

Land-based biomass and energy crops

Technical Note

March 2024



Land-based biomass and energy crops

Technical Note

Authors Olivier Dubois, Jouk Hogenhuis, Emma Beroske
 studio Gear Up B.V., Amsterdam, the Netherlands
 www.studiogearup.com

Date: March 2024

© Platform Hernieuwbare Brandstoffen / NL Platform Renewable Fuels

Address: Cruquiusweg 111A
 1019 AG Amsterdam
 The Netherlands
 contact@hernieuwbarebrandstoffen.nl
 www.hernieuwbarebrandstoffen.nl

Context and background of this Technical Note

Biomass and biofuels play a crucial role in the European Commission's (EC) strategy towards energy security and greenhouse gas emissions reduction (EC, 2019). While biomass is a renewable energy source that is integral to the energy transition of many sectors, its current share in the renewable energy mix will have to grow substantially to meet policy goals set by the European Commission (EU/2023/2413) (EC, 2023). For the road sector, biofuels are essential as a bridging renewable fuel until full electrification can be achieved. In other mobility segments, such as aviation and shipping, biofuels will likely play an important role for decades to come, in moving away from fossil fuels. Also, biomass will be an essential feedstock in the transition to green chemicals and materials.

Biomass feedstocks are available in many different forms and their potential for mobilisation differs according to several factors such as availability, removal rate or other competitive uses. The latest estimates of biomass mobilisation potentials in Europe provided by the European Commission confirm that the largest potential will become available from the agricultural sector (Figure 1) (EC, 2024). In a technical potential, a significant contribution can be achieved from primary production of intermediate cover crops. This category presents a limited contribution in the other scenarios due the fact that only a modest mobilisation is assumed. When comparing the different biomass mobilisation potentials in the various scenarios to the green carbon required to meet the demand for renewable fuels in the transport sector, biomass availability potentials match the demand for renewable fuels, especially when considering synergies with the production of e-fuels.

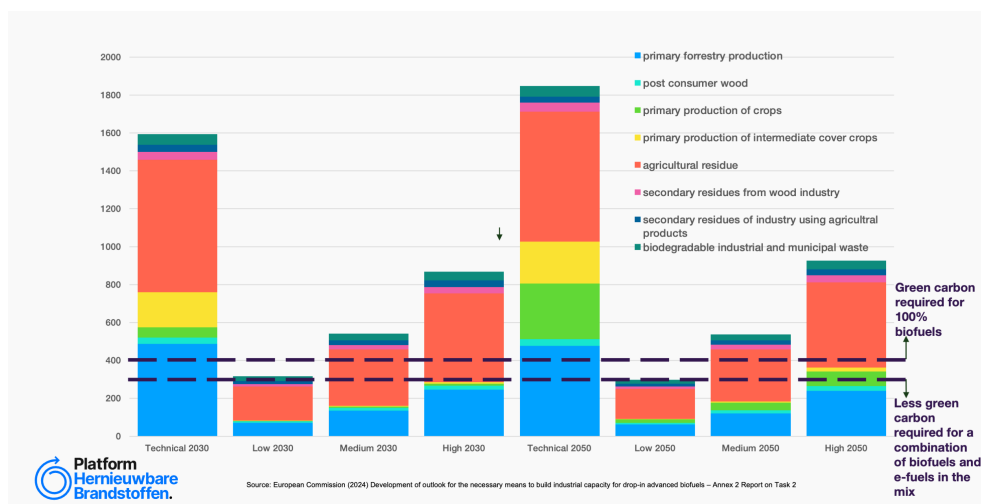
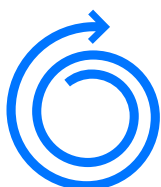


Figure 1: Biomass potentials in technical, low, medium and high potentials in 2030 and 2050 and distributions over biomass categories (Adapted from EC, 2024)

In January 2024, the Dutch Platform Renewable Fuels hosted a strategy event on Biomass Mobilisation (BioMob) to explore the topic of sustainable bio-feedstock mobilisation for the further development of a green production cluster for renewable fuels and green chemical building blocks. Various avenues for developing a new feedstock base were explored such as the use of agri-residues, intermediate crops, or crops on marginal land. A key takeaway from this event is the influence of developing bio-feedstock supply chains on other sustainable development goals. Various bio-feedstock pathways can be integrated into the current food production system and provide many opportunities for improvements in soil quality and water retention, as well as increased food security, job creation, additional revenues.

Following up on the BioMob event, Dutch Platform Renewable Fuels sees that a biomass deployment strategy towards the realisation of a green production cluster must be defined.

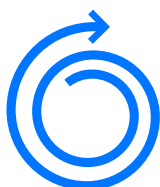


There is a need for better policy guidance to steer the sectors on the right path. This technical note serves as an exploratory research project as part of a longer process towards the write up of a whitepaper. This whitepaper acts as an instrument for better policy guidance on feedstock mobilisation.

Currently, the guidance provided by the European Commission is not optimal. Market players along the bio-feedstock supply chain are at the mercy of unclear definitions (i.e. marginal lands, 'advanced'), unclear direction (i.e. idea of mature technology, elements of indirect land use change (ILUC)) and unclear integration between the different demand markets.

A bio feedstock guidance should consider a long-term vision of bringing renewable fuels to the aviation and maritime sectors and the feedstocks for the green materials and chemicals. The road sector can serve in the short to medium term as a demand market to ramp up the production volumes of biofuels. For the expansion of the biofuels, mainly for road, the feedstock base needed to meet the demand must be expanded beyond the predominantly food and feed crop-based feedstocks that are currently used and beyond the cap on the use of used cooking oil and animal fat uses (Annex IX B). To provide input for such a guidance, Dutch Platform Renewable Fuels is executing an analysis into various pathways for mobilising biomass to develop a whitepaper with policy recommendations.

The following Technical Note on Land-based biomass and energy crops provides a deep dive into one of the many potential avenues for bio-feedstock mobilisation. In this analysis, there is a focus on two feedstock categories namely, the use of marginal lands and intercropping. These feedstock categories or the particular set-ups they are produced in do not compete with food and feed production nor for the use productive agricultural land. Furthermore, the choice of these two avenues is aligned with the needs of biofuel producers where the control of feedstock quality and security of supply are a priority.



Executive summary

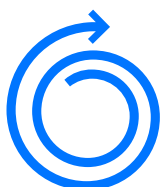
Land availability and its use have been a topic of debate as the question of land use for the production of bioenergy becomes increasingly important in the energy transition. Land systems are dynamic and used for various purposes by different people which makes decision making about sustainable land management inherently complex and multi-faceted. Bioenergy is one of the many possible uses of land and developing sustainable land-based bioenergy systems requires careful planning. An integrative approach must be considered starting from the land use side where the best fit for bioenergy system can be determined along with the optimisation of synergies with other land management goals.

While residual biomass is seen as the most sustainable biomass feedstock, residues and waste streams alone will not be enough to satisfy the expected future biomass demand. Additional sourcing from dedicated cropping of land-based biomass will be needed to meet the rising demands for biomass feedstocks. On a global level, it is generally agreed that the land needed for bioenergy is not a major constraint. Instead, the main challenge is to expand land-based bioenergy in a sustainable way. In Europe, between 17 and 71 million ha of productive land in the form of arable land and pasture land could be made available for bioenergy, on condition that improvements in agricultural production are sufficient, a majority of which would be located in Eastern Europe. Additionally, a large potential can be seen in the use of marginal lands.

The technical note provides insights on opportunities and constraints to scale up non-food energy crops by exploring the possibilities on the supply and demand side. First, the supply side is considered by investigating several land and crop options. Two types of land are identified where energy crops can be grown, either on productive agricultural or forest land or on marginal lands. On productive agricultural land, energy crops could be integrated in a crop rotation with food crops which would bring a variety of benefits. The main advantage of annual energy crops lies in the fact that agronomic management can be easily adapted in used cultivation practices as fit in current (rotation) farming systems without creating land use change and providing further agronomic and environmental advantages (i.e. soil production, fertility enhancement). Annual energy crops are usually preferred over perennial crops as they are more familiar to farmers and require less farm management change.

Energy crops could also be grown on surplus land that is not suitable for food production which is mainly abandoned or marginal land. Although the concept of marginal land is understood differently across countries and regions, they are often uninteresting to farmers for food production because of their low yields. They do present an interesting opportunity for the cultivation of perennial energy crops, as they are low in costs and maintenance, and can help to rehabilitate these lands. In Europe, land that is most susceptible to agricultural marginalisation is likely to be found in extensive farming regions and those where traditional small-scale farming is prevalent. Such practice of growing perennial crops on surplus land could benefit farmers by providing additional income and improve local economy once the land is rehabilitated. However, the factor time is important to consider before competitive yield resulting in attractive income can be reached. Other disadvantages are related to the fact that not enough information on the performance of perennial crops in field conditions is available as well as competition with other land uses. Nevertheless, the environmental advantages of perennial crops versus annual crops can occur both in productive and marginal land. It is usually easier for farmers to start growing energy crops on their own productive land rather than perennials on marginal land. Generally, low-intensity input supply and farming practices are recommended for the cultivation of energy crops.

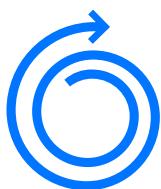
On the demand side, developing bio-feedstock value chains through the right stakeholder processes is examined. Biomass producers, biomass buyers and governments (local and national) are the main actors in the implementation of



biomass feedstock value chains. Interactions between these different stakeholders can be strengthened to facilitate a cost-effective, just, and sustainable implementation of these value chains. Transparency and inclusivity are required in their decision-making to maximise benefits and minimise harm to local communities and the environment. Strengthened interactions between the various stakeholders can be achieved by contracting farmers to improve their market security whereby a company purchases farmers' products. Furthermore, the terms of the purchase should be arranged in advance through contracts and addressing the stakeholder power imbalances are key aspects to consider to achieve fair and durable agreements.

The different cropping set-ups present many potential benefits and can play an important role to fulfil ambitious climate targets. Yet the uptake of energy crop cultivation has continued to stagnate, and significant policy intervention will be required to overcome the present barriers for the growth of energy crops on marginal lands or integrated onto productive land. Several public and private instruments needed to support the scale up of energy crops are explored. Policy measures to support the growth of energy crop on marginal land include integrated land use policy, planting grants, government-backed contract for biomass supply. Incentives could include either direct incentives by government or the private sector combined with safeguard mechanisms to avoid overuse or wrong use of land for energy crops. Otherwise, indirect incentives in the form of payment for environmental services should be provided in the case of perennial crops. As a switch in agricultural practices presents risk for farmers, sufficient financial incentives must be provided for them to adopt new farming practices. Increasing the uptake of sequential cropping practices could be done by creating a dedicated market for the produced feedstock. In addition, policies that reward improvements in soil health, carbon stock and other environmental benefits can also help to create a push for the uptake of such practices.

Currently the cultivation and supply of energy crops on the supply side as well as renewable fuels on the demand side are insufficiently incentivised by policies. On the supply side, the Common Agricultural Policy (CAP) is taking tentative first steps in supporting farmers in the uptake of energy crop cultivation in their practices. The overall design of the framework is useful to foster beneficial environmental and climate results. However, it does not yet set high ambitions and the flexibility in implementation is used by Member States makes that ambitions end up being lower, resulting in little to no incentives yet for the adoption of energy crops in different agricultural set-ups. On the demand side, the Renewable Energy Directive (RED) is offering an opportunity to incentivise the demand for sustainable agricultural feedstock under a set of conditions. The production of energy crops should be done in specific agricultural set-ups, whether on marginal land or integrated in a cropping rotation. However, some feedstock categories are subjected to capped contributions, such as biofuels produced from food and feed feedstocks and biofuels produced from feedstocks listed in Annex IX Part B, and others are stimulated by a sub-mandate, such as biofuels produced from feedstocks listed in Annex IX Part A. However, the RED should not impose caps and sub-targets on the basis of feedstock categories. Instead, these sub-targets and caps should be set according to the benefits various agricultural set-ups bring to objectives other than only the biofuel feedstock production. In conclusion, there is a need for better coherency in EU policies that incentivises the deployment of renewable energy both on the supply and demand side and provides security for feedstock suppliers for instance in the form of crops insurance schemes for energy crops.



