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Synergies between agriculture and bioenergy in Latin American countries: A circular economy strategy for bioenergy production in Ecuador

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ABSTRACT

This study quantifies the synergies between agriculture and bioenergy considering biodiesel production as part of a set of systemic initiatives. We present a case study in Ecuador taking into account the recent government measures aimed at developing the bioenergy sector. Four scenarios have been evaluated through a newly designed systemic scheme of circular-economy initiatives. These scenarios encompass three production pathways covering three energy crops: palm oil (PO), microalgae in open ponds (M1) and microalgae in laminar photobioreactors (M2). We have applied Benefit-Cost Analysis (BCA) methodology considering the Net Present Value (NPV) and the Benefit-Cost Ratio (BCR) as the main evaluation criteria. In terms of private investment, biodiesel production from PO is more attractive than from M2. However, regarding efficiency and effectiveness of public funds, M2 is superior to PO because the public BCR and NPV are higher, and the pressure on agricultural land is lower. Moreover, M2 as part of a systemic approach presents a better carbon balance. These findings show that, under a systemic approach based on circular economy, strategies like the one analyzed in this study are economically feasible and may have a promising future.

Introduction

The production of bioenergy is a major global initiative to increase energy security while mitigating climate change. However, the development of bioenergy in combination with a growing demand for food could lead to a food-fuel competition for bio-productive land [1]. Algae-based biodiesel is considered a promising alternative that does not compromise arable land, but a fully competitive technology is only expected to be available by the end of this decade [2]. In several regions of South America, such as Brazil, the bioenergy sector has successfully incorporated the technology of algae-based biodiesel. In Ecuador, however, the full potential of this strategy has not yet been analyzed.

Bioenergy production has increased dramatically over the last decade as a result of climate mitigation policies [3]. During this period of time, the USA has invested more than two billion dollars in private funds for algal research, development, and demonstration activities [4,5]. Adaptation policy has had a slower development due to the lack of guidance on implementation of measures. There are very few studies that link adaptation and mitigation and highlight the synergies between specific biofuel projects.

In this article, we have evaluated the potential of algae-based biodiesel derived from a cycle that includes a set of bioprocesses for the production of biomass, valuation of by-products, mitigation of CO_2 emissions and reduction of competition for land use between energy crops and food crops. Additionally, we have quantified the synergies between agriculture and bioenergy, considering biodiesel production as part of a set of systemic initiatives based on circular economy [6]. Finally, the likely implications of policies promoting biofuels are discussed under different scenarios.

A circular-economy strategy for biodiesel production in Ecuador

Ecuador is the third fastest growing economy in Latin America and is currently one of the countries with the lowest unemployment rate in the Americas and around the world [7]. As a result of

Abbreviations: BCA, Benefit-Cost Analysis; BCR, Benefit-Cost Ratio; CER, Certified Emission Reductions; CM, cow manure; M1, microalgae in open ponds; M2, microalgae in laminar photobioreactors; MSW, municipal solid waste; NPV, Net Present Value; PO, palm oil.

