Chapter 1
Introduction

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1.1 Background and Character of Biofuel Production Expansion

Currently, the development of biofuel expansion is found worldwide. Any energy released from biomass through a chemical reaction is called bioenergy (Yamajji et al. 2000). "Biomass" does not only mean biotic mass or biotic standing stock in ecological science but also means biotic mass as an energy source because it has been considered an alternative energy of fossil fuel since the "oil shocks" in the early 1970s. There is no strict definition, but the generic term covers an accumulation of animal and plant resources, as well as waste materials from them, except fossil resources, from the view of energy resources (The Japan Institute of Energy 2009). Biofuels can produce bioenergy, but it is often thought to be a fuel for transportation and is in competition with food crops. The current biofuels for transportation are mainly bioethanol and bio-diesel. These are called first-generation biofuels. Most first-generation biofuels are produced through glycosylating, fermenting and distilling starch ingredients of maize, wheat and potato or through fermenting and distilling carbohydrate ingredients of sugarcane and beet. They are also produced

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from poaceous feed crops such as paddy and sorghums (The Japan Institute of Energy 2009 and Ohijiri 2004). Currently used first-generation bio-diesel is produced from animal oil and fat such as beef fat and lard, as well as vegetable oil such as *Elaeis guineensis* (for palm oil), crucifer (for canola oil), soybean (soybean oil) and sunflower (sunflower oil) (The Japan Institute of Energy 2009 and Matsumura 2006).

One of the reasons for introducing biofuels worldwide is its features.

Carbon Neutral The Kyoto protocol treats biofuels as carbon neutral because CO_2 emission for biofuel combustion is balanced out by absorbed CO_2 during growth of the plants for biofuel. In other words, while CO_2, one of the global greenhouse gasses (GHG), is emitted by fossil fuel burning, the Kyoto protocol views CO_2 emission as absent when biofuel is burned. We hypothesize that utilizing biofuels is a countermeasure against global warming. The most important reason for introducing biofuels is this carbon-neutral character in principle.

Renewable Energy According to the definition of renewable energy by the National Renewable Energy Laboratory, renewable energy is a non-exhaustible resource similar to wind and solar power (National Renewable Energy Laboratory 2008). Biofuel is thought to be a renewable energy because it is from plants and is not exhausted unless retarding the growth of the plants.

Prevention of Air Pollution An incomplete combustion of gasoline is inhibited by the addition of ethanol, which contains oxygen. Oxygenated gasoline by adding biofuels or bioethanol into gasoline reduces carbon monoxide emission. According to the IEA (International Energy Agency), not only carbon monoxide emission but also carbon hydride and particulate matter are reduced by adding bioethanol to gasoline. The US EPA (Environmental Protection Agency) reports that emissions of carbon monoxide, carbon hydride and particulate matter are reduced, although nitrogen oxide emissions are reduced by adding bioethanol to gasoline.

Contribution to Energy Security The production of biofuel from plants grown in a country may contribute to energy security in that country. In addition, producing biofuel can reduce the geopolitical risk of energy because of its even distribution, whereas fossil fuel often has high risk.

Development of Agriculture and Rural Areas Increasing agricultural profit, generating job opportunities in the agricultural sector and exporting agricultural production in developing countries are expected by biofuel production (Koizumi 2007; Hisano 2008).

These factors induce many countries and regions to focus on introducing biofuel production. In addition, a rapid increase in crude oil prices is also one of the major reasons for introducing biofuel production in many nations and regions. A decrease in the relative price of biofuel compared to the crude oil price as a substitute good leads to an increase in demand for it.

1.2 Current Situation of Biofuel Production in the World

According to the OECD-FAO (2013), the bioethanol production in the USA in 2013 is 55,769.8 million litres, and in Brazil, it is 28,684.5 million litres. The total production of both occupies 74.2% (USA, 48.9% and Brazil, 25.2%) of world production, 113,853.8 million litres. This trend is similar for the productions and shares of both countries; those of the USA are 79,997.3 million litres, 47.8%, and those of Brazil are 47,375.9 million litres, 28.3%, in 2022. Biofuel production has a long history. For instance, bioethanol was used for the Ford Model T in 1919, and blending bioethanol into gas was made obligatory in Brazil in 1931. However, increasing biofuel production in many countries and regions except Brazil is currently a possibility. The Energy Policy Act of 2005 and the Renewable Fuel Standard of the USA by President George W. Bush in 2005 as a midterm policy direction of energy in the USA and the State of the Union address by President Bush in 2006 and 2007 have had large impacts on biofuel policy in many countries and regions.

