MAGIC MAPS and MAGIC Crops Description of approach and results (Story map)

Mapping marginal lands in EU-27 +UK+Ukraine

The classification into marginal and non-marginal land involves an analysis of constraints. These constraints relate to soil and climate limitations for production or growth/establishment of crops (here wheat and maize were used as reference crops).

Marginality conditions should be severely limiting for normal agricultural production. For the selection of the limiting factors and the related threshold levels for 'severely limiting' (=marginal) we build on work done by:

1) JRC identifying Areas of Natural Constraints (ANCs) targeted in the Common Agricultural Policy (CAP) for payments in Pillar 1 and 2 (Van Oorschoven et al., 2014 and Terres et al., 2014)

2) Several land evaluation systems for agronomic suitability (e.g. USDA-Land Capability Classification System (LCC) , Muencheberg classification by Mueller et al., 2010 and Soil Quality Rating by Shepherd, 2000).

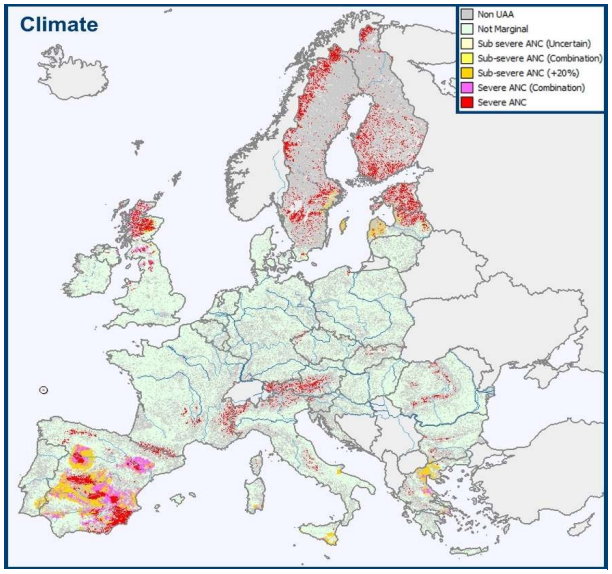
In total 18 single factors were identified that severely limit agriculture. The land units were identified with biophysical factors within the 20% margin of the threshold value of severity. This allows to map pair-wise limitations. When two factors are within this 20% margin the land units were classified from sub-severe to severe. To map the marginal lands the 18 single factors were grouped into 6 clustered factors:

1. Adverse climate
2. Excessive wetness
3. Low soil fertility
4. Adverse chemical conditions
5. Poor rooting conditions
6. Adverse terrain conditions

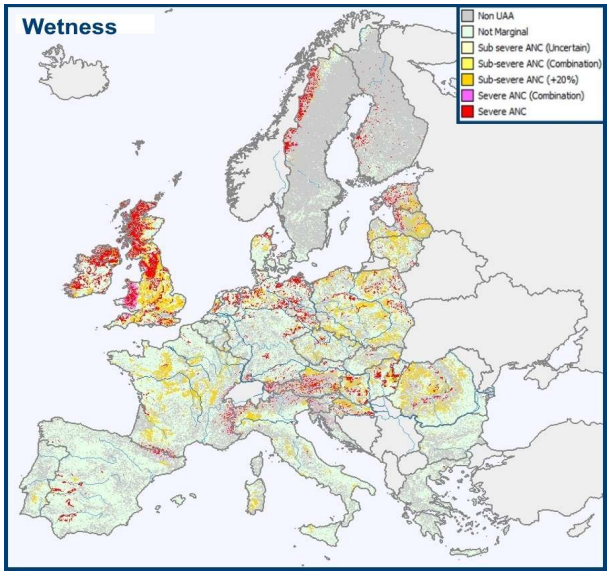
We mapped the marginal lands within a spatial agricultural area mask. This agricultural area mask includes all land that was classified in an agricultural land cover class in at least one of the four Corine Land Cover versions (1990. 2000, 2006, 2012) . It implies that this mask contains lands that have been abandoned already. Urbanized lands have been excluded from this mask.

A correction was made by excluding areas where natural constraints were neutralized via measures such as fertilisation, irrigation, drainage and creation of terraces. Different spatial data sources were used to identify the marginal lands where land improvements were made, and intensive agricultural production now occurs.

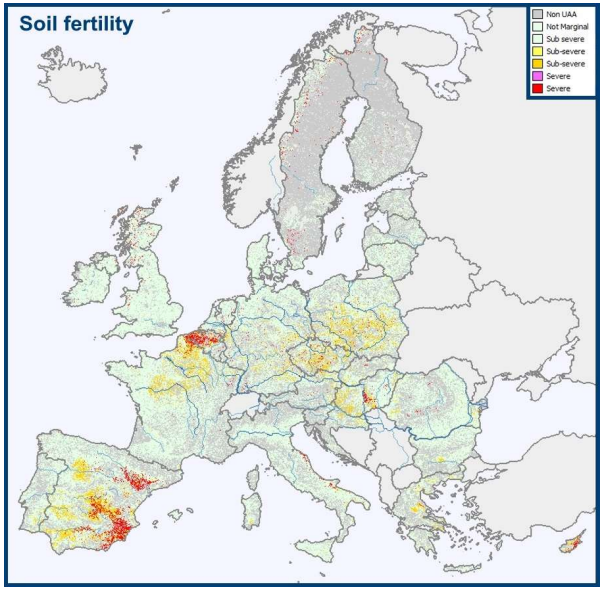
Cluster	Description cluster	Pairwise combination factor	+/-	Thresholds	
				Marginal limit	0-20% of limit
1A - Low temperature	Length of Growing Period: number of days with daily average temperature > 5°C (LGPt5) or Thermal-time sum (Tsum -degree-days) for Growing Period defined by accumulated daily average temperature > 5°C.			1500 degrees Tsum	1400 degrees Tsum
		Excess soil moisture	-	210 Days/Year	170 Days/Year
		Heavy clay	-	> 60% clay	> 50% clay
		Organic soil	-	Peat Soils	NA
1B - Dryness	Ratio of the annual precipitation (P) to the annual potential evapotranspiration (PET). Thresholdlimit: (P/PET ≤ 0.6)			35% (PET/PT)	45% (PET/PT)
		Stoniness	-	> 35% Stones	> 25% Stones
		Sand, loamy sand	-	> 70% sand	> 60% sand
		Heavy clay	-	> 60% clay	> 50% clay
		Rooting depth	-	Lithic-/Leptosols	Lithic-/Leptosols
		Salinity	-	> 50% of the area	< 50% of the area
		Slope	-	> 17.5 degr	> 15 degr
2A Excess soil moisture	Water content in the soil exceeds field capacity for at least 210 days (7 months)			> 210 days	>190-209 days
		Organic soils	-	Peat Soils	NA
		Rooting depth	-	Lithic-/Leptosols (WRB)	Lithic-/Leptosols
		Slope	+	> 17.5 degr	> 15 degr
2B Poor drainage	Soils with high water tables throughout the year that have a lack of oxygen in the rooting zone, effectively limiting growth of crops (e.g. lithis-/leptosoils (WRB))	-		Lithic-/Leptosols (WRB)	Lithic-/Leptosols
3. Adverse chemical conditions	Soils with high salinity content	-		salt level > 15 dS/m	-
	Soils with high sodicity content : Solonetz, 'natric' soils, or 'Sodic' soils.	-		Exchangeable sodium of more than 15% (ESP)	-
	High natural toxicity (with thionic qualifier)	-		-	-
4. Low soil fertility	Soils with pH below 4.5 or pH above 8	-		<4.5 or > 8	< 5
	SOC <0.5% at depth range 0-30 cm	-		SOC <0.5%	SOC <0.75%
5. Rooting - 5A –Sand, loamy sand or heavy clay	Texture class in half or more (cumulatively) of the 100 cm soil surface is sand, loamy sand defined as: silt% + (2 x clay%) > 30%			> 30% = max 70% sand	>40% = max 60% sand
		Organic soil	+	Peat Soils	NA
		Salinity	-	> 50% of the area	< 50% of the area
		Rooting depth	-	Lithic-/Leptosols (WRB)	Lithic-/Leptosols
		Rooting depth	-	Lithic-/Leptosols (WRB)	Lithic-/Leptosols
		Salinity/sodicity	-	> 50% of the area	< 50% of the area
		pH	-	<4.5 or > 8	< 5
5B – Coarse fragments & organic or shallow rooting	Course material At depth: 0-35 cm covering a surface of >35% and/or > 15% rock coverage (> 25% and/or > 10% respectively for sub-severe) or > 20% organic matter or rooting depth <30 cm.	Sand, loamy sand	-	> 70% sand	> 60% sand
		Organic soil	0	Peat Soils	NA
		Rooting depth	-	Lithic-/Leptosols (WRB)	Lithic-/Leptosols
		Slope	-	> 17.5 degr	> 15 degr
		Salinity/sodicity	-	> 50% of the area	< 50% of the area
6. Adverse terrain conditions	Slope		-	> 17.5 degr (>80% of area)	> 15 degr (>80% of area)
	Flood risk		-	> 2 m flood in 2yrs return	>1-2 m flood in 2 yr return time



