METHODOLOGY FOR ASSESSMENT OF AREA AND PROPERTIES OF FARMLANDS SUITABLE FOR ESTABLISHMENT OF SHELTER BELTS

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Abstract. The aim of the study is to develop a methodology for assessment of the area and properties of buffer zones around drainage ditches and areas surrounding protective belts around natural streams, for transformation into "biomass factories". In Latvia and neighboring countries, these buffer zones have significant biofuel production, as well as climate change mitigation and nutrient retention potential. A GIS based algorithm using various data sources to obtain information about conditions and land use in buffer zones has been created. Spatial data about drainage diches and surrounding areas are obtained from the Latvian Rural Support Service, Corine land cover, State Forest Service and Latvian Geospatial Information Agency. In this study 15-meter buffers are defined for soil scarification, planting, tending, harvesting and biomass production for energy and other appliances. Using the methodology elaborated within this study, 706797 features of buffer polygons (buffer sides) were identified, each labelled with a unique number. Each polygon is labelled with a number that determines from which ditch line the buffer is derived. Total area of the generated buffers – 167532 ha. The data obtained can make a significant contribution to assessing the potential of buffer zones suitable for establishment of shelter belts.

Keywords: ditch, buffer zone, biomass, agricultural land.

Introduction

Climate policies, such as the Paris agreement will increase the demand for biomass for bio economy needs, including energy, industry and even agriculture sector. Implementation of these policies requires urgent actions already now to increase efficiency of utilization of land resources and to develop new pools of biomass. Increasing demand and prices of solid biofuel, risks associated with deliveries of imported energy carriers and climate change mitigation targets set by the Paris agreement [1] determine the necessity to utilize more actively alternative sources of energy, including the buffer zones by transforming them into "biofuel factories". The growing role of bio economy and biomass as a primary resource enhances creation of new and improvement of existing technologies necessary for the "biofuel factories".

The potential area of "biomass factories" in Latvia in cropland and grazing land is 50-100 kha. The climate change mitigation potential of the "buffer zones" is 0.75 mill. CO_2 eq. yr. The potential area of the "buffer zones" depends on the design of planting, which in its turn depends on the width of a belt necessary to ensure nutrient retention from farm fields and optimal conditions for mechanization of production.

SRF (short rotation forestry) and SRC (short rotation coppice) have already proved for their ability to reduce nutrients in run-off water – they retain 30-99% of nitrates and 20-100% of phosphorus from run-off and shallow groundwater [2]. According to studies in Denmark the yield of woody biomass in SRC established in riparian buffer zones without additional fertilizing equals to 9 $t \cdot ha^{-1} \cdot yr^{-1}$ and in SRF – 6 $t \cdot ha^{-1} \cdot yr^{-1}$ [3]. A LCA study in Sweden demonstrated potentially significant climate change mitigation contribution of willows in the riparian zones – 11.9 t CO_2 $eq \cdot ha^{-1} \cdot yr^{-1}$ compared to 14.8 t CO_2 $eq \cdot ha^{-1} \cdot yr^{-1}$ in fertilized SRC [4].

According to the national regulations in Latvia, the protection zones of drainage systems in agricultural land are 10 meters on both sides from the top edge of the drain side. In agricultural land green belt buffer zones management practice is recommended because of important water quality and habitat functions they are providing. Though nitrogen is an important nutrient for all organisms, excess nitrogen is a pollutant that causes eutrophication in surface water and contaminates groundwater [5]. Streams receive regular nitrogen inputs from upland sources such as fertilizers, animal waste, leaking wastewater systems, atmospheric deposition, and run-off from highways [6]. Riparian buffers reduce nitrogen outputs through plant uptake, microbial immobilization and denitrification, and soil storage [7]. The buffer zones are also considered as a productive site of biomass production that can contribute to climate change mitigation and substitution of fossil fuel.

