Chapter 3.

Measuring biomass potential and sustainability

This chapter examines the issues around setting biomass sustainability as an essential element to a future bioeconomy. Use of biomass for bio-based production in ambitious bioeconomy plans is fraught with the risk of unsustainable, over-exploitation of natural resources. Developing only modest bioeconomy strategies is one option, but may not achieve the longer-term goals of highly ambitious reductions of greenhouse gas (GHG) emissions. Another option is to create ambitious bioeconomy plans that make biomass production and use more efficient. However, studies also point out that more land is needed to produce biomass. So a dual strategy can be envisioned – land intensification and extensification. Each brings its own problems; the most frequently discussed relate to sustainability, and the inevitable competition for land between food and industrial use. There is no international agreement yet on how to measure biomass sustainability. As a result, estimates of biomass potential (how much can be grown sustainably) vary greatly. New institutions may be necessary to harmonise sustainability assessments.

Introduction

Biomass potential refers to how much biomass can actually be grown at any scale – regional, national, supranational or global. Measurements generally fall into three different categories – agricultural, forestry and waste biomass – and may or may not consider marine biomass as the studies; they are usually focused on the sustainability of terrestrial sources. However, marine biomass will play important roles in securing biomass in the future. As seen in a later part of this book, marine biorefining models are among the least developed for mainly technical reasons.

Future bioeconomy policy must also consider the roles of non-biomass carbon that exist in huge quantities but are as yet barely used. These can take pressure off land use for industrial sources of biomass, allaying fears about using biomass for industry when the top priority is for food. Industrial sources of CO_2 are already used for specific purposes, such as for carbonating soft drinks. However, this hardly scratches the surface of the potential of waste CO_2 and other industrial gases for biorefining such as CO and H_2. The use of these waste gases in fermentation has already begun, but the technologies are in their infancy. A strong focus of biomass sustainability thinking and policy is how these vast reserves of carbon could, in future, greatly alleviate pressure on land.

Sustainable biomass potential can be defined as the fraction of the technical biomass potential that does not oppose the general principles of sustainable development, i.e. the fraction that can be exploited in an economically viable manner without causing social or ecological damage (Rettenmaier, 2008).

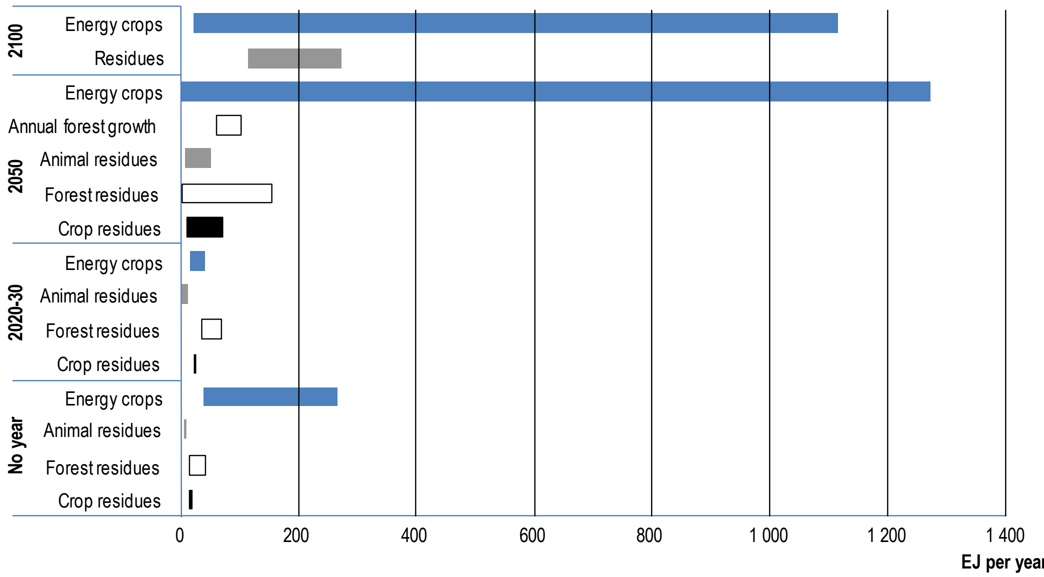
How much biomass can be grown and how much is needed: Biomass potential

The recurring theme around biomass potential is "uncertainty". There are no internationally accepted metrics or tools to apply questions of sustainability to biomass (Bosch et al., 2015). Not surprisingly, biomass potential estimates are extremely variable. Working from 17 separate studies, Saygin et al. (2014) identified a discrepancy in estimates of biomass potential of 20-fold from highest to lowest (75 to as high as 1 500 exajoules per year [EJ/yr] in 2050). Figure 3.1 helps illustrate these discrepancies. Schueler et al. (2016) observed a range of technically available potentials between 50-500 EJ per year by mid-century. Applying sustainability criteria to the available biomass potential decreases it considerably.

