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USAGE AND SUPPORT OF GEOINFORMATION TECHNOLOGIES IN ANALYSING THE POTENTIAL OF COMPOSTABLE BIOMASS IN THE CZECH REPUBLIC

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Abstract

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In the current society there is more and more effort to introduce, to make use of, and also to develop different information systems (IS). Nowadays it is already impossible to work without support of these systems for most institution of administration, private companies and single businessmen – if they want to be successful in their activities. So implementing and using of this IS become matter of fact. Waste management is one of sections, where these technologies are starting to influence as well. There is a development and implementation of the first IS in the level of single waste generators, regions and national administration as well. It happens to gradual data standardization presently because of unification and compatibility of single systems at all levels. The same situation is in section of Geographic information systems (GIS) as a one of parts of IS-subgroup. First nationwide projects, which can be also used in waste management, are starting to rise in GIS. Also this work is example of connection of GIS with one of waste management section – composting – and it shows possible practical usage on concrete examples.

At present, information systems (IS) affect a whole range of scientific disciplines that enable working with large amounts of data and consequently conducting their analyses. The IS support leads to the acquisition of outputs with considerably higher information capability. This also concerns the specific subgroups of geographic information systems – GIS as well as the associated technologies (Longley, 2001). These technologies can contribute to solving of the impact of human activities on the environment (Tuček, 1998).

The principal objective of this endeavour is to create a database for geographic information project in the sphere of waste management that will be entirely grounded on a GIS application. The field selected for the creation of a database of this geoinformation system are biologically degradable wastes with a focus on composting in the CR, namely on the potential of the use of selected biomass types suitable for composting. The produced database allows for analysing biomass potential based on a link to other geographic entities (districts, regions, etc.) and their attributes by way of the GIS software.

This project attempts to address and enables further GIS applications in one of the waste management fields, namely biomass management, and, more specifically, in biomass composting. Several simplified IS currently exist for this sphere that serve prevailingly information purposes, such as location of the specific composting facilities or which basic types of biomass they process. The form in which these data are stored is usually not suitable for any further work (modifications, conversion into other formats, updates, etc.).

The deficiency was eliminated by this project, which also addresses the issue of how GIS can be of assistance in the field of waste management by way of specific actual data.

MATERIAL AND METHODS

It generally applies that the creation of any (not only geographic) information system requires electronic data, which are used for further processing work. This project uses data such as the information on composting facilities (geographic, attributive – concrete selected information such as structural capacity, amount of compost produced annually, technology, etc.), territorial units (regions, districts) and other types of information.

The actual analysis of biomass management in the CR is based on several sources. One source of data on composting facilities was Agrointeg, s.r.o., which has its seat on the premises of Mendel University in Brno. These data were compared and supplemented with the information from the database of Zemědělská a ekologická regionální agentura, o. s. (ZERA, Agricultural and Environmental Regional Agency) residing in Náměšť nad Oslavou, data acquired from the website of T. G. Masaryk Water Research Institute (VUV) and, last but not least, information directly from the operators of the selected facilities. Data on territorial units and the percentage shares of plots of selected crops were taken from the database of the Czech Statistical Office (CSO).

The data were subsequently converted for compatibility with ArcView GIS 9.1, a product of ESRI from the USA, applied for the project elaboration.

The map groundworks for this project (ArcČR 500, version 2.0a) were provided by ARCDATA Praha, s. r. o. They are constituted by a database of "shapefiles" that form the individual layers of objects and raster files (e.g. grids representing the terrain model, colour relief, etc.). Layers (shapefiles) can be:

- *Points* (municipality location, location designation of a composting facility, etc.).
- *Lines* (roads, river network, geographic network, etc.).
- *Areas – polygons* (districts, regions, forest plots, etc.).

RESULTS AND DISCUSSION

The objective is to develop a geographic information system addressing the issue of composting in the CR that will be capable of displaying necessary information concerning the specific establishments and conducting analyses of the potential of selected biomass types suitable for composting based on the data included in attribute tables for the individual (geo-) objects.

