UNIVERSITÀ DEGLI STUDI FIRENZE

SCHOOL OF FORESTRY
SINCE 1869

AgriDigit

Stima spazialmente esplicita di variabili forestali inventariali tramite telerilevamento

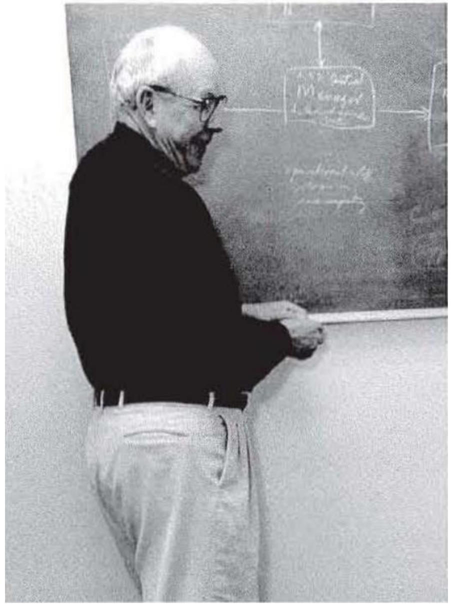
Prof. Gherardo Chirici

Dr. Walter Mattioli

geo LAB
Laboratory of Forest Geomatics

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

Dr. Daniel Goodman Horvitz
1921 - 2008



Dr. Donovan J. Thompson
1919 - 1991

A GENERALIZATION OF SAMPLING WITHOUT REPLACEMENT FROM A FINITE UNIVERSE*

D. G. HORVITZ† AND D. J. THOMPSON
Iowa State College

This paper presents a general technique for the treatment of samples drawn without replacement from finite universes when unequal selection probabilities are used. Two sampling schemes are discussed in connection with the problem of determining optimum selection probabilities according to the information available in a supplementary variable. Admittedly, these two schemes have limited application. They

with the development of more efficient sampling systems, the system including both the sample design and the method of estimation. One sampling system is said to be more efficient than another if the variance or mean square error of the estimate with the first system is less than that of the second, provided the cost of obtaining the data and results is the same for both. The development of stratified, multi-stage, multiphase, cluster, systematic, and other sample designs beyond

throughout.

The possibility of using unequal probabilities for selecting the sample elements from the universe as a means of increasing precision perhaps received its first impetus for applied sampling from Hansen and Hurwitz [2] in 1943. They introduced the selection of primary units (in a subsampling scheme) with probabilities proportionate to some measure of their size and presented the appropriate theory. Their sampling scheme was confined (when sampling without replacement) to samples of one primary unit per stratum, however, the theory not having been extended beyond this point. More recently, Midzuno [6] has generalized the Hansen and Hurwitz approach to sampling a combination of n elements of the universe with probability proportionate to some measure of size of the combination. Madow [5] has made some contributions to the theory of the systematic selection of several clusters with probability proportionate to a measure of size.

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* Journal Paper No. J 2139 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project 1005. Presented to the Institute of Mathematical Statistics, March 17, 1951.
† Now at the University of Pittsburgh.

Tabella 1.3.1 - Valori totali e per unità di superficie del volume del fusto e dei rami grossi per le categorie inventariali Boschi alti, Impianti di arboricoltura da legno e Aree temporaneamente prive di soprassuolo e per la macrocategoria Bosco

Distretto territoriale	Boschi alti				Impianti di arboricoltura da legno				Aree temp. prive di soprassuolo				Totale Bosco			
	Volume (m^3)	ES (%)	Volume (m^3 ha^{-1})	ES (%)	Volume (m^3)	ES (%)	Volume (m^3 ha^{-1})	ES (%)	Volume (m^3)	ES (%)	Volume (m^3 ha^{-1})	ES (%)	Volume (m^3)	ES (%)	Volume (m^3 ha^{-1})	ES (%)
Piemonte	126 821 547	3.1	151.0	2.9	2 947 269	15.7	103.2	12.7	7 613	60.2	3.3	45.9	129 776 430	3.0	149.1	2.8
Valle d'Aosta	15 334 302	7.6	156.0	6.9	0	-	0	-	0	-	0	-	15 334 302	7.6	155.8	6.9
Lombardia	105 423 629	4.2	182.4	3.9	2 613 095	19.6	97.4	17.8	0	-	0	-	108 036 723	4.1	178.3	3.9
Alto Adige	104 721 523	4.6	315.0	4.3	0	-	0	-	467 004	31.4	109.6	14.7	105 188 527	4.6	312.4	4.3
Trentino	105 715 538	4.8	283.5	4.6	0	-	0	-	61 011	97.3	24.2	89.8	105 776 549	4.7	281.8	4.6
Veneto	80 931 420	4.6	204.7	4.2	260 012	45.4	124.4	25.6	4 529	100.0	13.4	-	81 195 960	4.6	204.1	4.2
Friuli V.G.	67 066 949	5.4	212.1	5.1	763 052	26.8	100.3	18.7	0	-	0	-	67 830 001	5.3	209.5	5.0
Liguria	49 379 829	4.5	147.3	4.3	39 233	100.0	107.1	-	19 730	56.8	5.7	49.0	49 438 791	4.5	145.8	4.3
Emilia Romagna	71 063 339	3.9	128.7	3.7	1 274 428	20.6	130.8	13.1	356	72.6	0.3	53.7	72 338 122	3.9	128.4	3.6
Toscana	130 873 621	3.1	129.9	3.0	1 042 114	43.2	189.7	34.7	40 250	66.0	15.6	60.5	131 955 985	3.1	129.9	2.9
Umbria	29 142 004	4.8	79.2	4.6	112 665	55.0	33.3	44.6	0	-	0	-	29 254 669	4.8	78.7	4.6
Marche	24 231 008	6.6	83.5	6.3	62 614	66.5	51.6	41.1	0	-	0	-	24 293 622	6.6	83.4	6.3
Lazio	57 249 600	4.7	107.0	4.4	180 483	66.2	105.9	46.5	80 552	46.9	11.1	41.4	57 510 635	4.6	105.7	4.4
Abruzzo	50 404 587	4.6	129.5	4.4	87 051	71.8	77.5	42.2	1 193	100.0	1.0	-	50 492 831	4.6	129.0	4.4
Molise	14 523 394	9.0	110.5	8.5	106 992	93.1	120.0	54.1	5 598	100.0	22.4	-	14 635 984	8.9	110.4	8.4
Campania	42 353 904	6.0	111.5	5.7	112 595	48.3	97.4	42.7	36 194	59.6	11.2	49.3	42 502 693	6.0	110.6	5.7
Puglia	12 046 337	11.0	84.2	10.5	108 303	95.5	123.5	66.4	5 844	100.0	3.0	-	12 160 485	10.9	83.4	10.4
Basilicata	27 415 389	6.9	106.3	6.5	230 731	46.0	123.8	11.1	15 086	73.0	4.6	64.8	27 661 206	6.9	105.1	6.4
Calabria	86 990 394	4.7	190.0	4.3	706 558	54.8	267.7	39.2	270 501	57.0	35.5	53.1	87 967 454	4.7	187.9	4.3
Sicilia	23 125 002	6.7	91.2	6.1	56 190	95.7	49.4	76.4	1 605	86.9	1.1	70.6	23 182 797	6.7	90.5	6.1
Sardegna	31 286 179	5.8	57.1	5.4	1 543 109	22.2	60.4	20.0	53 445	56.1	5.6	53.1	32 882 733	5.6	56.4	5.2
Italia	1 256 099 493	1.1	146.4	1.0	12 246 493	8.7	100.2	7.4	1 070 512	21.4	19.8	20.0	1 269 416 499	1.1	144.9	1.0

Number of satellites	Purpose
3135	Communications
1030	Earth Observation
385	Technology development/demonstration
154	Navigation/positioning
22	Earth science
18	Other purposes

Copernicus
Europe's eyes on Earth

EU budget: A €16 billion Space Programme to boost EU space leadership beyond 2020

Space sector employs over **231.000** people

Its value is estimated at **€ 53-62** billion in 2017, 2nd largest in the world

A third of the world's satellites are made in Europe.

Sector keeps upgrading family of European launchers with next generation **Ariane 6** and **Vega C**.

