CANAPANI: A New Version of CANAPI for Mapping Tall Shrub Canopies in Arctic Tundra

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Objectives: Our goal is to leverage high spatial resolution satellite imagery to assess changes in tall shrub cover and aboveground biomass in sites across the Alaskan and Canadian erect dwarf-shrub and low-shrub Arctic tundra zones over a 10- to 15-year period. This will provide data that can be used to initiate, drive, calibrate and validate ecological models, assess the impact on terrestrial albedo in summer, and validate lower spatial resolution ABoVE remote sensing data products. To this end a new version of the Canopy ANalysis with Panchromatic Imagery (CANAPI) code was developed in summer 2017, following tall shrub mapping tests with WorldView-2 imagery over Alaskan Arctic tundra. The new version, CANopy Analysis with Panchromatic And NDVI Imagery (CANAPANI) incorporates multispectral measures to address imprecision in shrub mapping using the earlier code. **Methods:** CANAPI results have some dependence on user-determined settings, so the project team performed iterative tests on the impact of analyst subjectivity by having four team members plus one naïve user ("Chopping_C") perform multiple runs with different settings (each time attempting to find an optimal set) and subsequently labeling the set that produced the subjectively "best" result. Suitable test imagery was located using SQL queries in ArcGIS under the ABoVE Science Cloud Windows VM. QuickBird (QB02) panchromatic and multispectral imagery from June 20, 2003 and WorldView-2 (WV02) panchromatic and multispectral imagery from July 14, 2015 (Figures 1, 2), and a smaller QuickBird test image (Figure 3) were used in a series of CANAPI runs. Only tall shrub canopy measurement results from the "best" CANAPI runs from each user were considered.

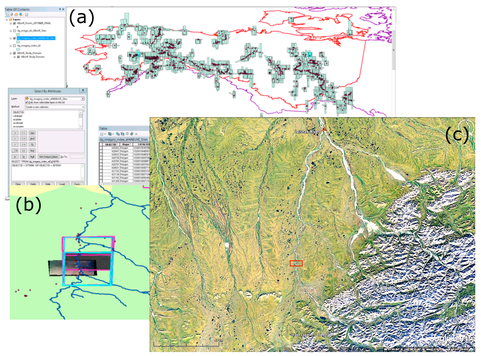

Figure 1. (a) Selection of intersecting early/late NGA QB02 imagery pairs over ABoVE field sites, using the ASC ArcGIS database (b) Selected results of search of dg_imagery_index_all gdb for early/late NGA imagery using the ABoVE Science Cloud's ArcGIS installation running in a Windows VM via Guacamole (c) overview of the selected area.

CANAPI Results: Tall shrub canopy measurement results from the "best" CANAPI runs by all users are shown in Table 1. The relative uncertainty in the estimates of mean crown radius is lowest at 4.3%, 3.2%, and 4.5% for the test, QB02, and WV02 image subsets, respectively, while the corresponding values for %tall shrub cover are 25.6%, 58.0%, and 35.2%; and for mean shrub height 25.2%, 24.7%, and 30.47%. Note that %cover is a scale-dependent variable, so values for the much smaller 6.25 ha area of the test image 1936_2893421.tif are much higher. The estimated absolute and % changes over 2003–2015 by user are given in Table 2, again considering only the "best" CANAPI runs. All results showed increases in the number of crowns detected, though there was a wide disparity from user to user: from 122% through 630% (though the latter was from the naïve user). Changes in mean crown radius were far less variable but showed changes in both directions, from -5% through +8%. Changes in estimated tall shrub cover were highly divergent, ranging from 7% to 105% (ignoring the 349% result from the naïve user), while changes in mean shrub height varied from no change through 129%, again, ignoring the result from the naïve user. Visual inspection of the results for the QB02 and WV02 imagery from the most experienced user (Duchesne) in Fig. 2 (b) and (d), respectively, indicates that there are unambiguous increases in shrub number, size, cover, and height over the 2003-2015 period, consistent with the quantitative results (+196%, +5%, +59%, and +15%, respectively).

