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Mapping Shrub Abundance in Arctic Tundra from the Satellite High Resolution Record and Impacts on Albedo: Validation

Mark Chopping[1], Darko Radakovic[1], Angela Erb[2], Rocio Duchesne[3], Zhuosen Wang[4], and Crystal Schaaf[2]

[1] Montclair State University [2]University of Massachusetts, Boston [3]University of Wisconsin Whitewater [4]University of Maryland College Park, Earth System Science Interdisciplinary Center

Objectives High spatial resolution (2.5 m) shrub abundance maps were created for 127 sites of 2 km × 2 km in Alaskan Arctic tundra, with early / late QuickBird-2 (QB) / WorldView-2/3 (WV) panchromatic and NDVI image pairs over a 15- to 18-year period. The goal is to provide a dataset that can be used to assess the impact of changes in shrub abundance on summer surface albedo, to inform studies of ecological changes, and to validate lower spatial resolution ABoVE remote sensing data products. Here, validation of shrub maps was effected using the 'Toolik' map from the ABoVE 'High-Resolution Vegetation Community Maps for the Toolik Lake Area, 2013-2015' (Greaves et al. 2018; an ABoVE Sentinel site).

Imagery In the project, the commercial satellite high spatial resolution imagery used included QuickBird (~0.6 m) ca. 2005 and Worldview-2 (~0.5 m) and Worldview-3 (~0.3 m) from 2015 - 2021, to form early/late period image pairs for diverse cloud free summer tundra landscapes (Figure 1). All imagery was orthorectified to the ABoVE Albers Conic Equal Area grid at 0.5 m using ArcticDEM (Porter et al. 2018) and simultaneously converted to calibrated spectral radiances using the Polar Geospatial Center pgc_ortho.py code.

Mapping Approach A generalization of the CANAPI approach (Chopping 2011) was used to delimit the extent and abundance of shrubs.

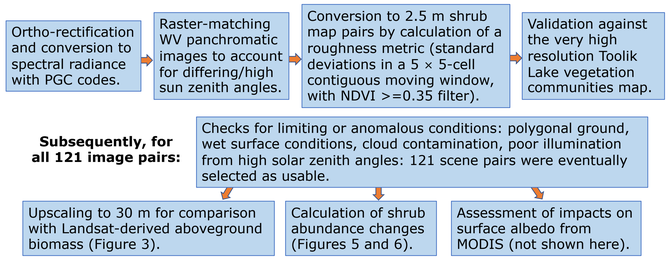


Figure 2. Sequence of operations.

Validation The Toolik Lake Vegetation Community Map was reprojected onto the same 2.5 m grid as our maps. The classes 0_No_Data, 5_Low dense shrub, 8_Shrubby tussock tundra, 10_Shrubby moist non-tussock tundra, 11_Low to tall moist shrub, and 12_Tall shrub were recoded 0_No_Data→0; 5 & 8→1; 10 & 11 → 2; and 12 → 3. The 2009 QuickBird and 2017 WorldView-2 maps were recoded to the classes 'none', 'sparse', 'moderate', and 'tall', with <1.1, 1.1<1.5, 1.5<3, and >=3. All maps were masked for a small region of invalid imagery before calculation of confusion matrices and error metrics. The overall, user's, and producer's accuracies were calculated from the confusion matrices (Table 1).

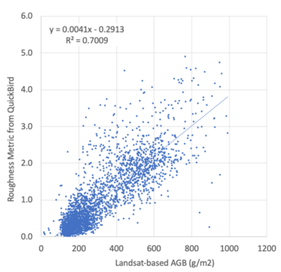


Figure 3. Roughness metric from an orthorectified QuickBird panchromatic radiance image averaged over 30 m pixels, as a function of Landsat-based shrub aboveground biomass (AGB; g/m²) from Berner et al. 2018, for a site near the Colville River, North Slope, Alaska.