1 Setting the bioenergy-land nexus scene

Land systems lie at the heart of several development issues, including food security, biodiversity conservation, healthy soils and habitats, clean energy, and climate change action. Decisions about sustainable land management are inherently complex and multi-faceted because land systems are dynamic and can be used simultaneously for different purposes by different people. Many of these features and their implications are reflected in Figure

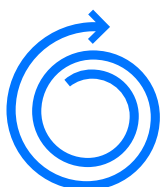
Facts About Land Systems		Challenges for sustainability	Implications for governance and practice
1	Multiple values and meanings	▷ Notions of land degradation and restoration are socially constructed and contested	More sustainable and just solutions require: ▷ Acknowledging multiples perceptions, beliefs and values, multiples versions of justice, and power differentials ▷ Developing contextual and adaptive solutions, avoiding silver bullets and "one-size-fits-all" panaceas ▷ Considering spatial and temporal spillovers ▷ Preventing undesired irreversible impacts ▷ Fostering synergies but also acknowledging and mitigating unavoidable tradeoffs ▷ Explicitly addressing inequalities and acknowledging unclear land tenure
2	Land as complex systems	▷ Consequences are difficult to foresee and trace	
3	Irreversibility & path-dependence	▷ Loss of option value, shifting baselines, no return to original state	
4	Large impacts of small footprints	▷ Spillovers may be more important than direct impacts	
5	Distant connections	▷ Solving local problems can displace issues elsewhere	
6	Used Planet	▷ No "free" land that does not already provide benefits	
7	Prevalence of trade-offs	▷ Prioritizing a single goal such as carbon nearly always reduce other benefits for some	
8	Multiple, overlapping, contested land tenure claims	▷ Identifying decision-makers and policy recipients is complicated	
9	Unequal distribution of control and benefit	▷ Interventions always have distributional consequences	
10	Multiple dimensions of justice	▷ Governance processes that do not acknowledge distinct form of justice will be considered as unjust	

Figure 2. Land systems facts, sustainability challenges and implications for governance and practice (Meyfroidt et al, 2021).

When applied to the management of land-based bioenergy, the features displayed in Figure 1 mean that (Dubois et al, 2022):

- Bioenergy supply is just one possible use of land, which means that multiple uses and integrative approaches need to be considered when the location of bioenergy systems is being planned;
- The links between bioenergy and land are influenced by climate and human activities. They affect natural resources, especially water, nutrients, and carbon as well as people's livelihoods and local development.
- As a result, land-based bioenergy planning must give due consideration to a potentially diverse range of locally important factors;
- Sustainable land-based bioenergy systems should be planned starting not from the energy side but from the land use side, so as to appropriately consider and address potential conflicts with stakeholders, find the best fit for bioenergy systems to minimize negative effects, and optimize synergies with other land management goals, such as productivity and biodiversity conservation;
- Land-based bioenergy solutions require transparent, inclusive decision-making to maximize benefits and minimize harm to the environment and to local communities;
- Given the possible multiple simultaneous and sequential uses of land by different actors, land-based bioenergy solutions and decision-making processes should extend beyond those who hold formal rights over the land or directly benefit from it; it should also include those with a stake in the land and those who derive benefits from it or perceive burdens.

While residual biomass is seen as the most sustainable biomass feedstocks there is also ample agreement that residues and waste streams alone will not be enough to satisfy the expected future biomass demand. Additional sourcing from dedicated cropping of land-based biomass is needed to satisfy rising demands. The amount of land available for bioenergy feedstock production is a contested issue, with



contrasting views and large ranges on land available for bioenergy. This can be explained by the fact that available land for bioenergy depends on several factors hard to predict with certainty, including feasible future agricultural crop yields, effects of future climates, proportion of diet shifts, livestock feeding efficiency, land availability for energy crops (in particular on marginal land), and yields of energy crops. That said, many scientists agree that increases in food and energy crop yields as well as higher feeding efficiencies and lower consumption of animal products would result in higher technical land-based bioenergy potential (Faaij, 2022). With the above in mind, the following indications on future prospects for land use for bioenergy are worth noting:

At Global level:

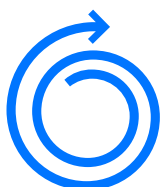
- There is broad agreement that land needed to produce bioenergy might not be the main constraint to large implementation of sustainable bioenergy as it would be a minor part of global land - the main challenge is to expand land-based bioenergy in a sustainable way. For instance, the proportion of land used for bioenergy would amount to about 22% rainfed agricultural land according to Woods et al (2015) estimate, which compares only the land areas considered suitable for rainfed agriculture and that is potentially available for bioenergy production (905 million hectares (ha), with the 200 million ha estimated to be required for production of 135 EJ¹ of modern bioenergy in a scenario that delivers 200 EJ/year of bioenergy in 2050. This assessment does not account for the potential use of marginal land to produce bioenergy feedstock. More recently, in its NZE scenario 2050 (IEA, 2021), IEA estimates that 410 million ha would be needed to produce 100 EJ bioenergy per year in 2050, broken down as follows:
 - 270 million ha forest land (66%) and
 - 140 million ha for bioenergy crops (345),
 - of which 130 million ha short rotation advanced bioenergy crops (93%), and
 - 10 million ha conventional crops (7%), half on marginal or grazing land and half on existing cropland.
- In addition, estimates of global availability of marginal land range from 250 million ha to 1.6 billion ha (ETIP-Bioenergy, 2019).

In the EU:

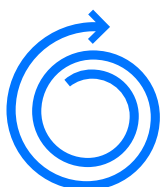
- As regards productive land, based on recent estimates, according to Faaij (2022), provided sufficient improvements in agriculture production and accounting for future food and feed needs, 7-52 million ha of arable land and 10-19 million ha of pasture lands could be released for bioenergy in Europe (plus Ukraine), equivalent to 3.3-15.8 EJ. Such land would be mostly located in Eastern Europe, due to the higher potential to bridge agricultural yield gaps in that part of the EU. Moreover, Ukraine would contribute about 1/3 of the freed land. Importantly, the wide range reflects the high dependence on the magnitude of agricultural yield increase and how fast these would be achieved;
- As regards marginal land, there is agreement that their theoretical potential is huge. For instance, recent research from the EC-funded MAGIC project estimates that the total marginal area across European land surface amounts to roughly 6.5 million ha - about the size of France (Von Gayl et al, 2019). Other studies give much lower potential, e.g., 20-21 million ha in 2030 and 2050 (Vera et al, 2021), still a significant potential.

Bioenergy has some specific land features compared to other types of renewable energy:

¹ 1 EJ = 1 exajoule, a unit of energy. 1 EJ = 10³ PJ or 10⁶ TJ or 10⁹ GJ or 10¹² MJ or 10¹⁸ J. Total world energy consumption in 2022 was ± 600 EJ according to Energy Institute, 2023 Statistical Review of World Energy 2023.



- It has a very high land footprint; i.e. more land is required to produce the same amount of energy from bioenergy than from other types of renewable energy. This disadvantage can be addressed in two ways (Fritzsche et al, 2017):
 - By optimizing the energy efficiency of land through the co-location of bioenergy and other types of renewables - for instance through agro-photovoltaic systems that combine solar panels and energy crops on the same field. A recent JRC report finds that using only 1% of the EU's utilised Agricultural Area with Agri-photovoltaic (PV) systems could allow 1 TW² of PV capacity, well above the 590 GW foreseen by 2030 in the recent EU Solar Strategy communication (EC, 2023);
 - By optimizing land use efficiency through the combination of energy and other land uses on the same field - for instance through integrated food energy systems/IFES (e.g., mixed cropping systems that include one energy crop, farming systems that produce bioenergy as by-product) (FAO, 2010, Koppelmäki et al, 2021).
- A particular feature of bioenergy is that it can be a co-product of land management designed to improve watershed and soil conditions, forest health (wildfire fuel reduction), habitat for endangered species (removal of invasive species), and other land-based ecological services, while also supporting phytoremediation and restoration of degraded lands - See examples related to water in GBEP (2016) and to forest land restoration in GBEP (2020)
- On the other hand, the use of by-products from bioenergy that can be used as animal feed can free land used to produce grain aimed at feeding livestock;
- For many years the risk of indirect land use change (ILUC) has played a significant role in the assessments, debates, and policies about the availability of sustainable land-based bioenergy feedstocks. The ILUC risk concerns a land use change that occurs elsewhere as a flow-on effect if bioenergy crops displace the production of food or feed. As the demand for these products (partially) remains, production may "move" somewhere else, which could result in land conversion. Such indirect land conversion could release carbon stocks and lead to greenhouse gas emissions. In theory, such indirect emissions could reduce or even negate the positive effect of biofuels replacing fossil fuels. Recent assessment of the performance of these models have shown that they suffer from major limitations (See in particular Daioglou et al, 2020 and IEA-Bioenergy, 2022). Moreover, the potential ILUC impact changes continuously over time, due to changes in the international agricultural commodity market and local land policies. Therefore, the ILUC notions may inform bioenergy, land use and climate policy but should not be used as sole guidance. As suggested by several authors (e.g., Daioglou et al, 2020; Faaij, 2022), it would be more constructive to develop comprehensive 'land-use' policies that aim to avoid the CO₂ and other impacts for all land-use related products, thus making ILUC 'disappear' and transforming it into 'Integrated Land use Changes'. The ILUC-risk is often considered specific to bioenergy. However, ILUC can happen with any activity with a land claim, which, as a result, displaces the current activities on that land to elsewhere; hence, in principle, it can also occur in the case of large-scale solar panel fields, local nature protection, or afforestation projects, if they effectively displace agriculture.



² 1 TW = 1 TeraWatt, a unit of energy capacity, i.e. how much energy can be provided per unit of time.
1 W = 1 J/s.

2 Brief overview of constraints and opportunities to scale up non-food energy crops adoption

2.1 From the supply side: land and crop options

For the purpose of this note, it is useful to consider two types of land where energy crops can be grown, i.e., productive agricultural or forest land on the one hand and marginal land on the other hand. The concept of marginal land is dynamic as the features of marginal land can vary in space and time. For instance, land considered unproductive where intensive industrial large-scale agriculture prevails may not be deemed so in areas dominated by small-scale extensive agriculture, and land that is unproductive for agriculture can become productive upon its rehabilitation and can therefore be reclaimed for food production. This dynamic character of the marginal land concept explains why there is currently no agreed definition of marginal land. Definitions vary across regions, countries, and organizations due to the need to consider both biophysical and socio-economic aspects of land marginality, and their potential uses, this latter aspect having led to fierce and often value-laden debates (Muscat et al, 2022). This note will not attempt to define marginal land. From a pragmatic point of view, we are just interested in the usability for crop production of the different types of land that can reasonably be encompassed in the marginal land concept, as illustrated in Figure . Importantly, what can be concluded from Figure is that some forms of agriculture are possible on some types of marginal land, primarily reclaimed, idle, fallow, abandoned land, and, to a lesser extent, degraded and contaminated land. Dauber and Miyake (2016) call them 'economic marginal land', and this is the type of marginal land where energy crops are likely to perform better in terms of yield and farmers' income.

Within marginal lands, the European Commission defines abandoned land as land that '*was used in the past for the cultivation of food and feed crops but where the cultivation of food and feed crops was stopped due to biophysical or socioeconomic constraints*' (EC, 2019b). Abandoned lands are estimated to increase by 4.8 million hectares in the EU for the 2015-2030 period, accounting for 3% of total agricultural lands (Fayet et al, 2022). Given their previous use for crop cultivation, they are likely to be more fertile than other types of marginal land, in particular when they have been abandoned for economic rather than biological reasons.

