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Modelling of intensive and extensive farming in CLUE

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Modelling of intensive and extensive farming in CLUE

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Abstract

Temme, A.J.A.M. & P.H. Verburg, 2010. *Modelling of extensive and extensive farming in CLUE.* Wageningen, Statutory Research Tasks Unit for Nature and the Environment. WOt-werkdocument 187. 80 p. 7 Fig.; 8 Tab.; 27 Ref.; 5 Annexes

This report presents a method to model agricultural land use intensity in Europe. The method is intended as an extension of land use modelling framework EURURALIS, and will allow EURURALIS to predict the effect on land use intensity of future policy under different scenarios. In turn, this makes it possible to predict policy effects on intensity-related biodiversity issues on the EU-level. Our method defines agricultural land use intensity in terms of nitrogen input. For arable land, it first combines the Land Use / Cover Area frame statistical Survey (LUCAS) dataset with Common Agricultural Policy Regionalised Impact modelling system (CAPRI) results to assess probability of occurrence for three classes of intensity. For grassland, it uses available spatially explicit predictions of livestock intensity to assess probability of occurrence for two classes of intensity. Then, agricultural land in different intensity classes is spatially allocated using a simple allocation algorithm.
We illustrate and evaluate this method for five countries: the Netherlands, Portugal, Spain, Greece and Poland. Intensity predictions are made for two years: 2000 (ex-post) and 2025 (using the Financial Policy Reform Scenario from the FP6 EU SENSOR project). This report contains building bocks for a possible future quality status of the method.

Key words: Land use, land use systems, Europe, EURURALIS, LUCAS, logistic regression.

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Contents

Summary

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1 Introduction

EU biodiversity objectives are to stop loss of biodiversity by 2010 (EU, 2002). This does not seem feasible at the moment (Donald *et al.*, 2006; Verboom *et al.*, 2007), and attention is increasingly being focussed on the possible contribution of changes in the European agricultural policies after 2013 to achieve biodiversity objectives. Current assessments of biodiversity have mostly been ex-post and on the case-study scale (e.g. (Kleijn *et al.*, 2009). The spatially explicit, EU-wide effects of future policies affecting land use are presently unknown. These possible effects need to be quantified to assess effects of proposed policy, or to design alternative policy (preferably minimizing conflict, (Henle *et al.*, 2008). Therefore, development of a method to predict such (agricultural) policy effects on agro-biodiversity is crucial.

The EURURALIS project aims to support the debate on agricultural and environmental policies in the EU by providing facts and figures on the impacts of several developments and policy options (Van Meijl *et al.*, 2006; Verburg *et al.*, 2008). For that purpose, Eururalis 1.0 and 2.0 included a biodiversity indicator. In Eururalis 1.0 a distinction was made between biodiversity in agricultural areas (Reidsma *et al.*, 2006) and biodiversity of nature areas (Verboom *et al.*, 2007). In Eururalis 2.0 only an indicator for total biodiversity was included, which was based on land-use pattern, infrastructure (fragmentation), livestock density and nitrogen deposition (Eickhout and Prins, 2008).

Agricultural intensity strongly influences agrobiodiversity (e.g. (Kleijn *et al.*, 2009; Matson *et al.*, 1997; Reidsma *et al.*, 2006; Stoate *et al.*, 2001). Agricultural intensity can be defined as the level of inputs and outputs of an agricultural system (Shriar, 2000). From these inputs and outputs, especially aggregate nitrogen input relates strongly to biodiversity (e.g. (Herzog *et al.*, 2006; Kleijn *et al.*, 2009) – although field size and management are also seen as important factors (e.g. (Burel *et al.*, 1998; Henle *et al.*, 2008; McLaughlin and Mineau, 1995). Agricultural intensity was operationalized in this study as the aggregate nitrogen input per area of agricultural land.

Intensity effects on biodiversity have been observed through farmland birds (e.g. (Donald *et al.*, 2006) and plant species (Kleijn *et al.*, 2009; Uematsu *et al.*, 2009). A first projection of the effect of intensity on biodiversity at the EU25 level was made by (Reidsma *et al.*, 2006) through classification of farm types with Farm Accountancy Data Network (FADN) data. Their approach had limited spatial resolution because the FADN dataset has limited availability and spatial resolution.

In this study, we aim to support biodiversity modelling efforts by providing a generic method for the modelling of agricultural intensity that can be used for the whole EU27 and that has better spatial resolution than possible with the FADN dataset.

2 Methods

2.1 General description

Figure 1 presents an overview of the method to model intensity of agricultural land use. The figure is subdivided into four sections. The first two sections calculate probability maps for different intensities of arable and grassland respectively, the third section allocates arable and grassland of different intensities for the years 2000 and 2025. In the fourth section, year 2000 and year 2025 results are compared to calculate locations of agricultural abandonment, claiming, extensification and intensification.

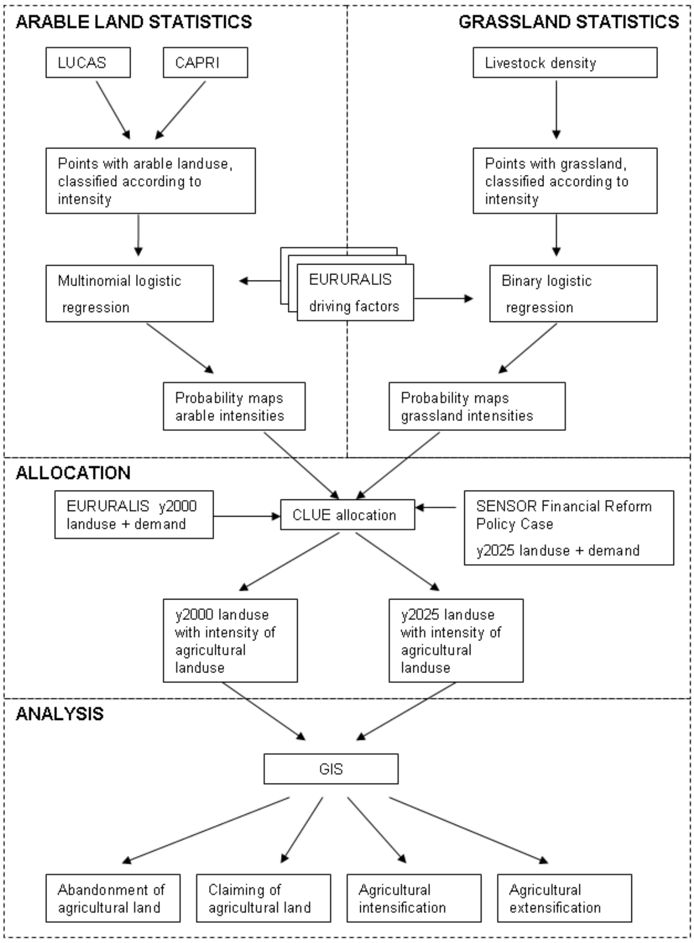

Figure 1: an overview of the method to determine intensity of agricultural land use

For arable land, crop observations from the 2003 and 2006 LUCAS datasets were linked to NUTS2-specific and crop-specific aggregate amounts of nitrogen input per hectare from the Common Agricultural Policy Regionalised Impact modelling system (Bettio *et al.*, 2002). These observations were then classified into three intensity classes and used in multinomial logistic regression on a set of 49 biophysical and socio-economical location factors as collected for the CLUE model application in EURURALIS (Verburg *et al.*, 2006) and Table 1, Figure 2).

Table 1: The 49 biophysical and socioeconomic EURURALIS location factors

Name	**Description**	**Biophysical / Socio-economical**
ACCESS1_06M	Timecost to cities > 100.000 (s)	S
ACCESS2_06M	Timecost to cities > 500.000 (s)	S
ACCESS3_06M	Timecost to ports > 15.000 kTon/year	S
ACCESS4_06M	Timecost to cities > 650.000 (s)	S
ACCESS5_06M	Airlinedistance to nearest road level 0,1 (m)	S
ACCESS6_06M	Timecost to major airports (s)	S
ACCESS7_06M	Timecost to airports & ports (s)	S
claycont_06pc	soil clay content (%)	B
ddw_shortage	water deficit growing season	B
dem_final	Elevation	B
envmap01	ALN: Alpine north	B
envmap02	BOR: Boreal	B
envmap03	NEM: Nemoral	B
envmap04	ATN: Atlantic north	B
envmap05	ALS: Alpine south	B
envmap06	CON: Continental	B
envmap07	ATC: Atlantic central	B
envmap08	PAN: Pannonian	B
envmap09	LUS: Lusitanian	B
envmap10	ANO: Anotolian	B
envmap11	MDM: Mediterranean mountains	B
envmap12	MDN: Mediterranean north	B
envmap13	MDS: Mediterranean south	B
EUAC120_2006	# of people that reach a location from their home within 120 minutes	S
EUAC30_2006	# of people that reach a location from their home within 30 minutes	S
EUAC60_2006	# of people that reach a location from their home within 60 minutes	S
Geomorf01	Average height difference of 0-20 m: flat	B
Geomorf02	Average height difference of 20-80 m: rolling	B
Geomorf03	Average height difference of 80 - 200 m: hilly	B
Geomorf04	Average height difference of 200 - 400 m: mountainous	B
Geomorf05	Average height difference of > 400 m: very mountainous	B
IL_2006	Presence of an impermeable layer within the soil profile	B
Landsc_06	ORNL LandScan (population) derived from World02	S
mean_temp_06	mean yearly temperature	B
Peat_06	peat 1/0	B
poppot_1mi06	populatiepotentiaal, instelling 12.5 km inflection point (afgenot op 1 mil)	S
poppot_log06	log (populatiepotentiaal, instelling 12.5 km inflection point)	S
poppot_sum06	populatiepotentiaal, instelling 12.5 km inflection point	S
rain_wc_5m	accumulated rainfall march, april, may, june july	B
rain_wc_yr	accumulated rainfall per year	B
Salinity	saline soils	B
slope_final	Slope	B
soildepth_06	soil depth	B
stoniness100	Stoniness	B
Swap	soil water available to plants	B
sz_landsc_rur	if landsc_06 >100, 100, landsc_06	S
t_min0_1000	Count of months a year with average temperature < 0 degrees C	B
t_plus15_1000	Count of months a year with average temperature > 15 degrees C	B
wr_06	Soils with water restriction (too much water)	B

For grassland, livestock density (Neumann *et al.*, 2009) was used for classification into two intensity classes. In this case binomial logistic regression on the same set of location factors was used.

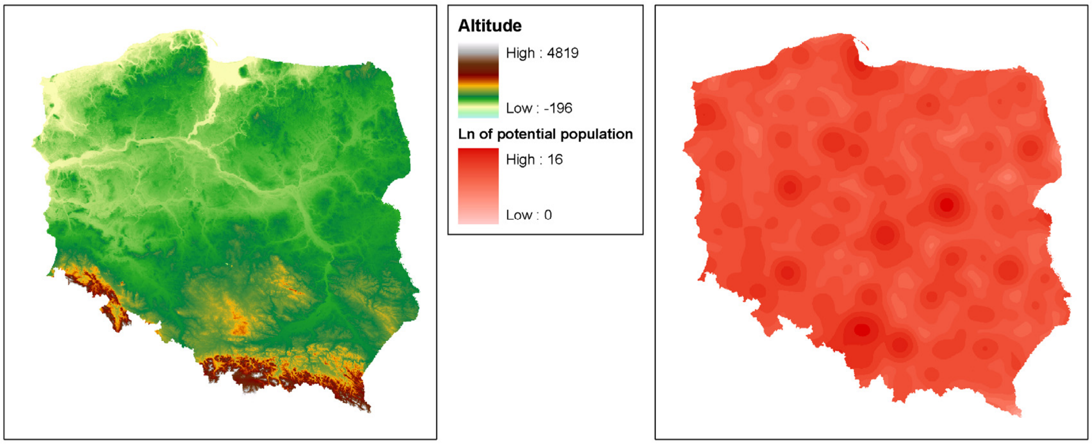

Figure 2: Example of two CLUE location factors for Poland : Altitude (dem_final in Table 1) and the natural logarithm of potential population (poppot_log06 in Table 1)

Allocation of arable and grassland in intensity classes was performed per country with a simple allocation procedure. This procedure is part of the dyna-CLUE model (Verburg and Overmars, 2009). Within every country, NUTS2 regions were assigned individual relative demands for the arable and grassland intensity classes. These demands were calculated from CAPRI-provided crop areas and crop aggregate N-inputs.

Final analysis of the outputs compared the example output maps for year 2000 and year 2025 and also identified four classes of change in agricultural land use: abandonment – claiming – intensification – extensification. These four classes provide a quick overview of areas that experience different changes.

The method is illustrated for five countries: the Netherlands, Spain, Portugal, Greece and Poland. These five countries were selected to cover a wide range of socio-economic and biohpysical conditions. They are also covered differently by LUCAS: Portugal and Greece are only covered by LUCAS 2003, Poland is only covered by LUCAS 2006 and the Netherlands and Spain are covered by both LUCAS 2003 and LUCAS 2006

2.2 Arable land

2.2.1 Intensity classification

The LUCAS datasets for the years 2003 and 2006 were the starting point for arable land use intensity. The sampling design for these two years was markedly different (Figure 3).

In 2003, groups of observations (Primary Sampling Units) were taken in regular grids of 18*18 km. Within these groups, up to 10 observations (Secondary Sampling Units) were taken in two East-West facing rows. Observations within the groups were 300 m apart (Bettio *et al.*, 2002). In 2006, a stratified random sampling scheme was adopted, leading to an approximate average density of 1 observation per 21 square kilometres (Jacques and

Gallego, 2005). In both years, two different crops were sometimes observed in one observation. In that case only the first crop was used in classification.

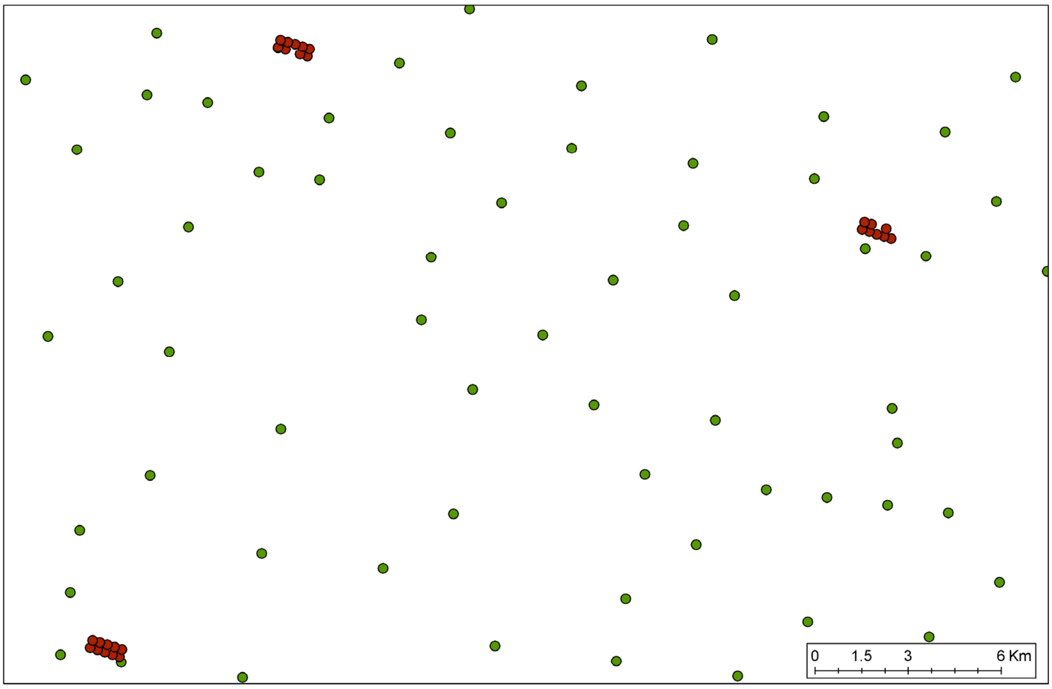

Figure 3: Example map showing the difference in sampling design between LUCAS 2003 observations (Secondary Sampling Units, red points) and LUCAS 2006 observations (green points).

Even though the scale of individual agricultural fields is typically less than 300 * 300 m, it is conceivable that crop type observations in the 2003 dataset have a higher spatial autocorrelation than those in the 2006 dataset. This can lead to an overestimation of the performance of regression models.

For the eventual calculation of regression models, the LUCAS 2003 and 2006 observations were combined into one dataset. This dataset contains about 99 thousand observations of agricultural crop type of which 31 thousand are in the five selected countries. It was assumed that the distribution of classified agricultural intensity of these observations in space was the same as in the year 2000.

Year 2000 EUROSTAT data (the Economic Accounts for Agriculture as available from within CAPRI) for aggregate N-input per ha were used to assign intensity to these observations. Although these data are crop-specific, translation was required from CAPRI-classes to 2003 and 2006 LUCAS-classes. Table 2 shows this translation.

Table 2: Translation of CAPRI crop types to LUCAS crop types

CAPRI		**LUCAS 2003**		**LUCAS 2006**	
code	**name**	**code**	**name**	**code**	**name**
SWHE	Soft wheat	B11	Common wheat	B11	Common wheat
DWHE	Durum Wheat	B12	Durum Wheat	B12	Durum Wheat
BARL	Barley	B13	Barley	B13	Barley
RYEM	Rye and Meslin	B14	Rye	B14	Rye
OATS	Oats	B15	Oats	B15	Oats
MAIZ	Grain Maize	B16	Maize	B16	Maize
PARI	Paddy Rice	B17	Rice	B17	Rice
OCER	Other cereals	B18	Other cereals	B19	Other cereals
POTA	Potatoes	B21	Potatoes	B21	Potatoes
SUGB	Sugar beet	B22	Sugar beet	B22	Sugar beet
-	Not included	B23	Other root crops	B23	Other root crops
SUNF	Sunflower	B31	Sunflower	B31	Sunflower
RAPE	Rape	B32	Rape and turnip seeds	B32	Rape and turnip seeds
SOYA	Soya	B33	Soya	B33	Soya
OIND	Other industrial crops	B34	Cotton	B34	Cotton
OOIL	Other oils	B35	Other fibre and oleaginous crops	B35	Other fibre and oleaginous crops
TOBA	Tobacco	B36	Tobacco	B36	Tobacco
OIND / TEXT	Other industrial crops / Flax and hemp	B37	Other non permanent industrial crops	B37	Other non permanent industrial crops
PULS	Pulses	B41	Dry pulses	B41	Dry pulses
TOMA	Tomatoes	B42	Tomatoes	B42	Tomatoes
OVEG	Other vegetables	B43	Other fresh vegetables	B43	Other fresh vegetables
FLOW	Flowers	B44	Floriculture and ornamental plants	B44	Floriculture and ornamental plants
OFRU	Other fruits	B45	Strawberries	B45	Strawberries
OFAR	Fodder other on arable land	-	Not included	B51	Clovers
OFAR	Fodder other on arable land	-	Not included	B52	Lucerne
OFAR/ROOF	Fodder other on arable land / Fodder root crops	-	Not included	B53	Other Legumes and mixtures for fodder
FALL	Fallow land	B60	Fallow land	-	Not included
APPL	Apples, pears and peaches	B71	Apple fruit	B71	Apple fruit
APPL	Apples, pears and peaches	B72	Pear fruit	B72	Pear fruit
OFRU	Other fruits	B73	Cherry fruit	B73	Cherry fruit
	Not included	B74	Nuts trees	B74	Nuts trees
OFRU	Other fruits	B75	Other fruit trees and berries	B75	Other fruit trees and berries
CITR	Citrus fruits	B76	Oranges	B76	Oranges
CITR	Citrus fruits	B77	Other citrus fruit	B77	Other citrus fruit
OLIV / TABO	Olives for oil / Table Olives	B81	Olive groves	B81	Olive groves
TWIN	Table wine	B82	Vineyards	B82	Vineyards
NURS	Nurseries	B83	Nurseries	B83	Nurseries
OIND	Other industrial crops	B84	Permanent industrial crops	B84	Permanent industrial crops

The NUTS2-specific and crop-specific aggregate N/ha for the year 2000 from CAPRI was then assigned to each observation of arable land in LUCAS. The observations were then divided into three intensity classes: low intensity (0-100 kg N-input/ha), medium intensity (100-250 kg N-input/ha) and high intensity (>250 kg N-input/ha) arable land.

