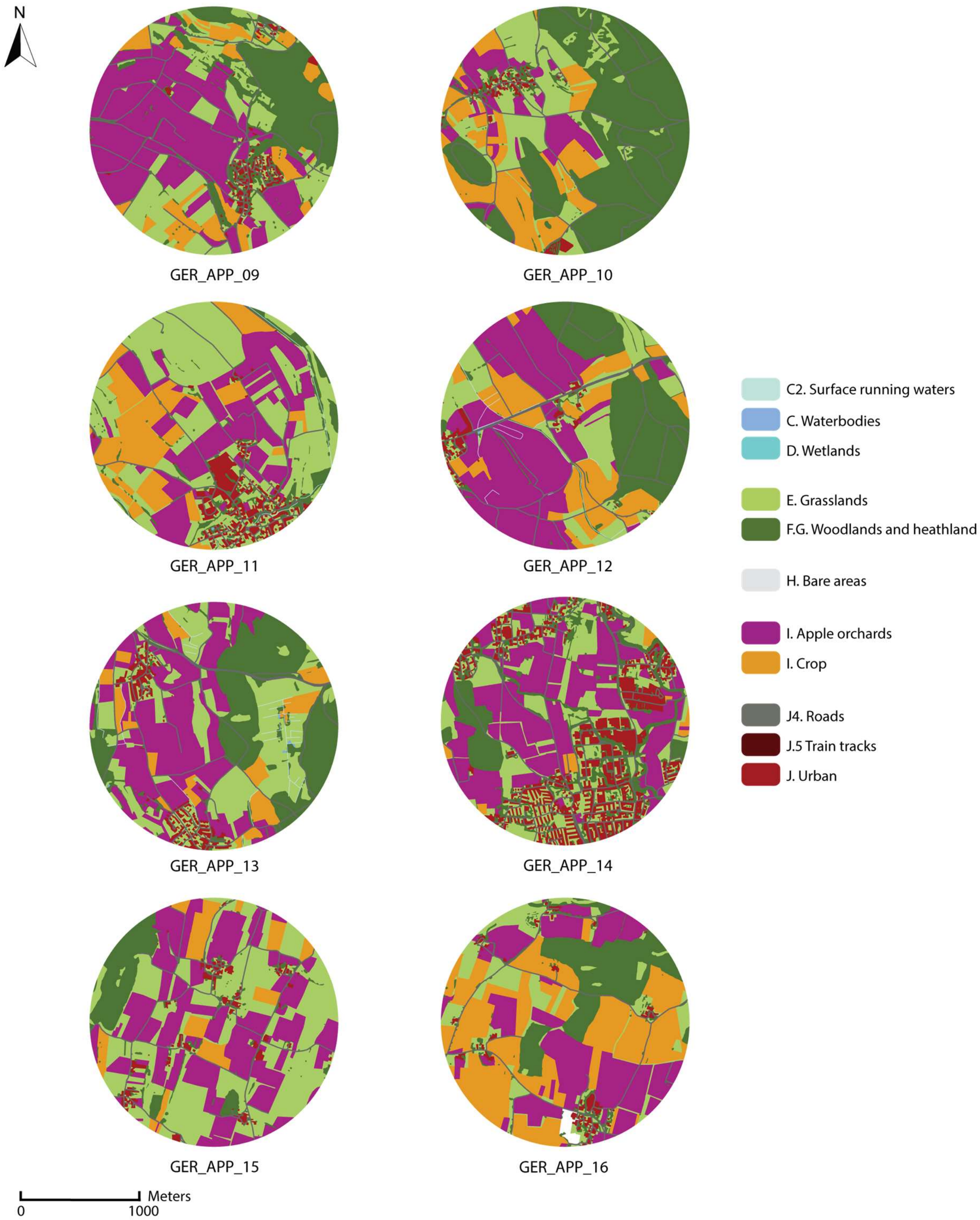


**Figure 21 Digitized habitat maps of the apple sites (APP) located in Germany (GER).