Concepts for a multi-criteria sustainability assessment of a new more biobased economy in rural production landscapes

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Abstract
This study presents a new approach to model the biophysical potentials for increased biomass harvest in Denmark, and a multi-criteria sustainability assessment of the socio-economic and environmental effects of different scenarios for such increased production and new biobased economy in rural landscapes. Thereby the results serve as input to the ongoing productivism – post-productivism debate related to rural spaces in Europe. Empirical results from a case study of large scale conversion to biorefenery technologies, aiming to increase the total Danish harvest of biomass by 10 million tonnes via the conversion to new types of crop production and land management, is used as an example, and will be related to the common conceptual model presented by the workshop convenors, and a so called "Traffic-light" multi-criteria sustainability assessment scheme introduced and exemplified in the present paper. The aim is to contextualize how the problems in relation to the concrete scenario results can be considered with the landscape as the meeting basis, and used as input for a discussion of innovative models for future farming systems, landscape research and management.

1. Introduction

The European Commission (2012) has a vision for a renewed biobased economy, with more multifunctional production landscapes. This implies both an increased production of biomass for food, fibres and energy, and an increased delivery of other beneficial services in form of environmental protection and rural development (Langeveld et al., 2010). Thereby it is an example where new research approaches are needed to make it possible to combine the multiple dimensions that shape rural spaces, based on the landscape as the meeting platform for biophysical and socio-economic dimensions.
In line with that, this paper aim to present results from a Danish biobased economy development study, including three scenarios for increased biomass harvest, and a new "Traffic-light" concept for multi-criteria sustainability assessment of such scenarios.

2. Materials and methods

2.1 Sustainable development criteria

Evaluation of a sustainable development implies the assessment of both social, economic and environmental criteria, and the *compeeding objectives* of economic development, environmental protection and social security (Dalgaard et al., 2006). In this context, pathways for a sustainable development can be defined as those leading to an overall improvement of these criteria, measured via defined indicators in each dimension (Waarts et al., 2009). However, the challenge remains: how to evaluate and compare potential improvements of the different pathways towards a more sustainable, biobased economy? This is the main discussion point of the present paper!

2.2 Data sources

The availability to digital geo-data about economic, environmental and social indicators related to land use changes and agricultural production is exceptional for Denmark, compared to most other countries. Therefore, the present study is based on a collation of georelated data for the Danish landscapes, including detailed farm production statistics and:

- Crop type, soil type, fertilisation and irrigation practices for each field
- Livestock type and numbers for each farm
- Socio-economic indicators in relation to economic income, gross margin, farmers age and sex etc. for each farm
- High resolution digital, land-use maps, including maps about nature areas, water bodies, watersheds, hedgerows, roads, soil management sustainability etc.

Most of these data are available at a national scale (See Dalgaard et al. 2002, 2009, 2010, and Turner et al. 2012), and in addition more detailed data and information about farmers motivations for land-use changes etc. are available for selected study landscapes (see for example Andersen et al. 2012a,b and Dalgaard et al. 2009).

2.3 Multi-criteria evaluation framework

A ”traffic light” approach is proposed to assess and discuss potentials for new land-use configurations and technologies to develop the bioeconomy in rural landscapes (Table 1).

Table 1. “Traffic-light” scheme for the evaluation of an extra area unit of specific land use types compared to a list of environmental, economical and social evaluation criteria for a sustainable development. Green light indicates improvement, yellow status quo, and red a negative development compared to the present situation (Exemplified with G, Y and R’s).

	Environmental Impact					**Economical/ Technical Impact**					**Socio-political impact**			
Evaluation object:	Nitrogen losses	Phosphor balance/ erosion	Biodiversity	Climate Chance mitigation	Etc…	Biomass production per area	Total biomass production	Production economy	Welfare economy	Logistical challenges etc…	Conflict with other activities	Robustness to political changes	Sensitivity to climate/env. changes	Changed legislation needed etc…
<u>Land Use type</u>:														
1. Type 1	R	G	G	Y	R	G	R	Y	R	G	R	R	Y	Y
2. Type 2	G	Y	R	Y	G	Y	G	R…..						
3. Type 3…	G	R	Y…..											

