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An Integrated Assessment of Energy Crops Production in Taiwan

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Abstract

For countries with scarce fossil fuel resources and limited cropland, how would energy crops production increase energy security and affect land use and farmer's income? To address such questions, we develop an integrated assessment model to evaluate land use changes and economic impacts of energy crop policy in Taiwan. The model consists of several submodels linked together interactively, representing different components of the integrated agricultural-energy-environmental-economic system. Five major findings and policy implications can be drawn from our study: 1) There is lack of economic incentives for farmers to produce energy crops using set-aside croplands without government subsidies. The required subsidies for energy crops production will be 50% to 120% higher than the original subsidies for set-aside croplands. 2) There is very little economic incentive for farmers to switch to energy crop production from existing crop production even with government subsidies. Therefore, the impacts on the supply and demand of existing agricultural crops are very minor. 3) Among four soil grades, more than half of the total energy crop output comes from Grade II soil, which is mostly located in the West Tainan County. This implies that energy crop mills and refining plants should be located in the West Tainan County to minimize the transportation costs. 4) The results from general equilibrium modeling show that the Miscellaneous Crops sector will incur the largest increase in output due to energy crop production. In the case of sunflower production, the ratio of total output increase to total government subsidies is about 1.12, which is the only energy crop with benefit-cost ration greater than 1.0. This implies that sunflower is the most economical feasible choice among three energy crops. 5) In the case of sunflower production, the total employment and average monthly wage rates in the Agricultural Sector will increase by 6.7% and 71.7%, respectively. This indicates that sunflower production will have significant positive economic impacts on the employment and income of farmers in Tainan County.

Keywords

Energy Crop, Integrated Assessment, Land Use Change, Economic Impacts

1. Introduction

During the past few decades, there has been increasing attention given to the issue of global climate change and its consequences for natural systems and human society. Several options could be used to reduce greenhouse gas (GHG) emission to mitigate its impacts on global climate. For example, increasing biomass energy production, changing agricultural land use, carbon sequestration by forests, and other economic policy instruments, including carbon tax and carbon permit trading, all have potentials to reduce the atmospheric concentration of GHG [1] [2] [3]. In addition to reducing overall fossil fuel demand and improving energy use efficiency, all policy instruments provide incentives to shift energy consumption from high-carbon fuels to low or non-carbon fuels in the short run and mitigate the impacts of global climate change on natural systems and human society in the long run.

Sustained high crude oil prices since the early 21 century has once again become a major concern to the world, especially countries with scarce energy resources. Since crude oil imports will continue to remain a dominant part of energy supply in Taiwan, the need for a robust domestic renewable energy industry to increase energy security has never been greater. For countries with scarce fossil fuel resources and limited cropland, how would energy crops production increase energy security and affect land use and farmer's income? To address such questions, we develop an integrated assessment model to simulate the land use changes and economic impacts of energy crop policy in Taiwan. The model consists of several submodels linked together interactively, representing different components of the integrated agricultural-energy-environmental-economic (IAEEE) system.

Most of the integrated economy-climate studies are aggregated models which specify economic behavior from a top-down perspective. There are many top-down models for individual countries or regions that have detail production technologies for the agriculture sector and that are able to investigate the impacts of shifting agricultural production on the whole economy [4] [5] [6]. However, what lacks is a detail description of land use types, land productivity and rent, agricultural products, and energy sectors and specific technologies from a bottom-up perspective to fully investigate the dynamic interactions between land use change, agriculture production, energy demand, and GHG emissions in the economy [7] [8]. Therefore, our approach is to make the IAEEE assessment model a full integration of a computable general equilibrium model of the economy with detail agriculture production, energy input, and land use modeling components to analyze the underlying dynamics of economic and land use and cover changes over time in relation to energy crop production.

The empirical results show five major findings: First, there will be lack of economic incentives for farmers to produce energy crops using set-aside croplands without government subsidies. The required subsidies for energy crops production will be 50% to 120% higher than the original subsidies for set-aside croplands. Second, there is very little economic incentive for farmers to switch to energy crop production from existing crop production even with government subsidies. Therefore, the impacts on the supply and demand of existing agricultural crops are very minor. Third, based on the geographic distribution of cropland land and soil grades, West Tainan County accounts for more than two-third of total energy crop output in Tainan County. This implies that energy crop mills and refining plants should be located in the West Tainan County to minimize the transportation costs.