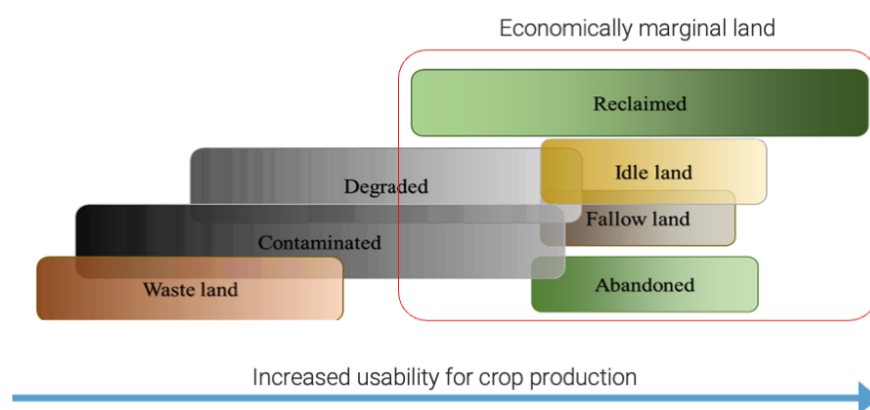
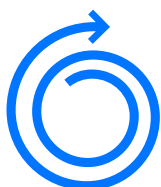


Figure 3. Types of marginal land and their interrelations to productivity and need for restoration (Adapted from Csikos and Toth, 2023).

In Europe, land most susceptible to agricultural marginalisation is likely to be found in extensive farming regions and those where traditional small-scale farming is prevalent (EC, 2022a).

Land can be used in two ways to produce bioenergy feedstocks:

- A food/energy integration option, where energy crops are inserted in existing food cropping systems, either together with existing crops - i.e., intercropping,



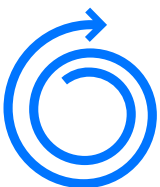
including agroforestry - or annual crops in a sequence between existing crops, i.e., cover, relay or catch crops;

- A food/energy segregation option, where energy crops - mainly perennial ones, are grown on surplus land.

Using land to produce energy crops faces trade-offs and synergies. In that respect, according to a recent review of environmental factors by Vera et al (2022):

- There are almost an equal number of trade-offs and synergies;
- Most synergies are observed when perennial crops are produced on arable land, pastures or marginal land in the 'cool temperate moist' climate zone and 'high activity clay' soils;
- Most trade-offs are related to food security, economic revenue and water availability. Importantly, several studies report negative effects on farmers' revenue when they shifted from 1st to 2nd generation crops as bioenergy feedstock. In most cases, the shift reduced GHG emissions and decreased revenue for farmers, with exceptions for the latter when the energy crop complemented rather than replaced the main crop;
- Previous land use and feedstock type are more impactful in determining synergies and trade-offs than climatic zone and soil type;
- This study highlights the importance of considering context-specific conditions in evaluating synergies and trade-offs and their relevance for developing appropriate policies and practices to meet worldwide demand for bioenergy in a sustainable manner.

Low-intensity farming systems often found on marginal land, such as extensive land, are of great importance for agricultural biodiversity preservation. Many marginal lands in Europe are dominated by permanent grassland systems. Species conservation value and soil carbon storage potentials of permanent grassland are potentially in conflict with the strategy of targeting marginal or degraded land for energy crop cultivation. However, restricting the production of energy arable land to prevent the conversion of permanent grassland could however aggravate the food/energy-conflict and stimulate increased ILUC. Dauber and Miyake (2016) suggest a potential way out of this conflict by using the natural or semi-natural grassland biomass directly for energy conversion. The same authors contend that high biodiversity levels of semi-natural grasslands can only be maintained through continuous management and thus using the biomass yield from semi-natural grasslands could promote the sustainable management of such sites in areas threatened by farm abandonment.



On low indirect land use change risk certification

At the EU level, the interest in marginal land also stems from the fact that marginal lands include land types (i.e., degraded and abandoned) that fulfil EC low indirect land use change (ILUC) requirements.

The Renewable Energy Directive requests that for biofuels produced from feedstocks with a high indirect land use change (ILUC) risk, being produced from food or feed crops with a significant expansion into land with high carbon stock, these biofuels can only be allowed when certified as a low ILUC-risk biofuel. Delegated Regulation (EU) 2019/807 (EC, 2019b) describes the criteria for feedstocks to qualify as high-ILUC risk feedstock. At this moment in time, following these criteria only palm oil is qualified as a high-ILUC risk feedstock. The regulation also indicates what is needed for a biofuel to be certified as low-ILUC risk biofuel, which would mean that they are exempted from the specific and gradually decreasing limit (to 0% in 2030) that is to be applied for biofuels from high ILUC risk feedstocks.

Low-ILUC certification can be granted if fuels meet the following cumulative criteria (EC, 2019a):

- 'Compliance with the sustainability criteria set in the recast Renewable Energy Directive, which entails that feedstock can only be grown on unused land that is not rich in carbon stock;
- use of additional feedstock resulting from measures increasing productivity on the already used land, or from cultivating crops on areas which were previously not used for cultivation of crops (unused lands), provided that a financial barrier has been overcome, or the land was abandoned or severely degraded, or the crop has been cultivated by a small farmer; and
- robust evidence proving that the two previous criteria are met'.

Most estimates of the potential of energy crops focus on ligno-cellulosic ones (both annual and perennial), without mentioning annual starch or oil crops (e.g., the case for IEA, 2021 at the global level and Imperial College Consultants, 2021 regarding the EU). This is quite surprising and unfortunate given that (i) they play an important role, in particular oil crops, as feedstocks for increasing biofuel markets, not least sustainable aviation fuels (SAF) (e.g., World Energy Forum, 2020 and Yang et al, 2023); (ii) the fact that, conversely to ligno-cellulosic crops, starch and oil crops can produce animal feed as a by-product of bioenergy, which can free land used to cultivate crops for livestock, potentially reducing tensions on land use, and (iii) there are multiple examples of sustainable farming systems using starch and oil crops for bioenergy purposes, including palm oil (See for example Van de Laan et al. in Indonesia, 2017 and Ramirez Contreras, 2020 in Colombia).

There is broad agreement that the main advantage of the annual energy crops lies in the fact that agronomic management can be easily adapted in used cultivation practices as fit in current (rotation) farming systems, without committing land use change for a long time, in addition to agronomic advantages like soil protection and possible fertility enhancement (in particular regarding leguminous cover crops). Farmers are usually more familiar with frequently used annual food oil and starch crops that can be used in sequence in productive land (e.g., rye, sugar beet, rapeseed, sunflower or castor bean) than concerning recently promoted energy crops that often still requires domestication, hence time to produce reasonable yields (e.g., switchgrass, camelina, or brassica

carinata), and whose performance currently lacks predictability. The above-mentioned factors explain why annual crops are often preferred by farmers compared to perennial crops. Another advantage is that, so far, the European Commission Renewable Energy Directive does not apply a limit to biofuels produced from food and feed crops grown as intermediate crops, which are crops other than the main crop, "provided that the use of such intermediate crops does not trigger demand for additional land" (EC, 2018).

However, despite these advantages, farmers' adoption of annual energy crops in existing cropping systems varies. For instance, a recent study related to food and feed cover crops in four EU regions found adoption rates ranging from 12 to 99 % (Kathage et al, 2022). The main reason for adoption was a legal obligation, followed by financial incentives. Environmental and climate considerations played only a small role. The same study, as well as others, found that common challenges of cover crops concern yield variability; possible competition for water, which can affect the production of the main crops; additional costs; additional workload (e.g., for planting and harvesting) not always balanced by revenues; and uncertain market opportunities. More knowledge on cover crop agronomy and economics as well as site-specific cover crop approaches are needed, even more regarding energy ones.

On the other hand, the main advantages of perennial energy crops lie in their low production costs (not always the case for short rotation coppice though), suitability to marginal lands, relative low water needs, low nutrient and agrochemical requirements, and positive environmental benefits (Alexopoulou et al, 2013).

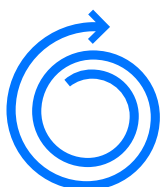


Table 1 summarises the main advantages and drawbacks of land and energy crop options.

Table 1. Summary of advantages and disadvantages of using productive versus surplus land and annual versus perennial crops to produce bioenergy feedstock

	Main advantages	Main disadvantages
On productive land, with energy crops integrated in a crop rotation with food crops	• Can potentially be applied in all cropping systems through inter or sequence cropping - hence potentially on a very large area • Does not require additional land, so no ILUC risk if it does not negatively affect the production of food crops • So far, no EC limit to the use no limit to the use of food and feed crops so long as it does require additional land use • Usually improves the environmental and productive performance of existing cropping systems (e.g. 4FCROPS, 2010, Heaton et al, 2013, Veldkamp et al, 2023) • Relatively more field results available, in addition to experimental plot results, compared to marginal land (e.g., Heaton et al, 2013) • No long-term land commitment	• Possible competition with food and ILUC effect if it reduces food production or leads to the need to use additional land • Farmers might lack knowledge regarding rotations that include energy crops, in particular non-food ones • Inclusion of energy crops in rotation depends on the available time window left between the main crops included in the rotation. This can vary every year, mainly due to yearly changes in climate and market conditions • Available land where to include energy crops strictly related the amount of used cropland. There has been a reduction trend in cropland area in the EU, while area of grazing land has increased (EC, 2022a)
Surplus land not suitable for food production (mainly abandoned or marginal land)	• Can result in land rehabilitation, hence improved soil quality • As a result, can lead to additional farmer's income and improve local economy once the land is rehabilitated • Can improve environmental conditions provided low-input farm intensification practices are applied (e.g., Von Cossel et al, 2020a and b; Englund et al, 2022; Kiesel et al, 2023; Scordia et al, 2023). These can include precision agriculture practices • Linked to the above, can benefit from payments for environmental services, e.g., biodiversity enhancement (Von Gayl et al, 2020b)	• Many possible uses of marginal land, so need to compare the advantages of the use for bioenergy feedstocks to other possible uses (e.g., natural growth, hunting, extensive grazing) (EC, 2022a) • Bioenergy use not always advantageous from an environment and socio-economic point of view • More time needed to reach competitive yields that result in attractive income for farmers - Likely less so in the case of abandoned land compared to marginal land due to frequent initial higher fertility of the former • Many results on performance relate to plot level tests, with very few results from field level trials - so existing knowledge gaps, despite interesting recent initiatives to bridge this gap - e.g. through the EC-funded PANACEA project (ETIP-Bioenergy, 2019, Panoutsou et al, 2021 a and b) • Not enough information on perennial crop performance in field conditions • Can lead to competition with food production once the land is rehabilitated

Table 1 can be used as a basis to draw some key conclusions regarding these options to scale up energy crop use.

Regarding land options

- Compared to productive agricultural land, marginal land is usually at a disadvantage from two standpoints:
 - It can seldom compete in terms of financial profitability, both from a quantitative point of view and the time lag until reasonable profits can be made. This means that without sufficient incentives, the use of marginal land to produce energy crops will unlikely reach meaningful levels;
 - Conversely to productive agricultural land whose purpose is clear, marginal land can be used for different purposes besides bioenergy feedstocks, both

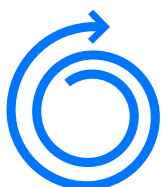


at the planning stage (e.g., compared to extensive agriculture and recreational activities or rewilding) and once their soil quality is rehabilitated (e.g., with their use to produce food). In that respect, it is worth pointing out that, from a strict climate mitigation point of view, the use of marginal land for bioenergy feedstocks compared to natural regrowth or reforestation is often only advantageous if it is combined with yield increase and Bioenergy with carbon capture and storage (BECCS) (e.g., Kalt et al, 2019 and 2020; Lowenskiød et al, 2022; Sandstad Naess et al, 2023, Fehrenbach et al, 2023, and Rowe et al, 2020 and Martani et al, 2022a regarding the carbon balance when perennial crops systems are reverted to arable land). Therefore, judicious choices must be made between different possible uses of marginal land. This requires a science-based integrated approach that considers not only climate change mitigation but also all land use change-related environmental and socio-economic aspects, as well as an all-inclusive decision-making process where local stakeholders should play a key role.

