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Strengths, Weaknessness, Opportunities and Threats Analysis of Bioenergy Production on Marginal Land

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Abstract

Planting energy crops on marginal land is a potentially attractive way for bioenergy production that retains better land for food crops and offers a new source of income to poor farmers. Although such lands would be less productive and subject to higher risks, their use for bioenergy plantations could have secondary benefits, such as restoration of degraded vegetation, carbon sequestration and local environmental services. In most countries, however, the suitability of this land for sustainable biofuel production is poorly documented. We summarized and defined the marginal land and then applied the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis to diagnose and identify the economic, environmental and social impacts from bioenergy production on marginal land. The results show the strengths include land available, energy crop adaptability and rural economy development, while the weaknesses include economic viability, environmental impacts, and equity and gender concerns. The renewable energy planning target, consideration of food security, biofuel policies and technology development will create the external environment to promote bioenergy production on marginal land, but also rise in fuel price and higher labour cost, natural hazards as well as crisis on financial market will be the threats.

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Keywords: SWOT; Bioenergy; Marginal Land; Energy Crops

1. Introduction

Bioenergy is important renewable energy from vegetation. It can be produced in a carbon-neutral way and contribute to socio-economic development [1]. However, feedstock for most current bioenergy comes from food crops. There is growing concern that the production sugarcane, maize, oil palm and canola

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/rapeseed for bioenergy are affecting the food supply [2]. Therefore, marginal lands have received an increased attention by the bioenergy industry as an alternative to cropland for feedstock supply. This could help to address the food vs. fuel debate that is challenging the industry's further development [3].Campbell and Lobell et al. (2008) estimated global area of abandoned agricultural is 385-472 million hectares and showed the global potential for bioenergy on abandoned agriculture lands to be about 8% of current primary energy demand, based on historical land use data, satellite derived land cover and global ecosystem modeling [4]. Milbrant and Overend (2009) estimated that about 400 million hectares of marginal lands are available in the APEC (Asia-Pacific Economic Cooperation) region, representing 6.5% of the total land area. Economies with the largest marginal lands include Australia (13.5% of total land area); Canada (4%); China (5%); Russia (2%); and the United States (13%) [3]. Although growing energy crops on marginal land addresses food security concerns, there remain concerns about whether the widely held assumption of massive bioenergy production on that marginal, abandoned and degraded lands is overly optimistic when including a broader technical, economic, social and environmental perspective. Existing studies of bioenergy production on marginal land rarely consider broad range of economic, social, and environmental issues. We used the Strengths, Weaknesses, Opportunities and Threat (SWOT) analysis to investigate the current state of energy crop growing on marginal land and identify future action needed regarding economic viability, environmental impact, and social development.

2. Definition of Marginal land

The definition of marginal land differs across discipline and geography (table 1) [3-6].

Ecologists have paid much more attention on eco-frangibility of land and marginal land is defined as the eco-tone of two or more than two heterogeneous systems [7]. Economists have defined marginal lands as land uses that are at the margin of economic viability [8]. For example, Schroers (2006) concluded that marginal land is an area where a cost-effective production is not practical, under given site conditions (e.g., soil productivity), cultivation techniques, agriculture policies as well as macro-economic and legal conditions [9]. Evidently, the term marginal land is an economic approach which does not include subsistence agriculture. Hence, marginal land might supply food, feed, medical plants, fertilizer or fuel to local people, but not through a structured, market-based approach. Further, land classified as marginal is often subject to tenure issues where disputes arise on rights of those who use these areas [9].

In this paper, we defined marginal land based the specific physical criteria (table 2) and including unused land as cultivable potential land sources and land that is marginally located and not usually in use for food crops due to the smallness of size, or unclear ownership [5] [10]. We then identified the available and suitable marginal land for biomass energy production (Figure 1) as our SWOT analysis scope and target [3] [5] [10].