Availability of high-resolution terrain data (LiDAR) and satellite data (Sentinel-2) provides new possibilities for innovations in management planning of the buffer zones, particularly identification of areas with exceeding moisture, the structure of run-off water streams, planning of harvesting and deliveries of biomass and monitoring of the growth conditions in the buffer zones [8; 9]. In other studies, conducted in Canada [10] and New Zealand, the shelterbelt analysis and carbon stock estimation have been performed using satellite imagery. In these studies, more attention is paid to determination of the area and tree species in the shelterbelts, as well as carbon stock estimates [11].

This study is contributing to indexing of growing conditions in the future "biofuel factories" and elaboration of typical "site types" and crop communities for these "site types". The buffers in further studies will be used for evaluation of plant communities suitable for different growth conditions in the drainage system buffer zones and areas surrounding protective belts of natural streams; socio-economic analysis of transformation of the buffer zones into "biomass factories". Remote sensing methods in combination with LPIS (Land parcel information system), Corine Land Cover and stand wise forest inventory are utilized for spatial data analysis. Parameters considered in the analysis are the soil type, moisture regime, management and land use.

Materials and methods

The first step is to prepare Latvian cadastral geographical information systems (GIS) data of ditches for further processing with the aims of selecting ditches that are located in agricultural lands and to prepare lines that can be used for generation of proper buffers for classification of growth conditions, using the following datasets:

- Database of Rural Support Service agricultural land database of Direct payments in 2019;
- Corine Land cover spatial dataset of 2018, agricultural areas found in Latvia;
- Soil data using historical soil database from agricultural lands;
- Drainage cadastre spatial dataset from Latvian Cadastre.

Further data processing using these input files was performed using the following workflow, which is performed as a batch process using QGIS software:

- selection of ditches that touch agricultural land;
- calculating and grouping lines by geographical azimuth;
- splitting lines into grids to create dissolved buffers split by grids for easier and faster algorithm processing;
- creating ditch riparian buffers using Voronoi polygons to build geometrically correct polygons without self-intersections, ditch direction with attribute information of ditch line azimuth (direction) and area information. We are creating two buffers – 4 m buffer which corresponds to supposed average width of the ditch, and 19 m buffer to build 15 m buffer around 4 m wide ditch (Fig 1);
- determination of the ditch bank side according to vector azimuth (Fig. 2).