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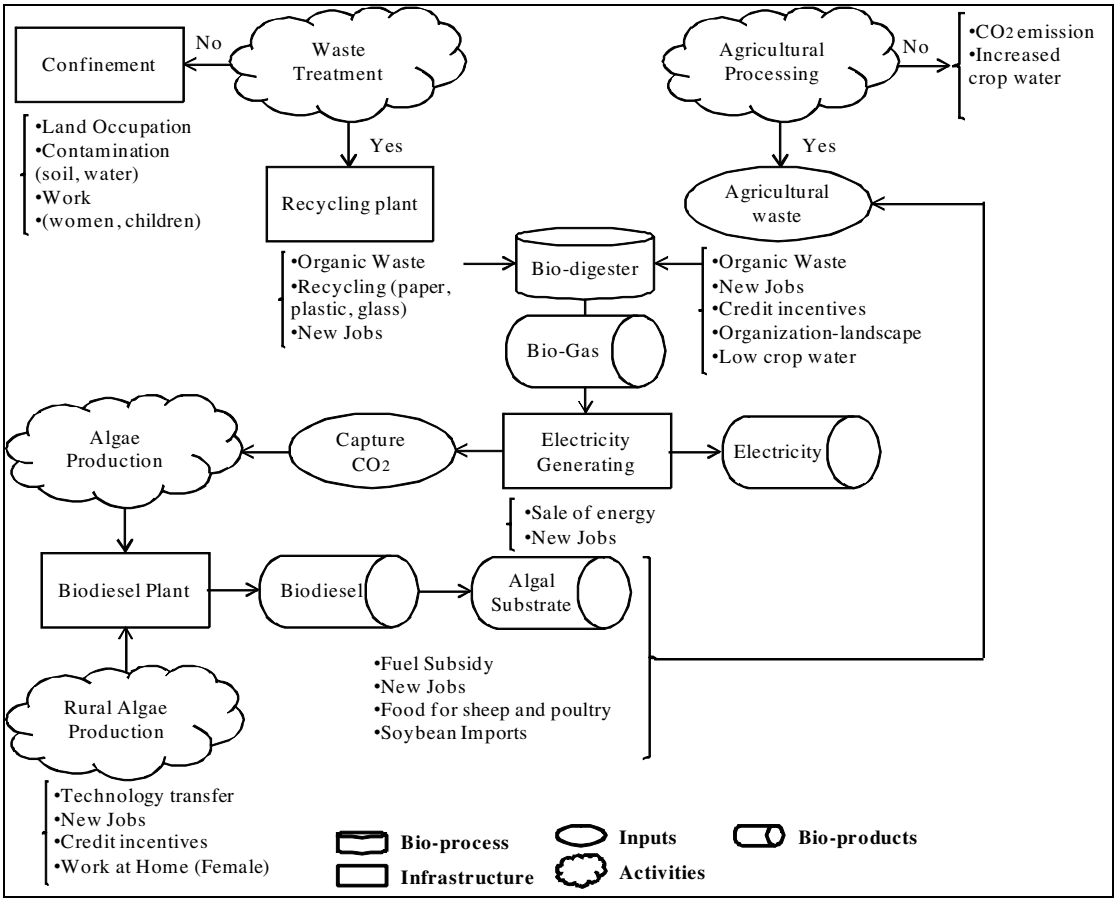

Fig. 1. Schema of the set of proposed initiatives for bioenergy production in Ecuador shows a flow chart relating polluting activities such as urban and agricultural waste with bioenergy production, considering employment generation and byproducts generated in the various processes.

the continuation of a long lasting trend, the government policy framed in the National Plan for Good Living 2009–2013 – one of the aims of which is to exploit synergies between agriculture and bioenergy – placed emphasis on sustainability, as stated in its 4th goal: "Ensure the rights of nature and promote a healthy and sustainable environment" [8]. The new National Plan for Good Living 2013–2017 also pays particular attention to the "Diversification of the national energy matrix", promoting efficiency and increasing the contribution of sustainable renewable energies through a development plan that will eventually be implemented until 2025 [9].

In this context, the Ministry of Agriculture, Livestock, Aquaculture and Fisheries promotes the production of first, second and third generation energy crops required as raw material for biodiesel production.[1]

This paper is relevant in this political and economic context because, besides analyzing the bio-economic potential of biodiesel in Ecuador, it makes a specific proposal for a systemic set of initiatives developed as a circular-economy strategy. This proposal takes into account (1) current biotechnological advances that provide crucial information to establish the pathway towards sustainable development of biofuels in Ecuador; (2) information on how to diversify the energy matrix; (3) plans for rural development; and (4) energy and food security issues in rural areas.

In this study we have assumed that the production of algae-based biodiesel has a high bio-economic potential as part of a set of initiatives that can be implemented by incorporating the concept of circular economy. Fig. 1 shows the flowchart of the systemic proposal developed in this study, which prioritizes the use of biomass waste for power generation. The proposal considers the production of biogas through a mixture of municipal urban waste and livestock manure in order to generate power by burning biogas. Biogas combustion generates CO_2 which, instead of being released to the atmosphere, is used in the process of production of microalgae, converting CO_2 into biomass and oxygen through photosynthesis. The biomass obtained from microalgae production is processed through thermochemical liquefaction. This process allows separation of lipids from proteins and carbohydrates to produce biodiesel through transesterification. The glycerin obtained during the transesterification process is sold on the local market. Furthermore, as the algal residue containing protein and carbohydrates is reused as animal feed, farmers are encouraged to collect livestock manure for transfer to the biogas plant.

An economic and environmental evaluation of this circular agriculture strategy is crucial to guide the design of synergy-coherent policy measures.

Material and methods

A review of the existing literature showed that there are scientific publications addressing in detail some of the initiatives proposed in this work, such as the production of biogas from municipal urban waste and manure [10], the potential of biogas production from waste and its conversion into electricity [11], and

[1] Executive Decree 1303 of 28 September 2012, of the Presidency of the Republic of Ecuador, declaring of national interest the development of biofuels. Retrieved from http://www.presidencia.gob.ec/, June 2015.

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