Fourth, the results from general equilibrium modeling show that the Miscellaneous Crops sector, which includes energy crops, will incur the largest increase in output due to energy crop production. It accounts for more than 50% of total output increase (51.6 million NT$) in Tainan County. In the case of sunflower production, the ratio of total output increase to total government subsidies is about 1.12 (=51.6/46.0), which is the only energy crop with benefit-cost ration greater than 1.0. This implies that sunflower will be the most economic feasible choice among three energy crops. Finally, in the case of sunflower production, the total employment and average monthly wage rates in the Agricultural Sector will increase by 6.7% and 71.7%, respectively. This indicates that sunflower production will have significant positive economic impacts on the employment and income of farmers in Tainan County.

The remainder of this paper is organized as follows: the next section includes a brief discussion of previous literature in this field of research. Section 3 describes the theoretical model and integrating modeling approach. Section 4 shows the empirical results for three different energy crop production simulations. The final section provides policy implications for energy crop production in Taiwan.

2. Literature Review

Recent rapid growing demand in Europe and North America for biofuels from energy crops is one of the responses to stringent environmental policies to reduce GHG emissions and sustained high oil prices. Biofuels production from energy crops not only can lessen the negative impacts of global climate change and soaring crude oil prices on the economy, but also can increase energy security, improve farmland use efficiency, and increase farmer income [9] [10] [11] [12] [13]. However, with limited available cropland supply, large-scale energy crops production might increase pressure on the current productive cropland and might induce a substantial increase of agriculture product prices [14] [15] [16]. One of the possible solutions is to plant energy crops using currently set-aside cropland, which can deliver large quantity of energy at low GHG emissions levels without increasing pressure on the current productive cropland.

Several studies have quantified the potential biofuels supply from energy crops on the global and national scales. For example, Berndes *et al.* [17] estimate the global potential biofuels supply from biomass and agricultural and forestry residuals ranges from 311 to 706 EJ/year in the business as usual and GHG emissions mitigation scenario, respectively. Gurgel *et al.* [13] estimate by the year of 2100 global biofuels production could reach 221 to 267 EJ/year in a business as usual scenario, and 319 to 368 EJ under a global effort to reduce GHG emissions scenario. On the national scale, Walsh *et al.* 9] estimate that energy crops could supply approximately 1.6 EJ/year of primary energy in the US if high productivity management practices are permitted on Conservation Reserve Program lands. According to Yamamoto *et al.* [10], the potential biofuels supply from energy crops produced on unused arable land is about 0.24 EJ/year in Japan, which accounts about 1.0% of the total primary energy supply.

Most of the global studies are aggregated models which specify economic behavior from a top-down perspective. There are many top-down models for individual countries that have detailed production technologies for the energy sector and that are able to investigate the impacts of shifting energy production [18] [19] [20]. However, what lacks is a detailed description of land use classes, agricultural products, and energy sectors and specific technologies from a bottom-up perspective to fully investigate the dynamic interactions between land use change, agriculture production, energy supply, and GHG emission mitigation in the economy.

3. Theory and Approach

3.1. Theoretical Model

The work of the Intergovernmental Panel on Climate Change (IPCC) has, over the past few decades, encouraged use of integrated assessment processes and models to understand socio-economic and environment aspects of bioenergy systems. Many of the models focus on one kind of process or sector–such as models relating agricultural productivity, energy production technology, or water resources to energy crop production [13] [17]. Our approach differs from previous integrated models by focusing on interactive relationship between agricultural production, energy supply, environmental impacts, and economic growth. The basic model goal is to investigate the potential impacts of energy crop production in Taiwan with a high degree of geographic resolution of land use classes.

To estimate the potential impacts of energy crop production in Taiwan, our model consists of two interrelated systems: human-socioeconomic system and human-environmental system (**Figure 1**). The human-socioeconomic system is used to simulate socioeconomic activities and population growth in the study region and to compute GHG emissions. The major submodel included in the

