Supplementary Materials: Exploring the Inclusion of Small Regenerating Trees to Improve Above-Ground Forest Biomass Estimation Using Geospatial Data. *Remote Sensing* 2018, *9*, remotesensing-325477

Anh V. Le [1,2,3,*], David J. Paull [1] and Amy L. Griffin [4]

3. Methodology

3.2. Remotely Sensed Data Pre-Processing and Creation of Derived Variables

We used six spectral bands of visible and infrared reflectance (Bands 2–7) from Landsat-8 OLI. This analysis required spectral information to be in the form of top of atmosphere (TOA) reflectance rather than digital numbers (DN), thus, we converted the Landsat-8 OLI scene first to TOA reflectance using the formulas (Equations S1 and S2) provided in the USGS guidelines (https://landsat.usgs.gov/using-usgs-landsat-8-product).

Equation S1. Formula for calculating TOA planetary reflectance, without correction for solar angle:

$$\rho\lambda' = M\rho Qcal + A\rho$$

where:

$\rho\lambda'$ = TOA planetary reflectance, without correction for solar angle;

$M\rho$ = band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x,
where x is the band number);

$A\rho$ = band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x,
where x is the band number); and,

$Qcal$ = quantized and calibrated standard product pixel values (DN).

Equation S2. Formula for calculating TOA reflectance with a correction for the sun angle:

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})}$$

where:

$\rho\lambda$ = TOA planetary reflectance;

θ_{SE} = local sun elevation angle with the scene centre sun elevation angle in degrees as provided in the metadata (SUN_ELEVATION); and,

θ_{SZ} = Local solar zenith angle, $\theta_{SZ} = 90° - \theta_{SE}$.

In the present study, we calculated texture measures using five window sizes, from small to medium sizes, including: 3 × 3, 5 × 5, 7 × 7, 9 × 9 and 11 × 11 pixels; we then determined the final optimal window size after comparing the outputs. Considering the results of correlation coefficients between texture parameters obtained from testing different window sizes and in situ biomass, along with the pixel size of Landsat data, a final window size of 3 × 3 was selected for the experiments (Table S1). This is in line with a number of other studies, which also ended up choosing a 3 × 3 window size for their final biomass estimation models after testing a range of window sizes.

Table S1. Correlation coefficients between GLCM texture parameters (in different window sizes) and in-situ biomass (calculated from Equation 1).

Landsat 8 OLI	Texture Parameters	Window Sizes				
		3 × 3	5 × 5	7 × 7	9 × 9	11 × 11
Band 2 Blue	ME	−0.54	−0.53	−0.53	−0.50	−0.53
	VA	−0.30	−0.30	−0.30	−0.21	−0.22
	HO	0.27	0.27	0.26	0.27	0.26
	CO	−0.27	−0.22	−0.24	−0.27	−0.25
	DI	−0.27	−0.27	−0.25	−0.20	−0.21
	EN	−0.30	−0.29	−0.30	−0.22	−0.23
	SE	0.29	0.29	0.29	0.21	0.23
	CC	0.26	0.23	0.22	0.24	0.16
Band 3 Green	ME	−0.41	−0.40	−0.40	−0.31	−0.32
	VA	0.18	0.10	0.07	0.11	0.16
	HO	−0.15	−0.15	−0.15	−0.15	−0.15
	CO	0.13	0.13	0.13	0.13	0.11
	DI	0.14	0.14	0.05	0.12	0.11
	EN	0.18	0.17	0.16	0.08	0.08
	SE	−0.19	−0.15	−0.15	−0.12	−0.11
	CC	−0.13	−0.13	−0.07	0.03	0.06
Band 4 Red	ME	−0.51	−0.44	−0.46	−0.48	−0.48
	VA	0.08	0.04	0.01	0.01	0.02
	HO	−0.04	0.01	0.04	0.03	0.03
	CO	0.02	−0.02	−0.00	−0.00	−0.00
	DI	0.04	−0.04	−0.04	−0.01	−0.03
	EN	0.06	0.02	−0.01	−0.02	−0.01
	SE	−0.06	−0.01	0.02	0.04	0.04
	CC	−0.01	0.00	0.01	−0.03	−0.02
Band 5 NIR	ME	0.40	0.38	0.38	0.38	0.37
	VA	0.10	0.09	0.08	0.07	0.08
	HO	−0.14	−0.12	−0.12	−0.12	−0.13
	CO	0.17	0.14	0.12	0.12	0.13
	DI	0.15	0.13	0.12	0.12	0.14
	EN	0.09	0.09	0.08	0.08	0.09
	SE	−0.11	−0.10	−0.09	−0.08	−0.09
	CC	−0.14	−0.11	−0.08	−0.07	−0.05
Band 6 SWIR 1	ME	−0.33	−0.35	−0.28	−0.30	−0.31
	VA	0.11	0.10	0.09	0.10	0.11
	HO	−0.16	−0.16	−0.15	−0.14	−0.16
	CO	0.11	0.10	0.09	0.09	0.12
	DI	0.15	0.14	0.13	0.12	0.15
	EN	0.11	0.10	0.10	0.11	0.13
	SE	−0.09	−0.07	−0.07	−0.09	−0.08
	CC	−0.02	−0.01	−0.01	−0.01	0.02
Band 7 SWIR 2	ME	−0.60	−0.60	−0.51	−0.52	−0.52
	VA	−0.08	−0.06	−0.06	−0.08	−0.07
	HO	0.13	0.09	0.11	0.11	0.10
	CO	−0.12	−0.11	−0.12	−0.09	−0.11
	DI	−0.13	−0.08	−0.13	−0.13	−0.09
	EN	−0.13	−0.11	−0.11	−0.12	−0.13
	SE	0.11	0.11	0.13	0.06	0.08
	CC	0.15	0.04	0.03	0.01	−0.01

4. Results

4.3. Assessment of Optical Imagery-Derived Variables

To identify which Landsat-derived variables were most important in building the AGB models, we computed correlation coefficients between field-based biomass and each group of predictor variables (Table S2).

