Cereal Straw in Germany (Potentials and Costs of Straw Recovery)

Soil is the fundamental part of the agricultural production system. It is limited and exposed to many different claims. The production of renewable raw materials increased in 2011 to a level of 2.3 million hectares. An efficient use of the resource soil is strongly advised. Bioenergy strategies and policy initiatives focus on the implementation of the agricultural residue potential, due to possible environmental and cost benefits of these resources. The Agency for Renewable Resources assumes that by the year 2050 agricultural residues can deliver 300 Petajoule (PJ) respectively 4.3 % of the projected total energy consumption in 2050. In Fig. 1 the theoretical potential of agricultural by-products is shown. It seems obvious that cereal straw is the most relevant agricultural residue, with a share of approximately 42 % of the total amount.

Fig. 1: Theoretical potential of agricultural residues in million tons dry matter (dm) per year (left) and straw-fired heating plant (right).

Straw use and management practices have changed during the last decades. Coupled with the intensification of agriculture the transition from straw to slurry based animal housing types diminished the need of cereal straw significantly. The prohibition of straw burning on the field hampers the disposal of this by-product. The recent practice is to rupture the straw after threshing the grain and spread it onto the field with the combined harvester. Problems occur mainly in regions with a high share of small grain cereals in the crop rotation. Since tight crop rotations, with a high share of cereals become more common problems with soil tillage, sowing, pest control and immobilization of nitrogen are observed.

Apart from the use as litter, minor utilization for fodder, building material and horticulture can be presumed. But cereal straw can also be used to be transformed into heat (Fig. 1) and/or electricity. In contrast to some European neighbors burning straw in heat or power plants is not relevant in Germany. Straw seems to be able to act as a feedstock for the production of second generation biofuels or as a building material and as a feedstock for the chemical industry. A common result of these conversion types is that no or only little recirculation of organic matter to the soil takes place. The soil organic matter (SOM) or humus plays an important role for crop production. The ratio between input (manure, by-products) and loss (decay, harvest) of SOM is a crucial criterion for the assessment of sustainable agricultural practice. For this reason the removal of crop residues from croplands is limited. To visualize the potential of cereal straw without harming the soil functions the following study was conducted. In Germany 16.8 million hectares are considered as agricultural land and nearly 71% of it is used as cropland. The area occupied by cropland was nearly constant between 11.8 and 11.9 million hectares since 1994. The production of cereals alters since 1990 between 6 and 7 million hectares. The five-year-average cereal yield (2003 – 2008) is 6.62 tons fresh matter (fm) per hectare. Winter wheat as the most dominant crop reached average values of 7.41 tons fm per hectare in the same time period. The area for wheat cultivation increased continuously within the last 20 years. Nowadays winter wheat covers more than one quarter of the total cropland area. Animal husbandry as the main consumer of cereal straw demands 5 million tons fm of cereal straw each year. It is necessary for straw based housing systems. Since 1990, straw based housing types for cattle and pigs decreased significantly.

The site-specific reproduction of soil organic matter in agricultural farms is an important precondition to ensure high and stable yields. The legislative authority claims the preservation of soil organic matter in the Federal Soil Protection Law. A practical implementation of this request can be found in the Cross-Compliance regulations for farmers. In Germany, one of the possibilities to give evidence to adhere these regulations concerning soil organic
matter, is to conduct a humus balance on farm respectively enterprise level. The final criterion to report a straw potential on the NUTS3-level is the humus balance calculated with the models VDLUFA (lower and upper values) - and dynamische Humuseinheitenmethode (HE) [1,2].

The data acquisition for modeling the potential is determined by the humus balance model and the spatial resolution. This approach defines the districts of Germany (NUTS3-level) as the farm respectively the model entity. That means that for each of the 412 districts in Germany a humus balance is compiled. The temporal resolution covers the years 1999, 2003 and 2007.

The assumption that only 66% of the cereal straw could be baled on the field due to losses while threshing with a combined harvester anyway leave one third at the field for humus reproduction. If the humus balance of a district is negative, all grown straw is necessary as organic input to ensure long-term soil quality. If the results suggested that straw remained on the field which is not necessary as organic input, this amount was dedicated for energetic use. To access the straw potential for energetic use, the straw for animal housing was subtracted and another 10% reduction was calculated to consider straw for fodder or horticulture. The remaining value represents the surplus straw for each district. In the consulted years 1999, 2003 and 2007 a mean area of 6.2 million hectares were observed for the considered small grains. The total amount of straw was 30 million tons fm respectively 25.8 million tons of dm. Straw demand by the animal husbandry was higher in the western regions. Overall 4.8 million tons fm straw were required by animal husbandry, which accounts to 16% of the total straw occurrence. The humus balance showed a positive to very positive ratio of accumulation and decomposition for most of the districts. In two districts negative balances were found considering the “lower values” respectively the Cross-Compliance regulations. The humus balances exhibits spatial patterns. For example root crops like sugar beet and potatoes were negatively correlated with the humus balance results. Thus districts with a high share (35%) of these crops like the district Uelzen had a lower humus balance output than most other districts. Also the three times lower ratio of livestock to agricultural land in the eastern federal states compared to the western is expressed in lower balances.

Combining the calculations of straw occurrence, the demand by animal husbandry and the restrictions by humus balance led to the individual straw potential for every district. The study indicated a large regional difference in the share of straw that can be recovered from the fields without endangering the long-term soil fertility. The amount of cereal straw per district compiled according to the VDLUFA lower values / Cross Compliance regulations makes a total value of 13 million tons fm. Regarding the mean caloric value of 14.3 MJ/kg cereal straw fm, an energy potential of 186 PJ is resulting. In two districts negative balances were found and in 13% (52 from 412) of the entities no straw potential was obtained. The potential according to the VDLUFA higher values is in total 10 million tons fm, which represents a caloric value of 143 PJ. The number of districts with negative humus balances is 31 and districts without any potential are 20% of the total number (81 of 412).

Considering the HE-method the straw potential of 8 million tons fm was derived. This amount represents 114 PJ. The number of districts with negative humus balances is 57 and districts without any potential are 26% of the total number (109 of 412).

The spatial distribution shows favorable sites for straw based facilities. Nevertheless sensitivity analysis showed the massive impact of the harvest index of cereal crops and rapeseed. This effect was even higher in regions with a low share of livestock farming. Before selling their straw, farmers are advised to calculate humus balances at field scale. To meet two additional sustainability criteria’s erosion issues and nutrient losses through straw removal should be considered as well. Besides the determination of straw recovery costs showed a significant influence of current fertilizer prices. Approaches from the literature to delineate the monetary value of soil organic matter are also discussed within the project.

Altogether, an amount of 8-13 million tons straw fresh matter is available for recovery according to the HE- and VDLUFA models. This potential accounts for 27-43% of the total straw occurrence in the country. The gap between the reported results and current publications on carbon losses from croplands points out the research needs on a long term scale concerning the balance tools as well as the reproduction behavior of straw. Short term improvements are only expected in updating the input parameters. The most promising parameter therefore is a site adjusted grain-to-straw ratio for cereals crops and rapeseed. More detailed description of the methods, results and references are published elsewhere [3,4] or can be obtained through the author. The study was kindly financed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.


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