

HIGH RESOLUTION SATELLITE IMAGERY FOR FORESTRY STUDIES: THE BEECHWOOD OF THE PORDENONE MOUNTAINS (ITALY)

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ABSTRACT:

In this paper we used high resolution satellite imagery in order to study the Pordenone Mountain forests (Friuli Venezia Giulia - North-East of Italy). Our aim is to *develop a method able to estimate wood biomass using a vegetation index* (NDVI - Normalized Difference Vegetation Index). In order to do this we analysed a Quickbird satellite image, dated 24 June 2003, and we compared our results with biomass data in weight, cut from two small forest areas.

The adopted methodology is subdivided in two principal stages:

1. Checking of the precision of the traditional forestry methods in order to estimate the weight of the wood biomass. These methods use dendrometric tablets to estimate wood biomass from measured tree diameters and heights. This stage is developed in the following steps:
 - a. Identification of two small testing areas (around 300m²) in the beechwood. This forestall typology is the most common in this territory.
 - b. Collection of some forestry information (height and diameter of plants).
 - c. Cutting of all the timbers in the two training areas. The cutting operation has been realized soon after the acquisition of the satellite image.
 - d. Weighing of the cut logs and of the leaves.
 - e. Estimation of the wood biomass using some different dendrometric tablets.
 - f. Comparison of the biomass weighted data with the tablet-estimated values, in order to verify the precision of the standard forestry methodology.
2. Analysis of the correlation between NDVI and weighted wood biomass. This stage is developed in the following steps:
 - a. Rectification of the Quickbird scene.
 - b. Analysis of the correlation between NDVI values and weighted biomass data (cut logs and leaves).

Further developments of this research will employ dendrometric tablet estimated biomass values and NDVI values to improve their relationship. When the correlation will be enough satisfying, only the NDVI values will be used to estimate beechwood biomass.

1. INTRODUCTION

1.1. Remote Sensing and Forestall Biomass

In order to use the forestall biomass as renewable resource of energy, we need to know its amount. At the present time we can only do this by measuring with external survey in a systematic sampling way. In this case, the instrument used (dendrometric tablet) allows predicting the amount of a forestall biomass sampled measuring height and diameter of the trees. However, to get global information, this way is too much expensive and it takes a lot of time. That's why we don't know the total amount of our forestall resources (Jodice and Nassimbeni, 1999).

A new way to have an updated database about this renewable resource could be represented using satellite imagery. In this work we use the high-resolution image to try to define the relationship between wood biomass and a vegetation index.

1.2. Estimate Biomass by Remote Sensing

Many Authors (e.g.: Tucker et al., 1985; Cook et al., 1989; Benedetti et al., 1991; Rondeaux et al., 1995; Clevers and Leeuwen, 1996; Borfecchia et al., 2001) point out the relationship between indexes vegetation (from satellite data) and biophysical variables of vegetation, as productivity or healthy. We would test the following flux process:

Satellite image > Vegetation index > Leaf crown > Forestall Biomass

To do this we need test correlations among these variables. We choose NDVI (Normalized Difference Vegetation Index) as vegetation index, because it is generally used in this kind of research.

2. STUDY AREA

Two small areas test, located in the Pordenone Mountains forest (Friuli-Venezia Giulia – North East of Italy) (fig.1), have been studied in this paper.



Figure 1. Pordenone District location (Friuli-Venezia Giulia Region - Italy).

Privileged by climate¹, the beechwood is the most important forest in this district (table 1). However, the beech is very widespread in Italy: in particular, in Friuli-Venezia Giulia mountains, there are a large number of beautiful beechwoods (fig.2).

Forestall typology	%
Beechwood	40,4
Pinewood	21,8
Red Fir wood	10,1
Hop-hornbeam wood	9,4
Other	18,3

Table 1. The Pordenone Mountains forest typology.



Figure 2. Typical beechwood in the study area (source: CETA).

3. DATABASE

To explore the relationship between applied vegetation index (NDVI) and biophysical variables ground forest, we collected data about weight wood and leaves in two small sampling areas (around 300m²). To define where to locate them (“G. Ceconi” forest - Vito D’Asio municipality), we studied slope and aspect conditions, in order to avoid logistic (e.g., transfer wood) or image acquisition (e.g., shadow) problems. All this work has been realised with the full concordance of Forestall Direction of Friuli-Venezia Giulia Region.

Furthermore, our test areas represent the two situations more common in this region. In fact, the first is located in a coppice-wood beech becoming a high forest and the second is in a forest of tall beech trees.