- While ILUC risks exist for productive agricultural land and not for marginal land, farming practices to address it, like sustainable yield increase and sequence cropping, are well known and relatively easy to implement.

Regarding crop options

- The environmental advantages of perennial crops versus annual crops can occur both in productive and marginal land;
- Linked to the above, low-intensity input supply and farming practices are usually recommended for the cultivation of energy crops. This stems from the need to ensure a favourable overall carbon balance of the cropping system. In the case of perennial crops, this also ensures that the environmental advantages of these crops are maintained, with prospects to benefit from payments for environmental services. Precision agriculture should be part of low-input farming systems, and successful experience in its use to grow energy crops exist (e.g., Heaton et al, 2013). Among low-intensity inputs, biochar should be given special consideration because it combines being a proven low-carbon intensity means to enhance soil health (Lehman et al, 2021 Martani et al, 2022b and Chiaramonti and Barsani, 2023) and its fulfilment of circular bioeconomy as a by-product of pyrolysis;
- It is usually easier for farmers to start growing energy crops on their own productive land than perennials on marginal land, and annual crops than perennials because the former require less farm management change. More specifically, factors related to stronger resistance to adopt perennial crops versus annual crops concern primarily high upfront investments (e.g., for new harvesting material), lack of long-term mature and uncertain markets at the end of the crop life span, and long-term commitment of land (Clifton Brown et al, 2023). The capacity to absorb these risks varies according to farming system characteristics (e.g. size, tenure, level of investment in other enterprises and a positive grower attitude towards innovation of new products and markets);
- For the above-mentioned reasons, adoption potential of perennial crops is likely to be higher for large-scale farms (Clifton Brown et al, 2023). This might complicate their implementation on marginal land as these are often dominated by small-scale farming;
- While some commercial scale experience exists regarding the performance some types of energy crops (e.g., short rotation coppice) on productive land, this is not the case regarding energy crops on marginal land. In that respect, research programs, in particular some recent EC-funded ones through the H20/20 programme, have significantly helped fill knowledge gaps, but most of them have not lasted more than the duration of the projects that funded them, i.e. usually less than five years. While such project durations cover the life span of annual crops, it is not the case for many perennial crops. Therefore, these research projects do not give results about the performance of these crops at the end stages of their cultivation, including on important aspects such as soil

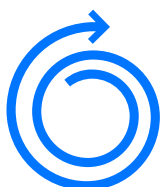


carbon balance and harvesting costs. Longer projects and more commercial-scale ones are therefore needed to overcome this research weakness; which is more likely to happen with national funding (Clifton Brown, 2023), as in the case of the SUSFACE project in Italy (Pari et al, 2019). In addition, there is hardly any information on the impacts of future climate (in particular extreme weather events such as heat waves and floods) on the performance of all types of energy crops. Moreover, there is much to do in agronomy and crop management beyond plot trials to upscale the uptake of these crops to commercial fields, including commercial-scale trials to be evaluated by truly independent bodies. Modern information technologies, including those related to precision farming and remote sensing, are showing great promise for forecasting energy crop performance, e.g. remote sensing for perennial bioenergy grass yields (Hamada et al, 2021).

The above considerations show that, while there is significant potential and some experience regarding the growth of non-food energy crops, their wide adoption by farmers still faces significant challenges. However, time is of the essence; we cannot afford to wait until we have all the answers to address these challenges and deploy energy crops on a meaningful scale. The 'best bet' approach in that direction would be to follow the following 'no regret' twin-track pathway, which would combine:

- Prioritizing the large-scale implementation of energy crops for which there is sufficient farm-level and commercial scale experience on productive land, including:
 - On the one hand, annual crops in existing crop rotations for which sufficient experience exist. i.e. food and feed crops;
 - On the other hand, perennial crops. In that respect, recent studies show (i) the capacity of strategic perennialization of productive agricultural land in mitigating environmental impacts and enhance carbon sequestration without compromising food production (Englund et al, 2020a and b, and 2022), and (ii) that a significant amount of land where this is possible exist in Europe - focusing on priority areas, strategic perennialization could concern over 15-60 million ha, harboring 10-46% of total annual crop production in EU - See Figure 4. (Englund et al, 2020a);
- Strengthening knowledge and data about the agronomic feasibility and sustainability of both non-food annual energy crops as part of crop rotations on productive land and perennial energy crops on marginal land. This would include demonstration farms and on-farm trials over long period of time, based on existing knowledge and priorities decided by local stakeholders.

More broadly, implementing good sustainable land use practices in the deployment of energy crops is a 'no regret' way to promote the deployment of energy crops. The good news is that good sustainable land use are well known and well documented, for instance in the database of the World Overview of Conservation Approaches and Technologies (WOCAT). However, in selecting and implementing good practices,



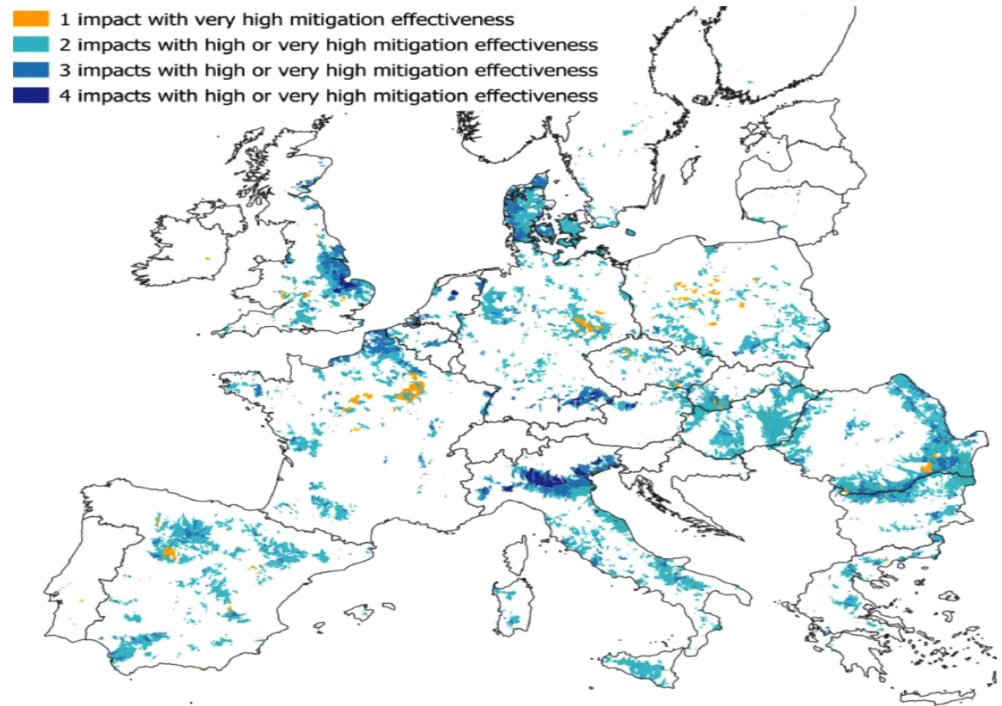


Figure 4. Priority areas for strategic perennialization of productive agricultural land (Englund et al, 2020a)

good practices, it is important to address trade-offs between benefits to land and possible risks regarding other development aspects. One example of a trade-off is the use of agricultural residues for bioenergy instead of soil cover or animal feed. Feedback loops are needed to review the validity of existing indicators and practices., because contextual conditions are linked to sustainable land use and land users' needs can change over time. Such process to select good practices is illustrated in Figure 5.

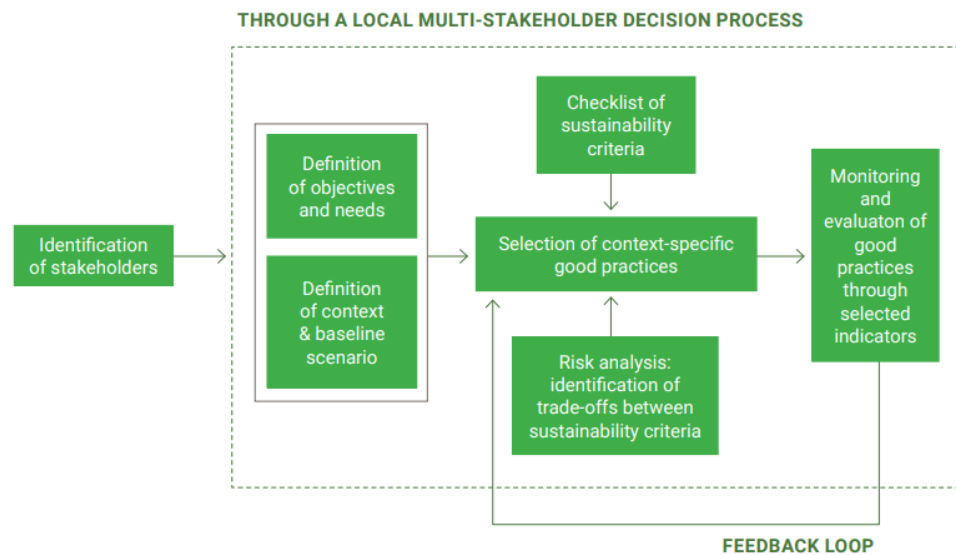
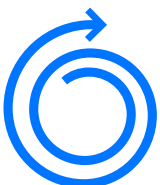


Figure 5. Process to select good sustainable land use practices (Dubois et al, 2022)

2.2 The demand side: Making biomass feedstock value chains work through the right stakeholder processes

Biomass producers, biomass buyers and governments (local and national) are the main actors in the implementation of biomass feedstock value chains. This section briefly discusses two ways interaction between these stakeholders can be strengthened to facilitate the cost-effective, just, and sustainable implementation of these value chains.



Contract farming to improve farmers' market security

Adequate initial market demands need to be assured to reduce the risk of failure for bioenergy products. This can be achieved through contract farming whereby a company purchases farmers' products, and the terms of the purchase are arranged in advance through contracts. The terms of the contract vary and usually specify how much produce the contractor will buy and what price they will pay for it. The contractor frequently provides credit, inputs and technical advice.

As a form of agricultural production contract farming has been practiced for a long time. It can bring several benefits to both the contractor/company and farmers, but it can also come with constraints and risks for both parties. The most common ones and possible ways to address these are summarised in Table 2.

Key requirements for successful contract farming schemes include (World Bank and UNCTAD, 2018):

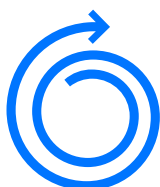
- Careful pre-investment evaluations of the business plan, sustainability, and benefits for participating farmers and communities;
- Early-stage community consultation, particularly with respect to community impacts and access to land;
- Written contracts, with effective monitoring and grievance procedures;
- Efforts at multiple levels to improve the productivity and quality achieved by smallholders;
- Processes for managing risk in responding to changing circumstances; and
- Support for community engagement and capacity to engage.

Before setting up biofuel contract farming operations, biofuel companies must give detail consideration to a number of issues (Shepperd, A.W., 2013):

- Do the identified farmers have the capacity to produce the necessary quantities required by the factory?
- What company support will be required to ensure the targets are met?
- What are the potential implications of biofuel contract farming on food production, land tenure arrangements, and gender relations?
- What support is necessary to farmers growing long-gestation crops?
- How can trust be built up and maintained between farmers and the companies?
- What sort of contract is required?

Table 2. Possible constraints/risks for farmers and companies relating to contract farming, and possible solutions to overcome them (Adapted from Vermeulen and Goad, 2006).

