Ref. Ares(2021)6276300 - 14/10/2021

Marginal lands for Growing Industrial Crops

Economic Analysis of selected Value Chains

WP 6.4

Deliverable D 6.5

1st July 2021

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Horizon 2020
European Union Funding
for Research & Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No. 727698.

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Volume I. Economic Analysis of Growing, Harvesting and Transporting MAGIC Crops

Executive Summary and Conclusions

The Economic Analysis of agricultural production of the selected Magic crops has shown that in general, their ability to grow in marginal land with reduced inputs combined with a lower rent of marginal land, does not compensate for the loss in production volumes. Consequently, there is no sufficient economic incentive to the farmer to grow such crops without subsidisation. In most cases that we have examined in all three agro-ecological zones of Europe, in spite of the fact that they may not always fall into losses, the cultivation of wheat in the same lands is more rewarding than the Magic Crops.

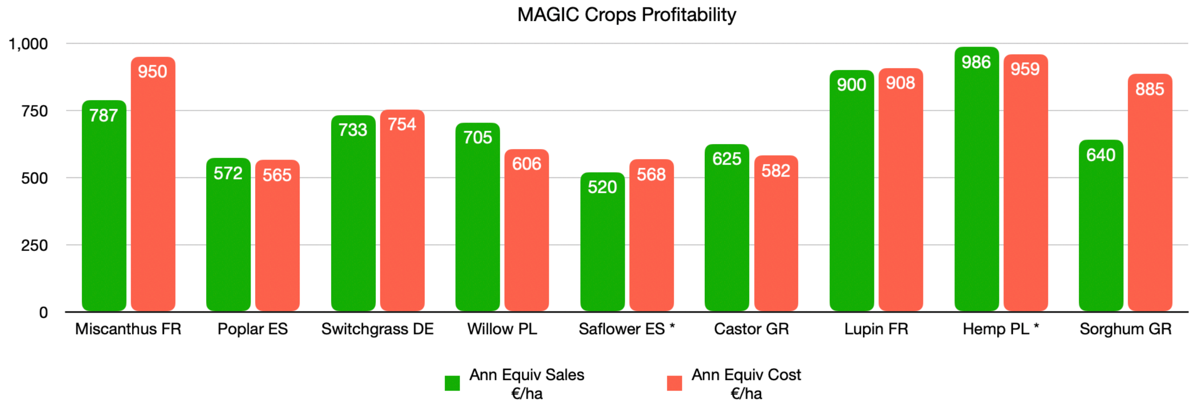
It must be stressed though that the term “Marginal Land” covers a very wide variety of lands and it is understood that one should rather explore case specific situations rather than generalising on a very uneven plain. Marginal lands in the South, which are not water stressed may give high yields and consequently higher returns. Also, fertile contaminated lands may be more appropriate for growing industrial crops, while being banned from food crop production. Therefore, the present report offers only a general overview of the financial position of the selected crops in each of three climatic zones of the EU and tries to estimate general agro-economic conditions for which the cultivation of these crops in marginal land would break even.

Farmers will not decide to produce without the confidence (contract) that they will be able to sell their product at a reasonable price in order to cover the opportunity cost of their land. Similarly, no investor would finance a conversion plant, before securing adequate flow of feedstock throughout the year at prices that allow a reasonable return to his investment. Furthermore, new, environmentally friendly technologies do not usually generate sufficient financial returns from the early stages and therefore the role of the State as the initiator and supporter of such investments is crucial.

The present study is a Life Cycle Cost analysis of Magic Crops including comparisons with close competitors in the market. It shows that Magic crops are close to economic viability (breakeven), which however may not be sufficient return to motivate farmers. Comparisons with wheat cultivation on the same lands is in favour of the Magic crops only in very few cases.

The following chart shows illustrative annual equivalent costs for each of the nine Magic crops cultivated on modestly marginal lands, together with expected revenue from sales at current or expected market prices. On the rightmost column there is an estimate of the required selling price to breakeven, which gives an order of magnitude of the necessary incentives to the farmer (price subsidization).

Table 1.1 Selection of Indicative economic results of Magic crops in different EU climatic zones



MAGIC Crops Details

	Avg annual Yield t/ha	Selling Price ** €/t	Ann Equiv Sales €/ha	Ann Equiv Cost €/ha	Ann Equiv Profit €/ha	Breakeven Price *** €/t
Miscanthus FR	9.60	80	787	950	-163	**97**
Poplar ES	6.32	100	572	565	7	**100**
Switchgrass DE	9.00	80	733	754	-21	**82**
Willow PL	7.50	100	705	606	99	**86**
Saflower ES *	1.10 / 4,00	400 / 20	520	568	-48	**444**
Castor GR	1.25	500	625	582	43	**466**
Lupin FR	3.00	300	900	908	-8	**303**
Hemp PL *	0.70 / 5.30	500 / 120	986	959	27	**181**
Sorghum GR	8.00	80	640	885	-245	**111**
	** Seeds / Stems*	*** Usually quoted*	**** Zero NPV for perennial crops. Zero profit for annual crops..*			

BOTTOM LINE:

- *EU Marginal Lands can and should be used for growing industrial crops in order to avoid disturbances in the food market and because of the upcoming scarcity of fertile agricultural land.*
- *Marginal Lands will surely claim an economic land rent, especially the more productive, and therefore a "zero opportunity cost of land" scenario has been excluded (although it may easily be observed in the results tables).*
- *Our estimates indicate the need for financial incentives to the farmers, until technological progress in harvesting equipment and varieties with increased yields will make "Magic Crops" more profitable.*
- *There is very wide range of the degree and type of land marginality, so we may concentrate on the more favourable marginal lands, since they will be exploited first.*
- *Economic results of perennial crops should guarantee a return (IRR) higher than the cost of funds to cover the risk of the investment of establishing the crops. Annual crops are more flexible, generate income from the first year*

and require much less initial capital investment, so they are probably more appropriate in this early period of marginal land utilisation.

- *The hypothesis of farmers utilising existing spare (idle) capacity of constructions and equipment at no extra capital cost for extending their activity in marginal lands, would further reduce total costs. In this study it has not been introduced.*
- *Long term targeted financial incentives or quotas are imperative in order to attract investment in such new ventures with so high beneficial environmental and social impact.*

Acknowledgments

We thank our partners in the "Magic" Project who have shared with us their expertise and experience in order to improve this study. Especially, we thank our colleagues in WP-6 for their concern and closer collaboration on all the topics covered in this report.

Introduction

This report outlines the methodology and structure of the economic analysis of cultivation and transformation of MAGIC crops into useful bio-products. The evaluation of economic performance of whole value chains examines the economic viability of the agro-industrial process, which is based on biomass grown in EU marginal lands, in order to avoid undesirable impacts on food and feed quantities and prices, as well as ILUC effects.

EU strategy is to encourage research on the cultivation of biomass crops on European marginal land and identify those that may economically be grown and profitably used for the production of energy and other bio-products. The Renewable Energy Directive (RED-II) that was recently agreed, emphasizes the role of solid biomass and at the same time sets high pan-European targets for GHG savings and efficiency in the production of bioenergy for the years to come. Agricultural production of bioenergy crops will have to accord with the new directive and reach the same targets with industrial production, since they are the main suppliers of the bioenergy industry.

The definition of land marginality is still under discussion. The emphasis on bio-physical measurements offers some (deceptive?) objectivity, because the applicability of limiting constraints depends upon the selected crop and the land use alternatives that may exist. Besides, current non-agricultural uses of land are much less related to the usual bio-physical limits. In the absence of sufficient market for marginal lands, and given the difficulty of marginality measurement, we may adopt the simplifying “zero opportunity cost" assumption. This allows direct evaluation comparisons among possible alternative land uses (by measuring “return to land and management”) and maintains the option of subtracting land rent afterwards. However, in most cases the market will demand some rental for the use of marginal land and for practical reasons one may be more pragmatic by charging a low rental in financial calculations.

Besides the wood, fibre and paper industries, a major use of biomass is in the energy sector, through transformation into various solid, liquid or gaseous fuels, which offer environmental benefits versus the mineral fuels. The cost of biofuels depends heavily on the cost of biomass and therefore its estimation is very important for the energy sector.

Nine value chains were finally selected by the *Magic Project* consortium and are being examined in the present report:

1. Miscanthus (*Miscanthus x giganteus L.*) for the production of pyrolysis fuel
2. Poplar (*Populus spp.* L.), for the production of SNG through gasification
3. Switchgrass (*Panicum virgatum* L.) for the production of ethanol through fermentation
4. Willow (*Salix spp.* L.), for the production of bitumen ("biotumen") via pyrolysis
5. Safflower (*Carthamus tinctorius* L.), for the production of various organic acids
6. Castor (*Ricinus communis* L.) for the production of undecanedioic acid
7. Lupin (*Lupinus mutabilis L.*), for the production of bio-adhesives
8. Industrial Hemp (*Cannabis sativa L.*), for the production of insulation materials
9. Fibre Sorghum (*Sorghum bicolor L.*), for the production of biomethane

Throughout this report, for uniformity and comparability, we have made the assumption that the machinery used for each crop is the same in all EU regions and since all costs are net of Vat, machinery cost differences are small. In general, there are three major cost analysis differences among the various European regions/countries: (a) biophysical variation in the quantities of yields and inputs used for agricultural production and (b) differences in the cost of labour and (c) difference in the cost of material inputs from country to country.

Also, the yields of the selected crops that have been based in past experience and current experimentation, are rather low if we consider a time horizon, e.g. to the year 2030, when more widespread cultivation of such crops in European marginal lands will inevitably result in the reduction of the cost of agricultural operations and increase the productivity of the crops (see for example Smets et al. 2009). More detailed analysis has revealed significant sensitivity of economic results with varying yields.

Detailed results for a large number of cases of agricultural production cost analysis are included in the Appendix.

1 Methodology

Economic analysis examines the profitability and financial sustainability of projects in order to assess the attractiveness of funding investment opportunities. In particular, the economic examination of perennial crops requires the estimation of all costs and revenues as well as the cash flows generated in each and every year during the economic life of the examined crop and the necessary size and timing of the required investments.

Discounted Cash Flow methods (Koller T. et al., 2020, Weaver S. C., 2012, Knuschwitz L. and A. Loeffler, 2005 and 2020) are adopted for the investigation of multi annual crops cultivation, because economic analysis needs to explore the economic behaviour of such projects throughout their economic life and applies time value of money techniques for the assessment of their economic viability (Life Cycle Economic Analysis, LCEA, J. Kulczycka and M. Smol, 2016).

1.1 Structure of the Analysis

There are four major steps in the Economic Analysis:

- *Literature review and analysis:* identifies key features of current scientific work, good practice and applications of crop production on marginal land and subsequent transformation of crop yields for the production of the selected final bio-products.
- *Collection, Analysis and Utilisation of MAGIC partners' experience from past and current findings of (a) experimental cultivation of crops on marginal lands,* and (b) *commercial applications and production* of bio-products relevant to the project.
  MAGIC project agricultural partners are among the most experienced in non-food crops cultivation in Europe. The collaborating industrial partners have also supplied the necessary information for Life Cycle cost analysis of each value chain. Appropriate Machinery and Equipment selection and use, is also suggested by the project engineers. Economic data, such as purchase prices or opportunity costs, is supplied by the economists, current information and our own databases. As a result, the economic analysis is based on both actual commercial and experimental data for the cultivation and conversion of bio materials. Charged costs and expenses are based on prices for human resources, materials, machinery capital service cost, maintenance & operation.
- *Economic Analysis* (Life Cycle Economic Analysis - LCEA) incorporates life-long costs and revenues of all factors of production along the selected value chains. The adopted "cradle to grave" approach explores the possibilities of complete bio value chains. The economic evaluation is based on Discounted Cash Flow (DCF) methodologies and annual equivalent costs of constructions, machinery and equipment. Reporting includes "per hectare", "per tonne" or "per unit of output" tabulations and graphs, as well as

comparisons of final products' costs vs. selling prices of competitive commodities. Furthermore, from a different perspective, the analysis identifies cost allocations (a) by "operation" or "activity" (e.g. for agricultural production, land preparation, fertilisation, irrigation, etc…) and (b) by "factor of production" (human resources, machinery usage, raw materials, etc…). Therefore, Economic Analysis measures costs and revenues of typical, reasonably managed agro-industrial value chains based on biomass, which is grown on marginal land in different European Climatic Zones. The analysis is based on typical mean values for the examined regions and processes and on the accumulated experience and data from MAGIC partners. The experimental cases which are being analysed have been described by MAGIC partners according to their experience and experiments.

- Examination of *commercial good practice cases,* and comparisons with experimental cultivation analyses.

1.2 Land marginality

For the purpose of estimation of the cost of biomass production, marginal lands (lands not used for the cultivation of food / feed crops) can be identified on the basis of bio-physical, environmental, socio-economic and legislative/political issues. While bio-physical constraints have a direct impact on agricultural productivity and increase the unit cost of agricultural products, economic, social and other handicaps, such as distance from market, small size of agricultural property, biodiversity, etc., should be equally considered in the analysis, although they are less direct, or more difficult to measure their impact on the economic assessment of land utilisation.

Detailed examination of the thresholds, implications and impacts of each factor affecting land productivity and suitability for agricultural production have been discussed in many recent publications on the subject, as well as extensively researched in MAGIC Work Package 2

MAGIC partners have classified land handicaps in six main bio-physical constraints' categories

- *Adverse climate*
- *Excessive soil moisture*
- *Soil salinity/contamination*
- *Low soil fertility*
- *Poor rooting conditions*
- *Terrain problems*

It is clear that land marginalities affect the economic evaluation of agricultural projects in different ways and varying degrees, depending on the type and degree of marginality conditions and the nature of the crops under consideration. Therefore, it is not possible to analyse the economic viability of crops on marginal lands without knowing the relevant marginality conditions, the agronomically optimal quantities of agricultural inputs and the corresponding yields of the crop under examination.

A major question regards the cost of marginal land that is used in the economic analysis. We have found that in most regions there is no market for marginal land (marginal land is not really being leased as such) and therefore occasional spot rental charges that happen to be recorded are not consistently expressing the real cost of using this land for agriculture. Rather, they are rentals charged on an occasional or opportunistic basis, not really expressing the real “opportunity cost” of marginal land. The current definition of marginal land, in most cases implies that this land cannot be profitably used for agricultural production, therefore, if there is no other use (recreational, urban, habitat, …), we may conclude that its “economic rent” is very low. The zero rent of marginal land is consistent with economic reasoning and avoids the need of generally subjective scaling of land rental according to different degrees of marginality. Although economic comparisons of competing crops cultivated on the same marginal land are not affected by cost of land, since they cancel out, one may argue that from the point of view of the grower, any rent or land rates actually charged, is a real cost item for him. For this reason, our analysis estimates costs “with” and “without” land charges. i.e. we have used “low quality land’ charges from the literature and in all cases we also estimate the “return to Land” and compare it with the corresponding value of wheat, which is used as a benchmark value.

Some of the physical handicaps of marginal lands may be counterbalanced by increased agricultural inputs, such as higher irrigation or fertilisation quantities, etc., which however increase the cost of production and jeopardise the economic and environmental viability of the crop. Besides, since the purpose of MAGIC is the identification of crops that may sustainably be cultivated on marginal land and support the production of useful bio-products at minimum environmental impact, priority is given to the examination of low input agricultural production.

In general, the task of evaluating cultivation on marginal land is very difficult, because of the great variety or reasons or handicaps that make a land marginal (water stress, climatic conditions, soil quality and productivity, contamination, etc.) and the degree of marginality or intensity of the handicaps. In addition, marginality should be examined with respect to the plant which is being considered. Some marginal lands may be inappropriate for the cultivation of a crop, but ideal for another. In the present study, we have adopted common criteria with the rest of the work in the project with regard to the nature of the marginality and the effect on yields of the selected crops in the three climatic zones of the EU.

1.3 Land size scenarios in agricultural production

Farmers will be willing to cultivate marginal land with industrial crops only if they believe that they will be able to sell their product at prices that can guarantee financial sustainability. This, of course, is more important in the case of perennial crops, where the commitment of the farmers is far greater. In most cases they will demand contracts with usually large biomass transformation plants, which will absorb their production.

You cannot run a conversion plant without prior agreement for contracting sufficient supply or feedstock with farmers in the area. At the same time, farmers will not decide to cultivate industrial crops as long as there is no conversion plant that will absorb their production.

With regard to the size of marginal land parcels, we distinguish two cases:

1.3.1 Small plots

This is the case of farmers who own land including unused marginal patches, i.e. areas they do not cultivate because of low soil productivity or other reasons. In such cases we should analyse the cost of growers for marginal land acreage up to 10 ha, assuming that the new activity (the project) is complementary to the usual farming activities of the particular farmer. This also means that the farmer is possibly utilising existing surplus capacity of fixed assets, and human resources.

For the purpose of investment appraisal, the cost of land, as has been discussed before, may assume an opportunity cost of zero, since it is not being utilised. For the use of surplus capacity of pre-existing machinery and other fixed assets, the actual capital cost incurred to the farm is only due to the fact that more intensive usage will result in earlier retirement and shorter replacement time with consequent interest cost, proportionate to the purchase cost of the equipment, which should eventually be charged to the new project. In the case of additional project requirements for new fixed assets, the cost is shared between the project and other possible uses of equipment and buildings within or outside the farm according to usage. For sharing existing human resources, we charge the project with its fair share, based on person-hours.

Transportation logistics costs are estimated on similar principles and discussed below.

1.3.2 Large size projects

Large size crop cultivation is assumed at total marginal land acreages well above 10 ha, where the project can enjoy economies of scale and make use of powerful, more efficient modern machinery and dedicated resources, which significantly reduced unit costs. Such projects may also include or closely collaborate with a biomass transformation facility, which is usually situated in the vicinity.

In the case of such schemes, marginal land may bear rental rates that should be charged to the project. The number and size of machinery and equipment is estimated based on the cultivation and harvesting windows in combination with the efficiency and capabilities of each machine. The annual equivalent cost of all fixed assets and constructions is charged to the project in the form of “economic depreciation”.

1.4 Typical farms and case studies

MAGIC incorporates the current research and experience of collaborating scientists and Institutions in the cultivation of non-food crops on marginal lands both in experimental and commercial fields. Furthermore, relevant research by third parties on the cultivation of MAGIC crops is extensive and provides important additional information and data for economic analysis.

Consequently, the economic analysis and evaluation of selected crops cultivation on marginal lands can be examined by means of a large number of "typical farm" studies identified within the set of combinations of selected Crops / EU climatic Zones / Marginal Land types.

A "typical farm" is a notional agricultural unit, which reasonably represents the average farm in the region and although it is not real, it fairly reflects what may be expected. By adopting the method of "typical farms" we avoid the problem of real life mismanagement (sometimes significant) and we measure production, income and expenses of "reasonably well managed" typical farms. This method leads on average to a somewhat optimistic bias, but, in general, shows the potential economic performance of the crops in question.

In addition, some "actual" case studies in different climatic regions are presented, generally based on the data recorded by experimenting MAGIC partners as well as other cases mainly found in the literature. "Good practice" examples are included in the analysis because they demonstrate the capabilities and possibilities of achievement. However, they cannot be generalised, as they would overestimate expected results.

A very important issue affecting cost is the *degree* or severity of each type of marginality (water problems, soil infertility, unfavourable climatic conditions, etc). On the whole, for any crop and region, each case is based on information relating to (a) the *type* and *degree* of major marginality, (b) the amount of agronomically specified cultivation inputs and (c) the corresponding yields. Combinations of coexisting handicaps are also treated in an analogous manner.

Variations in cost analysis may additionally arise when the crop can be cultivated with lower or higher inputs, corresponding to lower or higher yields. Although the purpose of this project is to identify crops that can grow under specific marginality conditions with minimal quantities of agricultural inputs, we cannot exclude the use of somewhat higher inputs that would improve more than proportionately economic results. In general though, the optimal amount of supplied agricultural inputs is a complex decision, not only an economic issue, and for this reason we adopt a more pluralistic approach, involving agronomists, environmentalists, biomass transformers, etc.

Harvesting method and effort depends upon the volume of the biomass, the type of the subsequent industrial conversion process and the final product(s) that will eventually be produced. For example, if biomass is to be burned in a nearby power plant, very little on-farm treatment is required. If instead it is supplying the needs of chemical industry, it may have to be cleaned, chopped, bundled or pelleted during or after the harvesting operation and then, packed and transported differently.

In summary, with regard to the estimation of agricultural production costs, for each case we identify:

1. *Which Crop / Region / Type and Degree of Land Marginality*
2. *Selected amount of inputs and corresponding Yields*
3. *Harvesting / Warehousing requirements depending upon Region, volume of production, type of consequent Industrial treatment and Distance from farm*.
4. *Transport of farm product(s) to the conversion plant assuming average distance from farm.*

Significant Cost and Yield variability from case to case make generalisations inappropriate and possibly misleading, thus a set of case specific studies could also be suitable and useful. There are three distinct groups of case studies: (a) those based on experimental cultivations, with possible positive bias, (b) commercial applications, which may also be positively or negatively biased, due to various case specific reasons and (c) good practice cases, which show the potential of various applications.

1.5 Optimal Harvest Timing for all perennial crops

The optimal time of harvesting or optimal rotation cycle of perennial crops is being discussed in a number of publications with varying proposals. In most cases, this is decided based on agricultural experience and gut feeling, but there is also a neet justification for what farmers usually approximate by experience. The fact that besides the obvious economic parameters that we take into account, there are a lot of other uncertainties (weather, price fluctuations, demand unpredictability, etc.), makes the farmer's guess at least equally useful as any theoretical approach.

From the economist's point of view, crops should be harvested when marginal revenue is equal to marginal cost of growing and maintaining the crop plus the capital cost (interest cost) of delaying the revenue from the sale of the crop for one more period. This is important for deciding the rotation cycle of SRF crops, such as poplar and willow. So, this decision is made based on the volume and selling price of the yield, the annual maintenance cost of the plantation, the interest rate (cost of funds), which are probably changing from year to year. In the appendix we have included a somewhat technical justification for the determination of optimal harvesting period for anyone who would like to investigate further.

1.6 Life Cycle Cost Analysis (LCCA)

Strategic decision making is increasingly becoming the subject of combined socio-economic and environmental impacts, since social objectives are interlinked with economic and environmental sustainability. Multi-criteria optimisation methods, which are needed to support decision making, are a compromise of conflicting economic, social and environmental goals.

In the bioenergy and bioproducts sector production value chains, the multiplicity of direct and indirect incentives and constraints imposed by society and the State, poses a serious problem of comparisons among financial and societal costs, environmental damage or benefits both in the short and long run. The inevitable question is usually the choice between “the environmentally clean” and “the economically affordable”, or some combination in-between.

An additional complication of the analysis is that Europe is insisting in limiting biomass cultivation to lands that are not cultivated with food crops (although some of them are being cultivated only because of existing incentives), lands which are generally known as “marginal”. In such lands one has to decide whether to cultivate with increased amounts agricultural inputs (fertilisers, chemicals, water, etc), or keep inputs low at the expense of lower yields. This very much depends upon the examined crop and the bio-physical conditions of the region. A high input scenario gives higher yields, but it is more expensive in both economic and environmental terms. The low input scenario on the other hand is environmentally attractive, but sometimes profoundly uneconomic, since in some cases the yield is too low and hence, it may need higher social financial support. MAGIC agricultural partners have suggested good practice options that we have applied in our economic evaluations.

Another dimension of the problem relates to the installation cost of multi annual crops and the use of buildings, constructions and the purchase of machinery and equipment, which have useful economic lives that may extend over the economic life of crops. For cost analysis, investment costs are spread in all the years of the life of these assets. Discounted Cash Flow methods (annual equivalent costs) are suitable for such spreads. The case of unused surplus capacity is examined below.

Our analysis, as well as the mechanism of the ABC Software system (www.abcsofware.org), concentrates on the evaluation of all relevant (paid and imputed) economic cash inflows and outflows along the value chain and records the timing of actual payments and receipts as they occur. For fixed assets and investment expenses the cost is distributed in the form of annual equivalent expense with the use of relevant discount factors. Marginal land rent in the small plot cases is set equal to zero (as surplus farmer’s land), while for applications, where large marginal areas are rented, a low marginal land rental is applied. Zero land rent implies zero opportunity cost of marginal land and therefore reflects cases where land is abandoned / unused and in general, not expected to be otherwise used in the near future.

Negative economic results of the cultivation of marginal lands, e.g. due to low yields, signify the necessity of financial incentives for the adoption of the relevant value chains. In some cases this is reasonable, if resulting environmental or other non-financial benefits are of higher priority.

The identification of crops that may be profitably grown on unused marginal lands of Europe is a major challenge for this project.

1.7 Cost of machinery and equipment

The cost of machinery consists of two main elements.

(a) the *annual capital service cost (CSC),* based on its purchase cost, the length of its useful economic life and its *Maintenance, & Insurance* annual cost (*M*), and
(b) its variable *operating cost*, i.e. the cost of the machine Operator (*L*) and the cost of Fuel & Lubricant (*f*) consumed for its operation.