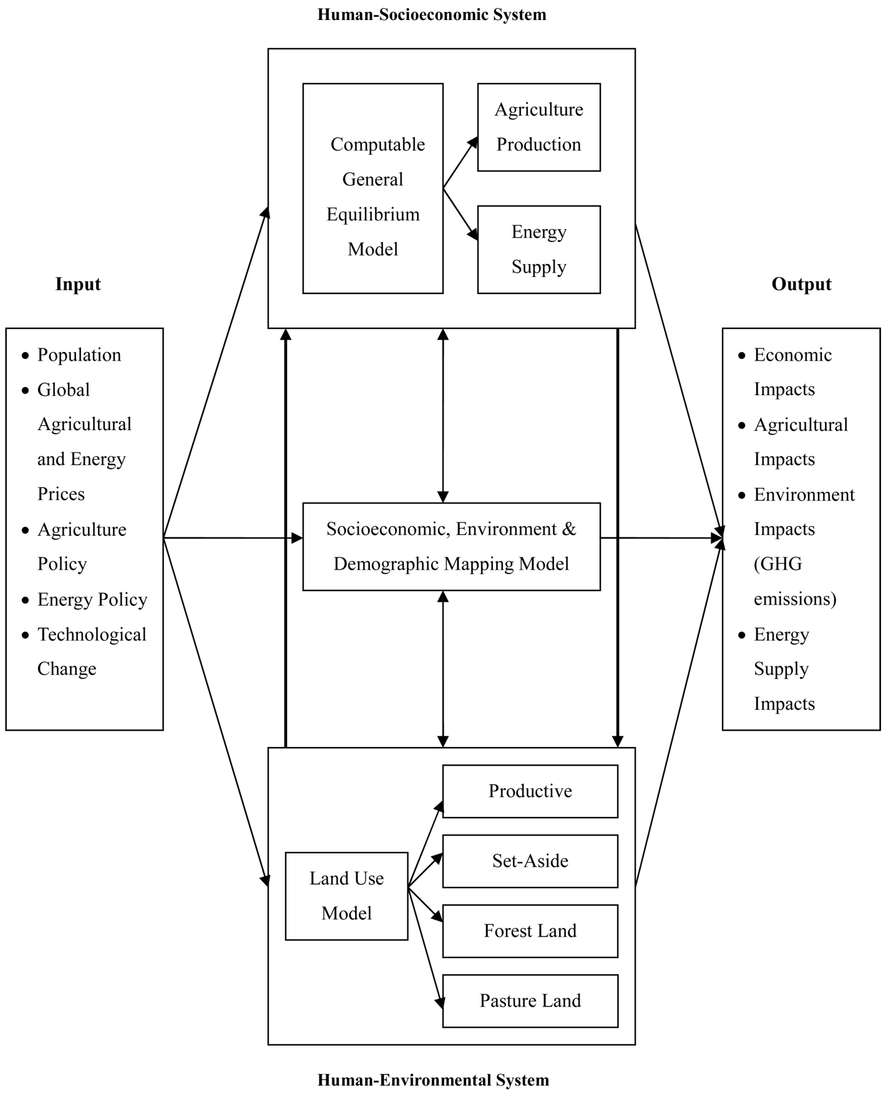

Figure 1. IAEEE modeling framework.

system is a computable general equilibrium (CGE) model and a land use (LAND) model with detailed agriculture and energy sectors. The human-environmental system is used to simulate the change in cropland use based on socioeconomic factors. The major submodelis an agricultural sector model with detailed regional productive cropland use and set aside cropland data. The socioeconomic, environmental, and demographic mapping model is designed to map employment, population, and land use at regional level consistent with the employment and population simulation in the CGE model and cropland use simulation in the agricultural sector model.

3.2. Scope and Data Source

The Taiwan agricultural sector model consists of 60 traditional crops, 5 floral crops, 7 livestock species, 3 types of forests (conifers, hardwoods, and bamboo) and 27 secondary commodities. In the year 2004, the total value of primary agricultural commodities accounted for more than 85 percent of Taiwan's total agricultural product value. Sub-regional production activities are specified in the model for each commodity. Crop and livestock mixes activities and constraints are also specified at the sub-regional level, while the input markets for four different land classes and farm labor are specified at the regional level.

Our empirical model was validated based on the comparison between the equilibrium solution and actual statistics. The year 2004 was chosen as the baseline to construct the database because preliminary energy crop plantation experiment was conducted in the year 2005. We used both the total production and prices as the basis to validate our model. The data sources are mainly from published government statistics and research reports, which include Taiwan Agricultural Yearbook, Production Cost and Income of Farm Products Statistics, Commodity Price Statistics Monthly, Taiwan Agricultural Prices and Costs Monthly, Taiwan Area Agricultural Products Wholesale Market Yearbook, Trade Statistics of the Inspectorate-General of Customs, and Forestry Statistics of Taiwan. Demand elasticities of agricultural products were estimated through a comprehensive survey of various sources.

The land use model is based on a Tainan County geographic information system (1/25,000), which is one of the major crop producing counties in Taiwan. It includes five major database: 1) natural environment database which includes geology, soil, and hydrology data; 2) natural resource and ecological database which includes agriculture and forestry data; 3) social and economic database which includes population, income, regional economy, agriculture, industry statistics data; 4) rural and urban planning database which includes land use and zoning information; 5) transportation network database which includes highway, railway, and transportation data.

