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Short communication

Large-scale biofuels production: A possible threat to soil conservation and environmental services

Tiziano Gomiero[a,b,*]

[a] Fellow at Department of Environmental Studies, Faculty of Social Studies, Masaryk University, 602 00 Brno, Czech Republic
[b] Independent researcher Mogliano Veneto, Treviso, Italy

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ABSTRACT

Biofuels have been promoted as a sustainable energy carrier, able to supply fuels while reducing Greenhouse Gas emissions (GHGs) within the energy sector. It is also believed that biofuels will offer new income opportunities to farmers and create new jobs in rural areas. I argue that this may be a far too optimistic picture. Biofuels have poor energy performance (in actual fact, their use requires a high volume of subsidies), are potentially in conflict with food production and have high environmental impacts, especially on soil, forests and natural resources. Large scale biofuels production may cause detrimental effects on those key ecosystem services that we should strive to preserve, in particular when considering soil health. Assessing the sustainability of energy carriers requires a comprehensive assessment able to address multiple issues at the same time. It is necessary to rethink biofuels policy in view of preserving soil heath and key ecosystem services. Agricultural policies would better focus on supporting farmers in the adoption of more sustainable farming practices. Policies aiming at preserving forests are also necessary. Subsidies could be used to explore different renewable energy sources, with a lower impact on our support systems, and more sustainable agricultural practices. Eventually, rethinking our development patterns may become necessary in order to cope with the Earth's limited resources and reduce the alarming trends associated with the environmental impact of human global societal metabolism.

1. Introduction

Biofuels have been promoted as a sustainable energy carrier, able to supply fuels while reducing GHGs within the energy sector (ECOFYS, 2014). Aiming at a transition to a decarbonised energy system, the European Union (EU) set the goal to reduce EU-wide greenhouse gas (GHG) emissions by 80–95% below 1990 levels by 2050. The EU planned to increase the share of renewable sources in final energy consumption to 20% by 2020.[1] By 2020, the EU aims to have 10% of transport fuel of every EU country come from renewable sources such as biofuels (EEA, 2017). ECOFYS (2014) estimated that the total acreage required to produce the biofuels consumed in the EU in 2012 amounted to a maximum of 7.8 Mha. Of this, 4.3 Mha (58%) was produced within the EU and 3.1 Mha (42%) outside the EU. In the USA, the 2007 Energy Security and Independence Act established a corn-ethanol production target of 56.8 billion litres by 2015, and a further target of 136 billion litres of ethanol for 2022, of which 80 billion should come from corn (HLPE, 2013). In 2011, under the Obama administration, the Open Fuel Standard Act required that 50% of automobiles made in 2014, 80% in 2016, and 95% in 2017, be manufactured and warrantied to operate on non-petroleum-based fuels (*i.e.*, natural gas, electric, alcohol fuels, hydrogen or biodiesel) (US Congress, 2011). It is also believed that biofuels will offer new income opportunities to farmers and create new jobs in rural areas (*e.g.*, USDE, 2013; ECOFYS, 2014; Kim and Dale, 2015).

Claims suggesting biofuels to be sustainable energy carriers capable of replacing fossil fuels are far too optimistic if we consider: (1) the very poor energy performance of biofuels in relation to the complex metabolic pattern of industrial societies, (2) the impact of biofuels on soil, ecosystems and ecosystem services, and the environment in general (*i.e.*, GHG emissions, water consumption, pollution, deforestation and land use change), (3) conflict with food security, both direct (crops for fuels vs. crops for food) and indirect (soil degradation, water use). Indeed, biofuels may turn out to cause more problems than they are supposed to solve. The impact on soil and natural resources requires special attention, also in view of the challenges posed by climate change, because preserving soil health is of key importance to guarantee food production in the long run. Subsidies granted to biofuels

* Correspondence to: Mogliano Veneto, Via Cortellazzo, 77, 31021, Treviso, Italy.
E-mail address: tiziano.gomiero@libero.it.

[1] For 2030, the EU's binding renewable energy target is to reach a share of at least 27% of renewable energy in its gross final energy consumption (EEA, 2017). According to EEA (2017) progress since 2005 allowed the EU to cut its fossil fuel use by 11% and its GHG emissions by 10% in 2015.

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may be better used to foster more sustainable agricultural practices.

The appropriateness of implementing biofuels policies as set out by countries such the USA and the European Union (EU) has been challenged. In February 2015, pressure from civil society and many scholars drove the European Parliament's environmental committee to review the EU biofuel policy, agreeing that biofuels from food crops should not exceed 6% of final energy consumption in the transport sector by 2020, and accepting that changes in land use and ensuing emissions should be accounted for (EU, 2015). A recent report produced by the European Parliament (EP, 2017) further stresses the limits of biofuels as a means to produce energy sustainably.

Most works on the topic tend to focus on specific issues. The scope of this work is to provide a comprehensive overview of this field in order to raise awareness among soil scholars, researchers and policy makers about the problems posed by large scale biofuels.

The paper is organised as follows. In Section 2, I discuss the energy efficiency of biofuels, and compare it to that of fossils fuels, both in terms of net energy gains and their capacity to power our society. I argue that the implications of the latter issue have not been properly addressed by biofuels supporters and policy makers alike. Nevertheless, power and societal metabolism are key concepts to consider in order to conduct a sound assessment of energy carrier efficiency. In Section 3, I address the impact that biofuels may have on soil and on the environment. In Section 4, I argue that a systemic, multicriteria approach should be embraced when assessing the sustainability of biofuels (and should be adopted whenever the sustainability of complex issues is addressed). A positive net energy return cannot stand as proof that an energy carrier is a sustainable and desirable option for society. Society should be properly informed about the different impacts that different energy options have in order to choose where to invest its resources, and to decide whether to accept the consequences of a given energy policy or not. In Section 5, I present my conclusions and their policy implications.

