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Marginal lands for Growing Industrial Crops

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Lead beneficiary			
Imperial College London			
Exhibition Road, SW72AZ London			
www.imperial.ac.uk			
Responsible Author			
Calliope Panoutsou	Imperial College London	c.panoutsou@ic.ac.uk	+44 7557341846
Additional Authors			
Name	Organization	Email	Telephone
Asha Singh	Imperial College London	asha.singh@ic.ac.uk	-
Thomas Christensen	Imperial College London	thomas.christensen17@ic.ac.uk	-
Alba Martin	Cooperativas Alimentarias	amartin@agro-alimentarias.coop	0034 91 535 1035
Pilar Ciria Ciria	CIEMAT	pilar.ciria@ciemat.es	
Marina Sanz	CIEMAT	marina.sanz@ciemat.es	

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Table of contents

List of figures

List of tables

Publishable executive summary

This report capitalises on the analysis of Good Practices (D7.1, D7.2) and lessons learnt (D7.3) and delivers a set of guidelines in terms of i) barriers and enabling factors for the rehabilitation of marginal land with the cultivation of industrial crops and ii) issues that influence their successful implementation per development stage of the value chains. All these can offer useful insights and information to other European regions in the case they wish to investigate opportunities for restoring marginal land and cultivating industrial crops as feedstock for biobased sectors.

The guidelines reflect the nature of the research in the Magic project and refer to:

- Good practice guidelines for restoration of land with biophysical/ environmental marginality
- Good practice guidelines for the establishment and cultivation of industrial crops in marginal land

1 Introduction

The Magic project explores opportunities for returning abandoned, marginal land to productivity with the cultivation of industrial crops. Within this context, the research has explored a set of Good Practice cases across Europe and analysed their performance for biophysical/environmental, economic and social issues within the respective regions (Deliverables 7.1 and 7.2).

The aim of identifying 'Good Practices' within the research of the Magic project is to understand the context of the regions they are set, the relevant marginality challenges and the prospects for industrial crops. The process of identifying the 'Good Practice' has been participatory and involved surveying, interviews, and discussion to collect information on successes and failures of growing industrial crops in marginal land with a variety of biophysical/ environmental marginality challenges.

This report capitalises on the findings of the Good Practice cases analysis and provides a set of Good Practice Guidelines (that includes both success and failures to avoid replication of mistakes). It also suggests guidelines from the lessons learnt in terms of i) barriers and enabling factors for the rehabilitation of marginal land with the cultivation of industrial crops and ii) issues that influence their successful implementation per development stage of the value chains. All these can offer useful insights and information to other European regions in the case they wish to investigate opportunities for restoring marginal land and cultivating industrial crops as feedstock for biobased sectors.

2 Understanding land marginality challenges

The research for Good Practices in Magic addressed the following biophysical/ environmental marginality challenges: low soil carbon, soil contamination and soil erosion. Detailed maps for each country (EU27 and UK) can be found at:
https://iiasa-spatial.maps.arcgis.com/apps/webappviewer/index.html?id=96bec7f4c7ee49df8e4fd24a82039ea3

2.1 Biophysical/ environmental marginality challenges addressed in Magic

2.1.1 Low soil carbon

Soil organic carbon is a commonly used trait to monitor and assess soil quality, productivity and stability and is related to the applied agricultural practices.

Research in the Magic project has mapped biophysical marginality for three issues which are directly related to low soil carbon: low soil fertility and adverse rooting conditions.

Figures 1 and 2 illustrate the project results.

