THE MODELLING OF AGROFORESTRY SITE SELECTION

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ABSTRACT

In the last decades regional growth of arable land has a significant effect in global and European land use, thereby reducing the percentage of natural forest area. In Europe are 29 % crop lands, and in Central and Eastern Europe in Hungary arable land ratio is near to 50%, which is much higher than the European average. The global environmental problems justifies the necessary of forestation in each countries.

Agroforestry systems are part of the history of the European Union rural landscapes, but the regional increase of size of agricultural parcels had a significant effect on European land use in the 20th century, thereby it has radically reduced the coverage of natural forest. However, this cause conflicts of interest between the agricultural and environmental sectors. The agroforestry land uses could be a solution of this conflict management.

Nowadays one real – ecological - problem with these forests is the partly missing of network function without connecting ecological green corridors; the other problem is verifiability for the agroforestry payment system, monitoring the arable lands and plantations.

Remote sensing methods are currently used to supervise European Union payments. Nowadays, next to use satellite imagery the airborne hyperspectral and LiDAR (Light Detection And Ranging) remote sensing technologies are becoming more widespread use for nature, environmental, forest, agriculture protection, conservation and monitoring and it is an effective tool for monitoring biomass production.

In this Hungarian case study we made a Spatial Decision Support System (SDSS) to create agroforestry site selection model. The aim of model building was to ensure the continuity of ecological green corridors, maintain the appropriate land use of regional endowments. The investigation tool was the more widely used hyperspectral and airborne LiDAR remote sensing technologies which can provide appropriate data acquisition and data processing tools to build a decision support system.

Keywords: agroforestry, remote sensing, LIDAR, green corridor, site selection

1. Introduction

Agroforestry systems are part of the history of the European Union rural landscapes, but the regional increase of size of agricultural parcels had a significant effect on European land use in the 20th century, thereby it has radically reduced the coverage of natural forest. In 2004 the Article 41 contains for the first time a mechanism to support the establishment of agroforestry (EURAF). Hungary (Central Europe) has recently completed the 2007-2013 program period and HUF 240 million support was paid out until 2013, and 1,162 hectares has been referred to, area-based, non-refundable payment to farmers. Hungary – similarly other Member States -

also aims to involve our agroforestry areas (with 400-600 thousand hectares), partly converted from arable land, partly as new forestation. One real – ecological - problem with these forests is the partly missing of network function without connecting ecological green corridors, which are determining in the case of introduction of an agroforestry land use system. The other – economical - problem is verifiability for the agroforestry payment system, monitoring the arable lands and plantations. Remote sensing methods are currently used to supervise European Union payments for vineyards and olive groves (e.g. in Italy, Spain, Portuguesa, French and Greece). With these methods could be used to help distinguish agroforestry areas from forest. (Lawson et. al, 2005). Nowadays, next to use satellite imagery the airborne hyperspectral and LiDAR (Light Detection And Ranging) remote sensing technologies are becoming more widespread use for nature, environmental, forest, agriculture protection, conservation and monitoring and it is an effective tool for monitoring biomass production (Curran, 1981; Kale *et al*., 2002).

2. Materials and methods

The study area of the model was carried out in part of West Hungary (near Sopron, extension part of the east Alps) which is about 2350 hectares area. Based on CORINE Land cover (CLC2006), DTA50 (Topological map of the Hungarian Republic in 1:50.000 scale) database the main land use classes were specified in different land use categories: arable land (clc06_c211), pasture (clc06_c231), forest, built-up area (city of Sopron, town of Ágfalva), farm, watercourses, channels, roads (dirt and highway). The study area contains part of the Sopron Mountains which is part of Natura2000 habitat sites in Europe.

2.1. The airborne hyperspectral data

The airborne surveys of the study area were carried out within the framework of ChangeHabitats2 project. Important aim of this project to evaluate the advantages of the novel hyperspectral and LiDAR technology for habitat mapping, biodiversity monitoring, environmental and nature conservation in NATURA 2000 habitat sites.