The *annual CSC* cost is calculated by amortising the machine's cost (*C*) over the period of the machine useful economic life (*n* years), assuming zero salvage value. Therefore, the annual *CSC* of the machine is

$$\mathrm{CSC} = \frac{\mathrm{C}\,i}{1-(1+i)^{-n}}$$

where *i* is the discount rate that reflects the expected cost of funds, (Bierman H. Jr and Smidt S., 2007).

For the annual maintenance & insurance costs of the machine, we assume that they remain about the same in each year. So, the fixed annual cost of the machine is

$$\mathrm{CSC}M = \frac{\mathrm{C}\,i}{1-(1+i)^{-n}} + M$$

and the hourly fixed cost is

$$\frac{\mathrm{CSC}M}{H}$$

where *H* is the average annual hours of operation of the machine, including all possible uses of the machine.

The hourly variable operating cost is the sum of the operator's hourly fee plus the cost of fuel and lubricants

The total machinery cost in any agricultural operation depends on the machine efficiency (*e*), its specific fuel consumption for the particular operation (*f*) and the hourly cost of the machine operator(s) (*L*).

If we assume that the size of the cultivated area is equal to *A* hectares and the machine efficiency for the operation is *e* hours/hectare, then the machine can complete the task in

$$h = A \times e$$

hours.

If the fuel consumption of the machine for this task is *f* litres/hour, then the amount of fuel required for the completion of this operation is *h* x *f,* and consequently, fuel cost, *F*, in monetary units is

$$F = u \times h \times f$$

where *u* is the cost of fuel in €/litre.

Similarly, the labour cost, *B*, is equal to

$$B = n \times h \times L$$

where n is the number of required machine operators and *L* is their hourly rate (€/hour)

The machine cost, *N*, *for* the operation is

$$N = \frac{h}{H} \times \mathrm{CSC}M$$

and therefore, Total machinery cost for the operation (E) is

$$\mathrm{E} = N + B + F$$

If the operation must be completed within a limited time period of, say, *T hours in the year*, the number of machines (*m*) necessary to carry out the task, will be *h/T* (rounded upwards).

Note that the hourly fuel cost of the machine depends upon the kind of the operation performed. For example, a tractor consumes more fuel when ploughing than when fertilising or transporting; a harvester's fuel consumption is analogous to the volume of the yield, etc.

The cost of other fixed assets, such as buildings, constructions, warehouses, is equal to *CSCM* unless they are shared with other projects, in which case the cost is distributed accordingly.

1.8 Use of surplus (idle) capacity

In evaluating the attractiveness of a project which extends the current activities of a farm, we need to pay attention to the use of existing *surplus capacity* of machinery or other existing fixed assets that may be used by the project. Such use may have very low opportunity cost of capital and should be charged accordingly. For example, if a new project needs 100 tractor-hours per year and can use the existing farm tractor in its idle time, the only cost incurred to the farm, is caused from the fact that the tractor's replacement time may come about earlier, because of more intensive usage. Therefore, the project should be charged only with the interest of the tractor value for this time difference plus the operating expenses and possibly its share of the maintenance cost.

The base case scenario below assigns full capital service cost for each machine hour assuming extensive and full usage of the equipment by the project. Surplus capacity discount is only applied in sensitivity analysis.

1.9 Profitability vs Cash Flows

Income and expenses of agricultural projects may vary significantly from year to year, especially due to the physical development of multi annual plantations and the changing needs and yields, which are specified by agronomic practices.

Project *profitability* is calculated as the difference between Income and Expenses. Revenue (income) is earned mainly from the sale of products and services. Expenses consist of categories such as human resources, machinery and equipment, raw materials, rented services (outsourcing), land rent, financial and tax expenses, etc. Income and Expenses are not constant during the economic life of the plantations and as a result, profitability varies from year to year. It is not uncommon for agricultural projects to suffer losses during the first years of the crop and enjoy good profits afterwards, when the plantation is mature and yields are high. Usually, profitability values and indices are reported for mature plantations and are missing the accumulated losses during the early years, which are most important for the farmer or the entrepreneur due to time value of money.

Although *profitability metrics* are generally the most widely used and easily understood measures of performance, they do not offer the investor complete information, because they do not reveal vital cash flow details, which are most important. The analysis of project *Cash Flows* is essential, especially for the purpose of capital budgeting and investment decisions, when we need to contrast the present value of net inflows to the invested amount, which is usually paid up front.

Due to the time value of money (Weaver S. C., 2012), the stream of costs and revenues of agricultural projects is difficult to compare with alternative opportunities with different cash flow patterns, unless money values are expressed in some common “denomination”, e.g. present values. Discounting of future monetary flows (cash flows) is common in Economic Evaluation, because it allows the calculation of one value figure, the Present Value or its annual equivalent, which embodies the whole stream of cash flows.

1.10 Activity Based Costing Methodology (ABC)

Each crop is examined for the whole of its useful economic life. To estimate costs, agricultural production is broken down to single operations or activities and the needs of each activity are identified and measured in terms of human or machine-hours, volumes of raw materials consumed, land rental, etc. The initial investment is separately identified and valued. (For Activity Based Costing, see for example ABC Software system, 2020, Kaplan & Anderson, 2007, Anthony et al., 2010).

Practical Farm Accounts do not always identify the full cost of agricultural production, probably due to lack of consensus and data on imputed costs, such as family labour, own land, etc. For economic analysis, these items should be estimated at their opportunity cost in order to identify the cost and income attributed to the project.

ABC economic methodology decomposes the project into a number of operations or activities, which sufficiently describe crop installation, cultivation, harvesting and storage activities. Each operation is characterised by its timing (both duration and seasonality) and its needs for land, labour, equipment and materials. Seasonality is important if peak labour, machinery and water needs have to be identified. Fuel consumption depends upon the type of operation and machinery used.

All cost items are firstly measured in physical quantities, for example land area, man and machine hours, litres of fuel, raw material volumes, etc. This provides a cost measurement system independent of prices of resources. The required quantities of factors of production and raw materials can be multiplied by their corresponding prices in order to calculate total cost in monetary terms and be able to sum them up.

Mechanical equipment may be hired if own machinery is insufficient or non-existent. When hired, its cost is equal to the rental paid. The annual cost of the use of own equipment is the sum of depreciation, interest, maintenance, insurance, labour and fuel. If divided by average hours of operation per year, it gives an estimate of the total hourly cost of the equipment, which can be compared with the cost of hiring the operation.

Land is an essential factor of agricultural production and in most cases a major cost item. The “per hectare” cost of agricultural products may be significantly increased if planted on fertile, high cost land and vice versa. Therefore, land cost must be carefully estimated in all agricultural projects. If there is a fairly competitive market for land, one may assume that its rental adequately reflects its real cost. However, if there is no market, as is usual in the case of marginal land, the cost of land is not easily identifiable. In such cases one needs to estimate its opportunity cost as e.g. expressed by the net economic gain of current use. Marginal land rent is more difficult to estimate because its opportunity cost is very case specific (various degrees of marginality, access to irrigation water, geographical and economic environment, etc.) and because of existence of possible distorting subsidisation schemes.

Human labour is usually provided by the farmer and his family, but it may also be hired, especially during peak labour demand, e.g. at planting or harvesting periods. Hired labour in most cases has a market specified rate, which can be used in the analysis. Imputed labour cost should be principally evaluated at its opportunity cost, i.e. the amount of income forgone for shifting labour from current activity due to the needs and requirements of the project.

In general, when there is no market for a commodity, the opportunity cost of the relevant factor or production should be used to estimate the cost of inputs. Opportunity costs should implicitly reflect market values. For example, produced expendable inputs should be valued at the cost of purchasing the input from off-farm. Similarly, capital services provided by the owners of a given enterprise should be valued at the cost of obtaining these services from an alternative source in a market transaction.

1.11 Economic Indices

In order to summarise the findings of economic analysis, it is useful to estimate economic indices, which reveal the potential and viability of agricultural investments. Generally adopted indices also provide a basis for comparison between alternative investment plans.

The basic financial indices, appropriate for economic analysis of multiannual crop sustainability are among others (see for example: Lumby S and Jones C, 2001; Götze et al., 2007, Walsh C., 2010, Garrison et al., 2017, H. Geman, 2015)

Return on Investment (ROI): It shows how efficiently total invested capital generates Earnings, i.e. as a percentage of the Investment. It shows the profitability achieved by each euro of the assets invested in the project.

Payback Period: It is one of the simplest and most widely used investment appraisal indices. It measures the number of years needed for net project inflows to payback the initial investment. In the case of multi-annual agricultural projects, *initial investment* includes the cost of machinery & equipment, buildings & constructions and the expense of purchasing and establishing the plantation. The simple form of this index does not require discounting of future cash flows.

This index shows the speed of capital recovery, and consequently the degree of risk, since the shorter the payback period, the lower the risk.

Net Present Value (NPV): It is the Present Value of the stream of net Cash Flows (inflows minus outflows) during the economic life of the plantation. This financial metric is a measure of the economic attractiveness of projects. Positive NPVs indicate projects capable of generating entrepreneurial surplus after having paid all project costs and expenses, including the initial investment outlay.

The mathematical formula for the calculation of NPV is:

$$NPV = \sum_{t=0}^{n} [\, CF_t \times (1 + d)^{-t} \,]$$

Where:

CF_t is the Net Cash Flow of year *t* (inflows minus outflows)

CF_0 is the Net Cash Flow of year *0,* usually, the initial investment outflow (negative)

CF_n is the Net Cash Flow of year *n,* including possible land restoration costs or positive terminal value of the plantation

n is the number of years of the economic life of the plantation

d is the discount rate

Internal Rate of Return (IRR): It is the discount rate (d^*) for which NPV=0. The higher the discount rate, the lower is the NPV. Therefore, the Internal Rate of Return indicates the rate of return that the project cash flows can achieve (the interest returned to the initial investment), or the maximum interest charge of invested capital beyond which the project is not financially rewarding. For investing in a project, investors need to be reassured that the IRR is higher than the expected interest on borrowed capital over the lifetime of the project.

Investment projects are being financed if their *IRR*s are sufficiently higher than the cost of borrowing to cover the risk of investment and leave adequate return to the investors.

1.12 Financial and Economic Aspects of Crop Production and Use

Financial analysis is concerned with the measurement of performance against set targets on every aspect of the project. It identifies the efficiency of use of resources and provides suggestions for improving overall performance. It also measures the effectiveness of management in mobilising the factors of production for the achievement of financial goals and supports the search for improved approaches. Finally, it is a useful tool for determining areas of possible economic improvement, assisting management in their efforts towards the overall improvement of performance.

Financial analysis of biomass production comprises three easily identifiable steps. The first is Farm Income Analysis, based on Balance Sheet and Profit & Loss accounts. This is based on an opening Balance Sheet and Farm Budgets projecting income and expenses for the following years. The second step consists of the estimation of future Balance Sheets based on Farm Sales and Income forecasts and on assumptions regarding the timing of receipts and payments (Walsh, 2010; Peterson, 2004). This step identifies project related future Cash Flows, which can be achieved either directly (based on timed receipts from sales, etc. minus payments for purchases and expenses) or indirectly (based on net earnings before depreciation plus changes in Working Capital) (Walsh, 2010; Lumby 2011). The third step is Farm Investment Analysis. It utilises Cash Flows from step two to estimate the attractiveness of the project, by comparing future net inflows with initial investment outlay (Bierman, 2007; Lumby, 2011)

Financial Sustainability of perennial crops identifies thresholds of financial viability indicators in comparison to alternative courses of action for the supply of final products that may be produced from bio-chains based on such industrial crops.

From the view point of the producer of bio products (farmer, industry, supplier, investor, etc.) sufficient return to invested effort or capital must be secured within affordable risk levels, reasonably fast and with adequate prospects for maintaining the activity in the future (sustainability). With regard to the production of bio-energy, the European Commission has set high targets for carbon reduction and renewable energy contribution to the EU energy sector. The targets for 2030 are much higher than the 2020 goals and this signals a consequent expansion of the cultivation of perennial energy crops.

The potential value of the final products of perennial crops is measured by the difference of selling price and estimated annual equivalent life cycle cost, which is a measure of profitability. We assume no intermediate sales profit among the various actors along the bio chains. Any positive overall profit margin is distributed among all contributors (farming, transport, warehousing, conversion, marketing, etc.) according to relative contribution and market forces.

1.12.1 Cultivation of industrial crops in marginal land

The European Commission have repeatedly declared the intention to avoid the cultivation of non-food, and especially energy crops in fertile agricultural land, in order to avoid the consequential effects on food supply and prices (EC/JRC, 2013; EC, 2009a; EEC, 1975). Direct or indirect land use changes, mainly caused by renewable energy initiatives, have frequently affected the food market in many areas (EC 2009b). Therefore, it is not unreasonable to encourage the cultivation of such perennial crops on various types of marginal land.

Land rent varies significantly from region to region. The rent of marginal land is not set equal to zero, unless the land has no potential for production and income. For marginal land, we have identified a 30-60% discount off the rental of fertile agricultural land, depending upon the degree of marginality and other factors. However, as this is very much site and case specific, it is best to estimate the rent of marginal land at its opportunity cost, i.e. the profit forgone because of the change of land use (Lewis and Kelly, 2014; Kang et al., 2013). Nevertheless, if marginal land is considered for growing industrial crops, it is reasonable to assume that eventually it will be necessary for the farmer to endure a positive land rental.

Irrigation is another major cost item, especially for cultivation in marginal lands, because they are usually water stressed areas and the water may have to be transported from far. Considerable amount of energy and subsequent expense may therefore be necessary for the irrigation of marginal lands. In many cases we have found that irrigation costs may be totally prohibitive. It has been observed though that cultivation of some crops in marginal lands with minimal irrigation and other inputs is not usually an optimal choice, because of the disproportionately low agricultural yields.

Subsidies that may exist along the bio-products chain should not be included in basic calculations, because of their temporary character and because we need to evaluate the net financial position of the crop under evaluation. Such financial incentives are best considered *after* the basic evaluation of the attractiveness of the project "before subsidies", in order to show their effect separately.

1.12.2 Annual equivalent economic performance

Life Cycle performance estimation is important for perennial crops. Inspecting costs and benefits of only one particular year is of little use because some operations are not repeated regularly and uniformly year after year and therefore annual costs may differ through time during the plantation life. Furthermore, the productivity of the plantation may also differ from year to year. For example, perennial energy crops are expensive to establish and have lower annual costs for the rest of their productive life, while they are also giving lower yields at the early years and have increased productivity later.

Consequently, costs and returns estimation could be reported either for "every individual year" or for a "typical year" when the crop is mature. The first approach leads to results that are less comprehensive and are difficult to use for comparison with other investment proposals. The second, usually reflecting conditions "at maturity", disregards the inferior economic performance in periods of lower yields or increased input requirements such as the early years.

Economists seek to estimate an annual figure, representative of the whole economic life of perennial plantations, which allows direct comparisons among different crops, with different life times. This life cycle economic approach incorporates the cost of initial investment and all lifetime inflows and outflows. The life cycle economic performance of a crop is calculated as an *annual equivalent* value (consistent and in harmony with the NPV of the project) incorporating all relevant lifetime cash flows by adopting DCF methods (Kruschwitz L. and A. Loeffler, 2005 and 2020). To calculate the annual equivalent value of a project, the present value of all net cash flows over the useful life of the plantation is transformed into an equivalent annuity extended over the same time period.

Given a discount rate (*d*) and the plantation useful life (*n*),

$$Annual\ Equivalent\ Value\ (R) = NPV\ \times \frac{d}{1-(1+d)^{-n}}$$

where

$$NPV = \sum_{t=0}^{n} [\,CF_t\ \times\ (1+d)^{-t}\,]$$

and year zero is the investment year.

1.13 Activity Based Costing: The New ABC Software © System

ABC Software© is a high quality, user-friendly software package for the analysis of costs of investment projects in agriculture. ABC Software was developed to serve the purpose of extensive Life Cycle Cost Analysis in a multiple crop environment. The package has been extensively augmented to provide special scientific support to Project needs (such as Cost Analysis of a variety of crops and plants of any type and nature as well as the incorporation of industrial activities).

We have used ABC Software extensively for the estimation of the production cost of crops in the framework of project MAGIC and this has secured compatibility and comparability of our findings. The fact that the package calculates costs "by agronomic operation" and "by production input" is very convenient for our work, especially for the integration of economic, social and environmental results.

ABC Software features include:

1. Multiple Crop support. It is easy to develop projects including as many crops as necessary and to save them in external files (.abc)
2. Multiple cultivating operations support for each crop.
3. Multiple operation needs (machinery, labour, raw materials, etc.) that will be used in each operation.
4. Unique Database for each project; an embedded module that is being used to support easy handling of creation and update of needs (machinery, labour, fuel, etc.).
5. Reporting module with data export features (eg. Export to MS-Office applications, html format, PDF, etc.). ABC reports cover a wide range of needs, such as report by operation, report by materials used, energy usage, human resources requirements, graphical presentation of project profitability, investment evaluation indices, etc,
6. Specialised Operation scheduler module; a feature that helps users to provide frequency and timing information related to how often an operation is taking place within the crop's cultivation plan or during its economic life.

ABC can be found at www.abc.aua.gr.

Complementary to ABC, is the data collection facility ABC-dc©, a Web based dynamic electronic facility created by our team, which is used to collect the basic technical data for economic analysis, which are later supplied to the ABC system for evaluation.

The ABC system has been recently developed in order to facilitate collection and maintenance of agronomic data regarding the cultivation and harvesting of crops in a systematic and uniform manner. It records major and minor operations, and agricultural inputs associated with each one. It shares the same machinery, labour and raw materials databases with ABC and uses common naming and definitions for each piece of equipment or material. It marks the frequency of occurrence of each operation during the life time of the plant.

Users may use ABC Software for submitting data and sharing their experience with economic analysis. Agricultural experimenting researchers may also use the data collection system in order to record and analyse experimental records.

Capabilities such as saving to and opening ABC-dc files and export to MS Office local files, combined with exceptional user friendliness and input flexibility make it a handy and practical data recording facility.

2 Sources of information

2.1 Agronomic data

Information regarding the cultivation and in-farm handling of harvested material, has been collected and organised after extensive literature search and interviews with MAGIC partners after a series of organised meetings and other bilateral communications.

Colleagues from the Agricultural University of Athens as well as the University of Thessaly have supplied us with data on machinery usage and fuel consumption. The Centre of Renewable Energy Sources (CRES) has reviewed our estimates and background information.

Information from AUA and other EU projects (Optima, MultiHemp, Becool, Panacea, Crops2Industry, S2Biom, Cosmos, etc.) has been reviewed and utilised, especially for the cultivation of perennial grasses and SRF. Ongoing research and experimentation on oil seed crops by MAGIC partners in Europe are estimating and supplying useful parameters for our cost analysis.

Finally, under the coordination of IFEU, internally agreed yields by region and marginality condition, as well as agricultural inputs for the cultivation of the selected crops have been used in our final economic calculations, reflecting the interaction of collected information from all sources.

2.1.1 The cost of Marginal Land

Marginal land is by definition land which is not used, mainly due to biophysical and / or economic, social and other reasons. It is usually land financially unattractive to the farmer, because the cost of crop cultivation is higher than the expected revenue from the sale of its produce. Therefore, the use of such land for the cultivation of novel crops, which may endure difficult biophysical conditions, is a potentially interesting proposition, mainly because it is utilising abandoned land with low or even "zero" opportunity cost and consequently may allow additional net income to growers.

Naturally, there are many different types of land that we classify as "Marginal", with various degrees of marginality and opportunity cost, but in general, in spite of the fact that some rent or land charges may exist, many researchers estimate crop production cost before the whichever cost of marginal land. Net financial benefits from the cultivation are in this case what is termed "return to land and management".

Land owners who decide to cultivate areas of unused marginal land within their property, obviously bear no extra cost, since this part of their land was not used before. However, if the land is not owned by the farmer, some rental will have to be paid to the land owner. Panoutsou and Alexopoulou, 2020, have reviewed and estimated land cost for all EU countries and we have used their estimates to a great extent. These figures are expected to change significantly through time, so we estimate life cycle costs and returns “with” and “without” the cost of land (return to land and management).

With regard to the “Degree of Marginality”, it is obvious that farmers will first utilise the most productive or suitable part of marginal lands. Therefore, our calculations mainly refer to such “best marginal” lands, with the highest productivity among all marginal land.

2.1.2 The cost of Labour

The cost of labour differs from country to country quite significantly and although farm activity is basically mechanised, it is a significant cost item. In our calculations we use data from FADN, for average national labour remuneration statistics.

Hourly labour cost is the minimum wage that is paid by each country to full-time workers (operators and assistants). The information and data collected from the publication of “Eurofound, (2019) and records the monthly and hourly rate applied to full-time employees. The range of labour costs is from 2,46€ (Latvia) to 10,03€ (France). Additionally, we examined data from Eurostat’s database, the monthly minimum wage, which adds 20% for employees’ insurance and is divided by 160, (working hours per month) to estimate the hourly labour rate.

Table 1: Monthly and hourly minimum wages in 2018 and 2019 (in euro)

Country	2018 (monthly rate)	2019 (monthly rate)	Nominal change*	Real change**	2018 (hourly rate)	2019 (hourly rate)
Belgium	€1,562.59	€1,593.76	+1.99%	+0.16%	€9.22	€9.41
Bulgaria	€260.76	€286.33	+9.81%	+7.39%	€1.47	€1.62
Croatia	€462.10	€505.90	+9.48%	+8.42%	€2.64	€2.89
Czechia	€477.78	€518.97	+8.62%	+7.24%	€2.87	€3.10
Estonia	€500.00	€540.00	+8.00%	+4.98%	€2.86	€3.09
France	€1,498.47	€1,521.22	+1.52%	+0.10%	€9.88	€10.03
Germany	€1,497.79	€1,557.09	+3.96%	+2.19%	€8.84	€9.19
Greece* **	€683.76	€758.33	+10.91%	+10.35%	€3.85	€4.27
Hungary	€444.69	€464.20	+4.39%	+4.95%	€2.53	€2.65
Ireland	€1,613.95	€1,656.20	+2.62%	+1.80%	€9.55	€9.80
Latvia	€430.00	€430.00	0.00%	-2.90%	€2.46	€2.46
Lithuania	€400.00	€555.00	+38.75%	+36.53%	€2.45	€3.39
Luxembourg	€1,998.59	€2,071.10	+3.63%	+1.97%	€11.55	€11.97
Malta	€747.54	€761.97	+1.93%	+0.91%	€4.25	€4.33
Netherlands	€1,578.00	€1,615.80	+2.40%	+0.35%	€9.11	€9.33
Poland	€502.75	€523.09	+4.05%	+6.39%	€2.84	€2.95
Portugal	€676.67	€700.00	+3.45%	+2.83%	€3.81	€3.94
Romania	€407.86	€446.02	+9.36%	+5.97%	€2.32	€2.54
Slovakia	€480.00	€520.00	+8.33%	+5.95%	€2.76	€2.99
Slovenia	€842.79	€886.63	+5.20%	+3.94%	€4.76	€5.00
Spain	€858.55	€1,050.00	+22.30%	+21.08%	€4.98	€6.09
United Kingdom****	€1,638.36	€1,746.73	+4.85%	+2.38%	€8.95	€9.54

We also utilised information from Panoutsou and Alexopoulou 2020, (giving full tables for hourly wages in agriculture for all EU countries).

2.1.3 The cost of Fertilisers

The cost of fertilisers is also different in different countries and for that reason we have applied appropriate costs for each fertiliser, pesticide and herbicide used in our analysis. We have consulted and used information on fertiliser costs from Rose C. 2004, Pennington D. 2012, Argus 2018, European Commission 2019, Panoutsou and Alexopoulou 2020, Nix 2019.

2.1.4 The cost of Machinery and Equipment

The capital cost of machinery and equipment used in crop production is important because in modern agriculture, very expensive specialised machinery is used for high efficiency and performance. In some cases, modifications of existing machines are tested in experimental plantations with improved capabilities. The scenery is changing year after year with new equipment being made available.

Economic data for all the types of machinery are based on the purchase cost excluding VAT. Additionally, the agricultural machines we used are available for farmers in all EU countries. Machinery purchase cost data refer in general to new, from John Deere or CLAAS.
Tractors are in the range 75hp-200hp, with average economic life of 15 years.

Specifically:

- Tractor Utility, 75hp, Model: 5075E,
- Tractor Utility, 85hp, Model: 5085E
- Cab Tractor, 130hp, Model: 6130R
- Tractor, 195hp, Model: 6195R
- Tractor, 215hp, Model: 6215R

Data have been extracted from the official site of John Deere Company https://www.deere.com/en/.

Additionally, for used CLAAS Tractors 75hp, 120hp and 200hp, we gathered information from online data sources of companies supplying new and used agricultural machinery to farmers.

