Why diversify annual biomass production for energy – exemplified by green house gas emissions from the Danish IBUS bioethanol production concept

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Introduction

There is a need for integrating the biomass starting point into the energy manufacturing steps. It will secure that bioenergy is produced with limited use of non-renewable fossil fuel to secure that in the application of biomass a net emission reduction of green house gasses take place along the whole chain.
Intercropping, defined as the cultivation of two or more species simultaneously on the same area of land, is an traditional practice still widespread in the tropics and common in developed countries before the 'fossilization' of agriculture. This cropping strategy is based on the manipulation of plant interactions in time and space to optimize resource use and productivity. It is regarded as the practical application of basic ecological principles such as diversity, competition and facilitation (Hauggaard-Nielsen et al., 2007).
Cereal-legume annual intercropping show the possibility to increase input of leguminous symbiotic nitrogen (N) fixation into cropping systems reducing the need for fertilizer N applications (Jensen, 1996). Moreover, less need for pesticides are obtained due to improved competition towards weeds (Hauggaard-Nielsen et al., 2001) and less general damages on intercropped species by pest and disease organisms (Hauggaard-Nielsen et al., 2007). Intercropping is a more adaptive management practice as compared to the present arable crop rotations consisting mainly of sole crops.
Perennials like clover-grass intercrops or mixtures are obviously more diversified than traditional annual crops. Clover-grass leys are important in many agroecosystems today due to quality as feed for livestock, a high dry matter production (10 t ha^{-1} yr^{-1} unfertilized, where 95% of the N accumulation is N_2 fixed by clover (Jørgensen et al., 1999) providing a nitrogen-rich residue, which may significantly reduce fertilizer requirements for the succeeding crop when mineralized (Hauggaard-Nielsen et al., 1998). Furthermore, clover-grass lays can be harvested several times a year and processed to ethanol throughout the year.
It is very much questioned whether bioethanol is a sustainable energy resource that can offer environmental and long-term economic advantages over fossil fuels, like gasoline or diesel. The aim of the present presentation is to debate the substitution of fossil fuels by crop biomass requiring the right selection of plant species according not only to chemical quality for efficient conversion but also to secure the development of ecologically benign farming system including biomass for energy.

Discussion

The Danish Integrated Biomass Utilization System (IBUS) has developed both first generation and second generation principal bioethanol technologies characterized by integration with an existing coal-fired Combined Heat and Power plant. When looking

at the entire ethanol production cycle, biomass production and thereby management is a very prominent source of GHG emissions, respectively 60-70 % of total GHG emissions for wheat grain ethanol and 30-45 % for wheat straw based ethanol when utilizing the Danish IBUS concept (van Maarschalkerweerd, 2007).
Nitrogen fertilization is responsible for more than 85 % of GHG emissions from wheat grain production in Denmark (LCA Food, 2006). The energy intensive production of N-fertilizers and soil emissions of N_2O (directly linked to the application of N-fertilizer which is significantly increasing the nitrification and denitrification activity) contribute with approximately equal weight to the 85 % share. The remaining emissions primarily originate from diesel combustion for traction. Straw can be regarded as a by-product from existing cultivation and hence no incremental cultivation is required which is reducing GHG costs. Nevertheless, removal of straw has a negative impact on the carbon sink in the soil, which in turn is detrimental to the overall GHG balance for straw based ethanol production. However, soil carbon reducing effect of straw removal can be compensated for by benign choice of cultivation practice.
Another interesting feature of combining both leguminous and cereal species is a higher mineral, especially N, content, as compared to the current cereal dominated raw material technologies. Such higher N content is very useful in down-stream processing, since the utilization of mineral nutrients in the fermentation step can be reduced or even avoided. Especially, in 2. generation technology macro- and micro-nutrients are important, because high dry matter concentrations (20-35%) are used in order to keep a feasible process (Thomsen et al., 2006). The high concentrations of fermentation inhibitors formed during the pretreatment step stress the microorganisms, and an optimal substrate is needed to achieve high ethanol yields.
The right combination of several energy technologies, biorefinery concepts, adapted to available biomass resources might be the right path to follow. In the biorefinery concept crops are converted to bioenergy carriers together with upgrading of “waste streams” to useful materials such as feed products and additives, as well as materials, organic chemical compounds, etc.

Conclusion

Different crop species and cropping systems offer different ecosystem services, which should be validated together with their bioenergy production potential. In order to achieve sustainable bioenergy production it is thus of outmost importance to focus on the choice of feedstock and the cultivation patterns. However, bioenergy systems are relatively complex, intersectional and site-specific and it requires synergic contribution from agriculture, forestry, energy industry and environmental sectors. Thus, the question is whether we are able to create such collaboration?

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