Hyperspectral remote sensors collect data of surface in hundreds of narrow, adjacent spectral bands. This imagery is an effective tool to detect material quality characteristics of objects (eg. different plant species) and could provide relatively more information that multispectral imaging (Smith, 2006). The hyperspectral data was acquired by AISA DUAL hyperspectral imaging system. The two sensors - AISA Eagle and Hawk - are assembling in one house. The Eagle can perceive in the visible and near infrared ranges (400-1300nm), the Hawk can process in short wave infrared ranges (1300-2500nm). The system has a so-called push-broom hyperspectral imagery sensor with fibre optic radiation meters (FODIS), which collect information about the incoming light.

Certain reflectance values in the electromagnetic radiation are useful to create vegetation indices, which correlate with the changes in biomass (Silleos *et al*., 2006). Plants reflect the visible (VIS) band but in the near infrared (NIR) the reflectance increases depend on the chlorophyll content of leaves. Using the reflection from the RED (630-690 nm) and the NIR bands (760-900 nm), the green mass may be defined by the Normalized Difference Vegetation Index (NDVI):

$$NDVI = (R_{NIR} – R_{RED}) / (R_{NIR} + R_{RED})$$

Thanks to NDVI - whose value varies between -1 and 1 – we can separated easily from each other the dense vegetation and non-vegetation areas. Naturally it is also possible to determine the sparse vegetation or moderate vegetation, but in our case we calculated only with the areas extension of dense and non-vegetation. The NDVI image proccessed in ENVI 5.0 software, used Vegetation Delineation tool. This tool identified the presence of vegetation and visualized the vigor levels of it.

2.2. The airborne LiDAR survey

Laser scanning is an active surveying technology for obtaining detailed - elevation, structural - information about the land surface. Result of the survey generates a point cloud consisting of millions of points, with evaluation value of each point. This point cloud useful to get spatial 3D information about the objects, surfaces. High laser point density provides to create high resolution digital elevation model (DEM) or digital surface model (DSM) (Wagner, 2007). The LiDAR image created by RIEGL LMS-Q680i full waveform laser scanner. The scanned area was approximately 90 km^2, which made in 22 flight stripes, contains more than 530 million laser points with 9.83 pts/m^2 average point density During the survey seven return pulses (first, second, last, single, first-of-many, second-of-many, third-of-many, last-of-many returns) and four LiDAR point classes (unclassified, ground, medium vegetation, high vegetation) were identified. The LiDAR image was evaluated in GlobalMapper 15.0 and ArcGIS 10.2 software.

2.3. The Spatial Decision Supporting System (SDSS)

The applied Spatial Decision Supporting System used two types' criteria: constraints and factors. Constraints are those logical criteria that limit our analysis, so 1 or 0 Boolean logical value is added to each investigated decision factors. In our case, this logical values were ideal for distinguish land use areas, which could be suitable or unsuitable for forestation under any condition. Factors are criteria that define some degree of suitability for all geographic regions. ArcGIS 10.2 software was used to create the site selection model for determined the potential areas of forestation.

In generally in the most geographic region important factors are the elevation of the surface, hydrological conditions and soil type. In this case of our conceptual model building the constraint layers were: forest, built-up area, farm, watercourses, channels, dirt and highway roads. These land uses cannot be directly forested but in the immediate vicinity of them the forestation can be done – if there are no other limitation constraints. Thus we created uniformly a 10 meters buffer zone around areas and then we merged them into one "Constraints" layer, and erased out from the study area. The other constraint of the forestation was the dense vegetation (without forest, because earlier it was involved into constraints) based on NDVI. Dense vegetation most probably also contains tree hedges, isolated trees, shrubs etc. that cannot be classified into forest land use. Similarly the merged constrains dense vegetation has erased out from the area. Dense vegetation of pastures and arable land has calculated separately in order to determine the extension of the potential forestation sites there (*Figure 1*).

3. Results

3.1. Results of airborne hyperspectral analysis

Based on hyperspectral image we ran the NDVI index used Vegetation Delineation tool in ENVI 5.0.