4. METHODOLOGY

The adopted methodology is subdivided in two principal stages:

1. Checking of the precision of traditional forestry methods in order to estimate the weight of the wood biomass. In forestry the standard method to evaluate the wood biomass

¹ The Pordenone Mountains District (also named Prealpi Carniche) is characterized by a sub Mediterranean climate of medium latitude: extended and wet autumns, dry and snowy winters, rainy springs and warm summers (Del Favero, 1998).

before a cutting operation (in order to define the labour charges and the possible returns) is to use the dendrometric tablet. With this, it is possible to estimate the biomass from tree height and diameter. In this stage of our research, we want to study how much this method is accurate.

2. Analysis of the correlation between NDVI and weighted wood biomass. To understand the relationship between a vegetation index (NDVI) and biomass and other biophysical variables we compared these variables in a Cartesian Graphic.

The *first stage* has been developed in the following steps:

4.1. Collection of some forestry information

The data collected are the following:

- a. Some forestry information (height and diameter of plants).
- b. Placement by GPS and repeated topographic survey;
- c. Measure of LAI (Leaf Area Index).

Some forestry information (height and diameter of plants)

We measured height (with hypsometer) and diameter (with dendrometric measure instrument) for each tree test areas. From this data we estimated forestall biomass in the classic way (by dendrometric table). We also marked those to cut (fig.3). For each test area a plan has been realised; every tree has been located and identified.



Figure 3. The measuring and marking operation (source: CETA).

Placement by GPS and repeated topographic survey

Some repeated measurements have been realized with GPS instrument (GARMIN 12 CX) to locate the two test areas. With present digital cartography and in parallel with GPS instrument, we defined in quite exact way some waypoints (Estimating Position Error – EPE: about 1,5mt). Furthermore we realised some repeated topographic surveys, using as references ground targets. For example, to locate the area test 26, we used a large piece of white cloth, easily recognizable on the satellite image (fig.6).

Measure of LAI (Leaf Area Index)

The LAI (Leaf Area Index) is commonly used to define the photosynthetic surface of a tree crown. At the same time it measures the cover degree and it can be associated with full forestry development or its primary productivity.

For each test area we measured this index with the LICOR-LAI2000 Plant Canopy Analyser. To get more data, we split a sample area (test area 26) in four subplots (NE: North East; NW: North West; SE: South East; SW: South West). It wasn't possible to do the same to the other parcel (test area 36) for two reasons: slope conditions and forestry management (high forest).

	LAI
Area test 26 NE	4,2
Area test 26 NW	4,23
Area test 26 SE	4,3
Area test 26 SW	3,97
Area test 36	4,37

Table 2. The LAI values measured in the test areas.

4.2. Cutting of all the timbers in the two training areas

In order to have a real measure of biomass present in the two small test areas, soon after the acquisition of the satellite image we cut all timbers. Trees have been cut at 0,3m of height on the trunk. All branches have been cut and divided from logs (fig.4). All trunks have been cut every 2 m (so 2,3m, 4,3m and so on), in order to transport easily all the wood outside the forest.



Figure 4. Branches divided from logs (source: CETA).

4.3. Weighing of the cut logs and of the leaves

All trunks and the secondary branches also have been weighted. At regard of leaves weighing, the procedure adopted has been quite complicated. For each area test, after the cutting operation, we have first removed all trunks and branches, and after we collected all the leaves on the large piece of cloth. We have stocked all leaves to make a parallelepiped form (fig.5) and we weight a volume evaluate indicative. From sample weight we derived the weight of foliage.

	Wood Biomass q. (Trunk + Branches)	Foliage Kg
Area test 26 NE	29	93
Area test 26 NW	35	102
Area test 26 SE	19	90
Area test 26 SW	31	60
Area test 36	178	144

Table 3. The wood biomass and foliage weighted.



Figure 5. The parallelepiped form of leaves (source: CETA).

4.4. Estimation of the wood biomass, using some different dendrometric tablets

From height and diameter of trees, we estimated the wood biomass using three different dendrometric tablets: Regional tablets (from Friuli-Venezia Giulia, FVG, and Emilia-Romagna) and Alpine table (from I.S.A.F.A. Institute – "Istituto Sperimentale per l'Assessment Forestale e per l'Apicoltura").

Wood Biomass	FVG	Emilia-Romagna	I.S.A.F.A.
Area test 26 NE	19	26	31
Area test 26 NW	23	28	34
Area test 26 SE	28	17	20
Area test 26 SW	12	16	28
Area test 36	107	131	166

Table 4. The wood biomass estimated by dendrometric tablets.