For harvesting, there are available harvesters both combine and forage.

Combine harvester: John Deere S790, 5483 hp which economic life is about 8-10 years

Forage harvester: John Deere 9600, 616 hp, economic life is about 8 years

Windrower: John Deere W155, 155 hp

Attachments:

Round Baler: John Deere 560R or 450E with 8/10 years economic life

We have used longer lives for all machinery than those suggested by the official sources, since experience has shown that they are very low.

Data source: John Deere official website, https://www.deere.com/en/

For machinery, used in planting, tillage and soil preparation such as: planter, tillage, rotavator, power rake, disk harrow, mower, roller etc., info was gathered from the official website of John Deere and furthermore from sites which sell/promote agricultural machinery to farmers all over the world (also excluding VAT).

It has been difficult to manage to get meaningful machinery purchase prices in different EU countries, but it also was clear that there would be no significant cost differences within the Union, since a significant price difference would insentivise farmers to purchase machinery from another EU country. We have assumed that the capital cost of machinery used in different European countries (net of VAT) has no significant difference from country to country.

3 Economic analysis of crop production and transport

3.1 Economic Analysis

Recent research has revealed the financial possibilities of cultivation of non-food crops in marginal lands of EU regions and their conversion into a number of bio-products as part of a wider sustainability evaluation.

The present study assumed various land marginality conditions in three different EU agro-ecological zones, as illustrated in Report 6.1 of project MAGIC,

AEZ 1: Mediterranean South and North

AEZ 2: Atlantic

AEZ 3: Continental and Boreal

and assessed the economic performance of the selected crops under different agro-eco conditions.

Most crops in the South need to be irrigated, at least at the installation period, in order to achieve proper establishment and successful growth. Cultivation in marginal land increases the need for agronomic inputs such as irrigation, fertilisers, etc., according to the deficiencies of the particular marginal land. Therefore, from an economic point of view, it is examined whether the disadvantage of the increased need for inputs is counterbalanced by the low economic rent of marginal land.

3.2 Activity levels

It is obvious that farmers will not decide to cultivate industrial plants before contracting the sale of their products with an industry that will process their produce. On the other hand, industry will not invest in the establishment of a transformation plant until they secure sufficient feedstock for uninterrupted operation throughout the year. In addition, due to economies of scale, the size of the industrial units for economic operation, requires large amounts of biomass, which corresponds to very large cultivated marginal land areas. The fact that yields in marginal land are lower, intensifies the demand for land. As an example, a typical pyrolysis plant requires 60 thousand tonnes of feedstock corresponding to 5 to 10 thousand ha of marginal land if biomass is supplied by dedicated crops.

The logistics of such large-scale activities are crucial for the economic viability of projects and have to be centrally managed. The number of farmers involved, the plantations distance from the transformation plant and the existing road network, dictate the choices for harvesting, warehousing and transport.

Given the average concentrations of marginal lands in the EU, it seems inevitable that commercial applications will involve large numbers of farmers. In MAGIC we examine two distinct cases:

a. The case of farmers utilising relatively small size marginal areas in their property, using mainly existing capacity of machinery and equipment
b. The case of large scale, centrally organised agricultural production, with investment in high cost and efficiency specialised machinery shared by all parcels.

The crops and EU zones that have been analysed are tabulated as follows:

Table 3.1 Magic Value Chains

Value Chain	Crop	Transformation Technology	Climatic Zone
VC.1	**Miscanthus**	Pyrolysis	South/Continental/Atlantic
VC.2	**Poplar**	Gasification	South/Continental/Atlantic
VC.3	**Switchgrass**	Hydrolysis & Fermentation	South/Continental/Atlantic
VC.4	**Willow**	Pyrolysis	South/Continental/Atlantic
VC.5	**Safflower**	Oxidative Cleavage	South/Continental/Atlantic
VC.6	**Castor**	Oleochemical process	South/Continental
VC.7	**Lupin**	Extraction	South/Continental/Atlantic
VC.8	**Hemp**	Mechanical Processing	South/Continental/Atlantic
VC.9	**Sorghum**	Anaerobic Digestion	South/Continental/Atlantic

For each case we model the economic analysis using data from a representative country in each climatic zone. Since the cost of labour, energy, raw materials, etc. differ from country to country, each case is only moderately representing the situation in the zone.

4 Logistics of biomass value chains

The cost of moving and storing the biomass in the farm and then transporting harvested material from the farm gate to the conversion plant is significant and could amount for anything up to 70% of total biomass delivered cost (ETSU 1996). This depends upon the type of transported biomass, harvesting method, moisture content, the bulk density of the material, the distance of transportation, the condition of the road network, size of storage facilities in the farm and the conversion plant, daily feedstock needs, etc. The cost of moving and storing / stacking biomass within the boundaries of the farm has been included in the cost of harvesting and storing, while loading, unloading and transportation to the conversion plant appears separately with the code name “transport 37”.

In all value chains examined, we assume that the conversion plant is located somewhere around the middle of the plantations area and that the most remote plantation is located at a radius of R= 60 km. In addition, we assume that the density of cultivated marginal patches is twice as high close to the conversion plant than at distances in excess of 42km (The area of a circle of radius 42 km, is half the area of a circle of radius 60km).

This can be seen in the following Figure, where the conversion plant is in the middle and plantations are located within a radius of 60km around the plant. The area of the outer ring with the light grey colour equals 50% of the total. We assume that the density of plantations in the grey outer ring is half the density in the green area. So, the average transport distance radius is equal to: R x ✓(3 / 8)= 37km, which defines a circle (blue dotted line) which contains half the cultivated patches.

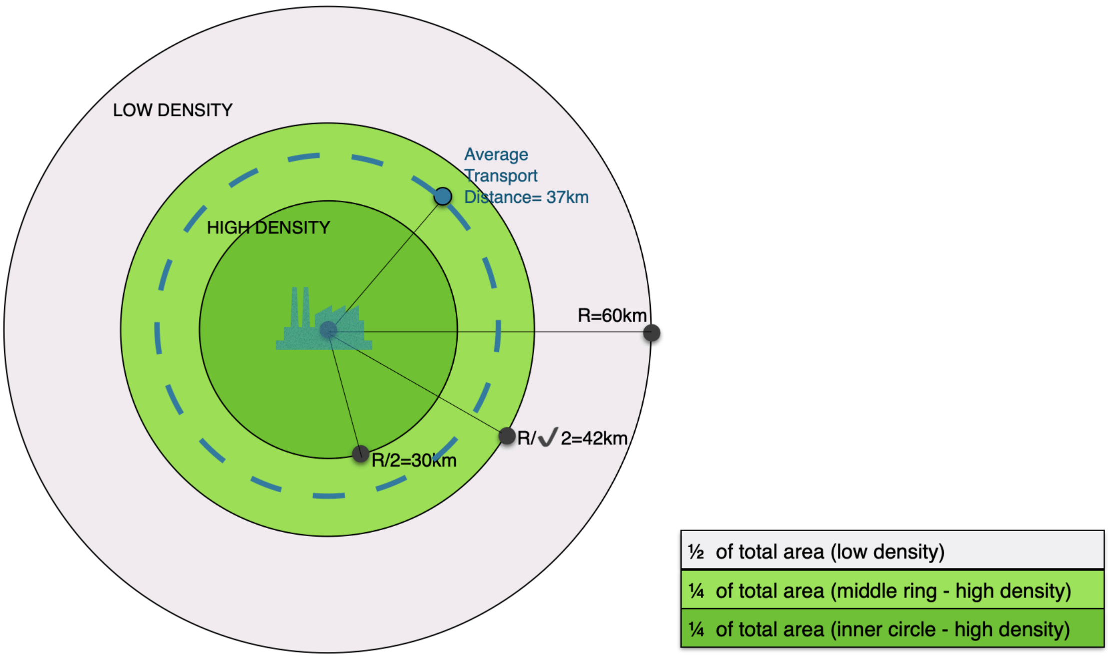


Figure 4.1.1.Estimating average transport distance.

As a result, our transport cost estimations are based on an average distance of 37km (74km return trip) from the conversion plant.

4.1 Estimation of Road Transport costs

Transportation of biomass is performed mainly with the use of big trucks, which may carry large loads of biomass. Since the bulk density of biomass ranges from 200 to 600 kg/m3 increased by the amount of moisture content, the volume of the load is usually the transport limiting factor.

In our calculations we assume maximum truck load space equal to 60 m3. The cost of such vehicles ranges from 60,000 to over 100,000 euros. We adopted an average cost of 80,000 euros (Bioboost 2013).

4.2 Transport of bales, chips and seeds

Most Crops have harvesting windows of up to about three to four months and as a result, in order to supply conversion plants all year round with the required quantities, optimal storage methods have to be adopted.

The cost of biomass road transport consists of the following items:

1. Truck and loading-unloading equipment capital service cost (CSC)
2. Truck and loading-unloading equipment insurance, repairs, maintenance and Lubricants (IRML)
3. Variable cost of Loading truck at farm gate and Unloading at conversion plant reception
4. Total labour and fuel cost for loading, unloading and transport

Transport, as well as other mechanised farming activities, may be performed by own means or by contracting the operation. Contractors usually enjoy relatively lower costs because of extensive use of their machinery and equipment, as compared to the use made by small farming businesses, but they expect to earn a profit for their service. Therefore, for large area cultivations, it may be sensible to have their own fleet of agricultural machinery, because they can make good use of it and because of the flexibility and security that it offers.

In any case, for larger farms, e.g. 100 ha or more, the cost of operating own or hired machinery is not very different (by disregarding the contractor’s profit).

The annual capital service cost of the truck (tractor plus trailer), loading and unloading equipment is estimated by the following formula as was explained in the methodology section:

$$CSC = \frac{C\,i}{1 - (1+i)^{-n}}$$

where C is the equipment purchase cost, n is its economic life and i is the discount (interest) rate.

We assume that due to the low bulk density of bales (250 dry kg/m3 or 312 wet kg/m3 @ mc=20%) and chips (150 dry kg/m3 or 250 wet kg/m3 @ mc=40%) the volume of biomass is the limiting factor (Gasol et al. 2008).

Truck annual Insurance is set at 2% of C. Average annual Repairs, Maintenance and Lubricants cost, is estimated at 8%. So, IRML= (2%+8%) x C.

Loading and Unloading cost is estimated based on the time required for these activities. Chips are loaded with front loader. Bales are loaded (unloaded) with bale loader.

Average fuel consumption of loaded truck is about 0.35 L/km (Bioboost 2013, ETSU, 1996, AUA database)

In order to get an approximate figure for the cost of transporting biomass to a possible conversion plant, the following table, assumes an average transport distance of 37 km, and uses average EU cost for labour and fuel. This table is later adapted for each of the MAGIC crops according to volume of production and the country of cultivation.

Table 4.1 Transport Cost Estimation

Capital Cost of Equipment

Excluding Fuel and Human costs	
TRUCK	
Truck max load m3	50
Truck diesel consumption Lt/km	0.33
Average Truck speed on road km/hr	40
Average Truck speed off road km/hr	20
Truck purchase cost €	100,000
Truck life yrs	10
Truck annual operating hrs	1,200
Truck Capital Service Cost (CSC) €/yr	12,950
Truck CSC €/hr	**10.79**
Truck annual IRML cost % of purchase cost	10%
Truck annual IRML cost €/yr	10,000
Truck IRML cost €/hr	**8.33**
Total Truck (CSC+IRML) cost €/hr	**19.13**
CHIPS and SEEDS LOADER	
Chips Front loader purchase cost €	6,900
Chips Front loader life yrs	12
Chips Front loader annual operating hrs	200
Chips Front loader CSC €/yr	778
Chips Front loader CSC €/hr	**3.89**
Chips Front loader annual IRML cost % of purchase cost	10%
Chips Front loader annual IRML cost €/yr	690
Chips Front loader IRML cost €/hr	**3.45**
Total Chips Front loader cost €/hr	**7.34**
BALES LOADER	
Bale loader purchase cost €	6,900
Bale loader life yrs	12
Bale loader annual operating hrs	200
Bale loader CSC €/yr	778
Bale loader CSC €/hr	**3.89**
Bale loader annual IRML cost % of purchase cost	10%
Bale loader annual IRML cost €/yr	690
Bale loader IRML cost €/hr	**3.45**
Total Bale loader cost €/hr	**7.34**

CSC= Capital Service Cost, IRML= Insurance+Repair+Maintenance+Lubricants

Total Transport Cost Estimates

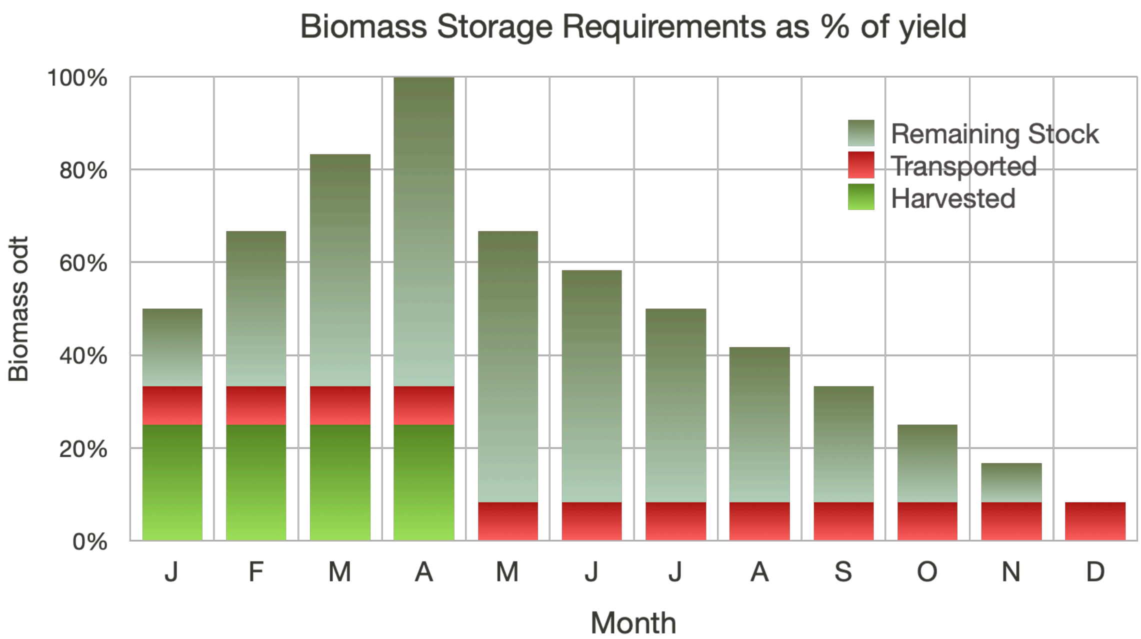
	Miscanthus Bales	Switchgrass Bales	Poplar Chips	Willow Chips	Sorghum Chips	Hemp Bales	Safflower seeds	Castor beans	Lupin seeds
HARVESTING									
Total Area (ha)	100	100	100	100	100	100	100	100	100
Harvest dry matter (tonnes/ha/yr)	10	9	6	6	11	8	1.1	1.5	2.5
Total dry weight (odt/total area/yr)	1000	900	600	600	1100	800	110	150	250
MC% at harvest	50%	50%	50%	50%	50%	50%	30%	30%	30%
Total Fresh matter (tonnes of total area/yr)	2,000	1,800	1,200	1,200	2,200	1,600	157	214	357
VOLUMES									
MC% at transport	20%	20%	40%	40%	40%	20%	20%	20%	20%
Bulk density, dry tonnes/m3	**0.25**	**0.25**	**0.15**	**0.15**	**0.15**	**0.25**	**0.50**	**0.50**	**0.50**
Bulk density, fresh tonnes/m3	0.31	0.31	0.25	0.25	0.25	0.20	0.50	0.50	0.50
Fresh tonnes transported per trip	15.63	15.63	12.50	12.50	12.50	10.00	25.00	25.00	25.00
Dry tonnes transported per trip	12.50	12.50	7.50	7.50	7.50	12.50	25.00	25.00	25.00
EU AVERAGES									
Average Cost of operator €/hr	12	12	12	12	12	12	12	12	12
Average Fuel cost €/Lt	1	1	1	1	1	1	1	1	1
interest rate %	5%	5%	5%	5%	5%	5%	5%	5%	5%
Average truck transport Distance (return) km	74	74	74	74	74	74	74	74	74
Additional truck distance for loading, km per trip	10	10	15	15	15	10	10	10	10
HOURS per trip									
Truck transport hrs for return trip	2.35	2.35	2.60	2.60	2.60	2.35	2.35	2.35	2.35
Loading duration hrs per trip	1	1	0	0	0	1	1	1	1
Unloading duration hrs per trip	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
COST per trip									
Total labour cost €/return trip	42.60	42.60	33.60	33.60	33.60	42.60	42.60	42.60	42.60
Truck fuel cost €/return trip	27.72	27.72	29.37	29.37	29.37	27.72	27.72	27.72	27.72
Truck CSC+IRML €/return trip	67.90	67.90	53.55	53.55	53.55	67.90	67.90	67.90	67.90
Bale loader CSC+IRML €/trip	8.81	8.81				8.81			
Chips Front loader CSC+IRML €/trip			1.47	1.47	1.47		8.81	8.81	8.81
TOTAL COSTS									
TOTAL TRANSPORT COST €/trip	**147.03**	**147.03**	**117.99**	**117.99**	**117.99**	**147.03**	**147.03**	**147.03**	**147.03**
TOTAL TRANSPORT COST €/Fresh tonne	**9.41**	**9.41**	**11.76**	**11.76**	**11.76**	**14.70**	**5.88**	**5.88**	**5.88**
TOTAL TRANSPORT COST €/Dry tonne	**11.76**	**11.76**	**19.60**	**19.60**	**19.60**	**11.76**	**5.88**	**5.88**	**5.88**
TOTAL TRANSPORT COST €/ha	**117.62**	**105.86**	**117.62**	**117.62**	**215.64**	**94.10**	**6.47**	**8.82**	**14.70**

4.2.1 Miscanthus and Switchgrass transport costs

Perennial grasses are harvested and baled in order to be easily stored and keep moisture at a minimum (Cassling et Al. 2011). The harvesting window depends on the climatic conditions but in general it is not wider than 3-4 months (Teagasc 2007). Therefore, the logistics of managing the large volumes of biomass produced are very important, as they may represent a significant portion of delivered costs, especially if they must supply conversion plants all year round.

In the case of baled perennial grasses, storage may be in the open, for several months without significant loss of biomass. Land requirement for storage is about 1% of cultivated area if we take into account that biomass is harvested within 4 months, but disposed in equal volumes in 12 months (Turhollow 2013). Storage losses are between 2.5% and 5% if we consider that part of the biomass is transported to the conversion plant as soon as it is harvested and some of the biomass remains in stock for over six months.

The assumptions in the Miscanthus and Switchgrass transport model are:



	J	F	M	A	M	J	J	A	S	O	N	D
Harvested	25%	25%	25%	25%								
Transported	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Remaining Stock	17%	33%	50%	67%	58%	50%	42%	33%	25%	17%	8%	0%

Figure 4.2.1. Biomass Storage Requirements

5 Cost Analysis of Selected Crops

In this section we present the findings of the examination of the financial performance of the selected crops and estimate the cost of agricultural production in different European countries at different climatic zones as have been specified in the MAGIC project.

For comparison of financial sustainability of crop growing by farmers, we supply observed spot market or estimated selling prices for all products, in order to estimate the net financial outcome of the cultivation. Nevertheless, the cost of feedstock supply to the conversion plant is net of any farm profit, since the whole chain is regarded as one financial entity. Value chain profit is estimated only at the sale of the final products to external customers. Also, subsidies and other financial incentives that might exist have been excluded from the analysis, because of their temporal and uncertain nature. The reader may easily estimate their overall net effect.

In the appendix there is a collection of financial tables and graphs with details of all cases that have been examined.

5.1 *Miscanthus (Miscanthus x giganteus L.) for the production of pyrolysis fuel*

Value chain 1: Industrial heat from Miscanthus (via pyrolysis)

Miscanthus is being studied in Europe during the last 30 years mainly for its potential in the energy sector, because in good agricultural land it may produce up to 20+ tonnes of biomass per hectare and requires little attention during its productive life, estimated to about 15-20 years.

Figure 5.1.1 Miscanthus

The productivity of the crop drops if planted on lands of natural or agronomic handicap and it is the goal of this project to measure the net financial result from reduced biomass yields against lower cost of inputs and rent of marginal land. Miscanthus yields in the EU, as agreed by project partners, range from 9 to 10 dry t/ha/year on average, the lowest yield in South Europe (with little irrigation) and the highest in the Continental zone.

The establishment cost of Miscanthus is high and the fact that its’ first-year yield is very low, pose a serious cash-flow problem to farmers, who might be unwilling to undertake a high-risk investment with delayed financial inflows. Long term contracts with a central pyrolysis facility and crop establishment grants may help to overcome this problem.

Today, the cultivation of Miscanthus for commercial purposes is minimal both in Europe and in the US. Around the beginning of the century, establishment grants and long-term contracts with electricity generation facilities in the UK, have stimulated some interest from the side of the farmers, which relates to environmental targets that Britain needed to achieve. In the South of Europe Miscanthus is still cultivated in small experimental fields with little practical or commercial value.

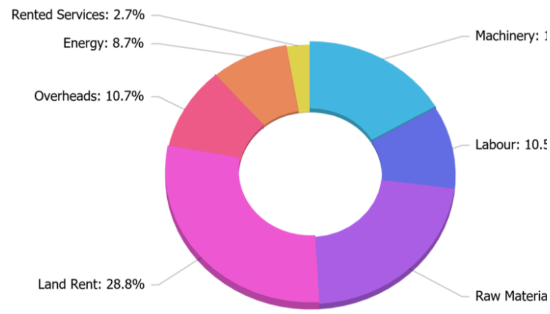
In Marginal Land, Miscanthus is rather expensive per tonne of output (almost 100 €/t), because it is expensive to establish and harvest and because it is usually not harvested in the first year of the plantation because of low yield. It is worth observing that, due to considerably lower yields in marginal land, cultivation on low quality land is in general more expensive per tonne of produced biomass, in spite of the lower opportunity cost of land and usually smaller amounts of agricultural inputs.

Witzel and Finger 2016 have reviewed 51 publications on Miscanthus economics, which reveal an average yield of almost 20 dry tonnes per hectare per year and an average selling price of 75 €/t. According to more recent information, these figures may be a little higher today. A cellulosic biomass price of 80 €/t for the following years may be quite reasonable or even on the low side (Manzone M. et al., 2009, Dutta A. et al. 2015, Panoutsou C. and Alexopoulou E. 2020, Pari L. 2020, Zixu Yang 2018).

5.1.1 Cost analysis

Miscanthus DE

Country/Region:	Germany
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Miscanthus DE,
Sales:	935.32 €/ha
Cost:	**936.24** €/ha
Subidies:	
Profit/Loss:	-0.92 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.64	0.87		1.03				*2.54*
Farm Storage							25.52	*25.52*
Fertilisation	3.28	7.22		8.04		43.35		*61.89*
Harvesting/Bale Management	8.98	6.59		34.27				*49.84*
Harvesting/Baling	26.2	26.37		39.98				*92.55*
Harvesting/Mowing	11.23	13.19		21.93				*46.35*
Planting	1.59	5.37		17.41		160.49		*184.86*
Ploughing	1.77	2.49		2.84				*7.10*
Transport 37	27.28	36.15		29.68				*93.11*
Weed Control	0.14	0.25		0.1		1.93		*2.42*
TOTAL (€/ha)	81.11	98.50	270.06	155.28	100.00	205.77	25.52	***936.24***

Figure 5.1.2. Miscanthus DE breakeven Economic analysis

The results of economic analysis show that growing Miscanthus in European marginal land needs a rather high selling price in order to to break even. The tables and figures of cost analysis below, show that large scale cultivation of industrial crops is in general not sufficiently profitable for the investor without some incentive, and that a price of around 90-100 €/t would be necessary to avoid losses.

The annuitised cost of delivered miscanthus biomass in Germany is 936.24 €/ha/yr and with an average yield of 10.05 dry tonnes per year, the cost per tonne is 93-94 €.

