Misura di parametri biometrici “in situ” e costruzione di equazioni allometriche per la stima della crescita e dello stoccaggio di carbonio in particelle forestali

Sebastien Comin

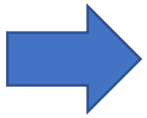
Equazioni allometriche

- **Assimilazione:** quantità di CO2 assimilata per unità di tempo per unità di superficie fogliare. C utilizzato anche per metabolismo effimero

- **Stoccaggio:** quantità di CO2 immobilizzata sul lungo periodo nella biomassa legnosa dell'albero

Definizione del campione

CATEGORIA FORESTALE	N°	% N°
PECCETE	1125	55,7%
LARICETI	356	17,6%
FORMAZIONI SECONDARIE	185	9,2%
ORNO-OSTRIETI	112	5,5%
CASTAGNETI	63	3,1%
PICEO-FAGGETI	45	2,2%
FAGGETE	41	2,0%
QUERCETI	29	1,4%
ACERO-TIGLIO-FRASSINETI	26	1,3%
ABIETETI	24	1,2%
PINETE	8	0,4%
ALTRO	5	0,2%



Picea abies

Larix decidua

Fraxinus ornus

Ostrya carpinifolia

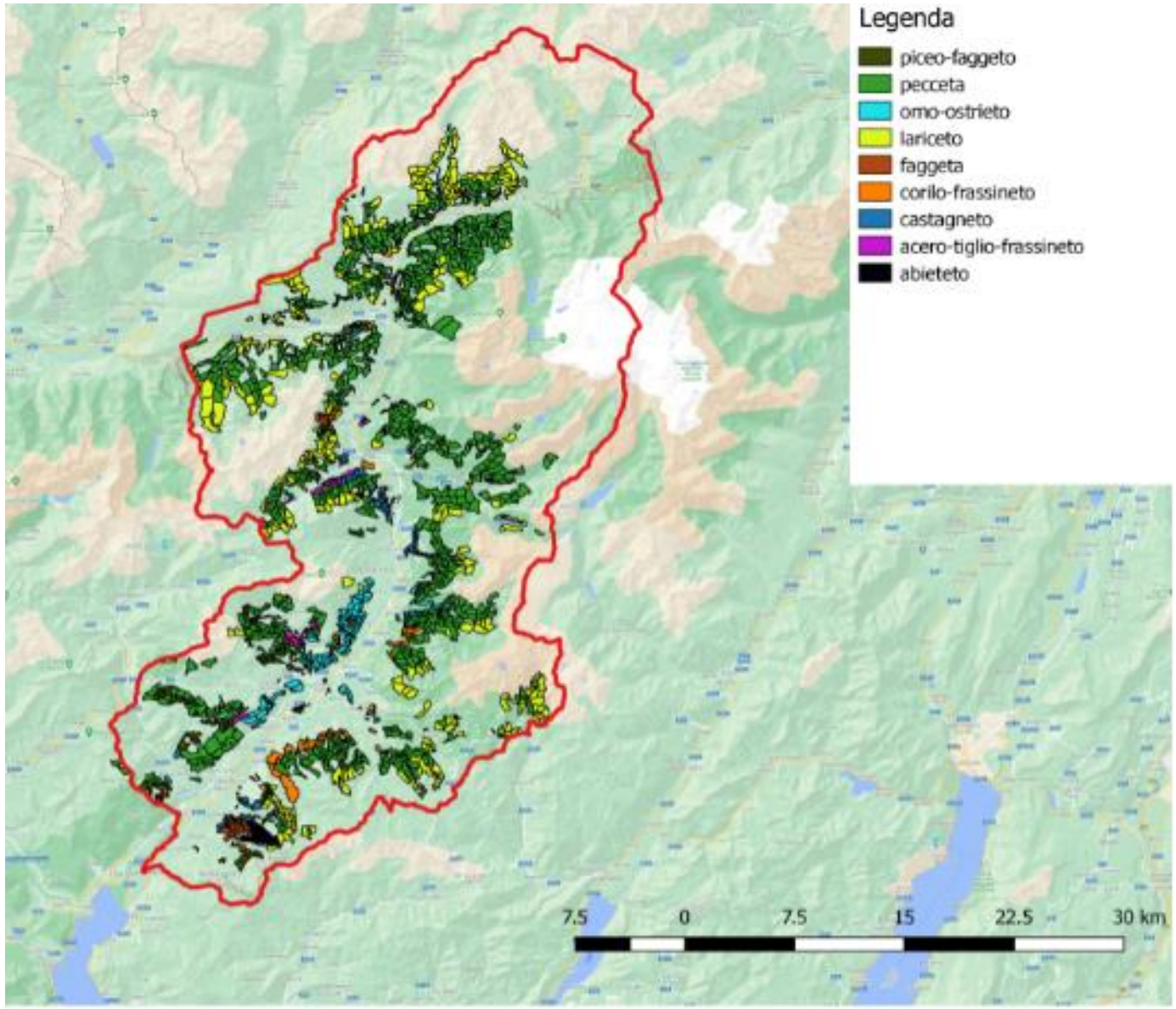
Castanea sativa

