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Technical note

Low cost poplar inventory in the plain of Piemonte (Italy)

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Abstract - A forest inventory is an important tool to assess and estimate the amounts of wood for industrial use available and to be expected in the future. It generally requires a high effort, both in terms of costs and time, if based on the direct sampling of the areas or on the classification of aerial photoghaphs or satellite images. The paper presents a methodology to carry out an inventory of the areas occupied by poplar stands based on open source software (QGIS®) and free images available on the web ('Google EarthTM™'). In Italy poplar cultivation is characterized by short rotations - about ten years - and the material obtained is very important for the wood processing industry, particularly for the production of plywood. The results of an experimental survey carried out in the plain of Piemonte Region (north-west Italy) are presented in order to evaluate the timing effectiveness of the methodology. The data obtained on land cover, regarding poplars, other forest plantations and natural forests, are showed and compared with those of older inventories, carried out with traditional methods. Although the evident reduction of costs in terms of manpower, time, and materials involved is counterbalanced by a few problems due to the different age of the web images, this alternative methodology, if applied by an experienced operator, can guarantee quite precise results at very low costs.

Keywords - Forest inventory; Poplar; Open source; QGIS®; Google Earth™

Introduction

Forests inventories are an important tool to estimate land cover, to monitor national forests and assess their distribution, characteristics and time dynamics. In particular, a forest inventory applied to poplar cultivation can provide a highly precise estimate of the crown coverage of poplar stands and, consequently, of the poplar wood available in the near future. This is due to a few peculiarities of the cultivation of poplar for industrial use, i.e. to the fact that all plantations have the same or similar layout and density (about 277 trees per hectare with a regular layout), tend to be monoclonal (clone 'I-214' in most cases) and are managed according to standardized methods. Moreover, tree height and shape of the crown, recognizable by the shadow on the aerial or satellite images, make poplar easily distinguishable from other woody species (both for wood and fruit production). Additionally, there are many data and models that allow a very precise estimate of the volume of trees, based on the age and diameter of the stems.

Italian poplar cultivation accounts for more than 26 % of total domestic industrial wood production and 61 % of domestic industrial wood production from broadleaves (ISTAT 2013) while covering an area little over 0.76 % of the total forest land (CFS-CREA MPF 2005). It therefore represents an important wood source, characterized by high productions with rotations of only 10 years: about 20 cubic meters of wood per hectare are produced annually, most of which are used by the plywood industry.

Given the dynamic nature of such cultivation, it is of paramount importance that information useful for planning wood production and industry supply be always available and updated. For this reason a first inventory of poplar cultivation was carried out in the 1980's (Lapietra et al. 1980), using infrared aerial photographs taken expressly to this purpose. The inventory system was based on sample points systematically geo-referenced on the semi-kilometer UTM grid and on the photo interpretation on the basis of 4 crown cover classes for poplar plantations (Cellerino and Lapietra 1977) and one for natural forests. Because of the fast ageing of the results and of the need to provide information to the stakeholders, a new survey system was developed based on the ground survey of permanent sample plots located over the same system of geographic coordinates as the previous one. Because of the high costs of ground surveys this inventory was interrupted in 1996 (Coaloa and Chiarabaglio 1997) and only occasionally some regional inventories were carried out when useful aerial photographs were available (Coaloa and Chiarabaglio 1998a, 1998b, 2000b, Coaloa 2006).

In this paper we present an experimental inventory technique, particularly useful for wood plantations with poplar and other woody species (such as walnut, cherry tree and others) or to mixed planta-

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tions. It is based on open source tools, and applied, for the time being, on the plain areas of a single Italian region, Piemonte, historically interested by poplar cultivation. This new inventory method is characterized by fast implementation and low time and economic cost, specially thanks to the use of new open source web data and software: Google Earth™ and QGIS® (QGIS Development Team 2009).

The aim of this paper is to describe such method, showing the time required for its execution, the advantages and the problems related to it, at the same time presenting data acquired on the poplar and other forests cover and their reliability (Borecki et al. 2015).

