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Carbon sequestration potential via energy harvesting from agricultural biomass residues in Mekong River basin, Southeast Asia

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ABSTRACT

Climate change is receiving an ever-increasing attention due to the accelerated global warming. Undoubtedly, CO_2 from anthropogenic sources is the major contributor to this undesirable effect and thus, there has been a growing attempt to curb it. Utilization of biofuels to replace fossil fuels has been considered a viable method to mitigate CO_2 emissions. However, there has been some concern about the indirect greenhouse gas emissions from the production and consumption of biofuels, such as land-use change, carbon leakage, and biomass transportation. It was suggested that these indirect factors can increase the CO_2 emission and may offset the benefits of CO_2 sequestration from biofuel utilization. In this study, all these challenges in biofuel production have been comprehensively reviewed and the importance of using the agricultural residues for biofuel production in countries with high reliance on agricultural development has been emphasized upon. A case study for the utilization of the agricultural residues in the Great Mekong Subregion (GMS) for biofuel production has been presented and the carbon balance for different bioenergy production scenarios in five Southeast Asian countries has been calculated. The results of the regression models show that Thailand and Lao PDR have the highest and lowest amounts of biomass residues per unit mass crop, respectively, suggesting the substantial differences in the harvesting technologies and/or economics of those countries. The overall annual CO_2 sequestration potentials of the biomass for replacing gasoline through bioethanol production, and for substituting coal for power generation via anaerobic digestion and gasification have been determined to be approximately 104/ Tg and 488 Tg, respectively. It has been suggested that using the crop residues as feedstock for the second generation biofuel production without affecting the food market could indeed provide considerable carbon credits for sustainable agricultural development as the major industry in the developing countries.

Contents

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1. Introduction

Climate change has become the most serious challenge for all the nations in the world. Global temperature rise, as a result of swift climate change, has drastic consequences on the natural environment and is causing irreparable damage to the ecosystem. The major contributor to the climate change is the emission of greenhouse gases (GHGs) mainly from anthropogenic sources, which is, in turn, a result of the reckless use of fossil fuels as energy source [1,2]. Considering the urgency of the climate change issue and the devastating impacts of this eco-disrupting chain, a landmark global agreement has recently been established in Paris, France in 2015 to reduce the dependence of economy on fossil fuels in a bid to curb the climate change calamity [3].

In order to achieve this goal, fossil fuels should be substituted with more renewable resources with low carbon footprints in order to decarbonize the global economy [4]. In this regard, the utilization of biofuels, as a replacement for fossil fuels, has been the focus of many countries. Accordingly, there is a growing amount of national-scale incentives to drive industries toward biofuel production and consumption [5,6]. Biofuel production from corn and sugarcane feedstocks is a well-established process, which has been commercialized [7]. Despite the efficiency of the process, there has been a huge outcry regarding the global food security challenge, where the utilization of food stock may jeopardize the food security, especially in the vulnerable countries [8,9]. The use of non-edible biomass, such as agricultural or forest residues, has become an attractive alternative approach widely-investigated in the recent years [10]. However, although many biorefinery processes have been developed to utilize the non-edible biomass, they have not been widely adopted commercially due to some techno-economic concerns [11]. It is highly essential to address these technical challenges and seek for economical approaches in resolving these problems, so that not only food security remains uncompromised, but also the global economy can contribute to controlling the issue of climate change for a brighter future. Meanwhile, as many of the recent research and technologies have been carried out in the developed countries, it is unclear whether similar benefits (or challenges) can be also attributed to the developing countries where agricultural industries account to a much more significant fraction of the countries' economy.

This study aims to provide a comprehensive review of the current studies in quantifying the carbon sequestration potential of different biomass-to-bioenergy techniques, in particular those more appropriate to be used in the developing countries. The key potential challenges, i.e., land use change, biomass transportation, and carbon leakage, have been emphasized. A set of measurement results collected from five countries in the Great Mekong Sub-region (GMS), including Thailand, Lao PDR, Cambodia, Vietnam, and Myanmar, has been used as a case study to verify the discussed concept. According to the current status of the studied GMS countries, a set of regression models with proper parameters have been established to correlate the predicted model values to the real statistics. The model has been used to evaluate the carbon sequestration potentials when applying the crop residues for four scenarios, i.e., uncontrolled disposal, fermentation-based bioethanol production, anaerobic digestion, and combustion. Finally, conclusive remarks and future perspectives were presented for the future development of biofuels from agricultural residues in the GMS countries.

2. Opportunities and challenges in biofuel production from agricultural activities – CO_2 emission/sequestration

2.1. *Carbon sequestration potential of the biomass-to-bioenergy practices*

As the major goal of producing bioenergy from lignocellulosic biomass is to replace fossil fuel-based CO_2 emissions, establishing a mathematical model has become imperative to quantify the CO_2 sequestration potential of the biomass-to-bioenergy industry. Kilpeläinen et al. [12] used a combination of a forest ecosystem model simulation (SIMA) and a life cycle assessment (LCA) tool for the evaluation of the CO_2 sequestration by biomass utilization in biosystems. The CO_2 sequestration of the forest-based ecosystem was compared with the fossil fuel-based system considering the carbon neutrality of energy biomass. They showed that using the most intensive management regime, there was a more significant CO_2 emission reduction than only compensating for fossil fuel-based emissions. Kraxner et al. [13] employed a forest growth model to analyze the uneven-aged temperate stands and integrated it with biomass-to-bioenergy systems to determine the CO_2 sequestration potential of the process. The authors proposed a carbon-neutral energy production using biomass as feedstock and demonstrated that long-term capturing and storage of CO_2 on a continuous basis is feasible with bioenergy production from biomass. It was also suggested that negative CO_2 balance can be achieved when coupling the biofuel production with basic CO_2 capture and sequestration in the biomass [14]. The model applied

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