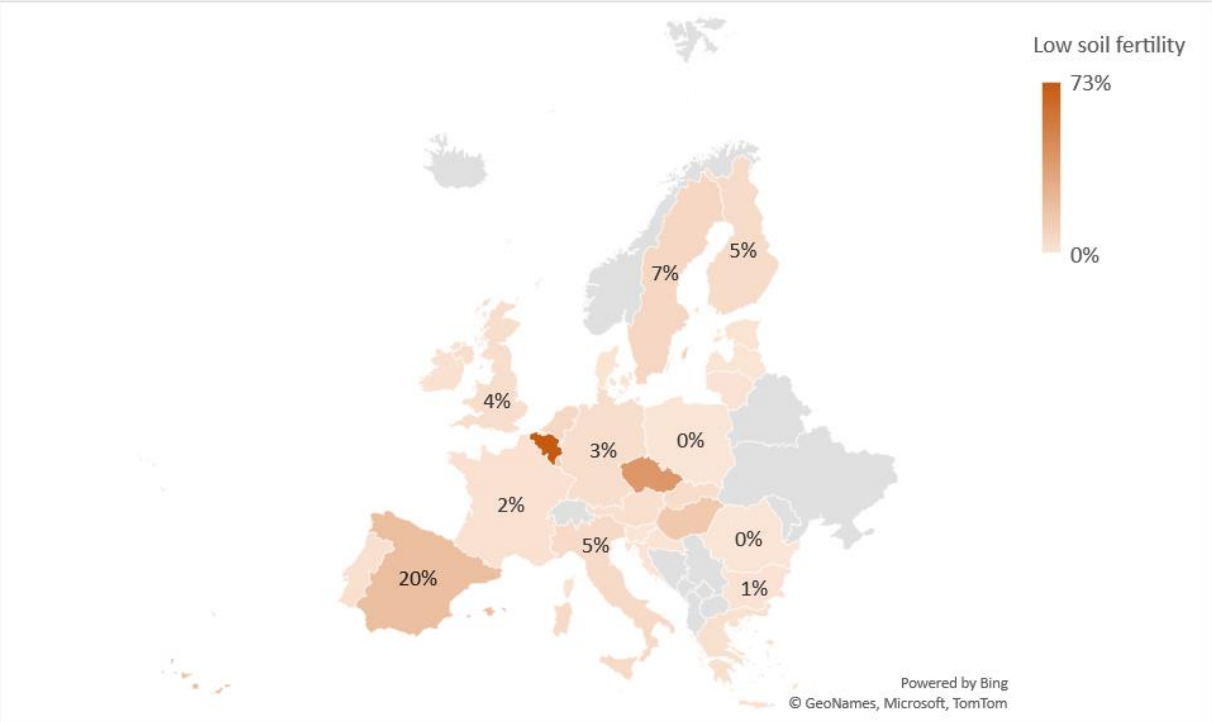


Figure 1 Marginal land with low soil fertility (%)

Belgium, Czech Republic, and Spain are countries with the highest occurrence of low soil fertility according to the results of Magic.

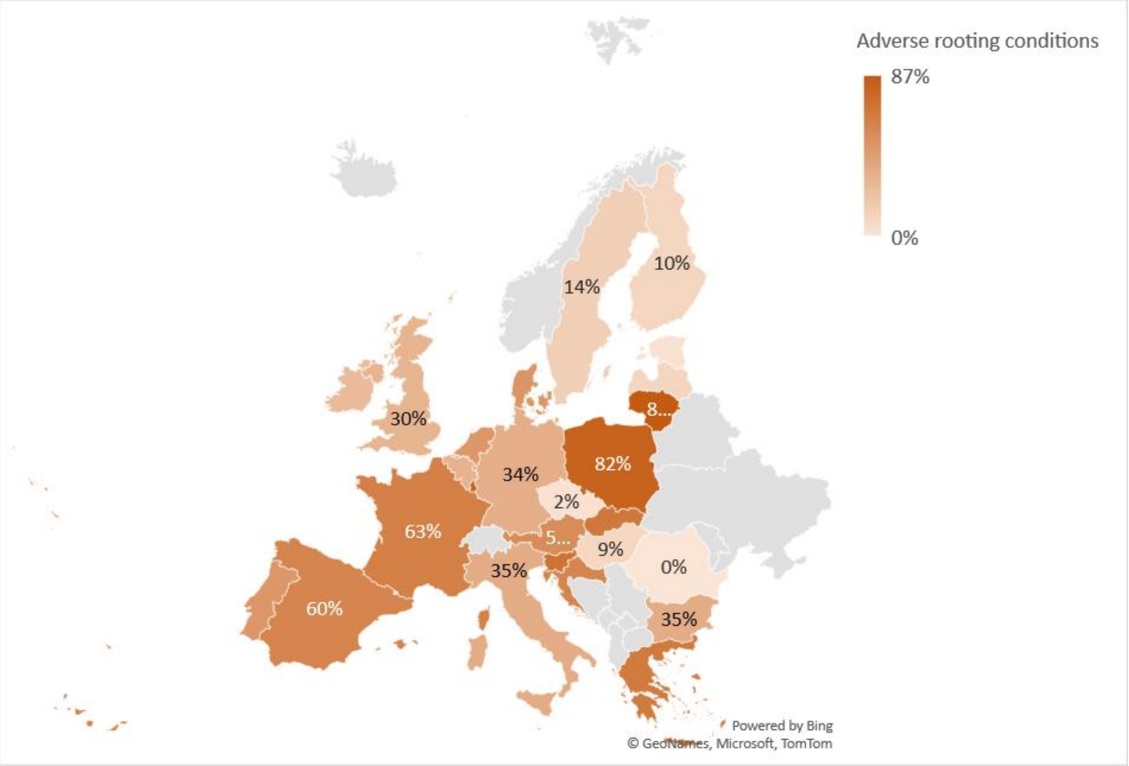


Figure 2 Marginal land with adverse rooting conditions (%)

