SEEMLA

Sustainable exploitation of biomass for bioenergy

from marginal lands in Europe

SEEMLA Project Grant Agreement no. 691874

Final report on socio-economic assessment

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I. About the SEEMLA project

The aim of the Horizon 2020-funded 'Sustainable exploitation of biomass for bioenergy from marginal lands in Europe' (SEEMLA) project is the reliable and sustainable exploitation of biomass from marginal lands (MagL), which are used neither for food nor feed production and are not posing an environmental threat. The project focusses on three main objectives:

- the promotion of re-conversion of marginal lands for the production of bioenergy through the direct involvement of farmers and foresters
- the strengthening of local small-scale supply chains
- the promotion of plantations of bioenergy plants on marginal lands

The expected impacts are: Increasing the production of bioenergy, famers' incomes, investments in new technologies and the design of new policy measures. FNR will coordinate the project with its eight partners from Ukraine, Greece, Italy and others from Germany.

Project coordinator

Agency for Renewable Resources

Fachagentur Nachwachsende Rohstoffe e.V.	FNR	Germany

Project partners

Salix Energy Ltd.	SALIX	Ukraine
Institute for Bioenergy Crops & Sugar Beet of the National Academy of Agricultural Science	IBC&SB	Ukraine
Legambiente	LEGABT	Italy
Democritus University of Thrace	DUTH	Greece
Decentralized Administration of Macedonia and Thrace	DAMT	Greece
Brandenburg Technical University Cottbus-Senftenberg	BTU CS	Germany
ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH	IFEU	Germany

II. About this document

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III. Executive summary

The aim of the Horizon 2020-funded 'Sustainable exploitation of biomass for bioenergy from marginal lands in Europe' (SEEMLA) project is the reliable and sustainable exploitation of biomass from marginal lands, which are used neither for food nor feed production and are not posing an environmental threat. The expected impacts are: Increasing the production of bioenergy, famers' incomes, investments in new technologies and the design of new policy measures. For details see www.seemla.eu.

This study analyses the socio-economic impacts of different options for the cultivation of perennial energy crops (grassy and woody biomass with up to 20 years rotation period) on marginal land. The profitability is assessed by means of life cycle costing (LCC), with a focus on the farmer's perspective. The developed LCC model proved to be suitable for calculating the bioenergy costs for countries, regions and case studies under different boundary conditions.

The main results of our socio-economic analysis:

- **Bioenergy from marginal land is more expensive than from standard land:** In Europe, the cultivation of perennial energy crops on standard arable land is in most cases unattractive without financial incentives due to low profitability combined with risks of crop failure and sales difficulties. Bioenergy from marginal land is significantly more expensive than from standard arable land and can involve higher risks. Lower land rents due to lower land qualities can only partially compensate for this.
- **Necessity of financial incentives:** The cultivation of perennial energy crops on marginal land will not be profitable outside niches in the foreseeable future. Revenues that are in part considerably too low must be offset by financial incentives.

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- **Risk minimisation necessary:** For example, the harvest of woody crops (unlike grasses) can be postponed by one or a few years depending on the market situation.
- **Large differences between cropping systems, countries and even sites due to different cost drivers and risks:** Cost drivers such as costs for machinery, seedlings or land rent and thus profitability can vary significantly depending on the actual conditions - also because marginal sites are subject to very different biophysical constraints.

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- **Package of measures necessary:** Due to the large differences in costs and risks, it will be necessary to adapt measures such as support and qualification programs in a differentiated manner to these costs and risks as well as to countries and regions. Cost reductions through a continuous cultivation of perennial energy crops also seem possible. Calculation models such as those used in this study can provide very helpful support in this respect.

- **Advantageous social effects:** If perennial energy crops can be cultivated profitably on marginal land in the long term, a number of socially relevant advantages can be achieved, such as truly additional jobs, more added value or the development of new qualifications. In order for these to actually be of benefit to rural areas and to avoid unintentional displacement of extensive land users and important ecosystems, amongst other things, local actors must be strengthened.


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In addition to the main results listed above, **many other detailed results** were derived in the course of this study, which are explained in this report, see in particular chapter 4.

In summary: Overall, a number of socio-economic advantages can be associated with the expansion of perennial energy crop plantations on marginal land. To ensure these benefits, calculations such as those carried out in this study are helpful and necessary. However, financial incentives, not least because of the use of public funds, should not only be designed according to economic criteria. Social and ecological impacts must also be taken into account in order to guarantee the development of marginal land for the benefit of society as a whole.

IV. Background

This 'Final report on socio-economic assessment' summarises the findings of Task 4.4 'Socio-economic assessment'.

- Task T4.4 *Short description* (Lead: IFEU)

This task will give a conclusive picture of economic and social implications of the SEEMLA value chains identified in WP2 and the more specific, exemplary ones in the pilot cases defined by WP5 by two main parts: first, a detailed social analysis for all value chains will be conducted to get an overview of impacts such as influence on rural development and other local effects and/or implications. Secondly, life cycle costing (LCC) based analyses cover the economic performance of the value chain investigated on a life cycle basis. It produces economic indicators such as investment cost, production costs, product costs and target costing, internal rate of return and external costs.

The methodology of both analyses will be adjusted to the necessities of the SEEMLA approach. This includes, like in the other tasks, the definition of all specific indicators to be investigated or that the socio-economic performance of the SEEMLA value chains investigated is compared to that of the respective reference system. Finally, potential optimizations of the socio-economic outcome will be revealed and depicted.

The approach of this task regarding methodology but also definitions and settings is iterative as in the former tasks. Therefore, if the process of analysis leads to any changes in this approach, all definitions, settings, system boundaries and methodology are updated and fed back changes that relevant to the complete WP or the project to Task 4.1 while executing the calculations in the changed way.

This task will provide input for WP5 on the results for the specific pilot cases and for WP6 on general results. Both are adapted to the specifications and needs established in those WPs and include conclusions and recommendations as well.

V. Acknowledgement

The authors would like to thank all SEEMLA partners sincerely for fruitful discussions and close and successful collaboration within the SEEMLA project. We are very grateful in particular to Werner Gerwin, Frank Repmann (BTU CS), Fotios Kiourtsis, Dimitrios Keramitzis (DAMT), Vadym Ivanina, Oleksandr Hanzhenko (IBC&SB), Iryna Gnap, Maksym Zibtsev and Karine Podolian (SALIX) who kindly provided data on their respective pilot cases and/or country-specific data and took us on interesting field trips. We would also like to thank Spyros Galatsidas (DUTH), Werner Gerwin (BTU CS) and Diego Piedra-Garcia (FNR) for reviewing the final draft of this document. Last but not least, we would like to express our thanks to our IFEU colleagues Sven Gärtner, Meike Schmehl and Marie Hemmen for their support, internal review and valuable suggestions.

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1 Methodological approach

The main objective of the SEEMLA project is the establishment of suitable innovative land-use strategies for a sustainable production of plant-based energy on marginal lands while improving general ecosystem services (see also chapter I 'About the SEEMLA project'). The use of marginal lands could contribute to the mitigation of the fast growing competition between traditional food production and production of renewable bio-resources on arable land. An essential part of the project is to ensure the environmental and socio-economic sustainability of the foreseen actions, which is the aim of work package 4 (WP 4).

1.1 Motivation and approach

1.1.1 Motivation for sustainability assessment within this project

The implementation of the concepts proposed by the SEEMLA project can have significant impacts on the society and the environment. This is even more valid since one goal of the project is to provide a basis for a large-scale implementation which might affect millions of hectares of land. Obviously, various advantages but also disadvantages are related to the use of marginal lands for biomass production. Whether the advantages or the disadvantages predominate cannot be determined a priori. Against this background, detailed analyses are necessary to obtain a holistic answer to the following question: Which (global) changes will occur, if SEEMLA pathways are implemented in the future? This is the major aim of WP 4.

1.1.2 The pillars of sustainability

The most well-known definition of sustainability can be found in the report of the Brundtland Commission: 'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [UN 1987]. At the 2005 World Summit it was noted that this requires the reconciliation of environmental, social and economic demands – the 'three pillars' of sustainability. This view has been expressed as a scheme using three overlapping circles indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing (Fig. 1-1).

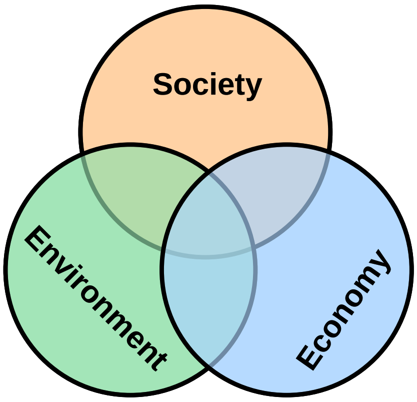

Fig. 1-1 Scheme of sustainable development: at the confluence of three constituent parts

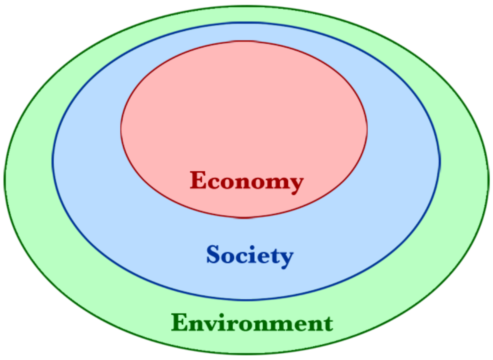

Fig. 1-2 Scheme indicating the relationship between the three pillars of sustainability [Scott-Cato 2008]

The UN definition has evolved and undergone various interpretations. For example, many environmentalists think that the idea of sustainable development is an oxymoron as development seems to entail environmental degradation. From their perspective, the economy is a subsystem of human society, which is itself a subsystem of the ecosphere, and a gain in one sector is a loss from another. This can be illustrated as three concentric ellipses (Fig. 1-2). Nevertheless, other interpretations exist as well.

As a result of the growing pressure on the environment and increased scarcity of natural resources, the sustainability discussion is often focussed on the environment, as both society and economy are constrained by environmental limits. There is abundant scientific evidence that humankind is currently living unsustainably and jeopardising the living conditions of future generations, e.g. by excessive use of resources and excessive use of the environment as a sink, e.g. for greenhouse gas emissions etc. Hence, strong efforts are needed to identify and develop sustainable technologies which are able to reconcile economic, social and environmental demands.

1.1.3 Socio-economic sustainability assessment within SEEMLA

The objective of the sustainability assessment within this project is to provide a multi-criteria evaluation of the implications on sustainability associated with the value chains to be analysed. All three pillars of sustainability are analysed using techniques that are based on life cycle thinking. This report focusses on socio-economic sustainability, while environmental aspects are assessed in the report on life cycle assessment and life cycle environmental impact assessment [Rettenmaier et al. 2018].

This socio-economic sustainability assessment analyses the scenarios outlined in chapter 1.2 using the methodology summarised in chapter 1.3. The findings are reported in two parts: In chapter 2 the profitability of cultivation perennial bioenergy crops on marginal land is analysed from the perspective of farmers (or investors operating the cultivation). Here, options are identified how to improve the economic viability of such crops. Chapter 3 widens the view from economic value for owners or operators to benefits and risks for directly involved stakeholders and the general society. In chapter 4, perspectives and open questions for future studies are outlined.

1.2 Overview of analysed scenarios

The scope of this economic assessment is the cultivation of perennial energy crops analysing the economic perspective of the farmer. It includes the purchase/rent of all required inputs, the establishment and maintenance of the plantation, harvesting, transport and storage of bioenergy carriers, delivery of air dried bioenergy carriers (logs, chips and bales) to the customer and restoration of the plantation into cleared crop land.

The sustainability assessment in SEEMLA defined *'case study scenarios'* and *'generic scenarios'* for an analysis of environmental and socio-economic impacts.

'Case studies' are carried out by the SEEMLA partners in WP 5. Original data from pilot level case studies was partially generalised and adapted to general agricultural practise because the pilot level case studies were conducted under scientific but not under competitive boundary conditions. This was done to meet the technical reference 'mature, commercial

scale application' as selected by the project partners. The main part of this study is based on these generalised case study scenarios listed in Table 1-1.