The aim of this scheme is to facilitate further research, and the discussion of scenarios for the development of the rural bioeconomy, and the defined sustainable development evaluation criteria. To exemplify the use of this scheme, the “traffic-light” is set-up for all major land-use elements in rural Danish landscapes (see results and discussion section), and used to compare the following synthesis scenarios for a larger biomass production from Danish agriculture:

2.4. Scenarios

Three scenarios, proposed by Jørgensen et al. (2012) to achieve a larger biomass production from Danish agriculture in year 2020, is used as a case study to demonstrate and discuss the "traffic-light" concept for multi-criteria sustainability assessment:

1. Business As Usual (BAU):
   - A continuation of the present development in land use, crop yields, resource use efficiency improvements and agro-environmental policies, and with unchanged crop mix and biomass harvest technologies, except for an increased utilization of existing resources of straw, livestock manure and meadow grass harvested for bioenergy.
   - Exports of cereals and imports of soy protein etc. are not included.
2. Optimised biomass production (2020 BIO):
   - New harvest technologies and varieties with more straw are implemented to increase and optimize straw harvest.
   - Conversion of half of the area with oilseed rape *(Brassica napus)* to high yielding sugar beets (14 t/ha/yr dry matter yield from roots plus 5 t DM/ha/yr from top).
   - Areas used for the existing cereal export is converted to energy crops (Sugar beets).
   - Vegetation from roadsides and rivers, and the catch crop areas planned according to existing Danish legislation are harvested
3. Environmental protection (2020 ENV):
   - No straw removed in areas with critical low soil carbon content (Dexter-index > 10, blue colors in Figure 2).
   - As compared to the "Optimised Biomass production" scenario, Increased areas with catch crops are planted and harvested, and the new areas with sugar beets are planted with perennial energy crops (e.g. grasses or willow Short Rotation Coppice, SRC) instead (with a dry matter yield of 15 t/ha in 2020)
   - In areas with a poor nitrate retention (i.e. more than 35% of the nitrogen in leached water from the fields reaches the aquatic environment), all areas with cereals are shifted to SRC energy crops.
   - No nitrogen fertilization of wetland meadows, to protect flora diversity.

4. Results and discussion

4.1 Scenario evaluation

The estimated biomass production from the three scenarios defined, yields between about 4 and 9 Mt extra dry matter (DM) biomass harvested annually, compared to the present situation in Denmark year 2009 (Figure 1). However, this potential should off course be evaluated against other advantages and disadvantages from the implementation of the scenarios, and other possibilities to harvest more biomass, than the three predefined scenarios, which focus primarily on a change in agriculture related land uses.

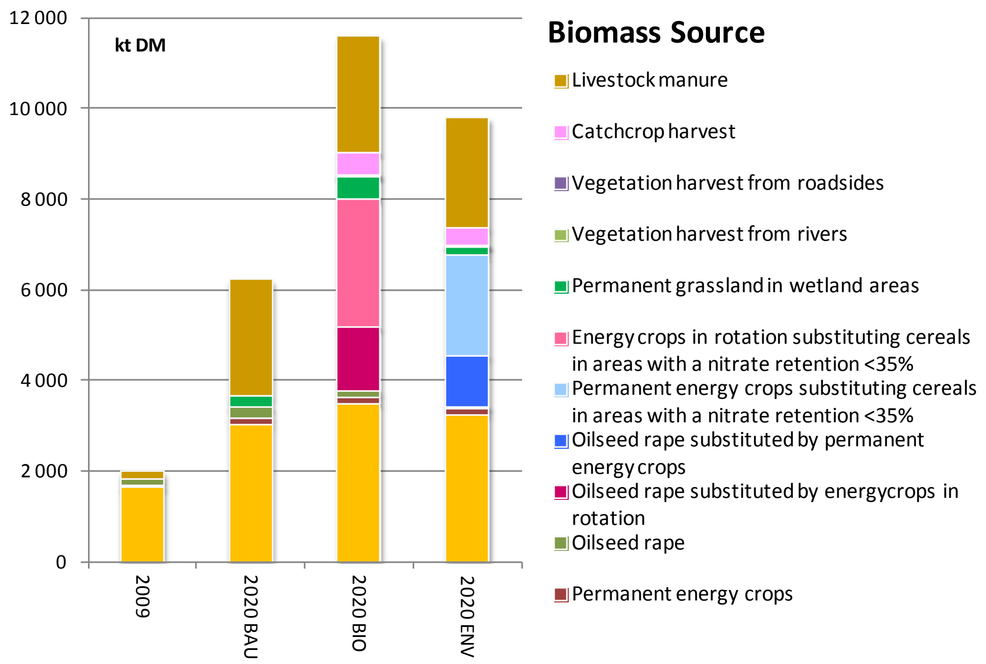

Figure 1. Estimated non-food biomass harvest (kt/yr) for the three scenarios: 1. Business as usual, 2. Optimised biomass production, and 3. Environmental protection (defined for the year 2020), and compared to the present situation in Denmark 2009 (Jørgensen et al. 2012).