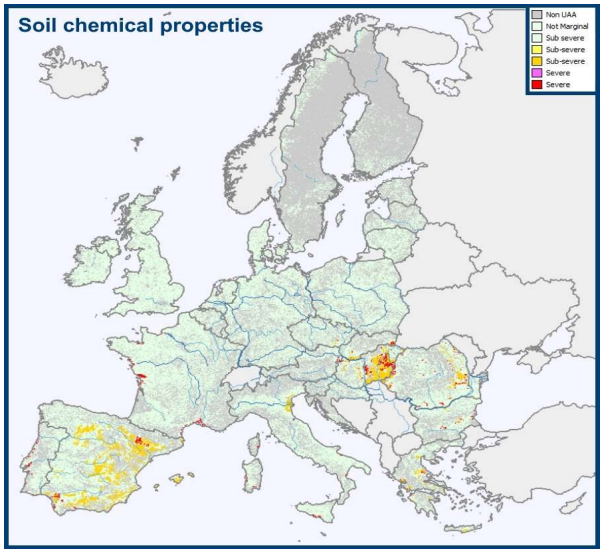
1. Adverse climate: low temperature and/or dryness



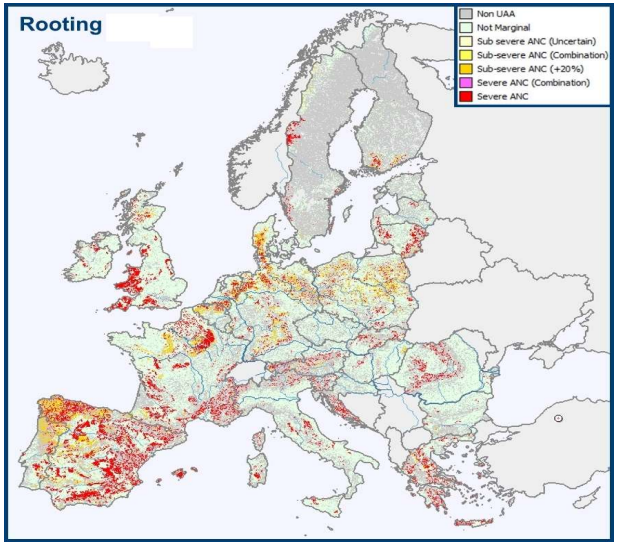
2. Excessive (soil) wetness: excess soil moisture and/or poor soil drainage



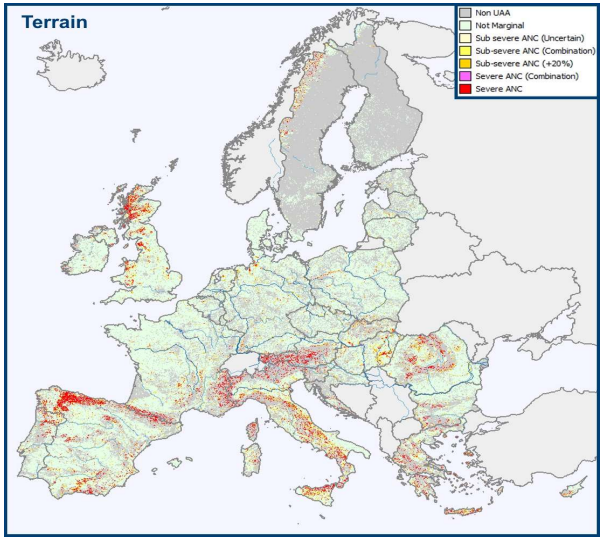
3. Low soil fertility: acidity or alkalinity and/or low soil organic carbon