The *second stage* has been developed in the following two steps:

4.5. Acquisition of the Quickbird scene

After having located our test areas, we acquired a high-resolution satellite image. We needed this kind of information because we could cut only these small test areas. If you want to compare real wood biomass and vegetation index, you need a high-resolution image. In fact, with a Landsat7 ETM+ image (pixel resolution 30m), for example, you need at least 900 m² sampling area. For this reason we used a Quickbird image (pixel

multispectral: 2,8m) dated 24 June 2003 at 09:51 GMT centred at 46,28° N and 12,88° E (Spheroid WGS84). So we had a large number of pixels to study the vegetation index and biophysical variables correlations. This image presented a cloud cover around 5%, but these clouds didn't cover our test areas.

4.6. Pre-processing of the Quickbird scene

The acquired image has been already geometric processed (method: nearest neighbour) by reseller (www.digitalglobe.com); instead of this, we checked different location problems. In order to achieve a good result, we again rectified a small portion of the satellite data with our regional vectorial map (scale 1:5.000) and different ground targets (fig.6) as reference.

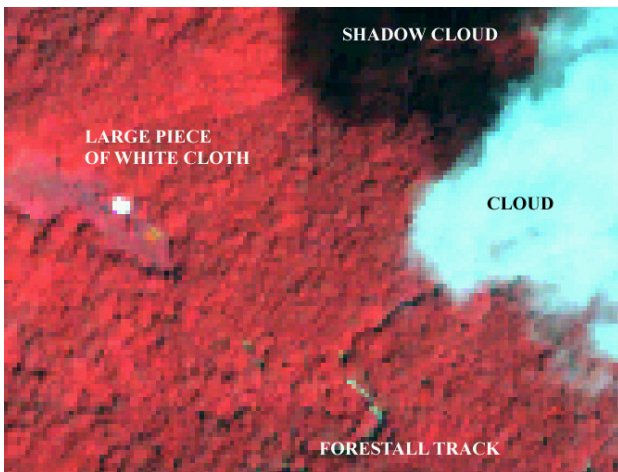


Figure 6. The large piece of white cloth from satellite (RGB composite: 432).

Moreover we applied the dark-objects method² as atmospheric correction. Finally, we applied the NDVI index as vegetation index (fig.6).

5. RESULTS

5.1. Comparison of the biomass weighted data with the tablet estimated values

The biomass weighted has been compared with the estimated (derived from dendrometric tablets) biomass. Unfortunately the sample number is very little, but it was necessary to have a low-impact on the vegetation. Previously this way of research (with real ground data by cutting operation) has been experienced only on grass sample areas (Borfecchia et al., 2001; Balzarolo et al., 2003). Cutting grass is clearly simpler than cutting trees, also for ecological effects. Having a small number of sampling, our comparisons have a very limited statistical significance, but they can provide an idea of relationship trend.

After these proper remarks, we can make some considerations from comparison between real and estimated wood biomass. In general, the dendrometric tablets tend to undervalue the real wood biomass. However, from table 3 and 4 results that the Alpine (ISAF) dendrometric table provides a good amount

² The classic dark-objects method assumes that an image has pixels whose surface reflectance is negligible (e.g., in a complete shadow), and the image pixel values of each band are subtracted by its minimum value (Liang, 2004).

information. We have to point out that, unlike the other tablet, the last has been realized using a lot of samples in all Italy, but especially in Friuli-Venezia Giulia.

5.2. Comparison between the foliage and LAI

Even if the number of sample is very small, the comparison between foliage and LAI index points out the good quality of this index to study the leaf crown (and so the maturity of forest). In fact, the R^2 correlation index reaches a value around 0,81 (fig. 7). In this case we used Kg/m^2 to normalize the area extension of test area 36 and 26 subdivided in four subplots. The same is for fig.8.

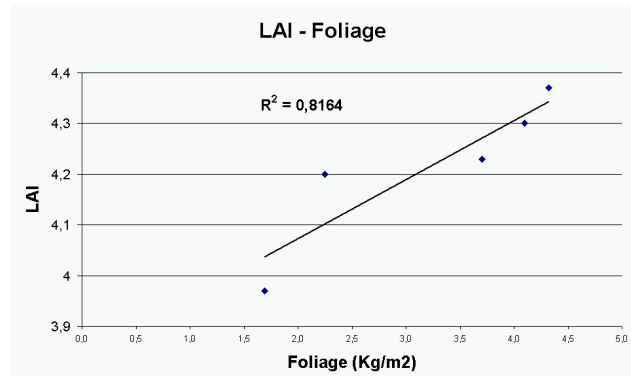


Figure 7. Correlation between LAI and Foliage.

