Sustainable Bioenergy Solutions for Tomorrow

BEST WP4 TASK 4.2

Difficulties in the sustainability assessment of agribiomass chains

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MTT

Environmental sustainability framework for agribiomass chains

- In the task 4.2, a framework for ecological sustainability of agribiomass based biofuel production has been created based on a literature review and the discussions at the 1st WP4 workshop held on 18.11. 2013

- The framework is tested with two raw materials: cereal straw (for combustion) and turnip rape (for biodiesel)

Environmental sustainability framework for agribiomass chains

Challenge	Causes	Solutions	Indicators
Climate change	Fertilization, liming, energy use, cultivation of peatlands	Optimal fertilization, good yield level	Ghg-emissions
Eutrophication	N & P fertilization, volatilisation of ammonia from manure	Optimal fertilization, practices following manure spreading	N & P balance, soil water purification potential (mechanical & chemical), (assessed according to Koellner et al. 2013)
Land use/soil quality: erosion	Soil tilling, absence of vegetation cover in winter, field slope steepness, soil texture	Reduced tilling, wintertime vegetation cover or stubble specially on land with high erosion risk	Erosion resistance (t/ha/year) (assessed according to Koellner et al. 2013)
L/s: loss of organic matter	Removal of plant residues, exclusive use of mineral fertilizers	No removal of plant residues, use of organic fertilizers	Organic matter deficit (assessed according to Koellner et al. 2013)
Ecotoxicity	Use of plant-protection products	IPM	Level of pesticide use, soil water purification potential (mechanical & chemical), (assessed according to Koellner et al. 2013)
Biodiversity	Monoculture, use of plant-protection products, land use change, invasive species	Crop rotation, IPM, no clearance of new fields	Share of new field area (%), species diversity per area (assessed according to Koellner et al. 2013)
Use of non-renewable natural resources	Machinery, drying of cereals	Use of renewable energy, organic fertilizers	Share of renewable energy (%), share of organic fertilizers (%), P balance
Water use and quality	Irrigation, eutrophicating and acidificating emissions	No cultivation in arid areas, optimal fertilization, energy efficiency	Use of irrigation water, groundwater recharge rate (assessed according to Koellner et al. 2013)
Low efficiency of farming	Unsuitable weather conditions, low soil fertility, choice of plant species and cultivar	Long-term soil fertility maintenance, choice of suitable plant species and cultivars, plant breeding	Yield level, land area use

Method selection

- First, several indicators included in the UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA (Koellner et al. 2013) were planned to be used in this study.
- However, the characterisation factors published for these indicators cannot differentiate between different arable field crops and management options (Mila i Canals et al. 2013 & Helin et al. 2014)
- As one of the goals of this study was to identify improvement options, these indicators were not seen practical enough

Environmental sustainability framework for agribiomass chains, updated

Challenge	Causes	Solutions	Indicators
Climate change	Fertilization, liming, energy use, cultivation of peatlands	Optimal fertilization, good yield level	Ghg-emissions
Eutrophication	N & P fertilization, volatilisation of ammonia from manure	Optimal fertilization, practices following manure spreading	N & P balance
Land use/soil quality: erosion	Soil tilling, absence of vegetation cover in winter, field slope steepness, soil texture	Reduced tilling, wintertime vegetation cover or stubble specially on land with high erosion risk	**Erosion (VIHMA –model, Puustinen et al. 2010)**
L/s: loss of organic matter	Removal of plant residues, exclusive use of mineral fertilizers	No removal of plant residues, use of organic fertilizers	**Organic matter decline (Yasso 07-model, Tuomi et al. 2009)**
L/s: compaction	**Use of heavy machinery in wet conditios**	**Optimal field operation times**	**Compaction risk**
Ecotoxicity	Use of plant-protection products	IPM	**Ecotoxicity**
Biodiversity	Monoculture, use of plant-protection products, land use change, invasive species	Crop rotation, IPM, no clearance of new fields	Share of new field area, **Indicators for the biodiversity of agri-environments (population trends of farmland breeding birds, butterflies and arable weeds, Tiainen et al. 2007, Hyvönen & Huusela-Veistola 2007, Kuussaari et al. 2007)**
Use of non-renewable natural resuorces	Machinery, drying of cereals	Use of renewable energy, organic fertilizers	Share of renewable energy (%), share of organic fertilizers (%), P balance
Water use and quality	Irrigation, eutrophicating and acidificating emissions	No cultivation in arid areas, optimal fertilization, energy efficiency	Use of irrigation water, **freshwater availability**
Low efficiency of farming	Unsuitable weather conditions, low soil fertility, choice of plant species and cultivar	Long-term soil fertility maintenance, choice of suitable plant species and cultivars, plant breeding	Yield level, land area use

