



Forest Research in the Big Data Era
September 6-9, 2017 Beijing, China

LiDAR as a bigdata source to improve the assessment of forest resources in NFM

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Performance of two area-based LiDAR processing methods to improve national forest maps

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Introduction

- ✓ **National forest maps** reflect the distribution of forest resources and their main use at the country level.
- ✓ They represent a discrete moment along a continuous dynamic process of change.
- ✓ However, many areas undergo continuous changes in spatial distribution of forest resources (i.e., **NFM may be out-of-date** rather quickly)
- ✓ Often, national forest maps rely on information from NFIs (i.e., of **limited spatial resolution** if no further auxiliary data are used).
- ✓ The **combination** of NFI data with remote sensing information (satellite images) led the way to the first national forest maps.

Introduction

- Still the case of current official national forest maps in several countries (e.g., Spain).
- NFI-based information was processed together with remote sensing imagery to create a continuous layer of tessellations, each one representing homogeneous forest characteristics



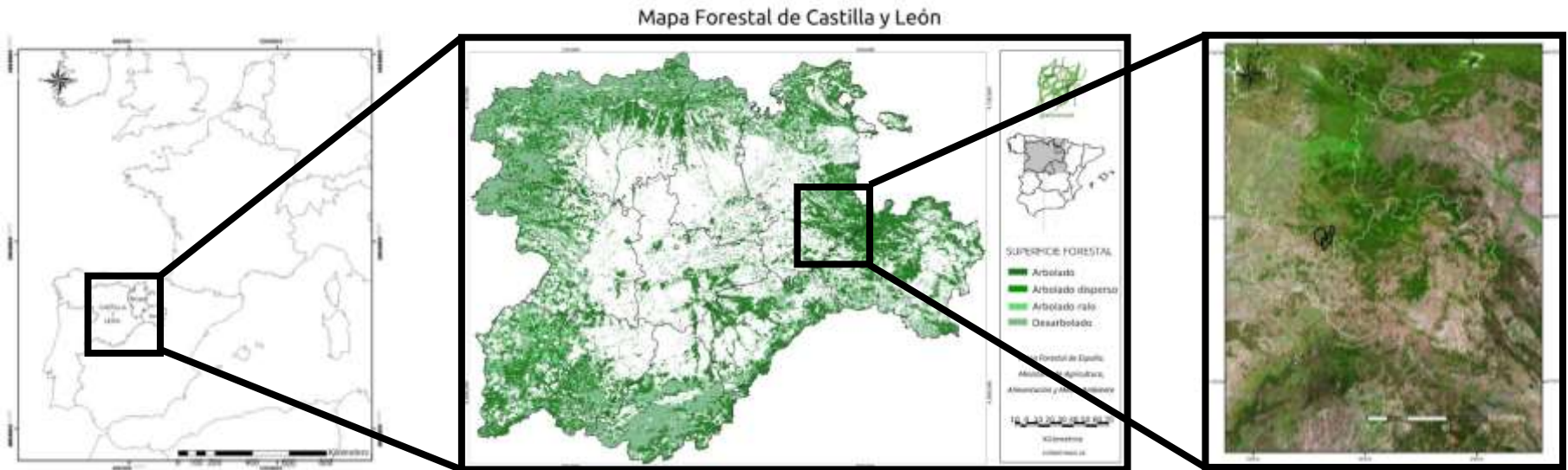
Introduction

- ✓ Nowadays, **improved RS techniques** are widely used as auxiliary information for many land-use and forestry applications
- ✓ Among the available RS sources, **Light Detection and Ranging (LiDAR)** has been widely used for describing the biophysical properties of vegetation aboveground
- ✓ In recent years, many countries throughout the world have launched nationwide airborne laser scanning (ALS) survey programmes for increasing the spatial resolution of existing land-use and forest maps

Objective

- ✓ This study aimed at assessing to what extent the use of LiDAR metrics can contribute to improve existing national forest maps...
- ✓ ... so that decision-making in land and forest management planning can rely on more accurate and updated information.