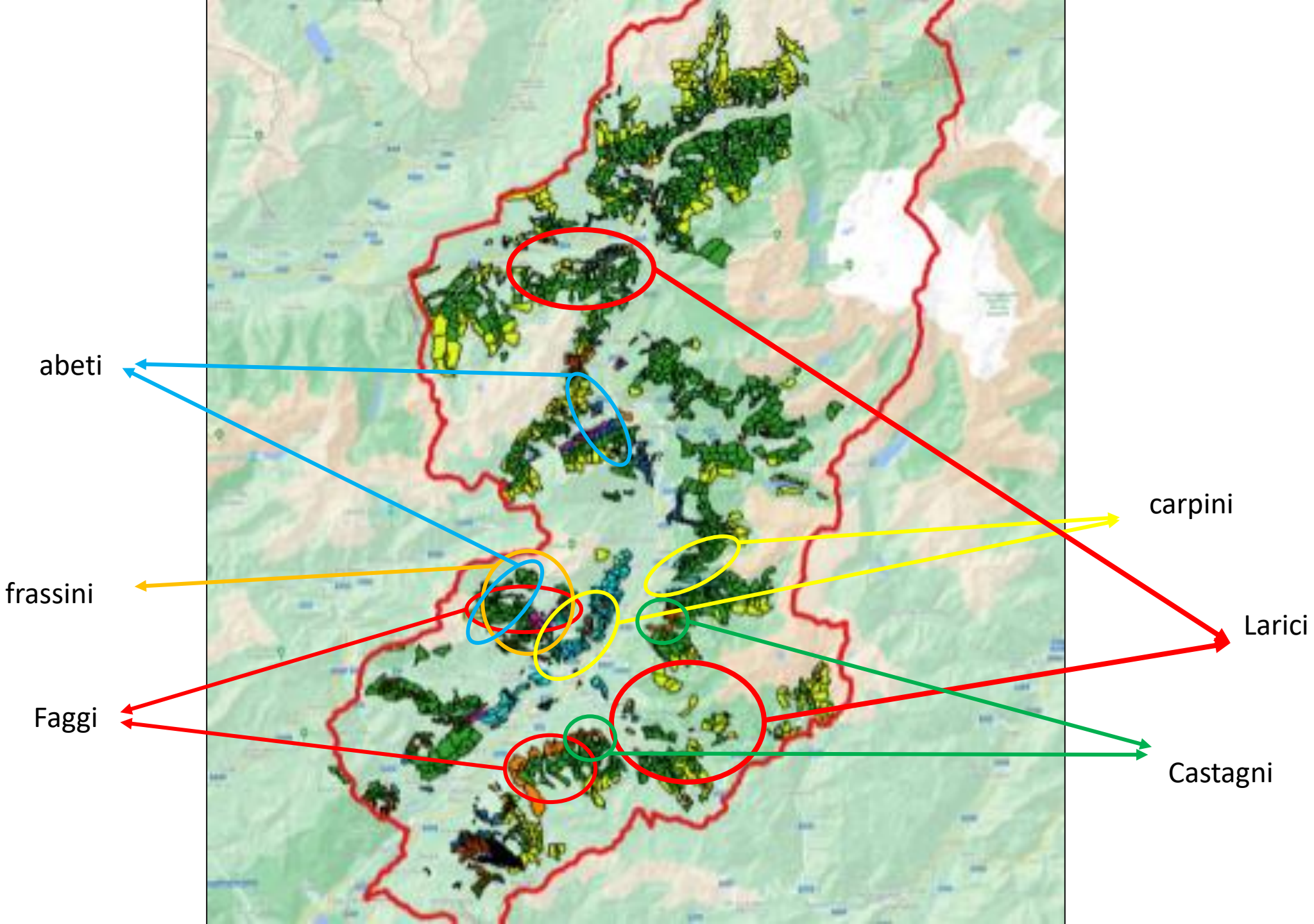
Fagus sylvatica

Definizione del campione

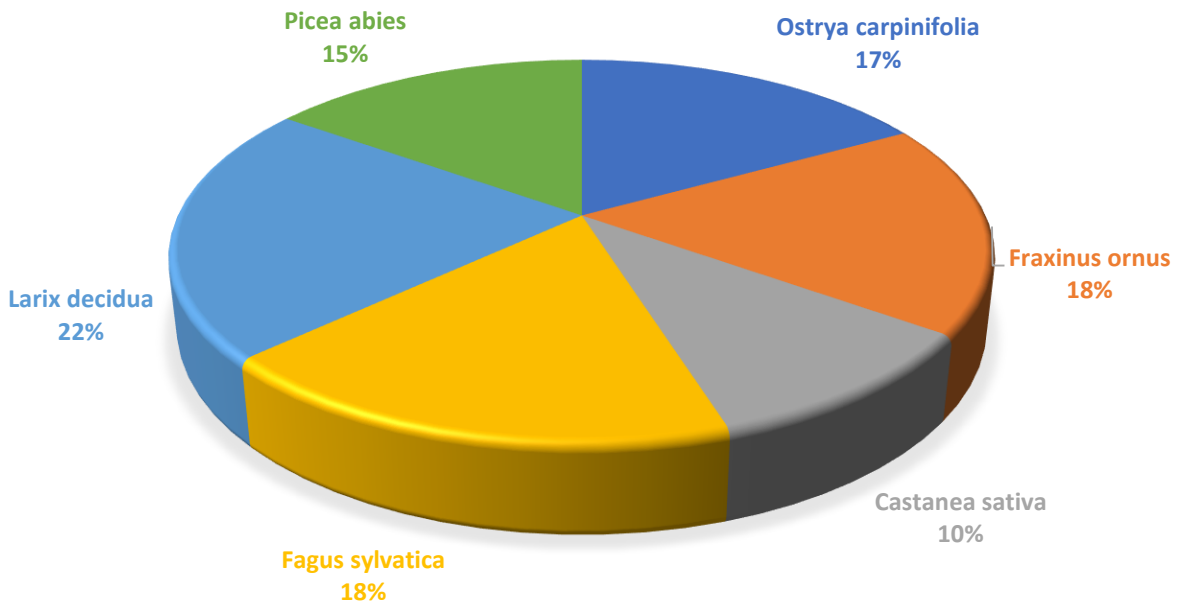
Nel CPA riportate 2019 parcelle

- Altitudine
- Esposizione
- Consociazioni
- Età




abeti
frassini
Faggi
carpini
Larici
Castagni

Specie	Numero di parcelle
Larix decidua	9
Fagus sylvatica	6
Fraxinus ornus	7
Ostrya carpinifolia	6
Picea abies	6
Castanea sativa	4

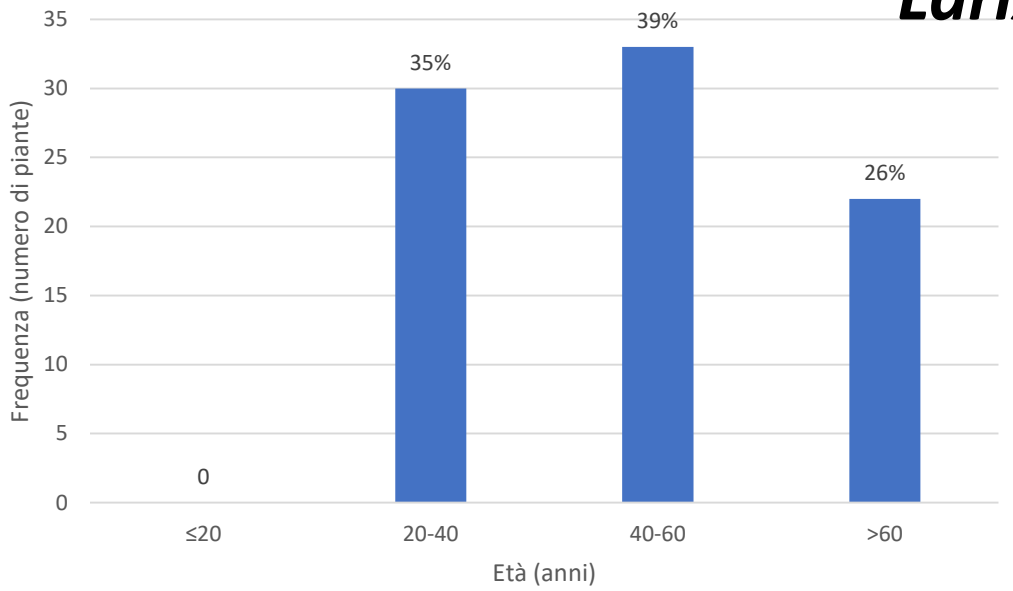


10 piante per parcella per specie

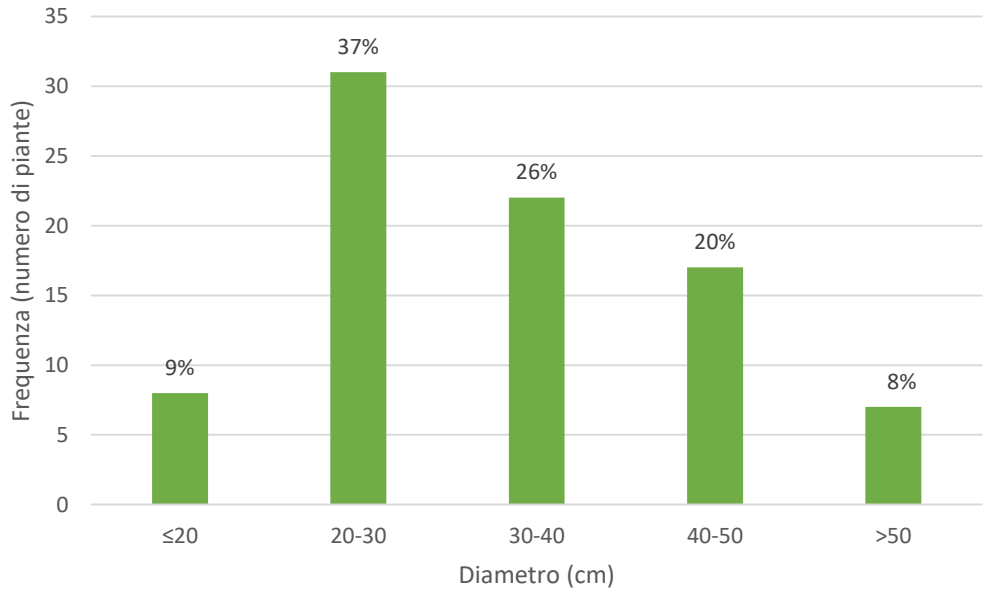
N° totale piante: 397

Larix decidua

Età



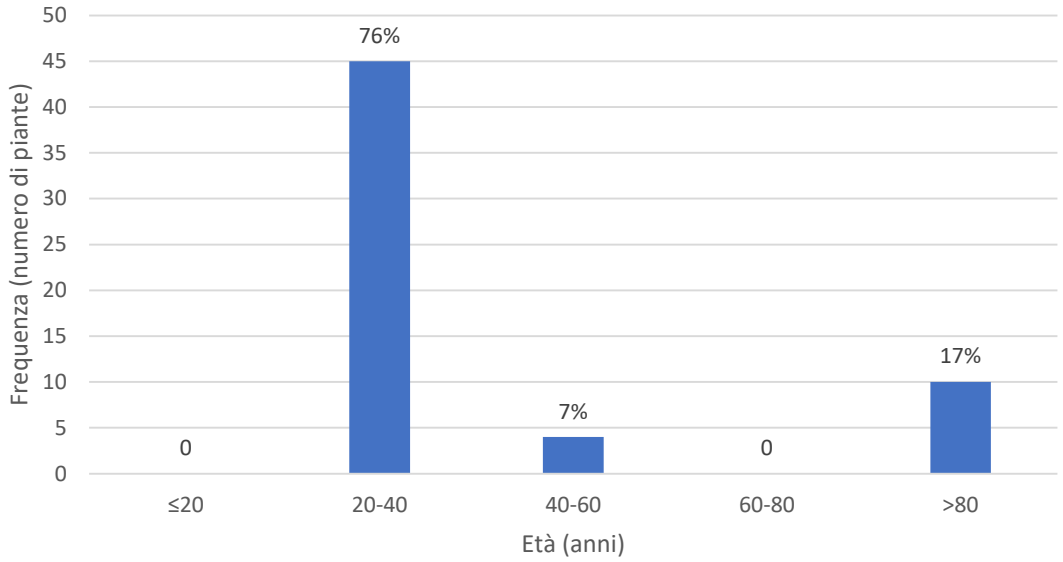
diametro



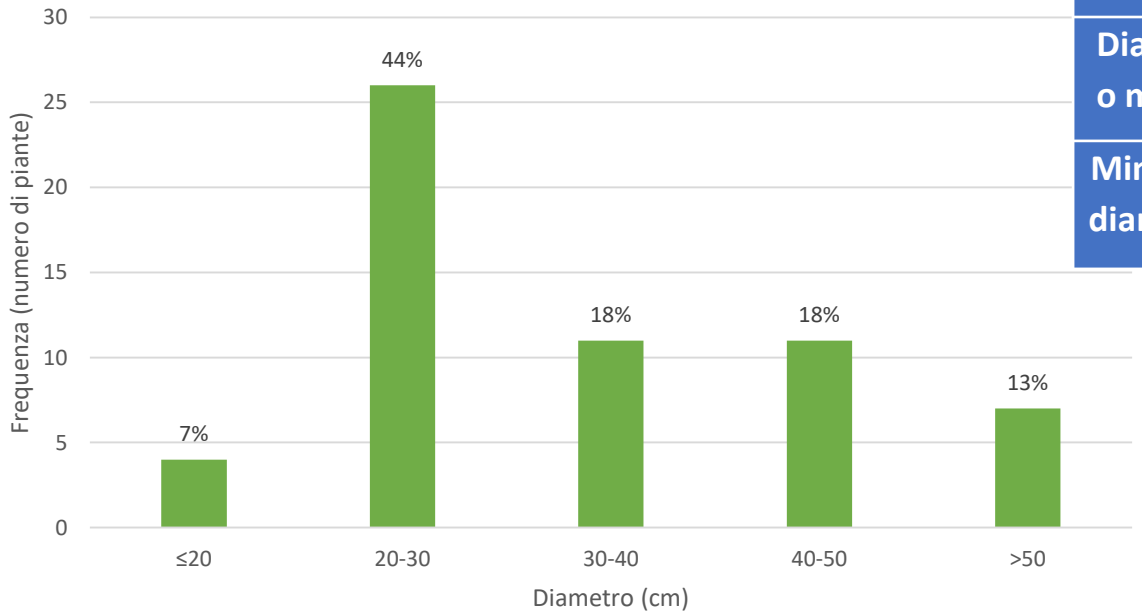
	Larix decidua	Fagus sylvatica	Fraxinus ornus	Ostrya carpinifolia	Picea abies	Castanea sativa
N°piante	85	70	70	66	59	40
Età media	51	52	28	24	42	32
Min-max età	30 - 93	33 - 75	9-59	6-65	27-93	8-55
Diametro medio	33	25	14	9.9	33.8	27.8
Min-max diametro	14-61	16-55	1.6-35.7	1.2-22.9	17.5-66.8	7.32-59.2