PROGRAMME OF THE EUROPEAN UNION

Copernicus
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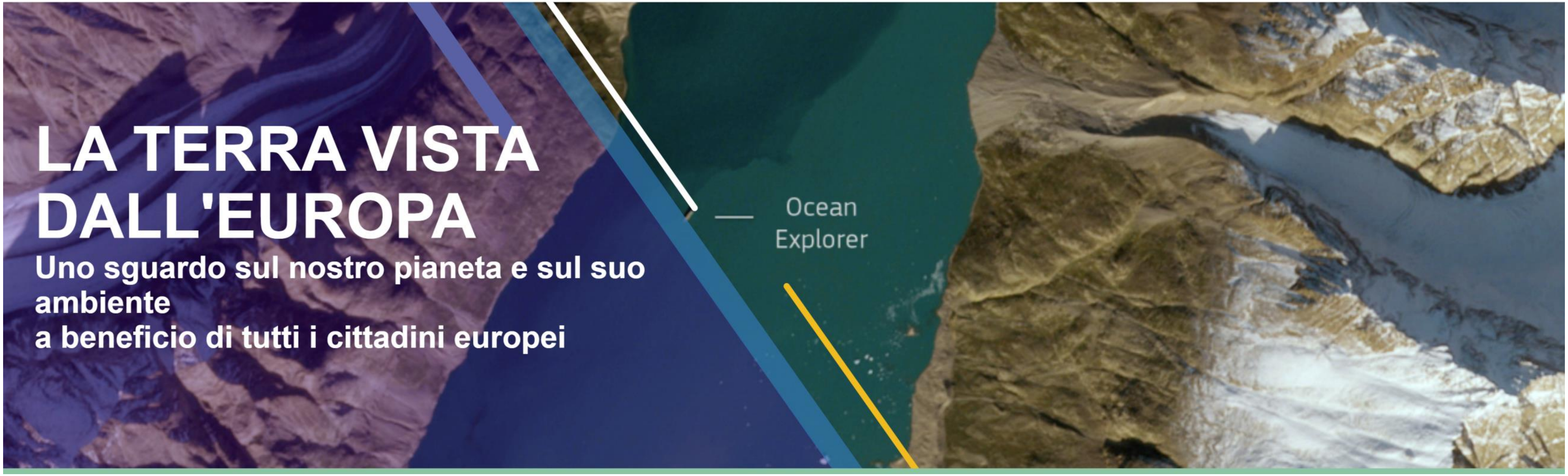

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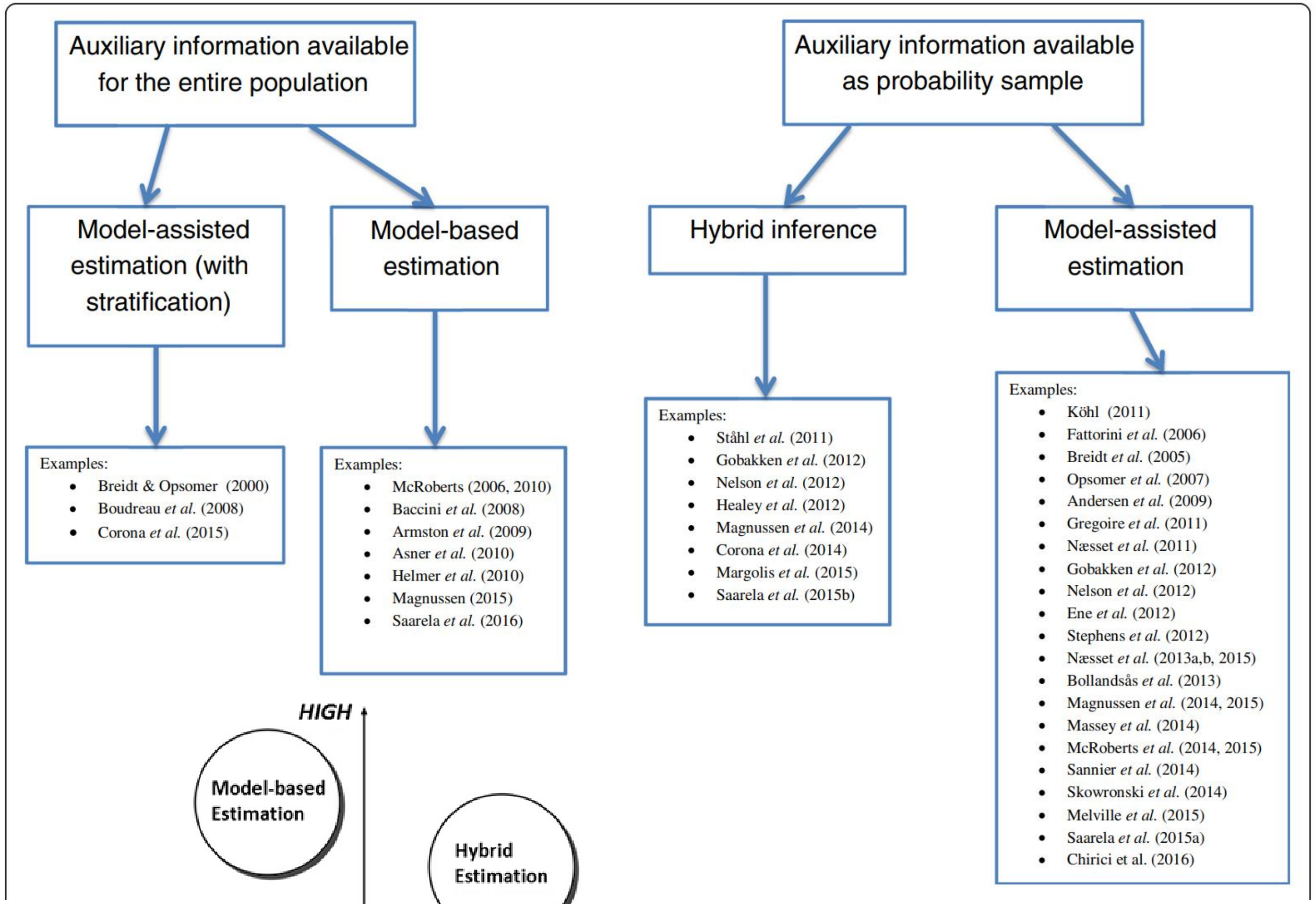
In NFIs Remote sensing contributed:

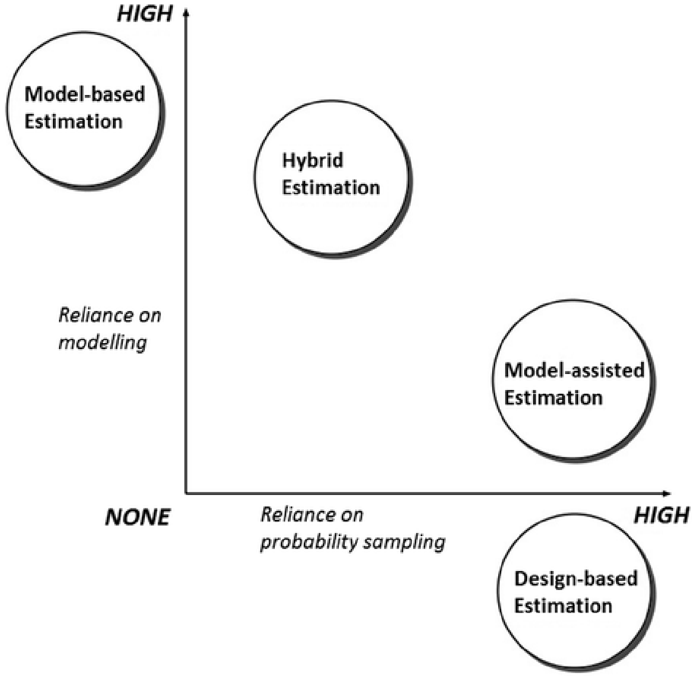
- To the production of more timely, cost efficient, and precise **traditional inventory estimates**

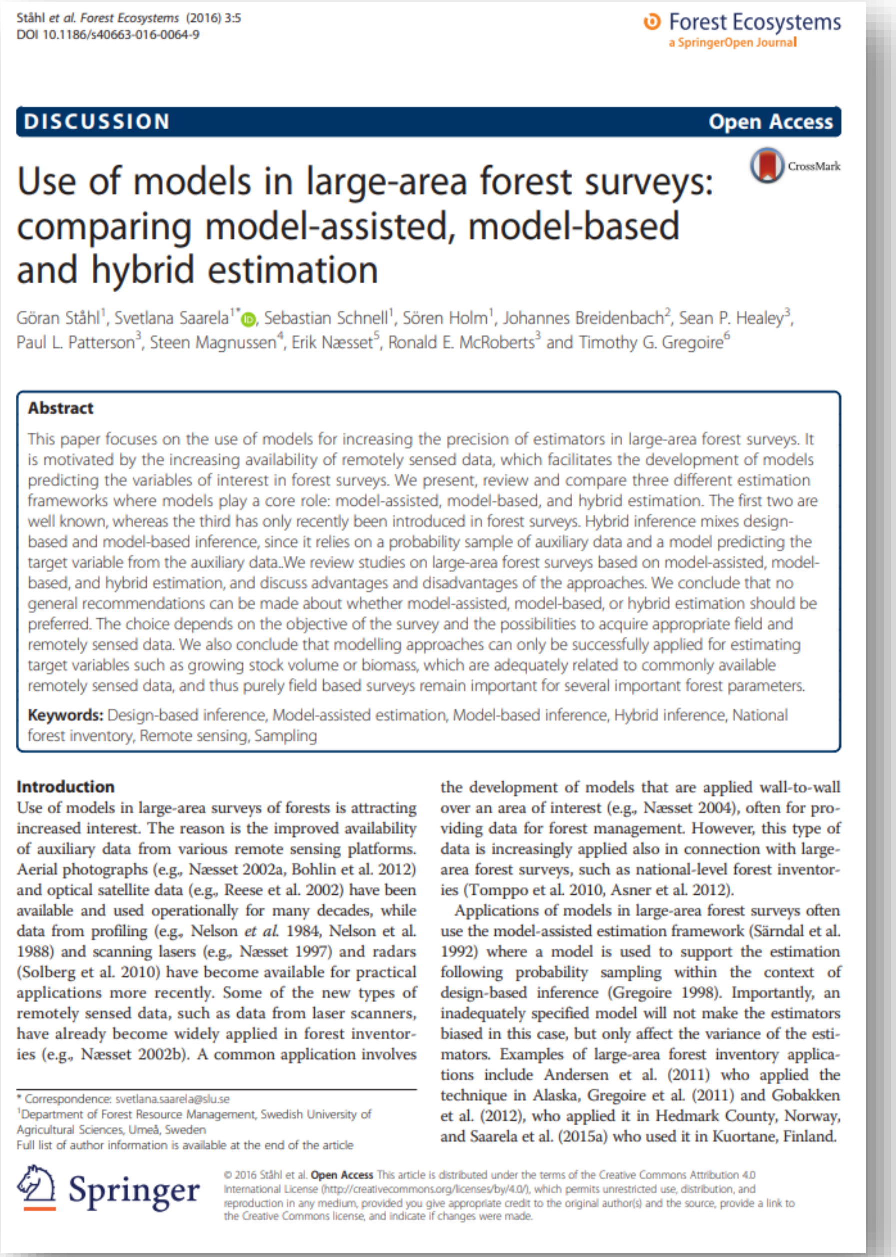
- To derive **new spatial products** (maps, small area estimates)

Technologies that are now on the horizon have the potential to alter radically the ways in which trees are measured,estimates are produced, and products are delivered.