**

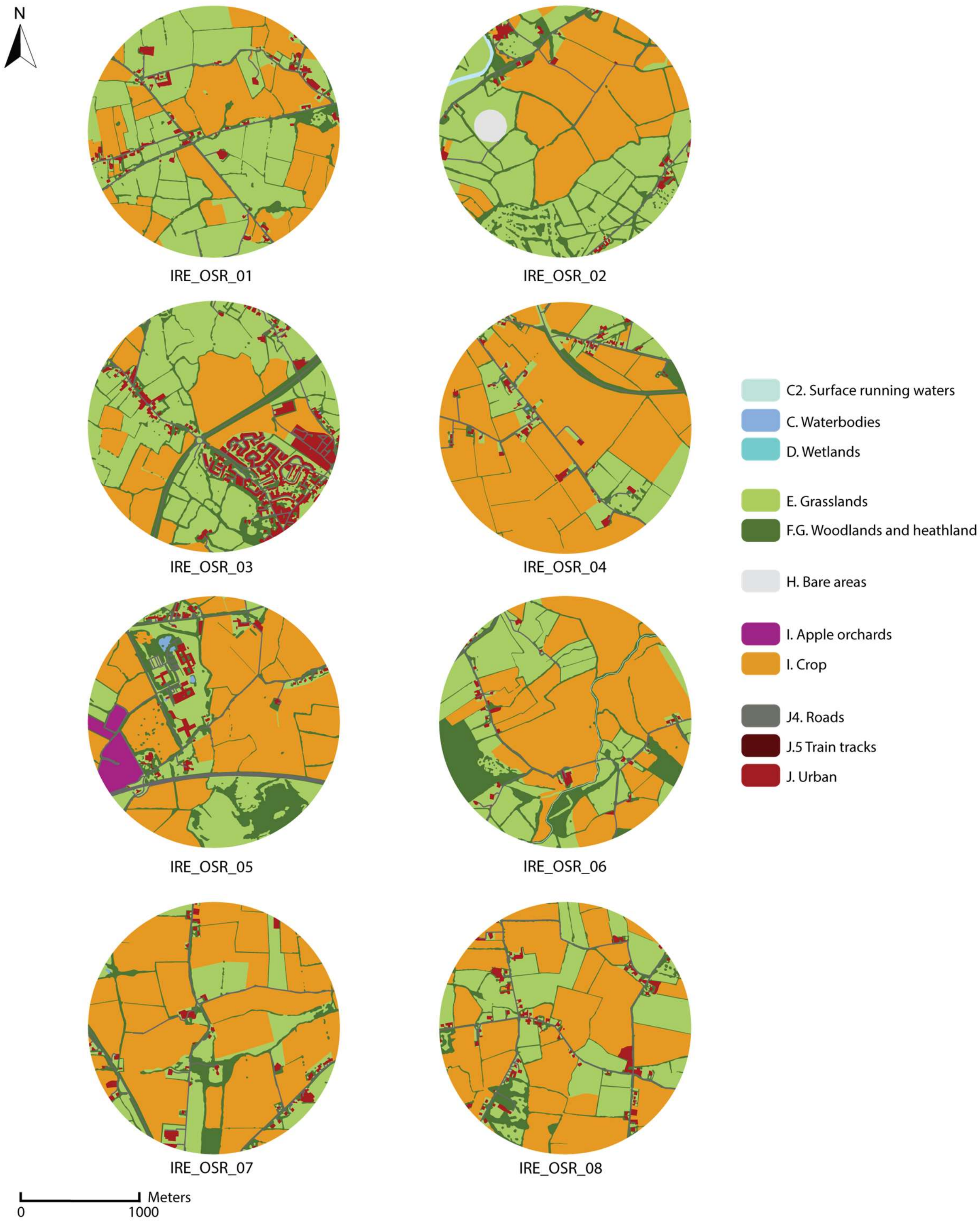


**Figure 22 Digitized habitat maps of the oilseed rape sites (OSR) located in Ireland (IRE).