Landscape data

Deliverable 1.7

25 April 2022

Jordan Chetcuti[1], Alina Premrov[1], Cecilia Costa[2], Elżbieta Ziółkowska[3], Jane Stout[1], Christopher John Topping[4]

[1]Trinity College Dublin, [2]Council for Agricultural Research and Agricultural Economy Analysis, [3]Jagiellonian University, Kraków, [4] Aarhus University

PoshBee

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

Prepared under contract from the European Commission

Grant agreement No. 773921
EU Horizon 2020 Research and Innovation action

Project acronym:	**PoshBee**
Project full title:	**Pan-european assessment, monitoring, and mitigation of stressors on the health of bees**
Start of the project:	June 2018
Duration:	60 months
Project coordinator:	Professor Mark Brown Royal Holloway, University of London www.poshbee.eu
Deliverable title:	Landscape data
Deliverable n°:	D1.7
Nature of the deliverable:	Other
Dissemination level:	Public
WP responsible:	WP1
Lead beneficiary:	TCD
Citation:	CHETCUTI, J., PREMROV, A., COSTA, C., TOPPING, CJ. & STOUT, JC. (2022). *Landscape Data*. Deliverable D1.7 EU Horizon 2020 PoshBee Project, Grant agreement No. 773921.
Due date of deliverable:	Month n° 47
Actual submission date:	Month n° 47

Deliverable status:

Version	Status	Date	Author(s)
1.0	Draft	25 April 2022	CHETCUTI, J., PREMROV, A., COSTA, C., E. ZIOLKOWSKA, STOUT, JC., & TOPPING, CJ.

Table of Contents

1. Summary

Deliverable 1.7 is the collated high-quality landscape data for Ireland and Italy that will be used in the Animal, Landscape and Man Simulation System (ALMaSS) to run the MUST-B models for risk assessment of bee health. The dataset consists of land cover, agriculture and vegetation data, collected from various external sources including national high-resolution topographical databases, and Land Parcel Identification System (LPIS), and supported by expert knowledge. This process has been conducted separately for Ireland and Italy, with researchers at Trinity College Dublin (Ireland) and Council for Agricultural Research and Agricultural Economy Analysis (Italy) collaborating on a common methodology, tailored to each country, defined and guided by the needs of ALMaSS and Social-Ecological Systems Simulation centre partners at Aarhus University in Denmark (AU) and Jagiellonian University in Kraków, Poland (UJ). All data is collected and collated but cannot be shared in the report due to data ownership restrictions. However, a derived data set will be provided as open access before the end of May 2023. This work was assisted by Elżbieta Ziółkowska (UJ) through collaboration with the H2020 EcoStack project.

In this report, first a general overview of the ALMaSS landscape generation process is presented followed by description of the main data sources identified and collected in each country.

2. Overview of ALMaSS landscape generation process

2.1. Landscape representation in ALMaSS

The landscape data collected was targeted for use by the ALMaSS simulation system (Work Package 8, Task 8.5: Develop a multi-species Environmental Risk Assessment (ERA) tool for evaluating the potential effects of agrochemicals or farming practices on bees). ALMaSS, is an open-source project hosted on GitLab with online documentation using the ODdox (Overview Design doxygen) protocol (Topping et al., 2010). ALMaSS integrates agent-based models of selected species with a detailed description of an environment (landscape) from which modelled individuals obtain information necessary to simulate their behaviour. The data collected under WP1 was aimed at providing the ALMaSS with basis for simulating Irish and Italian landscapes.

In ALMaSS, landscapes are modelled using a detailed, spatio-temporal representation which provides a realistic environment for agent-based simulations of the focal species. In this representation:

- *Spatial landscape heterogeneity* is described by a detailed raster land cover map with complete coverage and spatial resolution of 1 m^2. Each unit in the raster land cover map is classified in accordance with its landscape element type (e.g., natural or permanent grassland, field in rotation, build-up area), including detailed structures important for the species under consideration, such as hedgerows or field margins. To facilitate the primary agricultural risk assessment role of ALMaSS, the model also uses agricultural LPIS data, allowing for the identification of field boundaries and fields belonging to the same farm (managed by the same farmer). Farm units are classified into different types, e.g., cattle, pig or arable farms, based on structure of crops grown and animals present in the farm. This structure allows to incorporate information on farm management to the description of spatial heterogeneity in a given point of time (Topping et al. 2003, 2016).
- *Temporal landscape heterogeneity* includes both crop management throughout a year, described through individually tailored management plans for each crop, and the cropping system understood as a pluriannual crop rotation. Associated vegetation growth models for

all modelled vegetation types and crops supply vegetation height, green and total, biomass on a daily basis and are fed by weather conditions (mean daily temperature, mean daily wind speed and daily sum of precipitation).

The generation of the ALMaSS landscape models follows the methodology described in detail in Topping et al. (2016), and it is based on previous experiences with model landscape generation for Denmark. The whole process can be divided into the following sub-tasks: (i) spatial (landscape) and non-spatial data collection & quality check, (ii) ALMaSS landscape map generation (spatial component), (iii) incorporation of crop management & vegetation growth (dynamic component).

2.2. Major categories of data needed for the generation of ALMaSS landscape model

The generation of the ALMaSS landscape model is based on the information from different data sources of sufficiently high resolution and quality. The following categories of data are necessary (Fig. 1):

i. *Land use/ land cover information* including the map layers presenting natural and/or semi-natural landscape elements (e.g., rivers or streams, lakes, bare sand or rock, steep slopes); natural or semi-natural vegetation (e.g., hedgerows, open vegetation types, forest, isolated trees); infrastructure (e.g., roads, buildings or industry); and protected areas.
   Such information usually comes from different data sources, but in most cases the topographic object databases with level of details corresponding with topographic maps at the scale of 1:5 000 – 1:25 000 are the most important source of land cover/land use information needed for the ALMaSS landscape model generation.
ii. *Agriculture* (e.g., field boundaries linked to farm management) - Under the Common Agricultural Policy (CAP), if farmers want to apply for the EU subsidies they are obligated to report for each individual reference parcel of crop/crops they grow (with information of area of each crop grown) and the number of livestock they own. The LPIS has been developed in each of the EU country to support CAP. This stores geographic information on 'reference parcels'. Different types of 'reference parcels' can be used including (i) agricultural parcels, (ii) farmer blocks, (iii) physical blocks, and (iv) cadastral parcels, depending on the country. The data on 'reference parcels' together with agricultural register (related information on type of crops grown and their coverage) needs to be merged with the land use/ land cover information from (i).
   Since the parcel layer is based on subsidy payments from EU, and it is mandatory for farmers claiming subsidy to make the delineation/definition of the parcel(s), this layer has a biased level of detail depending on the country / region. On those landscape windows where the information regarding the field parcels is too scarce or incomplete, one strategy is to use fine spatial resolution image data (e.g., Sentinel-2 time series data, orthophoto), pixel and object-based image processing and analysis methods to determine the field boundaries and the crop types.
iii. *Farm animals data* (Animal Identification and Reg. System) - together with the register of crops this data is used to classify farm units into general farm types.
iv. *Soil type* information for vegetated landscape elements – the ALMaSS landscape simulator modifies the actual production on each field based on the dominant soil type. Soil data at the EU level were obtained from the European Soil Database provided by the Joint Research Centre.