Picea abies

Età



diametro



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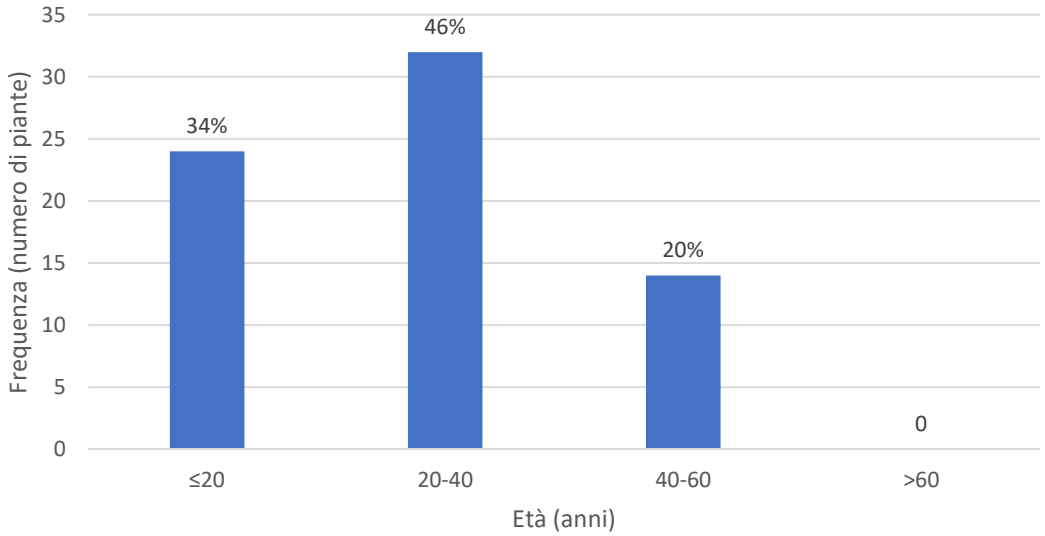
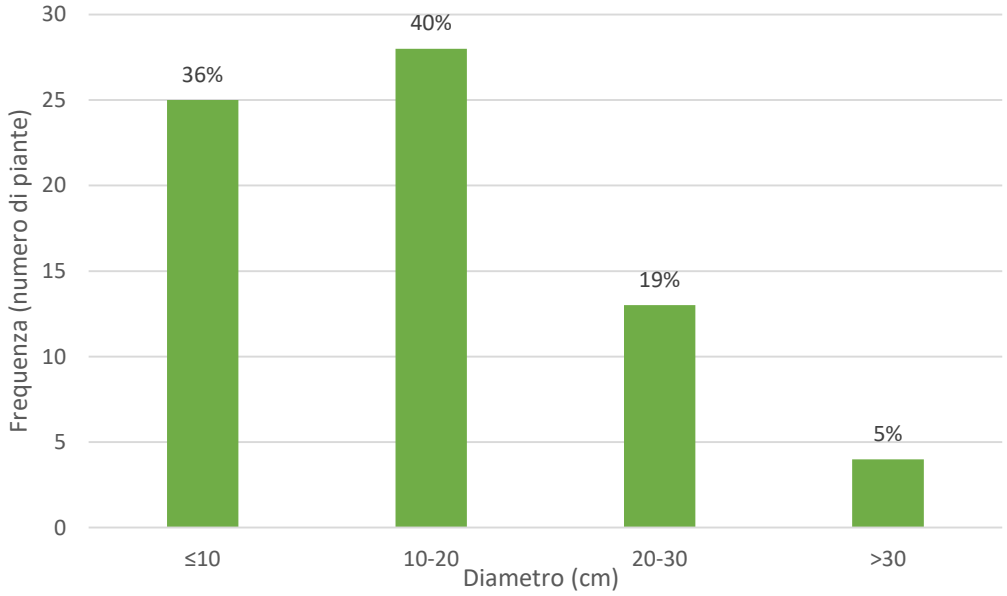
Fraxinus

Età



Diametro



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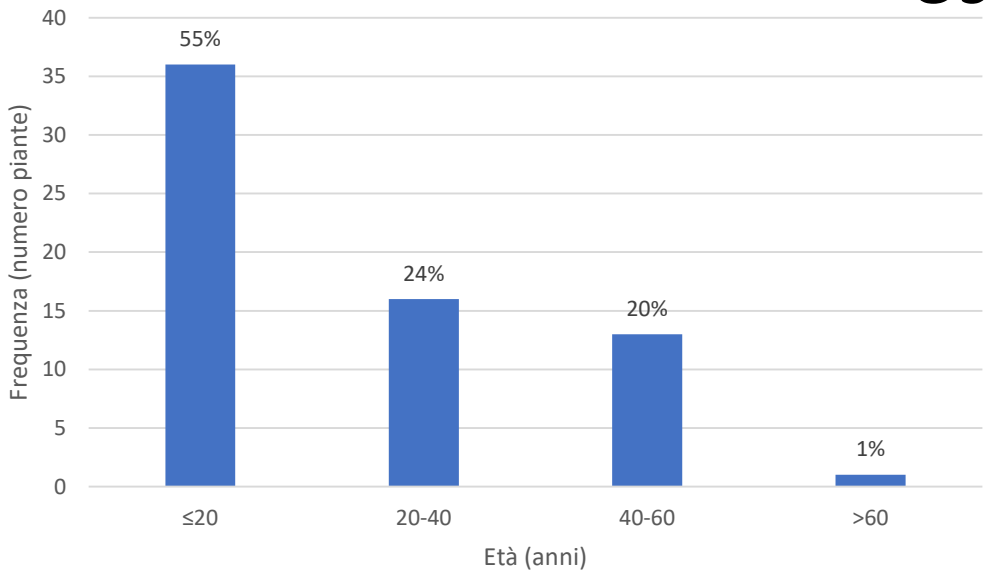
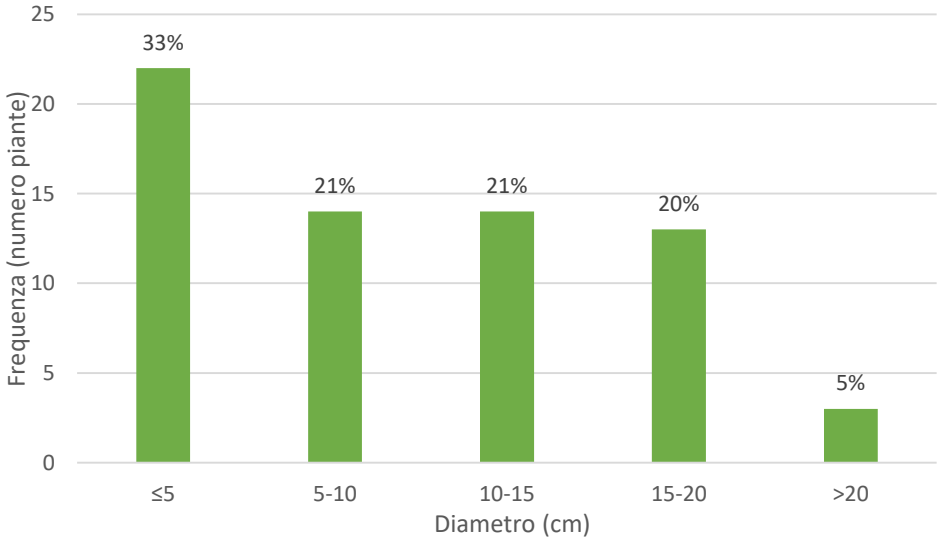
Ostrya carpinifolia

Età



diametro



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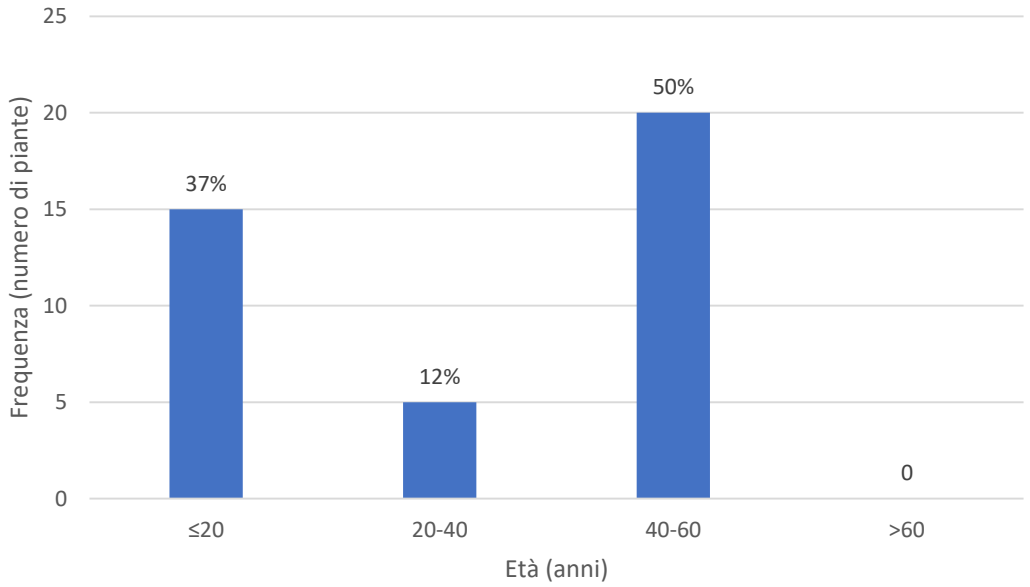
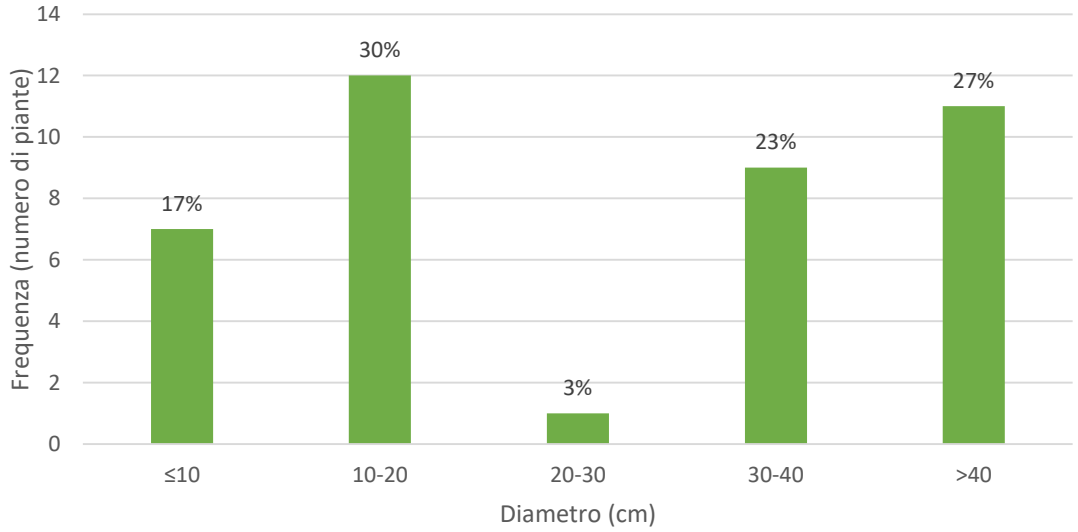
Castanea sativa

