Straw potential for non-agricultural purposes in Lublin province

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Abstract

The use of renewable energy sources with application of innovative technologies for that purpose is one of the elements of the bioeconomy, and constitutes one of the smart specializations of the Lublin region. The growing demand for energy will force increasing the share of renewable energy in the total energy production. The paper presents theoretical and technical potential of straw, which can be used for non-agricultural purposes, including energy production. The estimation of this potential takes into account utilization of straw for agricultural purposes in the first place, indicating only its surplus to be used for other purposes. The analysis was carried out for all NUTS-5 of the Lublin province.

Key words: bioeconomy; straw; theoretical-, technical-, economic- potential

Introduction

According to 'Bioeconomy strategy for Europe' a bioeconomy is a key element for smart and green growth (EC, 2012). In Poland, a unitary and comprehensive bioeconomy strategy for all involved economic sectors is still in the making. Some of the elements of bioeconomy were implemented in the Strategy for the Development of the Country which defines developmental goals for Poland up to 2020. The other national strategies which contain bioeconomy issues are Strategy for Innovation and Efficiency of the Economy, Strategy of Energy Safety and Environment and Strategy for Sustainable Development of Agriculture, Rural Areas and Fisheries.

The European Commission emphasizes the need for each Member State to take effective and targeted action at union and global level responding to new global challenges: ensure the food security, deal with the sustainable management of natural resources, reduce nonrenewable resource dependence and mitigate climate change (Chyłek et al., 2017).

Sustainable economic development of each country needs to be uninterruptedly supplied by energy. Polish agriculture holds great potential in that field, but needs financial support and practical use of the approaches developed by scientists in the local economy (Babuchowska and Marks Bielska, 2016). The agricultural character of the Lubelskie region, which is the main area of interest, makes it a natural arena for the development of biogas plants – the energy supply. The Lubelskie region is one of the 16 provinces (voivodeships), NUTS-2 territorial units in Poland. It is located in the eastern part of Poland.

In 2014, the Marshal's Office in Lublin published Regional Innovation Strategy for the Lublin province by 2020, in which the bioeconomy was indicated as one of the areas of intelligent development of the voivodeship. The strategy also describes the emerging specialization which is low-carbon energy. Both these areas are interrelated and their development may contribute to the development of the region, both in social and economic terms.

Biogas production from biomass may be the key factor for Lublin Province. Countries with sufficient biomass endowment and well-developed primary sectors have certainly many opportunities to develop downstream value chains. The use of the existing indicators for broad analysis of individual Member States has to be accompanied by more in-depth investigation at

sector level and including the breakdown of information at regional (NUTS-2) level (e.g. Lublin Province) (Ronzon et al., 2017). Better use of biomass coming from the primary production sectors can create economic opportunities, social benefits, and environmental improvements and avoid waste. On the other hand, implementation of the EU Bioeconomy strategy requires governance and political decisions at regional, national, European and global level to ensure a sustainable approach with fewer trade-off situations and better exploitation of synergies. In this context, investment in research and innovation plays a key role. (EC, 2015).

Straw constitutes the most accessible source of biomass from agricultural production which can be used for other, non-agricultural purposes. After considering reusing part of these resources in agriculture, the surplus may be directed to „green energy" production or used as material for production of bio-products (Rozakis 2013) as part of the new strategies for supporting bioeconomy development.

The aim of this work was modelling of the theoretical and technical potential of straw, which can be utilized for the non-agricultural purposes.

Materials and Methodology

Total straw resources (theoretical potential) can be easily estimated based on the statistical data of the Central Statistical Office (CSO, 2018) on cereal production and the knowledge of primary and side yield proportion. The technical potential of straw available for energy purposes is, however, much lower due to the need to use part of the straw resources for agricultural production. The main purposes of using straw in agriculture are: straw incorporation by ploughing, in order to increase the reproduction of organic matter in soil and its nutritional content, as well as direct use for bedding and feed for animals (Harasim 2011, Pudełko 2013, Syp et al., 2013). The extent to which straw may be reused in agriculture depends largely on production systems in particular regions. Due to the need for sustainable farming, however, modelling the potential of agricultural waste from crop production should take into account full compensation of agricultural demand for straw (Jarosz et al., 2014, Jędrejek et al., 2017, Kuś et al. 2006). On the other hand, directing the straw surplus to chemical, food or construction industry may constitute a competitive objective for energy purposes (Kuś 2012). Therefore, the final destination of straw surplus should be decided based on both economic, as well as ecological reasons and support for innovative technologies (Zaliwski et al., 2013).

