

Supplementary material: Automatic Filtering and Classification of Low-Density Airborne Laser Scanner Clouds in Shrubland Environments

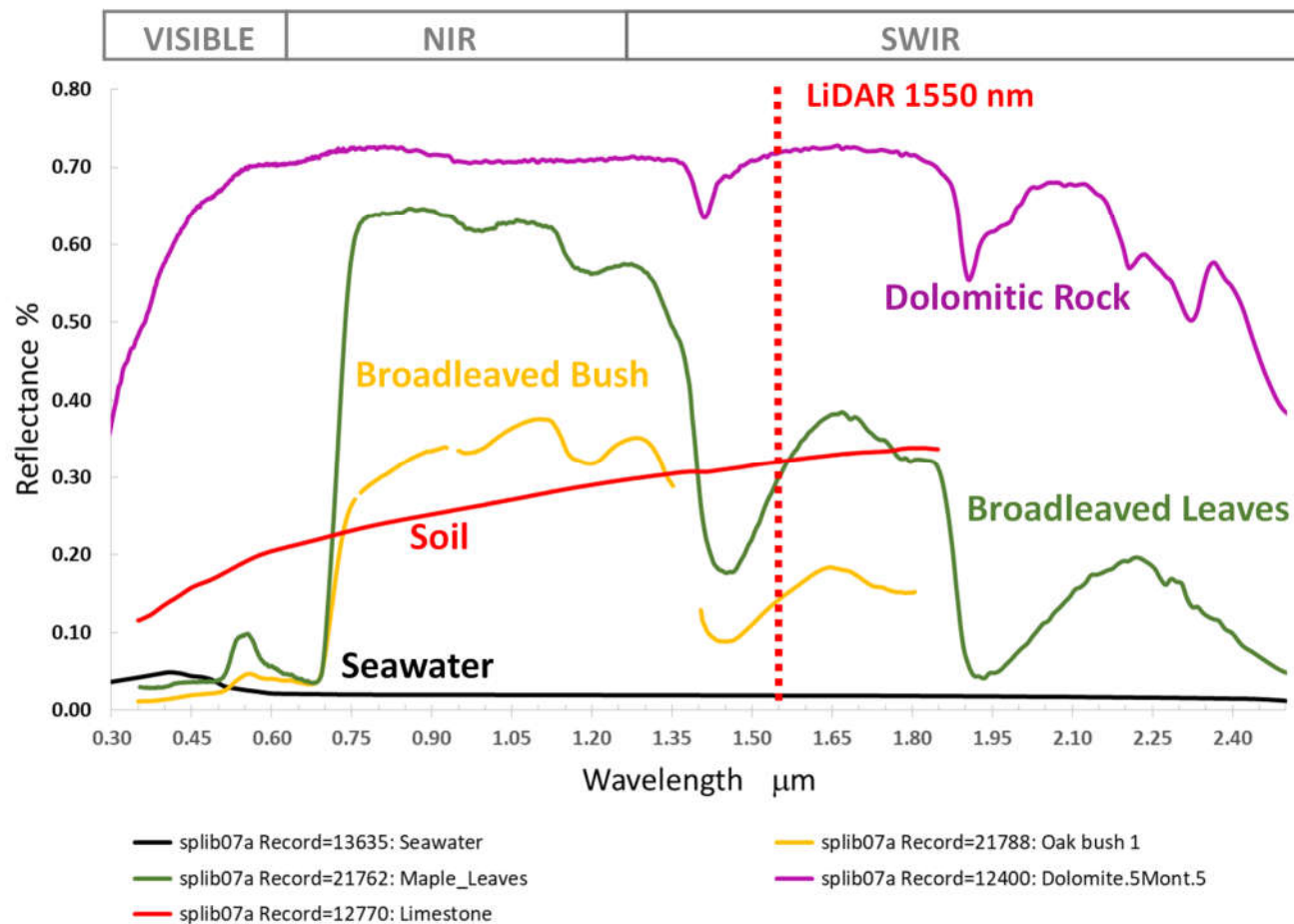


Figure S1. Spectral reflectance of different materials across visible and SWIR wavelengths with the position of the RIEGL LMS-Q560 spectral channel (Spectra from the USGS Spectral Library Version 7 [85]).