The **lack** of standardized, spatially exhaustive **open access datasets**, as well as community consensus on methods and best practices limits the broader uptake and operationalization of these approaches







Ståhl et al. Forest Ecosystems (2016) 3:5
DOI 10.1186/s40663-016-0064-9

Forest Ecosystems
a SpringerOpen Journal

DISCUSSION **Open Access**

Use of models in large-area forest surveys: comparing model-assisted, model-based and hybrid estimation

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Abstract

This paper focuses on the use of models for increasing the precision of estimators in large-area forest surveys. It is motivated by the increasing availability of remotely sensed data, which facilitates the development of models predicting the variables of interest in forest surveys. We present, review and compare three different estimation frameworks where models play a core role: model-assisted, model-based, and hybrid estimation. The first two are well known, whereas the third has only recently been introduced in forest surveys. Hybrid inference mixes design-based and model-based inference, since it relies on a probability sample of auxiliary data and a model predicting the target variable from the auxiliary data..We review studies on large-area forest surveys based on model-assisted, model-based, and hybrid estimation, and discuss advantages and disadvantages of the approaches. We conclude that no general recommendations can be made about whether model-assisted, model-based, or hybrid estimation should be preferred. The choice depends on the objective of the survey and the possibilities to acquire appropriate field and remotely sensed data. We also conclude that modelling approaches can only be successfully applied for estimating target variables such as growing stock volume or biomass, which are adequately related to commonly available remotely sensed data, and thus purely field based surveys remain important for several important forest parameters.

Keywords: Design-based inference, Model-assisted estimation, Model-based inference, Hybrid inference, National forest inventory, Remote sensing, Sampling

Introduction

Use of models in large-area surveys of forests is attracting increased interest. The reason is the improved availability of auxiliary data from various remote sensing platforms. Aerial photographs (e.g., Næsset 2002a, Bohlin et al. 2012) and optical satellite data (e.g., Reese et al. 2002) have been available and used operationally for many decades, while data from profiling (e.g., Nelson et al. 1984, Nelson et al. 1988) and scanning lasers (e.g., Næsset 1997) and radars (Solberg et al. 2010) have become available for practical applications more recently. Some of the new types of remotely sensed data, such as data from laser scanners, have already become widely applied in forest inventories (e.g., Næsset 2002b). A common application involves the development of models that are applied wall-to-wall over an area of interest (e.g., Næsset 2004), often for providing data for forest management. However, this type of data is increasingly applied also in connection with large-area forest surveys, such as national-level forest inventories (Tomppo et al. 2010, Asner et al. 2012).

Applications of models in large-area forest surveys often use the model-assisted estimation framework (Särndal et al. 1992) where a model is used to support the estimation following probability sampling within the context of design-based inference (Gregoire 1998). Importantly, an inadequately specified model will not make the estimators biased in this case, but only affect the variance of the estimators. Examples of large-area forest inventory applications include Andersen et al. (2011) who applied the technique in Alaska, Gregoire et al. (2011) and Gobakken et al. (2012), who applied it in Hedmark County, Norway, and Saarela et al. (2015a) who used it in Kuortane, Finland.

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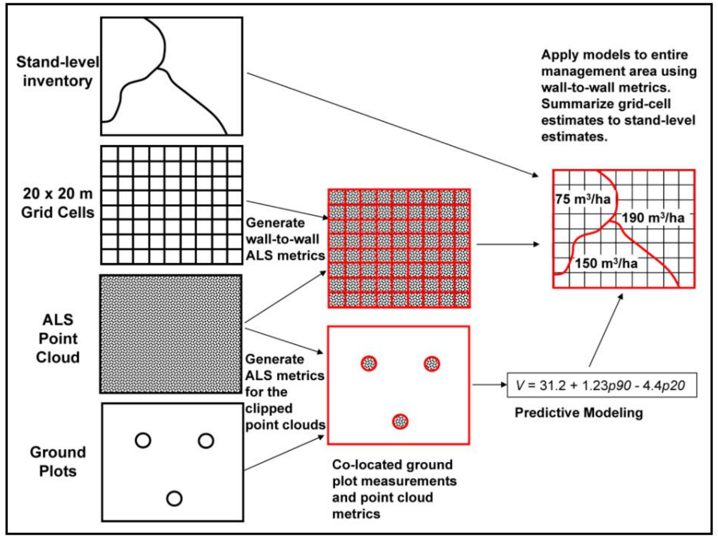


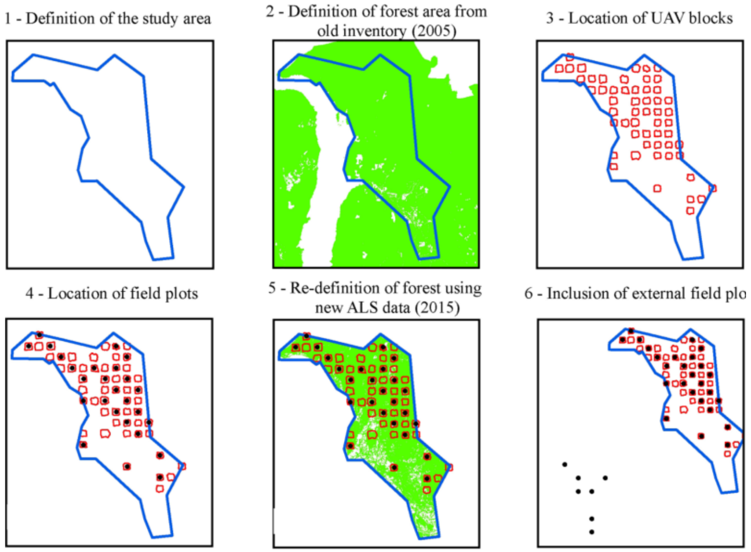
White et al., 2013. The Utility of Image-Based Point Clouds for Forest Inventory: A Comparison with Airborne Laser Scanning. https://doi.org/10.3390/f4030518

Data assimilation/data integration

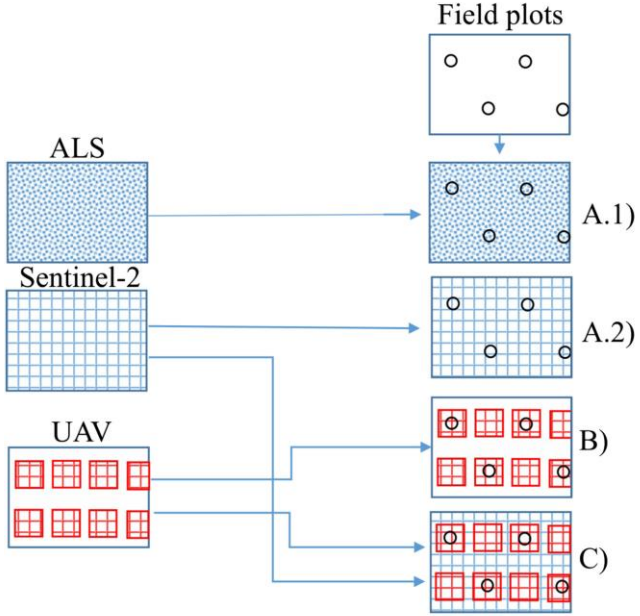
How to integrate multiple input data from multiple sources?

We just have to choice!

