Memo: **Report[1] on BUS ticket no 30**
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HOW MUCH BIOMASS CAN BE REMOVED FROM A SYSTEM WITHOUT NEGATIVE EFFECTS ON SOIL FERTILITY?

Definition of the problem
Crop residues usually are left on the fields or put back to contribute to the maintenance of soil fertility (C, N, K, P, etc). In case all biomass is going to be harvested the nutrient cycle is no longer in balance and deminishing of soil fertility may occur.

Questions
1. How much biomass can be removed from a system without negative effects on soil fertility?
2. Discuss the factors that determine these effects on soil fertility, with special emphasis on straw in Poland.
3. Discuss the effect on farm management and agri-economy.

1. Rational and question

The main driver for sustainable energy production is solving environmental problems of which climate change is the most important. Sustainable energy options being developed should therefore be implemented in a way that does not compromise other environmental values like soil C-loss, nutrient loss, soil erosion, etc.
Large quantities of inexpensive agricultural by-products, such as straw, are available at relative low cost. Many of these by-products do have a value though in the current systems. How much straw can be removed without compromising sustainability and soil fertility? The benefits of removing or leaving behind crop residues like will have to weighed. A short list of the arguments is given below.
Benefits of leaving crop residues behind are:

- Less erosion
- Retention of soil moisture
- Recycling of nutrients
- Increase or maintenance of soil organic matter (if no-till methods are used)
- Reduction in diurnal temperature cycling

Benefits of removing (part of) the crop residues are:

- Less hampering of mechanical management
- Reduction of weeds and diseases
- Alleviation of low spring temperatures
- Less nutrient loss to the environment
- Additional revenues for agriculture

In this exercise we calculate the amount of straw that can sustainably be removed from fields in Poland.

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2. Approach
This study is a quickscan on crop residue management in relation to soil fertility with a special focus on Poland. It draws on existing readily available material and expert knowledge. Data on crop production levels and area are derived from the FAO statistical database. Indices and parameters are derived from literature.

3. Agriculture in Poland
Polish agriculture is characterized by significant fragmentation; an average farm size is 8.44 ha of utilized agricultural area with about 50% of agricultural holding owners producing exclusively or mainly to satisfy their needs, in order to lower the costs of living of their families. Systematic changes in the ownership and area structure as well **as those in land use are taking place, however at a slow** pace. As compared to 1996, when the previous General Agricultural Census was conducted, in 2002 the total area of land utilized by agricultural holdings diminished from 20.8 million ha to 19.3 million ha, i.e. by 1.5 million ha (6.9%), including a decrease of the utilized agricultural area from 17.9 million ha to 16.9 million ha, i.e. by 1 million ha (5.5%). The number of agricultural holdings of the area over 1 ha fell by 91000 (4.4%) and at present it is 1956000.

A significant part of farms are involved in agricultural production applying traditional methods with a low usage of mineral fertilizer and plant protection chemicals as well as industrial feedstuffs to feed farm animals, in particular cattle. There are also commercially oriented farms, using modern methods of agricultural production capable of competing with EU agricultural holdings in terms of quality and productivity (MINISTRY OF AGRICULTURE, 2003).

3.1. Cereal production in Poland
In Poland the follow cereal are grown barley, buckwheat, mixed grain, oats, rye triticale and wheat. FAO reports a total cereal production of 21.507.080 ton for the year 2003. This is equivalent to 18.281.018 ton dry matter (assuming moisture content of 0.15). Total area used for cereal production in that year was 7.806.920 hectare.
No specific information on soil tillage, fertilizer or farm management is readily available.

4. Soil organic matter
Soil quality, soil structure, soil fertility and the water holding capacity of the soil are some of the functions related to organic matter. Recently soil organic matter as carbon reservoir was added to the list. In this quickscan we will focus on the soil fertility aspects in relation to crop residue management which are positively correlated to the size of the soil organic matter pool.
The soil organic matter content is related to biophysical factors (e.g. soil texture, climate) and management practices (soil tillage, fertilizer, crop residue management) In agricultural systems the annual dynamic related to crop growth and harvest that determines the carbon dynamics. The soil organic matter pool is mainly supplied by remains of the crop in the field after harvest. Soil organic matter is lost via erosion and decomposition. Via the decomposition of soil organic matter nutrients, of which N is the most important, needed for crop growth are released. The rate of decomposition of the accumulated organic matter in the soil is determined by the type of organic material and the environmental conditions (notably water and temperature).
Increasing the soil carbon content can be done by increasing the carbon input, decreasing the output or a combination of the two. For North West Europe the decomposition rate is approximately 2%. The fraction of carbon in soil organic matter is 0.58.