The “traffic-light” scheme is used for such evaluation of the three scenarios, based on a preliminary expert assessment carried out by the authors (Table 2). In general, this quick evaluation shows low effects of the “Business as usual” scenario (1, dominated by yellow traffic lights), whereas the “Optimised biomass production" scenario (2) show the best performance in relation to the technical-economic sustainability development dimension (green light), but the worst performance in relation to environmental sustainability (red light), and in contrast, the “Environmental protection” scenario (3) shows the reverse, compared to the scenario (2). However, a general problem is that all three scenarios tend to show a bad performance in relation to the socio-political criteria (dominated by red and yellow light). Maybe other types of scenarios, could increase this performance? This will be discussed further in the following.

Table 2. Example where "traffic-light" scheme is used for a preliminary evaluation of the three scenarios, based on an expert assessment carried out by the authors.

	Environmental impact				**Economical/technical impact**					**Socio-political impact**			
Evaluation object:	Nitrogen losses	Phosphor balance/ erosion	Biodiversity	Climate Chance mitigation etc…	Biomass production per area	Total biomass production	Production economy	Welfare economy	Logistical challenges etc…	Conflict with other activities	Robustness to political changes	Sensitivity to climate/env. changes	Changed legislation needed etc…
Synthesis scenarios:													
1. Business As Usual	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	Y
2. Opt. Biomass	R	R	R	G	G	G	G	Y	R	Y	R	G	R
3. Env. Protection	G	G	G	G	R	G	R	Y	Y	R	R	G	R

4.2 Future perspectives for further scenario development and evaluation

To discuss and evaluate alternative pathways, which, in addition to the three scenarios above, may contribute to a more sustainable development of the land based bioeconomy, the major rural land use types with potential for an increased biomass harvest in Denmark can also be put into a "traffic-light" scheme, which can be used for the following discussion of the three basic scenarios set-up (1. BAU, 2. BIO and 3. ENV). The aim with setting up this scheme (Table 3) is not to make a full assessment of all combinations, but to help prioritize the most important information needed in order to discuss and further develop the scenario pathways towards a higher and more sustainable biomass harvest. In line with that, the major research tasks will now be to qualify and quantify figures for the major sustainability impact assessment criteria, in order to facilitate the discussion of how to fill in the red, yellow and green colors in the scheme, and subsequently to prioritize certain land-use types, and assess the overall effects of revisions and additions to the three preliminary scenarios defined.

This discussion is further qualified by information about the estimated land use impacts of the three basic scenarios (1. BAU, 2. BIO and 3. ENV, Figure 3), and information about the general, estimated land use trends of Denmark (Figure 2). Here, the general land use trends of the last decades, and those expected in the future generation, are shrinking areas with agriculture, and increased areas with forests, nature, infrastructure and urban settlements (Figure 3, Dalgaard et al 2012). However, because of expected yield increases per area, and an increased efficiency in the livestock production, it is expected that the present food production can be sustained; and this even with an increasing area available for other biomass production, or alternatively with an increased food production or an increase in other land use types than those used for biomass harvest. Therefore, it is realistic to find sustainable pathways for the increased biomass harvest of about 10 million tonnes of dry matter annually, targeted in the scenarios discussed in the present paper. In the following section we will argue why landscape level assessments are especially important to achieve and facilitate such development.