Table 1. Definition of marginal Land

Organizations or countries	Definition
Committee on World Food Security (2003)	In farming, poor-quality land that is likely to yield a poor return. It is the last land to be brought into production and the first land to be abandoned.
USDA-NRCS(United states Department of Agricultural – Natural Resources Conservation Service,1995)	Land is restricted by various soil physical/chemical properties, or environmental factors, for crop production. Class 4-8 defined as the marginal land based on NRCS`S State Soil Geographic database.
European Environmental Agency (EEA)	Low quality land the value of whose production barely covers its cultivation costs.
Organization for Economic Co-operation and Development(OECD,2001)	Land of poor quality with regard to agricultural use and unsuitable for housing and other uses.
Asia-Pacific Economic Cooperation Energy Working Group(APEC,2009)	Marginal lands are characterized by poor climate, poor physical characteristics, or difficult cultivation. They include areas with limited rainfall, extreme temperatures, low quality soil, steep terrain, or other problems for agriculture. Examples include deserts, high mountains, land affected by salinity, waterlogged or marshy land, barren rocky areas, and glacial areas. Evidently, not all of these areas are suitable for agriculture.
Ministry of Agriculture, the People's Republic of China(MOA,2008)	Marginal land is winter-followed paddy land and waste land that may be used to cultivate energy crops.
Agriculture and Agri-Food Canada(AAFC,2008)	Classifying Land Class 4-7 as marginal based on the Canada Land Inventory (CLI).

Table 2. Marginal Land biophysical identification criteria

Criteria
Bare and herbaceous areas (not in use or with only moderately intensive pastoralism). Lands with intensive and extensive pastoralism are not included.
Lands with moderate (8-16%) and steep (16-30%) slope.
Lands with soil problems: - Shallow soils (depth < 50 cm) - Soils with low to moderate natural fertility - Coarse textured or sandy soils - Soils with cracking clays - Salt-affected soils - Soils with gypsic horizon - Acid soils [pH is strongly (5.5 – 4.5) to extremely acid (<4.5)] - Soils with high calcium level or Calcisols - Peat soils

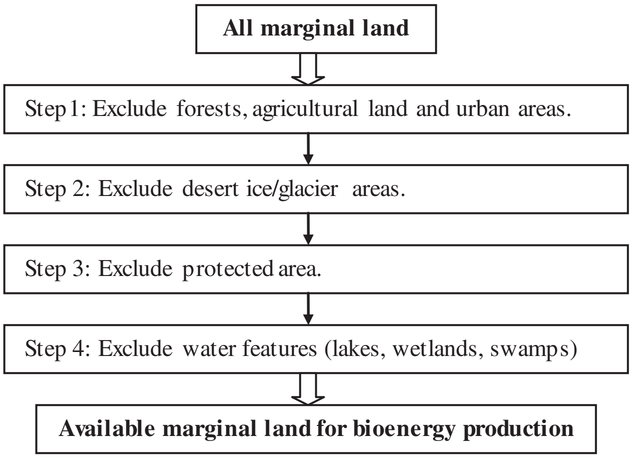

Fig.1. Identification process of available marginal land

3. Methodology

SWOT analysis is a planning tool which aims to identify the strengths and weaknesses of an organisation and the opportunities and threats in the environment and was adopted in 1980s by public administration across such areas as regional development and municipal planning [11-12]. When facing a situation and making a decision, we should consider the positive and negative aspects, advantage and disadvantage of this option. SWOT analysis can help us to identify the current situation and consider more compressive before making a choice. We can consider the bioenergy production on marginal land as an action or project and then be analysed by SWOT. There have been several examples of successful application of SWOT analysis in the fields of bioenergy sustainable development and industry planning strategy [13-16]. However, bioenergy production on marginal land has its own particularity when facing different internal situation and external environment. The analysis of the introduction of energy crops growing on marginal land includes several steps. Production cost, transportation distance, Greenhouse gas balance should be studied in detail. The SWOT analysis was carried out to analyse the opportunities and threats in the global external environment, and the strengths and weakness looking internal to the project. The analysis steps were the following [17]:

- Identification of all the internal aspects of bioenergy production on marginal land, corresponding with the bioenergy energy developed target, which could influence or be affected by planting energy crop on marginal land. These include favourable or unfavourable factors such as land availability, energy crop adaptability, and economic viability.
- Identification of external factors, with potential influence on the bioenergy production on marginal land.
- Characterisation of the identified internal factors. Consider rations of factors that could provide strength or weakness to the project's competitiveness compared to other alternatives. Characterisation of the identified external factors. Consideration of factors that could present threats or opportunities to the development of the project.
- Development of the internal factors, such as choosing appropriate energy crops for planting, that strengthen the project and of the external factors that could provide opportunities for it. Proposal of actions to point out the strengths of the project and to make good use of the discovered opportunities.

- Development of the internal factors that weaken the project and of the external factors that could be threats for its development. Proposal of actions to solve the weaknesses of the project and to avoid the considered threats.