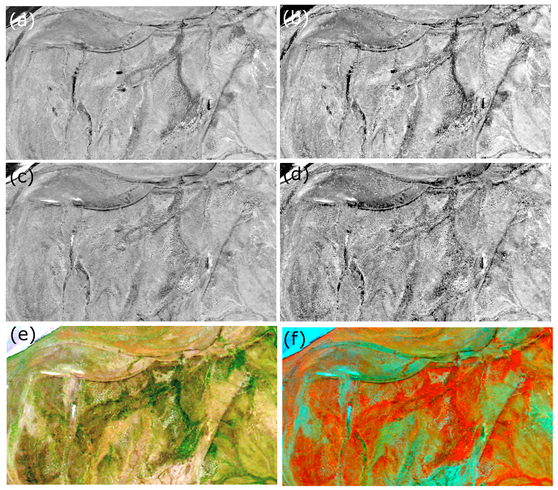

Figure 2 (Left). Imagery near the Ivishak River, North Slope, Alaska: QuickBird-2 (QB02) image subset for June 20, 2003 and WorldView-2 (WV02) image subset for July 15, 2015 (a) QB02 panchromatic image subset (b) tall shrub detections on QB02 pan, best run. (c) WV02 panchromatic image subset (d) Tall shrub detections on WV02 pan, best run (e) WV02 432 composite (f) WV02 742 composite.

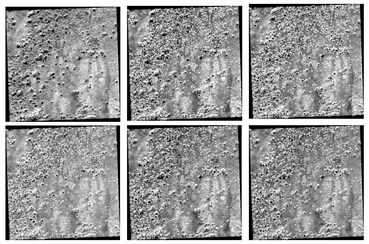

Figure 3. "Best" tall shrub detections for QuickBird panchromatic image subset for site "1936". White circles indicate shrub detections; straight lines trace shadows. L-R, top-bottom: contrast-stretched image; Duchesne, Chopping_M, Erb, Wang, Chopping_C shrub maps. Imagery © 2003, 2015 DigitalGlobe NextView License.

These values are outside the uncertainty values given in Table 1 for individual images, with the exception of the change estimate for mean height (15% vs 25% and 31% uncertainty for QB02 and WV02, respectively). However, several caveats must be added to these results; notably that – all other things being equal – it is probable that the higher quality and resolution of the WV02 panchromatic imagery allows easier detection of shrubs. We will attempt to control for this in future work by degrading the higher resolution imagery and assessing the impact of image resolution. **CANAPANI:** In order to reduce the impact of analyst subjectivity and improve precision, a new version of the code was developed to exploit image spectral content as well as spatial. Orthorectification was performed for the WV02 July 14, 2015 scene on the NCCS ADAPT Linux VM using the Polar Geospatial Center ortho processing code and the Alaska NED mosaic digital elevation model to produce accurately-geolocated panchromatic and multispectral image files on a 0.5 m grid; a Normalized Difference Vegetation Index (NDVI) image was also produced. CANAPANI first identifies candidate tall shrubs in the same way as CANAPI (i.e., by locating crescent-shaped areas of bright pixels arising from shrub crown illumination), then calculates the mean pan and NDVI values for each candidate crown and flags objects unlikely to be shrubs using fixed thresholds. This improved accuracy by removing false positives (Fig. 4); however, it was found that some areas with tall shrubs have surprisingly low NDVI values (shadow, understory, water), potentially limiting this approach in some areas, while high NDVI can reflect dwarf shrub cover (Fig. 4(f)).

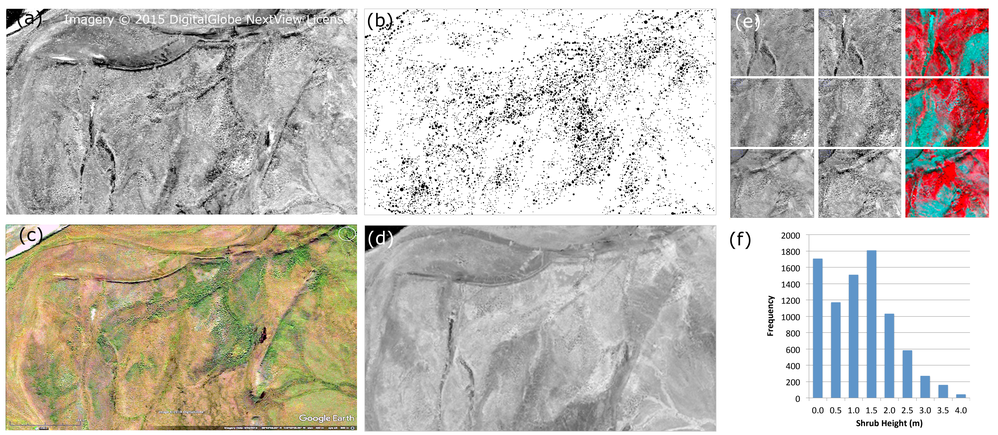

Figure 4. (a) WorldView-2 7/14/15 pan image subset with CANAPANI shrub detections (b) filled crowns (c) enhanced Google Earth true color imagery (d) NDVI (b7-b5)/(b7+b5) (e) detail of pan, detections, 753 false color composite (high NDVI can reflect dwarf shrub cover) (f) shrub height distribution, including zero values recorded for invalid heights where shadow length could not be measured.

