Raising the bio-based industrial feedstock capacity of Marginal Lands

Available marginal lands map with relevant stakeholders

Deliverable 1.1

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[1] PU = Public
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MarginUp! in a nutshell

The MarginUp! project proposes solutions to secure the use of, and return profitability on, marginal lands while enhancing biodiversity by cultivating climate-resilient and biodiversity-friendly non-food crops for sustainable industrial feedstock on marginal lands.

Working closely with land managers, farmers, and stakeholders from the growing bioeconomy industry, MarginUp! will create sustainable and circular value chains and increase the resilience of rural farming systems. To further improve biodiversity and environmental benefits, MarginUp! will focus on understanding which marginal lands are suitable with the lowest impact for low indirect land-use change (ILUC) biomass production.

MarginUp! will provide viable outcomes to ecosystems which are water-stressed as a result of climate change, including desertified areas of Mediterranean and Central European member states, as well as contributing to, restoring, and stimulating ecosystems in abandoned mine lands, and boosting land yield and health in low productivity marginal lands.

MarginUp! Is building on learning from seven use cases: Five implementations across Europe – in Spain, Greece, Sweden, Germany, and Hungary – as well as use cases in Argentina and South Africa, together increasing the replication potential of the project's results. MarginUp will identify the best practices for sustainable biomass production and biobased products that safeguard biodiversity and local ecosystems. Each use case considers the current use and properties of the area and proposes crops and crop rotation strategies that enhance biodiversity and increase soil productivity according to local requirements from Mediterranean soils in Spain to mining lands in Greece, boreal soils in Sweden, wetlands in Germany, desert lands in Hungary, degraded pastures in Argentina, and areas with bush encroachment in South Africa. The proposed crops create a sustainable supply of resources to foster the development of the bioeconomy businesses at local and regional levels while providing ecosystem benefits and building resilience to climate change.

On that basis, the MarginUp! project will enhance European industrial sustainability, competitiveness, and resource independence, by reducing the environmental footprint, including on biodiversity, enabling climate neutrality and increasing resource efficiency (particularly through upcycling and cascading use of biomass) along 5 value chains, and developing innovative bio-based products and enhanced technologies that will lessen EU reliance on fossil-based products.

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Summary

The specific objective of task 1.1 in the MarginUp project is to access the availability of marginal lands for five low ILUC biomass value chains in associated countries. This activity involves conducting a study through desktop studies, interviews, an expert workshop, and the production of maps depicting marginal land and stakeholders using GIS. The study focuses on five use cases in Europe as well as one in South Africa and one in Argentina. The activity is a part of the MarginUp! project "Raising the bio-based industrial feedstock capacity of Marginal Lands" and is within the scope of the task 1.1 "Marginal lands availability for low ILUC bio-based products focused on the use cases." The result will be used for the upcoming tasks in the MarginUp project and by external stakeholders in the different countries.

The five European use cases with low ILUC biomass value chains include (i) short rotations forest for MDF (Greece), (ii) abutilon and willow SRC to produce oyster mushroom substrate (Hungary) (iii) turnip rape for biofuel (Sweden) (iv) reed canary grass for erosion and protection panels (Germany) and (v) hemp and kenaf for building panels (Spain). In the South African use case, the focus is on areas that have been invaded by invasive trees. The Argentinian use case focuses on land salinization.

Marginal lands are areas that has different limitations, and the term is used to describe several types of unproductive or underutilized lands, from fallow agricultural land to decommissioned mines. Biophysical factors such as soil quality, topography, climate, and water availability can be used to assess the suitability for different types of land use and asses its marginality. This can be done by identifying relevant factors such as slope or rooting depth, deciding a threshold for each factor. A useful tool to utilize in the classification of marginal land is geoinformatics systems (GIS). There is no clear definition of socioeconomic constraints when it comes to marginal lands, but there are several factors that are commonly associated with socioeconomic marginality such as low income, low accessibility and lack of infrastructure, ageing population, low population density and low density of economic activities.

The results from the interviews and expert workshop identified the following biophysical factors (BF) and socioeconomic constraints (SC) as characteristic for marginal land by the European use cases:

- Greece: contaminants as heavy metals, organic compounds, and acid mine drainage (BF), high unemployment rate and poor infrastructure (SC)
- Hungary: high temperature and low humus content (BF), labour challenges and unknown market is larger than the younger (SC)
- Sweden: low temperature and short vegetation period (BF), proximity to the farm (long distances) and low population (SC)
- Germany: high water levels (BF), land use conditions, lack of economic viability and stakeholder characteristics and engagement (SC)

- Spain: low precipitation and low content of organic matter (BF), market challenge and low economic activity density (SC)

Data collection and GIS-mapping was conducted to visualise marginal lands availability and relevant stakeholders in online maps to be published on the project's website. In terms of geographical scales, three different maps were produced, one at the local scale for the pilot site, and two others at regional and national scales. The Greek use case involved mapping lignite mines, both operational and shut down. Greece has committed to fully closing its lignite sector by 2028. In the Hungarian use case, land classified as vineyards and orchards within the region was mapped. For the Swedish use case, all agricultural land is classified as marginal land due to the heat sum reaching approximately 900°C days, which falls below the marginality threshold of 1500°C days. The German use case combined three biophysical factors, peat soil thickness exceeding 1 m, groundwater level less than 1 m below the surface, and the presence of grasslands, and the intersect was defined as marginal land. In the Spanish use case, marginal land was defined as maize fields with yields lower than 12 tonnes/ha. However, in the maps, marginal land encompassed all agricultural areas within the regional boundaries due to lack of more detailed data. For the international use cases, only stakeholders were included in the maps.

The mapped marginal land and the associated biophysical and socioeconomic factors in the different use cases are based on regional and local know how, opinions and own experiences to a large extent and not on research studies and other scientific material. As a result, there are assumptions and uncertainties in the maps and there is a need for a more extensive data collection on regional and local scale to further develop the maps and the different factors.

Between the countries there are different levels of data availability when it comes to GIS-data. There are gaps between European and International use cases, but also between the different European countries.

Spelling Guidelines

Standardised British Spelling (NOT Oxford Spelling!) should be used in all documents. Genetic terms are spelled in lower case, specific terms and proper names are spelled with initial capitals. For metric tonnes use the term "tonnes" and NOT tonnes.

Disclaimer

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List of Acronyms

BF	Biophysical factors
CO_2	Carbon dioxide
GIS	Geographic information system
ILUC	Indirect land use change
RME	Rapeseed methyl ester
SRC	Short rotation coppice
SC	Socioeconomic factors

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Keywords list

- Marginal land
- Biophysical factors
- Socioeconomic constraints
- Maps
- GIS
- Biobased value chain

1 Introduction

This report forms the output from the MarginUp project task 1.1. The assignment for this specific task is to visualise marginal lands availability and relevant stakeholders in online maps to be published on the project's website. The maps include information on marginality factors, including both biophysical and socioeconomic, and stakeholders that are connected to the use cases. The work in MarginUp! is based on seven case study sites around the globe, including Argentina and South Africa, and five full-scale use cases in Europe; Germany, Greece, Hungary, Spain, and Sweden. The five European low ILUC biomass value chains include (i) turnip rape for biofuel, (ii) hemp and kenaf for building panels (iii) short rotations forest for MDF (iv) reed canary grass for erosion and protection panels and (v) abutilon and willow SRC to produce oyster mushroom substrate. In the South African use case, producing biobased products from biomass cuttings from areas that have been invaded by invasive trees. The Argentinian use case focuses on remediation salinization of land.

The work in task 1.1 build further on the results from previous projects on production of non-food crops for bio-based products growing on marginal lands. As an example, the EU projects MAGIC - Marginal Lands for Growing Industrial Crops (MAGIC, 2023), BIKE - Biofuels production at low ILUC risk for European sustainable bioeconomy (BIKE, 2023) and GRACE - Growing advanced industrial Crops on marginal lands for biorefineries (GRACE, 2023) formed the baseline for the initial literature study on biophysical factors and socioeconomic constraints to assess marginal land. The scope of the literature study focused on the background and methodology for mapping marginal lands suitable for the use cases, and how to illustrate maps on local and regional scale.

The specific objective of task 1.1 is to identify the availability of marginal lands for five representative low ILUC biomass value chains and in associated countries. Example of research questions that was investigated in task 1.1 was: What factors causing biophysical and socioeconomic constraints for low ILUC biomass production to include in the different use cases? How to set the geographical boundaries for the online maps? How many layers to include in the online maps? Who are the stakeholders for the maps?

The result of this task will be used for the upcoming tasks in the MarginUp! project and by external stakeholders. The available GIS data varied between each region and/or country and affected the level of details in the maps.

2 Background

2.1 Literature review biophysical factors for marginal lands

2.1.1 Knowledge that exists today

The definition of marginal land is complex and depends highly on the perspective and context, varying across regions, countries, and organizations. Generally, it refers to land that has limited productivity due to challenging growing conditions (Haberzettl et al., 2021). The term marginal land has over time become an 'umbrella term,' used as a broad category for various types of unproductive or underutilized lands, including both agricultural and non-agricultural, Figure 1 (Mellor et al., 2021).

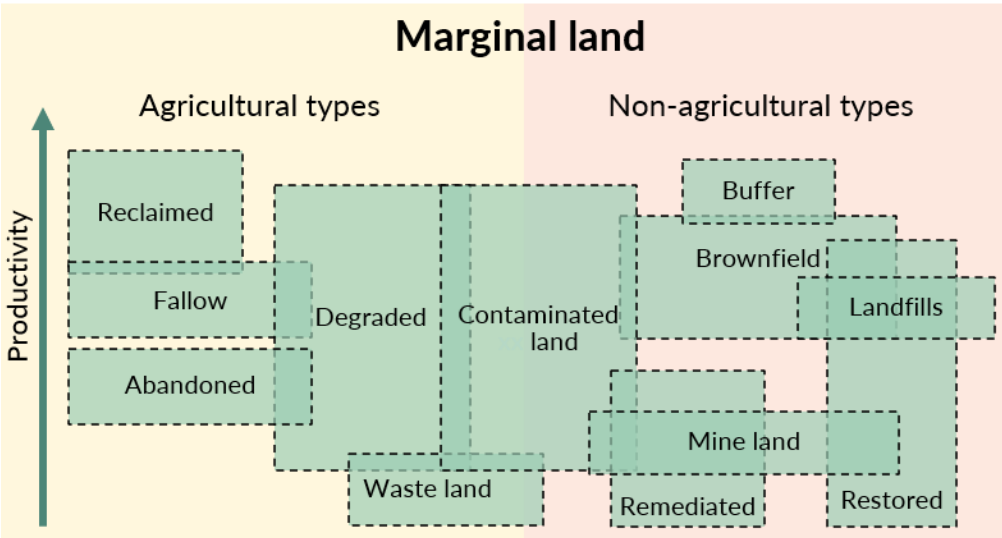

Figure 1. Marginal lands, agricultural, and non-agricultural by increasing productivity (Muscat et al., 2022)

The focus of marginal lands among researchers has been the production of biomass on marginal land for environmental and economic benefits (Csikós & Tóth, 2023). The main policies and projects targeting marginal lands in the European Union focus on sustainable bioenergy, rural development, and ecosystem restoration (Muscat et al., 2022). Marginal lands used as feedstock for biobased industries are typically biophysically poor, fallow, abandoned, degraded, or in crop production but suffering from soil degradation, erosion, or nutrient run-off. Focus has also turned to the cultivation of industrial crops on contaminated non-agricultural lands (Figure 1) (Csikós & Tóth, 2023).

When classifying marginal lands qualitative classification according to limiting biophysical factors are commonly used. Generally, geographical factors such as temperature, slope, and precipitation as well as soil suitability such as yield, physical and chemical soil properties are considered, Table 1 (Csikós & Tóth, 2023). Biophysical factors that make lands marginal is well defined and extensively researched with respect to the growth of bio-based feedstocks (industrial crops) in recent decades (Haberzettl et al., 2021).

The combination of individual biophysical factors can result in positive, negative, or unclear synergies, making it difficult to assess crop performance on marginal. Many models simplify the complexity when multiple negative synergies are present, basing it on only one threshold or a few averaged values. For instance, soil erosion can be enhanced by various factors such as high temperatures, limited rain, steep slopes and low vegetive soil cover. To access sufficiently high yields on marginal land, various soil conditions that influence the growth of the crop need to be assessed together (Haberzettl et al., 2021).

Table 1. Main biophysical factors (Csikós and Tóth, 2023; Muscat et al., 2022; Pulighe et al., 2019; Lewis and Kelly, 2014; Haberzettl et al., 2021)

Geographical	Soil suitability	Water availability	Human impact
Altitude	Acid sulphate soils	Flooding	Contaminated ground or surface water
Climatic water balance	Aluminium toxicity	Ground water level	
	Base saturation	Soil moisture content	Contaminated sites (e.g., brown fields, mines, landfills)
Climatic zone	Erosion		
Desert fringes	Nutrients availability	Surface water	High concentration of heavy metals
	pH	Waterlogging	
Evapotranspiration	Salinity		Significant irrigation (lead to depletion of water resources)
Growing degree days	Sandy soils and heavy clays		
Precipitation	Shallow rooting depth		
Slope	Shallow topsoil		
Temperature	Sodicity		
	Soil drainage		
	Soil organic carbon		
	Soil profile (e.g., gypsic horizon)		
	Soil texture		
	Surface stones and rocks		
	Water holding capacity		

Generally, the initial phase of mapping suitable areas for bio-based feedstocks involves identifying land that can be classified as marginal. Remote sensing is a useful tool for this, by identifying marginal land and yields of industrial crops based on lands' biophysical characteristics, such as soil quality, land cover, terrain, and climate. With the development of modern geoinformatics systems (GIS), more precise land assessment models are now possible. (Csikós & Tóth, 2023) GIS assessment can be conducted on a large scale, with 1-km resolution data for countries or continents, and local-level data of around 30 m can be obtained from satellite images (Zhang et al., 2021). However, variables are often aggregated to the lowest resolution in the dataset due to tractability concerns. The time of recorded data is also important, as studies use crop yield data from the last 20 years while climatic data from 1960 to 1990 is often used (Haberzettl et al., 2021).

To determine the optimal location for each industrial crop, biophysical factors are matched with crop requirements using GIS overlay analysis. Different databases are used in yield models to calculate biomass growth based on various limiting factors and crop demands. A combination of map layers is used to identify suitable marginal areas for industrial crop cultivation (Haberzettl et al., 2021). Several EU projects, including OPTIMA, FORBIO, SEEMLA, have identified promising industrial crops for cultivation on marginal lands in Europe, such as switchgrass, miscanthus, cardoon, and giant reed (Pulighe et al., 2019). Furthermore, the EU project MAGIC has created a database for selecting industrial crops based on the yield ratio of 37 different crop types under different soil conditions, providing information for choosing the appropriate crop type for specific marginal land types.

2.1.2 What to examine further

The main obstacle to cultivating industrial crops on marginal lands is the lack of a clear definition and understanding of what constitutes marginal land, leading to ambiguity and difficulties in identifying it. Combined with differences in models and datasets, has led to a wide range of estimates regarding the availability of marginal lands (Mellor et al., 2021; Haberzettl et al., 2021). Without a clear definition monitoring of marginal land will pose a significant challenge and equally important, ensuring that the land indeed is marginal and not used for other valued purposes (Muscat et al., 2022).

Suitable land for industrial crops is limited by the scale of assessment. Remote sensing can capture large monocropped agricultural landscapes but is insufficient in capturing smaller farms in many developing countries. Higher resolution data is needed for accurate assessment, but it is not routinely collected or suitable for Argentina purposes. Another obstacle is identifying if the proposed marginal land is being used for other purposes, such as grazing or fuel wood collection. Modelling non-agricultural lands such as brownfields and landfills is challenging as they are often represented as a point on a map, requiring more precise data encompassing the entire area (Mellor et al., 2021).

Cultivating industrial crops on marginal lands can be inefficient and expensive compared to productive lands. To achieve profitability, when mapping suitable areas, the focus should be on designing a profitable value chain by improving and focusing on finding optimal growing conditions for industrial crops using biophysical factors (Muscat et al., 2022). The use of GIS linear overlays is useful for suitability, but more advanced techniques, such as the incorporation of Fuzzy Set Theory are needed to better represent the different synergies for biophysical factors and its varying thresholds (Lewis & Kelly, 2014).

Suggested solutions include:

- A definition of marginal lands by clear criteria and methodology that can be used for a sustainable bioenergy production.
- To provide sufficient and reliable data to develop models and calculate biomass yields. The obtained data on industrial crop growth and yields should be documented and made available, for example, on statistical databases of the FAO.
- Studies are best suited to be performed on local and/or regional scale using a bottom-up approach and methods that takes the complex nature of marginal lands into consideration.

2.2 Literature review socioeconomic factors for marginal lands

2.2.1 Problem statement

In the literature on marginal land definitions and land classifications there is generally much consensus on the biophysical limitations that characterise marginal lands, and that can be used for identifying them. For the identification of marginal lands, however, there is no clear consensus in relation to defining and identifying marginal lands using socioeconomic constraints indicators. "While many studies have estimated marginal land availability using various methods, only a few studies have considered the role of socioeconomic factors in affecting perceptions about the availability of marginal land" (Yang et al., 2021).

2.2.2 Marginal land as a concept from a socioeconomic perspective

The socioeconomic dimension of marginality involves several aspects that drive the expected social and economic outcomes to lag. Marginality is closely related to the vulnerability of both people and environment as it victimizes location and communities that are characterized by one or more factors of vulnerability (poor location and scarcity of natural resources). The intended use of the land under assessment also needs to be considered so this human factor including the economic and cultural context are important in determining potential of land resources (Ahmadzai et al., 2022).

Economically, a broad definition characterizes marginal land by its often poor infrastructure, which leads to limited market access of the goods that could be produced on that land (Elbersen et al., 2018; Haberzettl, 2021) and thereby affects mostly rural areas in regions with difficult accessibility. In more concrete economic terms, marginal land can be utilized 'at the margin of economic viability' (Strijker, 2005), meaning that the profit obtained from these lands is close to zero. This definition suggests that under the given set of conditions marginal land should be used for industrial crop cultivation rather than for food crop cultivation to increase its economic viability (Shortall, 2013). The economic perspective on marginal land is not directly based on the fertility or the conditions of the soil but rather on the relation of inputs and outputs to and from the land. From this perspective, the degree of marginality can only be assessed based on the comparison of different crop production systems on this land as they have varying break-even points due to different inputs and outputs (Haberzettl, 2021). This understanding of marginality implies that food crops that could be grown on that land might not be cultivated there when a better, more economically beneficial alternative is present, leading to land use change (Searchinger, 2008).

2.2.3 Socioeconomic factors from the literature as constraints in marginal lands

There are several socioeconomic characteristics according to which plots, landscapes and regions can be characterized, but the basic characteristics found in the rural development literature about factors constraining the development of rural regions (OECD, 2006, 2007 & 2009, EC, 2017) refer to factors like relative location (remoteness, central-decentral), presence of infrastructure influencing the accessibility (lack of it), low population density, low density of economic activities, large dependence on primary sector, ageing population and others.

Often there is a strong relationship between several of the socioeconomic factors, e.g., low population density usually goes together with low accessibility, low income and an ageing population, which implies that a rural multidimensional typology would be the best approach to classifying marginal lands further according to socioeconomic constraints.

Most recent studies such as Esch et al. (2021) have done a complex delineation of economically marginal land by considering several types of factors including historical and present economic as well as population data. They used historical farm operating expenses and the amount of fertiliser used. They also employed market prices for farm product and crop prices, government subsidies and profits, and rental payments. Another study from Nándor Csikós et al. (2023) proposed a scheme using economic factors including profitable yield level, capitalization rate, rental payment, farm operating expenses, domestic stock market price and fertiliser used.