4. Adverse chemical properties: salinity, sodicity, natural toxicity

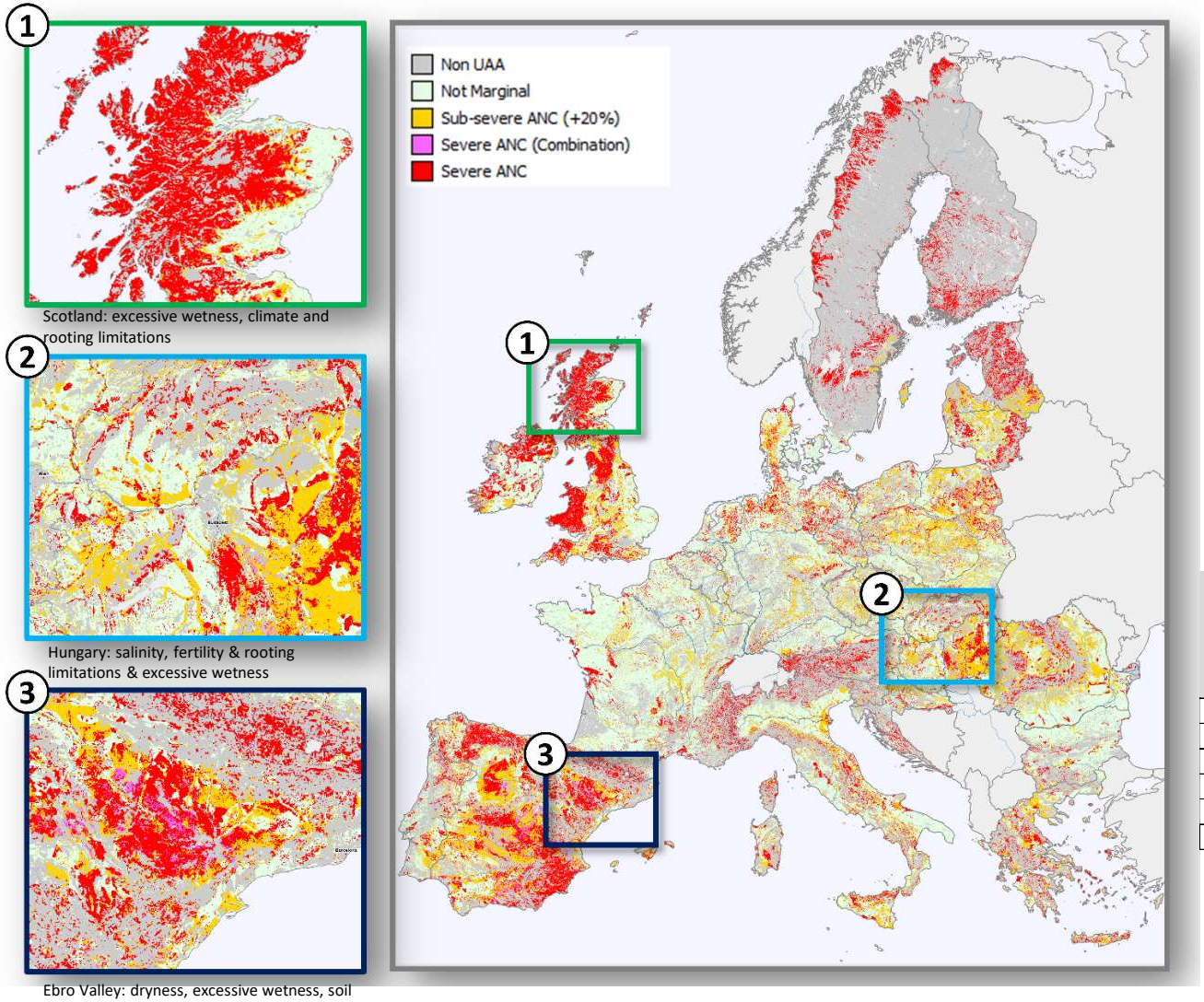


5. Poor rooting: Unfavourable texture & stoniness and/or shallow rooting depth



6. Adverse terrain: Steep slope and/or flooding risk

Final marginal land map



- In total 29% of the agricultural area is marginal in EU-27 & UK.
- The most common are rooting limitations (12% of agricultural area after correction for improvement), adverse climate and excessive soil moisture (11% and 8% of the agricultural land).
- The largest share of marginal lands is defined by one of the six clustered limitations, while in a much smaller share multiple limitations occur.

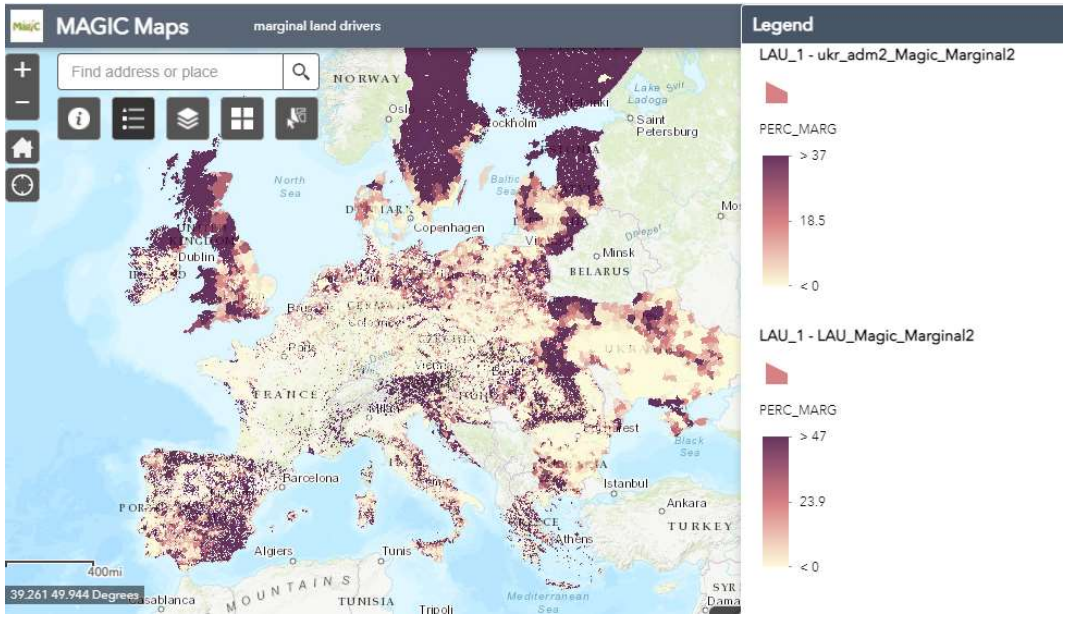
	1. Adverse climate	2. Excessive soil moisture	3. Adverse chemical comp.	4. Low soil fertility	5. Adverse rooting cond.	6. Adverse terrain	Marginal	Not marginal
Alpine	40%	21%	0%	2%	45%	47%	**61%**	39%
Atlantic	4%	14%	1%	1%	12%	5%	**26%**	74%
Continental	1%	5%	2%	1%	5%	2%	**14%**	86%
Mediterranean	13%	1%	1%	6%	18%	9%	**34%**	66%
North	62%	14%	0%	3%	13%	3%	**71%**	29%
Grand Total	**11%**	**8%**	**1%**	**2%**	**12%**	**6%**	**29%**	**71%**

Presentation of marginal land data in MAGIC-Maps dashboard

This app contains maps of the six clustered factors classifying agricultural lands as marginal. The map presents the results for Europe by Local Administrative Units (LAU) class, and for the Ukraine at the Administrative Level 2.