Austria, Croatia, Denmark, France, Greece, Lithuania, Luxemburg, Malta, Poland, Slovakia, Slovenia, and Spain are countries with the more than 50% occurrence of land with adverse rooting conditions according to the results of Magic.

2.1.2 Soil contamination

Soil contamination is the occurrence of pollutants, particularly man-made chemicals, in soil above a certain level, which leads to a deterioration in or loss of one or more soil functions[1].

Research in Magic evaluated soil contamination by mapping areas with adverse chemical composition. Figure 3 illustrates the project results.

[1] https://ec.europa.eu/jrc/en/research-topic/soil-protection

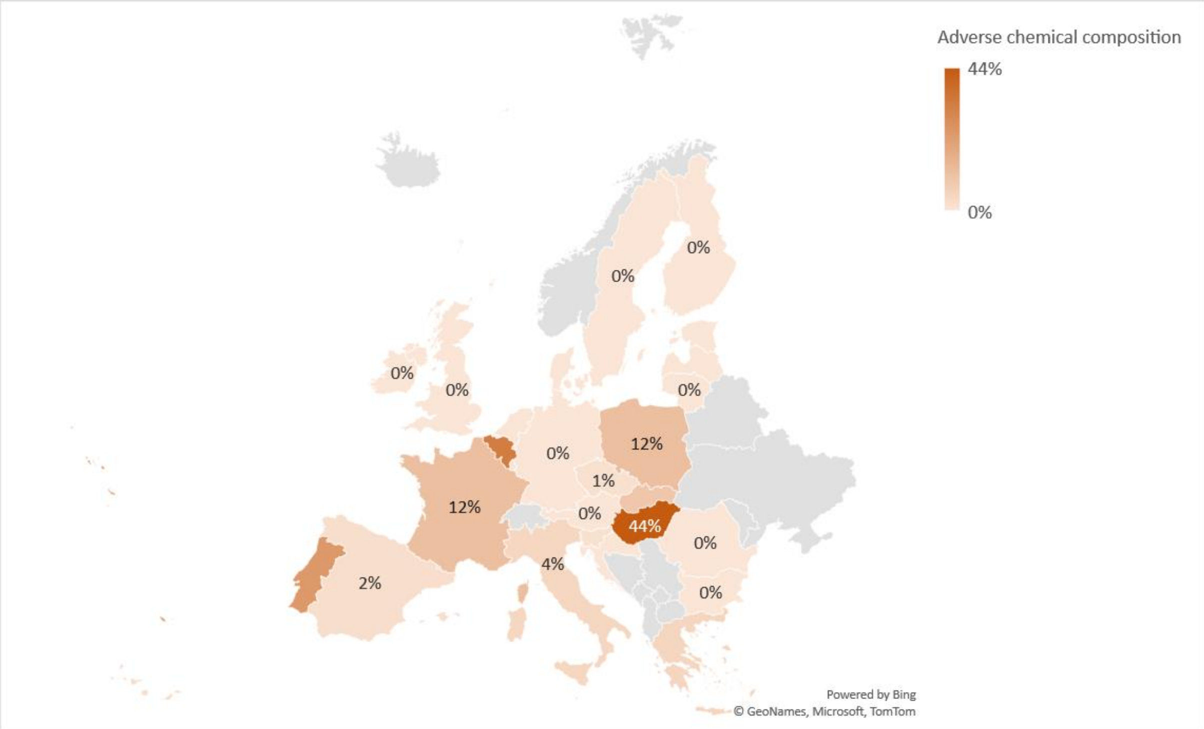


Figure 3 Marginal land with adverse chemical composition (%)

Belgium, Hungary, Poland and Portugal are countries with the highest occurrence of adverse chemical composition according to the results of Magic.