Materials & Methods: Study area and Forest Map of Spain



- ✓ Study area: 7,459 hectares
- ✓ The NFI-plots of the study area were measured in 2003

Materials & Methods: Study area and Forest Map of Spain

Ten different forest types.

Forest type	Description
A	Mixed Mediterranean hardwood forests
B	Riparian vegetation
C	Poplar plantations
D	<i>Quercus ilex</i> forests
E	<i>Quercus faginea</i> forests
F	Mixed forests of autochthonous Mediterranean coniferous
G	<i>Pinus sylvestris</i> forests
H	<i>Pinus pinaster</i> forests
I	<i>Pinus nigra</i> forests
J	<i>Juniperus thurifera</i> forests

Three stand development stages (SDS): **young** stands, **pole-wood** stands, and **old-growth** stands including seed-tree stands and regeneration stands.

Materials & Methods: LiDAR data

LiDAR data obtained from the Spanish National Plan for Aerial Orthophotography (**PNOA**)

The flight over the study area took place in **2010**

Nominal point density for was 0.5 points m⁻².

Data was downloaded as 2x2-km² tiles



Echoes classified as ground were used to interpolate a **digital terrain model** (DTM)

The **canopy height model** (CHM) was constructed using the first echoes

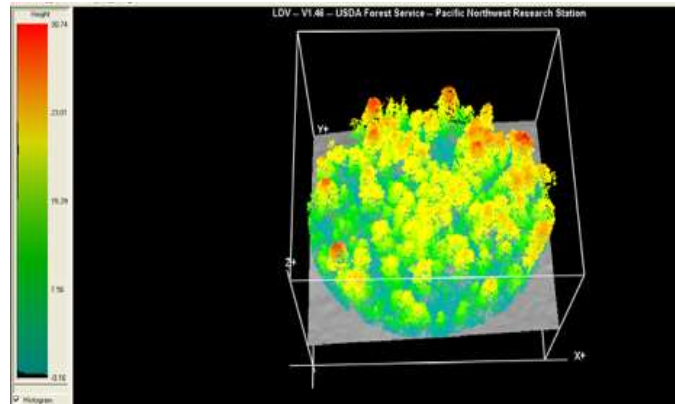
Forest canopy information using normalized values (i.e., the DTM subtracted from CHM)

FUSION (version 3.5, USDA Forest Service)

Materials & Methods: LiDAR processing approaches

Approach I: PIX

- ✓ Relied on the **gridding** concept for forestry applications (Næsset, 1997): a grid of spatially-continuous cells overlaps the study forest area and LiDAR statistics are computed for each element of the grid (pixel).
- ✓ **Square cells**: 0.05 hectares (22.4 x 22.4 m), enough to contain enough variability within each cell given the nominal point density (250 echoes approx.).



- ✓ The output was a continuous wall-to-wall layer of **149,193 cells** for which to obtain LiDAR-based FC estimates further averaged for a given FMS tessellation.

Materials & Methods: LiDAR processing approaches

Approach II: *POLY*

- ✓ Based on existing forest tessellation: the LiDAR tiles were shaped using the 196 FMS polygons (*POLY*) contained within the study area.
- ✓ In this approach, the same LiDAR statistics calculated for the gridding were computed but for each FMS polygon individually: tessellation boundaries were used as a mask to extract only the LiDAR echoes inside each polygon.
- ✓ The average polygon area was 32.6 ha, ranging from 0.1 to 500 hectares.