Information on agricultural production in lubelskie voivodeship, which are the basis for estimating straw resources, were obtained from CSO. It includes mainly data on cultivation of cereal crops (wheat, barley, rye, triticale, oat, and mixed cereals), oilseeds (rape and turnip rape) and maize for grain. In this study data from the Statistical Yearbooks of Agriculture, National Agricultural Census of 2010 and the CSO Local Data Bank were used. The methodology used for estimating straw resources obtained as a side yield was developed in the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB).

For each local district (gmina) the theoretical potential of straw was estimated according to the following equation:

$$Straw\ yield = \sum^{n} (sown\ area_n * grain\_yield_n * ratio\_straw/grain\_n)$$

Where n stands for the given crop (wheat, barley, triticale, rye, oat, mixed cereals, rape, maize)

The analyses were carried out at a local district level in order to present the regional differences within the voivodeship. The results were updated based on data on agricultural production trends from the years 1999-2015. It is generally assumed that straw yield is approximately similar to the grain yield. In this study the following crop yields and coefficients have been adopted (Table 1):

Table 1. Crop-specific coefficients and yield size [Harasim 2011, Pudełko 2013]

Crop	Ratio straw/grain	Grain yield [t/ha]
Wheat	0.9	3.46
Barley	0.8	3.07
Rye	1.1	2.37
Triticale	1.0	2.90
Oat	1.1	2.46
Mixed cereals	0.9	2.77
Rape and turnip rape	1.0	2.48
Maize for grain	1.0	5.30

The technical potential of straw was modelled based on methodology developed in the frame of BioBoost (2013) project. The resources were assessed by subtraction of the amount of straw necessary for animal bedding and feeding in addition to the part of straw that is needed for incorporation into the soil. Straw that is needed for soil protection was calculated at minimum of 30% for technical potential in each region (NUTS-5).

In the first step the amount of straw, which can be used for animal feeding and bedding, was calculated. In the case of a higher demand for straw for animals than the size of the theoretical potential of straw, then the assigned value was set at zero for the technical potential. No compensation of straw between regions was modelled due to economic inefficiency of such activities, which is confirmed by practice. In practice, this situation applies only to a few municipalities. In most NUTS-5, after the allocation of straw for animal production, large quantities of straw are still available. In this case, it was assumed that at least 30% of its resources should be used for soil conservation.In modelling the use of straw as a fertilizer, the following rules were adopted:

- In case of oilseed rape and turnip rape 100% of straw is used as a fertiliser because of its low suitability for combustion as it is high in ash and N-compounds. It is very brittle and baling is associated with high losses. Moreover, within the other types of straw this one is the least suitable for livestock bedding. For these reasons, it was assumed that the most appropriate form of its use is incorporation into soil. The properties of straw, which also create their fertilisation quality, include no risk of fungal diseases transmission (not found on rape) and this type of straw when ploughed in the soil decomposes faster than cereal straw and contains more nitrogen (no need for additional fertilisation).

- The technical potential of corn (maize) straw grown for grain is calculated as 50% of the theoretical capacity, assuming the validity of ploughing at least half of its yield. This is because of the field demand for soil organic matter after this type of crop production and the common practice during the harvest, where the plant is cut in half of its length.
- Modelling the technical potential of other cereals was done by following scenario assuming the use of straw for soil conservation. In the algorithm, it was assumed that the first kind of straw which could be used is obtained from the crops defined as "other cereals" (oat, rye, triticale, mixed crops).

Modelling of the technical potential of straw used in horticulture, food processing, construction, etc. is not included. The alternative use of straw is dependent on economic conditions. In some cases, instead of the straw, interchangeable materials can be used (saw dust, wood chips, plastic, etc.). Therefore, the competitiveness of the straw for energy purposes with other uses outside agriculture should be estimated using calculations of the economic potential.