Table 1-1 Overview on biomass production case studies investigated in this report based on [Ivanina & Hanzhenko 2016].

No	Country	Cultivated crops
1	Germany	Poplar
2	Germany	Black locust (SRC)
3	Greece	Black pine
4	Greece	Calabrian pine
5	Greece	Black locust (tree)
8	Ukraine	Willow
9	Ukraine	Poplar
14	Ukraine	Miscanthus

'Generic scenarios' aim at representing typical conditions in the climatic zones 'Continental', 'Mediterranean' and 'Atlantic'. These scenarios were mainly defined for the analysis of environmental impacts. Since very different economic backgrounds can exist in countries of the same climatic zone (e.g. Eastern Germany and Ukraine), '*generic scenarios*' are only used in this study to determine result ranges.

In addition, each scenario is subdivided into the following three subcategories:

- Very marginal land: Very poor yield potential caused by different factors such as pronounced water stress, pronounced salt stress, high inclination, etc.; very low yield, very low nutrient demand; SQR value[1] < 20; far from economic cultivation.
- Marginal land: Poor yield potential caused by different factors such as moderate water stress, moderate salt stress, moderate inclination, etc.; low yield, low nutrient demand; 20 < SQR value[1] < 40; close to economic cultivation.
- Standard land (used as reference): Standard yield potential based on climate and soil conditions; standard nutrient demand; 40 < SQR value[1] < 80; economic cultivation.

[1] Within the SEEMLA project, a definition of the term 'marginal land' was elaborated in Deliverable D 2.1 'Report of general understanding of MagL' [Ivanina & Hanzhenko 2016]. Based on the Müncheberg Soil Quality Rating (SQR) [Mueller et al. 2007], the definition classifies land as being 'marginal' if its SQR score is below 40 (further differentiated here into 'marginal' and 'very marginal'). According to the SEEMLA definition, marginal land mainly includes sites which were affected by degradation processes, in most cases triggered by anthropogenic impact. Apart from degraded land, overlaps exist with abandoned land, reclaimed land and brownfields [Ivanina & Hanzhenko 2016].

1.3 Summary of methodology

The following goal and scope questions relevant for the socio-economic assessment were selected by the project partners at the beginning of the project:

- Which implications on economy and society are associated with the proposed SEEMLA concepts, i.e. with
  - the use of marginal land as defined in WP 2,
  - the pilot cases carried out in WP 5 and
  - the general SEEMLA exploitation scenarios defined in WP 6?
- Do some crops show a better performance regarding the main pillars of sustainability than others?
- Are the production chains economically viable under the current political and economic framework conditions?
- Which life cycle steps and unit processes determine the results significantly and which optimisation potentials can be identified?
- Are there sites or types of land that should be prioritised for bioenergy production?
- Which boundary conditions have to be met in order to advocate bioenergy production from marginal land in Europe?

The assessment for answering these questions is based on the methodology of life cycle costing (LCC) [Swarr et al. 2011]. The LCC analysis focusses on the perspective of the farmer because profitability for this actor has been identified as bottleneck for viability of the whole value chain. The LCC thus encompasses the following life cycle stages, processing steps, cost items[2] and revenues:

- Land use: land rent and subsidies[3].
- Plantation establishment: field preparation, planting, fertilisation, crop protection, irrigation.
- Plantation maintenance.
- Harvesting: harvesting, partially fertilisation, crop protection, transportation to storage, storage, transportation to customer, sales of unprocessed biomass to end user or processing plant
- Field restoration: plant removal, herbicides, fertilisation
- Overhead costs[4]

Data used for scenario calculations is summarised in chapter 8.

Static cost benefit principles were applied in most calculations. Benefits (revenues) and costs of one average year are compared without taking into account interest rate and inflation rate

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[2] Some processing steps and cost items do not occur in all scenarios.

[3] Some subsidies (mainly direct payments according to the CAP) are granted, too, if no harvest is obtained from that piece of land and only low-cost interventions are applied, e.g. to prevent natural succession towards a forest. Since these are not relevant for farmers' decision to establish one of the scenarios analysed here, they are not included in the calculations.

[4] Overhead costs are calculated for an active farm that establishes bioenergy crop cultivation additionally to its other activities.

etc. This is based on the calculation of EBIT (Earnings before Interests and Taxes). More detailed net cash flow analysis requires very good information on all benefit and cost items. Given the uncertainty and variability in particular of future revenues from biomass sales, indicators based on net cash flow analysis like net present value (NPV) or internal rate of return (IRR) did not lead to additional robust conclusions (see also chapter 2.2.3).

2 Attractiveness of investment in bioenergy production on marginal land

This chapter analyses the attractiveness of investment in the cultivation of perennial lignocellulosic crops on European marginal land from the perspective of farmers. As a reference, available information on the competitiveness of bioenergy production on standard land is researched in the first place (chapter 2.1). This is followed by an analysis of costs and revenue structures of these crops on marginal land in comparison to standard land (chapter 2.2). Finally, risks for investors are analysed (chapter 2.3) and options to increase attractiveness are discussed (chapter 2.4).

2.1 Bioenergy production on standard land

The profitability of cultivating perennial lignocellulosic crops for bioenergy on standard land is well researched and documented. Two kinds of information are available that allow conclusions on how economically attractive this is for farmers. First, many micro-economic/agronomic studies are published in scientific literature that analyse the profitability of perennial energy crops. Second, statistics on land use show how often farmers actually decide to grow these crops. In combination, these two sources give a good economic view on bioenergy production on standard land. We evaluated these sources as a starting point and reference for analysing the profitability and attractiveness of bioenergy production on marginal land.

2.1.1 Micro-economic studies on bioenergy production on standard land

Generally, micro-economic studies on cultivating perennial lignocellulosic crops for bioenergy on standard land vary considerably in the figures on costs and even more so on profitability that are presented [Faasch & Patenaude 2012; Hauk et al. 2014; Witzel & Finger 2016]. Large uncertainties in particular regarding yields and biomass prices are highlighted. Overall, most analysed cases are marginally profitable or unprofitable for the farmers [Bocquého & Jacquet 2010; Ericsson et al. 2006; Faasch & Patenaude 2012; Hauk et al. 2014; Witzel & Finger 2016]. Furthermore, risks of these perennial crops are highlighted that make them unattractive for investments even if they are more profitable than competing crops such as wheat since expected returns on investment are not very much higher [Bocquého & Jacquet 2010; Ericsson et al. 2006; Hauk et al. 2014]. Nevertheless, several publications identify advantageous conditions in certain niches under which perennial bioenergy crops are attractive for farmers, in particular as a diversification of crops [Bocquého & Jacquet 2010; Faasch & Patenaude 2012; Witzel & Finger 2016].

2.1.2 Statistics on bioenergy production on standard land

Bioenergy production on agricultural land is increasing in Europe. However, the by far biggest share of land is used for biogas and first generation biofuels production. Perennial lignocellulosic energy crops cover comparatively very small areas. For example, in Germany and England about 0.1% and 0.3% of the total arable land, respectively, are covered by short rotation coppice and Miscanthus [Becker et al. 2018; Department for Environment Food & Rural Affairs 2017]. No clear tendency for Europe can be seen for the development of the cultivation area (see Fig. 2-1 for examples), while regional trends are dependent on introduction and termination of support schemes by regional and national governments

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[Lindegaard et al. 2016]. This underlines that perennial lignocellulosic energy crops are no attractive option for farmers unless dedicated financial incentives are in place.

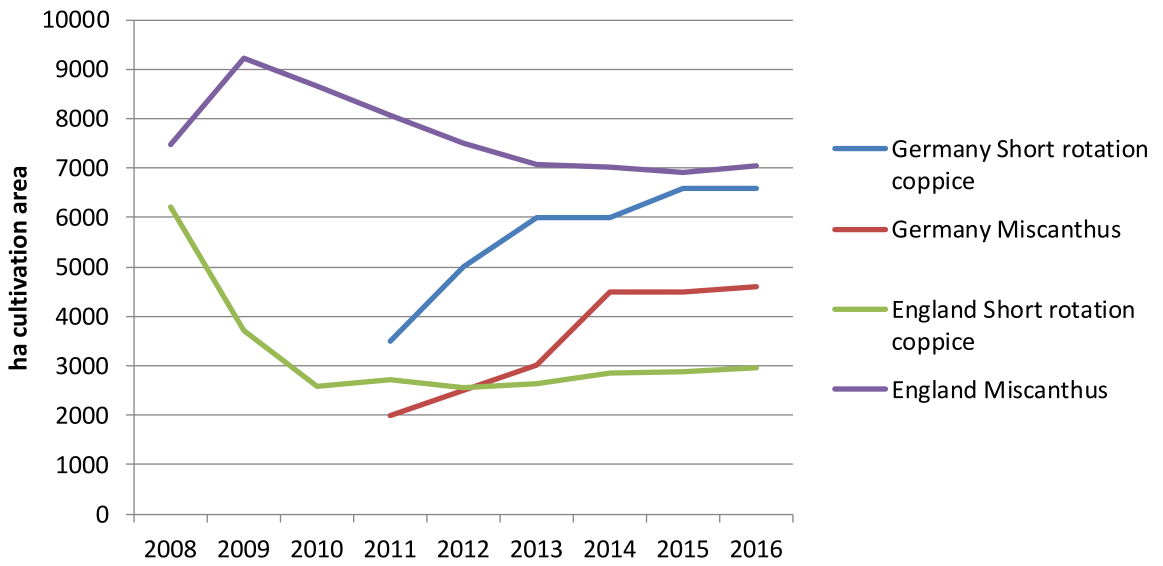

Fig. 2-1 Cultivation area of perennial lignocellulosic energy crops in England and Germany according to [Becker et al. 2018; Department for Environment Food & Rural Affairs 2017].

Conclusions on profitability of bioenergy production on standard land

Taken together, both micro-economic studies and statistics show that the cultivation of perennial crops for bioenergy on standard agricultural land only pays off for farmers under certain advantageous boundary conditions. No clear trends were identified that this situation is substantially improving. Thus, bioenergy from perennial lignocellulosic crops is expected to remain a niche market on standard agricultural land.

2.2 Costs and revenues on marginal land

The costs and revenues of bioenergy production on marginal land are less well researched than those on standard agricultural land. Both are analysed in chapters 2.2.1 and 2.2.2. The variability of the results requires considering which conclusions can be drawn from them and which not (chapter 2.2.3). Finally, cultivation on marginal and standard land is compared to identify specific bottlenecks and perspectives (chapter 2.2.4).

