Energy and CO_2 balance in biodiesel fuel production

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Many theoretical studies have been carried out on carbon and energy balances in oilseed crops for the production of biodiesel fuel. Most of them are based on statistics of average yield, cultivation techniques, and crop inputs in a certain territory. Thus, balances are very often considered as a whole, and relative differences, due to differing agricultural practices, are not taken into account. However, this variability is the most important factor in determining the success of a crop and in allowing statistical considerations on carbon and energy balances to be properly made.

Sunflower and rapeseed, the two most promising crops for biodiesel fuel production in the Veneto region were examined and more than 400 cases of cultivation were examined.

Materials and Methods

A spreadsheet based on Microsoft Excel was developed, allowing the cultivation data for each crop to be easily introduced. The output of this spreadsheet is a conversion of data on cultivation and technical means data into energetic equivalents ($MJ*ha^{-1}$). The spreadsheet then calculates the energy balance of the cultivation using a method based on the work of Bullard et al. [1] and modified by Bona et al. [2]. The model also calculates the CO_2 balance on the same cultivation data. For the two crops considered, the model, using only sowing dates and yields, estimates CO_2 fluxes using a period of one year as a time base.

In addition, the processes most affecting energy and CO_2 balances may be identified, thus allowing a choice of cultural practices according to optimization of one or both balances.

Concerning the CO_2 balance, the quantity of carbon stored was considered in all its forms and in all transformations, and the length of period of storage of CO_2 in different forms was computed.

Energy and carbon dioxide balance were determined from a survey based on data from questionnaires on 403 cultivations of sunflower and rapeseed. The questionnaires were presented to farmers by a survey manager who asked details of techniques and products used for cultivation. The data were introduced to the spreadsheet. The transformation into energy and carbon dioxide equivalents allowed comparisons to be made of the efficiency of the techniques used by farmers in terms of CO_2 storage and energy produced.

Results and Discussion

In rapeseed, the average energy output was 69 $GJ*ha^{-1}$ but the range of variation was very high: from 13 to 122 $GJ*ha^{-1}$. For this crop, much energy comes from meal (about 57%) which cannot be considered as a by-product but as a true product. The main factors affecting energy input in cultivation were fertilizers and fuels. This is particularly important as rapeseed, in our environment (Veneto) and throughout Europe, is considered very dangerous for the environment because of its high nitrogen input requirements and because the crop cycle of the plant which occurs in the rainiest periods of the year.

In sunflower, the average energy output was higher than that of rapeseed, 79 $GJ*ha^{-1}$, with a range of variation from 14 to 124 $GJ*ha^{-1}$. This result was very unexpected because sunflower is known to tolerate input reductions. For this crop, the quantity of energy deriving from meal was relatively lower (about 45%) mainly because of the lower energy value of meal. Instead in sunflower, the main factor affecting energy input in cultivation, as a percentage, was fuel; that deriving from fertilizer was lower. Concerning the CO_2 balance, the main sources of emission for rapeseed were consumption and fertilizer; for sunflower the main factor was fuels. For most of the parameters considered here, there was a strict relationship between energy values and corresponding CO_2 emission.

In sunflower, the energy gain tends to decrease with increasing energy input so that the crop is able to optimize low input levels. The relative high variability of the data must be considered by taking into account the fact that soil fertility, fertilization level or effect due to farmer's skill were not considered separately.

In both crops, the efficiency of immobilization of CO_2 per unit of energy input tended to decrease with increasing energy input levels. This is particularly interesting, because of efficiency increases at low energy inputs, if low-impact crop techniques are adopted, it is possible to store more carbon than with high inputs. If the main concern is the reduction of CO_2 emission farmers should decrease the quantity of input, thus optimizing the efficiency of CO_2 storage. This can be done only if the crops can tolerate reductions in input without significantly decreasing their yields. Sunflower was more stable at low energy input.

It should be borne in mind that a reduction in input can produce a decrease in final yie lds so that farmers are faced with economical patterns. On one hand, They can optimize the energy input to increase the efficiency of CO_2 storage, but, on the other, lower yields mean lower income.

Conclusions

The data processing spreadsheet produced here can very easily be used for evaluating energy and carbon fluxes of a crop. Its results can be used for evaluating single farming operations in terms of energy and carbon balances and thus allowing comparisons among various cultivation strategies. Energy crops do represent a valid method of accumulating CO_2 over a period of time. There is an objective advantage in cultivating crops for methylester production using sunflower and rapeseed as crops supplying energy, showing that the use of vegetable oils is practicable in terms not only of techniques (in the field but also in transformation processes) but also of energy.

In the Veneto environment, sunflower can be cultivated with very low energy input and it is more efficient in storing CO_2 than rapeseed. It should be borne in mind that a reduction in input can produce a decrease in final yields so that farmers are faced with economical problems. On one hand they can optimize the energy input to increase the efficiency of CO_2 storage but, on the other, lower yields mean lower income. For this reason, it is highly desirable that the production of energy crops should be supported by governments by providing funds for farmers who decide to cultivate them and the amount of support should be related to the reduction of input.

References

[1] Bullard, C.W., Penner, P.S. and Pilati, D.A., 1976. Energy analisys handbook. CAC Doc. 214 Cntr. for Adv Computation Univ. of Ill., Urbana.

[2] Bona S., Mosca G., Vamerali T., 1999. Oil crops for biodiesel production in Italy. Renewable Energy, 16, 1053-1056.