Types of biomass potential assessment

Several studies over the past years have used a range of techniques to estimate the available land for bioenergy production – from simple data assumptions to robust high-resolution land mapping. Hence, large differences in estimates exist. Most studies provide detailed insights into future biomass potential, but fail to include all critical factors involved in the assessment. An "ideal" study to evaluate biomass potential should consider global and regional trends, as well as local conditions such as soil types, water availability, possibility of irrigation and land-use planning. It should further consider biodiversity and soil quality (Dornburg et al., 2008). However, this ideal may only be possible at a restricted regional level, if at all. These crucial factors can hugely alter the range of sustainable biomass potential. Seidenberger et al. (2008) have attempted to compile global biomass potential ranges from 18 different studies (Figure 3.1).

Figure 3.1. **A compilation of estimates for global biomass potentials**



Note: EJ = exajoules.

Source: Adapted from Seidenberger et al. (2008), *Global Biomass Potentials – Investigation and Assessment of Data, Remote Sensing in Biomass Potential Research, and Country-specific Energy Crop Potentials*.

This shows the minimum and maximum potentials estimated by different studies.

Discrepancies in biomass potential estimates

Studies attempting to estimate the availability of biomass have considered both optimistic and pessimistic approaches. The range varies for several reasons. There are different objectives elaborated over different time frames. Many biomass potential studies have future estimates until 2050, but less information is available on the short term. Various methodologies and approaches have also been used to estimate biomass potential. In addition, the lack of a commonly agreed definition on the types of biomass (forest residues, harvest and process residues) influences estimates. This leads to different data sets generated with different criteria. Estimates depend on developing scenarios, but scenario assumptions vary widely. Further, some studies lack transparency and may omit factors. Finally, the geographical scope of different studies can make results confusing to compare.

Calculating biomass potential and estimating the size of a potential bioeconomy

Numerous options exist for replacing liquid fossil fuels in the long term. Material uses, for example, include plastics, chemicals and textiles. But once the options are examined, the only serious contender in terms of quantity is biomass. Bioenergy is the most important renewable energy option, at present and in the medium term (Ladanai and Vinterbäck, 2009). However, bioenergy also offers the greatest potential for unsustainable, over-use of biomass due to the volumes required.

Dual use of biomass is effectively a competition for land with food use always taking first priority. The availability of sustainable biomass as a future substitute for fossil resources depends on the available land for biomass cultivation, and options to use the biomass produced in agriculture and forestry more efficiently.

To understand these two factors, it is necessary to know how biomass flows in agriculture and forestry. If these flows of biomass over the world can be quantified, the potential to use more biomass for new applications without disturbing current applications can be assessed. Unsurprisingly, there have been many estimates of biomass flows, all with high levels of uncertainty.

One main source of uncertainty is the underlying assumption regarding the amount of unused agricultural land available for cultivation of bioenergy crops, and to what extent natural grasslands contribute to this potential. In particular, assumptions regarding future agricultural productivity and future consumption of animal products have a great impact on the results. Furthermore, the amounts of available waste and residue resources strongly depend on the still uncertain future demand for other applications such as animal feed and soil quality improvers. Moreover, estimates are necessarily indicative because future trade is uncertain.

The energy content of agricultural crops, including their residues produced across the world, is estimated at 200 EJ; grass- and rangelands produce about 115 EJ. Both mainly deliver the inputs for human food. Most of the energy is not available for the energy system because it is vital in the livestock system and also for people. Setting aside the unused and sometimes burned crop residues for energy could increase the extraction by about 24 EJ. This assumption considers sustainable soil carbon management (roughly half of the above-ground carbon should remain in the soil). Other potential energy sources are better use of waste flows from industrial processing and consumption. This could produce an additional 21 EJ.

Another uncertainty around estimating biomass potential is the future extent of the bioeconomy, which is decided politically as well as scientifically. Estimates therefore often rely on scenario development. The Netherlands Environmental Assessment Agency (PBL) defined three different scenarios for biomass potential to 2050 (PBL, 2012):

- High:
  - very productive agriculture, leaving land for energy crops
  - use of almost all sustainably available residues and waste
  - successful new developments.
- Mid:
  - more productive agriculture, but quite limited land for energy
  - use of about half of the sustainably available residues and waste
  - only a few new developments for niche markets.
- Low:
  - unsustainable land use for energy crops
  - use of only a small part of residues and wastes
  - no new developments.

