Quantitative and qualitative potential of shelterbelts. Ground measurements of shelterbelts with laser scanner

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Abstract. Shelterbelts as linear objects in the open landscape are a very important element affecting the maintenance of a high level of bio- and geodiversity. Their nature determines the need for intensive conservation and their rational management. The use of teledetection techniques for geographical environment mapping in its biotic part is a new challenge in terms of obtaining complementary data about these objects (quantitative and qualitative structure of objects). Remote diagnosis of the health status of trees and shrubs that form shelterbelts is a scientific and application task. The beneficiaries of such information in a form of scanning or spectral database can be botanists, foresters, environmental managers, environmentalists or urbanists. Moreover, the use of ground-based and aerial laser scanning techniques will allow to build a thematic catalog of scanning metrics for the network of shelterbelts, taking into account all various types of shelterbelts, eg. in terms of structure, species composition, phytosanitary state.

Keywords: shelterbelts, laser scaning , inventory, point cloud, metrics;

1. Introduction

Shelterbelts are one of the few anthropogenic objects in the agricultural landscape that provide many benefits, not only for humans but also for the environment (prevention of soil erosion, water retention, biodiversity stimulation). However, the intensification of agricultural production and spatial development leads to the marginalization of the system of shelterbelts. The progressive degradation of the natural environment in the areas of high-yield agriculture indicates the need to protect agricultural landscapes, including the network of shelterbelts (Nowak 2011). As a consequence, there is a lack of studies on quantitative and qualitative properties of this kind of woodlands.

Spatial arrangements of above mentioned shelterbelts are subject to the interpretation of aerial photos on landscape level with the use of both available archival teledetection materials and modern high resolution satellite and aerial pictures. Application of GIS techniques and precise parameterization of spatial and landscape systems of shelterbelts is one of the research problems. Another element which is highly advisable from the shelterbelts phytosanitary state point of view, is the use of precise ground and aerial laser scanners for the development of geometrical metrics of trees in terms of species and spectral patterns in order to monitor stress and healthy state (Jones 2010; Doneus, Briese, Airborne 2010). The main part of the research is a verification of the possibility of ground laser scanning use for the identification of the phytosanitary state of different shelterbelts types (criteria of classification in terms of location, vertical structure, mutual location, the share of invasive species shape and size of trees and shrubs in a shelterbelt). In relation to the criteria of shelterbelts network classification, there can be distinguished their individual functional parameters

(among others: species composition, share of invasive species, the amount of biomass, health condition, canopy closure/transparency) for which, within the project, there will be created indexes that will characterize them. Their determination will enable automation of the processes inventorying shelterbelt resources in large areas. Apart from the scientific importance, the results of above mentioned works can also be useful from the economic point of view, i.e. for the evaluation of agricultural potential of a given area (Jarocińska, Zagajewski 2009).

The use of ground laser scanning for the inventory of trees allows to precisely determine standard measured trees characteristics (diameter at breast height, height and location) but it also enables detailed measurement of many other properties, e.g. crown base height, its length and range, slope of the trunk, the trunk thickness at any height. The result of scanning is the set of points, each of which has XYZ coordinate, together with the information about the intensity of laser beam reflection.

Authors presenting above mentioned subject will undertake research in the following fields:

- ground measurements of trees with laser scanner;
- parameterization and visualization of shelterbelts in 3D formula;

2. Methods

For the scan of a stand there was used Optech's ILRIS HD laser scanner. It is a long-range pulse scanner that has a scanning distance in the range of 3-1250 m. The above mentioned scanner is so-called camera-type laser and its field of view is 40° horizontally and vertically. Scan speed is up to 10 000 points/s. This scanner measures the points with spatial coordinates XYZ together with the intensity of a laser signal reflection.

The set of points measured with a laser scanner is a point cloud. After the measurement, individual scanning images from each position are subjects to a process in which the separate scans are being oriented to each other and linked in a whole. This way we obtain a point cloud representing the measured object in a real scale in the scanner's local system. In the next stage of work the scanning data are transformed into the coordinate system PUWG 1992 using the control points measured with GPS-RTK technique. Raw data from laser scanning can be subjected to any processing and it is possible to get information about the actual size of the measured object. Due to high metric accuracy, the resulting documentation can take any form: vector, 3D models, situation and high-altitude plans. During the research and development of remote inventory method for the network of shelterbelts, there should be assumed a three-tier methodology verifying the above idea: research at the teledetection level [1)] understood as ground and aerial scanner measurements, the second level [2)] is the classical ground phytosociological study of trees and shrubs and the third level [3)] relates to the study of biological structure of a plant (plant stress parameters, chlorophyll, carotenoids).

1.) Remote sensing. The demonstration of ground tests capabilities using aerial laser scanner and providing technical possibilities is an opportunity to create aerial metrics of shelterbelts. The use of LIDAR leads to generation of a point cloud, which is the basis for the development of DEM model of the object which are shelterbelts. The spatial arrangement and detailed analysis of the micro-morphology of the object together with ground laser scanning measurements are the basis for a complete description of the structure of shelterbelts.

2.) GIS-based analysis. Phytosociological studies in terms of GIS is a combination of botanical and geo-computer research. Field studies identifying the object of study is a task of typology, quantitative analyzes of trees and shrubs forming shelterbelts. The data obtained at this stage in the form of quantitative and qualitative indicators is another contribution to the characteristics of the shelterbelts scanning metrics, representing a document used to verify the reliability of the interpreted scan data.