This task consists of several interrelated parts. The following steps, discussed in a greater detail below, were taken in the course of creating this project:

1. Creation of attribute tables on the basis of available data (on composting facilities, percentage shares of crops in a specific area, etc.) for the concrete layers (composting facilities, individual biomass sources, etc.).
2. Processing of these data and production of thematic maps of the individual biomass sources in the CR.
3. Inclusion of supplementary information (that are not suitable for inclusion in an attribute table) via a hyperlink (hot link).
4. Determination of composting specifics (C:N, balance equation) in selected types of biomass (straw, slurry).
5. The actual analysis of the potential of selected biomass types by way of forming buffer (absorption) zones around the composting facilities.
6. Evaluation and conclusions.

After the creation of the elementary map groundwork depicting the location of the composting facilities, we need to enter the data on the objects since without them the map groundwork would be merely a passive representation of the distribution of the facilities and would not allow for any further processing.

This can be carried out in several ways. The principal one tends to be the editing of *attributes* of the geo-objects and their entry into an attribute table compatible with the specific software. Another alternative for entering data is an interactive connection by the "*hyperlink*" function (Booth and Mitchell, 2001).

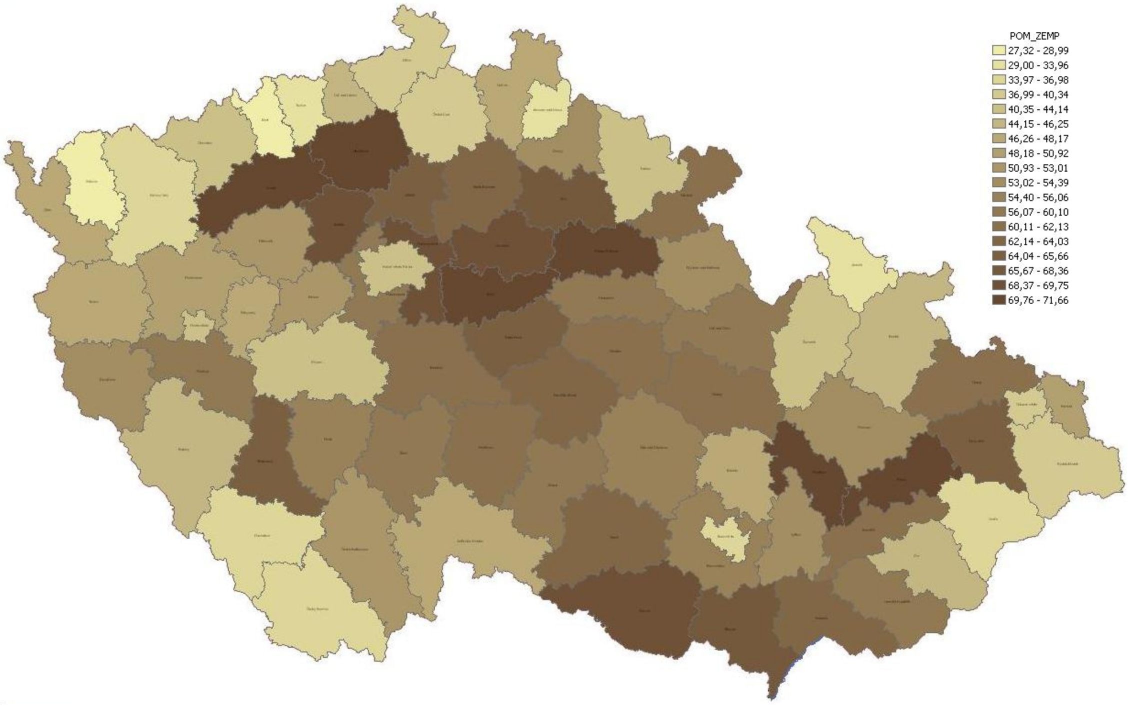
In the process of editing layers in ArcMap, an attribute table (*.dbf) is automatically generated for each layer. Every object is represented by one line into which data can be entered after the editing is finished (e. g. in Microsoft Excel).