These scenarios assessed the global biomass potential for energy use in 2050. According to the PBL and ECN (Energy Research Centre of the Netherlands), most studies estimate the potential availability of 150-250 EJ of sustainable biomass by 2050, which is considered economically feasible. For 2030, PBL considers 100 EJ as a "realistic" estimate and 200 EJ as an "optimistic" estimate of available sustainable biomass on the world market.

As a further illustration, the potential for Europe (including trade) would be about 10 EJ based on "mid" expectations assuming an equal distribution per capita in 2050. With a distribution based on income, the potential might double. The European Union will therefore probably depend on the world market to supply biomass for its bioeconomy in the future.

Policy implications

- The total supply of sustainable biomass in 2030 may be enough to fulfil the demand in a 10% bio-based economy (PBL, 2012).
- A highly ambitious bioeconomy increases the risk of a non-sustainable supply and over-exploitation of natural resources.
- In light of growing trade, the numbers need to be continuously re-assessed.
- Looking beyond 2030 to 2050, many new initiatives and technologies will be required to reach the potential of sustainable biomass.
- Algal biomass may be useful in the future, but costs are currently much too high for bioenergy. However, if future development of aquatic biomass is successful, this type of biomass production could offer new possibilities. Suggesting any number for future potential is just a first guess. At this stage, feasibility studies and research and development (R&D) support are the most obvious policy options.

Experience with estimating biomass potential in the United States

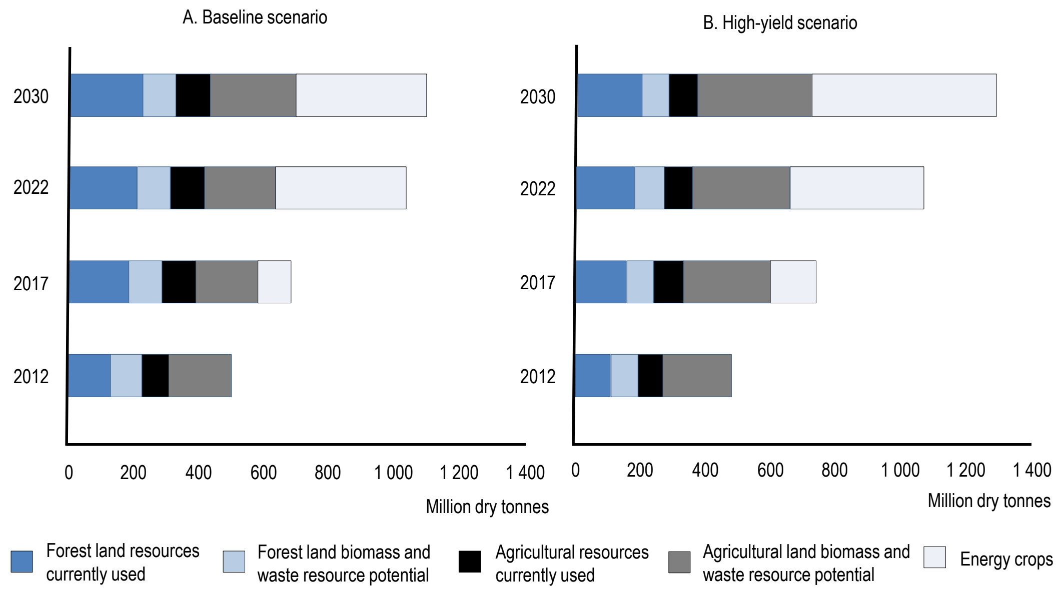
Over the past decade, the United States has made a concerted effort to discover the national biomass potential. This resulted in the first *Billion Ton Report*, completed in 2005 and subsequently updated (US DOE, 2017, 2016, 2011, 2005). The basics remain the same throughout these reports: the United States, depending on assumptions, might produce 1 billion tonnes of dry biomass per annum. This would substitute 30% of gasoline requirements with renewable biofuels. The authors estimate the country uses 365 million dry tonnes of agricultural crops, forestry resources and waste to generate biofuels, renewable chemicals and other bio-based materials. The most recent updates also evaluate the policies and economic conditions needed to direct investment to the bio-based economy and to build the biorefineries that will use potential biomass resources.