5.3. Analysis of the correlation between LAI, Wood Biomass and NDVI values

Correlations between variables of flux process (from satellite image to forestall biomass) seem to be different. Indeed the LAI seem most sensitive to wood biomass ($R^2 = 0,75$) (fig.8) than to vegetation index ($R^2 = 0,58$) (fig.9). Obviously, all these correlations would need a larger number of samples to be checked.

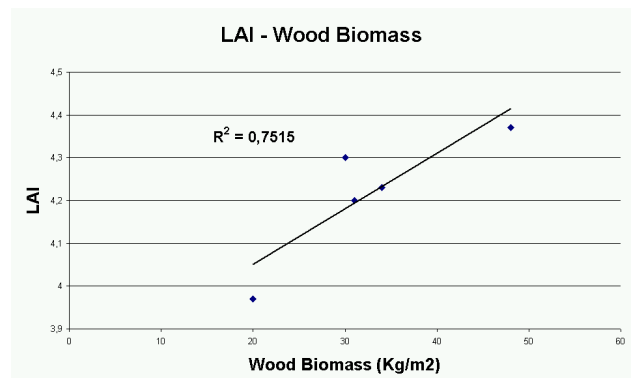


Figure 8. Correlation between LAI and wood biomass.

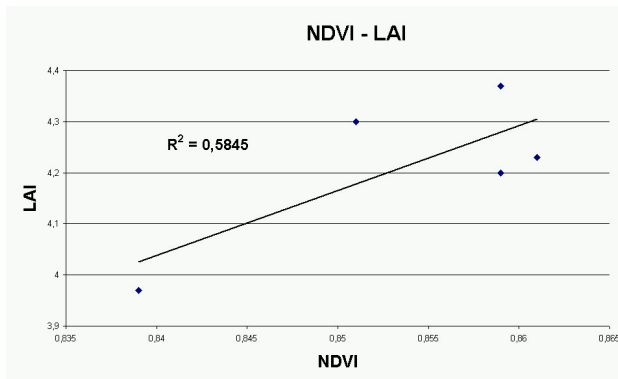


Figure 9. Correlation between LAI and NDVI.

5.4. Analysis of the correlation between NDVI values and weighted biomass data

As second step we compare NDVI values and weighted biomass data; also for this analysis we had a small number of samples. The R^2 correlation index reaches values around 0,55 when we compare the five values. This value increased till 0,745 (fig.10) when we examined also theoretical values of wood biomass derived from the application of dendrometric table, on the second area test (parcel 36).

Generally speaking, the relationship between wood biomass and NDVI is sufficiently marked, but it would need a major number of samples.

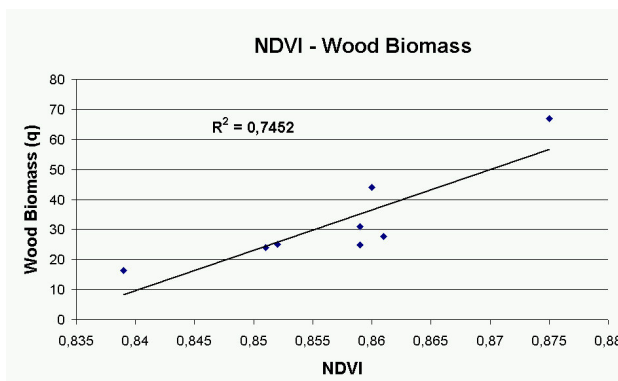


Figure 10. Correlation between wood biomass and NDVI.

6. CONCLUSIONS

In this work we got some important advancements about the different (forestry and satellite) methods of wood biomass estimation.

In fact, we could compare ground data (obtained from cutting trees in two small test areas) with by standard method (dendrometric table) of biomass estimation. Then, we found out the poor precision of traditional forestry methods. However, some instruments (Alpine dendrometric table to estimate wood biomass) and biophysical indexes (LAI to estimate canopy) showed high accuracy. In research developments, these tools can be used in order to have ground data, without ecological impact.

Then, we could verify the high sensitivity of a vegetation index (NDVI) to wood biomass. This is very important when we use the satellite imagery to define forestall biomass, because it prove the remote sensing reliability.

In spite of many troubles, satellite imagery can represent a new estimation biomass tool. In this way, we will be able to employ the natural resources in a sustainable way: so, we can to improve, for example, the forestry residuals management as energy renewable source (Favretto and Santoprete, 1994).

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