Età



diametro



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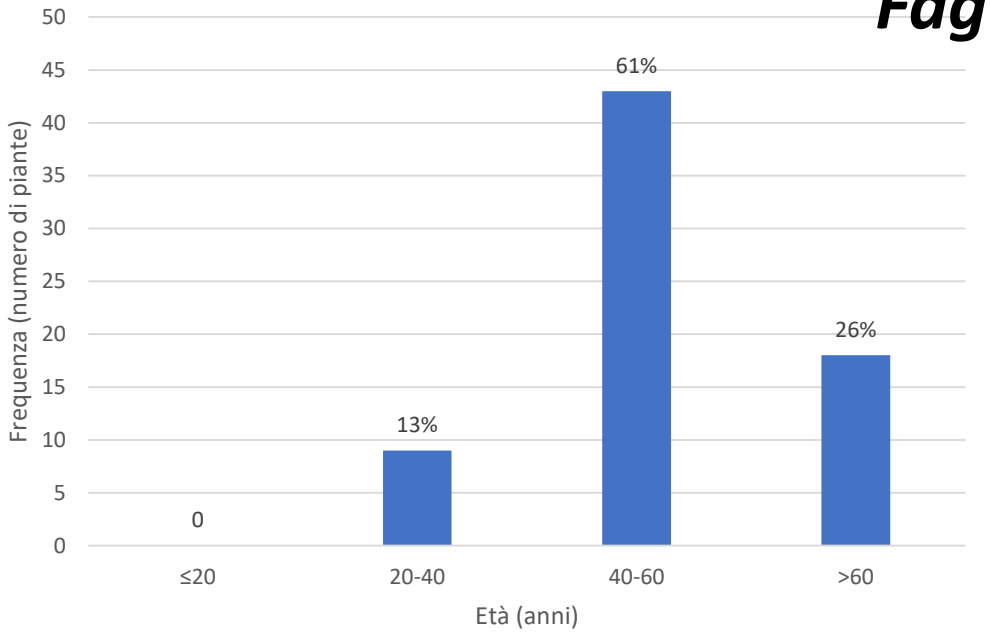
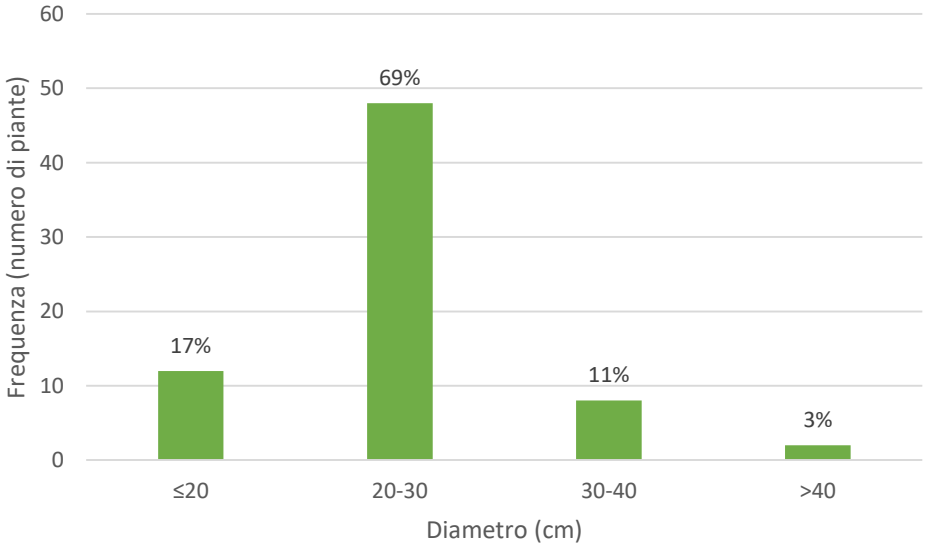
Fagus sylvatica

Età



diametro



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Misure dendrocronologiche

- Attribuire età a parcelle ignote
- Correggere errori presenti in CPA

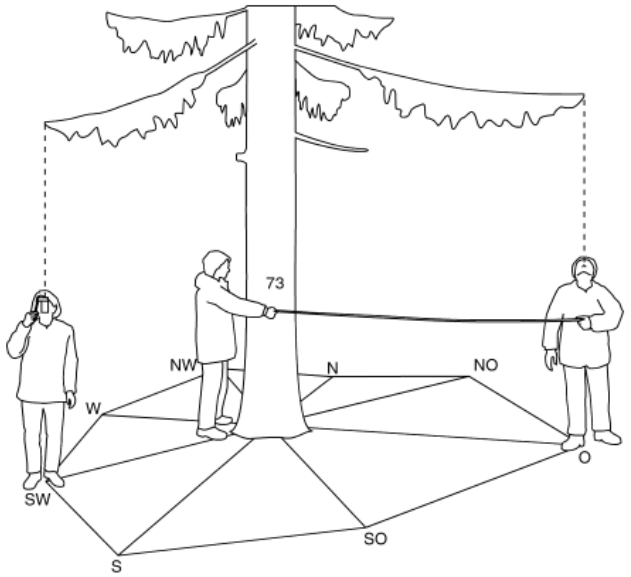
Sonda incrementale manuale da 40 cm
- Circa 45 carotaggi

misure biometriche

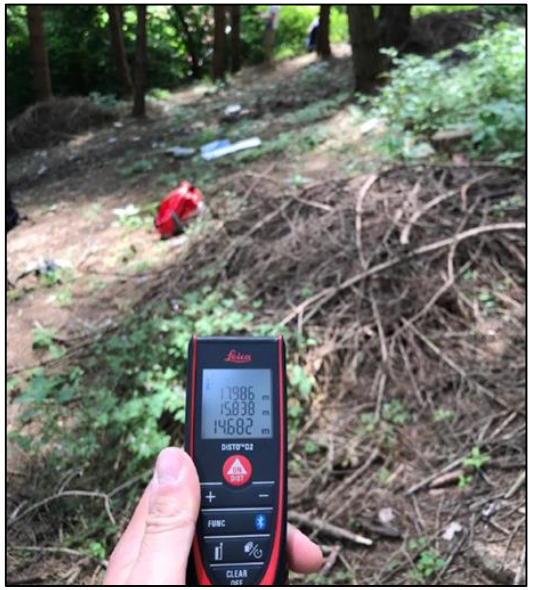
- Diametro

- Altezza tot e primo palco

- Area di proiezione della chioma

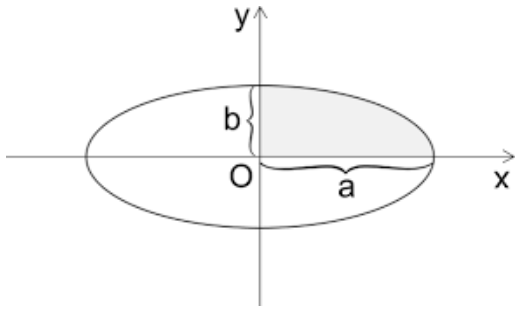


metodo visivo
[Preuhsler, 1979]



Variabili ricavate da misure «in situ»

Drip Line Area → $DLA = \pi ab$

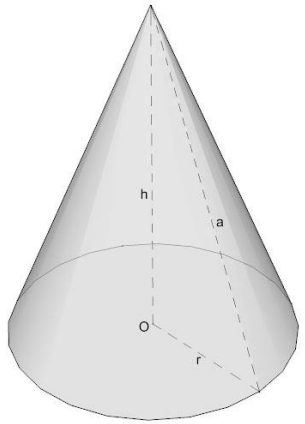


Volume della chioma

$$V\ crown = \pi r^2 \frac{h}{3}$$

- -Larici
- -Abeti

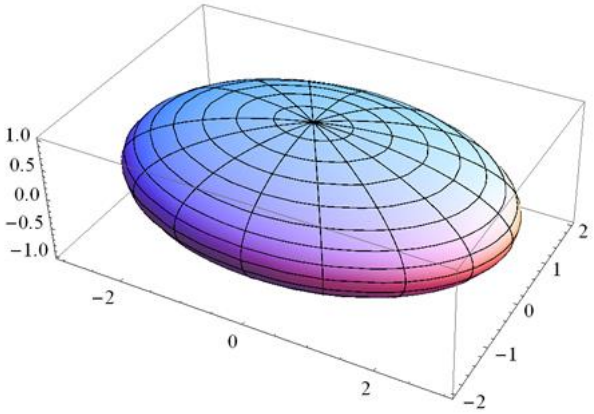
Cono



$$V\ crown = \frac{4}{3}\pi ab^2$$

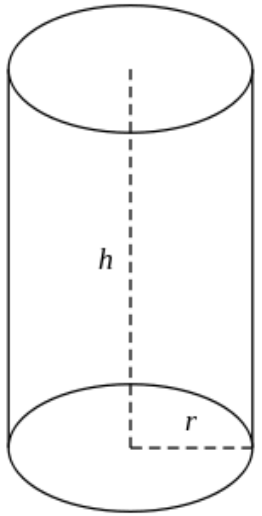
- -frassini
- -carpini
- -castagni
- -faggi