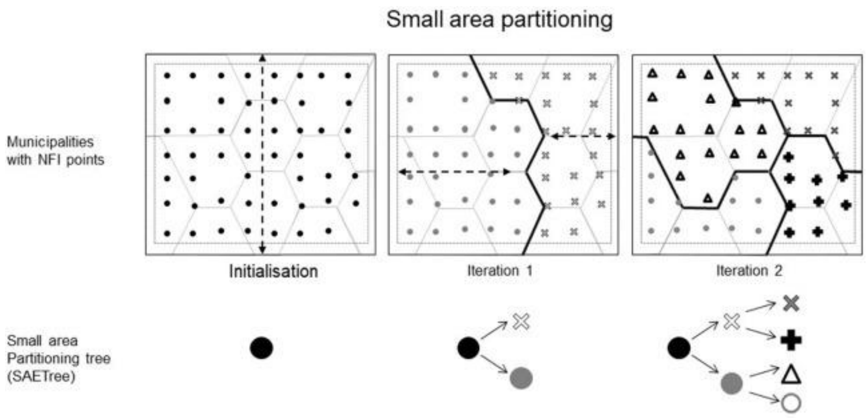
UAV->LiDAR->SATELLITE->NFI



Puliti et al., 2017
Use of partial-coverage UAV data in sampling for large scale forest inventories.
https://doi.org/10.1016/j.rse.2017.03.019



Puliti S, Saarela S, et al., 2018
Combining UAV and Sentinel-2 auxiliary data for forest growing stock volume estimation through hierarchical model-based inference
https://doi.org/10.1016/j.rse.2017.10.007



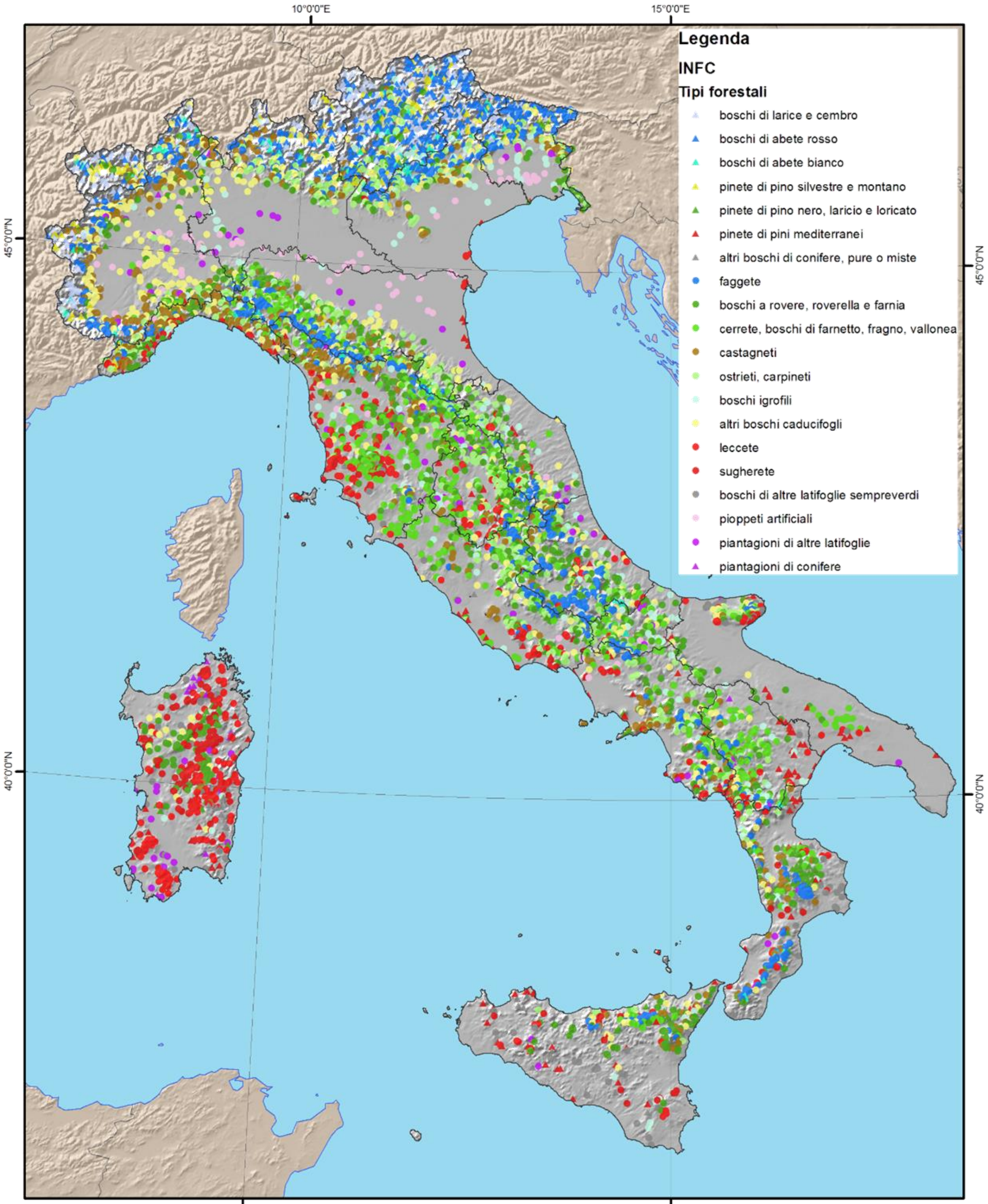
Vega et al., 2021
A new small area estimation algorithm to balance between statistical precision and scale
https://doi.org/10.1016/j.jag.2021.102303


Colocated Data + Computation + APIs

I risultati del progetto AGRIDIGIT

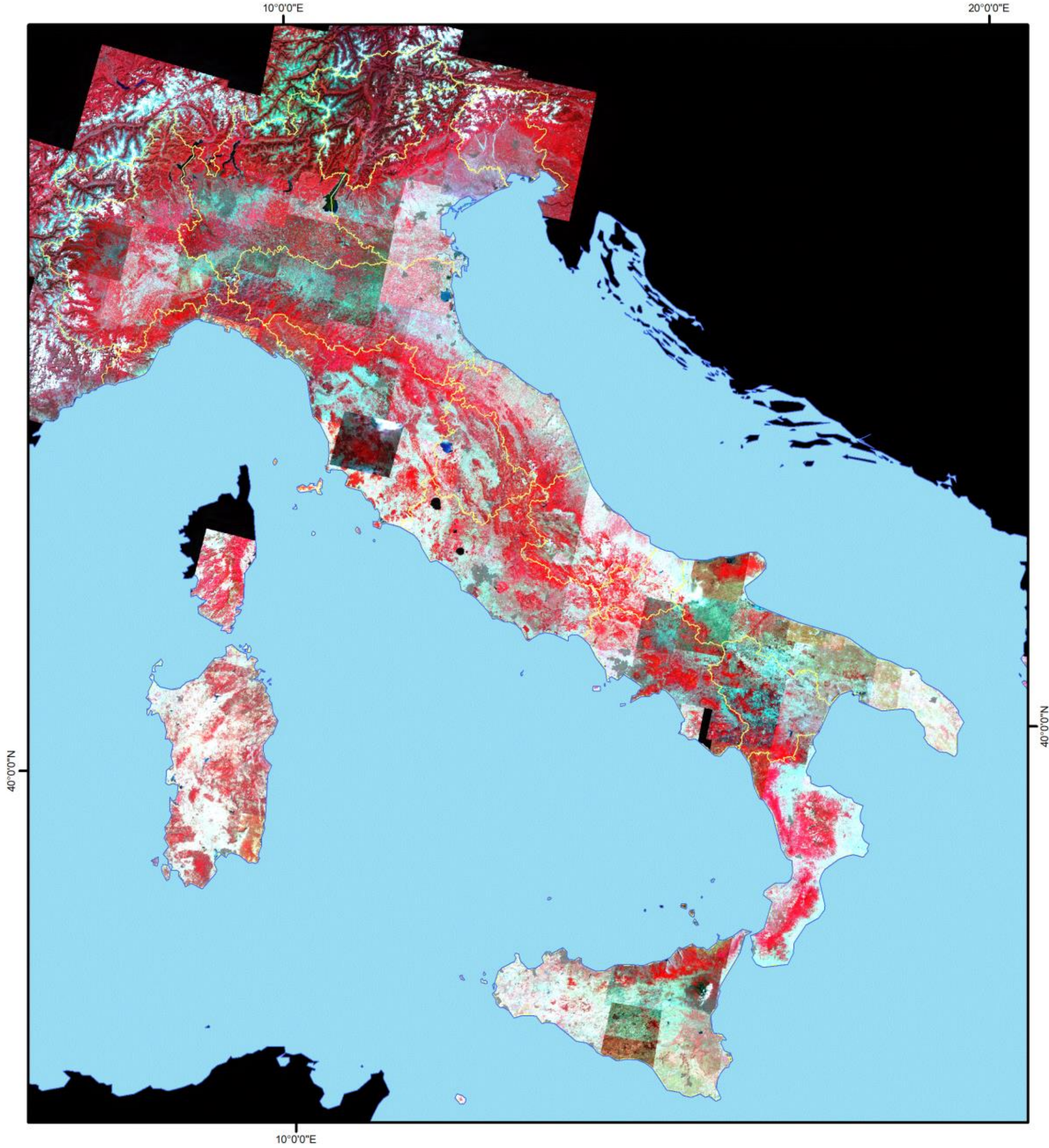
dalla ricerca all'applicazione

stima spazialmente esplicita di variabili forestali



Il problema dei dati di input

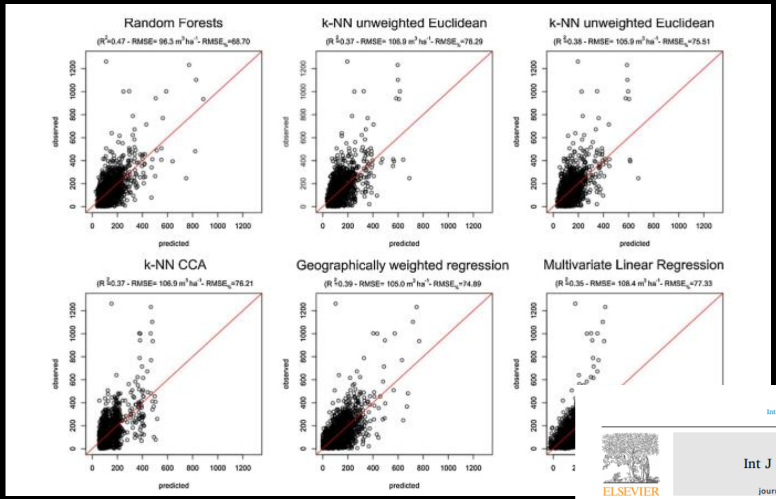
Con algoritmi di intelligenza artificiale è possibile spazializzare con immagini telerilevate e altri strati informativi geografici il dato osservato nelle aree di saggio a terra INFC