3.) Basic research. Knowledge of the operation of various trees species, among other things, in terms of annual growth, leaf area, the metabolism mechanisms may provide a basis for obtaining the above mentioned information using remote methods. The use of these parameters in estimating the natural and economic potential of the network of shelterbelts with remote methods can significantly improve its credibility.

The first stage of ground laser scanner measurements of the trees and shrubs vegetation phase was implemented using the proposed methodological approach in order to capture the overall morphological physiognomy of a tree and the spatial arrangement together with functional parameters of the scanned object.

3. Study sites and results

Sites selected for preliminary scanner measurements (fig. 1) relate to the locations previously studied by the authors in the vicinity of Turew in Gen. D. Chłapowski Landscape Park (60 miles south of Poznań (fig. 2).)

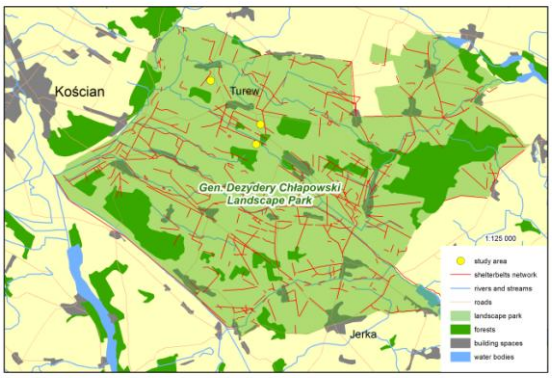

Figure 1 and 2. Location of study area.

Aerial photos illustrate the spatial arrangements of shelterbelts in the study area (picture 1 and 2).

Picture 1 and 2. The study area (aerial photo by W. Rączkowski 2013).

Three types of shelterbelts were scanned on 24-25 April 2013: a shelterbelt along the stream with the dominant Alnus glutinosa species (picture 3), a roadside two-rowed shelterbelt with the

dominant Robinia pseudoacacia and Querus robur (picture 4), a roadside one-row shelterbelt with Populus nigra species (picture 5).

Picture 3,4 and 5. Three types of shelterbelts (photo by M. Nowak 2013).

Due to the type of a scanner (so-called camera type) and its limited field of vision, in order to scan the interesting object, it is necessary to move a certain distance. The laser beam is of a divergent character and a laser spot diameter increases with the distance from the measured object, which causes considerable "noise" (errors) around the edges of objects, i.e. the edges of a tree trunk, the tree crown (picture 6 and 7). Removing the "noise" resulted in large defects in the measured point cloud. In addition, the mobile measurement could not be used due to the scanner's field of view.

Picture 6 and 7. Scan image before and after filtration (W. Plewa, D. Światłoch 2013).

In order to optimize the measurement it would be advisable to use a different type of scanner, eg. phase scanner capable of recording 0.5 - 1 million points/s with panoramic field of view: 360° horizontal and 320o vertical. Using that kind of a scanner allows taking measurement at a shorter dis-

tance, and thus free of most of the "noise". It is also recommended to measure with method of mobile scanning (it is possible to adopt for that purpose the inertial Applanix system that is in the authors' possesion). However, in such case it would be reasonable to use at least a pair of scanners located on the back of the vehicle on its both sides for two-row roadside shelterbelts. Moreover, the use of mobile scanning would significantly shorten the time of the field work.

At the moment, the measurement of parameters such as a breast height diameter and tree height, aimed at determination of the size of biomass of the shelterbelt is taken manually and is a very time consuming process. In order to be able to use laser scanning for the inventory of shelterbelts, there should be developed an algorithm that could automate this process to some extent. The following activities should be a subject to automation:

- measurement of a breast height diameter; generation of a plane corresponding to the area next to the studied shelterbelt - increasing the plane by the height of 1.3m - developing the cross-section through the point cloud with the plane - obtaining the trees diameter;
- filtration of the point cloud in terms of reflection intensity - keeping only the points characterizing the studied objects;
- measurement of an average altitude of a shelterbelt;

4. Conlusions

Obtaining point clouds from ground laser scanning, both stationary and mobile, combined with aerial scanning opens up new possibilities for data collection in terms of local positions - case studies and large-scale - which are the basis for the creation of spatial databases on the state of the network of shelterbelts preservation. Use of teledetection tools in form of laser scannings provides a basis for precise determination of the economic and natural potential of the shelterbelts network through detailed quantitative and qualitative inventory of studied objects (morphology, condition, biomass, phytosanitary condition). Moreover, the use of mobile laser scanning systems allows to create complementary local banks (municipal, basin) on the network of shelterbelts.It should be noted that they have significant impact on land use and spatial planning at the local level, which requires an access to the bank of environmental information about shelterbelts in their cultural, natural and spatial terms. Thus, the creation of shelterbelts metrics with teledetection methods will contribute to the spatial order created by planners who know the status of the network and will retain and transform it into local development plans.

The scientific approach in obtaining and interpreting the data from laser scanning opens up new, but already used by the researchers source of information about the morphology, quantitative parameters of the plant, spectral and reflectance characteristics of woody and shrubby species, which are a database of multi-functional phytosociological analysis. The authors' objective of the preliminary studies is to develop an integrated and remote method of estimating the actual value of the shelterbelts network in a supra-regional scale. A series of ground and aerial measurements correlated with the different plant vegetation phases will lead to development of a uniform procedure of collection and processing of data on shelterbelts.

Acknowledgements

The authors thank Mrs. Aleksandra Nowak, coordinator of field studies and SGS EKO-PROJEKT for making the measuring equipment available.

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