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Environmental and energetic assessment of sown irrigated pastures *vs* maize

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SUMMARY – One of the best options for some irrigated lands is the use of sown pastures. However, the conversion of such lands into maize production has become an attractive option due to the rising maize prices. Maize is used as a raw material for the production of ethanol, a biofuel. Extensive animal production, as an alternative to stable breeding, is a positive effect of the use of pastures but maize production leads to gasoline substitution. Our goal is to study which option is better in terms of environmental and energetic viability. We used the life cycle assessment software SimaPro 6.0 to analyse the impacts. Our results showed that in most environmental themes the use of grasslands is a better option (e.g. greenhouse gas emissions). These grasslands are responsible for carbon sequestration in soils. However, even if we neglect this effect, our results are still relevant. Maize production allows less energy resources to be used.

Keywords: Agriculture, environment, sustainability, grasslands, land use.

RESUME – *"Evaluation environnementale et énergétique des pâturages irrigués ensemencés par rapport au maïs". L'une des meilleures options pour certaines terres irriguées est l'établissement de pâturages ensemencés. Cependant, la conversion des terres à la production de maïs est devenue une option intéressante en raison de la hausse des prix du maïs. Le maïs est utilisé comme matière première pour la production d'éthanol, un biocarburant. La production animale extensive, comme alternative à l'élevage stable, est un effet positif de l'utilisation des pâturages, mais la production de maïs conduit à la substitution de l'essence. Notre objectif est d'étudier la meilleure option en termes de viabilité environnementale et énergétique. Nous utilisons l'évaluation du cycle de vie à l'aide des logiciels SimaPro 6,0. Nos résultats montrent que pour la plupart des thèmes environnementaux, l'utilisation des pâturages est une meilleure option. Ces prairies sont responsables de la séquestration du carbone dans les sols. Toutefois, même si nous négligeons cet effet, nos résultats sont toujours pertinents. La production de maïs permet une moindre utilisation des ressources énergétiques.*

Mots-clés : *Agriculture, environnement, développement durable, prairies, utilisation des terres.*

Introduction

There are two measures considered in the Kioto's Protocol to reduce the amount of CO_2 in the atmosphere:

(i) The carbon sequestration by certain land management systems.

(ii) The use of biofuels.

In this study, we consider that these two measures are directly competing and our goal is to understand which one is the best option.

To study the first measure we consider the presence of sown irrigated pastures which are able to sequester 19 ton CO_2 e.year^{-1}ha^{-1} (C. C. Belo, pers. comm.), and are grazed by cattle. In this case, it is considered the use of gasoline as a fuel. We call this scenario the "pasture scenario".

The second measure considers the production of bioethanol with maize as a raw material. The production of maize competes for the same area with the installation of sown irrigated pastures. We also consider two different land managements: conventional tillage and no-tillage. The land can not be grazed by the cattle, which remain stabled. Bioethanol is used as a fuel. We call this scenario the "maize scenario".

Although the two measures appear to be competitive, it is necessary to note that, nowadays, there is a very important discussion over the possibility of fossil fuels' extinction and pollution caused by its use. In this context the use of biofuels appears to be a solution. However, the growing demand for bioenergy crops may also create further competition for land and water between existing agricultural activities, energy production and the use of agricultural land for nature conservation and urbanization needs (EEA, 2006). It is necessary to understand that the environmental impact of bioenergy production depends to a large extent on the selection of areas that are used for bioenergy production, the crops cultivated and the farming practice (EEA, 2006). Potential additional pressures of bioenergy production may occur as a result of intensification of farm management across the agricultural land area; incentives to transform extensively used land for fodder production into arable land for growing bioenergy crops; an inappropriate bioenergy crop mix, which does not take into account the specific environmental pressures of different crops. According to EEA (2006), these factors would have an additional negative impact with regard to the main environmental problems of agriculture in the different regions of Europe.

Materials and methods

We used a Life Cycle Assessment (LCA) approach. We chose the software SimaPro 6.0, which was developed by the National Reuse of Waste Research Programme and Pré Consultants of the Netherlands. An LCA starts with a systematic inventory of all emissions and all raw material consumption during a product's entire life cycle that are compiled in a list which is termed the impact list (Ferrão, 1998). The impacts are sorted by the effect (classification) and organized in impact categories (Goedkoop, 1998).

As referred above, it is necessary to introduce the input inventory. The functional unit we chose is 1 ton of ethanol, which is equivalent to 0.27 ha in the case of conventional maize crops, 0.25 ha with no-tillage management, and 0.72 ton of gasoline. Although the conventional and no-tillage management only applies to maize crops, to make the two scenarios comparable, the corresponding areas must be considered also in the "pasture scenario".

Regarding the "maize scenario", it is necessary to consider all the aspects stated below.

