FORRISK - Final results

Silvicultural management in *Pinus radiata* and *Pinus pinaster* to improve wood quality and reduce fire risk: Intensive and silvopastoral regimes. Models to predict fire risk and biomass stocks

Hevia, A. , Barrero, P., Majada, J., & Prendes, C.
CETEMAS. Centro Tecnológico Forestal y de la Madera
(http://www.cetemas.es)

González-Ferreiro, E., Álvarez-González, J.G. & Ruiz-González, A.D
UXFS. Unidad de Gestión Forestal Sostenible
(http://www.usc.es/uxfs/)

Bilbao 9th September 2014

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Background:

Formación forestal dominante	Cabida (ha)
Castanea sativa	77.224,31
Fagus sylvatica	65.545,23
Eucalyptus globulus	52.295,01
Castanea sativa, Quercus robur y Betula spp.	46.326,55
Mezcla de frondosas autóctonas	35.802,97
Quercus robur y Q. petraea	25.005,89
Fagus sylvatica y frondosas	23.523,51
Eucalyptus globulus y Castanea sativa	21.545,47
Pinus pinaster y P. sylvestris	19.553,27
Pinus radiata	16.411,03
Quercus pyrenaica y Q. ilex	14.457,93
Eucalyptus globulus y Pinus pinaster	12.893,75
Quercus robur, Q. petraea, Betula spp. y Eucalyptus globulus	8.470,99
Árboles de ribera	15.847,55
Matorral con arbolado ralo	11.034,44
Matorral con arbolado disperso	5.178,85
Superficie forestal arbolada total	**451.116,75**

Annual timber harvest
~ 60.000 m^3/year (10%)

Chestnut, Beech, Eucalyptus globulus, Quercus and Pinus are the most important species in Northern Spain

Pinus radiata and *Pinus pinaster* – the most important timber conifers in the Northwest of Spain (area and production)

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Background:

Needs: Silviculture to reduce fire risk and improve timber production

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Study area:

Pruning and thinning experimental plots in conifer stands (Asturias)

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Study area:

Selection of plots

Young and even-aged stands.

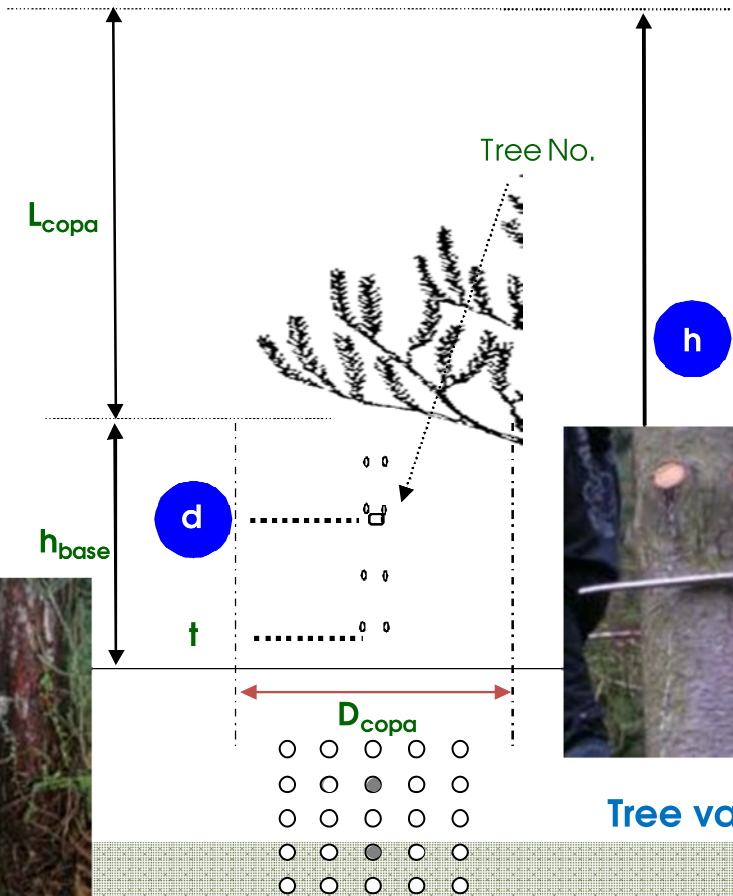
Species distribution in Asturias.