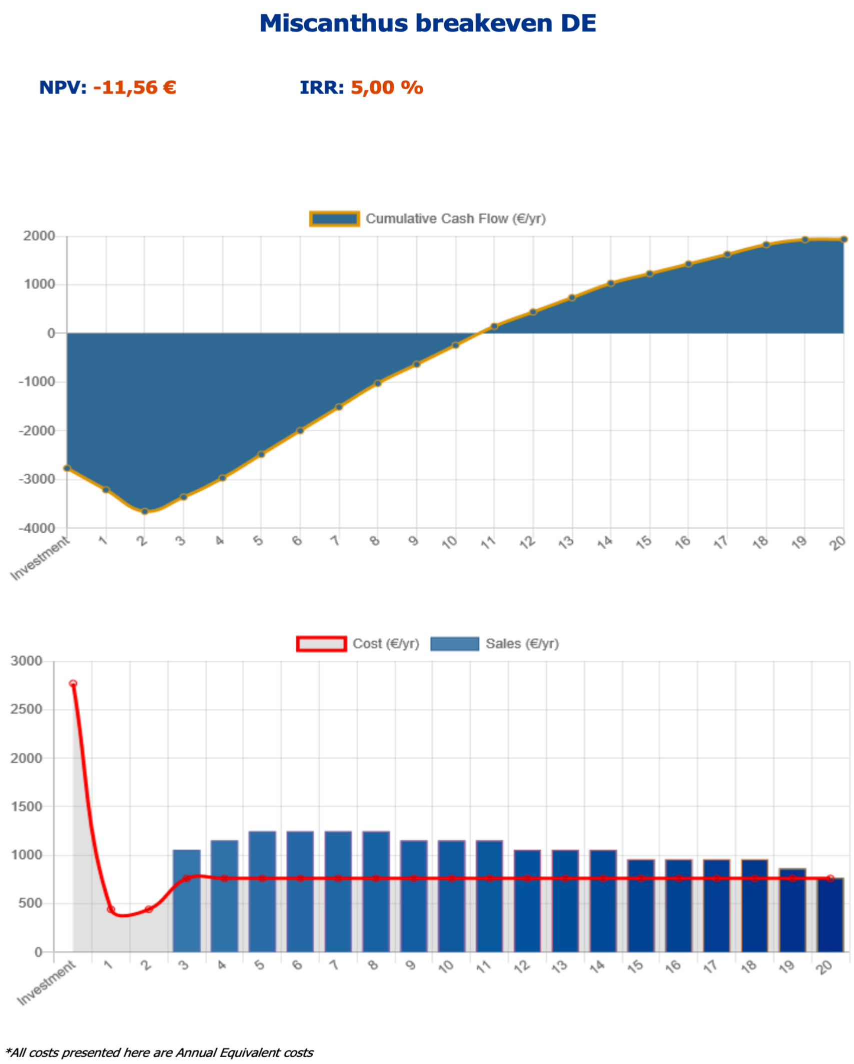


Figure 5.1.3. Miscanthus DE breakeven Cash Flows for 10 ha

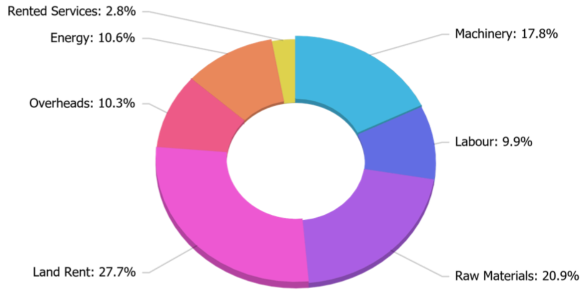
At breakeven selling price, the Net Present Value of the project (NPV) is near zero, while the Internal Rate of Return (IRR) is equal to the discount rate used throughout this volume (5%)

The breakeven Miscanthus price for Germany is 96 €/t, roughly equal to the cost of delivered biomass, i.e. the cost of producing, harvesting, storing and transporting bales of biomass to the conversion plant. The main cost items are the cost of (a) land, (b) crop establishment and (c) harvesting, accounting for two thirds of total cost. If we evaluate marginal land at zero opportunity cost, a very different picture emerges and the breakeven price or delivered cost drops to 66 €/t.

We have also analysed the cost of Miscanthus in Italy and Greece. It was found that in Italy the delivered cost was higher, (974 €/ha/yr or 105 €/t), because of relatively higher labour and material costs in comparison with Greece.

Miscanthus IT

Country/Region:	Italy
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Miscanthus IT,
Sales:	972.22 €/ha
Cost:	**973.80** €/ha
Subidies:	
Profit/Loss:	-1.58 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	1.02	1.11		1.41				*3.54*
Farm Storage							27.71	*27.71*
Fertilisation	4.45	7.72		9.32		38.09		*59.58*
Harvesting/Bale Management	11.42	6.6		37.21				*55.23*
Harvesting/Baling	33.3	26.41		43.41				*103.12*
Harvesting/Mowing	14.27	13.21		23.82				*51.30*
Irrigation	1.65	1.02		6.76		3.21		*12.64*
Planting	1.86	4.33		17.41		160.49		*184.09*
Ploughing	2.84	3.16		3.91				*9.91*
Transport 37	31.93	32.58		29.68				*94.19*
Weed Control	0.17	0.23		0.1		1.93		*2.43*
TOTAL (€/ha)	102.91	96.37	270.06	173.03	100.00	203.72	27.71	***973.8***

Figure 5.1.4. Miscanthus IT Breakeven Economic analysis

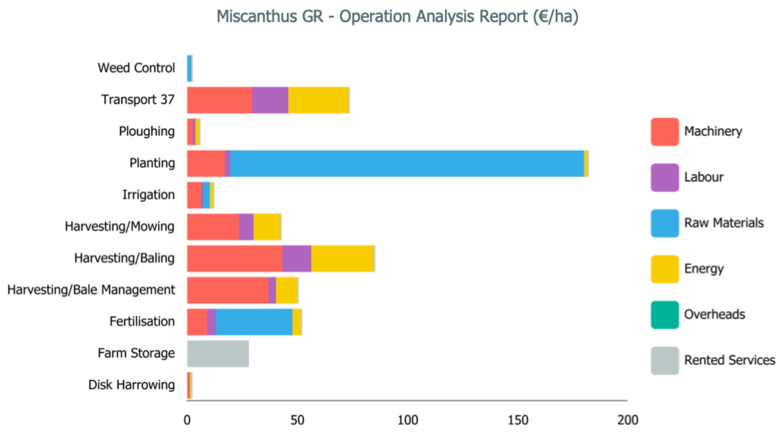


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
DISK HARROWING	1.03	0	0.4	0.64	0
FARM STORAGE	0	0	0	0	27.71
FERTILISATION	9.32	34.87	3.83	3.8	0
HARVESTING/BALE MANAGEMENT	37.21	0	3.28	9.75	0
HARVESTING/BALING	43.41	0	13.11	28.45	0
HARVESTING/MOWING	23.81	0	6.56	12.19	0
IRRIGATION	6.76	3.21	0.61	1.41	0
PLANTING	17.41	160.49	2.36	1.59	0
PLOUGHING	2.84	0	1.14	1.77	0
TRANSPORT 37	29.68	0	16.43	27.28	0
WEED CONTROL	0.1	1.93	0.11	0.14	0

**All costs presented here are Annual Equivalent costs*

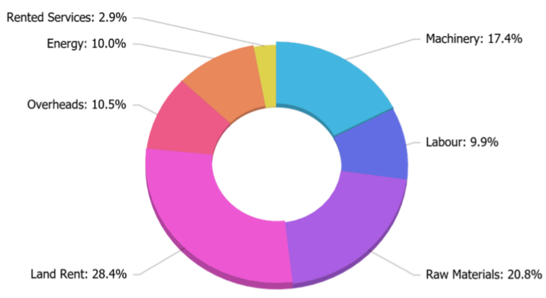
Figure 5.1.5. Miscanthus GR Breakeven Operations analysis

In France (Atlantic zone), miscanthus' yield averages 9.5 dry tonnes per hectare per year, a little higher than the yield in South Europe (9 t/ha/yr). However, energy, labour and materials are more expensive than in the Mediterranean zone and as a result, total annual cost per hectare is 950 € and the cost per tonne of output is 99€.

It is interesting to notice that Miscanthus crop establishment, which is a non-recurring operation, is a major item of the annualised cost list, in spite of the fact that it is paid only once. The upfront establishment cost of 20,000 rhizomes/ha @ 10¢ each is a significant expense for the farmer and a major obstacle to miscanthus financial attractiveness.

Miscanthus FR

Country/Region:	France
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Miscanthus FR,
Sales:	954.68 €/ha
Cost:	**950.26** €/ha
Subidies:	
Profit/Loss:	4.42 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.96	1.24		1.41				*3.61*
Farm Storage							27.71	*27.71*
Fertilisation	3.88	8		8.63		35.68		*56.19*
Harvesting/Bale Management	10.75	7.39		37.21				*55.35*
Harvesting/Baling	31.36	29.55		43.41				*104.32*
Harvesting/Mowing	13.44	14.78		23.82				*52.04*
Planting	1.75	5.23		17.41		160.49		*184.88*
Ploughing	2.68	3.54		3.91				*10.13*
Transport 37	30.07	23.77		29.68				*83.52*
Weed Control	0.16	0.26		0.1		1.93		*2.45*
TOTAL (€/ha)	95.05	93.76	270.06	165.58	100.00	198.10	27.71	***950.26***

Figure 5.1.6. Miscanthus FR breakeven Economic analysis.

The breakeven selling prices (or cost per tonne) of the examined crops were:

- Miscanthus IT: 105 €/t
- Miscanthus GR: 92 €/t
- Miscanthus DE: 96 €/t
- Miscanthus FR: 97 €/t

5.1.2 Miscanthus Summary

In the summary table below, sales of Miscanthus have been estimated at a selling price of 80€/t, which is currently most appropriate for many parts of Europe, as already mentioned above.

Table 5.1 Summary of Miscanthus Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Italy)	9.20	736	974	106	-238	12	186
Mediterranean Zone (Greece)	9.10	728	851	94	-123	77	186
Continental Zone (Germany)	10.05	804	936	93	-132	118	502
Atlantic Zone (France)	9.60	768	950	99	-182	68	392

** Panoutsou and Alexopoulou 2020*

5.1.3 Miscanthus Literature

There are many publications on the economics of miscanthus grown on usual agricultural land showing rather encouraging results. In project OPTIMA we have reviewed the literature to show the great variability on published yields and economic estimates of Miscanthus in EU and the US, with consequent implications on their economic performance results.

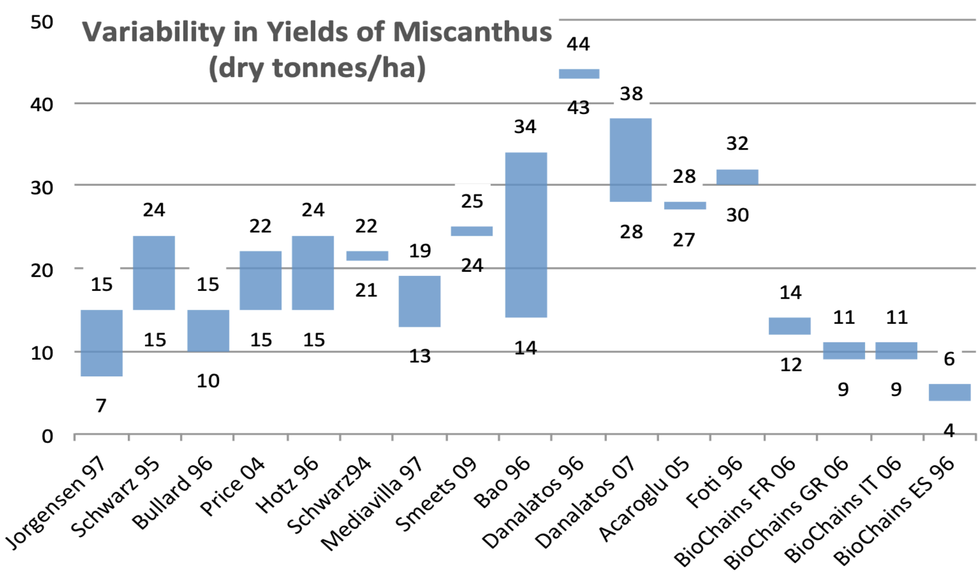


Figure 5.1.7. Miscanthus Yields variability in recent literature

5.1.4 Miscanthus Conclusions

Miscanthus has been studied by many researchers and agronomists and although there is very large spread in their findings, (which is natural to a certain extent), the general conclusion is that it is a promising biomass crop with great potential, useful physical properties and high yields.

On marginal EU land, yields do not exceed 10 dry tonnes per hectare per year, which poses a problem of economic uncertainty, because the costs of production, harvesting and transport to the conversion plant are about 650-800 €/ha before land charges. This means that the cost per tonne of miscanthus is in the area of 70-80 €/t and it is uncertain if miscanthus can achieve such prices in the market. In the industrial conversion chapter below, it is shown that if miscanthus feedstock for pyrolysis costs 80-100 €/t, the result is fairly costly pyrolysis oil, since the feedstock cost is the most important item in pyrolysis oil cost analysis.

The land charge used for all crops is probably somewhat high, especially if we consider that surplus land may be assigned very low opportunity cost. In a similar line of thought it may be argued that surplus agricultural production capacity of existing farmers' machinery and equipment has a very low real cost. Scenarios of low capital cost of machinery and zero cost of land estimate the cost of miscanthus in the range of 60-80 €/t (before any subsidy).

5.2 *Poplar (*Populus spp. *L.), for the production of SNG through gasification*

<u>Value chain 2</u>: SNG from poplar (via gasification)

Figure 5.2.1. Poplar

Poplar is a fast growing tree which has been studied mainly as an energy crop, usually harvested every 2-6 years. The optimal harvest rotation period and the re-establishment of the crop depend upon the existing economic and biophysical conditions of the region, and the yields expected on marginal land vary among European climatic zones and the type of land marginality (see also "Methodology" and "Appendix").

Poplar is well adapted and gives satisfactory yields in European marginal land (Fernandez M.J. 2020), especially during the first cycles of its life. Later, the crop's productivity gradually declines until the end of its economic life.

For optimal management, cultivation is arranged in such a way, that the human and mechanical capital is fully utilised in each year. For example, in a 3-year rotation cycle, total available land may be divided into three equal zones, established in three consecutive years and harvested every third year, in order to harvest similar amounts of biomass in each year.

In our analysis below, we observe only one such zone, in order to capture the cash flow fluctuations, which are necessary for the economic analysis.

5.2.1 Data and Assumptions

At the establishment year, 8000 rods (poplar cuttings), (e.g. Manzone et al. 2009) are planted and the base case scenario assumes harvesting every three years. There is no harvest during the first three years. Yields vary among climatic zones, with the Mediterranean giving at best an average of 6 dry tonnes per hectare p.a. (5.5 tonnes in the Continental and 5 tonnes in the Atlantic zone), under moderate fertilisation. Harvesting is performed with forage harvester with chipper followed by tractor and trailer for the collection of chips. Transport to the conversion plant is done with suitable big trucks to an average distance of 37 km (one way).

For an evaluation of farm profitability, the price of poplar chips following a moderate value from the literature, has been set at 100 €/DT (e.g. Schweier 2013, Manzone et al. 2009). Yields are higher in the first harvests and gradually decline in the following rotation cycles. Yields for marginal land in the three climatic zones are set as they have been agreed among the project partners. Similarly for the fertilisation amounts.

The short 3yr rotation cycle generates income relatively soon and maintains average biomass increments high (Kauter D. et al. 2003). 4yr rotation scenarios have shown very little economic difference and even higher rotations may probably require different machinery and management.

5.2.2 Poplar Cost analysis

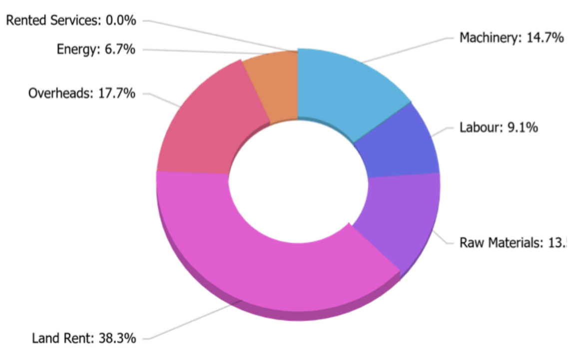
The expected yields of poplar depend upon the agro-ecological zone and the marginality characteristics of the land. Based on the experience of project partners, data from MAGIC experiments and the literature we have examined the range of yields between 3 and 6 t/ha/yr for the Mediterranean climate, 2.50 to 5 t/ha/yr for the Atlantic zone and 2.75 to 5.50 t/ha/yr for the Continental zone. These are very moderate yields compared to yields in standard agricultural land. As a result, economic estimates are also equally moderate.

The economic analysis below shows the case of cultivation in Spain, with average yield reaching about 6 dry tonnes per hectare, or 18 tonnes per hectare every third year, when it is harvested.

Land rent, machinery and raw materials cost dominate the cost list, while labour and energy are relatively lower, since harvesting is only performed 6 times during the life of the crop

Poplar ES

Country/Region:	Spain
Total Area:	1 ha
Projet Life:	19 yr
Product(s):	Poplar ES,
Sales:	571.78 €/ha
Cost:	**565.30** €/ha
Subidies:	
Profit/Loss:	6.48 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			216.55					*216.55*
(Overheads)					100			*100.00*
Cultivation	0.8	1.16		1.84				*3.80*
Disk Harrowing	0.6	0.81		1.06				*2.47*
Fertilisation	0.66	1.72		2.11		7.62		*12.11*
Field Preparation	1.68	2.32		0.97				*4.97*
Harvesting/Chipping	18.46	16.36		54.75				*89.57*
Planting	1.51	3.64		3.34		66.2		*74.69*
Ploughing	1.68	2.32		2.93				*6.93*
Pressing/Rolling	0.27	0.41		0.51				*1.19*
Transport 37	11.83	16.36		15.17				*43.36*
Weed Control	0.38	6.62		0.3		2.36		*9.66*
TOTAL (€/ha)	37.87	51.72	216.55	82.98	100.00	76.18		***565.3***

Figure 5.2.2. Poplar ES Economic Analysis

Poplar is harvested with forage harvester and chipper and it is transported by road to the conversion plant (Gasol et al. 2008). The cost of transporting the chips to an average distance of 37 km (single trip) is a little less than 10 €/t.

Total annual equivalent cost in Spain is 565.30 €/ha/yr or 93 €/t. This is lower than expected revenues at the selling price of 100 €/t (sales= 611 €/ha) and the farmer is able to make a profit of about 46 €/ha. The NPV of the investment is very small, but positive and as a result the IRR is a little higher than the cost of funds (5.50%).

In Germany, however, and France Poplar is more expensive to grow, not only because inputs are more expensive and so is land, but also because of lower yields, (5.58 dt/ha/yr in Germany and 5.05 dt/ha/yr in France).

The breakeven price in Germany is 119 €/t, which is higher thatn the expected selling price for poplar, i.e. 100 €/t.

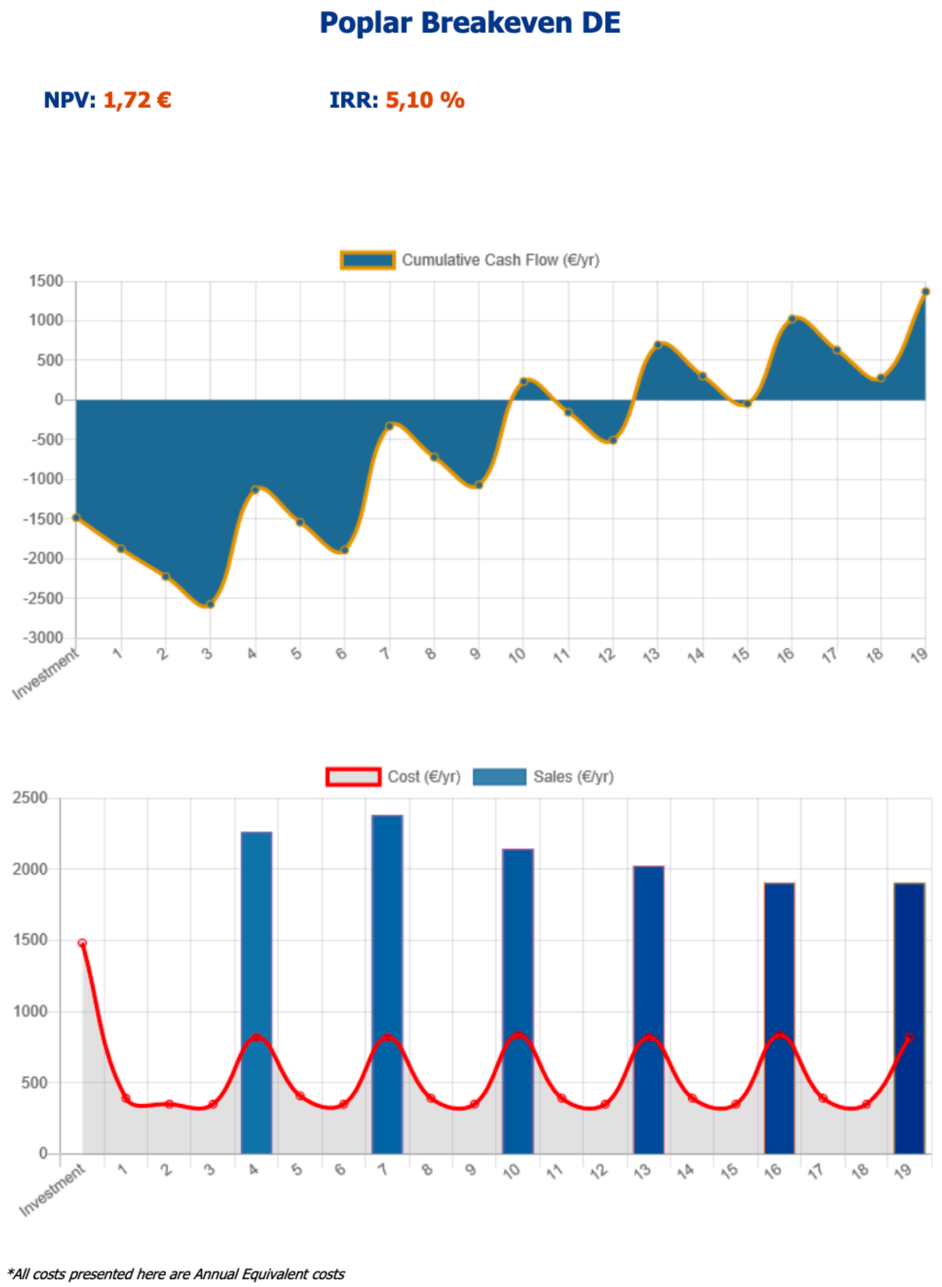


Figure 5.2.3. Poplar DE Cash Flow Analysis

As may be seen in the Cash flow diagram for Poplar DE, during the first 10 years, the cultivation is in need for cash, mainly because of the high costs of installation and a period of four years with no harvest or sales. It is only after 10-15 years that cumulative cash flows become positive, but with such payback periods the farmer would like to invest.

In France (Atlantic zone), reference yields are lower (5 t/ha/yr) and as a result the cost per tonne of poplar increases to 125 € (breakeven price). The annual equivalent cost of poplar in France is dominated by the cost of Harvesting and the cost of

Planting the crop. (The cost of land is not shown in this diagram). The transport cost, around 50 €/ha is also significant, but much lower than contractor's cost.

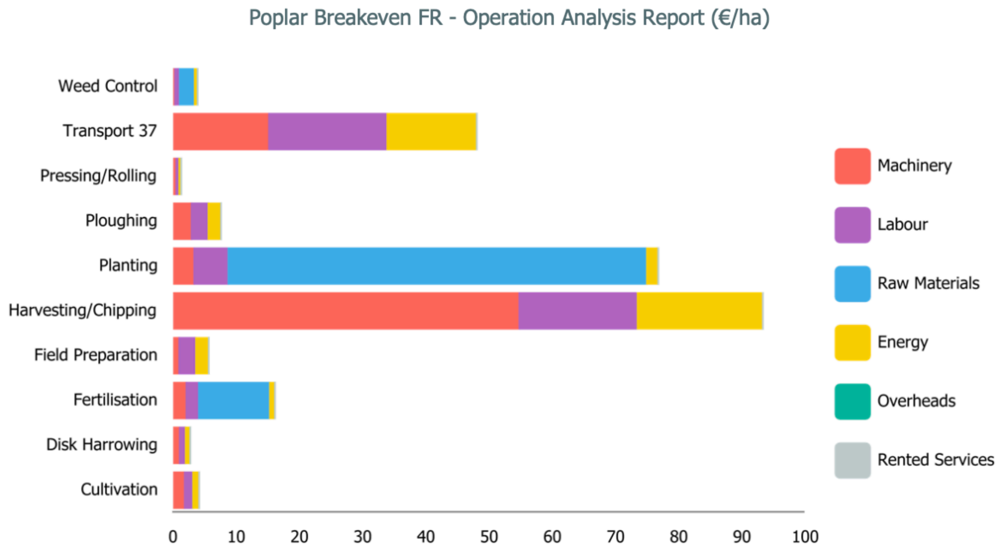


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
CULTIVATION	1.84	0	1.32	0.96	0
DISK HARROWING	1.06	0	0.93	0.72	0
FERTILISATION	2.11	11.25	1.96	0.79	0
FIELD PREPARATION	0.97	0	2.65	2.01	0
HARVESTING/CHIPPING	54.75	0	18.7	19.84	0
PLANTING	3.34	66.2	5.39	1.81	0
PLOUGHING	2.93	0	2.65	2.01	0
PRESSING/ROLLING	0.51	0	0.46	0.32	0
TRANSPORT 37	15.17	0	18.7	14.17	0
WEED CONTROL	0.3	2.36	0.76	0.46	0

**All costs presented here are Annual Equivalent costs*

Figure 5.2.4. Poplar FR Operations Analysis

5.2.3 Poplar Summary

The Summary table shows that the low yields of wheat cultivation in Spain and the relatively high yields of poplar in the Mediterranean climatic zone, result in a positive economic profile for poplar cultivation. However, this is not the case in the Atlantic and the Continental zones, where wheat productivity is much higher, while poplar yields are lower.