2.1.3 Soil erosion

Erosion risk depends on location and soil type. The Joint Research Centre of the European Commission (JRC) reports that soil degradation through erosion has been identified as a major threat to European soils and agriculture and further categorises it to wind, water and forest erosion.

Research in the Magic project has mapped biophysical marginality for one issue which is directly related to soil erosion: land with adverse terrain. Figure 4 illustrates the project results.

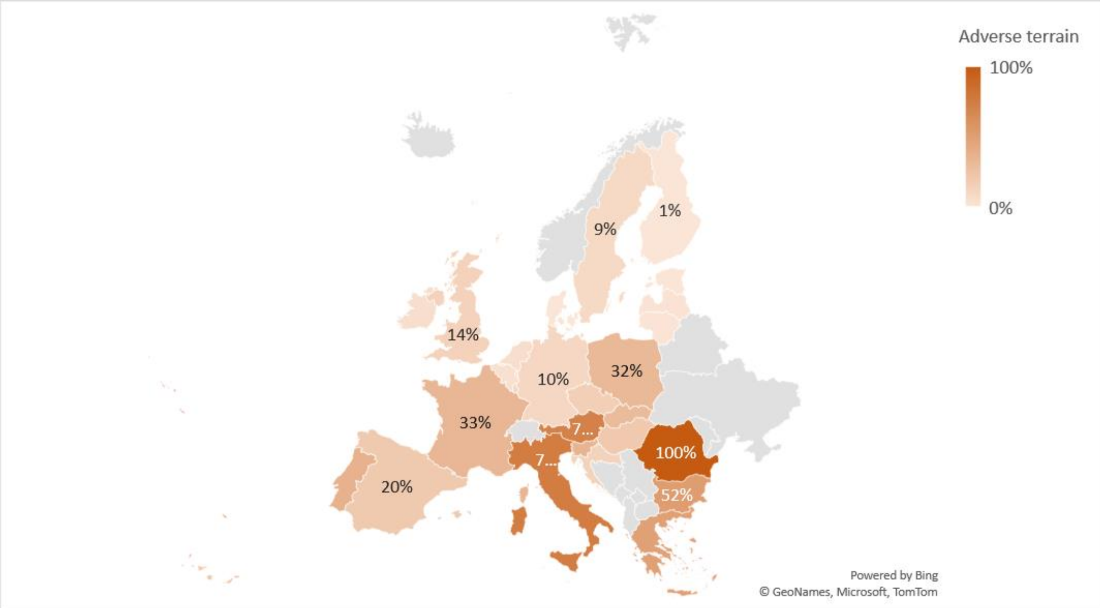


Figure 4 Marginal land with adverse terrain (%)

Austria, Bulgaria, France, Greece, Italy, Poland, Portugal, Romania, Slovakia and Slovenia are countries with the highest occurrence of land with adverse terrain according to the results of Magic.

2.2 Good practice guidelines for restoration of land with biophysical/ environmental marginality

This section outlines a set of guidelines for future projects that involve the restoration of land with biophysical marginality for the cultivation of industrial crops as feedstocks for the biobased sectors. These are the result of the analysis of twelve Good Practice cases across Europe and include both success factors (enablers) and failures/ risks (barriers).

Table 1 Enablers and barriers for the restoration of biophysical/ environmental marginality challenges

Biophysical/ Environmental marginality	**Enablers**	**Barriers**
Low fertility and sandy soils	It is important to restore the land with minimal tillage and cultivate very well-developed rooting system adaptable to the drought conditions and tolerant to severe water stress conditions	Application of intense ploughing; use of heavy machinery
Contaminated soil	Selection of plants that can help with the phytoextraction of heavy metals or have dense rooting system that makes them suitable for rhizoremediation.	High concentration of heavy metals that exceeds the dose that plants can tolerate and prohibits successful establishment
Excessive wetness	Selection of plants with ability to root well in wet conditions and ability to fix atmospheric nitrogen	Inefficient draining measures prior to crop establishment
Post-mining sites	Selection of plants that have high heavy metal and acid tolerance and can assimilate atmospheric nitrogen into the soil, prevent water formation and leaching of contaminants and promotes soil humus accumulation.	Lack of machinery and infrastructure to create an even soil surface for crop establishment
Adverse rooting	Selection of plants that can conserve soil by intensive rooting, humus accumulation and minimal nutrient removal.	Limited application of soil improvements during the stage of crop establishment

2.3 Further reading

More detailed information from the findings of the research can be found in the following Magic Deliverables:

