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Securing a sustainable biomass supply in a growing bioeconomy

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ABSTRACT

An analysis of the development of bioenergy has revealed that competing claims on biomass and agricultural land for its production are perceived as major obstacles to increasing sustainable biomass supply in the context of food security and environmental conservation. This study elaborates recommendations for dealing with competing claims on biomass for food, feed, fibre and fuel production and for securing a sustainable biomass supply in a growing bioeconomy. Suggested approaches include a better understanding of the drivers of competition, technical strategies and participatory approaches to realizing the sustainable biomass potential, and integrated approaches for optimizing bioeconomic value chain nets.

1. Introduction

The bioeconomy, often also referred to as "biobased economy" or “knowledge-based bioeconomy”, is high on the agenda of several countries. Dedicated strategies for a biobased economy have been developed by the European Commission (EC), the US, Canada, Australia, South Africa, Finland, Sweden and Germany. Altogether more than 30 countries worldwide acknowledge and politically support the potential benefits of the bioeconomy (German Bioeconomy Council, 2015). They define bioeconomy in different ways, focusing either on the contribution of biotechnological advances to solving global problems, on biotechnology in the life sciences or on the application of biomass as a replacement for fossil materials (Pfau et al., 2014).

There are several motivations for driving the development of the bioeconomy (for an overview, see McCormick and Kautto, 2013). First, fossil resources are depleting and their use leads to global warming with dramatic secondary effects. Although there are various ways of producing renewable energies to substitute fossil fuels, such as wind or solar energy, the renewable replacement of fossil resources for material use is only possible through biomass. Biomass is virtually ubiquitous and therefore also available to rural populations. Its production, processing and product development offer new job and income opportunities as well as the potential for development and implementation of innovative processes (McCormick and Kautto, 2013).

A substantive part of the bioeconomy builds on biomass as a resource base. In the envisioned "ideal" bioeconomy, biomass production will take ecological, social and health aspects into consideration and be internationally competitive. Through the development of new technologies and biotechnological processes, biomass will be used for food, feed and materials as well as for energetic purposes (Staffas et al., 2013). It is therefore clear that a major prerequisite for bioeconomic development is the availability of sufficient biomass of adequate quality for its intended uses, which should be supplied by sustainable production (see also van Dam et al., 2005). However, an analysis of the bioeconomy strategies of various countries by Staffas et al. (2013) reveals surprisingly that strategies for securing a (sustainable) biomass supply are absent from most national strategies. This is reminiscent of the approach taken with the introduction of bioenergy, a sector of the bioeconomy, during the last decade in the EU, where a political framework for introducing liquid biofuels was set up without a feedstock resource strategy. Today, public perception of competition between bioenergy and food resources (the “food versus fuel” debate) has emerged as a major drawback in the acceptance of bioenergy (Pfau et al., 2014; Solomon, 2010; Tait and Barker, 2011). There are also concerns about land-use change impacts and limited water and nutrient supply (Rosengrant et al., 2013; Searchinger et al., 2008). Similar concerns were raised regarding the bioeconomy in a public consultation of the EC (2012), where the majority of respondents indicated potential over-exploitation of natural resources and impacts on food security as most relevant risks accompanying bioeconomic development.

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Box 1: Presently, the term "**biomass**" is most frequently used to refer to organic material utilised for energy production and other non-food purposes such as the production of biogenic materials and chemicals. Here we use the more general definition of "biomass" which refers to all organic material that originates from plants, animals or microorganisms. This definition includes edible biomass, such as starch, sugar and oil-rich biomass, and non-edible lignocellulosic biomass from dedicated production, residues or wastes.

Therefore the objective of this study is to develop recommendations for securing sustainable biomass supply in a growing bioeconomy by addressing the problems revealed by bioenergy development relating to biomass supply issues.

2. What can we learn from bioenergy with regard to sustainable biomass supply?

In 2008, approximately 10% (50 EJ) of the world's total primary energy supply was biomass-based (Chum et al., 2011). About 80% of the biomass resource was wood and shrubs used in traditional form for heating and cooking, mainly in Africa and Asia (Chum et al., 2011). The remaining 20% came from the agricultural sector (in the form of energy crops and residues) and from various commercial and post-consumer waste and by-products. These were mainly used for bioenergy, such as liquid transportation biofuels, biogas for electricity production, and for heat production in modern biomass boilers, all employing advanced conversion technologies (Chum et al., 2011). Although many biomass supply issues apply to both traditional and advanced bioenergy forms, the following analysis focuses mainly on the latter.