4. SWOT analysis of bioenergy production on marginal land

4.1. Strengths

4.1.1. Land availability

Marginal land can increase the land availability to supply biomass production. It is estimated that the global abandoned agricultural land range from 430-580Mha, which is part of marginal land [4]. A nation-wide survey, organized by the China Ministry of Agriculture, on marginal land resources that may be used for energy crop production revealed an area of 34 million ha of which 7 million ha and 27 million ha are winter fallowed paddy land and wasteland marginal land, respectively (Kou et al. 2008). According to Yan et al. (2008)'s study, marginal land available for biomass production includes 82.3 million ha of which 24 million ha are cultivable. In consideration of economic operation of transportation, some 7 million ha can be considered available for energy crop use [10]. According our definition of marginal land, the available marginal lands in APEC economies are about 4 million km2 or 6.5% of total land area [3].

4.1.2. Energy crops adaptability

Energy crop is a crop grown specifically for their fuel values, which include food crops such as corn and sugarcane, and non-food crops such as poplar trees and switchgrass. A number of energy crops can potentially be grown on marginal land to provide feedstocks for bioenergy, non-food products and biofuels, such as miscanthus which requires limited fertilizer, few other inputs and adds significant amounts of organic matter to the soil [18]. According to the definition of available marginal land (Tab.2 and Fig.1), available marginal land will be not used for food crops according its biophysical characteristics but some dedicated energy crop can be grown on it. Perennial lignocellulosic crops such as eucalyptus, poplar, willow or grasses require less-intensive management and fewer fossil-energy inputs and can also be grown on poor-quality land, while soil carbon and quality will also tend to increase over time [19].Meanwhile, the development of energy crops on marginal lands, provided that they are reasonably productive, has a major advantage over development of these crops on croplands from the standpoint of carbon impacts of direct land use change [3].

4.1.3. Improving rural economy and enhancing rural economy

If farmers choose the proper energy crop growing on the marginal land it maybe increase their incomes. There are some marginal lands in developing countries with large population. Bioenergy production on marginal land can create the working opportunities for these labours especially the poor people. When multipurpose trees are planted, the rural economy will be improved in different ways. Selling of biomass will increase household income. For example, in Lu et al.(2009)'s study in a remote county of southwestern Sichuan Province of China, each household will have no less than 10 tons of mulberry biomass in excess of need, which can be sold, bringing additional income [5][20].

4.2. Weakness

4.2.1. Economic viability

According to the marginal land quality, the yield of biomass on marginal land will be lower than it on agriculture land with good quality. Marginal lands in APEC economies have low productivity. The predominant NPP (Net Primary Productivity) value is less than 6 t/ha/yr [3]. FAO (2008) also found that switchgrass can be highly productive on fertile soils, especially when fertilizer and pesticides are applied, but that its performance on poor soils is lower [19]. Meanwhile, the irregular shapes of marginal land increase overlap (the amount of turning required during field operations) and can result in overapplication of seed, pesticides and fertilizers, increased fuel consumption and increased work time but would not be a issue with woody biomass[21]. Also, the marginal land usually has long distance away from the market, which will increase the bioenergy production cost. Therefore, the production investment will be higher than production on normal agriculture land. Low productivity and high production cost will restrict the economic viability. Some marginal land can be used for grazing, so the opportunity cost should also be concerned and it will also increase the production cost of planting energy crops on marginal land.

4.2.2. Environmental impact uncertainty

Although the energy crop production on marginal land have the positive environmental impact such as restoration of degraded land and carbon sequestration. But if the marginal land is covered by permanent grassland, a carbon dept might occur when converted to energy crops. Further, if only dispersed areas of marginal land are used for energy feedstock production, the CO^2 emissions associated with transport of the feedstock to the end user could negate all the potential C-mitigation. Failing in C mitigation could put a break on the development of energy crop production and full lifecycle and regional specific Life-Cycle Analysis (LCA) would be necessary to assess the GHG mitigation potentials of energy crops [22].

4.2.3. Equity and gender concerns

Marginal lands often provide subsistence services to the rural poor, including many agricultural activities performed by women. The emphasis on exploiting marginal lands for biofuel crop production may work against female farmers. For example, in India, these marginal lands, or so-called “wastelands”, are frequently classified as common property resources and are often of crucial importance to the poor. Evidence from India shows that gathering and use of common property resources are largely women’s and children’s work – a division of labour that is also often found in West Africa [19].However, women are rarely involved in the management of these resources. Whether the poor stand to benefit or suffer from the introduction of biofuel production on marginal lands depends critically on the nature and security of their rights to land [19].