v. *Weather data* – including historical data on mean daily temperatures, wind speed and daily sum of precipitation for at least 10 years. At the EU level these data can be obtained from the European Climate Assessment & Dataset project.

vi. *Up-to-date crop management plans* – describing time windows and probabilities of occurrence of all farming operations including soil cultivation practices, as well as fertilizer and pesticide applications.

vii. *Vegetation growth models* if not already in ALMaSS.

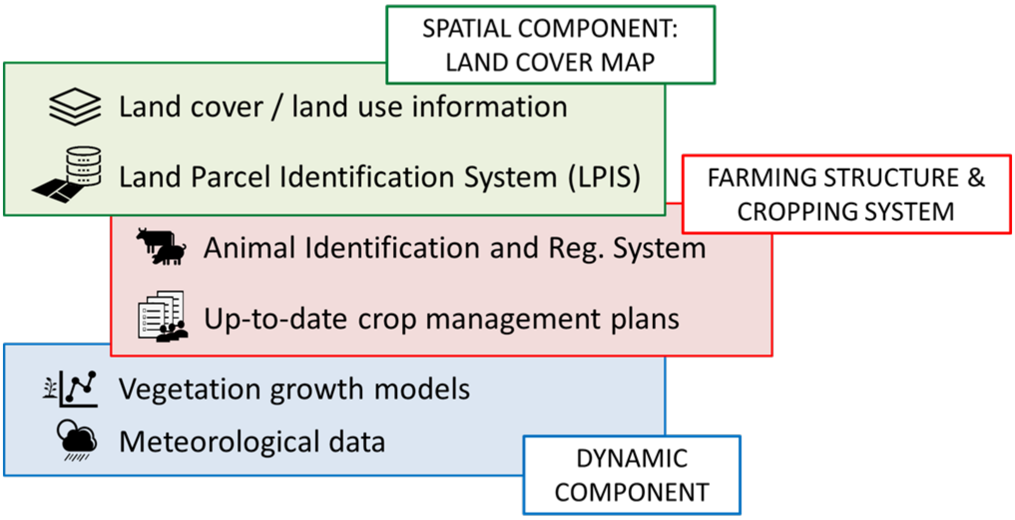

Figure 1. Main types of input data needed for generation of the ALMaSS landscape model

2.3. Overview of processing steps

2.3.1. Generation of ALMaSS landscape map (spatial component)

Generation was done by combining individual layers of land use / land cover information together with information on agricultural fields into a single raster landscape map in a step-by-step process. As layers from different data sources were used, this resulted in inconsistencies related to spatial alignment of features (i.e., overlaps or gaps between features). In addition, some objects were represented as points or lines and therefore as dimensionless and had to be expanded first to represent them as two-dimensional polygons. However, this process increased the number of inconsistencies in the combined map even more, so a special step-by-step procedure was applied to be able to obtain a landscape raster map with no gaps in information and with removal of sliver polygons.

The overall process to generate the ALMaSS landscape map consisted of the following general steps (although some specific processing steps were needed in the case of each country due to specific national / regional data):

i. Clipping the input layers to the study area extent;

ii. Converting the input vector data to raster format (with spatial resolution of 1 m), object class by object class;

iii. Combining individual layers into thematic maps (e.g., transportation theme, built-up theme);

iv. Stacking of thematic maps to generate raw landscape map (Fig. 2);

v. Reclassification of large 'background' polygons, and removing of inconsistencies in the landscape raw map (multi-stage process);

vi. Reclassification and regionalization of resulting landscape map. The landscape map contains more details than are used in ALMaSS. Therefore, to be consistent with landscape element types used in ALMaSS we used simple reclassification based on a text file (separate for each analysed country). All features in the ALMaSS landscape map, consisting both of single and multiple raster cells, have a unique value that is common to all cells within the feature. This was achieved by regionalizing the raster before exporting the map as a final ASCII file.
vii. Exporting results;
viii. Generating input files for ALMaSS.

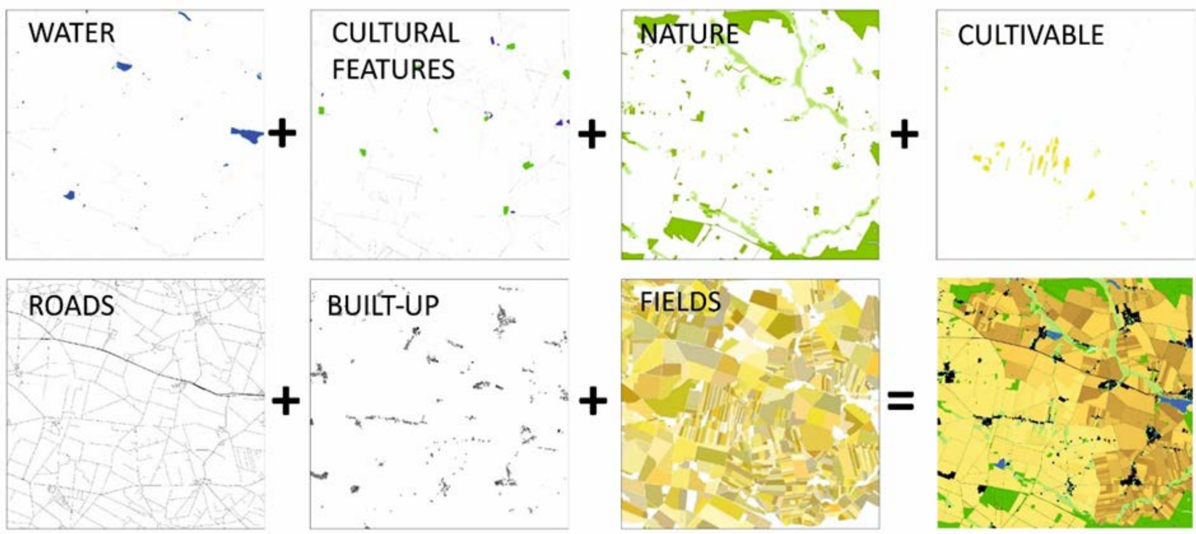

Figure 2. Stacking of GIS layers

2.3.2. Farming structure and cropping system

In ALMaSS, crop management is applied at the farm level, therefore individual agricultural parcels (fields) need to be grouped into farm units of different types (e.g., conventional cattle, pig or arable farms). Farm classifications were generated for each country / region separately based on LPIS and farm animal data.