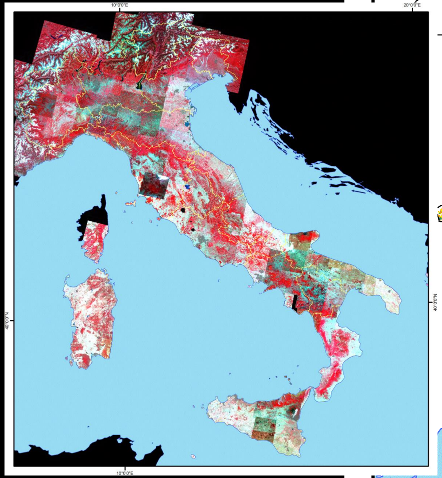


Esempio di applicazione sul dato INFC2005

National application

LOO $R^2 = 0.61$ and RMSE $\cong 52\ m^3ha^{-1}$





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Wall-to-wall spatial prediction of growing stock volume based on Italian National Forest Inventory plots and remotely sensed data

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ARTICLE INFO

Keywords:
National Forest Inventory
Spatial estimation
Growing stock
Landsat
Italy
Growing stock volume

ABSTRACT

Spatial predictions of forest variables are required for supporting modern national and sub-national forest planning strategies, especially in the framework of a climate change scenario. Nowadays methods for constructing wall-to-wall maps and calculating small-area estimates of forest parameters are becoming essential components of most advanced National Forest Inventory (NFI) programs. Such methods are based on the assumption of a relationship between the forest variables and predictor variables that are available for the entire forest area. Many commonly used predictors are based on data obtained from active or passive remote sensing technologies. Italy has almost 40% of its land area covered by forests. Because of the great diversity of Italian forests with respect to composition, structure and management and underlying climatic, morphological and soil conditions, a relevant question is whether methods successfully used in less complex temperate and boreal forests may be applied successfully at country level in Italy.

For a study area of more than 48,657 km^2 in central Italy of which 43% is covered by forest, the study presents the results of a test regarding wall-to-wall, spatially explicit estimation of forest growing stock volume (GSV) based on field measurement of 1350 plots during the last Italian NFI. For the same area, we used potential predictor variables that are available across the whole of Italy: cloud-free mosaics of multispectral optical satellite imagery (Landsat 5 TM), microwave sensor data (JAXA PALSAR), a canopy height model (CHM) from satellite LiDAR, and auxiliary variables from climate, temperature and precipitation maps, soil maps, and a digital terrain model.

Two non-parametric (random forests and k-NN) and two parametric (multiple linear regression and geographically weighted regression) prediction methods were tested to produce wall-to-wall map of growing stock volume at 23-m resolution. Pixel level predictions were used to produce small-area, province-level model-assisted estimates. The performances of all the methods were compared in terms of percent root mean-square error using a leave-one-out procedure and an independent dataset was used for validation. Results were comparable to those available for other ecological regions using similar predictors, but random forests produced the most accurate results with a pixel level $R^2 = 0.69$ and $RMSE_{\%} = 37.2\%$ against the independent validation dataset. Model-assisted estimates were more precise than the original design-based estimates provided by the NFI.

1. Introduction

Forest data are essential for multiple purposes including international and national forest monitoring programs, reporting and assessing forest resource distribution (e.g. Kyoto protocol) (Corona et al., 2011; FAO, 2010), monitoring biodiversity (Chirici et al., 2012; FOREST EUROPE, 2015), improving restoration programs (FAO and UNCCD, 2015; Smith et al., 2016) and managing at local scales to improve decision-making processes, silvicultural measures, harvesting and conservation activities.

Usually, in the context of international and national programs, this type of data is collected using sample-based National Forest Inventories (NFIs) that are designed to provide aggregated estimates of forest parameters such as forest area, growing stock volume, biomass, increments at national and regional levels (Brosofske et al., 2014; Kangas et al., 2018). These aggregated statistics are essential to support decision-making processes and to develop strategies over large areas only, because they just provide limited explicit geographic spatial detail, such as large sub-national regions. In these traditional NFIs, remote sensing is used for purposes such as initial stratification of sampling units

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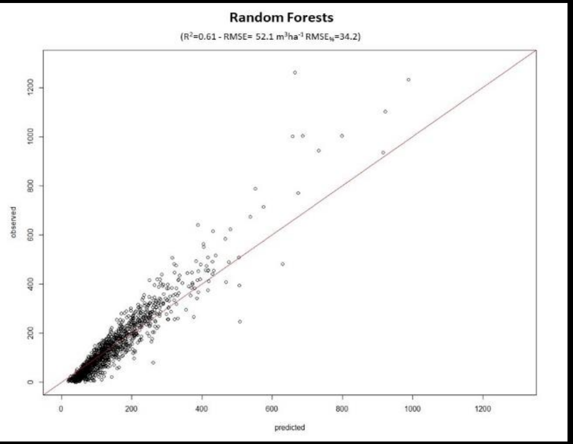

forests

MDPI

Article

Wall-to-Wall Mapping of Forest Biomass and Wood Volume Increment in Italy

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5 Department for Innovation in Biological, Agri-Food and Forestry Systems, University of Tuscia, 01100 Viterbo, Italy
6 Council for Agricultural Research and Economics, Research Centre for Forestry and Wood (CREA), 52100 Arezzo, Italy
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Abstract: Several political initiatives aim to achieve net-zero emissions by the middle of the twenty-first century. In this context, forests are crucial as a carbon sink to store unavoidable emissions. Assessing the carbon sequestration potential of forest ecosystems is pivotal to the availability of accurate forest variable estimates for supporting international reporting and appropriate forest management strategies. Spatially explicit estimates are even more important for Mediterranean countries such as Italy, where the capacity of forests to act as sinks is decreasing due to climate change. This study aimed to develop a spatial approach to obtain high-resolution maps of Italian forest above-ground biomass (ITA-BIO) and current annual volume increment (ITA-CAI), based on remotely sensed and meteorological data. The ITA-BIO estimates were compared with those obtained with two available biomass maps developed in the framework of two international projects (i.e., the Joint Research Center and the European Space Agency biomass maps, namely, JRC-BIO and ESA-BIO). The estimates from ITA-BIO, JRC-BIO, ESA-BIO, and ITA-CAI were compared with the 2nd Italian NFI (INFC) official estimates at regional level (NUT2). The estimates from ITA-BIO are in good agreement with the INFC estimates (R^2 = 0.95, mean difference = 3.8 t ha^{-1}), while for JRC-BIO and ESA-BIO, the estimates show R^2 of 0.90 and 0.70, respectively, and mean differences of 13.5 and of 21.8 t ha^{-1} with respect to the INFC estimates. ITA-CAI estimates are also in good agreement with the INFC estimates (R^2 = 0.93), even if they tend to be slightly biased. The produced maps are hosted on a web-based forest resources management Decision Support System developed under the project AGRIDIGIT (ForestView) and represent a key element in supporting the new Green Deal in Italy, the European Forest Strategy 2030 and the Italian Forest Strategy.

