Semi-automated mapping for the National Inventory of Landscapes in Sweden (NILS) using Landsat and LiDAR data

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1. Introduction

The National Inventory of Landscapes in Sweden (NILS, http://www.slu.se/nils) is a sample based landscape inventory used to monitor biodiversity on a continuous basis. NILS is carried out by the Swedish University of Agricultural Sciences (SLU) on behalf of the Swedish Environmental Protection Agency. NILS captures vegetation data for all terrestrial environments: agricultural lands, wetlands, urban environments, forests, and coastal and alpine areas. Thus, NILS complements the National Forest Inventory (NFI; also carried out by SLU), which has an emphasis on productive forest land.

NILS is based on a nationwide stratified sample of 631 squares (Ståhl et al. 2011). For each sample location, a 1 * 1 km square is photo-interpreted and 12 plots within this square are inventoried in the field. There are 39 variables with sets of classes to be estimated for the delineated polygons. By using variables instead of predefined habitat classes, the data are more likely to be compatible with other programs, such as those for surveillance and monitoring of European habitats.

An outer 5 * 5 km square around each 1 * 1 km inner square is presently used for special inventories by different authorities. An example of such an "add on" survey to NILS is collection of data on small biotopes and their management in rural landscapes which is financed by the Swedish Board of Agriculture. There is a need to create wall-to-wall data within the 5 * 5 km area so that the measurements in the inner square and the special inventories can be analyzed in a landscape perspective. The mapping of the 5 * 5 km square should be done with automated remote sensing methods, possibly in combination with complementary photo-interpretation. The aim of the development project presented here is thus to establish a method for semi-automated mapping of vegetation type, vegetation height and cover within the 5 * 5 km^2 squares. Earlier research has shown that 3D data from airborne sensors and multispectral satellite data complement each other when used for vegetation mapping (Nordkvist *et al.* 2012; Reese *et al.* 2014). The primary method investigated in this project is therefore to combine LiDAR data (from an ongoing national airborne laser scanning carried out by the Swedish mapping authority) together with Landsat 8 images. Since the aim is to develop methods that can be used operationally in a nationwide application, we try to use existing field plots from NILS and the NFI as reference data in the final product. Here we present intermediate results from classifications with these data sources. The ongoing national laser scanning is not expected to be repeated in the foreseeable future. The possibility of replacing the laser data with 3D point clouds obtained by matching digital aerial photographs will therefore also be studied in the project.

2. Material and methods

The national laser scanning, acquired primarily for the construction of a new elevation model, has a posting density of 0.5 – 1 laser returns / m^2. The scanning is divided into blocks of 25 by 50 km. In order to obtain a sufficient number of field plots from NILS and the NFI as training data, the remote sensing datasets should cover large areas, encompassing many field plots. We are therefore using Landsat 8 images (185 x 185 km) in the present project, while waiting to use Sentinel 2 data (290 x 290 km) in a future operational phase.

To combine 3D datasets of different extents and properties together with satellite images, a stratified approach is tested. Forest variables can be estimated from smaller areas due to a relatively dense sample of field plots in the NFI. Predictions of canopy cover and basal-area weighted mean height are made based on regression models built using the NFI plots and a 25 x 50 km LiDAR block. A minimum of 200 field plots inventoried within a five-year period from the LiDAR scan date are used. Field plots from adjacent LiDAR blocks with similar properties might be needed for obtaining a sufficient number of reference NFI plots. Using predictions based on the LiDAR data trained with NFI plots, the 5 * 5 km NILS squares are stratified into forest and non-forest, where forest is defined as areas with more than 20% canopy cover and having trees more than 3 m tall. Within these two strata, separate classifications are made of the Landsat 8 data. The training of the subsequent satellite data classification will be done with NFI plots in the forest strata and NILS field plots in the non-forest strata, but in the development phase, subjectively chosen photo-interpreted plots were used for training of the field layer classification. The forest strata is classified as coniferous or deciduous, based on the majority of basal in the plots used for training these two classes

3. Early results

Initial tests show that canopy cover predictions from LiDAR had an acceptable error level when using photo-interpretation as training data, but had higher error levels when subjective field judgments of canopy cover was used as training data. Tests also show that accurate measurements of canopy cover are best obtained from the NFI plots by using the measured stem diameters in combination with functions for the relationship between stem diameter and crown diameter (Jakobssons 1970). The RMSE for basal area weighted tree heights obtained when using NFI plots for training data was 9-11 %, when evaluated at plot level.

Furthermore, a classification system for field and bottom layer vegetation suitable for the NILS inventory is currently being tested. Results for the classifications are expected at the time of the conference.

Table 1. Error matrix for forest strata from a test site in southern Sweden, using random forest on a balanced training data set of NFI plots and OOB estimate of error.

	Coniferous	Deciduous	Producer’s accuracy
Classified as coniferous	99	10	90.8 %
Classified as deciduous	11	94	89.5 %
User’s accuracy	90 %	90.4 %	Overall accuracy: 90.7 %

An early tests has also been made where the use of 3D point clouds from digital photogrammetry where compared with the use point clouds from laser data, in both cases using colour information from a SPOT HRG image. Training data was in this test obtained by photo interpretation. For classification into four classes: coniferous forest, deciduous forest, vegetation outside forest, and water were 88% overall accuracy obtained with only SPOT data and 93% with using SPOT data in combination with either digital photogrammetry or LiDAR data.

4. Discussion

Monitoring and assessing habitats needs not only information of site quality but also landscape context information at various scales. The NILS inventory gives information on plot level via a field inventory, and detailed information on the local context via manual interpretation. A very real aim of the inventory program is to optimize the relationship between workload, time consumed and statistical soundness of the data collected. Taking the work load into account, use of automated remote sensing methods and existing field data from the NFI and NILS inventories for the provision of context information on a larger scale seems feasible. Preliminary results show sufficiently good results for forested lands, and a potential vision for forested lands could be to provide new classifications based on the combination of optical satellite data and 3D data from laser scanning or digital photogrammetry.

Acknowledgements

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