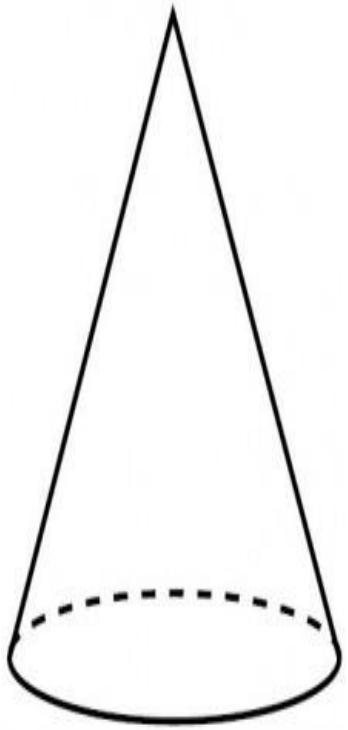
Ellissoide



Volume del Tronco

$$V\ trunk = (\pi r^2 h_1) + (\pi r^2 \frac{h_2}{3})$$





elaborazione dati → Machine learning

↓

Le curve di regressione che sono state costruite sono:

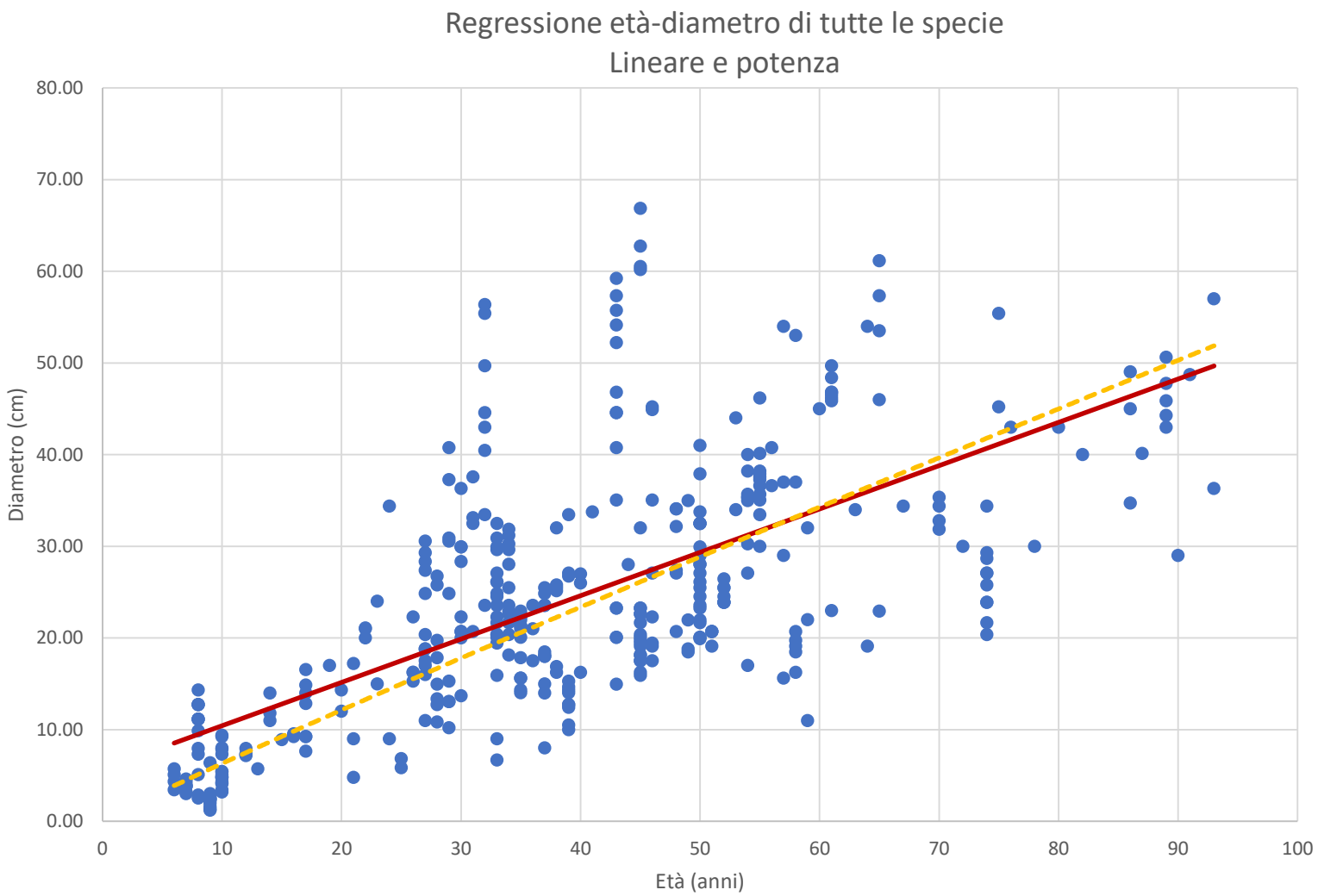
- **Età – Diametro**
- **Diametro – Altezza**
- **Diametro – DLA**
- **Diametro – Volume del fusto**
- **Diametro – Volume della chioma**

→

- Regressione lineare
- Regressione logaritmica
- Regressione potenza
- Regressione sigmoidea