The data, which concurrently describe the individual facilities and enable further analysis and processing (annual capacity of the composting plant, quantity of the actually processed biomass per year, standard of mechanization equipment of the composting plant, etc.) were gradually entered into the attribute tables. The data (chiefly from the CSO database) on selected crops in the districts of the CR were processed next (average yields, percentage shares of the plots used for their cultivation, etc.). These data were then entered into another attribute table.

The data on the share of farm and non-agricultural land in every district of the CR were processed in a similar fashion. With regard to farmland, the classification data of land use in the individual districts were further processed. Specifically, the land was classified into arable land, gardens, orchards and permanent grassland. In non-agricultural land, the processed data concerned the proportions of forest stands in all districts. A map of mean production of bio-degradable municipal waste (BMW) for every district was created, too.

These data were used for the creation of a map of *percentage share of farm land in the CR by district* in ArcMap (see Fig. 1). Other maps were designed in a similar fashion according to the aforementioned more refined classification (gardens, orchards, etc.).

During the practical application of information systems, users frequently require information types



1: *Percentage shares of farmland plots in the CR by districts*

(e.g. operational information, object photographs, etc.) that cannot be entered and retroactively displayed by way of an attribute table. ArcView therefore makes use of the specially designed *Hyperlink* tool. It was deemed suitable that the project would include a *hyperlink* connection with the following information:

- Address of the composting plant with an overview of the most commonly collected biomass for the filling (*in Microsoft Excel format*).
- Web link (if it exists) to the composting plant operator.
- Photos of individual composting operations (if available).

The project includes several composting plants, which focus on the composting of residual biomass (straw, slurry), which has certain specifics. These materials are characterized by a high (straw) or low (slurry) C:N ratio. This is why the material balance has to be determined for these composting plants. Before the addition of these materials to the composting foundation filling, their mass ratio must be established to ensure that the resulting C:N ratio is favourable (ca. 30:1) (Zemánek, 2001).

The ratio was determined by dint of alligation equation. After the adjustment according to the moisture conditions of both materials, the ratio between straw and slurry equals *0.575:1.* This ratio assures (at observing other conditions – turning, etc.) that the composting of these two raw materials proceeds correctly.

A similar procedure was used to determine the ratio between dendromass and slurry. Namely, this ratio *(dendromass : slurry)* amounts to *1.14:1*. The obtained weight ratios between the specific materials were applied in calculations for the compost filling foundation.

Based on the available data, the mean production of the selected materials suitable for composting (grass from the maintenance of permanent grasslands, straw, slurry, waste wood, BMW, etc.) was calculated. Next, it was necessary to determine the overall yield of all aforementioned raw materials for composting facilities in the selected territorial units (districts). Since the percentage shares and mean yields of the raw materials are known, their total yield per unit of area can be calculated from the following relation (1):

$$V_c = \sum_{i=1}^{n} v_i \times p_i \ [\mathrm{t.ha^{-1}}], \qquad (1)$$

where:

V_c – total yield [$\mathrm{t.ha^{-1}}$],

v_i – yield of the i-th raw material for the composting plant [$\mathrm{t.ha^{-1}}$],

p_i – acreage of the i-th raw material [-] in the specific territory (district).

Following the determination of the quantity of material sources within individual territories (this project works with districts), the surface area from which the capacity of a composting plant can be covered by these biomass sources (Zemánek, 2001) had to be established. It is the smallest possible area of interest (in professional literature it is sometimes referred to as an *absorption area*) of the composting facility that can satisfy the required amount. It can be thus reasoned that the smaller the area, the better cost-efficiency of operation that can be achieved.

In the ArcView, this situation can be addressed by creating "*buffers*" around the composting plants. It is a graphical representation of the smallest possible area containing the required quantity of raw materials for composting plants. The design of these buffers is grounded on the following relation (2):

$$P_{OZ} = \frac{k_p}{\sum_{i=1}^{n} v_i \times p_i} = \frac{k_p}{V_c} \text{ [ha]}, \qquad (2)$$

where:

P_{OZ} – buffer size *(absorption area)* [ha],

k_p – annual operational capacity of the composting plant [t].

