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Environmental and economic assessment of *Cynara cardunculus* for local bioenergy production under rainfed conditions in the context of climate change impact

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Introduction

The IPCC Special Report Global Warming of 1.5ºC states that current emission reduction commitments at global level are insufficient to limit global warming to 1.5°C. Among the possible measures to avoid it, the substitution of fossil fuels by renewable energies is proposed and outstanding contribution of biomass technologies. Most climate change scenarios consider the Mediterranean region as one of the most vulnerable region in the world with expected higher temperatures and lower rainfall trends. Local production of energy crops in marginal conditions could contribute to improve local development and prevent rural depopulation, as long as the biomass production entails lower environmental impacts and is produced at a reasonable cost.

This study assesses the environmental and economic impact of biomass production from cardoon (*Cynara cardunculus* L.) under rainfed conditions in abandoned farmland or marginal lands (which do not compete with food crops) for heat generation in domestic boilers as well as electricity production in a combustion plant.

Materials & Methods

Cardoon is a Mediterranean perennial crop with a lifespan of about 10 years, which is yearly harvested from the 2nd year (Figure 1). A carbon footprint analysis and an economic assessment along the life cycle have been conducted. Five different agronomic scenarios of correlated agricultural inputs and crop yields were assessed.

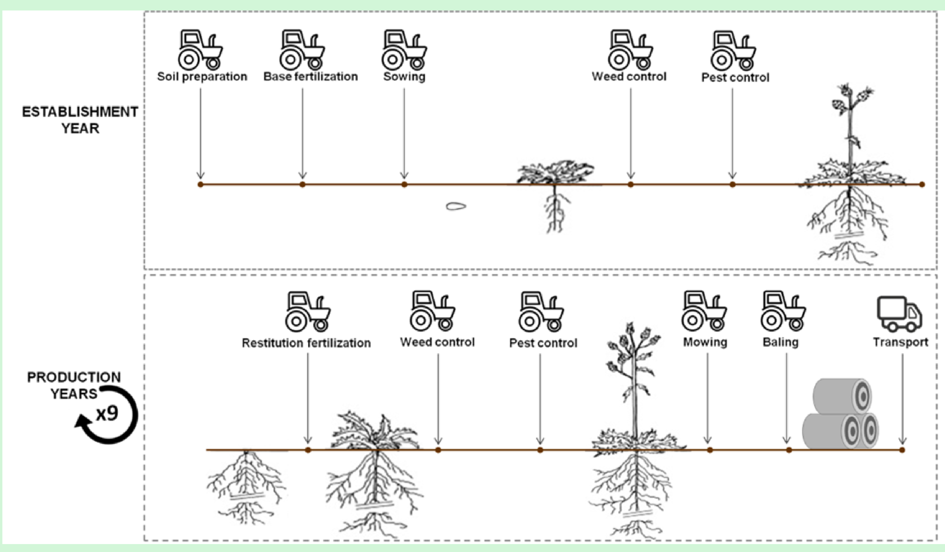

Fig. 1.- Cardoon agronomy diagram

LCA methodology described in RED II [1] has been used to calculate the carbon footprint of the cardoon production. N_2O and fertilizers emission factors have been adapted to Spanish conditions [2, 3].

The economic assessment has been carried out in accordance with the basic principles of economic analysis. The allocation of costs distinguishes the different production factors: land; machinery; inputs and labour. Input costs included are: seed [4, 5], fertilizers [6], pesticides (market price) and fuel [7]. The land cost considered was 116 €/ha, which represents average land rent in the Spanish regions where cardoon cultivation in rainfed conditions is adequate [8].

Carbon sequestration along the 10 years cycle has not been considered due to the uncertainty of the fraction of sequestered carbon, which is released again to the atmosphere, in the most common rotation cycle cardoon-legume. According to the experience gathered in the cultivation of cardoon in Spain, it could not be assumed a direct-seeding practice of the next crop, which would improve the environmental performance of the value chain in terms of soil carbon sequestration.

Results & Discussion

Environmental assessment

The environmental performance of cardoon cultivation in marginal lands shows the typical environmental profile of energy crops (Figure 2 and 3).

