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Short communication

Energy return on investment of Austrian sugar beet: A small-scale comparison between organic and conventional production

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ARTICLE INFO

Article history:
Received 29 September 2014
Received in revised form
23 February 2015
Accepted 24 February 2015
Available online 18 March 2015

Keywords:
Energy return on investment (EROI)
Organic farming
Sugar beet
Bioeconomy
Ecological energetics

ABSTRACT

In near future it is essential for human society to switch its primary energy use from finite sources to renewable ones. Ethanol has been claimed to be a potential candidate to replace oil use to great extent. This study illustrates that ethanol production has the potential to rely on organic agriculture and thereby to reduce reliance on fossil fuels. Case studies were carried out by examining three farms (2 conventional, 1 organic) in Austria who are mainly producing sugar beet. We found that organic sugar beet production provided an overall energy return on investment (EROI) of 11.3 whereas the conventional farming practice showed an EROI of 14.1 and 15, respectively. Our study indicates that organic sugar beet production shows potential to substitute conventional industrial sugar beet production to provide inputs to ethanol production. By using organically produced sugar beets as inputs to the ethanol production, fossil fuels can perhaps be avoided to a large extent in the production process, thus, it may be possible to mitigate some of the environmental impacts associated with ethanol production. Larger studies are however needed to better visualise such results.

1. Introduction

Energy return on investment (EROI) is the ratio between the energy harvested from an energy source and the energy that went into the energy harvesting process [1]. When an energy source reaches an EROI of 1, it has reached the point where as much energy is retrieved from a process as goes into harvesting. It is inevitable, that in the near future, finite natural

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http://dx.doi.org/10.1016/j.biombioe.2015.02.032
0961-9534/

resources such as fossil fuels will reach that point [2]. For society to maintain economic growth, and to power its industrial processes, it is essential to have access to high EROI resources. Oil from U.S.A. fossil resources has an EROI of approximately 15–20 [3], and has been on a steady decline since 1930's when it had an EROI of approximately 100 [3]. Oil, as it is known to society today, is a very valuable material; it can be stored relatively easily, has high energy density, it can be used to produce different materials such as plastics and has so far been easily accessible. However, oil comes with the price tag of environmental degradation and the inevitable fact that it will not last forever.

It is therefore of great importance to find renewable energy resources that can replace oil. A variety of solutions are available that provide high EROI [4]. Electricity production using hydropower has been shown to have one of the greatest EROI available so far, approximately 100 [5], however, it has the problem of storage for the electricity (running of river plants), and lack of rivers to dam. Geothermal resources with an EROI of around 33 [6] are not easily available and can only be accessed when geological conditions are favourable. Wind with an EROI of around 18 [4,7] is not a stable source and energy storage is still in its infancy, in essence also effecting solar panel solutions.

One of the promising proposed candidates to mitigate fossil fuel use is ethanol [8]. Ethanol, disregarding the production method, has been shown to have an EROI from 0.8 to 11 [9–11]. Corn based ethanol has been shown to have a lower EROI, around 1.3, compared to sugar based which can be expected to have an EROI around 4-11 [11]. Ethanol is mainly produced from two ingredients, either from sugar beet, or corn because of their high energy content and the ingredients used in ethanol production can be used to create plastics such as polylactide [12]. So far, sugar beet based ethanol shows all the characteristics of a material which can serve society as oil has, even though it currently has 3-4 times lower EROI. Environmental impact from sugar beet based ethanol production has been claimed to be minimal [13], as it is derived from biological materials. However, for sugar beet based ethanol to have less environmental impact, and be truly renewable, it needs to be non-reliant on fossil fuels throughout the whole production chain. Farming methods that exclude synthetic fertilizers and pesticides (which are heavily reliant on fossil fuels in production), i.e. organic farming practice, could prove to be promising. The main difference between organic and conventional farming practice is that conventional farms use synthetic pesticides, herbicides and fertilisers to increase plant growth, whereas organic farming practice relies on organic fertilizers, such as manure and compost, and on diverse crop rotation to provide the required nutrients into the soil system. It should however be noted that sometimes the manure is brought from external sources, which may not rely on the same agricultural practices.

EROI in agriculture has been studied to some extent [14–16], however, most often the agricultural sector is studied as a whole [17], and not by different farming management practises, providing skewed results as different agricultural products and practices return different amount of energy. Studying a specific type of farming system with regards to energy efficiency will therefore provide a more accurate answer to given questions, such as, what is the EROI of specific crop production in different geographical regions. In Marocco and Turkey conventional sugar beet production has been shown to have EROIs of 4.14 and 25.75, respectively [18,19]. Until now, the question still remains whether organic sugar beet farms can provide high enough or similar EROI values to conventional sugar beet farms to serve as a energy source replacing oil to some extent.

In this study we investigate the EROI of three farms that produce sugar beets and other products such as wheat, onions and potatoes. Two of the farms are managed conventionally and one organically. This study determines the EROI of the farms at the farm gate, before any processing has taken place. Knowing the EROI of organic sugar beet is important, such knowledge could perhaps shift ethanol production to organically grown sugar beet which does not rely on fossil fuels to the same extent as conventionally grown sugar beet [8].

2. Materials and methods

2.1. Study sites

This study analyses one organic and two conventional farms in the agricultural area of Marchfeld, South East of Vienna, Austria: 1) ORG1 is an organic vegetable farm of 62 ha, which has been managed according to Austrian guidelines [20] for organic farming since 1995. Horse manure is used as organic fertilizer. The crops for the year of the study, 2011, were sugar beet, wheat, maize, potatoes, and barley; 2) CON1 is a conventional vegetable farm of 150 ha. The crops for 2011 were sugar beet, potatoes, onion and wheat; 3) CON2 is a conventional vegetable farm of 95 ha. The crops for 2011 were sugar beet, maize, wheat, barley, sunflowers, and pumpkins. The farmers adjusted use of mineral fertilizers, pesticides and herbicides according to the Austrian guidelines and recommendations for each crop [21,22].

2.2. Energy return on investment

EROI is the ratio between energy outputs and inputs from any given process within the boundaries set. In general, the equation for EROI calculations can be described as [1]:

$$EROI = \frac{ED_{out} + \Sigma \upsilon_j o_j}{ED_{in} + \Sigma y_k I_k}$$

where ED_{out} is the direct energy output, υ_j is a set of well defined co-efficient output, o_j is the energy per unit of the given output co-efficient, ED_{in} is the direct energy input, y_k is a set of well defined input co-efficient and I_k is the energy per unit of the given co-efficient. The chosen boundaries, $EROI_{1,d}$, were selected according to [1] and [6]. The $EROI_{1,d}$ boundary resembles gate-to-gate boundaries in the LCA literature. In this case, the gate is when the product leaves the farm.

The data on direct inputs and outputs was collected directly from the farmers through questionnaires and interviews. We included the indirect energy consumption of synthetic fertiliser production, as it is so energy intensive that it would not give realistic results to exclude them. For the fertilisers, the energy need for the production of Nitrogen (N),