Experimenting the design-based k-NN approach for mapping and estimation under forest management planning

Walter Mattioli [(1)], Valerio Quatrini [(1)], Silvia Di Paolo [(1)], Daniele Di Santo [(2)], Diego Giuliarelli [(1)], Alice Angelini [(1)], Luigi Portoghesi [(1)], Piermaria Corona [(1)]

Estimation and mapping of forest attributes are a fundamental support for forest management planning. This study describes a practical experimentation concerning the use of design-based k-Nearest Neighbors (k-NN) approach to estimate and map selected attributes in the framework of inventories at forest management level. The study area was the Chiarino forest within the Gran Sasso and Monti della Laga National Park (central Italy). Aboveground biomass and current annual increment of tree volume were selected as the attributes of interest for the test. Field data were acquired within 28 sample plots selected by stratified random sampling. Satellite data were acquired by a Landsat 5 TM multispectral image. Attributes from field surveys and Landsat image processing were coupled by k-NN to predict the attributes of interest for each pixel of the Landsat image. Achieved results demonstrate the effectiveness of the k-NN approach for statistical estimation, that is compatible with the produced forest attribute raster maps and also proves to be characterized, in the considered study case, by a precision double than that obtained by conventional inventory based on field sample plots only.

Keywords: Forest management planning, k-Nearest Neighbors, Landsat, Estimation, Mapping

Introduction

Over the last decades, conservation and sustainable use of forest resources have become among major issues of environmental and land policies, which foster reconsidering the meaning of silviculture in relation to a changed society and acknowledge the forest as a complex, multi-functional, biological system. That implies an increasing need of comprehensive and timely information to support their management at a variety of spatial scales (Corona & Scotti 2011).

Under such a perspective, survey cost effectiveness requirements have pushed towards the adoption of approaches able to integrate the statistical sampling and mapping processes within conventional inventories at stand level, to enhance synergies and mutual benefits. This integration is also emerging as a major issue for the development of programs aimed to monitoring and assessing land and multiple environmental functions (Köhl et al. 2006). This means an hybridisation of tools and techniques. In the light of the above considerations, a number of scientific experiences have been focused on the relationship between forest field data and satellite multispectral images. One of the most successful tools for synergistic estimation and mapping of forest attributes, coupling remotely sensed and field inventory data, is the k-Nearest Neighbors (k-NN) non-parametric approach (*e.g.*, Chirici et al. 2008, Tomppo et al. 2008, McRoberts 2011a), whose operational application has been steadily increased in the last decade, even at the professional level.

Here we report the results of a low-cost application of the design-based k-NN tool approach to estimate and map attributes relevant to support management planning, such as aboveground biomass and current annual increment of tree volume, in a relatively small area (the Chiarino forest in the National Park of Gran Sasso Monti della Laga, central Italy). Distinctively, the importance of the biomass and increment estimation and mapping is related to both the carbon dynamics quantification (*e.g.*, stand carbon sequestration) and the sustainable management of forest resources (*e.g.*, to apply adaptative management approaches). The interest of the application lies in the relative advantage to exploit design-based k-NN potential with respect to conventional stand inventory when supporting the modulation of forest stand management planning. The low-cost framework is referred to the type of remotely sensed data analyzed, *i.e.*, Landsat data freely downloadable from the Internet.

Forest attribute mapping and estimation

The establishment of relationship between remotely sensed data and the biophysical attributes of forest vegetation (like the aboveground biomass and the current annual increment of tree volume) allows maps of the attributes observed at the field inventory units to be derived for the entire area of interest, *i.e.*, the attributes can be predicted for all the pixels in the area, thus producing raster maps (Mayhew 2009). The exploited information from remotely sensed data are usually the DNs of the spectral bands (and/or their combination to produce vegetation indices, *e.g.*, Maselli et al. 2005) which are available for all the N pixels in the area, while the values of the Y-variable of interest (the forest attribute) are known only for the sample of n pixels corresponding to the field inventory units (each assumed to represent one pixel), characterized as the reference set. The mapping procedure is based on the non-parametric prediction of the values of Y for the pixels that do not correspond to the field inventory units, characterized as the target set. Non-parametric approaches are distribution-free, in that they do not rely on any underlying probability distribution for estimation. k-NN predicts the unknown value of Y for the j-th target pixel as a weighted mean of the Y values for the k reference pixels nearest to the j-th target pixel in the multidimensional space defined by the auxiliary (remotely sensed) variables (eqn. 1):

$$\tilde{y}_j = \sum_{i=1}^{k} w_i y_{ji}$$

where k ($<n$) denotes the number of neighbors adopted for the prediction and the w_i are weights such that $w_1 + ... + w_i = 1$. A straightforward choice for the weights is $w_i = 1 / k$ for any $i = 1, \ldots, k$ (McRoberts &

(1) Department for Innovation in Biological, Agro-food and Forest systems (DIBAF), University of Tuscia, v. San Camillo de Lellis snc, I-01100 Viterbo (Italy); (2) Gran Sasso and Monti della Laga National Park, Assergi (AQ - Italy)

@ Walter Mattioli (walter.mattioli@unitus.it)

Received: Oct 14, 2011 - Accepted: Jan 19, 2012

Citation: Mattioli W, Quatrini V, Di Paolo S, Di Santo D, Giuliarelli D, Angelini A, Portoghesi P, Corona P, 2012. Experimenting the design-based k-NN approach for mapping and estimation under forest management planning. iForest 5: 26-30 [online 2012-02-27] URL: http://www.sisef.it/iforest/contents/?id=ifor0604-009

Communicated by: Agostino Ferrara