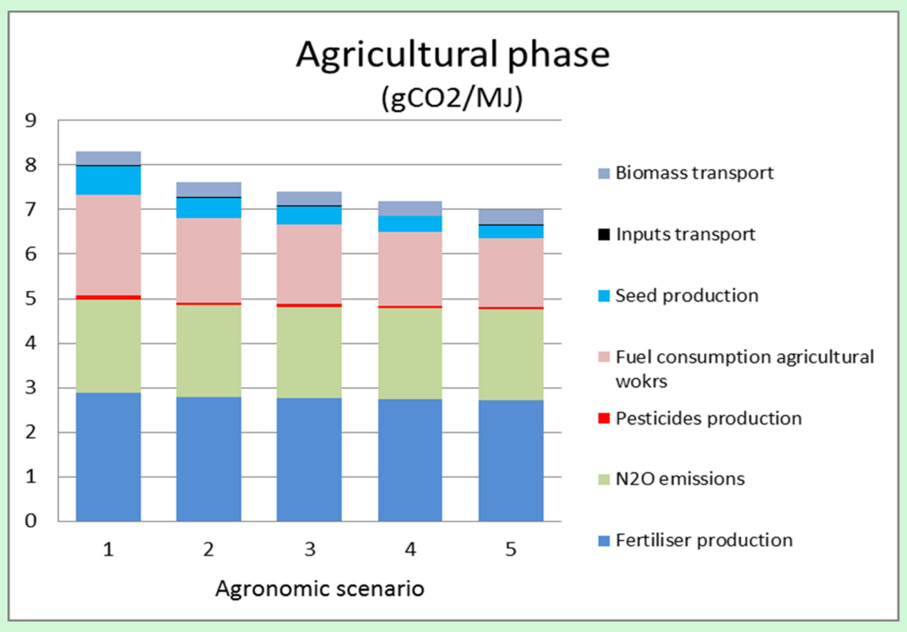

Fig. 2.- Climate change contribution in agricultural phase

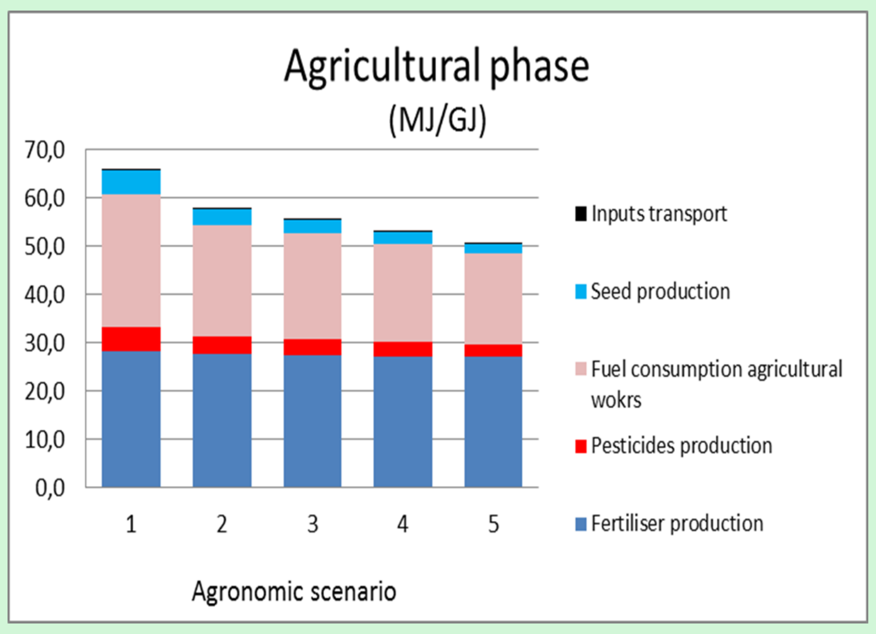

Fig. 3.- Fossil energy consumption in agricultural phase

Results & Discussion

GHG emission savings go from 81% to 84% for electricity purposes and from 87% to 89% for heat production according to different scenarios. Emission savings are compared to those generate by the use of herbaceous biomass residues such as straw pellets, whose default values for the GHG savings are 78% for electricity and 85% for heat production. In view of these values, *Cynara cardunculus* cultivation in these marginal lands could contribute to mitigate climate change. (Figure 4).