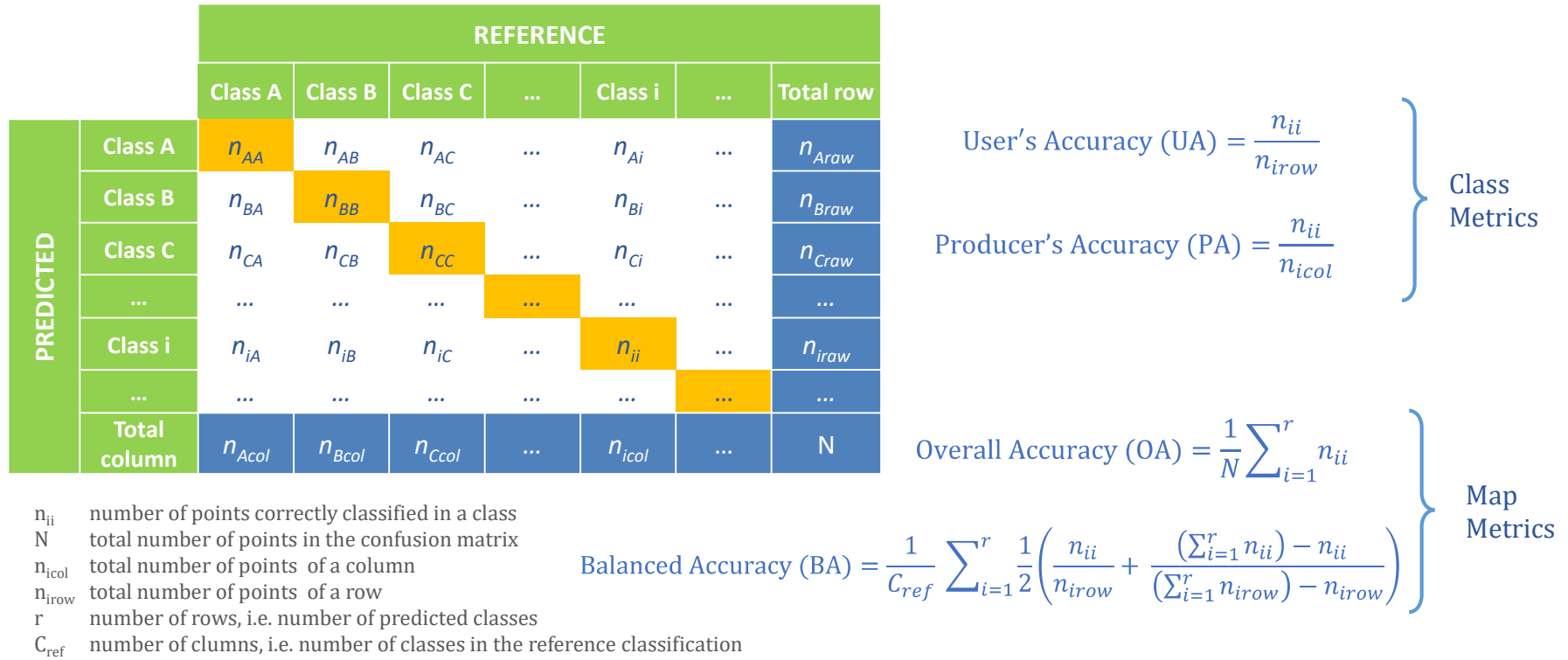


Figure S2. A general confusion matrix with the accuracy metrics adopted in the study (equations 1-4) [71–73].

For binary case as proposed by Brodersen et al. 2010

		Reference		
		Positive	Negative	
Predicted	Positive	TP	FP	P
	Negative	FN	TN	N

$$\text{Balanced Accuracy} = \frac{1}{2} \left(\frac{TP}{P} + \frac{TN}{N} \right)$$

TP = True Positive

P = Total Positive

TN = True Negative

N = Total Negative

Extension to multiclass cases

		Reference			
		Class 1	Class 2	Class 3	Total row
Predicted	Class 1	a (TP)	b (FP)	c (FP)	R1 (P)
	Class 2	d (FN)	e (TN)	f (FP)	R2
	Class 3	g (FN)	h (FN)	i (TN)	R3
	Total column	T			

(N) = T-R1

For Class 1

$$\text{Balanced Accuracy} = \frac{1}{2} \left(\frac{a}{R1} + \frac{(e + i)}{(T - R1)} \right)$$

For all Classes

$$\text{Balanced Accuracy} = \frac{\frac{1}{2} \left(\frac{a}{R1} + \frac{(e + i)}{(T - R1)} \right) + \frac{1}{2} \left(\frac{b}{R2} + \frac{(a + i)}{(T - R2)} \right) + \frac{1}{2} \left(\frac{c}{R3} + \frac{(a + e)}{(T - R3)} \right)}{RCN}$$

		Reference			
		Class 1	Class 2	Class 3	Total row
Predicted	Class 1	a	b	c	R1
	Class 2	d	e	f	R2
	Class 3	g	h	i	R3
	Total column	C1	C2	C3	T

$$\text{Balanced Accuracy} = \frac{1}{2RCN} \left[\left(\frac{a}{R1} + \frac{(e + i)}{(T - R1)} \right) + \left(\frac{b}{R2} + \frac{(a + i)}{(T - R2)} \right) + \left(\frac{c}{R3} + \frac{(a + e)}{(T - R3)} \right) \right]$$

T = Total number of points

RCN = Class number of Reference classification

Figure S3. Schematic example of the balanced accuracy (BA) generalized in equation 4; implementation from binary [73] to multi-class classifications (application for three classes).

Table S1. Confusion matrices of the automatic filtering and classification based on geometric feature (GEO) and automatic filtering and geometric classification integrated with the K-means segmented intensity (GIK).

			Reference					Reference			
			Tall Shrub	Low Shrubs	Rock	TOT.		Tall Shrub	Low Shrubs	Rock	TOT.
AREA 1	Tall Shrub	GEO	48352	0	747	49099	GIK	48215	0	505	48720
	Low Shrub		0	22540	5579	28119		0	20947	1731	22678
	Rock		0	0	0	0		137	1593	4090	5820
	TOT.		48352	22540	6326	77218		48352	22540	6326	77218
AREA 2	Tall Shrub	GEO	46339	0	213	46552	GIK	46334	0	212	46546
	Low Shrub		0	11721	1200	12921		0	11332	689	12021
	Rock		0	0	0	0		5	399	512	916
	TOT.		46339	11721	1413	59473		46339	11731	1413	59483
AREA 3	Tall Shrub	GEO	71433	0	4757	76190	GIK	70297	0	1483	71780
	Low Shrub		0	113965	10085	124050		0	104918	1326	106244
	Rock		0	0	0	0		1136	9047	12033	22216
	TOT.		71433	113965	14842	200240		71433	113965	14842	200240
AREA 4	Tall Shrub	GEO	6618	0	12	6630	GIK	6618	0	12	6630
	Low Shrub		0	2828	1170	3998		0	2595	457	3052
	Rock		0	0	0	0		0	233	713	946
	TOT.		6618	2828	1182	10628		6618	2828	1182	10628