Marginal lands for Growing Industrial Crops

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Publishable executive summary

During the last decade, the concept of marginal land have received high attention both in research and policy formation. The Magic project aims to improve scientific evidence and create new knowledge based on the extensive experience of the project partners with the cultivation of industrial crops in land facing a range of biophysical marginality constraints across Europe.

Within this research framework, the work presented in this report, analyses success stories of selected industrial crops in European regions addressing biophysical/ environmental, economic, and social issues. The methodological approach provides a conceptual link of Value Chain Analysis (VCA), and a two- dimensional perspective (value chain's key attributes in the form of competitive priorities (CP) and their performance in the different development stages) to analyse a set of Good Practice cases that cultivate industrial crops in marginal land.

The work presented here, uses a set of indicators, and evaluates the performance of the understudy Good Practice cases in the land use and biomass production stages. Following it discusses the relevance (in terms of creating competitive advantages once applied properly) of the under study competitive priorities across the development stages.

Results from this analysis illustrate how the cultivation of industrial crops in land with low soil fertility, high salinity, sandy soils, unfavourable texture and stoniness, contamination, etc. can help overcome both the biophysical challenges but also the socio-economic ones with providing outlets to rural communities for supporting the provision of raw materials to the biobased sectors.

The findings aim to inform on performance of industrial crops in land with biophysical marginality and facilitate the development of policy recommendations and Good Practice guidelines to promote the appropriate sourcing of renewable materials from marginal land at local/regional level.

1 Introduction

Low input cultivation of industrial crops in marginal land can provide raw materials for high added value biobased products and bioenergy. The research in Magic analyses the sustainable development of resource-efficient and economically profitable industrial crops grown on land with biophysical marginality across Europe.

The work in Work Package 7 (WP7) analyses success stories of selected industrial crops in European regions addressing biophysical/ environmental, economic and social issues. This will facilitate the development of policy recommendations and Good Practice guidelines to promote the appropriate sourcing of renewable materials from marginal land at local/regional level.

This report for Deliverable 7.2, capitalises on the findings from Task 7.1 Mapping Good Practices and the respective Deliverable 7.1 Good Practices and further:

- Specifies the methodological approach used for analysing the development path of the Good Practices.
- Analyses the Good Practice cases presented in Deliverable 7.1, and addresses biophysical/environmental, economic and social issues within the respective regions.

The work combines desk study, stakeholder interviews and consultations with regional actors. The deliverable analyses performance across a consistent set of indicators, addresses competitive priorities and further highlights successes and obstacles.

2 Methodology

The work provides a conceptual link of Value Chain Analysis (VCA), and a two- dimensional perspective (value chain's key attributes in the form of competitive priorities (CP) and their performance in the different development stages) to analyse a set of Good Practice cases that cultivate industrial crops in marginal land.

2.1 Value chain analysis

Value chain analysis (VCA) applies a systemic analysis which disaggregates value chain activities[1] to better understand challenges and identify practices which can overcome them and create competitive advantages[2]. In Magic, this approach enables more targeted evaluation of the complexity of restoring land with biophysical restrictions and introducing the cultivation of industrial crops for biobased markets.

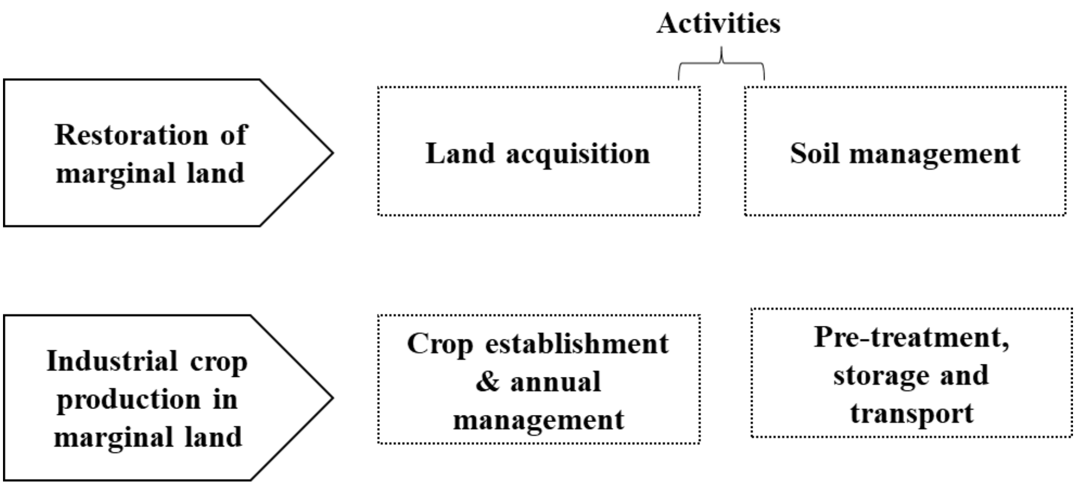

Figure 1*:* Organisational structure of activities within the land use and biomass production stages (adapted from Panoutsou et al., 2020)

Due to the nature of the research in the Magic project we have focused the analysis in two value chain stages (Figure 1): i) restoration of marginal land and ii) industrial crop production in such land types. The respective activities within the value chain stages include i) land

[1] M.E. Porter. Competitive Advantage: Creating and Sustaining Superior Performance, vol. 167 (1985)
[2] C. Panoutsou, A. Singh. 2020. A Value Chain Approach to Improve Biomass Policy Formation. Global Change Biology Bioenergy. (2020), 10.1111/gcbb.12685

acquisition and soil management and ii) crop establishment, annual management, pre-treatment, storage and transport.

2.2 Competitive Priority Theory

The analysis for Good Practices in Magic evaluates the organisational capabilities within the selected cases in the form of competitive priorities related to human capital, biophysical-environmental, economic and social terms and discusses how these help the Good Practice cases achieve an appropriate level of sustainable competitive advantage.

Both the selection of competitive priorities and baseline assumptions are established through own research[3] (Panoutsou et al., 2020) and validated by a tailored stakeholder online survey. We have identified five main competitive priorities: flexibility, quality, cost, innovation, and transparency, which are important to optimise the supply chain performance, overcome challenges and develop competitive advantages.

- Flexibility is the ability to expand or adjust capacity volume and adjust product design, range and variety[4]. Flexibility is essential firstly to ensure a broad, year- round biomass supply that can be adapted to local ecology and climate and secondly to adjust conversion pathways and scales of implementation to convert raw materials with variable qualities to energy, fuels and biobased products.

- Quality is defined as improving process and product performance and adherence to quality standards. Quality of raw materials, practices and end products are important for successful establishment and uninterrupted operation throughout the value chain lifetime[5].

- Cost addresses the reduction of production costs of goods sold as well as generating added value[6]. The competitiveness of biomass value chains relies on the costs of the

[3] Panoutsou, C., Singh, A., Christensen, Th., and L., Pelkmans. 2020. Competitive priorities to address optimisation in biomass value chains: The case of biomass CHP. Global Transitions. Volume 2, 2020, Pages 60-75; https://doi.org/10.1016/j.glt.2020.04.001
[4] Díaz-Garrido, E., M.L. Martín-Peña, and J.M. Sánchez-López, Competitive priorities in operations: Development of an indicator of strategic position. Journal of Manufacturing Science Technology, 2011. 4(1): p. 118-125 DOI: https://doi.org/10.1016/j.cirpj.2011.02.004
[5] Fritsche, U. and L. Iriarte, Sustainability criteria and indicators for the bio-based economy in Europe: State of discussion and way forward. Energies, 2014. 7(11): p. 6825-6836 DOI: https://doi.org/10.3390/en7116825
[6] Saarijärvi, H., H. Kuusela, and M.T. Spence, Using the pairwise comparison method to assess competitive priorities within a supply chain. Industrial Marketing Management, 2012. 41(4): p. 631-638 DOI: https://doi.org/10.1016/j.indmarman.2011.06.031

individual stages with land use and biomass production accounting for almost half of the total. Creating value and improving costs along the chain is important for the viability and commercial implementation especially when highly innovative components are involved[7].

- Innovation addresses the development of innovative equipment and processes[8]. With biomass being one of the key resources for the low carbon circular economy[9], innovation is the cornerstone defining which value chain configurations perform best technically whilst being sustainable and resource efficient.

- Transparency is defined as current information about status of system and immediate notification of unexpected event. Sustainability[10] and avoidance of displacing other activities or product sectors is of paramount importance to any development in the biomass sector. Including transparency in the competitive priorities of biomass value chains is therefore essential to improve clarity and awareness of the benefits from their implementation as well as create trust among society.

2.2.1 Baseline assumptions

(adapted from: Panoutsou et al., 2020)

Land use: Restoration of marginal land requires careful assessment of specialised practices and input required for each type of marginality. All cases are region and climate specific and provisions must be in place for any further marginality risks due to projected, climate change or human activity induced conditions. The main activities in this stage are land acquisition and soil management. Decision makers face challenges including the need to avoid displacement of other land-based activities once the land is restored and the need to ensure sustainable, low-input practices that improve soil quality. The competitive priorities examined in Magic for this stage are quality, cost, innovation and transparency.

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[7] Lee, H.L., Aligning supply chain strategies with product uncertainties. California management review, 2002. 44(3): p. 105-119 DOI: https://doi.org/10.2307/41166135
[8] Torjai, L., J. Nagy, and A. Bai, Decision hierarchy, competitive priorities and indicators in large-scale 'herbaceous biomass to energy'supply chains. Journal of Biomass Bioenergy, 2015. 80: p. 321-329 DOI: https://doi.org/10.1016/j.biombioe.2015.06.013
[9] S2Biom. 2015a. Consistent Cross-Sectoral Sustainability Criteria & Indicators. IINAS, p. (also available at http://www.s2biom.eu/
[10] FAO.2019. Indicators to monitor and evaluate the sustainability of bioeconomy. http://www.fao.org/3/ca6048en/ca6048en.pdf

Biomass production. Industrial crop production in marginal land presents challenges both for the selection of crop species that are tolerant to the marginality conditions but also for managing to achieve economically attractive yields whilst ensuring low input agricultural practices throughout the plantation lifetime. This stage includes the following activities: crop establishment and management, harvesting, pretreatment (chipping, drying, milling, briquetting, etc.), storage and transport.

Table 1 Competitive priorities that can lead to sustainability and resource efficiency within biobased value chains (*adapted from Panoutsou et al., 2020*)

		Land Use	**Biomass Production**
Flexibility			✓
Quality		✓	✓
Cost		✓	✓
Innovation		✓	✓
Transparency		✓	✓

Crop establishment and management practices must recognize and enhance biodiversity, enable low input cultivation systems, and minimise intensity of the applied practices. The competitive priorities examined in this paper for this stage are flexibility, quality, cost and innovation.

Transparency is also important; in the case there is higher application of phytosanitary products is required the farmer must report it as this would imply a higher CO_2 footprint and could affect the final biobased product composition, biodiversity, etc.

2.2.2 Stakeholders' responses

Fifty -eight stakeholders across Europe (farmers, logistics companies and local community) have been contacted throughout the surveying process (Table 2). They were requested to rank the importance of the five competitive priorities for the development of land use and biomass production stages.

