

Supplementary Materials

Table S1. Spectral variations of tree crown segments of multiple broadleaf species in this study.














































Species	Images						
Black oak							
White oak							
Northern Redoak							
Hickory (Shagbark+Pignut+Bitternut)							
Sugar maple							
Tulip poplar							
Others							

Table S2. Overstory tree species distribution at Site 1

Site 1: Plot 4D				
Common Name	Genus	Species	Frequency	Percent%
Black oak	<i>Quercus</i>	<i>velutina</i>	360	29.25
White oak	<i>Quercus</i>	<i>alba</i>	304	20.82
Tulip poplar	<i>Liriodendron</i>	<i>tulipifera</i>	160	11.56
Northern red oak	<i>Quercus</i>	<i>rubra</i>	120	8.03
Sugar maple	<i>Acer</i>	<i>saccharum</i>	88	6.39
Pignut hickory ^Δ	<i>Carya</i>	<i>glabra</i>	52	7.07
American basswood*	<i>Tilia</i>	<i>americana</i>	29	3.95
Black walnut*	<i>Juglans</i>	<i>nigra</i>	18	2.45
Black cherry*	<i>Prunus</i>	<i>serotina</i>	17	2.31
Bitternut hickory ^Δ	<i>Carya</i>	<i>cordiformis</i>	15	2.04
Bigtooth aspen*	<i>Populus</i>	<i>grandidentata</i>	11	1.50
Shagbark hickory ^Δ	<i>Carya</i>	<i>ovata</i>	10	1.36
American sycamore*	<i>Platanus</i>	<i>occidentalis</i>	8	1.09
American beech*	<i>Fagus</i>	<i>grandifolia</i>	3	0.41
Chinkapin oak*	<i>Quercus</i>	<i>muehlenbergii</i>	3	0.41
Red elm*	<i>Ulmus</i>	<i>rubra</i>	3	0.41
Hackberry*	<i>Celtis</i>	<i>occidentalis</i>	2	0.27
White ash*	<i>Fraxinus</i>	<i>americana</i>	2	0.27
American elm ⁸	<i>Ulmus</i>	<i>americana</i>	1	0.14
Eastern cottonwood*	<i>Populus</i>	<i>deltoides</i>	1	0.14
Sassafras*	<i>Sassafras</i>	<i>albidum</i>	1	0.14

^Δ Grouped as Hickory; * Species grouped into Other class

Table S3. Overstory tree species distribution in Site 2

Site 2: HEE Unit 3

Common Name	Genus	Species	Frequency	Percent
Sugar maple	<i>Acer</i>	<i>saccharum</i>	128	17.41
Tulip poplar	<i>Liriodendron</i>	<i>tulipifera</i>	106	14.42
Red maple	<i>Acer</i>	<i>rubrum</i>	79	10.75
American beech	<i>Fagus</i>	<i>grandifolia</i>	77	10.48
White oak	<i>Quercus</i>	<i>alba</i>	75	10.20
Chestnut oak	<i>Quercus</i>	<i>prinus</i>	65	8.84
Pignut hickory ^Δ	<i>Carya</i>	<i>glabra</i>	45	6.12
Eastern white pine *	<i>Pinus</i>	<i>strobus</i>	42	5.71
Northern red oak	<i>Quercus</i>	<i>rubra</i>	40	5.44
Sassafras*	<i>Sassafras</i>	<i>albidum</i>	32	4.35
Black gum*	<i>Nyssa</i>	<i>sylvatica</i>	27	3.67
Black oak	<i>Quercus</i>	<i>velutina</i>	25	3.40
Scarlet oak*	<i>Quercus</i>	<i>coccinea</i>	15	2.04
American elm*	<i>Ulmus</i>	<i>americana</i>	11	1.50
Bitternut hickory ^Δ	<i>Carya</i>	<i>cordiformis</i>	11	1.50
Muscle wood*	<i>Carpinus</i>	<i>caroliniana</i>	9	1.22
Black walnut*	<i>Juglans</i>	<i>nigra</i>	8	1.09
Flowering dogwood*	<i>Cornus</i>	<i>florida</i>	8	1.09
American sycamore*	<i>Platanus</i>	<i>occidentalis</i>	7	0.95
American basswood*	<i>Tilia</i>	<i>americana</i>	7	0.95
Bigtooth aspen*	<i>Populus</i>	<i>grandidentata</i>	7	0.95
Red elm*	<i>Ulmus</i>	<i>rubra</i>	7	0.95
Shagbark hickory ^Δ	<i>Carya</i>	<i>ovata</i>	6	0.82
Black cherry*	<i>Prunus</i>	<i>serotina</i>	5	0.68
Hackberry*	<i>Celtis</i>	<i>occidentalis</i>	5	0.68
Ironwood*	<i>Ostrya</i>	<i>virginiana</i>	3	0.41
Mockernut hickory ^Δ	<i>Carya</i>	<i>alba</i>	2	0.27
Black locust*	<i>Robina</i>	<i>pseudoacacia</i>	1	0.14
Chinkapin oak*	<i>Quercus</i>	<i>muehlenbergii</i>	1	0.14
Eastern redbud*	<i>Cercis</i>	<i>canadensis</i>	1	0.14
Green ash*	<i>Fraxinus</i>	<i>pennsylvanica</i>	1	0.14
Red pine *	<i>Pinus</i>	<i>resinosa</i>	1	0.14
White ash*	<i>Fraxinus</i>	<i>americana</i>	1	0.14