2.2.2 Multinomial logistic regression

In the five countries used for demonstration, for every LUCAS observation the corresponding values of the 48 location factors used in the CLUE application for EURURALIS (Verburg *et al.*, 2006) were sampled and multinomial logistic regression was performed.

Multinomial logistic regression first calculates the odds (logit) z_{ik} of an observation i falling in a class k relative to a reference class (medium intensity):

$$z_{ik} = b_{k0} + b_{k1}x_{il} + b_{k2}x_{i2} + \ldots + b_{kJ}x_{iJ} \tag{1}$$

Where x_{ij} is the jth predictor for the ith case, b_{kj} is the jth coefficient for the kth unobserved variable, and J is the number of predictors.
The corresponding probability π of observation i falling in class k is:

$$\pi_{ik} = \frac{e^{z_{ik}}}{e^{z_{i1}} + e^{z_{i2}} + \ldots + e^{z_{ik}}} \tag{2}$$

Regression was performed forward stepwise, with entry probability chosen such that the resulting regression model had between 5 and 10 predictors, and removal probability at 0.1. If any two predictors in the resulting model had a correlation > 0.7, one of them was removed and the model was recalculated. This minimizes problems due to multicollinearity (e.g. (Kempen *et al.*, 2009).

Regression model performance was assessed with the Receiver Operating Characteristic (ROC) curve (Swets, 1988). An ROC curve plots the fraction of true positives (sensitivity) versus the fraction of false positives (1-specificity). Areas under the curve typically range from 0.5 (where the regression model is as good as a random model) to 1 (a perfect model; i.e. without false positives or false negatives). Figure 4 is an example ROC curve for the regression model predicting occurrence of medium intensity arable land in Portugal (area under the curve = 0.856).

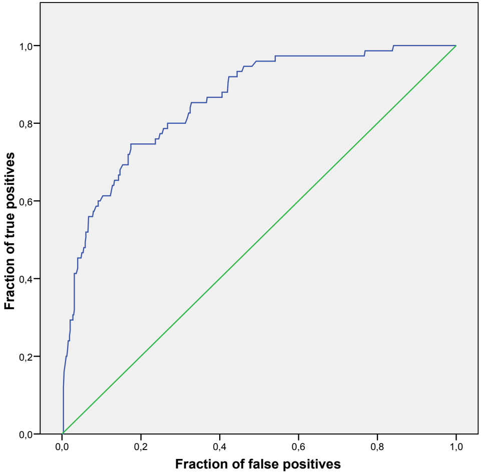

Figure 4 : ROC curve of medium intensity arable agriculture in Portugal.

2.3 Grassland

2.3.1 Intensity classification

For grassland, LUCAS distinguishes between grassland with trees and grassland without trees. CAPRI distinguishes between intensive grassland and extensive grassland. This means that for grassland, it is not possible to objectively link LUCAS crop types with CAPRI crops.

Instead, the EU-27 distribution of dairy cattle, available from (Neumann *et al.*, in press) at 1*1 km resolution[1], was used as a starting point. This dataset does not contain independent observations like the LUCAS dataset, but is the result of downscaling EUROFARM livestock statistics in an expert-based approach. This approach used decision rules that included classes of slope and soil suitability as location factors.

Neumann *et al*'s validation for twelve of the EU27 countries showed that dairy cattle maps produced with this expert-based downscaling approach are significantly better than those of a random distribution model. Incidentally, downscaling results for dairy cattle were better than those for beef cattle, sheep, pigs and poultry. Beef cattle distribution was not used as a starting point because beef cattle in Europe is predominantly stall-fed – hence not land based.

Neumann *et al* report cattle density in Livestock Units per ha. To convert from Livestock Units to heads, standard EUROSTAT tables at NUTS2 level were used. To further convert from heads to kg N/ha, we used an EU-wide uniform assumption of 100 kg N/ha per cow per year. This assumption is widely used, (e.g. (Van der Hoek, 1998). This amount of nitrogen was then classified into two intensity classes: low intensity (0-100 kg N/ha) and high intensity (>100 kg N/ha) grassland. We considered adding a third intensity class analogous to the third class for arable intensity (>250 kg N/ha), but this class would have been almost unpopulated and therefore lack a statistical background.

Moreover, assigning demand to more than two classes of grassland intensity would be possible but questionable (see 2.4).

2.3.2 Binary logistic regression

The resulting EU-wide distribution of dairy cattle in low and high intensity was used in binary logistic regression under the assumption that dairy cattle-related nitrogen input is a good estimate for overall nitrogen input on European grasslands.

Binary logistic regression first calculates the odds (logit) z_i of an observation *i* analogous to Eq. (2). Because only two outcomes are possible – in our case low intensity and high intensity grassland – Eq. (2 changes into:

$$\pi_i = \frac{1}{1+e^{-z_i}} \tag{3}$$

Where probability π of observation *i* is defined as the probability of high-intensity grassland. Datasets for the five countries were balanced by taking a random sample from the intensity class with highest prevalence to match the number of observations in the intensity class with

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[1] The EU27 comprises the 15 member countries of the European Union before the expansion in 2004 plus the 12 member countries that joined the European Union in 2004

lowest prevalence. Regression was performed forward conditional, with entry probability chosen such that the resulting regression model had between 5 and 10 predictors, and removal probability at 0.1. Multicollinearity problems were avoided as explained for multinomial logistic regression.

2.4 Allocation

A simple algorithm was used to allocate different land use classes within the NUTS2 regions given the specified areas of each of the classes. For grassland where only two classes are distinguished this allocation procedure is simply the determination of a cut-off value of the probability map that results in a division of the classes according to the specified areas at NUTS2 level. For arable land where three classes are present a discrete allocation procedure was used that maximized the suitability of each land use classes given the required area allocation at NUTS2 level. These allocation mechanisms are available in different software packages (e.g. (Hilferink and Rietveld, 1999). We have used the Conversion of Land Use and its Effects (Dyna-CLUE version; (Verburg and Overmars, 2009) model to assist in this allocation procedure.

Demands for the three arable and two grassland intensity classes for year 2000 and year 2025 were calculated with CAPRI outputs. In the case of arable land, crops were first classified according to their aggregate N-input/ha. Then, the areas under the different intensity classes were summed and relative areas were calculated for every NUTS2 region.
In the case of grassland, as mentioned before, CAPRI distinguishes between intensive and extensive grassland. These two crop types can not be linked to LUCAS observations, but they cán be used to calculate relative demand for intensive and extensive grassland.

CAPRI defines intensive and extensive grassland as each having half the area of total grassland, and defines extensive grassland as having 42% of the aggregate N-input per ha of intensive grassland. Classification directly from these intensity values would therefore lead to only three possible outcomes: all grassland in a NUTS2 region is extensive, all grassland is intensive, or half the grassland is extensive and half the grassland in intensive. This is clearly unsatisfactory from a gradual-change perspective.

Incidentally, this means that CAPRI essentially has only one prediction – overall grassland intensity and area - and from there makes EU-wide assumptions about the relation between intensive and extensive grassland to get to two predictions. Using these assumptions to define more than two classes of intensity for grassland would clearly go too far.

Making two additional assumptions allowed calculation of a meaningful distribution of low-intensity and high-intensity grassland. The first assumption is that only the midpoints of CAPRI-extensive and CAPRI-intensive grassland areas have the predicted intensities (Figure 5). The second assumption is that true grassland intensities range linearly from values lower than those predicted for CAPRI-extensive grassland to values higher than those predicted for CAPRI-intensive grassland.

From there, a linear relation between intensity and relative area can be calculated. Filling in the threshold intensity for classification (in our case 100 kg aggregate N-input /ha) finally yields the relative areas of low-intensity and high-intensity grassland. Note that any linear relation conforming to our assumptions above will have the same aggregate N-input of all grassland per NUTS2 region, and in that sense remains consistent with CAPRI-outputs.

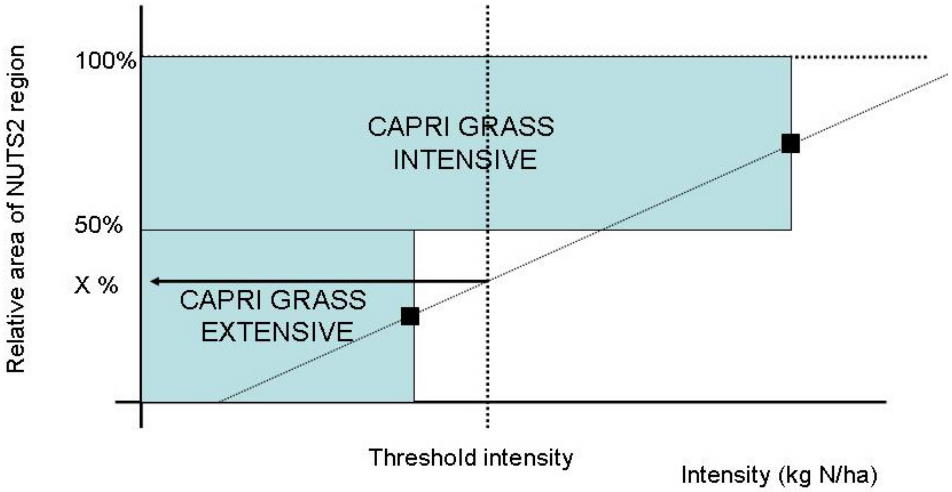

Figure 5: Determining relative demand of grassland intensities from CAPRI outputs. Relative demand for low intensity grassland is X%, relative demand for high intensity grassland is 100- X%.

For grassland and for arable land, absolute areas were obtained by multiplying the relative areas of the classes with the total available arable land respectively grassland in every NUTS region.

Using the absolute demand per NUTS region, and the regression models per country, dyna-CLUE allocated areas to intensity classes. Only grid cells that were known (y2000) or projected (y2025) to be agricultural land, were allowed to change. Arable land in intensity classes was only allowed in land that had been projected as arable (irrigated or non-irrigated) in EURURALIS, grassland in intensity classes was only allowed in land that had been projected as grassland in EURURALIS. For all other land the original observations (year 2000) or projections (year 2025) were maintained.

In CLUE studies, allocated changes are sometimes made irreversible, while others are dependent on the changes in earlier time steps (e.g. (Verburg and Overmars, 2009). These CLUE simulations tend to display the complex, non-linear changes in land use patterns that are characteristic for complex systems. In this study, it was assumed that changes in intensity were always possible within the arable and grassland areas. Therefore, no complex systems properties were involved, and only year 2000 and year 2025 runs were made. Incidentally, this means that the entire procedure can be performed as post-processing of existing sets of landuse and economic projections.

2.5 Analysis

To allow a multitemporal analysis of maps for the year 2000 and 2025 results, a closer look at possible combinations is needed. For our purposes, land can have only one of six land uses: no agricultural land use, three intensities of arable land use and two intensities of grassland land use. When comparing between years, this means that 36 combinations are possible. In Table 3, these combinations are classified according to the transition that they entail. An interpretation of the transitions is given in table 4.

Table 3: Classification matrix for land use change types as a function of year 2000 and year 2025 land use.

	Y2025	**No agri**	**A low**	**A med**	**A high**	**G low**	**G high**
Y2000		0	1	2	3	4	5
No agri	0	0	1	1	1	1	1
A low	1	2	0	3	3	0	3
A med	2	2	4	0	3	4	0
A high	3	2	4	4	0	4	0
G low	4	2	0	3	3	0	3
G high	5	2	4	0	0	4	0

Table 4: Interpretation of land use change types when comparing land use maps that include agricultural intensity classes.

Classification	**Interpretation**
0	No change in agricultural land use intensity
1	Agricultural expansion (converted to agriculture between 2000 – 2025)
2	Agricultural abandonment (converted from agriculture between 2000 - 2025
3	Intensification (more intensive management of agricultural land use between 2000 – 2025
4	Extensification (more extensive management of agricultural land use between 2000 – 2025

Importantly, this classification allows both intensification and abandonment, or both extensification and claiming without changing the aggregate N-input per NUTS2-region. Still, it is important to note that more information is available in the 36 combinations than can be presented in five classes. From a biodiversity perspective, the transition from high intensity arable land to medium intensity arable land, can be very different from the transition from medium intensity arable land to low intensity arable land – even though both transitions have classification 3: extensification.

3 Results

3.1 Regression models for arable land

Table 5 presents the overall results of the multinomial logistic regression analysis for the five demonstration countries. ROC-values are above 0.7, except for high intensity arable land in the Netherlands (0.687). Apparently, differences in arable agricultural intensity can be well characterised with logistic regression.

Table 5: results of multinomial logistic regression of classified arable land use intensity on 48 EURURALIS location factors

Country	Intensity class	LUCAS Observations	Number of predictors in model (J) - entry probability (p)	ROC-value
The Netherlands (LUCAS 2003, 2006)	Low	51	J = 7 (p <=0.05)	0.793
	Medium	134		0.752
	High	1073		0.687
Portugal (LUCAS 2003)	Low	326	J = 6 (p <= 0.025)	0.808
	Medium	524		0.856
	High	75		0.892
Poland (LUCAS 2006)	Low	4954	J = 6 (p = 0.00)	0.734
	Medium	5383		0.734
	High	72		0.725
Spain (LUCAS 2003, 2006)	Low	14034	J = 11 (p <= 0.00)	0.756
	Medium	3310		0.755
	High	542		0.774
Greece (LUCAS 2003)	Low	719	J = 9 (p <= 0.002)	0.836
	Medium	172		0.721
	High	216		0.897

Average ROC-values for the Netherlands (0.744), Poland (0.731) and Spain (0.762) are lower than those for Portugal (0.852) and Greece (0.818). This difference can be partly attributed to the fact that Portugal and Greece are only covered by LUCAS 2003 data that have higher autocorrelation. Also, the difference in model performance coincides with a different composition of the set of location factors in the regression model.

For Poland and the Netherlands, about half of the location factors are biophysical, and half are socio-economic (cf. Table 1). These two countries have the lowest average ROC values. For Spain, Portugal and Greece, almost all location factors are biophysical. Apparently, intensity of agricultural land use in Spain, Portugal and Greece is determined by biophysical factors to a larger degree than in Poland and the Netherlands. In turn, this apparently leads to better regression model performance.

The parameters of the five regression models were used in the CLUE intensity allocation for land that was previously observed (year 2000) or modelled (year 2025) as arable land.

3.2 Regression models for grassland

Table 6 presents the overall results of the binary logistic regression analysis for the five demonstration countries. Binary logistic regression results in only one regression model, instead of multinomial logistic regression, where regression models are calculated for every class (cf. Table 5). Therefore only one ROC-value is calculated per country.

ROC-values are below 0.66 for the Netherlands and Poland. For the Netherlands (0.561), this means that the regression model is not much better than a random model. Apparently, intensity of grassland (operationalized here as nitrogen input by dairy cattle excrement) is not well captured with this method for the Netherlands.

ROC-values are above 0.78 for Portugal, Spain and Greece. In these countries, intensity of grassland is clearly well captured with logistic regression.

Table 6: Results of binary logistic regression of classified grassland intensity on 48 CLUE location factors. Balancing was approximate.

Country	**Balanced class frequencies (high – low)**	**Number of predictors in model (J) and entry probability (p)**	**ROC-value**
The Netherlands	483 - 467	J = 2 (p <= 0.05)	0.561
Portugal	190 - 179	J = 5 (p <= 0.05)	0.787
Poland	9155 - 9164	J = 11 (p <= 0.01)	0.651
Spain	1328 - 1321	J = 9 (p <= 0.01)	0.812
Greece	54 - 60	J = 5 (p <= 0.01)	0.966

Again, the difference in performance coincides with a difference in the type of location factors that are included in the respective regression models. For the Netherlands and Poland, both biophysical and socio-economic factors are included, whereas for Portugal, Spain and Greece only biophysical factors are included.

Importantly, slope is not a factor in any of the five regression models for grassland intensity, even though classes of slope were used in the decision rules of (Neumann *et al.*, in press). For the classes of soil suitability this is more difficult to determine, because on the one hand several types of soil information were combined in that classification and on the other hand several factors in our regression models incorporate soil information. This means that we can not be sure that there is no circularity involved in the regression model for grassland intensity.

The parameters of the five regression models were used in the CLUE intensity allocation for land that was previously observed (year 2000) or modelled (year 2025) as grassland.

3.3 Allocated agricultural land use intensity

Allocation resulted in maps of agricultural intensity for the five countries for the year 2000 and for the year 2025. These 10 maps are given in Annex 2 . To introduce these maps, an example is given in Figure 6 for an area in the South East of Spain.