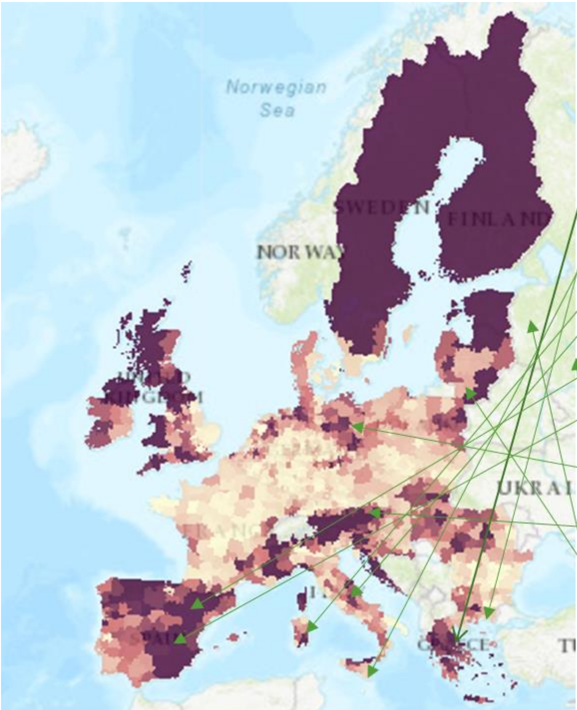
- Elbersen, B., Van Eupen, M., Verzandvoort, S., Boogaard, H., Mucher, S., Cicarreli, T., Elbersen, W., Mantel, S., Bai, Z., MCallum, I., Iqbal, Y., Lewandowski, I., Von Cossel, M., Carrasco, J., Ramos, C.C., Sanz, M., Ciria Ciria, P., Monti, A., Consentoni, S., Scordia, D., Eleftheriadis, I., 2018a. Deliverable 2.6. Methodological approaches to identify and map marginal land suitable for industrial crops in Europe WUR, Wageningen, Netherlands. In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, CRES, Greece. http://magic-h2020.eu/documents-reports/

- Elbersen, B., Van Verzandvoort, M., Boogaard, S., Mucher, S., Cicarelli, T., Elbersen, W., Mantel, S., Bai, Z., MCallum, I., Iqbal, Y., Lewandowski, I., Von Cossel, M., Carrasco, J., Ramos, C.C., Sanz, M., Ciria, P., Monti, A., Consentino, S., Scordia, D., Eleftheriadis, I., 2018b. Deliverable 2.1. Definition and classification of marginal lands suitable for industrial crops in Europe. In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, CRES, Greece. http://magic-h2020.eu/documents-reports/

3 Selecting crops

3.1 Crops with good adaptation and performance in marginal land

A mix of annual and perennial industrial crops have been analysed in the Good Practice cases in Magic (Deliverables 7.1 and 7.2). These are illustrated in Figure 5 below.



Region	Crop(s)	Low soil carbon	Soil contamination	Soil erosion	Dryness
Greece					
Central Greece	switchgrass, giant reed				
East Macedonia/ Thrace	black locust, sunflower				
Italy					
Catania	switchgrass, giant reed, miscanthus				
Sardinia	cardoon				
Central Italy, Lazio	poplar				
Spain					
Soria, Castilla y Leon	Rye, tall wheatgrass				
Castilla-La Mancha, Cuenca province	lavender				
Germany					
Brandenburg	black locust				
Hungary					
Észak-Magyarország	black locust				
Latvia					
Skriveri, Central Latvia	reeed canary grass, festulolium				
Ukraine					
Volynska and Lviv (West Ukraine)	willow				
Kyiv Oblast	miscanthus				

Figure 5 Industrial crops analysed in the Good Practice cases in Magic.

The key strengths of the crops included in the Magic Good Practice cases are:

- **Good adaptation:** all crops exhibit good adaptation to local climate and have high resistance to both biotic and abiotic stress, drought, high temperatures, pests and diseases.
- **Drought resistance for semi-arid and arid conditions**: Mediterranean countries face prolonged dry periods during summer followed by heavy, short time thunderstorms during autumn and winter, so it is critical that future cropping solutions exhibit high resistance to drought while maintaining sustainable growth patterns through these periods, without jeopardising their yielding potentials.

- **Low irrigation and nitrogen inputs:** all crops have high nutrient and water use efficiency, can grow with low or even no irrigation and have lower input requirements compared to cereals. These characteristics make them attractive options for marginal land facing low, uneven rainfall patterns and increased soil erosion risks.