Based on proportions of crops cultivated by farms of different types, crop rotation schemes can be generated for each farm type individually. Only crops with more than 1% share of the area of a farm type are considered. In such a case it is assumed that the rotation could be represented by 100 crops (1 crop for each 1%). The order of crops follows typical agronomic practices and issues such as late harvest leading to impossible sowing conditions are controlled by the built-in ALMaSS farm code. The result is a pattern of changing crops on a field that matches the overall crop distribution pattern for that farm type precisely over 100 seasons. If a specific crop, e.g., maize for silage, occurs 13 times out of 100 in the rotation, it will on average occur on 13% of all fields covered by that rotation at any point in time. It is also possible to use pre-defined crop rotation schemes.

2.3.3. Incorporation of crop management & vegetation growth (dynamic component)

Inside the model landscape, all vegetation types and crops have their own seasonal growth models supplying vegetation height and green and total biomass.

The result is a dynamic landscape with all vegetation growing in response to the weather. Crops and other vegetation also respond to management. Crops will grow from sowing and respond to management events such as harvest and cutting, which are coded into the ALMaSS according to crop management plans provided by farmer advisors or other experts from each analysed country. Non-crop vegetation can also be managed, e.g., roadside verges are mown during summer in the model.

2.3.4. Automatization

All handling and analysis of spatial data is done using Python 2.7 (https://docs.python.org/2.7/) and the Python library arcpy to access ArcGIS features (ESRI 2010), or directly in ArcGIS 10.x (migration to Python 3 and ArcGis Pro is underway). The entire process of producing a landscape model for ALMaSS is programmed in Python scripts with Pandas library (https://pandas.pydata.org/), separately for each country. As all procedures for generating landscape models for ALMaSS are automated or semi-automated, any landscape in each of the analysed countries/regions can be ‘captured’ and used for simulation.

3. Landscapes in Ireland

Irish landscapes are dominated by agriculture, particularly cattle farming for both beef and dairy production (Rotchés-Ribalta *et al.*, 2021). There is not a national land cover dataset for Ireland, however, there are datasets that cover Ireland. Many of these however are of low resolution or spatial accuracy, CORINE and OpenStreetMap for example (Büttner and Maucha, 2006; OpenStreetMap, 2022). Ordnance Survey Ireland (OSI) does have a dataset Prime2, which contains data on the whole of the Republic of Ireland (McGlinn *et al.*, 2021; Ordnance Survey Ireland, 2022). This OSI dataset has been used in conjunction with LPIS data to create the ALMaSS land cover for Ireland (Government of Ireland, 2021). For the primary vegetation types farm management plans have been created with the help of information from the Agriculture and Food Development Authority, Teagasc (Teagasc, 2022).

3.1. Land cover creation

The creation of the ALMaSS land cover for Ireland used ArcGIS (ver 10.8.1 © 2020 ESRI, Redlands, CA). Two sets of data were used, OSI Prime2 and DAFM LPIS data. OSI Prime2 data was spatially accurate, contiguous and contained enough information for the ALMaSS land cover, which was not rivalled by any other dataset. OSI Prime2 data provides a polygon dataset for many linear features such as roads, rail, streams and rivers. Therefore, there was no need to buffer polyline features to represent linear features. Field boundaries that contain hedges or trees are however not represented. The data gives the boundaries but records all as fences. Unfortunately, there are no suitable datasets that we could use to add these features. Prime2 datasets overlap due to the designed function of this particular element of data, but have topographically consistent boundaries. For example, the buildings dataset overlaps with the artificial dataset. When the different datasets of Prime2 were combined they were stacked with the uppermost overwriting those below, in the following in the order:

1. Buildings
2. Roads, rail, and paths
3. Water
4. Exposed rock and soil
5. Artificial surfaces
6. Vegetation

LPIS data have not been created to conform to the OSI boundaries despite the accuracy of these boundaries. There were not big differences in the boundaries in most cases, but there were many cases when LPIS areas contained multiple fields in OSI, that were real divisions when compared to aerial imagery. Likewise, there were large OSI areas, often on heathland or bog where LPIS assigned different agricultural usage to different areas of the OSI polygon. The OSI and LPIS data were combined in such a way as to maintain both boundaries. Very few LPIS polygons contained fields with multiple crops. At a national level this was only 0.6% of polygons and was therefore ignored as a very small inaccuracy. This could however be addressed for an area of interest that contained such a field. Having been combined, the whole dataset was assigned new identifiers which linked to the LPIS fields, holdings and crop types and the OSI classifications. The new identifiers were output to a one-meter resolution raster dataset and the linking information to a table. Within this table, agricultural fields were classified based on crop type and other elements into types of landscape elements (TOLEs) recognized by ALMaSS (see Fig. 3). But as the original information was retained, these could be classified differently as needed. In a deviation from normal ALMaSS procedure, which usually retains the raw data and runs python scripts to create the output only for an area of interest when needed (10 km or 50 km squares), the raster and table were created for the whole of the Republic of Ireland and scripts written to extract areas of interest from these data. This was done due to limitations of the LPIS data sharing agreement with DAFM. The delivered data consists of the raster data, accompanying table and all scripts used to create the raster data and to extract data for case study areas.