2.2.1 Costs

Costs were determined for the production of lignocellulosic energy carriers on marginal land. This includes all process steps from establishing the plantation via its maintenance, harvesting, transport and storage of the bioenergy carriers to the restoration of the field at the end of the cultivation period (see also chapter 1.3). Further processing of wood chips etc. into pellets or their use to produce heat, power or fuel are not analysed quantitatively because these steps are usually not done by farmers themselves. The analysed scenarios are described in chapter 1.2. They are based on case studies within the project and were

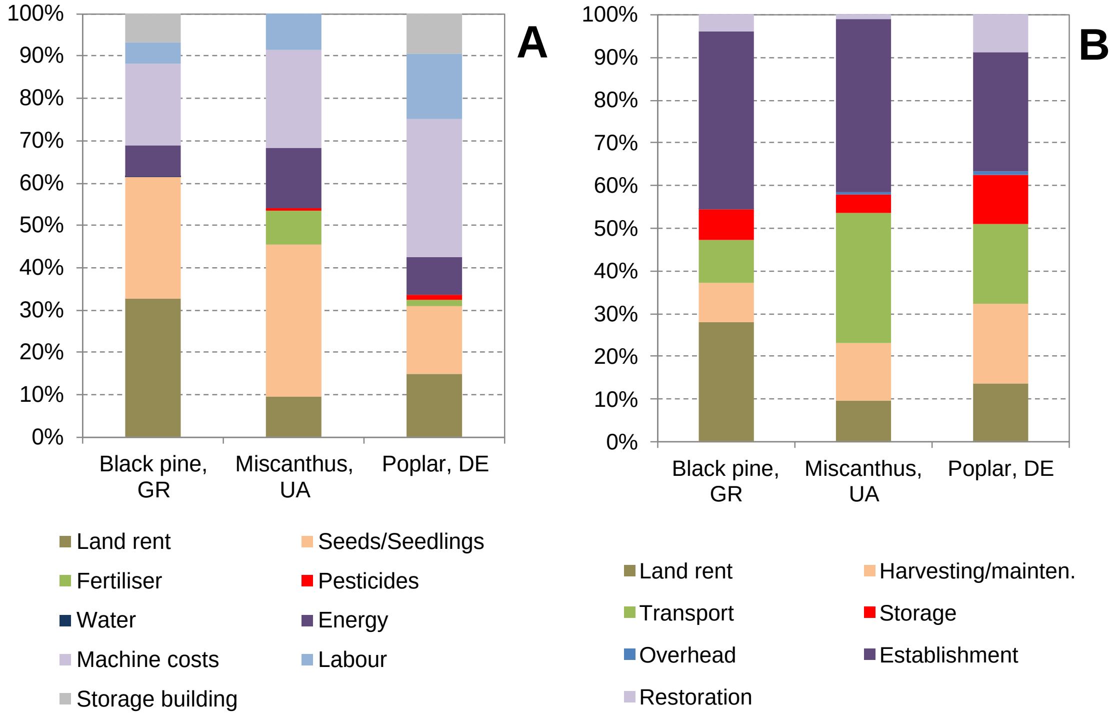

Fig. 2-2 Contributions to biomass production costs on marginal land without interest, taxes and subsidies in selected scenarios by type of costs (A) and by process steps (B).

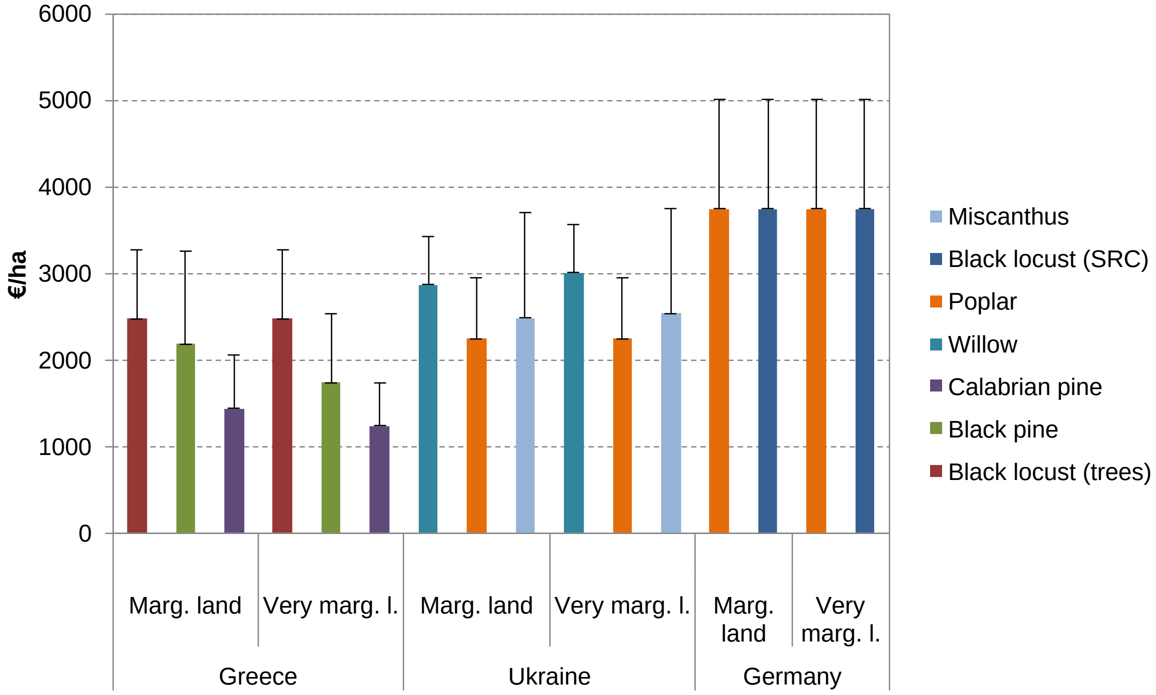

Fig. 2-3 One-time costs for plantation establishment (CAPEX) and field restoration (reserve funds) without interest, taxes and subsidies for case study scenarios on marginal land. Solid bars and thin lines indicate results of more optimistic and more conservative calculations, respectively. They cover ranges of input prices.

adapted from experimental settings to commercial settings. Some cost levels depend very much on conditions on each farm (e.g. availability of machinery, land rent, size and location of fields). Therefore, the scenarios analysed here represent a necessary generalisation based on settings derived from expert estimates (chapter 8 in the annex).

Cost drivers vary from scenario to scenario (Fig. 2-2). Machinery and seedlings are often among the cost drivers, which contribute to make plantation establishment and harvesting costly process steps. It can however be expected that a support programme creating regular demand for seedlings and specialised machinery, e.g. for harvesting short rotation coppice, could make these substantially less expensive. CAPEX (for plantation establishment) contributes about 30 – 55% to the overall costs depending on the scenario (Fig. 2-2 B and Fig. 2-4). Land rent and transportation can also be among the cost drivers. Land rents and transportation distances underlying the analysed scenarios were chosen by experts to reflect typical values in the respective regions although the situation on an individual farm can deviate to a large extent from these set values.

Biomass production costs can vary substantially from case to case (Fig. 2-4). In parts, these differences are due to the different cultivation approaches that result in different biomass yields (see Fig. 8-1 in the annex) and in different cost drivers analysed above. For example, Miscanthus reaches by far the highest yield and lowest costs per tonne of biomass among the analysed case study scenarios. In other parts, differences arise from price differences between countries (e.g. compare poplar in Ukraine and Germany) or within countries (compare solid bars and thin lines). To analyse the influence of various factors on the costs, we varied critical parameters.

Yields, which are mainly limited by the degree of marginality, are different in the subscenarios “marginal land”, “very marginal land” and, for comparisons, “standard land” (see also chapter 2.2.4). Furthermore, the efficiency of cultivating perennial bioenergy plants on marginal land, i.e. how much of each input is needed to produce a certain amount of biomass, can vary in particular because “marginal land” encompasses a wide range of sites with natural constraints due to e.g. inclination, altitude, aridity, salinity or acidity (included in the assessment of soil quality by the SQR method, see also chapter 1.2). These constraints may also result from human activities such as restoration after open pit mining. Each of these constraints requires an individual strategy for optimal use of bioenergy production using a suitable crop. These input efficiencies were set in each subscenario to values considered most typical by experts in the field. This is suitable for an overall analysis but cultivation on each individual site may deviate substantially from the analysed scenarios. Fig. 2-4 shows that the biomass production costs on more marginal land often are but do not necessarily have to be substantially higher. The more intensive the cultivation system, the more the quality of the land matters.

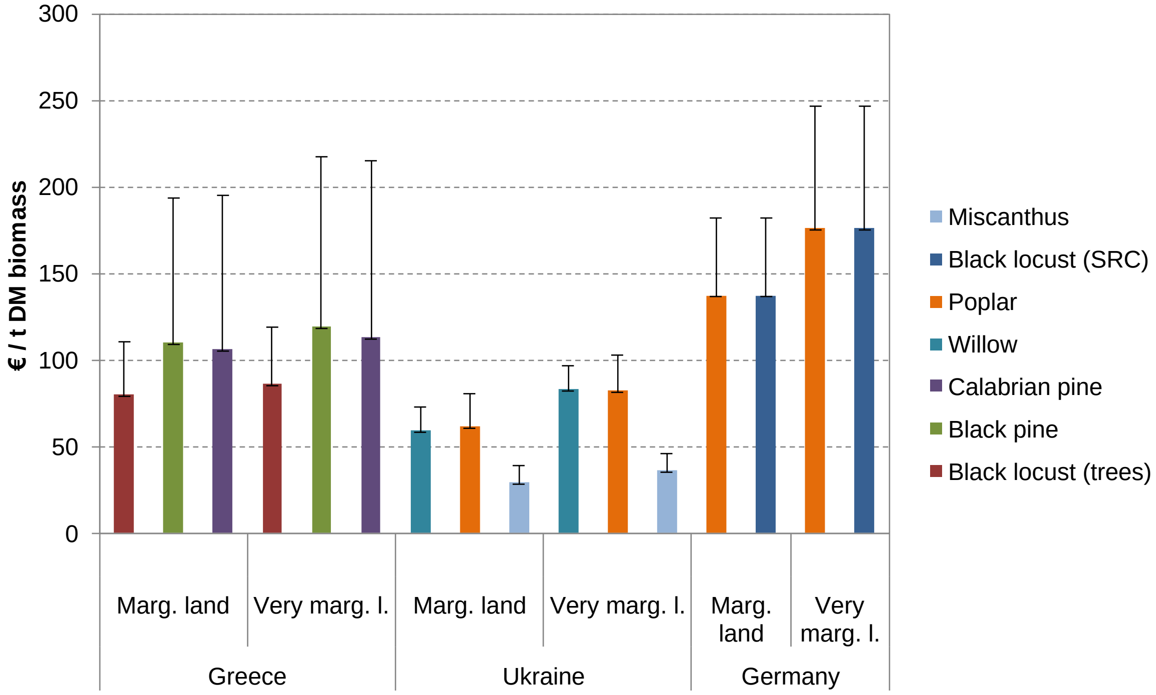

Fig. 2-4 Biomass production costs without interest, taxes and subsidies for case study scenarios. Solid bars and thin lines indicate results of more optimistic and more conservative calculations, respectively. They cover ranges of input prices.

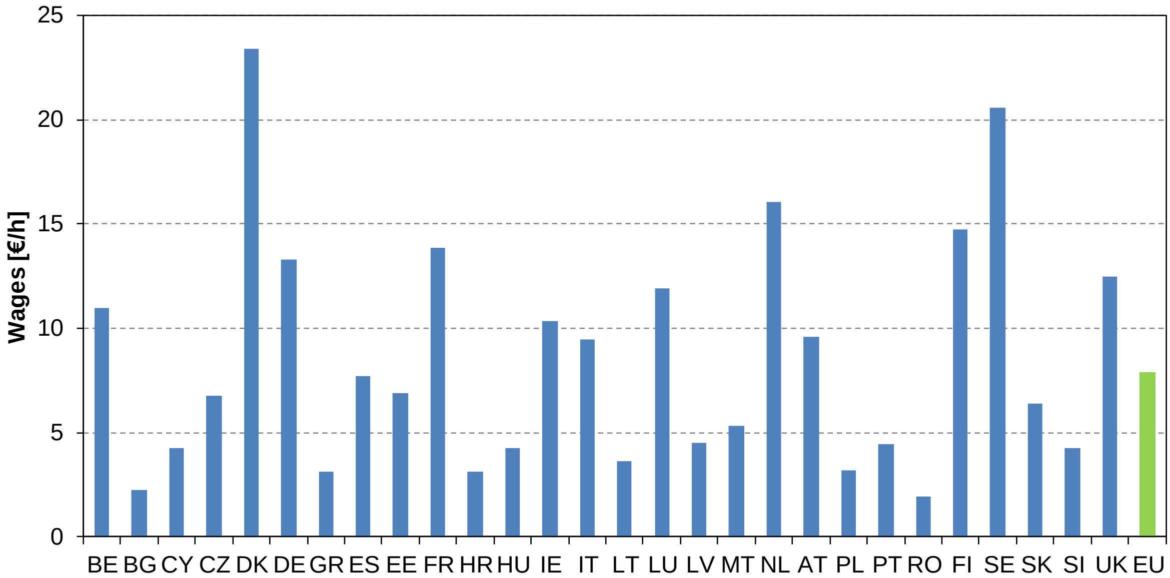

Fig. 2-5 Average paid wages for agricultural workers in the year 2015 (Own calculation based on [European Commission 2018]).