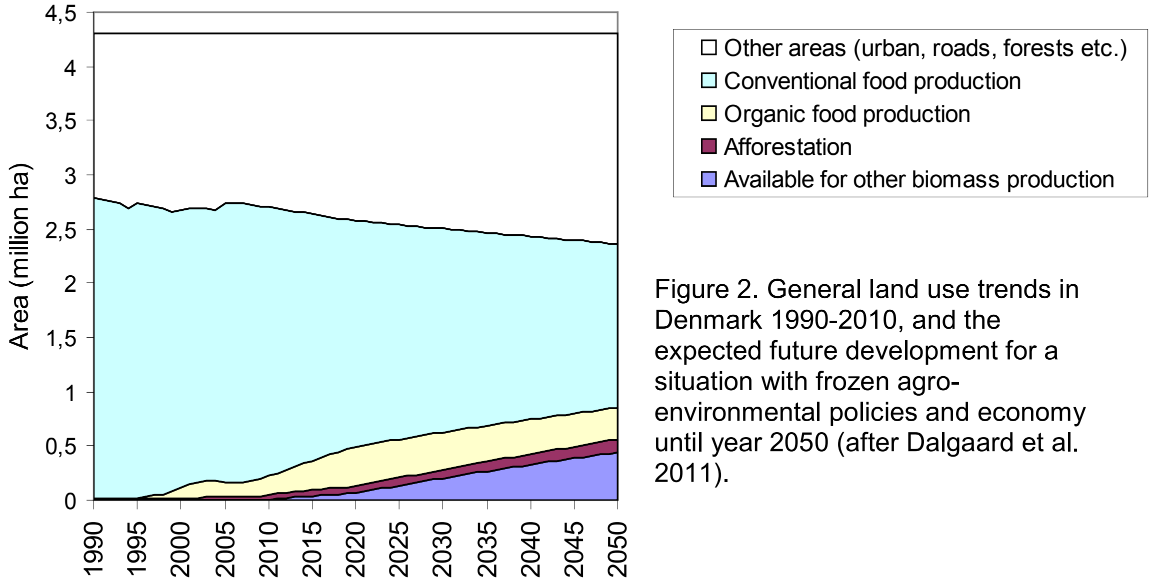

Figure 2. General land use trends in Denmark 1990-2010, and the expected future development for a situation with frozen agro-environmental policies and economy until year 2050 (after Dalgaard et al. 2011).

Table 3. "Traffic-light" scheme for the evaluation and discussion of the effect of different land use combinations and synthesis scenarios for an increased biomass harvest and bioeconomy development in Danish rural landscapes (see also Table 1).

	Environmental Impact				**Economic/technical Impact**					**Socio-political impact**			
Evaluation object:	Nitrogen losses	Phosphor bal./	Biodiversity	Climate Mitigation etc	Biomass pr ha	Total biomass	Prod. Economy	Welfare Econ.	Logistics etc...	Conflict other	Robustness to	Resiliense to change	Legislation etc
<u>Land use classes</u>:													
1. Cereals													
2. Grassland													
3. Beets													
4. Oil seed rape													
5. Pulses													
6. Potatoes													
7. SRC Energy Crops													
8. Straw removal													
9. Livestock systems manure utilisation													
10. Catch crop harvest													
11. Permanent grasslands													
12. Seminatural areas													
13. Roadside harvest													
14. Stream weed harvest													
15. Hedgerows													
16. Parks and gardens													
17. Waste recycling													
18. Afforestation													
19. Forests													