- **Dense rooting system:** All crops have dense rooting system, with giant reed having the deepest and most compact one due to its rhizomes. This characteristic can help break up compacted soils, increase water infiltration and crop productivity and makes the crops a suitable solution for sloping areas that are also prone to erosion.

Table 2 describes the main characteristics of the understudy crops.

Table 2 Main characteristics of the crops in the Magic Good Practice cases

Crop	Key characteristics	Good Practice case in Magic
Switchgrass	✓ well-developed rooting system- tolerant to severe water stress and drought ✓ increased potential for carbon storage in soil	Greece, Italy
Giant Reed	✓ perennial, well adpated to mediterannean region ✓ drought resistant and saline soil tolerant	Greece, Italy
Miscanthus	✓ Perennial, well adapted to Europe ✓ does not require a big input of fertilisers due to good nutrient use efficiency	Italy, Ukraine
Cardoon	✓ rainfed crop very well in the temperate region with semiarid and sub humid climatic conditions. ✓ low nutrient input	Italy
Black locust	✓ although it is sensitive to topsoil compaction and waterlogging ✓ has high heavy metal and acid tolerance. ✓ can assimilate atmospheric nitrogen into the soil, prevent water formation and leaching of contaminants and promotes soil humus accumulation.	Greece, Hungary
Sunflower	✓ drought tolerant and resistant to salinity ✓ efficient in stratified use of soil resources and has high water use efficiency ✓ grown for phytoextraction of heavy metals like lead and cadmium in contaminated lands	Greece
Poplar	✓ rooting ability that makes it suitable for rhizoremediation ✓ tolerance in soil acidity and salinity ✓ fast-growing tree species native to temperate climate zones ✓ can be grown in low quality soil and requires a moderate soil pH ✓ can be used to clean contaminated, abandoned land, conserve soil by intensive rooting, humus accumulation and minimal nutrient removal.	Italy, Germany, Ukraine

	✓ it has a low tolerance to heavy metals ✓ may exhibit irreversible vitality loss during strong summer droughts	
Tall wheatgrass	✓ Can grow in saline soils ✓ Can be adapted to water stress ✓ Pest resistant	Spain
Lavender	✓ Can be adapted to low quality soil conditions ✓ Oil content is sensitive to water stress	Spain
Rye	✓ good adaptation to poor sandy and saline soils ✓ can tolerate cold climatic conditions ✓ can grow with low water availability	Spain
Reed canary grass	✓ suitable to grow in sandy soil ✓ well adapted to low fertilisation input	Latvia
Festulolium	✓ well adapted to Baltic countries ✓ can tolerate soil texture of heavy clay and stones and can grow with inconsistent soil moisture patterns throughout the year	Latvia
Willow	✓ resistant to pest, frost and diseases ✓ good saline tolerance ✓ can be used for phytoremediation	Ukraine

3.2 Good practice guidelines for the establishment and cultivation of industrial crops in marginal land

This section outlines a set of guidelines for future projects that involve the establishment and cultivation of industrial crops in marginal land. These are the result of the analysis of twelve Good Practice cases across Europe and include both success factors (enablers) and failures (barriers).

Table 3 Enablers and barriers for the cultivation of industrial crops as feedstock for biobased industries

Goop Practice Case	Enablers	Barriers
Switchgrass and giant reed in central Greece	• Long term plantations (20 years for switchgrass and 16 years for giant reed). • Establishment of pellet production. • Increased awareness of local farmers.	• Limited mechanisation
Black locust & sunflower in northern Greece	• Black locust was a well established plantation • Sunflower has been a treditional crop in the region for many years	• Limited mechanisation
Giant reed & cardoon in Catania	• Growing giant reed and cardoon in Catania, under highly contaminated soil conditions has been suceesful. • Transferring knowledge to the farming and local community about the successful cultivation of industrial crops and the respective substantial benefits in terms of environmental impacts and socio-economic issues and supporting ecosystem services compared to intensive monocropping systems.	• Availability of water for irrigation, considering the frequent dry seasons typical of Mediterranean areas, but also the inefficient irrigation infrastructures (e.g. losses of irrigation networks up to 65%). • Active involvement of farmers.