Like other biomass potential studies, the *Billion Ton* studies are based upon scenarios:

- *The baseline scenario*: Combined resources from forests and agricultural lands total about 473 million dry tonnes at USD 60 per dry tonne or less (about 45% is used and the remainder is potential additional biomass). By 2030, estimated resources increase to nearly 1.1 billion dry tonnes (about 30% would be projected as already used biomass and 70% as potentially additional).
- *The high-yield scenario*: Total resource ranges from nearly 1.4 billion to over 1.6 billion dry tonnes annually of which 80% is potentially additional biomass. No high-yield scenario was evaluated for forest resources, except for woody crops.

The adopted methodology allowed estimates of the biomass potential of different sub-sectors (Figure 3.2). This is critical when developing future scenarios. Technological developments in one sub-sector may offset a lack of development in another. And as they change, this may alert governments to future policy needs.

Figure 3.2. **Biomass potential in the baseline scenario (a) and high-yield scenario (b)**



Source: Stokes (2014), "The 'Billion Ton Update': Methodologies and implications".

Stokes (2014) described ten principles for developing a methodology (Box 3.1). With this in mind, assessments should include:

- Adequate and verifiable data and information: biomass should be considered a commodity like other agricultural and forest products. Investments are needed to provide such information.
- Yield: a significant variable in biomass supply is yield either from residues and wastes or from energy crops. Geography and local climate alone create variability. The literature, empirical studies and expert opinion are used to develop yield estimates. Scenarios incorporated a range of annual yield increases.
- Supply curves: estimates for biomass availability assume different prices. Farm gate/roadside costs are developed for each feedstock and modelled to determine biomass availability at a given price.
- Sustainability: this is another important, underlying premise to be incorporated into the analysis. Different feedstocks require different approaches. These include using multipliers and coefficients to model certain parameters such as soil carbon retention.
- Land availability and land-use change: land availability is important in estimating biomass production and land-use change is an important sustainability issue. Land competition between conventional crops and energy crops, and among energy crops are modelled.

Box 3.1. Ten principles for developing a methodology to estimate biomass potential

1. Determine desired outcomes and probable uses; available data and analytical resources; and, then determine the “best” approach.
2. Use commonly accepted terminology and definitions of land-use classes and other variables and functions. Be consistent.
3. Use well- and consistently-defined feedstocks – from categories to a single feedstock.
4. Use various analytical tools dependent on availability of data and models; document and explain.
5. Use various data sources (mostly publicly available for transparency) and document extrapolation; rely on many disciplines and professionals to have the technical depth required to understand and use the data appropriately.
6. Use additional data, analyses and experts so that scenarios are both realistic and useable.
7. Put other models to work to overcome specific issues such as sustainability criteria.
8. Work at the most appropriate spatial level based on data and models. Try to complete analysis for smallest spatial units and aggregate upwards to area, state, region and national.
9. Provide and document all background work and assumptions.
10. Explain and document the details of the analyses and the outcomes and the application of the results.

Source: Stokes (2014), “The ‘Billion Ton Update’: Methodologies and implications”.

A regional example in the United States

Dedicated energy crops and crop residues are considered to be able to meet herbaceous demands for the new bioeconomy in the central and eastern United States. Perennial warm-season grasses and corn stover are well-suited to the eastern half of the country. They provide opportunities for expanding agricultural operations in the region. The Department of Agriculture’s Agricultural Research Service and collaborators associated with its Regional Biomass Research Centers have developed a suite of warm-season grasses and associated sustainable management practices. Second-generation biofuel feedstocks provide an opportunity to increase production of transportation fuels from recently fixed plant carbon rather than from fossil fuels. Although there is no “one-size-fits-all” bioenergy feedstock, crop residues like corn stover are the most readily available bioenergy feedstocks. However, on marginally productive cropland, perennial grasses provide a feedstock supply while enhancing ecosystems services. Twenty-five years of research have demonstrated that perennial grasses like switchgrass are profitable and environmentally sustainable on marginally productive cropland in the western corn belts and southeastern United States (Mitchell et al., 2016).

Harmonising sustainable biomass potential

The *Billion Ton* reports may give leads on how to harmonise the approaches, which, as already highlighted, vary in underlying methodologies, assumptions and analyses. It is important to estimate effectively the sustainable capacities for biomass production for both domestic use and international biomass trade.

Japan and biomass policy

Biomass availability is an issue for the development of a Japanese bioeconomy. However, Japan was one of the earliest developers of major biomass policy, which Table 3.1 charts from 2002. Other OECD countries could learn from Japan, especially considering its success in creating "biomass towns". Japan's practical experience in making value chains may also be transferrable.