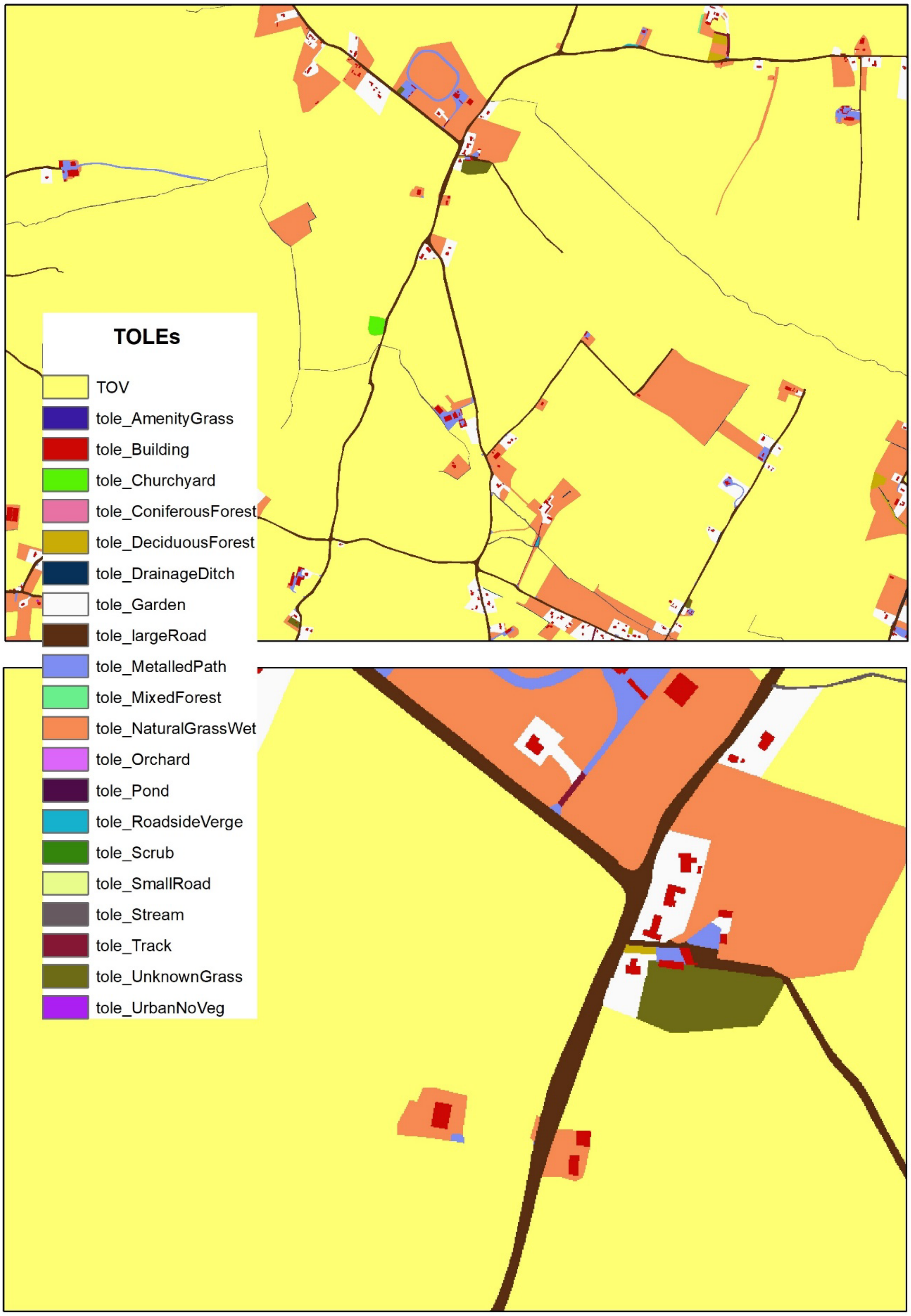

Figure 3. Area of the type of landscape element (TOLE) dataset showing the TOLE types in an agricultural landscape of type of vegetation (TOV). The TOV's are comprised of individual fields which dynamically change to different crop types.

3.1. Farm Classification

To prepare for ALMaSS simulation the farms in Ireland were classified into categories to allow creation of specific farm managements and rotations. This was based primarily on LPIS information. A heuristic was used to derive the classification based on summary statistics (Table 1) and the resulting number of farms in each category determined. These categories were then used as the basis for determining the crop management schemes for each farm type (Table 2).

Table 1. Rules used to classify Irish farms into eight main farm types

Rule applied	Category
%Area Arable >= 95 AND %Area Farmed Organic <= 95	Arable – non-organic
%Area Arable >= 95 AND %Area Farmed Organic >= 95	Arable – organic
%Area Grazed >= 95 AND %Area Farmed Organic < 95 AND Elevation Zone = 'Upland'	Grazed – non-organic upland
%Area Grazed >= 95 AND %Area Farmed Organic < 95 AND Elevation Zone = 'Lowland'	Grazed – non-organic lowland
%Area Grazed >= 95 AND %Area Farmed Organic >= 95 AND Elevation Zone = 'Upland'	Grazed – organic upland
%Area Grazed >= 95 AND %Area Farmed Organic >= 95 AND Elevation Zone = 'Lowland'	Grazed – organic lowland
All remaining AND Elevation Zone = 'Lowland'	Mixed arable and grazed - non-organic lowland
All remaining AND Elevation Zone = 'Upland'	Mixed arable and grazed - non-organic upland

Table 2. The number of farm holdings in each of the Irish farm categories.

Category	Number of holdings
Arable - non-organic	1783
Arable - organic	41
Grazed - non-organic lowland	98759
Grazed - non-organic upland	16372
Grazed - organic lowland	1428
Grazed - organic upland	353
Mixed arable and grazed - non-organic lowland	9331
Mixed arable and grazed - non-organic upland	570

3.2. Farm management plans

In addition to the landscape spatial component (section 2.1), the landscape part of the larger ALMaSS modelling framework also needs to include the non-spatial component. This non-spatial component is made of vegetation growth models, farming structure/management and cropping system models, which all represent the dynamic component of the ALMaSS landscape. These model structures form an important dynamic part of the larger modelling framework, providing detailed information about the environment in which species function.

The farm management plans here refer to the work performed on the development and construction of this non-spatial and dynamic component of the model, where farming structures/management models and cropping system models have been constructed in the form of conceptual modelling schemes, here named as 'Irish Farm Management Schemes' (IFMSs). These IFMSs are needed to define and introduce the new 'farming management variables' into the Irish landscape modelling framework, and to allow linking of non-spatial dynamic model components (i.e., dynamic farm management practices, actions and conditions) with the spatial components (section 2.1). In the IFMSs, the actions follow the logical order of farm management practices and situations on farms through the time ('management schedules'), depending on various factors, conditions and vegetation growth. The vegetation growth models are also an integral part of this work. Due to the lack of publicly available data needed for construction of Irish grassland vegetation growth models, the general Irish PastureBase Ireland national grassland growth curves (PastureBase Ireland 2020) were digitized instead (using 'digitize' R-package (Poisot 2011)). This potentially allows for possible further linking of grassland growth information with the Irish climate data available from, for example Irish Met Eireann (Met Éireann 2012, Met Éireann 2022) and some weather and climate potential data sources (ERDDAP-ICHEC 2019, ECA&D 2022).

The IFMSs were constructed specifically for Irish conditions using data and information gathered from various relevant sources. A desk-study was conducted for the purpose on obtaining the relevant information required for the construction of IFMSs, focusing on the Irish arable and grassland land-use and management practices (see Table 3, providing an example of categorisation of land use and management practices and accompanying information sources). Work involved gathering and compiling the variety of different information and data, such as information obtained from interviews / personal communication with Irish Teagasc specialised staff, information and data from various published sources, advice given to farmers from various Teagasc web-sites, data from Irish National Farm Survey (NFS) reports (Teagasc 2017), Irish Central Statistics Office (CSO 2021), information sourced from other relevant project/s [e.g. SOLUM-project (Saunders, Afrasinei et al. 2021), including their conducted analysis of LPIS extracted data and information from farmer interview/s (SOLUM 2021); e.g. PROTECTS-project including information on pesticide usage in Ireland (PROTECTS 2022)], as well as information obtained from various journals for Irish farmers, and videos from Irish farmers that are available on YouTube, and a variety of other sources (some detailed in Table 3).