Many projects such as *MAGIC* project (2017-2021) take the approach to base the assessment of marginality based first on biophysical constrains, and on top of that further determine which socioeconomic constraints occur simultaneously (MAGIC, 2023). The project team did not use economic return constraint to identify marginal lands initially given the dynamic nature of this constraint and the fact that economic returns are part of the sustainability evaluation in the project. They concluded that locational factors like accessibility and infrastructure can be used to further classify marginal lands identified according to biophysical constraints for the purpose of the project. In addition, the project team also considers the clustering of factors taking account of environmental zone-specific ranges and averages per factor.

FAO-CGIAR (1999) definition of marginal lands typically uses as socioeconomic constraint factors for marginal lands: the absence of markets, difficult accessibility, restrictive land tenure, small holdings, poor infrastructure, and unfavourable output/input ratios (Figure 2).

- The unfavourable output/input ratios: Given the dynamic nature of economic returns on marginal lands because of market drivers, the unfavourable input output ratio does not seem to be a stable indicator for identifying marginal lands, but for further characterisation to investigate the chances for competing uses on marginal lands it is useful though.
- Absence of markets, difficult accessibility and bad infrastructure: The distance factor which are indeed mentioned in several studies as key factors characterising marginal lands (Dale, 2010; Kang et al., 2013)
- The factor 'restrictive land tenure and small holdings' that is seen as typical to marginal lands in the FAO-CGIAR definition was not confirmed in many other studies providing marginal land definitions.

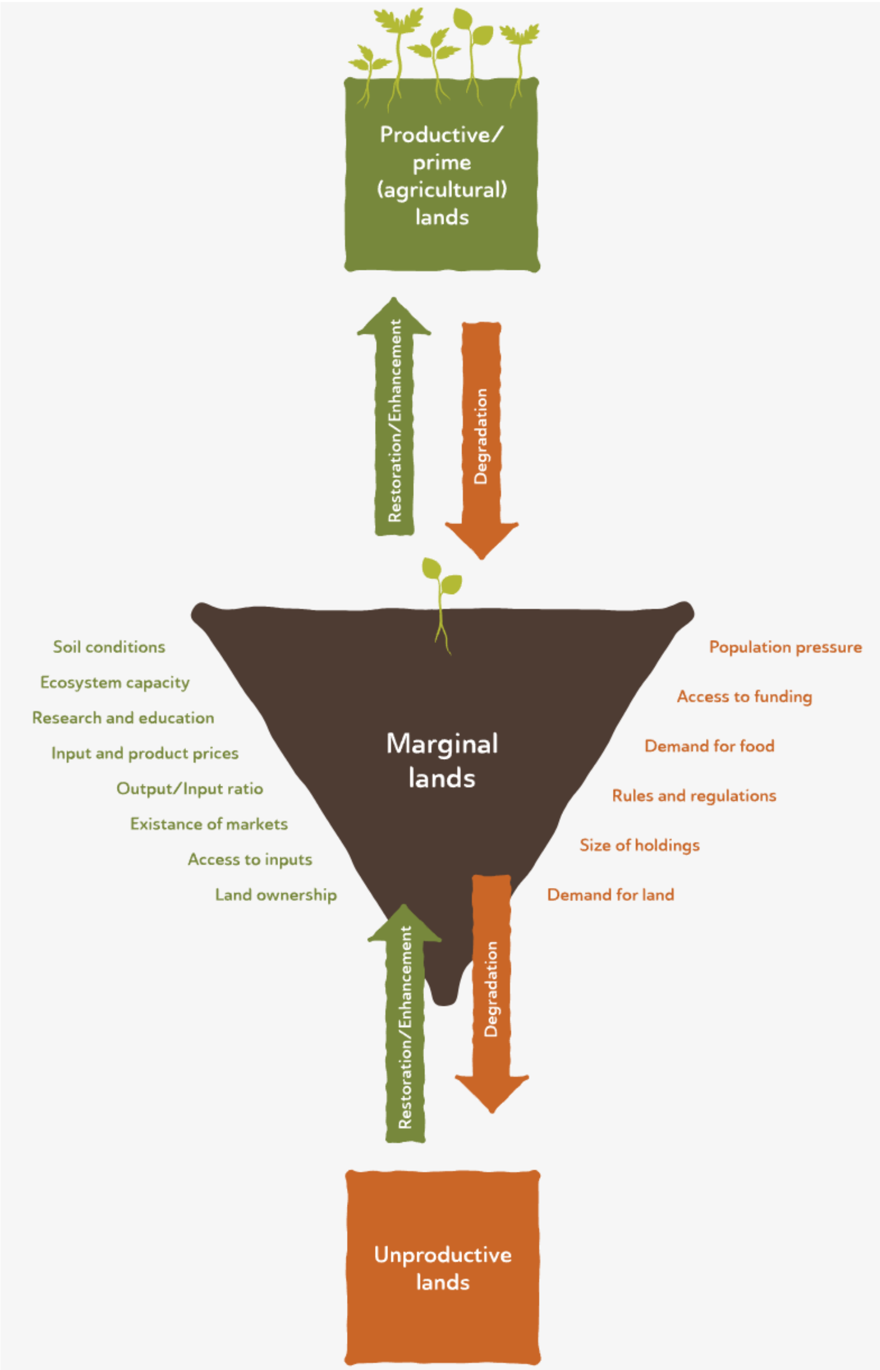

Figure 2. FAO-CIGR system approach, adapted by Grundmann, 2023

According to OECD (1994, 2011) and EC (2010 & 2017), the socioeconomic constraints typically applicable to these marginal situations, as discussed above, are also the ones captured by the different rural typologies.

The OECD classifies rural areas based on the population density of districts. In 2009, the OECD extended its classification to include the remoteness dimension, which was based on the approach developed by Dijkstra and Poelman (2008) for the EU.

The authors found significant socioeconomic differences between rural regions close to a city and remote rural regions. Following the urban-rural typology by OECD, based on population density, was further extended with a typology of areas based on Argentina Brezzi et al. (2011) showed that remoteness of rural regions is a significant factor explaining regional outflows of working age population, and that remote rural regions appear economically more fragile with lower economic output rates as compared to more central regions.

The *FARO* project (Van Eupen et al., 2012) developed an alternative typology of rural areas in Europe at high spatial resolution classified by socioeconomic factors and environmental zone. It is more dimensional than OECD as it combines indicators on agricultural land use, accessibility, population, and economic activity density.

The studies from Brouwer (1997) and Floor Brouwer et al. (2011) indicate that socioeconomic marginal definitions may exist at different geographical levels, for example:

(a) Regional: in Europe, a region may be marginal in broad physical and socio- economic terms, with unfavourable conditions and uncompetitive forms of agriculture involving low productivity and income levels, remoteness from markets, and aging populations. The possibility of widespread marginalisation in such a region may be considered high, although there may also be agricultural areas, which are highly productive and competitive.

(b) Local areas: within a region, certain types of land use may become marginal as a result of changing socioeconomic and technological conditions. Grazing marshes provide a good example. Such areas may exist even within very productive regions.

(c) Farm level: an individual farm may be uncompetitive for a variety of reasons, such as small size, fragmented land, degraded infrastructure and capital equipment, or the age of the farmer. Such holdings are taken over by other farmers or land uses, depending on local conditions. In more marginal regions, total farm abandonment may occur.

(d) Within a holding, an individual plot of land may be marginal due to physical handicaps, such as poor access, steep slopes, waterlogging or distance from the main holding.

2.2.4 Systemic approach including socioeconomic factors to identify and classify marginal land

A more comprehensive understanding of the factors that constrain the use of marginal lands requires a systemic approach that also includes the capacities of individuals, organisations, networks and societies. Furthermore, an adequate understanding of marginal lands from the perspective of socioeconomic constraints must also include constraining factors from the perspective of businesses and value chains.

Socioeconomic factors need to be considered together with other factors that make a particular situation a marginal one, such as biophysical characteristics, environmental factors, ecosystem services, geographical location, agricultural structures and political factors. Quantifying the individual and combined impacts of all challenges is important for policy making on marginal lands. This could eventually lead to the development of an analytical framework for the identification and assessment of marginal lands.

3 Methodology

3.1 Expert workshop

MarginUp! expert workshop on marginal land and factors causing biophysical and socioeconomic constraints was held with the aim to take stock of the current state of knowledge of biophysical and socio -economic constraints related to marginalised and low-productivity lands. Another aim was to analyse and understand the specific biophysical and socioeconomic factors of each use case in the MarginUp! project and challenges faced. Also, to learn from each other and the different use case.

The workshop was conducted online on the 3rd of May 2023, with a duration of three and a half hours. In total 22 people participated in the workshop. Two weeks before, the workshop material was sent out to the participants to be able to prepare for the workshop. The material consisted of summaries of existing knowledge and needs to examine further on biophysical and socioeconomic factors for marginal lands and instructions for the use case presentations. Three use cases were selected to present problems caused by biophysical factors in their use cases and two use cases was selected to present problems caused by socioeconomic factors in their use cases.

As an introduction to the first part in the workshop a presentation was held about biophysical factors. After the introductory presentation three use cases (Spanish, Swedish and Greek) presented their use case and problems caused by biophysical factors in their specific use case. The focus of the Spanish use case presentation was on the combination of low precipitation and high temperature. The focus of the Swedish use case presentation was on low temperature. The Greek use case focused on contaminants. After the presentations, a question-and-answer session was conducted about the three use cases and problems caused by biophysical constraints, the questions are presented in Annex B. As an introduction to the second part of the workshop a presentation was held about socioeconomic factors. Then two use cases (German and Hungarian) presented their use case and problems caused by socioeconomic factors in their specific use case. The focus in the German use case presentation was on farmers resistance towards new cropping recommendations due to high CO_2 emissions from cultivation of peat land. The Hungarian use case focused their presentation on demographic issues. After the presentations a question-and-answer session was conducted about the two use cases and problems caused by socioeconomic constraints, the questions are presented in Annex B. Then the international participants presented their use cases. The South African use case focused on socioeconomic factors and the Argentinian focused on biophysical factors. After that, the workshop was concluded.

The expert workshop was conducted online, there are a lot of challenges when it comes to online meetings. Example of risks and challenges are low involvement of the participants due to small opportunities for the participants for dialog and interactivity. This can lead to passivity and low motivation amongst the participants. To address this risk, prepared Q&A sessions were utilized. However, it would have been beneficial to provide additional chances for participants to converse in smaller groups, considering that the entire expert workshop was conducted in a large group.

3.2 Online maps

Data collection and GIS mapping were conducted to visualize the availability of marginal lands and relevant stakeholders in online maps and published on the project's website (MarginUp!, 2023).

3.2.1 Interviews with use cases as background for online maps

Interviews with all use case groups were conducted to create a better understanding for the online maps on marginal lands available for the five MarginUp! low ILUC biomass value chains and the possible stakeholders. The interviews were conducted via Teams in March and April in 2023 and the duration was around 1.5 hours. Background material was prepared and presented initially. The background material was based on a literature study with the scope of mapping the marginal land with focus on both biophysical and socioeconomic constraints. The interview questions were divided into 4 different parts: geographical scope, marginal land definition, online maps, and stakeholders. Example of topics that were discussed in the interviews were, e.g., scale of marginal land, marginality factors, and potential users of the maps. See Annex A for the interview questions. The two international use cases responded to the interview questions by e-mail.

3.2.2 Data collection

Background information from the interviews (section 2.2.1) was utilized for the data collection of each use-case. Firstly, an instruction guide was developed, using the Swedish use case as a template for the other use cases. This guide detailed the specific data to be collected, the required file format, and pictures of maps from the Swedish use case for data illustration. It was distributed to all relevant use case participants. Subsequently, data collection occurred iteratively, including the pilot site of the novel crop, regional boundaries of the pilot site, mapping of marginal land within these regional boundaries and identification of relevant stakeholders in the value chain. For more information see Annex C. The chosen file format was a shapefile, a geospatial vector data format compatible with GIS software. Except for the stakeholders, these were collected in an excel file with the corresponding addresses.

Pilot site

The pilot site was defined as the fields where crops were planted 2023 on marginal land to assess the novel cropping system for each use case. Information about each pilot site, including its coordinates and area, can be found in Table 2 The Swedish use case has two pilot sites, one in Västerbotten and one in Norrbotten (around 100 km apart). To maintain consistency with the other use cases in the online maps, only the pilot site in Västerbotten was chosen for the study. The German use case did not involve a specific pilot site. Instead, ATB collaborated with multiple farms by purchasing bales of reed, cat tail and reed canary grass. Table 2 lists all the fields belonging to a farm encoded as Farmer 2.

Table 2. Pilot site details for each use case

Use case	Pilot site	Coordinates	Area (ha)
Greece	North of Kozani	(40.4524846, 21.8219291)	4.3
Hungary	North of Kecskemet	(46.9864698, 19.6718976)	6.1
Sweden	Southwest of Skellefteå	(64.6862438, 20.5458903)	7.4
Germany	Northeast of Kremmen	(52.7898037, 12,9614832)	79
Spain[1]	South and southwest of Coria	(39.9653718, -6.5700145) and (39.9741275, -6.5277065)	5.8 (3.9 and 1.9)

[1] Two pilot sites were included.

Regional boundaries

The regional boundaries were defined by each respective use case, tailored to their specific requirements. A proposal was suggested for the regional boundaries to be an administrative border around the pilot site. A summary of the geographical scope of these boundaries for each European use case is presented in Table 3. The international use cases had not yet defined their geographical boundaries.

Table 3. Geographical scope of the regional boundaries for each use case

Use case	Regional boundaries	Data source
Greece	Western Macedonia region	(INSPIRE Geoportal-EU, 2015)
Hungary	Bács-Kiskun province	(Geofabrik – OpenStreetMap, 2023)
Sweden	Västerbotten and Norrbotten counties	(SCB, 2023)
Germany	Districts in Brandeburg state: Ostprignitz-Ruppin, Oberhavel, Havelland	(European Commission – Eurostat/GISCO, 2021)
Spain	Municipalities in Cáceres: Calzadilla, Casas de Don Gómez, Casillas de Coria, Coria, Gata, Guijo de Coria, Guijo de Galisteo, Holguera, Huélaga, Montehermoso, Moraleja, Morcillo, Pescueza, Portaje, Riolobos, Torrejoncillo	(INSPIRE Geoportal-EU, 2015)

Stakeholders

Stakeholders were identified at three levels: national, regional, and local. Local stakeholders included those in the surrounding area of the pilot site (see Table 2). Regional stakeholders were those residing within the specific regional boundaries delineated by the use cases, aligning with administrative borders around the pilot site (see Table 3). Stakeholders located outside these regional boundaries were classified as national stakeholders. For the international use cases, all stakeholders were mapped at the national scale.

Data on stakeholders was collected through interviews conducted as part of task 1.1 for each use case. These findings were then consolidated with information obtained from interviews conducted in task 5.1.

Marginal land

The definition of marginal land was tailored to the specific conditions of each country, site, and novel cropping system in each use case. Site-specific constraints for each use case were identified through interviews with members associated with each use case. However, the initially established theoretical definition had to undergo some modifications to align with the available GIS data in each country. The delineation of marginal land boundaries within the regional context was provided by use cases through a shapefile, as outlined in Table 4.

The Greek use case involved mapping lignite mines within the Western Macedonia region, which comprises eight mine units, including both those that are shut down and still operating. The Greek government has committed to fully closing the lignite sector by 2028 in order to achieve the climate goals set by the EU for 2030 and attain net-zero emissions 2050 (Hellenic Republic, 2019). Consequently, this leaves behind marginal land that is degraded and no longer productive.

In the Hungarian use case, land classified as vineyards and fruit orchards within the region was mapped using a database sourced from OpenStreetMap. The lack of accuracy of this data necessitated manual verification using a 5x5 km grid overlay, utilizing satellite imagery from Google Maps and Bing Maps. Due to insufficient data, abandoned vineyards and fruit orchards could not be mapped effectively. An alternative approach was adopted, focusing on mapping biophysical constraints for all agricultural land, including considerations of climatic constraints, soil conditions, and groundwater levels. A novel definition of marginal land is currently under development and will be updated during the course of the project.

In the two regions of the Swedish use case, Västerbotten and Norrbotten, all agricultural land is classified as marginal land since the heat sum reaches approximately 900°C days, which is below the marginality threshold of 1500°C days.

The German use case combined three biophysical factors and the intersect was defined as marginal land. These factors included peat soil thickness exceeding 1 m, a groundwater level less than 1 m below the surface, and the presence of grasslands. The grasslands encompassed agricultural land, with hay pastures and meadows as the dominant crop type and biotypes classified as grassland. The process entailed a spatial intersection of these parameters, leading to the identification of marginal land, for more information see Annex D.

In the Spanish use case, marginal land was defined as maize fields with yields lower than 12 tonnes/ha. However, in the maps, marginal land encompassed all agricultural areas within the regional boundaries. The inclusion was due to the prevalence of maize fields in most crop rotations within these boundaries and the lack of specific yield data for these fields. The use case acknowledged this limitation and planned to estimate the actual extent of marginal fields in future assessments.

Table 4. Definition and area of marginal land included in the online maps for each use case within the regional boundaries.

Use case	Marginal land	Area (km^2)	Data source
Greece	Lignite mine units	199	Unknown
Hungary	Vineyards and orchards	468	(Geofabrik – OpenStreetMap, 2023)
Sweden	Agricultural land with a heat sum below 1500°C days	1004 [1]	(Swedish Board of agriculture, 2023)
Germany	Intersect of thickness of peat soil > 1 m, depth of groundwater level < 1 m and grasslands	94	(Metaver, 2022; Metaver, 2023; Metaver, 2009)
Spain	All agricultural land.	215	(SITEX, 2023)

[1] Turnip rape is 20 % of the yearly potential as it can be incorporated in the crop rotation every 5 years.

3.2.3 GIS mapping

ArcGIS Pro was used for the assessment process. The resulting maps were categorized into three levels: national, regional, and local, as depicted in Figure 3. Specifically, the national map included national stakeholders and regional boundaries, the regional map displayed regional stakeholders along with marginal land mapping, and the local map featured the pilot site and local stakeholders.

The workflow for each use case included adding coordinates from the addresses to the Excel file containing stakeholder data. These coordinates were then converted into points on the map using the "Display XY Data" tool in ArcGIS Pro. Additionally, the other files, gathered in shapefile format, were added to the map. Subsequently, three layouts were created, each containing the national, regional, and local map. These layouts were exported as JPEG files. Furthermore, each layer was individually exported as a shapefile and archived into a zip file.

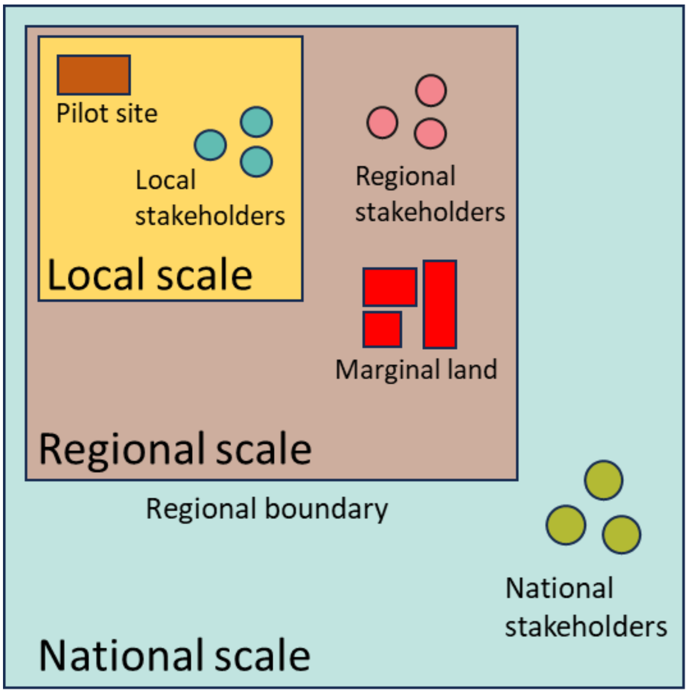

Figure 3. Map scale schematic

3.2.4 Socioeconomic factors

Two to three socioeconomic factors were selected based on the interviews with the use cases and the expert workshop, identified as having the most significant impact on marginal land. These were listed on the MarginUp! homepage along with the maps. Each socioeconomic factor was represented by an icon, as shown in Annex F.