Table 5.2 Summary of Poplar Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Spain)	6.11	611	565	93	46	246	44
Continental Zone (Germany)	5.58	558	626	112	-68	132	502
Atlantic Zone (France)	5.05	505	630	125	-125	75	392

** Panoutsou and Alexopoulou 2020*

5.3 *Switchgrass (*Panicum virgatum *L.) for the production of ethanol through fermentation*

Value chain 3: Ethanol from switchgrass (via hydrolysis & fermentation)

Figure 5.3.1. Switchgrass

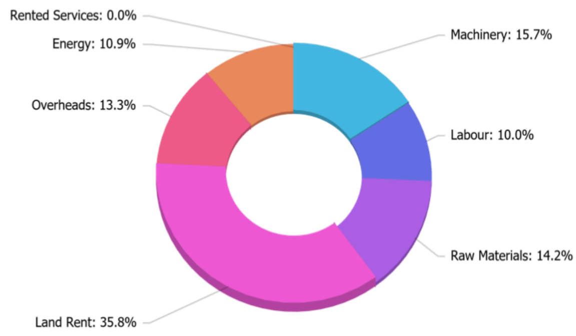
Switchgrass is the second perennial grass in MAGIC. It resembles miscanthus, but in general has lower yields and needs about the same inputs. Unlike miscanthus it is propagated with seeds and not with rhizomes. This reduces significantly the establishment cost of Switchgrass and compensates for the loss of yield volumes.

Switchgrass has been extensively studied especially in the US and current research indicates that it is quite competitive, especially in lands of low quality, i.e. lands where conventional crops do not perform well.

Switchgrass breakeven IT

Country/Region: Italy
Total Area: 1 ha
Projet Life: 20 yr
Product(s): Switchgrass IT,

Sales: 754.62 €/ha
Cost: **753.51** €/ha
Subidies:
Profit/Loss: 1.11 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.74	0.8		1.03				*2.57*
Fertilisation	3.09	4.29		5.18		93.24		*105.80*
Field Preparation	1.41	2.01		2.66				*6.08*
Harvesting/Bale Management	6.18	4.29		20.27				*30.74*
Harvesting/Baling	20.6	14.3		23.49				*58.39*
Harvesting/Mowing	14.27	13.21		23.81				*51.29*
Irrigation	1.24	0.77		5.07		2.41		*9.49*
Ploughing	2.07	2.29		2.84				*7.20*
Pressing/Rolling	0.33	0.4		0.49				*1.22*
Sowing	0.41	0.46		3.48		10.67		*15.02*
Transport 37	31.93	32.58		29.68				*94.19*
Weed Control	0.17	0.23		0.1		0.96		*1.46*
TOTAL (€/ha)	82.44	75.63	270.06	118.10	100.00	107.28		***753.51***

Figure 5.3.2. Switchgrass IT breakeven Economic Analysis

The breakeven selling price (or cost per tonne) of Switchgrass in Italy is 95 €/t. This is high because of relatively higher land rent and expensive labour and raw materials. In addition, Mediterranean countries have lower yields of less than 8 t/ha/yr. In Greece, with yields similar to Italy's (7.60 t/ha/yr), the higher IRR figure of 14.10% is due to the fact that the growth of switchgrass is faster during the first years of the plantation and this generates good early revenues, which raise the NPV and consequently the IRR (check detailed results in the Appendix).

Results in Spain and Greece are very similar.

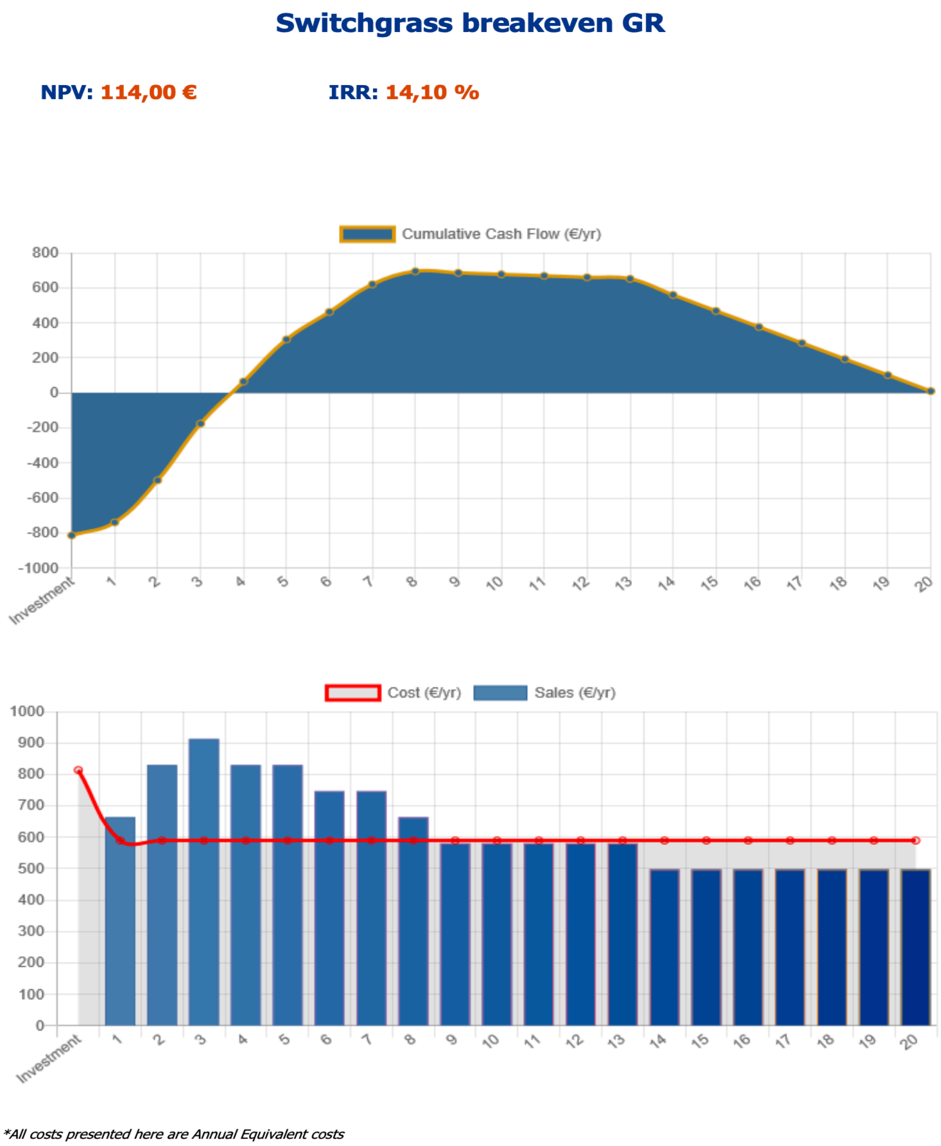


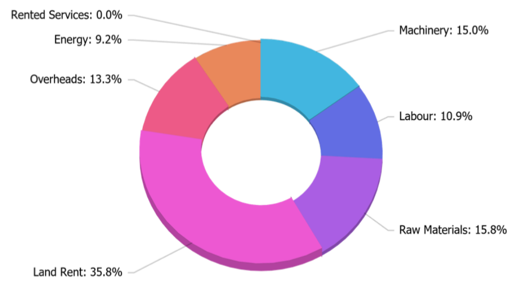
Figure 5.3.3. Switchgrass GR breakeven Cash Flows for 10 ha

It is important to stress again that the *timing* of yields is important from an economic point of view because of the time value of money (see e.g. Bierman 2007). Early high yields and consequent revenues are preferred to high revenues towards the end of the crop life (which actually is not the case in most plantations). Therefore, the expected yields in each year must be approximated based on experience and experimentation. We have agreed on the average annual yields in each climatic zone, but we only have experimental detailed annual data for Italy and Greece. For the rest of the countries modelled we approximately maintained the same distribution of yields among the years.

Another important observation is that after a number of years, the yields of the plantation are declining and in earlier experiments we have found that from an economic point of view, it may be more profitable to re-establish the plantation earlier than in 20 years. The optimal replacement period is easily identified by ABC and the use of the investment evaluation indices (when marginal revenues become less than marginal costs and cumulative benefit starts declining). Time to re-establish is when revenues become less than the cost to maintain the crop.

Switchgrass breakeven DE

Country/Region:	Germany
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Switchgrass IT,
Sales:	751.05 €/ha
Cost:	**753.53** €/ha
Subidies:	
Profit/Loss:	-2.48 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.64	0.87		1.03				*2.54*
Fertilisation	2.64	4.65		5.18		107.44		*119.91*
Field Preparation	1.2	2.18		2.66				*6.04*
Harvesting/Bale Management	5.28	4.65		20.27				*30.20*
Harvesting/Baling	17.6	15.5		23.49				*56.59*
Harvesting/Mowing	12.19	14.32		23.81				*50.32*
Ploughing	1.77	2.49		2.84				*7.10*
Pressing/Rolling	0.28	0.44		0.49				*1.21*
Sowing	0.35	0.5		3.48		10.67		*15.00*
Transport 37	27.28	36.15		29.68				*93.11*
Weed Control	0.14	0.25		0.1		0.96		*1.45*
TOTAL (€/ha)	69.37	82.00	270.06	113.03	100.00	119.07		***753.53***

Figure 5.3.4. Switchgrass DE breakeven Economic Analysis

In Germany (Continental Zone), where Switchgrass yield is highest (9 t/ha/yr) the cost of growing, harvesting, storing and transporting the biomass is 82 €/t and therefore the farmer breaks even if he can sell the biomass at this price per tonne.

The breakeven selling prices of the examined cases were:

- Switchgrass IT: 95 €/t
- Switchgrass GR: 83 €/t
- Switchgrass ES: 84 €/t
- Switchgrass DE: 82 €/t
- Switchgrass FR: 89 €/t

5.3.1 Switchgrass Summary

In the summary table below, the sales of Switchgrass have been estimated by using a reference selling price of 80 €/t, which is currently the going price in the market (Schweier J. 2013, Manzone 2009).

Table 5.3 Summary of Switchgrass Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Italy)	7.75	620	754	97	-134	116	186
Mediterranean Zone (Greece)	7.60	608	655	86	-47	153	186
Mediterranean Zone (Spain)	7.50	600	638	85	-38	162	44
Continental Zone (Germany)	9.00	720	754	84	-78	172	502
Atlantic Zone (France)	8.30	664	753	91	-89	161	392

** Panoutsou and Alexopoulou 2020*

5.3.2 Switchgrass Literature

There are plenty of publications on Switchgrass cultivation economics, mainly in the US. Since its establishment cost is relatively low, and its yield not very high, the economic life of the crop is examined for any period between 10 and 20 years.

The economic results for cultivation in usual agricultural land usually have a positive sign, but in the case of marginal land, each case is specific. In EU project OPTIMA we have reviewed important literature on the subject of economic analysis of switchgrass. Our results on marginal land with low cultivation inputs add up to 771 €/ha/yr which compares to the 655 €/ha/yr estimated in this report.

The following table, summarising findings of previous research on switchgrass was compiled from Monti A. 2012

Table 5.4 Switchgrass Literature Compilation

	YIELD	PRODUCTION COST	HARVESTING COST	TOTAL COST		Selling Price	Profit
	(odt/ha)	(€/ha)	(€/ha)	(€/ha)	(€/odt)	(€/odt)	(€/ha)
OPTIMA S.EU - Marg land[1] – 2015	9.33	564	113	677	72.6	65.0	-71
OPTIMA S.EU - Stand land - 2015	16.0	933	155	1088	68.0	65.0	-48
Brechbbill US IN[5] - 2008	11.2	420		420	37.5		-420
BIOchains FR – 2006	10.9	349	123	472	43.3	65.0	237
BIOchains GR – 2006	11.0	763	90	853	77.5	65.0	-138
BIOchains IT – 2006	10.9	502	111	613	56.2	65.0	96
BIOchains ES[2] – 2006	4.4	332	64	396	90.0	65.0	-110
Monti North IT[3,4] – 2007	11.6	404	281	685	59.1	55.0	-47
Monti South IT[3,4] – 2007	13.8	591	214	805	58.3	55.0	-46
Alexopoulou GR[3] – 2013	13.6	489	354	843	62.0	65.0	41
Duffy US IA[5] - 2007	9	608		608	67.5		
Epplin US OK[5] - 2007	11.5	426		426	37.0		
Gerloff US-TN[5,6] – 2009	11.4	760		760	66.7		
Halich US KY[5,6] – 2010	11.4	579		579	50.8	62.6	135
Khanna US IL[5] - 2008	6.4	432		432	67.5		-432
Perrin US NE – 2008	6.74	242	115	357	53.0	40.6	-83
USEPA[5] - 2009	13.8	600		600	43.5		
UT Extension US TN[5,6] - 2007	14.4	734		734	51.0		
Vadas US WI[5] - 2008	10.8	470		470	43.5		
Haque et al., 2014	12.4-19.2			723-1284	58-67	83	306-310

1. Avg of M0, ML, MH 2. Production failed, 3. Medium input q'ty 4. Breakeven yield 5. No distinction of Harvesting 6. No land rent

Part of the table adapted from Monti 2012

5.3.3 Switchgrass Conclusions

Switchgrass is the second perennial grass examined in this study. In many aspects it is fairly similar to miscanthus but it is propagated with seeds and its productivity is a little lower than miscanthus. The annualised switchgrass establishment cost is only 3-4% of total cost, in contrast with miscanthus, the establishment of which accounts for about 20% of total cost.

On the other hand, switchgrass yield in marginal land is only about 10% lower than the yield of miscanthus. Overall cost of switchgrass production, harvesting, farm storage and transport to the conversion plant (delivered cost) is between 84 and 97 euros per tonne, cheaper than miscanthus, the cost of which ranges from 93 to 106 euros per tonne.

It was found in earlier research that the optimal re-establishment of the plantation is around the 15th year, but this very much depends upon the achieved annual yields and the cost of maintaining the plantation as well as the anticipated selling price.

Under the conditions examined in Soldatos et al. 2019, it was found that the re-establishment period that maximised profits was 15 years. Similar results are obtained in the present analysis as may be seen in the cash flow diagrams of switchgrass.

As in all other cases of cultivation in marginal lands, land rent is an important expense and its opportunity cost should be carefully estimated. A zero land rent hypothesis, as e.g. in the case of farmers growing switchgrass in less productive, unused part of their land, would reduce total cost significantly.

5.4 *Willow (*Salix spp. *L.), for the production of bitumen ("biotumen") via pyrolysis*

Value chain 4: Biotumen from willow (via pyrolysis)

Willows, like poplars are growing in many parts of Europe, especially in the continental zone, where they grow faster and give higher yields. The wood of willows has several traditional uses besides its more recent applications in the biomass to energy sector. In recent years, due to the fact that willow gives high yields of cellulosic biomass in short time periods, many believe that it is going to be one of the most attractive crops for energy and other useful bio products.

Figure 5.4.1. Willow

Willow is a low input crop, the cultivation of which has minimal greenhouse gas emissions due to lower need for fertilisers and other chemicals as well as smaller number of mechanical operations throughout the life of the plantation.

Willow cultivation and harvesting is similar to poplar. The crop is installed with willow cuttings and it is harvested for the first time after four years. From then on, the rotation cycle is three years.

(Lindegaard et al. 2016}

5.4.1 Willow Economic Analysis

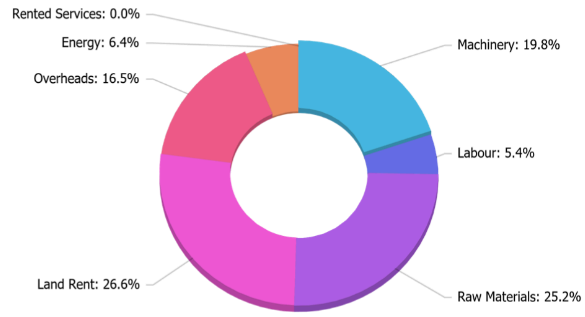
The cost of willow cultivation has been estimated for the three European agro-ecological zones in three different countries. Poland (Continental), France (Atlantic) and Spain (Mediterranean).

In Poland, the cost of growing, harvesting and transporting willow chips was found to be 81 €/t, which is much lower than the reference selling price (100 €/t).

This was mainly due to the higher productivity in the Continental zone and to a relatively low land rent (150 €/ha/yr) and lower labour costs.

Willow PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	22 yr
Product(s):	WillowPL,
Sales:	705.25 €/ha
Cost:	**605.81** €/ha
Subidies:	
Profit/Loss:	99.44 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			161.4					*161.40*
(Overheads)					100			*100.00*
Disk Harrowing	1.47	0.88		2.08				*4.43*
Fertilisation	2.26	2.43		5.44		35.36		*45.49*
Field Preparation	1.31	1.75		4.31				*7.37*
Harvesting/Chipping	18.99	13.6		82.7				*115.29*
Planting	1.63	2.37		4.6		113.96		*122.56*
Ploughing	1.31	1.75		4.03				*7.09*
Pressing/Rolling	0.65	0.58		1.34				*2.57*
Transport 37	10.55	9.06		15.28				*34.89*
Weed Control	0.48	0.51		0.42		3.31		*4.72*
TOTAL (€/ha)	38.65	32.93	161.40	120.20	100.00	152.63		***605.81***

Figure 5.4.2. Willow PL Economic Analysis

As may be seen in the economic analysis, Harvesting, Planting and Land rent are responsible for two thirds of total cost. Overheads, include all other costs and contingencies which are not explicitly in the cost list, such as administration overheads, stoppage times, accidents, bad weather, travel, communications, etc.

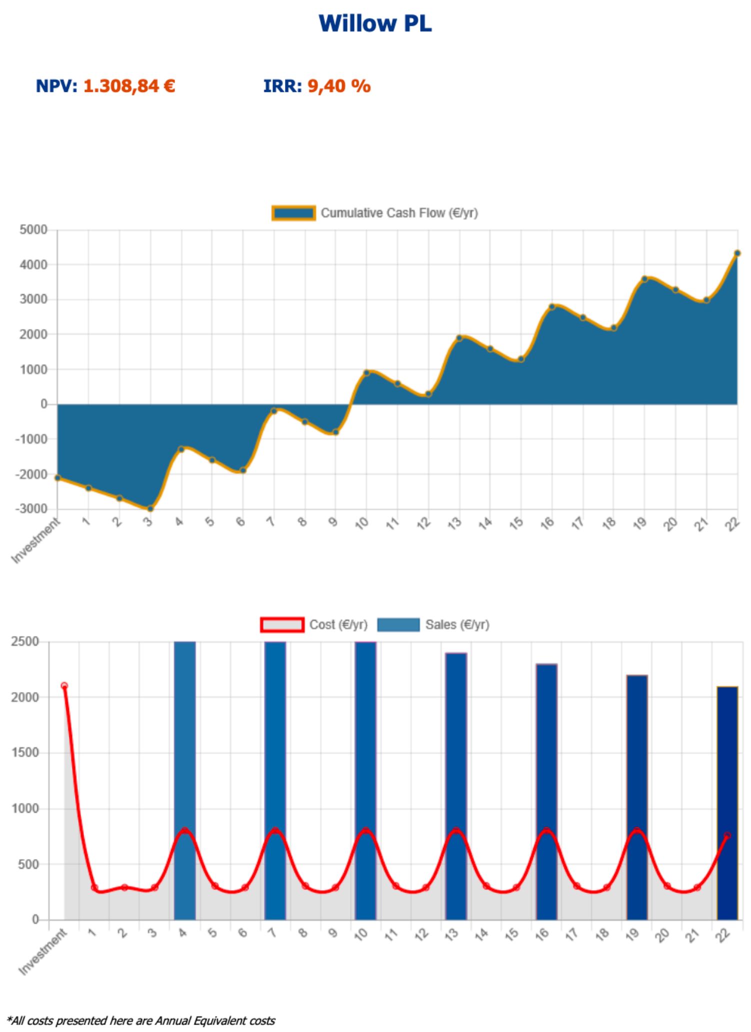


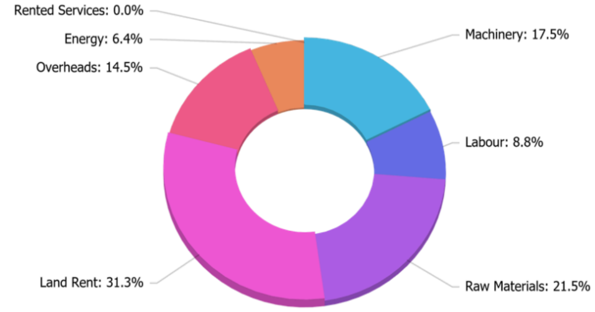
Figure 5.4.3. Willow PL Cash Flow Analysis

The Cash Flow diagram of Willow PL is reflecting this positive result with a positive Net Present Value per hectare and an Internal Rate of Return comfortably higher than the discount rate of 5%. Cumulative Cash flows turn positive after 9 years of the plantation (pay back period).

In Spain (Mediterranean zone) willow yields are low on marginal land, averaging 6 t/ha/yr and as a result, revenue is not sufficient to match costs. The delivered cost per tonne of willow chips, which is 118 €/t is higher than the reference selling price which is 100 €/t (Stolarski et al. 2015, Ericcson et al. 2005).

Willow Breakeven ES

Country/Region:	Spain
Total Area:	1 ha
Projet Life:	22 yr
Product(s):	WillowES,
Sales:	687.28 €/ha
Cost:	**687.45** €/ha
Subidies:	
Profit/Loss:	-0.17 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			215.19					*215.19*
(Overheads)					100			*100.00*
Disk Harrowing	1.66	1.6		2.08				*5.34*
Fertilisation	2.55	4.41		5.44		30.53		*42.93*
Field Preparation	1.48	3.19		4.31				*8.98*
Harvesting/Chipping	21.45	24.72		82.7				*128.87*
Planting	1.85	5.01		4.6		113.96		*125.42*
Ploughing	1.48	3.19		4.03				*8.70*
Pressing/Rolling	0.74	1.06		1.34				*3.14*
Transport 37	11.92	16.48		15.28				*43.68*
Weed Control	0.54	0.93		0.42		3.31		*5.20*
TOTAL (€/ha)	43.67	60.59	215.19	120.20	100.00	147.80		***687.45***

Figure 5.4.4. Willow ES Economic Analysis

In Spain, the NPV is negative and so is the IRR. For chips selling prices over 116 euros per dry tonne, the farmer can repay his investment before the end of the plantation’s economic life.

Willow cultivation in France (Atlantic zone) has more or less similar economic results as in Spain. In France, the delivered cost of willow is 793 €/ha/yr or 116 €/t

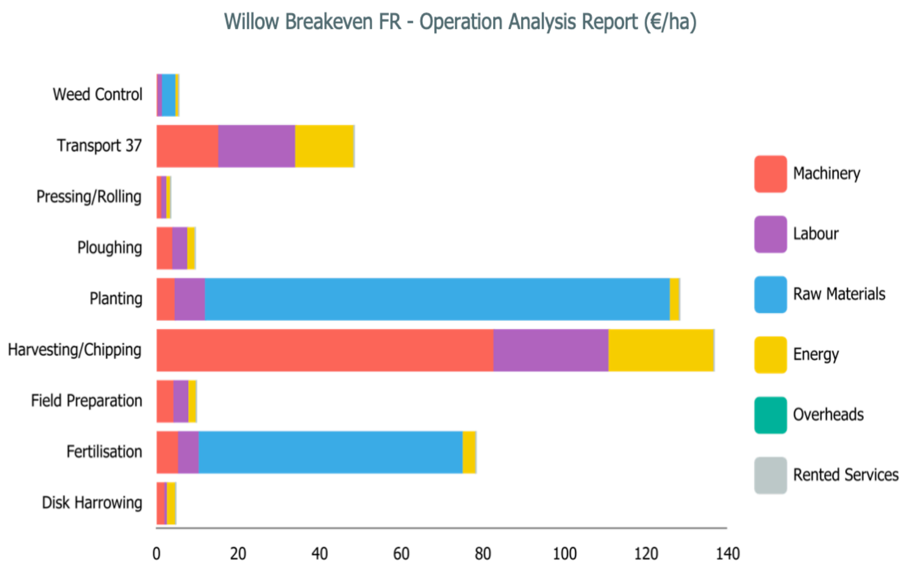


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
DISK HARROWING	2.08	0	0.62	1.99	0
FERTILISATION	5.44	64.69	5.04	3.06	0
FIELD PREPARATION	4.31	0	3.65	1.77	0
HARVESTING/CHIPPING	82.7	0	28.24	25.69	0
PLANTING	4.6	113.96	7.41	2.21	0
PLOUGHING	4.03	0	3.65	1.77	0
PRESSING/ROLLING	1.34	0	1.22	0.88	0
TRANSPORT 37	15.28	0	18.83	14.27	0
WEED CONTROL	0.42	3.31	1.06	0.64	0

**All costs presented here are Annual Equivalent costs*

Figure 5.4.5. Willow FR Operations Analysis

Harvesting and planting willow in France are the most expensive operations, exceeding 100 €/ha/yr. Fertilisation at almost 80 €/ha/yr is also an important cost item. Marginal land rent in France is high, 250 €/ha/yr and with yields of less than 7 t/ha/yr the result is loss.

