THE SOCIO-ECONOMIC IMPACTS OF LARGE-SCALE LAND USE CHANGE AND EXPORT–ORIENTED BIO-ENERGY PRODUCTION IN ARGENTINA

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ABSTRACT: This project assesses the impacts of large-scale, export-oriented bioenergy production on GDP, trade balance and employment in Argentina. Integrated in this analysis are the impacts of agricultural intensification, which is assumed to take place so that biomass can be produced on surplus agricultural land only. With an extended input-output model the impacts of bio-energy production on technically potential surplus land, as determined with Smeets et al's Quickscan model (2005), are calculated.
The technical potential for surplus land in Argentina in 2015 was found to be 28 million hectare. The socio-economic impacts of bio-energy production on this surplus land are positive and very large while agricultural intensification causes only insignificant reductions. The Fisher-Tropsch (FT) fuel chain has larger impacts than the pellet fuel chain. While needing more imports than the pellet chain, also a higher value product is produced so that the trade balance is increased even more than in the pellet chain. However, the FT fuel chain provides only few additional jobs as compared to the pellet production chain; indicating that only a small number of direct jobs are created in FT production and, because of large imports, jobs in the production of equipment and machinery are leaked abroad.
Keywords: biomass production, land use, socio-economic aspects

1 INTRODUCTION

Increasing awareness of the environmental damage caused by the current fossil fuel-based energy system and rising fossil fuel prices explain, in part, the growing interest in renewable energy sources. Given such, biomass-based energy is a promising alternative to fossil fuels because of the versatility of its use, its potential for greatly decreasing greenhouse gas emissions and the reduced dependence on foreign fossil fuels implied by alternative energy. While some of the biomass demanded in developing countries, such as the Netherlands, may be produced locally, future projections see biomass production taking place primarily in developing countries where land and labor costs are generally low and favorable climatic conditions for growing biomass can be found. Alongside the growing interest in international trade of bio-energy, the discussion of its sustainability has emerged. Among the areas of concern are the socio-economic impacts in bio-energy producing countries, especially those impacts associated with an intensification of agriculture. This intensification is required so that bio-energy may be produced on surplus agricultural land and does not compete with food production or cause further pressure on land. However, agricultural intensification may have large (positive or negative) impacts on the socio-economic situation of a developing country as it is generally associated with increased mechanization and decreased labor needs. Therefore, investigating the overall socio-economic impacts of large-scale, export-oriented bio-energy production also requires an examination of the effects of such agricultural intensification; this study attempts to do precisely that for a case study on Argentina.

2 APPROACH

Land use change is here associated with a changing (i.e. increasing) level of agricultural technology so that a more efficient agricultural production can free agricultural land, which is then available for bio-energy production without further increasing pressure on land and without competing with food production. Smeets et al.'s Quickscan model [1] is used to define such changes in the Argentinean agricultural production system and, based on those changes, to calculate the technical potential of surplus agricultural land in Argentina in 2015.

The Quickscan model studies the technical potentials of global bio-energy production [1]. This potential is based primarily on growing dedicated energy crops on land that is either surplus land not required for food production or land not suitable for food or feed crop production. The surplus land is obtained from increases in food production efficiency, which can be achieved by applying more efficient agricultural production systems and by a geographic optimization of crop production. As a result, bio-energy production does not hamper food production or cause any further pressure on land, a key aspect of ensuring sustainability.

The impacts of an intermediate level of agricultural technology advancement and a mixed animal production system were chosen for this study because this level requires the least changes in the production system while also being the most feasible within the given time frame. The intermediate level of agricultural technology refers to some use of fertilizers, pesticides, improved seeds and mechanical tools (for agricultural crop production) and to some use of breeding, feed supplements and dedicated animal housing [1].

Bio-energy production is then assumed to take place on this freed agricultural land. Two bio-energy production chains are defined: eucalyptus-pellet and eucalyptus–pellet–Fischer-Tropsch (FT) -fuel), each chain covers all production processes that take place within the borders of Argentina (Fig. 1).