Regressione lineare forzata per l'origine o per 1,3

Relazioni età - diametro → Potenza



$y = 0{,}481x + 5{,}4121$

$R^2 = 0{,}476$

- valori misurati diametro
- Lineare
- Potenza

$y = 0{,}695x^{0{,}953}$

$R^2 = 0{,}681$

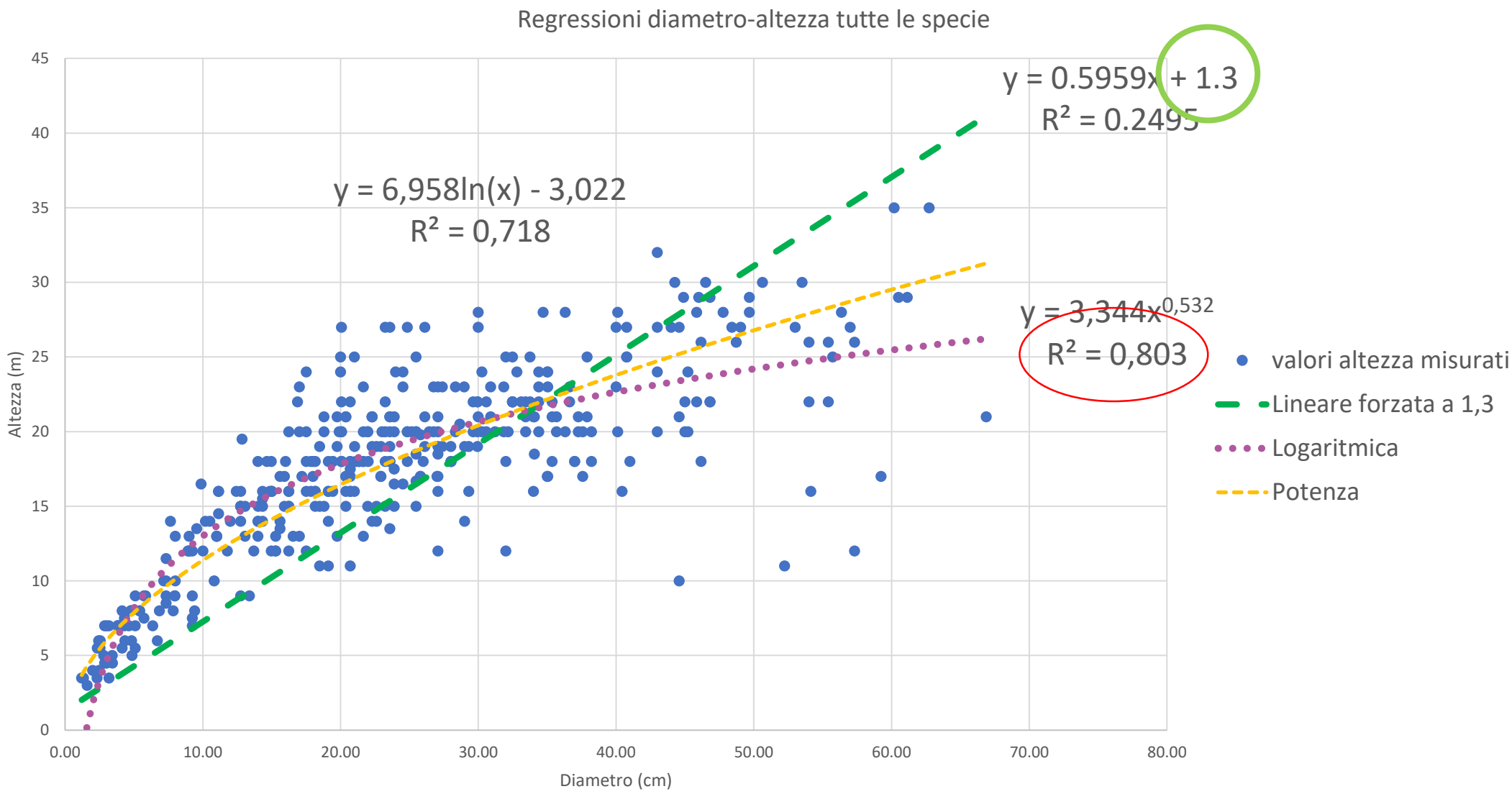
Relazioni età - diametro

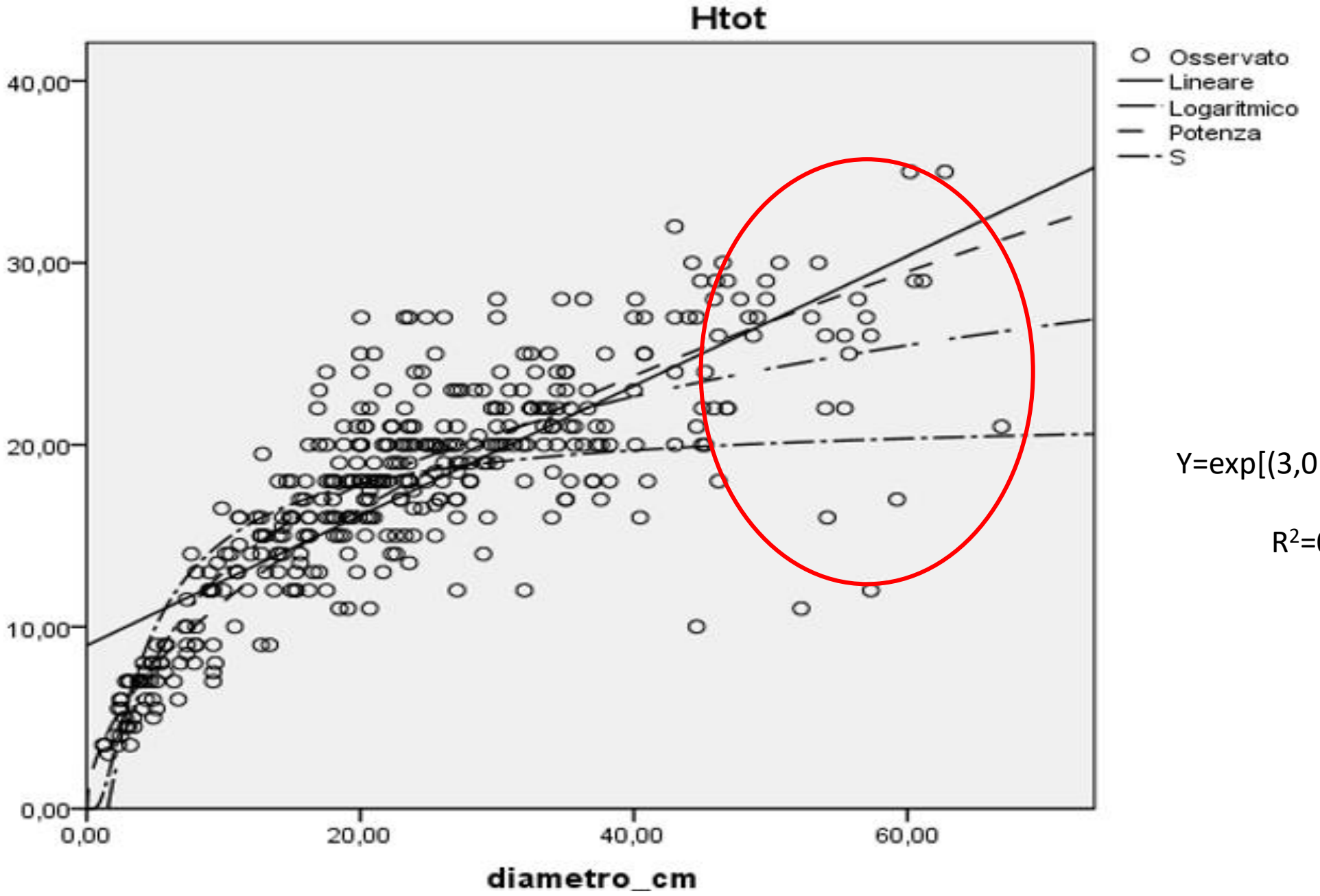
	Larix decidua	***Fagus sylvatica***	***Fraxinus ornus***	***Ostrya carpinifolia***	***Picea abies***	***Castanaea sativa***	***Tutte le specie***
Lineare	$y = 0,537x + 5,96$ $R^2 = 0,485$	$y = 0,254x + 11,69$ $R^2 = 0,268$	$y = 0,416x + 4,48$ $R^2 = 0,33$	$y = 0,319x + 2,233$ $R^2 = 0,870$	$y = 0,277x + 22,255$ $R^2 = 0,226$	$y = 0,759x + 3,763$ $R^2 = 0,704$	$y = 0,481x + 5,4121$ $R^2 = 0,476$
Potenza	$y = 0,853x^{0,927}$ $R^2 = 0,572$	$y = 4,167x^{0,449}$ $R^2 = 0,239$	$y = 0,428x^{1,06}$ $R^2 = 0,599$	$y = 0,745x^{0,817}$ $R^2 = 0,755$	$y = 5,496x^{0,482}$ $R^2 = 0,300$	$y = 1,736x^{0,796}$ $R^2 = 0,778$	$y = 0,695x^{0,953}$ $R^2 = 0,681$

Relazioni età - diametro

specie	età	D lineare (cm)	D potenza (cm)
frassino	5	6,56	2,36
carpino	5	3,83	2,77
castagno	5	7,56	6,25
faggio	5	12,96	8,59
larice	5	8,65	3,79
abete rosso	5	23,64	11,94
totale	5	7,82	3,22
frassino	35	19,03	18,54
carpino	35	13,40	13,58
castagno	35	30,34	29,42
faggio	35	20,57	20,58
larice	35	24,76	23,02
abete rosso	35	31,96	30,51
totale	35	22,24	20,61
frassino	50	25,26	27,05
carpino	50	18,18	18,16
castagno	50	41,73	39,08
faggio	50	24,38	24,15
larice	50	32,82	32,04
abete rosso	50	36,11	36,23
totale	50	29,45	28,96