5.4.2 Willow Summary

The following table summarises the most important findings of willow cultivation in Europe.

Table 5.5 Summary of Willow Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Spain)	6.09	609	688	113	-79	121	44
Continental Zone (Poland)	7.50	750	606	81	144	294	502
Atlantic Zone (France)	6,82	682	793	116	-111	139	392

** Panoutsou and Alexopoulou 2020*

It is clear from the values of the table that although cultivation in Poland, the only positive willow case, is profitable for the farmer, nevertheless, it is only in Spain that return to marginal land is higher than wheat cultivation. However, this is so only because of the very low wheat yields in Spanish marginal land (Panoutsou and Alexopoulou 2020).

Cost estimates in the literature vary widely, in some cases due to the underlying assumptions, (for a collection of cost estimates see for example Kasmioui and Ceulemans, 2012).

5.5 *Safflower (Carthamus tinctorius L.), for the production of various organic acids*

<u>Value chain 5</u>: Production of azelaic and pelargonic acid from high oleic safflower oil via oxidative cleavage

Safflower is an ornamental herbaceous plant originated from Asia or Eastern Europe, which is being cultivated today in Asia and America mainly for its oilseeds, which produce oil used for medical or energy purposes. Straw and foliage constitute up to 80% of total above ground biomass and may also be commercially exploited.

Figure 5.5.1. Safflower

The oil content in the seeds of safflower is about 40%. Half the oil production from safflower is directed to the energy market, although the quality of safflower oil is high in the food market, where it is used as cooking oil. Oleic and linoleic acids constitute 90% of total fatty acid content of safflower oil.

Safflower, belongs to the sunflower family and can be grown in many parts of Europe and can easily be adapted to grow on marginal arid land with small amount of inputs and no irrigation, due to its deep root, which can absorb soil moisture and nutrients.

Today, safflower seed oil is used for industrial purposes in combination with castor oil. High oleic safflower oil is produced for a range of industrial markets such as plastics, polymers, lubricants, resins, cosmetics and biofuels.

Safflower is sown in late winter or spring and is harvested a few months later with a combine and the seeds are transported to the conversion plant without storage in the farm. Seed yields in marginal lands vary according to land type and agro-ecological zone, ranging from 1 tonne or less per hectare in the Mediterranean zone to 1.25 in the Continental.

Table 5.6 Top 6 producers of Safflower Seed (Tridge 2021)

Rank	Country	%	Quantity (kt/yr)
1	Kazakhstan	33.81%	199.79
2	USA	14.92%	88.13
3	Russia	13.74%	81.19
4	Mexico	8.74%	51.66
5	China	5.61%	33.13
6	India	4.17%	24.64
SUM	TOP 6	81.09%	

5.5.1 Safflower Economic Analysis

The economics of Safflower depend very much on the yield that may be achieved in marginal land and the price that it may be sold. Yields vary substantially from region to region (Menegaes and Nunes, 2020), but for the purposes of marginal land plantations in Europe, seed yields are assumed to be between 1 and 1.25 t/ha/yr, with corresponding straw biomass between 4 and 5 t/ha/yr, (Khunania et al. 2019 and MAGIC partners interviews).

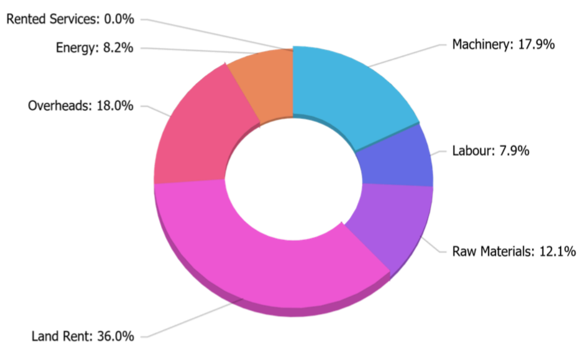
The reference selling price of safflower (400 €/t) is based on current information from the market and related literature (Pace et al. 2019, USDA AgMRC 2021), which however also vary from country to country. We have recorded market prices from 200 € to over 500 €/t.

We have also assigned a flat value of 20 €/t for the straw and foliage, which is regarded as by-product, without explicitly estimating the cost of collecting the stems and selling them in the energy market. All costs have been allocated to the seeds.

The economic results for the Mediterranean, low yield marginal land are not positive.

Safflower ES

Country/Region:	Spain
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Seeds, Straw,
Sales:	480.00 €/ha
Cost:	**556.27** €/ha
Subidies:	
Profit/Loss:	-76.27 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Fertilisation	2.43	4.2		5.18		34.48		*46.29*
Harrowing	4.86	4.2		8.33				*17.39*
Harvesting/Combine	12.15	9		53.06				*74.21*
Herbiciding	2.43	4.2		5.18		5		*16.81*
Ploughing	16.2	14		17.69				*47.89*
Sowing	6.48	5.6		7.99		28		*48.07*
Transport 37	0.95	2.52		2.14				*5.61*
TOTAL (€/ha)	45.50	43.72	200.00	99.57	100.00	67.48		***556.27***

Figure 5.5.2. Safflower ES Economic Analysis

Harvesting and crop installation are the major cost items in the cultivation of safflower.

Total (delivered) cost of growing, harvesting and transporting the seeds to the conversion plant is between 500 and 600 €/ha/yr, while the reference yield of 1 tonne of seeds per hectare can only pay for the costs at a price of 500 €/t

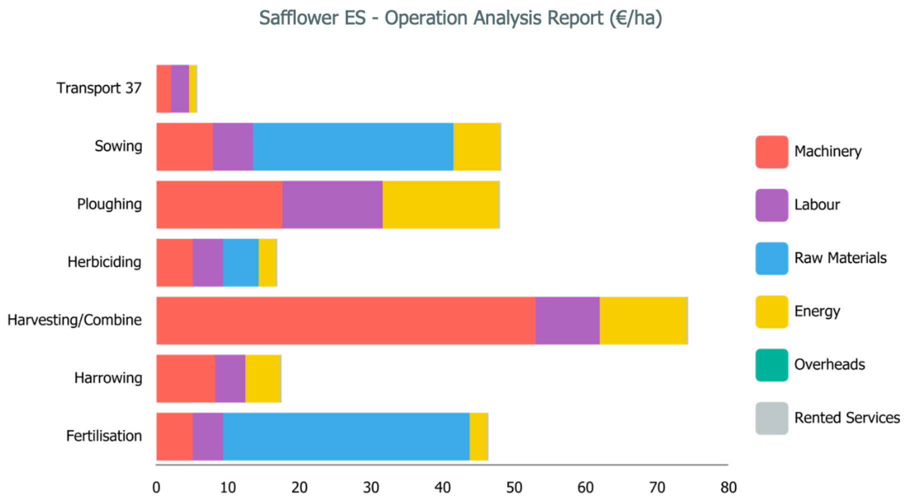


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
FERTILISATION	5.18	34.48	4.2	2.43	0
HARROWING	8.33	0	4.2	4.86	0
HARVESTING/COMBINE	53.06	0	9	12.15	0
HERBICIDING	5.18	5	4.2	2.43	0
PLOUGHING	17.69	0	14	16.2	0
SOWING	7.99	28	5.6	6.48	0
TRANSPORT 37	2.14	0	2.52	0.95	0

**All costs presented here are Annual Equivalent costs*

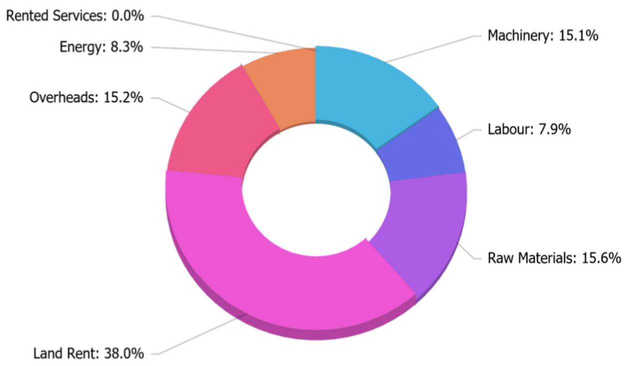
Figure 5.5.3. Safflower ES Operations Analysis

In the Atlantic zone, yield is expected to be slightly higher (1.1 t/ha/yr) but land rent in France is also higher as well as labour and materials, therefore the economic outcome for France is also negative.

Safflower FR

Country/Region: France
Total Area: 1 ha
Projet Life: 1 yr
Product(s): Seeds, Straw,

Sales: 528.00 €/ha
Cost: **658.58** €/ha
Subidies:
Profit/Loss: -130.58 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

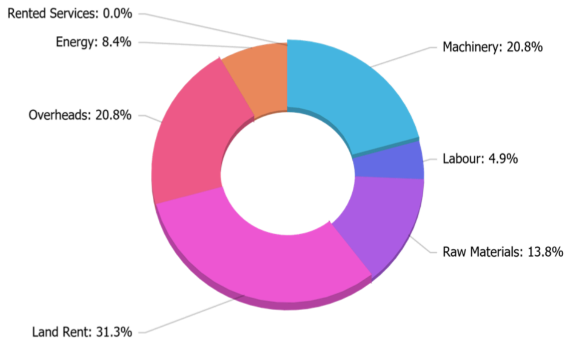
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					100			*100.00*
Fertilisation	2.91	4.8		5.18		68.71		*81.60*
Harrowing	5.82	4.8		8.33				*18.95*
Harvesting/Combine	14.55	12.14		53.06				*79.75*
Herbiciding	2.91	4.8		5.18		6		*18.89*
Ploughing	19.4	16		17.69				*53.09*
Sowing	7.76	6.4		7.99		28		*50.15*
Transport 37	1.13	2.88		2.14				*6.15*
TOTAL (€/ha)	54.48	51.82	250.00	99.57	100.00	102.71		***658.58***

Figure 5.5.4. Safflower FR Economic Analysis

In the continental agro-ecological zone (Poland) yields are higher than in any other zone, (at 1.25 t/ha/yr) and in Poland, with lower land rent (150 €/ha/yr) and other costs, the estimated total cost is lower than the expected revenue and safflower cultivation has a positive economic sign.

Safflower PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Seeds, Straw,
Sales:	600.00 €/ha
Cost:	**479.81** €/ha
Subidies:	
Profit/Loss:	120.19 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			150					*150.00*
(Overheads)					100			*100.00*
Fertilisation	2.15	2.31		5.18		33.34		*42.98*
Harrowing	4.3	2.31		8.33				*14.94*
Harvesting/Combine	10.76	4.52		53.06				*68.34*
Herbiciding	2.15	2.31		5.18		5		*14.64*
Ploughing	14.34	7.7		17.69				*39.73*
Sowing	5.74	3.08		7.99		28		*44.81*
Transport 37	0.84	1.39		2.14				*4.37*
TOTAL (€/ha)	40.28	23.62	150.00	99.57	100.00	66.34		***479.81***

Figure 5.5.5. Safflower PL Economic Analysis

5.5.2 Safflower Summary

The following table summarises the most important findings of safflower cultivation in the three agro-ecological zones of Europe.

We have allocated all costs to the main product (seeds) of the cultivation and we treat the extra income from the sale of straw as net “other income”.

It may be seen in the table that only in Poland cultivation of safflower seems profitable at a seeds’ selling price of 400 €/t. The comparison with wheat cultivation in the same marginal land in each of the climatic (or agro-ecological) zones shows that in Spain also the comparison is positive in favour of safflower, but as in all other cases this is mainly because of the low wheat yields in Spanish marginal land.

Table 5.7 Summary of Safflower Production, Harvesting and Transport Costs

	Yield** (t/ha/yr)	Sales** (€/ha/yr)	Total cost (€/ha/yr)	Total cost*** (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Spain)	1.00	480	556	556	-76	124	44
Continental Zone (Poland)	1.25	600	480	384	120	270	502
Atlantic Zone (France)	1.10	528	659	600	-131	119	392

** Panoutsou and Alexopoulou 2020   ** Seeds and Straw   *** Seed only*

5.6 Castor (Ricinus communis L.) for the production of undecanedioic acid

Value chain 6: *Fatty acids from castor oil*

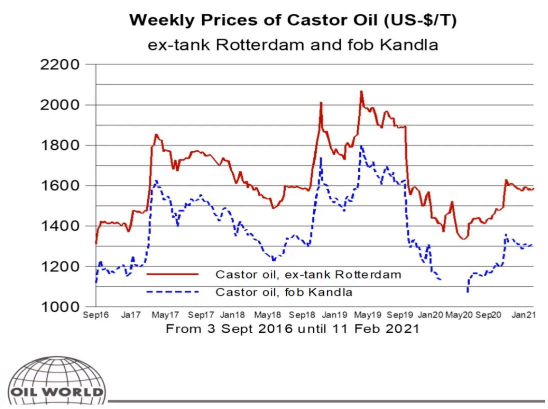
Castor is a multipurpose annual crop (or perennial in the tropics), which is grown in many parts of the world for thousands of years, mainly for its oil. Castor oil, from pressed castor seeds, contains almost 50% oil. Castor beans, leaves and stems are poisonous, but castor oil Is not.

Figure 5.6.1. Castor

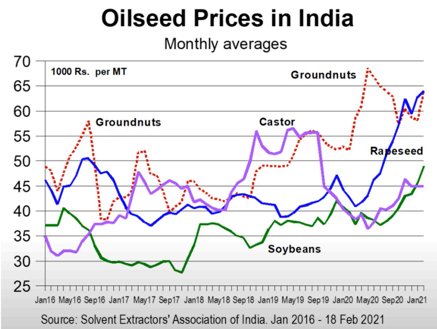
Castor oil has many applications, in the food, medical, pharmaceutical and industrial sectors and in some markets may be sold at high prices.

There is practically only one major producer and exporter of castor seeds and castor oil; India, exporting 95% of total world exports. China and Brazil, traditionally producing over 10% of the world's castor seed, are today down to 1-2% each, while India is today producing 90% (Commodities Control 2021).

Castor seeds are transformed into castor oil and then exported. The top five castor oil importing countries, absorbing 75% of total imports, are China (41%), France,



Germany, the US (with about 10% each) and Netherlands (5%). (Tridge 2021).



Castor seeds today are traded at prices above 500 euros (45,000 Rs) per tonne and Castor oil is sold at 1,580 $/tonne (Rotterdam) (ISTA, 2021) From other sources we also find the same order of magnitude for castor seeds selling prices. For example, castor beans are being sold at prices about 500 to 600 euros per tonne (Mint 2021, TRIDGE 2021, Pari 2020). With yields in European marginal land ranging from 1.25 to 1.5 t/ha/yr, revenues may approach 800-900 €/ha/yr.

5.6.1 Castor Economic Analysis

We have analysed the annual equivalent cost of castor production, harvesting and transport to the conversion factory for two European climatic zones: Mediterranean and Continental. Although castor husks, leaves and straws may be collected and sold separately, only castor seeds are considered in this report. The selected countries were Greece (GR), Italy (IT) and Poland (PL).

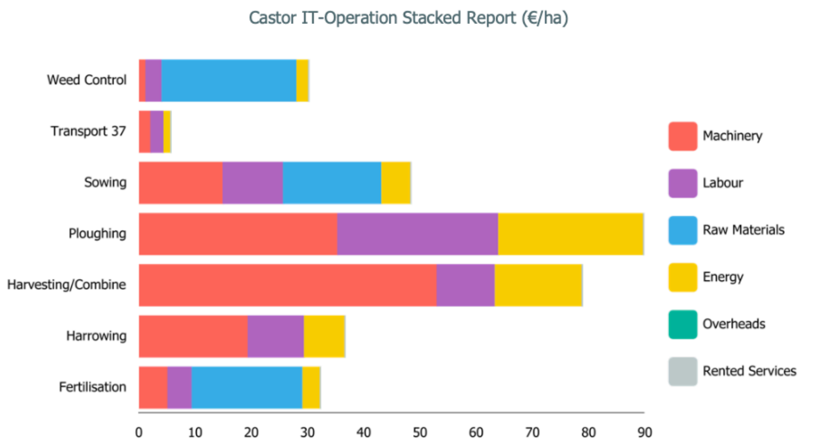


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
FERTILISATION	5.18	19.71	4.29	3.09	0
HARROWING	19.44	0	10.01	7.21	0
HARVESTING/COMBINE	53.06	0	10.33	15.45	0
PLOUGHING	35.39	0	28.6	25.75	0
SOWING	14.98	17.5	10.73	5.15	0
TRANSPORT 37	2.14	0	2.33	1.21	0
WEED CONTROL	1.27	24	2.86	2.06	0

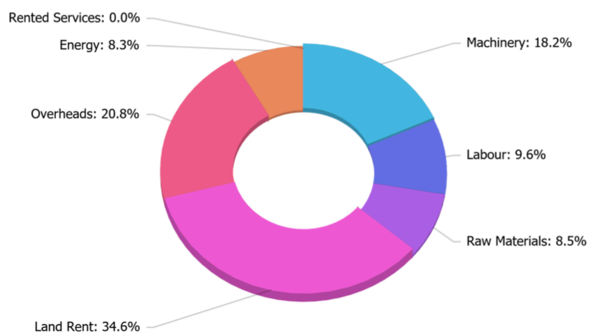
**All costs presented here are Annual Equivalent costs*

Figure 5.6.2. Castor IT Operations Analysis

Production of Castor beans in Italy and Greece is relatively expensive mainly due to higher land cost (in comparison to Poland) and yields about 15% lower than in the Continental Zone. The cost per tonne of seeds (delivered) was 586 €/t for Greece and 822 €/t for Italy.

Castor IT

Country/Region:	Italy
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Castor Seeds IT,
Sales:	625.00 €/ha
Cost:	**721.74** €/ha
Subidies:	
Profit/Loss:	-96.74 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					150			*150.00*
Fertilisation	3.09	4.29		5.18		19.71		*32.27*
Harrowing	7.21	10.01		19.44				*36.66*
Harvesting/Combine	15.45	10.33		53.06				*78.84*
Ploughing	25.75	28.6		35.39				*89.74*
Sowing	5.15	10.73		14.98		17.5		*48.36*
Transport 37	1.21	2.33		2.14				*5.68*
Weed Control	2.06	2.86		1.27		24		*30.19*
TOTAL (€/ha)	59.92	69.15	250.00	131.46	150.00	61.21		***721.74***

Figure 5.6.3. Castor IT Economic Analysis

The economic analysis in Italy shows that the revenue from selling castor beans at the price of 500 €/t is not sufficient to cover total costs of production, harvesting and transport to the conversion plant. Higher productivity or higher selling price would be needed to break even.

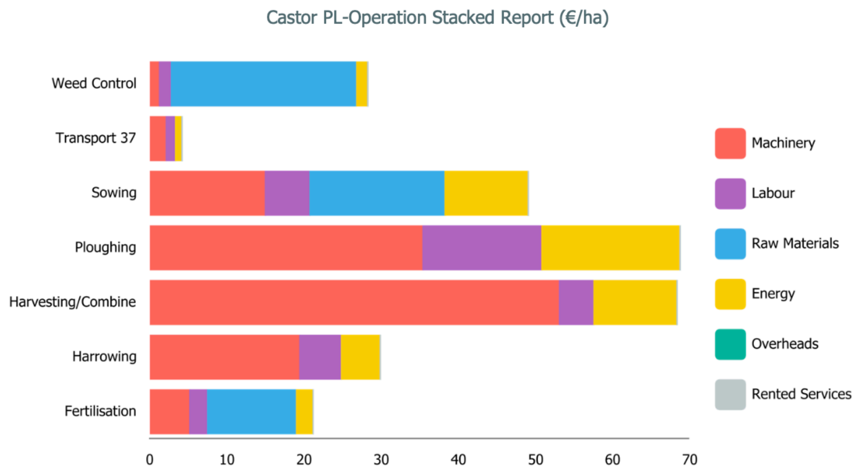


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
FERTILISATION	5.18	11.52	2.31	2.15	0
HARROWING	19.44	0	5.39	5.02	0
HARVESTING/COMBINE	53.06	0	4.52	10.76	0
PLOUGHING	35.39	0	15.4	17.93	0
SOWING	14.98	17.5	5.78	10.76	0
TRANSPORT 37	2.14	0	1.2	0.84	0
WEED CONTROL	1.27	24	1.54	1.43	0

**All costs presented here are Annual Equivalent costs*

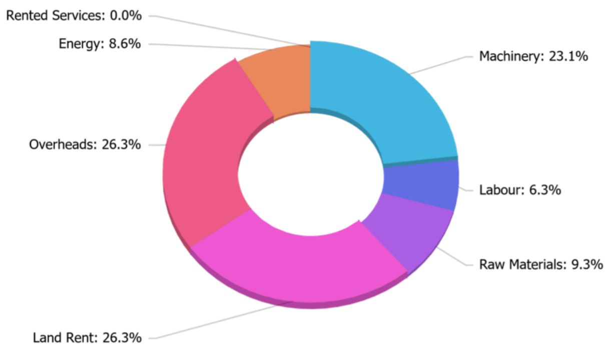
Figure 5.6.4. Castor PL Operations Analysis

In Poland with the cost of land at 150 €/ha/yr and 20% higher annual yield, the results show that castor seeds may be produced and delivered at a cost of 380 €/t, so it is possible for the grower to make a profit by selling Castor seeds to the market. This profit, estimated here at 181 €/ha/yr is indicative of the potential. It includes transport cost to a distance of 37 km (see transport above) but does not incorporate any other charges, packaging and fees, etc. that might be necessary for selling to the castor beans market.

As in all cases of this report, agricultural production is assumed to be part of the value chain under examination and therefore, the cost charged to the conversion plant is equal to the cost of producing, harvesting and transporting the seeds.

Castor PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Castor Seeds IT,
Sales:	750.00 €/ha
Cost:	**569.51** €/ha
Subidies:	
Profit/Loss:	180.49 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			150					*150.00*
(Overheads)					150			*150.00*
Fertilisation	2.15	2.31		5.18		11.52		*21.16*
Harrowing	5.02	5.39		19.44				*29.85*
Harvesting/Combine	10.76	4.52		53.06				*68.34*
Ploughing	17.93	15.4		35.39				*68.72*
Sowing	10.76	5.78		14.98		17.5		*49.02*
Transport 37	0.84	1.2		2.14				*4.18*
Weed Control	1.43	1.54		1.27		24		*28.24*
TOTAL (€/ha)	48.89	36.14	150.00	131.46	150.00	53.02		***569.51***

Figure 5.6.5. Castor PL Economic Analysis

5.6.2 Castor Summary

The following table summarises the results of economic analysis.

Table 5.8 Summary of Castor Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Italy)	1.25	625	722	578	-97	153	186
Continental Zone (Poland)	1.50	750	570	380	180	230	48

** Panoutsou and Alexopoulou 2020*

It is interesting to notice that on marginal land, castor is performing very well, at least in continental Europe. Under conditions of low cost of land, which is the case in Poland economic results are optimistic. In Southern Europe, with higher cost of land and lower productivity, results are less attractive, but not disappointing.

The selling price of castor seeds is high and this means that results are quite sensitive to yield changes. Today, the wholesale international price of castor beans seems to be steadily higher than 500 €/t, the figure that we have used in our analysis (Tridge 2021). The prospects for 2022 are that castor oil prices will further increase, due to increased demand from China.

5.7 *Lupin (*Lupinus mutabilis L.*), for the production of bio-adhesives*

<u>Value chain 7</u>: Lupin to protein

Lupin is a high protein grain legume, cultivated in Australia, Russia, Poland and Germany, and other minor producers. World production is 1 m tonnes of which almost half is grown in Australia.

Figure 5.7.1. Lupin

Three EU countries, Poland, Germany and Greece are in the top-10 list, contributing with 20% to world Lupin production (Poland 15%). However there is very little information on income and expenses of Lupin in Europe.

Lupin production figures globally are more or less remaining constant since 2000, with no significant trend being visible.

Lupin seeds are marketed mainly in the food market, as they have attractive characteristics, such as low fat and gluten index, high nutrition value, high fibre content and anti-cholesterol effects.

Therefore, their market value is basically determined by supply and demand in the food market.

"Cropping News", 2020: In Australia we are observing trading Lupin unusually high prices between 370 and 560 Australian dollars (278 and 420 USD) per tonne of lupins. In the Netherlands quoted prices are around 398 €/t (Berkum and Jassens 2019).