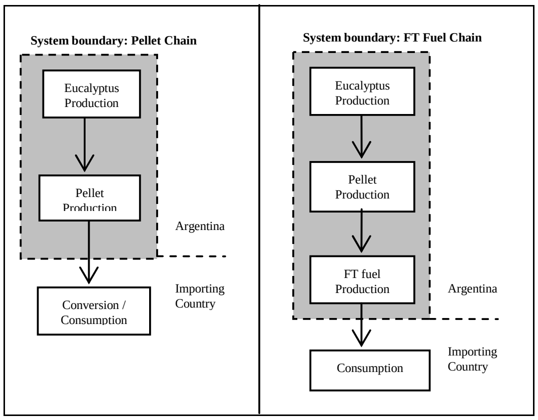

Figure 1: System boundaries for bio-energy production

Input-Output (I/O) analysis is applied to calculate the direct, indirect and induced socio-economic impacts of agricultural intensification and bio-energy. The basic I/O model is extended in order to allow accounting for the changes in the agricultural sector due to the intensification. To do so, first, an extended I/O table is built that includes different production methods for the two agricultural sectors crop production and animal production (based on methodology suggested in [2]). Assume that an economy has seven production sectors, S_1, S_2, S_3, S_4 S_5, S_6 and S_7 where

- S_1: original agricultural crop production
- S_2: advanced agricultural crop production
- S_3: original animal production
- S_4: advanced animal production
- S_5: agricultural crops (total)
- S_6: animals (total)
- S_7: rest of the economy.

Then, the I/O table of this system is presented by Table I below. The elements *w*, *g*, and *m* are defined as the production factors, government income, and imports, and *x* represents the total output of each sector, *y* represents the final demand from each sector and *a* is the technical coefficients, referring to the value of the input from sector *i* used in making a dollar's worth of output in sector *j*.

The production of sectors 5 and 6 is assumed to be linear, meaning that the necessary inputs can be combined in any ratio while the rest of the economy, here represented by sector 7, is described by the regular Leontief characteristics.

Sector 5 and 6 receive all its inputs from sector 1 and 2 (the total output of both of these sectors goes to sector 5) and from sectors 3 and 4 (the total output of both of these sectors goes to sector 6), respectively. Sector 5 and 6 then provide inputs to any other sector of the economy since it is assumed that for the consumers of agricultural crops or of animal products, it is not important how the product was produced. Thus, agricultural crops may be obtained in any combination of the outputs from sectors 1 and 2 so that

$$X_1 = \alpha X_5 \qquad (1)$$

$$X_2 = \beta X_5 \qquad (2)$$

where $\alpha + \beta = 1,\ 0 \le \alpha \le 1,\ 0 \le \beta \le 1$.

And animal products may be obtained in any combination of the outputs from sectors 3 and 4 so that

$$X_3 = \chi X_6 \qquad (3)$$

$$X_4 = \delta X_6 \qquad (4)$$

where $\chi + \delta = 1,\ 0 \le \chi \le 1,\ 0 \le \delta \le 1$.

The basic I/O model applied to the rows corresponding to sectors 5, 6 and 7 in the transaction table is

$$\begin{pmatrix} a_{51}X_1 + a_{52}X_2 + a_{53}X_3 + a_{54}X_4 + a_{57}X_7 + Y_5 = X_5 \\ a_{61}X_1 + a_{62}X_2 + a_{63}X_3 + a_{64}X_4 + a_{67}X_7 + Y_6 = X_6 \\ a_{71}X_1 + a_{72}X_2 + a_{73}X_3 + a_{74}X_4 + a_{77}X_7 + Y_7 = X_7 \end{pmatrix}$$

Substituting X_1 and X_2 by equation 1 and 2 and X_3 and X_4 by equations 3 and 4 and rearranging the *X*'s on the left and *Y*'s on the right results in

Table I: I/O table for the extended I/O model (based on [3])

		Output								
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	Final Demand	Total
Input	S_1					x_1				x_1
	S_2					x_2				x_2
	S_3						x_3			x_3
	S_4						x_4			x_4
	S_5	$a_{51}x_1$	$a_{52}x_2$	$a_{53}x_3$	$a_{54}x_4$			$a_{57}x_7$	y_5	x_5
	S_6	$a_{61}x_1$	$a_{62}x_2$	$a_{63}x_3$	$a_{64}x_4$			$a_{67}x_7$	y_6	x_6
	S_7	$a_{71}x_1$	$a_{72}x_2$	$A_{73}x_3$	$a_{74}x_4$			$a_{77}x_7$	y_7	x_7
	Production factors	w_1	w_2	w_3	w_4			w_4		
	Government income	g_1	g_2	g_3	g_4			g_7		
	Import	m_1	m_2	m_1	m_4			m_7		
	Total	x_1	x_2	x_3	x_4	x_5	x_6	x_7		