Table 3.1. **Japanese biomass policies 2002-12**

Year	Policies	Outline
2002	Biomass Nippon Strategy	– Basic national strategy to realise sustainable society with full biomass utilisation, and beginnings of Biomass Towns 2004
2005	Kyoto Protocol Target Achievement Plan	– Promoting widespread use of biofuels – Building Biomass Towns and developing biomass energy conversion technologies
2006	Biomass Nippon Strategy (revised)	– Biomass energy for fuels for transportation – Goal of 300 Biomass Towns by 2010
2009	Basic Act for the Promotion of Biomass Utilisation	– Planned promotion of biomass utilisation policy – Drawing up National Plan for Promotion of Biomass Utilisation – Setting up National Biomass Council
2010	Basic Energy Plan	– Introduced renewable energy in 10% primary energy supply by 2020
2010	Act Concerning Sophisticated Methods of Energy Supply Structure	– Required oil refiners to produce specified volumes of biofuels
2010	National Plan for Promotion of Biomass Utilisation	– Setting targets for 2020 – Setting basic policies on technology development for biomass utilisation
2012	Biomass Industrialisation Strategy	– Specified targeted conversion technologies and biomass for realising biomass industrialisation – Setting principles and policies for realising biomass industrialisation

Measuring biomass sustainability

No internationally agreed tools or indicators for biomass sustainability

There are no internationally agreed tools or indicators to measure biomass sustainability. Life cycle analysis (LCA) is frequently discussed as a tool, but only considers environmental performance, and not economic or social factors. Moreover, significant data gaps exist in the availability of life cycle inventory data (Grabowski et al., 2015). Other sustainability tools fail to meet fundamental scientific requirements for index formation: normalisation, weighting and aggregation (Böhringer and Jochem, 2007). No one assessment tool fits the needs of biomass sustainability.

There is also no international agreement on criteria to measure biomass sustainability. International harmonisation requires not only robust analysis, but also consensus, which is often more difficult to achieve. Social criteria are sometimes regarded as unreliable and impractical because they are difficult to measure. As a result, they tend to be assigned a low ranking (van Dam and Junginger, 2011). But they may have strong bearing on true sustainability by analysing issues such as workers' rights and land rights (Shawki, 2016).

As their major limitation, the vast majority of methods cannot aggregate the different sustainability issues into a single measure objectively (Gaitán-Cremaschi et al., 2015). Aggregation requires making complicated trade-offs between sustainability and other factors that are not necessarily intuitive. Practitioners can only generate an overall sustainability number by using their own weighting factors when aggregating the different impact categories; this introduces subjectivity.

LCA in assessment of biomass sustainability

LCA methodology has unique advantages when analysing the environmental performance of products. In theory, based on accounting for all relevant material flows throughout the entire life cycle, it allows a complete picture of certain environmental burdens associated with a product. This enables comparisons across technological boundaries and permits identification of relevant stages in the life cycle, as well as improvement options.

However, LCA methodology has fundamental shortcomings, including dependency on numerous subjective choices, need for simplifications, lack of adequate data and limited precision. These limitations cannot be overcome by another layer of rules in addition to existing standards; they are inherent in the system of life cycle assessment. The lack of a standardised accounting for the biogenic carbon storage in bio-based materials presents a key challenge to LCA practitioners (Pawelzik et al., 2013).

In addition, LCA is not the definitive tool to suitably characterise all environmental impacts. Many impacts cannot be reasonably related to reference flows because the effects depend on space, time and threshold. Sound environmental assessments require a mix of different tools (e.g. environmental impact assessment, human health and environmental risk assessment, technology assessment). These tools must take due account of their strengths and weaknesses.

LCA is suitable for orientation of certain aspects at the onset of developing indicators or setting regulatory requirements. It delivers rough estimates rather than precise figures. However, suitable production, consumption or disposal indicators are typically more robust, more meaningful or relevant, and cheaper. They can also be measured and are easier to verify (or to enforce).

Harmonised methodologies to calculate the environmental footprint (EF) of products have been developed. EF methodologies are by no means new; rather, they constitute a remix of existing tools and related guidance. A key concept for improving comparability is the development of "Product Environmental Footprint Category Rules" (PEFCRs) (European Commission, 2016) for specific products. These are being tested over three years in the European Union with the help of volunteer stakeholders and industry (European Commission, 2017). The objectives of the EF pilot phase are the following:

- Set up and validate the process of the development of product group-specific rules (PEFCRs), including the development of performance benchmarks.
- Test different compliance and verification systems to set up and validate proportionate, effective and efficient compliance and verification systems.
- Test different business-to-business and business-to-consumer communication vehicles for Product Environmental Footprint information in collaboration with stakeholders.