Bio-diesel productions of countries and regions in 2013 are as follows: EU27, 11,287.6 million litres (39.6%); USA, 6057.5 million litres (21.2%); Brazil,2405.0 million litres (11.5%); and Argentina, 2697.1 million litres (9.5%). This means that bio-diesel production is concentrated in a few countries and regions. Although it is expected that India produces a rather large amount of bio-diesels, it only produces 776.3 million litres (1.9%). EU27 is expected to produce 18,281.6 million litres (45.0%) along with the USA at 6267.2 million litres (15.4%), Brazil at 3336.6 million litres (8.2%) and Argentina at 3451.4 million litres (8.2%) in 2022. Bio-diesel production has a long history, as is the case of bioethanol. Although small-scale bio-diesel production was produced and used from the 1930s in some parts of the world, rapidly increasing bio-diesel production has been seen since approximately 2005, as is the case of bio-diesel.

While biofuel production has increased all over the world based on the futures indicated in Sect. 1.1, there is scepticism of the features. Promoting biofuel production may not only increase food supply and demand with adverse effects on agricultural production but also accelerate global warming.

1.3 Issues of Biofuels

The Kyoto protocol treats biofuels as carbon neutral; however, the whole producing process of biofuels, what we call the life cycle, should be evaluated. This process includes the energy input of agricultural production and energy crops for biofuels. Hill et al. (2006) estimated the energy balance of bioethanol production with DDGS (Distiller's Dried Grains with Solubles) from maize in 11 input cases. In addition, Hill et al. compared these results with five existing papers. Although it is difficult to compare directly because inputs and products are different among studies, producing excess input energy was shown in four of six studies, Wang et al., Shapouri et al. (2004), Graboski (2002) and Hill et al. (2006). On the other hand, two of the six studies, Parikka (2004) and Pimentel (2003), have opposite results. Based on those studies, a clear result has not been obtained in terms of carbon-neutral biofuel production from the viewpoint of the life cycle. Hill et al. noted that those results are not derived from a common consensus of included inputs for biofuel production. For instance, it is difficult to define the ratio of agricultural capital use for biofuel crops from total inputs of agricultural capital for agricultural production. The UN-GBEP (Global Bioenergy Partnership) and many other institutions, however, have discussed a unified evaluation method of biofuel production that may be established. It is expected to establish international standards to evaluate biofuel production (Technical Innovation Council on Biofuels 2008).

Not only the energy balance of biofuel production but also the greenhouse gas emissions from soil are important in producing energy crops in the field. With greenhouse gas emissions from the cultivation of energy crops, the affirmation of carbon-neutral bioenergy may not be held.

Expanding the demand for bioenergy provides an incentive for farmers to shift current crop production systems to new crop production systems with energy crops. In fact, the number of farmers who do not sign up for the CRP (Conservation Reserve Program) in the United States is currently increasing. The CRP was started in 1986 to shift agricultural land located in disadvantaged areas to grass fields or forests. Some of the benefits from the CRP are increasing stored carbon in the soil, maintaining the productivity of land, mitigating land degradation caused by water and wind and protecting biodiversity. Extensional expansion of energy crops may drain benefits from the CRP. As a result, reducing greenhouse emissions through using biofuels, which is the most important projected contribution, is not only expected but also adversely affected by agricultural production through decreasing productivity of the land and the loss of biodiversity. In addition, it is noted that increasing agricultural production based on economic incentives leads to excess inputs of chemical fertilizer and pesticides (Fike et al. 2006; Parrish and Fike 2005). The increasing pricing pressure caused by the increasing demand for biofuels likely brings the same consequences. Increasing energy crop production with excess inputs could lead to harmful effects for ecological systems, including water systems.

It is expected that the so-called second-generation biofuels may alleviate the tight food supply because of biofuel expansion. Second-generation biofuels are produced from lignocellulosic biomass. Lignocellulosic biomass is hemicellulose, lignin and lignifying tissue, which are cells in the blade and stem (McKendry 2002). Although it takes time to put them into practical use, second-generation biofuels are expected to avert acute competition between crops for food and crops for biofuels since any part of crops except the edible part and agricultural residue may be used to produce biofuels. Additionally, second-generation biofuels are projected to produce larger amounts of biofuels than current biofuel production because larger parts of crops might be converted into biofuels in the case of second-generation biofuels than in the case of current biofuels (Perlack et al. 2005; Sheehan et al. 2004). While waiting for the introduction and dissemination of second generation of biofuels, increasing energy crop production might be prospected even by introducing second-generation biofuels. This means that increasing crop production based on economic incentives may not avoid greenhouse gas emissions from land or decreased land productivity and environmental deteriorations by excess inputs of chemical fertilizers and pesticides. It should also be noted that converting any part of the crops other than edible parts into biofuels might not maintain land productivity and carbon sequestration in the soil since turning the residues of crops such as maize, wheat and paddy into soil may contribute to maintaining that sequestration.