The remaining coefficients are identical as in the relation (1).

Individual project outputs

Representation of a composting plant buffer with the use of selected biomass sources

Specifically in this case, the graphical depiction of composting plant buffers (absorption areas) of all of these biomass sources from the surrounding area will occur:

- Grass from the maintenance of gardens
- Waste wood from fruit plantations
- Grass from the maintenance of permanent grasslands
- Waste from vegetable gardening
- Compostable BMW
- Straw (10 % share from the total capacity of a composting plant – adjustment of the C:N ratio).

As it is apparent from Fig. 2, an area becomes delimited that contains exactly such a quantity of materials from the above-mentioned sources that would ensure maximum (100 %) use of the capacity of a composting facility.

The following Tab. I shows the comparison of selected parameters of two specific compost plants. These and other data are processed in a form of attribute tables for all composting plants in project. BZ means buffer zone and SBZ means surface of buffer zone.

Actual quantity of the processed matter

The preceding case addresses the situation when the annual capacity of a composting plant becomes fully utilised. It however often occurs in practice that this capacity is not entirely used up due to various reasons: Lack of suppliers with raw materials, high competition, not yet well-established facility, etc.

Regarding this fact, attributes were created expressing the surface area or, more precisely, the buffer radius of the composting plants with specified actual amount of processed biomass per year. This gave rise to the possibility of a new graphical output in the project – namely, a depiction contrasting the composting buffers at full capacity and during the actual utilisation stated by the operator.

Display of the buffer layer upon a change of raw materials

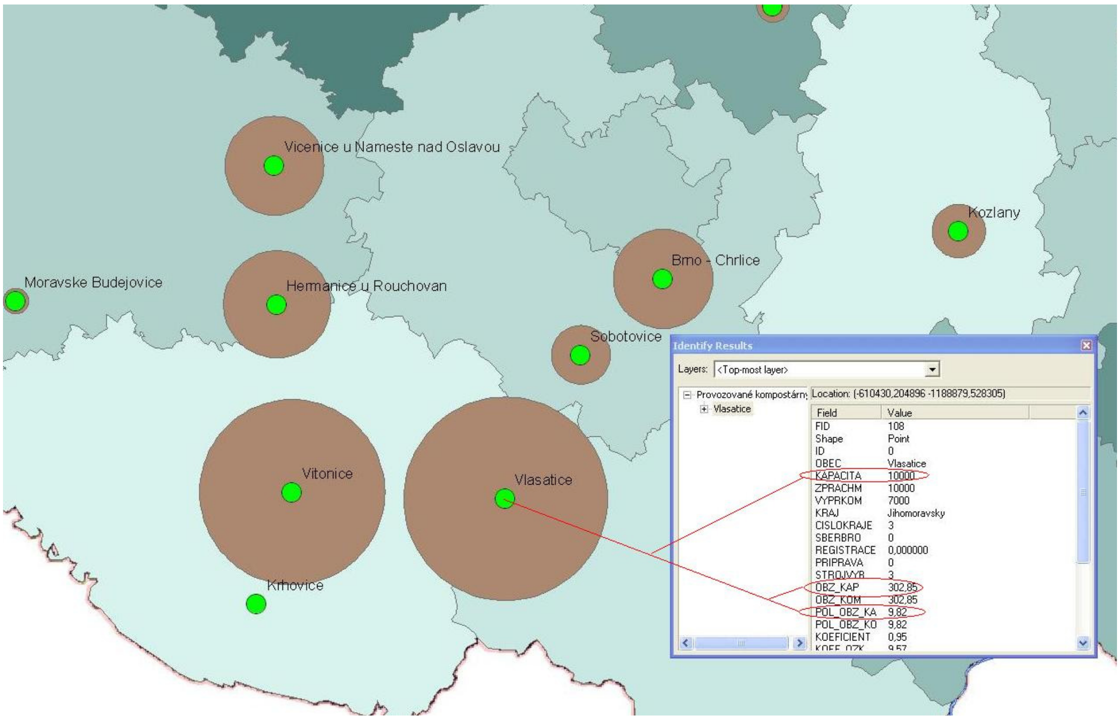
It often happens that users of this project may face a following situation. Either they are offered a supply of raw materials for the composting facility that were not originally planned or, conversely, a raw material is no longer available – for example, they do not succeed in concluding a contract on the offtake of raw materials for the composting plant which were originally planned for its operation. As a result, the *total yield (V_c)* value in the relation [2] would change.