Relazioni diametro – altezza





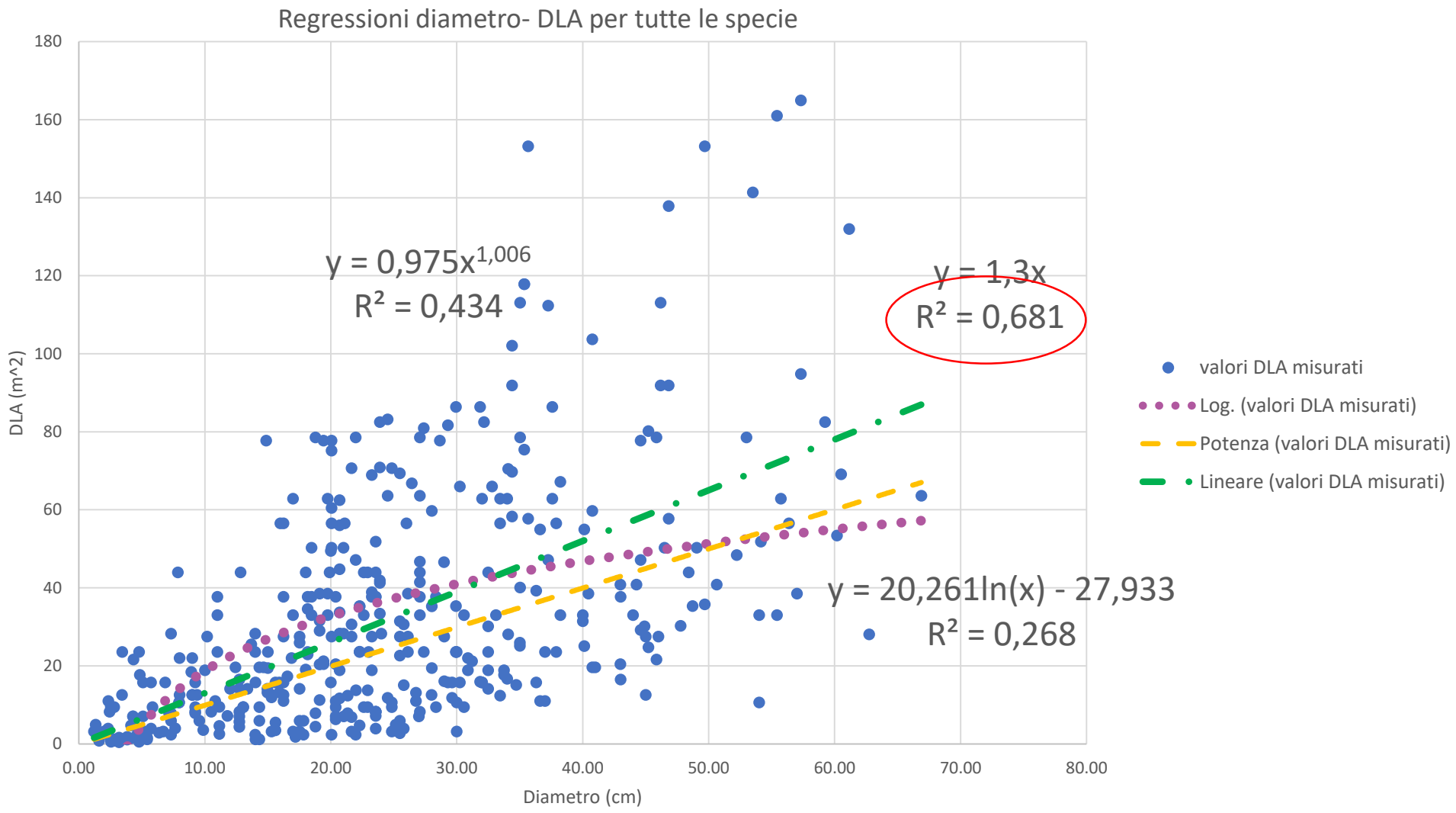
$Y=\exp[(3,01)+(-3,90)/x]$

$R^2=0,696$

	Larix decidua	***Fagus sylvatica***	***Fraxinus ornus***	***Ostrya carpinifolia***	***Picea abies***	***Castanaea sativa***	***Tutte le specie***
Lineare forzata a 1,3 m	y = 0,5589x + 1,3 R^2 = 0,5535	y = 0,6936x + 1,3 R^2 = 0,1429	y = 0,7588x + 1,3 R^2 = 0,6939	y = 0,8033x + 1,3 R^2 = 0,735	y = 0,5878x + 1,3 R^2 = 0,4917	y = 0,4376x + 1,3 R^2 = 0,242	y = 0,5959x + 1,3 R^2 = 0,6195
Potenza	$y = 4,302x^{0,453}$ R^2 = 0,531	$y = 7,369^{0,300}$ R^2 = 0,153	$y = 2,287x^{0,686}$ R^2 = 0,879	$y = 3,485x^{0,490}$ R^2 = 0,832	$y = 6,215x^{0,370}$ R^2 = 0,477	$y = 8,370x^{0,209}$ R^2 = 0,294	$y = 3,344x^{0,532}$ R^2 = 0,803
Logaritmica	y = 9,347ln(x) - 11,259 R^2 = 0,545	y = 5,768ln(x) + 1,088 R^2 = 0,146	y = 7,537ln(x) - 4,264 R^2 = 0,821	y = 4,525ln(x) + 1,010 R^2 = 0,755	y = 8,955ln(x) - 8,188 R^2 = 0,488	y = 3,632ln(x) + 5,295 R^2 = 0,311	y = 6,958ln(x) - 3,022 R^2 = 0,718
Sigmoide	Y=exp[(3,44)+(-12,41)/x] R^2=0,505	Y= exp[(3,27)+(-7,59)/x] R^2=0,149	Y=exp[(3,08)+(-4,58)/x] R^2=0,816	Y=exp[(2,64)+(-2,23)/x] R^2=0,729	Y=exp[(3,48)+(-11,30)/x] R^2=0,442	Y=exp[(3,01)+(-4,13)/x] R^2=0,332	Y=exp[(3,01)+(-3,90)/x] R^2=0,696

specie	diametro (cm)	h lineare forzata 1,3 (m)	h logaritmica (m)	h potenza (m)	h sigmoide (m)
frassino	5	10,25	7,87	6,90	8,70
carpino	5	1,30	8,29	7,66	8,98
castagno	5	3,66	11,14	11,71	8,84
faggio	5	5,01	10,37	11,95	5,79
larice	5	4,27	3,78	8,91	2,61
abete rosso	5	4,41	6,23	11,28	3,40
totale	5	4,48	8,18	7,87	9,95
frassino	25	20,96	20,00	20,83	18,12
carpino	25	5,79	15,57	16,86	12,83
castagno	25	13,10	16,99	16,38	17,12
faggio	25	19,85	19,65	19,37	19,51
larice	25	16,15	18,83	18,46	18,99
abete rosso	25	16,84	20,64	20,47	20,76
totale	25	17,21	19,37	18,53	18,57
frassino	50	34,35	25,22	33,51	19,86
carpino	50	23,74	18,71	23,67	13,41
castagno	50	24,89	19,50	18,93	18,60
faggio	50	38,41	23,65	23,84	22,72
larice	50	30,99	25,31	25,26	24,33
abete rosso	50	32,38	26,85	26,45	26,03
totale	50	33,12	24,20	26,79	20,08

