Potential Lidar Height, Intensity and Ratio Parameters for Plot-Dominant-Species Discrimination and Volume Estimation

Taejin Park[1,2,*]

Supplementary Figures

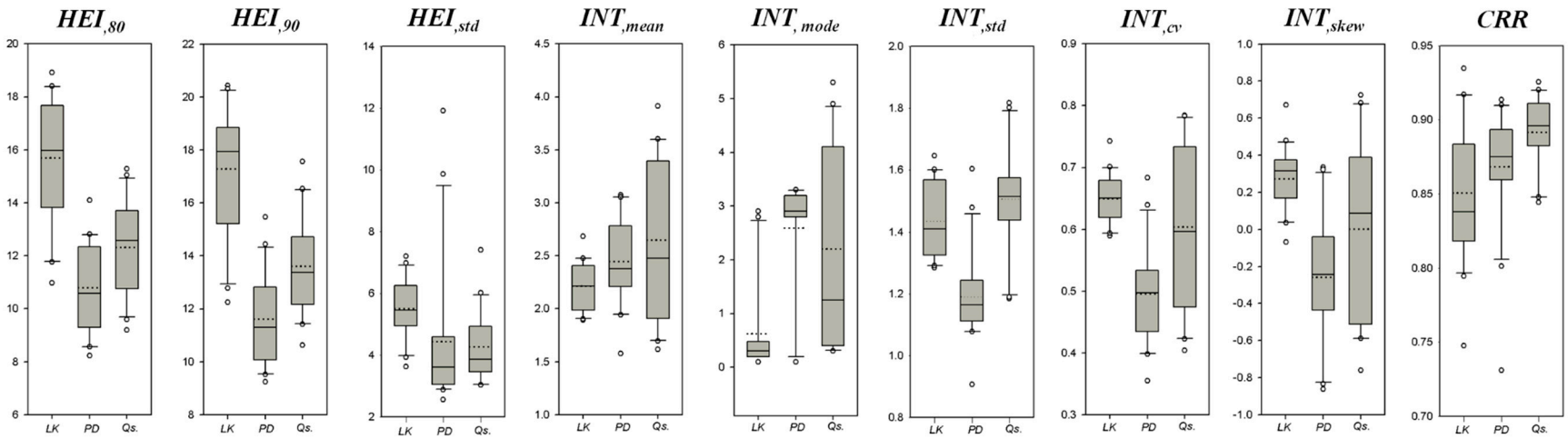


Figure S1. Box-whisker plots for visualizing the distributional characteristics of selected parameters by three plot dominant species. The HEI, INT, and CRR stand for height, intensity, and canopy return ratio, respectively. The box stretches from the 25th percentile to the 75th percentile, and the bars indicate the range with in 1.5 IQR (interquartile range). Median value is shown as a line and points stand for outliers.