The maps contain attribute fields in the database which indicate which identify the drivers of marginality:

- KM2_CHEMIC km2 marginality type adverse chemical conditions
- KM2_CLIMAT km2 marginality type adverse climate (dryness or low temperature)
- KM2_FERTIL km2 marginality type FERTILITY
- KM2_ROOTIN km2 marginality type ROOTING
- KM2_TERRAI km2 marginality type TERRAIN
- KM2_WETNES km2 marginality type WETNESS
- KM2_AREA km2 of unit
- KM2_AGRI km2 Agricultural Area
- KM2_MARG km2 Total Marginal Area
- PERC_MARG % Total Marginal Area (relative to agri. area)



The maps have been shaded based upon their percent marginality in relation to agricultural area. This agricultural area includes all land that was classified in an agricultural land cover class in at least one of the four Corine Land Cover versions (1990. 2000, 2006, 2012) The user may select any polygon on the map to visualize the data behind the map. The full attribute tables can be accessed at the bottom of the screen by clicking on the arrow button.

Additional widgets are available at the top of the screen for the map legend, layer list and basemap.

More information on the MAGIC project is available at: MAGIC

On the MAGIC project site you also find Deliverable 2.6 ‘ Methodological approaches to identify and map marginal land suitable for industrial crops in Europe’, providing all information on how the marginal areas were mapped.

Characterising marginal lands according to rurality, overlap with high nature value farmland and erosion risk

1. According to rurality

Total EU-27 + UK	Marginal km2	% of marginal area
Deep Rural	358,037	52%
Rural	274,019	39%
Peri-Urban	58,184	8%
Urban Area	4,155	1%
Total	694,395	100%

Data used for overlay:
FARO rurality classes (Van Eupen et al., 2012). Map A show nine rurality classes based on economic density and accessibility for each aggregate Environmental Zone (AEZ) (Alpine, Atlantic, Continental, Mediterranean and North (=Boreal & Nemoral)) derived from the Environmental zones of Metzger et al. (2005).

2. According to High Nature Value farmland share

	Marginal land	Non-marginal land
COUNTRY	% HNV farmland	% HNV farmland
Austria	63%	36%
Belgium	8%	21%
Bulgaria	61%	19%
Croatia	88%	83%
Czech Republic	19%	15%
Denmark	5%	2%
Estonia	12%	-
Finland	9%	-
France	46%	13%
Germany	17%	9%
Greece*	...	...
Hungary	38%	14%
Irish Republic	13%	2%
Italy	53%	15%
Latvia	10%	10%
Lithuania	14%	5%
Luxembourg	1%	4%
Netherlands	32%	7%
Poland	28%	10%
Portugal	48%	44%
Romania	57%	20%
Slovakia	17%	9%
Slovenia	81%	61%
Spain	44%	44%
Sweden	4%	9%
United Kingdom	39%	3%
Grand Total	34%	17%

3. Erosion risk by water and wind

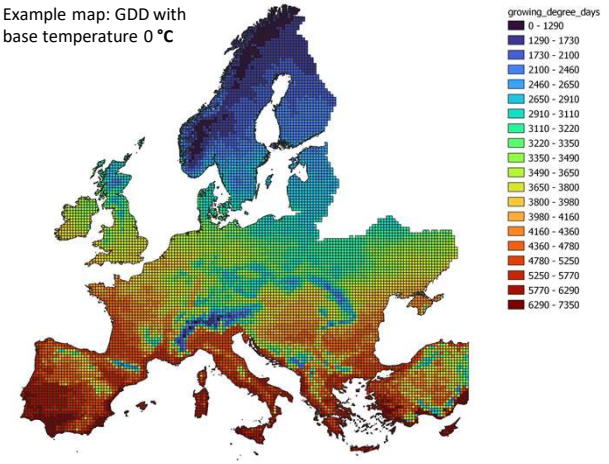
	Marginal land		Not marginal	
COUNTRY	% sensitive to erosion by water	% sensitive to erosion by wind	% sensitive to erosion by water	% sensitive to erosion by wind
Austria	23%	7%	28%	3%
Belgium	5%	6%	14%	3%
Bulgaria	14%	22%	24%	31%
Croatia	9%	0%	4%	0%
Czech Republic	25%	2%	31%	3%
Denmark	1%	53%	3%	55%
Estonia	0%	0%	0%	0%
Finland	1%	1%	0%	0%
France	16%	21%	17%	9%
Germany	6%	2%	17%	2%
Greece	30%	23%	30%	21%
Hungary	5%	1%	17%	1%
Irish Republic	1%	5%	5%	2%
Italy	54%	12%	41%	11%
Latvia	1%	0%	1%	0%
Lithuania	3%	0%	2%	0%
Luxembourg	35%	0%	28%	0%
Netherlands	0%	3%	0%	14%
Poland	5%	1%	12%	1%
Portugal	23%	0%	18%	0%
Romania	20%	14%	33%	31%
Slovakia	34%	6%	34%	2%
Slovenia	22%	0%	21%	0%
Spain	27%	28%	26%	19%
Sweden	3%	12%	5%	72%
United Kingdom	6%	7%	5%	20%
Grand Total	16%	13%	20%	12%

Data used for overlay:
For wind erosion: ILSWE dataset predicting wind erosion susceptability of land in Europe (Source: https://esdac.jrc.ec.europa.eu/content/Soil_erosion_by_wind)
For erosion by water: the WaTEM/SEDEM dataset predicting water erosion susceptability in Europe (Source: https://esdac.jrc.ec.europa.eu/content/estimate-net-erosion-and-sediment-transport-using-watemsedem-european-union)

Mapping climate suitability for crops: general approach

General approach:
Suitability is based only on climate suitability. It is mapped assuming that the crop will be able to grow in the climate zone, but not necessarily that it reaches an optimal production level. The climate suitability is mapped according to the following factors:
1) Minimum length of growth season (days), linked to base temperature*
2) Minimum length of growing degree days (GDD), linked to base temperature*
3) Level to which the crop (above and below ground biomass) can survive different levels of killing frost (KF), assuming this frost occurring for at least 5 days in a row.
4) Minimum level of precipitation the crop needs during the growing season
*In relation to annuals that produce seeds (or other storage organs) the growing season is scored more strictly as reaching maturing phase is crucial. For biomass crops it is acceptable if the minimal level of growth season and GDD is not completely reached as reaching maturity phase for harvesting the crop is not necessary for harvesting.