Further information regarding the socioeconomic impacts will be accessed as the project progresses, notably in Deliverable 4.3, where a socioeconomic impact assessment will be conducted.

4 Results

Table 5 summarizes the primary findings of each European use case, encompassing the novel crop system, the defined marginal land type, and the key biophysical and socioeconomic constraints.

Table 5. Overview of the use cases, overview, industrial crops, type marginal land, and the main biophysical and socioeconomic constraints associated with each case.

Use case	Industrial crops	Marginal land	Biophysical constraints	Socioeconomic constraints
Greece	Short rotation trees and herbs	Lignite mines	Contamination, poor soil quality	Poor infrastructure, unconventional field shapes, aging population with decreasing numbers, high unemployment
Hungary	Short rotation trees and herbs	Low organic matter and sandy soils	Sandy soil, low ground water level, precipitation, low humus/nutrient content	Lack of human resources, absent younger generation, competition with industrial sector, aging population, energy prices
Sweden	Turnip rape	Cold climate	Climate, growing season	Long distances, low population density and aging population
Germany	Reed and sedges	Drained peatlands	Carbon losses	Income security, long term perspective of business discipline, social awareness and acceptance, market development, funding
Spain	Hemp and kenaf	Hot climate and low yields	Low organic matter content, poor cation exchange capacity, acidic pH, desertification	Low to medium population, high unemployment rate and low GPD

4.1 Expert workshop

4.1.1 Biophysical factors

4.1.1.1 Contaminated land

The Greek use case was chosen for the workshop to present contaminated land as one important biophysical factor when considering marginal land. The main challenge in rehabilitating the land is related to biophysical factors, primarily the presence of contaminants resulting from lignite mining. Such mining activities can negatively impact the surrounding land, water, and air, disrupting natural ecosystems and releasing both natural and anthropogenic contaminants. The specific contaminants present depend on the methods used in each mine, as well as local geology and hydrology. Therefore, site-specific information is crucial to determine appropriate remediation measures.

Typical contaminants found in these areas include heavy metals such as arsenic (As), lead (Pb), cadmium, and mercury, which can accumulate in the soil and water. Organic compounds like polycyclic aromatic hydrocarbons (PAHs) may also be present.

Acid mine drainage, resulting from sulphide minerals in lignite mine waste, can further contribute to contamination. Naturally occurring radionuclides like radon, uranium, and thorium are often found in coal. Chloride, sodium, sulphate salts, dust, and particulate matter are additional contaminants of concern.

The presence of contaminants can have several negative effects. It can reduce soil fertility and crop yield, affect nutrient availability and water pH, and damage soil structure. Contaminants can also lead to soil compaction, making it harder for water and plant roots to penetrate the soil. Erosion and harm to soil microorganisms are common consequences as well. Contaminants may pose toxicity risks and hinder the absorption of essential nutrients, leading to health problems. Moreover, environmental damage to wildlife and nearby water sources can occur.

Remediation of such contaminated lands can be challenging, as it requires a time-consuming and expensive process that poses risks to human health and the environment. The first step is to measure the contaminants, which can be done through soil sampling and laboratory analysis, field screening, groundwater sampling, remote sensing, ecological assessment, risk assessment, and direct measurement.

Remediation can be performed by the plantation of fast-growing trees that are suitable for reforestation, agroforestry, and soil improvement. These trees, with their deep roots, help stabilize the soil, reduce erosion, and minimize water runoff. Additionally, they support the growth of other vegetation through their sustainable biomass.

4.1.1.2 Cold climate

For the workshop, the Swedish use case highlighted cold climate as a biophysical factor affecting marginality. The region of the use case is located in northern Sweden and experiences long, dark, and cold winters, leading to a short crop growing season. One biophysical factor illustrating this is the accumulated heat sum, which is calculated by determining the daily difference between the average temperature and 5°C over the course of a year. A value below 1500°C days is defined as marginal (Elbersen et al., 2019). Secondly, the vegetation period is also an important factor which is defined as the number of days with an average daily temperature exceeding 5°C. A value below 180 days is defined as marginal.

In this region, the heat sum generally reaches around 900°C days, indicating marginality (SMHI, 2023). The vegetation period spans 139 days, further reinforcing its marginal status (SMHI, 2023). Although the vegetation period has extended by one week due to climate change, it remains within the marginal range. Despite the region receiving abundant sunlight during the summer, the most limiting factors for turnip rape cultivation are short crop cultivation season, as well as temperature, rainfall, and humidity.

Cordelia is the specific turnip rape variety utilized in the given use case, exhibiting an average yield of 1500-2000 kg/ha (Bernes & Gustavsson, 2016). Despite the drawback of low yield associated with turnip rape cultivation, resulting in reduced profitability, its capacity to thrive and ripen in cold climates with a short cultivation season renders it a viable crop. The ripening time for spring turnip rape is approximately 110-120 days (Bernes & Gustavsson, 2016). It can also withstand pest and disease pressures while promoting biodiversity. However, temperatures below 5°C have a significant impact on its growth, affecting vital processes such as cell division, photosynthesis, and overall yield.

4.1.1.3 Arid and hot climate

In the Alagon Valley, when considering the quality of these lands, biophysical factors are the primary focus, where soil properties are the most important factor, followed by low pH and organic matter, and secondly, precipitation and temperature. The focus is on irrigated land, where industrial crops can be sown to decrease the need of irrigation and increase soil organic matter (SOM). The crops need to thrive in elevated temperatures and low precipitation. Therefore, it is crucial to select the appropriate management practices.

Firstly, the criterion used to designate marginal land is a low yield, typically around 10-13 tonnes per hectare, for commonly grown crops such as tomatoes and maize. The availability of water for irrigation purposes is not a problem in the region. However, crop production is hindered in marginal land due to high runoff of sodium and the loss of organic matter. Furthermore, other biophysical factors considered includes soil drainage, water table depth less than 50 cm, pH levels below 4 or above 8, cation exchange capacity (CEC) in the top 20 cm of soil less than 6 meq%, base saturation below 20%, and an electrical conductivity (EC) of the saturation extract exceeding 9. To address the issues of low pH and low CEC, dolomite is utilized to adjust the pH to a range between 5 and 7, and the CEC is increased to a range of 5.4-14.8.

4.1.1.4 Q and A session biophysical factors

During the Q and A session, several important points were discussed regarding marginal lands:

1. Marginality: Whether marginal lands are reversible or irreversible depends on how we address the factors contributing to their marginality. Factors like sunlight and water availability are difficult to reverse, making some aspects of marginality permanent. Whereas some may be altered due to improved land management and converted back to arable land. It is therefore essential to classify marginal lands in a specific manner.

2. Connection between Biophysical Factors and Geographical Boundaries: There is a clear connection between biophysical factors and geographical boundaries. Natural sources, industrial and agricultural activities, and pollution all contribute to the specific limitations observed in different areas. Conducting pilot studies with similar factors can help identify the geographical boundaries affected by similar biophysical limitations.

3. Improving Marginality: The degree of marginality can be influenced by the effects of climate change on biophysical factors. It is necessary to consider the extent to which climate change impacts marginality. For example, Sweden may benefit from increased temperatures, but other constraints like diseases and fungi could offset those benefits. Conversely, Spain may face negative effects, but certain crop varieties that tolerate higher temperatures and drought may offer potential solutions.

4. Economic Success and/or biodiversity: If a use case on marginal lands proves to be economically successful, the question arises whether it can still be considered marginal since the land now can be classified as productive. Another issue that arises with economic success and implementation of large-scale production is nature conservation and biodiversity. If we intensify the areas, we may overcome marginality, but we need to consider the biodiversity effects. Balancing nature conservation and production becomes a challenge, as they can sometimes contradict each other, especially on a large scale.

4.1.2 Socioeconomic factors

4.1.2.1 Labour challenges

The Hungarian use case was selected to present socioeconomic factors which contributes to marginal land. In the use case, there are several key socioeconomic factors are affecting the marginality of the land. The vineyards and orchards are facing a decline, primarily driven by challenges related to the labour-intensive practices, in combination with an absence of the younger generation in farming activities and competitive salaries from nearby industries. Increasing prices of energy and fertilizers is also a big problem.

To address these challenges, willow planting is being implemented. In contrast to vineyards and orchards, it is less labour-intensive due to its compatibility with automated cultivation techniques. The adoption of machinery and automation could help address the shortage of human resources.

4.1.2.2 Lack of economic viability

The main socioeconomic factor influencing this use case is the limited availability of alternative land uses of the peat soils and value chains, leading to a risk of abandonment. To support the new value chain, the development of new process lines for biomass processing is crucial. Conservation of bird populations is also a concern. Previous political attempts to reduce GHG emissions through rewetting have faced challenges due to the extensive drainage systems and their collateral impact on larger areas. The scale of the area makes artificial conservation management impractical, as it is not linked to specific land use practices.

To address these challenges, a new land system has been proposed, involving the elevation of the water level and the cultivation of reed or sedges. This approach, known as paludiculture, utilizes the biophysical marginality factors to create new income sources. However, there may be conflicts with bird conservation efforts. The availability of sufficient water for rewetting is also uncertain. The objective of this new land system is to retain carbon in the soil and explore industrial uses for the biomass.

4.1.2.3 Q and A session socioeconomic factors

In terms of monitoring socioeconomic factors in the use cases, there are varying approaches. In the German case, there has been limited monitoring of these factors thus far. In the Swedish use case, one indicator being monitored is the yield of different parts of the land that will be cultivated, which can provide insights into the economic viability of the agricultural practices.

The lack of a clear definition of marginal land considering socioeconomic factors is acknowledged. The project aims to address this by allowing each use case to define and identify their own specific socioeconomic factors relevant to their region. The goal is to develop a framework that considers these factors and provides a benchmark for assessing marginality. To achieve this, empirical evidence from the use cases will be gathered to determine which factors have the most significant impact and track improvements over time. By contributing to this discussion and sharing findings, the project can contribute to a better understanding of socioeconomic marginality in relation to land use.

4.1.3 International use cases

4.1.3.1 Salinity

The Argentina use case, representing one of the international scenarios, will focus on highlighting challenges related to soil salinity, particularly in the Pampas region. The Pampas, characterized by expansive plains and flat terrain, primarily serves for cereal production. Nevertheless, certain areas within the Pampas face challenges such as flooding, waterlogging, and soil affected by salinity and alkalinity. Originally, the Pampas were grasslands without trees, large herbivores, or significant human presence. However, with the arrival of cattle and horses, the human population in the region grew rapidly, and European settlers established large ranches.

The population in the Pampas is similar to other parts of the country, and the area lacks a proper drainage network, resulting in slow water flow. The climate in the Pampas is characterized as humid and temperate, with variable and irregular shifts between dry and wet periods. The construction of canals in the region has contributed to soil salinization, making it unsuitable for producing lignocellulosic biomass. Salt-tolerant plants can be cultivated to remediate the soils, such as *Lotus tenuis.*

4.1.3.2 Invasive plants

The second international use case in South Africa emphasizes issues arising from areas invaded by invasive plants. These invasive plants, predominantly trees, present challenges for agriculture, especially in terms of water management. The focus is on clearing the land from these trees, and there is potential to utilize the biomass obtained from the clearing process. The constraints are more related to access to the sites and have economic implications.

The density and distribution of the invasive trees vary which can undermine the financial feasibility of clearing efforts. This contrasts with plantation forestry, where costs are incurred for establishing and maintaining the plantations. Enforcement of laws regarding land clearing and the associated costs is often lacking.

Conflicts arise over resource use, as the invasive trees provide valuable resources such as firewood to the local community, creating tensions with the industry. However, over time, the trees can negatively impact the community, affecting grazing areas and other aspects of livelihoods.

The lack of a supportive policy environment for bioenergy further complicates the situation. Coal-generated electricity and heat are cheap, creating high competition. Additionally, carbon accounting and the release of carbon during tree cutting need to be considered, including the potential impact of carbon taxes.

Leaving the invasive trees may result in the loss of ecosystem services, such as water supply and biodiversity. Without financial support for preserving these ecosystem services, it becomes challenging to make a strong business case. Therefore, there is a need for economic valuation of ecosystem services to highlight their importance. The lack of a guaranteed long-term biomass supply poses risks for investors, which can be assessed through investor surveys. It is important to consider the potential negative effects of tree harvesting on land use.

4.2 Use case Greece

4.2.1 Definition

The Greek use case involves abandoned lignite mines that left behind contaminated, degraded, and non-productive lands. The project consists of a 26-hectare field and the goal is to rehabilitate the land and remove the contaminants via phytoremediation by the plantation of fast-growing trees, *Robinia pseudoacacia* is considered for the project. Additionally, the plan includes intercropping perennial wood species with aromatic herbs like, lavender. This combination allows for the production of bioenergy, as well as lotions and soaps from the blossoms. The success of this initiative can potentially be replicated in other regions with abounded lignite mines within the European Union.

4.2.2 Interviews as background for online maps

Yannis Fallas (CLUBE) and Theodora Kalea (CLUBE) participated in the interviews.

4.2.2.1 Geographical scope and online maps

The maps should encompass both the onsite scale and the entire region as the geographical scope. It is noteworthy that half of the western Macedonia region contains corridors of lignite. When asked about the inclusion of improved lands (irrigation, drainage, greenhouse, etc.) and abandoned/unused lands in the maps, the Greek use case group prefers to wait for the results from soil mapping to determine the specific needs. They emphasize that only land available for cultivation should be incorporated into the online maps.

With the lignite mines in the area closing, the use case group aims to utilize the maps to explore future possibilities for the establishment of permanent industrial plantations. They want to identify suitable areas for growth, including slopes and other factors. Policy makers, planning departments, farmers, wood companies, and various other stakeholders are expected to utilize the maps.

4.2.2.2 Marginal land definition

4.2.2.2.1 Biophysical factors

Climate – There is a variation in temperature throughout the year, but it does not impose any limitations on tree growth, especially with the availability of irrigation.
Precipitation – The soil is going to be evaluated regarding this.
Growing degree days – There are no concerns in this regard.
Soil properties – Currently, the soil exhibits high porosity, requiring tree roots for stabilization. There are no issues with the organic matter content in the soil.
Altitude, steep slopes, inundation risk and landslip – The area experiences challenges related to steep slopes and landslides. There may also be potential issues with inundation.
Contaminations/Adverse chemical conditions – The soil is contaminated with heavy metals.
Protected areas – There are protected areas surrounding the region, although not within the mines themselves. The Vermio Mountain is approximately 10 km away, and the Karioxori-Spilia area is about 4.5 km away.

4.2.2.2.2 Socioeconomic factors

Abandoned land - In a certain sense, a mine can be considered abandoned land.
Economic constraints - The area faces challenges with poor infrastructure and irregular field shapes.
Distance to city – There are no issues in terms of proximity to the nearest city, as it is only 10-15 km away.
Accessibility – No problem.
Population - The population in the area is aging, and there is a decrease in overall population numbers.

Economic activity density – The region experiences a significantly high unemployment rate, particularly among young people, which is one of the highest in Europe.

4.2.2.3 Mapping of stakeholders

The maps of the stakeholders will be utilized, for instance, to investigate logistical solutions for supplying the value chain. Another potential application of the maps is for policy makers to understand the importance of the case study, considering the presence of numerous stakeholders in the area.

4.2.3 Online maps

The maps depicting the Greek use case at national, regional, and local scales are presented in the following section. For additional information on the stakeholders illustrated in each map level, please refer to Annex E and Table E.1.

4.2.3.1 National scale

The national scale map of Greece, depicted in Figure 4, illustrates the geographical location of the region Western Macedonia, chosen as the regional boundary for the Greek use case. In addition, relevant stakeholders of the value chain on the national scale are illustrated, with most present in Athens.

Figure 4. National scale map of the Greek use case, illustrating the national stakeholders and regional boundaries

4.2.3.2 Regional scale

The regional-scale map in Figure 5 displays the lignite mines located in Western Macedonia[1], marked as marginal land. These mines are currently being phased out, often leaving behind degraded and contaminated land, suitable for phytoremediation. The southernmost mine, Central Mine Unit, has been shut down and is the one included in the use case. The main biophysical constraint in the use case is contaminations in the soil with heavy metals amongst others. There are several negative effects

[1] Amyntaio mine unit, Central mine unit, Melitis mine unit, Achlada mine unit, Vegora mine unit, Vevi mine unit, Kleidi mine unit and Lakkia mine unit

of the contaminants due to alteration of physical, chemical, and biological properties of the soil. For an example, reduced soil fertility, toxic effects in plants and animals, reduction of soil stability and increase of the risk of erosion.

The planting of *R. Pseudoacacia* (black locust) can have a significant impact on the marginality of a land in several ways. The ambition is to aid in the regeneration of the soil and promote the creation of new value chains that support abundant biodiversity. The biomass value chain will encompass participants from the wood industry, and small-scale cosmetic producers and beekeeping farmers, see Figure 5.

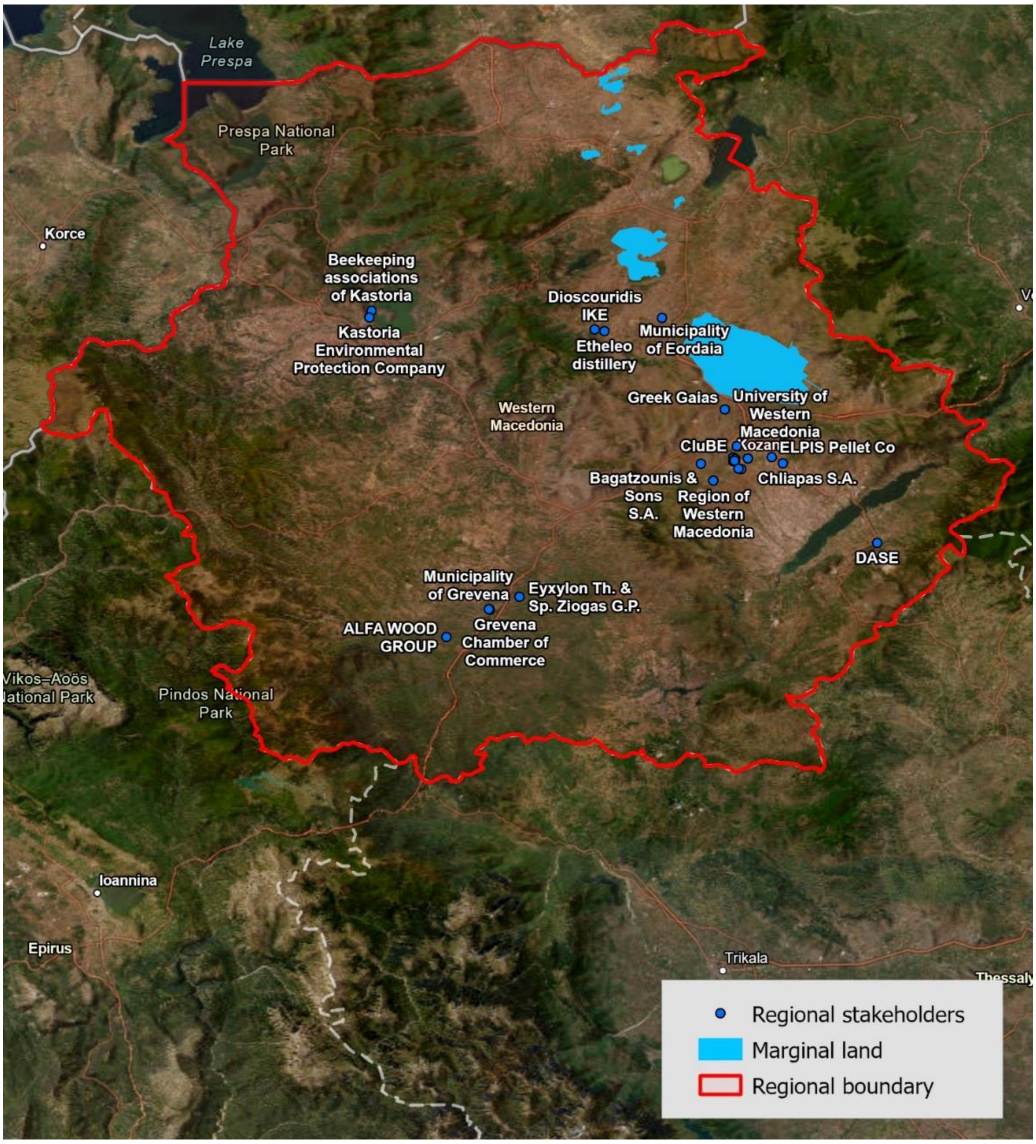

Figure 5. Regional scale map of the Greek use case, illustrating the regional stakeholders, marginal land and regional boundaries.