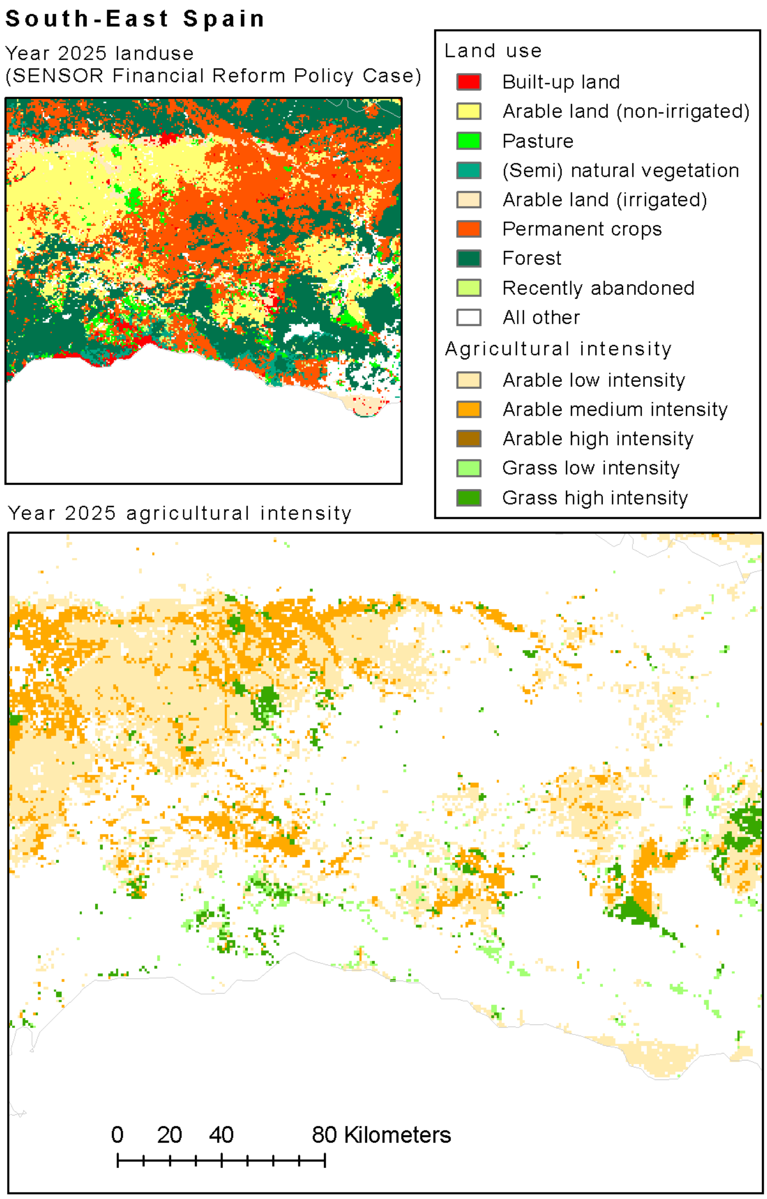

Figure 6: Example map of year 2025 agricultural intensity allocation for the South-East of Spain

Figure 6 illustrates properties that the five maps for year 2000 and the five maps for year 2025 have in common. First, arable or grassland in intensity classes are only projected in locations that have arable or grassland respectively in the land use map. No projection is made for other areas. Second, the pattern of different intensities within areas of arable or grassland is independent of the location of other land uses. In other words, the probability of a location for each intensity class is only dependent on the underlying location factors, not on the proximity of other land uses.

Note that the map presented in Figure 6 has been based on one of the many possible scenarios of future landuse change. Therefore, no claims are made regarding its accuracy.

3.4 Analysis

Combining the five intensity maps of the year 2000 with those of the year 2025 yielded, as discussed before, a map with 36 different combinations. These were classified according to Table 3. The resulting five maps of classified change in agricultural intensity are in Annex 5 . To introduce these maps, an example is given in Figure 7 for the area in the South East of Spain that was also used in Figure 6.

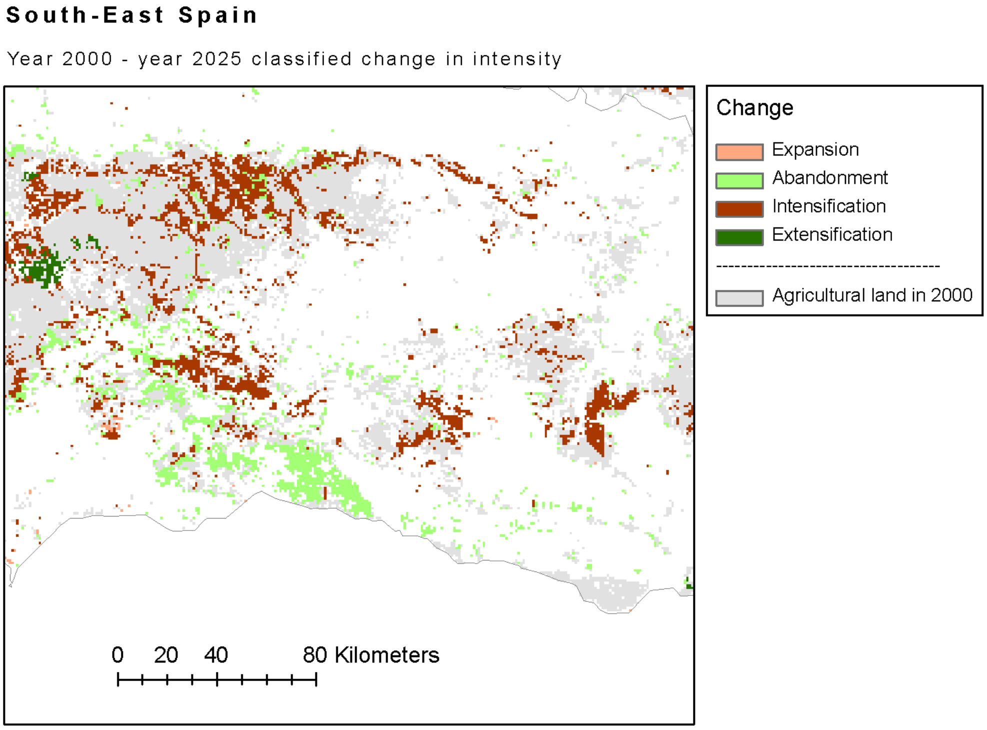

Figure 7: Example map of year 2000 – year 2025 classified change in intensity for the South-East of Spain. In gray, the area that was under agriculture in year 2000 is displayed.

Figure 7 illustrates properties that the five maps of change in intensity have in common. First, no classified change in intensity is projected for large parts of the agricultural area in year 2000. Note that this does not mean that no change occurred at all. For instance, a change from low intensity grassland to low intensity arable land is not captured in the classification of Table 3 and would not show in a map like Figure 7.

Second, agricultural land abandonment and intensification (or expansion and extensification) can occur at the same time. The reason for this can be - but need not be - that abandonment concerns grassland and intensification concerns arable land or the other way around, even if the observation concerns a single NUTS2 region. Intensification can for instance also coincide with a decrease in area when pressure on land increases and less productive arable land or grassland is abandoned, and more productive arable land or grassland is used more intensively.

In fact, and third, both intensification and extensification can occur at the same time. Analogous to the previous point, the reason for this can be - but need not be - that extensification concerns grassland and intensification concerns arable land or the other way around, even if the observation concerns a single NUTS2 region. Another explanation is for instance that the intensification concerns the transition from medium to high intensity arable land and that the extensification concerns the transition from medium to low intensity arable land. This can happen when some crops in the region intensify, and other crops extensify according to the CAPRI results.

Questions such as these can be answered by directly comparing the individual maps of intensity in year 2000 and year 2025 and their underlying CAPRI results. For the map of Figure 7, agricultural land that was abandoned was primarily grassland. Intensification and extensification both mostly concern arable land that changed from low intensity to medium intensity and changed from high intensity to medium intensity respectively. Ultimately, land of different intensity is allocated using the regression equations that best described year 2000 observed intensities for Spain.

4 Discussion

4.1 General

A comparison of regression results for arable and grassland shows that the difference in regression model performance between the northern two countries on the one hand and the southern three countries on the other hand, is larger for grassland than for arable land.

As mentioned before, no distinction was made between the (observed) EURURALIS classes of non-irrigated and irrigated arable land. A non-formal but informative test of the performance of our method can be made by assuming that irrigated arable land should have high intensity and checking whether our projections for the year 2000 are correct in this sense. Table 7 shows the results of this analysis for Spain and Greece.

Table 7: relative areas of intensity classes in irrigated and non-irrigated arable land for Spain and Greece.

Observed EURURALIS arable type	**Projected intensity**	**Spain**	**Greece**
Irrigated	Low	0.476	0.304
	Medium	0.333	0.472
	High	0.191	0.224
Non-irrigated	Low	0.726	0.647
	Medium	0.240	0.302
	High	0.034	0.052

It is apparent that not all irrigated arable land is assigned high intensity, and that the medium and high intensity classes combined occupy for only a bit more than half the irrigated land. However, in Spain, irrigated land is about six times more likely to have high intensity than non-irrigated land. In Greece, that number is between 4 and 5. This is an indication that the probability maps made with regression typically point to irrigated areas as having higher probability for high intensity than non-irrigated areas.

The method outlined in this paper projects the occurrence of classified intensity of agricultural land use. The choice for classification was necessary because discrete land use types are required for allocation. When only interested in the drivers of intensity, it would alternatively be possible to work with unclassified intensity (i.e. in units of kg aggregate N input/ha), and replace logistic regression with other appropriate forms of regression.

For the current intensity classification, limits of 100 kg N/ha and 250 kg N/ha were used. These limits were chosen from an operational perspective to ensure population of each class in as many NUTS2 regions as possible. From an utilitarian perspective, future class limits can reflect levels of nitrogen input that are deemed crucial for biodiversity transitions. For instance, a limit of 75 kg N input/ha has been identified as important (Kleijn *et al.*, 2009) and could be chosen as a limit for the lower class instead of 100 kg N input/ha. A change in the class limits entails repeating the method discussed in this paper from the point of classification of observations and would change the regression models presented.

The method we present in this paper is easily scalable to the EU-27 level. This includes the input data: LUCAS observations (http://www.lucas-europa.info) and Neumann *et al*s (2009) projections of dairy cattle intensity. Data related to scenarios of future land use at the EU27-

level are also available and should at least include (CLUE or other) projections of land use and CAPRI projections of total area and aggregate N-input/ha per crop per NUTS2 region. Such joint projections are for instance available from the EURURALIS and SENSOR studies. Complete automation of the method after the statistical analysis is possible in much the same way as in the EURURALIS project.

4.2 Assumptions

The method outlined in this paper involves accepting a number of assumptions that relate to the preparation of input data by others, and making a number of new assumptions. Below, we list and discuss some of these assumptions.

4.2.1 Assumptions relating to input data

- In CAPRI projections, it is assumed that within a NUTS2 region, every crop has a uniform intensity. In reality this assumption is likely violated. This violation decreases the validity of the combined LUCAS-CAPRI dataset for logistic regression.
- In CAPRI projections for grassland intensities and areas, a uniform relation between low intensity and medium intensity grassland is assumed to separate two classes. This assumption is unlikely to be valid for the whole EU and likely an oversimplification of the variation within grassland for a NUTS2 region. This violation decreases the confidence in the demands we calculate for the two grassland intensities.

4.2.2 Assumptions relating to the method

- We have assumed that aggregate nitrogen input per area is a good measure of intensity – or at least that aggregate nitrogen input per area is a good measure of the biodiversity implications of intensity. Conclusions about biodiversity that are drawn from the results of this method are only true to the degree that this assumption is true.
- In the calculation of grassland intensities, we have assumed that the N-input per area due to excrement of dairy cattle is a good measure for aggregate N-input per area. In reality, N-input due to excrement likely underestimates aggregate N-input to a certain degree. The more this is true, the more our class limit for grassland (100 kg aggregate N-input/ha) actually means a higher class limit. As a result, patterns of grassland intensity and the statistical model explaining them would no longer correspond with the demand calculated with CAPRI.
- Although we clearly account for some differences in behaviour between different classes of agricultural intensity, we do not account for differences that relate to the relation with land uses that are agricultural. Regardless of intensity, all arable land behaves the same when compared to all other land uses. The same goes for grassland. In this sense, our method is at a lower hierarchical level than the procedures that produce our input land use maps (e.g. CLUE allocation in EURURALIS). In reality, this assumption would be violated when for instance high intensity arable land is much less easy change its location than low intensity arable land. We believe that violations of this assumption are rare.
- The CLUE model makes a set of assumptions. Among these is the assumption that the influence of the different drivers of land use change does not change over time – i.e. the logistic regression models are stable over time. A violation of this assumption means that allocation is less correct. In practice, this means that projections for the future further than a few (e.g. three) decades from the present are not advised.

4.3 Validation

By definition, projections cannot be validated. Nevertheless, there are opportunities to validate parts of the method presented here. We list some of the most important below:

- Validating the multinomial regression model for intensity of arable land is possible by using a subset of the LUCAS observations. This subset can clearly not be used in model formulation. A subset that has not been used for model formulation in this paper is the set of LUCAS observations that are the second observation at their location (cf. section 2.2.1). Projecting probability of agricultural land at the observed intensity for each of these locations would allow calculation of a second ROC-graph for every regression model. This new ROC-curve would be the validation graph (as opposed to the calibration ROC-curve that was reported above).
- It is possible to partially validate the allocation by postdicting[2] distribution of different intensities of agricultural land for several years and compare those with the pattern of LUCAS-observed intensities in those years. The statistical relation between projected and observed intensities is obviously scale-dependent, which is why the pattern in the projected intensities does not have to be the same as the pattern in the observed intensities in any one year. However, the statistical relation between projection and observation must be constant over time. As discussed in section 0, year 2003 and year 2006 LUCAS data were not sampled in the same way, which makes this type of validation impossible for the moment. Use of more recent LUCAS data with sampling design similar to 2006 would make this possible.
- A more direct validation of the allocation would be to compare projected intensities with intensities observed with the FADN database. Note that this validation would also run the risk of making errors related to differences in spatial scale between the farm-level (FADN) and the spatial resolution of the data in our method (1*1 km). Also, restrictions apply to the use of the FADN database.

The last two validation efforts would allow a partial answer to open questions about the relative value of regression-based and process-based models for the projection of agricultural intensity and biodiversity effects (cf. (Lambin *et al.*, 2000; Petit and Firbank, 2006).

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[2] Postdiction is the prediction of something that lies in the past (and can hence be compared with observations).

5 Conclusions

We conclude that it is possible to project the amount and location of intensity of agricultural land in three classes for arable land and in two classes for grassland. As an example, these projections were made for the Netherlands, Poland, Portugal, Spain and Greece in the year 2000 (using available information) and in the year 2025 (for the SENSOR Financial Policy Reform Case).

Combination of year 2000 and year 2025 maps of agricultural intensity has allowed classification of transitions into broad categories of intensification, extensification, claiming and abandonment. These combinations and classifications are useful for subsequent quantification of (agro-)biodiversity changes.

We have outlined and illustrated the method to achieve such projections, discussed some of the assumptions that influence its validity and presented tests that could be performed to test that validity.

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Annex 1 Main project data

Dataset name	Destinations
Delivered by	WUR-LAD
Date	4-4-2008
Location	

Dataset	Destinations
Factsheet filled in by	Aurelien Letourneau
Origin	WUR-LAD
Description	Timecost to major destinations (i.e. major cities and ports).
Calculation procedure	Selection cities with more than 750,000 inhabitants or capitals from the UNEP major urban agglomerations and conversion to grid. Select ports with harborsize = 'Large' and conversion to grid. Combine destinations.
Uncertainty	
Inputs	UNEP major urban agglomerations with more than 750k Inhabitants. Global Maritime Ports Database.
Outputs	Destinations
Other remarks	
References	http://geodata.grid.unep.ch/ http://www.fao.org/geonetwork/srv/en/main.home

Annex 2 Logistic regression results

A2.3 Multinomial logistic regression results for LUCAS observations of arable land.

A2.3.1 Spain

Correlations

claycont_0 (1)	1
geomorf01 (2)	2
mean_temp_ (3)	3
poppot_1mi (4)	4
rain_wc_5m (5)	5
slope_fina (6)	6
Swap (7)	7
sz_landsc_ (8)	8
poppot_log (9)	9
t_plus15_1 (10)	10

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	.001	.016(*)	-.036(**)	.055(**)	.117(**)	.226(**)	-.033(**)	.022(**)	.004
2	.001	1	.045(**)	.011	-.152(**)	-.206(**)	.108(**)	-.024(**)	.068(**)	-.049(**)
3	.016(*)	.045(**)	1	.268(**)	-.434(**)	-.007	.150(**)	.386(**)	.438(**)	.572(**)
4	-.036(**)	.011	.268(**)	1	-.128(**)	-.040(**)	.087(**)	.314(**)	.475(**)	.207(**)
5	.055(**)	-.152(**)	-.434(**)	-.128(**)	1	.264(**)	-.208(**)	-.092(**)	-.169(**)	-.046(**)
6	.117(**)	-.206(**)	-.007	-.040(**)	.264(**)	1	-.183(**)	-.105(**)	-.053(**)	-.038(**)
7	.226(**)	.108(**)	.150(**)	.087(**)	-.208(**)	-.183(**)	1	.100(**)	.187(**)	.046(**)
8	-.033(**)	-.024(**)	.386(**)	.314(**)	-.092(**)	-.105(**)	.100(**)	1	.291(**)	.299(**)
9	.022(**)	.068(**)	.438(**)	.475(**)	-.169(**)	-.053(**)	.187(**)	.291(**)	1	.341(**)
10	.004	-.049(**)	.572(**)	.207(**)	-.046(**)	-.038(**)	.046(**)	.299(**)	.341(**)	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Nominal regression

Parameter Estimates

Intens_cls(a)		B	Sig.	Exp(B)
1	Intercept	2.64911417	.000	
	claycont_0	.01302493	.000	1.013
	geomorf01	-.03993479	.670	.961
	mean_temp_	.31597384	.000	1.372
	poppot_1mi	-.00000179	.000	1.000
	poppot_log	-.08273026	.000	.921
	rain_wc_5m	-.01214763	.000	.988
	salinity	-.53028841	.000	.588
	slope_fina	.06049319	.000	1.062
	swap	-.00701411	.000	.993
	sz_landsc_	-.00969152	.000	.990
	t_plus15_1	-.33025658	.000	.719
3	Intercept	-7.34599260	.000	
	claycont_0	.01301430	.000	1.013
	geomorf01	.91373871	.000	2.494
	mean_temp_	.33276448	.000	1.395
	poppot_1mi	-.00000240	.000	1.000
	poppot_log	.06285870	.087	1.065
	rain_wc_5m	-.00479497	.001	.995
	salinity	1.03966232	.000	2.828
	slope_fina	-.14290107	.000	.867
	swap	.00203107	.188	1.002
	sz_landsc_	.00063033	.712	1.001
	t_plus15_1	.17902676	.012	1.196

a The reference category is: 2.