It should be noted that very often different sources provided different information on certain management practices and timings, etc., which reflects the realistic situation that many farmers perform management differently, depending on their own needs. Therefore, very often the management activities and timings (i.e., 'management schedule') in the constructed IFMSs refer to assumed or most-likely practices, which often had to be further simplified for the purpose of modelling needs. In rare cases when information could not be found within Irish context, the alternative sources from UK were used, due to similar geographic and climatic conditions in UK and in Ireland (such as in the case of e.g., information that was needed for calculation of proportion of autumn and spring silage cutting for grassland land use). Based on the gathered data and the modelling needs, the new IFMSs were constructed and categorised into specific land-use management categories and specific IFMS management types, such as 'winter wheat', 'spring wheat', 'grazed grassland' for e.g., 'cattle ', 'sheep'' or grasslands e.g., with or without 'reseeding' or 'silage cutting', etc. (Table 3). Furthermore, although this is not presented in Table 3, the introduced IFMS also allow for accounting for 'non-organic'/'organic' farming practices, which refer to inclusion/exclusion of some activities from IFMS such as for example application of pesticides.

Table 3. Example of various sources of data and information used in the construction of specific IFMS and corresponding categorisation into different land use, crop/vegetation categories and management types for IFMSs

Land Use	Crop/vegetation category	IFMS -management type	Data /information sources used in construction of IFMS and 'management schedules'
Arable	Winter Cereals	e.g., IFMS -Winter Wheat; IFMS - Winter Barley; IFMS- Winter Oats	Personal communication with personnel from Teagasc, Ireland (2020) to estimates for specific on-farm activities and timings, and proportions. Various sources: CSO (2021), Dillon, Buckley et al. (2018), Government Publications Office (2017), Youtube; Moloney (2020), Teagasc (2017); Teagasc (2017), (CSO 2021).
	Spring Cereals	e.g., IFMS -Spring Wheat; IFMS - Spring Barley; IFMS- Spring Oats	
Grassland	Grazed	Different but linked schemes covering variable grassland managements e.g.: IFMS- grazed- cattle (dairy, beef); IFMS- grazed -sheep; IFMS- grazed-(various options) - reseeded; IFMS- grazed- (various options) - with silage cut, etc.	Personal communication with personnel from Teagasc, Ireland (2021) provided advice on obtaining information from specific relevant formal sources and statistics such as CSO, NFS published surveys, etc. Various sources: Agriland (2021); YouTube video by Agriland (2021); AHDB (2022); Coulter, Murphy et al. (2005); CSO (2021) DAFM (2017); Dillon, Buckley et al. (2018); Farmers Journal (2015); Glanbia Connect (n.d); Gormley (2020); Gilsenan (2019);Kelleher (2022); Lalor, Coulter et al. (2010); Lalor and Humphreys (2012); O'Keffe (2021), PastureBase Ireland (2022); PRCD (2022); PROTECTS (2022); SOLUM (2021); Saunders, Afrasinei et al. (2021); Tagasc (n.d.); Teagasc (2011); Teagasc (2014); Teagasc (2017); Teagasc (2017); Teagasc (2017);Teagasc (2017); Teagasc (2017); Teagasc (2020); Teagasc (2020); Teagasc (2020); Walsh (2017)

The information gathered for each farm management plan was collated in both table and flow diagram forms. The flow diagram (see Fig. 4 for an example) shows the progression of the farming tasks, including special notes concerning conditions and likelihood of occurrence. These tasks are connected by logical flows, with potential conditions attached. These tables and diagrams were passed to the Aarhus team and were translated to functioning modules ready for simulation using ALMaSS (WP8 Tasks 8.4: Integrative analysis of bee health and production of tools for risk assessment & Task 8.5).