4.2.3.3 Local scale

The local scale map in Figure 6 displays the former lignite mine site (Central Mine Unit), spanning approximately 20 hectares, as well as local stakeholders near the mine, including a recycling centre and a landfill. The primary objective is land rehabilitation and contaminant removal through phytoremediation and pilot site features the planting of fast-growing trees alongside indigenous herbs such as lavender (intercropping).

Figure 6. Local scale map of the Greek use case, illustrating the local stakeholders and pilot site.

4.2.4 Socioeconomic factors

Two of the socioeconomic factors that was estimated to have the most impact for marginal land for the Greek use case are listed below. Each socioeconomic factor is illustrated with an icon that can be found in Annex F.

High unemployment — The region experiences a significantly high unemployment rate, particularly among young people, which is one of the highest in Europe.

Ageing population — The population in the area is aging, and there is a decrease in overall population numbers.

4.3 Use case Hungary

4.3.1 Definition

In the Hungarian use case, the area is characterized as a semi-desert region with sandy soils. Within the economic environment of the region, the focus is on fruits, wine, vegetables, and food processing. The average farm size is around 5-8 hectares. The older generation involved in grape production faces challenges in maintaining labour-intensive practices, and the farms are at risk of abandonment due to several factors, including a growing older population, salary gaps, and increasing prices. Leaving the soil uncovered is also problematic as it can lead to deflation and soil degradation during windy seasons. To avoid abandonment and desertification of the lands, willow planting is suggested, around 6000 to 10 000 unrooted cuttings.

4.3.2 Interviews as background for online maps

Tunde Gyarmati (INNOMINE), Miklós Gyalai (Pilze-Nagy) and Tamás Szolnoky (Pilze-Nagy) from the Hungarian use case participated in the interviews.

4.3.2.1 Geographical scope and online maps

The Hungarian use case group suggested a geographical scope of a 15 km radius from the mushroom production plant. The biogas plant is located within 1 km of the mushroom production plant. The region is a plateau and is situated between two rivers, with the eastern and western borders being rivers. The group also suggested that the map should include shipping distances, covering an area of 30-50 km in diameter.

The use case group was asked whether improved lands (irrigation, drainage, greenhouse, etc.) and abandoned/unused lands should be excluded from the maps. They do not believe that irrigated land should be excluded since irrigation is included in the use case. However, the group is unsure about the abandoned/unused land and needs further investigation to determine whether it is suitable for cultivating willow. There are many old vineyards and orchards close to the use case area that require investment in irrigation, machinery, etc. in the coming years. If that is not possible, there are good opportunities now to switch to the cultivation of willow, according to the use case group.

The use case group's expectations for the maps are to identify additional areas that can supply the mushroom production plant with raw materials. The plant currently uses 6 000 tonnes of wheat straw annually. The group also believes that it would be beneficial to use the maps to identify similar areas. Additionally, the group wants to utilize the use case to motivate farmers who are facing difficulties by highlighting more profitable options.

When asked about the intended users of the maps, the group believes that they will be utilized by farming advisors, representatives from the Hungarian (national) Chamber of Agriculture, county-level representatives, research and innovation organizations such as the horticulture department at the university, and experts in soil science and rural development.

4.3.2.2 Marginal land definition

4.3.2.2.1 Biophysical factors

Climate – Experiences high temperatures, exceeding 40°C during the summer of 2022. According to the interviewed group, soil temperatures in the top layer can potentially reach over 50°C in the summer.
Precipitation – Heterogeneous precipitation patterns, with a lack of rainfall from May to August.
Growing degree days – Not a concern since perennial crops will be cultivated. Biomass, such as spent straw from oyster mushroom production, will be used to cover the soil between plantations, along with cover crops comprising a mixture of legumes and cereals. The crop will be harvested during the winter.
Soil properties – Soil moisture poses a problem for the sandy soils in the region. The use case group suggests using digestate from the biogas plant as one measure to reduce this issue. The soils in the area are loamy and heterogeneous, with very low humus content (<1%) and a high calcium content. Historic data on soil properties from the weather agency in Hungary, collected from the top and below layers (20-50 cm) of the soil, can be incorporated into the maps.
Altitude, steep slopes, inundation risk and landslip – As the area is situated on a plateau, soil deflation and erosion are the primary concerns. Stormy winds during the winter season cause sand movement, and nearby national parks in the region have sand dunes. To mitigate soil losses, trees have been planted at the use case sites.
Contaminations/Adverse chemical conditions – There are no contamination issues in the region, although glyphosates from pesticides have been used in the fields. Sewage sludge was previously used but is no longer utilized.
Protected areas – The region includes national parks with protected sand dunes, such as the Fülöpháza Sand Dunes at Kiskunsági Nemzeti Park (knp.hu).

4.3.2.2.2 Socioeconomic factors

Abandoned land – The region has many old vineyards and orchards that have been abandoned in recent years.
Economic constraints – The region faces a shortage of human resources, particularly in the agricultural sector, where the younger generation is not actively involved. However, the Hungarian use case requires less workforce compared to orchards and vineyards.
Distance to city – The use case site is located near a large city. There is a high demand for labour in mushroom production, and the workforce needs to be sourced from abroad. There is competition for labour between the industrial and agricultural sectors in the region.
Accessibility – Not a problem.
Population – The elderly population outweighs the younger population in the region.
Economic activity density – The group has to investigate this further.

4.3.2.3 Mapping of stakeholders

No input in the interviews on this topic.

4.3.3 Online maps

The maps depicting the Hungarian use case at national, regional, and local scales are presented in the following section. For additional information on the stakeholders illustrated in each map level, please refer to Annex E and Table E.2.

4.3.3.1 National scale

The national scale depicted in Figure 6 map shows where the region Bács-Kiskun is situated in Hungary. Majority of the national stakeholders are situated near Budapest, also shown in Figure 7.

Figure 7. National scale map of the Hungarian use case, illustrating the national stakeholders and regional boundaries.

4.3.3.2 Regional scale

The region Bács-Kiskun shown in Figure 8 includes the Sand Plateau (Kiskunsági Homokhátság), known for its semi-desert terrain characterized by sandy soils. Most regional stakeholders were situated in Kecskemét, the most populated city within the region. The primary agricultural activities are cultivation of fruits and vegetable as well as wine production. The average farm size in this region is typically small, with the presence of farmsteads being a common.

The marginal land is depicted in the map are all fruit orchards and vineyards within the regional boundaries. A more accurate definition of marginal land would include biophysical factors causing marginality. The most prominent are sandy soils, low (and decreasing) ground water level, low humus, and nutrient content, as well as low nutrient retention capability.

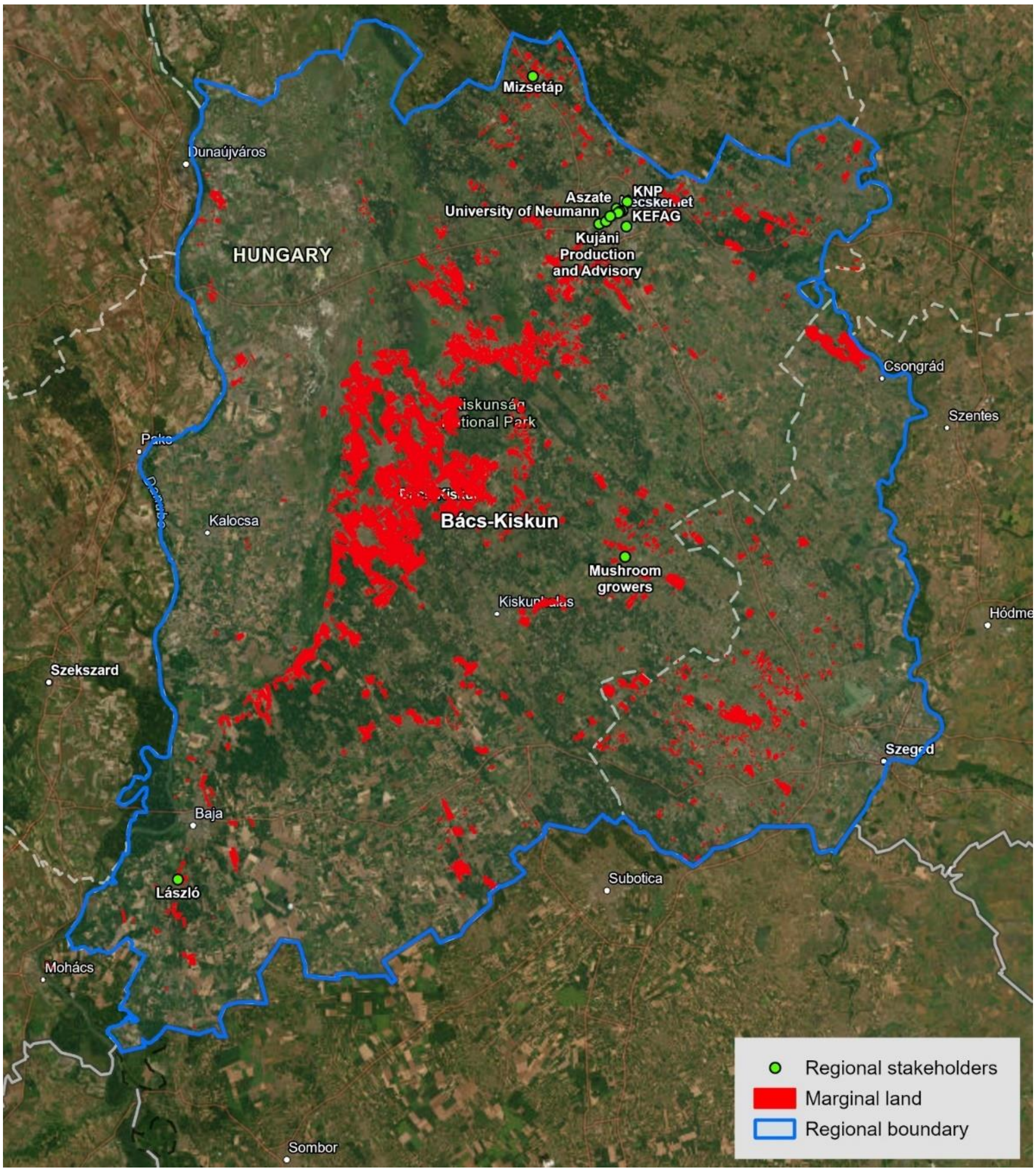

Figure 8. Regional scale map of the Hungarian use case, illustrating the regional stakeholders, marginal land and regional boundaries.

4.3.3.3 Local scale

The local scale map shown in Figure 9 depict the pilot site, a former orchard close to Kecskemét. One hectare of energy willow (*Salix viminalis*) and Virginia mallow (*Sida hermaphrodita*) was cultivated 2023. The introduction of the new crops aims to reduce irrigation requirements, boost soil organic matter, and produce substrate for the oyster mushroom production. Shown in the maps are also local stakeholders connect to the cultivation of fast-growing trees.

Figure 9. Local scale map of the Hungarian use case, illustrating the local stakeholders and pilot site.

4.3.4 Socioeconomic factors

Two of the socioeconomic factors that was estimated to have the most impact for marginal land for the Hungarian use case are listed below. Each socioeconomic factor is illustrated with an icon that can be found in Annex F.

Labor challenges – The region encompasses a growing aging population, widening salary disparities, and escalating costs. These issues are a result of labour-intensive practices, a diminishing younger generation's involvement in farming, and the lure of competitive salaries in neighbouring industries.

Unknown market — Lack of predictability about market potential of the end product from the use case and the market environment can be changed.

4.4 Use case Sweden

4.4.1 Definition

In northern Sweden, the region experiences a long, dark, and cold winter, leading to a short crop growing season. The soils in this area are particularly suitable for feed production, which is the dominant form of farming. More than 90% of the land is dedicated to cultivating fodder and forage grains for animals. However, dairy production has decreased, necessitating the need to explore alternative crops and mitigate the risk of abandoned land. One proposed solution is to plant trees, although this may have adverse effects on biodiversity. Instead, the cultivation of turnip rape is suggested, used for biodiesel production, to keep the open landscape. Plots of 11.5 hectares have been allocated for spring turnip rape cultivation. Turnip rape is a resilient crop that can thrive in colder climates and can withstand pest and disease pressures while promoting biodiversity. Side streams such as protein-rich cake can serve as animal fodder, replacing the reliance on soy.

4.4.2 Interviews as background for online maps

Susanne Paulrud (RISE) and Erik Häggbom (Hushållningssällskapet (HS)/The Rural Economy and Agricultural Societies) was interviewed regarding the Swedish use-case.

4.4.2.1 Geographical scope and online maps

Based on the results from the interviews the counties, Västerbotten and Norrbotten, will be the geographical scope for the online maps. There are restrictions within these counties, with colder temperatures as you move westward within the county. There is a possibility to create a detailed map of the farm in Djupliden, Skellefteå. However, a detailed map of HS experimental farm in Öjebyn, Piteå, will not be included.

One limiting factor to include is how often turnip rape can be included in the crop rotation. Turnip rape should not occur more often than every fifth year in the crop rotation. One layer in the maps could indicate where turnips can be cultivated based on factors like temperature and soil type. It would be useful to have all the cultivated land, as well as land that is currently being cleaned or is not in production, shown in one layer on the maps. This could also include abandoned land, which currently has vegetation with young trees and shrubs that need to be removed. It may be challenging to determine the condition of the abandoned land. It must be possible to grow turnip rape on the land, but it might prove a challenge on the abandoned lands.

The maps will be used by other researchers and authorities, e.g., the county board amongst others. During crisis years, the county board may want to identify unused or underutilized land.

The resolution on the maps should preferably be at field level.

4.4.2.2 Marginal land definition

4.4.2.2.1 Biophysical factors

Climate – There is a temperature limitation for cultivation of turnip rape in the two Swedish regions included in the use case. Different cultivation zones in the region can be looked more into. The regions have cold temperatures and a very short cultivation season. The number of growing degree days would be interesting to look more into.
Precipitation - The problem that can arise is high levels of precipitation and/or poor drainage.
Soil properties – It would be interesting to look at the soil type, soil fertility and soil humus content.
Protected areas – There are no known protected areas relevant to the use case.
Altitude, steep slopes, inundation risk, landslip, and contaminations/Adverse chemical conditions – These factors are not currently a focus in the use case.

4.4.2.2.2 Socioeconomic factors

Abandoned land - It would be interesting to examine abandoned land, taking into consideration its proximity to the farm and the distance involved.
Population - The region exhibits a low population density, with a predominantly elderly population.
Economic constraints, Distance to city, Accessibility, Economic activity density – No specific comments were provided on these factors.

4.4.2.3 Mapping of stakeholders

The stakeholders involved in the use case are situated at local, regional, and national levels. For instance, the seed breeders are located in Skåne, the southernmost part of Sweden. The buyers of RME (rapeseed methyl ester) include both regional and non-regional entities. However, the majority of the value chain is local. Various stakeholders such as farmers, machinery stations, technology providers, and biogas plants are involved. Technology suppliers not only from Sweden but also from other countries, such as Denmark, should also be included.

4.4.3 Online maps

The maps depicting the Swedish use case at national, regional, and local scales are presented in the following section. For additional information on the stakeholders illustrated in each map level, please refer to Annex E and Table E.3.

4.4.3.1 National scale

The national scale map of Sweden, depicted in Figure 10, illustrates the geographical locations of the regions Västerbotten and Norrbotten. In Sweden, efforts are being made to enhance land use efficiency in Västerbotten and Norrbotten by establishing and optimizing a value chain for turnip rape cultivation. Furthermore, national stakeholders involved in the value chain of turnip rape cultivation and its subsequent processing are highlighted in Figure 10.

Figure 10. National scale map of the Swedish use case, illustrating the national stakeholders and regional boundaries.

4.4.3.2 Regional scale

The regional scale map, Figure 11 illustrates the regional stakeholders, marginal land, and regional boundaries involved in this proposal. In these regions, agriculture is characterized by milk and meat production, with a notable emphasis on ley cultivation. A larger portion of the arable land is utilized for ley cultivation in these regions compared to Sweden as a whole. This value chain predominantly operates at a regional level, engaging various stakeholders such as farmers, machinery stations, technology providers, and biogas plants. The primary biophysical constraint in these regions is the presence of low temperatures and a short cultivation season. To address pests and diseases, turnip rape should not be included in the crop rotation more frequently than every fifth to sixth year, meaning that on a yearly basis maximum of one-fifth of the highlighted marginal land can be utilized for turnip rape cultivation.

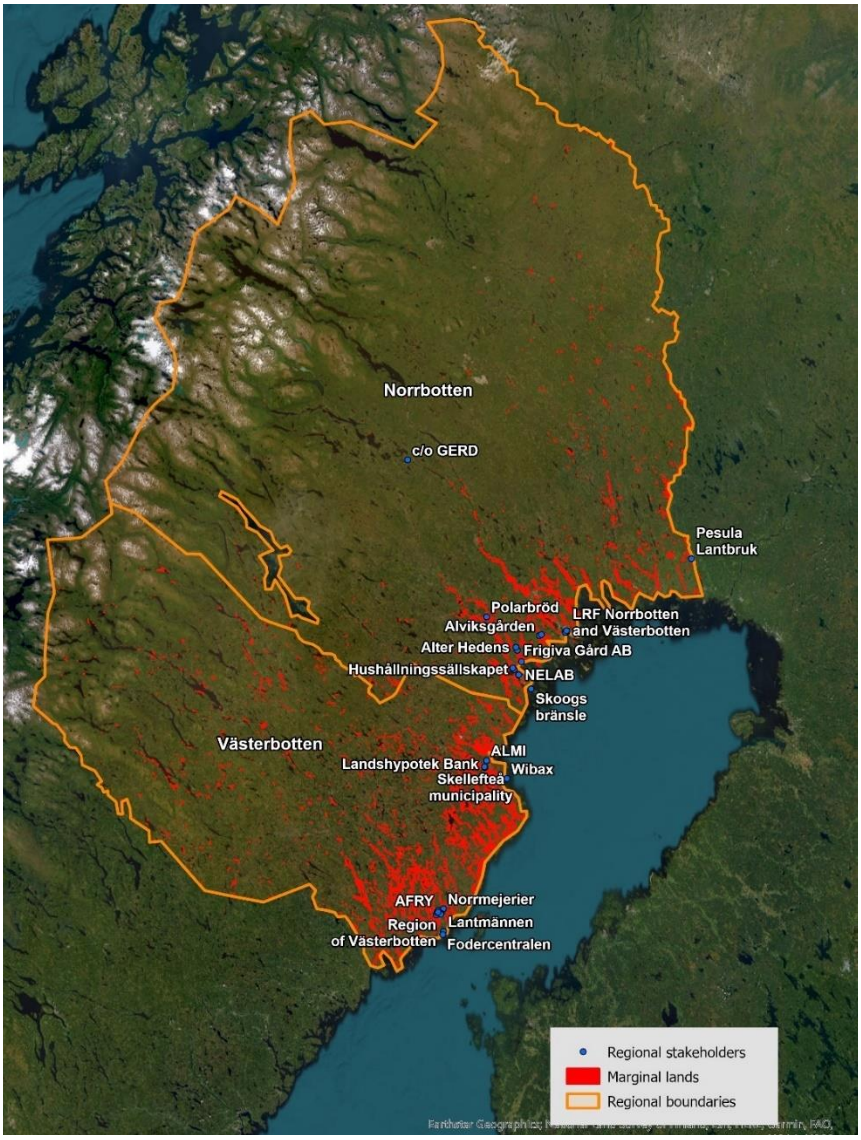

Figure 11. Regional scale map of the Swedish use case, illustrating the regional stakeholders, marginal land, and regional boundaries.