A framework for indicator development embedded in the system of political decision making would also be useful. This could translate priority environmental concerns and broad target setting into specific quantified environmental demands. It would do this at the country or region level (e.g. European Union), as well as at organisational and product levels. A useful starting point for a harmonised methodology would include a discussion of the pros and cons of current practices. On this basis, policy makers could identify needs for improvement covering all dimensions of the subject in question.

International harmonisation and a level playing field for biomass sustainability

Biomass sustainability assessment needs to be harmonised internationally. Assessments are a patchwork of voluntary standards and regulations with a lack of comparability. In a survey of 11 European countries (Knudsen et al., 2015), 8 saw the need for a more consistent and standardised approach to sustainability criteria across the different bioeconomy fields. This need covers widely different criteria and indicators, voluntary schemes and EU-level approaches. The general arguments for a uniform approach to sustainability criteria are to increase transparency, avoid market distortions and enable comparisons across countries.

Much of the biomass shipped internationally is for bioenergy. This risks too much attention on only one part of the bioeconomy and only the energy transition, distorting the playing field even further. Different fields of the bioeconomy are expected to interact. For example, the cascading use of biomass (Odegard et al., 2012; Keegan et al., 2013) envisages the same biomass in use for high- and low-value chemicals and materials, biofuels and bioenergy. A common, level playing field for all sustainable biomass uses is needed (Carus et al., 2014). This is vital for the economic operation of integrated biorefineries.

Policy implications

- LCA is an environmental tool that does not address economic and social impacts. However, these impacts are crucial for policy decisions, particularly where such impacts are vital. This seems to indicate the need for a fundamental review of LCA's utility in biomass sustainability assessment.
- Social impacts especially are difficult to quantify and are therefore easily sidelined. The most robust indicators must be carefully identified. Qualitative indicators (e.g. compliance with organic farming standards) merit inclusion in environmental assessment.
- Complementing and/or alternative environmental assessment approaches could be considered. These could involve indicators tailored to specific product groups that are relevant, robust, verifiable and cost-effective.
- An adequate forum with a broad range of stakeholders for the critical review of LCA methodology and possible alternative approaches for product assessment could be identified.

Is the market more able to provide a unified approach to biomass sustainability assessment?

An "index" approach requires expressing multiple input-output variables with a common denominator. Such an approach helps integrate and compare sustainability issues affecting human well-being at different temporal and spatial scales. One common denominator that the market understands is money. This would involve monetising the "good" and "bad" inputs and outputs. Importantly, the analysis would have to incorporate several sustainability issues into a single measure of sustainability.

Gaitán-Cremaschi et al. (2014) suggested the total factor productivity (TFP) approach to the problem. TFP reflects the rate of transformation of inputs (capital, labour, materials, energy and services) into outputs (biomass stock). In this case, negative social and ecological externalities associated with different sustainability issues are included in terms of "bad" outputs.

The TFP index would use prices that reflect the relative importance of input and output variables towards sustainability. In this solution, observed prices can be used for the marketable inputs and outputs. Shadow prices need to be estimated for externalities that are non-tradable in conventional markets. As a result, related price information does not exist. In other words, the TFP index would use (shadow) prices[1] to reveal the relative performance of a biomass production chain reflected in the form of price signals.

Thus, a biomass chain with the best sustainability performance – the highest TFP score – would produce the highest ratio of output to input where the "bads" are output penalties that lower the sustainability performance. Moreover, the TFP index could compare multiple chains with different sets of outputs and inputs.

Purported advantages of the TFP approach

- It includes externalities (social and economic).
- Numerical harmonisation allows aggregation into a common metric.
- Inputs, outputs and bad outputs are converted to a common, universally understood unit: money.
- Access to market price data makes policy negotiations easier – prices are tangible, while qualitative indicators such as child labour are not.

Policy implications

- The acceptance of such a tool would require consulting with all stakeholders (policy makers, business stakeholders, non-governmental organisations [NGOs]) on:
  - the selection of sustainability issues (i.e. the inputs and outputs)
  - the method for aggregating multiple input and output variables in the TFP index.
- The application of the TFP index would require a common base level of understanding of sustainability. This, in turn, would have to be defined from regional, national and/or international biomass sustainability debates. In this way, inputs and outputs could be selected around issues of sustainability that are of established concern for expert scientist communities, policy makers and the well-being of society. These include, for example, global warming, energy, innovation, human rights, equity and land use.
- The aggregation methodology would have to be agreed upon and accepted internationally. Aggregating sustainability issues using price information can benefit policy makers in data-poor situations, where information about different sustainability issues is still lacking. Nevertheless, it requires decisions about the importance of different sustainability issues expressed in the "true" shadow price. These decisions imply incorporating social, political and ethical values in monetary terms. These values often conflict, and could be deeply contentious in society. This would require careful handling and transparent stakeholder communication. Economic evaluation tools can help estimate shadow prices for decision making.
- The other approach to aggregation, using distance functions, allows easily integrating multiple environmental and social externalities without requiring (shadow) prices. Nevertheless, it must include a large set of observations for the multiple inputs and outputs in the sustainability assessment.

