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Evaluation of supply potential of energy crops in Japan considering cases of improvement of crop productivity ☆

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Abstract

Energy crops are not presently major energy resources as energy crops are more expensive than fossil fuels at present. However, energy crops may become important energy resources in the future.

In this study, the authors discuss the availability of energy crops in Japan. The supply potential of energy crops produced on unused arable land is estimated at 0.12 EJ yr^{-1} and that of secondary crops for bioenergy is estimated at 0.12 EJ yr^{-1} in Japan. However, it is difficult to utilize the supply potential considering the low food-self-sufficiency ratio and the high costs of crops in Japan.

In addition, the authors analyze the supply potential of energy crops produced on surplus arable land in Japan in cases of biomass productivity increment. The supply potential of energy crops is formulated into $0.12A$ (EJ yr^{-1}), where A means the index of productivity increment ($A = 1.0$ at present). On the other hand, in the case of every crop productivity increment, the supply potential of energy crops is formulated into $1.44A$–1.32 (EJ yr^{-1}). When it is assumed that the ratio is 2.0, the supply potential in the latter case is 1.44 EJ yr^{-1}, which is equivalent to about 7% of the total primary energy supply in Japan. When it is assumed that the ratio is 2.0 in the latter case in the world, the supply potential of energy crops is 435 EJ yr^{-1}, which exceeds the total primary energy supply in the world. It is difficult to improve the productivity of every crop. However, if the improvement is realized, energy crops will become one of the major energy resources in Japan and in the world.

Keywords: Energy crops; Bioenergy supply potential; Crop productivity

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1. Introduction

Energy crops are defined as crops grown for bioenergy. Energy crops are mainly produced on surplus arable lands.

In this study, the authors discuss the availability of energy crops in Japan. The authors calculate the supply potential of energy crops and discuss the realistic availability of energy crops considering the low food-self-sufficiency ratio in Japan and the differentials in major crop prices between Japan and the United States. Next, the authors conduct analyses in cases of biomass productivity increment.

In this paper, all the biomass tonnage will be on a dry basis.

2. Availability of energy crops in Japan

2.1. Productivity of energy crops in Japan

The productivity of double cropping in intensive agriculture in Japan can arrive at $40\,t\,ha^{-1}\,yr^{-1}$ [1]. However, the productivity in extensive agriculture in Japan is about $20\,t\,ha^{-1}\,yr^{-1}$, which is half of that in intensive agriculture [1]. Energy crops are usually produced in extensive agriculture as energy crops need to be inexpensive and are economically competitive with fossil fuels. On the other hand, the productivity of energy crops in the world is about $300\,GJ\,ha^{-1}\,yr^{-1}$ ($15\,t\,ha^{-1}\,yr^{-1}$ and $20\,GJ\,t^{-1}$) [1]. The productivity in extensive agriculture in Japan is close to that of energy crops in the world. Therefore, the authors assume that the productivity of energy crops in Japan is equal to that of energy crops in the world at $300\,GJ\,ha^{-1}\,yr^{-1}$.

The productivity of secondary energy crops in the double-cropping system is assumed to be $5\,t\,ha^{-1}\,yr^{-1}$ [1].

2.2. Supply potential of energy crops in Japan

Japan has a limited land area of 38 Mha (million hectares) and a high ratio of mountainous area to land area at about 70%, although Japan contains a population of about 130 million [2]. Therefore, the food-self-sufficiency ratio is only about 40% and there is a small area of unused arable land where they can produce energy crops in Japan [3].

The area of arable land is 4.4 Mha and the area of unused arable land is 0.27 Mha [3]. In addition, there is an area of rice production adjustment of 1.01 Mha in Japan. Most of the adjustment area is used for producing other crops, but about 0.14 Mha is unproductive [3]. The total of unused arable land and unproductive arable land is 0.40 Mha and is assumed to be available to produce energy crops with a productivity of energy crops of $15\,t\,ha^{-1}\,yr^{-1}$; the supply potential of energy crops produced on unused and unproductive arable land in Japan is $6\,Mt\,yr^{-1}$.

Moreover, it is assumed that the arable land that suits double cropping for bioenergy is about 1.2 Mha [3]. As it is assumed that the productivity of secondary crops for bioenergy is $5\,t\,ha^{-1}$ [3], the supply potential of secondary crops in Japan is about $6\,Mt\,yr^{-1}$.

The total of the supply potential of energy crops is $12\,Mt\,yr^{-1}$. As it is assumed that the higher heating value of the energy crops is $20\,GJ\,t^{-1}$, the supply potential of the energy crops in Japan is $240\,PJ\,yr^{-1}$, equivalent to about 1% of the amount of the total primary energy supply in Japan (Table 1).

For reference, the supply potential of fuelwood produced on the mountainous forest area in Japan is estimated at $1.6\,EJ\,yr^{-1}$ [4]. In this estimation, it is assumed that the productivity of fuelwood is $5.8\,t\,ha^{-1}\,yr^{-1}$ and fuelwood is produced not on the growing forest area (which is used for producing wood material) but on the mature forest area (i.e., the natural forest area). However, the mountainous forestry area in Japan is so steep that it is difficult to mechanize the fuelwood production system. Hence, it is difficult to produce fuelwood inexpensively.

2.3. Regionality of supply potential of energy crops in Japan

Unused arable land is distributed throughout Japan (Fig. 1). Unused arable land is large in Honshu (the main island in Japan) and Kyushu (the south-west island in Japan).