Results

Sown cereal area in lubelskie voivodeship

Spatial distribution of sown cereal area in NUTS5 level of lubelskie voivodeship is shown in Figure 1. The largest total sown areas are located in the north and south-east, while the smallest sown areas can be found to the west and south-east. The map presents absolute sown areas which leads to proportionally higher values in larger gminas. When analysing the total sown area a decreasing trend it can be observed in the recent years. There are also considerable differences between individual years studied. The largest sown area can be observed in the years 2008-2009, ca. 950 thous. ha. It has recently decreased to ca. 800 thous. ha (CSO Local Data Bank).

The decreasing sown area is to some extent compensated for by the growing crop yields. In the last two decades the average yield for the voivodeship has been regularly increasing from 2.5 to 3.5 t/ha. Despite the steady growth it is relatively small in comparison to other voivodeships – mainly in the north of Poland, where the average cereal yields range from 5 to 6 t/ha, and for wheat specifically even 1 t/ha higher (CSO Local Data Bank).

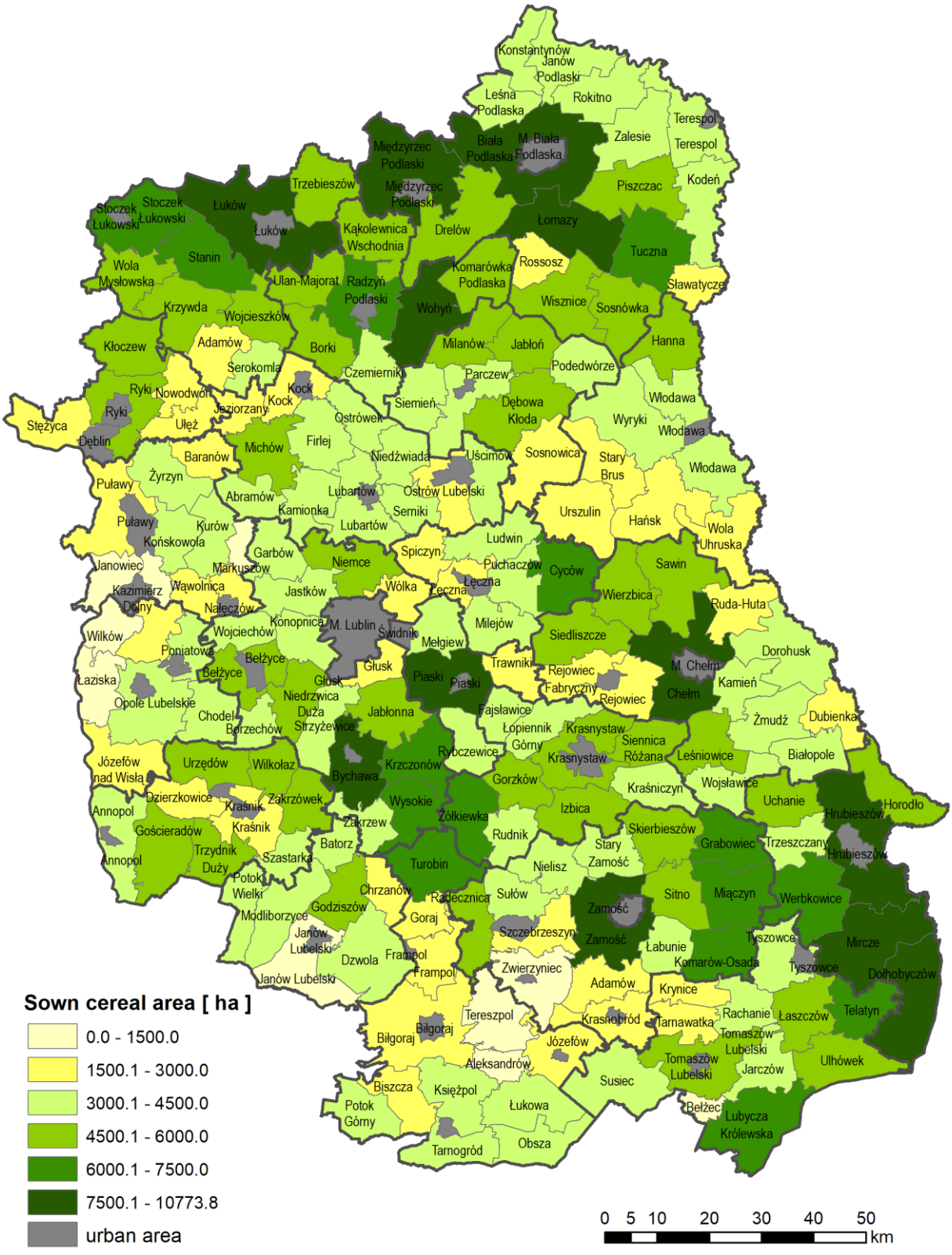

Figure 1. Sown cereal area in lubelskie voivodeship (Source: own study based on CSO, 2010)

Theoretical and technical potential of straw

The total straw production, which is equal to the theoretical potential was assessed as 9333 thous. tonnes. The map of its spatial distribution in the regions is presented in Figure 2. Spatial distribution of the total straw production is similar to the distribution of cereals, though differences may result from a different crop structure. These differences are observed between the northern regions of the voivodeship (cultivation mainly of maize and mixtures) and central regions (wheat and rapeseed) The highest production can be observed in the north and south-east of the voivodeship. Is has to be noted that straw constitutes an important resource in agriculture. When balancing the revenues and expenditures, straw production (yield) is counted as a revenue and expenditures include: feed, bedding (Figure 3) and incorporation in soil (ploughing-in) for fertilizing purposes. The highest rate of straw used for animal production is recorded in the north of lubelskie voivodeship. The rest called a surplus or side yield may be used for alternative purposes, including energy production.

It is difficult to determine the straw balance at national or voivodeship scale accurately, due to regionalisation and spatial variability of both production and demand for straw. Furthermore, the changes in agricultural production, which can be observed in the decreasing numbers of livestock, change in farming systems (loose housing with little or no bedding) or animal-free farming cause a decreasing demand for straw. Intensive agriculture often makes use of growth regulators which reduce the length of straw and influence its yield, compensated by the greater thickness of blades.

