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Water-Energy Nexus: the case of biogas production from energy crops evaluated by Water Footprint and LCA methods

Tommaso Pacetti, Enrica Caporali, and Giorgio Federici
University of Florence, Italy (tpacetti@unifi.it)

This study analyzes the production of biogas from aerobic digestion of energy crops. The production of biogas is an important case study because its spread, similar to other sources of bioenergy, creates questions about the environmental effects, the competition in the food market as well as the progressive change of land use. In particular is hereby analyzed the nexus between bioenergy production and water, which plays a key role because water resources are often the limiting factor in energy production from energy crops.
The environmental performances of biogas production were analyzed through Water Footprint (WF) and Life cycle assessment (LCA): the integration of LCA and WF represents an attempt of taking advantage of their complementary strengths in environmental assessment, trying to give a comprehensive analysis of bioenergy production sustainability. Eighteen scenarios were considered, trying to figure out the performances of different combinations of locations (north, center, south Italy), crops (maize, sorghum, wheat) and treatments (anaerobic digestion with water dilution or manure co-digestion). WF assessment shows that cultivation phase is the most impacting on water resource use along the entire system life cycle. In particular, water requirements for crop growth shows that sorghum is the more water saver crop (in terms of consumptive water use to produce the amount of crop needed to produce 1 GJ of biogas energy content). Moreover WF investigates the kind of water use and shows that wheat, despite being the most intensive water user, exploits more green water than the other crops.WF was evaluated with respect to water stress indicators for the Italian territory, underlining the higher criticalities associated with water use in southern Italy and identifying consumptive blue water use, in this area, as the main hotspot. Therefore biogas production from energy crops in southern Italy is unsustainable from a water management perspective. At a basin scale, WF results obtained for central Italy were compared with local water availability (Merse river basin), pinpointing the time dependence of the sustainability. This analysis highlights that wheat, even if more water intensive than other crops, has a WF that not burdens the driest period as maize and sorghum does, underlying importance of assessing the temporal distribution of water use.
Further, WF was combined with LCA. First WF results were used as input for LCA inventory, and then some indicators of the selected impact assessment method were analyzed to obtain additional information mainly on water resource quality. The overall results show that biogas production from energy crops has in general negative impacts (i.e. beneficial environmental performances), due to the savings associated with avoided conventional energy production, for all the indicators except water depletion, fresh water ecotoxicity and marine ecotoxicity.
WF and LCA results show the benefit of coupling the two methods. Since WF focuses on the water use and the LCA focus on an extended range of environmental loads, creating synergies between these two approaches can help having a comprehensive assessment and a better insight in the Nexus.