Material and methods

This new technique to carry out a forest inventory takes advantage of the characteristics of the open source QGIS, a software which allows to work with a raster layer with Google Earth™ images under a sample points vector layer. Indeed, the availability online of images freely accessible through Google Earth™ presents low cost interpretation options (Olofsson et al. 2014) useful for forest surveys.

A two-phase sampling was adopted: in the first phase the same semi-kilometer UTM grid already used in the previous inventory of poplar cultivation in Italy (Lapietra et al. 1980) was superimposed on the Google Earth images thanks to the Open Layers plug-in "Google maps". An inventory test was then carried out on the plain of the Piemonte Region (Fig.1) to evaluate the feasibility of the method.

The identification and classification of poplar stands were based on photographic models developed for aerial photographs in scale 1:18,000 (Cellerino and Lapietra 1977) and 1:75,000 (Coaloa and Chiarabaglio 1998a) and for digital orthophotos in scale 1:40,000 (Coaloa and Chiarabaglio 2000a, 2000b); for poplar 4 classes were established related to the canopy cover classes, which were in turn correlated with the age of the plantations. Plantations with other woody species and natural forests were also ordered in 2 other classes (Tab. 1).

Table 1 - Land cover classes (hectares) and sampling errors (%).

		Piemonte [ha]	Sampling points n.	Sampling error %
	1	325	13	*55.5*
	2	1275	51	*28.0*
Poplar plantations	3	3927	125	*13.4*
	4	5819	209	*11.4*
Total poplar		**11346**	**398**	***8.2***
Natural forests		41885	1635	*4.7*
Other forest plantations		2418	64	*14.9*
Total plain surface		671347	26854	

The recognition of types of wood plantations and forests on images (Google Earth) and the use of the software QGIS may require a period of training, especially if the operator has not previously worked with the classic methods of forest inventory; if a new operator is introduced to work, a short period of coaching must be provided for with an expert to recognize poplar stands from the pattern of the image. To be classified as one of the inventorial classes the sample point of the grid must fall into a field having an area greater than 1,000 m^2 and at least one side wider than 20 meters. The image-interpretation was performed at screen in scale 1:5,000 assigning the cover class to each sample point, and zooming, in case of doubt, to the scale 1:1,000. With this resolution the operator can simultaneously view 9 test points on the screen, and, with adequate training and knowledge of the characteristics of the plantations, classify them rather quickly (Fig. 2).

The classification process was completed by fill-

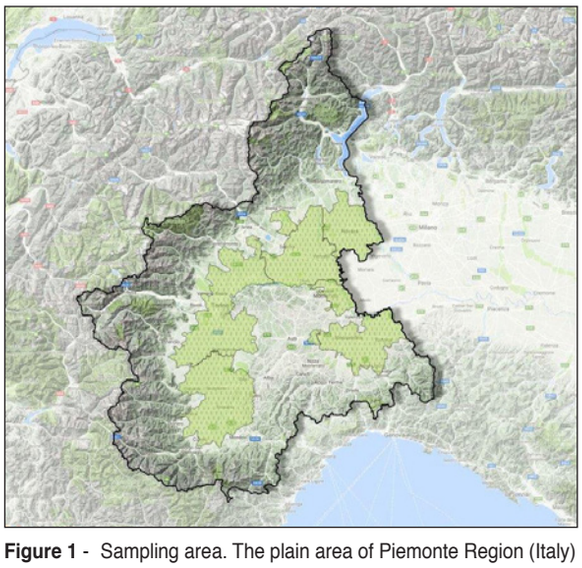

Figure 1 - Sampling area. The plain area of Piemonte Region (Italy) surveyed.