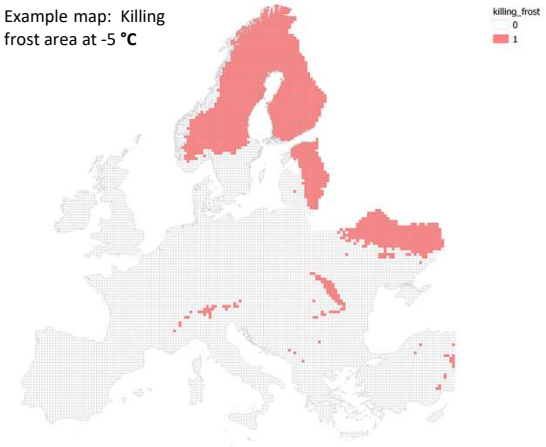
Example map: GDD with base temperature 0 **°C**



Scoring for minimal length of growth season and GDD -
<u>For annuals producing seeds:</u>
0 >20% below threshold
1=20% + and - threshold
2= 20% above threshold

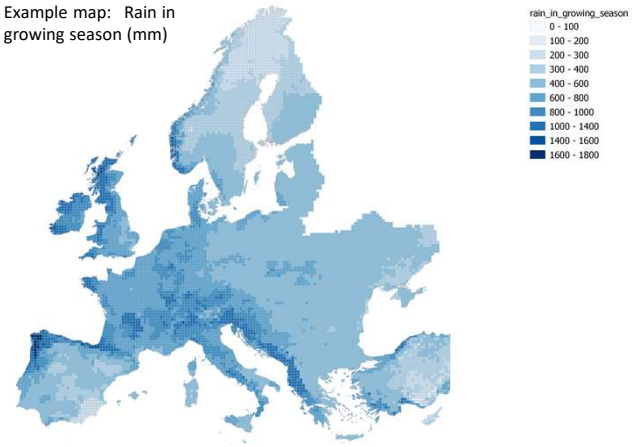
<u>For perennials producing biomass:</u>
0 > 30% below threshold
1=20% + and 30% - threshold
2= 20% above threshold

Example map: Killing frost area at -5 **°C**



Killing frost (°C)*:
0= No go/
1= crop can still handle this frost/
2=crop can easily handle this frost/
* for perennials this limitation applies through the whole year. For summer annuals this applies during the growing season. So normally KF cannot be a big problem, unless it is the reason for the short Growth season.

Example map: Rain in growing season (mm)



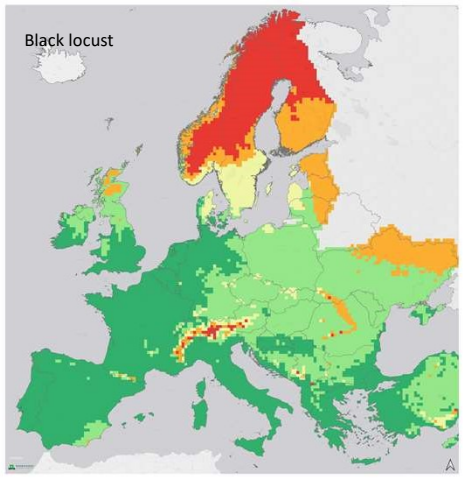
Threshold of minimal rainfall in growing season:
0= No go (0,1)
1=rainfall meets threshold of crop minimal precipitation need
2= Meets well with crop precipitation need

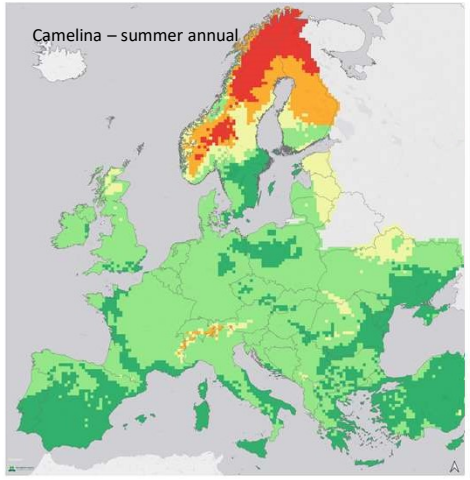
Classes for scoring are:
>1000 mm
999-800 mm
799-500 mm
499-300 mm
299-200 mm
<200 mm

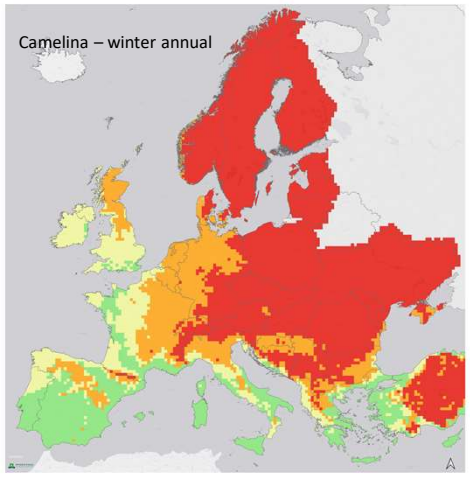
Mapping climate suitability: thresholds per crop

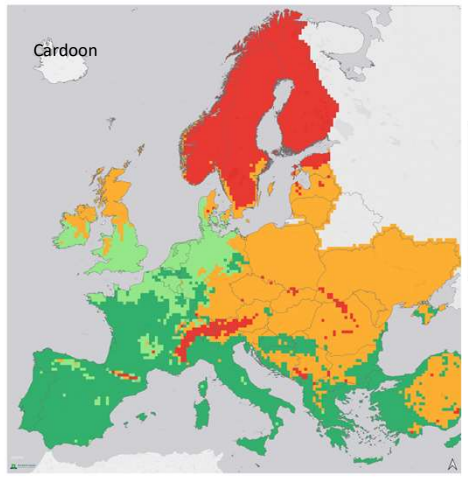
				Threshold of minimal GDD			Killing frost (°C)			Threshold of minimal rainfall in growing season: 0= No go (0,1)/1=rainfall meets threshold of crop minimal precipitation need (2)/2= Meets well with crop precipitation need (3,4)					
		1=Annual/ 2=perennial	Purpose: 1= (oil) seeds 2=biomass 3= combination	Minimum length of growth season (GS)	Minimum of growth degree days (thermal time)	Base temperature (°C)	-5 - 0 °C	-10 - 5 °C	< - 10 °C	>1000 mm	1000-800 mm	800-500 mm	500-300 mm	300-200 mm	< 200 mm
Panicum virgatum L.	Upland Switchgrass	2	2	126	1550	6	2	2	1	2	2	2	2	1	0
Panicum virgatum L.	Lowland Switchgrass	2	2	200	2300	6	2	0	0	2	2	2	1	0	0
Camelina sativa (L.) Crantz	Camelina (summer-annual)	1	1	90	1200	4	2	1	0	1	2	2	2	2	2
Camelina sativa (L.) Crantz	Camelina (winter-annual)	1	1	220	1300	4	2	2	2	1	2	2	2	2	2
Sorghum bicolor (L.) Moench	*Biomass sorghum*	*1*	*2*	120	1400	8	1	0	0	1	2	2	2	1	1
Crambe abyssinica Hochst x R.E. Fries	Crambe (summer annual)	1	1	110	1200	4	1	0	0	1	1	2	2	2	2
Crambe abyssinica Hochst x R.E. Fries	Crambe (winter annual)	1	1	150	1400	4	0	0	0	1	2	2	2	2	2
Ricinus communis L.	Castorbean	1	1	130	1200	8	0	0	0	2	2	2	2	1	0
Miscanthus x giganteus & synancys	Miscanthus	2	2	135	1500	6	2	1	0	2	2	2	1	0	0
Arundo donax L.	Giant reed	2	2	195	2200	**6**	**1**	**0**	**0**	**2**	2	2	1	1	0
Agropyron elongatum (Host.) Beauv.	Tall wheatgrass	2	2	125	1200	4	**2**	**2**	**2**	**2**	2	2	2	2	1
Brassica carinata A. Braun.	Ethiopian mustard (summer annual)	1	1	140	2000	4	0	0	0	1	1	2	2	2	2
Brassica carinata A. Braun.	Ethiopian mustard (winter annual)	1	1	180	2200	4	0	0	0	1	1	2	2	2	2
Phalaris arundinaceae L.	Reed canary grass	2	2	82	1400	0	2	2	2	2	2	1	0	0	0
Cynara cardunculus L.	Cardoon	2	3	120	1200	8	0	0	0	2	2	2	2	1	0
Salix spp.	Willow	2	2	180	2000	1	2	1	1	2	2	1	1	0	0
Populus spp.	Poplar	2	2	180	2200	0	2	1	1	2	2	1	1	0	0
Eucalyptus spp.	Eucalyptus	2	2	180	2400	6	0	0	0	2	2	2	2	1	0
Ulmus pumila L.	Siberian elm	2	2	150	1700	6	2	2	1	2	2	2	2	2	1
Crotalaria juncea L.	Sunn hemp	1	2	60	1300	8	0	0	0	2	2	2	2	1	0
Cannabis sativa L.	Hemp	1	2	90	1400	6	1	0	0	2	2	2	2	1	0
Saccharum spontaneum L.	Wild sugarcane	2	2	210	2400	8	0	0	0	2	2	2	1	0	0
Robinia pseudoacacia L.	Black locust	2	2	120	1200	6	1	0	0	2	2	2	1	0	0