4.1 Increasing the input to the soil

To increase the carbon input in agricultural soils there are two main sources: crop residues and organic fertilizer application.
Leaving behind cereal straw in the field is a simple option to increase inputs. In cereals, the straw that is usually harvested for several purposes may be left in the field to increase the amount of soil organic matter. The average effect on the amount of soil organic matter depends on straw yields but also on the proportion of cereals in the crop rotation. In general the harvested product is removed for direct consumption or processing the remainder of the crop (roots, straw, etc.) can be left behind in the field. The Harvest Index is the fraction of the economic yield of the above ground biomass. A typical Harvest Index for wheat (wheat is used as a proxy for cereals) is 0.4 but may range from 0.35 – 0.45. 15 % of the total biomass in cereals is below ground (roots) and is directly added to soil organic matter pool.

The application of organic fertilizers (e.g. manure, slurry) aiming to supply nutrients to the crop also increases or maintains the soil organic matter content.
The simplified approached followed here assumes that a constant fraction of the added organic material (biomass, manure) that remains after a year and contributes to soil organic matter. This fraction is called the humification coefficient. A typical humification coefficient is 0.3 but may range from 0.1 to 0.9 depending on the physical and chemical composition of the organic material. In this study a humifcation coefficient of 0.3 is used for the root biomass and 0.5 for the straw. The carbon fraction in biomass is around 0.45

4.2 Decreasing the output from the soil
Soil tillage stimulates the decomposition of soil organic matter, mainly because of aeration of the soil. Reducing soil disturbance by shallow tillage or no tillage, therefore, decreases the decomposition rate of soil organic matter. Reduced tillage may lower the decomposition rate of soil organic matter by 25%.

5. Carbon balance and soil fertility

5.1 The input to the soil
The total production in 2003 was 21.507.080 ton grain on a total area of 7.806.920. With a moisture correction of 15% this is 18.281.018 ton grain which is about 2.340 kg per ha. These reported yields are very low and indicate a low input farming system.

Assuming a harvest index of 0.4 the grain production equals a total above ground biomass production of 5.850 kg per ha. 15% of the total biomass or 1030 kg is below ground and is directly added to soil organic matter pool. Straw production in 2003 was 3.510 kg per ha.

Given a fraction carbon in the biomass of 0.45 a total of 460 kg C is added to the soil organic matter pool via the root system. With a humification coefficient of 0.3 the roots contribute some 140 kg C per ha to the buildup of soil organic matter. Straw represents a carbon stock of 3.510 kg C per ha., via straw, with a humifaction coefficient of 0.5, 790 kg C per ha can be added to the soil organic matter pool.

5.2 The output from the soil
Via decomposition of organic matter nutrients are released, on average 2% of the soil organic matter decomposes. How much organic material should be added to compensate the loss depends on the amount present and lost and the amount taken up by the crop. A soil with 34.800 kg C per hectare

(about equivalent with 2% organic matter over 25 cm soil depth and a bulk density of 1.200 kg per m3) about 700 kg C is lost via decomposition per year.

5.3 The balance

To compensate the 700 kg C lost from the soil organic matter pool per ha the roots already provide 140 ton C per ha to the soil organic matter pool. So some 560 kg C per ha should be compensated via the straw production. The pool available via straw is about 790 ton C per ha.