Materials & Methods: Assessing LiDAR processing approaches and FMS

- ✓ Both processing approaches compared in terms of forest cover (FC) (usually estimated in NFM and widely applied in forest ecology and management), and the estimates were further compared to the nominal FC values provided by the FMS
- ✓ The *PIX* dataset was used to calculate the **reliability of FMS information** by computing how many cells matched ($\pm 5\%$ error) the FC value assigned in the FMS.
- ✓ Correlation analysis for **the relationship between FMS and cell values for different SDS in two different forest vegetation types**: naturally regenerated forests (characterized by vertical continuity and horizontal discontinuity of the vegetation) and plantation forests (characterized by horizontal continuity and vertical discontinuity of vegetation).
- ✓ **Sensitivity analysis** of LiDAR-based FC estimates to **height-break value** (1, 2 and 3 meters aboveground)
- ✓ Height percentile distribution (i.e., 50th, 75th and 95th) compared between the two processing approaches. **95th** is widely used as for **dominant height prediction**, while intermediate height percentiles have been used to describe **structural complexity**

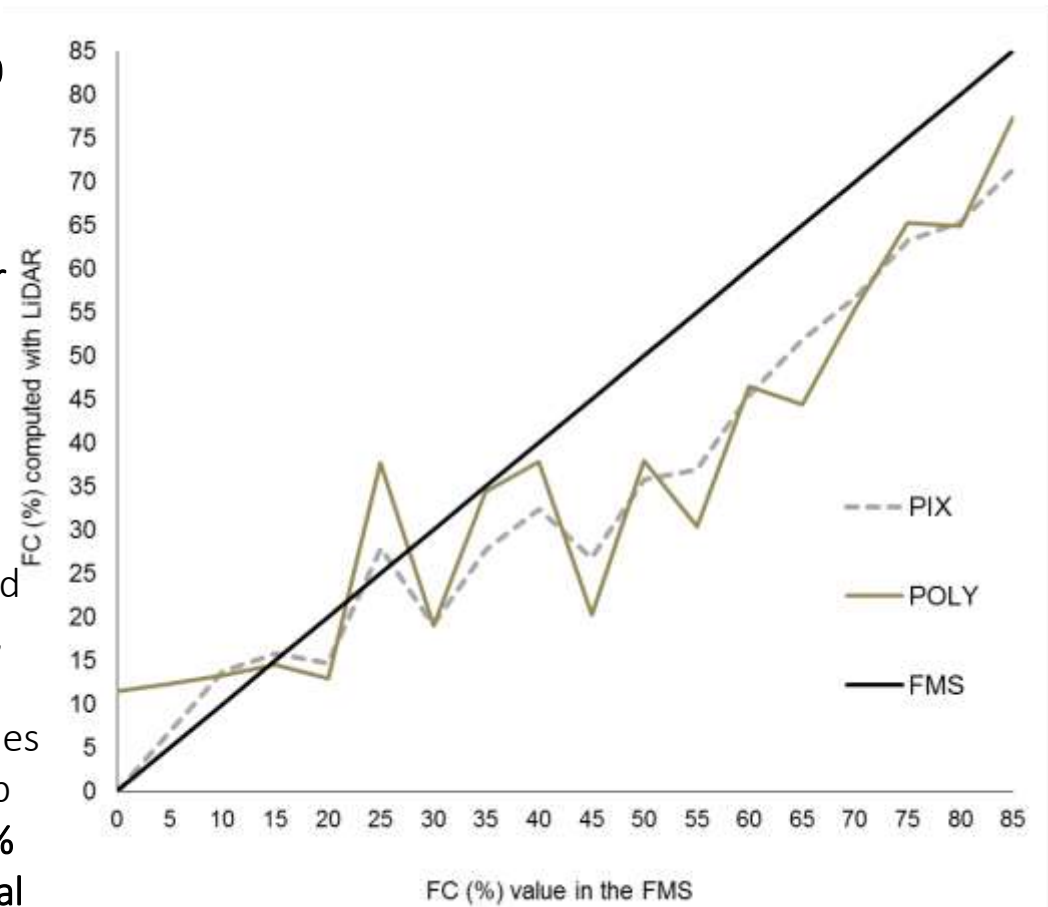
Results: comparing LIDAR and FMS forest cover estimates

PIX approach

- matched fairly well the FC values assigned in the FMS for FC classes from 0 to 25%,
- but tended to be 5 to 15% lower than in the FMS for FC classes equal to or greater than 30%.