Table 2 Stakeholder groups contacted during the surveying

Stakeholders contacted	Number	Country
Farmers	**40**	
Farmers (incl. representatives from cooperatives)	29	UK, BE, S, I, RO, BG, HUN, SI, DE, FIN, HR, BG
Landowners (incl. associations)	11	BE, UK, FR, FIN
Value chain actors	**5**	
Logistics companies	5	FR, DE, I, UK, RO
Local community	**13**	
Innovation clusters	3	NL, DE, UK
Local government	4	
Local business owners	2	UK, FR
NGOs	4	BE, DE, UK, BG

The figures below present their ranking across all case studies for the importance of competitive priorities in the land use and biomass production stages.

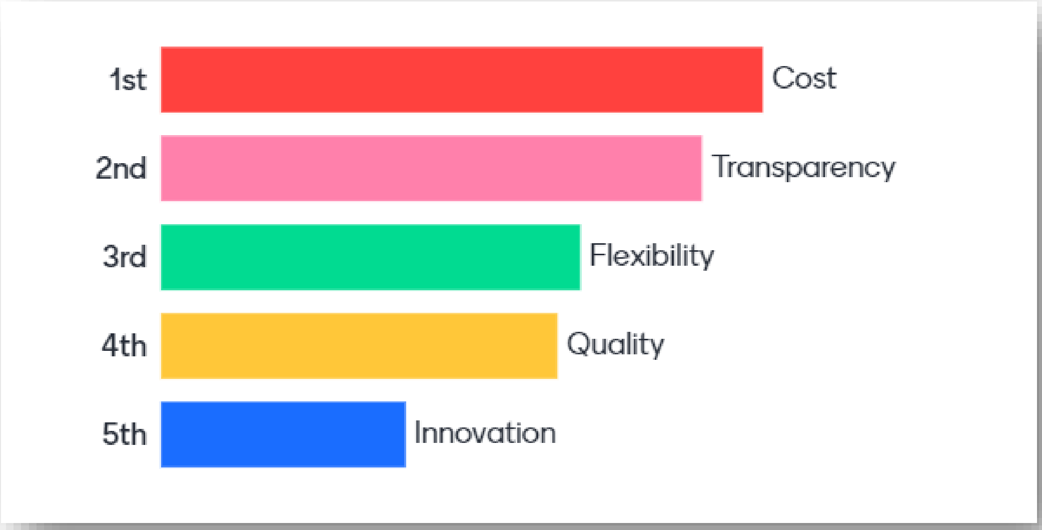

Figure 2 Stakeholders ranking of competitive priorities' importance in the land use stage

Cost and transparency have been identified by stakeholders as the key competitive priorities for land use.

Cost refers primarily to the funds required to restore the land and prepare it for crop cultivation.

Transparency refers to providing clear and transparent documentation for any direct or indirect land use change that might occur during the restoration of land that is categorised as marginal.

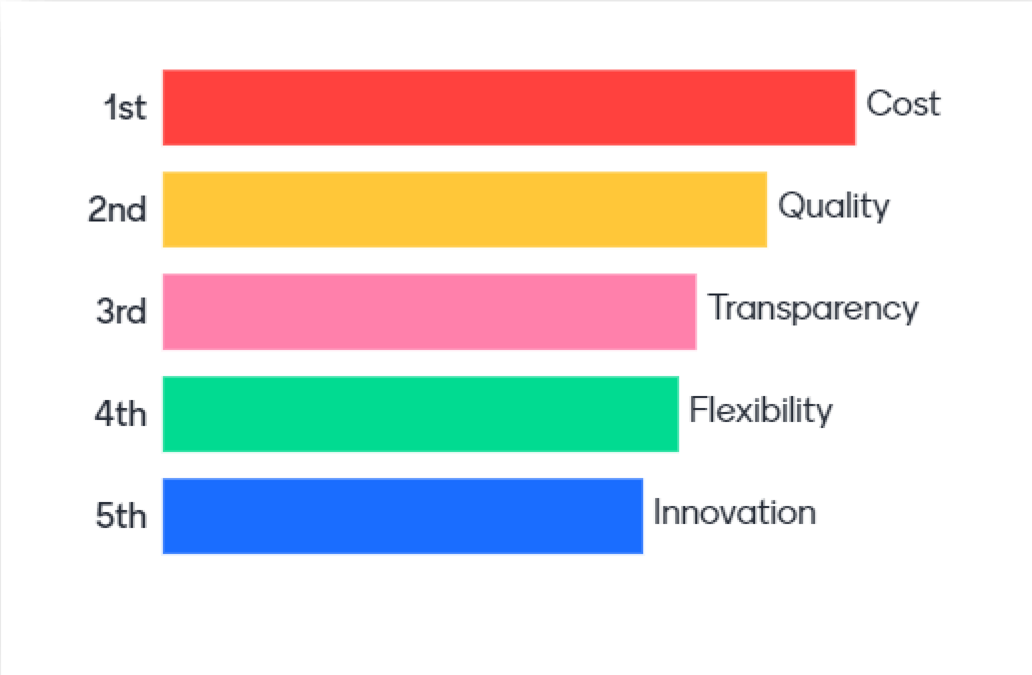

Figure 3 Stakeholders ranking of competitive priorities' importance in the biomass production stage

Cost and quality have been identified by stakeholders as the key competitive priorities in the biomass production stage.

Cost refers to the production costs of the raw materials aiming to ensure they are balanced and they can provide an economically attractive option for farmers when compared with the potential market prices the respective raw materials can get when they are sold to biobased industries.

Quality refers firstly to the low impact of the applied agronomic practices to ensure no harm to soil and water resources as well as to the material inputs (e.g. fertilisers, pesticides, etc.) which are added carefully accounting for biodiversity, air and water quality.

2.3 Biophysical-environmental, economic, and social attributes

Key attributes of the value chains with industrial crops in marginal land involve biophysical-environmental, economic, and social issues which are relevant for their improved performance. These are briefly described in Table 2 below and matched with the key challenges they can help overcome.

Table 3 Biophysical-environmental, economic, and social attributes, their relevance with competitive priorities and which marginality challenges they can improve or overcome

Competitive priority	**Challenges the attributes can improve**		
	Biophysical-environmental	**Economic**	**Social**
Land Use			
Quality	Improve soil carbon Increase water retention Remediate contamination Avoid water infiltration and avoid the possibility of subwater pollution (which here usually leads to the eutrophication of lakes and rivers)		Health and safety during operations
Cost	Lower restoration costs through innovative agronomic practices	Avoid displacement of other land-based activities	
Innovation	Safeguard low soil compaction Improve low soil carbon		New business partnerships for biomass producers
Transparency	Low impacts land use changes		

Competitive priority	Biophysical-environmental	Economic	Social
Biomass production			
Flexibility	Biodiversity	Diversification of crops/ additional income opportunities	New skills and knowledge for farmers
Quality	Low emission levels or pollution discharge from pre-treatment Reduced carbon footprint of storage & transport		Health and safety during operations
Cost		Year-round, sustainable biomass supply Reduce costs for logistics	Income opportunities
Innovation	low input & less intensive cropping practices	Improved Technological Readiness Level (TRL)	Improved skills and knowledge

This report uses traffic light colour coding to reflect the relative strength and importance of each key attribute in the progress and performance of the value chain. The traffic light colour coding provides a qualitative interpretation of responses by the interviewees from the cases and region as well as the partners from the Magic project. The code is as follows:

Low	Moderate	High

2.4 Key performance indicators for Good Practices

Indicators are quantitative or qualitative factors or variables providing means to measure achievement, to reflect changes, or to help assess performance or compliance, and - when observed periodically - demonstrate trends. Indicators should convey a single meaningful message (information). Indicators have to be judged on the scale of acceptable standards of performance. Closely related indicators are **verifiers** which provide specific details that would indicate or reflect a desired condition of an indicator. They are the data that enhances the specificity or the ease of assessment of an indicator, adding meaning, precision and usually also site-specificity.

The Good Practice performance has been assessed with individual indicators grouped under the biophysical- environmental, economic, and social attributes.

Several indicators have been adapted from the Eurostat list of Agri-environment indicators[11] and the list of CAP impact indicators[12]. Others are also derived from the GBEP sustainability indicators for bioenergy[13] and the key criteria and indicators listed in the Biomass Futures project[14] and Biomass Policies project[15]. They were also aligned with other on-going projects like S2BIOM[16] and BioTrade2020+[17]. Table 2 presents the indicators as broken down by stage of the value chain (from restoring land, to primary biomass production) which are used to evaluate different attributes quantitatively or qualitatively. These are:

- Quantitative: indicator can be monitored through a unit of measurement
- Qualitative: indicator can be monitored based on negative to positive impact scale assessment
- Descriptive: provides information about key characteristics not easy to compare but relevant for assessing the value chain

[11] https://ec.europa.eu/eurostat/web/agri-environmental-indicators/indicators
[12] EU Commission (2014) REGULATION (EU) No 834/2014 Common Agricultural Policy Impact Indicators, https://ec.europa.eu/agriculture/cap-indicators_en
[13] GBEP (2011). The Global Bioenergy Partnership sustainability indicators for bioenergy. December 2011
[14] U. Fritsche et al. (2012). Sustainable bioenergy: key criteria and indicators. Deliverable D4.1 of the Biomass Futures project (IEE).
[15] www.biomasspolicies.eu
[16] www.s2biom.eu
[17] www.biotrade2020plus.eu

Table 2 Key performance indicators for Good Practices

Good Practice attribute	Indicator	Value Chain Stage	Quantitative	Qualitative	Descriptive
Biophysical-environmental	Crop drought resistance	Biomass Production			√
	Crop installation	Biomass Production			√
	Bioremediation	Land use	√		
	Life cycle GHG emissions reduction	Full value chain	√		
	Agroforestry opportunities	Biomass Production			√
	Rotation/soil cover	Land, Biomass Production	√		√
	Tillage	Biomass Production			√
	Land use	Land	√		
	Soil erosion	Land	√	√	
	Biodiversity	Land, Biomass Production	√		
	Water use	Biomass Production	√		
Economic	Infrastructural accessibility	Land, Biomass Production	√		
	Levelised life cycle costs	Land, Biomass Production	√		
	Profitability	Land, Biomass Production	√		
	Diversification of rural industry	Land, Biomass Production	√		
	Agricultural income	Land, Biomass Production	√		
Social	Demographic composition	Land, Biomass Production	√		
	Social awareness and capital	Land, Biomass Production	√		
	Employment footprint	Land, Biomass Production	√		

2.4.1 Biophysical- environmental

2.4.1.1 Crop drought/salinity resistance

Descriptive

Different crops have different thresholds for withstanding soil sodium salinity.

Lack of watered soil is usually accompanied with high salinity levels and each crop has a certain threshold resistance. A distinction is made between plants able to tolerate only low levels of salinity (glycophytes) and those really adapted to saline soils (halophytes). Here we may include the cultivation of tolerant crops for reclaiming salinized soils, however, most crops are glycophytes and able to withstand only moderate levels of salinity, and only a few can be considered halophytes[18]. Some plants can perform ***reverse salinisation*** by accumulating salts in their cells and/or secreting it through specials organs. The idea implies the later disposal of the above ground material and the continuous growing of them to reverse salinization levels and reclaim salinized lands.

In southern countries such as Spain salinity is not usually associated with soil type, but just with the lack of water. This can be mitigated by increasing soil organic coverage, which maintains water contents or by growing crops with a higher rooting capacity.