4.4.3.3 Local scale

In 2023, a 1.5-hectare field located in Djupliden, Skellefteå, will be cultivated with spring turnip rape, as depicted in Figure 12. The cultivation area will be expanded to 2.5 hectares in 2024. The harvested turnip rape will be utilized for biodiesel production. When integrated into crop rotations with cereal crops, turnip rape can enhance soil qualities and productivity.

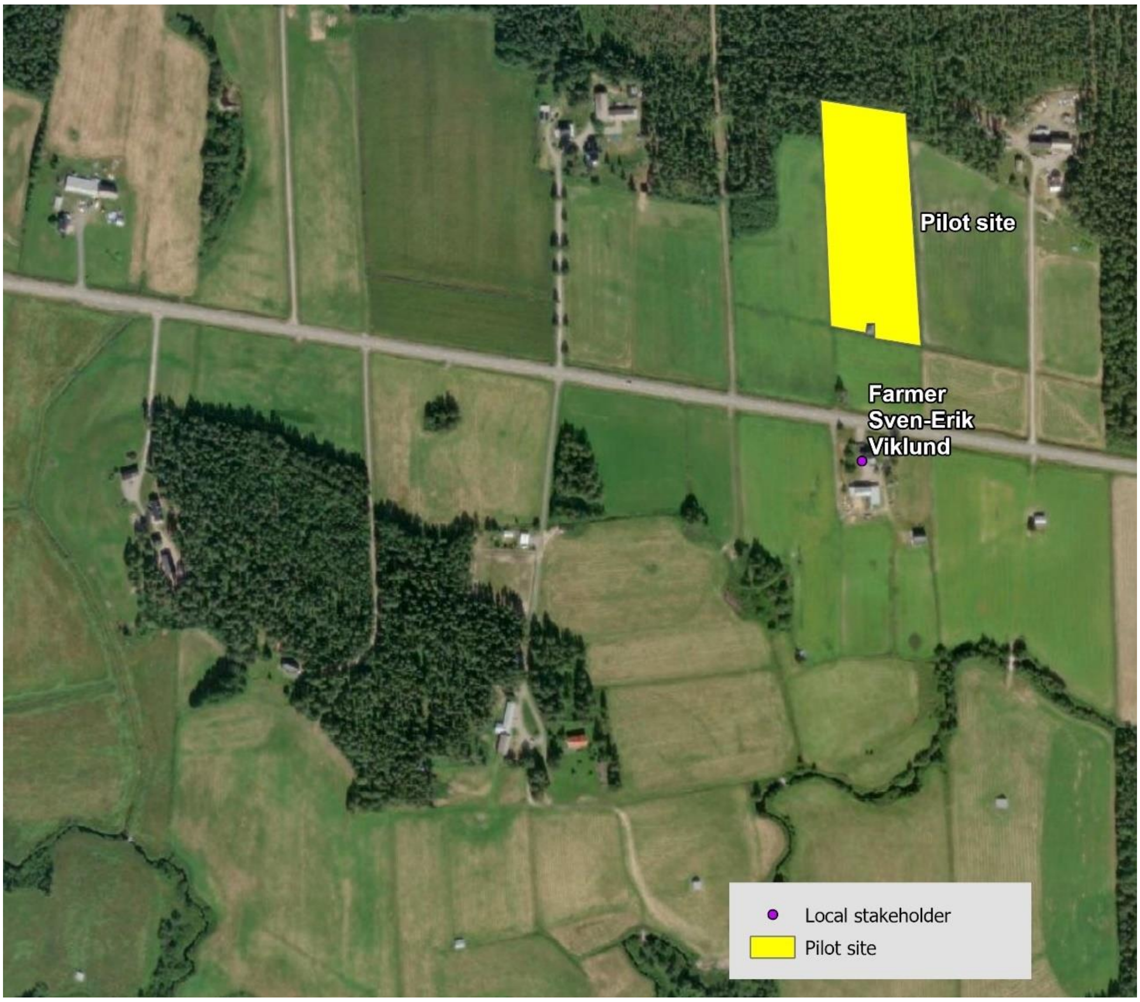

Figure 12. Local scale map of the Swedish use case, illustrating the local stakeholder and pilot site.

4.4.4 Socioeconomic factors

Two of the socioeconomic factors that was estimated to have the most impact for marginal land for the Swedish use case are listed below. Each socioeconomic factor is illustrated with an icon that can be found in Annex F.

Population — The region exhibits a low population density, with a predominantly elderly population. In the last 50 years the population structure has changed significantly with a large growth in the number of older people and a sharp decrease in the number of younger people.

Long distances — A specific challenge that the two use case regions have to address is the long distances. This challenge is particularly prominent in the rural areas, while the distances between towns along the coast are relatively shorter.

4.5 Use case Germany

4.5.1 Definition

The landscape of the German use case consists of flat grasslands with dewatered peat soils or fenlands, characterized by ditches and tree rows. However, the grass yield and fodder quality are low, and the land also emit greenhouse gases. The focus of the German use case is to rewet fenlands to retain carbon in the soil and explore industrial uses for the biomass, the designated area measures 30 km by 20 km. A new land system has been proposed, involving the elevation of the water level and the cultivation of reed or sedges, known as paludiculture.

4.5.2 Interviews as background for online maps

The questions were filled in digitally by Michael Glemnitz (ZALF).

4.5.2.1 Geographical scope and online maps

The suitable geographical scopes for the German use case are on county, natural unit (German landscape classification) and the field scale. The county and natural unit scale has the same scale, but different boundaries. Abandoned and used land should be included in the maps. The land that should be included in the maps are only the land that has similar marginality factors and is suitable for the tested new value chains.

4.5.2.2 Marginal land definition

4.5.2.2.1 Biophysical factors

Climate – Wetness
Precipitation – No
Growing degree days – Yes
Soil properties – Yes
Altitude, steep slopes, inundation risk and landslip – Yes
Contaminations/Adverse chemical conditions – No
Protected areas – Yes

4.5.2.2.2 Socioeconomic factors

Abandoned land - Yes
Economic constraints - Yes
Distance to city – Not applicable
Accessibility – Not applicable
Population - Yes
Economic activity density – Not applicable

4.5.2.3 Mapping of stakeholders

No input in was provided on this topic.

4.5.3 Online maps

The maps depicting the German use case at national, regional, and local scales are presented in the following section. For additional information on the stakeholders illustrated in each map level, please refer to Annex E and Table E.4.

4.5.3.1 National scale

The national scale map shown in Figure 13 displays the regional boundaries encompassing the counties Havelland, Oberhavel, and Ostprignitz-Ruppin, all of which are situated within the state of Brandenburg. Additionally, the map highlights national stakeholders relevant to the rewetting of fenlands and paludiculture activities.

Figure 13. National scale map of the German use case, illustrating the national stakeholders and regional boundaries.

4.5.3.2 Regional scale

The regions, Havelland, Oberhavel and Ostprignitz-Ruppin, showcased in Figure 14, has diverse landscapes, including fertile plains, lakes, wetlands, and forests. The map also identifies regional stakeholders involved in various aspects of nature conservation, regulatory activities, research, and product processing. The marginal land illustrated in Figure 14 is drained fenland, which is currently utilized as grasslands, since these lands has negative environmental impacts, including habitat loss, carbon release, and alterations in hydrology. The use case therefore suggests the rewetting fenlands with the purpose of using naturally growing fenland biomass as feedstock for new products.

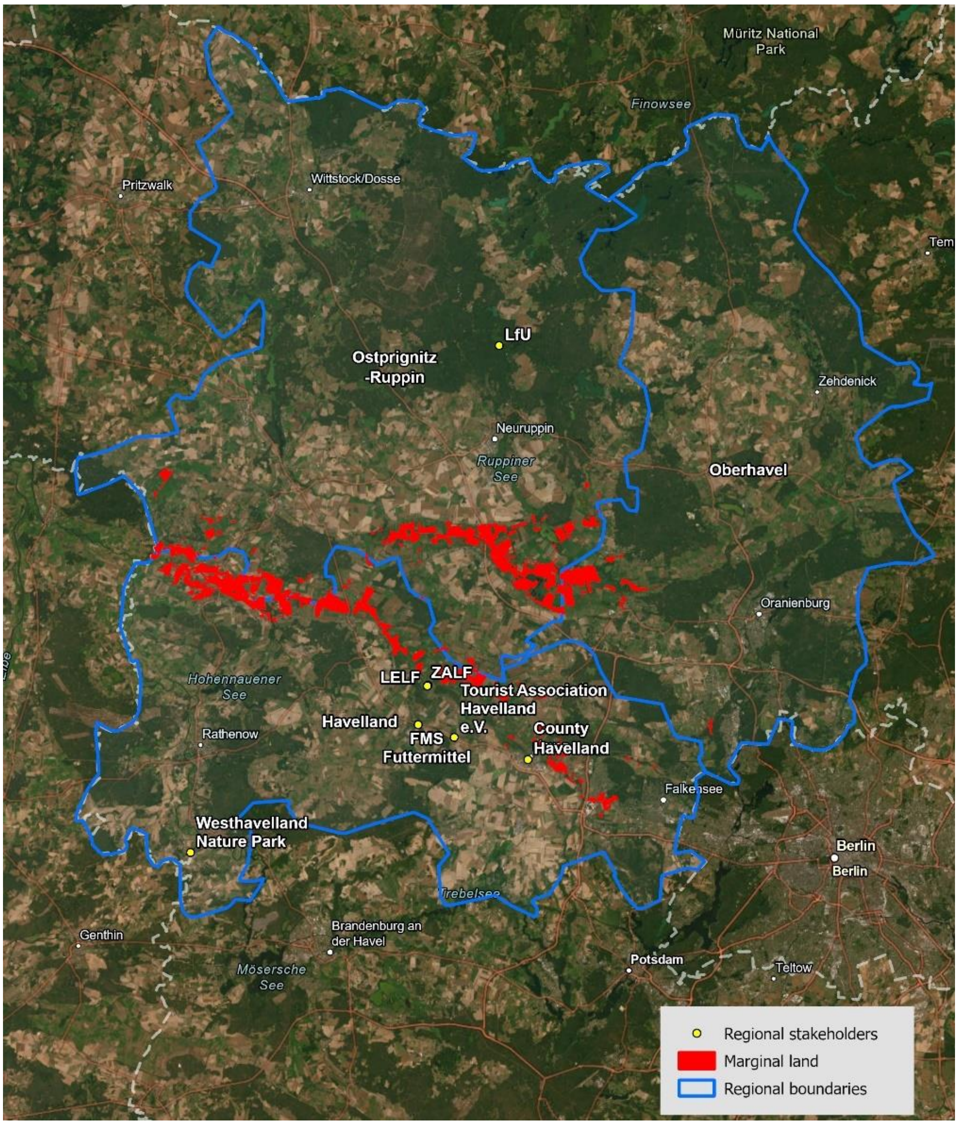

Figure 14. Regional scale map of the German use case, illustrating the regional stakeholders, marginal land and regional boundaries.

4.5.3.3 Local scale

The local scale map in Figure 15 illustrates the fields of a farmer who supplies bales of reed, cattail, and reed canary grass for product trials to paludiculture processing lines. The pilot site is located within a relatively intensive farming landscape. This area features natural grasslands on fenlands, distinguished by their unique ecosystem that supports a variety of specialized plant and animal species in waterlogged, acidic conditions. However, the drainage of these fenlands to enhance grass production for cattle has resulted in significant environmental consequences.

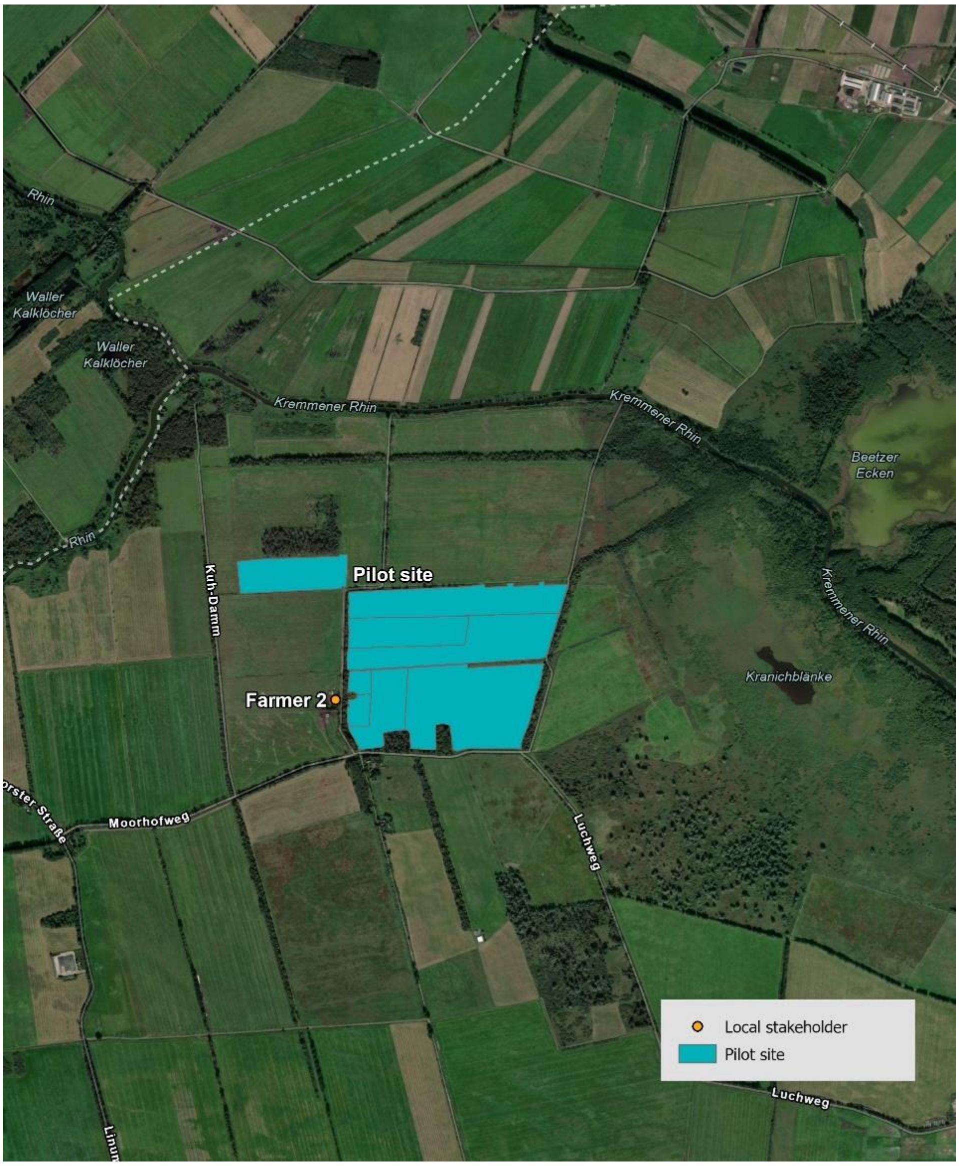

Figure 15. Local scale map of the German use case, illustrating the local stakeholder and pilot site.

4.5.4 Socioeconomic factors

Two of the socioeconomic factors that was estimated to have the most impact for marginal land for the German use case are listed below. Each socioeconomic factor is illustrated with an icon that can be found in Annex F.

Land use conditions – Competing uses of land and natural resources in the use case area, with regulatory requirements to protect biodiversity and reduce CO_2 emissions, among other things, limit the scope of action and land use options for farmers.

Lack of economic viability — The low yields and quality of the grasslands make traditional management of the land for dairy farming economically unviable. The current alternative uses, such as suckler cow husbandry, are becoming increasingly uneconomical.

Stakeholder characteristics and engagement – The highly heterogeneous structure and cultural characteristics of rural businesses make it difficult to coordinate and implement common strategies, collaborative structures, and processes.

4.6 Use case Spain

4.6.1 Definition

In the Alagon Valley, the aim is to improve food security and ecosystem services by identifying and defining agricultural marginal land. The focus is on irrigated land with low yields. The crops need to thrive in elevated temperatures and low precipitation. In year 2023, 1000 m^2 of hemp and kenaf will be cultivated on two plot sites. The cultivation of industrial crops such as kenaf and hemp is implemented, along with crop rotation involving traditional crops like tomatoes, maize, and peppers, to decrease the need for irrigation, enhance the organic matter content in the soil, and improve overall crop yield. This approach contributes to the sustainable use of the low-yielding land in the Alagon Valley.

4.6.2 Interviews as background for online maps

María Martínez (AMBIENTA), Antonio Sánchez Sánchez (CTAEX technology centre), Jeronimo Gonzalez Cortes (CICYTEX/JUNTAEX) participated in the interviews.

4.6.2.1 Geographical scope and online maps

Based on the interview results, the suitable geographical scope for identifying available marginal land in the Spanish use case includes both the Coria region and the trial fields. Five regions (Coria, Casillas de Coria, Casas de Don Gómez, Huélaga and Moreleja) will be surveyed where corn farms are located. These farms will be assessed in 2023 to identify fields with a yield lower than 12 000 tonnes ww/ha (14% water content). These fields will then be utilized for field trials in 2024.

Improved lands (irrigation, drainage, greenhouse etc.) should be included in the maps, since the cultivation requirements of the use case crops, hemp and kenaf, must be irrigated. However, the irrigation quantity for hemp and kenaf will be lower compared to that of corn. Additionally, the inclusion of abandoned/unused lands in the maps is not desired. Only the land that can be cultivated with hemp and kenaf should be included in the maps.

There is a possibility of future land abandonment if farmers continue their current practices. Presently, farmers often cultivate successive crops of corn (year after year), introducing kenaf and hemp in the rotation would benefit by diversifying the crop rotation.

The expectations for the maps are to provide more comprehensive information and facilitate its organization. The maps will be utilized by farmers, agricultural public administration, cooperatives, and irrigation communities (farmers are organized in communities for irrigation).

4.6.2.2 Marginal land definition

4.6.2.2.1 Biophysical factors

Climate – High temperatures.
Precipitation – The level of precipitation is very low, with zero precipitation in July and occasional absence of rainfall throughout the summer.
Soil properties – Water scarcity in the soil is a prevalent issue. The organic matter content is very low, measuring less than 1%. In sandy soils, there is high soil acidity, with pH levels ranging from 4 to 5. However, some soils have pH levels of 6 to 7.
Altitude, steep slopes, inundation risk and landslip – The use case group has to investigate this further.
Contaminations/Adverse chemical conditions - No problems with contaminants.
Protected areas – Yes, but only by the Alagon river.

4.6.2.2.2 Socioeconomic factors

Abandoned land, Economic constraints, Distance to city, Accessibility – As far as the use case group is aware, there are no known issues related to these factors. Agriculture is the primary and most important sector in the area, encompassing both plant production and animal husbandry. One problem is monoculture practices.
Population - The area has a low to medium population. There are no difficulties in finding employees for the farms.
Economic activity density – The region faces high unemployment rates and a low GDP, indicating lower economic activity in the area.