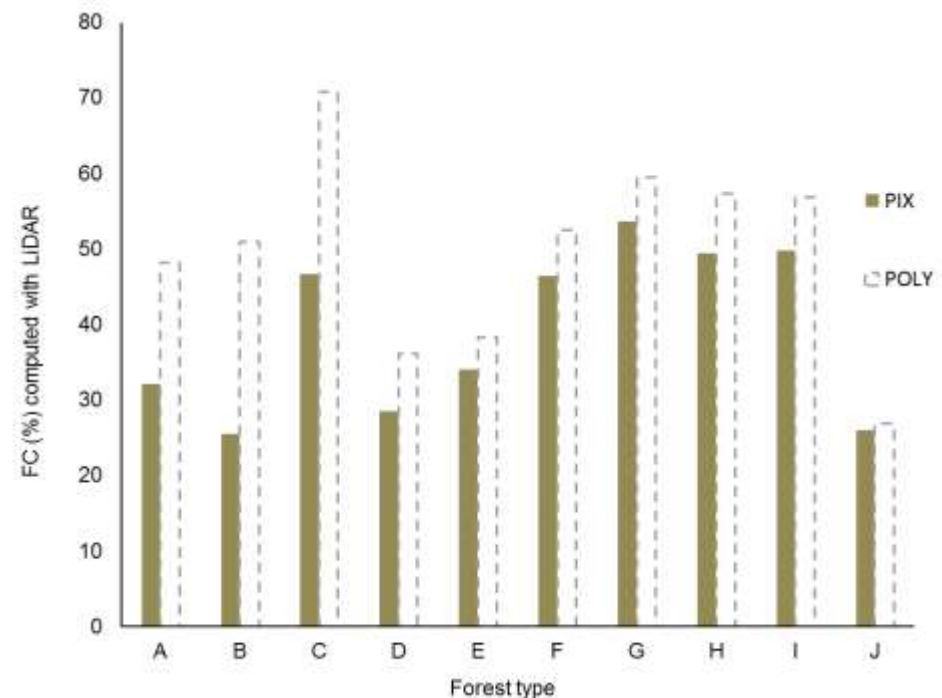
POLY approach

- matched fairly well the FC values assigned in the FMS for FC classes from 10 to 40%,
- but tended to **overestimate** the FMS values for the **lowest FC classes (i.e., 0-5%)** by up to 10%, and were approximately 5 to 20% **lower** than in the FMS for FC classes equal to or greater than 45%



Results: comparing LIDAR FC estimates between approaches by forest type

- FC estimates always **higher** for POLY method.
- **Greatest discrepancy in FC estimates:** forest types A (Mixed Mediterranean hardwoods), B (Riparian vegetation) and C (Poplar plantations) with an average difference in FC estimates of 16, 25 and 24%, respectively.
- **Less than 10% for the rest of forest ecosystems.**



- Plantation forests (forest types H and I): correlation of 0.67, 0.162 and -0.095 for young stands, pole-wood stands and old-growth stands, respectively (i.e. **decreasing**)
- Naturally regenerated forests: correlation -0.019, 0.438 and 0.487, respectively (i.e. **increasing**).
- **Reliability:** number of cells in which the LiDAR estimate of FC and the assigned value in the FMS matched ($\pm 5\%$) was **less than 35% in all forest types**.

