Evaluation of an advanced biofuel value chain based on five cellulosic feedstocks as part of a new agricultural model coupling food/energy production

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Abstract

Maize and wheat by-products are largely available at EU level. Moreover, dedicated energy crops such as biomass sorghum, industrial hemp and sunn hemp, can produce additional biomass without competing with food crops. This study describes a bioethanol production chain from the feedstock production to the barrel via biochemical conversion. A regional spatial analysis is, then, presented under three intensified cultivation scenarios to highlight the potential reduction dependency from fossil fuel of advanced biofuels. Field scale feedstock cultivation and harvest was carried out by the University of Bologna. The feedstocks storage and delivery from a catchment area to the conversion plant was hypothesized in the light of exploiting the most common farm facilities. As for maize stover and wheat straw handling and storage was referred to the common practices of agricultural contractors for straw and hay with bales of the same size. The sugar fermentation was derived from literature based on the total sugars outcoming from hydrolysis. A fine-grained spatial analysis based on geo-referenced data was carried out for Emilia-Romagna deemed as particularly suited for the intensiveness of its farm structure that could ease the chain scale up. Three cultivation scenarios where hypothesized for Emilia-Romagna. Scenario 1 (S1) is the baseline scenario in which no crop intensification is foreseen even though maize and wheat residues will be intended to bio-ethanol production. Scenario 2 (S2) is constituted by a low input intensification in which biomass sorghum, sunn hemp and industrial hemp are double cropped after an early harvested winter cereal such as Italian ryegrass, oats and rye. Scenario 3 (S3) was built to express the maximum potential of the considered feedstock in Emilia-Romagna and many other crops which are harvested in June were included in the list for double cropping. The energy crop late planting requires irrigation, indeed. Results highlights that biomass sorghum was able to supply over 20 Mg ha^{-1} of dry biomass in real conditions, which was double compared to sunn hemp, industrial hemp and maize stover, that recorded similar values. Otherwise wheat straw produced 5 Mg ha^{-1}, even though it registered the highest total (C5, C6) sugar content compared to maize stover, biomass sorghum, industrial hemp and sunn hemp. The overall ethanol produced per unit of land is highest for biomass sorghum (4725 L ha^{-1}) followed by industrial hemp, maize stover, wheat straw and sunn hemp (2240, 2194, 1554 and 1536 L ha^{-1}, respectively). The Emilia-Romagna scenarios showed that from 8 (S1) to 13 (S3) biochemical plants with an annual capacity of 200,000 Mg y^{-1} of feedstock can be installed. The bioethanol production ranged from about 200 ML (S1) to 760 ML (S3) which can replace from the 26% (S1) to 56% (S3) the Emilia-Romagna annual ethanol consumption. Therefore, the mentioned chain development, could significantly reduce the fossil fuel dependency in the short-term, helping to approach the demanding European target of the Green Deal without affecting food production.