2.4.1.2 Crop installation techniques

Descriptive

Plantations can be done using seedlings. Root cuttings, shoots and grafts may be used for propagation. Before sowing, seeds can be scarified, and processed by grinding sand, grating or by treating with boiling water. They can be placed to a certain depth. Then seedlings can be dug up and placed in a permanent place. Planting can be done by hand or using a planting machine.

Perennial energy plants that reproduce by seeds shall be sown in rows using grain-grass drills. Immediately after seeding (especially for small-seeded plants) rolling the soil

[18] Oenema, O., Heinen, M., Rietra, R., Hessel, R. (2017) A review of soil-improving cropping systems, Soilcare for profitable and sustainable crop production in Europe

surface with smooth rollers shall be done. This improves seed contact with the soil and provides its best germination.

2.4.1.3 Crop bioremediation of heavy metals

Quantitative

Marginality of land can often be attributed to land with contamination from landfill and waste disposal, heavy metals or post-mining operations, war affected zones, transport spills, and storages of chemical substances such as oil or obsolete chemicals. There are for four main metals: cadmium, zinc, lead and nickel. Cadmium has several more anthropogenic sources. It is a widespread contamination problem as it occurs where too intensive phosphate fertilisation has taken place. It is a large contamination problem worldwide[19] with at least 340,000 sites contaminated with metals and oil in Europe, 80,000 in Australia and at least 20 million hectares of farmland contaminated with heavy metals in China. Soil characteristics are very influential on whether plants can take up metals easily, particularly the pH level is key which is strongly influenced by levels of calcium.

Phytoremediation, or bioremediation, is a set of remediation techniques based on the use of tolerant plants and their microorganisms to decrease pollution risks due to excessive contaminants in soils, water, and sediments. A key target is to choose appropriate plants that are able to contain soil contamination, since marginal lands have already lower agricultural value. Miscanthus is an example of a non-food crop with the capacity to accumulate trace elements in roots, limit its transfer to shoots, promote degradation of organic xenobiotics and improve soil quality of contaminated sites[20].

Soil contamination from heavy metals and other pollutants can be dealt with by 1) withdrawing pollutants with phyto-remediating crops[21], 2) amending soil to stimulate biological breakdown or lock-up organic pollutants, and 3) growing bio-energy crops.

Indicators are changes in ***1) heavy metal content in soil, 2) percentage of critical load exceedance by sulphur and nitrogen, 3) concentration of persistent organic pollutants, and 4) topsoil pH. Extraction of soil pollutants is measured in µg kg-1.***

[19] FAO (2015) Status of the world's soil resources, http://www.fao.org/3/a-i5228e.pdf

[20] Nsanganwimana, F., Pourrut, B., Mench, M., Douay, F. (2014) Suitability of Miscanthus species for managing inorganic and organic contaminated land and restoring ecosystem services. A review, *Journal of Environmental Management*, 143: 123-134

[21] Šyc, M., Pohořelý, M., Kameníková, P., Habart, J. (2012) Willow trees from heavy metals phytoextraction as energy crops, *Biomass and BioenergyBiomass and Bioenergy, 37:106-113*

2.4.1.4 Life cycle greenhouse gas emissions reduction potential

Quantitative/Comparative to fossil fuel reference

Greenhouse gas (GHG) emissions, with the main greenhouse gases being CO_2, methane (CH_4) and nitrous oxide (N_2O), have to be considered over the full value chain (biomass supply – logistics – conversion – distribution – use).

They are typically expressed in ***% GHG reduction***. Sub-indicators are expressed in ***kg CO_2-equivalent per tonne and /or per GJ outputs***.

As the combustion of biomass is considered CO_2-neutral (the emitted carbon has been absorbed from the atmosphere during plant growth), the GHG balance mostly concerns the use of fossil energy in the chain, e.g. for transport, external heat, electricity or fossil inputs (e.g. fertilisers, phytochemicals, etc). In some cases, CH_4 and N_2O emissions need to be considered, when dealing with land use and agricultural processes, or even the production of fertilisers (more important for non-woody biomass). However, positive LUC effects occur when cropping leads to higher soil organic matter content, thus having a net greenhouse gas emissions reduction. This is known as carbon stock changes, which are annualised in a 20-year time frame.

Fossil fuel reference: reference situation where the same services are produced (heat, electricity, transport fuels and materials) for fossil fuels.

Eurostat baseline: Greenhouse gas emissions should be reduced by 20% compared to 1990.

2.4.1.5 Land improvement by agroforestry input

Descriptive

Agroforestry is the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions (den Herder et al, 2016). This indicator is linked to cropping rotation systems, nitrogen use efficiency, erosion rate, contour planting, since alley cropping systems are multi-purpose and represent a low-input system with a reduced demand of fertilisers, water and manpower, attributes which are highly desirable for low fertile soils or reclamation sites[22]. There are five basic types of agroforestry in European temperate areas: silvoarable

[22] Quinkenstein, A., Wöllecke, J., Böhm, C., Grünewald, H., Freese, D., Schneider, B.U., Hüttl, R.F. (2009) Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Environmental Science & Policy, 12 (8), 1112-1121.

agroforestry, forest farming, riparian buffer strips, silvipasture, improved fallow and multipurpose trees[23].

Silvoarable agroforestry involves widely spaced trees inter-cropped with annual or perennial crops, comprising alley cropping, scattered trees and line belts. Systems can be mixed dense, mixed sparse, laid in strips or in boundaries, overlapping or separate in temporal arrangements, with either low, medium or high technological level inputs, commercial, intermediate or subsistence management level. Functions range from provisioning services to habitat functions, to regulating and finally cultural functions[24].

The AGFORWARD project (Agroforestry for Europe) contains 10 Best practice leaflets for reference on how to operationalise alley cropping systems, choosing the right site and tree species, planting material, protecting trees against wildlife damage, preparing land, and mulching strategies.

2.4.1.6 Land improvement by rotations/soil cover

Descriptive

Soil cover, i.e. periods of the year when soil is covered by crops, including catch/cover crops, is important for preventing nutrient and pesticide runoff. In addition, soil cover may improve soil fertility and reduce the risk of soil erosion. These impacts are linked with information about intercropping and tillage systems. Cover crops can provide vegetative cover between rows of main crops or between periods of arable crops. They can also function as catch crops, which incorporate the remaining nitrogen after the main crop is harvested, thus reducing losses from leaching[25]. Crop rotations contribute to conservation agriculture techniques aimed at targeting the upper 0 – 20 cm zone of soil and prevent it from further degradation and erosion[26].

Cover crops are crops grown mainly to reduce soil erosion by covering the ground with living vegetation and living roots that hold the soil.

Green manure crops are crops grown to help maintain soil organic matter and fertility.

[23] Mosquera-Losada, M.R., McAdam, J., Romero-Franco, R., Santiago-Freijanes, J.J., RigueroRodríquez, A. (2009) Definitions and components of agroforestry practices in Europe. Agroforestry in Europe: Current Status and Future Prospects, 3-19.

[24] den Herder, M., Burgess, P., Mosquera-Losada, M.R., Herzog, F., Hartel, T., Upson, M., Viholainen, I., Rosati, A. (2015) Preliminary stratification and quantification of agroforestry in Europe, AGFORWARD Agroforesty in Europe

[25] Ten Berge, H. F. M., Schröder, J. J., Olesen, J. E., Giraldez Cervera, J. V. (2017) Research for AGRI Committee - Preserving agricultural soils in the EU, Policy Department for Structural and Cohesion Policies, European Parliament

[26] Shahid, S. A. and Al-Shankiti, A. (2013) Sustainable food production in marginal lands – Case of GDLA member countries, International Soil and Water Conservation Research¸1, 1: 24-38

Catch crops are crops grown to retrieve remaining nutrients in the soil following a cash crop, prevents nutrient loss over the winter. Statutory catch crops, i.e. under sown grass or crucifers sown just before or after harvest and ploughed before sowing the next crop, are included in the legislation in some countries to reduce nitrate leaching during autumn and winter.

Overall environmental impacts of soil cover on biotic and abiotic resources are the following: green cover and mulch provide habitats from many species and both contribute to the increase of soil fauna and flora by nutrients, more carbon dioxide gets fixed by crops and intercrops, soil fertility leads to a decrease of N_2O release, covered land lowers the risk of losing nutrients and decreases runoff and water erosion, finally cover crops slow down and potentially reverse degradation processes.

2.4.1.7 Land improvement by tillage practice

Descriptive

Marginal lands can be improved according to either ***conventional, conservation/reduced or zero/no tillage***[27].

Conventional tillage includes inversion ploughing whereas conservation tillage foregoes the use of ploughs and is characterised by direct sowing (also called direct drilling or no-tillage), reduced tillage (also called mulch tillage or minimum tillage), zone, strip or row tillage, surface incorporation of crop residues and cover crops.

Links to other indicators: The information about tillage practices helps assess other indicators as such on-soil cover, risks of nitrate leaching, and organic matter of soils. Any disturbance of soils may enhance turnover of nutrients and thereby increase the potential risk of loss of, for example, nitrogenous compounds and phosphorus through surface runoff and soil erosion. No - and reduced tillage (NT and RT) can diminish springtime run-off and erosion, provided the soil is sufficiently covered. However no-tillage combined with no soil cover can result in a significant increase in water erosion. Soil compaction occurs when mechanical pressure is applied, especially in wet conditions. It is assumed that with no-tillage, the number of tractor passages decreases significantly, which is not always true under reduced tillage. The reduced number of tractor passages on fields under NT or RT should result in a reduced compaction risk. Zero tillage is a fundamental principle of conservation agriculture where low disturbance seeding techniques for application of seeds and fertilizers gradually

[27] Shahid, S. A. and Al-Shankiti, A. (2013) Sustainable food production in marginal lands – Case of GDLA member countries, International Soil and Water Conservation Research¸1, 1: 24-38

increases organic matter of the surface layers because of reduced biological oxidation compared to conventionally tilled soils[28].

Additionally, reduced tillage may in the short-term lead to increased use of herbicides in order to compensate for the reduced mechanical weed control. Further, reduced tillage may contribute to carbon sequestration in soil and thereby impact soil organic carbon levels as well as the emissions of greenhouse gases (GHG).

2.4.1.8 Land use: footprint by sustainable harvest levels

Quantitative

This indicator is relevant for the harvest of trees, wood resources and the removal of wood harvest residues (including stumps), but also the removal of agricultural residues such as straw and stubbles and pruning residues from permanent crops. This indicator links to the soil organic carbon indicator (also included in carbon stock change for GHG emissions) but goes further as it also includes above ground carbon storage (in biomass).

The annual harvest of wood, agricultural and biomass resources (materials and energy) is expressed as ***a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy***. In a sustainable harvesting situation, long-term harvest levels should remain lower than net growth and forests or arable lands are allowed to expand their carbon storage. If not, there may be net depletion of biomass stands, meaning that it can't be considered a 'renewable' resource.

2.4.1.9 Soil erosion rate and linked prevention practice

Quantitative and qualitative

This indicator expresses the risk for soil erosion and depends on location and soil type. Perennial crops have a lower risk than rotational crops by providing soil structure and stability and soil quality and biodiversity as compared to annual species. Perennial grass species such as giant reed and Miscanthus help to contain soil erosion in sloping areas, increase carbon storage in the soil, and provide lignocellulosic biomass for energy and advanced biofuels[29]. Removal of stumps in forestry practices creates high erosion risk.