ROC

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 1

Area
.756

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 2

Area
.755

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 3

Area
.774

A2.3.2 Greece

Correlations

access2_06	1
access6_06	2
dem_final	3
envmap13	4
geomorf03	5
geomorf04	6
geomorf05	7
il_2006	8
slope_fina	9
soildepth_	10
t_min0_100	11

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1	.928(**)	.065(*)	.523(**)	.074(*)	.052	.168(**)	-.093(**)	.340(**)	-.371(**)	-.008
2	.928(**)	1	.051	.296(**)	.058	-.057	.175(**)	-.069(*)	.247(**)	-.265(**)	.038
3	.065(*)	.051	1	-.055	.036	.235(**)	.115(**)	.112(**)	.382(**)	-.269(**)	.307(**)
4	.523(**)	.296(**)	-.055	1	.097(**)	.168(**)	.073(*)	-.021	.361(**)	-.406(**)	-.066(*)
5	.074(*)	.058	.036	.097(**)	1	-.518(**)	-.200(**)	-.110(**)	-.041	-.127(**)	-.075(*)
6	.052	-.057	.235(**)	.168(**)	-.518(**)	1	-.156(**)	-.004	.263(**)	-.180(**)	.052
7	.168(**)	.175(**)	.115(**)	.073(*)	-.200(**)	-.156(**)	1	-.040	.270(**)	-.058	.158(**)
8	-.093(**)	-.069(*)	.112(**)	-.021	-.110(**)	-.004	-.040	1	-.034	.139(**)	-.015
9	.340(**)	.247(**)	.382(**)	.361(**)	-.041	.263(**)	.270(**)	-.034	1	-.483(**)	.180(**)
10	-.371(**)	-.265(**)	-.269(**)	-.406(**)	-.127(**)	-.180(**)	-.058	.139(**)	-.483(**)	1	-.056
11	-.008	.038	.307(**)	-.066(*)	-.075(*)	.052	.158(**)	-.015	.180(**)	-.056	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Nominal Regression

Parameter Estimates

Intens_cls(a)		B	Sig.	Exp(B)
1	Intercept	.372224998	.091	
	access2_06	.000025444	.004	1.000
	dem_final	-.000603434	.188	.999
	envmap13	.610122099	.012	1.841
	geomorf03	-.046931922	.855	.954
	geomorf04	.560276089	.061	1.751
	geomorf05	4.234925403	.007	69.057
	il_2006	2.626502573	.012	13.825
	slope_fina	.106541231	.000	1.112
	t_min0_100	-3.662842437	.000	.026
3	Intercept	1.850474926	.000	
	access2_06	.000001240	.943	1.000
	dem_final	-.003329932	.000	.997
	envmap13	-1.073708170	.007	.342
	geomorf03	-1.324383113	.000	.266
	geomorf04	-.858552856	.016	.424
	geomorf05	.458550391	.820	1.582
	il_2006	-18.940933548	.	5.94E-009
	slope_fina	-.254965081	.000	.775
	t_min0_100	2.341969279	.104	10.402

a The reference category is: 2.

ROC

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 1

Area
.836

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 2

Area
.721

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 3

Area
.897

A2.3.3 The Netherlands

Correlations

access3_06	1
access4_06	2
claycont_0	3
envmap06	4
euac120_20	5
landsc_06	6
poppot_1mi	7

	1	2	3	4	5	6	7
1	1	.878(**)	-.184(**)	.200(**)	-.516(**)	-.075(**)	-.461(**)
2	.878(**)	1	-.114(**)	.313(**)	-.616(**)	-.085(**)	-.444(**)
3	-.184(**)	-.114(**)	1	-.152(**)	-.065(*)	-.054	.081(**)
4	.200(**)	.313(**)	-.152(**)	1	-.242(**)	-.031	-.127(**)
5	-.516(**)	-.616(**)	-.065(*)	-.242(**)	1	.125(**)	.539(**)
6	-.075(**)	-.085(**)	-.054	-.031	.125(**)	1	.084(**)
7	-.461(**)	-.444(**)	.081(**)	-.127(**)	.539(**)	.084(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Nominal Regression

Parameter Estimates

Intens_cls(a)		B	Std. Error	Exp(B)
1	Intercept	-2.80616155	1.040	
	claycont_0	.05062284	.014	1.052
	access4_06	-.00042449	.000	1.000
	envmap06	3.54045736	1.071	34.483
	euac120_20	.00000980	.000	1.000
	landsc_06	.00071965	.000	1.001
	poppot_1mi	-.00000829	.000	1.000
3	Intercept	.06046111	.626	
	claycont_0	.01056684	.008	1.011
	access4_06	.00002143	.000	1.000
	envmap06	-.81094272	.387	.444
	euac120_20	.00000652	.000	1.000
	landsc_06	.00005148	.000	1.000
	poppot_1mi	-.00000518	.000	1.000

a The reference category is: 2.

ROC

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 1

Area
.793

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 2

Area
.752

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 3

Area
.687

A2.3.4 Poland

Correlations

access2_06	1
access3_06	2
access6_06	3
claycont_0	4
mean_temp_	5
swap	6

	1	**2**	**3**	**4**	**5**	**6**
1	1	.487(**)	.639(**)	.033(**)	-.423(**)	.046(**)
2	.487(**)	1	.317(**)	.156(**)	-.470(**)	.194(**)
3	.639(**)	.317(**)	1	.122(**)	-.115(**)	.155(**)
4	.033(**)	.156(**)	.122(**)	1	.019(*)	.447(**)
5	-.423(**)	-.470(**)	-.115(**)	.019(*)	1	-.016
6	.046(**)	.194(**)	.155(**)	.447(**)	-.016	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Nominal Regression

Parameter Estimates

Intens_cls(a)		**B**	**Sig.**	**Exp(B)**
1	Intercept	2.832200475	.000	
	access2_06	.000148835	.000	1.000
	access3_06	.000035953	.000	1.000
	access6_06	-.000169208	.000	1.000
	claycont_0	-.020359065	.000	.980
	mean_temp_	-.280066045	.000	.756
	swap	-.006066133	.000	.994
3	Intercept	-7.654054112	.000	
	access2_06	-.000060340	.155	1.000
	access3_06	.000102705	.000	1.000
	access6_06	-.000053006	.106	1.000
	claycont_0	.010415360	.363	1.010
	mean_temp_	.287635241	.244	1.333
	swap	-.010905758	.008	.989

a The reference category is: 2.

ROC

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 1

Area
.734

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 2

Area
.734

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 3

Area
.725

A2.3.5 Portugal

Correlations

access4_06	1
claycont_0	2
dem_final	3
rain_wc_yr	4
slope_fina	5
soildepth_	6
wr_06	7

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	-.167(**)	.628(**)	.412(**)	.435(**)	-.513(**)	-.113(**)
2	-.167(**)	1	-.186(**)	-.286(**)	-.143(**)	.417(**)	.115(**)
3	.628(**)	-.186(**)	1	.355(**)	.447(**)	-.554(**)	-.068
4	.412(**)	-.286(**)	.355(**)	1	.447(**)	-.557(**)	-.024
5	.435(**)	-.143(**)	.447(**)	.447(**)	1	-.408(**)	-.040
6	-.513(**)	.417(**)	-.554(**)	-.557(**)	-.408(**)	1	-.024
7	-.113(**)	.115(**)	-.068	-.024	-.040	-.024	1

** Correlation is significant at the 0.01 level (2-tailed).

Nominal Regression

Parameter Estimates

Intens_cls(a)		**B**	**Sig.**	**Exp(B)**
1	Intercept	4.44622881	.000	
	access4_06	.00011575	.006	1.000
	claycont_0	.02709867	.112	1.027
	dem_final	.00119404	.158	1.001
	rain_wc_yr	-.00658850	.000	.993
	slope_fina	.10027073	.033	1.105
	soildepth_	.01149561	.194	1.012
3	Intercept	6.03223081	.003	
	access4_06	-.00002349	.726	1.000
	claycont_0	-.00621059	.753	.994
	dem_final	-.00420457	.097	.996
	rain_wc_yr	-.01042402	.000	.990
	slope_fina	-.11471731	.401	.892
	soildepth_	.04001363	.002	1.041

a The reference category is: 2.

ROC

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 1

Area
.808

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 2

Area
.856

Area Under the Curve

Test Result Variable(s): Estimated Cell Probability for Response Category: 3

Area
.892

A2.3 Binary logistic regression results for LUCAS observations of grassland.

A2.3.1 Spain

Correlations

dairy_cls	1
ddw_shorta	2
euac120_20	3
geomorf04	4
il_2006	5
slope_fina	6
swap	7
t_plus15_1	8

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	.112(**)	.096(**)	-.013	.133(**)	-.194(**)	.335(**)	-.013
2	.112(**)	1	-.375(**)	.101(**)	.108(**)	.277(**)	-.410(**)	.020
3	.096(**)	-.375(**)	1	-.091(**)	-.032	-.083(**)	.206(**)	.108(**)
4	-.013	.101(**)	-.091(**)	1	-.005	.338(**)	-.073(**)	-.233(**)
5	.133(**)	.108(**)	-.032	-.005	1	-.054(**)	-.126(**)	.165(**)
6	-.194(**)	.277(**)	-.083(**)	.338(**)	-.054(**)	1	-.299(**)	.005
7	.335(**)	-.410(**)	.206(**)	-.073(**)	-.126(**)	-.299(**)	1	-.204(**)
8	-.013	.020	.108(**)	-.233(**)	.165(**)	.005	-.204(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

Logistic Regression

Variables in the Equation

		B	**Sig.**	**Exp(B)**
Step 7(g)	ddw_shorta	.01598677	.000	1.016
	euac120_20	.00000593	.000	1.000
	geomorf04	.68806899	.001	1.990
	il_2006	1.78466311	.000	5.958
	slope_fina	-.17889155	.000	.836
	swap	.02812636	.000	1.029
	t_plus15_1	.14533333	.003	1.156
	Constant	-2.71926621	.000	.066

ROC

Area Under the Curve

Test Result Variable(s)	Area
Predicted probability	.795

A2.3.2 Greece

Correlations

	dem_final	rain_wc_5m	rain_wc_yr
dem_final	1	.466(**)	.315(**)
rain_wc_5m	.466(**)	1	.572(**)
rain_wc_yr	.315(**)	.572(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

Logistic Regression

Variables in the Equation

		B	Sig.	Exp(B)
Step 3(c)	dem_final	-.0081277	.000	.992
	rain_wc_5m	.0626480	.000	1.065
	rain_wc_yr	-.0107568	.000	.989
	Constant	-1.4719395	.183	.229

ROC

Area Under the Curve

Test Result Variable(s)	Area
Predicted probability	.962
Predicted probability	.944

A2.3.3 The Netherlands

Correlations

	peat_06	euac120_20
peat_06	1	.009
euac120_20	.009	1

Logistic Regression

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	peat_06	1.598	.640	6.245	1	.012	4.945
	Constant	-.058	.066	.781	1	.377	.944
Step 2(b)	euac120_20	.0000009624	.000	7.257	1	.007	1.000
	peat_06	1.6279096500	.641	6.450	1	.011	5.093
	Constant	-.4624716061	.164	7.945	1	.005	.630

a Variable(s) entered on step 1: peat_06.
b Variable(s) entered on step 2: euac120_20.

ROC

Area Under the Curve

Test Result Variable(s): Predicted probability

Area
.561

A2.3.4 Poland

Correlations

access1_06	1
ddw_shorta	2
envmap05	3
envmap06	4
euac120_20	5
geomorf01	6
rain_wc_5m	7
t_min0_100	8

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	.182(**)	.129(**)	-.148(**)	-.181(**)	.050(**)	.020(**)	.331(**)
2	.182(**)	1	.084(**)	-.316(**)	-.611(**)	-.306(**)	.587(**)	.492(**)
3	.129(**)	.084(**)	1	-.246(**)	-.016(*)	-.127(**)	.190(**)	.062(**)
4	-.148(**)	-.316(**)	-.246(**)	1	.389(**)	.045(**)	.012	-.338(**)
5	-.181(**)	-.611(**)	-.016(*)	.389(**)	1	.148(**)	-.196(**)	-.396(**)
6	.050(**)	-.306(**)	-.127(**)	.045(**)	.148(**)	1	-.526(**)	-.041(**)
7	.020(**)	.587(**)	.190(**)	.012	-.196(**)	-.526(**)	1	.187(**)
8	.331(**)	.492(**)	.062(**)	-.338(**)	-.396(**)	-.041(**)	.187(**)	1

Logistic Regression

Variables in the Equation

		B	**Sig.**	**Exp(B)**
Step 10(i)	access1_06	.00002089	.000	1.000
	ddw_shorta	.01475342	.000	1.015
	envmap05	-3.22592958	.000	.040
	envmap06	-.25079682	.000	.778
	euac120_20	.00001221	.000	1.000
	geomorf01	.32726194	.000	1.387
	rain_wc_5m	-.00720727	.000	.993
	t_min0_100	-.13848680	.000	.871
	Constant	2.05236471	.000	7.786

ROC

Area Under the Curve

Test Result Variable(s)	Area
Predicted probability	.644

A2.3.5 Portugal

Correlations

	access4_06	**envmap12**	**envmap13**	**poppot_sum**	**rain_wc_yr**
access4_06	1	.121(*)	-.104(*)	-.490(**)	.339(**)
envmap12	.121(*)	1	-.396(**)	.169(**)	-.180(**)
envmap13	-.104(*)	-.396(**)	1	-.074	-.373(**)
poppot_sum	-.490(**)	.169(**)	-.074	1	-.097
rain_wc_yr	.339(**)	-.180(**)	-.373(**)	-.097	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Logistic Regression

Variables in the Equation

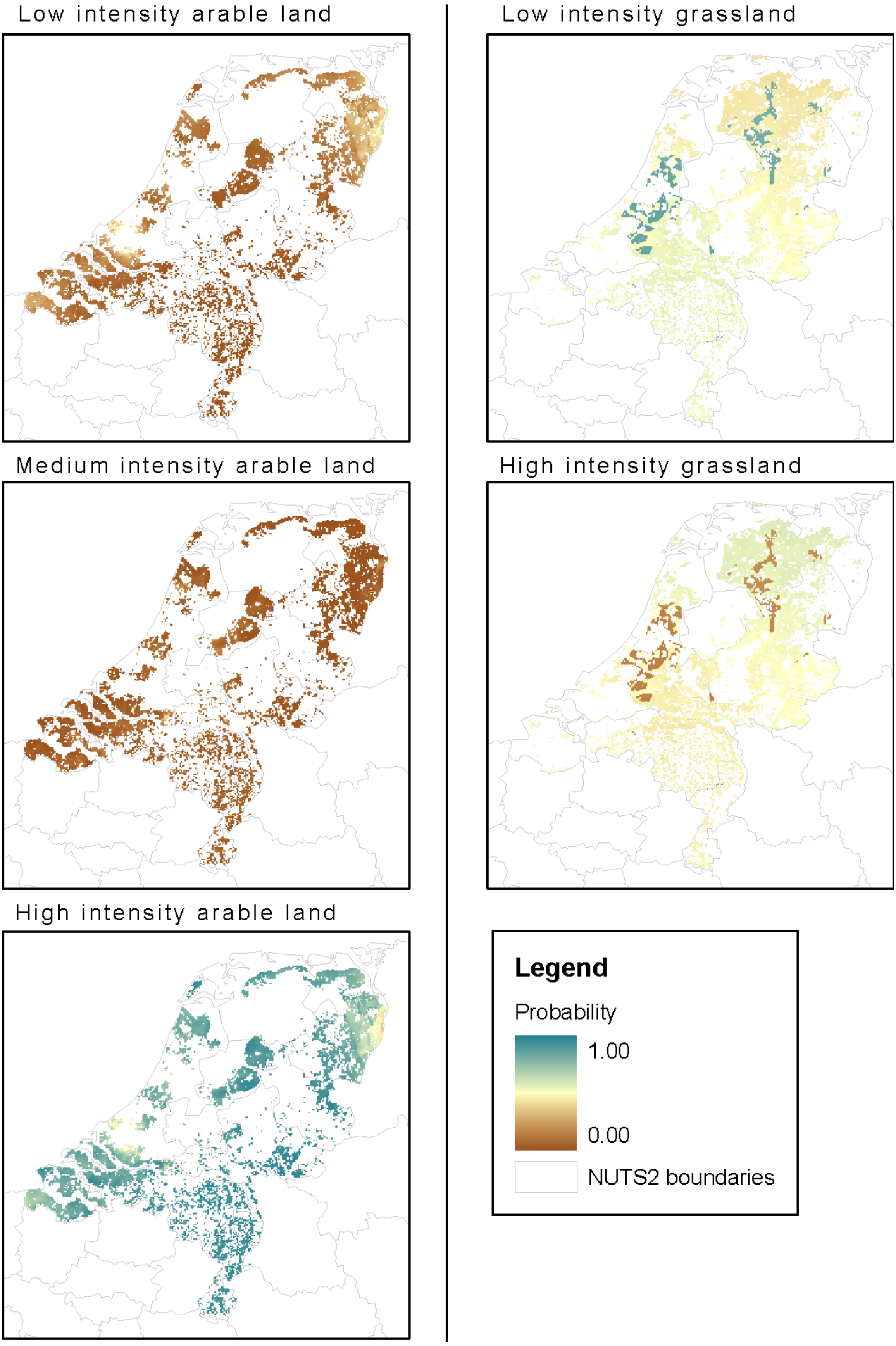
		B	**Sig.**	**Exp(B)**
Step 5(e)	access4_06	.00016000	.000	1.000
	envmap12	-.66830099	.026	.513
	envmap13	-4.22127601	.000	.015
	poppot_sum	.00000253	.006	1.000
	rain_wc_yr	-.00271712	.000	.997
	Constant	.22989174	.725	1.258