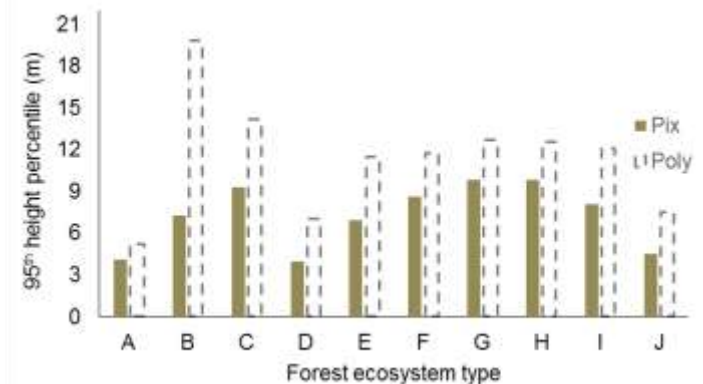
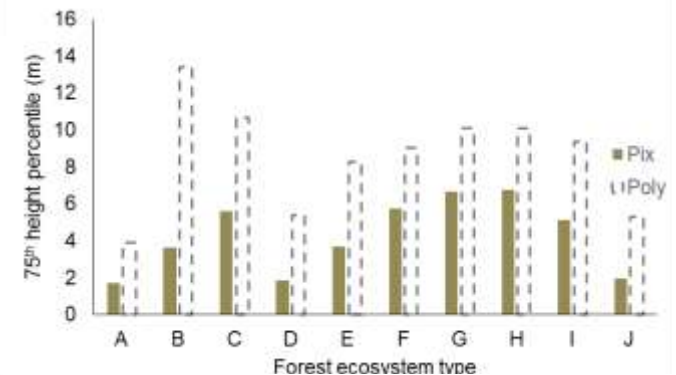
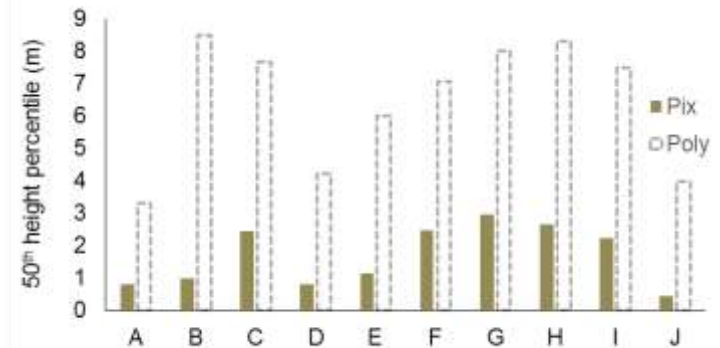
Results: effect of height-break value on FC estimates

- Increasing height-break threshold decreased FC estimates (i.e., decreased proportion of first echoes).
- Differences compared to the standard 2-m height-break were lower than 10% for forest types G (*Pinus sylvestris* forests), H (*Pinus pinaster* forests) and I (*Pinus nigra* forests).
- But, considerable differences for types D (*Quercus ilex* forests) and J (*Juniperus thurifera* forests), ranging from **10 to 41%**.
- The *PIX* and *POLY* approaches performed substantially differently for the case of forest type A (Mixed Mediterranean hardwood forests), so that the sensitivity of FC estimates to the height-break threshold value was **low under the *PIX*** approach (i.e., similar to forest types G, H, I), but the **highest under the *POLY*** method.

Forest type	1m	3m		
	FC (PIX)	FC (POLY)	FC (PIX)	FC (POLY)
A	3.5	25.8	-5.2	-41.0
B	5.8	5.9	-9.1	-13.8
D	34.0	10.2	-34.2	-12.9
G	2.5	3.9	-3.5	-5.2
H	2.8	4.2	-3.4	-4.4
I	3.7	3.9	-6.5	-6.9
J	16.1	18.2	-23.5	-24.5