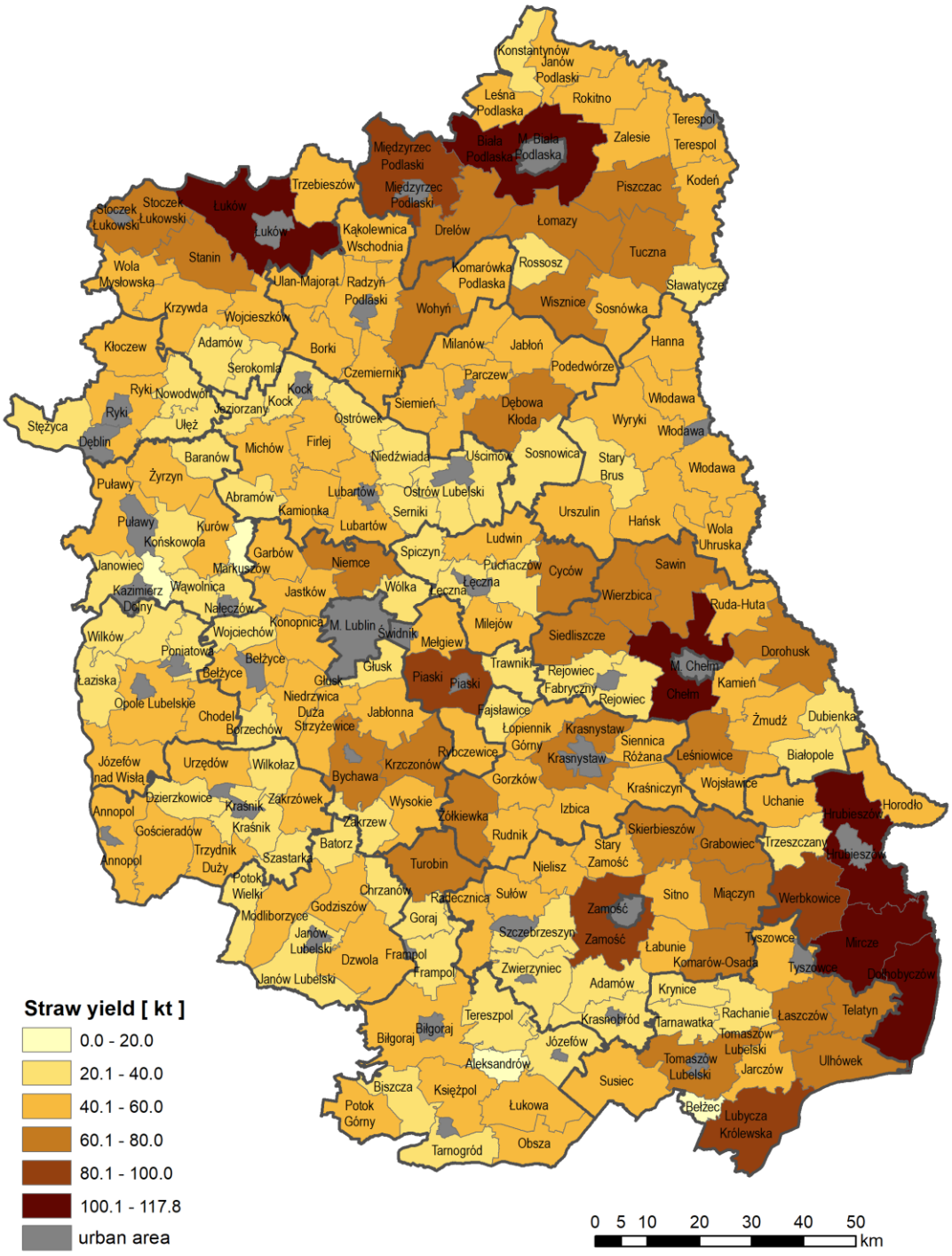

Figure 2. Total straw yield from wheat, barley, rye, oat, mixed cereals, rape, turnip rape and maize for grain – in lubelskie voivodeship (CSO, National Agricultural Census of 2010; Source: own study)