Regarding farmers and companies (or land development agencies)	
Constraints/Risks	Possible solutions to overcome constraints/risks
Land disputes and tenurial uncertainty	• Companies go beyond legislation in settling land disputes • Share-based systems can replace individual land holding. Whereby farmers rent out use rights of their land to a company or collect a share of profits based on the equity value of their land
Low productivity and quality of feedstocks	• Governments or companies support nurseries for high quality seed stock • Upfront cash incentives to encourage use of inputs and overcome cash flow problems • Farmers can selectively hire services of government extension agencies
Difficult for farmers to comply with standards, principles and criteria	• Group certification of farmers to lower costs of compliance • Possibility for differential standards for smallholders • Dedicated support by the certifying company, the government or the company
Lack of clear and reliable mechanisms for dispute resolution	• Some certification principles and criteria (e.g., RSPO for palm oil) require companies to set up workable dispute mechanisms • Government provides both policy context and actual mediation services
Regarding farmers	
Constraints/Risks	Possible solutions to overcome constraints/risks
Lack of access to capital for investment (and reluctance to use land as collateral)	• Cross-sectoral government subsidised credit schemes for individuals and cooperatives • Company provides interest-free credit for selected inputs



	• Equity or loans by through bank mechanisms • Credit based on government land guarantee rather than actual market value of smallholdings
Low access to reliable information	• Intermediate organisations (e.g., NGOs) provide additional information and help to find and interpret formal documents • Governments or international agencies write and share practical guidance relevant crops for farmers • Exchange of information through producer groups and associations
Trade-offs between energy and food crop production	• Allow intercropping of food and energy crops • Allow land to be set aside for food production • Flexible labour schemes between work on energy crops for companies and work on food crops • Intercropping of young trees in food crop fields, or mixed 'forest gardens'
Perennial crop with volatile world price, hence high risk compared to other land uses	• Intercropping and mixed land use to provide more diverse sources of income and food security, especially in early years • Income diversification schemes such as livestock • Government provision of business services such as predictive market information • Stepped harvesting to provide early income
Monopsony purchase by company (due to geographic farm dispersion)	• Standardised fair and transparent pricing systems • Government support to expansion of processing facilities causes their proliferation, hence more competition • Competitive, economically efficient chain of buyer intermediaries
Low bargaining power: difficult to negotiate terms and prices	• Farmers organize themselves into local associations and cooperatives • Links with national and international NGOs and trade unions • Farmers' contracts with built-in timeframes for renegotiation • Support from third parties such as government agencies and NGOs • Government-backed contracts
No share in post- harvest added value	• Farmers organized in cooperative biomass processing companies • Farmers' associations invest collectively in downstream processing
Lack of broader social development	• Company uses tax-breaks to fund local infrastructure • Free public transport scheme • Government allocation of land to companies contingent on social responsibility agreements with communities
Adverse environmental impacts (e.g., monocropping of the energy crop)	• Spatial planning, e.g., through agro-ecological zoning giving priority to degraded land • Civil society court cases to tackle illegal burning • Water-using companies exploring use of tax breaks to fund direct payments to farmers for upstream environmental protection • Company and/or government support against monocropping and in favor of crop diversification and guaranteed food production
Regarding companies and land development agencies	
Constraints/Risks	Possible solutions to overcome constraints/risks
Side-selling: Farmers do not respect contract and sell to other buyers	• Government-backed contracts • Trust-building between farmer and company, e.g., through adequate information provision on market conditions and involving farmers in decision-making (e.g., onsetting feedstock price)
Unreliable rates of supply from smallholders, from inaccessible plots	• Company takes full responsibility for collection of fresh fruit bunches, with dispersed collection points • Incentive schemes for flexible and efficient labour movement among smallholders' plots • NGOs provide assistance to small- scale business planning and projections
Transaction costs of dealing with large number of individual smallholders	• Smallholders organised into legally recognised local cooperatives (Indonesia) • Contracts are with farmers' associations and cooperatives of smallholders rather than individuals • Companies fund shared, centralised rather than individual extension service • Tax incentives for companies who buy feedstocks from smallholders • Cooperation between buyers, e.g. on information regarding defaulters or joint schemes
Smallholders default on loan repayments	• Repayment of loans as a proportion of crop rather than in cash



The solutions mentioned in Table 2. Possible constraints/risks for farmers and companies relating to contract farming, and possible solutions to overcome them (Adapted from Vermeulen and Goad, 2006). show that cost-effective and fair collaboration between stakeholders requires a balance between the 'carrot' (i.e., rights and benefits) and the 'stick' (i.e., responsibilities) both within and between stakeholder groups. This alludes to the fact achieving good stakeholder collaboration requires that issues related to stakeholders' power imbalances be addressed, a topic that is briefly discussed in turn.

Addressing stakeholder power imbalances - Key to achieve fair and durable agreements

There is increasing evidence that situations where significant disparity in power allows power to be exercised usually results in outcomes being potentially more unstable than in situations where parity in power favours constructive negotiation, and this even if active participation has been achieved - see Figure

Despite the recognition that stakeholder power differences exert a key role in the outcomes of negotiations over land use, hence also in the development of biomass feedstock value chains, information on how to address issues of power relations is scant. Nevertheless, the '4Rs' framework can help in addressing this gap. It allows to define/negotiate stakeholders' roles and, indirectly their respective power, through the balance of their rights, responsibilities, and returns/revenues (the '3Rs') regarding any collaborative deal, as well as the quality of their relationships in that respect (IIED, 2005). Other factors that help balance stakeholder power include multi-stakeholder platforms, a respected and trusted mediator and a referee.

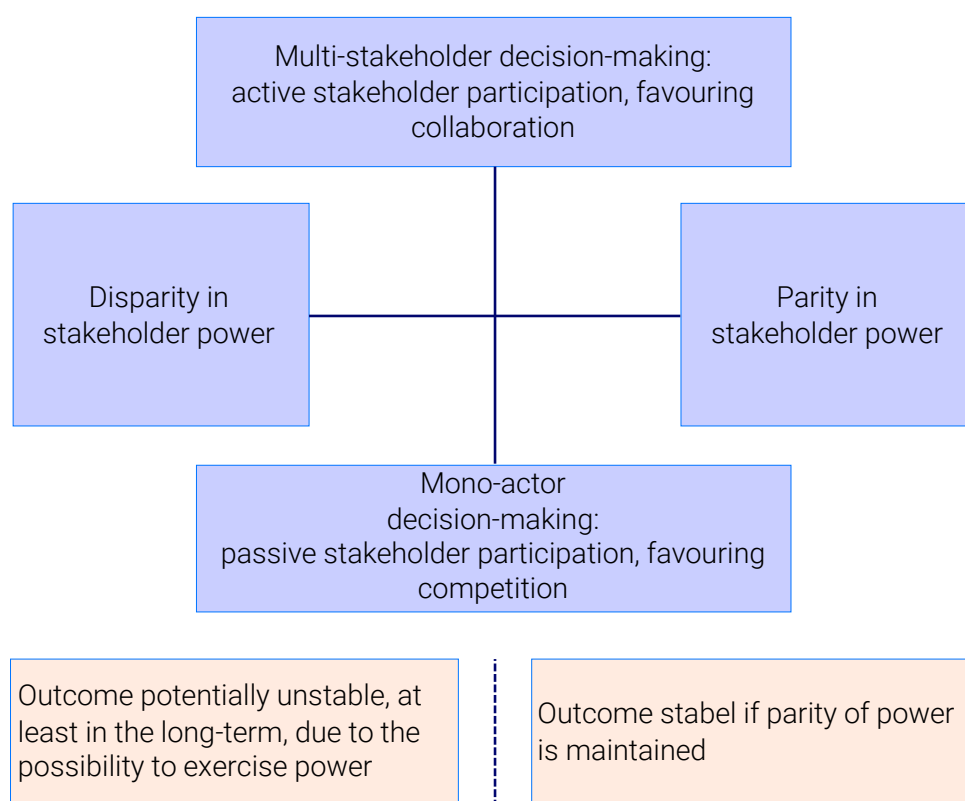
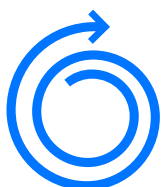


Figure 6. Linking participation and power to the quality of outcome in negotiations (Dubois, 2003).

The case energy crop-based biogas in Emilia Romagna, Italy, described by Cavicchi et al, 2017, illustrates how the above-mentioned measures can be difficult to implement, and in this case, led to unsuccessful outcome. Given tax break incentives regarding the use of land to produce biogas, there was a rush from external wealthy investors to buy or rent land from local and relatively poor farmers. This led to the rise of farmland rent price. In several cases, farmers did not have enough land to install the biogas facilities and cultivate energy crops in



addition to their food crops, resulting in competition between energy and food crops. This situation also meant that investors had to import feedstock from outside Reggio Emilia Province, which increased local traffic and pollution. This situation in turn triggered tensions and conflicts between farmers and biogas producers, and little acceptance by local people. In addition, the local government had a passive role because, formally, it could only deal with pertaining to urban planning. The above meant:

- Imbalance in stakeholders' '3Rs': Wealthy external investors took some rights to cultivate energy crops but without responsibilities to use the land in the right way. Moreover, the local government did not have any right and could not take any responsibility in local biogas development;
- No mediator or 'referee': The local government had a passive role because, formally, local governments only have urban planning responsibility
- No multi-stakeholder platform. The local government organised some meetings, but these were poorly attended and did not lead to constructive results due to the tensions between stakeholders.

3 Public and private instruments to support the scaling up of energy crops

The previous sections have discussed the potential benefits of multiple cropping set-ups, including sequential cropping practices that include energy crops in a rotation scheme or using energy crops as cover crops in sensitive periods. Moreover, the challenges and benefits of growing perennial energy crops on marginal lands were discussed. To date, the uptake of these practices is still limited. The following section explores how policy can support and incentivise these practices.

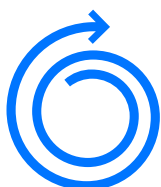
3.1 Possibilities to support energy crop growth

There is a significant opportunity for perennial energy crops to rehabilitate marginal lands and they can play an important role in meeting ambitious climate targets. Nevertheless, the uptake of perennial energy crop cultivation has continued to stagnate and significant policy intervention will be needed to overcome the present barriers to land use change for perennials. Possible policy measures include an integrated land use policy, planting grants, government-backed contracts for biomass supply, and government-supplied advice to farmers (Ford et al., 2024).

Incentives related to the growth of energy crops on marginal land could be of different types (Lewandowski et al., 2023):

- Direct incentives by governments or the private sector. Belgium, for example, is planning to pay a yearly premium of up to € 600/ha for the first five years of energy crop cultivation, covering the costs of establishment. Moreover, companies that want to secure their feedstock can either support or pay for the establishment of the crop and/or offer long-term contracts with fair and guaranteed payments for the biomass;
- Indirect incentives in the shape of payment for environmental services provided by perennial energy crop cultivation (Von Cossel et al., 2020). For example, by including environmental provisions into EU policies, in particular the Common Agriculture Policy (CAP), involving farmers in downstream stages of bioeconomy value chains through the use of biomass to fulfil their own needs (e.g., use of perennial crops as livestock bedding or as heating fuel, or to produce and sell pellets), and demonstration projects that can serve as information hubs for local farmers.

Alternatively, sequential cropping offers significant opportunity for implementing energy crop cultivation onto agricultural land. Energy crops can be integrated into a crop rotation with crops cultivated for food/feed purposes. This actually improves yields of the food/feed crops, while also improving soil health. In this way, valuable biomass feedstock for energy and materials can be supplied, without an increased land claim, minimising the risk of leading to indirect land-use changes into land with



high carbon stock. However, without sufficient financial incentive, farmers are not easily moved to adopt new farming practices. Therefore, governments and companies are needed to create financial benefit and security of demand for feedstock to stimulate the adoption of these practices.

Research shows that the most important condition to increase the uptake of sequential cropping practices, or the use of cover crops in winter periods, is the existence of a dedicated market for the produced feedstock (Magnolo et al., 2021). Policies that create incentives on the demand for energy crops as a feedstock for the production of biochemicals, biofuels and other end products can help create a commodity market for energy crops for non-food and feed purposes. In addition, policies that reward improvements in soil health, carbon stock and other environmental benefits can also help to create a push for the uptake of such practices.