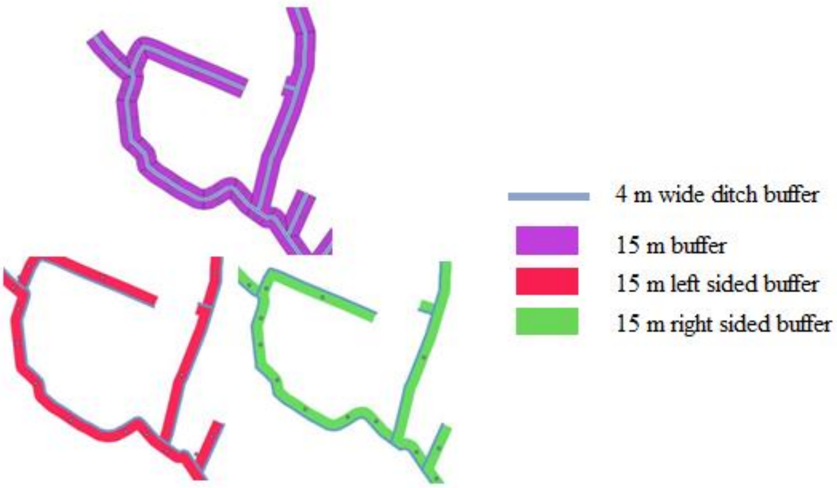

Fig. 1. **Example of ditch bank side determination using vector azimuth**

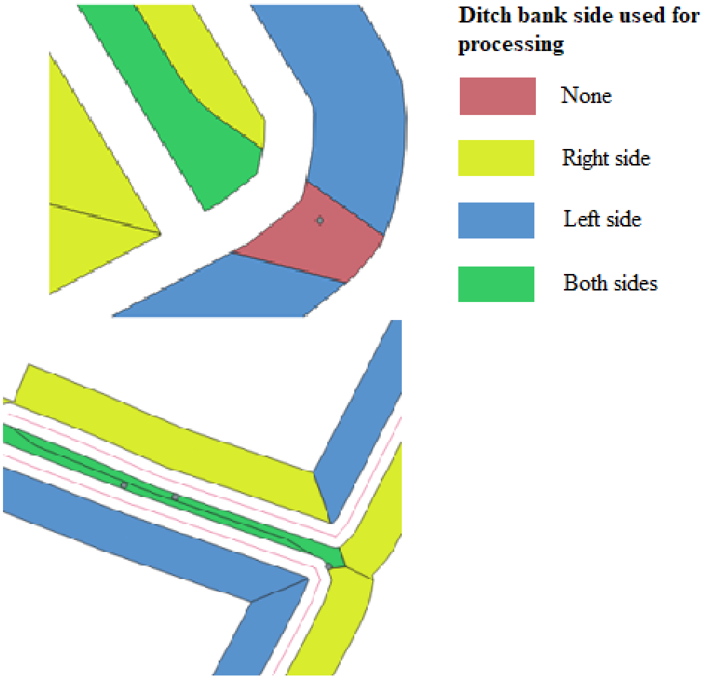

Fig. 2. **Ditch bank side classification**

The resulting point layer includes information about the ditch bank side. There are two types of exclusions: first – typological exclusion, and ditches are closer than 19 meters to each other. Therefore, they overlap and it impossible to determine one side. Second – no buffer information – the single sided buffers are generated from lines. If the point falls in the middle of the line ends there will be no side information.

To compare the Latvian soil classification system and the World Soil Reference (WRB) the scientific paper of Kārkliņš [12] was used. The comparison table was used to transform the historical dataset to the World Soil Reference. Texture composition also was simplified to 7 groups. The filter function and field calculator were used as before to create new groups. Soil texture groups are the primary criteria to classify the growth conditions. Peat soils are merged in a separate group of organic soils.

According to the State Forest register maintained by the State Forest Service there are 42.6 kha of forests in the buffer zones of drainage ditches. These areas are not considered as suitable for growing woody plants for biomass production.

Results and discussion

The inventory of drainage ditches in Latvia includes information on the drainage systems built so far, which are registered in the drainage inventory information system. The most important systems are water streams of national importance, the next level – shared artificial ditches or pipelines, which collect water from drainage networks. Information on drainage systems in farmlands is currently being reviewed and updated. Information on new or restored drainage systems might not be entered in the system.

The original dataset of the drainage system GIS layer was selected for generating of the buffer zones. The ditches fall both in forest and agricultural land, therefore, the first step was to select only ditches that are in agricultural lands. The total length of ditch vectors reduced from 73163 km to 57949 km.

The data set consisted of long ditch vectors with various forms. To generate buffers that can be analyzed the first step was to split vectors into segments and then group them by azimuth groups (Table 1). Although the total line length was diminished by selecting only agricultural lands, the total count of features in the dataset increased from 170955 to 357515.

Table 1

Azimuth range groups of ditch vector lines

Azimuth code	Azimuth range (degrees)	Line count
1	0 (360)-44 and 180-224	93959
2	45-89 and 225-269	95706
3	90-134 and 270-314	93605
4	135-179 and 315-359	95570

After clipping lines to divide them into grids the number of line features increased to 378840. The minimum value is 0 m, maximum length is 5362 m, mean value – 153 m, median value – 100 m. First quartile – 42 m, third quartile – 198 m.

In this study 15 m buffers are defined for soil scarification, planting, tending, harvesting and biomass production for energy and other appliances. The buffers will be used for evaluation of:

- plant communities suitable for different growth conditions in the drainage system buffer zones and areas surrounding protective belts of natural streams;
- conditions in the drainage system buffer zones and areas surrounding protective belts of natural streams;
- socio-economic analysis of transformation of the "buffer zones" into "biomass factories".