The coupling of IAEEE model and LAND model is established by exchanging crop prices, as determined by the CGE model, with land allocation changes, as calculated by the LAND model. In the coupled framework the energy crop allocation in LAND model is determined at county level. Aggregated to the national resolution and then the percentage change of allocated area shares is fed into the CGE model. The resulting price changes are calculated by the CGE model and used to update prices and yields in the LAND model. The coupling algorithm can be divided into two main procedures. The first step is a convergence test. The convergence test aims to investigate the convergence of the coupled system and, in case a divergence is detected, to adjust accordingly the key parameters (e.g., elasticities of substitution) in order to reach convergence. The second step is the baseline simulation which transfers both CGE model and LAND model into a consistent benchmark of the future. The values of key economic variables shaping the base-year equilibrium in the CGE model will be updated according to projected future changes. This step is done in the CGE model with endogenous land allocation. The resulting changes thus imply land allocation changes comparing with the base-year equilibrium.

3.3. Simulation Scenario

Taiwan imported about 98% of total primary energy use in 2004. Therefore, if the set-aside cropland could be utilized to plant energy crops, the amount of energy imports could be reduced eventually. In 2004, total agricultural cropland was 0.83 million hectares, with 0.28 million hectares of set-aside cropland. Set-aside area has increased substantially mainly due to falling prices and incomes caused by Taiwan's entry into the WTO and the consequent importation of low priced rice and other agricultural commodities. Since crude oil imports will continue to remain a dominant part of energy supply in Taiwan, utilizing set-aside cropland to plant energy crops is considered as one of the major policy instruments to increase energy security and reduce GHG emissions. Therefore, our simulation scenarios are based on existing agricultural energy crop policy and biofuels energy policy as well as potential policy changes in the future.

4. Empirical Results

Based on a small-scale pilot experiment of energy crop production, three different kinds of energy crops, including soybean, oilseed rape, and sunflower, were chosen to simulate the land use changes and economic impacts of energy crop production for the entire Tainan County. According to the results of the small-scale pilot experiment, **Table 1** shows that the gross profits of soybean, oilseed rape, and sunflower production are −46.2, −54.8, and −22.3 thousand NT$ per hectare (ha), respectively. With the government subsidy, the net profits of these three energy crops increase to 13.8, 5.2, and 37.7 thousand NT$ per hectare, respectively. This indicates that there will be lack of economic incentives for the farmers to planting energy crops even with extra production inputs subsidies (15 thousand NT$ per hectare) compared with initial set-aside cropland subsidies (45 thousand NT$ per hectare).

Table 2 shows the average yields and biodiesel output of energy crops based

Table 1. Energy crop production costs and revenues.

	Production Cost (NT$/ha)	Average Output (kg/ha)	Sales Revenue (NT$/ha)	Gross Profit (NT$/ha)	Subsidy (NT$/ha)		Net Profit (NT$/ha)	
					Set-Aside	Inputs	Before Subsidy	After Subsidy
Soybean	59,777	1089	13,613	−46,165	45,000	15,000	−46,165	13,836
Oilseed Rape	65,690	808	10,908	−54,782	45,000	15,000	−54,782	5218
Sunflower	46,565	1012	24,288	−22,277	45,000	15,000	−22,277	37,723

Table 2. Average energy crop yield and biodiesel output.

	Energy Crop (kg/ha)	Conversion Factor (%)	Biodiesel (liter/ha)
Soybean	1089	15.6	169.8
Oilseed Rape	808	36.4	294.1
Sunflower	1012	36.3	367.3

on the results of the small-scale pilot experiment. Among three energy crops, sunflower has the highest biodiesel output per hectare because of relatively higher yields per hectare and biodiesel conversion factor compared with soybean and oilseed rape. A summary of crop yields and biodiesel output for all municipals in Tainan County is shown in **Table 3**. **Figures 2-5** show the geographic

Table 3. Total energy crop yield and biodiesel output in Tainan county.