1.4 Biofuels and Sustainability Science

As discussed, biofuel utilization has a complex background and has broad impacts on many fields and sectors, such as the environment, economics and society. Therefore, a sustainable biofuel development strategy that may contribute to sustainable society is possible only if established by analysing the complex features of biofuels in a comprehensive manner.

The concept of sustainability has been discussed since sustainable development was discussed in the WCED (World Commission on Environment and Development) in 1987, which is known as the Brundtland Commission led by the Prime Minister of Norway, Brundtland (Maeda and Hibiki 2008). Through active debate in international arenas such as the UNCED (United Nations Conference on Environment and Development) and WBCSD (World Business Council for Sustainable Development), the atmosphere of building sustainability science, which is required to maintain a fundamental link between science and technology without policy bias, has been globally enhanced in academia (Komiyama and Takeuchi 2006). These active debates for sustainability science developed a common recognition of the need for transboundary/transdisciplinary academic systems that are different from traditional academic systems segmentalized in each academic field. A definition of sustainability science is propounded by Kates et al. based on historical debate and common recognition. The definition of sustainability science is that sustainability science sets out to solve global agendas of human subsistence such as global warming from the perspective point of sustainability (Maeda and Hibiki 2008).

A feature of sustainability science is solution-oriented science. Therefore, various research results and various researchers from many academic fields are joined in a transboundary/transdisciplinary way to solve global agendas. Global warming, for instance, is a problem shared by the entire human race that cannot be resolved by existing traditional approaches on a disaggregated basis, such as independent analysis regarding individual issues in individual regions and partial optimization analysis.

Sustainability science is still on the way to be mature in Europe, the United States and Japan. However, a common feature of sustainability science in academia is that the transboundary/transdisciplinary approach should be applied to resolve the issues that have multitiered and complex features by taking hold of those relationships (Komiyama and Takeuchi 2006; Clark and Dickson 2003; Kates et al. 2001; Lele 1991). In addition, resolving global agendas by applying sustainability science includes coordinating the related stakeholders.

While research results for the effects of biofuels on the environment from the natural science view have accumulated gradually, there is still room for biofuels research to be analysed. It should be considered to consolidate not only existing scientific results regarding biofuels but also new scientific knowledge to policymakers and stakeholders as scientific evidence. Biofuel utilization should be considered a trilemma of global warming, energy security and food security, promoting agriculture in other words. Moreover, biofuel utilization is seen as one of the factors of acute food price increases. It is imperative to coordinate among international institutions, policymakers across nations and other stakeholders to establish a sustainable biofuel development strategy based on an adaptation/mitigation strategy from various scientific knowledge for biofuel utilization. Applying the concept of sustainability science allows us to build that strategy. Meanwhile, applying sustainability science to establish a sustainable biofuel development strategy may contribute to an increasing global stream of building sustainability science.

1.5 Objectives

As discussed, biofuel utilization has a complex background and has broad impacts on many fields and sectors, such as the environment, economics and society. Therefore, a sustainable biofuel development strategy that may contribute to sustainable society is only possible by analysing the complex features of biofuels in a comprehensive manner. It is necessary to integrate the findings from the analysis of social sciences and natural sciences.

The objectives of this book develop a development strategy for biofuels at the multi-scale, national, regional and worldwide levels through integrating analysis by social sciences and natural sciences based on a sustainability science approach. As mentioned in other chapters, the feature of sustainability science is that various research results and various researchers from many academic fields are joined in a transboundary/transdisciplinary way to solve global agendas. Therefore, sustainability science is better suited for analysing biofuels that have a wide-ranging impact and establishing a sustainable development strategy.

To achieve our aims, this book has three main parts. In part I, the conceptual framework of this book is shown. Research results for biofuels from the views of natural science and social science are indicated in part II. Research has been conducted at the multi-scale, global, regional and national levels. Our main focus is the Asia Pacific region, including China, India, Indonesia and Japan. In part III, sustainable biofuel development strategies at the multi-scale level are shown as a result.

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