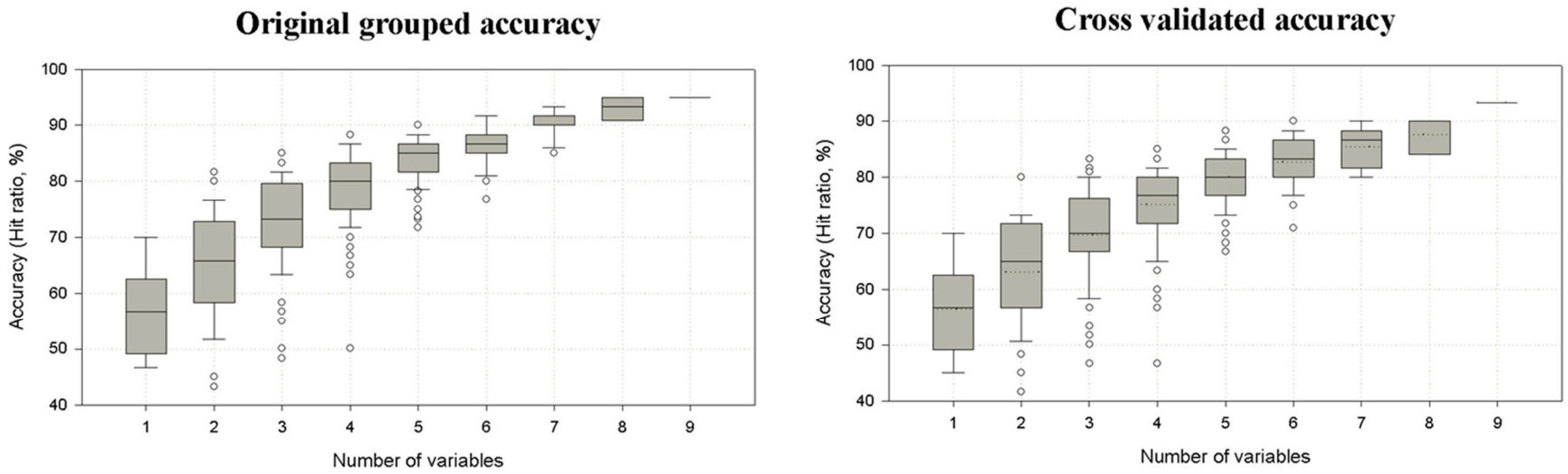


Figure S2. Original grouped- and Cross validated- accuracy of discriminant analysis by number of selected variables in combinations. The box stretches from the 25th percentile to the 75th percentile, and the bars indicate the range with in 1.5 IQR (interquartile range). Median value is shown as a line and points stand for outliers.

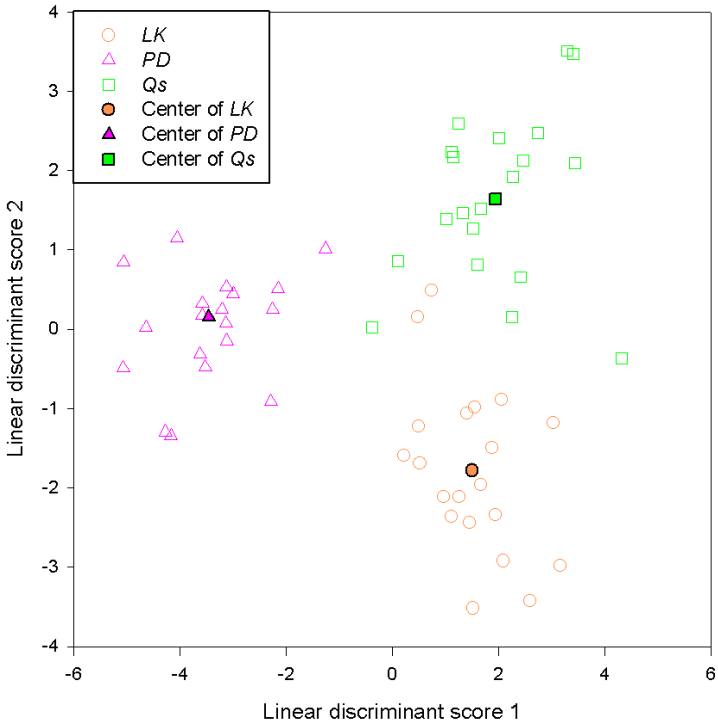
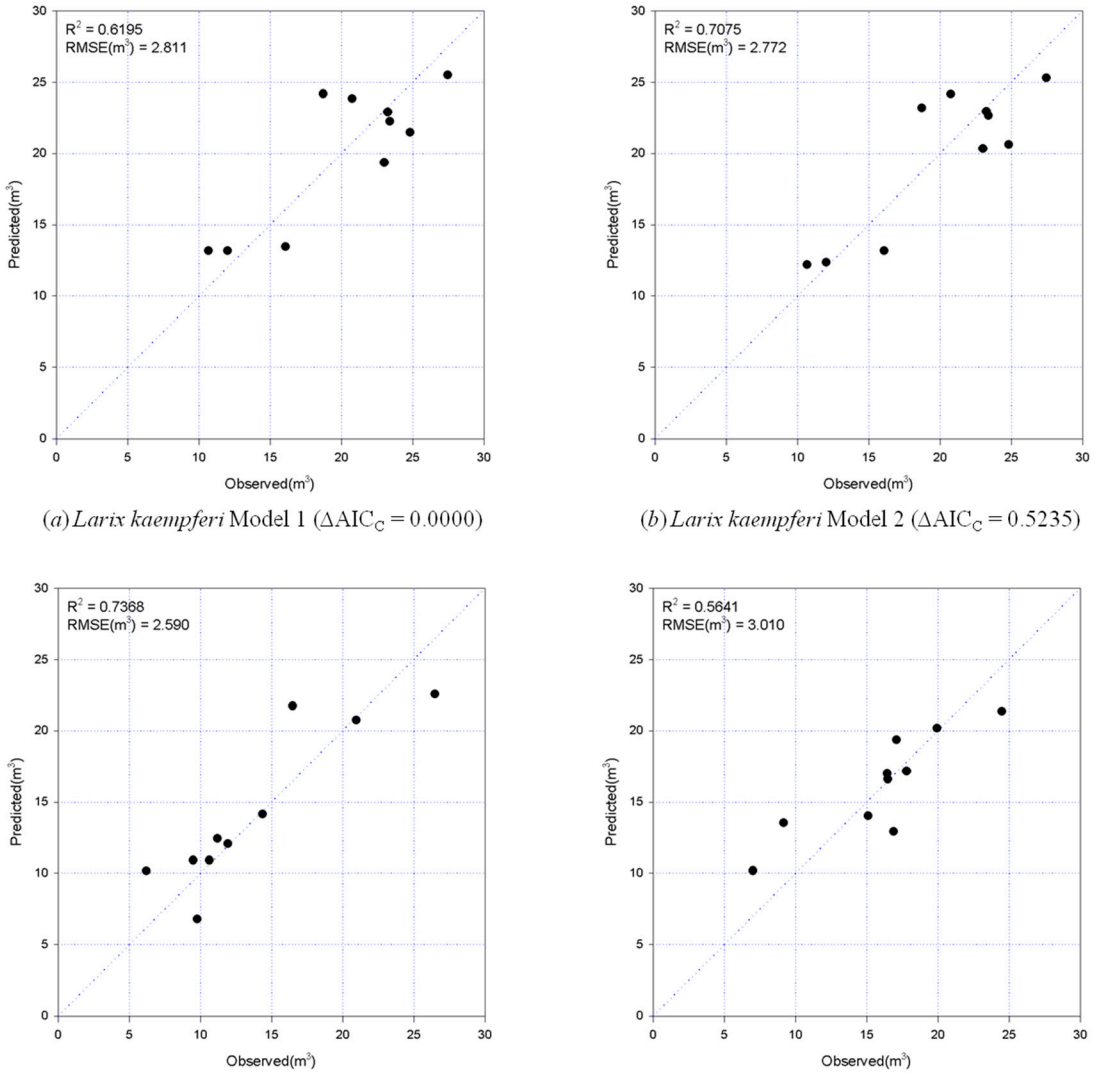