3.2 Agricultural policy envisions energy crops but does not provide the necessary incentives

All multi-purpose crops are able to deliver environmental functions and will, when these functions are rewarded, be favoured by farmers. The European Union's Common Agricultural Policy (CAP) EU/2021/2115 is taking tentative first steps in supporting farmers in the uptake of energy crop cultivation in their practices. The CAP changed its approach from more compliance-based toward more result-oriented and aims to deliver on the EU's overall objectives. The performance to deliver on these objectives is assessed bi-annually. Some of these objectives are:

- *To contribute to climate change mitigation and adaptation, including by reducing greenhouse gas emissions and enhancing carbon sequestration, as well as to promote sustainable energy;*
- *To foster sustainable development and efficient management of natural resources such as water, soil and air, including by reducing chemical dependency.*

75% of direct CAP funds used to support farmers income without many conditions that improve environment and climate

The bulk of the CAP's funds are spent on direct income support to farmers (about 75%). To be eligible at all to receive such direct income support, farmers need to comply with statutory management requirements (SMRs) and good agricultural and environmental conditions (GAECs). Two GAECs are particularly relevant for energy crop cultivation:

- *GAEC 6 - Minimum soil cover to avoid bare soil in periods that are most sensitive.*
This condition can in theory incentivise the uptake of sequential cropping practices. However, Member States are given flexibility to define the "sensitive period" over which the condition applies, which leads to them watering down the impact of the measure.
- *GAEC 7 - Crop rotation in arable land, except for crops growing under water.*
Although this condition theoretically obliges crop rotation, it allows for crop diversification to be implemented as an alternative. Moreover, in implementing the CAP into national strategies, Member States often define crop rotation very weakly, lacking clear definitions of main crops and secondary crops.

These examples show a lack of clear definitions. Combined with a significant amount of flexibility in implementation between Member States, this does not help deliver the right incentives for energy crop cultivation. Member States will want to not put too much burden on its own farmers, risking of creating an unfavourable unlevel playing field. This leads to a race to the bottom, effectively leading to unambitious and ineffective policy.



Limited funds directed to environmental and climate investments

A small part of these direct payment's funds (25%) is ringfenced for farmers that adopt so called eco-schemes, measures benefiting climate and environment that go beyond the SMRs and GAECs. Assessment of the eco-schemes proposed by Member States concludes that measures that are supposed to contribute to improved soil and nutrient management are only adding very little value to existing conditionality standards and lack overall ambition (Birdlife & EEB, 2022).

The remaining budget of the CAP is spent on indirect support to farmers via rural development programmes. The agri-environmental-climate measures (AECMs) opens another opportunity to support improvement of soil health and nutrient management. Until now, however, here too the translation of CAP into national strategies has seen very low ambition in that regard.

Assessment of CAP performance: right direction, poor execution

To assess the performance of the CAP on the objective on climate change mitigation and adaptation as discussed above, certain indicators (impact, result, context) have been defined on sustainable feedstock production for renewable energy production from agriculture and forestry. Furthermore, several result indicators are identified to assess the objective on soil health and nutrient management. Many of the targets for these indicators are set quite low by Member States, missing the opportunity to generate investment in beneficial practices.

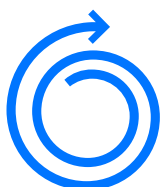
In conclusion, the CAP seems to set the right objectives and the overall design of the framework is useful to foster beneficial environmental and climate results. However, it does not yet set high ambitions, lacks clear shared definitions and the flexibility in implementation leads to a race to the bottom that waters down any ambitions of the overall policy. In effect, the agricultural policy in the EU fails to provide sufficient incentive for the adoption of energy crops in different agricultural set-ups.

3.3 Energy policy can be an important driver for energy crop cultivation

Cultivation and supply of energy crops is insufficiently incentivised by the CAP on the supply side, but the overall objective that the EU sets is clear on that sustainable production of renewable energy from agriculture is desired. The Renewable Energy Directive (RED) EU/2018/2001 and its recent amendments (RED III, EU/2023/2413) offer an opportunity for providing incentives on the demand for sustainable agricultural feedstock.

The RED's targets for renewable energy supply in different sectors and specifically in transport have proven strong incentives to the production of renewable fuels, and in effect to the sourcing of sustainable feedstock from agriculture. The RED can potentially send a strong incentive to the production of energy crops under specific conditions, such as in specific agricultural set-ups, whether on marginal land or integrated in cropping rotations.

Some feedstock categories are receiving additional stimulation by a sub-mandate, such as biofuels produced from feedstocks listed in RED Annex IX Part A, which mostly includes wastes and residues. On the other hand, some feedstock categories are subjected to capped contributions, such as biofuels produced from food and feed crops and biofuels produced from feedstocks listed in RED Annex IX Part B. Momentarily, energy crops grown as a main crop on agricultural land would classify as food and feed crop. The European Commission wants to limit the use of such food and feed crops for bioenergy usage, out of fear for indirect land use changes and competition with food security. Therefore, the Commission has set a cap on the contribution of these food and feed crops to the targets set in the RED. When grown in alternative agricultural set-ups such as the ones described previously, energy crops would not classify as food and feed crops nor any other



specific category. Therefore, they would not be subjected to any cap, but also not to any specific extra incentive.

Recently, however, the Commission proposed several changes to the feedstock list in Annex IX Part A and B (EC, 2022). This included several new additions, among which one proposed addition to Annex IX Part A that specifically offers a possibility for energy crop production on marginal lands:

(t) Non-food crops grown on severely degraded land, not suitable for food and feed crops.

In contrast, the proposed addition of another category to the list in Annex IX Part B, which is subjected to a capped contribution, poses further limitations to the possibilities for incentives to integrate energy crops into a crop rotation system with food and feed crops:

(p) Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained.

In case this category is added to the Annex IX Part B feedstock list, the incentive for fuel producers to source energy crops grown in such a set-up will be very weak, as there are other feedstock categories on that list that are already widely used and fill the capped contribution.

3.4 Need for more synergy between energy and agriculture policy to serve the climate, environment and the biobased economy

Neither policy on the supply side, the cultivation of feedstock, nor policy on the demand side, sourcing bio-feedstock is providing sufficient incentives for the adoption of energy crop cultivation practices on marginal lands or in crop rotations.

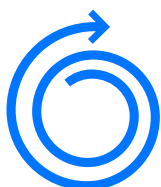
The overall objectives set by the EU give off a clear and positive signal to the cultivation of energy crops, when considering the climate, environmental and social benefits that energy crops can bring. The CAP's overall approach, targeting the supply side, is taking a result-oriented perspective and the fact that the policy's effectiveness is assessed on the basis of delivering on the abovementioned objectives would suggest a promising future for energy crop cultivation in the EU. However, the reality proves that this is insufficiently backed up by ambitious and coherent implementation to provide the needed incentives to farmers. The RED, targeting the demand side, is proving a strong impulse to demand for biomass feedstocks, especially for those feedstocks subjected to a sub-mandate. At the same time, its capped categories create an unfavourable situation for cultivation of certain types of feedstocks. This make-or-break type of situation creates uncertainty that prevents farmers from adopting new practices, such as including energy crops in their rotation, and investors from developing crop cultivation on marginal lands. This uncertainty is amplified by the possibility for feedstocks to be moved from a list subjected to a sub mandate to a list subjected to a cap, with changes being made to the Annex IX lists.

What is needed from policy is a more holistic strategy behind policy on different topic areas. While dedicated policy on agriculture and dedicated policy on renewable energy make sense from a practical point of view, they need to be aligned in order to effectively contribute to realising the overall objectives.

We would strongly recommend the European Commission to focus on the following policy actions:

- **Stick to a result-oriented approach to the CAP and the assessment of the policy on basis of key indicators.**
- **Improve the Good Agricultural and Environmental Conditions in the CAP to be more clear and less open to interpretation.**

These are minimum standards and should not be subject to interpretation by

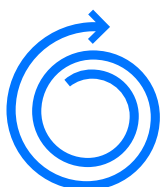


Member States. Apply a “Yes, unless” approach, obliging farmers to meet those conditions while providing an opportunity for derogation only on a well-reasoned argument backed up by evidence.

- **Increase the ringfenced budget for eco-schemes and impose a more stringent review of the Member States’ proposed eco-scheme measures.**
Farmers rely on income support so this cannot be just taken away. However, farmers should be supported by public money for delivering ecosystem services just as well as for supplying food (if not more since food is paid for by the consumer and ecosystem services are largely not).
- **Develop clear and coherent rationale as a basis for imposing a sub mandate or a cap on biofuels of a certain type in the Renewable Energy Directive.**
Sub mandates and caps can make or break business cases for biofuel production and can boost or hinder activities in other sectors, such as agriculture. Currently, the logic behind inclusion of certain feedstocks on one or the other list, is far from clear and coherent. It is evident that policy should be able to change over time. However, in order to protect investments and provide stability and perspective for farmers (but technology developers as well), a clear and coherent rationale is needed that forms the basis on which biofuels fall under a cap or are stimulated by a sub-mandate. This rationale should not be based on specific feedstock categories, but on the basis of what benefits the feedstock cultivation is bringing in terms of social, environmental and climate impact, and on basis of what technologies are used to process it (low TRL that requires additional support to further develop, or high TRL which does not need additional support).
- **Support the possibilities for energy crop cultivation in set-ups that do not compete for high value land by including them in a feedstock list with a sub mandate, not in a capped feedstock list.**
A dedicated market for energy crops can help unlock investments in energy crop cultivation on marginal lands, which helps to rehabilitate these lands. Moreover, they can convince farmers to adopt energy crops in a rotation with existing crops, which helps to increase yields of the existing crops, while improving soil quality. Finally, these energy crops provide valuable resources to the biobased economy and they substitute fossil resources from which we need to break away.

3.5 Market mechanisms: Crop insurance schemes for energy crops

Crop insurance schemes have been used for many years, but hardly any scheme exists specially regarding energy crops. Some recent work in that respect shows the positive role crop insurance could play in the deployment of energy crops (see for instance USDOE, 2023). More efforts are needed to address the gap in energy crop insurance, in particular due to the increasing threats of climate change, in particular extreme weather events such as droughts and floods. This would require partnerships between insurance providers and bankers, with government backing, like in the case of United States Department of Agriculture’s Risk Management Agency (USDA, 2021).



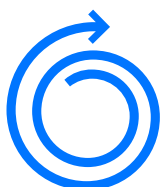
Conclusions

Residues and waste streams alone will not be enough to satisfy the future biomass demand. New avenues to unlock the biomass potential must be explored and facilitate a transition towards a new production cluster. One of the feedstock base with high potential is achieved through dedicated cropping of land-based biomass which is required to satisfy the rising demand. However, land systems are dynamic and are at the mercy of many factors such as human activity and climate variations which renders decision making around their sustainable use inherently complex. Although the notion of land availability for the production of bioenergy is often a concern, this technical note argues that land availability is not an issue. The main challenge is how can the production of bioenergy be expanded onto land in a way that is sustainable.

Many land aspects are important to take into account when considering the production of land-based bioenergy. Focusing on one issue such as ILUC is not productive. Although concerns around potential ILUC risks have for long shaped the debate, low ILUC practices are already known and include measures accepted by the European Commission. The technical note highlights the many options for the production of land-based biomass; either through 1) the use of productive land with energy crops or annual crops (i.e. intercropping, cover crops) integrated in a crop rotation with food crops or 2) the use of energy crops (i.e. perennial crops) on surplus land not suitable for food production. An integrated approach is required by the multiple stakeholders involved in the decision-making process where the synergies and different land management goals can be optimised.

