Assessing land use impacts of rapeseed production in drylands: a case-study of experimental plots in Mendoza, Argentina

Civit, B[1,2], Silva Colomer, J[3], Arena, AP[1,2] and Brandão, M[4]

[1] Facultad Regional Mendoza – Universidad Tecnológica Nacional, Rodríguez 273 (5500) Mendoza, Argentina
[2] Instituto de Ciencias Humanas, Sociales y Ambientales (INCIHUSA) Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Av Ruiz Leal s/n. (5500) Mendoza Argentina.
[3] Instituto Nacional de Tecnología Agropecuaria (INTA) Estación Experimental Agropecuaria Junín, Isidoro Busquet s/n La Colonia, Mendoza Argentina
[4] DG Joint Research Centre - European Commission, Institute for Environment and Sustainability, Via Enrico Fermi, 2749; 21027 Ispra (VA), Italy

Introduction

The use of biomass for energy purposes has raised high expectations for the production of liquid biofuels that can replace fossil fuels. Biofuels can be produced in many regions of the world, although developing countries have a competitive advantage over developed ones due to their lower land and labor costs. Although Argentina has a long tradition in producing and exporting plant oils, some emerging problems from land-use change, increasing energy use, carbon emissions and water withdrawal are causes of concern.

Mendoza, an arid province in Argentina, can potentially produce oil from winter rapeseed and thereby avoid the competition for irrigation water with traditional crops like vines and fruit trees that grow during spring and summer. Despite the uncertainties regarding the environmental impact of changes in land-use and management, this alternative cropping system has attracted many producers during the last five years.

In Argentina, as in many others Latin American countries, Life Cycle Assessment (LCA) has started to be used with a relative delay compared to the most industrialized countries of the world. When using LCA, most of the times, practitioners have to face up to two main difficulties: the lack of local and regional inventory data and the absence of regional indicators to be used in the environmental impact assessment phase. Many efforts have been done during the last decade to update and adapt the methodology to regional conditions [1], [2], [3], [4]. But, the definition of the most accurate indicators to represent the consequences of land use is under continuous discussion and development within the LCA community [5].

Regarding soil as a non-renewable resource, Soil Organic Carbon (SOC) has been selected as one of the indicators to evaluate the land use impact [5]. The same author refers that "impacts on BPP depend not only on the particular land use, but also on the sensitivity of the ecosystem where the activity is located". Results are supported by a regional desertification model.

Materials and methods

With reference to Life Cycle Assessment (LCA) we have evaluated the land use impact of rapeseed cultivation considering a sequence of farming steps until the product leaves the farm-gate (cradle-to-gate). During the farming year of 2008-09, five experimental plots on fields of the experimental station of INTA in Junín (Mendoza province) were assessed for changes in soil properties. The Biotic Production Potential (BPP) and the Desertification Factor ($FC_{Desertification}$) were selected to asses land use impact. Given improvements in some soil properties and other biological and ecological indicators, results suggest that rapeseed cultivation is, in the mid- and short-term, a novel and viable farming alternative for irrigated drylands in Mendoza.

As a case study, an experimental rapeseed cultivation performed by the National Institute of Agricultural Technology (INTA) located in the in the province of Mendoza, in the western arid region of Argentina. Soil organic matter values have been collected in situ and then converted to Soil Organic Carbon contents. The initial SOC was considered as the reference value.

To obtain the impact factors for land use, Equations 1 to 3 have been used, taken from [4] and [5].

$$\Delta C\ \ (\mathrm{KgC.m^{-2}.yr^{-1}}) = \frac{\left(SOC_{pot} - SOC_{ini}\right)\times\left(t_{relax} - t_{ini}\right) + \frac{1}{2}\left(t_{relax} - t_{ini}\right)\times\left(SOC_{ini} - SOC_{fin}\right)}{\left(t_{fin} - t_{ini}\right)} \qquad \text{Eq 1}$$

Where SOC_{pot} is the potential level of SOC if land is left undisturbed; SOC_{ini} the SOC level at the beginning of activity which uses the land studied; SOC_{fin} is the SOC level at the end of the cultivation period; t_{ini} and t_{fin} represents the moment when the studied land use starts; t_{relax}, is the moment when

BPP reaches the level prior to the activity which uses the land; and $t_{relax,pot}$ is the time when the system reaches its potential quality. t_{relax} may be calculated from the relaxation rate R.

$$FC_{Desertification}(\mathrm{m}^2 year) = \left(\frac{LCI_{Desertification}}{FS^e} \right) \times A_{activity} \times t \qquad \textbf{Eq 2}$$

FS^e is a sensitivity factor of each ecosystem to suffer desertification, $A_{activity}$ is the occupied area by the activity in area units, and t is the period of time of the activity in time units. The factor $LCI_{Desertfication}$ is given by equation 3:

$$LCI_{Desertification} = \sum_{1}^{e} \left(V_{Aridity} + (V_{Vegetation\ Coverfinal} - V_{Vegetation Coverinitial}) + V_{Water\ Balance} \right) \qquad \textbf{Eq 3}$$

Where $V_{Aridity}$ is the aridity index of each considered ecosystem, $V_{Vegetation\ Coverfinal}$ and $V_{Vegetation\ Coverinitial}$ is the vegetation cover in percentage and $V_{Water\ Balance}$ is ground water balance (positive or negative), all of them from the site where the activity takes place.