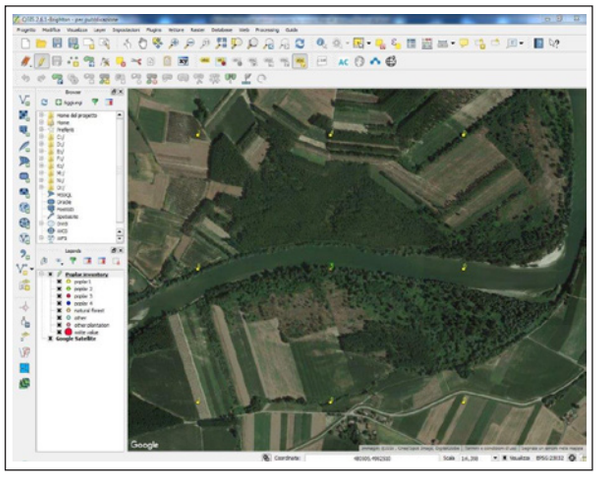

Figure 2 - Photo-interpretation of land cover. The Brighton-QGIS screen during the photo-interpretation of nine sample points.

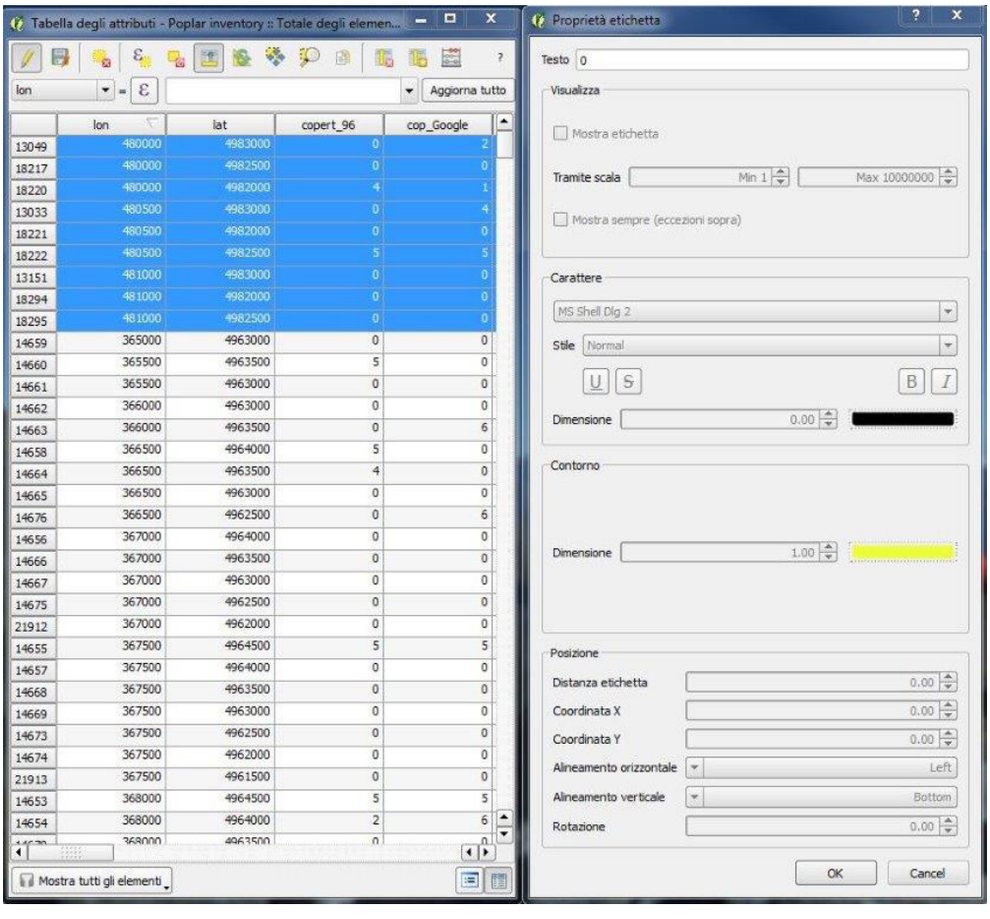

Figure 3 - The attribute table for the nine sample points selected (highlighted in blue) and the label property of one of each, where in the field "testo" it is possible to update the classification of the point.

ing the attribute table with the correct class cover (Fig. 3). When the photo-interpreter inserts in the QGIS software the value of the class for a sampled point, the point indicator assumes the color assigned to that class, otherwise the point remains highlighted as non-sampled; in this way it is difficult to make mistakes.