Figure S3. Distribution of discriminant score and its centroid by first and second canonical discriminant function.



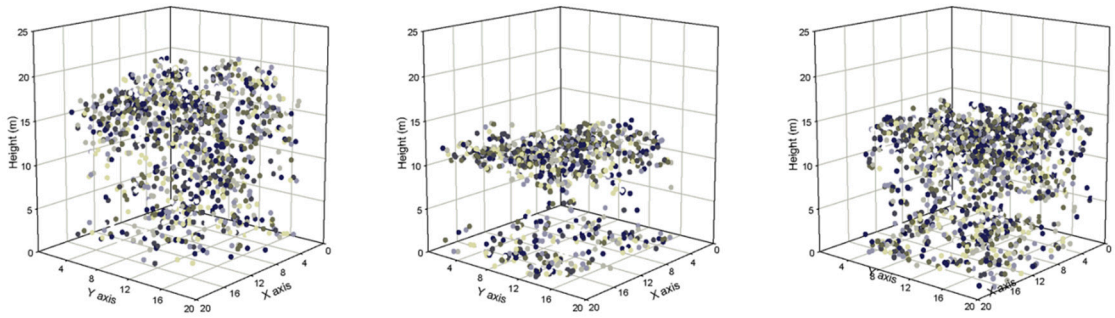
(*a*) *Larix kaempferi* Model 1 ($\Delta AIC_C = 0.0000$)

(*b*) *Larix kaempferi* Model 2 ($\Delta AIC_C = 0.5235$)

(*c*) *Pinus densiflora* Model ($\Delta AIC_C = 0.0000$)

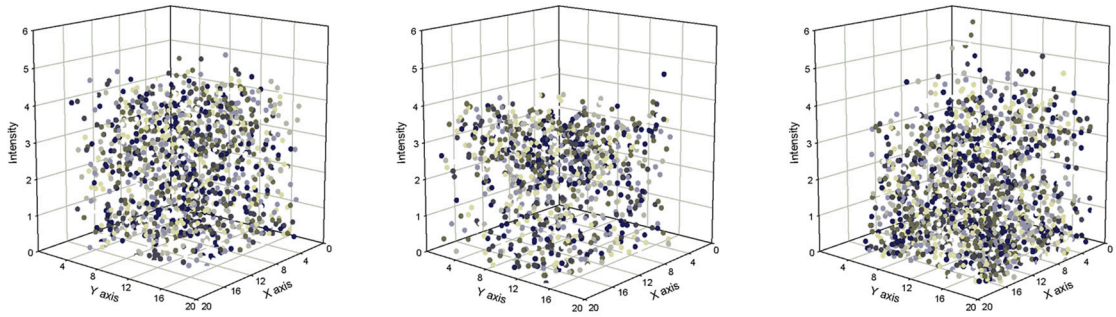
(*d*) *Quercus* spp. Model ($\Delta AIC_C = 0.0000$)

Figure S4. Evaluation of the developed plot volume models using independent testing data.