4.6.2.3 Mapping of stakeholders

The maps of the stakeholders will be utilized by farmers and cooperatives amongst others.

4.6.3 Online maps

The maps depicting the Spanish use case at national, regional, and local scales are presented in the following section. For additional information on the stakeholders illustrated in each map level, please refer to Annex E and Table E.5.

4.6.3.1 National scale

The national scale map shown in Figure 16 displays where the region is situated in Spain. The regional boundaries consist of selected municipalities[2] located within the province of Cáceres, which is a part of the autonomous region of Extremadura in western Spain. In addition, national stakeholders relevant for the value chain are displayed in Figure 16.

Figure 16. National scale map of the Spanish use case, illustrating the national stakeholders and regional boundaries.

4.6.3.2 Regional scale

The area, consisting of 16 municipalities as illustrated in Figure 17, is known for its agricultural activities, including cultivation of cereals, olives, grapes, and various fruits. Also highlighted are the regional stakeholders relevant for the cultivation of hemp and kenaf. The marginal land, depicted in Figure 17, comprises all corn fields within the regional boundaries. However, the marginal lands mapping will be refined in the future to only showcase fields with a yield lower than 12 tonnes ww/ha.

[2] Calzadilla, Casas de Don Gómez, Casillas de Coria, Coria, Gata, Guijo de Coria, Guijo de Galisteo, Holguera, Huélaga, Montehermoso, Moraleja, Morcillo, Pescueza, Portaje, Riolobos, Torrejoncillo.

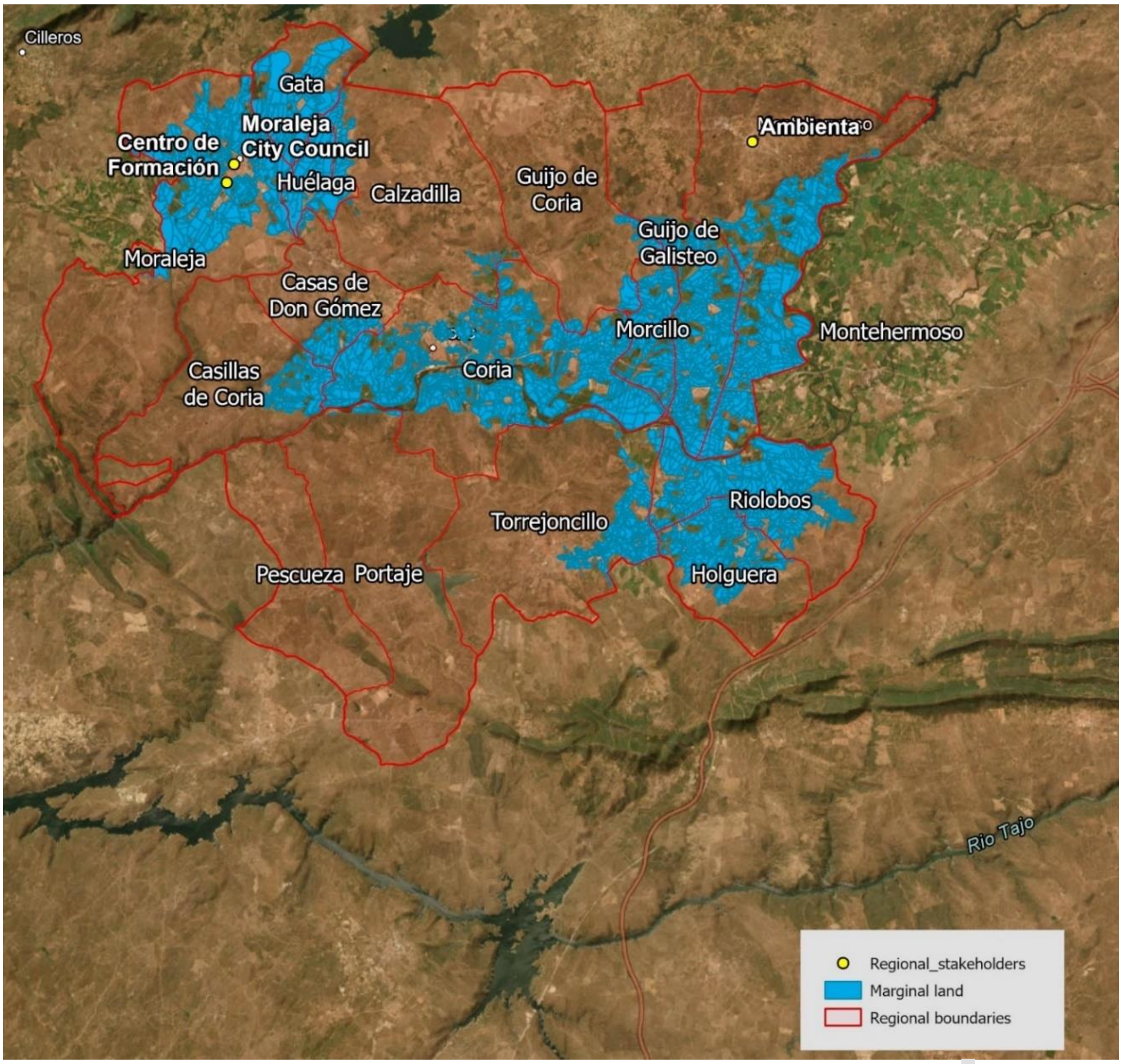

Figure 17. Regional scale map of the Spanish use case, illustrating the regional stakeholders, marginal land and regional boundaries.

4.6.3.3 Local scale

In 2023, 0.1 hectares of hemp and kenaf were cultivated alongside traditional crops like tomatoes, maize, and peppers, as shown in Figure 18 depicting the pilot sites. This crop rotation strategy aims to reduce irrigation requirements, boost soil organic matter, and enhance overall crop yields. Furthermore, relevant stakeholders in the value chain at the local scale are depicted (Figure 18).

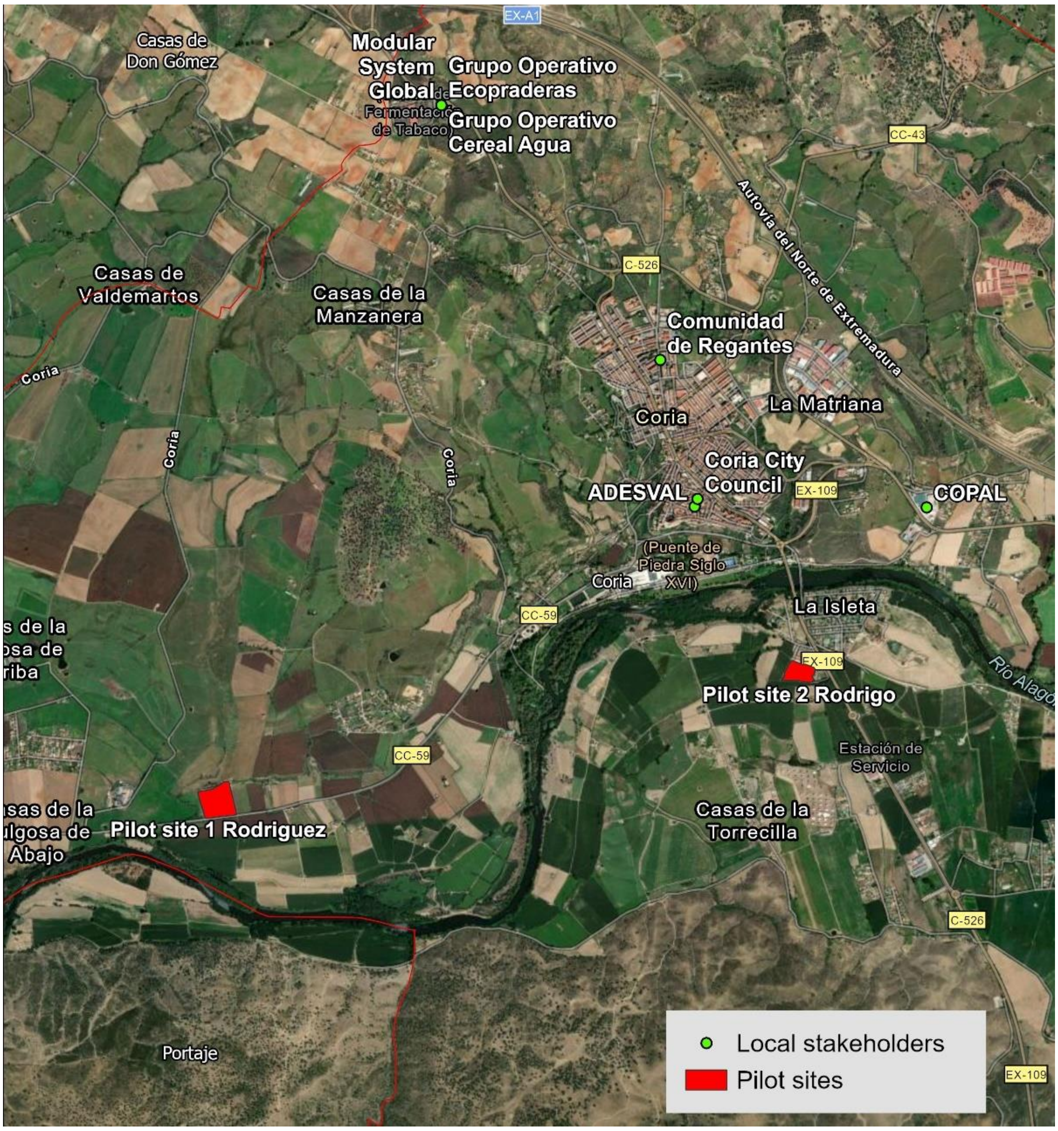

Figure 18. Local scale map of the Spanish use case, illustrating the local stakeholder and pilot sites.

4.6.4 Socioeconomic factors

Two of the socioeconomic factors that was estimated to have the most impact for marginal land for the Spanish use case are listed below. Each socioeconomic factor is illustrated with an icon that can be found in Annex F.

Low economic activity density – The region faces high unemployment rates and a low GDP.

Market challenge — Lack of established demand and limited processing and marketing infrastructure for the end products from the use case.

4.7 Use case Argentina

4.7.1 Definition

The focus of the use case is the Pampas region in Argentina, specifically the "Flooding Pampa" ecoregion. It is characterized by extensive flooding and waterlogging, with over 60% of its soils affected by salinity. The introduction of the forage legume, *Lotus tenuis*, also known as narrowleaf trefoil, a salt-tolerant crop that produces forage of high nutritional value, has transformed the area into a significant cattle region. To diversify the system, additional crops like rapeseed and hemp could be introduced. Furthermore, activities involving the utilization of lotus biomass are under evaluation, including mushroom cultivation, honey production, and biogas generation.

4.7.2 Interviews as background for online maps

The questions were filled in digitally by Raul S. Lavado (Universidad de Buenos Aires) and Oscar Ruiz (Universidad Nacional de General San Martin).

4.7.2.1 Geographical scope and online maps

There are soil maps in semi-detail and recognition scale (1:50,000 - 1:100,000) that could be utilized to produce the online maps of the Argentinian use case. It is not needed to remove improved lands (irrigation, drainage, greenhouse etc.) from the maps, because there are no such things in the studied area. The land that should be included in the maps are lands used for cattle grazing.

The Argentinian use case group think that the maps will be useful for them in their work. They think that the maps mainly will be used by agricultural advisory service and technical advisors.

4.7.2.2 Marginal land definition

Biophysical factors that are valid for the studied use case area is climate related; temperature and/or dryness, precipitation. As well as soil water, limited soil drainage or excess soil moisture, soil type and altitude, steep slopes, inundation risk, landslip.

No information on socioeconomic factors.

4.7.2.3 Mapping of stakeholders

No information was provided.

4.7.3 Online maps

The focus of the Argentinian use case was the Pampas region. The key stakeholders involved in this value chain are delineated in the national-scale map of Argentina presented in Figure 19, mostly situated near Buenos Aires. For additional information on the stakeholders, see Annex E and Table E.6.

Figure 19. Key stakeholders in the value chain of the Argentina use case.

4.8 Use case South Africa

4.8.1 Definition

In the South African use case, the definition of marginal land is based on areas that have been invaded by invasive trees. The focus is on clearing the land from these trees, and the potential to utilize the biomass obtained from the clearing process.

4.8.2 Interviews as background for online maps

The questions were filled in digitally by Romain Pirard (Stellenbosch University).

4.8.2.1 Geographical scope and online maps

In South Africa, the use case is land clearing of areas invaded by the main invasive exotic trees (pines, acacias, eucalyptus) for either restoration or productive purposes and with the supply of biomass to processing industries from the harvesting of invasive trees. This is relevant at national level as most of the country has cases of invasions. Yet data collection (depending on data and research objectives/questions) can also be done at a more local level (e.g., district or municipality) or via a sample that may cover entire regions but with a limited number of invaded sites included. Therefore, more detailed investigations are both possible and desired depending on the specific question that is addressed. All invaded areas are worth being mapped, but a useful distinction is between those that are less or more strategic either because land clearing/rehabilitation would provide more environmental services, or because biomass from land clearing could be processed and valued (economically feasible).

When it comes to the mapping of stakeholders as marginal lands (invaded areas) spread over the entire country, some stakeholders might be relevant to map at national level. But more local issues and land management cases are worth exploring with a more specific range of targeted stakeholders.

4.8.2.2 Marginal land definition

4.8.2.2.1 Biophysical factors

Climate – Not applicable
Precipitation – Not applicable
Growing degree days – Not applicable
Soil water - Land clearing of invaded areas is greatly justified by water services, and hydrological aspects are considered primarily to identify which invaded areas should be cleared in priority.
Soil properties – Carbon dynamics is an important factor to assess whether land clearing, and restoration provide net carbon gains or losses eventually.
Altitude, steep slopes, inundation risk and landslip – Steep slopes are an important factor to determine whether land clearing is economically feasible.
Contaminations/Adverse chemical conditions – Not applicable
Protected areas – Land clearing of invaded areas applies to all lands private, public, protected, etc.

4.8.2.2.2 Socioeconomic factors

Abandoned land – Not applicable
Economic constraints – No comment
Distance to city – Not applicable
Accessibility – Road infrastructure and distance to markets or industries is critical for the use of biomass from land clearing.
Population – Not applicable
Economic activity density – Not applicable

4.8.2.3 Mapping of stakeholders

The interest of having an assessment of the variety of stakeholders in South Africa would be to understand each stakeholder's position with respect to the use of biomass from invasive trees by value-added industries (with processing and marketing) and under what conditions. The issue is controversial and there has not been a proper stakeholder analysis on this yet. It would be valuable to map the stakeholders on both regional and local scale. Both are useful for different purposes (national scale for overall state of debate and positions, and local for more operational purposes).

4.8.3 Online maps

In the South African use case, the definition of marginal land is based on areas that have been invaded by invasive trees. Relevant stakeholders in this initiative are presented in Figure 20 and mainly includes regulatory bodies, biomass provision and industrial application. For additional information on the stakeholders, see Annex E and Table E.7.

Figure 20. Key stakeholders in the value chain of the South African use case.

5 Discussion

The mapped marginal land and the associated biophysical and socioeconomic factors in the use cases are, to a large extent, based on regional and local know how, opinions, and own experiences, rather than on research studies and other scientific material. As a result, the maps contain assumptions and uncertainties, highlighting the necessity for more extensive data collection at the regional and local scale to further develop the maps and the associated factors. The produced maps reflect the knowledge currently available.

Between the different countries there are different levels of data availability when it comes to GIS-data. There are gaps between European and International use cases, but also between the different European countries. As an example, Sweden and Germany had high data availability, while Spain and Hungary had a lower availability, and even less data was available for South Africa and Argentina. The marginal land shown in the maps does not always align with the defined criteria for marginal land in the respective use cases due to data limitations. In some instances, all agricultural land is shown on the maps due to these constraints. This issue needs further development throughout the project.

Only a few studies have considered the role of socioeconomic factors for marginal lands. There is a need for more studies that considers socioeconomic factors together with other factors that make a particular situation a marginal one, such as biophysical characteristics, environmental factors, ecosystem services, geographical location, agricultural structures, and political factors. Quantifying the individual and combined impacts of all challenges is important for policy making on marginal lands. This could eventually lead to the development of an analytical framework for the identification and assessment of marginal lands.

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Annex

Annex A: Interview questions preparations for online maps

Subarea	Question
1. Geographical scope	1.1 What geographical scope is suitable for your use case for the available marginal land? Would it work for you to look both at the whole region (administrative/political region) and more detailed on the site where field trials/farm are conducted?
	1.2 Do you want to have the same geographical scope for the available marginal land as for the stakeholders?
	1.3. Should we exclude Improved lands (irrigation, drainage, greenhouse etc.), used marginal lands and abandoned/unused
2. Marginal land definition	2.1 What type of land do you want to include in the maps? Only the land that we could utilize for cultivation?
	2.2 What types of factors are valid for your use case?
	Biophysical factors • Climate; Temperature and/or dryness • Growing degree days • Precipitation • Soil water; limited soil drainage or excess soil moisture • Soil properties: soil type, humus content, low soil fertility (acidity, alkalinity, or low soil organic matter, pH) • Altitude, steep slopes, inundation risk, landslip • Contaminations/Adverse chemical conditions (Salinity, sodicity and/or acid sulphate soils) Protected areas Natura 2000 Others “protected areas” Socio economic factors • Abounded land • Economic constraints: awkward field shapes, management restrictions e.g., along water bodies and poor infrastructure • Distance to city • Accessibility • Population; low population density, an elderly population • Economic activity density; a high unemployment rate and low GDP
3. Online maps	3.1 What are your expectations on the maps?
	3.2 Who will use the maps?
	3.3 What resolution do we need to have on the maps?
	3.4 When can you deliver the data?
4. Stakeholders	4.1 What will we use the mapped stakeholders for?
	4.2 Is it enough to map the stakeholders with one GIS-position on the maps?
	4.3 Should we map the stakeholders on regional scale or on a local scale?

Annex B: Interview questions Q&A session expert workshop

Biophysical factors

1. Is the marginal land classification reversible or irreversible related to a time perspective?
2. How do the biophysical factors impact the growth of the chosen industrial crop, which benefits and which limits? Can these be measured and in what way?
3. To what degree can the marginality be improved (productive land)?
4. What is the connection between the biophysical factor to geographical boundaries?
5. How do biophysical factors such as soil degradation, erosion, and nutrient run-off contribute to the classification of land as marginal, and what are the resulting effects on the growth of industrial crops?
6. How important is the biophysical factor (presented factor) compared to other marginality factors and how is it linked to other factors?

Socioeconomic factors

1. How do biophysical and socioeconomic factors influence each other in marginal lands in the project's use cases?
2. Is there empirical evidence or measurable parameters for the socioeconomic constraints factors that can be used in the use case?
3. How does a cost-effective production of industrial crops impact the classification of marginal lands?
4. What reference should the cultivation of industrial crop be compared to in terms of economic feasibility (current use, previous land use etc.)?
5. Should there be policy instruments to cultivate industrial crops on marginal land? What kinds?
6. Are there additional values other than economical to cultivate industrial crops, which ones?

Annex C: Instruction guide

GIS data for the online maps

We have completed the Swedish maps and are using them as an example of how we want the data to be presented on the webpage. Revolve will create a template for the MarginUp project, so the colours on the map will differ in the final layout.