Note: An empty cell means that no transaction takes place between the corresponding sectors.

$$\begin{pmatrix} (a_{51}\alpha + a_{52}\beta)X_5 + (a_{53}\chi + a_{54}\delta)X_6 + a_{57}X_7 + Y_5 = X_5 \\ (a_{61}\alpha + a_{62}\beta)X_5 + (a_{63}\chi + a_{64}\delta)X_6 + a_{67}X_7 + Y_6 = X_6 \\ (a_{71}\alpha + a_{72}\beta)X_5 + (a_{73}\chi + a_{74}\delta)X_6 + a_{77}X_7 + Y_7 = X_7 \end{pmatrix}$$

The structure of this matrix is similar to the well-known basic I/O model (see [3] and [4]), having exogenous variables Y_5, Y_6 and Y_7 and endogenous variables X_5, X_6 and X_7. α and β represent the fractions of the two technology options for producing agricultural crops (sector 5 total) and χ and δ represent the fractions of the two technology options for producing animal products (sector 6 total). In matrix notation this becomes

$$AX + Y = X \tag{5}$$

where

$$A = \begin{pmatrix} (a_{51}\alpha + a_{52}\beta) & (a_{53}\chi + a_{54}\delta) & a_{57} \\ (a_{61}\alpha + a_{62}\beta) & (a_{63}\chi + a_{64}\delta) & a_{67} \\ (a_{71}\alpha + a_{72}\beta) & (a_{73}\chi + a_{74}\delta) & a_{77} \end{pmatrix}$$

$$Y = \begin{bmatrix} Y_5 \\ Y_6 \\ Y_7 \end{bmatrix}$$

$$X = \begin{bmatrix} X_5 \\ X_6 \\ X_7 \end{bmatrix}$$

The solution of the extended I/O model is found in the same way as the basic I/O model and results in

$$X = (1 - A)^{-1} Y \tag{6}$$

In order to determine the effect of agricultural intensification, the extended I/O model is applied twice: The I/O model is applied first to the current agricultural production ($\alpha = \chi = 1$ and $\beta = \delta = 0$) and second to the projected intensified agricultural production ($\alpha = \chi = 0$ and $\beta = \delta = 1$).

Two more modifications to the basic I/O model are made. First, in order to account for a new sector in the economy, a new sector is added to the economy, assuming that large-scale bio-energy production becomes a sector integrated in the existing economy. This is done by adding an additional sector to the technology matrix of the I/O model (see [3] and [4] for additional information). Applying this method allows accounting for inputs being bought by the new sector and also for the new sector's outputs which may be consumed by the existing sectors.

The second modification is made because of the exogenous treatment of capital goods, a limitation of the basic input-output analysis: capital goods and their consumption for the production of a sector's product are counted as a production factor rather than as an intermediate expenditure. Therefore, I/O analysis does not take into account the effects of using capital goods; this also excludes the effects of the production of capital goods and the capital goods used for this production. As a result, the basic I/O analysis underestimates the actual impacts.

In this study an adjustment of the final demand vector was made in order to account for some of these impacts. This is done by adding the capital costs of the production – divided according to the I/O sector classification – to the final demand vector (Y) of equation 6 above.

With the I/O model as described above, the total output (X) is determined and used to calculate the direct and indirect effects on GDP, imports and employment as proposed by van den Broek [5].

In order to calculate the induced impacts, so that the household income earned directly or indirectly from the bio-energy production and the re-spending effect of this additional income can be accounted for, the I/O model is closed with respect to households (see [3] and [4] for the applied methodology). The total output (X) that is calculated with this modified I/O model is then used as in [5] to calculate the induced impacts on GDP, imports and employment.

3 INPUT DATA

Eucalyptus production costs are based on average production in Argentina [6]. Because pellets are not currently produced in Argentina, pellet production costs are assumed to be similar to average production in Sweden [7]. Fisher-Tropsch fuel costs are based on information from van Vliet et al. [8]. The Argentinean I/O table, retrieved from the Global Trade Analysis Project (GTAP) data base [9] is based on year 2001. The normalized employment vector is obtained from the Argentinean I/O table that was used for the GTAP database [10]. The projections of the intensified agricultural production in the Argentinean I/O table are based on the US I/O table from the GTAP database [9], while the normalized employment for agriculture is taken from the Bureau of Labor Statistics of the US Department of Labor [11].