Table 5.9 Top-10 Lupin World producers

Position	Country	Country 2019	Production capacity 2019	Growth in quantity in one year 2018-2019	Growth in quantity in three years 2016-2019	Growth in quantity in five years 2014-2019
1	Australia	47.14%	474.63K	-40.57%	-53.98%	-24.13%
two	Russia	16.51%	166.27K	+ 21.94%	-9.97%	+ 119.67%
3	Poland	14.47%	145.69K	+ 19.42%	-29.36%	+ 4.21%
4	Morocco	6.75%	67.93K	+ 3.79%	+ 12.29%	+ 22.12%
5	chili	4.53%	45.61K	+ 0.34%	+ 65.8%	+ 171.77%
6	Germany	2.54%	25.60K	+ 14.8%	-48.8%	-37.25%
7	Greece	2.27%	22.90K	+ 22.79%	+ 300.7%	+ 1422.61%
8	Peru	1.63%	16.46K	-2.42%	+ 17.4%	+ 35.39%
9	Ukraine	1.07%	10.76K	-28.46%	-65.52%	-62.81%
10	South Africa	0.72%	7.22K	+ 0.4%	+ 1.2%	-35.14%

5.7.1 Lupin Economic Analysis

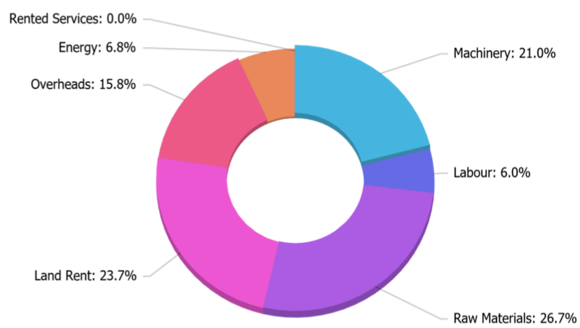
The cultivation of Lupin is limited in Europe and so is information regarding costs and revenues. The main market for Lupin is the food market where it is competing with soy and green peas.

Lupin's selling price in the industrial market for the production of bio-adhesives should be competitive with other raw materials used for the same purpose today, such as rubber, animal or cellulosic derived raw materials. In this report we have assumed a flat selling price of Lupin beans equal to 300 €/t, common in all countries examined (France, Italy, Greece, Poland).

In Poland the cost of growing, harvesting and transporting Lupins is 633 €/ha/yr or 211 €/t, while at a selling price of 300 €/t and yield of 3 t/ha/yr, revenues exceed profits by about 270 €/ha/yr

Lupin PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Lupin Seeds PL,
Sales:	900.00 €/ha
Cost:	**632.68** €/ha
Subidies:	
Profit/Loss:	267.32 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

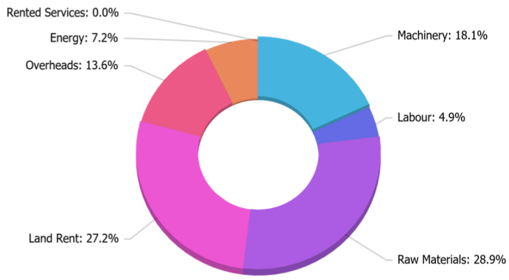
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			150					*150.00*
(Overheads)					100			*100.00*
Fertilisation	2.15	2.31		5.18		93.52		*103.16*
Harrowing	5.02	5.39		19.44				*29.85*
Harvesting/Combine	10.76	4.52		53.06				*68.34*
Pest Control	1.43	1.54		1.27		20		*24.24*
Ploughing	17.93	15.4		35.39				*68.72*
Sowing	3.59	5.78		14.98		35.6		*59.95*
Transport 37	0.84	1.2		2.14				*4.18*
Weed Control	1.43	1.54		1.27		20		*24.24*
TOTAL (€/ha)	43.15	37.68	150.00	132.73	100.00	169.12		***632.68***

Figure 5.7.2. Lupin PL Economic Analysis

In Greece, yields are low, 2 t/ha/yr in spite of generous fertilisation. Costs per hectare are higher, 734 €/ha/yr while revenues are only 600 €/ha/yr.

Lupin GR

Country/Region:	Greece
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Lupin Seeds GR,
Sales:	600.00 €/ha
Cost:	**734.35** €/ha
Subidies:	
Profit/Loss:	-134.35 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

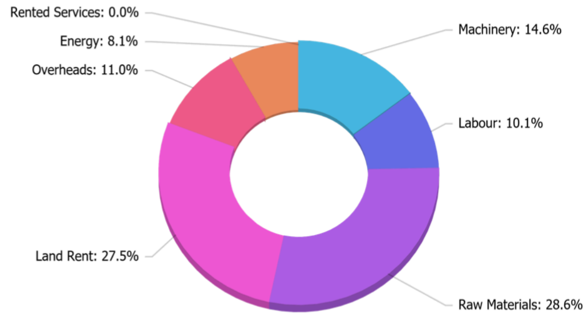
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Fertilisation	2.64	2.13		5.18		136.99		*146.94*
Harrowing	6.16	4.97		19.44				*30.57*
Harvesting/Combine	13.2	5.45		53.06				*71.71*
Pest Control	1.76	1.42		1.27		20		*24.45*
Ploughing	22	14.2		35.39				*71.59*
Sowing	4.4	5.32		14.98		35.6		*60.30*
Transport 37	1.03	1.17		2.14				*4.34*
Weed Control	1.76	1.42		1.27		20		*24.45*
TOTAL (€/ha)	52.95	36.08	200.00	132.73	100.00	212.59		***734.35***

Figure 5.7.3. Lupin GR Economic Analysis

A yield as high as in continental Europe (3 t/ha/yr) in the Atlantic climatic zone rises French revenue to 900 €/ha/yr. Annual costs in France are about the same and therefore the farmer is breaking even.

Lupin FR

Country/Region:	France
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Lupin Seeds FR,
Sales:	900.00 €/ha
Cost:	**908.14** €/ha
Subidies:	
Profit/Loss:	-8.14 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					100			*100.00*
Fertilisation	2.91	4.8		5.18		180.48		*193.37*
Harrowing	6.79	11.2		19.44				*37.43*
Harvesting/Combine	30	22.47		53.06				*105.53*
Pest Control	1.94	3.2		1.27		20		*26.41*
Ploughing	24.25	32		35.39				*91.64*
Sowing	4.85	12		14.98		35.6		*67.43*
Transport 37	1.13	2.65		2.14				*5.92*
Weed Control	1.94	3.2		1.27		24		*30.41*
TOTAL (€/ha)	73.81	91.52	250.00	132.73	100.00	260.08		***908.14***

Figure 5.7.4. Lupin FR Economic Analysis

5.7.2 Lupin Summary

The summary table for Lupin shows that Poland is by far more attractive place for the cultivation of Lupin with a very satisfactory return to land when compared with wheat cultivation in the same piece of land.

In South Europe with yields much lower than in the Continental and Atlantic zones, returns are lower than costs and therefore either increase in returns or cost reductions are necessary in the absence of subsidisation.

Table 5.10 Summary of Lupin Production, Harvesting and Transport Costs

	Seeds Yield (t/ha/yr)	Total Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land* (€/ha/yr)
Mediterranean Zone (Greece)	2	600	734	367	-134	66	186
Continental Zone (Poland)	3	900	633	211	267	417	48
Atlantic Zone (France)	3	900	908	303	-8	242	392
Mediterranean Zone (Italy)	2	600	836	418	-236	14	186

** Panoutsou and Alexopoulou 2020*

5.8 *Industrial Hemp (Cannabis sativa L.), for the production of insulation materials*

<u>Value chain 8</u>: Hemp as raw material for insulation material

Industrial Hemp is a fast-growing annual crop being cultivated for many industrial uses (food, body care, textile, paper, automobile parts, construction and insulation materials). Hemp was freely cultivated and used worldwide until the 1930:s when its use was forbidden in the USA, followed by many other countries including Europe. Today, since the beginning of the century many countries have legalised the industrial and pharmaceutical use of cannabis under certain conditions. This has generated large investment opportunities in many industrial fields, where cannabis-based products and materials are gaining market shares at the expense of less environmentally friendly competitors.

Figure 5.8.1. Cannabis Sativa

Hemp is a fibrous plant with great potential because it may be used for the production of so many cannabis products. Cannabis cultivated for seeds may be more *attractive from an economic point of view, because of the rapid growth of a market for CBD products in the cosmetics, medical and food sectors. The cultivation of fibrous hemp has also many possible applications in paper, clothing and construction. Insulation materials from hemp fibres has excellent characteristics, superior to other synthetic alternatives. Hemp may be cultivated for both straw and seeds, with the fibrous straws being its primary product, suitable for the production of insulation materials.*

Hemp yields in EU marginal lands vary among climatic zones. In the South productivity is higher, while in the North, it does not exceed 6 t/ha/yr with no irrigation. We have estimated hemp annual equivalent costs in three countries, namely Poland, France and Greece. (France is the largest producer of hemp in Europe).

5.8.1 Hemp Economic Analysis

The cost estimates of the production, storage and transportation of Industrial Hemp feedstock for the manufacturing or insulation materials, ranges between 136 (Greece) and 190 €/t (Poland), mainly due to yield differences. The cost is relatively high and at best leaves slim margin, estimated at current selling prices of hemp straw, reported around 120 to 150 €/t (Pecenka et al, 2012, Mark and Shepherd, 2019, Massey 2020). We have used 120 €/t.

In addition, a small quantity (around 10%) of grain which is produced as by-product may also be sold at much higher prices and increase total revenue of the crop. This necessitates the use of combine harvester for the separation of seed and straw.

Cost analysis of cannabis shows that the two main cost drivers are the capital cost of machinery and raw materials (seeds and fertilisers), accounting for more than 50%.

The crop is established at a seed rate of 40 kg/ha of hemp certified seeds, costing 5 €/kg (Piotrowski Stephan and Niels de Beus, 2017, Blue Forest Farms, 2021). Sowing is carried out by tractor equipped with sowing machine for hemp seeds. Fertilisation is very moderate contributing less than 5% of total cost.

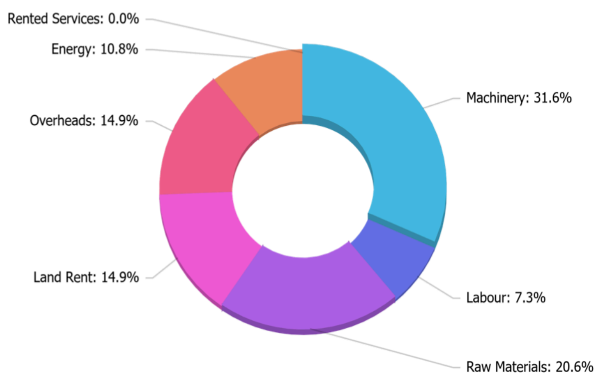
Harvesting is the most expensive operation. It consists of cutting with the use of combine harvester, baling the straw and storing the products by stacking the bales in appropriate space within the farm. The cost of harvesting comprises 1/3 of total production and transport cost.

Road transportation of the biomass from the farm to the conversion plant, including loading and unloading, has a cost of about 10 €/t under the assumptions made, which is rather on the low side of published data. Naturally, contractor’s cost is much higher.

Total energy required for the production and transport is 138 L of diesel, of which 67 L for harvesting and 31 for transporting the biomass

Hemp PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Hemp Fibres PL, Hemp Seeds PL,
Sales:	986.00 €/ha
Cost:	**1008.95** €/ha
Subidies:	
Profit/Loss:	-22.95 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			150					*150.00*
(Overheads)					150			*150.00*
Fertilisation	2.15	2.31		5.18		7.64		*17.28*
Harrowing	5.02	5.39		19.44				*29.85*
Harvesting/Bale Management	11.04	3.85		40.29				*55.18*
Harvesting/Baling	32.2	15.4		47				*94.60*
Harvesting/Combine	14.34	9.04		126.97				*150.35*
Ploughing	17.93	15.4		35.39				*68.72*
Sowing	3.59	5.78		14.98		200		*224.35*
Transport 37	22.23	16.71		29.68				*68.62*
TOTAL (€/ha)	108.50	73.88	150.00	318.93	150.00	207.64		***1008.95***

Figure 5.8.2. Hemp PL - Economic Analysis

The relative significance of the operations and the associated input needs can be seen in the bar diagram which summarises the most important cost elements by operation and by production input.

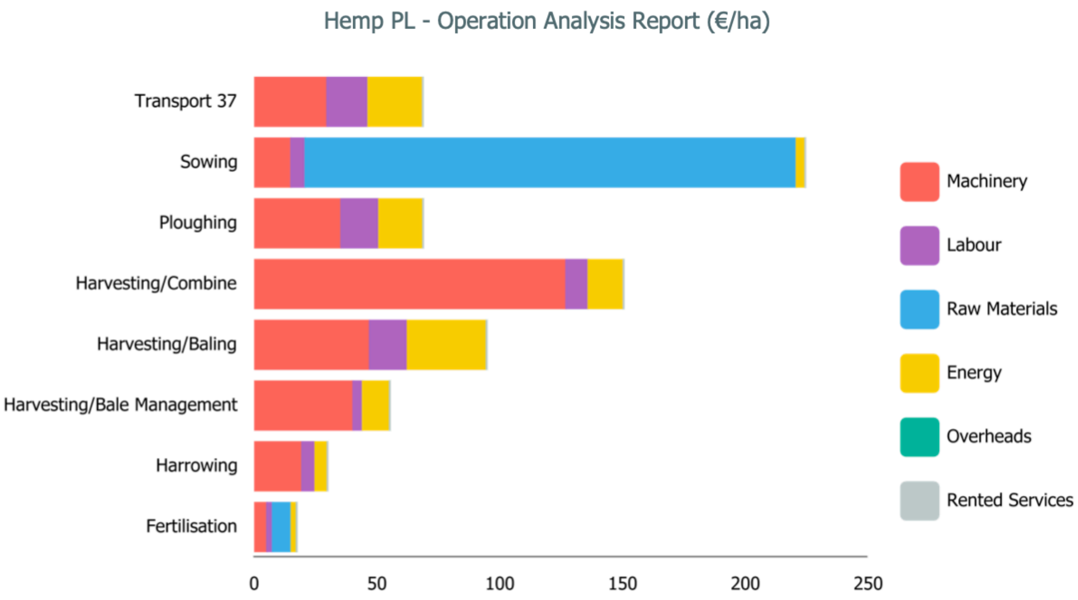


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
FERTILISATION	5.18	7.64	2.31	2.15	0
HARROWING	19.44	0	5.39	5.02	0
HARVESTING/BALE MANAGEMENT	40.29	0	3.85	11.04	0
HARVESTING/BALING	47	0	15.4	32.2	0
HARVESTING/COMBINE	126.97	0	9.04	14.34	0
PLOUGHING	35.39	0	15.4	17.93	0
SOWING	14.98	200	5.78	3.59	0
TRANSPORT 37	29.68	0	16.71	22.23	0

**All costs presented here are Annual Equivalent costs*

Figure 5.8.3: Hemp PL - Operations Analysis

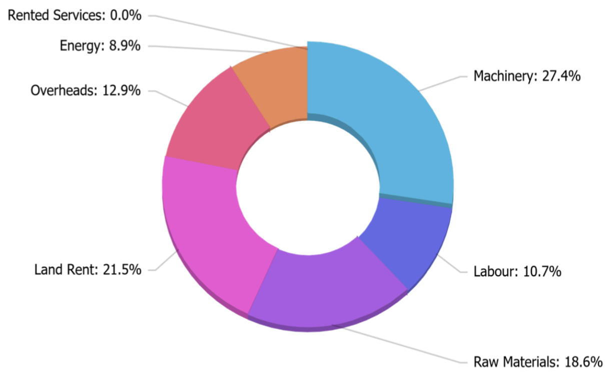
The cost of marginal land has been found in Panoutsou and Alexopoulou, 2020, where rental values are quoted for all EU countries. This cost represents actual (market) figures for low productivity land. Otherwise, one may estimate land rent based on opportunity cost i.e. expected gain from any other use of the marginal land in the region. In several cases this amount may even be too high, since marginal land in general, being land not used, has from an economic point of view a very low opportunity cost.

We have also calculated costs of production and transport of hemp in several countries, in different climatic zones of the EU.

In France (Atlantic zone), where straw yield is 6.6 t/ha/yr and seeds 0.9 t.ha/yr (IFEU and project partners estimates), total sales value is estimated at 1242 €/ha/yr which is higher than total cost of growing, harvesting and transporting fibre and seeds to the conversion plant by almost 80 €/ha/yr. By allocating all total cost to the straw output only, the cost per tonne of hemp is around 170 euros

Hemp FR

Country/Region:	France
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Hemp Fibres PL, Hemp Seeds PL,
Sales:	1242.00 €/ha
Cost:	**1163.32** €/ha
Subidies:	
Profit/Loss:	78.68 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					150			*150.00*
Fertilisation	2.91	4.8		5.18		16.33		*29.22*
Harrowing	6.79	11.2		19.44				*37.43*
Harvesting/Bale Management	11.64	8		40.29				*59.93*
Harvesting/Baling	33.95	32		47				*112.95*
Harvesting/Combine	19.4	24.27		126.97				*170.64*
Ploughing	24.25	32		35.39				*91.64*
Sowing	4.85	12		14.98		200		*231.83*
Transport 37	0	0		29.68				*29.68*
TOTAL (€/ha)	103.79	124.27	250.00	318.93	150.00	216.33		***1163.32***

Figure 5.8.4: Hemp FR – Economic Analysis

5.8.2 Hemp Summary

The following table summarises the most interesting values for the Continental, Atlantic and Mediterranean zones.

Table 5.11 Summary of Hemp Production, Harvesting and Transport Costs

	Straw Yield (t/ha/yr)	Total Sales*** (€/ha/yr)	Total cost (€/ha/yr)	Total cost* (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land** (€/ha/yr)
Mediterranean Zone (Greece)	7.9	1,498	1,077	136	421	621	186
Continental Zone (Poland)	5.3	986	1,009	190	-23	127	48
Atlantic Zone (France)	6.6	1,242	1,163	170	79	329	392

Straw only ** Panoutsou and Alexopoulou 2020 * Straw and seeds*

It is obvious that yield differences among climatic EU zones are the most important reason for differentiation of cost per tonne of output. Total cost per hectare has small differences among zones with the lowest cost in Poland, where nevertheless cost per tonne is higher. Yield sensitivity verifies the conclusions.

5.8.3 Hemp Literature

Literature on the economics of growing hemp is somewhat limited, because interest on the crop was stimulated after its legalisation in various EU countries. The extension Departments of several American Universities have published agricultural hemp production budgets with substantial spread of costs.

The following table summarises their estimates.

Table 5.12 Hemp Economic Estimates in the Literature

HEMP	YIELD t/ha/yr	Sales €/ha/yr	Cost €/ha/yr	straw price €/t	NOTES
MAGIC (EU average)	**6.6 t straw 0.9 t seeds**	**1242**	**1083**	**straw 120 seeds 500**	**Marginal land,**
Rice Bernard 2008	13 t straw				
Robbins et al. 2013	5 t straw 0.6 t seeds	1410		straw 75 seeds 1725	straw and seeds
Cole C. and B. Zurbo 2008	10 t straw	2450	800-1200	245	
Pecenka et al. 2012				140-160	
Hanchar John 2020	10 t straw	1588	1348	220	
Massey and Horner 2020	12 t straw	1650	1593.55	140	
USDA 2000	7-15 t straw	425-1898	715	60-120	No land charge
Blue Forest Farms 2020	7 t straw separate 1.2 t seeds	1750-2100	812	straw 250-300 seeds 130 - 1430	$ before land, machinery and process after harvest
Närep Merili 2018	11.4 t straw	1250	1062	110	$ includes land
Piotrowski S. and de Beus 2017	7 t straw 1 t seeds				

The table and previous analysis show that there is substantial variation in the economic indices calculated from the literature and internal project information, most of which show that the cultivation of industrial hemp is profitable for the farmer. However, hemp straw selling prices are rather unsettled because the market is not yet mature and therefore, estimates for future development of prices are still uncertain.

5.9 *Fibre Sorghum (*Sorghum bicolor L.*), for the production of biomethane*

Value chain 9: Sorghum as substrate for biomethane via anaerobic digestion

Figure 5.9.1. Fibre Sorghum

Sorghum is an annual herbaceous crop capable to offer satisfactory biomass yields under water stress conditions. It is native in Africa, but it can also be cultivated in Europe. In marginal land, European yields are not high, ranging between 5 and 13 t/ha/yr depending upon marginality conditions and climatic zone.

The moisture content of the freshly harvested crop is about 60%, but under normal late Spring conditions in the Mediterranean climatic zone it drops to 25% after a month drying in the open.(Belocchi et al., 2003)

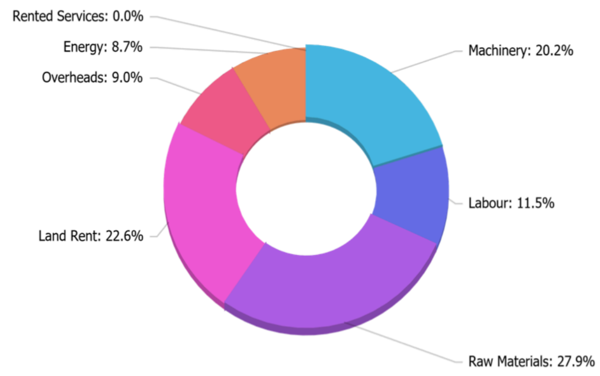
5.9.1 Fibre Sorghum Economic Analysis

As with several MAGIC crops, Sorghum cultivated in marginal land gives relatively low yields and as a result, revenues are not sufficient to match production costs.

In continental Europe, where marginal land yields are highest under good fertilisation, (13 t/ha/yr) sorghum is not profitable for the farmer in the absence of any financial support. The details of cost and revenues of the production, harvesting and transporting sorghum chips to the conversion plant are shown in the following figure

Sorghum DE

Country/Region:	Germany
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Sorghum DE,
Sales:	1040.00 €/ha
Cost:	**1105.80** €/ha
Subidies:	
Profit/Loss:	-65.80 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					100			*100.00*
Cultivation	7.04	7.75		9.86				*24.65*
Fertilisation	4.4	7.75		8.63		211.55		*232.33*
Harrowing	7.04	4.65		8.33				*20.02*
Harvesting/Chipping	22	46.5		140.51				*209.01*
Herbiciding	4.4	3.1		3.46		25		*35.96*
Ploughing	17.6	15.5		17.69				*50.79*
Sowing	7.04	6.2		7.99		72		*93.23*
Transport 37	26.4	36.15		27.26				*89.81*
TOTAL (€/ha)	95.92	127.60	250.00	223.73	100.00	308.55		***1105.8***

Figure 5.9.2. Fibre Sorghum DE Economic Analysis

High fertilisation and harvesting costs together with a marginal land rent of 250 €/ha/yr in Germany account for three quarters of total cost.

In the Operations Analysis diagram the dominance of harvesting and fertilising costs is obvious

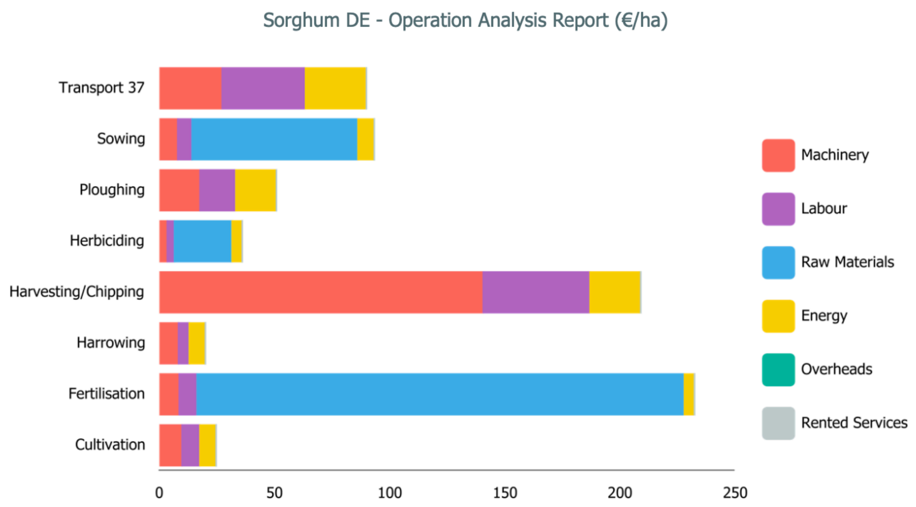


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
CULTIVATION	9.86	0	7.75	7.04	0
FERTILISATION	8.63	211.55	7.75	4.4	0
HARROWING	8.33	0	4.65	7.04	0
HARVESTING/CHIPPING	140.51	0	46.5	22	0
HERBICIDING	3.46	25	3.1	4.4	0
PLOUGHING	17.69	0	15.5	17.6	0
SOWING	7.99	72	6.2	7.04	0
TRANSPORT 37	27.26	0	36.15	26.4	0

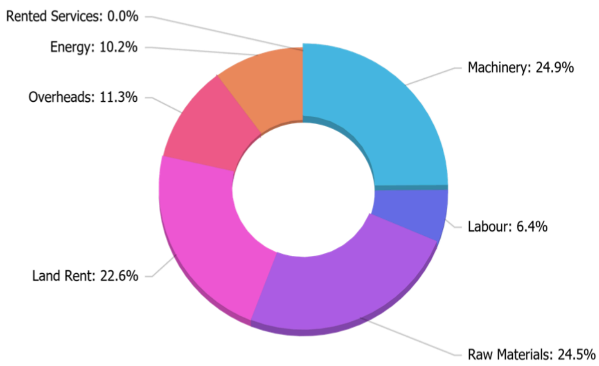
**All costs presented here are Annual Equivalent costs*

Figure 5.9.3. Fibre Sorghum DE Operations Analysis

In Greece and France cost per tonne of sorghum is much higher, 111 and 105 respectively.

