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Effect of Biofuel Production on Sustainability of Agriculture

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Abstract

The article investigates the influence of energy efficiency achieved in biofuel production on the potential fulfilment of agricultural energy demand, and consequently on the sustainability of agricultural processes. The mathematical model of energy efficiency in biofuel production is extended to a more general form aiming to describe the effects of exclusion of a fraction of crops from food production towards satisfaction of the industrial demands.

The derived model gives quantitative relations between energy efficiency of "energetic plantations", energetic efficiency of industrial biofuel processing plants, and energy demand for other types of agricultural production.

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Keywords: agriculture; biomass; biofuels; energetic efficiency; sustainability

1. Introduction

The idea of sustainable development is the main driving force towards the search of roads to stable economic growth accompanied by long-lasting accessibility of natural resources, and the values of the natural environment, both indispensable for correct functioning of the single man as well as the whole societies.

On the other hand, the growth of industrial production is an unquestionable cause of exhausting of natural resources, as well as the reason for degradation of natural environment. It seems, however, impossible to maintain contemporarily achieved standard of life of the present world's population without supporting further economic growth, based on the development of industry. The development of industrial production and growing standard of life of the human communities is strongly dependent upon availability of energy, which so far is mainly harvested from fossil resources. Two dangers, related to fossil resources, are of interest: the first is expected "oil peak", which can be understood as

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a resource peak, in general. After reaching maximum yield of fossil resource, like petroleum or coal, its availability will decrease. The other factor is emission of carbon dioxide inseparably connected to coal or petroleum derived fuels. An increase of carbon dioxide concentration in atmosphere as well as dissolved in ocean waters brings dangerous consequences to environment, and to human beings. The search of technical solutions which would be able to reduce the negative influence on the environment, and to slow down exhaust of natural resources, become important task for contemporary engineers and manufacturers.

It is believed that sustainability can be achieved by means of shifting from fossil resources to renewable ones, which to great extend are bio-resources coming either from "wild" resources or from agriculture. However, when agricultural production, at least to some extent, has to replace fossil energy resources, it is necessary to analyze whether or not, and to what extent this replacement will affect productivity in other branches of agriculture, as well as its sustainability, understood as an ability to maintain agricultural production basing on biofuels.

Biofuels, actually not only achieved theoretical, scientific interest, but also reached strong share in fuels market. Nigam, and Singh [1] indicate a number of biological resources, like seeds, fruits and other parts of various plants, animal fat, etc. that are converted into biofuel, as well as many technologies of this conversion have been elaborated Bharathiraja et al. [2], Abnisa et al. [3] or Russo et al. [4] indicate that biofuels are strategically important sustainable energy sources, playing substantial role in mitigation of carbon dioxide emission.

Several papers, e.g. Talens et al. [5], Liao et al. [6], Schneider and Smith [7], Singh et al. [8], Smith et al. [9] have discussed energetic yield of particular plants, and its effects on sustainability of plantation. Also several attempts to evaluate some quantitative indicators of sustainability were published. The long list of such indicators is given by Krajnc and Glavic [10]. Estimation of values of some indicators, like EROEI – "Energy return on energy invested" gave input to several conclusions, not necessarily being in agreement. Arodudu et al. [11] estimate rather good perspectives for biofuels as a factor helping in reduction of CO_2 emission as well as showing good potential for meeting future energy demand. The paper gives also estimate of actual share of biofuels in global primary energy consumption as equal to 10%, and 80% share in total renewable energy production. Similar visions are frequently expressed as point of view by many political officials. On the other hand, several Authors e.g. Mediavilla et al. [12], Field et al. [13] indicated some problems –namely either too high energy requirements for particular crop production or in global analysis evident lack of arable land that would be sufficient for global energy demand, as well as Pimentel et al. [14] showing strong competition between biofuel and food production leading to evident limits for expansion of biofuel production. The results, above mentioned, indicate the importance of biofuels for the world, as well as need for further research to investigate the energetic efficiency of biofuel production system.

The aim of present paper is an analysis of the influence of two limiting factors, i.e. limited resources, and limited space being dedicated to biofuel production, on sustainability of agriculture. The mathematical models for energetic efficiency introduced by Wasiak and Orynycz [15], and by Wasiak [16] – for sustainable development are used for description of phenomena occurring in the agricultural part of biofuel production system.

2. Analysis of sustainable development

The terms "sustainability" and "sustainable development" are frequently used as synonyms. This might lead to some misunderstanding. Namely sustainability might be understood as "plateau" – stagnation – constant state. Sustainable development, in turn, may rather be associated with constant rate of some transition (growth, development). In processes (transitions) occurring in nature constant rate can, however, be expected in situations where both: space and resources are unlimited. When the resource is limited, and its availability decreases during transition, the rate of the process varies in time. In the previous work Wasiak [16] proposed to use of kinetic function, usually applied to the description of the physical, chemical or biological processes, for mathematical modeling of technological or economic processes occurring in conditions of limited resources. The function assumes form

$$x(t) = a[1 - \exp(-kt^n)] = a[1 - \exp\left(-\frac{ln2}{t_{1/2}^n} t^n\right)] \tag{1}$$

where: *a, k, n* are numerical coefficients, constant in a given process, and $t_{1/2}$ is half-time of the process. The coefficient, *a,* represents the full accessible quantity of the substrate undergoing transition, while coefficients *k* and *n* affect the time dependent rate of the process. Variable *x(t)* describes the quantity (or fraction) converted into the