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[28] Dumanski, J., Peiretti, R., Benites, J. R., McGarry, D. & Pieri, C. (2006) The Paradigm of Conservation Agriculture, *Proceedings of World Association of Soil and Water Conservation,* P1: 58-64
[29] Cosentino, S. L., Copani, V., Scalici, G., Scordia, D., Testa, G. (2015) Soil Erosion Mitigation by Perennial Species Under Mediterranean Environment, *BioEnergy Research,* 8(4): 1538-1547

This indicator can be measured as the ***estimated rate of soil loss by water erosion in t ha-1 / year-1.***

If the rate of erosion cannot be calculated, there are certain biomass types, indicators (such as tillage, agroforestry, nutrient recycling, mulching…etc.) and practices which can highlight whether there is a general high risk, no link or reverse impact on soil erosion.

Indicative qualitative scoring:

--	High risk for soil erosion when growing and harvesting this type of biomass and using this type of practice(s)
o	No relation to soil use
++	Growing and harvesting this type of biomass with this type of practice(s) declines the risk of soil erosion

2.4.1.10 Water use: footprint measured by water use efficiency

Quantitative/comparative to biomass reference

Water use for biomass production, irrigation and processing is calculated in ***m^3 water / GJ outputs***.

In the case of marginal lands, water levels can already exhibit high stress or depletion rates. Negative environmental consequences of excess irrigation and additional water depletion from newly established cropping activities with deep rooting crops or trees can occur.

However, certain cropping systems can increase either groundwater or watershed levels.

Water availability is a sub indicator which can monitor this change: water footprint, together with existing agricultural, industrial and human water uses must not exceed the average replenishment from natural flow in a water.

Water use efficiency can also be measured during the primary biomass production stage in order to assess how a particular crop performs in terms of water needs.

2.4.2 Economic

2.4.2.1 Infrastructural accessibility

Descriptive

According to FAO-CGIAR land classifications, there is a higher probability for larger land degradation where there is higher population pressure and demand for land. Degraded marginal lands are more likely to occur in central locations rather than remoter ones, unless degradation occurs through land abandonment and encroachment of shrubs increasing chances for forest fires. Socio-economic limitations have a clear influence on the development opportunities of regions, particularly where they occur in combination with biophysical limitations. Furthermore, the more remote/decentral regions are located, the higher chance there is for abandonment of farmland with biophysical limitations. Remote location should be seen as an additional complicating factor for part of the marginal lands.

One sub-indicator is the designation of either a peri-urban, rural or deep-rural zone, based on the FARO project[30] which combines indicators on agricultural land use, accessibility, population and economic activity density.

2.4.2.2 Levelised life cycle costs

Quantitative

In terms of economics we should consider the ***levelised life cycle costs*** of the bioenergy carriers and biomaterials, in comparison to the reference (usually fossil counterpart), where possible distraction of subsidies or support systems should be made.

The outcome expressed in ***€/GJ or tonne of outputs*** is compared to the reference providing the same services (electricity, heat, transport fuels, products). Different components of the costs are biomass processing, CAPEX (investment costs, for a certain annual capacity) and OPEX (operating costs) in terms of feedstock costs and other costs.

2.4.2.3 Profitability relative to size of market, trade and investments

Quantitative

The ***profitability (gross and net profit) per ha, per tonne of raw material used,*** in relation to the total is an indicator used for the upstream section of the value chain.

Targeted markets of the products and services can range from small niche (e.g. specialised products) to very large worldwide markets. When focusing on small niche markets (e.g. specialised products), these markets may saturate quite fast, which complicates the roll-

[30] van Eupen, M., Metzger, M.J., Pérez-Soba, M., Verburg, P.H., van Doorn, A., Bunce,R.G.H., (2012) A rural typology for strategic European policies, Land Use Policy, 29, 473–48

out of these technologies. In large worldwide markets (e.g. energy/fuels) there are more opportunities to find customers.

A sub-indicator of ***export potential and complementary industries*** can evaluate the potential of exporting the feedstock or biomaterial due to high market demand and the potential to support more than one industry. The ***market size*** to valorise outputs can be used: from a niche market (<1000 tonnes/year worldwide to worldwide market (~1 million tonnes/year worldwide) to a large worldwide market (>100 million tonnes/year worldwide).

2.4.2.4 Diversification of rural industry and enterprise

Descriptive

Diversified rural industry and enterprise can positively impact the economy of rural areas. Diversified value chains can induce more regional job creation, stimulate the rural economy, while other value chains may be more directed to large scale industry, often in the hands of international players/multinationals.

The re-allocation of some of a farm's productive resources, such as land, capital, etc., for new value-adding activities can reduce the risk of changing markets, consumer demand, government policy or climate change. Diversifying output can be an opportunity to exploit existing infrastructure, knowledge, human resources, and equipment.

The diversification indicator will be the assessment of ***a range of end product options*** for farmers in rural agricultural industry options and ***the economic viability of such diversification***. Economic analysis studies may lack for certain cases however similar cases can be used as a basis of comparison.

2.4.2.5 Agricultural income compared to national average

Quantitative

What is the capacity of farmers to reimburse capital, pay for wages and rented land, and reward their own production factors? What is the level of policy support?

Agricultural factor income measures the remuneration of all factors of production (land, capital and labour) regardless of whether they are owned or borrowed/rented and represents all the value generated by a unit engaged in an agricultural production activity. It represents the net value added at factor costs.

Agricultural factor income = value of agricultural production – variable input costs – depreciation – total taxes + total subsidies

To compare to a national average, income per annual work unit (AWU) is used to correspond to one person occupying an agricultural holding (defined as a single unit both technically and economically operating under a single management to grow crops, for plant propagation or animal production) on a full-time basis. ***This index is available in: Eurostat Economic Accounts for Agriculture, Indicator A.***
Unit of measurement: EUR/AWU

2.4.3 Social

2.4.3.1 Role composition of regional actors

Descriptive
Indicators identifying whether regional actors involved represent all four corners of society or whether one is lacking between:

- ***researchers***: research institutes, universities, technology centres, technology platforms, agricultural students and EU projects
- ***farmers & landowners***: young farmers, foresters, land owners, associations, cooperatives, unions
- ***extension service providers & government***: agricultural chambers, ministries, regional government and authorities from sectors like agriculture, waste, circular economy, industry, rural development, EIP-AGRI, other thematic networks, operational groups
- ***businesses and industry representatives***: all bio-based industries including small and medium enterprises, and investors

Such multi actor initiatives are analysed based on the principles of the quadruple helix approach which beyond the 'triple helix' components of university, industry and government also recognises the important role of the society in the process of sustainable development of knowledge[31].

[31] Carayannis E. G. and Campbell D. F. J. (2010) Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology, International Journal of Social Ecology and Sustainable Development 2010, 1(1):41–69

2.4.3.2 Awareness through social capital or community bonds

Qualitative and descriptive

Indicators assessing the level of awareness within a holding, community or industry can range from presence of non-governmental organisations which act as facilitators of local group formation, farmer field-schools which act as models for social learning and high level cooperation for sharing agro-ecological principles and farmer groups partnering with research institutions to help them become more responsive to local needs and create additional local value by working on technology generation and adaptation[32].

Awareness is also represented through social capital structures: such as norms, trust and bridging and bonding relationships[33]. These are complex to quantify, however they can be qualitatively assessed through processes of meetings, exchanges, and regular interaction which can happen at community events, social media platforms and partnerships.

--	Low social capital: low bonding or bridging social capital, low levels of combined trust, norms and network relationships, low representation of relevant stakeholders and very little legitimacy in partnership decision-making process
-	Average social capital: bonding but not bridging social capital, average levels of combined trust, norms and network relationships but only average representation relevant stakeholders and lacking complete diversity and political legitimacy in partnerships
+	High social capital: bonding and bridging social capital, high levels of combined trust, norms and network relationships, high degree of representation of relevant stakeholders, and procedural and political legitimacy in partnership decision-making process

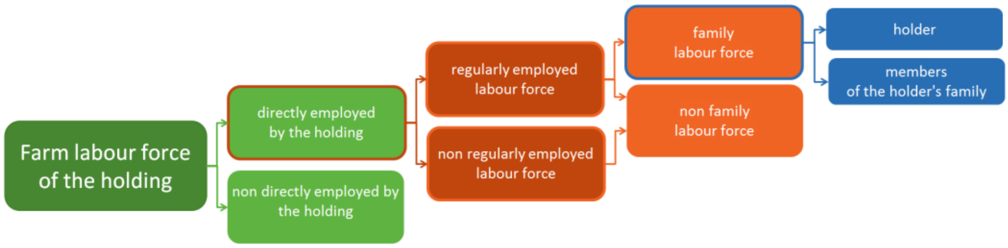
[32] Pretty, J. (2002) *Agri-Culture: Reconnecting People, Land and Nature*, Earthscan
[33] Pretty, J. N. (2003) Social Capital and the Collective Management of Resources, Science, 302(5652): 1912-1914

2.4.3.3 Employment footprint by direct job equivalents

Quantitative and comparative to fossil fuel reference

Net job creation as a result of the deployment of biomass should be regarded over the full value chain. This can be expressed in ***number of full-time jobs per GJ or tonne of biomass or end products***. The indicator can be disaggregated into skilled vs unskilled jobs, permanent vs temporary jobs or local vs global job creation.

There is possibility to add full ***regional*** direct job equivalents where the biomass is being promoted. This indicator can tie in with other socio-economic indicators. It is expressed in ***number of regional full-time jobs/tonne or GJ of end products (yearly)***.



2.5 Time horizon and stages of development

Developing value chains to supply raw material for biobased industries, entail a high level of innovation. The additional complexity of using marginal land and going through a restoration process increases the level of innovation required to achieve technical, environmental and economic efficiency. The value chain development passes through sequential development stages through time and typically take a few years to reach maturity (more than five in the case of perennial species). The challenges differ according to each stage. The stages of development examined in Magic are[34]:

- **Initial stage and take off (IS):** Introducing industrial crops (field trials) in the regional planning agenda, market scoping and creating the policy, socioeconomic and R&D landscape for the establishment and operation of the value chains. Development of long term, stable contracting systems.

- **Drive to maturity stage (DMS):** The first crops are cultivated by farmers at pilot scale and sold to the market. The value chains grow with the addition of new farmers, farmer cooperatives, companies, regional infrastructure (machinery, storage facilities and transport networks, etc.) has improved, and the activities attract both private and public funding.

- **Maturity stage (MS):** The value chains can produce crops at an extensive commercial scale and operate with a well-functioning market organisation.

The selected Good Practice cases include all development stages.

Table 3 presents the Good Practice cases and their development stage.

[34] Inspired by Rostow's stages of growth.

Table 4: Development stages of the Good Practice cases in Magic

Goop Practice Case	Initial stage	Driving to maturity stage	Mature stage
Switchgrass and giant reed in central Greece			
Black locust & sunflower in northern Greece			
Giant reed & cardoon in Catania			
Giant reed in Sardinia			
Poplar in Italy			
Rye and Tall wheatgrass in Spain			
Lavender in Spain			
Black locust and poplar Germany			
Black locust in Hungary			
Reed canary grass and Festulolium in Latvia			
Willow in Ukraine			
Miscanthus in Ukraine			

3 Analysis of case studies

This section translates the findings from literature review, stakeholder interviews and consultations with regional partners in a narrative that analyses the Good Practice performance across value chain stages, the key attributes and development stages.