Keywords: forest biomass; National Forest Inventories; remote sensing; Mediterranean forest; forest increment

Citation: Giannetti, F.; Chirici, G.; Vangi, E.; Corona, P.; Maselli, F.; Chiesi, M.; D'Amico, G.; Puletti, N. Wall-to-Wall Mapping of Forest Biomass and Wood Volume Increment in Italy. *Forests* 2022, *13*, 1989. https://doi.org/10.3390/f13121989

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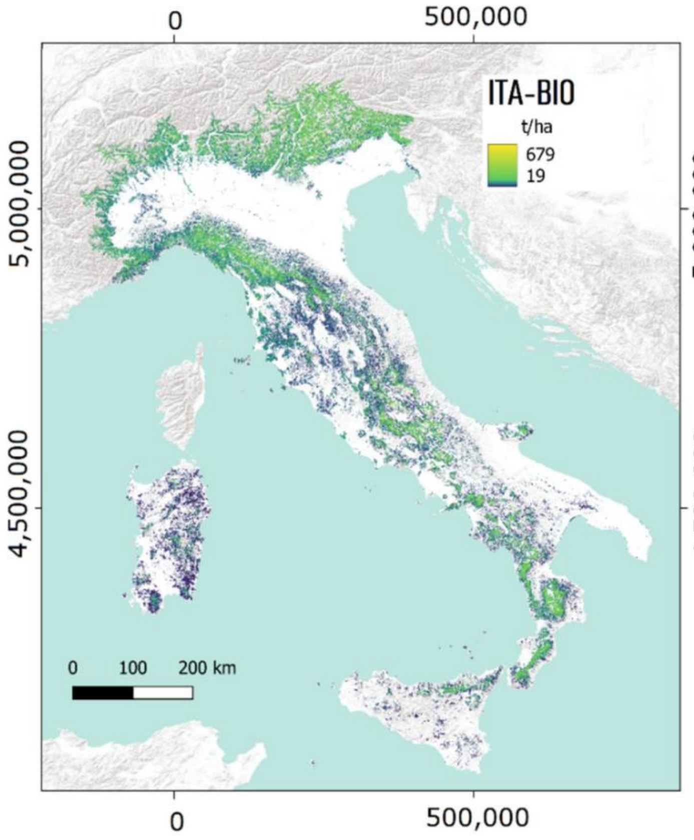
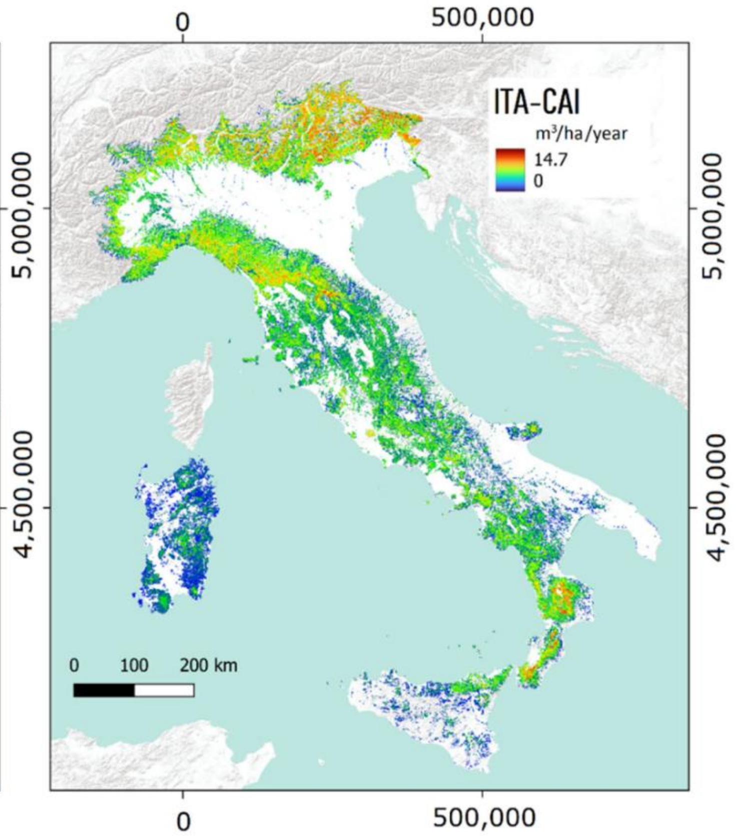
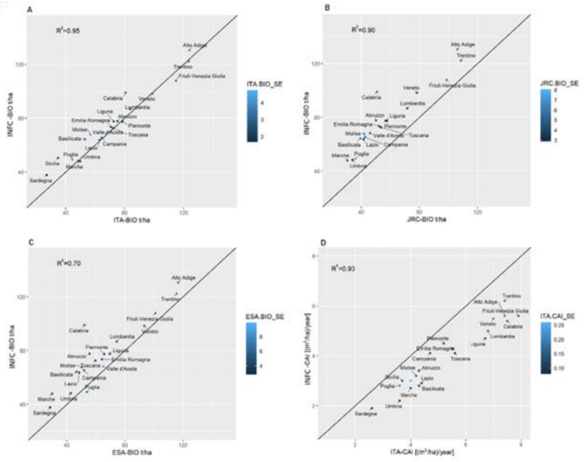
Accepted: 20 November 2022
Published: 24 November 2022

1. Introduction

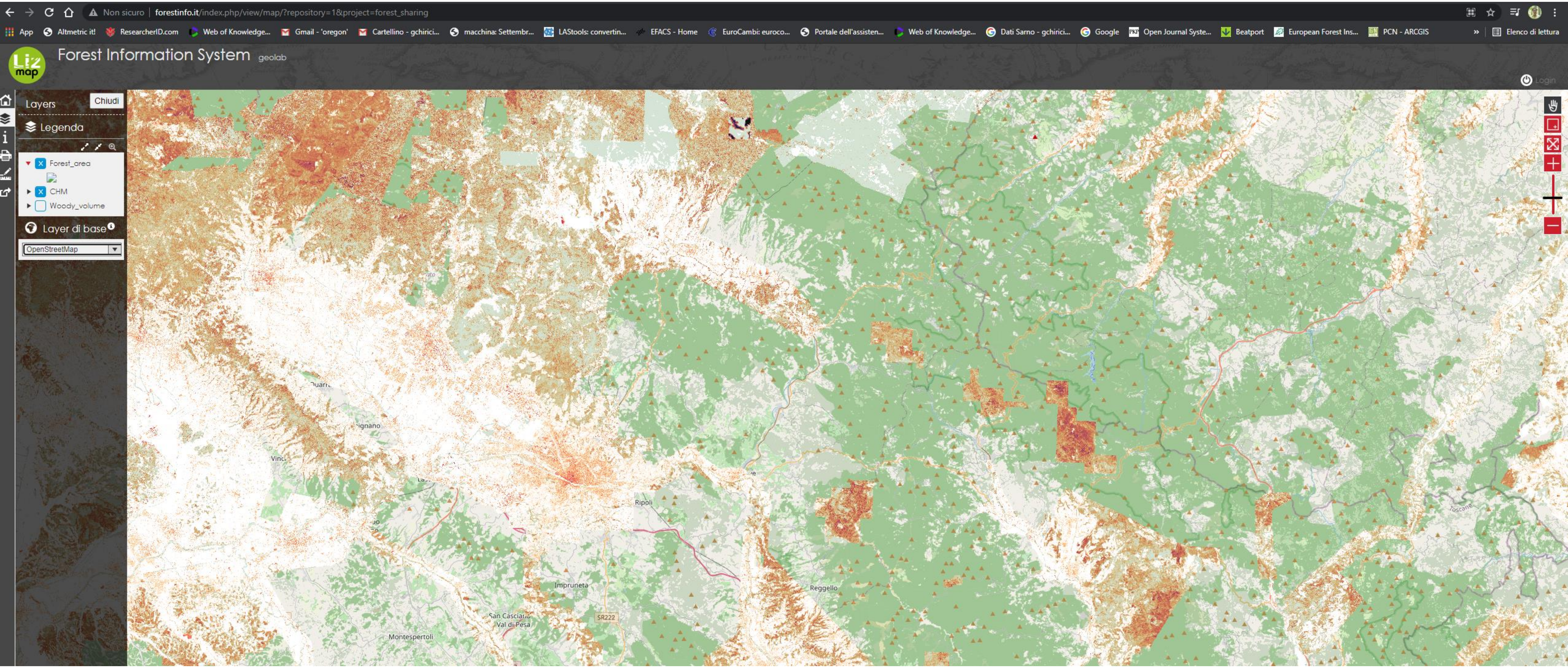
Measuring the amount of CO_2 stocked in forest ecosystems is mandatory to support the new European (EU) Forest Strategy for 2030, a flagship initiative of the European Green Deal, in sight of achieving neutrality with respect to greenhouse gas emission in







Le mappe derivanti dalla spazializzazione possono essere facilmente condivise on line
Senza dover condividere la posizione geografica precisa delle aree di saggio



http://forestinfo.it/

Remote Sensing of Environment 209 (2018) 90–106

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Large-area mapping of Canadian boreal forest cover, height, biomass and other structural attributes using Landsat composites and lidar plots

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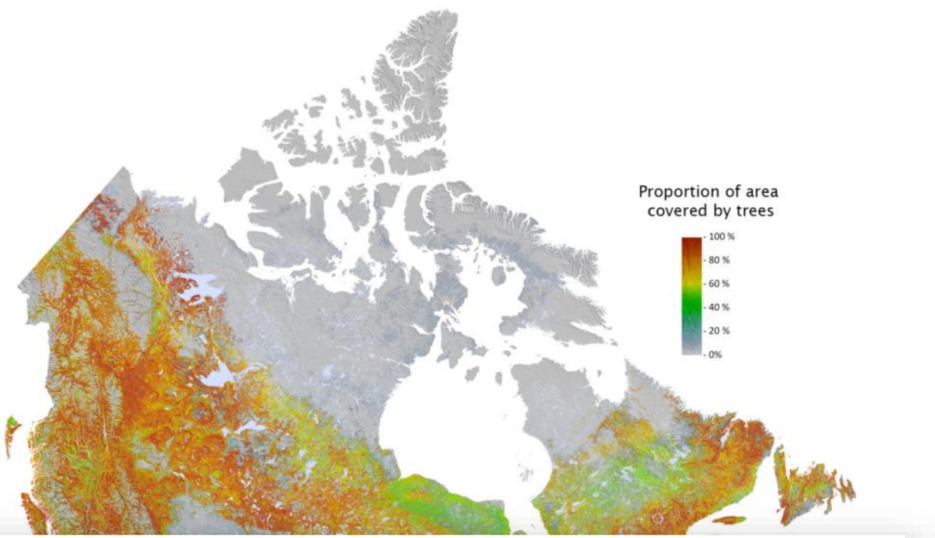
ABSTRACT