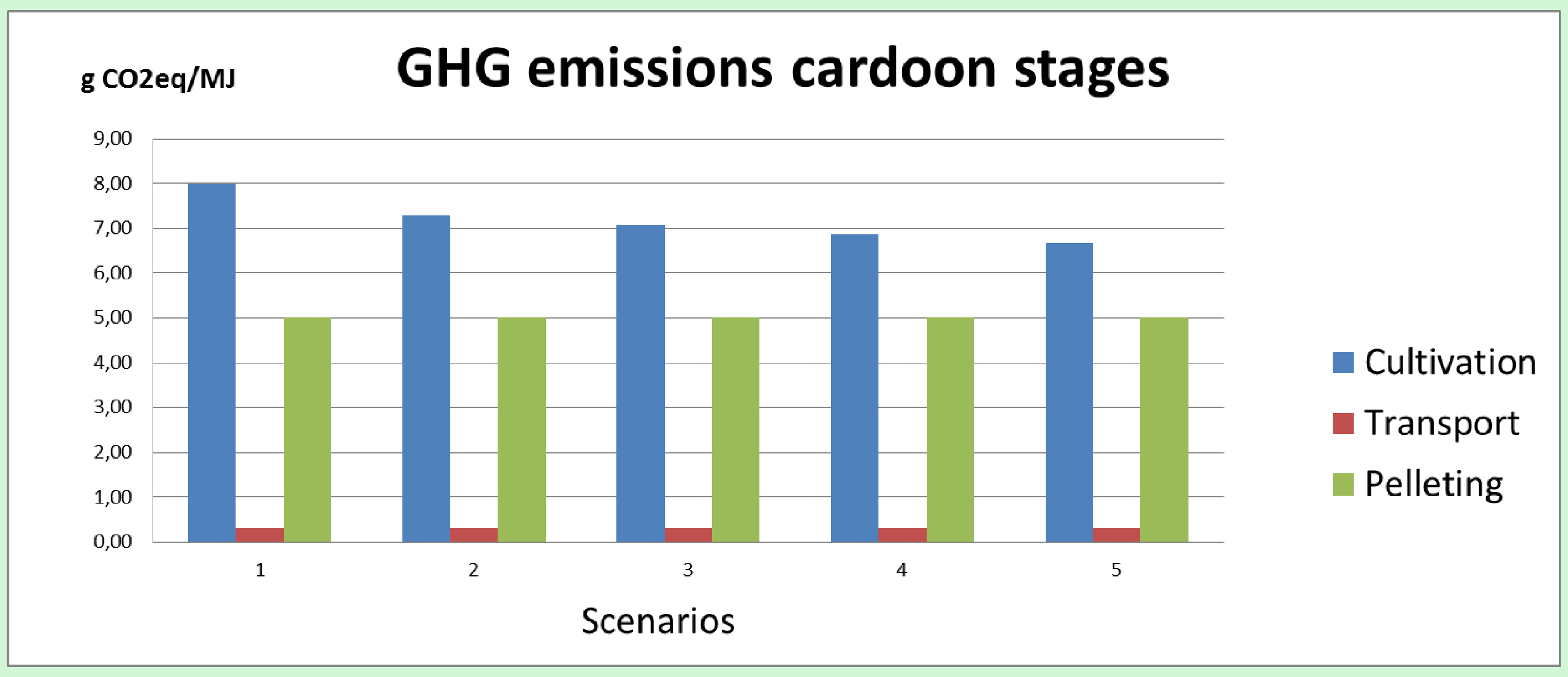

Fig. 4.- Climate change contribution by cardoon stages

Economic assessment

Costs of the different stages of agricultural production phase are shown in Table 1. Discount rate of 4% has been applied.

Scenario	Yield	Seed	Fertilizer	Pesticide	Machinery	Fuel	Labour	PRODUCTION COST
	t dm/ha	Euros/ha/year						
1	5.76	3.25	98.15	17.56	149.51	40.78	13.94	323.19
2	7.65	3.25	119.68	17.56	174.93	45.79	16.07	377.28
3	8.46	3.25	129.02	17.56	186.45	47.94	16.99	401.20
4	9.63	3.25	142.65	17.56	202.50	51.04	18.31	435.30
5	11.07	3.25	159.63	17.56	222.14	54.87	19.94	477.38

Table 1.- Production cost (€/ha/year

Scenario	Mowing	Packing	HARVESTING COSTS
	Euros/ha/year		
1	41.21	80.89	122.10
2	51.13	103.53	154.66
3	55.59	113.65	169.24
4	62.01	127.70	189.71
5	69.93	144.88	214.81

Table 2.- Harvesting costs (€/ha)

In accordance with these results, the cultivation of *Cynara cardunculus* on marginal land would only be profitable for farmers with the support of CAP subsidies or income from the carbon sequestered in this perennial crop.

Economic profits have been calculated according to different selling prices (Table 3) using the following formula:

Selling price	65	70	75	80	85	90
1	-70.89	-42.09	-13.29	15.51	44.31	73.11
2	-34.69	3.56	41.81	80.06	118.31	156.56
3	-20.53	21.77	64.07	106.37	148.67	190.97
4	0.94	49.09	97.24	145.39	193.54	241.69
5	27.36	82.71	138.06	193.41	248.76	304.11

Profit = Yield (t/ha) x (Price at farm gate (€/t) – cost production (€/t).

Table 3.- Profitability (€/t)

Conclusions

Cardoon, as a dedicated energy crop well adapted to Mediterranean conditions to produce local and sustainable biomass resources for heat and power purposes, could play an important role in reducing GHG emissions.

There is a lack of data on what happens in the next crop rotation with the carbon sequestered throughout the cardoon cultivation cycle. Experimental and field data on the potential of carbon sequestration of cardoon cropping should be a priority research topic to analyse the possibility of best practices to mitigate climate change.

Cardoon cultivation (unrestricted management practices), without subsidies or carbon sequestration revenues, is not profitable under marginal conditions, even at high biomass-selling prices. The new CAP could represent an opportunity for the implementation of perennial crops to reduce soil erosion and contribute to carbon sequestration.

References

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