Municipal Code	Cropland Area (ha)	Soybean		Oilseed Rape		Sunflower	
		Crop Yield (kg)	Biodiesel Output (liter)	Crop Yield (kg)	Biodiesel Output (liter)	Crop Yield (kg)	Biodiesel Output (liter)
M1	16.12	17,564	2740	13,032	4744	16,323	5925
M2	25.95	28,266	4409	20,972	7634	26,267	9535
M3	20.22	22,027	3436	16,343	5949	20,470	7430
M4	7.60	8282	1292	6145	2237	7696	2794
M5	15.24	16,602	2590	12,318	4484	15,428	5600
M6	20.20	22,002	3432	16,325	5942	20,447	7422
M7	17.37	18,926	2953	14,043	5112	17,588	6385
M8	16.13	17,575	2742	13,040	4747	16,332	5929
M9	18.76	20,434	3188	15,161	5519	18,989	6893
M10	68.50	74,597	11,637	55,349	20,147	69,323	25,164
M11	13.25	14,431	2251	10,707	3898	13,411	4868
M12	62.00	67,519	10,533	50,096	18,235	62,745	22,776
M13	187.79	204,507	31,903	151,737	55,232	190,047	68,987
M14	9.99	10,882	1698	8074	2939	10,113	3671
M15	7.25	7902	1233	5863	2134	7344	2666
M16	3.64	3971	619	2946	1073	3690	1340
M17	33.71	36,718	5728	27,244	9917	34,122	12,386
M18	17.84	19,430	3031	14,417	5248	18,057	6555
M19	4.58	4991	779	3703	1348	4638	1684
M20	11.89	12,950	2020	9608	3497	12,034	4368
M21	17.34	18,890	2947	14,015	5102	17,554	6372
M22	28.57	31,121	4855	23,091	8405	28,921	10,498
M23	0.31	347	54	258	94	323	117
M24	11.47	12,498	1950	9273	3375	11,614	4216
M25	13.58	14,799	2309	10,980	3997	13,752	4992
M26	34.79	37,886	5910	28,110	10,232	35,207	12,780
Total	684.22	745,119	116,239	552,853	201,238	692,434	251,354

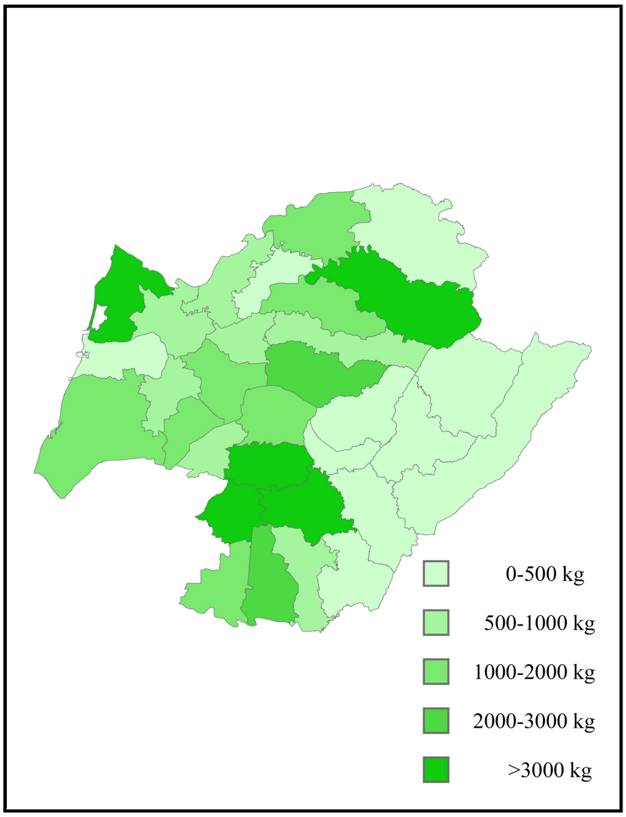

Figure 2. Geographic distribution of grade I soil yield.