Passive optical remotely sensed images such as those from the L
spatially comprehensive, well-calibrated reflectance measures that
as an alternative to field plot data, the use of Light Detection and Ra
validation purposes in combination with such satellite reflectance
response variables has become well established. In this research, w
forest structural attributes over the ~552 million ha boreal fores
dependent validation we utilize airborne lidar-derived measuremen
plots) obtained in 2010 via a > 25,000 km transect-based national
lidar plot structural variables to wall-to-wall 30-m spatial resolution



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Remote Sensing Technologies for Enhancing Forest Inventories: A Review

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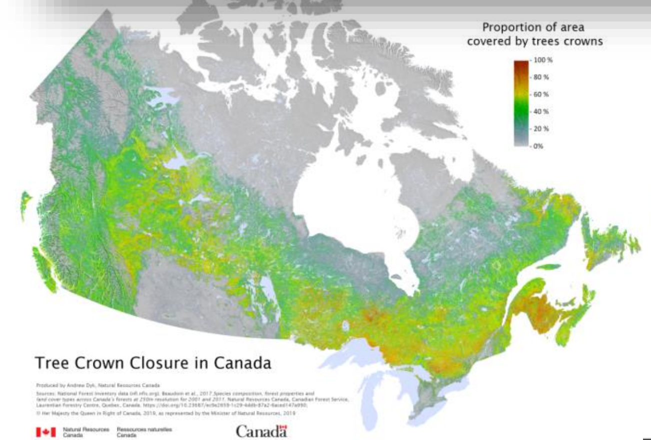
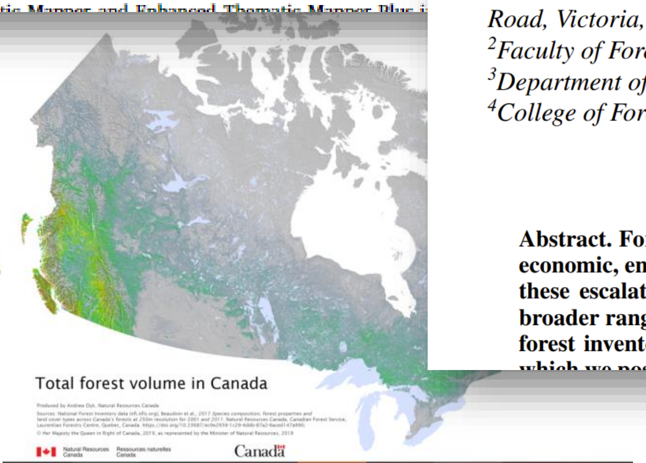
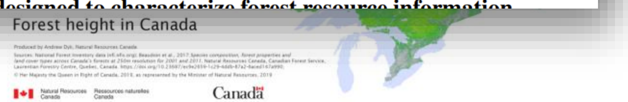
Abstract. Forest inventory and management requirements are changing rapidly in the context of an increasingly complex set of economic, environmental, and social policy objectives. Advanced remote sensing technologies provide data to assist in addressing these escalating information needs and to support the subsequent development and parameterization of models for an even broader range of information needs. This special issue contains papers that use a variety of remote sensing technologies to derive forest inventory or inventory-related information. Herein, we review the potential of 4 advanced remote sensing technologies,





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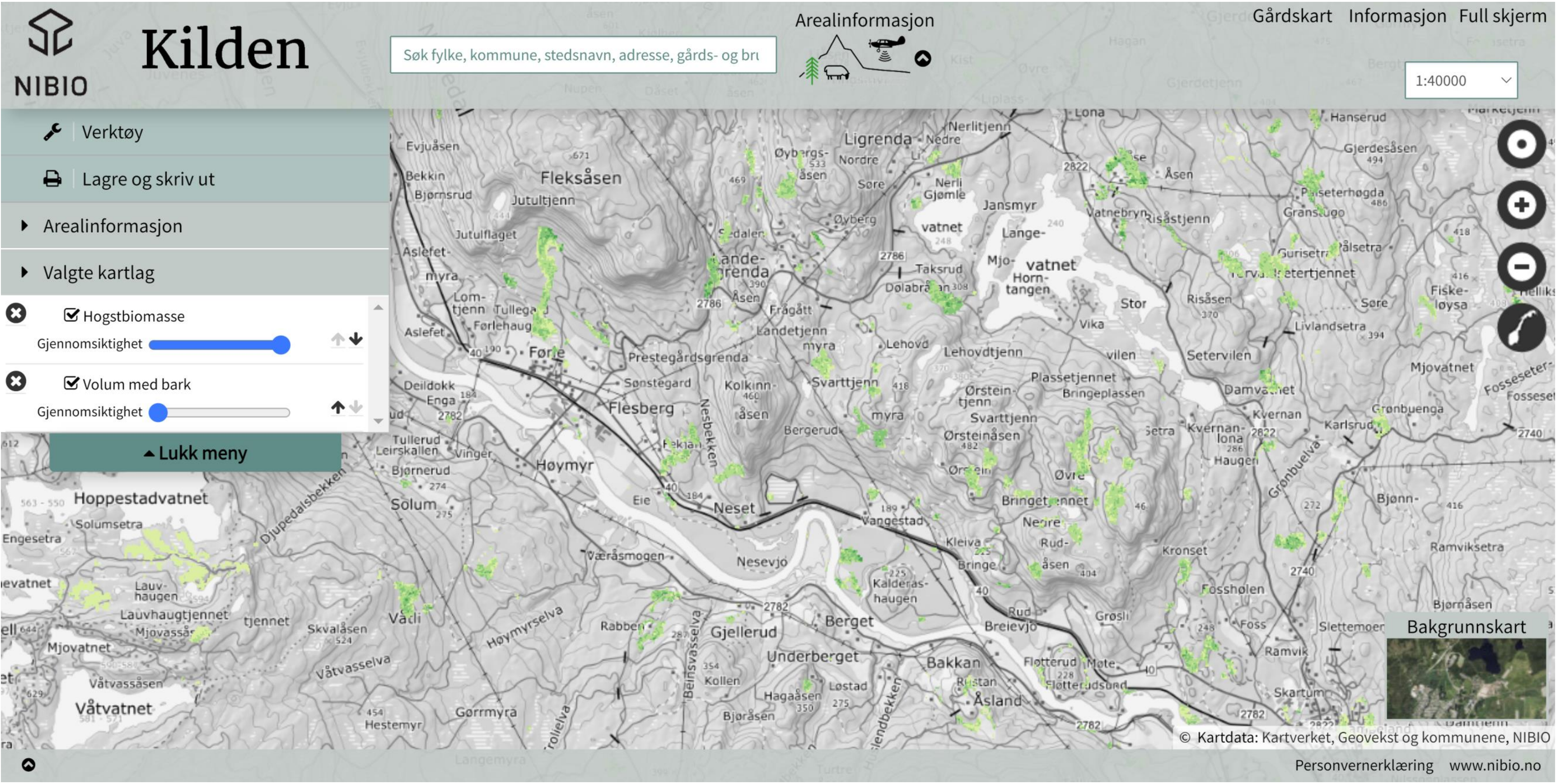
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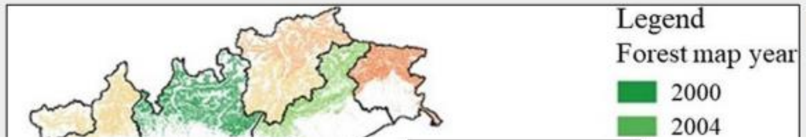
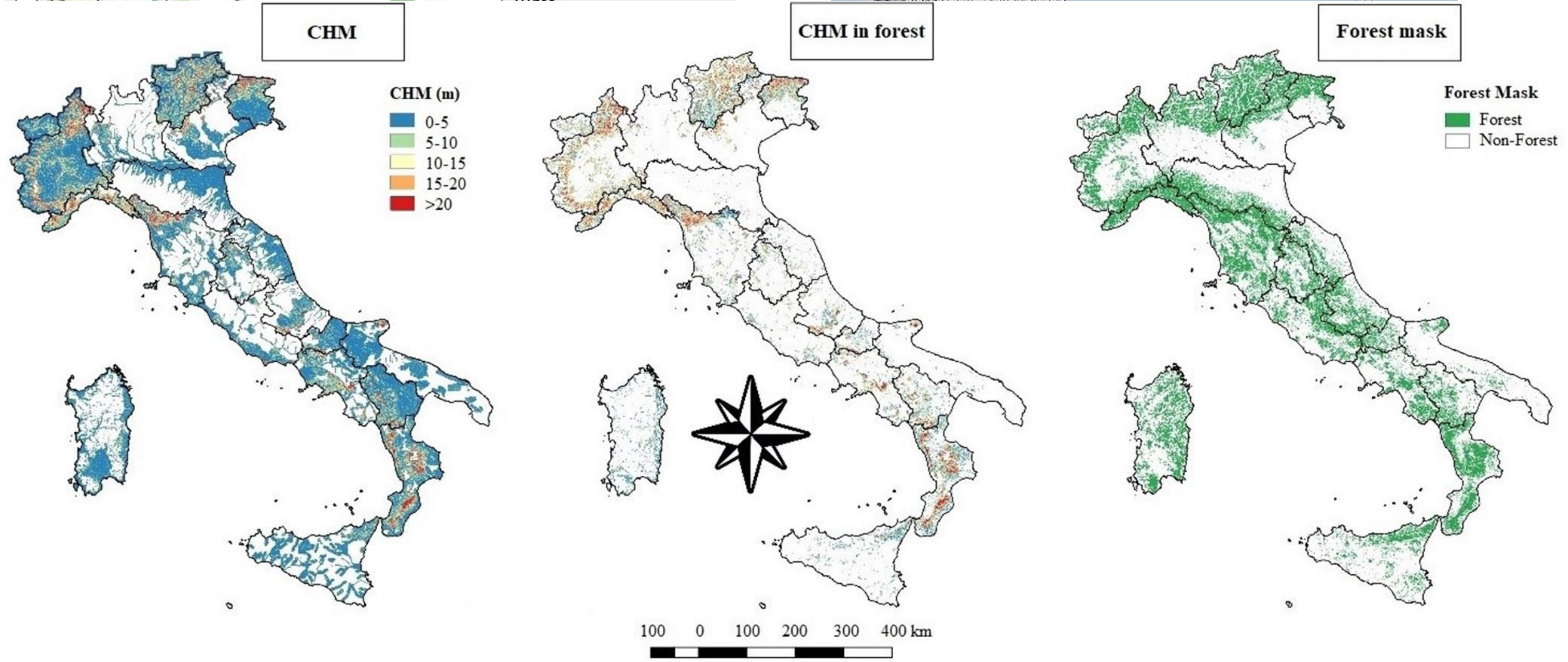
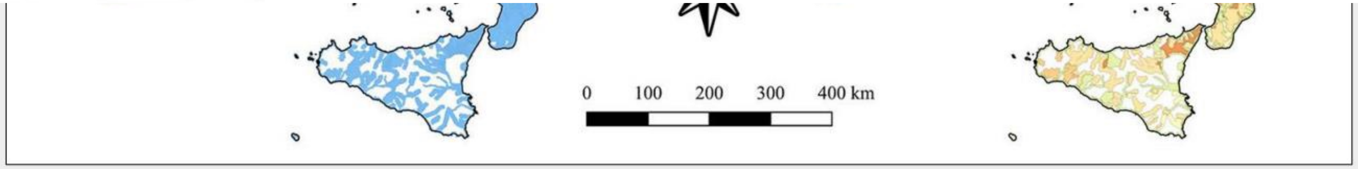
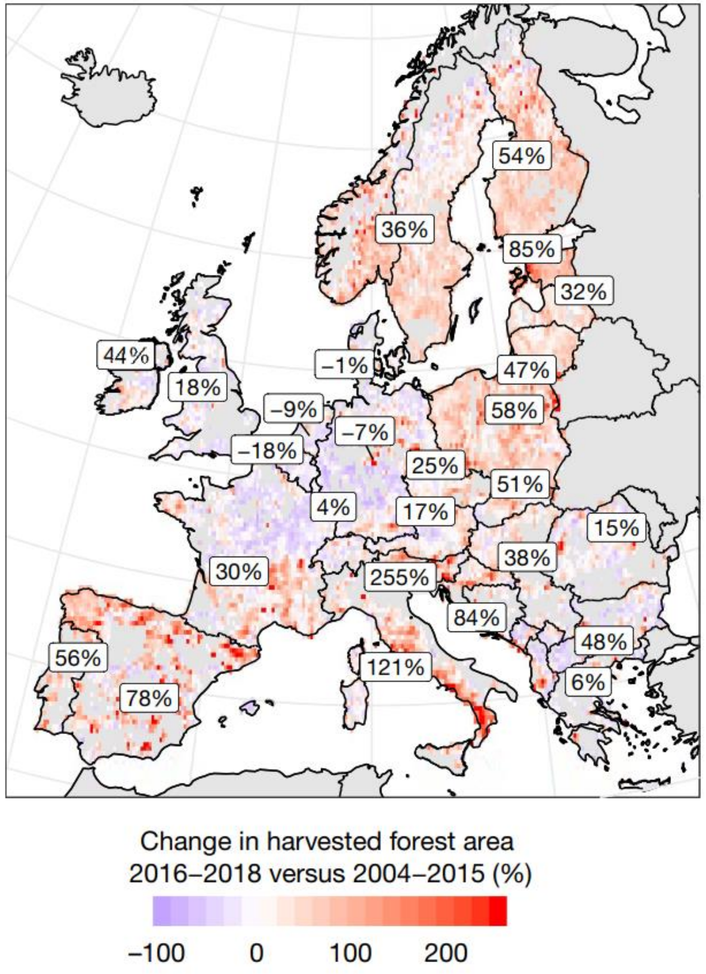