Prices of inputs depend on regional and global markets. Exemplarily, contributions of wages are analysed in the following. Hourly wages of agricultural workers vary between European countries. It is however difficult to determine comparable average rates. Following [Hill &

Bradley 2015], we calculated country specific hourly wages by dividing the total paid wages of the agricultural sector by the paid working hours based on data by [European Commission 2018]. Fig. 2-5 shows the hourly wages for agricultural workers in the European countries for the year 2015.

The direct influence of wage differences within one country on biomass production costs is mostly not decisive (Table 2-1). Differences between countries are however much higher. Thus, production systems such as extensive cultivation of pines, which require comparatively much work per harvested biomass, could be challenging to establish in high wage countries. Furthermore, wage levels indirectly influence many other important cost items such as machine costs or costs of seedlings. Direct and indirect influences together contribute to significant differences in biomass production costs between countries (see also Fig. 2-6).

Variation of further cost items are shown in Table 2-1. In particular the cost of land use is a very variable factor. Its cost can even be zero e.g. if a farmer owns marginal land that is otherwise unused. Additionally, opportunity costs need to be taken into account, which are zero for truly unused land but may vary substantially in the future (see also chapter 2.5). The influence of the costs of land use on biomass production costs varies substantially between scenarios (compare extensive pine cultivation and intensive Miscanthus cultivation in Fig. 2-4).

Costs for interest and taxes are not shown because these critically depend on the cash flow, which varies from case to case and from country to country. For example, some but not all national or regional support schemes for perennial biomass cultivation pay financial incentives cumulated in the first years thus reducing interest payments [Lindegaard et al. 2016].

Table 2-1 Sensitivity analyses on selected cost items and exemplary scenarios. Exemplary changes in costs for single items indicated in the first column lead to the changes in biomass production costs without interest, taxes and subsidies given for the respective case study scenario (own calculations).

		Black pine, GR	**Miscanthus, UA**	**Poplar, DE**
Wages	30% ↗	Costs 1% ↗	Costs 3% ↗	Costs 4% ↗
	30% ↘	Costs 1% ↘	Costs 3% ↘	Costs 4% ↘
Machine	30% ↗	Costs 5% ↗	Costs 7% ↗	Costs 9% ↗
costs	30% ↘	Costs 5% ↘	Costs 7% ↘	Costs 9% ↘
Land rent	50% ↗	Costs 14% ↗	Costs 5% ↗	Costs 7% ↗
	100% ↘	Costs 28% ↘	Costs 10% ↘	Costs 14% ↘
Seeds/	30% ↗	Costs 12% ↗	Costs 11% ↗	Costs 7% ↗
seedlings	30% ↘	Costs 12% ↘	Costs 11% ↘	Costs 7% ↘

Other studies came to similar conclusions. E.g. costs for land use (rent or other fees) can vary so widely that e.g. a study by Soldatos [Soldatos 2015] came to the conclusion that in their case the economic figure with highest informative value is the “return to land and management” meaning costs without land rent and equity costs. This shows that generalized cost calculations as they are common for standard crops on standard land cannot yield the same kind of conclusions for perennial bioenergy crops on marginal land due to high variability. Still, lessons can be learned from these results (chapter 2.2.3).

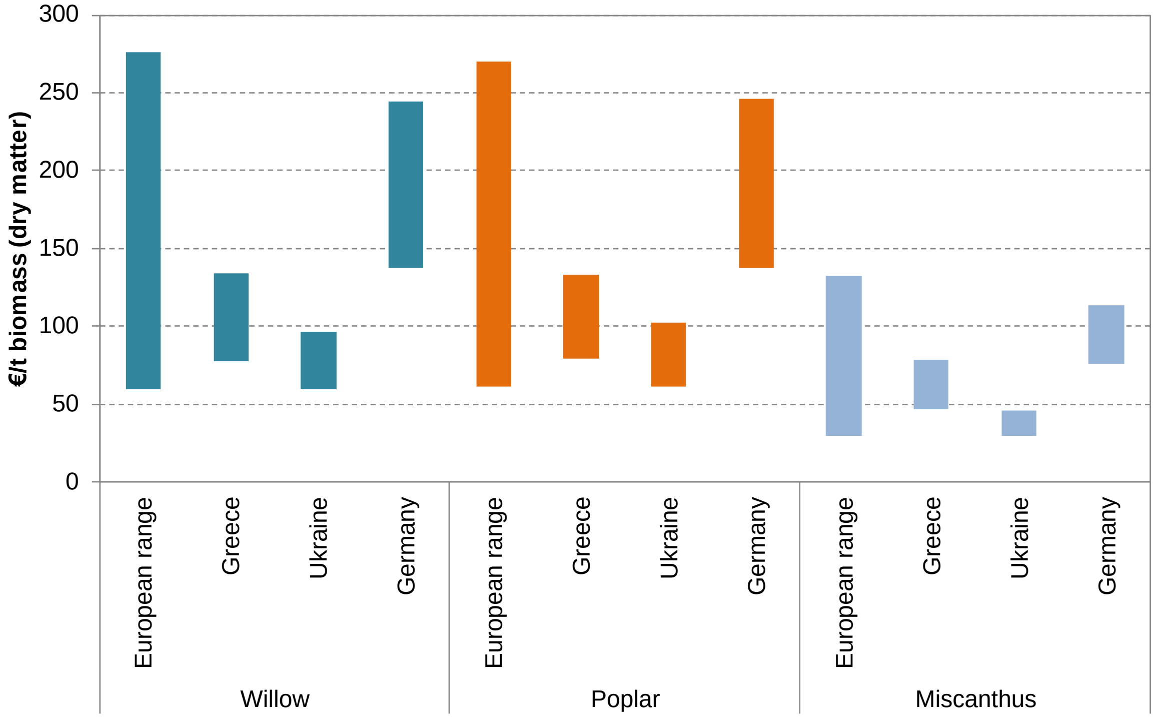

Fig. 2-6 Range of biomass production costs without interest, taxes and subsidies for generic European scenarios and case studies in Greece, Ukraine and Germany.

Fig. 2-6 shows that the selected case studies cover major parts of the result range of generic scenarios in Europe. This supports that further case studies do not need to be analysed to derive comprehensive conclusions. Additional conclusions cannot be drawn directly from the generalized scenarios because price differences between countries mask any other differences.

2.2.2 Revenues

Revenues for farmers originate from biomass sales and subsidies. Both depend on many factors and are hard to anticipate for the lifetime of a plantation of about 20 years.

Revenues from biomass sales

Revenues from biomass sales depend on yields and prices. Biomass yields are dependent on how well each crop fits the specific conditions at each site, weather and management. Thus, yields can vary from case to case and can be influenced by several factors, which creates several risks for the farmer (see chapter 2.3 for details).

Prices for bioenergy carriers that are not further processed and therefore are limited in their transportability can fluctuate considerably because local markets are often relatively small and vary from region to region. However, events such as the accumulation of timber from storm damage or new suppliers can cause prices to fall. Pelleting plants that make the biomass transportable over longer distances can only reduce this risk to a limited extent. It is only worthwhile to create stand-by capacities for these plants if they can purchase the biomass at a very low price in few years with biomass oversupply. In addition, the long-term development of prices is also influenced by world market prices for fossil fuels. Their development over 10 to 20 years is largely unpredictable. It can therefore be risky for individual farmers to offer biomass freely on local markets, even though there is generally a high demand for energy. According to current market experience by project partners, prices for unprocessed biomass can range around 65, 35 and 150 €/t biomass (dry matter) in Greece, Ukraine and Germany, respectively, with above mentioned volatility and regional variability. A comparison of biomass production costs without interest, taxes and subsidies to these price ranges (Fig. 2-7) is in agreement with the findings in chapter 2.1 that the cultivation of perennial energy crops is only viable under certain advantageous boundary conditions and/or with financial incentives. Due to the volatility and regional differences in prices, no profits/losses, target costing or cash-flow-based indicators such as internal rate of return (IRR) or net present value (NPV) are reported in this study because such figures are not robust in this context. In this case, conclusions can be reached better without these indicators (see chapters 2.2.3 and 2.2.4).

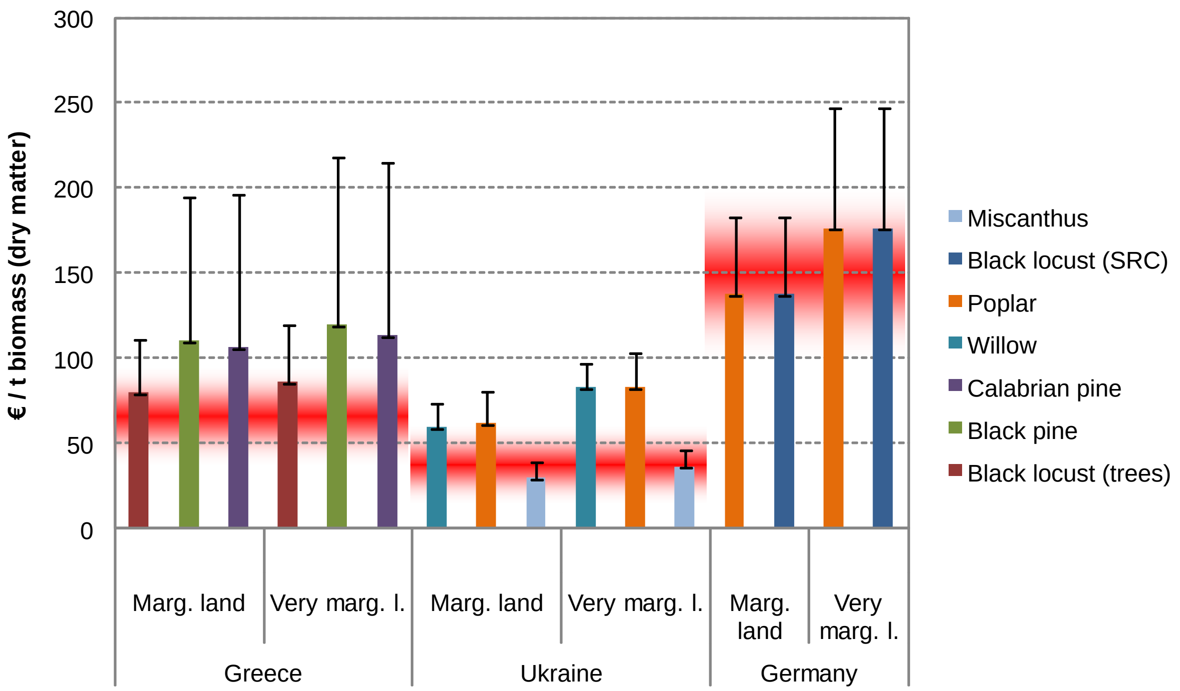

Fig. 2-7 Comparison of biomass production costs without interest, taxes and subsidies for case study scenarios to price ranges for produced bioenergy carriers (shaded in red in the background). Solid bars and thin lines indicate results of more optimistic and more conservative calculations, respectively. They cover ranges of input prices.

Mobilising these bioenergy potentials while at the same time reducing price risks for farmers could be achieved despite the market situation. Investors could simultaneously build new bioenergy plants from combined heat and power plants to second-generation biofuel plants and enter into long-term purchase agreements, management contracts or even lease agreements with farmers (vertical integration). Such a spectrum from merely renting land to contract farming is an established practice at various industrial customers (e.g. Vattenfall [Riess & Grundmann 2017]). Investors do not necessarily have to be energy companies, but could also be local organisations such as cooperatives.

Furthermore, cultivation of woody (but not grassy) biomass on marginal land with lower productivity can also contribute to the stabilisation of the biomass supply. If there is an increased supply of biomass in the planned harvest year, it is easier to postpone the harvest due to slower growth.

Revenues from subsidies

Within the EU, subsidies are an important part of the income of farmers. In European countries outside of the EU such as in the Ukraine, subsidies may not exist.