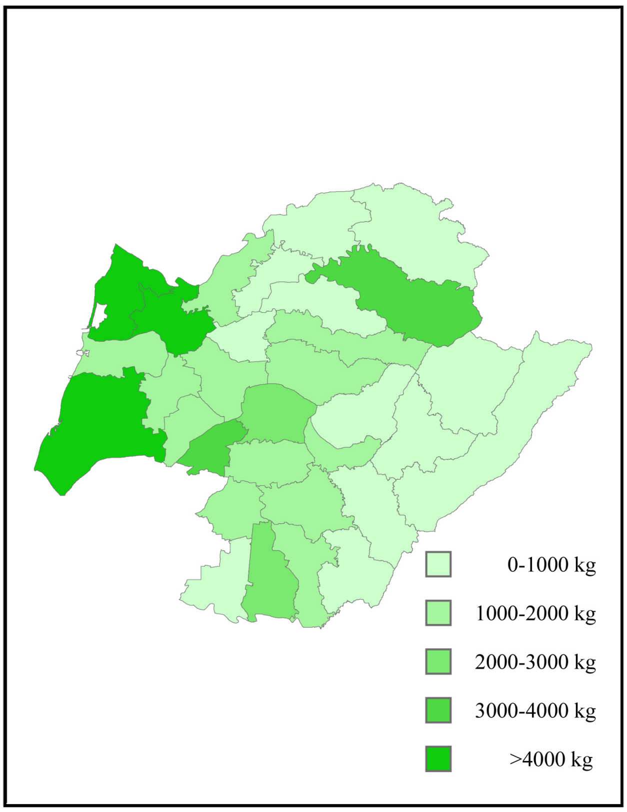

Figure 3. Geographic distribution of grade II soil yield.

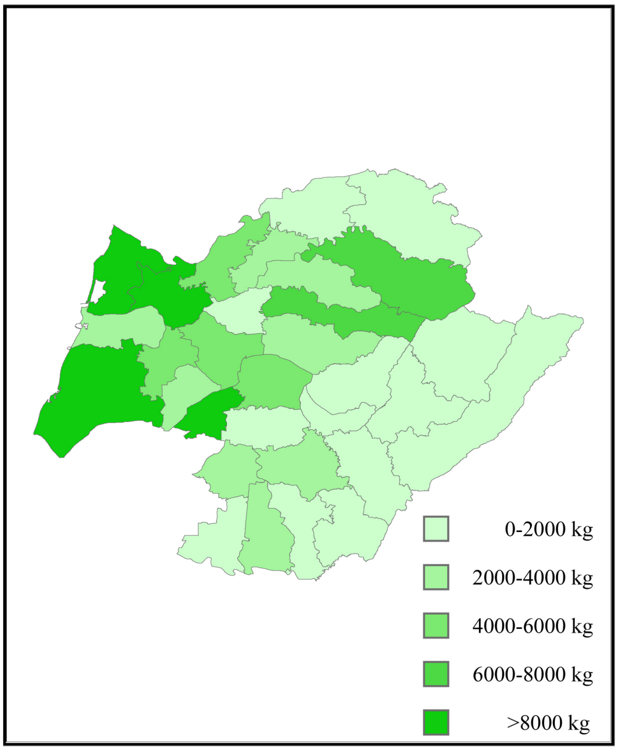

Figure 4. Geographic distribution of grade III soil yield.

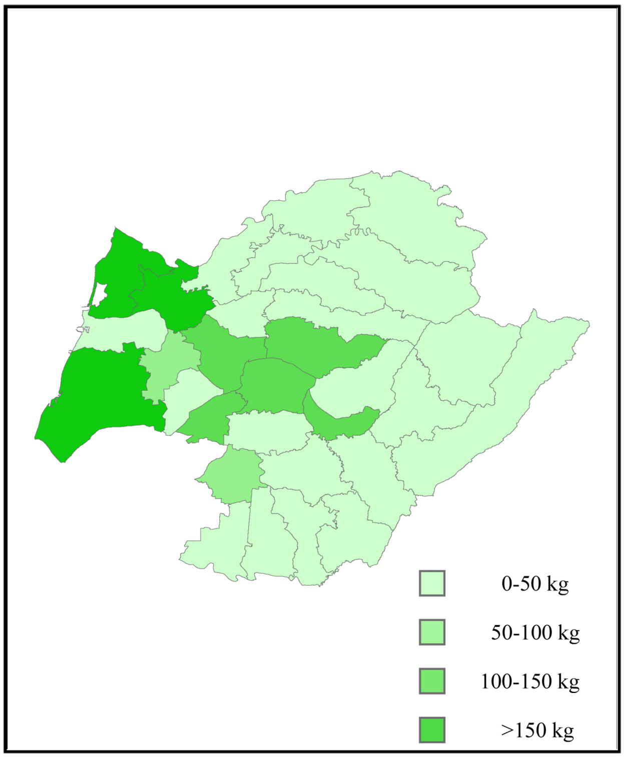

Figure 5. Geographic distribution of grade IV soil yield.

distribution of sunflower yields for four different grades of soil. The areas of set-aside cropland are different for each municipal. Each unit of set-aside cropland is furthered categorized into four different grades of soil. Therefore, each municipal has its own unique geographic distribution of different grades set-aside cropland. For example, **Figure 2** shows the sunflower yields of Grade I set-aside cropland in each municipal. Municipals with high sunflower yields are mainly because they have larger areas of Grade I set-aside cropland compared with others. Therefore, crop yields for different grades of soil in each municipal are directly related to their areas of different grades set-aside cropland. According to **Figures 2-5**, municipals with relatively high crop yields are concentrated in the West Tainan County. For example, Bay-Mum Municipal (M13), which is located at the southwest of Tainan County, accounts for more than one quarter of total crop yields and biodiesel output. In the case of sunflower (see **Table 4**), more than 90% of total crop yields are from Grade II and III soil, which are located mostly in the West of Tainan County.