**

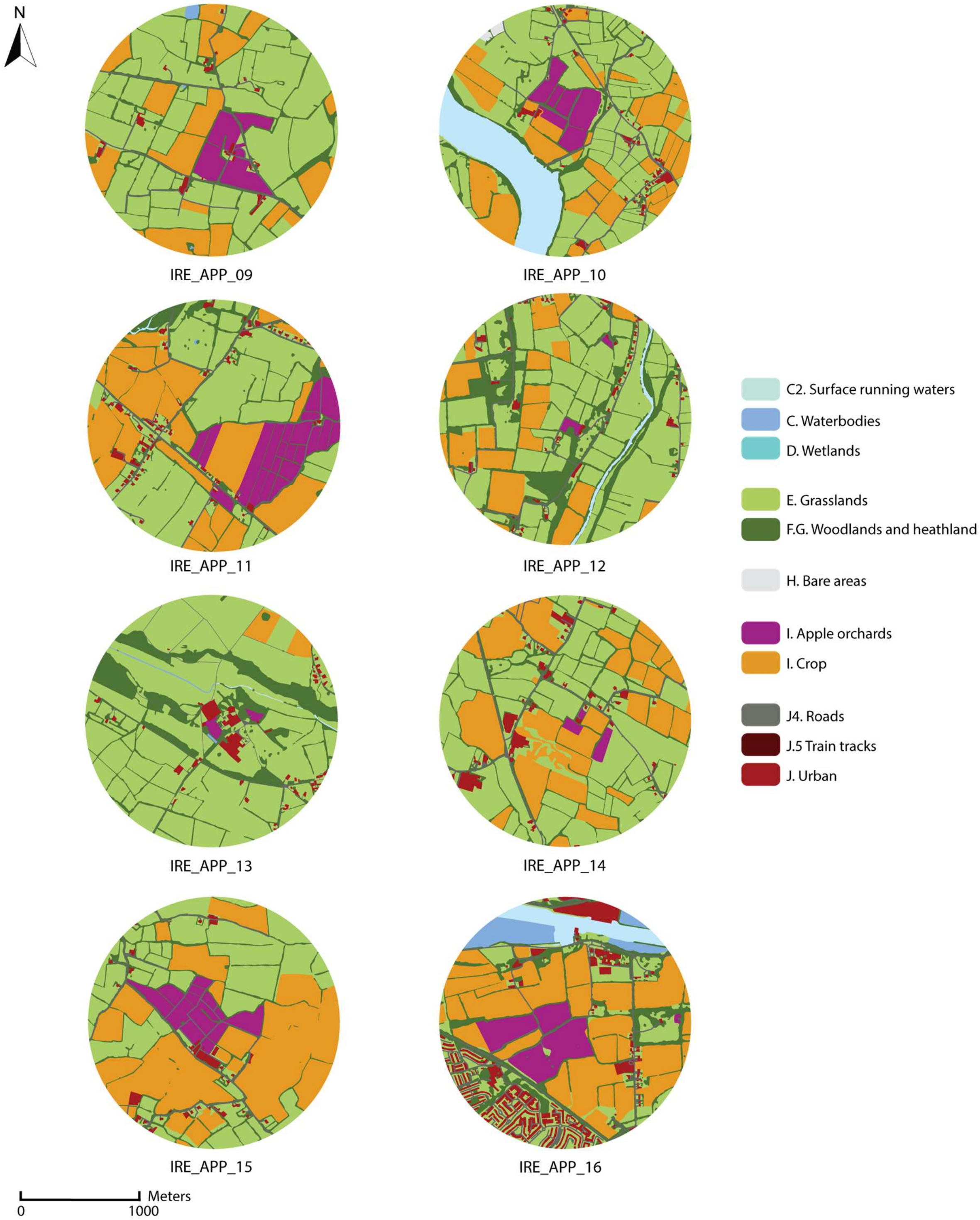


**Figure 23 Digitized habitat maps of the apple sites (APP) located in Ireland (IRE).