In this project, it is possible to compare the original situation with the new one in a well-arranged graphical representation. The users would thus acquire the overview of absorption area increase or decrease and are immediately informed about the areas (expressed in the form of municipal cadastral areas) that were added to their absorption area or, conversely, (upon the acquisition of a new source of raw materials) about the reduction in the size of the buffer and the areas in which the biomass would no longer be collected if they wish to fulfil the annual capacity of the composting plant.

The case when an owner of a composting facility acquires a new source of raw materials is shown in Fig. 3 depicting a reduction in the buffer size after the acquisition of a new source. The larger buffer (brown colour) represents the situation described in

I: *Comparison of selected parameters of specific compost plants*

Composting plant	Vodňany	Chomutov
Region (administrative unit)	**Jihočeský kraj**	**Ústecký kraj**
Maximum capacity (t)	25 000	9 000
Actual quantity of the processed matter (t)	10 000	5 200
Quantity of compost production (t)	8 000	3 000
SBZ for maximum capacity (km^2)	255,31	100,94
SBZ for act. quantity of proc. matter (km^2)	102,12	50,32
Radius of BZ for maximum capacity (km)	9,02	5,67
Radius of BZ for act. qnt. of proc. m. (km)	5,70	4,31

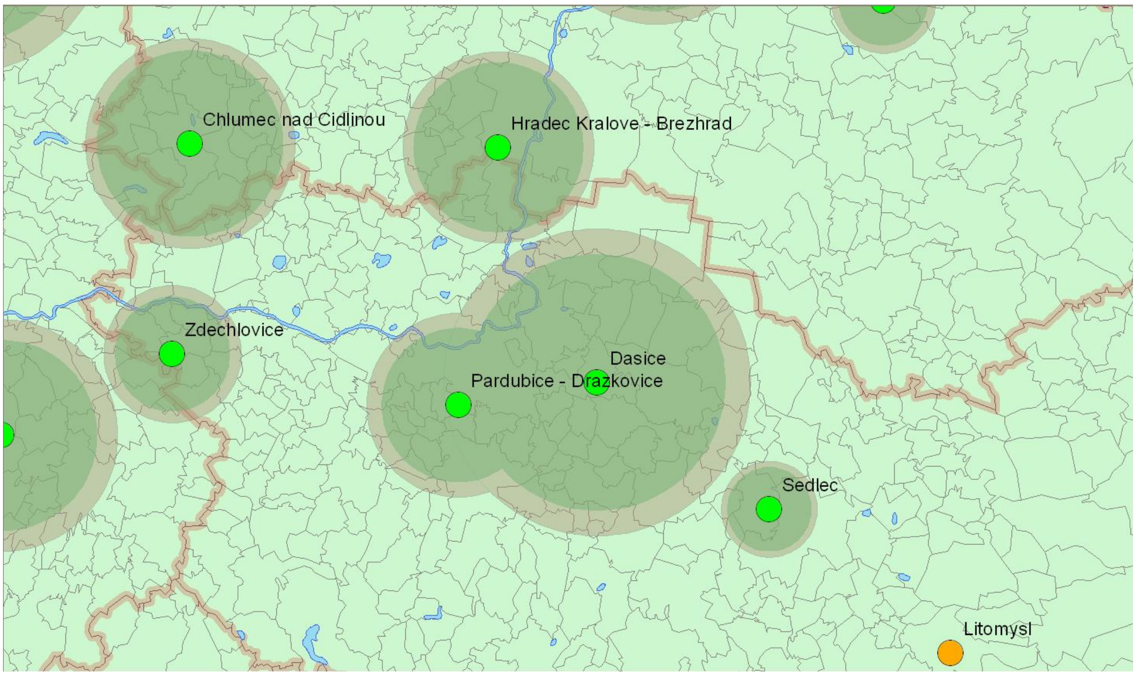


2: *Graphical representation of buffer zones around the composting facilities with the displayed attributes of concrete plants*