Figure. Pruning and thinning trial plots (permanent plots) location.

Intensive silviculture :
3 *P. radiata* stands.
4 *P. pinaster* stands.

Silvopastoral system: 1 *P. pinaster* stand.

Data collection: traditional inventory



Tree variables related to growth and productivity.

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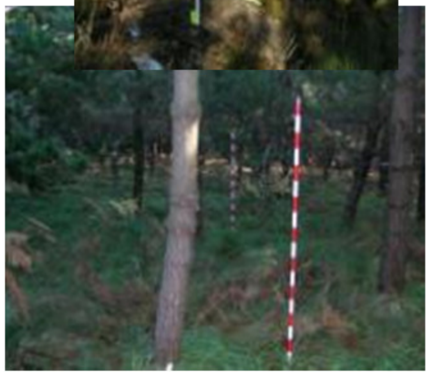
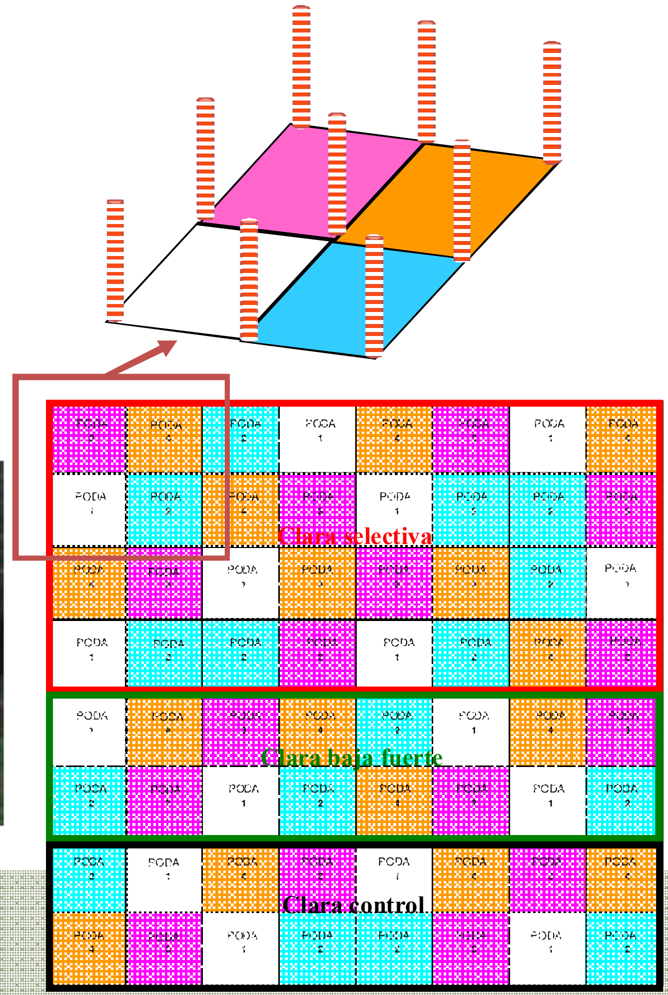
Data collection: Non-destructive techniques & LiDAR subplots limited

Collaboration with HAZI (A. Cantero).





ST 300 and FAKOPP instruments.

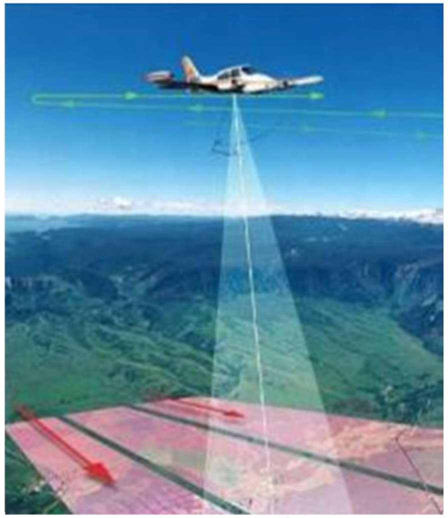
Pruning different intensities.

Data collection: above-ground biomass

Trees

shrub

Data collection: LiDAR



LIDAR (8 and 16 pulses/m^2)

High resolution LiDAR

Vegetation analysis – stand level

Figure. Pruning and thinning trial plots (permanent plots) location.