The output from this analysis provides input to the development of recommendations for the transferability of knowledge and experience to other regions with similar characteristics in terms of marginality factors and assets (D7.3 Key findings and transferability).

3.1 Comparative performance of Good Practice cases

The work presented here provides comparative analysis of the key attributes, their performance and rationale as well as their evolution and interactions across the development stages of the value chain.

3.1.1 Land Use

3.1.1.1 Biophysical- Environmental

Bioremediation is a Good Practice in i) giant reed & cardoon in Catania, ii) giant reed in Sardinia and iii) poplar in Italy. In these cases, contaminated soil has been restored through the cultivation of lignocellulosic perennial species.

Performance for *Life cycle GHG emissions reduction* is ranked medium in all cases. The main reason is that while restoration of marginal land and cultivation of industrial crops can in general reduce life cycle emissions through low input practices there are still significant amounts of energy and input required to turn such land types to productive systems.

Land use change was ranked highly positive in i) giant reed & cardoon in Catania, ii) giant reed in Sardinia, iii) black locust Germany and poplar in Germany and black locust in Hungary. In all other cases the performance for the respective indicator was ranked at medium scale.

Prevention of *soil erosion* ranks high in i) rye and tall wheatgrass in Spain, ii) lavender in Spain, iii) black locust and poplar in Germany and iv) black locust in Hungary. In all these regions the soil erosion risk is very high, and the Good Practice cases have exhibited significant benefits for its restoration.

Biodiversity improvement is ranked high in all cases where land is contaminated or left after mining activities. In these cases, the biodiversity value is rather limited due to the restricted ability to grow any plant is such soils. Therefore, the cultivation of perennial species which are tolerant to the contamination and have robust rooting systems is considered beneficial.

3.1.1.2 Economic

Infrastructure accessibility improved in all cases through the development of appropriate logistical routes and purchase of specialised equipment.

Regional funding was available in all cases with higher scores in i) black locust & sunflower in northern Greece and ii) black locust and poplar in Germany.

3.1.1.3 Social

Social awareness and capital is scored high in all cases since the activities that took place while restoring marginal land are considered highly informative and educational for the farming community and the local stakeholders.

The ranking for *employment prospects* ranges from average to high, and in the land use stage relates to the time required during the restoration of the land.

3.1.2 Biomass Production

3.1.2.1 Biophysical- Environmental

Crop drought resistance ranks medium in all cases since all crops require moderate amounts of water (rainfall) especially during their establishment stages for perennials. Otherwise there are failure risks during the establishment and also low, most likely uneconomic yields.

Crop installation had high performance in Good Practice cases with annual and perennial species: i) rye and tall wheatgrass in Spain and lavender in Spain. In all other cases, ranking was medium due to the higher intensity of practices that are involved in the establishment of perennial species and Short Rotation Coppice.

Life cycle GHG emissions reduction is ranked medium is all cases. The main reason is that while restoration of marginal land and cultivation of industrial crops can in general reduce life cycle emissions through low input practices there are still significant amounts of energy and input required to turn such land types to productive systems.

Agroforestry opportunities are high in all Good Practice cases with tree species: i) black locust & sunflower in northern Greece, ii) polar in Italy, iii) black locust and poplar in Germany, iv) black locust in Hungary and willow in Ukraine.

Rotation (R) and/ or *Soil cover* (SC): Crop rotation opportunities are high in i) rye, tall wheatgrass and lavender in Spain. In all other Good Practice cases there are high opportunities to improve soil carbon in marginalised soils that face water retention, stoniness, erosion, etc.

Low tillage opportunities are high in all cases with perennial species (grasses and Short Rotation coppice). These crops once established require limited input during their annual management activities.

Water use is very efficient in all cases with perennial species (grasses and Short Rotation coppice). These crops once established have deep rooting system and efficient water absorption throughout their lifecycle.

3.1.2.2 Economic

Levelised life cycle costs rank high performance in annual, traditional and perennials established with seeds. For perennials established with rhizomes and Short Rotation Coppice species they rank medium performance due to high establishment costs. Another cost element is low opportunity cost/ land rent for countries towards central, east Europe in combination with low wages for both skilled and unskilled workers.

Profitability has similar performance with *levelised life cycle costs,* but it is also relevant to the commercial maturity of the biobased markets. For example, the energy market for lignocellulosic biomass is not as well developed in the understudy countries as the markets for lavender and rye.

Diversification of rural industry ranks high for all the Good Practice cases. The selected industrial crops offer significant opportunities to farmers, landowners and producers and broaden their supply routes to new, biobased markets and products.

Agricultural income follows the same high ranking of the previous indicator as it is closely related to the new economic prospects the industrial crops bring and the interactions with the biobased industries.

3.1.2.3 Social

The ranking for *employment prospects* ranges from average to high, and in the biomass production stage relates to the time required during the establishment and annual crop management. It is therefore higher for perennial species and trees.

Demographic composition is ranked with high performance in all the under study Good Practice cases, since they are established and operated in regions with large areas of marginalised land and in most cases low economic development which results to young people's migration, when compared to the national average.

Table 5 Key performance indicators for Good Practices in the land use stage

Good Practice attribute	Indicator	Switchgrass and giant reed in central Greece	Black locust & sunflower in northern Greece	Giant reed & cardoon in Catania	Giant reed in Sardinia	Poplar in Italy	Rye and Tall wheatgrass in Spain	Lavender in Spain	Black locust Germany	Poplar in Germany	Black locust in Hungary	Reed canary grass and Festulolium in Latvia	Willow in Ukraine	Miscanthus in Ukraine
Biophysical-Environmental	Bioremediation	n.a	n.a				n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Life cycle GHG emissions reduction													
	Land use (change)													
	Soil erosion													
	Biodiversity													
Economic	Infrastructural accessibility													
	Regional funding													
Social	Social awareness and capital													
	Employment footprint													

Table 6 Key performance indicators for Good Practices in the biomass production stage

Good Practice attribute	Indicator	Switchgrass and giant reed in central Greece	Black locust & sunflower in northern Greece	Giant reed & cardoon in Catania	Giant reed in Sardinia	Poplar in Italy	Rye and Tall wheatgrass in Spain	Lavender in Spain	Black locust Germany	Poplar in Germany	Black locust in Hungary	Reed canary grass and Festulolium in Latvia	Willow in Ukraine	Miscanthus in Ukraine
Biophysical-environmental	Crop drought resistance													
	Crop installation													
	Life cycle GHG emissions reduction													
	Agroforestry opportunities													
	Rotation (R) Soil cover (SC)	SC	SC	SC	SC	SC	R	R	SC	SC	SC	SC	SC	SC
	Tillage (low)													
	Water use													
Economic	Levelised life cycle costs													
	Profitability													
	Diversification of rural industry													
	Agricultural income													
Social	Demographic composition													
	Employment footprint													

3.2 Competitive priorities across development stages

This section discusses the relevance (in terms of creating competitive advantages once applied properly) of the under study competitive priorities across the development stages of the land use and biomass production stages.

Tables 6 and 7 describe the competitive advantages that can be achieved in the land use and biomass production stages if their implementation is planned according to the understudy competitive priorities.

Table 7 Competitive advantages per competitive priority and development stages for land use.

	Initial stage	**Driving to maturity**	**Maturity**
Flexibility	Safeguard low soil compaction and appropriate soil carbon levels	Optimised land use patterns to ensure improvement in land quality	
Quality		Improve land quality and maintain soil organic matter	Enhance biodiversity
Innovation			Maintain low input and less intensive soil improvement practices
Cost	Low input/ cost land restoration	Cost efficient annual soil management	
Transparency	Minimising competition with current land uses, avoid displacement of other land-based activities or create value through land regeneration		

Table 8 Competitive advantages per competitive priority and development stages for biomass production.

	Initial stage	Driving to maturity	Maturity
Flexibility	Design flexible biomass production schemes	Harvesting techniques to incorporate long-term sustainable management	
Quality		Design sustainable quality specifications for the harvested biomass and soil	Maintain low input and less intensive cropping practices
Innovation	Low input and less intensive cropping practices		Year-round sustainable provision of biomass
Cost	Cost effective crop establishment	Optimised annual harvesting and management practices	Cost efficient provision of raw materials to ensure that crop cultivation can be an economically attractive option for farmers when compared with the potential market prices the respective raw materials can get when they are sold to biobased industries.
Transparency	Compatibility with certification and regulations for the provision of sustainable raw materials		

4 Individual case study performance

4.1 Switchgrass & giant reed in central Greece

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Flexibility in raw material production and year round supply
	Innovative low input practices to restore marginal land

The value chain is at the driving to maturity stage which means that the crops are cultivated by farmers and used as raw material for biobased markets. The value chains grow with the addition of new farmers, farmer cooperatives, companies. Regional infrastructure (machinery, storage facilities and transport networks, etc.) has improved, and the activities attract both private and public funding.

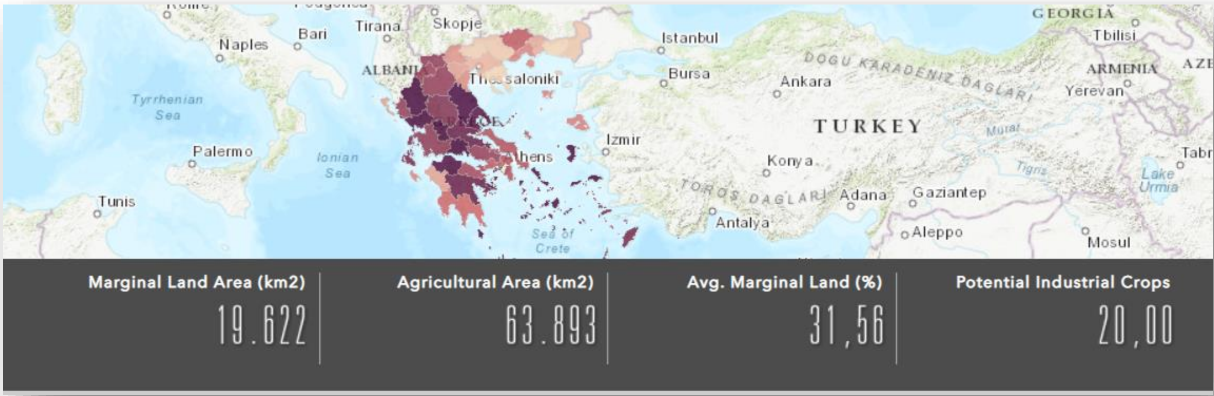


Figure 4 Estimated marginal land in Greece (source: Magic project)[35]

Good Practice performance

Switchgrass and miscanthus have been cultivated in Greece for more than twenty years and exhibit high yields. The highest performance of this Good Practice is at social awareness and

[35] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

capital, rotation, low tillage, water use efficiency, production costs, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Key success facts

- Long term plantations (20 years for switchgrass and 16 years for giant reed). This was quite difficult since funding was available only for few years.
- Establishment of pellet production.
- Increased awareness of local farmers.