(a) *Larix kaempferi* (b) *Pinus densiflora* (c) *Quercus* spp.

Figure S5. Three dimensional view of the lidar height distribution of each species. X and Y axes are a spatial coordinate of the plot (meter scale).



(a) *Larix kaempferi* (b) *Pinus densiflora* (c) *Quercus* spp.

Figure S6. Three dimensional view of the lidar intensity distribution of each species. X and Y axes are a spatial coordinate of the plot (meter scale).

Supplementary Tables

Table S1. Descriptive statistics of the field measurements.

		Sample plot			Test plot		
Estimator	statistics	*L. kaempferi* (20 plots)	*P. densiflora* (20 plots)	*Q.* spp. (20 plots)	*L. kaempferi* (10 plots)	*P. densiflora* (10 plots)	*Q.* spp. (10 plots)
Age (years)	Max.	50.0	45.0	46.0	45	38	35
	Min.	32.0	35.0	29.0	35	32	28
	Mean.	44.4	40.5	33.4	40.2	37.3	32.3
	Std.	5.2	3.9	4.7	6.7	3.5	5.1
DBH (cm)	Max.	34.2	29.4	22.1	32.7	28.8	21.9
	Min.	12.7	17.8	12.5	17.3	16.7	13.1
	Mean.	25.2	23.2	18.2	24.7	22.4	18
	Std.	6.5	3.3	3.3	5.1	3.4	3.2
Height (m)	Max.	22.4	17.4	14.8	20.7	17.3	13.5
	Min.	10.4	8.7	9.8	12.3	10.4	10.1
	Mean.	16.5	13.1	13.5	16.8	13.5	12.4
	Std.	4.6	2.3	1.7	3.8	2.5	2.1
Tree Density (N/ha)	Max.	525	1,375	2,075	575	1,200	1,675
	Min.	275	800	325	375	875	500
	Mean.	442.5	1,007.5	985	480	1,095	1,127.5
	Std.	3.2	7.1	19.7	3.1	6.8	15.4

Table S2. Sorted the highest accuracy results of linear discriminant analysis by number of variables (one by each variable number).

No. (AE1, AE2)	Variable combination (RD1, RD2)									Number of variables	Accuracy (%)	
											Original grouped	Cross validated
1 (46.6, -)	$INT_{,std}$ (1, -)									1	63.3	63.3
2 (71.9, 23.2)	$HEI_{,80}$ (1, 2)	$INT_{,std}$ (2, 1)								2	81.7	80.0
3 (74.5, 38.8)	$HEI_{,90}$ (3, 3)	$INT_{,mean}$ (1, 2)	$INT_{,cv}$ (2, 1)							3	83.3	83.3
4 (75.7, 41.5)	$HEI_{,80}$ (3, 2)	$INT_{,mean}$ (1, 3)	$INT_{,cv}$ (2, 1)	CRR (4, 4)						4	88.3	85.0
5 (74.5, 53.1)	$HEI_{,80}$ (3, 3)	$INT_{,mean}$ (1, 4)	$INT_{,mode}$ (4, 5)	$INT_{,cv}$ (2, 1)	$INT_{,skew}$ (5, 2)					5	90.0	88.3
6 (76.2, 50.8)	$HEI_{,90}$ (1, 4)	$INT_{,mode}$ (4, 3)	$INT_{,std}$ (2, 6)	$INT_{,cv}$ (3, 1)	$INT_{,skew}$ (6, 2)	CRR (5, 5)				6	91.7	90.0
7 (81.7, 53.6)	$HEI_{,80}$ (4, 3)	$HEI_{,90}$ (1, 6)	$HEI_{,std}$ (5, 7)	$INT_{,mean}$ (3, 5)	$INT_{,mode}$ (6, 4)	$INT_{,cv}$ (2, 1)	$INT_{,skew}$ (7, 2)			7	93.3	90.0
8 (85.4, 60.1)	$HEI_{,80}$ (5, 5)	$HEI_{,90}$ (3, 7)	$HEI_{,std}$ (4, 8)	$INT_{,mean}$ (1, 2)	$INT_{,mode}$ (8, 4)	$INT_{,std}$ (6, 3)	$INT_{,cv}$ (2, 1)	CRR (7, 6)		8	93.3	90.0
9 (86.3, 67.4)	$HEI_{,80}$ (4, 4)	$HEI_{,90}$ (3, 7)	$HEI_{,std}$ (6, 8)	$INT_{,mean}$ (2, 2)	$INT_{,mode}$ (9, 6)	$INT_{,std}$ (5, 3)	$INT_{,cv}$ (1, 1)	$INT_{,skew}$ (7, 5)	CRR (8, 9)	9	95.0	93.3

Table S3. Error matrix of plot dominant species classification results by discriminant analysis (case on the highest performance of 93.3%).