ROC

Area Under the Curve

Test Result Variable(s)	Area
Predicted probability	.787

Annex 3 Probability maps for agriculture



The Netherlands

Low intensity arable land

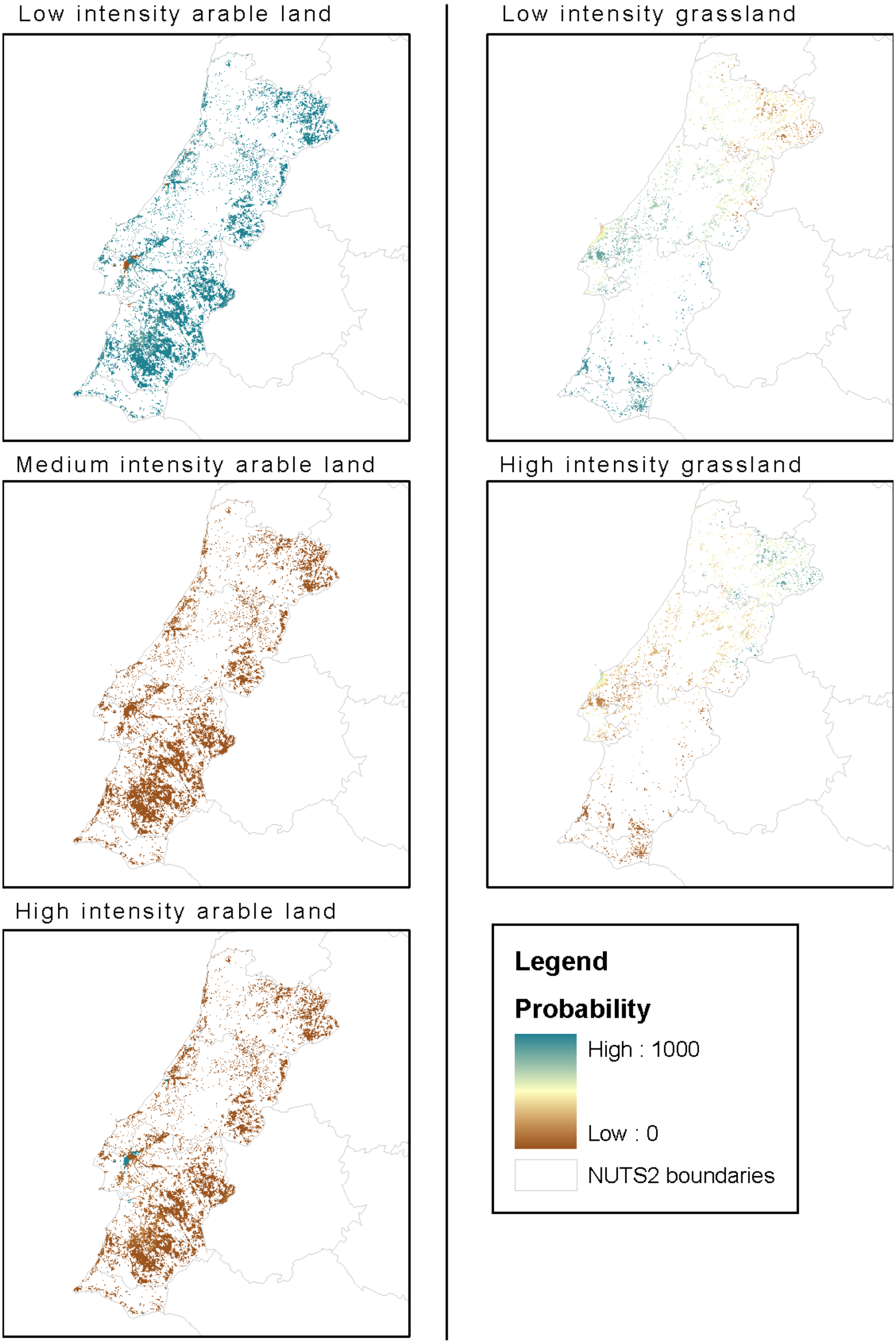
Low intensity grassland

Medium intensity arable land

High intensity grassland

High intensity arable land

Portugal

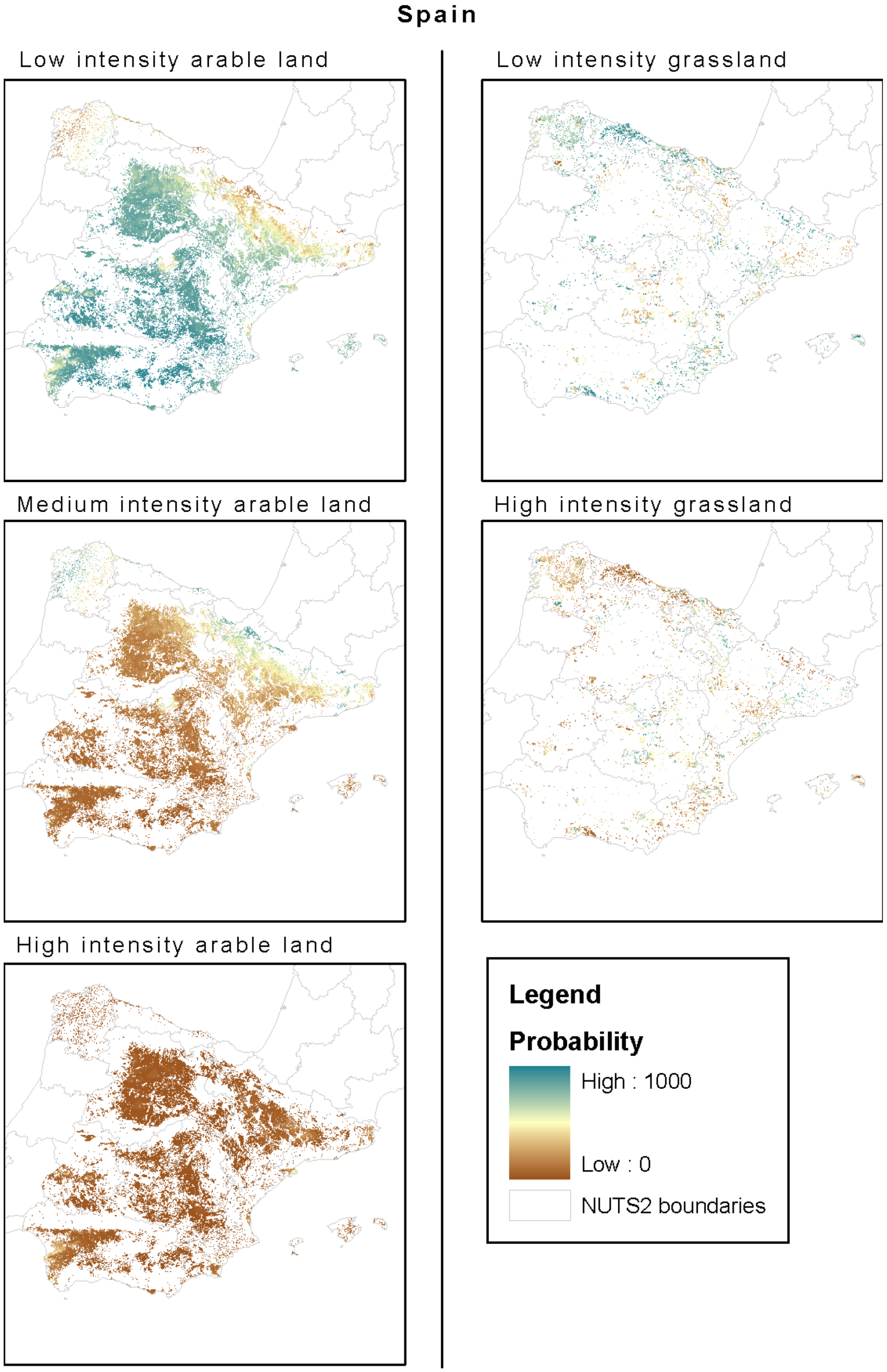

Low intensity arable land

Low intensity grassland

Medium intensity arable land

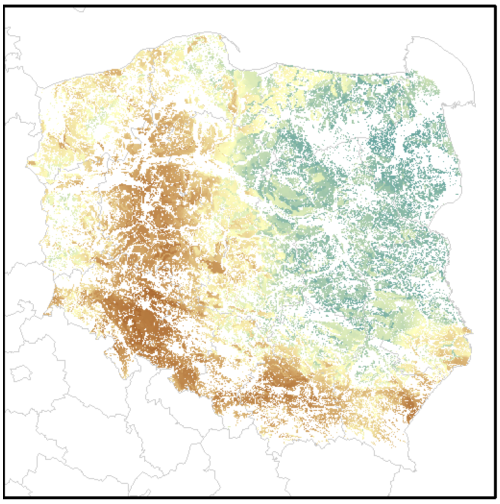
High intensity grassland

High intensity arable land

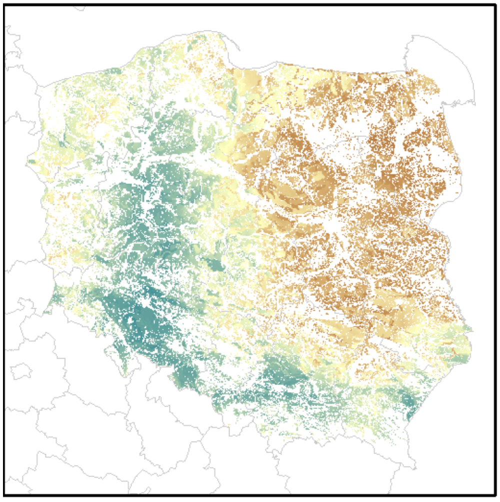

Spain
Low intensity arable land
Low intensity grassland
Medium intensity arable land
High intensity grassland
High intensity arable land
Legend
Probability
High : 1000
Low : 0
NUTS2 boundaries