Sorghum GR

Country/Region:	Greece
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Sorghum GR,
Sales:	640.00 €/ha
Cost:	**884.80** €/ha
Subidies:	
Profit/Loss:	-244.80 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Cultivation	7.04	3.55		9.86				*20.45*
Fertilisation	2.64	2.13		5.18		119.98		*129.93*
Harrowing	5.28	2.13		8.33				*15.74*
Harvesting/Chipping	22	21.3		140.51				*183.81*
Herbiciding	2.64	1.42		3.46		25		*32.52*
Ploughing	17.6	7.1		17.69				*42.39*
Sowing	7.04	2.84		7.99		72		*89.87*
Transport 37	26.4	16.43		27.26				*70.09*
TOTAL (€/ha)	90.64	56.90	200.00	220.28	100.00	216.98		***884.8***

Figure 5.9.4. Fibre Sorghum GR Economic Analysis

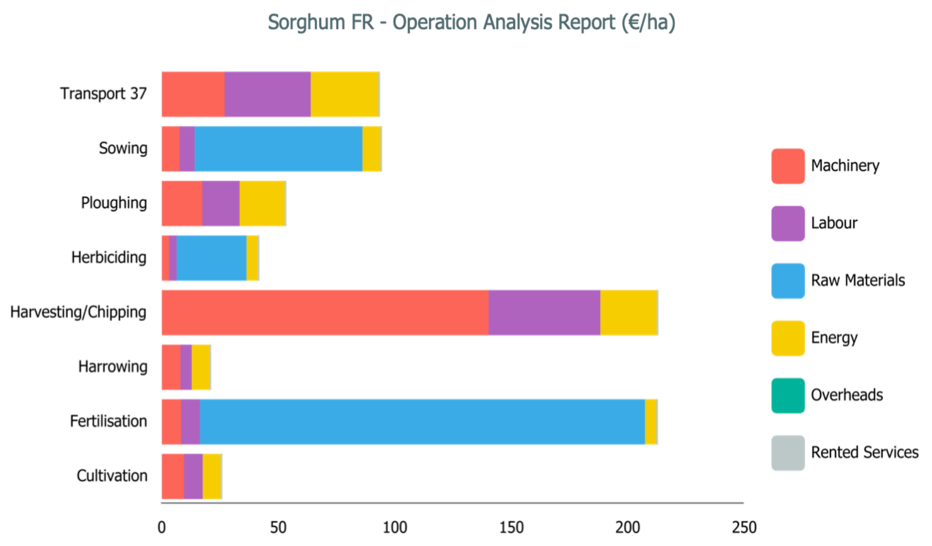


Table 1: Operation Annual Equivalent Costs

OPERATIONS	MACHINERY	RAW MAT	LABOUR	ENERGY	SERVICES
CULTIVATION	9.86	0	8	7.76	0
FERTILISATION	8.63	191.05	8	4.85	0
HARROWING	8.33	0	4.8	7.76	0
HARVESTING/CHIPPING	140.51	0	48	24.25	0
HERBICIDING	3.46	30	3.2	4.85	0
PLOUGHING	17.69	0	16	19.4	0
SOWING	7.99	72	6.4	7.76	0
TRANSPORT 37	27.26	0	36.91	29.1	0

**All costs presented here are Annual Equivalent costs*

Figure 5.9.5. Fibre Sorghum FR Operations Analysis

5.9.2 Sorghum Summary

As may be seen in the summary table, the cost per tonne of sorghum produced is in all cases higher than the reference selling price of 80€/t. Cultivation in Germany is the closest to break even du to the fact that yields are significantly higher in continental Europe

Return to marginal land is in all cases less than expected return for wheat in the same lands.

Table 5.13 Summary of Sorghum Production, Harvesting and Transport Costs

	Yield (t/ha/yr)	Total Sales (€/ha/yr)	Total cost (€/ha/yr)	Total cost* (€/t)	Profit (€/ha/yr)	Return to Land (€/ha/yr)	Wheat return to Land** (€/ha/yr)
Mediterranean Zone (Greece)	8	640	885	111	-245	-45	186
Continental Zone (Germany)	13	1040	1106	85	-66	184	502
Atlantic Zone (France)	10.5	840	1104	105	-264	-14	392

**Straw only   ** Panoutsou and Alexopoulou 2020*

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7 Appendices

7.1 Conventions, Parameters & Data

Unless otherwise specified, in this report, all tonnes of biomass are “dry”,
i.e. Dry tonnes = Mg = t = DT = odt = tonne in formulas and units

Basic Interest / discount rate is 5% in all cases examined and annuities used.

Marginal Land rent and wheat production volumes are based on Panoutsou and Alexopolpou 2020

Selling prices of agricultural products were found in EU and FAO official databases, but also in the literature, country statistics, websites of large private consulting and marketing companies.

Reference selling prices per dry tonne of output are as follows:

-

Table 7.1 Reference selling prices (delivered) for the nine Magic crops

CROP	Price	Units
Miscanthus, Switchgrass, Sorghum	80	€/t
Poplar, Willow	100	€/t
Safflower Seeds	400	€/t
Safflower Straw	20	€/t
Lupin Seeds	300	€/t
Hemp Seeds	500	€/t
Hemp Straw	120	€/t

Table 7.2 Reference yields (supplied by IFEU after consultation with MAGIC partners)

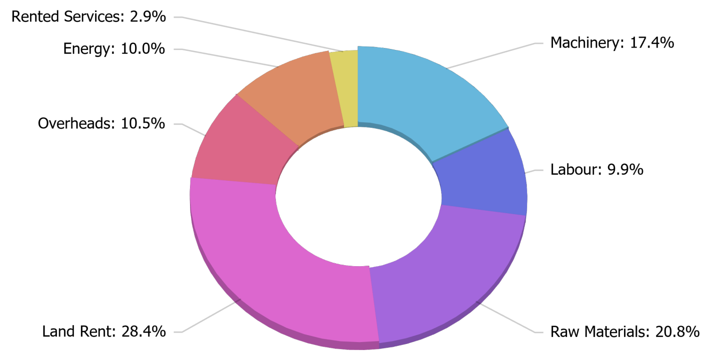
Crop	Zone	Constraint 1	Constraint 2	Standard land ("Medium")	Constraint 1	Constraint 2
Miscanthus	**MED**	7.5	9	12.5	Climate	Rooting
	ATL	7.75	9.5	13.75		
	CON	8	10	15	Climate	Wetness
Switchgrass	**MED**	5	7.5	10	Rooting	
	ATL	5.5	8.25	11		
	CON	6	9	12	Climate	
Poplar	**MED**	3	6	9		
	ATL	2.5	5	7.5		
	CON	2.75	5.5	8.25		Climate
Willow	**MED**	3	6	9		
	ATL	4	6.75	9.5		
	CON	5	7.5	10		Climate
Castor	**MED**	0.5	1.25	2		Climate
	ATL	impossible	impossible	impossible		
	CON	0.75	1.5	2.5		Climate
Safflower	**MED**	0,5 (0,2 oil | 0,3 cake)	1 (0,4 oil | 0,6 cake)	1,5 (0,6 oil | 0,9 cake)		Climate
	ATL	0,625 (0,25 oil | 0,375 cake)	1,125 (0,45 oil | 0,675 cake)	1,75 (0,7 oil | 1,05 cake)		
	CON	0,75 (0,3 oil | 0,45 cake)	1,25 (0,5 oil | 0,75 cake)	2 (0,8 oil | 1,2 cake)		
Hemp	**MED**	6 (0,7 seeds | 5,3 straw)	9 (1,1 seeds | 7,9 straw)	12 (1,4 seeds | 10,6 straw)	Rooting	
	ATL	5 (0,6 seeds | 4,4 straw)	7,5 (0,9 seeds | 6,6 straw)	10 (1,2 seeds | 8,8 straw)		Rooting
	CON	4 (0,5 seeds | 3,5 straw)	6 (0,7 seeds | 5,3 straw)	8 (1 seeds | 7 straw)	Climate	
Sorghum	**MED**	5	7.5	15	Rooting	Climate
	ATL	5	10	17.5		
	CON	5	12.5	20		
Lupin *	**MED**	1 (0,2 oil | 0,8 meal)	2 (0,4 oil | 1,6 meal)	3 (0,6 oil | 2,4 meal)		
	ATL	1,5 (0,3 oil | 1,2 meal)	2,5 (0,5 oil | 2 meal)	3,5 (0,7 oil | 2,8 meal)		
	CON	2 (0,4 oil | 1,6 meal)	3 (0,6 oil | 2,4 meal)	4 (0,8 oil | 3,2 meal)		

7.2 Selection of Detailed Results tables

Cost Analysis (€/ha)

Miscanthus FR

Country/Region:	France
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Miscanthus FR,
Sales:	787.36 €/ha
Cost:	**949.93** €/ha
Subidies:	
Profit/Loss:	-162.57 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

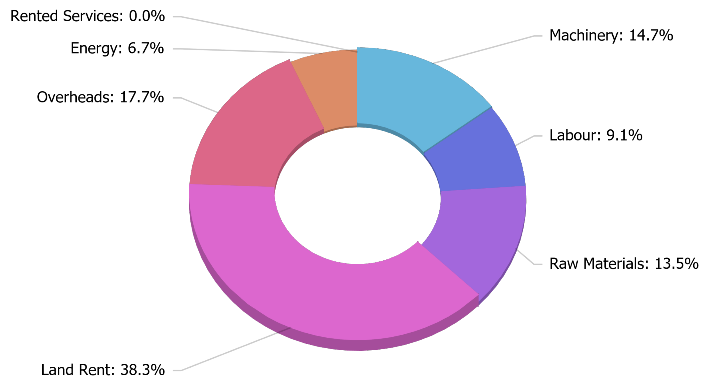
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.96	1.24		1.41				*3.61*
Farm Storage							27.71	*27.71*
Fertilisation	3.88	8		8.63		35.68		*56.19*
Harvesting/Bale Management	10.75	7.39		37.21				*55.35*
Harvesting/Baling	31.36	29.55		43.41				*104.32*
Harvesting/Mowing	13.44	14.78		23.82				*52.04*
Planting	1.75	5.23		17.41		160.49		*184.88*
Ploughing	2.68	3.54		3.91				*10.13*
Transport 37	30.07	23.77		29.68				*83.52*
Weed Control	0.16	0.26		0.1		1.6		*2.12*
TOTAL (€/ha)	95.05	93.76	270.06	165.58	100.00	197.77	27.71	***949.93***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Poplar ES

Country/Region:	Spain
Total Area:	1 ha
Projet Life:	19 yr
Product(s):	Poplar ES,
Sales:	571.78 €/ha
Cost:	**565.30** €/ha
Subidies:	
Profit/Loss:	6.48 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

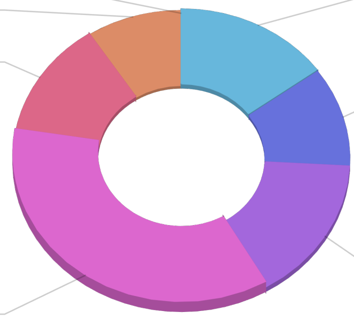
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			216.55					*216.55*
(Overheads)					100			*100.00*
Cultivation	0.8	1.16		1.84				*3.80*
Disk Harrowing	0.6	0.81		1.06				*2.47*
Fertilisation	0.66	1.72		2.11		7.62		*12.11*
Field Preparation	1.68	2.32		0.97				*4.97*
Harvesting/Chipping	18.46	16.36		54.75				*89.57*
Planting	1.51	3.64		3.34		66.2		*74.69*
Ploughing	1.68	2.32		2.93				*6.93*
Pressing/Rolling	0.27	0.41		0.51				*1.19*
Transport 37	11.83	16.36		15.17				*43.36*
Weed Control	0.38	6.62		0.3		2.36		*9.66*
TOTAL (€/ha)	37.87	51.72	216.55	82.98	100.00	76.18		***565.3***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Switchgrass DE

Country/Region:	Germany
Total Area:	1 ha
Projet Life:	20 yr
Product(s):	Switchgrass IT,
Sales:	732.73 €/ha
Cost:	**753.37** €/ha
Subidies:	
Profit/Loss:	-20.64 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

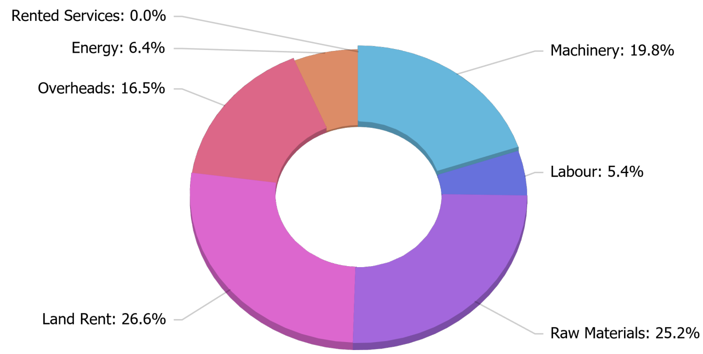
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			270.06					*270.06*
(Overheads)					100			*100.00*
Disk Harrowing	0.64	0.87		1.03				*2.54*
Fertilisation	2.64	4.65		5.18		107.44		*119.91*
Field Preparation	1.2	2.18		2.66				*6.04*
Harvesting/Bale Management	5.28	4.65		20.27				*30.20*
Harvesting/Baling	17.6	15.5		23.49				*56.59*
Harvesting/Mowing	12.19	14.32		23.81				*50.32*
Ploughing	1.77	2.49		2.84				*7.10*
Pressing/Rolling	0.28	0.44		0.49				*1.21*
Sowing	0.35	0.5		3.48		10.67		*15.00*
Transport 37	27.28	36.15		29.68				*93.11*
Weed Control	0.14	0.25		0.1		0.8		*1.29*
TOTAL (€/ha)	69.37	82.00	270.06	113.03	100.00	118.91		***753.37***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Willow PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	22 yr
Product(s):	WillowPL,
Sales:	705.25 €/ha
Cost:	**605.81** €/ha
Subidies:	
Profit/Loss:	99.44 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

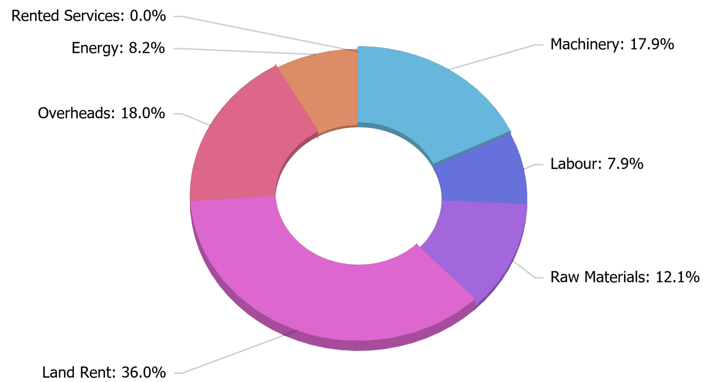
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			161.4					*161.40*
(Overheads)					100			*100.00*
Disk Harrowing	1.47	0.88		2.08				*4.43*
Fertilisation	2.26	2.43		5.44		35.36		*45.49*
Field Preparation	1.31	1.75		4.31				*7.37*
Harvesting/Chipping	18.99	13.6		82.7				*115.29*
Planting	1.63	2.37		4.6		113.96		*122.56*
Ploughing	1.31	1.75		4.03				*7.09*
Pressing/Rolling	0.65	0.58		1.34				*2.57*
Transport 37	10.55	9.06		15.28				*34.89*
Weed Control	0.48	0.51		0.42		3.31		*4.72*
TOTAL (€/ha)	38.65	32.93	161.40	120.20	100.00	152.63		***605.81***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Safflower ES

Country/Region:	Spain
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Seeds, Straw,
Sales:	480.00 €/ha
Cost:	**556.27** €/ha
Subidies:	
Profit/Loss:	-76.27 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Fertilisation	2.43	4.2		5.18		34.48		*46.29*
Harrowing	4.86	4.2		8.33				*17.39*
Harvesting/Combine	12.15	9		53.06				*74.21*
Herbiciding	2.43	4.2		5.18		5		*16.81*
Ploughing	16.2	14		17.69				*47.89*
Sowing	6.48	5.6		7.99		28		*48.07*
Transport 37	0.95	2.52		2.14				*5.61*
TOTAL (€/ha)	45.50	43.72	200.00	99.57	100.00	67.48		***556.27***

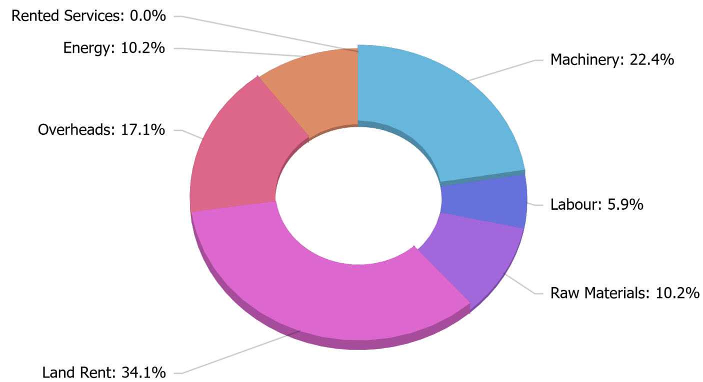
This Report has been generated by the ABC software

Cost Analysis (€/ha)

Castor GR

Country/Region: Greece
Total Area: 1 ha
Projet Life: 1 yr
Product(s): Castor Seeds GR,

Sales: 625.00 €/ha
Cost: **585.67** €/ha
Subidies:
Profit/Loss: 39.33 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

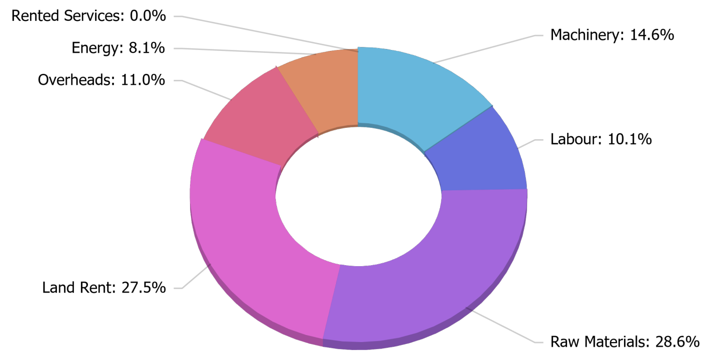
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Fertilisation	2.64	2.13		5.18		18.06		*28.01*
Harrowing	6.16	4.97		19.44				*30.57*
Harvesting/Combine	13.2	5.45		53.06				*71.71*
Ploughing	22	14.2		35.39				*71.59*
Sowing	13.2	5.32		14.98		17.5		*51.00*
Transport 37	1.03	1.17		2.14				*4.34*
Weed Control	1.76	1.42		1.27		24		*28.45*
TOTAL (€/ha)	59.99	34.66	200.00	131.46	100.00	59.56		***585.67***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Lupin FR

Country/Region:	France
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Lupin Seeds FR,
Sales:	900.00 €/ha
Cost:	**908.14** €/ha
Subidies:	
Profit/Loss:	-8.14 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

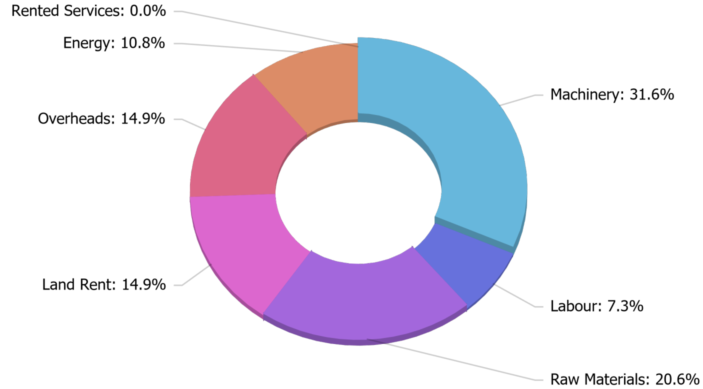
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			250					*250.00*
(Overheads)					100			*100.00*
Fertilisation	2.91	4.8		5.18		180.48		*193.37*
Harrowing	6.79	11.2		19.44				*37.43*
Harvesting/Combine	30	22.47		53.06				*105.53*
Pest Control	1.94	3.2		1.27		20		*26.41*
Ploughing	24.25	32		35.39				*91.64*
Sowing	4.85	12		14.98		35.6		*67.43*
Transport 37	1.13	2.65		2.14				*5.92*
Weed Control	1.94	3.2		1.27		24		*30.41*
TOTAL (€/ha)	73.81	91.52	250.00	132.73	100.00	260.08		***908.14***

This Report has been generated by the ABC software

Cost Analysis (€/ha) | Cost Analysis (€)

Hemp PL

Country/Region:	Poland
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Hemp Fibres PL, Hemp Seeds PL,
Sales:	986.00 €/ha
Cost:	**1008.95** €/ha
Subidies:	
Profit/Loss:	-22.95 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

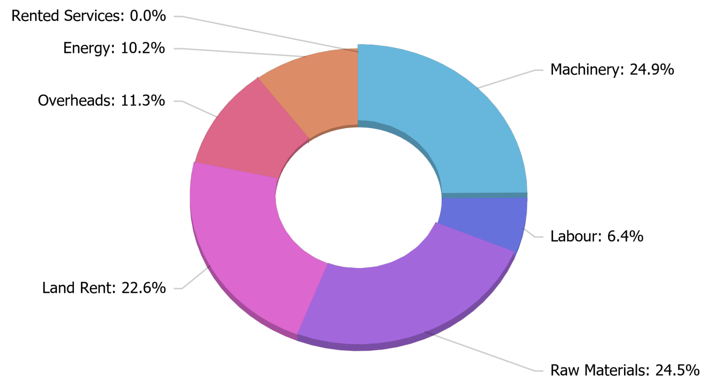
Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			150					*150.00*
(Overheads)					150			*150.00*
Fertilisation	2.15	2.31		5.18		7.64		*17.28*
Harrowing	5.02	5.39		19.44				*29.85*
Harvesting/Bale Management	11.04	3.85		40.29				*55.18*
Harvesting/Baling	32.2	15.4		47				*94.60*
Harvesting/Combine	14.34	9.04		126.97				*150.35*
Ploughing	17.93	15.4		35.39				*68.72*
Sowing	3.59	5.78		14.98		200		*224.35*
Transport 37	22.23	16.71		29.68				*68.62*
TOTAL (€/ha)	108.50	73.88	150.00	318.93	150.00	207.64		***1008.95***

This Report has been generated by the ABC software

Cost Analysis (€/ha)

Sorghum GR

Country/Region:	Greece
Total Area:	1 ha
Projet Life:	1 yr
Product(s):	Sorghum GR,
Sales:	640.00 €/ha
Cost:	**884.80** €/ha
Subidies:	
Profit/Loss:	-244.80 €/ha



*Annual costs are expressed in Annual equivalent values

TOTAL ANNUAL EQUIVALENT COSTS INCLUDING INITIAL INVESTMENT(€/ha)

Operations	Energy	Labour	Land	Machinery	Overheads	Raw Materials	Rented Services	Total
(Land Rent)			200					*200.00*
(Overheads)					100			*100.00*
Cultivation	7.04	3.55		9.86				*20.45*
Fertilisation	2.64	2.13		5.18		119.98		*129.93*
Harrowing	5.28	2.13		8.33				*15.74*
Harvesting/Chipping	22	21.3		140.51				*183.81*
Herbiciding	2.64	1.42		3.46		25		*32.52*
Ploughing	17.6	7.1		17.69				*42.39*
Sowing	7.04	2.84		7.99		72		*89.87*
Transport 37	26.4	16.43		27.26				*70.09*
TOTAL (€/ha)	90.64	56.90	200.00	220.28	100.00	216.98		***884.8***

This Report has been generated by the ABC software