Key obstacles

- Limited mechanisation

Table 9 Good Practice performance for switchgrass and giant reed in Greece

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

4.2 Case 2. Black locust & sunflower in northern Greece

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Improved quality of stony, low fertility land
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

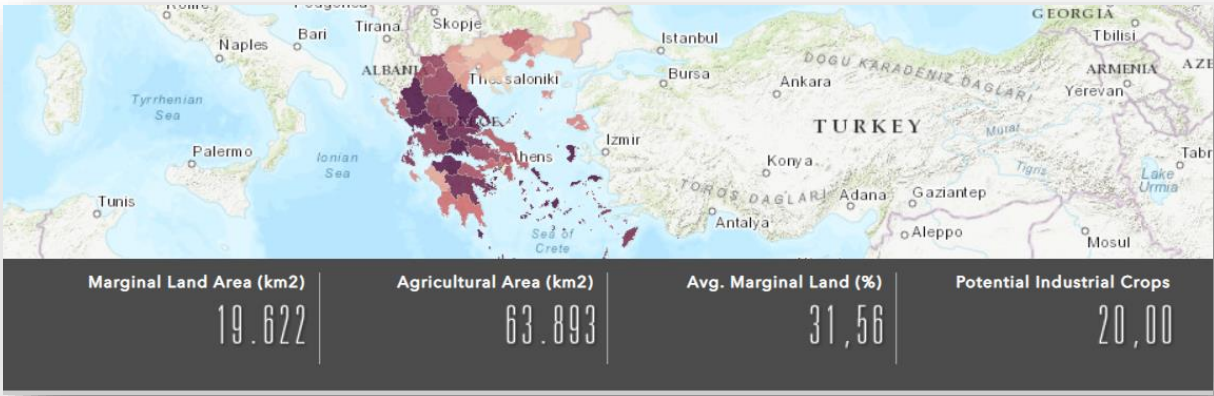


Figure 5 Estimated marginal land in Greece (source: Magic project)[36]

Good Practice performance

Black locust has been cultivated for more than twent years in Greece. It is considered an important bioenergy crop which can be grown in marginal lands in Europe because it is salt tolerant, needs less soil moisture and soil fertility and can make soil fertile by fixing nitrogen.

[36] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

The highest performance of this Good Practice is at regional funding, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Key success facts

- The project site has a well-established black locust plantation proving that this crop can be grown in marginal sites affected by adverse terrain conditions.

Key obstacles

- Limited mechanisation

Table 10 Good Practice performance for black locust and sunflower in Greece

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

4.3 Case 3: Giant reed & cardoon in Italy

Competitive Priority	Competitive advantage
	Restored contaminated or bordering contaminated sites
	Flexibility in raw material production and year round supply
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

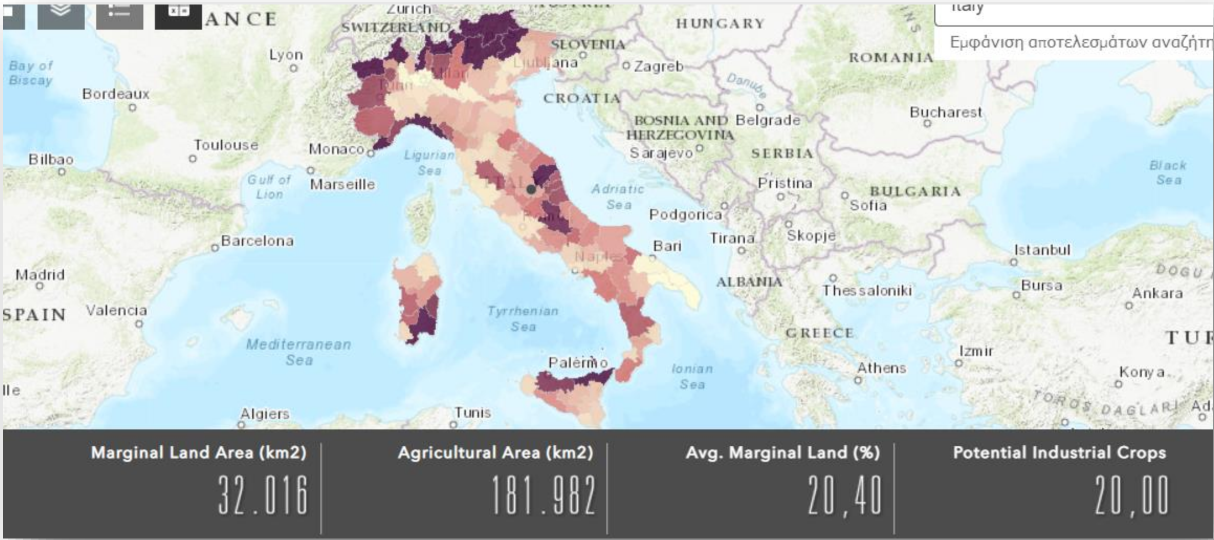


Figure 6 Estimated marginal land in Italy (source: Magic project)[37]

Good Practice performance

Giant reed is a low input crop for Italy, characterised by high water use efficiency and relevant carbon storage potential. Cardoon is also a perennial lignocellulosic energy crop which is considered as a promising bioenergy crop in the country.

[37] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

The highest performance of this Good Practice is at bioremediation, land use change, biodiversity, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, crop production costs, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 11 Good Practice performance for giant reed & cardoon in Italy

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation		Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

Key success facts

- Growing giant reed and cardoon in Sardinia, under highly contaminated soil conditions.
- 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.

Key obstacles

- 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.

4.4 Case 4: Perennial grasses in Italy

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income & jobs
	Flexibility in markets for industrial crops
	Innovative systems of vegetative propagation for Giant reed and Miscanthus

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

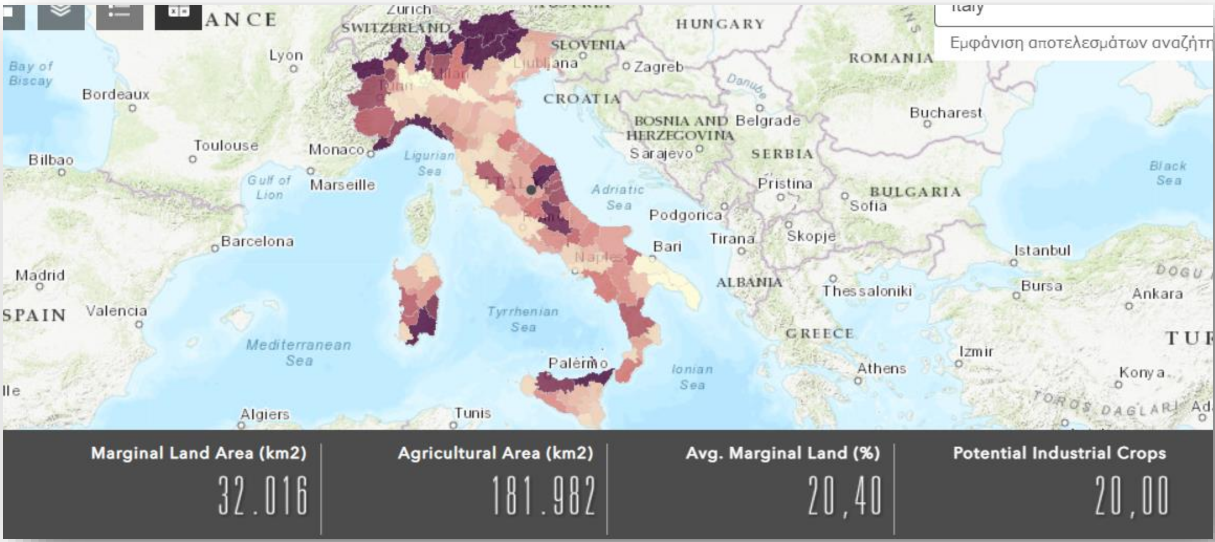


Figure 7 Estimated marginal land in Italy (source: Magic project)[38]

Good Practice performance

Miscanthus, giant reed and switchgrass have been cultivated for more than twenty years in Italy, are well adapted to local agro-ecological conditions and have good yields.

[38] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

The highest performance of this Good Practice is at bioremediation, land use change, biodiversity, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, crop production costs, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 12 Good Practice performance for giant reed & cardoon in Italy

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation		Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

Key success facts

- 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.

Key obstacles

- Difficulty in establishment when the climatic conditions are extremely arid during the first year. Irrigation maybe required.

4.5 Case 5: Poplar in Italy

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Poplar improved soil quality with phytoremediation of polluted sites
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

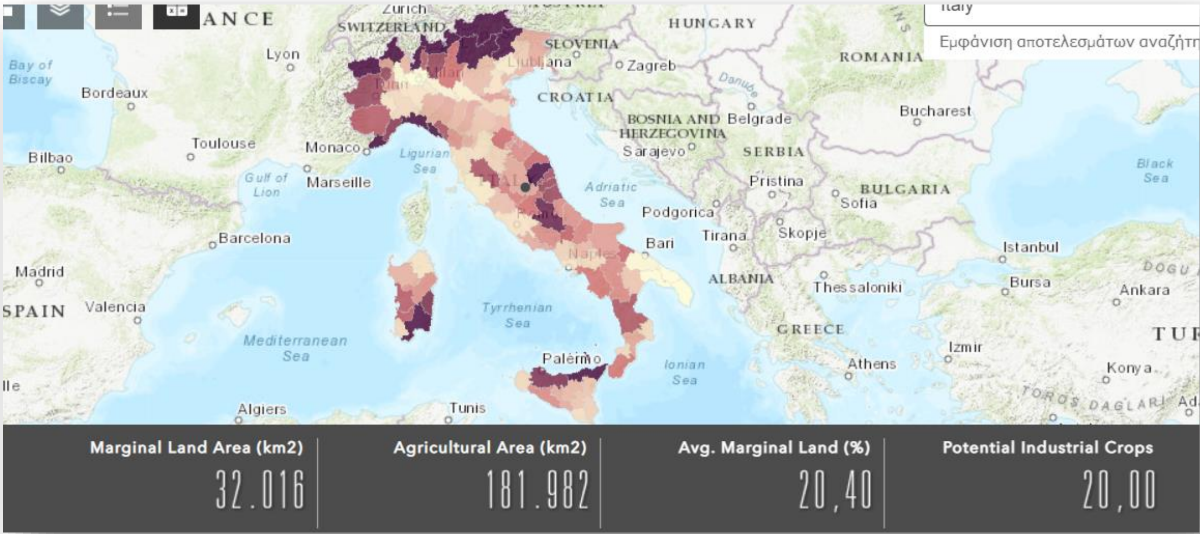


Figure 8 Estimated marginal land in Italy (source: Magic project)[39]

Good Practice performance

Poplar has a rooting ability that makes it suitable for rhizoremediation, which is a kind of phytoremediation comprised of a complex rooting system. Results from the field trials in Italy have shown potential that growing poplars on their contaminated soils is beneficial to farmers

[39] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

as it results in sustainable recovery of soils, making them suitable for food-agricultural activities.

The highest performance of this Good Practice is at bioremediation, biodiversity, infrastructure accessibility, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, crop production costs, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 13 Good Practice performance for poplar in Italy

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation		Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

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Key success facts

- 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.

Key obstacles

- 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.