Poland

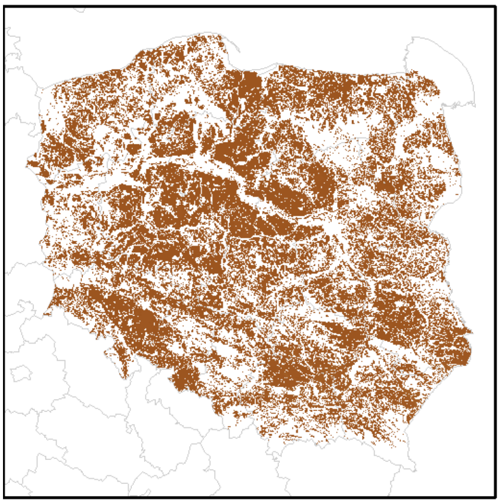
Low intensity arable land



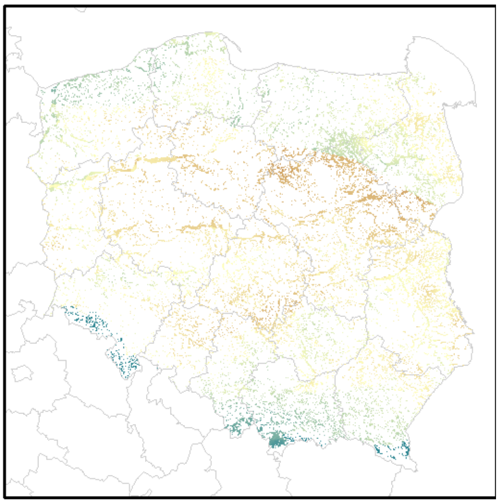
Medium intensity arable land



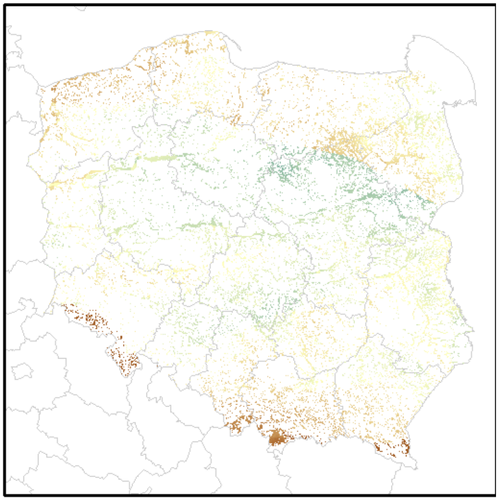
High intensity arable land

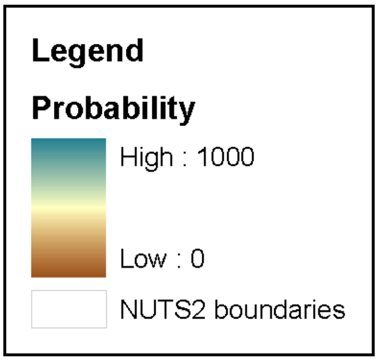


Low intensity grassland

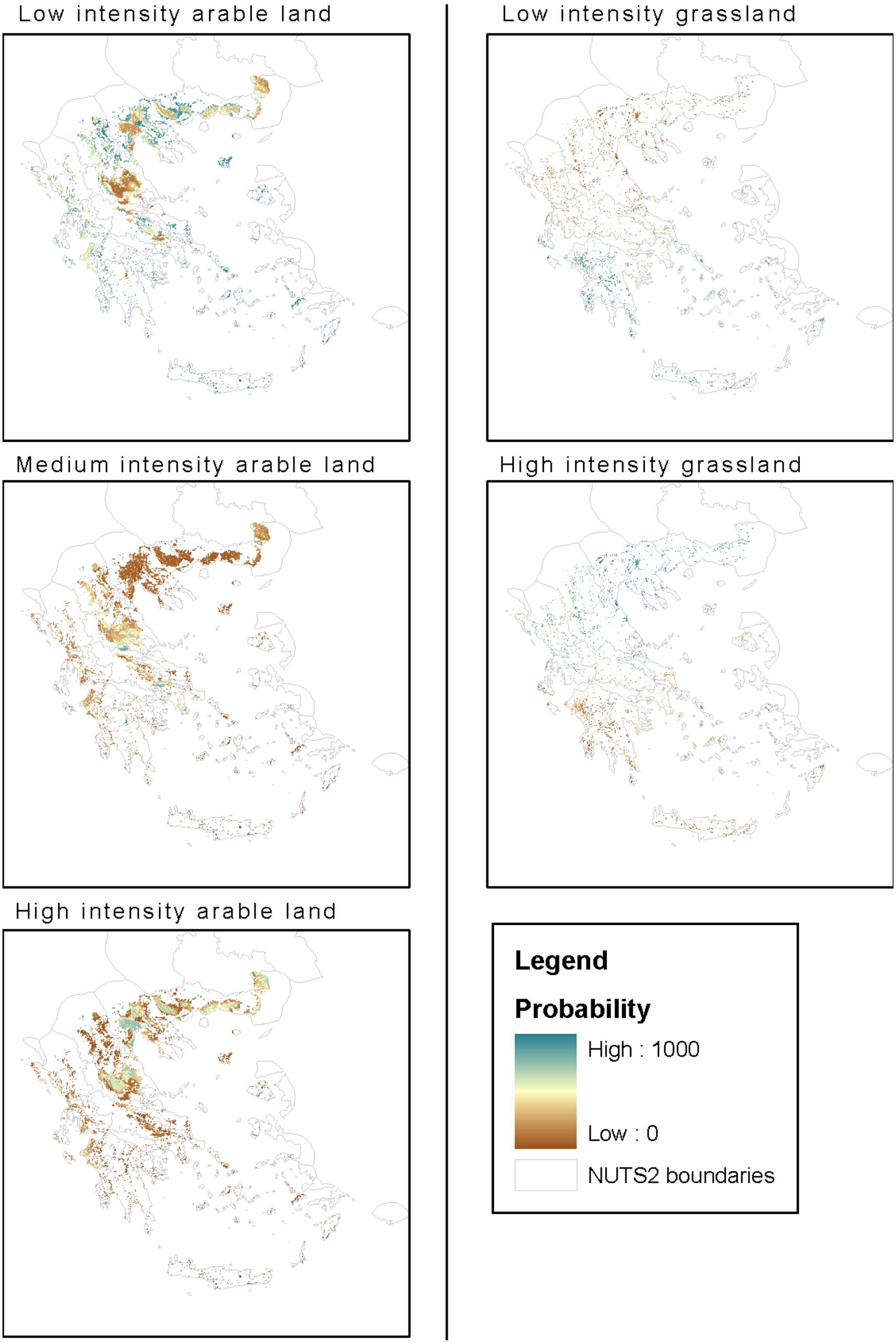


High intensity grassland





Greece



Low intensity arable land

Low intensity grassland

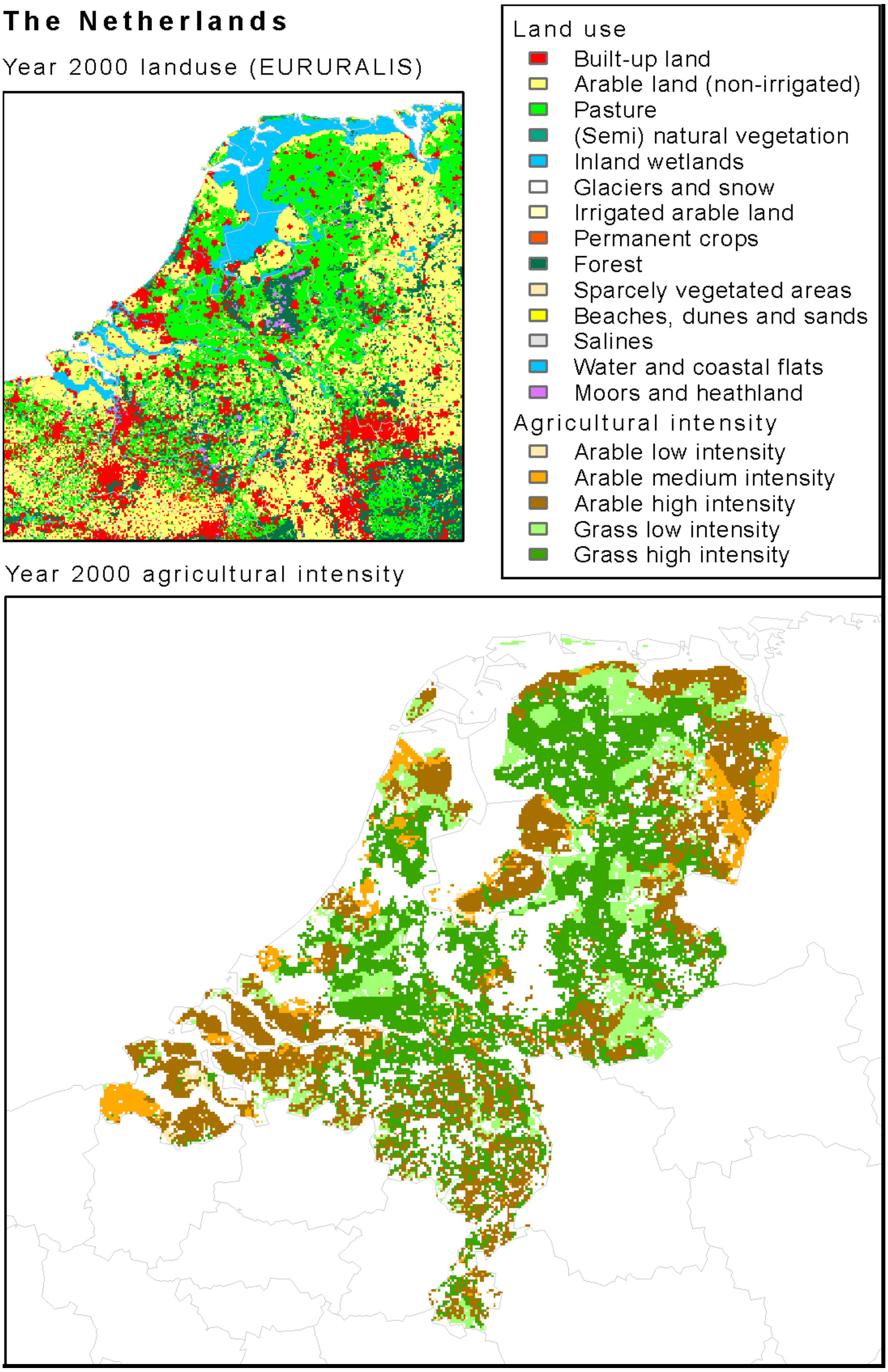
Medium intensity arable land

High intensity grassland

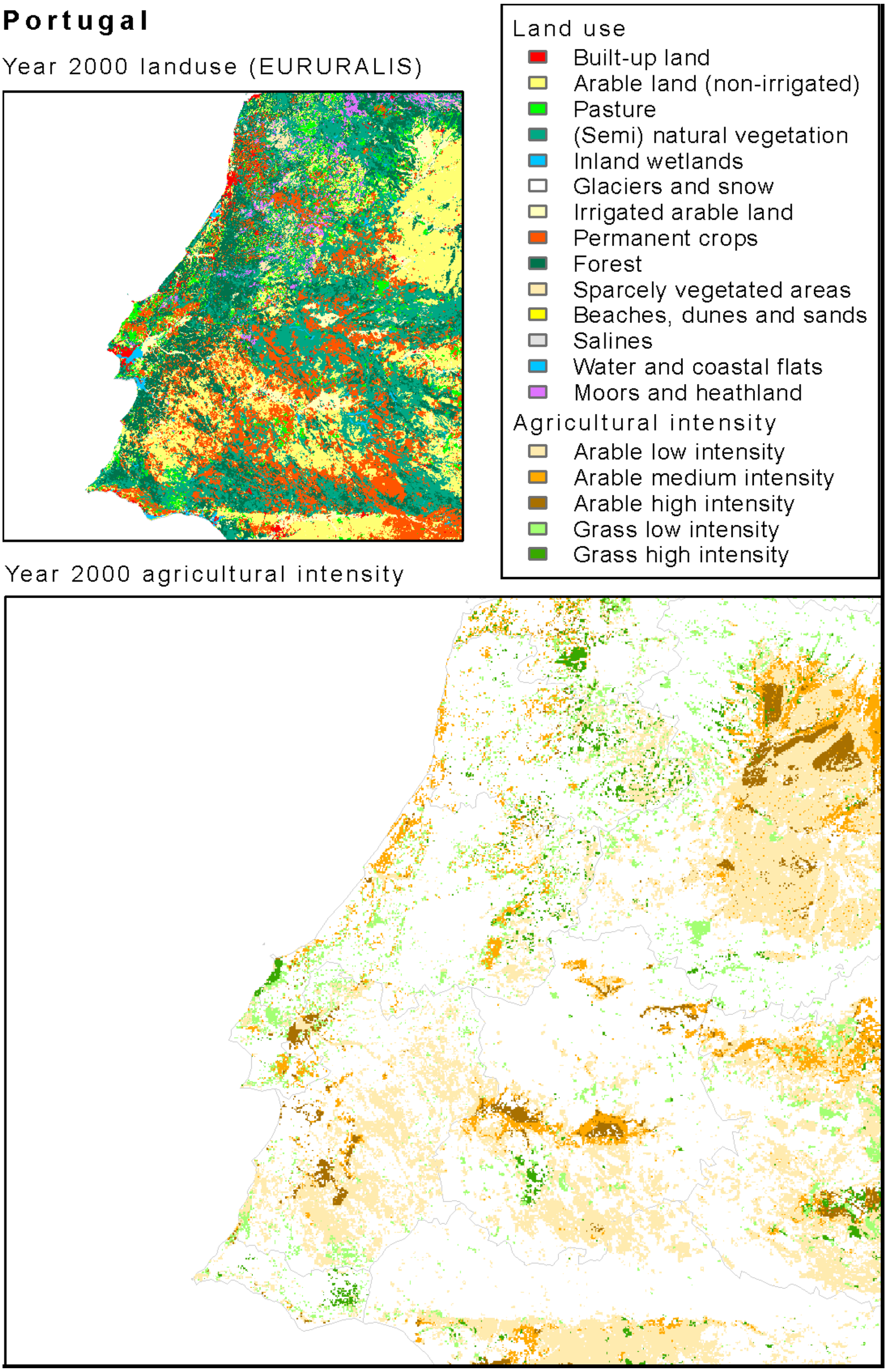
High intensity arable land

Annex 4 Maps of agricultural intensity

Maps of classified Agricultural intensity, year 2000



Portugal

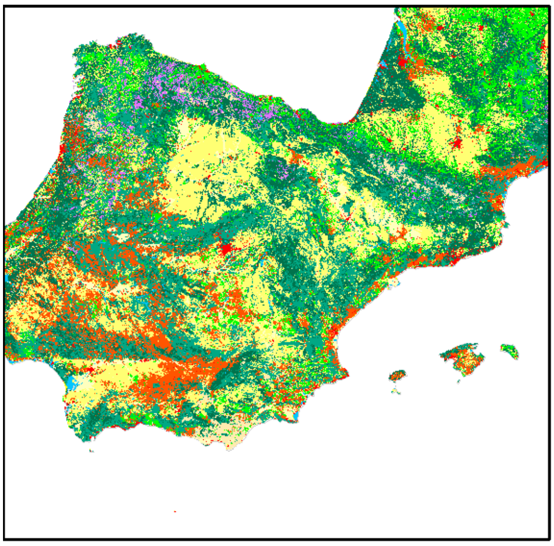


Year 2000 landuse (EURURALIS)

Year 2000 agricultural intensity

Spain

Year 2000 landuse (EURURALIS)



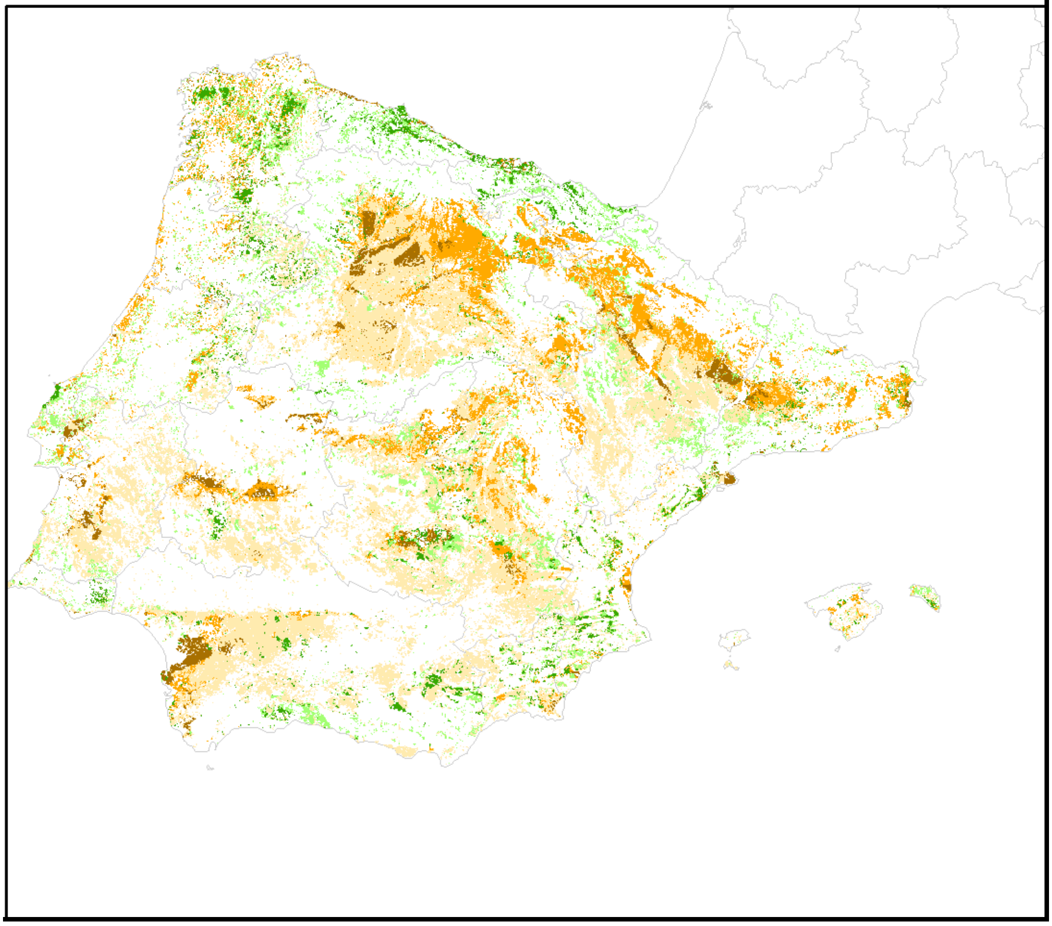
Land use

- 🟥 Built-up land
- 🟨 Arable land (non-irrigated)
- 🟩 Pasture
- 🟩 (Semi) natural vegetation
- 🟦 Inland wetlands
- ⬜ Glaciers and snow
- 🟨 Irrigated arable land
- 🟧 Permanent crops
- 🟩 Forest
- 🟨 Sparcely vegetated areas
- 🟨 Beaches, dunes and sands
- ⬜ Salines
- 🟦 Water and coastal flats
- 🟪 Moors and heathland

Agricultural intensity

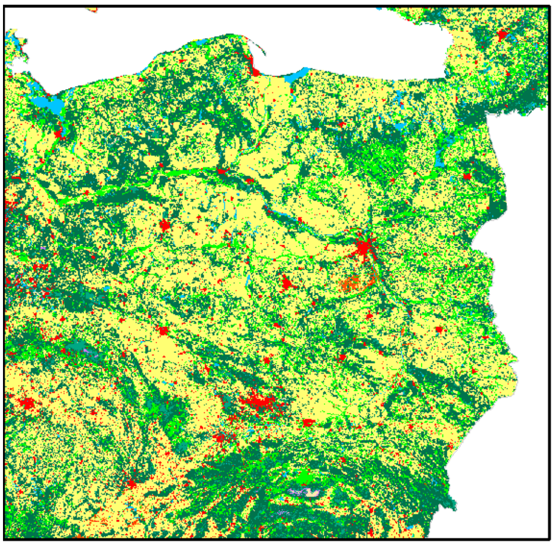
- 🟨 Arable low intensity
- 🟧 Arable medium intensity
- 🟫 Arable high intensity
- 🟩 Grass low intensity
- 🟩 Grass high intensity

Year 2000 agricultural intensity



Poland

Year 2000 landuse (EURURALIS)



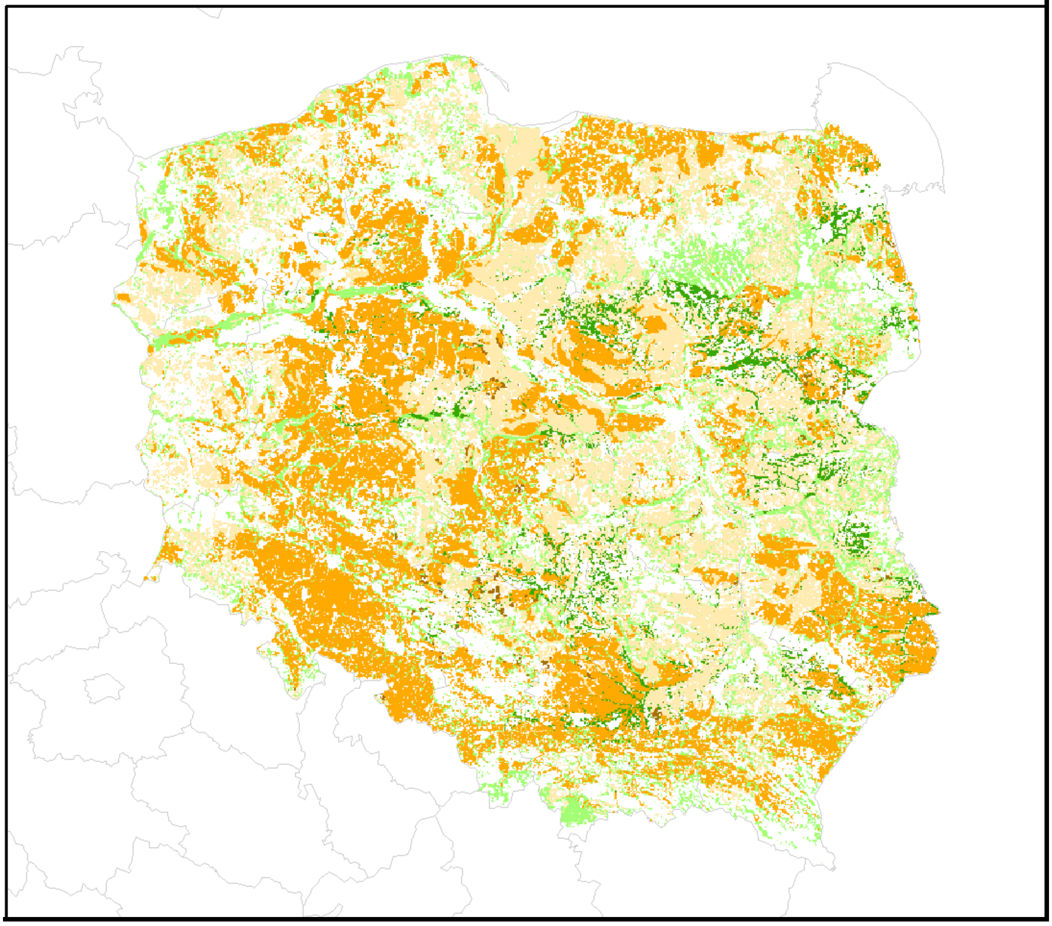
Land use

- 🟥 Built-up land
- 🟨 Arable land (non-irrigated)
- 🟩 Pasture
- 🟩 (Semi) natural vegetation
- 🟦 Inland wetlands
- ⬜ Glaciers and snow
- 🟨 Irrigated arable land
- 🟧 Permanent crops
- 🟩 Forest
- 🟨 Sparcely vegetated areas
- 🟨 Beaches, dunes and sands
- ⬜ Salines
- 🟦 Water and coastal flats
- 🟪 Moors and heathland

Agricultural intensity

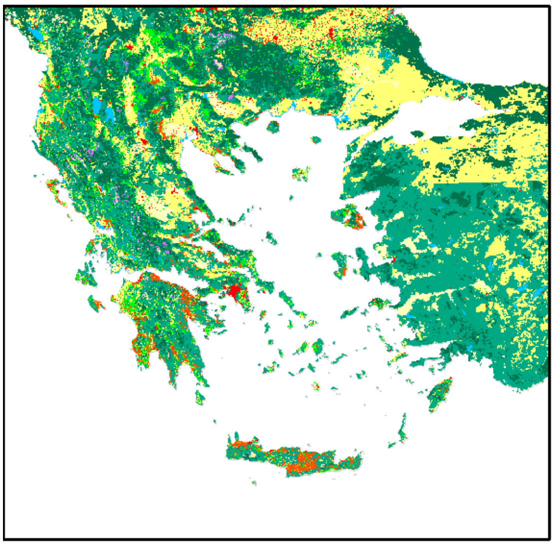
- 🟨 Arable low intensity
- 🟧 Arable medium intensity
- 🟫 Arable high intensity
- 🟩 Grass low intensity
- 🟩 Grass high intensity

Year 2000 agricultural intensity

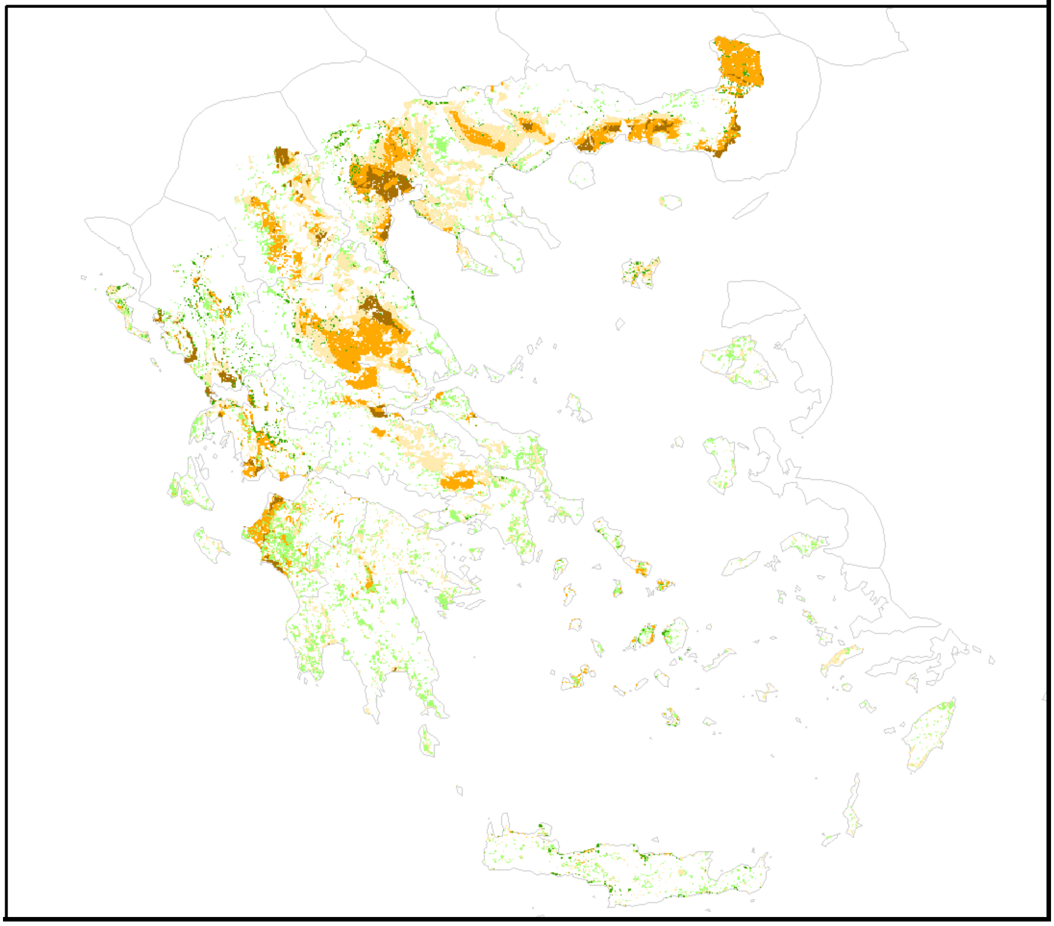


Greece

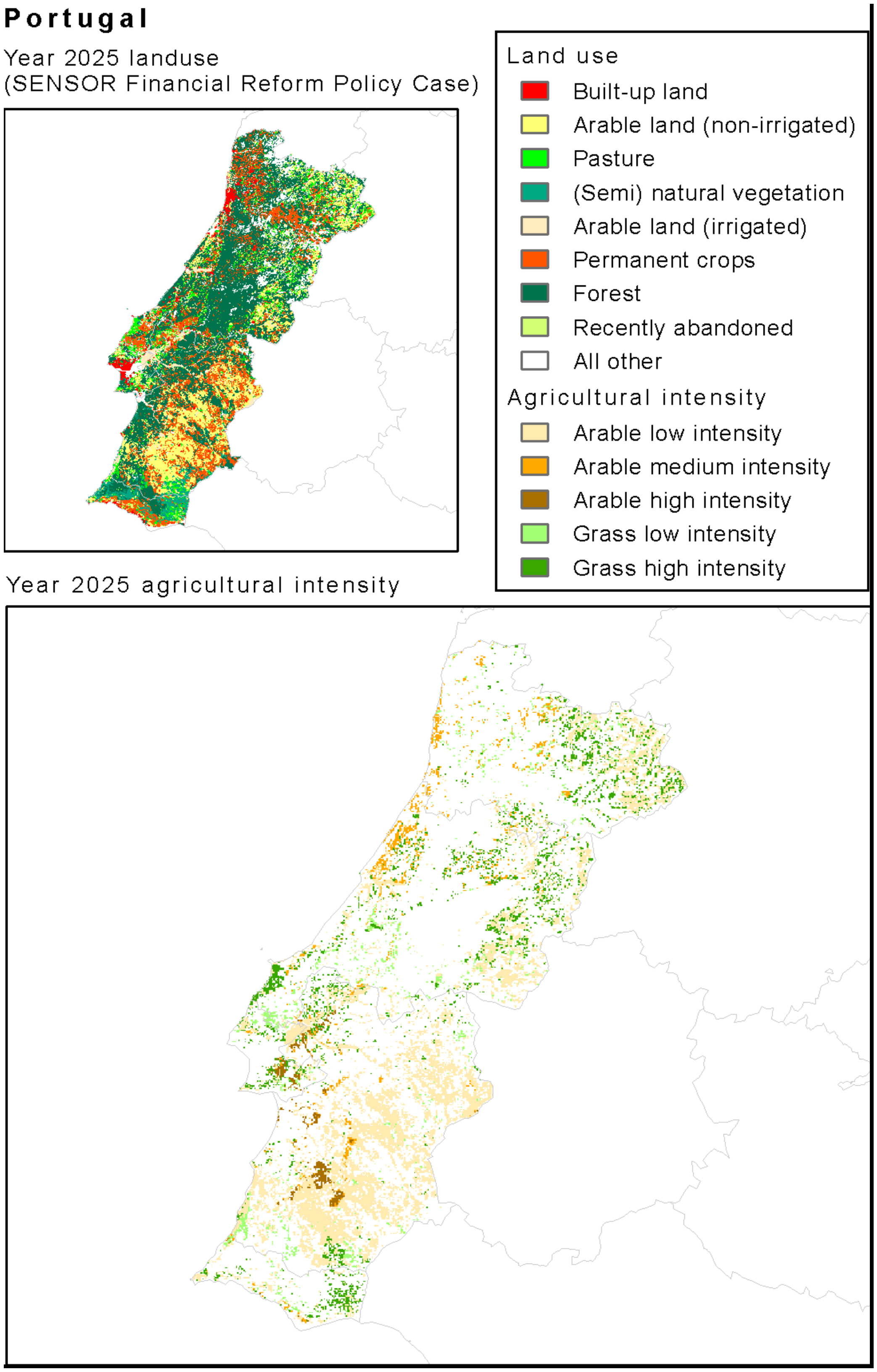
Year 2000 landuse (EURURALIS)