The extra government subsidies needed to make farmers willing to plant energy crops in addition to current set-aside cropland subsidies are shown in **Table 5**. Among three energy crops, sunflower requires the lowest additional subsidies of 15.2 million NT$, which is about 50% of initial set-aside cropland subsidies (30.8 million NT$). As for the other two energy crops, the required additional subsidies are more than the initial set-aside cropland subsidies. This implies that it will be economically infeasible to produce biodiesel from soybean, oilseed rape, and sunflower without considering the general equilibrium economic impacts of energy crop production on the economy of Tainan County.

Table 6 represents the general economic impacts of energy crop production on the economy of Taiwan County by sector. Among three energy crops, sunflower has the largest total output increases of 51.6 million NT$. In terms of sectoral output increase, the Miscellaneous Crops sector will incur a significant increase in output (15.7 million NT$) due to energy crop production. In the case of sunflower production, the ratio of total output increase to total government

Table 4. Energy crop yield by soil grade in Tainan county (kg).

	I	II	III	IV	Total
Soybean	26,033	582,725	49,593	86,768	745,119
Oilseed Rape	208,543	190,183	149,772	4356	552,853
Sunflower	34,154	466,851	187,006	4424	692,434

Table 5. Energy crop production subsidies for set-aside cropland in Tainan county.

	Without Energy Crop Planting			With Energy Crop Planting				
	Set-Aside Area (ha)	Subsidy (NT$/ha)	Total Subsidy (NT$)	Breakeven Price (NT$/kg)	Wholesale Price (NT$/kg)	Average Yield (kg/ha)	Additional Subsidy (NT$)	Total Subsidy (NT$)
Soybean	684.22	45,000	30,790,058	96.2	12.5	1089	31,586,836	62,376,894
Oilseed Rape	684.22	45,000	30,790,058	136.9	13.5	808	37,483,132	68,273,190
Sunflower	684.22	45,000	30,790,058	90.4	24.0	1012	15,242,447	46,032,505

Table 6. Economic impacts of energy crop production on Tainan county by sector (output increase in NT$).

Sector	Soybean	Oilseed Rape	Sunflower
1) Rice	4949	4274	9038
2) Miscellaneous Crops	15,667,386	13,528,286	28,608,684
3) Sugarcane	2752	2376	5024
4) All Other Grains	5733	4950	10,470
5) Fruit and Tree Nut	44,887	38,758	81,965
6)Vegetable and Melon	778	672	1421
7) Greenhouse and Nursery	208,055	179,650	379,910
8) Support Activities for Crop Production	4,224,103	3,647,378	7,713,223
9) Animal Production	136,787	118,111	249,773
10) Forestry and Logging	7883	6806	14,394
11) Fishery	1670	1442	3049
12) Mining	701,838	606,014	1,281,558
13) Food Manufacturing	89,177	77,002	162,838
14) Beverage and Tobacco Product	1876	1620	3427
15) Textile Mills	21,876	18890	39,948
16) Textile, Apparel, Leather Product	3184	2750	5815
17) Wood Product Manufacturing	39,753	34,326	72,590
18) Paper and Printing	163,398	141,088	298,365
19) Chemical Manufacturing	659,541	569,492	1,204,323
20) Artificial Synthetic Fibers	7992	6901	14,594
21) Plastics and Rubber Products	284,818	245,931	520,079
22) Other Chemical products	1,210,436	1,045,172	2,210,258
23) Petroleum Products	775,739	669,826	1,416,502
24) Coal Products	19,771	17,072	36,103
25) Nonmetallic Mineral Product	35,900	30,998	65,553
26) Iron and Steel	244,557	211,167	446,561
27) Other Primary Metal	98,420	84,983	179,716
28) Fabricated Metal Product	74,399	64,242	135,855
29) Machinery	259,642	224,192	474,108
30) Computer and Electronic Product	25,600	22,105	46,747
31) Electrical Equipment	58,002	50,082	105,911
32) Appliance and Component	59,840	51,670	109,269
33) Transportation Equipment	23,712	20,474	43,298
34) Miscellaneous Manufacturing	31,739	27,406	57,955
35) Construction of Buildings	14,846	12,819	27,110
36) Public and Other Construction	52,494	45,327	95,856