**

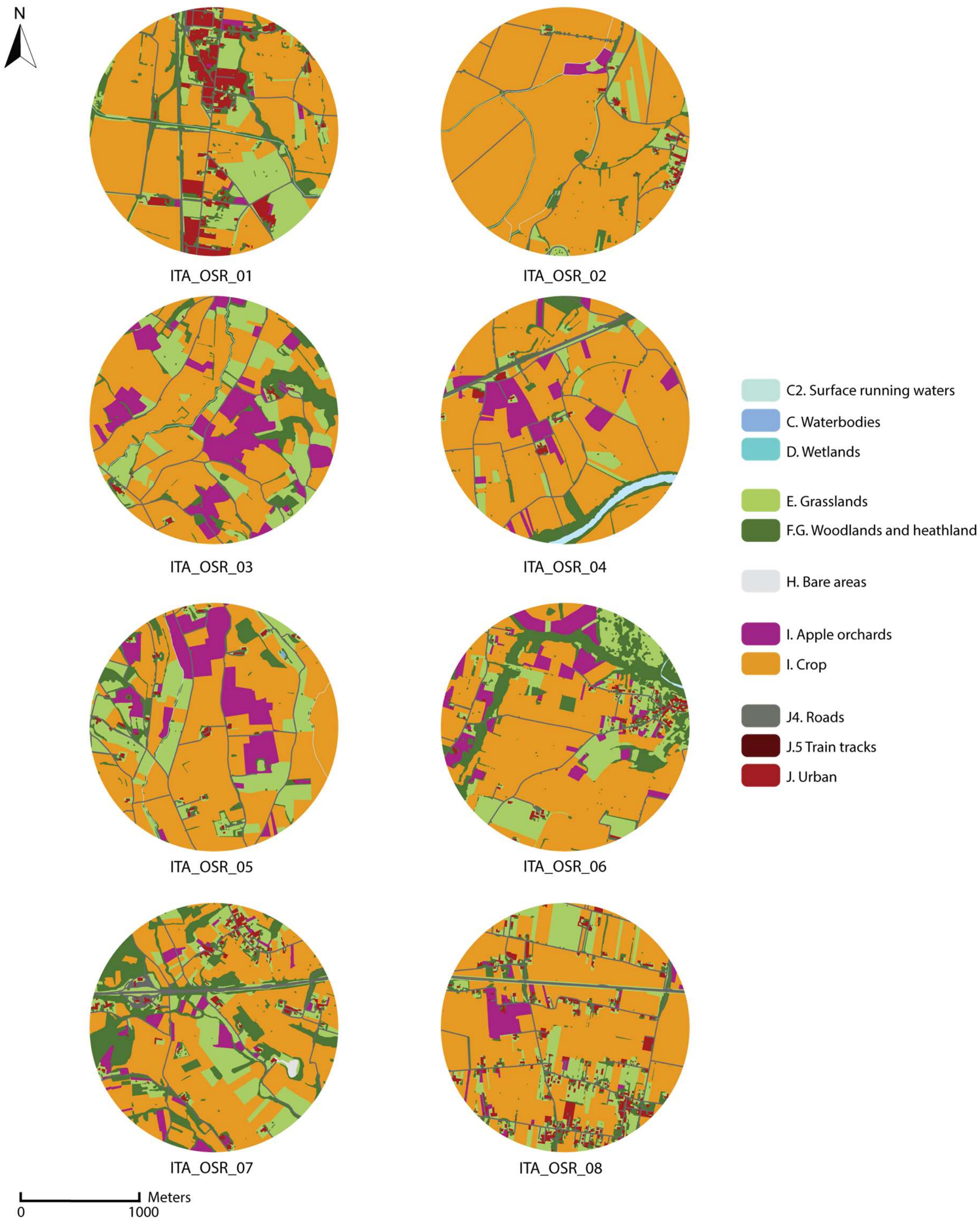


**Figure 24 Digitized habitat maps of the oilseed rape sites (OSR) located in Italy (ITA).