Year 2000 agricultural intensity

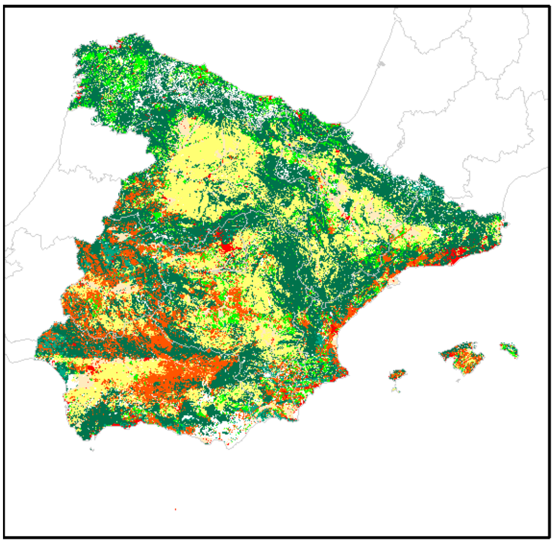


Maps of classified agricultural intensity, year 2025



Spain

Year 2025 landuse
(SENSOR Financial Reform Policy Case)



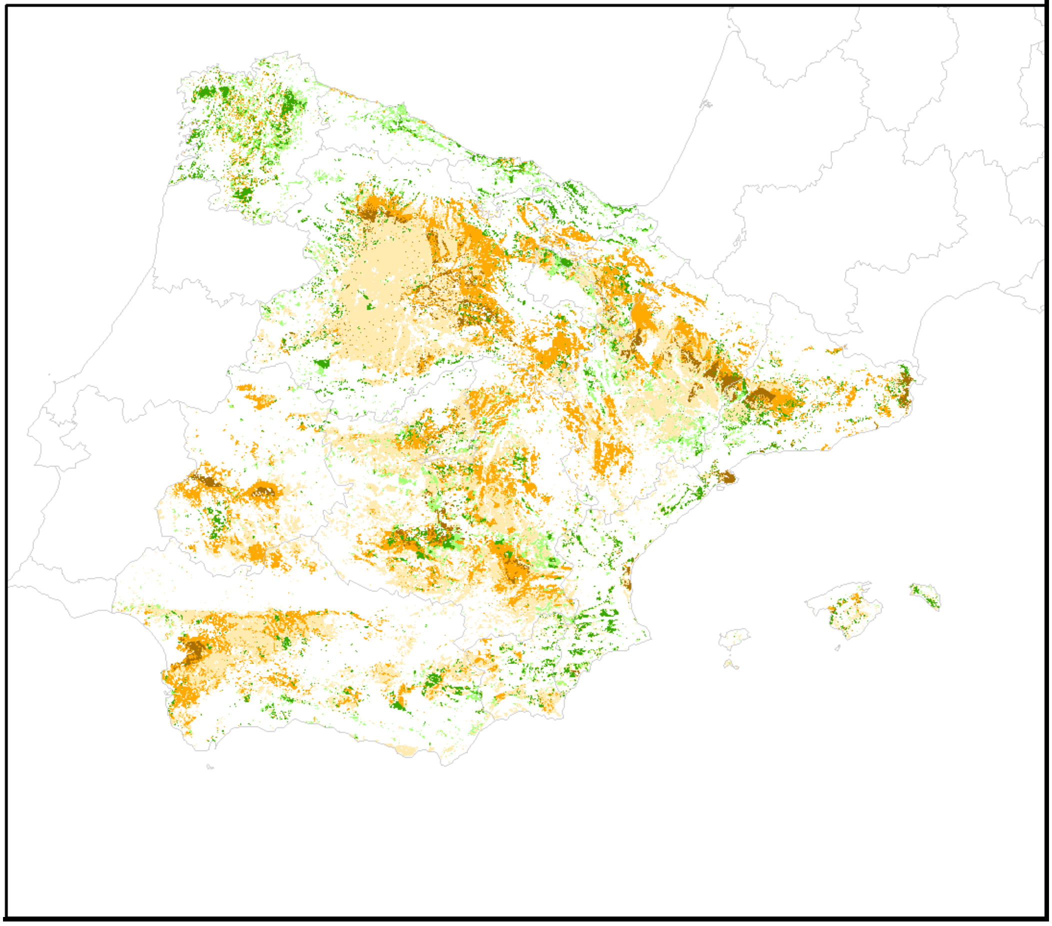
Land use

- 🟥 Built-up land
- 🟨 Arable land (non-irrigated)
- 🟩 Pasture
- 🟩 (Semi) natural vegetation
- 🟨 Arable land (irrigated)
- 🟧 Permanent crops
- 🟩 Forest
- 🟩 Recently abandoned
- ☐ All other

Agricultural intensity

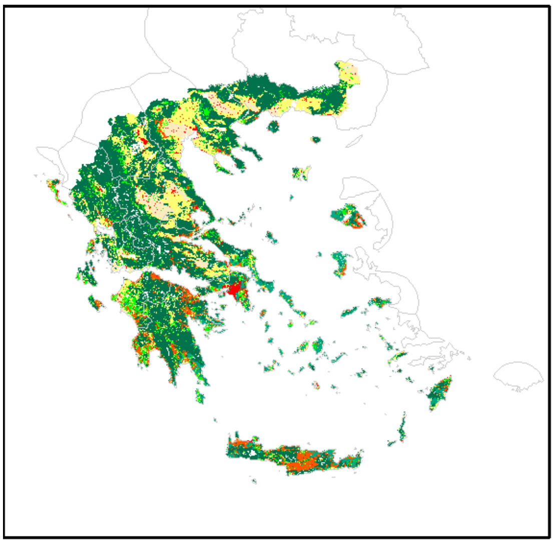
- 🟨 Arable low intensity
- 🟧 Arable medium intensity
- 🟫 Arable high intensity
- 🟩 Grass low intensity
- 🟩 Grass high intensity

Year 2025 agricultural intensity



Greece

Year 2025 landuse
(SENSOR Financial Reform Policy Case)



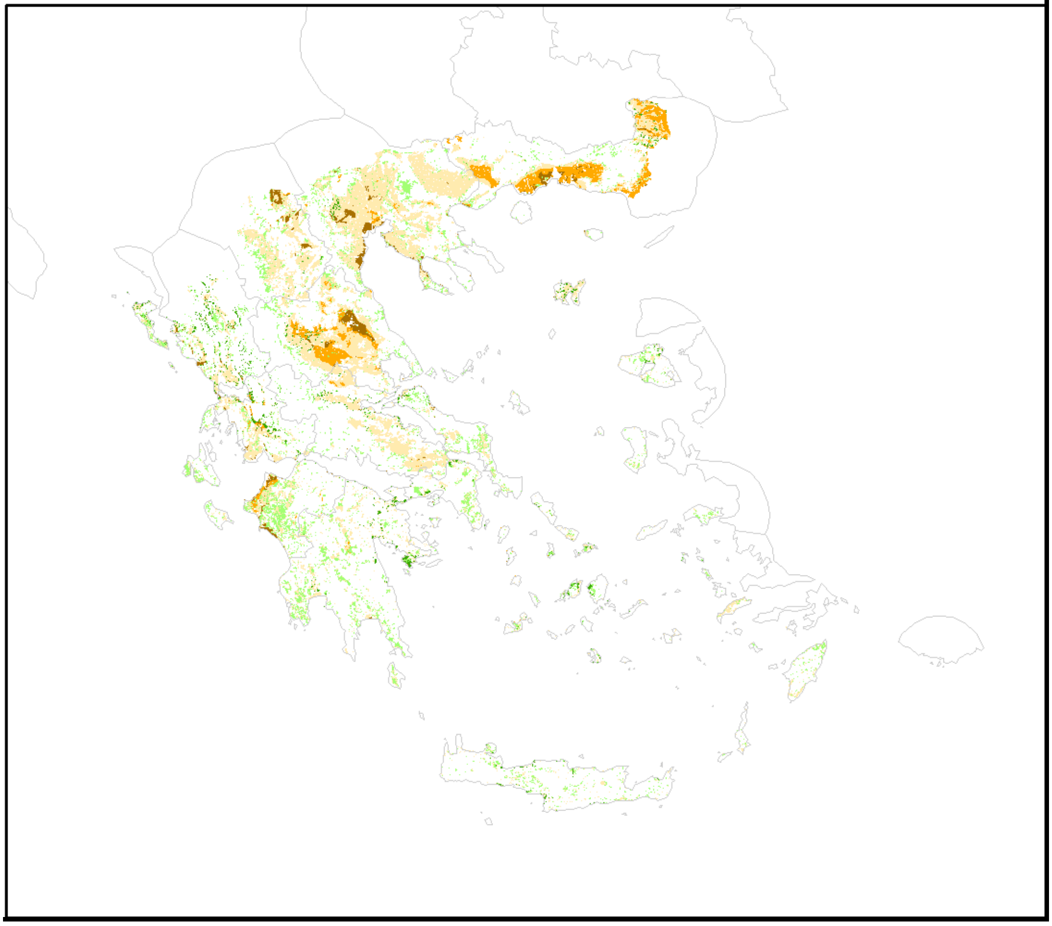
Land use

- 🟥 Built-up land
- 🟨 Arable land (non-irrigated)
- 🟩 Pasture
- 🟩 (Semi) natural vegetation
- 🟨 Arable land (irrigated)
- 🟧 Permanent crops
- 🟩 Forest
- 🟩 Recently abandoned
- ☐ All other

Agricultural intensity

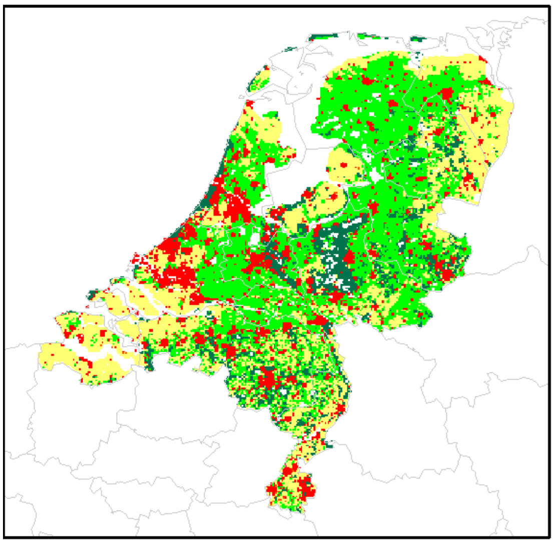
- 🟨 Arable low intensity
- 🟧 Arable medium intensity
- 🟫 Arable high intensity
- 🟩 Grass low intensity
- 🟩 Grass high intensity

Year 2025 agricultural intensity



the Netherlands

Year 2025 landuse
(SENSOR Financial Reform Policy Case)



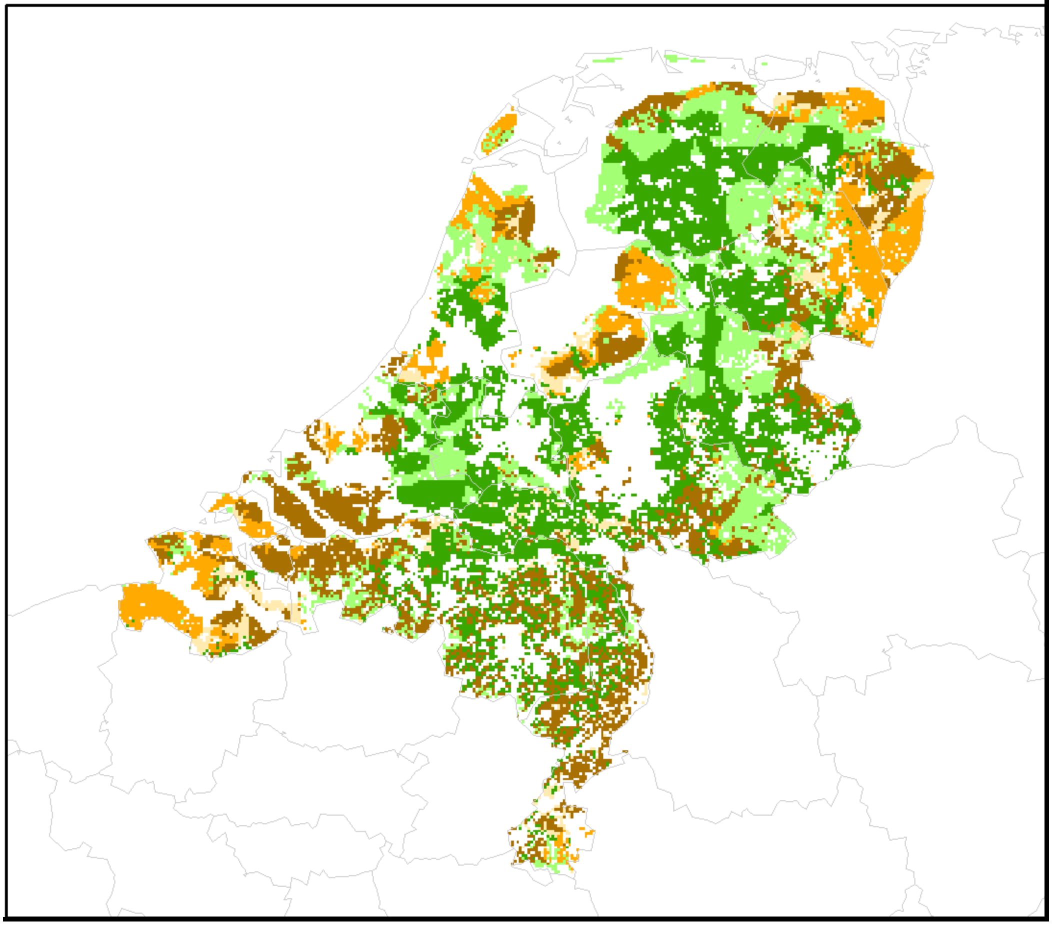
Land use

- 🟥 Built-up land
- 🟨 Arable land (non-irrigated)
- 🟩 Pasture
- 🟩 (Semi) natural vegetation
- 🟨 Arable land (irrigated)
- 🟧 Permanent crops
- 🟩 Forest
- 🟩 Recently abandoned
- ⬜ All other

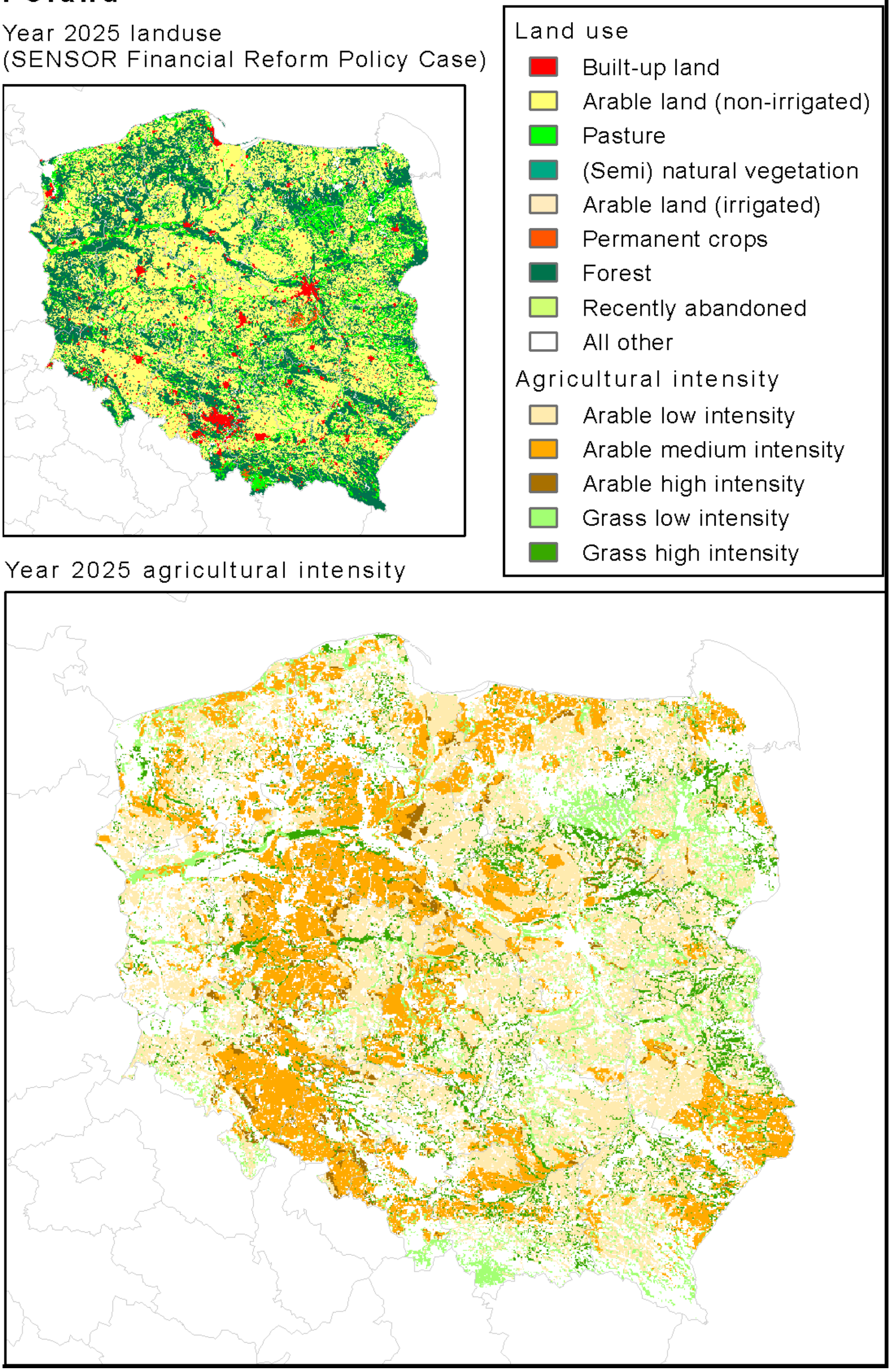
Agricultural intensity

- 🟨 Arable low intensity
- 🟧 Arable medium intensity
- 🟫 Arable high intensity
- 🟩 Grass low intensity
- 🟩 Grass high intensity