Fig. 1 - Acquisition year of local maps used to create the high resolution forest mask







Article

Abrupt increase in harvested forest area over Europe after 2015

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Check for updates

Guido Ceccherini[1]✉, Gregory Duveiller[1], Giacomo Grassi[1], Guido Lemoine[2], Valerio Avitabile[1], Roberto Pilli[1] & Alessandro Cescatti[1]

Forests provide a series of ecosystem services that are crucial to our society. In the European Union (EU), forests account for approximately 38% of the total land surface[1]. These forests are important carbon sinks, and their conservation efforts are vital for the EU's vision of achieving climate neutrality by 2050[2]. However, the increasing demand for forest services and products, driven by the bioeconomy, poses challenges for sustainable forest management. Here we use fine-scale satellite data to observe an increase in the harvested forest area (49 per cent) and an increase in biomass loss (69 per cent) over Europe for the period of 2016–2018 relative to 2011–2015, with large losses occurring on the Iberian Peninsula and in the Nordic and Baltic countries. Satellite imagery further reveals that the average patch size of harvested area increased by 34 per cent across Europe, with potential effects on biodiversity, soil erosion and water regulation. The increase in the rate of forest harvest is the result of the recent expansion of wood markets, as suggested by econometric indicators on forestry, wood-based bioenergy and international trade. If such a high rate of forest harvest continues, the post-2020 EU vision of forest-based climate mitigation may be hampered, and the additional carbon losses from forests would require extra emission reductions in other sectors in order to reach climate neutrality by 2050[3].

Quantifying forest change in the European Union

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Iddo K. Wernick[1]✉, Philippe Ciais[2], Jonas Fridman[3], Peter Högberg[4], Kari T. Korhonen[5], Annika Nordin[4] & Pekka E. Kauppi[4,6]

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INRAE
Annals of Forest Science

OPINION PAPER Open Access

Harvested area did not increase abruptly—how advancements in satellite-based mapping led to erroneous conclusions

Check for updates

Johannes Breidenbach[1*], David Ellison[2,3,4], Hans Petersson[2], Kari T. Korhonen[5], Helena M. Henttonen[5], Jörgen Wallerman[2], Jonas Fridman[2], Terje Gobakken[6], Rasmus Astrup[1] and Erik Næsset[6]

Abstract

Key message: Using satellite-based maps, Ceccherini et al. (Nature 583:72-77, 2020) report abruptly increasing harvested area estimates in several EU countries beginning in 2015. Using more than 120,000 National Forest Inventory observations to analyze the satellite-based map, we show that it is not harvested area but the map's ability to detect harvested areas that abruptly increases after 2015 in Finland and Sweden.

Keywords: Global Forest Watch, Landsat, Remote sensing, National Forest Inventory, Greenhouse Gas Inventory

Concerns about reported harvests in European forests

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Marc Palahí[1,26]✉, Rubén Valbuena[2,26]✉, Cornelius Senf[3], Nezha Acil[4,5], Thomas A. M. Pugh[4,5,6], Jonathan Sadler[4,5], Rupert Seidl[3], Peter Potapov[7], Barry Gardiner[8], Lauri Hetemäki[1], Gherardo Chirici[9], Saverio Francini[9,10], Tomáš Hlásny[11], Bas Jan Willem Lerink[12], Håkan Olsson[13], José Ramón González Olabarria[14], Davide Ascoli[15], Antti Asikainen[16], Jürgen Bauhus[17], Göran Berndes[18], Janis Donis[19], Jonas Fridman[13], Marc Hanewinkel[17], Hervé Jactel[20], Marcus Lindner[21], Marco Marchetti[22], Róbert Marušák[11], Douglas Sheil[23], Margarida Tomé[24], Antoni Trasobares[25], Pieter Johannes Verkerk[1], Minna Korhonen[1] & Gert-Jan Nabuurs[12,23]

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Conclusioni

- Integrazione INFC e Sistema Informativo Forestale Nazionale -> produzione di cartografie con telerilevamento
- Mappe UFFICIALI a 23 m di risoluzione da INFC2005 e INFC2015 saranno rilasciate a breve (collaborazione CUFA-AISF)
- Passaggio al nuovo programma permanente IFNI2025
- Maggiore collaborazione con enti di ricerca e accesso ai dati grezzi
- E' necessario il completamento delle informazioni di base: LiDAR e carta forestale