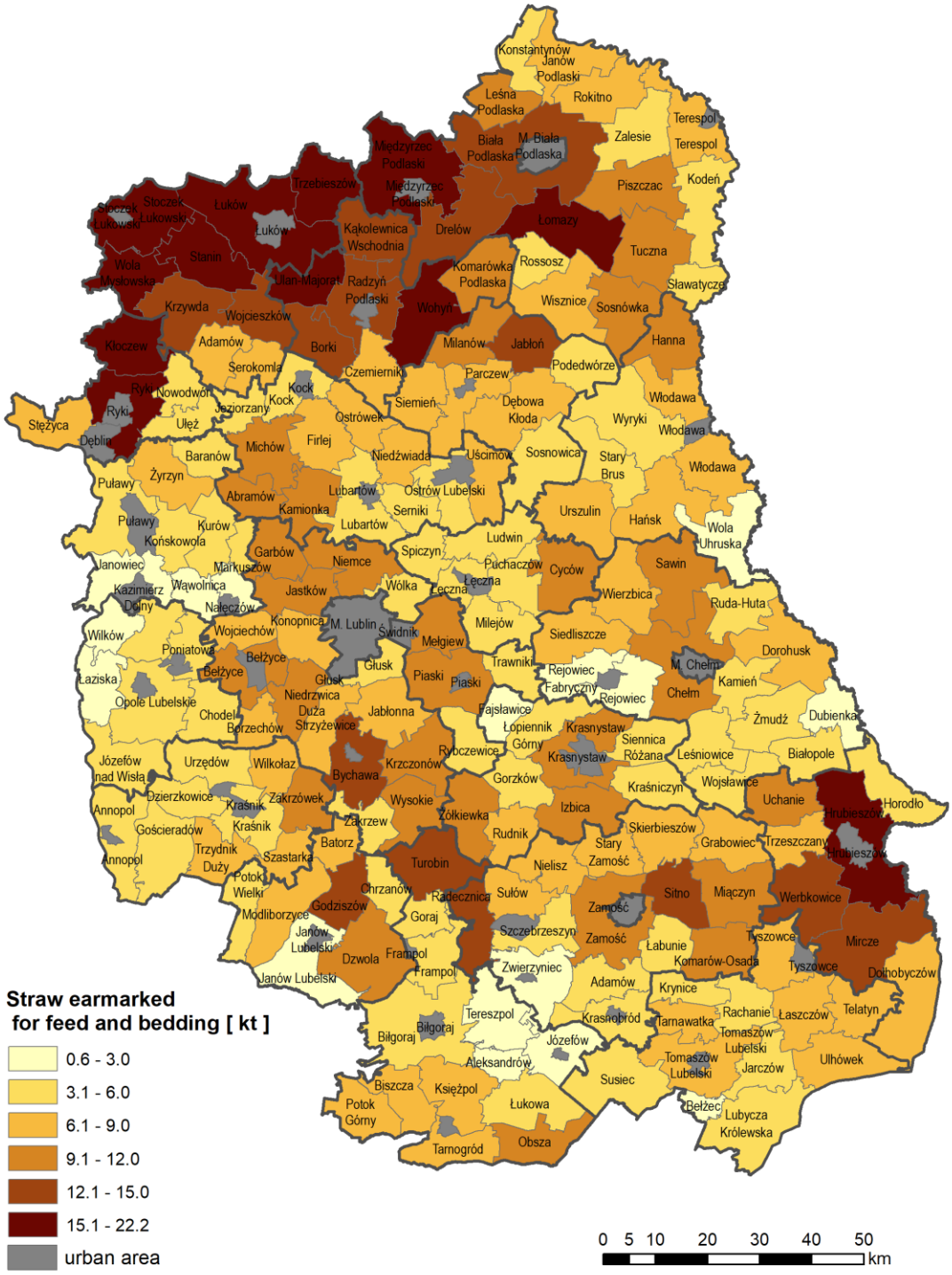

Figure 3. Straw for animal production purposes in lubelskie voivodeship, according to National Agricultural Census of 2010 (Source: own study)

Calculations allowed to estimate the side yield potential of straw in lubelskie voivodeship at 660 thous. tonnes. Spatial distribution of the straw surplus in the local districts of lubelskie voivodeship is presented in Figure 4

The differences between grain yield in subsequent years were mainly caused by meteorological conditions and may exceed 20-30% in the years affected by drought. Therefore, when estimating the side yield potential of straw, the possibility of such differences needs to be taken into account. It may be assumed that not more than 660 thous. tonnes of straw should be utilized for non-agricultural purposes. However, production plants with greater demand for straw may lead to increased competition for straw resources in this voivodeship and activities aiming at obtaining straw even from small agricultural farms with extensive agricultural production.