Goop Practice Case	Enablers	Barriers
Perennial grasses in Italy	• Positive environmental impacts on a global scale and provides benefit to the soil conditions, although it may contribute to the depletion of water resources • Effective water use due to deep rooting system allows cops to be cultivated in dry, arid climatic conditions.	• Difficulty in establishment when the climatic conditions are extremely arid during the first year. Irrigation maybe required.
Poplar in Italy	• Poplar has proven to be a Good Practice example to grow in contaminated lands with poor soil conditions such as soil acidity and salinity through its capacities of phytoremediation.	• The long distance between the poplar plantation sites where the land needs the phytoremediation and the industrial boilers sites where the wood chips are stocked and utilised. In this case, the longer the distance, the higher the environmental burden was when using these poplar wood chips.
Rye and Tall wheatgrass in Spain	• The demonstration of tall wheatgrass in the marginal lands area has shown the highest farm production with gross margin of 134-138 €/ha which is about a 12% increment in the gross farm production on marginal lands. Rye increased the gross margin of farm production by 4.5%. Similarly, tall wheatgrass has shown positive results increasing energy production and energy efficiency of the farm production system.	• There are no established markets for farmers to sell their produced biomass. Thus, the price/cost of biomass is estimated and there is limited understanding of actual price.

Goop Practice Case	Enablers	Barriers
Lavender in Spain	• Currently, market price is very profitable, a principal reason for why the cooperative wishes to continue the crop production.	• Although the prices have maintained a general profitability during the last decade, there have been some bad years where the prices provoked problems with the land rent.
Black locust and poplar Germany	• Planting black locust on severely disturbed post-mining areas despite low soil fertility can produce high biomass yields through a beneficial land-use system.	• Farmers are reluctant to cultivate black locust because they think it will be uneconomic.
Black locust in Hungary	• Creating new raw material opportunities by managing invasive species in floodplains	• The continuation of the case study faced difficulties once the funding ended.
Reed canary grass and Festulolium in Latvia	• In year 2013, hot and dry periods were interrupted by short and heavy rainfall and lack of moisture in July and August had negative impacts on development of plants.	• hot and dry periods were interrupted by short and heavy rainfall and lack of moisture. This had negative impacts on development of plants.
Willow in Ukraine	• Successful establishment of willow plantation at an agronomical level for bioenergy (heat and electricity) production at an industrial scale.	• Engaging the farming community and reassuring them the cultivation will provide good economic returns.
Miscanthus in Ukraine	• Miscanthus has been successfully established and facilitated the restoration of degraded low productive land which was not suitable for commercial agriculture.	• Lack of commercial interest as there are no biorefineries in the region

Text summarising the findings from the Table

3.3 Further reading

More detailed information from the findings of the research can be found in the following Magic Deliverables:

- von Cossel, M., Iqbal, Y., Scordia, D., Cosentino, S. L., Elbersen, B., Staritsky, I., van Eupen, M., Mantel, S., Prysiazhniuk, O., Maliarenko, O., Lewandowski, I. (2018): Low-input agricultural practices for industrial crops on marginal land (Deliverable D4.1). In: MAGIC project reports, supported by the EU's Horizon 2020 programme under GA No. 727698, University of Hohenheim, Stuttgart (Hohenheim), Germany. http://magic-h2020.eu/documents-reports/
- Alexopoulou E., Christou M., Eleftheriadis I. (2018) https://doi.org/10.5281/zenodo.3539166. 822 MAGIC Deliverable 1.5 "Handbook with fact sheets of the existing resource-efficient industrial crops"

4 Good Practice guidelines based on lessons learnt

This section describes Good Practice guidelines, based on the lessons learnt from the Good Practice cases in Magic, in terms of i) barriers and enabling factors for the rehabilitation of marginal land with the cultivation of industrial crops, ii) issues that influence their successful implementation per development stage of the value chains.

The guidelines are further categorised for their relevance to biophysical- environmental, economic and social attributes.

4.1 Barriers and enabling factors

Table 4 presents Good Practice guidelines, based on the lessons learnt through barriers and enabling factors across the three key attributes examined in Work Package 7, i.e., biophysical/ environmental, economic, and social. This provides evidence to policy and regional governments on what to pursue and what to avoid when planning actions for the cultivation of industrial crops in marginal land.