	Predicted species			
	Larix kaempferi	*Pinus densiflora*	*Quercus* spp.	Row total
Referenced species				
Larix kaempferi	18	0	2	20
Pinus densiflora	0	20	0	20
Quercus spp.	1	1	18	20
Colum total	19	21	20	60
User accuracy (%)	94.7	95.2	90.0	
Producer accuracy (%)	90.0	100.0	90.0	
Overall accuracy	93.3			
***Kappa* value** ($\hat{K}$)	**0.90**			

Table S4. Result of plot volume parameters estimated multiple regression analysis to *Larix kaempferi.*

No.	Intercept	$HEI_{,90}$	$INT_{,mode}$	$INT_{,se}$	$INT_{,TSum}$	RMSE	SSE	R^2	Adjusted R^2	$AINT_C$	$\Delta AINT_C$
1	**-4.71040**	**0.44771**	**-0.69894**	**.**	**0.000753**	**2.9475**	**347.4985**	**0.81366**	**0.77873**	**-17.6027**	**0.0000**
2	**-5.85002**	**0.43730**	**-0.68725**	**24.2152**	**0.000782**	**2.9338**	**344.2873**	**0.82693**	**0.78077**	**-17.0792**	**0.5235**
3	-5.13540	0.45399	.	.	0.000776	3.4196	467.7466	0.73351	0.70216	-12.4468	5.1559
4	-6.38033	0.44243	.	26.6189	0.000808	3.4171	467.0492	0.74956	0.70260	-11.6893	5.9134
5	-2.79655	0.41578	-0.73511	.	.	3.7425	560.2373	0.68081	0.64326	-8.8381	8.7646
6	-3.44416	0.40871	-0.72885	14.7069	.	3.8276	586.0056	0.68578	0.62686	-7.1515	10.4512

Table S5. Result of plot volume parameters estimated multiple regression analysis to *Pinus densiflora.*

No.	Intercept	$HEI_{,mean}$	$HEI_{,mode}$	$INT_{,std}$	$INT_{,range}$	RMSE	SSE	R^2	Adjusted R^2	$AINT_C$	$\Delta AINT_C$
1	**1.19921**	**0.38271**	**0.07408**	**2.54207**	**-0.85953**	**2.9619**	**350.9022**	**0.79490**	**0.74020**	**-16.6989**	**0.0000**
2	2.64933	0.38166	.	2.59838	-1.01080	3.1719	402.4253	0.74910	0.70205	-14.6681	2.0308
3	3.82277	0.32662	0.07575	.	-0.69251	3.1772	403.7713	0.74826	0.70106	-14.6013	2.0976
4	5.36580	0.32427	.	.	-0.84348	3.3628	452.337	0.70035	0.66510	-13.1169	3.5820
5	8.03553	.	0.07448	.	-1.00925	3.7034	548.592	0.63658	0.59383	-9.2581	7.4408
6	9.52304	.	.	.	-1.15547	3.8215	584.1545	0.59026	0.56750	-8.8587	7.8402

Table S6. Result of plot volume parameters estimated multiple regression analysis to *Quercus* spp.

No.	Intercept	$HEI_{,80}$	$INT_{,mode}$	$INT_{,kurt}$	RMSE	SSE	R^2	Adjusted R^2	$AINT_C$	$\Delta AINT_C$
1	**-0.71001**	**0.28685**	**0.07623**	**0.31517**	**3.3533**	**449.7848**	**0.67930**	**0.61917**	**-12.4426**	**0.0000**
2	-0.78485	0.25922	0.10226	.	3.6064	520.2448	0.60588	0.55951	-10.3196	2.1230
3	-0.46668	0.33777	.	0.52472	3.9118	612.0715	0.53632	0.48177	-7.0687	5.3739
4	2.21758	.	0.11427	.	4.2278	714.9548	0.42652	0.39466	-4.8181	7.6245
5	2.50174	.	0.09646	0.22681	4.1995	705.4152	0.46560	0.40272	-4.2296	8.2130
6	-0.44895	0.31571	.	.	4.7600	906.2850	0.27305	0.23266	-0.0754	12.3672

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