We used the four basic classes: no vegetation (0 value), sparse (0.25 value), moderate (0.5 value) and dense (0.7 - 1 value) vegetation. Typically the no vegetation contains dirt roads, highway, buildings, bare soil. Into the sparse and moderate vegetation can be classified the weedy area, grasslands, and dense vegetation collected the forest areas, tree hedges, isolated trees, shrubs and sown area. In bare soil could be vegetation, so we segmented that areas. In the sown we also can make forestation but the software detected this areas like forests, based on NDVI value. Due to we calculated with their area extension during the investigation and added to the potential area sites.

3.2. Results of airborne LiDAR analysis

The LiDAR image was used to create a DEM of study area. Thanks to LiDAR survey we could get the high values of the area in every laser point from which could make DEM and work in 3D. Extremely high the importance of this kind of remote sensing technology because it is suitable for inter alia measure the high and diameter of trees, forecast estimate the biomass production, and create the runoff conditions in a large extension of area. We created the digital elevation model in the end we compared it with the potential sites of forestation

3.3. Results of Spatial Decision Supporting System (SDSS)

Determined the constrains and factors the model was run and we have received the potential sites for forestation (Figure 1).

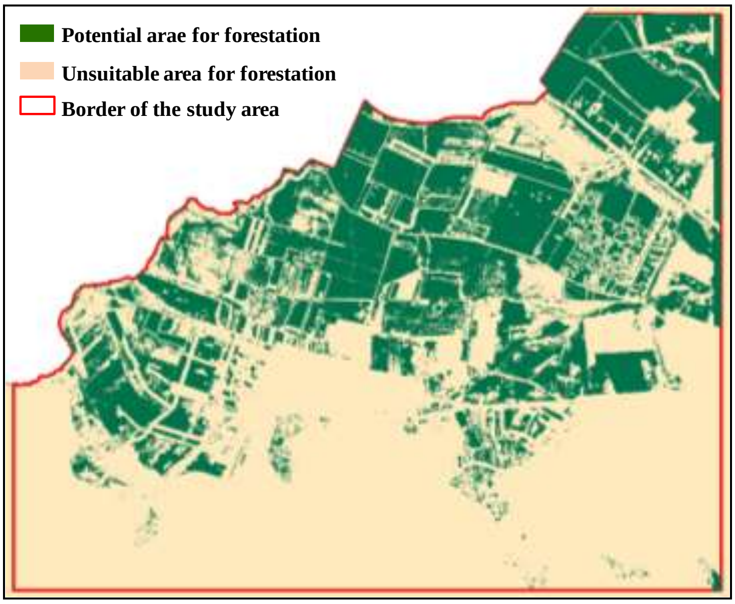

Figure 1: Result of the site selection model

The large part of the potential tree-planting areas are located in lower surface levels (about 250-400 meter) in the arable lands, pastures and parallel with roads. Smaller part of potential sites can be found in higher levels (about 400-550 meter), in the hillside. The areas of potential sites in hectares are shown in Table 1. More than 1000 ha is suitable for forestation from the all study area.

Table 1: Currently and potential forestation areas in the study area

Land use category	Area (ha)	Potential forestation (ha)
Forest	755	12
Arable land	797	797
Pasture	343	219
City/town	412	0
Farm	20	0
Total	2327	1028

4. Conclusions

During the plantation we need to consider of species and their canopy coverage, this is the subject of further research. Knowledge of results and the naturally occurring tree species we suggested the following species for plantation: in the hillside sessile oak, hornbeam, scots pine; into the lower surface birch, poplar, elm, and ash tree etc. species. At all events planting native tree species according to geographical conditions. Taking into consideration the criterions of national "First establishment of agroforestry system" support fund we are not entitled for support in case of conifer plantation, woody plantations for energy purposes, sick, comma plantation and state-owned area above 50%. Based on the results of site selection model we concluded that remote sensing technology clearly integrated into process of agroforestry planning, and effectively use for supervise payments.

Increasingly large numbers of countries across Europe are using these technologies which will get important role during the spread of agroforestry systems.

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