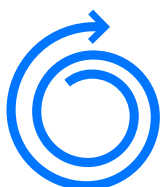
The key findings and recommendations are the following:

- Developing appropriate policies and practices to meet the worldwide demand for bioenergy in a sustainable manner must consider context specific conditions in evaluating synergies and trade-offs.
- More knowledge on cover crop agronomy and economics as well as site-specific cover crop approaches are needed, even more regarding energy ones.
- The use of energy crops on marginal land is not sufficiently known. Longer projects and more commercial-scale ones are therefore needed to overcome this research weakness.
- The main advantages of perennial energy crops lie in their low production costs (not always the case for short rotation coppice though), suitability to marginal lands, relative low water needs, low nutrient and agrochemical requirements, and positive environmental benefits.
- Compared to productive agricultural land, marginal land is usually at a disadvantage from two standpoints: can compete in terms of financial profitability and marginal lands can be used for other purposes besides bioenergy feedstocks. Therefore, judicious choices must be made between different possible uses of marginal land. This requires a science-based integrated approach that considers not only climate change mitigation but also all land use change-related environmental and socio-economic aspects, as well as an all-inclusive decision-making process where local stakeholders should play a key role.
- Priority should be place on the large-scale implementation of energy crops for which there is sufficient farm-level and commercial scale experience on productive land either in the form of annual crops in existing crop rotations or perennial crops.
- Strengthening knowledge and data about the agronomic feasibility and sustainability of both non-food annual energy crops as part of crop rotations on productive land and perennial energy crops on marginal land
- More broadly, implementing good sustainable land use practices in the deployment of energy crops is a 'no regret' way to promote the deployment of energy crops.



References

- Alexopoulou, E. et al 2013 - Annual versus Perennial Energy Crops, 21st European Biomass Conference and Exhibition.
<http://www.etaflorence.it/proceedings/index.asp?detail=9483&mode=topic&categories=0&items=%2D%2D&searchstring=cover%20crops&limit=0>
- Birdlife International, European Environmental Bureau, 2022. Soil and carbon farming in the new CAP: alarming lack of action and ambition -Policy briefing.
<https://eeb.org/wp-content/uploads/2022/06/Briefing-Soil-Health-No-Branding-V2.pdf>
- Burland, A., Von Cossel, M., 2020. Towards Managing Biodiversity of European Marginal Agricultural Land for Biodiversity-Friendly Biomass Production, *Agronomy* 2023, 13(6). <https://www.mdpi.com/2073-4395/13/6/1651>
- Calvin, K. et al, 2021. Bioenergy for climate change mitigation: Scale and sustainability, *GCB Bioenergy*.
<https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12863>
- Cavicchi, B. et al, 2017. The Influence of Local Governance: Effects on the Sustainability of Bioenergy Innovation. *Sustainability* 2017, 9, 406.
<https://doi.org/10.3390/su9030406>
- Centre for Renewable Energy Sources (CRES), Project Final report of project 4FCROPS - Future Crops for Food, Feed, Fiber and Fuel, 2010. Final Report.
https://www.etipbioenergy.eu/images/4fcrops_final-report.pdf
- Chiaramonti, D., Barsani, T., 2023. BIO4A Advanced Sustainable Biofuels for Aviation. <https://www.bio4a.eu/wp-content/uploads/2023/08/BIO4AFinal-Publication.pdf>
- Clifton-Brown, J. et al, 2023. Perennial biomass cropping and use: Shaping the policy ecosystem in European countries, *GCB-Bioenergy*.
<https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13038>
- Csikós, N., Tóth, G., 2023. Concepts of agricultural marginal lands and their utilisation: A review, *Agricultural Systems*, Volume 204 -
<https://www.sciencedirect.com/science/article/pii/S0308521X22001962>
- Daoglou, V. et al, 2020. Progress and barriers in understanding and preventing indirect land-use change, *Biofuels, Bioproducts and Biorefining*, Volume 14, Issue 5. <https://onlinelibrary.wiley.com/doi/full/10.1002/bbb.2124>
- Dauber, J. and Miyake, S., 2016. To integrate or to segregate food crop and energy crop cultivation at the landscape scale? Perspectives on biodiversity conservation in agriculture in Europe. In *BMC Energy, Sustainability and Society*.
<https://energysustainsoc.biomedcentral.com/articles/10.1186/s13705-016-0089-5>
- Dubois, O. et al, 2022. Addressing interlinkages between Energy (SDG 7) and Life on Land (SDG 15) - pp 47 to 65 of the UN Energy Report on 'Addressing Energy's Interlinkages with other SDGs'. https://sdgs.un.org/sites/default/files/2022-06/2022-UN_SDG7%20Brief-053122.pdf
- Dubois, O., 2003. Trade-offs between conservation and development in forestry - Setting the stage and some guiding principles - paper submitted to the XII Forestry Congress, 2003, Quebec City, Canada. https://www.fao.org/3/XII/0576-A2.htm#P10_167
- EC, (2024). Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels – Annex 2 Report on Task 2.
<https://op.europa.eu/en/publication-detail/-/publication/bae246b8-c4da-11ee-95d9-01aa75ed71a1/language-en>



EC, 2023. Overview of the potential and challenges for agri-photovoltaics in the European Union, Publications Office of the European Union.
<https://data.europa.eu/doi/10.2760/208702>

EC, 2022b. Update of list of sustainable biofuel feedstocks. Commission Delegated Directive amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council, as regards adding feedstocks for the production of biofuels and biogas. https://eur-lex.europa.eu/legal-content/EN/PIN/?uri=PI_COM:Ares%282022%298413323

EC, 2022a. Analysis of actual land availability in the EU; trends in unused, abandoned and degraded (non-) agricultural land and use for energy and other non-food crops: Final report. Publications Office of the European Union.
<https://data.europa.eu/doi/10.2833/609071>

EC, 2019b. Commission Delegated Regulation (EU) 2019/807 of March 2019.
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0807>

EC, 2019a. Sustainability Criteria for Biofuels Specified.
https://ec.europa.eu/commission/presscorner/detail/en/MEMO_19_1656

EC, 2018. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

Englund, O. et al, 2020a. Beneficial land use change: Strategic expansion of new biomass plantations can reduce environmental impacts from EU agriculture. *Global Environmental Change*.
https://www.researchgate.net/publication/331825959_Beneficial_land_use_change_Strategic_expansion_of_new_biomass_plantations_can_reduce_environmental_impacts_from_EU_agriculture

Englund, O. et al, 2020b. Multifunctional perennial production systems for bioenergy: performance and progress, *WIREs Energy and Environment*.
<https://wires.onlinelibrary.wiley.com/doi/10.1002/wene.375>

Englund, O. et al, 2021. Strategic deployment of riparian buffers and windbreaks in Europe can co-deliver biomass and environmental benefits. *Commun Earth Environ* 2, 176 (2021). <https://doi.org/10.1038/s43247-021-00247-y>

Englund et al, 2022. Large-scale deployment of grass in crop rotations as a multifunctional soil-based climate mitigation strategy.
<https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.13015>

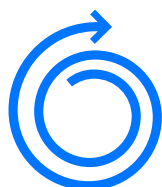
Faaij, A.P.C., 2022. Repairing What Policy Is Missing Out on: A Constructive View on Prospects and Preconditions for Sustainable Biobased Economy Options to Mitigate and Adapt to Climate Change. *Energies*. 15.
https://www.researchgate.net/publication/362776267_Repairing_What_Policy_Is_Missing_Out_on_A_Constructive_View_on_Prospects_and_Preconditions_for_Sustainable_Biobased_Economy_Options_to_Mitigate_and_Adapt_to_Climate_Change

FAO, 2020. Sustainable bioenergy potential in Zambia, Environment and Natural Resources Working Paper #84, Rome.
<https://www.fao.org/3/cb1528en/cb1528en.pdf>

FAO, 2010b. The BEFS analysis in Tanzania, Environment and Natural Resources Management Working Paper #35, Rome. <https://www.fao.org/3/i1544e/i1544e.pdf>

FAO, 2010a. Making Integrated Food-Energy Systems Work for People and Climate - An Overview, Environment and Natural Resources Management Working Paper # 45, Rome. <https://www.fao.org/3/i2044e/i2044e.pdf>

Fayet, C.M.J. et al, 2022. The potential of European abandoned agricultural lands to contribute to the Green Deal objectives: Policy perspectives, *Environmental*



Science & Policy, Volume 133, pp.44-53.

<https://www.sciencedirect.com/science/article/pii/S1462901122000946>

Fehrenbach, H. et al, 2023. The Carbon and Food Opportunity Costs of Biofuels in the EU27 plus the UK, IFEU. <https://www.ifeu.de/en/publication/the-carbon-and-food-opportunity-costs-of-biofuels-in-the-eu27-plus-the-uk/>

Ford, J.S. et al, 2024. The factors determining uptake of energy crop cultivation and woodland creation in England: Insights from farmers and landowners, Biomass and Bioenergy, Volume 180.

<https://www.sciencedirect.com/science/article/pii/S0961953423003203>

Fritsche, U. et al, 2017. Energy and Land Use - Global Land Outlook Working Paper.

http://www.globalbioenergy.org/uploads/media/1709__UNCCD_Irena_Energy_and_Land_Use..pdf

GBEP, 2020. Collection of examples: Positive Relationships between Sustainable Wood Energy and Forest Landscape Restoration.

http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG4/AG4_Collection_of_examples_links_sust_wood_energy_and_FLR_June2020.pdf

GBEP, 2016. Examples of Positive Bioenergy and Water Relationships.

https://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2015_events/AG6_workshop_25-26_August_2015/AG6_Examples_of_Positive_Bioenergy_and_Water_Relationships_Final.pdf

Gelfand I et al, 2020. Empirical Evidence for the Potential Climate Benefits of Decarbonizing Light Vehicle Transport in the U.S. with Bioenergy from Purpose-Grown Biomass with and without BECCS. Environmental Science and Technology 2020 Mar 3;54(5):2961-2974. <https://pubmed.ncbi.nlm.nih.gov/32052964/>

Hamada, Y. et al, 2021. Remote Sensing-Based Estimation of Advanced Perennial Grass Biomass Yields for Bioenergy. Land 2021, 10.

<https://doi.org/10.3390/land10111221>

Heaton, E.A. et al, 2013. Managing a second-generation crop portfolio through sustainable intensification: Examples from the USA and the EU, Biofuels, Bioproducts and Biorefining.

<https://onlinelibrary.wiley.com/doi/abs/10.1002/bbb.1429>

IEA, 2021. Net Zero by 2050 A Roadmap for the Global Energy Sector. [Net Zero by 2050 - A Roadmap for the Global Energy Sector \(windows.net\)](https://www.iea.org/net-zero)

IEA-Bioenergy, 2022. Towards an improved assessment of indirect land-use change. https://www.ieabioenergy.com/wp-content/uploads/2023/06/IEA-Bioenergy-iLUC-report_Final.pdf

IEA Bioenergy, 2017. Is there enough room for bioenergy in agriculture?

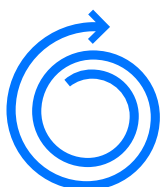
<https://www.ieabioenergy.com/iea-publications/faq/agriculture/>

IIED, 2005. The '4Rs', in Policy-Power Tools. <https://policy-powertools.org/Tools/Understanding/TFR.html>

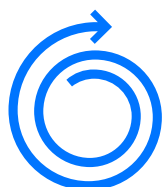
Imperial College Consultants, 2021. Sustainable Biomass Availability in the EU to 2050. <https://www.concawe.eu/wp-content/uploads/Sustainable-Biomass-Availability-in-the-EU-Part-I-and-II-final-version.pdf>

Kalt, G. et al, 2019. Natural climate solutions versus bioenergy: Can carbon benefits of natural succession compete with bioenergy from short rotation coppice? GCB-Bioenergy.