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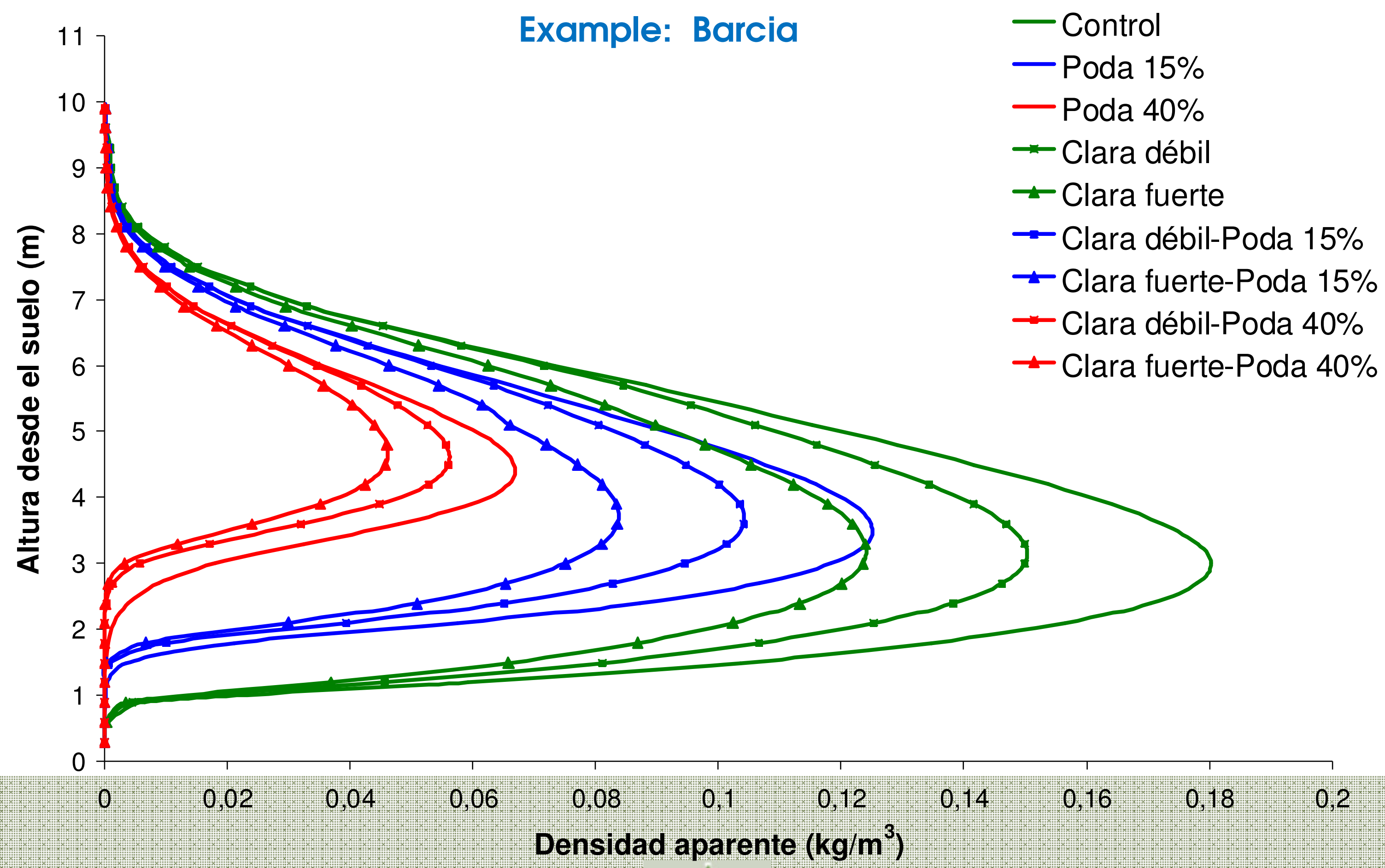
Some results: Biomass distribution – fire risk



Bilbao 9/9/2014

Some results: Estimation of stand and Canopy variables related to crown fire hazard

•**Table. Mean values of the main stand characteristics for the different thinning treatments. Different letters represent significant differences between mean values using the Tukey's adjusted pairwise comparisons ($P \leq 0.05$).**