Continued

37) Electricity	236,974	204,619	432,715
38) Natural Gas	2811	2426	5133
39) Water, Sewage and Other Systems	7052	6089	12,878
40) Transportation and Warehousing	184,279	159,119	336,494
41) Information	74,817	64,602	136,616
42) Wholesale and Retail Trade	716,579	618,743	1,308,475
43) Finance and Insurance	961,066	829,850	1,754,910
44) Real Estate and Rental	69,339	59,872	126,614
45) Accommodation and Food Services	23,683	20,448	43,244
46) Other Industrial and Commercial Services	462,430	399,294	844,399
47) Public Administration	8066	7565	16,655
48) Educational and Health Care Services	27,129	23,425	49,538
49) Arts, Entertainment, and Recreation	27,721	23,936	50,619
50) Other Services	168,113	144,499	304,853
Total	28,233,588	24,378,738	51,554,430

subsidies is about 1.12 (=51.6/46.0), which is the only energy crop with benefit-cost ration greater than 1.0. This implies that sunflower production will be the most economic feasible choice among three energy crops when we take general economic impacts into account.

The general equilibrium economic impacts of energy crop production on the agriculture related sectors are summarized in Table 7. In the case of sunflower production, the total employment and average monthly wage rates in the Agricultural Sector will increase by 6.7% and 71.7%, respectively. This indicates that sunflower production will have significant positive economic impacts on the employment and income of farmers in Tainan County.

5. Concluding Remarks

In this study, we develop an integrated assessment model to simulate the land use changes and economic impacts of energy crop policy in Taiwan. Our main findings can be summarized as follows: 1) There is lack of economic incentives for farmers to produce energy crops using set-aside croplands without government subsidies. The required subsidies for energy crops production will be 50% to 120% higher than the original subsidies for set-aside croplands. Among three energy crops, sunflower has the lowest production costs and highest potential biodiesel output. 2) There is very little economic incentive for farmers to switch to energy crop production from existing crop production even with government subsidies. Therefore, the impacts on the supply and demand of existing agricultural crops are very minor. 3) Based on the geographic distribution of cropland land and soil grades, West Tainan County accounts for more than

Table 7. Economic impacts of sunflower production on the agricultural sectors in Tainan county.

	Initial Employment (person)	Employment Increase (person)	Total Employment (person)	Monthly Income Increase (NT$)	Average Monthly Income (NT$)
1) Rice	72,335	2222	74,557	11,235	22,056
2) Miscellaneous Crops	7566	1482	9048	15,403	26,224
3) Sugarcane	603	113	716.3	6623	17,444
4) All Other Grains	7120	198	7318	4287	15,108
5) Fruit and Tree Nut	39,069	2440	41,509	4431	15,252
6)Vegetable and Melon	24,834	1488	26,322	6865	17,686
7) Greenhouse and Nursery	2751	1673	4424	3958	14,779
8) Support Activities for Crop Production	1358	699.6	2058	4338	15,159
Total	155,636	10,316	165,952	7143	17,964

two-third of total energy crop output in Tainan County. Among four soil grades, more than half of the total energy crop output comes from Grade II soil, which is mostly located in the West Tainan County. This implies that energy crop mills and refining plants should be located in the West Tainan County to minimize the transportation costs. 4) The results from general equilibrium modeling show that the Miscellaneous Crops sector will incur the largest increase in output due to energy crop production. It accounts for more than 50% of total output increase in Tainan County. In the case of sunflower production, the ratio of total output increase to total government subsidies is about 1.12, which is the only energy crop with benefit-cost ration greater than 1.0. This implies that sunflower is the most economical feasible choice among three energy crops. 5) In the case of sunflower production, the total employment and average monthly wage rates in the Agricultural Sector will increase by 6.7% and 71.7%, respectively. This indicates that sunflower production will have significant positive economic impacts on the employment and income of farmers in Tainan County.

Based on our modeling approach and simulation results, the policy implications are expected to be multifaceted, including 1) provide a tool for developing agriculture land-use outlook for the decision-maker; 2) estimate trends in CO_2 emission reduction and changes in land use and productivity; 3) assess the impacts of energy crop production and afforestation plantation on various economic sectors, especially on agriculture and farmer income.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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