4.3. Opportunities

4.3.1. Renewable energy requirement and food security consideration

A lot of countries have their renewable energy planning targets in the future to reduce greenhouse gas emissions to mitigate climate change. For example, the US Energy Independence Security Act of 2007 mandated the production of 36 billion gallons of biofuels by 2022, of which 21 billion gallons must be advanced biofuels. This mandate would result in an increase in biomass production of approximately seven times the current amount—from 190 million dry tons to 1.36 billion dry tons of biomass. Biomass is a land-based renewable resource and such a significant increase is likely to result in large-scale conversion of land, from current uses to energy feedstock generation, potentially causing increases in the prices of food, land, and agricultural commodities as well as disruption of ecosystems [23].Therefore, to achieve the renewable energy planning target and ensure food safety, marginal land will be an attractive option for biomass production. Based on Milbrant and Overend’s (2009) estimation, the total annual biomass resource potential on marginal lands in APEC economies was about 1.3 Gt, which converts roughly into 260 Mt of gasoline equivalent. By comparison, APEC uses about 621 Mt of gasoline and crude oil import is about 1.3 Gt annually (IEA 2006). So the gasoline potential from marginal lands could displace two-fifths of the region’s gasoline consumption and one-fifth of its crude oil imports. [3].

4.3.2. Policy encouragement and technology development

There already been a lot of energy policies and climate change policies to encourage bioenergy development, such as subsidies and carbon credit and tax. Although there are not policies directly related to biomass production on marginal land, the existed biofuel promoting policies will drive farmers to consider plant energy crops on marginal land. Also, the agriculture policies about marginal land will affect the use of marginal land and create the opportunities for farmers to consider plant energy crops. For example, the new Greencover program, a $110 million national initiative, encourages landowners to convert marginal cultivated land to permanent cover [24]. This program will make landowners to accept planting energy crops on marginal land as the economic driving. Meanwhile, as the biomass conversion technology development, the non-food energy corps conversation cost will decrease; it will make dedicated energy crop production on marginal land much more competitive.

4.4. Threats

4.4.1 Rise in fuel price and higher labour costs

Marginal lands are usually far away from the market, so biomass transportation will consume much more fuel from marginal land. The high energy price will increase the transportation cost and will make biomass from marginal land less competitive than other feedstocks. Also the labour cost is higher in developed countries than it in developing countries. Therefore, bioenergy production on marginal land will have the comparable advantage in developing countries according to the lower labour cost.

4.4.2. Natural hazards and Crisis on financial market

Natural hazards threaten energy crops harvest, such as poplar is usually harvested every six years. If there is a natural hazard before the harvest year, it will reduce a great loss of energy crops from marginal land than annual crops from agricultural land. Meanwhile, the crisis on finical market will also pose a threat to bioenergy production on marginal land, because it will be in a difficult condition for new investments to improve the production and conversion technologies of dedicated energy crops from marginal land.

5. Conclusions

From the analysis of the Strengths/Weaknesses and Opportunities/Threats (Table 3), whether taking an action or building a project of planting energy crops on marginal land depends on a lot of factors.

The strengths of bioenergy production on marginal land lie largely in its large land supply potential and strong energy crops adaptability. Energy crops can be planted on marginally economically is vital. Other strengths include increase farmers' income, job creation, probably environmental benefits and energy resource security, which in turn secure the gross domestic product (GDP) of the local area. Weaknesses involve economic viability, environmental impacts uncertainty, and equity and gender concerns. Low productivity, high production and transportation cost will decrease the competition ability of this choice. Also, overlap and dispersed problems of marginal land will increase the CO_2 emissions. Opportunities include the renewable energy requirement and food security consideration. Policy encouragement and technology development also create opportunities for bioenergy production on marginal land development. Threats to the action include rise in fuel price, higher labour cost, natural hazards and crisis on financial market

Table 3. Relevant factors identified in each SWOT category

	Internal	External
Positive	Strengths • Land availability • Energy crops adaptability • Improving rural economy and enhancing rural economy	Opportunities • Renewable energy requirement and food security consideration • Policy encouragement and technology development
Negative	Weakness • Economic viability • Environmental impact uncertainty • Equity and gender concerns	Threats • Rise in fuel price and higher labour cost • Natural hazards and Crisis on financial market

Currently, we lack studies of detail analysis of economic viability and environment impacts assessment of bioenergy production marginal land, which should contain the concept of sustainability—"It's not just about planting energy crops." Therefore, much more experiments and investigations are in need in the future. Meanwhile, we can consider combining SWOT framework with AHP (Analytical Hierarchy Process) to quantify the advantage and disadvantage of bioenergy production on marginal land. It will be easier for stakeholders to make a wise decision.

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