ifeu -
Institute for Energy
and Environmental
Research Heidelberg

Assessment of energy and greenhouse gas inventories of Sweet Sorghum for first and second generation bioethanol

Executive summary

Commissioned by the
Food and Agriculture Organization of the United Nations (FAO), Rome

Authors:
Dipl.-Landscape ecol. Susanne Köppen
Dr. Guido Reinhardt
Dipl.-Phys. Ing. Sven Gärtner

Heidelberg, Germany, 2009

Assessment of energy and greenhouse gas inventories of Sweet Sorghum for first and second generation bioethanol

Commissioned by the Food and Agriculture Organization of the United Nations (FAO), Rome

Executive Summary

In light of increased discussions regarding the competition between bioenergy and food, Sweet Sorghum has emerged as a promising energy crop that also offers potential solutions to this conflict. Due to the fact that it can be used for the production of food, first and second generation biofuels as well as for fertilizer, its cultivation is to be encouraged. However, to date neither a consistent picture nor sufficiently reliable scientific documentation exists regarding the crop's sustainability. Consequently, the Food and Agriculture Organization of the United Nations (FAO), Rome, commissioned the ifeu-Institute for Energy and Environmental Research GmbH Heidelberg (IFEU) to investigate the environmental impact of different Sweet Sorghum production systems. These production systems include the production of first and second generation bioethanol from different crop parts as well as a combined use for both biofuels and food.

The study focuses on three main topics:

– The energy and greenhouse gas balances of different Sweet Sorghum pathways are examined by means of a quantitative analysis. For this purpose a so-called screening assessment is conducted which analyses the energy and greenhouse gas impacts along the entire life cycle of Sweet Sorghum for each examined production and use system. The results are compared to the environmental impacts of equivalent fossil fuels.
– Additional environmental impacts from the cultivation of Sweet Sorghum are examined qualitatively.
– Sweet Sorghum is compared to other crops available for biofuel production regarding selected technical aspects.

Results: Energy and greenhouse gas balances – First and second generation bioethanol from Sweet Sorghum can contribute significantly to the conservation of fossil resources and to the mitigation of greenhouse gases. If the crop is used for the production of ethanol (from grains and sugar) and green electricity (from surplus bagasse), 3 500 litres crude oil equivalents can be saved per hectare cultivation area. If both food from grains and ethanol from the juice are produced, 2 300 litres crude oil equivalents can be saved per hectare cultivated area. Regarding greenhouse gases, between 1.4 and 22 kg CO_2 equivalents can be saved depending on yields, production methods and the land cover prior to Sweet Sorghum cultivation. For both categories, the exact values vary greatly with specific scenarios and local conditions. In general, the following parameters determine the results: type and efficiency of conversion technology, the use of by-products (e.g. bagasse), the crop yield per cultivation area, land use changes, as well as the type of fossil energy carriers that are replaced. Even if the seeds were used as food, bioethanol from the stem's sugar juice still shows clear advantages to fossil fuels. If both sugar and seeds were used as food, the respective conversion related energy and greenhouse gas expenditures could be compensated by producing second generation ethanol from the bagasse.

Energetically self-sufficient combined production of first and second generation bioethanol could be achieved by using part of the bagasse to generate process energy. However, the energy and greenhouse gas balances would produce a more favourable result if green electricity is produced from bagasse.

Results: Other environmental impacts – The fact that Sweet Sorghum has a low water demand is especially advantageous if it were grown in arid regions or areas with water shortages. Its low fertilizer demand reduces the risk of nutrient leaching and thus soil and water pollution, as well as making it well suited for small-scale subsistence farming. Its relatively short vegetation cycle allows Sweet Sorghum to be grown in double cropping systems, which in turn can lead under certain circumstances to greater agrobiodiversity and a reduced demand for fertilizers and pesticides. Under intensive practices Sweet Sorghum production risks similar disadvantages as other intensive monocultures, like soil degradation and loss or soil and water pollution due to more fertilizer and pesticide use. Establishing new Sweet Sorghum cultivation sites instead of integrating the crop into existing agricultural systems may lead to a loss of biodiversity, which is more detrimental for species-rich ecosystems. Like many other biofuels, Sweet Sorghum-based bioethanol has disadvantages with regards to certain emissions compared to its fossil equivalents, especially regarding acidification, eutrophication, photochemical smog and ozone depletion.

Results: Comparison with other biofuel crops – Due to a lack of cultivation and breeding experience, the yield stability of Sweet Sorghum is not as favourable as for many firmly established crops such as sugar cane. In principle, the cultivation and harvesting steps can be mechanized to a great extent, yet in practice affordable machines such as for harvesting, especially at small scale, are not yet available. A special advantage of Sweet Sorghum is that with currently existing cost-efficient conversion technologies both food and biofuels can be produced from this crop at the same time. This could reduce competition between food and bioenergy production. Additionally, Sweet Sorghum still delivers appreciable yields in soil of restricted suitability for food crops, a characteristic that many fully established energy crops, such as corn, do not share.

Need for further research and development – In order to be able to calculate specific energy and greenhouse gas balances, which are required for certification and emission's trade, some basic data and specific interactions still have to be elaborated, such as: conversion technologies, carbon sequestration in the crop parts and in the soil under different production systems, the exact demand of and yield response to mineral fertilizer as well as the yields from different production systems under different climate and soil conditions. Since the crop's yield has a considerable influence on the energy and greenhouse gas balances, it should be the starting point of future breeding endeavours which also need to include efforts towards stable yields and an optimized composition of single crop parts. Furthermore, the capacities to integrate the crop into low input cultivation systems and to produce it on carbon poor soils should be actively developed. In order to tap the full potential of this energy crop, environmental research should be accompanied by investigations with economic and social focus.

Conclusions and recommendations – Sweet Sorghum has a great potential to help save fossil resources and reduce greenhouse gas emissions. It is also a promising crop as regards competition between bioenergy and food production and the creation of new income sources for subsistence farmers. If its production and use is increased, it should generally be strived to comply with sustainable, low environmental impact agriculture practices and to support the pro-poor development. In order to better determine and develop the best potentials, FAO should encourage further research and development described above. In addition, a series of case studies in different regions and under varying framework conditions could shed significantly more light on many environmental, economic and social aspects. As a starting point, a virtual and real expert workshop should gather species specific data to fill gaps highlighted in the study and be the beginning of a time-limited network effort to bring sufficient practical and technical knowledge together to enable well informed decision making at different levels. Adequate dissemination efforts may have to follow.