^Δ Grouped as Hickory; * Species grouped into Other class

Table S4. Overstory tree species distribution in Site 3

Site 3: HEE Unit 4				
Common Name	Genus	Species	Frequency	Percent
Chestnut oak	<i>Quercus</i>	<i>prinus</i>	275	21.60
Red maple	<i>Acer</i>	<i>rubrum</i>	170	13.35
Sassafras	<i>Sassafras</i>	<i>albidum</i>	136	10.68
American beech	<i>Fagus</i>	<i>grandifolia</i>	131	10.29
Sugar maple	<i>Acer</i>	<i>saccharum</i>	102	8.01
Northern red oak	<i>Quercus</i>	<i>rubra</i>	89	6.99
Black oak	<i>Quercus</i>	<i>velutina</i>	73	5.73
Black gum	<i>Nyssa</i>	<i>sylvatica</i>	69	5.42
Pignut hickory ^Δ	<i>Carya</i>	<i>glabra</i>	69	5.42
White oak	<i>Quercus</i>	<i>alba</i>	56	4.40
Tulip poplar	<i>Liriodendron</i>	<i>tulipifera</i>	32	2.51
Scarlet oak*	<i>Quercus</i>	<i>coccinea</i>	17	1.34
Red pine *	<i>Pinus</i>	<i>resinosa</i>	8	0.63
Bigtooth aspen*	<i>Populus</i>	<i>grandidentata</i>	7	0.55
White ash*	<i>Fraxinus</i>	<i>americana</i>	6	0.47
American elm*	<i>Ulmus</i>	<i>americana</i>	5	0.39
Shagbark hickory ^Δ	<i>Carya</i>	<i>ovata</i>	5	0.39
Eastern white pine *	<i>Pinus</i>	<i>strobus</i>	4	0.31
Red elm*	<i>Ulmus</i>	<i>rubra</i>	4	0.31
American basswood	<i>Tilia</i>	<i>americana</i>	3	0.24
Chinkapin oak*	<i>Quercus</i>	<i>muehlenbergii</i>	3	0.24
Flowering dogwood*	<i>Cornus</i>	<i>florida</i>	2	0.16
Bitternut hickory ^Δ	<i>Carya</i>	<i>cordiformis</i>	1	0.08
Black cherry*	<i>Prunus</i>	<i>serotina</i>	1	0.08
Black locust*	<i>Robina</i>	<i>pseudoacacia</i>	1	0.08
Black walnut*	<i>Juglans</i>	<i>nigra</i>	1	0.08
Hackberry*	<i>Celtis</i>	<i>occidentalis</i>	1	0.08
Ironwood*	<i>Ostrya</i>	<i>virginiana</i>	1	0.08
Muscle wood*	<i>Carpinus</i>	<i>caroliniana</i>	1	0.08

^Δ Grouped as Hickory; * Species grouped into Other class

Table S5. Brief survey of different tree crown segmentation techniques

Author, Year	Application	Natural/plantation	Data	Method	Edge/Region	Parameters	Accuracy	Observation
[59]	Species classify	Mixed forest	Airborne lidar scanner-CHM	Large scale Mean shift segmentation	Region	Spatial and spectral thresholding (Global)	Under-segmentation problem	Segmentation accuracy not provided
[60]	ITCD	Young plantation-nursery	UAS-RGB	Gradient-based MCWS	Edge	Window size	F-score: 67%-89%	Well distributed single species plantation
[61]	ITCD	Conifer forests	UAS-RGB oblique images	Supersixel and VGG16	Hybrid	Global thresholding to maximize inter-crown differences	F-score: 86%-92%	Did not consider hardwood forests
[30]	ITCD	Broadleaf	UAS-CHM	Multiple methods-IWS, Region grow and local maxima	Region and edge	Window size and height thresholds (Global)	F-score: 70%-80%	Provided a comparison of established algorithms
[58]	ITCD	Pine-dominated mixed forest	UAS-RGB and CHM	Region growing using growth space constraints	Region	Mean pixel intensity (Global)	Oversegmentation accuracy-85.3%	Used a global threshold
[53]	Species classify	Mixed forest	UAS-RGB	Discrete wavelet Transform	Edge	Image contrast	IoU of 90-96%	crown edges-image enhancement
[62]	ITCD	Tropical forest	Multi-source:	Logistic regression model	Region	Merging based on height, texture and pixel intensities (Global)	F-score: 81.8%-83.5%	Expensive and complicated to operate
[63]	ITCD	Rainforest; Deciduous forest	Google Earth	Marker-controlled watershed segmentation	Edge	Used gradient image to identify tree tops	F-score 76%	Relies on treetop identification to segment crowns

Equation S1

$$Grayscale = (0.299 \times Red) + (0.587 \times Green) + (0.114 \times Blue)$$

For this study, the above formula was converted to,

$$\text{Grayscale} = (0.299 \times \text{Band1}) + (0.587 \times \text{Band2}) + (0.114 \times \text{Band3})$$

where, band 1 is Green, Band 2 is Red and Band 3 is Blue.

Table S6. Hyper-parameters for our ORF model based on stratified 10-fold validation for the study.

Hyper-parameter	Values
Number of features (max_feature)	5
Number of samples (max_samples)	0.7
Number of trees (n_trees)	100
Tree depths (max_Depth)	4
N_cores	-1

Note - The hyperparameters of the RF classifier were set based on a stratified k-fold validation step.