TABLE 1. TALL SHRUB CANOPY MEASUREMENT RESULTS FROM THE "BEST" CANAPI RUNS

Image: 1936_2893421.tif	#Valid Crowns Detected	#Valid Heights Measured	Heights: Crowns Ratio	Mean Crown Radius (m)[3]	%Tall Shrub Cover[4]	Mean Height (m)[3]
Duchesne	861	842	0.98	2.68	11.8	1.34
Chopping_M	1028	930	0.90	2.66	17.5	1.14
Erb	800	719	0.90	2.58	12.3	2.27
Wang	634	594	0.94	2.43	9.1	1.73
Chopping_C	653	609	0.93	2.43	9.1	1.39
Mean	795	739	0.93	2.55	12.0	1.57
RMSE	145	131	0.03	0.11	3.1	0.40
Rel. Uncertainty (%)	18	18	3.03	4.31	25.6	25.20
Image: QB02_2003[1]						
Duchesne	2073	2011	0.97	2.26	4.5	1.22
Chopping_M	2732	2609	0.96	2.13	5.1	0.84
Erb	4041	3766	0.93	2.15	8.2	0.96
Wang	679	678	1.00	2.32	1.8	1.67
Chopping_C	598	550	0.92	2.19	1.5	1.43
Mean	2025	1923	0.96	2.21	4.2	1.22
RMSE	1297	1209	0.03	0.07	2.5	0.30
Rel. Uncertainty (%)	64	63	2.92	3.19	58.0	24.65
Image: WV02_2015[2]						
Duchesne	6128	5940	0.97	2.37	7.1	1.40
Chopping_M	6073	5850	0.96	2.08	5.5	0.85
Erb	9052	7407	0.82	2.31	11.0	2.20
Wang	2891	2751	0.95	2.21	3.8	1.66
Chopping_C	4365	3706	0.85	2.19	6.6	1.26
Mean	5702	5131	0.91	2.23	6.8	1.47
RMSE	2061	1676	0.06	0.10	2.4	0.45
Rel. Uncertainty (%)	36	33	6.99	4.48	35.2	30.47

Notes: 1 QB02_20030620213218_101001000200E200_03JUN20213218-P1BS-500065265160_01_P001.tif
2 WV02_20150714220324_10300100442BD900_15JUL14220324-P1BS-500437598080_01_P001.tif
3 The absolute values are incorrect for the WV02 imagery as the scale was set at 0.6 m/pixel; however, here we are interested in the variability between users rather than absolute values.
4 For the area in the subsets (6.25 ha for 1936_2893421.tif; and 44.32 ha for QB02 and WV02)

TABLE 2. CHANGES IN TALL SHRUB CANOPY, 2003-2015 FROM THE "BEST" CANAPI RUNS[1]

Absolute change (value in 2015 over 2003)	#Valid Crowns Detected	#Valid Heights Measured	Heights: Crowns Ratio	Mean Crown Radius (m)	%Tall Shrub Cover[2]	Mean Height (m)
Duchesne	4055	3929	0.00	0.10	2.64	0.18
Chopping_M	3341	3241	0.01	-0.05	0.34	0.01
Erb	5011	3641	-0.11	0.17	2.77	1.24
Wang	2212	2073	-0.05	-0.11	1.94	-0.01
Chopping_T	3767	3156	-0.07	-0.01	5.12	-0.17
Relative change (%)						
Duchesne	196	195	0	5	59	15
Chopping_M	122	124	1	-3	7	1
Erb	124	97	-12	8	34	129
Wang	326	306	-5	-5	105	0
Chopping_T	630	574	-8	0	349	-12

Notes: 1 Source images as for Table 1.
2 For the area in the subsets: 6.25 ha for the small QB02 subset and 44.32 ha for QB02 and WV02.

Findings: Evaluating changes in shrub cover, size and height distributions using CANAPI to interpret the high resolution record is dependent on accurate shrub detection and measurement that is sensitive to user settings; however, imprecision in shrub mapping can be mitigated by using spectral as well as spatial information. A newly-developed version of the code, CANopy Analysis with Panchromatic And NDVI Imagery (CANAPANI), was used to improve on the earlier results, largely by removing false positives. Further improvements may be made using other spectral matching metrics, perhaps using automatic collection of training data and filtering on infeasible heights.

ABoVE Project Chopping-03: Changes in Shrub Abundance in Arctic Tundra from the Satellite High Resolution Record for the Arctic-Boreal Vulnerability Experiment and Impacts on Albedo

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