The common agricultural policy (CAP) structures the financial support for EU farmers into two pillars: direct payments and rural development policy, which also includes subsidies for areas with natural constraints (ANC) [European Commission 2017]. Within the pillars, several different kinds of payments are individually regulated in each EU member state. Currently, the CAP is being renegotiated for the period from 2021 - 2027, which is the relevant timeframe for this assessment. Even when the CAP is decided upon for the next years, this only guarantees a regulatory framework for payments in a smaller part of the usual plantation lifetimes of about 20 years. Therefore, this study can only analyse a range of potential future financial incentives as it seems likely based on past developments [Tropea 2016].

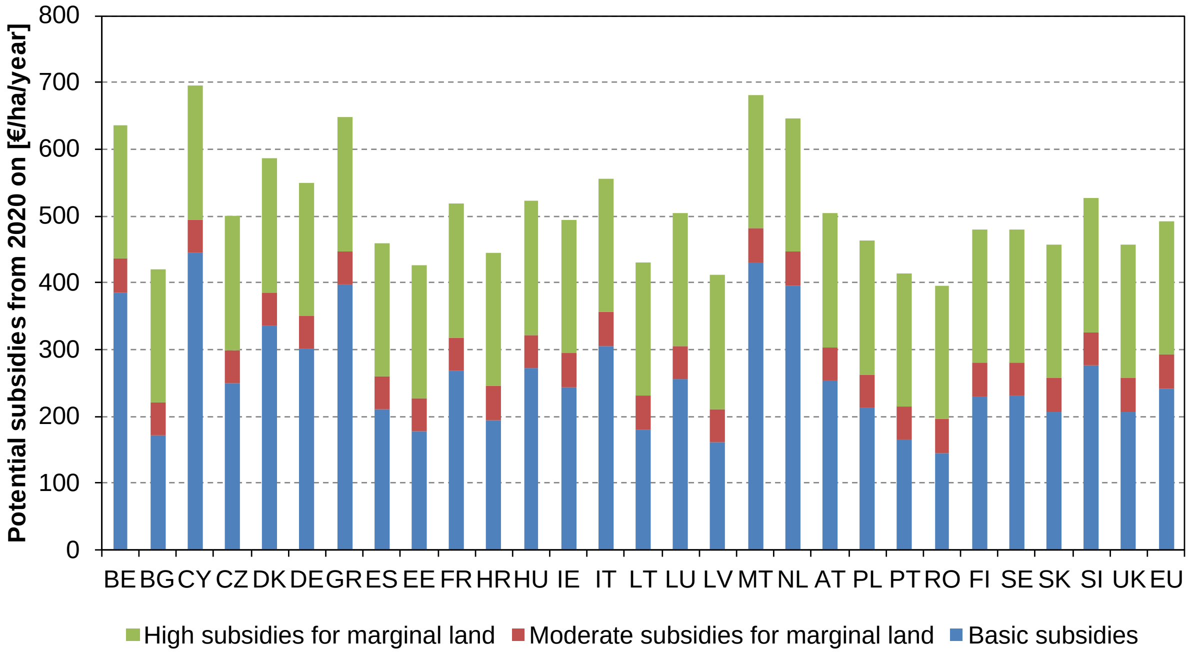

Fig. 2-8 Potential subsidies from 2020 on in the EU member states according to [Tropea 2016]. Subsidies for marginal land follow existing regulations for areas with natural constraints.

Relevant for the scenarios studied here are in particular financial incentives for "areas with natural constraints (ANC)", which is overlapping with but not identical to "marginal land" as defined in this study. These payments only make up a small part of each country's total subsidies but can range from low to very substantial for individual sites (Fig. 2-8). It depends on the concrete regulatory definitions in each member state if and how far each individual site is eligible for these subsidies. For most sites qualifying as "areas with natural constraints", subsidies are currently much lower than the maximum foreseen in the CAP and, according to current negotiations, these subsidies are rather declining. Direct payments are not relevant for farmers' decision to establish one of the scenarios analysed here, as they receive these subsidies even if no harvest is obtained from that piece of land and only low-cost interventions are applied. In the case of grassland, this could be achieved by mulching the field once per year in order to prevent natural succession towards a forest.

To analyse the impact of subsidies, we calculated potential subsidised biomass production costs based on the range of subsides foreseen in the current CAP (Fig. 2-9). This shows that subsidies can be decisive parameters. If maximal subsidies for areas with natural constraints according to current directives would be received, biomass production costs could partially even get negative. This shows that the range of subsidies for marginal land in the current CAP is sufficient to substantially support farmers in the production of biomass for bioenergy on marginal land and that the highest possible additional subsidies can be too high. It also means that biomass production costs depend on the design of the next CAP, the implementation in each member state and characteristics of each site.

2.2.3 Lessons to be learned

The variability of costs and revenues from case to case detailed in chapters 2.2.1 and 2.2.2 has two consequences for the insights this study can provide:

Lessons to be learned for bioenergy strategies

This study analyses exemplary bioenergy scenarios on marginal land originating from concrete cases studies that were adapted to typical conditions in a range of European countries. The range of crops covers most typical perennial lignocellulosic crops and some particularly adapted ones (in this case pine species), the range of cultivation systems is comprehensive (perennial grasses, short rotation coppice and forestry-like cultivation with rotation times below 20 years) and the range of countries covers the range from high-cost to low-cost countries. This portfolio of scenarios shows that few results and thus conclusions on e.g. cost drivers, risks and optimisation options apply to all scenarios but many results and conclusions are to be considered in most scenarios and should thus be taken into account in future bioenergy strategies. On the basis of these scenarios, typical barriers to the expansion of perennial bioenergy crops on marginal land can be identified and approaches to solutions found.

Lessons to be learned for individual farmers

For each particular site, the farmer has to find suitable crops that could grow with reasonable yields and are resilient to the natural constraints of that site (e.g. drought resistant crops). Thus, only a few of the crops under investigation in this study may be suitable. Of these, one may be agriculturally more suitable than others. This means that e.g. one crop may reach the yields set in the respective scenario on marginal land in this study, while other crops may miss this level. Furthermore, the costs of using land may vary substantially depending on local markets. Thus, generic European marginal land scenarios or country-specific generalised calculations are of very limited value for individual investment decisions. Because of the variability, more detailed calculations of indicators such as internal rate of return (IRR) cannot increase the informative value of the results for individual farmers either. Instead, case-specific business cases have to be calculated. Nevertheless, this report can give valuable information on which costs, revenues, risks and benefits should be considered in the individual business plans.

Conclusion on costs and revenues on marginal land

Variability in profitability between bioenergy crop cultivation cases on marginal land can be enormous and range from economically viable to unviable depending on the scenario and the boundary conditions in each case. Thus, the generalised scenarios used here cannot be used as a basis for assessing the economic viability of individual cases. However, these scenarios can be used to identify typical barriers to the expansion of perennial bioenergy crops to marginal land and to find solutions. To this end, costs are compared between cultivation on standard land and on marginal land in the following to identify bottlenecks and perspectives.

2.2.4 Comparison of biomass production costs on marginal and standard land

Perennial lignocellulosic bioenergy crops are only cultivated on limited areas of standard agricultural land. Barriers hindering a wider application have been researched in several studies such as [Bocquého & Jacquet 2010; Ericsson et al. 2006; Faasch & Patenaude 2012; Hauk et al. 2014; Witzel & Finger 2016]. Now it is to be determined how far bioenergy crops on marginal land face similar restrictions.

Biomass sales prices are determined by similar market mechanisms. We cannot see relevant premium prices (voluntary additional payments) for bioenergy carriers from marginal land. Apparently, any kind of bioenergy from non-food crops is perceived as similarly “green” independent of its origin. Future energy market regulation, such as the successor of the renewable energy directive, which is currently under negotiation [General Secretariat of the Council 2018], could in principle differentiate between biomass from marginal and standard land and thus create different prices but such approaches are not to be expected. Therefore, the production costs per unit of bioenergy carrier are compared between marginal land and standard land in the following.

Fig. 2-9 (A) shows that the more marginal the land, the higher the biomass production costs are. This is mainly due to lower yields at largely constant inputs. In the worst case, which was not explicitly modelled here, marginal land can also consist widely distributed individual plots in distributed smallholdings. These structures require an organisation of individual farmers in order to avoid even higher costs, especially for specialised machines.

The possible range of additional subsidies as they are foreseen in the current CAP is large enough to cover additional costs (Fig. 2-9 B). However, these subsidies are currently much lower and rather expected to decline (chapter 2.2.2). Appropriate support schemes covering additional costs but not overcompensating them will need to be developed in order to make the cultivation of lignocellulosic crops on marginal land for bioenergy possible.

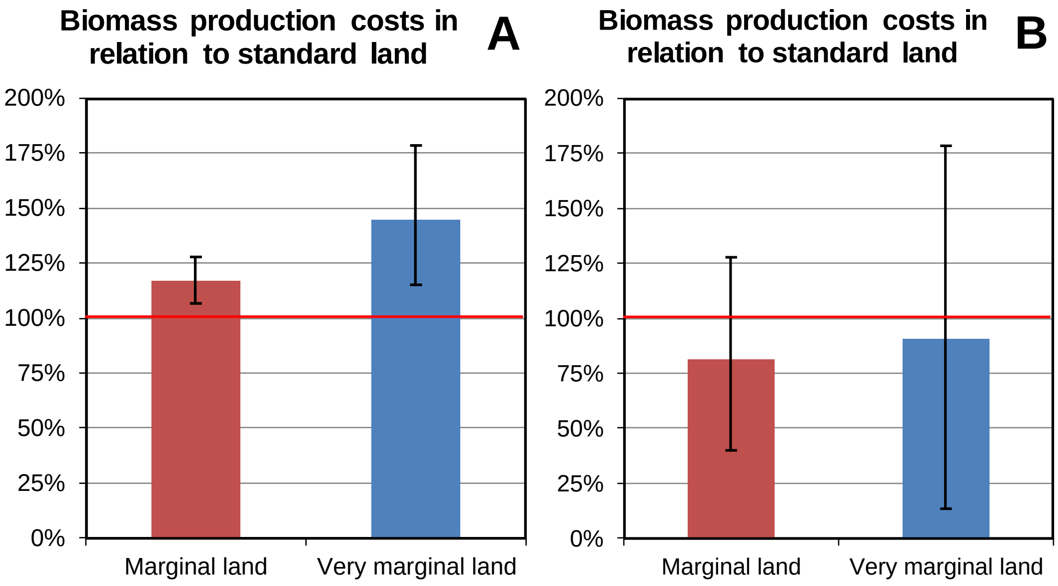

Fig. 2-9 Comparison of biomass production costs on marginal or very marginal land to costs on standard land (100%, red line). Displayed are costs before interest and taxes without (A) or with (B) maximum additional subsidies for areas with natural constraints (ANC) foreseen in the current CAP (2014-2020) outside of mountainous areas. Thin lines indicate ranges covering all case study scenarios.

Conclusion on the comparison of cultivation on marginal and standard land

Our calculations show that biomass production for bioenergy on marginal land is mostly more expensive. Depending on individual circumstances and current policies, higher cost might be compensated by lower land rent and additional subsidies (chapter 2.2.4). Since additional subsidies for marginal land are only intended to compensate for additional costs, it is however not to be expected that cultivation on marginal land turns more profitable than cultivation on standard agricultural land.

2.3 Risks for farmers

This chapter analyses the risks of cultivating perennial energy crops on marginal land that can impact farmers or investors operating the cultivation together with farmers.

For constant yields as well as to reduce the risk of complete losses, varieties and cultivation must be well adapted to the location. However, marginal land is much more diverse than standard land, which is why good knowledge and experience are required. Farmers, however, often have little experience with perennial crops and it can only be acquired much more slowly due to long plantation lifetimes. This increases the risk of lower yields due to sub-optimal management. Therefore the development and exchange of experiences is more important than with other crops and should be promoted in a structured way.

Total losses of plantations, e.g. due to extreme weather events such as ice breakage or drought, are possible. Depending on the point in time, this can mean high economic losses. Sites that are more prone to such events, e.g. because of their location or soil characteristics, are more often found among marginal sites than among normal sites. This can give rise to existential risks for farmers, who have to be mitigated if society wants to make greater use of marginal land for bioenergy production. This can be achieved not only by compensation in the event of extreme weather events, but also, for example, by investment subsidies rather than incentives in sales prices.