**

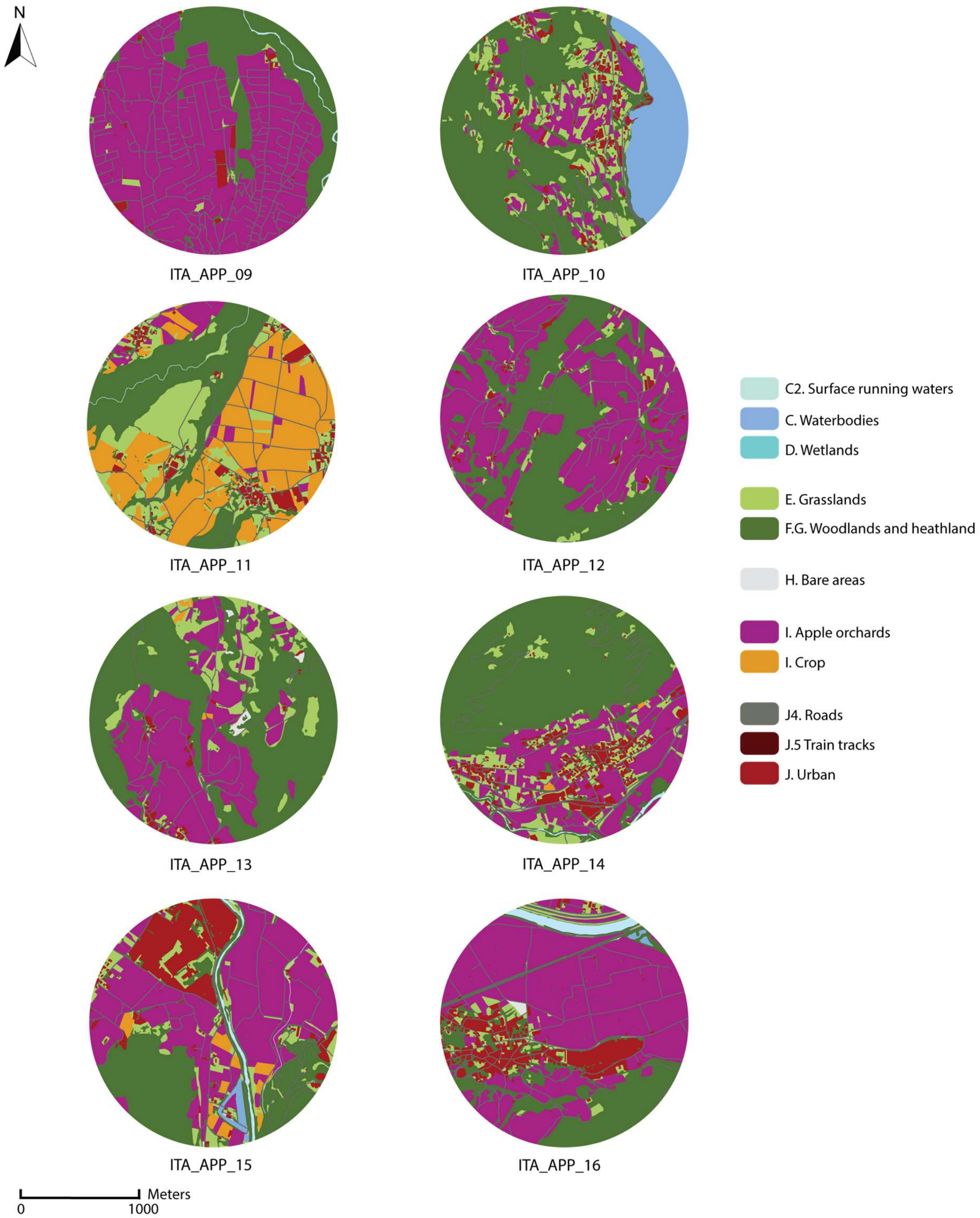


**Figure 25 Digitized habitat maps of the apple sites (APP) located in Italy (ITA).