ILUC: Where food and non-food uses of biomass collide

There is a direct land-use change (LUC) where previously uncultivated land is used to grow crops for industrial use. In this case, there are protocols to calculate the GHG impact of LUC. The protocols are used, for example, in the Renewable Energy Directive (RED). Perhaps the most controversial issue regarding bio-based production from biomass is indirect land-use change (ILUC); this occurs when land for food production is converted to grow a crop for non-food use. It is assumed that food production is essential and that the lost food production will be diverted elsewhere. Using previously uncultivated land causes large initial increases in GHG emissions e.g. by encouraging deforestation. Since a primary purpose of biomass for industrial use is to reduce GHG emissions, the impacts of ILUC should be considered.

As an example, the UK Government's Gallagher Review (Renewable Fuels Agency, 2008) stated that biofuel policy must address ILUC to have clear climate benefits. However, its measurement is extremely complex, and some would contend impossible. Further, uncertain conditions undermine investor confidence, which affects the political viability of biofuels.

Political progress on ILUC has been slow with Europe – a good example of divided opinion. ILUC was considered to be inadequately addressed in both RED and the Fuels Quality Directive (FQD). As a result, some biofuels may consequently have few environmental benefits compared with fossil fuels. Indeed, they may even increase GHG emissions rather than generate net savings. In 2012, to address ILUC, the European Commission proposed a directive amending the RED and FQD. It was subsequently adopted by the Council and Parliament, and published in September 2015 (Europa, 2015). In it, fuel suppliers and the European Commission are to report on emissions deriving from ILUC. However, these emissions are not included in the sustainability criteria for the biofuels or the GHG calculation methodology of the RED and FQD. Implementation of the ILUC Directive has been slow. This is partly because it is still quite new, but also because EU member states hold different positions (CE Delft, 2015).

What can be done to ease tension between food and non-food uses of biomass?

Promoting uses of biomass that are unlikely to have a large impact on ILUC is one alternative to the tension between food and non-food uses of biomass. This would provide a means of mitigating ILUC, while avoiding the need for relying on controversial modelling results. In essence, to demonstrate a low ILUC impact, biomass needs to prove the feedstock has not come from land in competition with food production or from carbon-rich lands (forests, peat lands).

Mitigation options that use supply chain certification schemes could provide a workable solution for addressing ILUC. Such a process could allow developers to provide evidence that their biomass for industrial uses has minimal ILUC impact. For example, they could use abandoned or degraded land, or improve crop yields. As such, they should be exempt from application of any ILUC penalty, such as an ILUC factor. Policy makers could build upon this concept to provide a more satisfactory outcome to addressing ILUC in policy.

Policy implications

- ILUC modelling is in no state to be used in policy making relating to biomass sustainability.
- All forms of biomass could be acceptable as feedstock for the bioeconomy; this could be mirrored in public debate and perception, as well as in specific policies.

- Biomass must meet established international sustainability standards covering GHG savings, sustainable land use and environmental protection. These criteria could be integrated into supply chain certification schemes.
- Public financial incentives should only be based on higher resource and land-use efficiencies, sustainability and GHG savings and the lowest possible level of competition with food.
- Food or non-food biomass should not be taken as the sole acceptance criterion.
- Policies for producing sugar for industry use should be examined. For example, sugar beet is an attractive feedstock for the European chemical industry. It has low impact on the food and feed sector as increased yield is decreasing areas under cultivation.
- Added value, employment and innovation speak in favour of supporting industrial use of biomass for materials and chemicals. This would replace disproportionately allocating biomass to fuels and energy applications. Greater value added can only improve on ILUC calculations and implications relating to biomass sustainability.

Does the use of marginal land alleviate the complexities of sustainability?

Sustainable biomass and marginal land

Large quantities of food and/or feed crops such as corn and soybean are used to produce grain-based ethanol and biodiesel. While cultivating highly productive crops on prime agricultural land can produce large quantities of biofuels, it can also harm the environment. Along with other factors, the practice could contribute to rising food prices as well (i.e. the food vs. fuel debate).