Higher production costs on marginal land can often only be offset by additional subsidies for areas with natural constraints (see also chapter 3.2.4). In many cases, however, the smallest amount of support will not suffice. Annual subsidies also expose farmers to the risk of being unprofitable if the subsidy policy, within the EU first and foremost the CAP, changes within the plantation life of about 20 years.

The cultivation of perennial energy crops can also reduce the overall risks of farmers by diversification as the risks of these crops are different from the risks of other crops. The downside of cultivating perennial energy crops only on a small share of land would be that a fragmented market with many small suppliers would be created.

2.4 Options to increase attractiveness of investment

The cultivation of perennial lignocellulosic energy crops on marginal land faces the same barriers as their cultivation on standard agricultural land plus increased costs and potentially also risks when using marginal land (chapter 2.1 - 2.3). Thus, measures to generally support the cultivation of perennial energy crops are necessary but not sufficient to increase the attractiveness of investment into these crops on marginal land.

General support for perennial energy crops

In the last decades, many regional grant programmes supporting the first years of perennial plantations were temporarily successful. They prompted the establishment of plantations by farmers in the respective region and time [Lindegaard et al. 2016]. However, overall areas covered by these crops remained low and often spikes of planting activities rather than continuous growth of cultivation area were triggered. This shows that the general concept of initial financial support is very suitable but also that amounts and continuity are not sufficient. Continuity would be particularly important to support the development of a professionalised value chain including experienced planning and establishment of plantations and a bioenergy market that can rely on supply from perennial energy crops.

An alternative approach in establishing perennial energy crop plantations is the vertical integration of the value chain by investments of e.g. large energy companies (e.g. Vattenfall [Riess & Grundmann 2017]). Here, large investors rent land from farmers, contract specialised service providers with planning and establishing plantations as well as harvesting. If at all, farmers are only contracted for routine work such as plantation maintenance. This facilitates a professionalization and easier central management of activities. Limited areas cultivated based on this business model suggest that it has not turned out to be overly profitable under current conditions but is rather seen as investment in future alternatives to fossil energy sources. Such vertically integrated business models could be supported by measures on the energy market such as quota etc. rather than by subsidies to farmers. Such measures have been successfully established e.g. for first generation biofuels and could be adapted to other sectors. Besides financial incentives to farmers, also demand-based measures can influence the profitability. For example, the new renewable energy directive ("RED II"), which is currently in the last steps of the decision process [General Secretariat of the Council 2018], aims at increasing the share of non-food-crop renewable fuels. How far and when this may have an effect on the prices of lignocellulosic bioenergy carriers remains to be analysed once this directive is finally adopted.

Support for perennial energy crops on marginal land

On marginal land, costs are generally higher and risks can be higher due to the characteristics and variability of conditions on marginal land (chapter 2.2 and 2.3). Higher costs could be compensated for by additional subsidies as they are foreseen in the CAP for areas with natural constraints (ANC, see also chapter 2.2.1). These financial incentives however must be established at an appropriate level and in a reliable manner by each member state. Integration of additional support of marginal land into schemes providing initial financial support could add valorisation of marginal land into subsidy concepts that have proven successful. Of course, conditions of grants need to avoid excessive support, which however has not been a major concern in the past. With increasing funding, this may nevertheless require more differentiated and thus complex rules.

Risks of unreliable yields on marginal land could be minimised by experienced farmers or other organisations involved in planning and operating the plantation. Building such experience requires in the first place a continuous development of and stable perspectives for planting activities. This could also increase the long-term effectivity of qualification programmes for farmers or contractors. Such continuity has not been achieved by temporary support programmes of the past.

Taken together, measures for increasing the attractiveness of investment into perennial energy crops have been successfully tested but not continuously applied. Measures to support perennial energy crops on marginal land do not need to be fundamentally different but would require more funding and long-term perspectives for establishing required experience. The kind of support could influence whether large investors such as energy companies or individual farmers are responsible for the implementation and thus take both risks and benefit from potential profits.

2.5 Competing alternatives

Marginal land, defined in this project mainly via low soil quality [Ivanina & Hanzhenko 2016], could also be used for other purposes than bioenergy production. The main potential competing use options are nature conservation and solar power via photovoltaics. Since most marginal land is currently unused or underused, substantial competition for (economic) use of this land does not exist. This may change if policies change or if other use options gain in technological efficiency. Since bioenergy policies for marginal land need to be developed with long-term perspectives (see also chapter 2.4), potential future competition needs to be taken into account.

2.5.1 Solar power

All decarbonisation strategies require enormous amounts of additional renewable power. The main sources are usually solar power (mainly photovoltaics) and wind power. If decarbonisation is to be approached seriously, additional land in Europe will be required for photovoltaics. Land currently not used for agriculture or nature conservation will have to be discussed in this regard. Thus, marginal land will be one potential target for additional solar power although solar power does not need minimum soil requirements.

From a land owner's perspective, solar power on marginal land may become an attractive alternative to bioenergy production. The economics of photovoltaics in Europe are determined by almost steadily declining costs and constant adaptations of subsidy strategies, regulations and fees [Ritchie 2018; Wirth 2018]. This generates considerable volatility in annual installation volumes. However, prices have fallen that much that photovoltaics power can already be produced below household electricity prices. The market is already preparing for entirely subsidy-free installations starting probably in Arabic countries provided that other boundary conditions are acceptable [Ritchie 2018]. Even if subsidy-free installations are not yet in reach in Middle or Northern Europe, boosting renewable power could be realised at comparatively low costs if desired by politics. Recent studies report levelised costs of energy ranging from 4 to 7 ct/kWh power output [Ritchie 2018; Wirth 2018]. This seems competitive compared to bioenergy carrier production costs before interest and taxes on marginal land of 2.5 – 15 ct/kWh as determined in this study (referring to biomass needed to produce 1 kWh in a typical power plant).

2.5.2 Nature conservation

Unused land from an economic perspective can still have a high value for nature and thus provide ecosystem services that are mostly not accounted for. Nevertheless, agriculture and many more aspects of human life depend on these services. The more intensive the use of agricultural land gets the more important unused or extensively used land will become for maintaining these unpaid ecosystem services. Thus, the more support policies for bioenergy or declining prices e.g. of photovoltaics make it economically attractive to take marginal land in use the more important nature conservation will become. This is likely to generate restrictions for cultivation of perennial energy crops.

Conclusion on competing alternatives

Installing large ground-mounted photovoltaic systems could become economically attractive alternatives for owners of European marginal land in less than a plantation period of perennial lignocellulosic energy crops. Additionally, nature conservation aspects may lead to restrictions of marginal land use. For the cultivation of bioenergy crops this would mean higher opportunity costs of land use and less available marginal land. This competition needs to be taken into account when designing future renewable energy strategies to ensure a balanced mix of fluctuating and storable renewable energy sources for power, heat and fuels as well as robust ecosystem services.

3 Social benefits and risks

The economic viability discussed in chapter 2 analyses under which circumstances it can be feasible/attractive or not for farmers to cultivate perennial energy crops on marginal land. This chapter enlarges the scope and analyses whether other stakeholders or the general society may socially and economically profit from the analysed value chains.

3.1 Benefits for stakeholders

3.1.1 Job creation

The obvious benefit of using previously unused/underused land is that new jobs are created in rural areas. In contrast to substituting e.g. wheat by energy crops on standard arable land, using unused/underused land will create additional jobs instead of replacing a similar number of existing jobs. Depending on the definition of marginal land (chapter 1.2), all or parts of it can be unused or underused. Its use for perennial energy crop cultivation can generate significant numbers of direct jobs (Fig. 3-1). The amount of jobs depends on the cultivation schemes in the different scenarios. Since the number of jobs varies much less per tonne of biomass than per hectare of land, the intensity of cultivation is one important aspect of this.

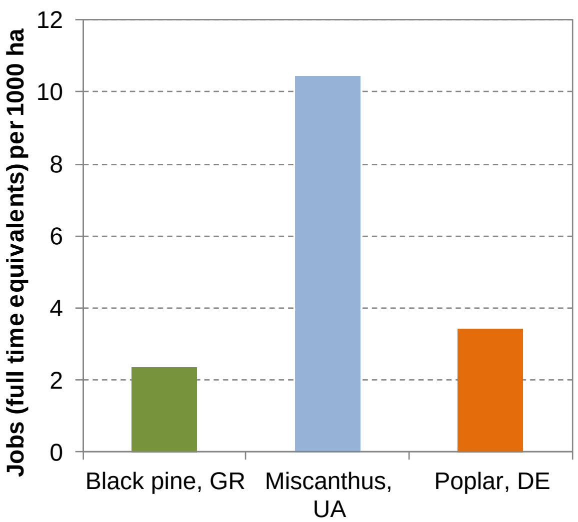

Fig. 3-1 Creation of direct jobs per cultivated area for selected scenarios. This figure is based on the use of previously unused marginal land.

In addition to direct jobs, indirect jobs will be created by additional demand of goods and services created by new bioenergy plantations. Like for the direct jobs, they will be additionally created jobs since no other agricultural use of the same land is replaced. Since about half of the money for the cultivation of perennial energy crops can be spent in the region or in other rural areas (chapter 3.1.2, Fig. 3-2), this job creation can substantially contribute to socio-economic benefits in rural areas. Indirect jobs are not quantified in this project because very specific services such as seedling production are expected to dominate this figure (see also Fig. 2-2). Standard employment multipliers derived from social accounting matrices cannot provide such specific information and it is questionable whether sector averages lead to useful information. Instead, the analysis would have to be extended to dedicated services for perennial crop cultivation. Nevertheless, created indirect jobs will be in the same order of magnitude as the created direct jobs, which is sufficient information for this analysis. The creation of income for workers and farmers via wages and profits can also induce jobs by increased general consumption. The number of these jobs critically depends on the profit made, which can be quantified on a case-by-case basis and is subject to several risks and uncertainties (chapters 2.2.2 and 2.3). Thus, induced jobs cannot be reliably quantified for the assessed scenarios.

Further processing and use of the biomass such as pelletising, combustion or also conversion into 2nd generation biofuels can create further direct, indirect and induced jobs but also replace jobs because of competition with fossil fuels etc. If e.g. a wood chips heat plant replaces a fuel oil heat plant, the number of jobs connected to the heat plant will remain largely constant. A few jobs may be lost in crude oil refineries in the long term but considering the amount of work per energy content of the fuel, this will be a very limited effect. Therefore, employment effects from cultivation are expected to dominate the employment effects of the whole value chain.

Whether the identified positive employment potentials are permanent, only transient or not realisable at all depends on the long term economic viability of the value chain. Chapter 2 of this study concludes that it depends on the scenario, public support and on the concrete boundary conditions in each case whether such viability can be achieved. Taking into account previous market developments, the number of jobs depends to a large degree on how much and how public money is spent to support the cultivation of perennial energy crops. Retrospective studies on previous support policies may therefore give valuable further indications on job creation potentials (see also chapter 2.1.2).

3.1.2 Contribution to rural economy

One important goal of public support for the bioeconomy is the stimulation of the economy in rural areas. An indicator quantifying this stimulus is the share of all costs incurred in biomass production that stems from regionally sourced goods and services. We determined the share of the money that can be spent regionally (Fig. 3-2), while parts may equally be spent in other regions despite local availability. Depending on scenario and boundary conditions, these shares range from 20-80% with values around 50% in most scenarios.

Most of the goods and services required for the analysed scenarios are typical agricultural goods and services, which are mainly available in agriculturally dominated areas. So even if the origin is not from the same region or of local employment is replaced by contracting, it is likely that these costs are stimulating rural economies elsewhere.