There will be three different maps, with different scales:

1. National map
2. Regional map
3. Use Case map

The required format for these different files is known as shapefiles. Each layer consists of six different files (as illustrated below):

Local_stakeholder.cpg	2023-09-01 11:58	CPG-fil	1 kB
Local_stakeholder.dbf	2023-09-01 11:58	DBF-fil	8 kB
Local_stakeholder.prj	2023-09-01 11:58	PRJ-fil	1 kB
Local_stakeholder.sbn	2023-09-01 11:58	SBN-fil	1 kB
Local_stakeholder.sbx	2023-09-01 11:58	SBX-fil	1 kB
Local_stakeholder.shp	2023-09-01 11:58	SHP-fil	1 kB

Table F.1: Geographical boundaries and marginal land

Use case	Local scale	Regional scale	Marginal land
Greece	Trial area of use case	Western Macedonia, Lignite Centre [1]	Abandoned and on-going lignite mines
Hungary	15 km radius from the mushroom production plants [2]	Between two rivers, eastern border (Tisza River) and western boarder (Donau river). Norther part of Bács-Kiskun county [3]	Abandoned vineyards and orchards
Sweden	Trial field in Skellefteå	Västerbotten and Norrbotten county	Arable land
Germany	Trial field	-	Excavated peatlands
Spain	Trial fields	Coria, Moraleja, Huélaga, Casas de Don Gómez, Castillas de Coria regions	Maize fields with yield <12 000 tonnes ww/ha (14% water content)

[1] https://www.gem.wiki/Western_Macedonia_Lignite_Centre

[2] https://maps.app.goo.gl/6JoQCgtPg5yXMxCw7

[3] https://en.wikipedia.org/wiki/B%C3%A1cs-Kiskun_County

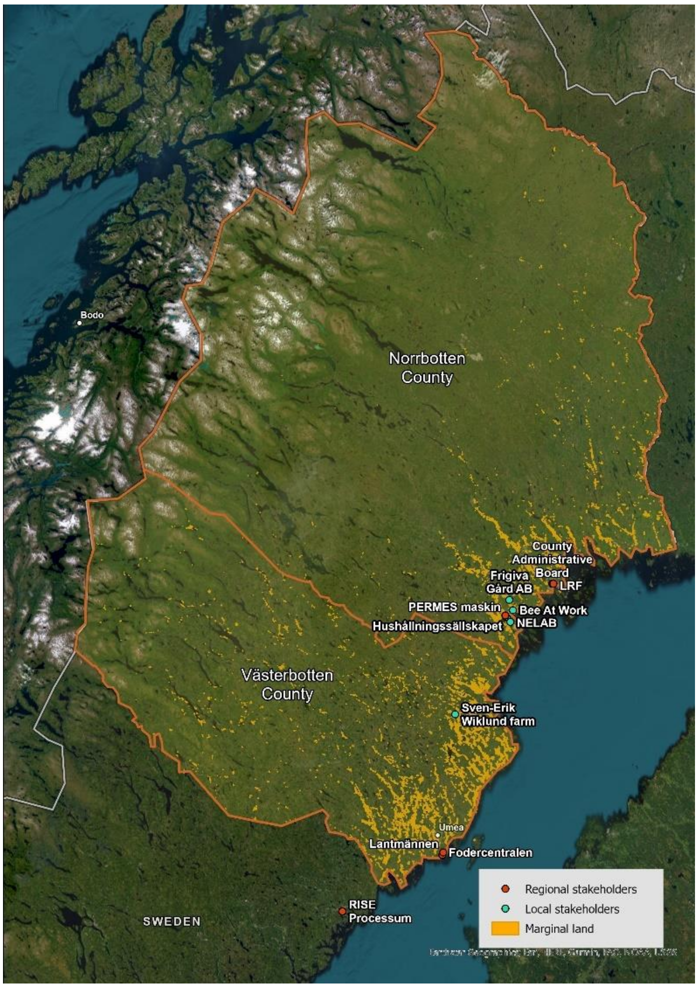
National map

The national map includes a layer representing the region where the Use Case can be applied, along with the national stakeholders presented as dots. In Sweden, these two regions are Västerbotten and Norrbotten, depicted in the image as light green with orange borders.

We need the borders of the regional area where you think the Use Case can be applied in the future. If you can't find borders for the regions, please draw them on a map and we will make the borders for you in the GIS-program.

Regional map

The regional map displays areas where marginal land is depicted. In the Swedish context, this includes all arable land (heat sum below 1500 °C days is marginal), indicated as yellow on the map, together with the regional and local stakeholders.



We need you to outline the areas you define as **marginal land** (see above). This could be abandoned fields, wetlands, soil with low organic matter, and more. If you have different factors, give us a separate layer for each one and specify the range for each factor. This way, we can identify were marginal land fits specific criteria. For example, if ’you’re looking for areas with both low organic matter and abandoned land, we can locate them and label them as marginal land.

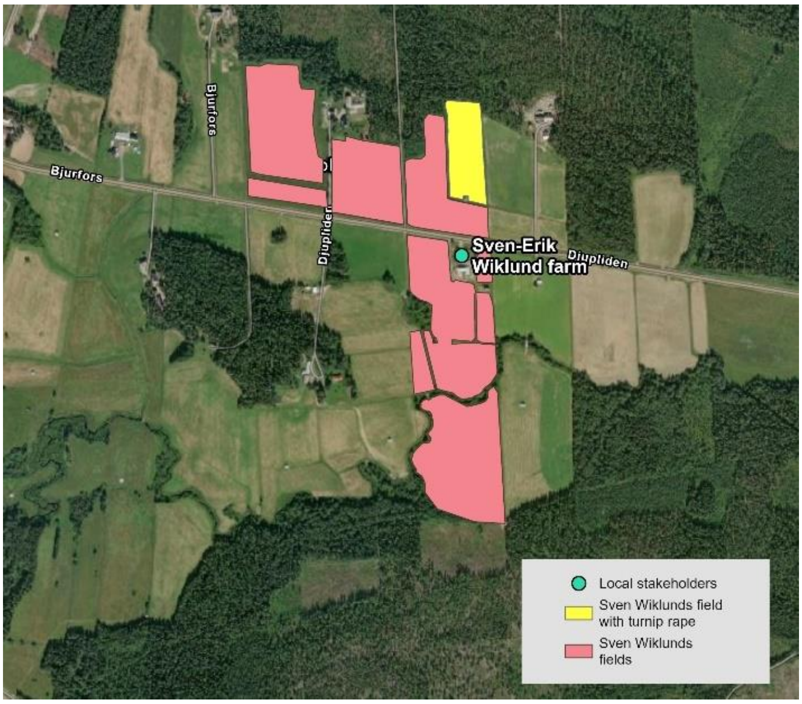
Please provide these files in the shape file format.

Use case map

This map illustrates where the Use Case will be implemented within the MarginUp project. In the map below, the yellow field indicates where the turnip rape will be cultivated for the Swedish Use Case.

We want you to provide the specific area where the Use Case can be applied in the MarginUp project.

If you are unable to locate the borders for the Use Case, please draw them on a map, and we will assist in defining the borders using the GIS program.



Annex D: German use case marginal land

1) Thickness of peat soils

Originates as a merge of two spatial layers:

A) Moorlands with special functional characteristics from the point of view of soil protection (Moorböden mit besonderer Funktionsausprägung aus Bodenschutzsicht, 2020)

Data source: (Metaver, 2022)

Thickness value derived from the attribute called „UTARC"(Endtiefe Archiv) > 100 cm

B) Moorbodenkarte 2001

This layer includes the attribute "MOORTIEF" (thickness), classified into 5 categories. Only areas with categories 2 (120-300 cm) and 3 (>300 cm) were selected.

Source: Available at internal ZALF storage

Totally, this merged layer covers about 13 % (13 528 ha) of the use case area.

2) Depth of groundwater level

Data compiled as part of the "Karten des Grundwasserflurabstandes Brandenburg 2013". The basis is formed by interpolation of in-situ groundwater measurements in spring 2011. It contains information on depth of groundwater level beneath the surface.

Selection of areas with a depth of groundwater level lower than 1 meter below the surface. Attribute FA "= "<" 1".

Data source: (Metaver, 2023)

Totally, this layer covers about 47 % (47 637 ha) of the use case area.

3) Agriculturally used grasslands

Agricultural field bloc—s - InVeKOS dataset for the last 5 years (2018 – 2022)
Selection of dominant crop type as a hay pasture or meadow,
Attribute „CODE_mj" == 452 (Mähweiden) or 451 (Wiesen)
+ DGL (592,444), Feuchgebiete (004), Grünland (53), Hutugen (454), Streuwiesen (458), Weiden und Almen (453)
Data source: Available at internal ZALF storage
Totally, this layer covers about 34 % (34 502 ha) of use case area

4) Agriculturally not-used grasslands:

Because not all grasslands have to be registered as field blocks in Invekos database, we also included those areas that are classified as grasslands in Biotoptypen dataset (a comprehensive recording of biotope types and land use data for the state of Brandenburg in 2009).
Selection of all grasslands based on attribute "Klasse" == 05 (Gras- und Staudenfluren)
Additionally, to agriculturally used grasslands, not-used grasslands cover about 34 % (34 502 ha) of the use case area.

Data source: (Metaver, 2009).

Procedure:

GIS-based analysis (spatial union, erase and intersect) of biophysical constraints (input parameters) within the Rhinluch region (Germany use case, landscape scale).

A) Marginal lands within agriculrally used fields only

Spatial intersect of parameters 3) Agriculturally used grasslands, 2) Depth of groundwater level, and 1) Thickness of peat soils. These areas were subsequently assigned (joint) back to agriculturally used grasslands (field blocks) and the proportion of the total area of each field covered by thick peatland and high groundwater was calculated. As potential marginal lands, we identify agriculturally used grasslands (field blocks) with at least 20 % of the area covered by thick peat soils and high groundwater levels. Totally, this layer contains 909 fields, and covers about 9 % (9 061 ha) of the use case area.

B) Marginal lands within agriculturally not-used grasslands

Areas classified as grasslands in Biotoptypen dataset within the use case but not spatial included as fields in Invekos were again intersected with parameters 2) Depth of groundwater level, 1) Thickness of peat soils. Thus, we created a layer of marginal lands not used as agricultural fields. Totally, such marginal lands cover about 0.4 % (357 ha) of the use case area.

C) Marginal lands within all agriculturally used and not-used grasslands

Finally, we joint Marginal lands within agriculturally used fields and Marginal lands within agriculturally not-used grasslands. Thus, we created a map of potential marginal lands based on biophysical constraints within all agriculturally used and not-used grasslands. Totally, such marginal lands cover about 9 % (9 418 ha) of the use case area.

Annex E: Stakeholders online maps

Table E.1: Stakeholders identified in the Greek use case, illustrated in the online maps.

Stakeholder	Involvement in use case	Value chain segment	Type	Scale	Website
World Bioeconomy Forum	Scale-up	Representation of interests	Network/ platform	International	https://wcbef.com/
Innovawood	Ecosystem	Representation of interests	Network/ platform	European	http://www.innovawood.com/innovawood
Apivita S.A.	Scale-up	Market, value chain management and development	Entrepreneur	National	https://www.apivita.com/hellas/
Public Power Corporation S.A. (DEI)	Value chain	Biomass provision, market	Investor	National	https://www.dei.gr/en/home/
Greek agricultural organization	Ecosystem	Processing	Research Institute/ Academia	National	https://www.elgo.gr/index.php?option=com_content&view=featured&Itemid=638
Federation of Greek Beekepers Associations	Scale-up	Representation of interests	Association/ Cooperative	National	https://www.omse.gr/
Greek Just Transition Pl—n - SDAM (Schedio Dikaias Anaptyksiakis Metavasis)	Scale-up	Value chain management and development	Network/ platform	National	https://www.sdam.gr/
HELLABI—M - Hellenic Biomass Association	Scale-up	Representation of interests	Network/ platform	National	https://hellabiom.gr/
Just Transition Platform (JTP)	Scale-up	Value chain management and development	Donor	National	https://ec.europa.eu/regional_policy/funding/just-transition-fund/just-transition-platform/about_en
Korres S.A.	Scale-up	Market, value chain management and development	Entrepreneur	National	https://gr.korres.com/
OKIROI S.A.	Value chain	Industrial application of biomass, market	feedstock user	National	https://www.linkedin.com/company/okiroi-s-a-/about/

University of Thessaly, Department of Forestry	Value chain	Biomass provision, processing, market	Research Institute/ Academia	National	https://fwsd.uth.gr/en/
WWF Greece	Scale-up	Representation of interests	NGO/ CSO	National	http://www.wwf.gr/
Association of Medicinal and Aromatic Plants of Greece	Scale-up	Representation of interests	Association/ Cooperative	National	https://eng.eaffe.org/
Municipality of Megalopoli	Scale-up	Regulations and policies	Government (subnational)	National	https://megalopoli.gov.gr/
Cluster of Bioeconomy and Environment of Western Macedonia (CluBE)	Value chain	Value chain management and development, market	Network/ platform	Regional	https://clube.gr/en/about/
Region of Western Macedonia	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://www.pdm.gov.gr/
Technical Chamber of Greece-Division of Western Macedonia	Scale-up	Regulations and policies	Administration (subnational)	Regional	https://tdm.tee.gr/
Geotechnical Chamber of Greece, West Macedonia section	Scale-up	Regulations and policies	Administration (subnational)	Regional	www.geoteepdm.gr
Small local producers (herbs and blossoms value chain)	Scale-up	Processing, market	feedstock user	Regional	https://herbsandoils.gr/en/ https://anagro.gr/ https://fontedivita.gr/
Bagatzounis & Sons S.A.	Scale-up	Pre-treatment, processing, market	Biomass provider/ farmer	Regional	https://bagatzounis.com/web/el/greek/
Chliapas S.A.	Scale-up	Industrial application of biomass	feedstock user	Regional	https://xliapas.gr/
Dioscouridis IKE	Scale-up	Processing, industrial application, market	feedstock user	Regional	https://www.dioscurides.gr/en/
Etheleo distillery	Value chain	Processing, market	feedstock user	Regional	https://www.etheleo.gr/
4G Greek G'ia's Global Gate	Value chain	Pre-treatment, market	Food producers	Regional	https://greekgaias.com/?lang=en
HEDNO S.A. (Hellenic Electricity Distribution Network Operator)	Value chain	Market	Trader	Regional	https://deddie.gr/en/
Paraskevas Patsilias	Ecosystem	Biomass provision	Consultancy	Regional	https://www.patsiliasfytorio.gr/index.php

University of Western Macedonia	Scale-up	Regulations and policies, representation of interests	Research Institute/ Academia	Regional	https://uowm.gr/
ELPIS Pellet Co	Scale-up	Industrial application of biomass	feedstock user	Regional	https://www.elpis-mepe.gr/
Beekeeping associations of Kozani	Scale-up	Pre-treatment	Association/ Cooperative	Regional	https://melisokomikoskozanis.gr/ www.melikastorias.gr https://beegrevena.wordpress.com
Beekeeping associations of Kastoria	Scale-up	Pre-treatment	Association/ Cooperative	Regional	https://melisokomikoskozanis.gr/ www.melikastorias.gr https://beegrevena.wordpress.com
Municipality of Kozani	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://cityofkozani.gov.gr/
Municipality of Eordaia	Ecosystem	Regulations and policies	Government (subnational)	Regional	http://www.ptolemaida.gr/
Union of Young Farmers of Kozani	Scale-up	Biomass provision, representation of interests	Association/ Cooperative	Regional	
Environmental protection company	Scale-up	Representation of interests	NGO/ CSO	Regional	https://www.facebook.com/eppkast/?locale=el_GR
Forest Agricultural Cooperatives (DASE) of Palaiogratsa—o - Elati	Value chain	Biomass provision	Cooperatives for the protection of forests	Regional	
Grevena Chamber of Commerce	Scale-up	Representation of interests	Administration (subnational)	Regional	http://www.epimelitiriogrevenon.gr/
ALFA WOOD GROUP	Value chain	Pre-treatment, processing, market	Entrepreneur	Regional	https://alfawood.gr/en/
Eyxylon Th. & Sp. Ziogas G.P.	Scale-up	Industrial application of biomass	feedstock user	Regional	http://www.eyxylon.gr/
Municipality of Grevena	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://www.dimosgrevenon.gr/
DIADYMA S.A.	Value chain	Biomass provision	Landowner	Local	https://diadyma.gr/en/

Table E.2: Stakeholders identified in the Hungarian use case, illustrated in the online maps.

Stakeholder	Involvement in use-case	Value chain segment	Type	Scale	Website

Alliance for Living Tisza	Scale-up	Biomass provision	NGO/ CSO	National	http://elotiszaert.hu/
Alliance of plant protection	Ecosystem	Biomass provision	NGO/ CSO	National	https://hucpa.hu/
Axial Kft.	Scale-up	Biomass provision, processing	Trader	National	https://www.axial.hu/
Bioculture Association	Ecosystem	Biomass provision	Association/ Cooperative	National	http://kmobio.hu/
BIOEAST	Scale-up	Representation of interests	Government (supranational)	National	https://bioeast.eu/
BAY ZOLTAN ALKALMAZOTT KUTATASI KOZHASZNU NONPROFIT	Ecosystem	Biomass provision, industrial application of biomass	Research Institute/ Academia	National	www.bayzoltan.hu
Champex Ltd.	Scale-up	Processing, industrial application of biomass, market	feedstock user	National	www.champex.hu
Danuba	Ecosystem	Biomass provision	Consultancy	National	https://www.danuba.hu/
Debrecen University, Institute of Horticultural Sciences	Value chain	Biomass provision, market	Research Institute/ Academia	National	https://unideb.hu/
Eurofins Kft.	Scale-up	Biomass provision	Entrepreneur	National	https://www.eurofins.hu
Fruitveb	Ecosystem	Regulations and policies, value chain management and development	Association/ Cooperative	National	https://fruitveb.hu/
Hungarian Bioeconomy Cluster	Scale-up	Representation of interests	Network/ platform	National	https://www.bayzoltan.hu/en/company-management/hungarian-bioeconomy-cluster/
Hungarian Biogas Association	Ecosystem	Processing, market, regulations and policies	Association/ Cooperative	National	http://bio-gaz.hu
Hungarian Chamber of Plant Protection Engineers	Ecosystem	Biomass provision, representation of interests	NGO/ CSO	National	https://magyarnovenyorvos.hu/
Hungarian Meteorological Service	Scale-up	Biomass provision	Administration (national)	National	https://www.met.hu/
Hungarian University of Agriculture and Life Sciences (MATE)	Ecosystem	Biomass provision	Research Institute/ Academia	National	https://uni-mate.hu/
INNOMINE DIGITAL INNOVATION HUB NONPROFIT	Ecosystem	Regulations and policies, value chain management and development	Consultancy	National	0
Institute for Soil Sciences	Scale-up	Biomass provision	Research Institute/ Academia	National	https://www.elkh-taki.hu/hu
Kapacitásenergia Kft.	Value chain	Market	Entrepreneur	National	https://kapacitasenergia.hu/
Körös-Maros Biofarm Kft.	Scale-up	Biomass provision	Biomass provider/ farmer	National	https://biotej.hu/
Lajtamag Kft.	Scale-up	Biomass provision	Entrepreneur	National	https://www.lajtamag.hu/

MAPER Permakultúra (Hungarian Permaculture Association)	Ecosystem	Biomass provision	NGO/ CSO	National	https://permakultura.hu/
MBH Bank (Hungarian Bankholding Group)	Scale-up	Value chain management and development	Investor	National	https://www.mbhbank.hu/
Ministry of Agriculture	Ecosystem	Regulations and policies	Government (national)	National	https://kormany.hu/agrarminiszterium
National Association of Agricultural Cooperatives and Producers	Ecosystem	Representation of interests	NGO/ CSO	National	http://www.mosz.agrar.hu/
National Food Chain Safety Office (Nébih)	Ecosystem	Regulations and policies	Administration (national)	National	www.nebih.hu
Organic Research Institute and Botanical Garden Vácrátót	Ecosystem	Regulations and policies	Research Institute/ Academia	National	https://elkh.org/en
OTP Bank	Scale-up	Value chain management and development	Investor	National	https://www.otpbank.hu/
Sopron University, Forestry Scientific Institute	Value chain	Biomass provision, market	Research Institute/ Academia	National	www.uni-sporon.hu
Syngenta	Scale-up	Biomass provision	Entrepreneur	National	https://www.syngenta.hu/
UBM AGRO Ltd.	Scale-up	Industrial application of new feed additives	Entrepreneur	National	www.ubm.hu
Vitafort Ltd.	Value chain	Industrial application of biomass	end user	National	http://vitafort.hu/
ÖMKi - Research Institute of Organic Agriculture	Ecosystem	Biomass provision	Research Institute/ Academia	National	https://www.biokutatas.hu/
Zsila Gardening Center	Value chain	Biomass provision, market	Entrepreneur	National	https://firmania.hu
Nagykun 2000 Zrt	Scale-up	Biomass provision	Biomass provider/ farmer	National	https://nagykun.hu/
Kujáni Production and Advisory Ltd.	Value chain	Mass provision, processing	Biomass provider/ farmer	Regional	www.kujani.hu
KEFAG AG	Scale-up	Biomass provision	Administration (subnational)	Regional	www.kefag.hu
KNP Kiskunság National Park	Ecosystem	Regulations and policies	Administration (national)	Regional	https://www.knp.hu/en
Bács-Kiskun County	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://www.bacskiskun.hu
Agrogeo	Value chain	Biomass provision	Entrepreneur	Regional	www.agrogeo.hu
Associations of Agricultural Advisors	Ecosystem	Biomass provision, regulations, and policies	Association/ Cooperative	Regional	https://aszate.hu/

Mushroom growers as Kratók Gomba Ltd.	Scale-up	Processing, industrial application	feedstock user	Regional	
National Chamber of Agriculture	Ecosystem	Regulations and policies, value chain management and development	Administration (national)	Regional	www.nak.hu
University of Neumann János Horticulture and Rural Development Faculty	Ecosystem	Biomass provision	Research Institute/ Academia	Regional	https://nje.hu/
Kecskemét Municipality	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://kecskemet.hu/
Bács-Kiskun County Government Office	Ecosystem	Regulations and policies	Administration (subnational)	Regional	https://www.kormanyhivatal.hu/hu/bacs-kiskun
László Gál farmer	Scale-up	Biomass provision	Biomass provider/ farmer	Regional	https://galtanya.hu/
Kamra-Túra egyesület	Ecosystem	Biomass provision, market, representation of interests	Association/ Cooperative	Regional	https://www.kamra-tura.hu/
Mizsetáp Kft.	Value chain	Processing	Alternative land user	Regional	
Auditker	Ecosystem	Biomass provision, pre-treatment, market	Entrepreneur	Local	www.auditker.hu
PILZE	Value chain	Pre-treatment, processing	feedstock user	Local	www.pleurotus.hu

Table E.3: Stakeholders identified in the Swedish use case, illustrated in the online maps.