Year 2025 agricultural intensity



Poland

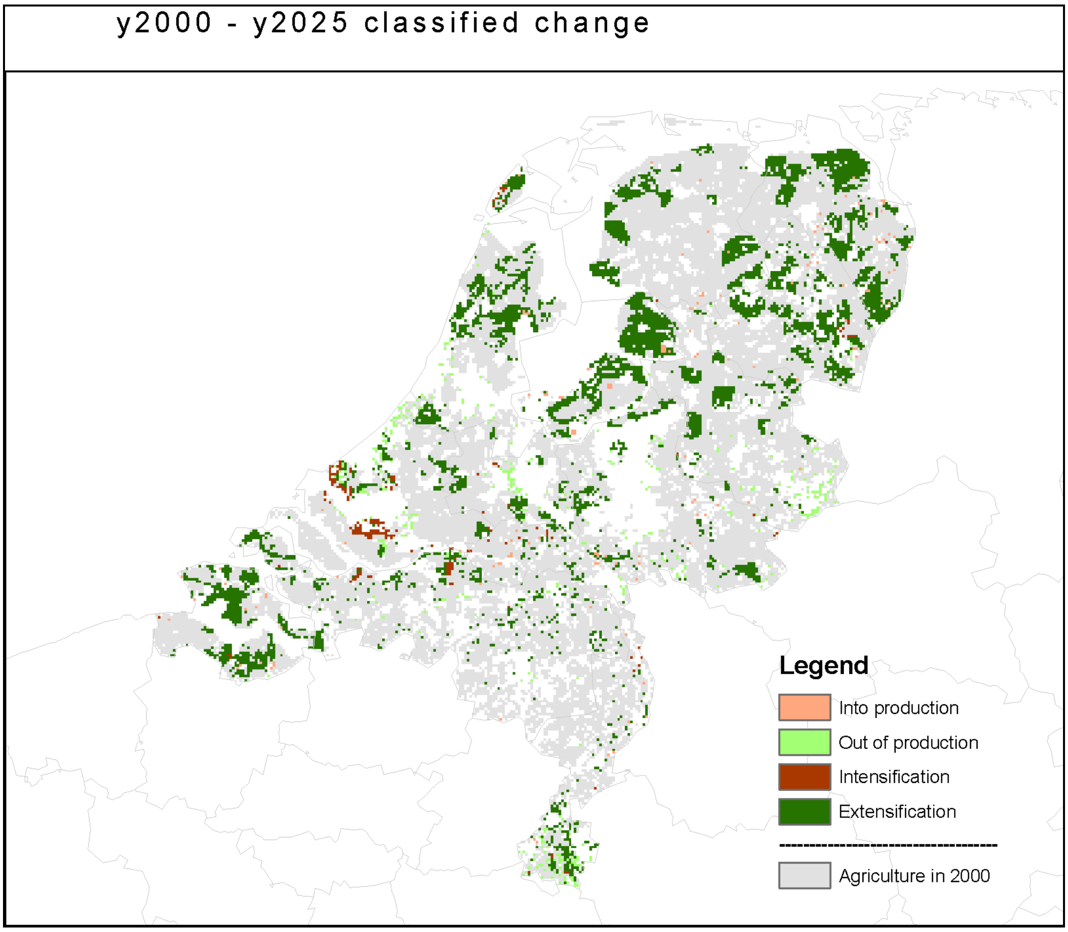


Year 2025 landuse
(SENSOR Financial Reform Policy Case)

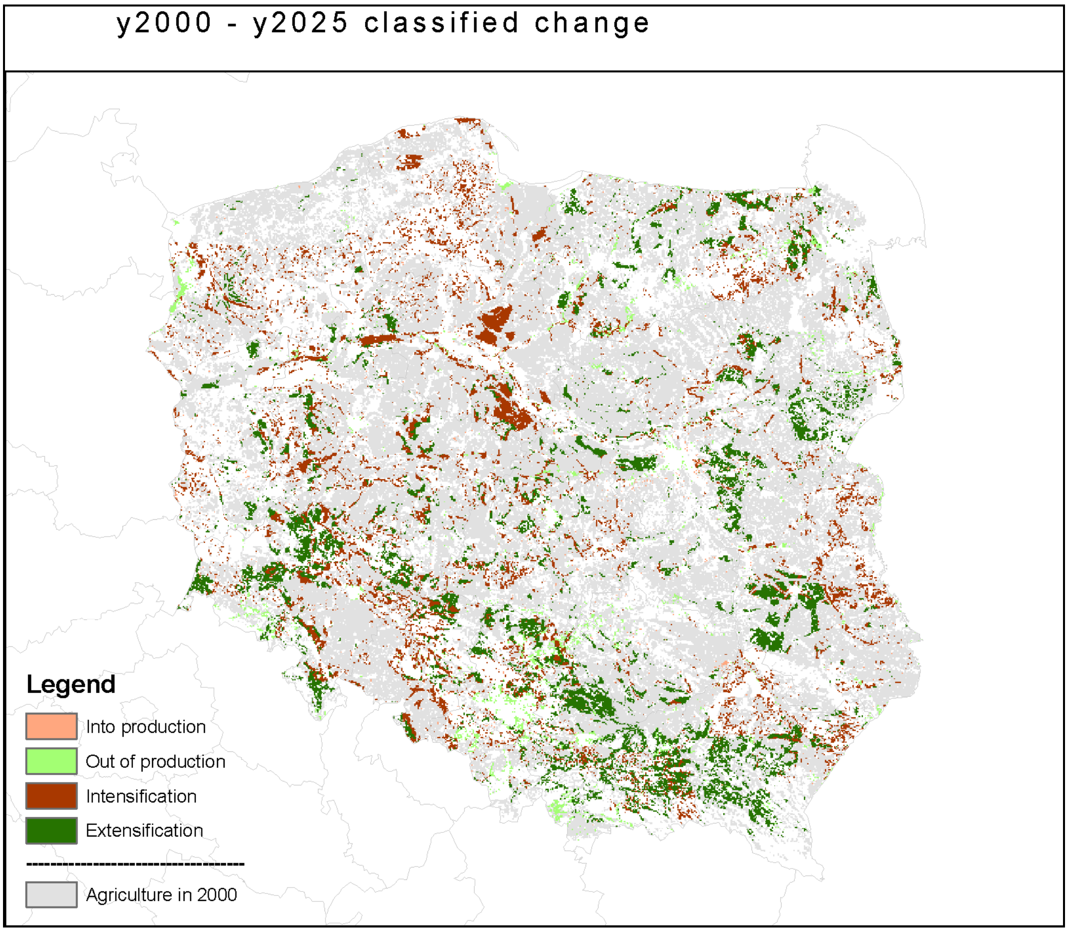
Year 2025 agricultural intensity

Annex 5 Maps of classified change in agricultural intensity

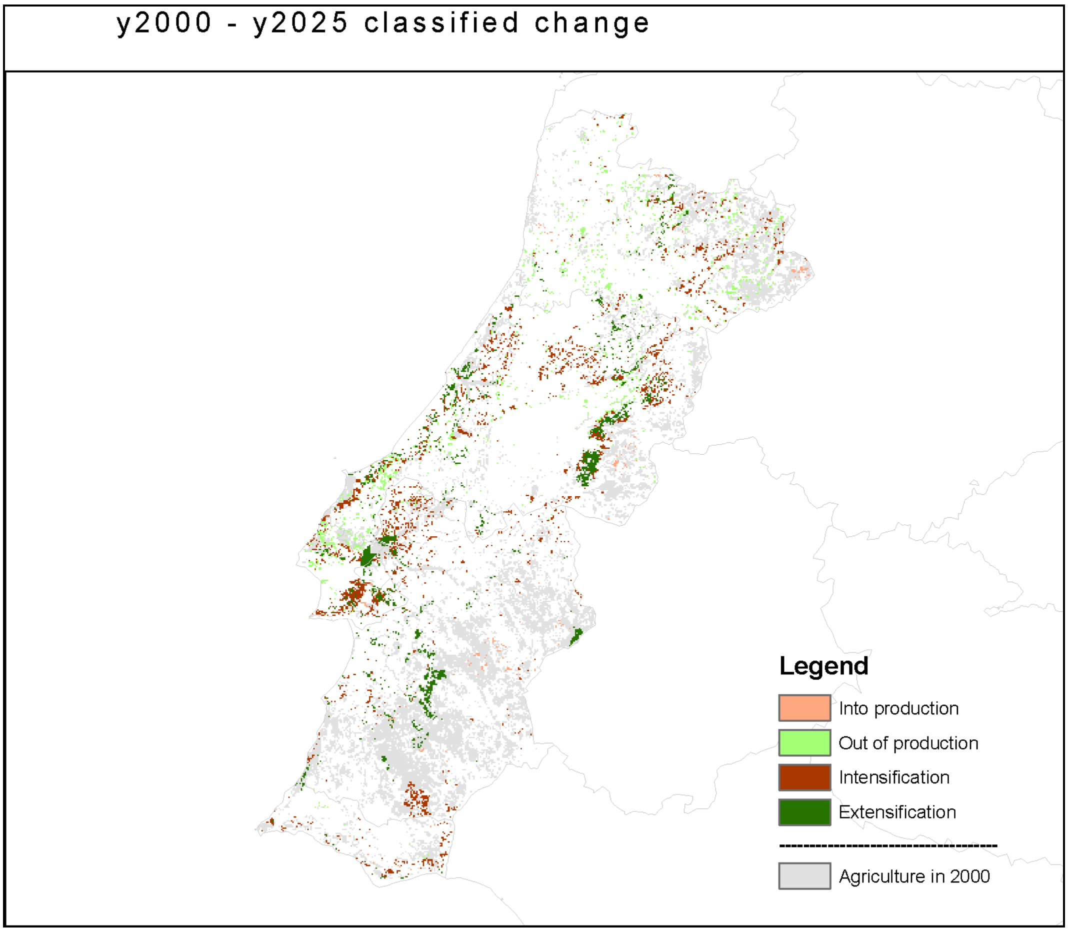
The Netherlands



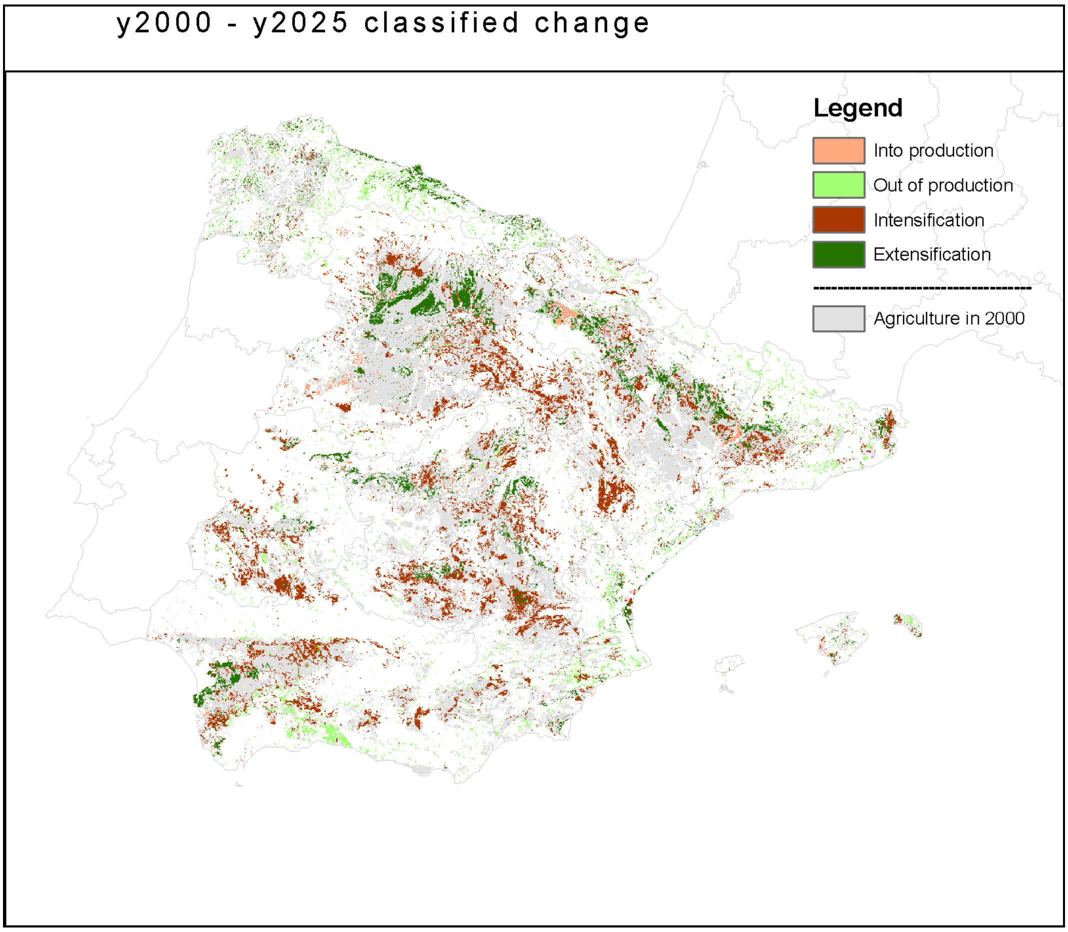
Poland


y2000 - y2025 classified change
Legend
Into production
Out of production
Intensification
Extensification
Agriculture in 2000

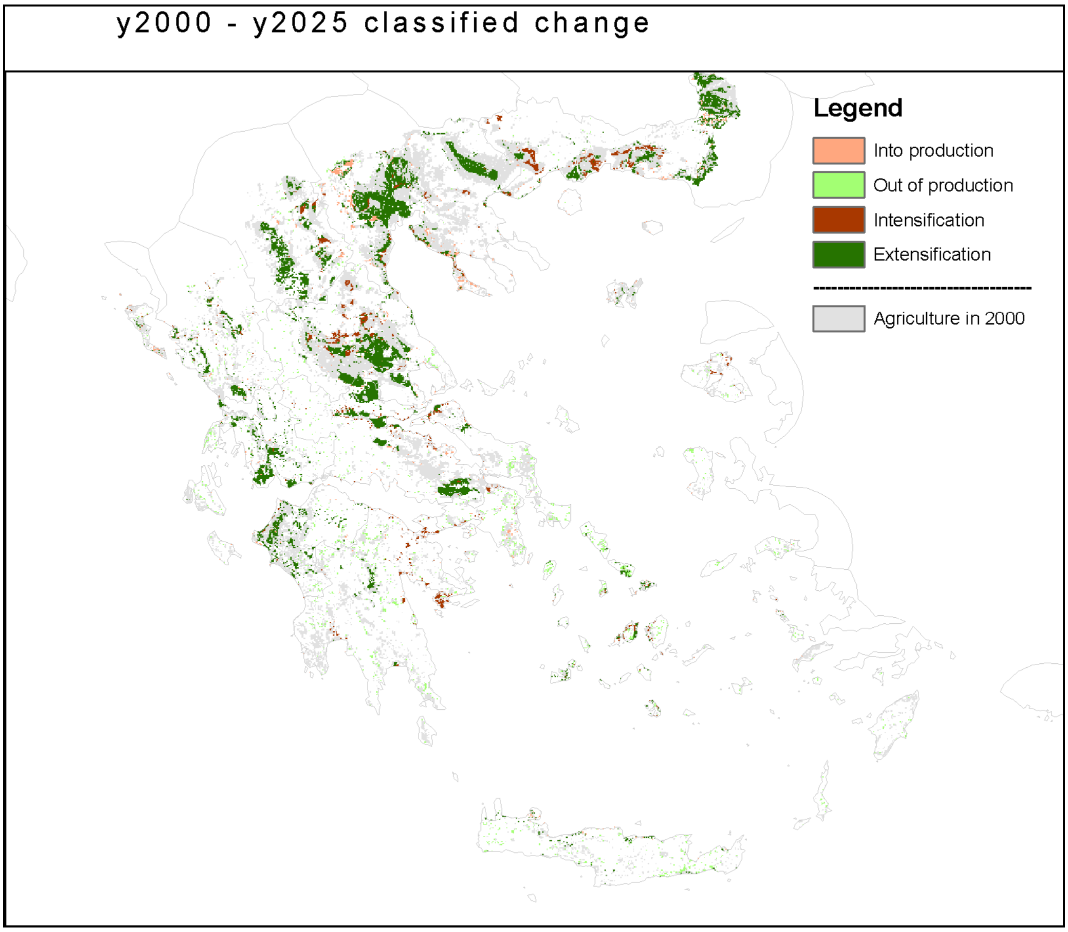
Portugal


y2000 - y2025 classified change
Legend
Into production
Out of production
Intensification
Extensification
Agriculture in 2000

Spain


y2000 - y2025 classified change
Legend
Into production
Out of production
Intensification
Extensification
Agriculture in 2000

Greece


y2000 - y2025 classified change
Legend
Into production
Out of production
Intensification
Extensification
Agriculture in 2000

Verschenen documenten in de reeks Werkdocumenten van de Wettelijke Onderzoekstaken Natuur & Milieu vanaf 2007

Werkdocumenten zijn verkrijgbaar bij het secretariaat van Unit Wettelijke Onderzoekstaken Natuur & Milieu, te Wageningen. T 0317 – 48 54 71; F 0317 – 41 90 00; E info.wnm@wur.nl
De werkdocumenten zijn ook te downloaden via de WOt-website www.wotnatuurenmilieu.wur.nl

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