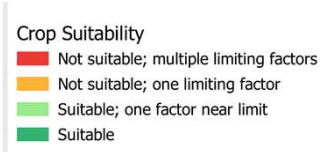
Mapping climate suitability for crops: result maps (I)

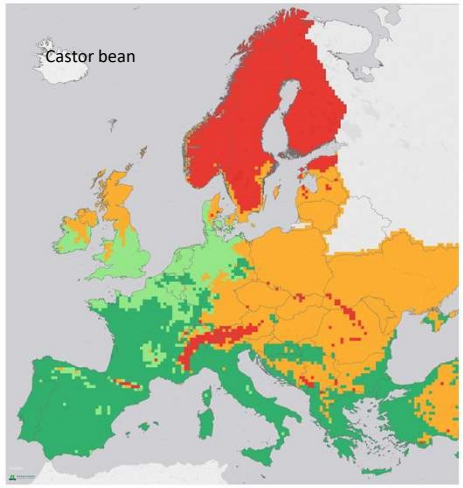


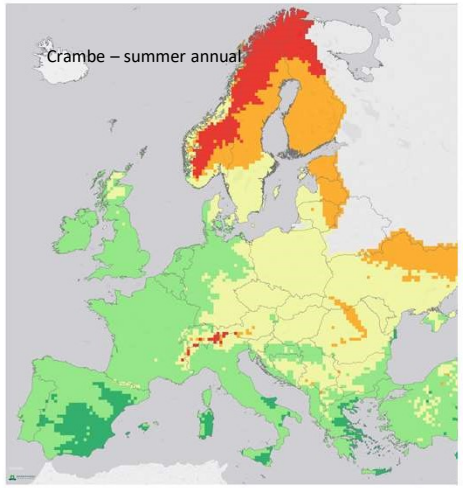


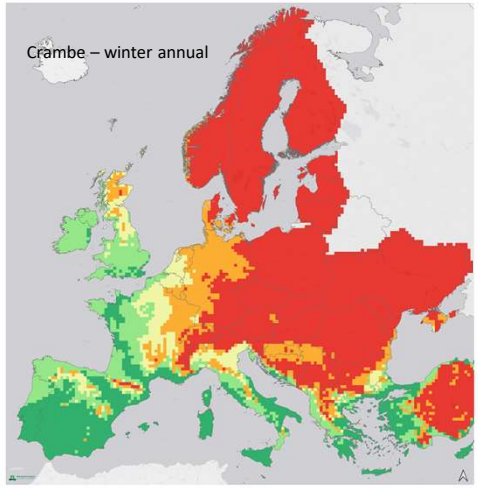


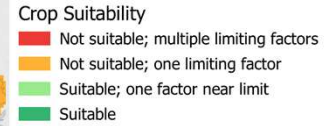




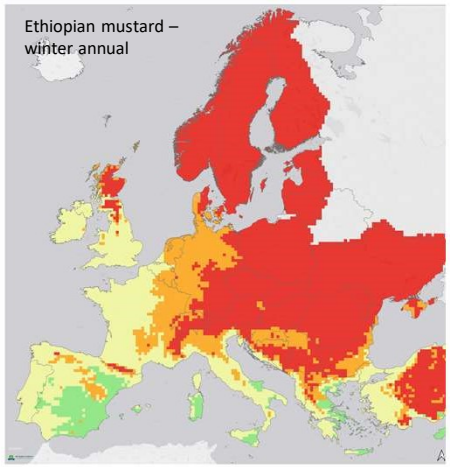


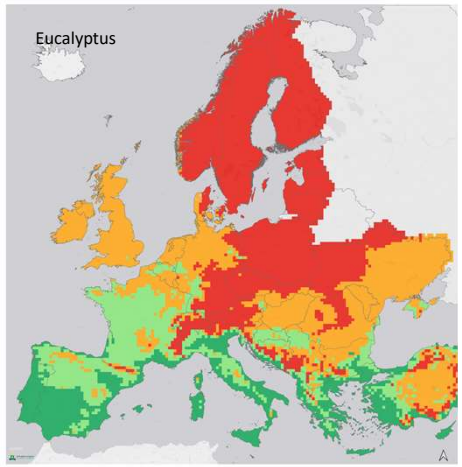


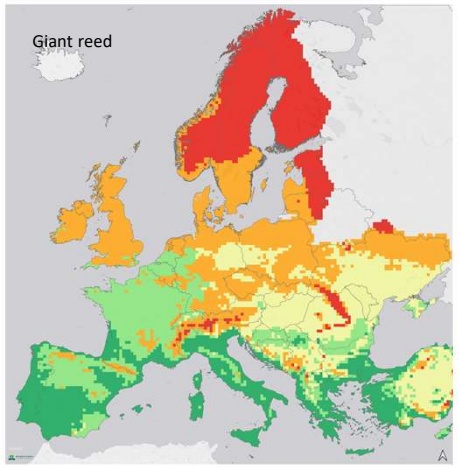


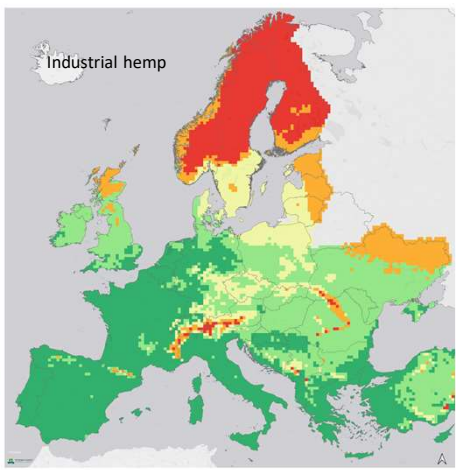


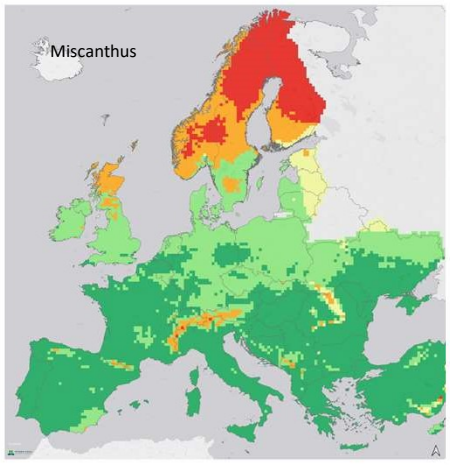
Mapping climate suitability for crops: result maps (II)