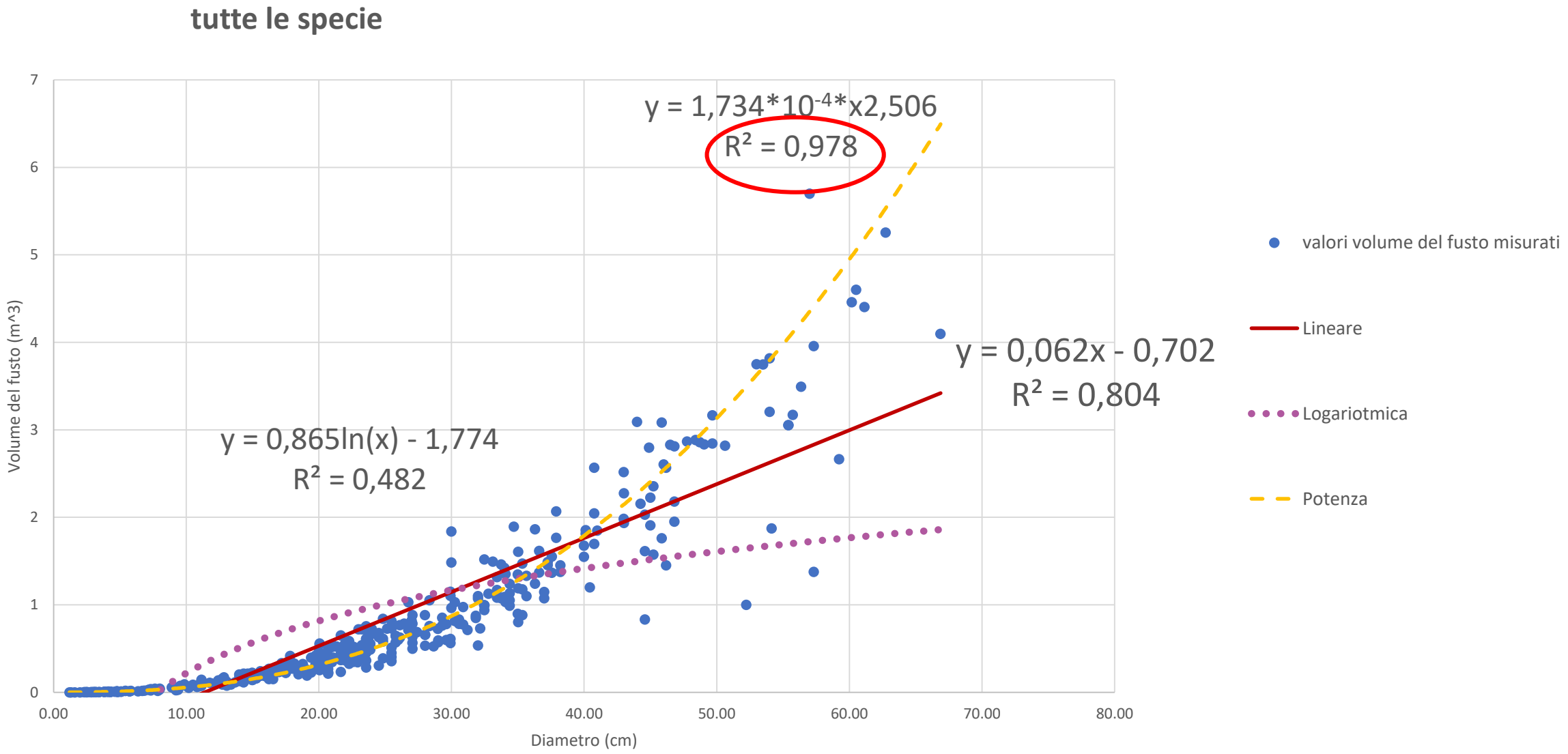
Relazioni diametro – DLA



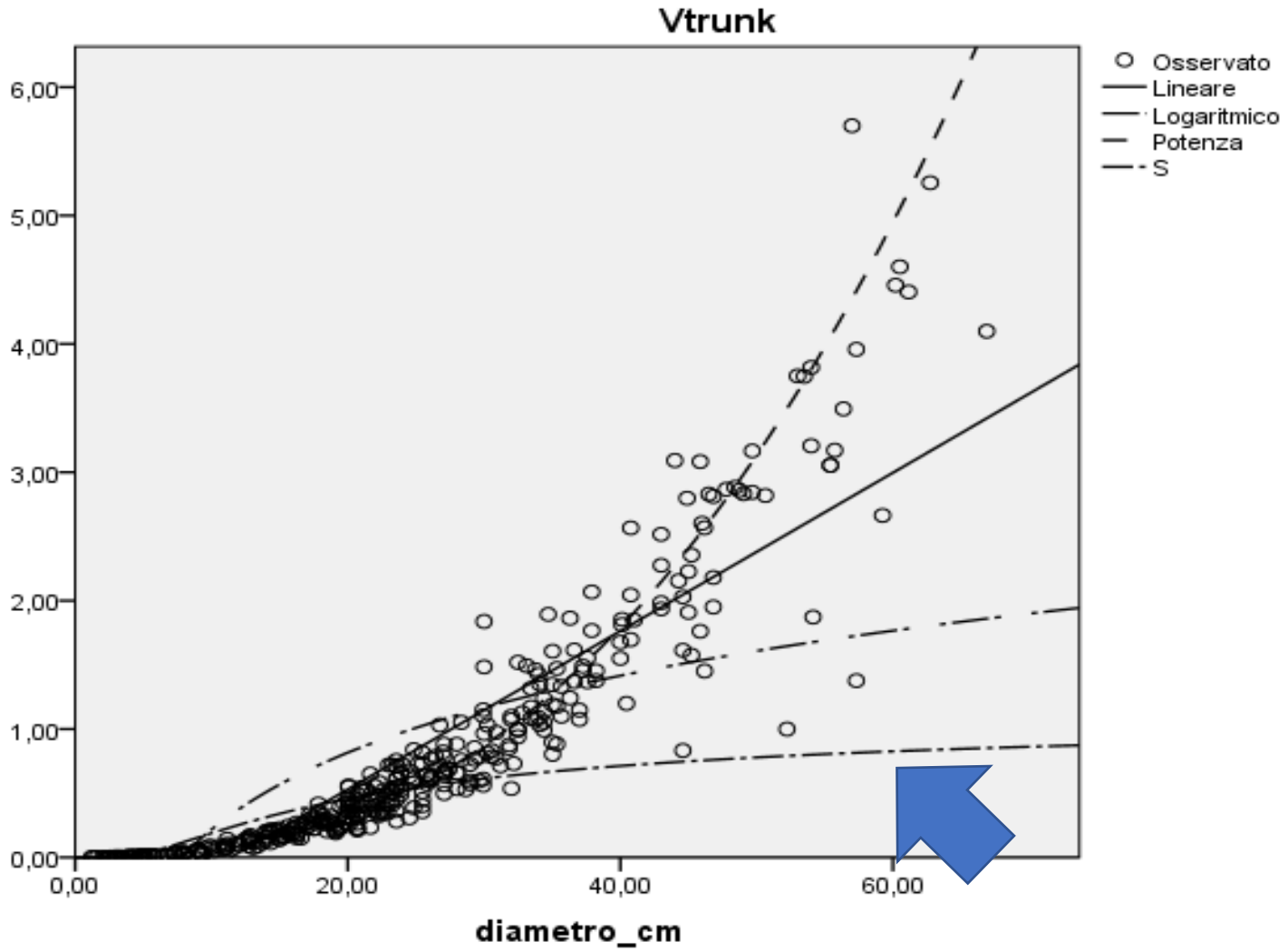
	Larix decidua	***Fagus sylvatica***	***Fraxinus***	***Ostrya carpinifolia***	***Picea abies***	***Castanaea sativa***	***Tutte le specie***
Lineare forzata per origine	$y = 1{,}055x$ $R^2 = 0{,}584$	$y = 2{,}066x$ $R^2 = 0{,}891$	$y = 2{,}144x$ $R^2 = 0{,}804$	$y = 1{,}677x$ $R^2 = 0{,}7303$	$y = 0{,}772x$ $R^2 = 0{,}849$	$y = 1{,}358x$ $R^2 = 0{,}896$	$y = 1{,}3x$ $R^2 = 0{,}681$
Potenza	$y = 0{,}002x^{2{,}610}$ $R^2 = 0{,}627$	$y = 0{,}261x^{1{,}606}$ $R^2 = 0{,}447$	$y = 0{,}752x^{1{,}288}$ $R^2 = 0{,}6703$	$y = 0{,}788x^{1{,}153}$ $R^2 = 0{,}445$	$y = 0{,}075x^{1{,}608}$ $R^2 = 0{,}6074$	$y = 0{,}232x^{1{,}461}$ $R^2 = 0{,}816$	$y = 0{,}975x^{1{,}006}$ $R^2 = 0{,}434$
Logaritmica	$y = 64{,}404\ln(x) - 190{,}933$ $R^2 = 0{,}371$	$y = 80{,}3601\ln(x) - 206{,}331$ $R^2 = 0{,}490$	$y = 27{,}358\ln(x) - 36{,}167$ $R^2 = 0{,}462$	$y = 13{,}155\ln(x) - 10{,}985$ $R^2 = 0{,}366$	$y = 36{,}495\ln(x) - 101{,}253$ $R^2 = 0{,}564$	$y = 37{,}640\ln(x) - 81{,}152$ $R^2 = 0{,}756$	$y = 20{,}261\ln(x) - 27{,}933$ $R^2 = 0{,}268$
Sigmoide	$Y=\exp[(5{,}27)+(-72{,}71)/x]$ $R^2=0{,}616$	$Y=\exp[(5{,}54)+(-41{,}99)/x]$ $R^2=0{,}463$	$Y=\exp[(3{,}92)+(-8{,}43)/x]$ $R^2=0{,}598$	$Y=\exp[(2{,}86)+(-4{,}24)/x]$ $R^2=0{,}255$	$Y=\exp[(4{,}69)+(-51{,}39)/x]$ $R^2=0{,}617$	$Y=\exp[(4{,}53)+(-25{,}91)/x]$ $R^2=0{,}740$	$Y=\exp[(3{,}46)+(-6{,}64)/x]$ $R^2=0{,}305$

specie	diametro (cm)	DLA lineare forzata per origine (m^3)	DLA logaritmica (m^3)	DLA potenza (m^3)	DLA sigmoide (m^3)
frassino	5	10,722	7,863	5,973	9,368
carpino	5	8,383	10,188	5,040	7,493
castagno	5	6,788	-20,572	2,433	0,524
faggio	5	10,330	-76,996	3,454	0,058
larice	5	5,273	-87,279	0,136	0,00009
abete rosso	5	3,861	-42,517	1,001	0,004
totale	5	6,500	4,676	4,926	8,414
frassino	25	53,612	51,894	47,444	36,108
carpino	25	41,916	31,360	32,234	14,777
castagno	25	33,942	40,008	25,533	33,091
faggio	25	51,649	52,339	45,769	47,798
larice	25	26,366	16,375	9,107	10,632
abete rosso	25	19,307	16,219	13,324	13,965
totale	25	32,501	37,285	24,888	24,358
frassino	50	107,225	70,857	115,818	42,741
carpino	50	83,831	40,479	71,682	16,087
castagno	50	67,885	66,099	70,270	55,565
faggio	50	103,299	108,040	139,285	110,696
larice	50	52,733	61,017	55,608	45,522
abete rosso	50	38,614	41,515	40,624	39,028
totale	50	65,002	51,329	49,998	27,819

Relazioni diametro-volume del fusto



Relazioni diametro-volume del fusto



$Y=\exp[(0,11)+(-17,75)/x]$

$R^2=0,791$

	Larix decidua	***Fagus sylvatica***	***Fraxinus ornus***	***Ostrya carpinifolia***	***Picea abies***	***Castanaea sativa***	***Tutte le specie***
Lineare	y = 0,091x - 1,594 R^2 = 0,857	y = 0,061x - 0,950 R^2 = 0,867	y = 0,040x - 0,311 R^2 = 0,832	y = 0,016x - 0,067 R^2 = 0,895	y = 0,093x - 1,742 R^2 = 0,921	y = 0,046x - 0,408 R^2 = 0,827	y = 0,062x - 0,702 R^2 = 0,804
Potenza	$y = 6,915*10^{-4} *x^{2,131}$ R^2 = 0,922	$y = 3,272*10^{-4}* x^{2,287}$ R^2 = 0,8224	$y = 1,125*10^{-4}* x^{2,681}$ R^2 = 0,986	$y = 1,457*10^{-4}*x^{2,5653}$ R^2 = 0,982	$y = 4,527*10^{-4}* x^{2,230}$ R^2 = 0,9445	$y = 7,203*10^{-4}*x^{2,033}$ R^2 = 0,957	$y = 1,734*10^{-4}*x^{2,506}$ R^2 = 0,978
Logaritmica	y = 2,732ln(x) - 7,979 R^2 = 0,750	y = 1,633ln(x) - 4,636 R^2 = 0,764	y = 0,416ln(x) - 0,720 R^2 = 0,534	y = 0,117ln(x) - 0,146 R^2 = 0,703	y = 3,180ln(x) - 9,579 R^2 = 0,841	y = 1,094ln(x) - 2,529 R^2 = 0,787	y = 0,865ln(x) - 1,774 R^2 = 0,482
Sigmoide	Y=exp[(2,05)+(-58,23)/x] R^2=0,872	Y=exp[(1,72)+(-58,21)/x] R^2=0,806	Y=exp[(-0,35)+(-17,41)/x] R^2=0,886	Y=exp[(-1,55)+(-11,64)/x] R^2=0,854	Y=exp[(-1,55)+(-11,64)/x] R^2=0,914	Y=exp[(1,19)+(-37,43)/x] R^2=0,935	Y=exp[(0,11)+(-17,75)/x] R^2=0,791

specie	diametro (cm)	Vfusto lineare (m^3)	Vfusto logaritmica (m^3)	V fusto potenza (m^3)	V fustosigmoide (m^3)
frassino	5	-0,111	-0,050	0,008	0,022
carpino	5	0,014	0,042	0,009	0,021
castagno	5	-0,178	-0,769	0,019	0,002
faggio	5	-0,645	-2,008	0,013	0,00005
larice	5	-1,140	-3,582	0,021	0,00007
abete rosso	5	-1,276	-4,462	0,016	0,00001
totale	5	-0,394	-0,382	0,010	0,032
frassino	25	0,692	0,619	0,629	0,353
carpino	25	0,336	0,230	0,563	0,134
castagno	25	0,741	0,992	0,500	0,733
faggio	25	0,576	0,620	0,516	0,547
larice	25	0,678	0,816	0,660	0,753
abete rosso	25	0,589	0,656	0,594	0,641
totale	25	0,839	1,009	0,552	0,546
frassino	50	1,695	0,907	4,030	0,500
carpino	50	0,739	0,312	3,331	0,169
castagno	50	1,890	1,750	2,045	1,550
faggio	50	2,102	1,751	2,516	1,752
larice	50	2,951	2,709	2,890	2,417
abete rosso	50	2,921	2,860	2,785	2,575
totale	50	2,380	1,608	3,133	0,779

CONCLUSIONI:

CURVE DI REGRESSIONE → Indagini future:

1) Assimilazione di CO_2

Regressione diametro – DLA + LAI → SUP. FOGLIARE TOT

specie	diametro (cm)	DLA (m^2)	LAI	Stot foglie (m^2)	A frax media (gCO^2/m^2*gg)	A tot (gCO2/m^2*gg)
frassino	5	10,33	2,50	25,83	10,40	268,58
frassino	20	41,32	2,50	103,30	10,40	1074,32
frassino	30	61,98	3,70	229,33	10,40	2384,99
frassino	50	103,30	3,70	382,21	10,40	3974,98

1) stoccaggio di CO_2

Regressione diametro – V del fusto → quantità di CO_2 stoccata nel fusto

Regressione potenza diametro – V trunk (Frassino)

Y = 0,0001125* x^2,681

specie	diametro (cm)	V tronco (m^3)	densità (g/cm^3)	kg CO2
frassino	5	0,00842	0,56	4,7128
frassino	20	0,34611	0,56	193,8215
frassino	30	1,02640	0,56	574,7813
frassino	50	4,03730	0,56	2260,8884

Grazie per l’attenzione