**

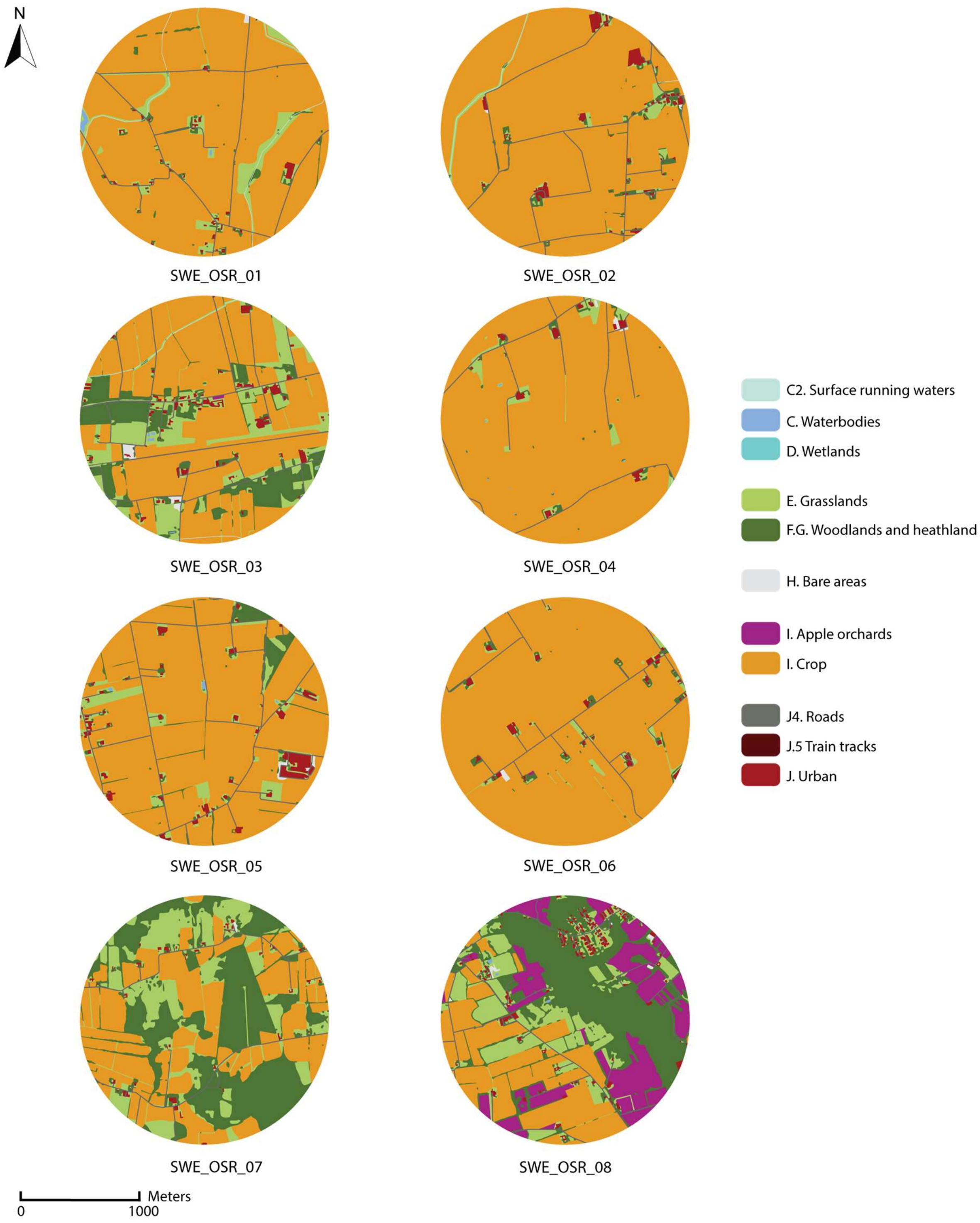


**Figure 26 Digitized habitat maps of the oilseed rape sites (OSR) located in Sweden (SWE).