Stand variable	Thinningtreatment		
	Control	Crown thinning	Heavy thinning
N	1339.6^{A}	808.1^{B}	850.7^{B}
dg	16.56^{A}	16.83^{A}	16.94^{A}
G	29.01^{A}	17.58^{B}	19.07^{AB}
H_m	10.39^{A}	11.02^{A}	11.09^{A}
H_0	12.07^{A}	12.46^{A}	12.26^{A}
V	131.38^{A}	77.63^{A}	86.67^{A}
W	98.41^{A}	62.37^{A}	67.16^{A}
W_{cff}	18.54^{A}	11.90^{A}	12.87^{A}
CFL	0.8540^{A}	0.5143^{B}	0.5583^{AB}
CBH	5.0935^{A}	5.6858^{A}	5.6970^{A}
CBD	0.1748^{A}	0.1105^{B}	0.1188^{B}
CBHe	3.7383^{A}	4.0453^{A}	4.0650^{A}
CBDe	0.1353^{A}	0.0825^{B}	0.0878^{AB}

Significant differences between control and crown thinning treatment were found in *N*, *G*, CFL, CBD and CBDe.
Significant differences between control and heavy thinning treatment for *N* and CBD.

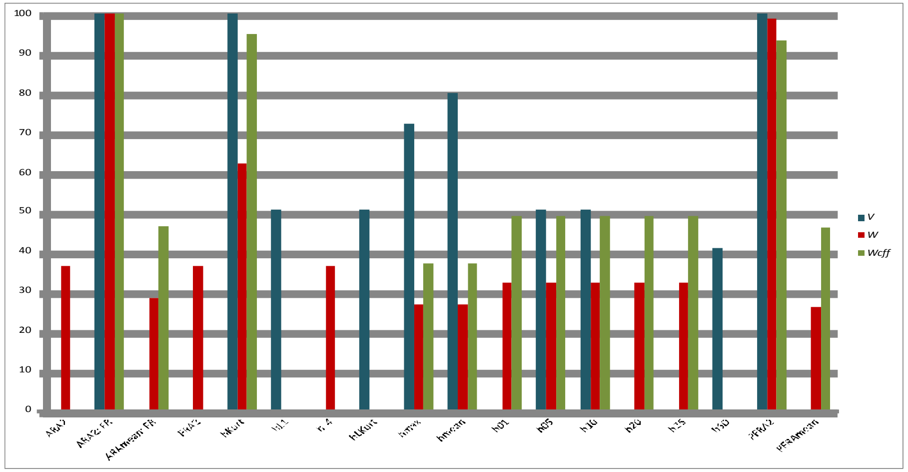
Some results: Estimation of Canopy variables related to crown fire hazard

•**Table . Parameter estimates, standard errors and goodness-of-fit statistics obtained for the fitted models relating the main stand and canopy variables with the LiDAR information.**

Dependent variable	Independent variable	Parameter estimate	Standard error	Fitted model RMSE	Fitted model R^2_{adj}	Cross-validation RMSE	Cross-validation MEF_{adj}
N	*Intercept*	-1545.0569	252.7722	82.5625	0.9255	123.0776	0.8345
	PFR_{42}	68.2711	8.3027				
	$AR_{Amean} \cdot FR$	-88.2483	12.8421				
	h_{kurt}	290.7741	100.4132				
dg	*Intercept*	19.5249	1.8581	0.3699	0.9570	0.7576	0.8198
	FR_{Amean}	0.0003293	0.00002972				
	h_{kurt}	-4.4156	0.5690				
	h_{ID}	-7.1340	1.0306				
	h_{95}	2.1993	0.2352				
G	*Intercept*	-39.2165	3.5432	[illegible]	[illegible]	[illegible]	[illegible]
	$AR_{42} \cdot FR$	[illegible]	[illegible]				
	h_{95}	[illegible]	[illegible]				
H_m	*Intercept*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	AR	[illegible]	[illegible]				
	h_{kurt}	[illegible]	[illegible]				
H_0	*Intercept*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	AR	[illegible]	[illegible]				
	$h_{AADmode}$	[illegible]	[illegible]				
	h_{kurt}	[illegible]	[illegible]				
V	*Intercept*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	$AR_{42} \cdot FR$	[illegible]	[illegible]				
	h_{90}	[illegible]	[illegible]				
W	*Intercept*	-141.9026	13.0840	4.8569	0.9622	7.1776	0.9174
	$AR_{42} \cdot FR$	1.6309	0.1420				
	h_{10}	14.5498	1.6777				
W_{df}	*Intercept*	-27.4691	3.7143	1.3788	0.9210	1.8220	0.8621
	$AR_{42} \cdot FR$	0.3286	0.0403				
	h_{10}	2.6117	0.4763				
CFL	*Intercept*	-1.1754	0.1057	0.03969	0.9648	0.05880	0.9228
	$AR_{42} \cdot FR$	0.01578	0.0011				
	h_{05}	0.1055	0.0134				
CBH	*Intercept*	6.3172	0.7630	0.3489	0.9391	0.4824	0.8836
	AR	0.00007425	0.0000075				
	h_{Skurt}	-24.8696	5.1851				
CBD	*Intercept*	-0.1800	0.0231	0.00892	0.9446	0.01342	0.8747
	$AR_{42} \cdot FR$	0.003070	0.0002512				
	h_{01}	0.01784	0.00297				
CBHe	*Intercept*	4.4102	0.4027	0.1842	0.9435	0.2501	0.8951
	AR	0.00004070	0.00000396				
	h_{Skurt}	-13.7009	2.7365				
CBDe	*Intercept*	-0.1801	0.0221	0.00832	0.9373	0.01277	0.8522
	PFR_{42}	0.002800	0.0002451				
	h_{01}	0.01587	0.00277				