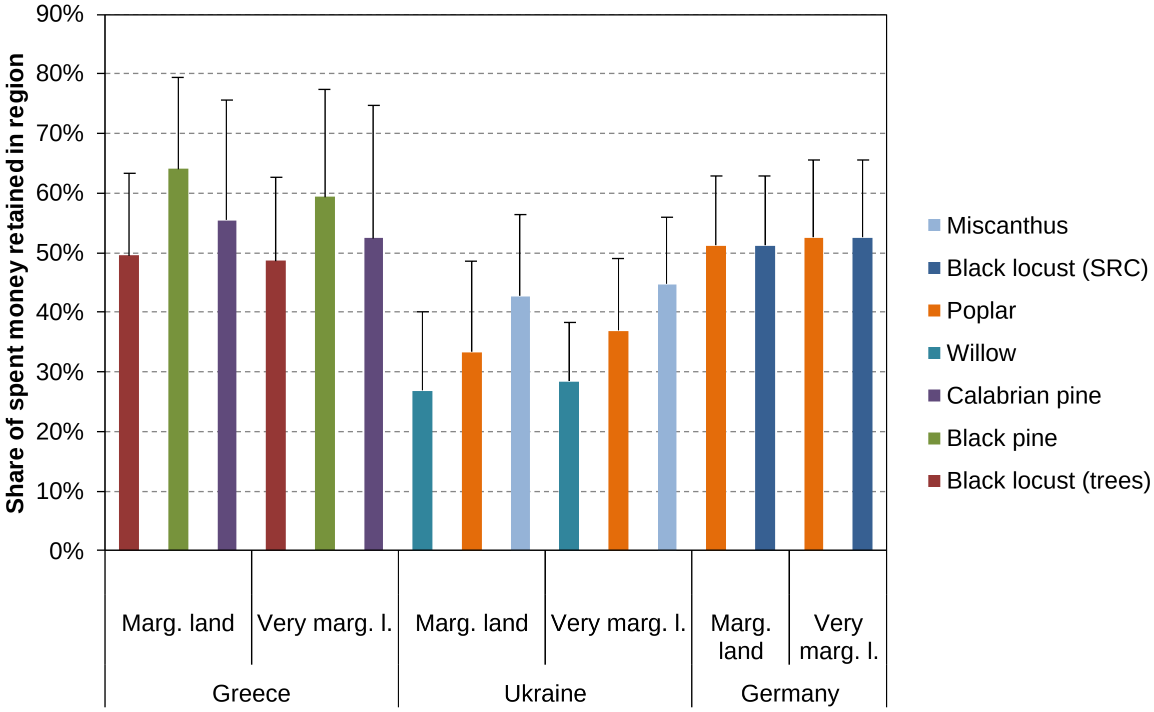

Fig. 3-2 Share of biomass production costs without interest and taxes that can be spent for regionally sourced products and services (including direct employment). Solid bars and thin lines indicate results of more optimistic and more conservative calculations, respectively. They cover ranges of input prices.

3.1.3 Further social benefits

An important further benefit for stakeholders is the generation of new skills and expertise among the farmers or contractors involved. Compared to other agricultural techniques, the efficient production of perennial energy crops in particular on marginal land is very innovative. Adding this option to the portfolio of usual crops and cultivation techniques makes farmers and workers more independent of international markets for agricultural products. Using parts of the crop land on a farm for perennial energy crops helps to stabilise incomes in the short term and the gained skills open long-term opportunities if demand for other crops may change structurally.

3.2 Risks for stakeholders

We have identified the following risks for stakeholders to be taken into account:

- Investments that turn out to be unsuccessful have greater negative effects for perennials than for annual crops because of the much higher investment volume. Additionally, the removal of plantations creates considerable costs that still need to be covered even if losses already occurred.
- "Idle" marginal land is often still used extensively and/or informally e.g. for periodic grazing. Even if perennial energy crops generate more income, profits and demand for the rural economy, other people may benefit from it than the replaced former extensive users of the land.
- It is an option to outsource planning, establishment and harvesting to specialised service providers. This is particularly attractive to operators of integrated value chains including biomass production and use (e.g. biomass-fired combined heat and power plants that contract bioenergy plantations). On the one hand, this can help to increase efficiency, to build profound expert knowledge and to transfer risks from single farmers to bigger portfolios held by bigger organisations. On the other hand, it can also lead to profits being absorbed by large companies rather than by local farmers and to knowledge and control being lost to non-local organisations. This depends on who owns and controls central service providers. This does not need to be a large company but could also be e.g. a cooperative. Here too, a stakeholder process could help to safeguard the interests of smaller players.

To mitigate risks in concrete projects, stakeholders have to be integrated in knowledge development and decision making [Di Lucia et al. 2018]. This can avoid unintended negative impacts, e.g. by displacing extensive use for e.g. animal grazing, external project developers may be simply unaware of. Additionally, it can foster support by the local community for the project.

Conclusion on socio-economic benefits and risks for stakeholders

The cultivation of perennial energy crops on marginal land can generate *additional* jobs, income, profits and stimuli to the economy in rural areas, provided it is economically viable. Furthermore, this can contribute to building skills and knowledge and to a diversification of risks. Some stakeholder groups, in particular smaller players, may however be negatively affected unless their interests are addressed in a dedicated stakeholder process: It should e.g. be taken into account that marginal land that seems to be unused may still be used extensively. Furthermore, a professionalisation and centralisation of planning, establishment and management of energy crop plantations via specialised service providers may lead to a transfer of profits, skills & knowledge and control but also entrepreneurial risks from farmers to larger companies. A compromise needs to take all stakeholders interests into account.

3.3 Benefits and risks for general society

Since perennial energy crops on marginal land are dependent on publicly funded subsidies, society expects sustainability advantages in return. Society expects above all robust environmental benefits and jobs in rural areas. Subsidies must therefore be linked to robust criteria and measures for achieving these objectives not to risk misspending public money or even create damage. All expected benefits align with goals of the EU Rural Development Policy also known as the "second pillar" of the Common Agricultural Policy (CAP). Therefore, this framework would be ideally suited to harbour newly developed and/or expanded support for cultivating perennial energy crops on marginal land. This however would require additional funding of this pillar instead of the cuts currently under discussion in the political process on the further development of the CAP for the period from 2021-2027.

Expected socio-economic benefits and the required economic viability are discussed in chapters 3.1 and 2, respectively. They could be ensured by support schemes discussed in chapter 2.4 and accompanying stakeholder engagement processes discussed in chapter 3.2.

Environmental benefits and risks are analysed in [Rettenmaier et al. 2018]. Some cultivation concepts on marginal land can provide specific local benefits such as erosion control, bioremediation or soil quality improvement. More generally, two aspects are particularly important: On the one hand, unused marginal land is more likely than standard agricultural land to develop/have developed into biodiverse ecosystems because these are often native e.g. to poor soils. This can also apply to sites outside of protected areas. On the other hand, additional bioenergy provision can help mitigate climate change.

This leads to a fundamental conflict between using marginal land for the benefit of the population in rural areas and of the climate and leaving marginal land to nature, ultimately to ensure a stable ecosystem that sustains our livelihood. Measures to minimise overall environmental and ecological risks are also discussed in [Rettenmaier et al. 2018]. These are based on weighting the ecological value of individual sites against the attainable yield and thus climate change mitigation potential. How far a strict compliance to such boundary conditions avoiding critical long-term risks for society can still leave room for a development of large-scale bioenergy plantations on marginal land remains to be negotiated, explored, tried and verified in a long-term political process with all relevant societal groups. This will require local solutions rather than uniform schemes for whole Europe.

Conclusion on socio-economic benefits and risks for the society

Perennial energy crop cultivation on marginal land can provide socio-economic benefits in rural areas. The environmental effects of climate change mitigation and human appropriation of potentially biodiverse land however can have conflicting indirect socio-economic long-term effects. These critical economic and social benefits provided by resilient ecosystems (ecosystem services) have to be taken into account and continuously monitored if a process is to be started to substantially increase the volume of perennial energy crop cultivation on marginal land.

4 Key results, conclusions and recommendations

The following key results, conclusions and recommendations can be summarised or derived, respectively, from the preceding chapters:

The use of marginal land for bioenergy production can solve several problems in connection with competition for agricultural land such as increasing biomass imports or deforestation outside the EU and also support the rural economy. This requires economically viable use of the land.


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The use of marginal land can help to ensure that traditional food and feed production is not further displaced by the production of renewable bio-resources from traditional arable land (chapter 1.1). This displacement increases biomass imports into the EU and exacerbates problems such as deforestation or land grabbing in other parts of the world. In addition, the local economy in rural areas can benefit from additional income. However, this can only be achieved if the cultivation of perennial bioenergy crops on marginal land pays off for farmers.

The cultivation of perennial energy crops on standard arable land only pays off for the farmer under certain advantageous boundary conditions.

This is well documented in both microeconomic studies and statistics:

1. Published microeconomic studies conclude that perennial energy crops on standard arable land are hardly profitable or even unprofitable for farmers compared to food crops (chapter 2.1.1).
2. Statistics on land use show that the cultivation of perennial crops such as grasses or short rotation coppice plays only a minor role and that the cultivated area often fluctuates with the start and end of support programmes (chapter 2.1.2).

The dominant cost items can vary depending on the circumstances, e.g. regional purchase prices, but often machine costs and seedlings are among the cost drivers for the cultivation of perennial bioenergy crops on marginal land.


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Machine costs are generally high and vary greatly depending on machine utilisation and distribution of sites (15 - 60% of biomass production costs), because in many cases expensive dedicated machines are used for harvesting (chapter 2.2.1). Cost advantages can be achieved if, for example, contractors achieve a high level of machine utilisation. In addition, seedlings can be cost drivers. This could become less significant if there is a continuous demand for larger quantities of seedlings. Land rent can be of subordinate importance or can be among the largest single items. Therefore, case-specific calculations are necessary for investment decisions.

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The costs for biomass production on marginal land are usually higher than on standard land, but can be compensated by lower land rents and additional subsidies.

Our calculations show that biomass production on marginal land is more expensive for the following reasons (chapter 2.2.4):

- Agricultural yields are lower on marginal land than on standard land.
- The main cost drivers such as costs for establishing plantations and machinery are largely constant or even higher per area under cultivation.
- Overall, this can lead to about 20 % (up to about 30 %) higher costs per tonne of biomass on marginal land and about 45 % (up to 80 %) higher costs on very marginal land.
- Depending on individual circumstances and current policy, higher costs can be offset by lower land rents and additional subsidies. Current EU rules allow for sufficient additional subsidies for areas with natural constraints, but actual payments under national legislation are mostly insufficient.

Important findings on improving the economic viability and attractiveness of investments in perennial bioenergy plantations on marginal land were obtained in this study, although individual cases can vary greatly.

The profitability of perennial bioenergy plantations on marginal land varies particularly strongly from case to case, because marginal sites can differ greatly from each other. Biophysical properties such as inclination, altitude, aridity, acidity or salinity can determine the marginality of a site (in some cases resulting from human activities). Therefore, costs, biomass yield and risk of crop failure for the same plant may vary considerably not only from country to country but also from site to site (chapters 2.2.1 and 2.2.2). This is also reflected in the fact that bioenergy crops on marginal land are only established in individual, apparently advantageous niches. Consequently, the generalised scenarios used here cannot be used as a basis for assessing the economic viability of individual cases (chapter 2.2.3). However, these scenarios can be used to identify typical barriers to the expansion of perennial bioenergy crops on marginal land and to find approaches to solutions.

Risks that are difficult to quantify, such as the total loss of a plantation, can make investments unattractive, even if cultivation should be profitable.

An investment in the establishment of plantations with a lifetime of around 20 years is only attractive for the farmer if either high profits are anticipated (which can only be expected in individual cases) or if risks are low. However, such risks can be significant and higher on marginal than on standard land (chapter 2.3).

Risks associated with cultivation could be mitigated by building up experience and by support concepts designed to mitigate existential risks for farmers.