**

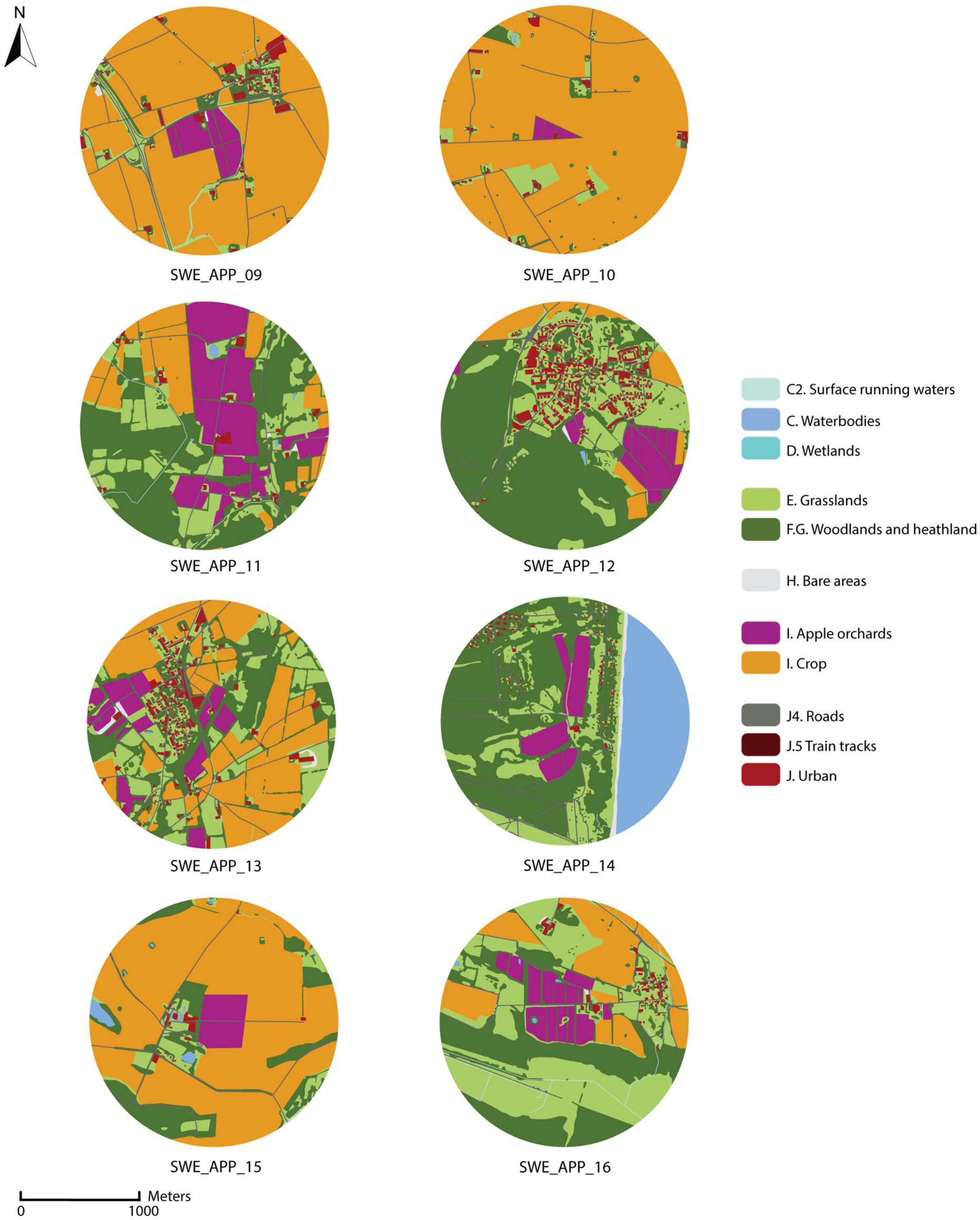


**Figure 27 Digitized habitat maps of the apple sites (APP) located in Sweden (SWE).**