The sampling error was calculated applying the formulas for double sampling for stratification to correct the misinterpretation in estimating stratum proportion from aerial photographs (Loetsch and Haller 1964).

Ground control points (second-phase sample)

To verify the interpretation of the Google Earth™ images, a subsample of 695 points was drawn from the 26,854 first-phase points (about 2.6% of the total) and controlled in the field. The data obtained were then utilized to calculate the sampling errors with 95 % confidence limits.

Results and discussion

The photo-interpretation on the QGIS software lasted 15 days, including training in the use of the program. It was possible to process the data obtained in just a few hours by exporting them into an electronic sheet. For the second sampling phase 20 hours and about 500 km by car were necessary to visit the ground control points. The total working time required by the survey amounted to about 104 hours, i.e. 1.5 hours per 100 km^2 of land.

A total of 26,854 sampling points covered the area of interest (671,347 hectares) and each point was classified. Table 2 shows the land cover strata for 4 poplar classes, natural forest and other wood plantations as well as the sampling errors.

A total of 11,346 hectares of poplar stands were

Table 2 - Land cover (hectares) and its changes (%) referred to old inventories.

	1979 ha	1996 ha	2006 ha	2016 ha	Changes [%] 2006-16	1996-16	1979-16
Poplar 1	3850	625	200	325	+62.50	-48.00	-91.56
Poplar 2	6825	3425	600	1275	+112.50	-62.77	-81.32
Poplar 3	10625	5750	4600	3927	-14.63	-31.70	-63.04
Poplar 4	9500	7600	6800	5819	-14.43	-23.43	-38.75
Total poplar	30800	17400	12200	11346	-7.00	-34.79	-63.16
Natural forest	30625	31475	30400	41885	+37.78	+33.07	+36.77

identified, equal to 1.7 % of the Piemonte plain area. About 86 % of poplar stands belong to 3rd and 4th class, thus indicating a general decrease on new plantations in the last years. In comparison with old inventories (Tab. 3), poplar stands have decreased by 19,454 ha (-63.2 %) if referred to 1979, by 6,054 ha (-34.8 %) to 1996 and by 854 ha (-7.0 %) if referred to 2006. Between all the classes, 'natural forests' shows a higher value, with a total of 41,885 ha (forest area index of 6.2 %). Compared with 1979 inventory (Tab. 3), the surfaces of natural forests have increased by 36.8 %. Other forest plantations cover a total of 2,418 ha (equal to 0.36 % of the land).

Conclusions

The methodology proposed allowed to quickly update the area covered by poplar plantations in the plain of Piemonte using free and easily available images. The methodology is very simple and easy and it is especially suited to monitor the fast changes of the cultivated poplar areas. Given the variability of woody plantations (forests, pure poplar, mixed plantations and orchards), a period of training can be necessary to recognize images with confidence, in which the on-screen recognition is accompanied by ground controls. However, the recognition of poplar plantations is simpler, due to the characteristics already mentioned. The organization of the classification process together with the opportunity of QGIS software and the good spatial resolution of the Google Earth images reduced misclassifications.

This method is similar to that proposed by FAO in the Open Foris (Miceli et al. 2011), a free open-source solution for environmental monitoring. This inventory technique, could allow to update in a short time the data related to poplar cultivation in Italy; it has the advantage of being able to quickly and cheaply carry out an inventory and is particularly valid for plantations like poplar, characterized by rapid growth, 10 year rotations, and which rapidly alternate on agricultural lands making an inventory soon obsolete. The most important limits are related to the free availability of updated images, especially for poplar. Remotely sensed data obtained just 2 or 3 years before, can negatively affect the accuracy of the estimate of the area covered by poplar stands, and above all the difference in age classes, while there are minor problems for other types of stands with longer cultivation cycles.

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