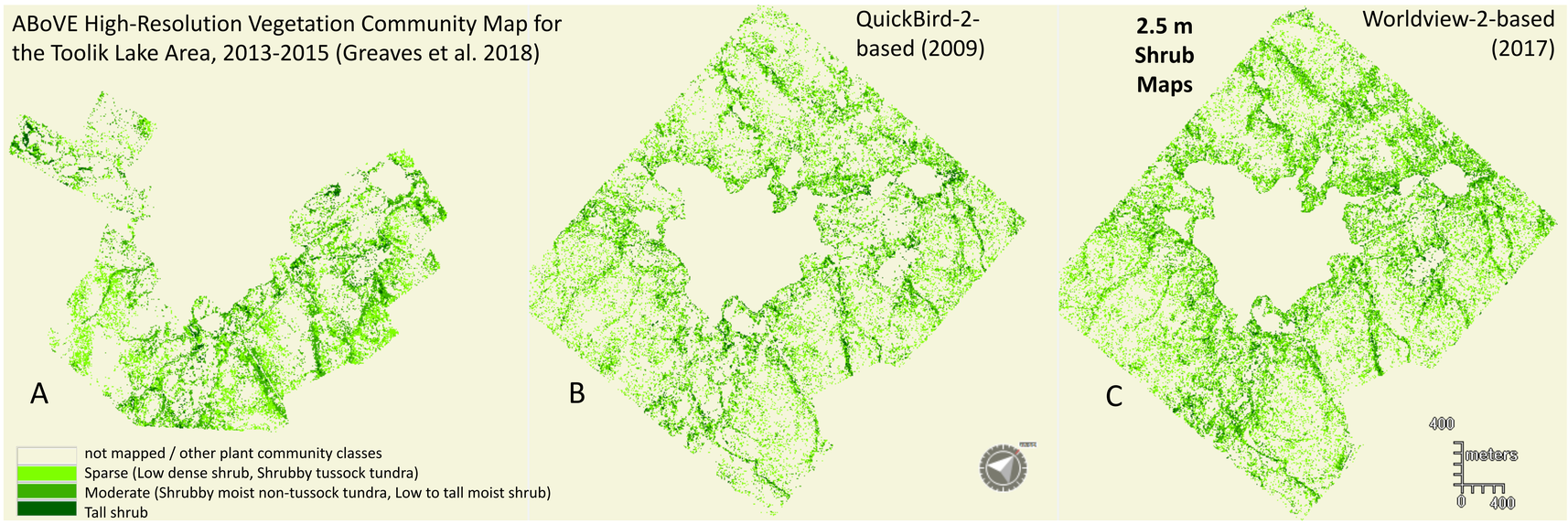
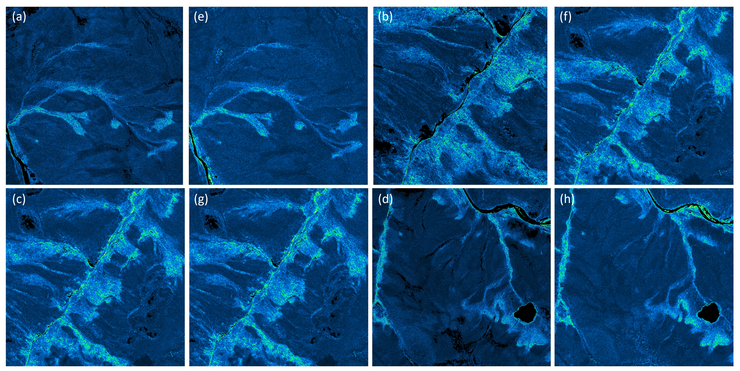


Figure 4. Toolik Lake ABoVE Sentinel site in Alaska (a) shrub class of the Vegetation Community Map, Toolik Lake Area, Alaska, 2013-2015 (Greaves et al. 2018) (b) mapped shrub classes derived from panchromatic image roughness based on QuickBird (QB), July 18, 2009 (image catalog ID: QB021500009JUL18220421-P1BS-500071841070_01_P001) (c) the same, from WorldView-2 (WV02), August 11, 2017 (image catalog ID: WV02_20160612215015_1030010057A6E600_16JUN12215015-P1BS-501511474060_01_P012).