4 RESULTS

The Quickscan model resulted in a technical potential of agricultural surplus land in Argentina of 28 million hectares (Fig. 2).

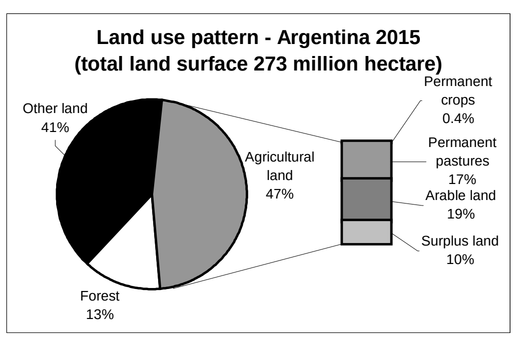

Figure 2: Land use pattern of Argentina in 2015

The input-output analysis shows that if bio-energy production were to take place on this surplus land, enormous overall socio-economic impacts would take place (Table II): overall impacts in 2015 for the pellet production chain are a 21% increase in GDP, 24% increase in imports and 20% more employment. For the FT fuel production chain these impacts are 27%, 44% and 22%, respectively.

Table II: Overall socio-economic impacts

	GDP		Imports		Employment	
	Billion US $				**Million jobs**	
Chain	**1**	**2**	**1**	**2**	**1**	**2**
Overall impacts	50	64	7	13	2.7	2.9
Reference situation 2001	243		29		13	
Percentage change (%)						
Percentage change	**21**	**27**	**24**	**44**	**20**	**22**

The agricultural intensification impacts in Argentina were found to be negative but insignificant compared to the large bio-energy impacts (Table III).

Table III: The influence of agricultural intensification on the socio-economic impacts

	GDP		**Imports**		**Employment**	
Chain	**1**	**2**	**1**	**2**	**1**	**2**
	Billion US $				**Million jobs**	
Bio-energy	50	64	7	13	2.7	2.9
Agricultural intensification	-0.04	-0.07	0.2	0.3	-0.09	-0.1
Overall	50	64	6	12	2.6	2.8
Percentage change (%)						
Effect of agricultural intensification	**-0.7**	**-0.1**	**3.7**	**2.7**	**-3.2**	**-3.3**

For both chains, the large bio-energy exports easily compensate for the increasing imports so that the trade balance for each chain remains positive and causes the overall trade balance for Argentina to increase (Fig. 3).

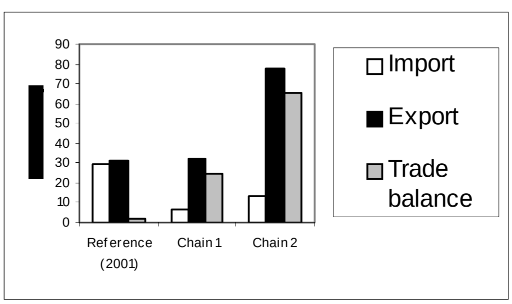

Figure 3: Effects on trade balance by bio-energy chains

5 DISCUSSION AND CONCLUSION

The FT fuel production chain has larger socio-economic impacts (greater GDP, larger positive trade balance and more employment) than the pellet production chain, which principally implies that more processing results in more benefits. However, these impacts are only slightly larger than those of the pellet production chain and they can show that, as long as Argentina does not have its own manufacturing industry supplying to the FT fuel industry, many of the benefits are leaked abroad.

The analysis has also shown that, in the case of Argentina, the agricultural intensification effects are insignificant compared to the bio-energy impacts. However, Argentina may not be representative (with respect to the agricultural intensification and its effects on the socio-economic situation of a country) of other developing country because Argentina has an unusually developed agricultural production system that is more comparable to developing countries such as the United States or the Netherlands than to other developing countries. Therefore, it is recommended that future studies examine the intensification impacts in a more “typical” developing country.

The Quickscan model with which the agricultural intensification has been projected has shown two main problems. First, national data may vary significantly from regional averages and, second, this national data is only available partially so that regional averages must be applied. Therefore, more national data needs to be collected and applied in the Quickscan model in order to increase the reliability of results and also to determine the likeliness of the presumed changes regarding the agricultural production system to be realized.

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More information can be found in the background document: Wicke, B. (2006). The socio-economic impacts of large-scale land use change and export-oriented bio-energy production in Argentina. Msc. Thesis. Department of Science, Technology and Society, Utrecht University, Utrecht, the Netherlands.