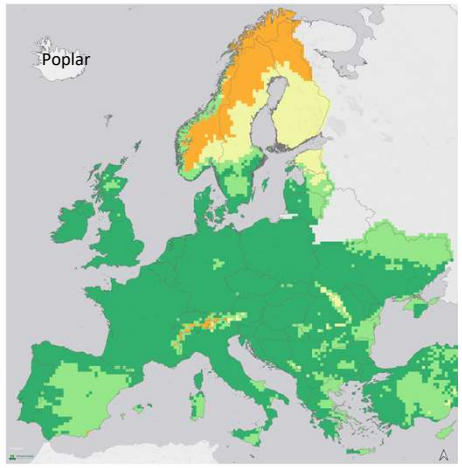


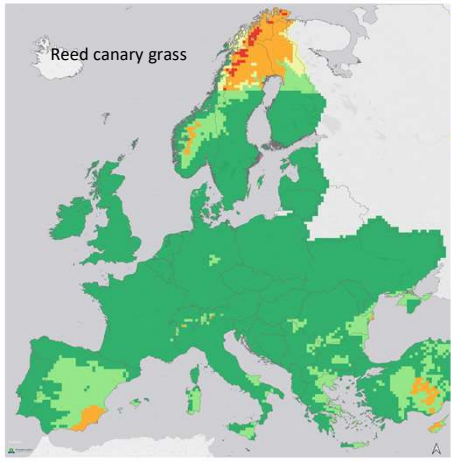


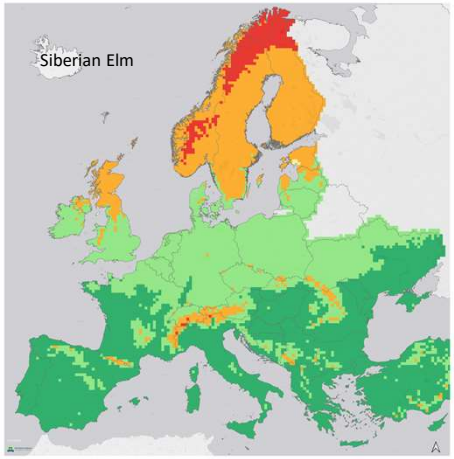


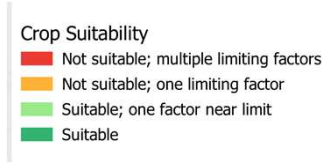


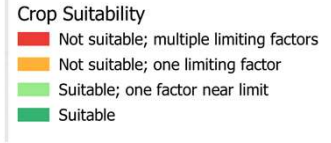




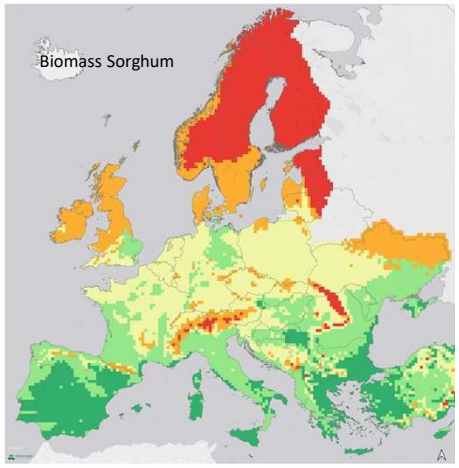


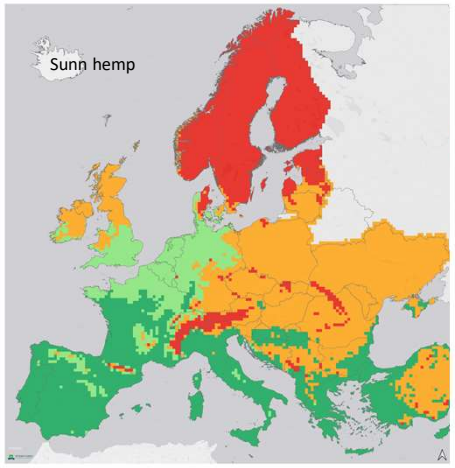


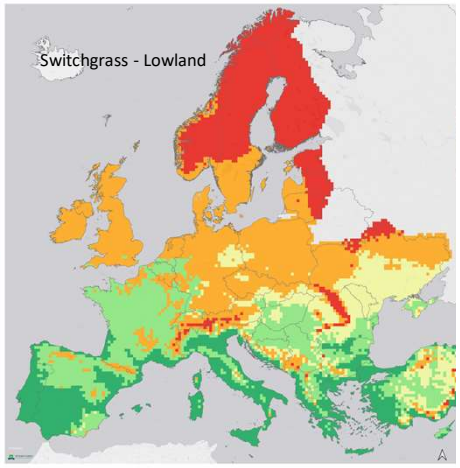


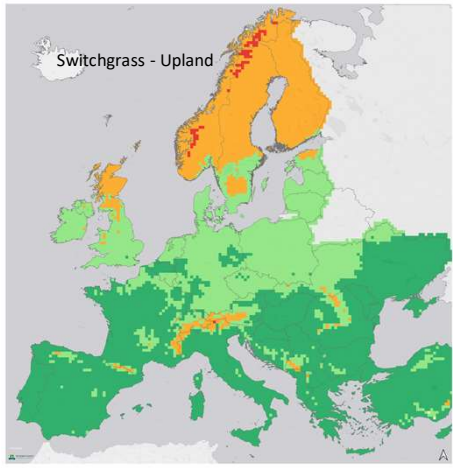


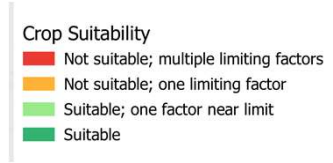
Mapping climate suitability for crops: result maps (III)