4.6 Case 6: Rye and Tall wheatgrass in Spain

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Improved quality of very low fertility and sandy soils
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

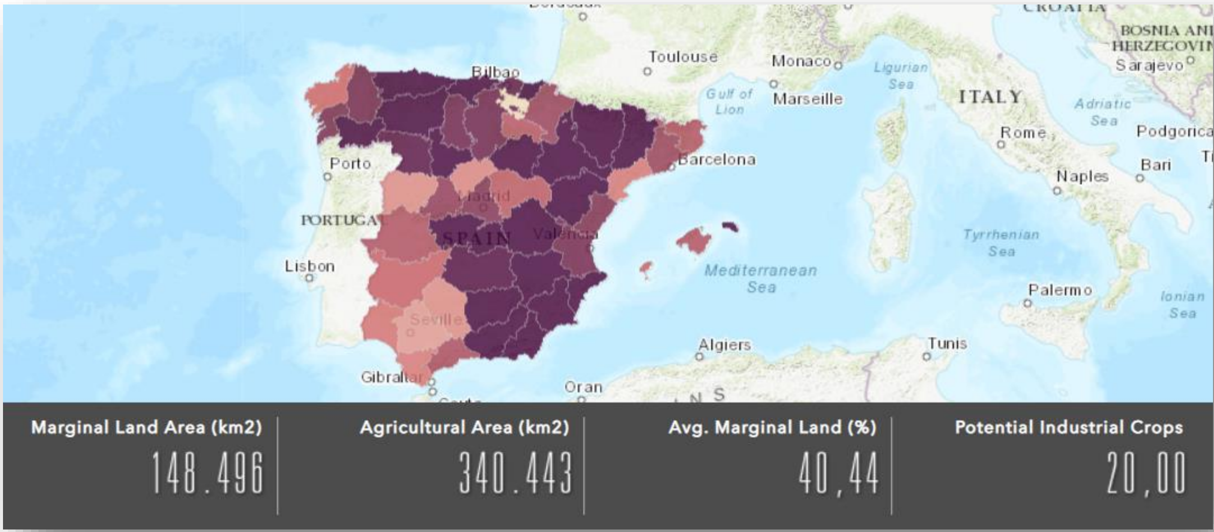

Figure 9 Estimated marginal land in Spain (source: Magic project)[40]

Good Practice performance

Rye has been a traditional cereal crop grown in Europe and known to have high rusticity and better adaptation to colder climatic conditions compared to tall wheatgrass. Tall wheat grass

[40] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

is native to Eurasia and was later introduced to other regions of the world. It has proven to be a new low-cost alternative for farmers allowing them to meet CAP requirements in Spain.

The highest performance of this Good Practice is at soil erosion, social awareness and capital, crop installation, rotation, low tillage, crop production costs, profitability, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 14 Good Practice performance for rye and tall wheatgrass in Spain

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	R
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

Key success facts

- 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.

Key obstacles

- 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.

4.7 Case 7: Lavender in Spain

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Improved quality of very low fertility and sandy soils
	Innovative low input practices to restore marginal land

The value chain is at the maturity stage. This means that the value chain can produce the crop at an extensive scale and operate with well-functioning market mechanisms.

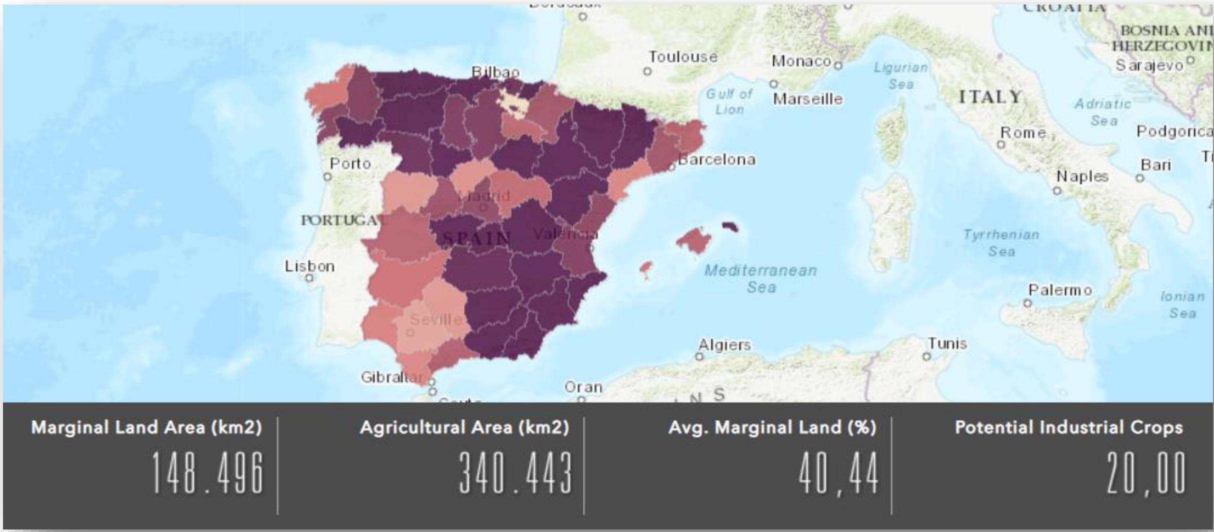

Figure 10 Estimated marginal land in Spain (source: Magic project)[41]

Good Practice performance

Lavender has been long cultivated in small farms in Spain and has been used as an essential oil for the cosmetics and perfume industries.

[41] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

The highest performance of this Good Practice is at soil erosion, social awareness and capital, crop installation, rotation, low tillage, crop production costs, profitability, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 15 Good Practice performance for lavender in Spain

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	R
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

Key success facts

- Though the co-operative has managed to cultivate with success *Lavandula hybrida* in marginal lands, it will take time until it gets its first harvest (two years from planting). Currently, market price is very profitable, a principal reason for why the cooperative wishes to continue expanding production of this crop.

Key obstacles

- In spite of this, taking advantage of the experience from COCOPE, the ALCAMANCHA co-operative is aware of the fact that 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.

4.8 Case 8: Short Rotation species in Germany

Competitive Priority	Competitive advantage
	Improved quality of degraded land due to anthropogenic interventions
	Transparency in restoring post mining land
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

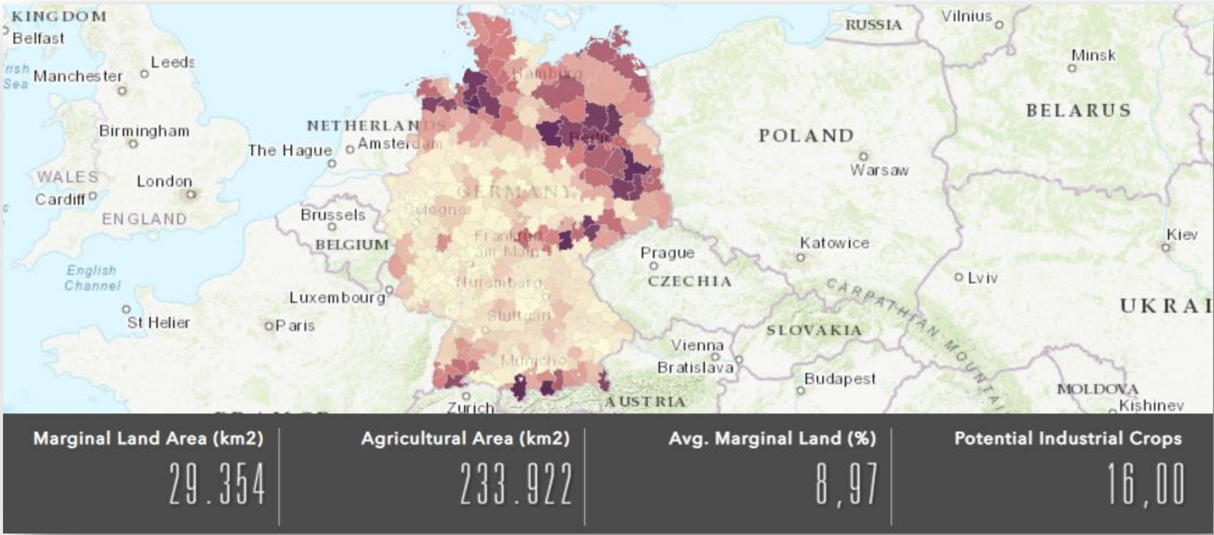

Figure 11 Estimated marginal land in Germany (source: Magic project)[42]

Good Practice performance

Poplar can be used to clean contaminated, abandoned land, conserve soil by intensive rooting, humus accumulation and minimal nutrient removal. Black locust can grow on a wide variety of soils: although it is sensitive to topsoil compaction and waterlogging, it has high heavy metal

[42] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

and acid tolerance. It can assimilate atmospheric nitrogen into the soil, prevent water formation and leaching of contaminants and promotes soil humus accumulation.

Table 16 Good Practice performance for Short Rotation species in Germany

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

The highest performance of this Good Practice is at land use change, soil erosion, biodiversity, infrastructure accessibility, regional funding, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Key success factors

- Planting black locust (*Robinia pseudoacacia L.*) on severely disturbed post-mining areas despite low soil fertility can produce high biomass yield with the creation of beneficial land-use system. To reduce nutrient exports from short rotation coppice, a better selection of species and clones with a high nutrient use efficiency can be recommended, such as the use of N-fixing species i.e. black locust (especially for N poor sites), as well as an increase in the rotation period.

Key obstacles

- Farmers are reluctant to cultivate black locust because they think it will be uneconomic

4.9 Case 9: Black locust in Hungary

Competitive Priority	Competitive advantage
	enhance the conservation status of floodplain habitats by harvesting invasive black locust species
	New income opportunities for the local community
	Innovative low input practices to restore marginal land

The value chain is at the driving to maturity stage which means that the crops are cultivated by farmers and used as raw material for biobased markets. The value chains grow with the addition of new farmers, farmer cooperatives, companies. Regional infrastructure (machinery, storage facilities and transport networks, etc.) has improved, and the activities attract both private and public funding.

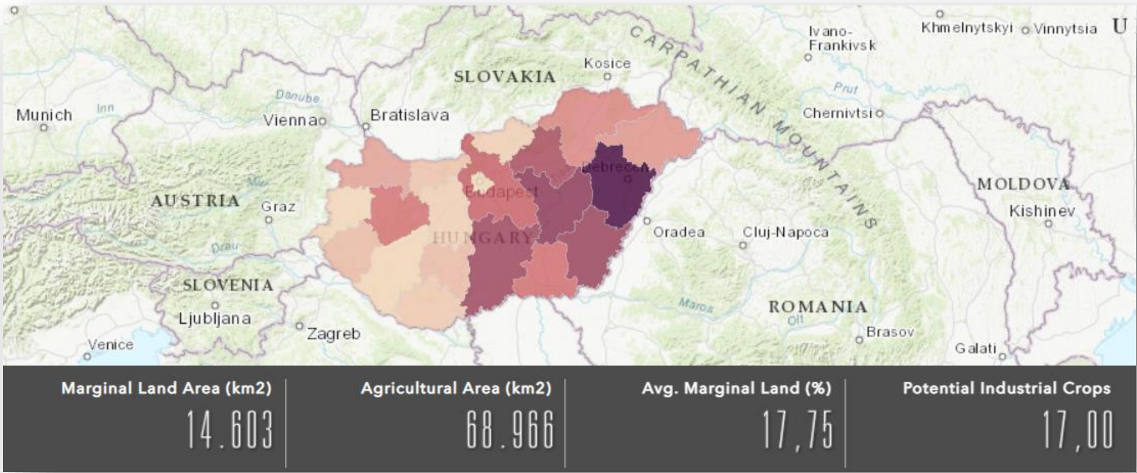

Figure 12 Estimated marginal land in Hungary (source: Magic project)[43]

Good Practice performance

In the 1960s, Hungary had more black locust forests than all the other European countries, two thirds of which were used for coppice. It has multi-industrial (mining, construction, furniture) agricultural (post and pole wood) and energy uses.