Difficulties in assessment

- There were difficulties in the assessment of some sustainability indicators:
  - Soil organic matter decline
  - Level of pesticide use
  - Population trends of farmland breeding birds, butterflies and arable weeds
  - Share of renewable energy
  - Use of irrigation water

- These will be individually discussed on the following slides

Soil organic matter decline

- For the assessment of soil organic matter decline, the model Yasso07 (Tuomi et al. 2009) has been shown to be reliable in Finland

- The use of this model is however challenging, because to get the most reliable results, the whole cultivation history and the time point when the field was originally cleared from forest should be known

  → If too challenging, we will instead use the general values for Finnish field soils reported by Heikkinen et al. (2013)

Level of pesticide use

- National statistic data on pesticide use on our target crops is yet not available
- Because the toxicity of different pesticides varies greatly, ecotoxicity impact assessment (Rosenbaum et al. 2008, Räsänen et al. 2013) is a better method
- As comprehensive crop specific studies cannot yet be made, the more general results reported in the below mentioned publications will be referred to in this study
  - Räsänen et al. (2013), demonstration study, included three model crops (spring wheat, feed barley and oats) and 4 model substances
  - Räsänen et al. (2014), study on the ecotoxicity pressure and use of pesticides in Finnish arable farming as a whole, including 54 model substances

Population trends of farmland breeding birds, butterflies and arable weeds

- The population trends of farmland breeding birds, butterflies and arable weeds were chosen as indicators for biodiversity
- These are included in the indicator system describing the state and development of the diversity of the farming environment, that has been developed to be used in Finnish agricultural policy making (Tiainen 2007, Tiainen et al. 2007)
- All of these can only be used to assess the effect of the farming system as a whole
- We will refer to the results of the follow-up studies presented at biodiversity.fi (2014) and by Kuussaari et al. (2007) and Hyvönen & Huusela-Veistola (2007)

Share of renewable energy

- Data is only available on the share of different energy sources used on farms producing the crop groups cereals and special crops (including turnip rape) in the Finnish farm structure survey (Tike 2010)

- In farm scale turnip rape based biodiesel (RME) production, the fuel is mainly produced and used on the same farm (Virtanen et al 2009), but the actual share of the total energy use is not known

Use of irrigation water

- Crop specific data on irrigation water use is not available
- Data is only available on the share of irrigated area and the origin of irrigation water for the crop groups cereals and special crops (including turnip rape) in the Finnish farm structure survey (Tike 2010)
- To get a broader view, freshwater use and availability statistics from FAOSTAT (2013) and FAO-AQUASTAT database (2013) will be also used in this study
- Water footprint would be a more comprehensive method for the assessment of the sustainability of freshwater resources (WBSCD 2010, Aldaya et al. 2012), but suitable methodology and required data are not yet available for Finnish agricultural products (Lehtinen & Usva 2011)

A further addition to the framework: Compaction

- A further indicator representing soil quality, compaction, was added to the framework during the assessment phase.
- It appeared in the reviewed literature and in the discussions of the 1st workshop, but not as frequently as the previously selected indicators
- The assessment of compaction is currently problematic, as it requires field plot and operation specific knowledge of farm machinery, soil properties and moisture conditions (Saarinen et al. 2014)
- It was however decided to be included in the framework, because in the future there might be practical assessment tools, that don't require too intensive data collection
- In this study, compaction was assessed on a more general level based on literature

A few points to be taken into account

- Straw is a by-product of barley grain production, while turnip rape is a main product

- With some indicators, such as greenhouse gas emissions, no impacts from cultivation are allocated for straw

- With some indicators, such as N and P balances, the difference between straw harvesting and the situation where it is left on the field needs to be studied

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