2. Biofuels: energy efficiency, power and the metabolism of societies

Although biofuels have been promoted as an alternative sustainable energy carrier, their supposed sustainability was questioned already in the 1970s by energy experts such as Prof. David Pimentel (Pimentel et al., 1981), and Prof. Vaclav Smil (Smil, 1983), due to their low energy efficiency and high environmental impact. Recent analysis integrating energy efficiency and societal metabolism (Giampietro et al., 1997, 2012, 2013; Giampietro and Mayumi, 2009) further contributed to clarifying the limitations of biofuels as a possible sustainable energy carrier for industrial societies.

2.1. *Energy efficiency of biofuels*

Energy Return on Investment (EROI) is a key indicator when assessing the feasibility of an energy carrier. EROI is a measure of the net energy made available to society by an energy carrier after discounting the costs associated with the energy production process (for details see Murphy and Hall, 2010; Hall et al., 2014). Obviously, an EROI ≤ 1 means that there is no energy gain, therefore the enterprise is not even feasible, as it will result in a net loss of energy. An EROI > 1 may, in theory, mean that we can use biofuels to produce net energy. In practice, we should compare the efficiency of biofuels to that of energy carriers in use today, *i.e.* mainly fossil fuels, and then carefully analyse what substituting an energy carrier for another might entail. It has to be pointed out that EROI does not address the differences in the quality of delivered energy: flexibility, convenience, portability, cleanliness at the point of use (Smil, 2003, 2008).

EROI for first generation biofuels (derived from sources like starch, sugar and vegetable oil) has been estimated to range between 0.8 and 2–3, with sugarcane in Brazil as an outlier, reaching a top value of 8–10 (Pimentel et al., 2007; Patzek, 2008; Giampietro and Mayumi, 2009; MacKay, 2009; Whitaker et al., 2010; Hall et al., 2011, 2014). Second generation biofuels (derived from lignocellulosic biomass or woody crops, agricultural residues or waste) are much less efficient (Smil, 2003; Giampietro and Mayumi, 2009; Hall et al., 2014; Gomiero, 2015). Third generation biofuels (derived from algae) are so inefficient that fuel has been sold at about 100 US$ per litre (to the US Navy) (Biello, 2011).

A fierce debate has been ongoing since the 1990s concerning the accuracy of these estimates, with arguments over a unit, or even a few decimals, arguments that make little sense when we know that EROIs for the fossil fuels powering industrial societies are 20–30 or more (Smil, 2003, 2008; Giampietro et al., 1997; Giampietro and Mayumi, 2009; Hall et al., 2011, 2014; Gomiero, 2015). Such huge differences should already warn us that biofuels cannot be competitive when compared with fossil fuels. The low EROI of biofuels means that the energy produced will cost much more than the energy derived from fossil fuels, and this is precisely why biofuels production needs to be sustained by a large amount of subsides (money from taxpayers, money generated by the use of fossil fuels). In the USA, even with oil above 100US$/barrel, biofuels were still not competitive (Gomiero, 2015). Gomiero (2015), using official statistics, calculated that in 2009, at the global level, subsidies were 3.1 million US$ per Mt oil eq. for fossil fuels (US$ 3/t), and 423 million US$ per Mt oil eq. in the case of biofuels (US $423/t), 136 times more.

Is the relatively high EROI of sugarcane a reason for optimism? Not really. Firstly, because as soon as a society develops the cost of labour increases (along with taxes, cost of services *etc.*), and along with that the cost of biofuels increases too. Secondly, due to the low power density of biofuels, which cannot match the rate of energy demand of industrial societies (see Section 2.2). In poor developing countries, the low level of per capita consumption, the very low cost of labour and a limited concern for the environment might make biofuels an option. Nevertheless, competition with food production is a very serious issue that greatly reduces their viability. Brazil supplies nearly 50% of internationally-traded sugar, is the second-largest of ethanol producer (after the USA) and the largest exporter; in order to support its ethanol market, it had to implement a taxation policy penalising the use of gasoline and promoting the use of ethanol, and provides considerable subsidies to producers (Chatenay, 2013; Barros, 2015). De Queiroz and Cabral da Costa (2014) estimated that during 2002–2011, in Brazil, average annual ethanol subsidy levels were 2.1 billion US dollars (7.2 billion US dollars in the United States). Chatenay (2013) estimated that, in recent years, Brazilian sugar producers received no less than $2.5 billion annually in direct and indirect government programmes (Chatenay, 2013). Furthermore, the government had to resort to a massive 38 billion US dollars credit and tax benefit to help ethanol industries (Anon., 2012; Trevisani and Lewis, 2014). In the 1970–80 s the convenience of Brazilian ethanol may have relied on the extremely cheap cost of labour: about 500,000 people working 10–12 h per day for less than 0.5 euro per ton of cane harvested, with no protection or social security (de Andrade, 2008). At present, the fact that, in spite of the still very cheap cost of labour, large amounts of public subsidies and an ad hoc energy policy are needed to keep the ethanol industry alive should say it all. In short, as soon as Brazil developed, the increase in rate of energy consumption, wages and cost of production were such that biofuels could no longer compete with fossil fuels, and biofuels production needs to be highly subsidised.

2.2. *Biofuels in the context of societal metabolism*

The structure (*i.e.*, number of people, age class structure) and functioning (*i.e.*, distribution of activities, level of wealth) of a society, is determined by the rate at which energy and materials flow through society (Smil, 2003, 2015; Giampietro and Mayumi, 2009; Giampietro et al., 2013). The study of these relations is named societal (or social)