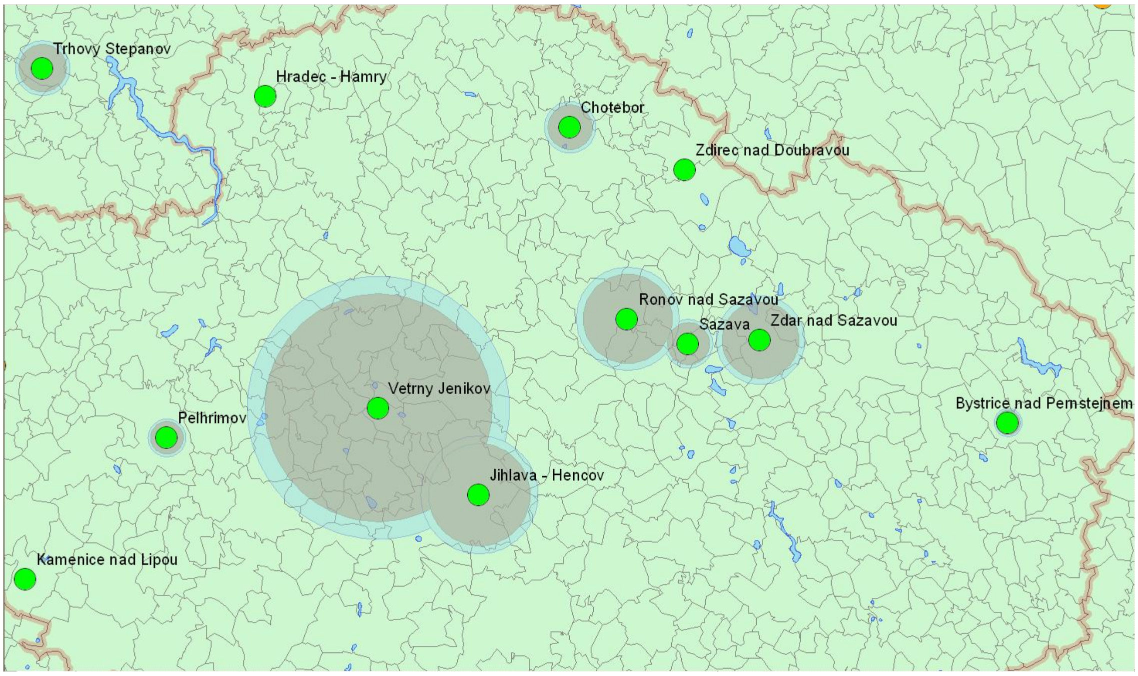
one part of the article *Actual quantity of the processed matter* using the above-mentioned raw materials. The smaller buffer shows the change in the absorption area, while there is still a possibility of processing dendromass from the environs.

Exploitation rate of available sources

In the previous cases, it was considered for the calculation of the size of specific buffers that 100 % of selected raw materials would be acquired within the area of interest. This is practically unachievable because certain losses always occur, such as when the owner of a composting plant does not have access to



3: *Reduction in the buffer zone size – the larger brown circle; acquisition of a new source (dendromass) for the composting facility from the environs – the smaller concentric circle*



4: *Change in the size of the original buffer zone (inner brown circle) to a larger one (blue concentric circle) at respecting the coefficient of losses*

or possibility to obtain all of the waste biomass occurring in the area of interest. Further losses may be incurred during material transport and handling, etc.