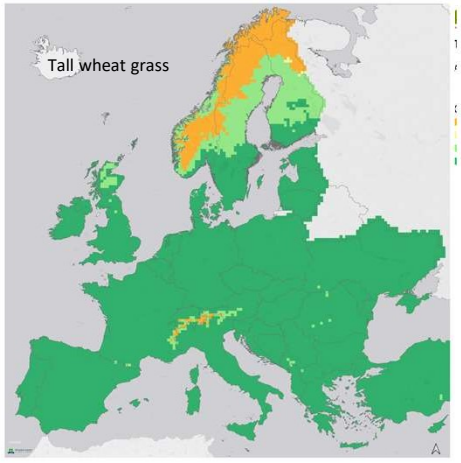


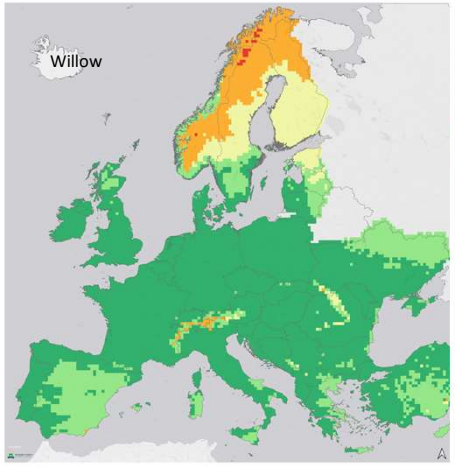


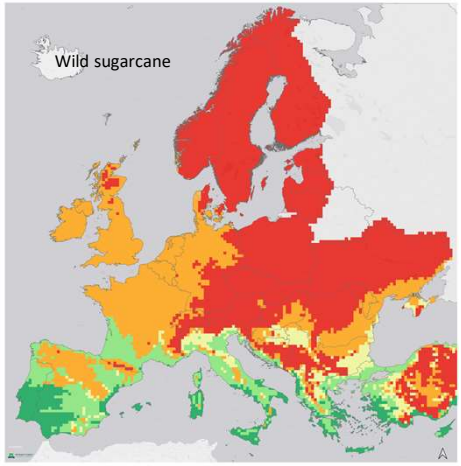


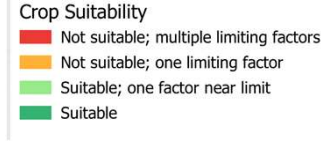












Mapping yield reduction for marginal factors for crops: approach

General approach:
Crop experts in WP1 made estimates of yield reduction effects per crop per marginal limitation. The yield reduction factors applied followed a classification in yield reduction (YR) ranges:
1= YR>50%;
2= 25%< YR <50%;
3= YR < 25%;
0= Unfeasible

The yield reduction levels were estimated by the MAGIC crop experts for (a selection of 14 of the 18) marginal factors and thresholds that were used to map marginal lands in Europe. Underneath an overview of the factors and thresholds:

1. Climate limitations
- Length of growing season: < 195 accumulated days with daily average temperature > 5°C.
- Thermal-time sum (Tsum -degree-days) < 1575 degree days for growing period defined by accumulated daily average temperature > 5°
- Dryness: Ratio of the annual precipitation (P) to the annual potential evapotranspiration (PET). Threshold limit: P/PET ≤ 0.6

2. Soil moisture:
- Water content in the soil exceeds field capacity for at least 210 days (7 months)
- Poor drainage: Soils with high water tables throughout the year that have a lack of oxygen in the rooting zone, effectively limiting growth of crops (e.g. lithic-/leptosoils (WRB))

3. Adverse chemical conditions:
- High salinity > 3.2 dS/m
- High sodicity >15% ESP (exchangeable sodium level)

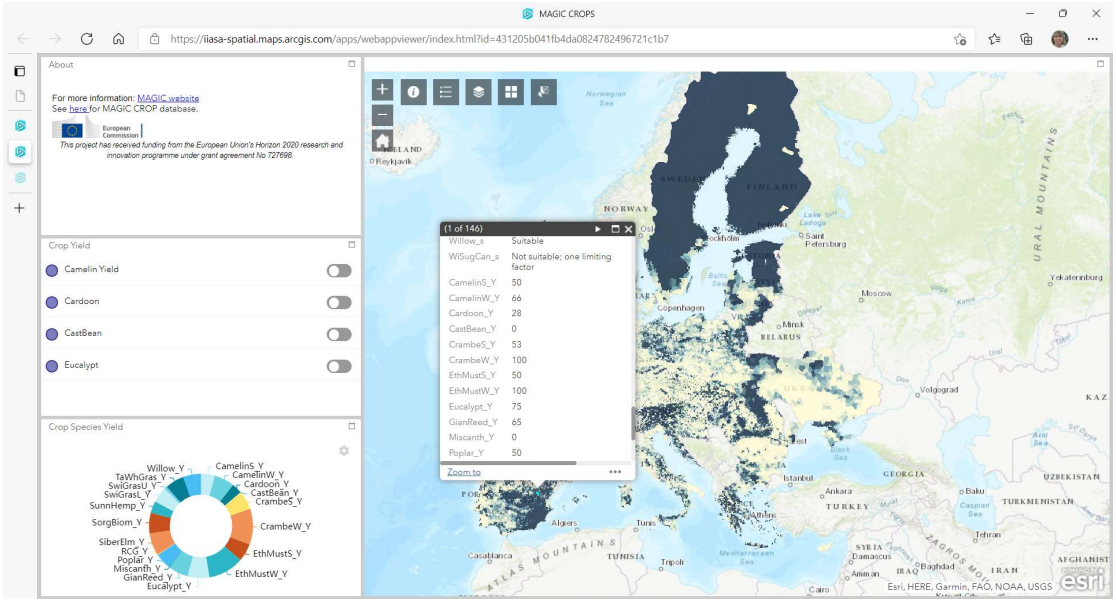
4. Low soil fertility
- High acidity <5.5 pH

5. Rooting:
- Coarse material: At depth: 0-35 cm covering a surface of >35% and/or > 15% rock coverage
- High organic matter level: > 20% organic matter
- Shallow rooting depth <30 cm.
- High sand/loamy sand level>70%

6. Slope
- Steep slope > 17.5%

Mapping yield reduction for marginal factors for crops: results

- By selecting one LAU region the user gets a long list of attributes for that LAU regarding marginality conditions, suitability of every crop and at the end the average yield reduction factors per crop given the marginal conditions present in the LAU region selected.



Mapping risk for land abandonment: approach