Results and discussion

Soil Organic Carbon

Soil Organic Carbon content in each plot considered is shown in Table 1. The initial carbon content is low compared to other regions of Argentina. The average potential SOC is about 0,4 % [6]. This behavior is typical of arid lands in the mid west of the country. The organic mater does not exceed 0.9 % in none of the five plots analyzed

	Potential SOC (in the region) tC/ha/yr	Initial SOC (average) tC/ha/yr	Final SOC tC/ha/yr
Plot 01	9,07	20,41	26,75
Plot 02			31,52
Plot 03			32,42
Plot 04			24,03
Plot 05			24,94

Table 1: Soil Organic Carbon content of the five analyzed rapeseed plots.

Desertification

Information needed to calculate the desertification factor is the same for the five plots because they are located in the same place. Data were collected in situ during the farming year of 2008/2009. Aridity index in taken from [7], ground water balance is calculated from [8] and vegetation cover was estimated by the authors and determined by CobCal 1.2 [9]. The Desertification factor is expressed in area by time units (m^2 year).

Site where the activity takes place	INTA - Junín, Mza, Argentina
Type of ecosystem	Ecosistema Del Monte [10]
Occupation area:	450 m^2
Veg $Cover_{ini}$	0-15 %
Veg Cov_{fin}	>75 %
$V_{Water\ Balance}$	positive
$V_{Aridity}$	0,182 (arid)

Land use factors

After applying Equations 1, 2 and 3 in each considered plot, characterization factors for land use were determined. Characterization factors for the five plots are shown in Table 2.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
FC_{SOC}	-217,65	-253,43	-260,17	-197,25	-204,07
$FC_{Desertification}$	-64,82	-64,82	64,82	-64,82	64,82

Table 2: Impact factors for rapeseed cultivation in Junin, Mendoza, Argentina

All cases have a negative figure meaning that the final state after rapeseed cultivation is better than the initial one. This situation could be interpreted as a benefit on soil conditions because the rapeseed crop adds organic matter to a land lacking in carbon soils. On the other hand, crop cover diminishes the adverse effects of wind and water erosion, typical phenomena in drylands.

Conclusions

The impact model proposed is a suitable model for determining land use impact caused by the cultivation of energy crops. Soils in arid regions like Mendoza are poor on organic matter content. Any external contribution of organic carbon improves the initial conditions. This assertion is supported by the results obtained when the regional desertification model was applied to the same plots.

References

[1] Civit B, Arena AP, Puliafito, E. 2005. Site-dependent Acidification factors for Argentinean western arid region. Life cycle management international conference. Barcelona, 5 to 7 de septiembre.

[2] Arena AP and Civit B. 2006. Towards the identification and calculation of characterization factors for land use in western Argentina. Expert Workshop: definition of best indicators for land use impacts in Life Cycle Assessment. University of Surrey, Guildford, 12-13 June.

[3] Civit B, Arena AP y Puliafito E. 2006. Estudio de deposiciones de nitrógeno en suelos para la evaluación de la eutrofización terrestre en la región oeste árida argentina. Caso de estudio", Avances en Energías Renovables y Medio Ambiente. ISSN 0329-5184

[4] Civit BC. 2009. Sostenibilidad Ambiental. Desarrollo de indicadores regionales para su aplicación en estudios de Análisis de Ciclo de Vida en la región árida del centro oeste argentino. PhD Thesis. Universidad Nacional de Cuyo, Mendoza, Argentina.

[5] Brandão M, Milà i Canals L and Clift R. (unplublished). Biotic Production Potential. Part C: modelling characterization factors for ecosystem services. Handbook on LCIA of Global Land Use within the framework of the UNEP/SETAC Life Cycle Initiative.

[6] Guevara JC, Martinez Carretero E, Juarez MC and Berra AB. 1997. Reclamation of degraded lands in the piedmont of mendoza, argentina, through the opuntia ficus indica f. Inermis plantation. MULTEQUINA 6: 1-8, 1997

[7] Roig F.A., M.M. Gonzalez L., E. M. Abraham, E. Mendez, V. G. Roig, Y E. Martinez Carretero, (1991) Maps of desertification Hazards of Central Western Argentina, (Mendoza Province). Study case. (En: UNEP, De. "World Atlas of thematic Indicators of Desertification", E. Arnold, Londres.

[8] Departamento General De Irrigación (2008) Planes Directores de los Recursos Hídricos de la Provincia de Mendoza. Secretaría de Agricultura, Ganadería, Pesca y Alimentación de la Nación Gobierno de Mendoza - Departamento General de Irrigación - Proyecto PNUD/FAO/ARG/00/008

[9] Ferrari, D; Pozzolo, O y Ferrari, H (2007) CobCal Versión 1.2. Instituto Nacional de Tecnología Agropecuaria. Concepción del Uruguay, Entre Ríos, Argentina.

[10] Roig, FA; Martínez Carretero, E; Méndez, E; Cobos, D; Lenzano, L y Bottero, R (1993) Mapa de Ecosistemas de Mendoza. Unidad Botánica y Fitosociología , IADIZA-CRICYT