The risk of total losses of the plantations, e.g. due to extreme weather events, and the risk of lower yields due to non-optimal management can be higher on marginal land than on standard land. Therefore, building experience with perennial crops and marginal land is particularly important. In addition, existential risks for farmers must be mitigated by appropriate support if society wishes to make greater use of marginal land for bioenergy production. This may be achieved not only by compensation in the event of extreme weather events, but also, for example, by investment subsidies rather than incentives in sales prices. Since planning reliability is particularly important for plantation lifetimes of around two decades, appropriate framework conditions must be created, e.g. long-term support or a payment cumulated in the first few years.

The risk of lower earnings due to price fluctuations on energy markets could be offset by certain contract structures and, in the case of woody biomass, in part by flexible harvests.

Prices for unprocessed bioenergy carriers, which are therefore limited in transportability, can fluctuate strongly because local markets are often relatively small (chapter 2.2.2). In addition, price developments are largely unpredictable over about two decades, also because of the globally linked energy markets. It can therefore be risky for individual farmers to offer biomass at their own risk on local markets.

Mobilising these bioenergy potentials while simultaneously reducing price risks for farmers could be supported, among other things, by partially integrating the value chain from the farmer to the user of the bioenergy carriers (vertical integration). In this case, risk diversification can be achieved for both the farmer and the buyer (chapter 2.4).

Furthermore, the cultivation of woody biomass on marginal land can also contribute to the stabilisation of the biomass supply through the possibility of shifting harvests.

If viable business models are found, additional jobs can be created in rural areas.

In contrast to many other new value chains of the bio-economy, the use of previously unused marginal land actually creates additional jobs because it does not simply replace other uses of the same land (chapter 3.1.1). However, it must be borne in mind that many sites that appear to be unused at first are used extensively and/or free of charge (e.g. grazing) and thus provide jobs. Therefore, especially in projects with external investors, a stakeholder participation process must precede the investment decision in order to ensure broad support.

In order to maintain relevant added value in rural areas and protect local interests, local actors must be strengthened.

With the exception of fuel costs and production costs for machinery, all major cost items can make a relevant contribution to local value creation (chapter 3.1.2). Ambivalence arises from the contract structure: Risks can be spread, costs reduced and experience gained and used more effectively if organisations only rent the land from farmers and have it managed by specialised contractors. If this is done by large companies, however, then profit, knowledge and control also flow out of the region and the consideration of local interests such as nature conservation or existing extensive land use becomes more difficult (chapter 3.2). Furthermore, achieving specific local benefits like erosion control, bioremediation or soil quality improvement may require site-specific instead of scalable concepts. Such investors could also be local bioenergy cooperatives, which have the necessary size to achieve efficiency advantages without losing local roots. Small projects such as biomass cogeneration plants for public buildings or district heating networks are promising.


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If the aim of public funding is to strengthen rural areas, appropriate measures should be taken to ensure that local actors are involved in a central position and that local added value is generated.

In addition to short to medium-term socio-economic impacts, long-term socio-economic risks to the general public must also be taken into account: Environmental criteria and an examination of alternatives can reduce these risks, but can also limit the development of large-scale bioenergy plantations on marginal land.

Bioenergy plantations on marginal land can contribute to slowing climate change, but also require land that could otherwise have a higher biodiversity. Thus, they can contribute positively and negatively to critical economic and social benefits of resilient ecosystems (ecosystem services) (chapter 3.3). In addition, photovoltaics, for example, can generate several times more electricity per area and thus leave more space for nature. At the same time, lower public costs for financial incentives[5] per kWh of electricity can be expected. In this case, it must be examined to what extent storable bioenergy sources are actually needed and where fluctuating solar power can also be used. Therefore, environmental and sustainability criteria are needed to identify locations with relatively high advantages for bioenergy with relatively low disadvantages. Land allocation and use allocation plans at regional, national or supranational level (depending on the objective) can also be a tool to reduce potential competition for marginal areas and their uses. Restrictions on supporting the use of marginal land with public funds appear justified because public funds should be used for the benefit of society as a whole. How much room strict compliance with such boundary conditions, which


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[5] Not identical to overall economic costs but only one contribution. For its calculation, further societal advantages and disadvantages e.g. as elaborated in this study and in [Rettenmaier et al. 2018] would need to be included. Here, these aspects are discussed without monetarisation because we consider required pricing/valuation as not robust enough to yield additional insights.

could avoid critical long-term risks for the general public, leaves for the development of large-scale bioenergy plantations on marginal land must be negotiated, researched, tested and verified in a long-term political process with all relevant groups in society.

The following recommendations can thus be derived:

- If a significant expansion of bioenergy production on marginal land is desired by society, incentives must be introduced.
- However, alternatives must also be examined in advance for their overall sustainability. For example, more regenerative energy per area could be provided by photovoltaics at expectedly lower costs.
- Incentives for bioenergy should be designed in a differentiated way, because conditions and thus profitability vary greatly from case to case. Moreover, unlike many current subsidy programmes, they should be designed for the long term in order to reduce costs and maximise socio-economic benefits.
- The design of financial incentives such as support programmes should be based on sound calculations.
- In addition to project-related profitability criteria, medium- to long-term socio-economic impacts must also be taken into account because public funds are used. First and foremost, it is important to minimise environmental impacts, because destabilising ecosystems can cause serious societal disadvantages in the long term. Furthermore, it should be taken into account, among other things, where the added value is generated.

5 Perspectives

This study identifies bottlenecks, benefits and risks of a potential extension of the cultivation of perennial energy crops on marginal land and proposes strategies to overcome, maximise and minimise them, respectively. The available information and models are found to be sufficient for drawing the presented conclusions and recommendations.

If suggested subsidy schemes with more than minimal funding were to be drafted in the future, this would require a more differentiated and in-depth analysis of the economic viability of perennial energy crop cultivation on marginal land. Otherwise, undifferentiated subsidies would give unnecessarily high grants to some farmers and insufficient ones to other farmers given the diversity inherent to marginal land. This would require the definition of a variety of scenarios that cover a relevant range of climatic zones, suitable crops and cultivation schemes as well as national and potentially regional market prices. Similar models are in place for existing support regulations on liquid or gaseous biofuels, for example.

Individual farmers will have to calculate the profitability of an investment into energy crop plantations based on specific data such as prices and yields suitable for their individual situation in order to reduce uncertainty to an acceptable level for an investment decision.

The socio-economic modelling and evaluation tool developed for this study or any equivalent tool could be used for both more differentiated scenario-based analyses and case specific calculations.

6 Abbreviations

ANC	Areas with natural constraints
CAP	Common agricultural policy
CAPEX	Capital expenditure
EBIT	Earnings before interest and taxes
IRR	Internal rate of return
LCC	Life cycle costing
NPV	Net present value
OPEX	Operating expenditure
RED	Renewable Energy Directive
SQR	Soil Quality Rating
SRC	Short rotation coppice
UN	United Nations
WP	Work package

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8 Annex: Overview of scenario data

This chapter summarises key data of analysed case study scenarios.

Table 8-1 Key data on case study scenarios in Greece.

		Greece					
		Marginal land			Very marginal land		
Input parameter	Unit	Black locust (trees)	Black pine	Calabrian pine	Black locust (trees)	Black pine	Calabrian pine
Plantation period	years	13	20	20	13	20	20
Number of harvests	-	1	1	1	1	1	1
Yield (harvested biomass)	t (fresh matter) / (ha · year)	12	3.8	3.5	11	3.0	2.7
Seedlings	Pieces / ha	1 600	3 500	2 000	1 600	2 600	1 600
Diesel	L / (ha · year)	60	26	25	62	24	23
Nitrogen fertilizer	kg N / (ha · year)	25	0	0	25	0	0
Phosphorous fertilizer	kg P_2O_5 / (ha · year)	25	0	0	25	0	0
Working hours	h / (ha · year)	11	4	4	11	4	3
Machinery costs	€ / (ha · year)	115	58	57	119	56	54

Table 8-2 Key data on case study scenarios in Ukraine.

		Ukraine					
		Marginal land			Very marginal land		
Input parameter	Unit	Willow	Poplar	Miscan-thus	Willow	Poplar	Miscan-thus
Plantation period	years	25	20	17	25	20	15
Number of harvests	-	5	4	16	5	4	14
Yield (harvested biomass)	t (fresh matter) / (ha · year)	12	10	21	7.0	6.0	17
Seedlings	Pieces / ha	18 000	10 000	20 000	18 000	10 000	20 000
Diesel	L / (ha · year)	62	76	98	44	56	92
Nitrogen fertilizer	kg N / (ha · year)	30	0	39	30	0	45
Phosphorous fertilizer	kg P_2O_5 / (ha · year)	0	6	4	1	6	5
Working hours	h / (ha · year)	9	7	17	7	5	16
Machinery costs	€ / (ha · year)	195	140	121	151	102	113

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Table 8-3 Key data on case study scenarios in Germany.

		Germany			
		Marginal land		Very marginal land	
Input parameter	Unit	Poplar	Black locust (SRC)	Poplar	Black locust (SRC)
Plantation period	years	20	20	20	20
Number of harvests	-	4	4	4	4
Yield (harvested biomass)	t (fresh matter) / (ha · year)	8.0	8.0	5.0	5.0
Seedlings	Pieces / ha	10 000	10 000	10 000	10 000
Diesel	L / (ha · year)	64	64	49	49
Nitrogen fertilizer	kg N / (ha · year)	0	0	0	0
Phosphorous fertilizer	kg P_2O_5 / (ha · year)	6	6	6	6
Working hours	h / (ha · year)	6	6	4	4
Machinery costs	€ / (ha · year)	204	204	156	133

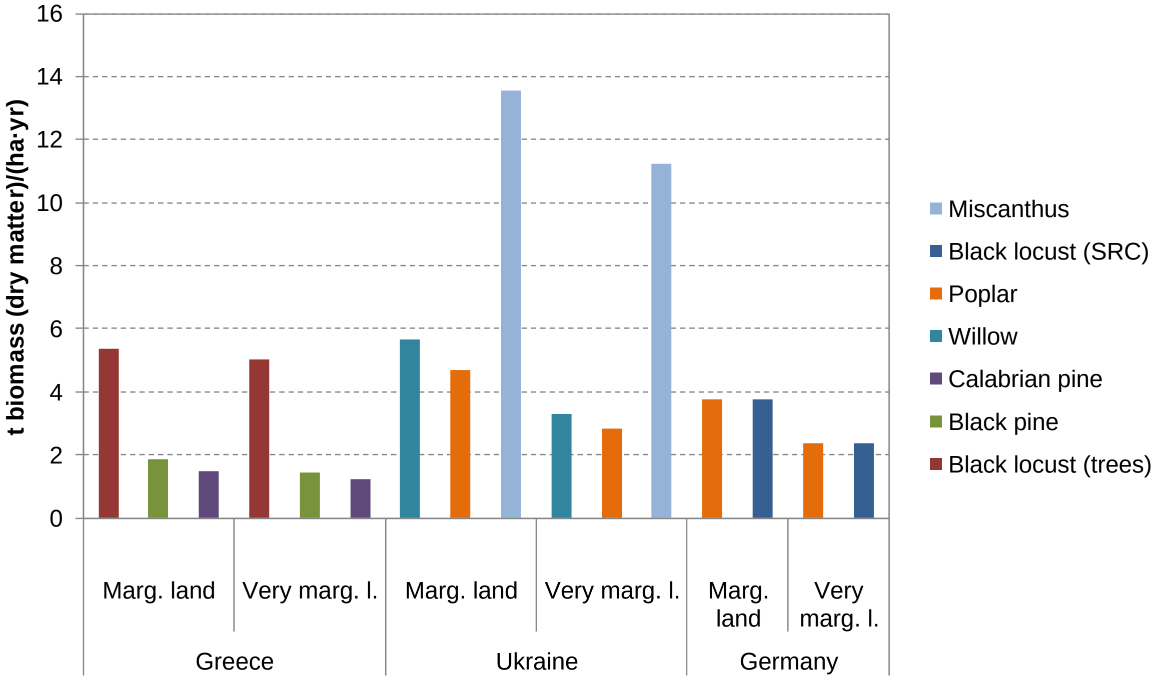

Fig. 8-1 Biomass yields (sold biomass, dry matter) averaged over the whole plantation period in analysed case study scenarios.

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