An alternative approach is to grow lignocellulosic (or cellulosic) crops on "marginal lands". Marginal land may be defined as follows: land not used for food production because of some inherent limitation; low fertility, highly erodible, or otherwise not suitable for annual crops and not used for grazing. Growing cellulosic feedstocks on such lands is advantageous due to the low management intensity required, increased soil carbon stocks, and reduced soil erosion and GHG emissions.

There are two main challenges to achieving this:

1. Choosing the right crops to ensure sufficient productivity with environmental benefits: achieving sufficient yields on inherently unproductive lands requires choosing plants that can grow well on marginal soils.
2. Understanding the landscape dynamics that influence the supply and distribution of feedstocks: growing biofuel feedstocks on marginal lands may further amplify the complexity of feedstock supplies. Parcels of marginal lands might be spread across landscapes. They may or may not be connected by a suitable road network, or be large enough for successful harvesting and handling of biomass. Transport, management and biodiversity implications need to be understood.

Gelfand et al. (2013) identified 35 locations across the north-central United States where biorefineries with production potential above 133 million litres could be built. These biorefineries could produce ~ 21 billion litres of cellulosic ethanol per year. By 2022, this will equal about 25% of the mandate for the US Energy Independence and Security Act of 2007.

However, before establishing a sustainable biofuel economy, three questions must be answered.

1. What are the direct and indirect effects of land conversion on GHG emissions? As previously noted, ILUC issues are complex. The models are not ready for use in policy or legislation.
2. What is the availability of marginal lands for biofuel crop production? What is the potential productivity of available lands, and where are they located relative to potential biorefineries? How will this interact or interfere with social issues, such as tourism? In addition, are landowners willing to grow biofuel crops in the first place?
3. What is the ideal biofuel feedstock? For example, what are the trade-offs associated with annual and perennial biofuel crops? Perennial feedstocks provide various ecosystem services such as soil carbon sequestration and stabilisation in addition to the biomass produced. They require a low input of agrochemicals. Further, they have a high ratio of energy return on investment and generate high climate mitigation benefits. And they have potential to produce greater yields than annual plants on marginal lands. However, if the demand changes, other crops could replace annual plants. Perennial crops need to be grown for several years before harvesting is possible; they cannot be rotated as often as annual feedstocks.

An inter-disciplinary approach could support better understanding of public and landowner perspectives. Specifically, it could shed light on use of existing landscapes for renewable energy production as part of more general ecosystem services such as clean water and biodiversity.

Policy implications

- Yield alone does not justify supporting an energy crop. Policy makers should assess additional benefits through, for example, enhanced ecosystem benefits that foster biodiversity.
- Best management practices are needed for biofuel feedstock production. Combining the right crop with the right location and the right cultivation practices can generate maximum environmental benefits. Guidelines for sustainable feedstock production need to be developed and will require monitoring tools for assessment.
- The time dimension should be integrated into assessment of the environmental impacts of biofuel feedstocks. Forest will require decades to grow back and to uptake CO_2, which will be released due to harvest and use of forest biomass as a biofuel feedstock. Harvesting of existing mature forests therefore is not providing expected climate mitigation.
- Best management practices can help select suitable marginal lands and implement the growth of cellulosic feedstocks on them. Although they are potentially less productive than high-input/high-yield crops, such feedstocks can provide more environmental benefits, which would need to be monitored.
- Development of breeding and selection programmes for new feedstock crops should be supported.
- Implementation of low-input cropping systems, such as grasses, should have high priority.

- A spatial inventory of lands in areas suitable for biofuel production is needed to inform development of land-use guidelines.
  - Include land connectivity and assessments of potential yields. This must identify existing land-use patterns at a small spatial scale to be relevant for the growth of feedstocks, as an alternative land use (i.e. sub-kilometre).
  - Impacts of agricultural intensification are experienced domestically (i.e. direct land-use change) and globally (i.e. indirect land-use change), and both should be considered.

Technology tools

Lynch et al. (2013) suggest that forests are best monitored through satellite technology. An interesting development is the combination of machine vision software and light detection and ranging (liDAR) technology by Arbonaut of Finland. Flying at an altitude of around 2 kilometres, laser beams can generate three-dimensional point cloud data on an object as small as a single tree on the ground. And knowing the diameter of the crown of the tree, its volume can be predicted (Ministry of Economic Affairs and Employment of Finland, 2017). Making such forestry inventories supports sustainable forestry management. The technology can also be used to assess carbon stocks in tropical forests. It can calculate the amount of CO_2 removed from the atmosphere, entitling a country to payments for carbon capture via forests under the Paris Agreement.

Note

1. Shadow price is the opportunity cost of an activity or project to a society, computed where the actual price is not known or, if known, does not reflect the real sacrifice.

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