2.1. The initiative for the introduction of advanced bioenergy came from the political, not the private sector

In Brazil, decades of political support finally resulted in a competitive bioethanol production sector (McCormick and Kaberger, 2007). However, in Europe, where mandates have been set for biofuels and incentives given for biomass and bioenergy production, either large subsidies for biomass production or high taxes on fossil fuels are necessary to keep bioenergy on the market (Lauri et al., 2014). Political support for bioenergy was legitimatized by expectations of economic development, in particular additional income opportunities in rural areas, and by ecological benefits, especially climate change mitigation.

2.2. Although the promise of additional jobs was fulfilled, expectations regarding ecological benefits, especially greenhouse gas (GHG) emission reductions, were partly disappointed

Some studies on intensively managed, fertilized energy crops, such as rape seed and maize, have shown that ethanol or biodiesel production from these crops has only limited potential for curbing GHG emissions (Crutzen et al., 2008; Fargione et al., 2008). This is partly due to uncertainties about the level of nitrous oxide (N_2O) emissions from nitrogen fertilization, as N_2O is a GHG with a 310-times stronger climate impact than CO_2 (Crutzen et al., 2008). Another reason is additional GHG emissions from land-use change, an initially unanticipated effect of increased demand for biomass. The cultivation of biomass for bioenergy production has brought about several forms of land-use change. Negative ecological effects, such as soil carbon losses, GHG emissions and adverse impacts on biodiversity, have been observed where extensively managed systems (e.g. grasslands) have been replaced by intensively managed annual crops (Fargione et al., 2008). Prominent examples are the conversion of permanent grassland to maize cultivation for biogas production in Germany and the expansion of oil palm plantations in Indonesia. Although the latter was, for the most part, intended to satisfy additional food and biomaterial demand, it is accompanied by the clearing of tropical rainforest, which often stands on carbon-rich peatlands. This has led to biodiversity loss and high GHG emissions (Wilcove and Koh, 2010). Oil palm is also often mentioned in the context of so-called indirect land-use change (iLUC). Searchinger et al. (2008) use the following example to explain indirect land-use change. The increased use of US corn for ethanol production led to an increase in corn prices, which in turn brought about a rise in demand for crops, notably soya and wheat, in other parts of the world. Previously uncultivated land was converted to arable land as an indirect consequence of ethanol production from corn. Today, there is controversial debate in the EU on how to account for GHG emissions from iLUC because it is very difficult to assess, quantify and allocate these to specific activities (Brinkman et al., 2015).

2.3. It should be noted that negative reports on land-use change, whether direct or indirect, mainly refer to the production of edible biomass resources (oil, sugar, starch)

By contrast, conversion of land to the cultivation of perennial grasses and trees which deliver lignocellulosic biomass can actually increase soil carbon levels and often reduces the need for agrochemicals, such as nitrogen fertilizer (Lewandowski, 2013). However, most of the additional biomass demand created by the development of advanced bioenergy is related to oil, sugar and starch feedstocks. This increased demand has been met by either extending the cultivation area of these crops (oil palm in Indonesia, sugar cane in Brazil) or by the intensification of crop management. These negative impacts of land-use change are accompanied by concerns that genetically modified (GM) crops and novel, alien crops will be increasingly used to boost biomass yields (Sheppard et al., 2011). In this context, it should be noted that additional biomass demand is expected not only for bioenergy, but also for food. One of the main drivers of increased competition for land is the anticipated rise in world population, the changing diets, and the goal of reducing malnutrition (Harvey and Pilgrim, 2011). Additionally, it is expected that this increased demand for biomass will also increase pressure on other limited resources, such as water and phosphorus (Cordell et al., 2009; Rosengrant et al., 2013).

2.4. Today, experts criticize the one-sided political support of and incentives for liquid transportation biofuels because it increased the global demand for edible biomass and consequently impacted food prices

However, studies investigating the effects of the increased use of edible biomass for biofuels on food prices have shown that price increases are only partly caused by biofuel production and for some commodities the effect is minimal. Other factors which impact the price of important commodities such as wheat, corn, rice and sugar, include weather conditions (e.g. drought), political and economic developments, speculations, trade barriers, storage quantities, oil prices, land prices and land availability (Schmitz, 2013; Zilberman et al., 2012). Zilberman et al. (2012) conclude that the introduction of biofuels has a lower impact on food-commodity prices when biofuel production does not compete with food crops for resources such as land and water. They expect the expansion of sugar cane ethanol in Brazil and 2nd generation biofuels grown on non-agricultural land to have a much smaller