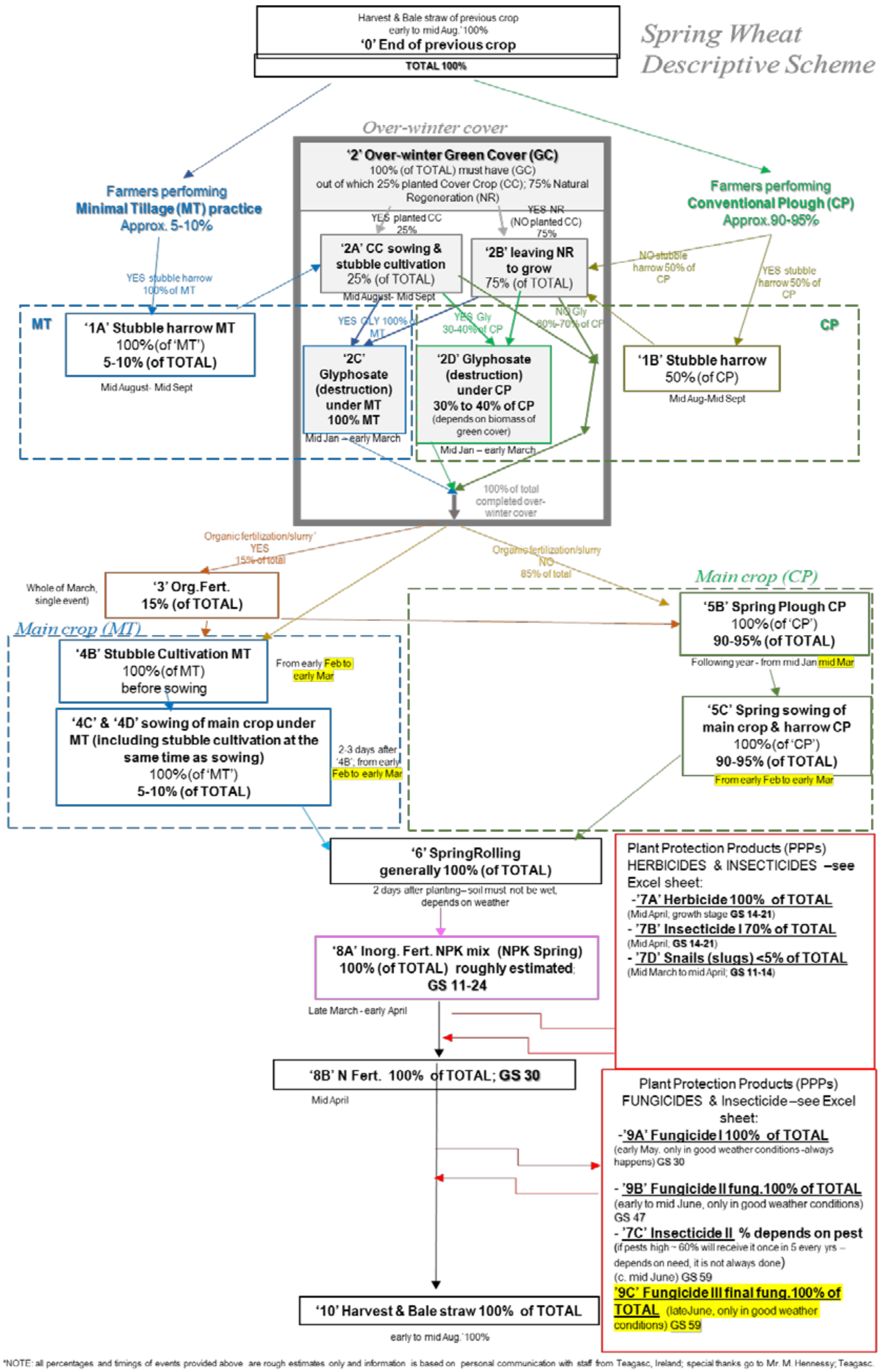

Figure 4. An example of a farm management scheme derived from data sources listed in Table 3 and ready to use for programming into the ALMaSS simulation.

4. Data sources for the generation of ALMaSS landscape models in Italy

Due to data constraints, ALMaSS landscape models were generated only for the Trentino region. The overview of the specific input data used is provided in Table 4.

Table 4. Spatial data sources for the Trentino region in Italy – an overview

Data type	**Data properties**	
Topographical database	Availability	YES
	Source	APPAG TRENTO
	Format	Vector database
	Scale	1:10,000
	Cost	Free for research purposes
Other land use / land cover data	Availability	YES: land cover map
	Source	Fioravante et al. (2022): https://doi.org/10.3390/land11010035
	Format	Raster
	Resolution	10 m
	Cost	Free
The Land Parcel Identification System (LPIS)	Availability	YES
	Source	APPAG TRENTO
	Format	Vector
	Cost	Free for research purposes
Soil maps (EU level)	Availability	YES
	Scale	1:1,000,000
	Source	European Soil database of the Joint research Centre
	Format	Vector
	Cost	Free
Satellite images[1]	Availability	YES / every 5-10 days, 10 or 20 me spatial resolution
	Source	European Space Agency
	Format	Raster
	Cost	Free
[1] **if necessary for data validation**		

4.1. Land use / land cover information

For land use / land cover information, we used vector map layers for 2020 from the topographic database of the APPAG (Agenzia provinciale per i pagamenti) Trento – the regional agency for payments in agriculture. The layers used include: (i) water network (rivers, canals, etc.); (ii) communication network (roads of different categories, railways, road verges); (iii) built-up areas and individual buildings; (iv) land use information; and (v) punctiform natural areas of different types (EFAs) (see Fig. 5). This database was complemented by the raster land cover map of Italy (Fioravante et al. 2022), this being a product integrating various national and European data from the Copernicus Land Monitoring System (i.e., Urban Atlas, Riparian Zones, various high-resolution layers etc.).

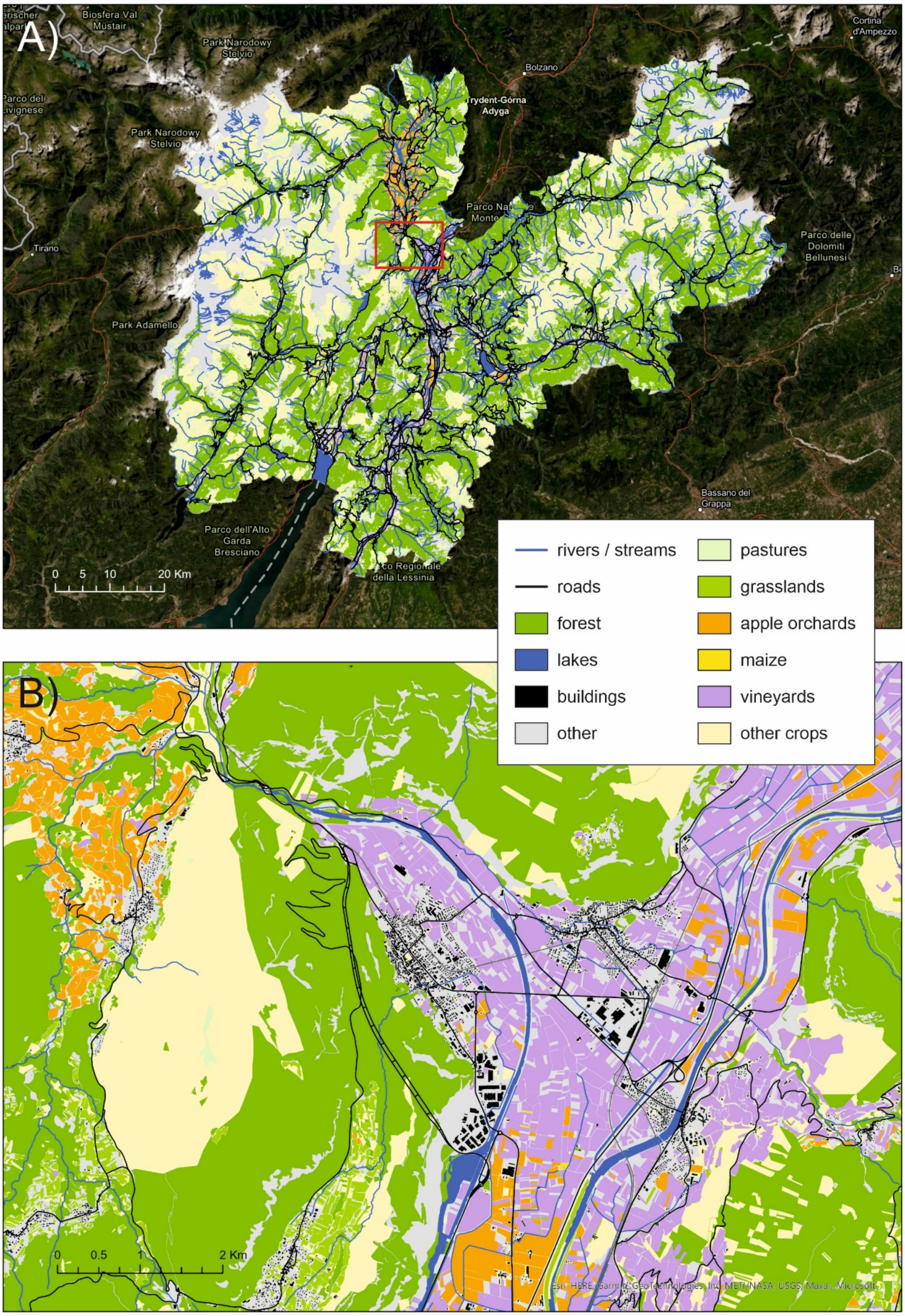

Figure 5. Land cover / land use in the Trentino region: (A) an overview, and (B) zoom in around the Mezzolomardo in the Noce valley