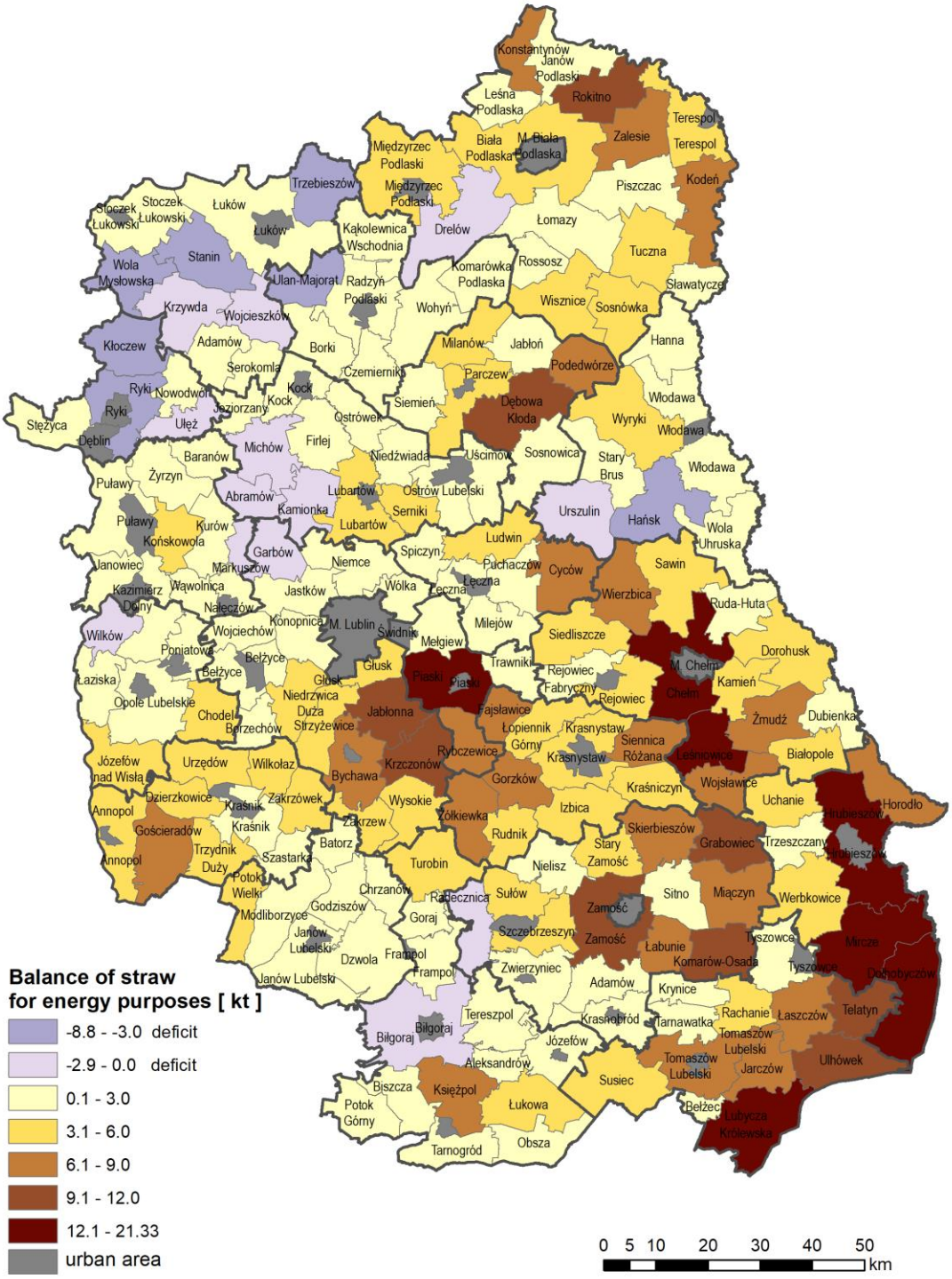

Figure 4. Technical potential of straw for non-agricultural purposes (Source: own study)

Summary and conclusions

Management of straw resources is a crucial element of agricultural practices. Its rational use may contribute to soil improvement (carbon sequestration, providing nutritional content, protection against soil erosion) which directly influences the yield obtained. Straw is also an important resource in animal production, which should be a priority purpose in straw management in view of the projections of world population growth.

Bioeconomy is the key intelligent specialisation of lubelskie voivodeship which covers various kinds of economic activity based on biotechnology, especially plant and animal production, feed production and agri-food processing, and renewable Energy sources (biorefineries, biofuel) (RIS, Lubelskie). Due to the above, rational and innovative management of straw should be a challenge for all levels of government and entrepreneurs.

The use of straw for non-agricultural purposes, including energy purposes, may lead to depletion of organic carbon in soil in the long run, and in some regions even contribute to increased soil erosion. There are agricultural farms which use the total amount of straw produced for incorporation in soil to improve soil fertility, water management and protect soil against erosion.

Straw is or will be a valuable resource for a variety of industries. At the moment its use in energy production or chemical industry is not economically competitive in comparison to traditional fossil fuels. Conventional combustion energy purposes is the least efficient way to obtain electric energy and heat from straw. During combustion of straw ashes are produced, whilst chemical substances and dust are emitted to the atmosphere. Therefore, it is necessary to support the development of technologies used in the process and focus on projects that will bring the greatest benefits to the environment – measurable through emission reductions, improvement of soil conditions and productivity or arable land.

Due to the fact, that straw constitutes the greatest biomass potential in lubelskie voivodeship – a strategic programme should be developed for its utilization, directing the possibilities of financing innovative technologies for development of bioeconomy in this region.

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