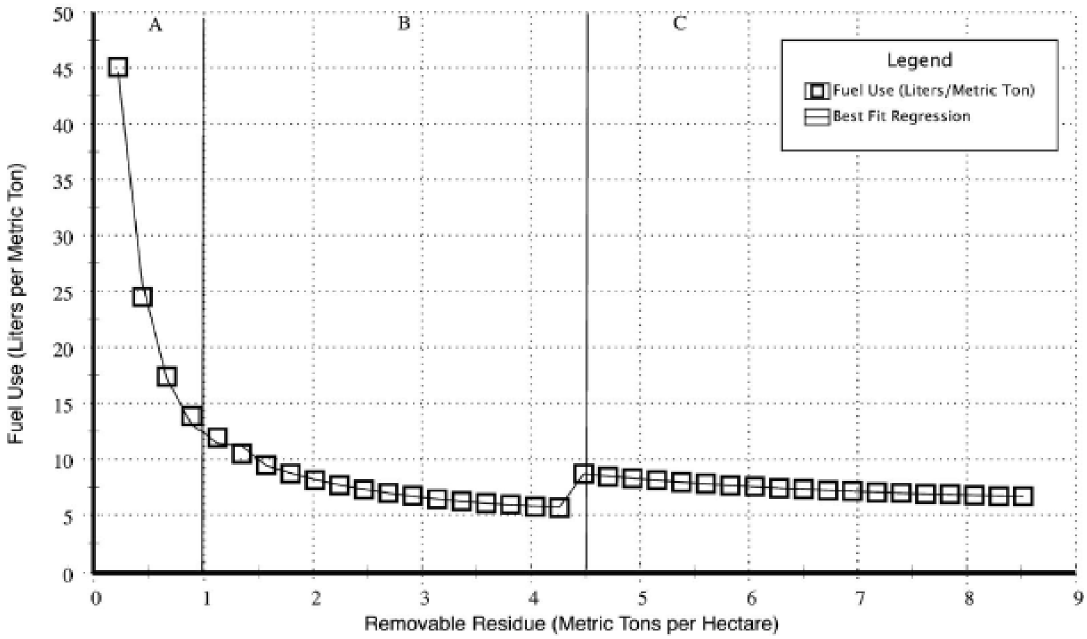
The soil contains 3.480 kg N (assuming a C/N ratio of 10) of which 2% or 70 kg is released via mineralization. Assuming a nutrient use efficiency rate of 0.5 (this may range from 0.2 to 0.5) some 35 kg N is taken up by the crop. Given that 60 kg grain is obtained per kg N, with 35 kg N a yield of about 2.100 kg grain per hectare is possible without fertilizer input. The average yield for cereals is about 2.340 kg grain per ha, which would indicate an N uptake of 39 kg N per ha. These differences are small compared to the ranges in the used parameters, so it seems indeed hardly any manure is used.

So we assume no organic fertilizer is used and the loss of soil organic matter is to be compensated via crop residues. The straw that can be removed from the field amounts to 230 kg C per ha which was available to contribute to the built-up of soil organic matter. This is equivalent to 470 kg C in the biomass or about 1.040 kg straw per ha.
For Poland this would mean a straw removal of 8.111.214 ton.

6. Logistics and Economics

The main cost of removing straw will lie in baling and transport followed to a storage and transport to a conversion facility. The efficiency of such a system will depend on the density of biomass at the field level and at the regional level. This is illustrated by figure 1 which shows the how fuel use increases as the amount of removable biomass per ha decreases.

The cost per tonne of straw will include the cost of collection, storage and regional transport, compensation for extra fertilizer (N, P and K) and a profit for the farmer. Determining the total cost for Polish conditions is not possible here. An indication can be gotten from other cases like corn stover in the USA. Where the cost for delivery of have been estimated at 32$(US) per tonne delivered in a 80 km radius (Glassner and Hettenhaus 1999).
Figure 1. Relation between straw residue per ha and the fuel use per tonne of residue (Glassner and Hettenhaus 1999).



7. Results & Discussion

This study is a quickscan which gives a first indication of what under current conditions in Polish agriculture can be removed. The parameters indicate an order of magnitude and direction of the amount of straw that can be removed. In the calculation we took the average of all cereals (except maize) grown in Poland. The range of production levels, fertilizer input and management will vary strongly between the different crops.

Crop are grown in rotation in this study a single crop type was taken. The effect of soil type and management were not taken into account.

Adding fertilizer to the soil is a very common practice. Adding fertilizer will increase production levels and consequently allow more straw to be more removed, but also fraction of straw that can be removed will be higher simply because of the increase in root biomass.

Using organic manure will also directly contribute to build up of soil organic matter. A relative low input of 4 ton manure per ha with a C content of 5% and a humification coefficient of 0.5 already 100 kg C is added to the soil organic matter pool. Which in the presented example is equivalent to about 440 kg straw biomass per ha or 3.435.045 ton straw for Poland.

A tool that combines the knowledge about soil carbon loss and uptake mechanisms with spatial information on soil characteristics and farming systems should make it possible to evaluate the amount of biomass that can be removed from agricultural systems in a sustainable way in Europe. This would greatly help scenario forecasting and design of sustainable biomass delivery chains in Europe.

References

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