[43] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

Table 17 Good Practice performance for black locust in Hungary

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction		Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

The highest performance of this Good Practice is at land use change, soil erosion, biodiversity, infrastructure accessibility, social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Key success facts

- Creating new raw material opportunities by managing invasive species in floodplains

Key obstacles

- The continuation of the case study faced difficulties once the funding ended.

4.10 Case 10: Reed canary grass and Festulolium in Latvia

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Flexibility in raw material production and year round supply
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

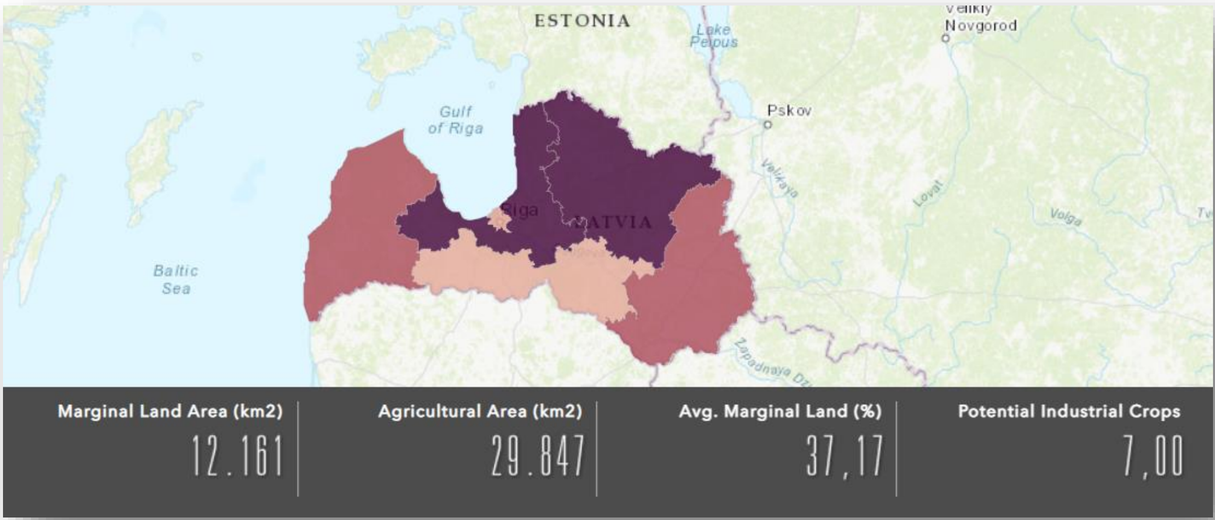

Figure 13 Estimated marginal land in Latvia (source: Magic project)[44]

Good Practice performance

Reed canary grass, festulolium, galega are well known species in Baltic countries as long-persisting, productive grasses and legumes suitable for biogas or solid biofuel production.

[44] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

The highest performance of this Good Practice is at social awareness and capital, improving soil carbon, low tillage, water use efficiency, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Table 18 Good Practice performance for reed canary grass and Festulolium in Latvia

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction	n.a	Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

Key success facts

- The agroforestry system has given an opportunity to increase the value of the total production through marketing multiple products from given limited spatial and soil resources.

Key obstacles

- 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.

4.11 Case 11: Willow in Ukraine

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Improving marginal areas prone to waterlogging, flooding and with high underground water tables
	Innovative low input practices to restore marginal land

The value chain is at the maturity stage. This means that the value chain can produce the crop at an extensive scale and operate with well-functioning market mechanisms.

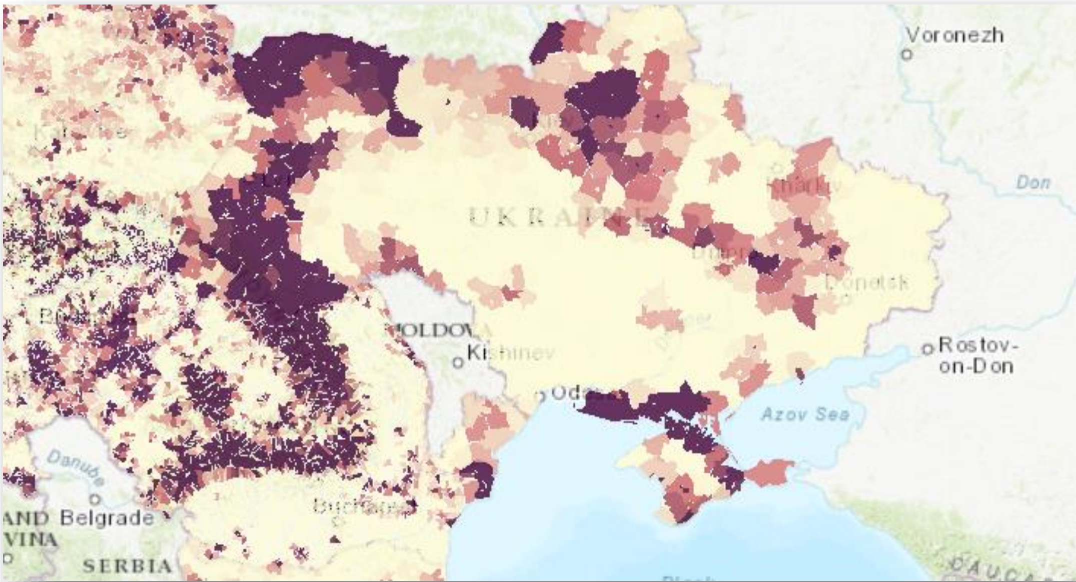

Figure 14 Estimated marginal land in Ukraine (source: Magic project)[45]

Good Practice performance

Willow is well adapted and has good yields in Ukraine. Willow trees are resistant to pest, frost and diseases. They also show moderate tolerance to salinity. Willow trees grown for phytoextraction can be used for energy purposes if composting is used as a pre-treatment

[45] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

method, however the ashes cannot be used as fertilisers due to their high toxic metal concentration.

Table 19 Good Practice performance for willow in Ukraine

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction	n.a	Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

The highest performance of this Good Practice is at social awareness and capital, agroforestry, improving soil carbon, low tillage, water use efficiency, diversification of rural industry, agricultural income, demographic composition and employment footprint.

Key success facts

- Successful establishment of willow plantation at an agronomical level for bioenergy (heat and electricity) production at an industrial scale.

Key obstacles

- Engaging the farming community and reassuring them the cultivation will provide good economic returns.

4.12 Case 12: Miscanthus in Ukraine

Competitive Priority	Competitive advantage
	Improved opportunities for local farm income
	Transparency in establishing low indirect land use change biomass crops
	Innovative low input practices to restore marginal land

The value chain is at the initial and take off stage which means that industrial crops are being introduced to the regional planning agenda and creating the policy, socio-economic and R&D landscape for the establishment and operation of the value chains.

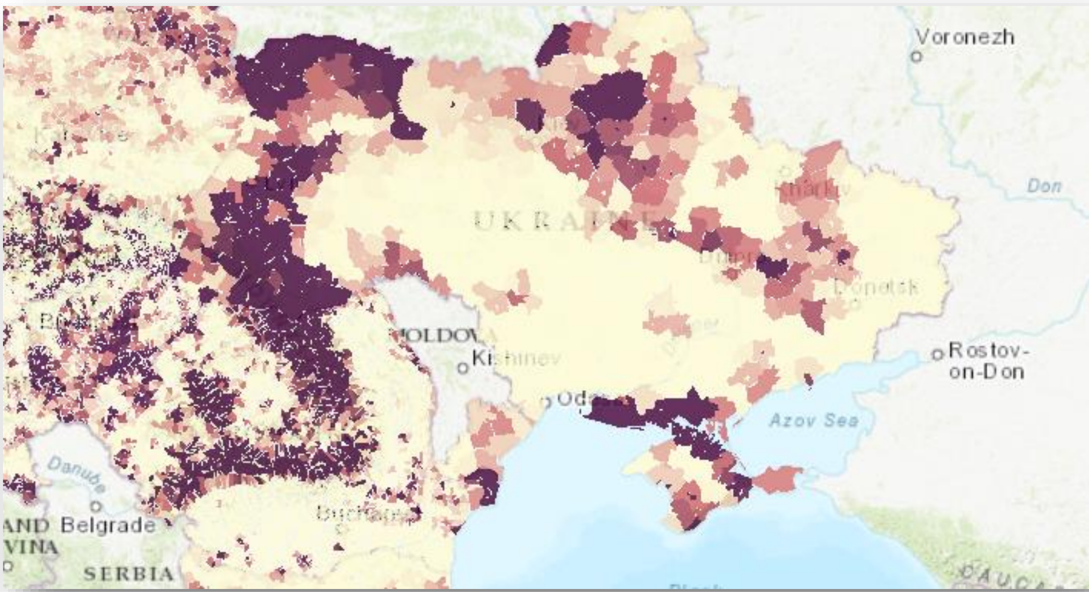

Figure 15 Estimated marginal land in Ukraine (source: Magic project)[46]

Good Practice performance

Miscanthus is well adapted in Ukraine and has good yields. The crop does not require a high input of fertilisers due to good nutrient use efficiency, is disease resistant and can grow in cold temperature in wet/heavy soil conditions.

[46] https://iiasa-patial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c

Table 20 Good Practice performance for miscanthus in Ukraine

Restoration of marginal land		Cultivation of industrials crops	
Bioremediation	n.a	Crop drought resistance	
Life cycle GHG emissions reduction	n.a	Crop installation	
Land use (change)		Life cycle GHG emissions reduction	
Soil erosion		Agroforestry opportunities	
Biodiversity		Rotation (R) Soil cover (SC)	SC
Infrastructural accessibility		Tillage (low)	
Regional funding		Water use	
Social awareness and capital		Levelised life cycle costs	
Employment footprint		Profitability	
		Diversification of rural industry	
		Agricultural income	
		Demographic composition	
		Employment footprint	

The highest performance of this Good Practice is at social awareness and capital, improving soil carbon, low tillage, water use efficiency, crop production costs, diversification of rural industry, agricultural income, demographic composition, and employment footprint.

Key success facts

- Miscanthus has been successfully established and facilitated the restoration of degraded low productive land which was not suitable for commercial agriculture.

Key obstacles

- Lack of commercial interest as there are no biorefineries in the region

5 Conclusions

The performance of twelve Good Practice case studies cultivating industrial crops in land with biophysical marginality has been analysed around:

- Value chain stages with focus on land use and biomass production
- Competitive priorities in different development stages (initial, drive to maturity, maturity)

The most common marginal land challenges that the cultivation of industrial crops helped overcome include:

- introduced low input practices (low tillage, etc.) to restore land with low fertility, soil contamination, unfavourable texture, stoniness, drought, etc.
- increased transparency in establishing low indirect land use change biomass crops
- created new income opportunities for farmers in rural areas with high share of marginality

Overall, the results from this analysis show, through operational case studies, that the cultivation of industrial crops in land with low soil fertility, high salinity, sandy soils, unfavourable texture and stoniness, contamination, etc. can help overcome both the biophysical challenges but also the socio-economic ones with providing outlets to rural communities for supporting the provision of raw materials to the biobased sectors.