The determination of the actual buffer zone size of a concrete composting facility requires incorporation of relation (2) by the *loss coefficient* expressing the percentage value of total losses as follows:

$$P_{OZ} = (1 + \frac{z}{100}) \frac{k_p}{\sum_{i=1}^{n} v_i \times p_i} = (1 + \frac{z}{100}) \frac{k_p}{V_c} \text{ [ha]}, \qquad (3)$$

where:

z – coefficient of losses [%] *(caused by limited access to all raw materials within the area in question, and further by losses during transport, handling, etc. Its value varies in each facility and is determined by the operator).*

Figure 4 is a model situation showing the region for which a total profit stood at 75 % of the raw materials from the area's maximum amount and the *coefficient of losses* amounted to 25 % after the summation of all losses incurred due to transport and handling of the material and with the specification that access was not possible to all of the raw materials (competitors fight, inability to conclude agreements for access to certain raw materials, etc.).

Possible directions for utilisation of the project

One alternative employment of this project is its posting on internet in the form of a web application with several mutually independent sections. Access to the created database would be granted to all interested companies and individuals (engaged in the field of biomass management). The access would be guaranteed by means of an allocated user name and password selected by the user.

Users can access the database in which they are interested ranging from a concrete area – region, district or another specific area up to complete data from the whole territory of the Czech Republic.

Thus, individual users will have an overview about the locations in the region suitable for building new composting facilities (based on the plotted buffer zones) and about which locations are already engaged by competition, which would – from this perspective – render a potential business plan risky.

A *biomass stock marke*" appears to be another possible suitable section of this web application. Access to this section would be granted to all those users who either produce or further manage biomass (e.g. operators of composting facilities).

The graphical representation of the buffers based on the current data for a specific area would then indicate the operators of composting facilities who dispose of free capacity and its size at a given moment. A biomass producer would choose a specific plant (e.g. according to the transport distance, if more facilities with free capacity would be available in the environs) to which he would direct his material. A composting plant owner will therefore be able to use the capacity that he would have otherwise difficulties covering.

In composting facilities that do not fully utilise their total annual capacity, raising the quantity of composting commodities can present one alternative for increasing the use of their annual capacity. In the project, this situation would be manifested by a reduction in the buffer area size used for the collection of the composted material necessary for covering the full capacity of a composting plant. The operator can therefore compare which extra raw material (or several raw materials) would be economically most profitable and decide accordingly.

This database can also serve those public administration authorities, which co-decide in allocating subsidy classes in the field of biomass management at considering the risk rate of the management potential of this commodity in individual regions.

SUMMARY

The objective of the project that is discussed in this paper was the creation of a practically applicable GIS of biomass management in the Czech Republic with the use of commercially available geographical information systems (namely ArcView GIS 9.1).

Data necessary for the creation of the database were obtained from a number of sources (Agrointeg, s.r.o., ZERA, o.s., CSO data, etc.). Attribute tables were created based on the available data to be further processed in ArcView 9.1. This programme was used to produce graphical outputs from the database created in this manner of the representation of selected biomass types by districts in the territory of the CR. Supplementary information were then added to the composting facilities (addresses of the plants, web links, etc.) by way of connecting them to the project via the hyperlink function. In selected types of biomass (straw, slurry) the specifics for their composting (the C:N ratio by way of the balance equation) were defined. The following step consisted in conducting the actual analysis of the potential of selected biomass types taking the form of synoptic map outputs by forming buffers around the composting facilities in ArcView.

The result is a system that allows for modelling the size of the working areas of the composting facilities by pre-selected criteria. The user-entered parameters are used to display a new facility and the size of its operating area. The system further shows competitive areas of more facilities and it is capable of coming forth with a solution by modifying some of the parameters (e.g. by an adjustment of raw materials for the composting plant). The new and former situations are displayed in a lucid graphical form.

Some of the possibilities were assessed for employing such a project in practice and for its potential development in future. It follows out from the foregoing facts that several alternatives exist for the use of this project by individual users and firms doing business in biomass management or by state administration authorities concerned with this sphere.

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