Net-energy analysis of integrated food and bioenergy systems exemplified by a model of a self-sufficient system of dairy farms

Agriculture is expected to contribute in substituting of fossil fuels in the future. This constitutes a paradox as agriculture depends heavily on fossil energy for providing fuel, fodder, nutrients, and machinery. The aim of this paper is to investigate whether organic agriculture is capable of providing both food and surplus energy to the society as evaluated from a model study. We evaluated bioenergy technologies in a Danish dairy-farming context in four different scenarios: (1) vegetable oil based on oilseed rape, (2) biogas based on cattle manure and grass-clover lays, (3) bioethanol from rye grain and whey, and (4) a combination of (1) and (2). When assessing the energetic net-contribution to society from bioenergy systems, two types of problems arise: how to aggregate non-equivalent types of energy services and how to account for non-equivalent types of inputs and coproducts from the farming? To avoid the first type, the net output of liquid fuels, electricity, useful heat, and food were calculated separately. Furthermore, to avoid the second type, all scenarios were designed to provide self-sufficiency with fodder and fertilizer and to utilize coproducts within the system. This approach resulted in a transparent assessment of the net-contribution to society, which is easy to interpret. We conclude that if 20% of land is used for energy crops, farm-gate energy self-sufficiency can be achieved at the cost of 17% reduction in amount of food produced. These results demonstrate the strong limitations for (organic) agriculture in providing both food and surplus energy.