FORRISK - Models

Some results: Estimation of Canopy variables related to crown fire hazard



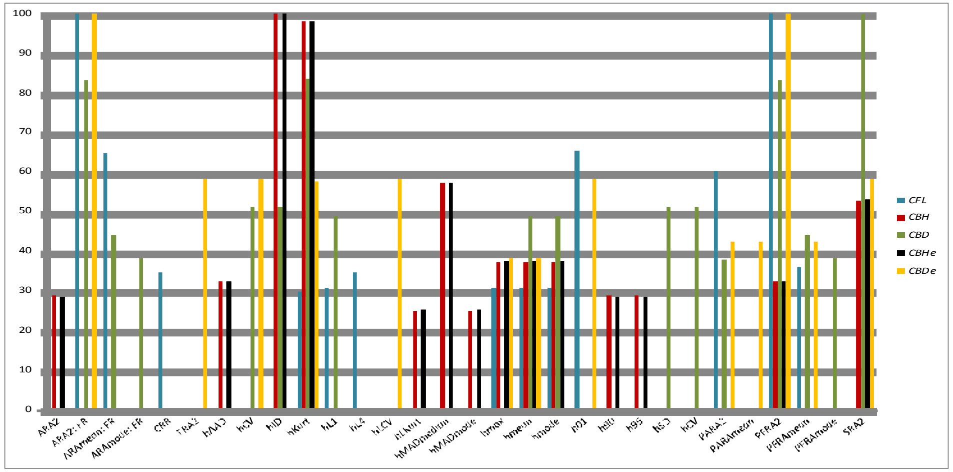


Figure. Relative importance of the LiDAR variables to classify the main stand yield variables. *V* is the total stand volume (m^3 ha^1), *W* is the total stand biomass (Mg ha^1) and W_{cff} is the crown fine fuel biomass (Mg ha^1).

Figure. Relative importance of the LiDARvariables to classify the main canopy fuel complex structural characteristics.CFL is the canopy fuel load (kg m^{-3}), CBH is the canopy base height (m), CBD is the canopy bulk density (kg m^{-2}), CBHe is the “effective” canopy base height (m) and CBDe is the “effective” canopy bulk density (kg m^{-2}).

Some conclusions

Silvicultural interventions, like pruning or thinning can modify the fuel complex structure into a less flammable (higher CBH, lower CBD).

Regression models between the LiDAR data and inventory field data (canopy fuel metrics and management-relevant forest stand variables) can be used to **generate maps** that informs about canopy fuel complex structural characteristics, stand yield and stand density over the entire area of the LiDAR data coverage.

These maps can be used for forest manager as direct input for **fire behaviour models** to support the analysis of fire risk and the implementation of ***fuel management*** programs (Andersen et al. 2005; González-Olabarría et al. 2012) and also ***for thinning operations and timber harvesting*** management.

Thank you

Merci

Obrigado

Gracias

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