Using the methodology elaborated within the scope of the project, 706797 features of buffer polygons (buffer sides) were identified, each labeled with a unique identifier. Each polygon is labeled with a number that determines from which ditch line the buffer is derived. The total area of generated buffers – 167532 ha.

Land parcel information system (LPIS) of agricultural lands maintained by the Rural Support Service was used to determine the agricultural lands in buffer zones and to identify the potential economic impact of establishment of buffer zones in farmlands.

The total agricultural area under the potential buffer zones (112188 ha) was estimated by combination of Corine and LPIS data. There are 148714 buffer sides that do not contain any agricultural lands. 59% of the buffer sides' polygons are covered to 76-100% extent by farmland that contributes to 60% of the total area of buffer sides. 21% of the buffer polygons are not laying under agricultural land at all (Table 2).

Table 2

Agricultural land coverage in buffer polygons

Agricultural area that occupies single buffer polygon (%)	Number of polygons	Number of polygons (%)	Area (ha)	Buffer polygon area (%)
0	148714	21.0	55344	33.0
1-25	74284	10.5	1215	0.7
26-50	28081	4.0	2760	1.6
51-75	38495	5.4	6711	4.0
76-100	417186	59.0	101502	60.6
errors	37	0.0	-	-
total	706797	100.0	167532	100.0

The Law of the Republic of Latvia "About highways" defines the minimum road right of way (subdivision zone). Section 27.1 of the Law sets that a road subdivision zone shall be established for the construction, maintenance and protection of state, local government, and merchant roads.

For the largest state-importance roads 25 m buffers should be cleared, and these areas are not considered to be unsuitable for growing biomass. 15 m wide buffers were generated along all other roads. Planting trees and bushes near roads may reduce visibility, especially at the crossroads and turns. The further bushes and trees are being grown from the road, the better.

The area of agricultural lands in buffer zones of drainage ditches is considerably smaller than the total generated buffer area and the sub-divisional zones of roads are one of the reasons for that.

According to the topographical geodatabase maintained by the Latvian Geospatial information agency (LGIA) the approximate area of roads and their sub-divisional zone area are 26 120 ha.

The protection zone of large diameter collectors (30 cm or more) is defined 8 m from the collector's centerline. According to this assumption the collector protection zone area is 198 m^2. In total 488420 collectors were found in the buffer zones, that takes 9647 ha of protection zone.

There are 493206 buffers that do not contain any collectors. The number of collectors per buffer varies from 1 to 136. The biggest number of collectors is associated with long buffers and faulty information on the underground drainage systems – one or few pipelines cross buffer zones multiple times. The median is 2, average 2.29 collectors. There are 213591 buffer polygons that contain at least one collector. The total length of drains that fall into buffers is 184 km.

A similar methodology has not been used in other studies with the aim to analyze shelterbelts. Different studies have been performed using satellite imagery and automatic image classification tools [10]. Relatively high accuracy of 73% crop species has been obtained as well as 93% accuracy of the existing shelterbelt identification using 2.5 m pixel resolution satellite imagery [11]. The results of these studies suggest that widely available satellite imagery and drone data can be used to optimize shelterbelt management.

Conclusions

The outputs of this study contribute to developing guidelines for selection of tree species suitable for "biomass factories" in different types of buffer zones and growth conditions; productivity and cost estimates for establishment, early management and harvesting of "biomass factories"; decision on the support tool for management of the biomass factories. Further studies with the aim to identify natural stream networks, classify drainage ditch networks to obtain more precise data about ditch buffer zones, their types which are suitable for specific crop communities.

Acknowledgements

The study is implemented within the scope of the project "Economic and environmental assessment of biomass production in buffer zones around drainage systems and territories surrounding the protective belts of natural water streams" (No. 1.1.1.2/VIAA/3/19/437).

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