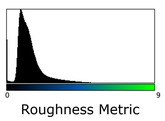


Figure 5. Examples of shrub abundance map pairs for four 2 km² areas in Project Site 01, North Slope of Alaska (a)-(d) 24 JUL 2005 map, based on QB021600005JUL24225626-P1BS-052560072400_01_P001 (e)-(h) 16 JUL 2020 map, based on WV021600020JUL16223511-P1BS-504533229020_01_P003. Mapped shrubs were limited to the areas shown using the "Moments" auto-thresholding algorithm (Tsai 1985).

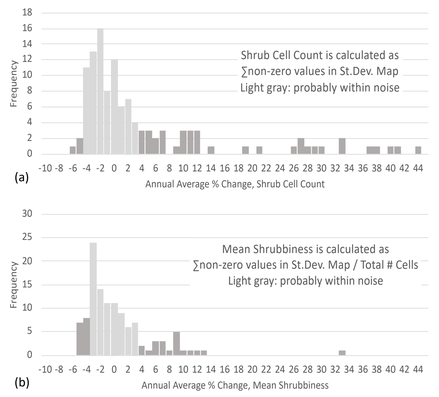


Figure 6. Change in shrub abundance across 121 sites on the North Slope of Alaska, from mapping using 242 QuickBird / WorldView-2/3 image pairs, (a) count (b) "shrubbiness".

TABLE 1. CONFUSION MATRICES & ACCURACY VS TOOLIK LAKE MAP

QuickBird-2	Not Shrub	Sparse	Moderate	Tall shrub	User's	Producer's
Not Shrub	**82.5**	65.9	51.6	46.1	0.77	0.82
Sparse shrub	10.2	**19.9**	19.0	8.4	0.55	0.20
Moderate shrub	6.5	13.2	**24.2**	28.5	0.44	0.24
Tall shrub	0.8	1.0	5.2	**17.0**	0.32	0.17
WorldView-2	**Not Shrub**	**Sparse**	**Moderate**	**Tall shrub**	**User's**	**Producer's**
Not Shrub	**76.3**	62.2	41.5	37.0	0.78	0.76
Sparse shrub	13.7	**22.6**	23.1	8.8	0.59	0.23
Moderate shrub	9.2	14.5	**31.2**	38.4	0.48	0.31
Tall shrub	0.8	0.7	4.2	**15.8**	0.37	0.16

Results The overall, user's, and producer's accuracies were 64%, 77%, and 82%, respectively, for the QB-derived map; and 61%, 78%, and 76%, respectively, for the WV-derived map. If classes are combined to none/sparse and moderate/tall, the accuracies are 82%, 87%, and 92% (QB); and 81%, 88%, and 89% (WV; Table 1). Shrub cover was calculated as 11.4% and 14.5% in 2009 and 2017, respectively, though this may partly reflect the higher intrinsic spatial resolution of WorldView vs QuickBird images rather than real change; if so, the rate of 0.39/year can be used to correct change estimates for all 121 sites with usable pairs (Figure 5).

Findings High resolution maps of shrub abundance generated using a roughness metric on panchromatic imagery are strongly related to aboveground biomass determined from 30 m Landsat imagery (Berner et al. 2018) and highly compatible with shrub distributions seen in very high resolution plant community maps (Greaves et al. 2018; Fig. 4). The impact of source image spatial resolution was quantified. Although the approach described generates estimates that are consistent with Landsat-based AGB (Fig. 3), both methods are known to be inaccurate over polygonal ground with non-shrub vegetation in troughs, for different reasons (respectively: because surface roughness at the scale of the high resolution imagery is enhanced importantly; and because spectral measures appear similar for shrub and locations where there is relatively lush and abundant non-shrub vegetation cover, e.g., in the troughs of polygonal ground where water has collected).

Future Work Annual % change in shrub abundance outside probable noise (±3%) indicates increased shrub size and abundance (Fig. 6), but the precision of change estimates is limited. Future work will seek to improve precision by reducing sources of noise in the imagery and leveraging machine learning approaches; see the poster by Radakovic et al.

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