Concerning maize production, we used data from Basílio *et al*. (2007) document. From this document, we collected all the operations that take place as well as all the added substances. We also considered the emissions proceeding from the use of fertilizers and NO_3^- leaching with the values considered in the document of Van der Werf (2005). In the case of no-tillage, we considered a carbon sequestration of 3 tonCO_2e.year^{-1}.ha^{-1} (ECCP, 2003). The cattle, in the stable, are fed from 7.2 to 12 months, increasing their weight in 216 kg. We considered the cattle emissions resulting from enteric fermentation and manure, according to the values recommended by IPCC (1997) and PNAC (2003). For the ethanol production are considered the inputs and productivity given by Pimentel (2003). There is a subproduct from the process, which is dry distiller grain (DDG). DDG may be used for feeding ruminants, and is generally used as substitute for soybean feed. According to Pimentel (2003), 2.1 kg of soybean is required to provide the equivalent of 3.3 kg of DDG. In order to evaluate the emissions from the combustion of 1 ton ethanol, we used the values recommended by Portugal *et al*. (2007). They consider the emissions of CO_2, CO, NO_x, CH_4 as the most important ones.

In the "pasture scenario", we considered the following aspects.

Concerning the inputs of SIP (sown irrigated pastures), we used data from a personal communication by Carlos Carmona Belo. We considered two different moments: installation and maintenance. Installation is only required once each ten years, but these pastures require yearly maintenance. Regarding emissions, we considered those of N_2O from legumes, according to Rochette e Janzen (2005), as well as carbon sequestration, according to a personal communication by Carlos Carmona Belo, and phosphate run off in Van der Werf (2005). Apart from grazing, in these pastures the cattle require feed only as a complement, in the equivalent to their needs for 2 months in the stable. We also considered the emissions resulting from enteric fermentation and manure, according to IPCC (1997) and PNAC (2003). Using the data base from SimaPro, we simulated the production of 0.72 ton of gasoline. For the emissions analysis it is used the document considered in the "maize scenario".

Results and discussion

The main results (Table 1) shows that the choice of the best scenario depends on the impact category. In the context of the Kyoto's Protocol, the most relevant category is the "Greenhouse gases". In order to study the energetic viability of both scenarios the most important category is the "Energy resources". These are, therefore, the most important categories in analysis.

Regarding the impact on the greenhouse gases theme, with conventional farming systems and considering the carbon sequestration, the "maize scenario" originates the double of the impact of the "pasture scenario". No-tillage practices do not improve significantly the impact of the "maize scenario". A reasonable explanation lies in the fact that the pastures are able to sequester 19 ton $CO_2.ha^{-1}.yr^{-1}$ and for the "maize scenario", the carbon sequestration only happens with no-tillage farming and in a smaller amount. In order to understand the influence of carbon sequestration in results, and because carbon sequestration represents a temporary effect, we consider the analyses without it. In this case the "pasture scenario" continues to be favorable although the difference between scenarios is smaller.

In the context of Kyoto's Protocol fulfillment, it does not matter if the carbon emission is avoided or if it is sequestered.

Respecting the use of energy resources, in all cases it is necessary more energy to the "pasture scenario" than to the "maize scenario". This is related to the use of fossil fuels in the gasoline production. This means that as an energy policy it is favorable the presence of maize crops instead of pastures.

Regarding all the other categories, the "pasture scenario" is favorable for most of them. The exceptions are the categories "Ozone layer" and "Acidification".

Table 1. Final results of the environmental analysis

Method	Impact category	Unit	Ethanol (CT)	Gasoline (CT)	F (CT)	Ethanol (NT)	Gasoline (NT)	F (NT)
Ecoindicator 95	Greenhouse gases, without carbon sequestration	kg CO_2	1,5E+04	1,3E+04	1,2	1,4E+04	1,2E+04	1,2
	Greenhouse gases, with carbon sequestration	kg CO_2	1,5E+04	7,5E+03	2,0	1,3E+04	7,5E+03	1,8
	Ozone layer	kg CFC11	3,8E-04	4,8E-04	0,8	3,7E-04	4,8E-04	0,8
	Acidification	kg SO_2	9,2E+00	9,4E+00	1,0	8,2E+00	9,2E+00	0,9
	Eutrophication	kg PO_4	2,8E+00	1,8E+00	1,6	2,5E+00	1,7E+00	1,5
	Heavy metals	kg Pb	5,5E-02	1,2E-02	4,7	5,3E-02	1,1E-02	4,7
	Carcinogens	kg B(a)P	2,6E-04	5,3E-05	4,9	2,3E-04	5,0E-05	4,6
	Winter smog	kg SPM	5,9E+00	5,4E+00	1,1	5,6E+00	5,3E+00	1,1
	Summer smog	kg C_2H_4	1,4E+00	1,1E+00	1,3	1,4E+00	1,1E+00	1,3
	Energy resources	MJ LHV	3,5E+04	4,4E+04	0,8	3,4E+04	4,3E+04	0,8
	Solid waste	kg	1,4E+01	5,9E+00	2,4	1,3E+01	5,5E+00	2,4

CT – Conventional tillage; NT – No-tillage; F represents the ratio between the impact of the "maize scenario" and the "pasture scenario", for each category.

Conclusions

We conclude that, in terms of greenhouse gas emissions, the "pasture scenario" is the favorable one. However, in terms of energy resources the "maize scenario" is the favorable one. Regarding all the other impact categories, the "pasture scenario" is favorable for all of them, except for the "Ozone layer" and "Acidification".

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