Table S2. Correlation coefficients between optical image-derived variables and total field-based biomass (both large woody and small regenerating trees), computed from different allometric equations

Variables		Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (5)
			Raw Spectral band			
	Band 2 (Blue)	0.62	0.59	0.61	0.60	0.59
	Band 3 (Green)	0.49	0.50	0.50	0.49	0.49
	Band 4 (Red)	0.51	0.53	0.53	0.53	0.53
	Band 5 (NIR)	−0.39	−0.34	−0.37	−0.35	−0.36
	Band 6 (SWIR 1)	0.32	0.35	0.34	0.34	0.34
	Band 7 (SWIR 2)	0.58	0.57	0.59	0.58	0.58
			Vegetation Indices			
	NDVI	0.57	0.54	0.57	0.55	0.55
	SAVI	−0.48	−0.43	−0.45	−0.44	−0.45
	EVI	−0.50	−0.45	−0.48	−0.46	−0.47
	DVI	−0.52	−0.48	−0.51	−0.49	−0.50
	RVI	0.56	0.55	0.56	0.56	0.56
	ARVI	0.58	0.58	0.59	0.58	0.58
	GEMI	−0.21	−0.15	−0.18	−0.17	−0.17
			Band ratios			
	BLUE/GREEN	−0.09	−0.03	−0.06	−0.05	−0.05
	BLUE/RED	0.36	0.43	0.40	0.41	0.41
	BLUE/NIR	−0.45	−0.40	−0.44	−0.42	−0.42
	GREEN/RED	0.48	0.52	0.50	0.51	0.51
	GREEN/NIR	−0.51	−0.46	−0.49	−0.47	−0.47
			Principal Components			
	PC1	0.35	0.38	0.37	0.37	0.37
	PC2	−0.58	−0.55	−0.57	−0.56	−0.56
	PC3	−0.02	−0.07	−0.05	−0.05	−0.05
			Texture			
Band 2 Blue	ME	−0.54	−0.52	−0.54	−0.52	−0.52
	VA	−0.30	−0.26	−0.28	−0.27	−0.28
	HO	0.27	0.23	0.26	0.24	0.24
	CO	−0.27	−0.23	−0.26	−0.24	−0.24
	DI	−0.27	−0.23	−0.26	−0.24	−0.24
	EN	−0.30	−0.25	−0.28	−0.27	−0.27
	SE	0.29	0.25	0.28	0.27	0.27
	CC	0.26	0.21	0.25	0.23	0.23
Band 3 Green	ME	−0.41	−0.43	−0.42	−0.43	−0.43
	VA	0.18	0.20	0.20	0.19	0.20
	HO	−0.15	−0.16	−0.16	−0.16	−0.18
	CO	0.13	0.15	0.15	0.15	0.16
	DI	0.14	0.16	0.16	0.16	0.17
	EN	0.18	0.19	0.20	0.19	0.20
	SE	−0.19	−0.19	−0.20	−0.19	−0.20
	CC	−0.13	−0.14	−0.14	−0.13	−0.14
Band 4 Red	ME	−0.51	−0.53	−0.53	−0.53	−0.53
	VA	0.08	0.05	0.07	0.09	0.08
	HO	−0.04	−0.03	−0.04	−0.06	−0.05

	CO	0.02	0.03	0.02	0.05	0.04
	DI	0.04	0.03	0.04	0.06	0.05
	EN	0.06	0.02	0.06	0.06	0.05
	SE	−0.06	−0.02	−0.06	−0.06	−0.05
	CC	−0.01	−0.02	−0.02	−0.05	−0.05
Band 5 NIR	ME	0.40	0.34	0.37	0.36	0.36
	VA	0.10	0.11	0.11	0.10	0.09
	HO	−0.14	−0.15	−0.15	−0.16	−0.15
	CO	0.17	0.15	0.17	0.16	0.16
	DI	0.15	0.16	0.17	0.17	0.16
	EN	0.09	0.10	0.11	0.11	0.11
	SE	−0.11	−0.12	−0.12	−0.13	−0.13
	CC	−0.14	−0.17	−0.17	−0.18	−0.18
Band 6 SWIR 1	ME	−0.33	−0.37	−0.35	−0.36	−0.36
	VA	0.11	0.11	0.10	0.12	0.11
	HO	−0.16	−0.14	−0.14	−0.17	−0.15
	CO	0.11	0.12	0.09	0.13	0.11
	DI	0.15	0.14	0.13	0.15	0.14
	EN	0.11	0.09	0.11	0.11	0.10
	SE	−0.09	−0.07	−0.09	−0.09	−0.08
	CC	−0.02	−0.04	0.00	−0.04	−0.04
Band 7 SWIR 2	ME	−0.60	−0.58	−0.60	−0.59	−0.59
	VA	−0.08	−0.08	−0.09	−0.06	−0.07
	HO	0.13	0.12	0.15	0.11	0.11
	CO	−0.12	−0.10	−0.13	−0.09	−0.09
	DI	−0.13	−0.12	−0.15	−0.10	−0.11
	EN	−0.13	−0.14	−0.14	−0.12	−0.12
	SE	0.11	0.12	0.12	0.10	0.10
	CC	0.15	0.14	0.15	0.12	0.12