Results: effect of height-break value on FC estimates

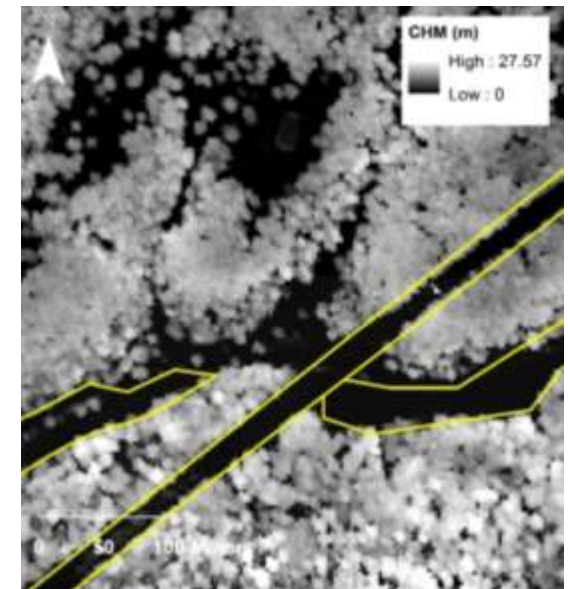
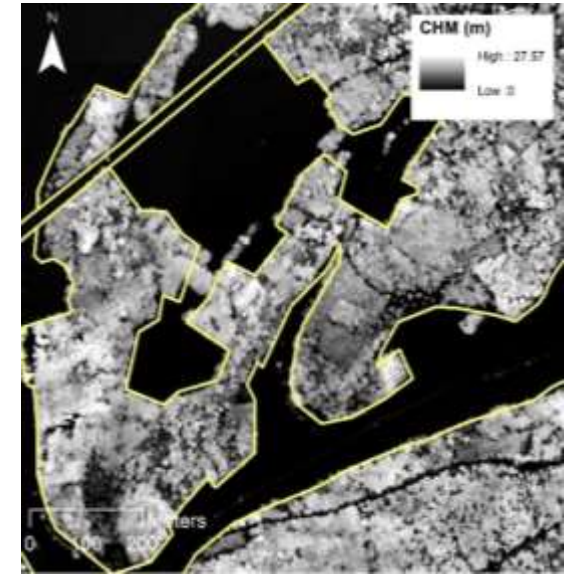
- Height percentile estimates always **higher for the POLY** approach
- Both processing approaches tended to **converge with increasing height percentile** except for forest type B (Riparian vegetation)
- The smallest difference was occurred in forest type A (Mixed Mediterranean hardwood forests)



Results: preliminary analysis of vegetation changes

Two different patterns leading to discrepancies between the FMS and LIDAR-based forest characterization:

- Expansion of forest area towards abandoned agricultural fields and scrublands, (54% of those FMS polygons contained forest patches from nearby forest areas).
- Presence of discontinuities within FMS polygons due to forest management or other activities in the area.



Discussion

- ✓ Sources of discrepancy between LiDAR and FMS:
 - ✓ The gap between FMS and flight campaign was **7 years**
 - ✓ Correlation between FMS and FMS **FC estimates decreased with increasing maturity of plantation forests** and trees are ready to be cut.
 - ✓ In **naturally regenerated forests**, the correlation between FMS and LiDAR estimates of FC was **the lowest in young stands** where natural regeneration is hard to distinguish from the scrub layer and the tree canopy in certain forest types (limitations in the interpretation of low-resolution aerial images at the time?)
- ✓ Discrepancies between LiDAR processing approaches
 - ✓ High spatial resolution versus flexibility
 - ✓ Solvable with segmentation... at very large scales?

Discussion

- ✓ Different levels of sensitivity to height-break threshold value:
 - ✓ The effect of changing the height-break on FC estimates was **minor** in stands presenting considerable discontinuity between the scrub and tree canopy layers (i.e., vertical discontinuity) such as in *Pinus sylvestris* or *Pinus nigra* forests.
 - ✓ ... but **larger** in more sparse and heterogeneous forest ecosystems such as *Quercus ilex* or *Juniperus thurifera* forests, with considerable vertical continuity, so that the proportion of echoes classified as first returns decreased with increasing height-break.
- ✓ The heterogeneity of vegetation structure, needs to be considered when using LiDAR-based estimation of forest resources, as estimates of forest stand characteristics can differ considerably between forest ecosystem types depending on the **LIDAR** processing approaches.
- ✓ The utility of small-footprint LiDAR data as a bigdata source for improving forest mapping over large scales, will be enhanced when multi-temporal information will become available worldwide and, as a result, changes (e.g., growth dynamics, forest productivity, detection of natural disturbances) can be monitored quantitatively and mapped.

谢谢

Thank you!