Table 4 Barriers and enabling factors for overcoming the marginality challenges

Key attribute	Barriers and Enabling factors
Biophysical/ Environmental	***Barriers*** Restoring marginal land with low input practices to keep low GHG emission levels can be very challenging since most cases require significant input to turn land to productivity. This can be particularly challenging in land with high contamination Establishment of perennials through dry arid climate without irrigation available for the first year
	Enabling Factors The cultivation of lignocellulosic perennial species facilitated improvements in contaminated land Regions surrounded by strong primary resource activities were more interested to undertake industrial cropping in marginal land
Economic	***Barriers*** Lack of long-term funding prohibited the continuation of Good Practice cases Low level of farming community- industry collaboration caused scepticism to farmers about the long-term economic viability of cultivating industrial crops in marginal land Financial uncertainty of the farmers/ landowners makes difficult to commit their time and resources for a medium to long term implementation
	Enabling Factors Strong and continuous public and private project fund acquisition.

	Availability of both public and private funds with simplified rules and procedures
Social	***Barriers*** Small scale of farming implies time-consuming and significant level of training, networking and complex interactions that delays the integration of the value chain to the agricultural systems Low level of collaboration/ interaction of farmers with the research community
	Enabling Factors Close relationship between the farmers/ landowners and the regional government. Availability of well-educated farmers/ landowners and good interactions with the research institutions. Growing public awareness about restoring marginal land with industrial crops for biobased products

4.2 Value chain development stages

The development of value chains for the rehabilitation of marginal land with the cultivation of industrial crops faces different challenges during the initial, development and maturity stages. These can be successfully overcome through a series of actions and practices which facilitate their compliance with environmental principles, enhance the opportunities for economic gains and enable their endorsement by the local communities.

Table 5 presents the most important lessons learnt, that can be used by other regions as Good Practice guidelines, from the analysis of the Good Practice case studies in Magic per development stage and key attribute.

Table 5 Key lessons learnt, that can be used by other regions as Good Practice guidelines, for overcoming marginality challenges per development stage and key attribute

	Initial stage	**Driving to maturity**	**Maturity**
Biophysical/ environmental	Address land use change transparently	Ensure low input/ low impact practices	Compliance with certification and regulations
		Location close to regions with high agricultural activity	Long term commitment of landowners
Economic	If financing is only dependent on public funding, then there is a risk of stopping the project at this stage	Start up financing from the industry creates better prospects for the longevity and commercial success of the value chains	Proximity to raw material users enables cost effectiveness
		Start up financing from the industry	

	Initial stage	Driving to maturity	Maturity
Social	Networking is of great importance; focus on bringing together farmers, landowners, researchers and the local community.	Facilitate openness and organise field visits during key stages of land restoration and crop productivity	Establish robust contractual relationships and effective, continuous communication channels between farmers/ land owners and raw material users
	"Open & participatory" approach that ensures efficient transfer of knowledge for the innovative practices required to cultivate industrial crops in marginal land	Improve skills and competences of farmers and local workers	Develop a broad network with institutions from the soil, agriculture and environment sectors both within the region/ country as well as cross-boundary.

5 Conclusions

This report presents Good Practice guidelines for the restoration of land with biophysical marginality and the key characteristics of crops that are suitable for such land types and can also provide feedstock for biobased sectors. Following the report outlines a set of Good Practice guidelines, based on lessons learnt. These include both barriers and enabling factors and as such provide rounded evidence to policy and regional governments on what to pursue and what to avoid when planning actions for the cultivation of industrial crops in marginal land.

The key enabling factors that can be used as guidelines include:

- ✓ The cultivation of lignocellulosic perennial species facilitated improvements in contaminated land.
- ✓ Regions surrounded by strong primary resource activities were more interested to undertake industrial cropping in marginal land
- ✓ Strong and continuous public and private project fund acquisition.
- ✓ Availability of both public and private funds with simplified rules and procedures
- ✓ Close relationship between the farmers/ landowners and the regional government.
- ✓ Availability of well-educated farmers/ landowners and good interactions with researchers.
- ✓ Growing public awareness about restoring marginal land with industrial crops for biobased products

While key barriers on which attention should be drawn for future potential applications are:

- ✓ Restoring marginal land with low input practices to keep low GHG emission levels can be very challenging since most cases require significant input to turn land to productivity. This can be particularly challenging in land with high contamination
- ✓ Establishment of perennials in dry climate conditions without irrigation is risky
- ✓ Low level of farming community- industry collaboration caused scepticism to farmers about the long-term economic viability of cultivating industrial crops in marginal land
- ✓ Financial uncertainty of the farmers/ landowners makes difficult to commit their time and resources for a medium to long term implementation
- ✓ Small scale farming implies time-consuming and significant training, networking that delays the integration of the value chain to the agricultural systems
- ✓ Low level of collaboration/ interaction of farmers with the research community