4.2. The Land Parcel Identification System (LPIS)

LPIS records information on all agriculturally managed reference parcels (geographically delimited areas with unique identification codes) in the EU Member States and serves as a controlling mechanism under the Common Agricultural Policy (CAP). From LPIS we used information from 2019, on the type of crops cultivated in reference parcels (from the register of direct payments), and ID numbers of agricultural holdings enabling grouping of individual reference parcels into farm units. We obtained the necessary information from the APPAG Trento.

4.3. Crop management plans

Based on LPIS data examination, we have selected only major crops in Trentino for further modelling. Besides pastures (74% of the agricultural land), the vast majority of cropland is cultivated with apples (12%) and both extensive and intensive crop schemes were created for these. The areas of other crops are limited hence these were represented by vineyards (9%) and maize (2%), along with fodder grass, potatoes, berries and olive groves. Crop management plans were collected by CREA based on interviews with field technicians and the crop management programming performed by Aarhus in the same way as for Ireland.

5. Data publication and further dissemination

Whilst all data has been collected and collated for use in ALMaSS simulation for both countries, it cannot be made publicly available in its current form due to data ownership restrictions, in particular with respect to CAP subsidy information. Therefore, we will develop a derived data set which forms the actual input to ALMaSS. This derived data set will be made available through two publications. The first will be a data set uploaded to an open access data repository (Zenodo). This will make the simulation basis available to researchers wanting to use the simulations themselves or explore the derived data. The second output is an open access publication detailing the landscape generation process for ALMaSS as a collaborative output from H2020 projects B-GOOD, EcoStack and PoshBee. Both publications are in process and will be available before the end of PoshBee, the data publication preceding the collaborative paper.

6. Acknowledgements

Thanks to personnel from Teagasc for advice on information and sources needed for constructing the farm management schemes for Ireland.

7. References

Agriland (2021). "Green Acres. Agriland. URL: https://www.agriland.ie/farming-news/category/green-acres/."

Agriland (2021). "Teagasc Green Acres Calf to Beef: The importance of making quality silage on calf to beef farms. YouTube video. URL: https://www.youtube.com/watch?v=pYz9ykcErps&t=6s."

AHDB. (2022). "When to reseed grassland – autumn or spring? AHDB. URL: https://ahdb.org.uk/knowledge-library/when-to-reseed-grassland-autumn-or-spring."

Büttner, G. and Maucha, G. (2006) *The thematic accuracy of Corine land cover 2000. Assessment using LUCAS (land use/cover area frame statistical survey)*, *EEA Technical report*. Available at: www.eea.europa.eu.

Coulter, B. S., W. E. Murphy, N. Culleton, G. Quinlan and L. Connolly (2005). A survey of fertilizer use from 2001-2003 for grassland and arable crops, End of Project Report. Teagasc. URL: https://t-stor.teagasc.ie/handle/11019/975 , https://t-stor.teagasc.ie/bitstream/handle/11019/975/eopr4568.pdf?, Teagasc Johnstown Castle Research Centre, Wexford , Ireland.

CSO (2021). " Central Statistics Office,. URL: https://www.cso.ie/en/index.html."

DAFM (2017). Pesticide Usage in Ireland. DAFM. URL: https://www.pcs.agriculture.gov.ie/media/pesticides/content/sud/pesticidestatistics/2GrasslandReport2017FinalVersion290520.pdf.

Dillon, E., C. Buckley, M. Brian, J. Lennon and D. Wall (2018). Teagasc National Farm Survey. FERTILISER USE SURVEY 2005 - 2015, Tagasc, Ireland.

ECA&D. (2022). "E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations. European Climate Assessment & Dataset (ECA&D), Copernicus. URL: https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-gridded-observations-europe?tab=overview. Latest Date Accessed: March, 2022.".

ERDDAP-ICHEC (2019). EPA_Climate-WRF. ICHEC ERDDAP Server. ERDDAPv.1.82. Irish Centre for High-End Computing (ICHEC) . URL: https://erddap.ichec.ie/erddap/files/EPA_Climate/WRF/.

ESRI (Environmental Systems Resource Institute) (2020) 'ArcGIS Desktop: Release 10.8.1', *Redlands CA*.

Farmers Journal (2015). "Understanding how perennial ryegrass grows. Farmers Journal. URL: https://www.farmersjournal.ie/understanding-how-perennial-ryegrass-grows-191678."

Gilsenan, E. (2019). "Grass growth: Finally we are all back on the same page. Agriland.ie. URL: https://www.agriland.ie/farming-news/grass-growth-finally-we-are-all-back-on-the-same-page/."

Glanbia Connect. (n.d). "Weed Control in Grassland – what you need to know. Glanbia Connect. URL: https://www.glanbiaconnect.com/farm-advice/detail/article/weed-control-in-grassland."

Gormley, O. (2020). "Grassland weed control on dairy farms. CAFRE, UK. URL: https://www.cafre.ac.uk/2020/05/11/grassland-weed-control-on-dairy-farms/."

Government of Ireland (2021) *Land Parcel Identification System (LPIS)*. Available at: https://www.gov.ie/en/service/1eb4d-land-parcel-identification-system-lpis/# (Accessed: 7 March 2022).

Government Publications Office (2017). "Statutory Instrument S.I. No. 605 of 2017. European Union (Good Agricultural Practice for Protection of Waters) Regulations 2017. Government of Ireland, Government Publications Office, Stationery Office Dublin, Ireland. URL: https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/2017/SINo605271217.pdf.."

Kelleher, J. (2022). "How much should you be paying for silage ground?. Farming Independent. URL: https://www.independent.ie/business/farming/dairy/how-much-should-you-be-paying-for-silage-ground-37926616.html."

Lalor, S. and J. Humphreys (2012). Soil fertility and nutrient management. Teagasc Dairy Manual. A best practice manual for Ireland's dairy farmers (Chapter 20). Teagasc. Ireland**:** 103-113. https://www.teagasc.ie/media/website/animals/dairy/SoilFertility.pdf.