Stakeholder	Involvement in use case	Value chain segment	Type	Scale	Website
RISE PROCESSUM	Value chain	Processing, industrial application of biomass	Research Institute/ Academia	National	https://www.ri.se/sv/processum-biorefinery-cluster
RISE AB	Value chain	Value chain management and development	Research Institute/ Academia	National	https://www.ri.se/en
Swedish Board of Agriculture	Ecosystem	Regulations and policies	Government (national)	National	https://djur.jordbruksverket.se/swedishboardofagriculture.4.2cab68ce1860be3977730da9.html
Energifabriken	Ecosystem	Industrial application of biomass, market	Trader	National	https://energifabriken.se/
PREEM	Scale-up	Market	Entrepreneur	National	https://www.preem.com/in-english/
Polargas	Scale-up	Market	Trader	National	https://polargas.se/

Swedish Bioenergy Association (Svebio)	Ecosystem	Representation of interests	Association/ Cooperative	National	https://www.svebio.se/
Association of Swedish Oil Crop Farmers	Ecosystem	Representation of interests	Association/ Cooperative	National	www.sfo.se
Energimyndigheten	Ecosystem	Regulations and policies	Change agent	National	https://www.energimyndigheten.se/en/
EEXP (Ernst Express)	Value chain	Industrial application of biomass, market	End user	National	www.ernstexpress.se
PM Bioenergi & Smide	Ecosystem	Pre-treatment, processing	Technology provider	National	https://www.pmsmide.se/
Lantmännen	Scale-up	Biomass provision, pre-treatment, processing	Feedstock user	Regional	https://www.lantmannen.se/
ALMI, Nyföretagarcentrum	Ecosystem	Value chain management and development	Investor	Regional	https://www.almi.se/en/in-english/
AFRY	Ecosystem	Value chain management and development	Consultancy	Regional	https://afry.com/en
Hushållnings-sällskapet	Value chain	Biomass provision, pre-treatment, processing	Network/ platform	Regional	https://hushallningssallskapet.se/alla-sallskap/valj-sallskap/hushallningssallskapet-norrbotten-vasterbotten/
Bee At Work	Ecosystem	Biomass provision	Entrepreneur	Regional	http://www.beeatwork.se/
Frigiva Gård AB	Value chain	Processing, industrial application of biomass	End user	Regional	
Alviksgården	Scale-up	Value chain management and development	Biomass provider/ farmer	Regional	
Pesula Lantbruk	Scale-up	Industrial application of biomass	Biomass provider/ farmer	Regional	https://pesulalantbruk.se/
NELAB	Value chain	Provides electrical installation	Entrepreneur	Regional	https://www.nelab.se/
PERMES maskin	Value chain	Agro-Services Entrepreneur	Entrepreneur	Regional	
Fodercentralen	Value chain	Biomass provision, processing	feedstock user	Regional	https://fodercentralen.se/
LRF Norrbotten and Västerbotten	Scale-up	Biomass provision	Association/ Cooperative	Regional	https://www.lrf.se/regioner/norrbotten/kontakta-lrf-norrbotten/
c/o GERD	Scale-up	Industrial application of biomass	Entrepreneur	Regional	www.careofgerd.se

Luleå municipality	Ecosystem	Market	Government (subnational)	Regional	https://www.lulea.se/boende--gator/energi-klimat-och-uppvarmning/biogas.html
Skellefteå municipality	Ecosystem	Market	Government (subnational)	Regional	https://skelleftea.se/invanare/startsida/bygga-bo-och-miljo/avfall-och-atervinning/skelleftea-biogasanlaggning
Växa	Scale-up	Biomass provision	Consultancy	Regional	
Norrmejerier	Scale-up	Biomass provision	Association/ Cooperative	Regional	
County Administrative Board in Västerbotten and Norbotten	Ecosystem	Regulations and policies	Government (subnational)	Regional	https://www.lansstyrelsen.se/norrbotten/natur-och-landsbygd.html and https://www.lansstyrelsen.se/vasterbotten.html
Swedish University of Agricultural Science	Ecosystem	Biomass provision	Research Institute/ Academia	Regional	https://www.slu.se/en/
Region of Västerbotten	Ecosystem	Value chain management and development	Government (subnational)	Regional	https://regionvasterbotten.se/
Region of Norrbotten	Ecosystem	Value chain management and development	Government (subnational)	Regional	https://www.norrbotten.se/
Maskinring Norrland	Scale-up	Market	Association/ Cooperative	Regional	https://www.mrsverige.se/mrnorrland
BioFuel Region	Ecosystem	Value chain management and development	Network/ platform	Regional	https://biofuelregion.se/
Wibax	Scale-up	Market	Entrepreneur	Regional	https://www.wibax.com/en/
Skoogs bränsle and Skelleftebränslen	Scale-up	Market	Trader	Regional	https://skoogsbransle.se/
Polarbröd	Scale-up	Market	Entrepreneur	Regional	https://www.polarbrod.se/
Länsförsäkringar	Scale-up	Value chain management and development	Investor	Regional	https://www.lansforsakringar.se/vasterbotten/other-languages/english/
Norrmaskiner	Scale-up	Market	Entrepreneur	Regional	
Landshypotek Bank	Scale-up	Value chain management and development	Investor	Regional	https://www.landshypotek.se/en/
Alter Hedens	Scale-up	Industrial application of biomass	Entrepreneur	Regional	https://www.alterhedens.se/halsa-i-bar/rybs/
Farmer Sven-Erik Viklund Djupliden	Value chain	Biomass provision	Biomass provider/ farmer	Local	

Table E.4: Stakeholders identified in the German use case, illustrated in the online maps.

Stakeholder	Involvement in use-case	Value chain segment	Type	Scale	Website
Arge Klimamoor	Research, Project coordination		NGOs	National	https://www.klimamoor-brandenburg.de/en/contact/
Brandenburg State Farmers' Association	Policy hub to farmers		NGOs	National	https://www.lbv-brandenburg.de/
Investment Bank of the State of Brandenburg	Project funding		Government/authorities	National	https://www.ilb.de/de/
Brandenburg Nature Conservation Fund Foundation	Project funding		NGOs	National	https://www.naturschutzfonds.de/
Specialist agency for renewable raw materials	Research, Project coordination		Government/authorities	National	https://international.fnr.de/
Brandenburg Nature Conservation Union	Policy hub		NGOs	National	https://en.nabu.de/
Brandenburg State Tourism Association	Policy hub		NGOs	National	https://www.ltv-brandenburg.de/
Ministry of Agriculture, Environment and Climate Protection (MLUK)	Rural development		Government/authorities	National	https://mluk.brandenburg.de/mluk/de/landwirtschaft/laendliche-entwicklung/
State Office for Rural Development, Agriculture and Land Consolidation	Rural development		Government/authorities	National	https://lelf.brandenburg.de/lelf/de/
Leibniz Institute for Agricultural Engineering and Bioeconomy	Research, Project coordination		Research and Development	National	https://www.atb-potsdam.de/en/
Federal Ministry for the Environment	Nature conservation and environmental protection policy	Policy	Government/authorities	National	https://www.bmuv.de/en/
Greifswald Mire Centre	Contacts	Policy, guidance, research	NGOs	National	https://www.greifswaldmoor.de/home.html
Lower Environmental Authorithy (Untere Umweltbehörde)	Approval procedures	Public administration	Government/authorities	National	https://service.brandenburg.de/service/de/adressen/weitere-verzeichnisse/verzeichnisliste/~umweltbehoerden-untere#
Landesanstalt für Umwelt	Regulatory mission		Government/authorities	Regional	https://lfu.brandenburg.de/lfu/de/
Naturpark Westhavelland	Regulatory mission		Government/authorities	Regional	https://www.westhavelland-naturpark.de/

County Havelland	Research, Project coordination		Government/authorities	Regional	https://www.havelland.de/landkreis/
Tourist Association Havelland e.V.	Policy hub		NGOs	Regional	https://www.dein-havelland.de/impressum
FMS Futtermittel GmbH Selbelang	Production and marketing of products	Processing of greening elements	Private company	Regional	www.trockenwerk.de
ZALF Versuchsanstalt Paulinenaue	Research, Project coordination		Research and Development	Regional	https://www.zalf.de/de/struktur/eip/Seiten/Arbeitsgruppen.aspx
Landesanstalt für Landwirtschaft	Research, Project coordination		Government/authorities	Regional	https://lelf.brandenburg.de/lelf/de/ueber-uns/kontakt/
Farmer 2	Provider of biomass		Entrepreneur	Local	

Table E.5: Stakeholders identified in the Spanish use case, illustrated in the online maps.

Stakeholder	**Involvement in use-case**	**Value chain segment**	**Type**	**Scale**	**Website**
Asociación Nacional de la Industria del Prefabricado de Hormigón (ANDECE)	Ecosystem	Representation of interests	Network/ platform	National	https://www.andece.org/
CTAEX (National Agri-Food Technology Centre)	Ecosystem	Biomass provision, market	Research Institute/ Academia	National	https://ctaex.com/
Confederación Hidrográfica del Tajo (CHT)	Ecosystem	Regulations and policies	Administration (subnational)	National	http://www.chtajo.es/Paginas/default.aspx
CICYTEX (Center for Scientific and Technological Research in Extremadura)	Value chain	Biomass provision, pre-treatment, processing	Research Institute/ Academia	National	http://cicytex.juntaex.es
Consejería de Agricultura, Desarrollo Rural, Población y Territorio	Ecosystem	Value chain management and development	Government (subnational)	National	https://www.juntaex.es/lajunta/consejo-de-gobierno/consejeria-de-agricultura-desarrollo-rural-poblacion-y-territorio
Consejería para la Transición Ecológica y Sostenibilidad	Ecosystem	Value chain management and development	Government (subnational)	National	https://www.juntaex.es/lajunta/consejo-de-gobierno/consejeria-para-la-transicion-ecologica-y-sostenibilidad
Unión de Pequeños Agricultores (UPA-UCE)	Scale-up	Representation of interests	Trade union	National	https://www.upa.es/
University of Extremadura	Ecosystem	Processing	Research Institute/ Academia	National	

Diputación de Cáceres (province)	Ecosystem	Value chain management and development	Government (subnational)	National	https:\\www.dip-caceres.es
ASAJA (Asociación Agraria Jóvenes Agricultores)	Scale-up	Representation of interests	Trade union	National	https://www.asaja.com/organizaciones/extremadura
CETARSA	Scale-up	Processing	Entrepreneur	National	www.cetarsa.es | Compañía Española de Tabaco en Rama S.A., S.M.E. (CETARSA)
Moraleja City Council	Scale-up	Regulations and policies	Government (subnational)	Regional	
Centro de Formación del Medio Rural de Moraleja	Value chain	Pre-treatment, industrial application of biomass	Research Institute/ Academia	Regional	http://rurex-formacion.gobex.es/centros_detalle.php?centro_id=1
Ambienta Ingeniería y Servicios Agrarios y Forestales S.L.U.	Ecosystem	Biomass provision	Consultancy	Regional	https://www.ambientaing.es/
COPAL (Sociedad Cooperativa del Alagón)	Value chain	Biomass provision, representation of interests	Biomass provider/ farmer	Local	
ADESVAL	Scale-up	Value chain management and development	NGO/ CSO	Local	
Comunidad de Regantes de la margen derecha del Alagón	Ecosystem	Representation of interests	Association/ Cooperative	Local	
Coria City Council	Scale-up	Regulations and policies	Government (subnational)	Local	
Grupo Operativo ECOPRADERAS. EIP AGRI Agriculture & innovation	Ecosystem	Value chain management and development	Consultancy	Local	https://www.ambientaing.es/index.php/i-d-i/grupo-operativo-ecopraderas
Grupo Operativo CEREAL AGUA. EIP AGRI Agriculture & innovation	Ecosystem	Value chain management and development	Consultancy	Local	https://cerealagua.es/GOS-cereal-agua/
Modular System Global S. L.	Value chain	Processing, industrial application of biomass, market	Entrepreneur	Local	https://modularhome.es

Table E.6: Stakeholders identified in the Argentinian use case, illustrated in the online maps.

Stakeholder	Value chain segment	Type	Scale	Website
Instituto Tecnológico de Chascomús INTECH (CONICET-UNSAM)	Provides the human resources, facilities, laboratories, specialised knowledge	Research Institute/ Academia	National	https://intech.conicet.gov.ar/
San Martín University (UNSAM)	Provides the human resources, facilities, laboratories, specialised knowledge	Government (national)	National	https://unsam.edu.ar/

Buenos Aires University (UBA)	Provides the human resources, facilities, laboratories, specialised knowledge	Government (national)	National	https://www.agro.uba.ar/
Ministerio de Desarrollo Agrario de la provincia de Buenos Aires (MDA)	Network between academic sector and farmers	Government (subnational)	National	https://www.gba.gob.ar/desarrollo_agrario
Experimental farm Chascomús	Location of experimental research regarding crop breeding	Government (subnational)	National	https://www.argentina.gob.ar/inta
Subsecretaría de Medio Ambiente y Desarrollo Sustentable - Municipalidad de Chascomús	Local Council in charge of environmental regulations regarding the land use and agrochemical applications	Government (subnational)	National	https://www.chascomus.gob.ar/
Cooperativa de productores hortícolas	Producers associated to the research groups. T	Association/ Cooperative	National	-
GPE Systemas S.A.S	Supporters of research activities with informatic technology	Technology provider	National	https://gpesistemas.ar/
MICELIO BIO	Substrate production	feedstock user	National	https://www.micelio.bio/somos
CIAFA	Buyer of chemicals	Network/ platform	National	https://www.ciafa.org.ar/
CASAFE	Buyer of chemicals	Network/ platform	National	casafe.or
CASEM	Buyer of seeds	Network/ platform	National	casem.com.ar
CAFMA	Buyer of machinery	Network/ platform	National	cafma.com.ar
CAENA	Buyer of animal food	Network/ platform	National	caena.com.ar

Table E.7: Stakeholders identified in the South African use case, illustrated in the online maps.

Stakeholder	Involvement in use-case	Value chain segment	Type	Scale	Website
Criterion Africa Partners	Scale-up	Value chain management and development	Change agent	National	https://www.criterionafrica.com/
Council for Scientific and Industrial Research (CSIR)	Ecosystem	Industrial application of biomass, market	Research Institute/ Academia	National	
Department of Forestry, Fisheries and the Environment	Ecosystem	Regulations and policies	Government (national)	National	
Department of Science and Innovation, Directorate of Industry and Environment	Ecosystem	Regulations and policies	Government (national)	National	
Promethium Carbon	Scale-up	Regulations and policies	Consultancy	National	https://www.promethium.co.za/

REHAB	Ecosystem	Value chain management and development	Research Institute/ Academia	National	
SAEON	Ecosystem	Biomass provision	Research Institute/ Academia	National	https://www.saeon.ac.za/
Stellenbosch University, Center for Invasion Biology	Ecosystem	Processing	Research Institute/ Academia	National	
Stellenbosch University, Climate studies	Value chain	Biomass provision, value chain management and development	Research Institute/ Academia	National	
Stellenbosch University, Geographical Analysis	Ecosystem	Biomass provision	Research Institute/ Academia	National	
Stellenbosch University, Process Engineering	Ecosystem	Industrial application of biomass	Research Institute/ Academia	National	
Working for water	Ecosystem	Regulations and policies	Government (national)	National	
WWF South Africa	Scale-up	Industrial application of biomass	NGO/ CSO	National	https://www.wwf.org.za/
Africa Biomass Company	Scale-up	Pre-treatment	Biomass provider/ farmer	National	
Aghulas Biodiversity Initiative (ABI)	Ecosystem	Biomass provision, value chain management and development	NGO/ CSO	National	https://agulhasbiodiversity.co.za/
Coega Biomass Center	Value chain	Pre-treatment, processing	Entrepreneur	National	https://coegabiomass.com/
Green Cape	Ecosystem	Value chain management and development	Consultancy	National	https://green-cape.co.za/
NRGen Advisors	Ecosystem	Industrial application of biomass	Consultancy	National	http://nrgen.co.za/
Angus farm	Value chain	Biomass provision, processing	Land owner	National	
G&K Mouldings	Scale-up	Processing, industrial application of biomass	feedstock user	National	
Gribbon Trading 23	Scale-up	Processing, industrial application of biomass	feedstock user	National	
Municipality of Knysna	Value chain	Industrial application of biomass	Government (local)	National	
Overberg Renosterveld Conservation Trust	Ecosystem	Value chain management and development	NGO/ CSO	National	https://overbergrenosterveld.org.za/
Thekga startup	Scale-up	Processing	Investor	National	
UNILEVER	Scale-up	Market	feedstock user	National	
Zonderend Water Users Association	Scale-up	Biomass provision	Association/ Cooperative	National	http://zonderend.co.za/

Annex F: Icons of socioeconomic factors

Use case Greece

High unemployment

Ageing population

Use case Hungary

Labor challenges

Unknown market

Use case Sweden

Ageing population

Long distances

Use case Germany

		
Land use conditions	Lack of economic viability	Stakeholder characteristics and engagement

Use case Spain

	
Low economic activity density	Market challenge