<https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12626#:~:text=Natural%20climate%20solutions%20versus%20bioenergy%3A%20Can%20carbon%20benefits%20of%20natural%20succession%20compete%20with%20bioenergy%20from%20short%20rotation%20coppice%3F>



- Kalt, G. et al, 2020. Greenhouse gas implications of mobilizing agricultural biomass for energy: a reassessment of global potentials in 2050 under different food-system pathways, *Environmental Research Letters*, Volume 15, Number 3. <https://iopscience.iop.org/article/10.1088/1748-9326/ab6c2e/pdf>
- Kathage, J. et al, 2022. How much is policy driving the adoption of cover crops? Evidence from four EU regions, *Land Use Policy*, Volume 116. <https://www.sciencedirect.com/science/article/pii/S0264837722000436>
- Kiesel, A. et al, 2023. Valorisation of marginal agricultural land in the bioeconomy, *GCB-Bioenergy*. <https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13105>
- Koppelmäki, K., Lamminen, M., Helenius, J., & Schulte, R. P. O. 2021. Smart integration of food and bioenergy production delivers on multiple ecosystem services. *Food and Energy Security*, 10, 351-367. <https://doi.org/10.1002/fes3.279>
- Lehmann, J. et al, 2021. Biochar in climate change mitigation. *Nat. Geosci.* 14, 883-892 (2021). <https://doi.org/10.1038/s41561-021-00852-8>
- Lewandowski, I. et al, 2023. Fostering the delivery of private and public goods from perennial cropping systems through policy measures, 2023 European Biomass Conference and Exhibition Proceedings. <http://www.etaflorence.it/proceedings20Proceedings%20&limit=0>
- Lowenskiöld, A.C. et al, 2022. Comparing the climate change mitigation potentials of alternative land uses: Crops for biofuels or biochar vs. natural regrowth, *Geography and Sustainability*, Volume 3, Issue 4, pp.347-357. <https://www.sciencedirect.com/science/article/pii/S266668392200075X#bib0010>
- Magnolo, F. et al, 2021. The Role of Sequential Cropping and Biogasdoneright TM in Enhancing the Sustainability of Agricultural Systems in Europe. *Agronomy*, Volume 11, Issue 11, 2102. <https://doi.org/10.3390/agronomy11112102>
- Martani, E. et al, 2022b. Energy Crops and Biochar: A Win-Win Strategy for Energy Production and Soil Improvement, 30th European Biomass Conference and Exhibition. <http://www.etaflorence.it/proceedings/?detail=19494>
- Martani, E. et al, 2022a. Reversion of Perennial Biomass Crops to Conserve C and N: A Meta-Analysis. *Agronomy* 2022, 12, 232. <https://doi.org/10.3390/agronomy12020232>
- Mertens, A. et al, 2019. Overcoming non-technical challenges in bioeconomy value-chain development: Learning from practice, *Journal of Cleaner Production* 231, pp.10-20. <https://core.ac.uk/download/pdf/225020873.pdf>
- Meyfroidt, P. et al, 2021. Ten facts about land systems for sustainability. *PNAS* Vol 119/No7. www.pnas.org/doi/10.1073/pnas.2109217118
- Muscat, A. et al, 2022. The Promised Land: Contrasting frames of marginal land in the European Union, *Land Use Policy*, Volume 112. <https://www.sciencedirect.com/science/article/pii/S0264837721005834>
- Muscio, A. et al, 2023. Bridging the valley of death in the EU renewable energy sector: Toward a new energy policy, *Business Strategy and the Environment* 32(1). https://www.researchgate.net/publication/368771979_Bridging_the_valley_of_death_in_the_EU_renewable_energy_sector_Toward_a_new_energy_policy
- Panoutsou, C. et al, 2022b. Social considerations for the cultivation of industrial crops on marginal agricultural land as feedstock for bioeconomy, *Biofuels, Bioproducts and Biorefining*. <https://onlinelibrary.wiley.com/doi/10.1002/bbb.2376>
- Panoutsou, C. et al, 2022a. Opportunities for Low Indirect Land Use Biomass for Biofuels in Europe, *Appl. Sci.* 2022, 12, 4623. <https://doi.org/10.3390/app12094623>
- Panoutsou, C. and Alexopoulou, E., 2021. D3.2: PANACEA Roadmap, PANACEA Project. <https://ec.europa.eu/research/participants/documents/downloadPublic?documentId=s=080166e5dd3592fd&appId=PPGMS>



Panoutsou, C. et al, 2021. D1.3 Strength and opportunities of near-to-practice non-food crops (NFCs), PANACEA project.

<https://ec.europa.eu/research/participants/documents/downloadPublic?documentId=080166e5db5b04c&appId=PPGMS>

Pari, L. et al, 2019. The SUSCACE Project - Scientific Support for Agricultural Conversion to Energy Crops, 27th European Biomass Conference and Exhibition.

<http://www.etaflorence.it/proceedings/index.asp?detail=16959&mode=topic&categories=0&items=%2D%2D&searchstring=energy%20crops&limit=0>

Ramirez-Contreras, N.E et al, 2020. The GHG emissions and economic performance of the Colombian palm oil sector; current status and long-term perspectives. J. Clean. Prod., 258.

<https://www.sciencedirect.com/science/article/pii/S0959652620308040?via%3Dihub>

Reinhardt, J. et al, 2021. A Review of Industrial Crop Yield Performances on Unfavorable Soil Types, Agronomy 2021, 11(12), 2382.

<https://doi.org/10.3390/agronomy11122382>

Rowe, R., et al, 2022. Land Use Decision-Making for Biomass Deployment, Bridging the Gap between National Scale Targets and Field Scale.

Decisions. https://www.super-gen-bioenergy.net/wp-content/uploads/2022/07/Report-_Land-use-decision-making-Super-gen-Bioenergy-Hub.pdf

Rowe, R. et al, 2020. Soil carbon stock impacts following reversion of Miscanthus x giganteus and short rotation coppice willow commercial plantations into arable cropping, GCB-Bioenergy. <https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12718>

Sandstad Næss, J et al 2023. Climate change mitigation potentials of biofuels produced from perennial crops and natural regrowth on abandoned and degraded cropland in Nordic countries, Journal of Environmental Management.

<https://www.sciencedirect.com/science/article/pii/S0301479722020473?pes=vor>

Scordia, D. et al, 2023. Towards identifying industrial crop types and associated agronomies to improve biomass production from marginal lands in Europe, GCB-Bioenergy. <https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12935>

Selena, A. et al, 2021. Systematic review on effects of bioenergy from edible versus inedible feedstocks on food security, npj Science of Food, 5, 9 (2021).

<https://doi.org/10.1038/s41538-021-00091-6>

Shepperd, A W., 2013. Contract farming for biofuels: a literature review, Food Chain 2013 Vol.3 No.3 pp.186-196.

<https://practicalactionpublishing.com/article/2897/contract-farming-for-biofuels-a-literature-review>

Smit, B. et al, 2019. Adoption of cover crops for climate change mitigation in the EU, EUR 29863 EN, Publications Office of the European Union.

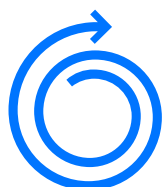
https://r.search.yahoo.com/_ylt=AwrLD1Szk7JI3EUMJIPc5oIQ;_ylu=Y29sbwNpcjIEcG9zAzQEdnRpZAMEc2VjA3Ny/RV=2/RE=1706230835/RO=10/RU=https%3a%2f%2fpublications.jrc.ec.europa.eu%2frepository%2fbtstream%2fJRC116730%2fccc_report.pdf/RK=2/RS=C2Y39ZO_RG9RM6aGK5tat43H2gc-

US Department of Agriculture, 2021. Risk Management Agency Fact Sheet.

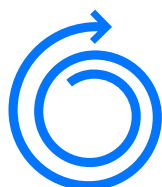
<https://www.rma.usda.gov/en/Fact-Sheets/National-Fact-Sheets/About-the-Risk-Management-Agency>

US Department of Energy, 2023. Deploying Purpose-Grown Energy Crops for Sustainable Aviation Fuel - Workshop Summary Report | June 2023.

<https://www.energy.gov/eere/bioenergy/articles/deploying-purpose-grown-energy-crops-sustainable-aviation-fuel-workshop-0>

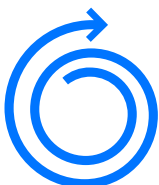


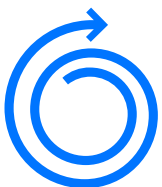
- Van der Laan, C. et al, 2017. Mitigation of unwanted direct and indirect land-use change-An integrated approach illustrated for palm oil, pulpwood, rubber and rice production in North and East Kalimantan, Indonesia. *GCB Bioenergy* 9, pp. 429-444. <https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12353>
- Veldkamp, E. et al, 2023. Multifunctionality of temperate alley-cropping agroforestry outperforms open cropland and grassland, *Commun Earth Environ* 4, 20 (2023). <https://doi.org/10.1038/s43247-023-00680-1>
- Vera, I. et al, 2022. Land use for bioenergy: Synergies and trade-offs between sustainable development goals, *Renewable and Sustainable Energy Reviews*, 10.1016/j.rser. <https://www.sciencedirect.com/science/article/pii/S1364032122003173?pes=vor>
- Vera, I. et al, 2021. Supply potential of lignocellulosic energy crops grown on marginal land and greenhouse gas footprint of advanced biofuels—A spatially explicit assessment under the sustainability criteria of the Renewable Energy Directive Recast, *GCB-Bioenergy*. <https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12867>
- Vermeulen, S. and Goad, N. 2006. Towards better practice in smallholder palm oil production. *Natural Resource Issues Series No 5*, IIED, London, UK. <https://www.iied.org/13533iied>
- Von Cossel, M. et al, 2020b. Bridging the gap between biofuels and biodiversity through monetizing environmental services of *Miscanthus* cultivation. *Earth's Future*, 8, e2020EF001478. <https://zenodo.org/records/4749161#.YJucki8evuQ>
- Von Cossel, M. et al, 2020a. Deliverable 4.1: Low-input agricultural practices for industrial crops on marginal land, MAGIC Project. https://zenodo.org/records/3539369/files/D4.1_UHOH.pdf?download=1
- Von Cossel, M. et al, 2019. Marginal Agricultural Land Low-Input Systems for Biomass Production, *Energies*, Volume 12, Issue 16. <https://www.mdpi.com/1996-1073/12/16/3123>
- Welfle, A. and Mirjam Röder, M., 2022. Mapping the sustainability of bioenergy to maximise benefits, mitigate risks and drive progress toward the Sustainable Development Goals, *Renewable Energy*, Volume 191, 2022, Pages 493-509. <https://www.sciencedirect.com/science/article/pii/S0960148122004463>
- Wicke B et al, 2015. ILUC prevention strategies for sustainable biofuels: Synthesis report from the ILUC Prevention project. Utrecht University, Utrecht, the Netherlands - <http://www.geo.uu.nl/iluc>
- Winberg, J. et al, 2023. Bioenergy crops, biodiversity and ecosystem services in temperate agricultural landscapes—A review of synergies and trade-offs. *GCB Bioenergy*. https://www.researchgate.net/publication/373444915_Bioenergy_crops_biodiversity_and_ecosystem_services_in_temperate_agricultural_landscapes-A_review_of_synergies_and_trade-offs
- WOCAT, ND. WOCAT SLM Database, Global Database on Sustainable Land Management. https://qcat.wocat.net/en/wocat/list/?type=wocat&filter__qg_funding_project_funding_project=1
- Woods, J.L.L. et al, 2015. Land and Bioenergy in Scientific Committee on Problems of the Environment (SCOPE), *Bioenergy & Sustainability: Bridging the Gaps*; Oak Ridge National Laboratory (ORNL): Oak Ridge, TN, USA, 2015. http://bioenfapesp.org/scopebioenergy/images/chapters/bioen-scope_chapter09.pdf
- World Bank and UNCTAD, 2018. Outgrower Schemes, RAI KN04. <https://openknowledge.worldbank.org/handle/10986/29466>



World Economic Forum & McKinsey & Company, 2020. Clean Skies for Tomorrow Insight report, November 2020. <https://www.weforum.org/publications/clean-skies-for-tomorrow-sustainable-aviation-fuels-as-a-pathway-to-net-zero-aviation/>

Yang, L. et al, 2023. A Review on Potential Biofuel Yields from Cover Crops. Fermentation 2023, 9, 912. <https://doi.org/10.3390/fermentation9100912>





Platform Hernieuwbare Brandstoffen
Cruquiusweg 111A
1019 AG Amsterdam
The Netherlands
contact@hernieuwbarebrandstoffen.nl
www.hernieuwbarebrandstoffen.nl
February 2024