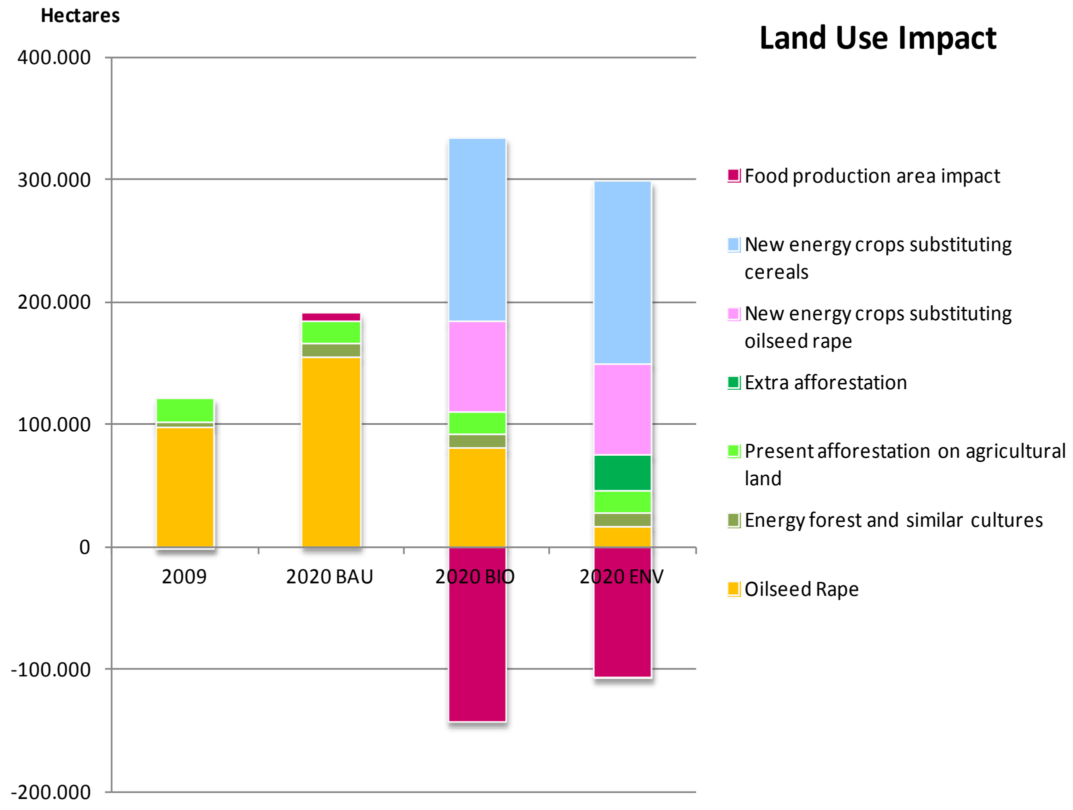

Figure 2. Estimated land use impacts of the three scenarios of Figure 1 and Table 2 (see also section 2.3 for further description). This information is used in the following discussion of the three basic scenarios set-up (1. BAU, 2. BIO and 3. ENV)..

4.3 The landscape scale as a scene for the development of innovative models for future farming systems and bioeconomy

The above mentioned scenarios are related to Danish agriculture and land use in general. However, in reality they have to be implemented and adapted to the local production landscapes, with all the regional and local differences this implies. For instance, in some areas a high livestock density inhibits the potentials for the introduction of alternative crops for extra biomass harvest, than those fodder crops needed to feed the livestock, and agricultural crop areas are needed to spread livestock manure, so conversion to other types of land use like afforestation maybe difficult (Dalgaard et al., 2011b). In addition, biomass harvest from- and integrated management of other landscape elements than the agricultural crop areas – for instance hedgerows, streamline- and roadside bufferstrips, small forests and other biotopes (see Table 4) – may be important to include in new and innovative scenarios for the development of new biomass harvest sources, and for promotion of a new bioeconomy, and in combination with other landscape functions and ecosystem services like nature conservation, aquatic environment protection and amenity values (Christen and Dalgaard 2012; Turner at al. 2012; Andersen et al. 2012a,b; Cellier et al. 2011).

In the context of the International Farming Systems Association (IFSA) Conference workshop 5.1 on “The landscape as the basis for integrating different levels of management, policy making and other dimensions of the rural” a common “conceptual model which aims to contextualize how empirical research driven by problems set up in practice can be considered with the landscape as the meeting basis” will be presented (www.IFSA2012.dk). The present papers scenarios’ and multi-criteria-impact assessment schemes will be presented in that context, and based on the detailed digital data available we will illustrate examples on the conceptual model implementation, feeding into the workshop discussion and the further paper elaboration.

5. Summary and Conclusions

Results from the three scenarios are used to demonstrate the "traffic-light" scheme for sustainability evaluation, and to facilitate the discussion of concepts for multi-criteria assessment of a new more biobased economy in rural production landscapes. In this context, the primary target for this presentation is to open up for a further discussion of these scenarios, and the new concepts for evaluation of the potential implementation of such landscape scenarios. Further research is needed in this area, and especially on how a new and more sustainable, biobased economy may be implemented in concrete rural landscapes. The present scenarios and sustainability evaluations presented are primarily based on national scale results and political aims, but new methods are needed to downscale results to the landscape level. Moreover, results from the traffic-light scheme evaluation (Table 2) revealed a demand for a better integration of socio-economic and political issues in the scenario development and evaluation. This will be an important point for further research, and for the discussions during the www.IFSA2012.dk workshop 5.1 on "The landscape as the basis for integrating different levels of management, policy making and other dimensions of the rural".

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