Lalor, S. T. J., B. S. Coulter, G. Quinlan and L. Connolly (2010). A survey of fertilizer use in Ireland from 2004-2008 for grassland and arable crops. Project Report, Teagasc. URL: https://www.teagasc.ie/media/website/publications/2010/13_Fert_Use_Survey_2008-Final.pdf, Teagasc Johnstown Castle Environment Research Centre, Wexford, Ireland.

McGlinn, K. *et al.* (2021) 'Publishing authoritative geospatial data to support interlinking of building information models', *Automation in Construction*, 124(January), p. 103534. doi: 10.1016/j.autcon.2020.103534.

Met Éireann (2012). 30 year averages, Met Éireann - The Irish Meteorological Service, Ireland. URL: https://www.met.ie/climate/30-year-averages.

Met Éireann. (2022). "Met Éireann - The Irish Meteorological Service, Ireland."

Moloney, D. (2020). "YouTube video: Wheat Growing & Harvest 2019. URL: https://www.youtube.com/watch?v=AcXQ76tMlm0."

O'Keffe, B. (2021). "Farmer Writes: grass growing again as farmers are bombarded with new rules. Farmers Journal, URL: https://www.farmersjournal.ie/farmer-writes-grass-growing-again-as-farmers-are-bombarded-with-new-rules-640600."
OpenStreetMap (2022) *FAQ - OpenStreetMap Wiki*. Available at: https://wiki.openstreetmap.org/wiki/FAQ (Accessed: 8 March 2022).
Ordnance Survey Ireland (2022) *OSi Products*. Available at: https://osi.ie/resources/downloads/osi-products/ (Accessed: 7 March 2022).
PastureBase Ireland. (2020). "PastureBase Ireland national grass-growth curve. URLs: https://germinal.ie/pasturebase-national-grass-growth-curve/; https://pasturebase.teagasc.ie/; https://www.teagasc.ie/crops/grassland/pasturebase-ireland/grass-curve/."
PastureBase Ireland. (2022). "PastureBase Ireland. URL: https://pasturebase.teagasc.ie/. Latest Date Accessed: March, 2022."
Poisot, T. (2011). "The digitize package: extracting numerical data from scatterplots." The R Journal **3.1**: 25-26.
PRCD. (2022). "Pesticide Registration and Control Divisions (PRCD) of the Department of Agriculture, Food & the Marine (DAFM). URL: https://www.pcs.agriculture.gov.ie/."
PROTECTS. (2022). "PROTECTS project. URL: https://protects.ucd.ie/."
Rotchés-Ribalta, R. *et al.* (2021) 'Assessment of semi-natural habitats and landscape features on Irish farmland: New insights to inform EU Common Agricultural Policy implementation', *Ambio*, 50(2), pp. 346–359. doi: 10.1007/s13280-020-01344-6.
Saunders, M., G. M. Afrasinei, J. Zimmerman, A. Premrov, K. Black and S. Green (2021). Soil Organic Carbon and Land Use Mapping (SOLUM) (2016-CCRP-MS.40) EPA Research Report.
SOLUM. (2021). "The Soil Organic carbon and Land Use Mapping (SOLUM) project. https://epasolumproject.wixsite.com/solum." Retrieved 19/04/2018, 2018, from URL: https://epasolumproject.wixsite.com/solum.
Tagasc (n.d.). Grassland Weed Control. Teagas. URL: https://www.teagasc.ie/media/website/crops/crops/Grassland-Weed-Control.pdf.
Teagasc (2011). "Grazing Guide Book. teagasc. URLs: https://www.teagasc.ie/media/website/crops/grassland/Grazing-Guide-Book-2011_0-21.pdf; https://www.teagasc.ie/media/website/crops/grassland/Grazing-Guide-Book-2011_27-48.pdf; https://www.teagasc.ie/media/website/crops/grassland/Grazing-Guide-Book-2011_49-69.pdf."
Teagasc (2014). "Pocket manual for reseeding. URL: https://www.teagasc.ie/media/website/animals/dairy/pocketmanualforreseeding.pdf."
Teagasc. (2017). "Grassland Management. Teagasc. URL: https://www.teagasc.ie/animals/beef/grassland/grassland-management/."
Teagasc. (2017). "Grassland. Teagasc. URL: https://www.teagasc.ie/crops/soil--soil-fertility/grassland/."
Teagasc. (2017). "National Farm Survey, Teagasc. URL: https://www.teagasc.ie/rural-economy/rural-economy/national-farm-survey/."
Teagasc. (2017). "Reseeding. Teagasc. URL: https://www.teagasc.ie/animals/beef/grassland/reseeding/."
Teagasc. (2017). "Soil Fertility. Grassland."
Teagasc (2017). "Spring Cereals. URL: https://www.teagasc.ie/crops/crops/cereal-crops/spring-cereals."
Teagasc (2017). "Winter Cereals. URL: https://www.teagasc.ie/crops/crops/cereal-crops/winter-cereals/."
Teagasc. (2020). "Planning 1st cut silage on beet farms. Teagasc. URL: https://www.teagasc.ie/publications/2020/planning-1st-cut-silage-on-beef-farms.php."

Teagasc. (2020). "Planning 1st cut silage on beef farms. Teagasc. URL: https://www.teagasc.ie/publications/2020/planning-1st-cut-silage-on-beef-farms.php."

Teagasc. (2020). "Silage – When to Cut and Need to Budget. teagasc. URL: https://www.teagasc.ie/publications/2020/silage--when-to-cut-and-need-to-budget.php."

Teagasc (2022) *Teagasc | Agriculture and Food Development Authority*. Available at: https://www.teagasc.ie/ (Accessed: 7 March 2022).

Topping, C. J. (2021) *Landscape model*, *Aarhus University*. Available at: https://projects.au.dk/almass/landscape (Accessed: 7 March 2022).

Topping, C. J., Dalby, L. and Skov, F. (2016) 'Landscape structure and management alter the outcome of a pesticide ERA: Evaluating impacts of endocrine disruption using the ALMaSS European Brown Hare model', *Science of the Total Environment*, 541, pp. 1477–1488. doi: 10.1016/j.scitotenv.2015.10.042.

Topping, C.J., Hansen, T.S., Jensen, T.S., Jepsen, J.U., Nikolajsen, F., Odderskær, P. (2003) ALMaSS, an agent-based model for animals in temperate European landscapes. *Ecological Modelling,* 167, pp. 65–82. doi: 10.1016/S0304-3800(03)00173-X.

Topping, C.J., Hoye, T.T., Odderskaer, P., Aebischer, N.J. (2010) A pattern-oriented modelling approach to simulating populations of grey partridge. *Ecological Modelling*, 221, 729–737. doi: 10.1016/j.ecolmodel.2009.11.004.

Walsh, T. (2017) "Have you delivered on "Low Input Permanent Pasture" or "Traditional Hay Meadow" Options for your GLAS Plan?".