Parks Canada Parcs Canada

Ecotype Mapping Report for Nahanni National Park Reserve

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Introduction

This report describes the process and products associated with ecotype mapping for Nahanni National Park Reserve. The ecotype mapping project for Nahanni began through the International Polar Year (IPY) and was concluded under the auspices of the Climate Change Vulnerability Assessment (CCVA) project. The IPY objective that supported this work was "to develop methods and products for terrestrial and freshwater inventories in support of ecological integrity (EI) monitoring and other park management needs"[1]. The focus of IPY was on four pilot parks: Wapusk, Ivvavik, Torngat Mountains, and Nahnni. The CCVA project expanded this ecotype mapping work to all northern national parks across the country and created links to the ParkSPACE program to support the expanded application of remote sensing monitoring methods to parks' ecological integrity monitoring programs.

ParkSPACE, National Office's IPY project, and CCVA are often confused. All three initiatives are similar in that they all focus on remote sensing. ParkSPACE focuses on the development of remote sensing protocols for long term ecological integrity monitoring. The IPY project focused on developing and testing methods for creating high resolution ecotype maps. The CCVA project brings together the monitoring measures from ParkSPACE and the ecotype mapping methods from IPY and applies them to all northern national parks to improve climate change adaption planning.

An ecotype map is analogous to standard land cover maps, however, ecotype units are informed by more than land cover. Ecotypes are defined as: "areas of the landscape more or less uniform in plant community, in soil and site properties, and in the ecological drivers and interactions that determine their species composition, structure, function, and landscape distribution"[2]. The result is that ecotype maps will contain units that may be defined by more than simple land cover and may also include descriptors that relate to soil moisture, soil nutrient regime and/or topographic position. The intent is that ecotype maps will provide more ecologically relevant information than simple land cover and will be more informative to support a range of park management needs.

Contained within this report is detailed information regarding the development of the ecotype map for Nahanni. This report and all associated files are archived on the Parks Canada FTP site at the following address:

ftp://external@ftp.pcan2.ca/CCVA/Nahanni

For additional information on the ecotype map for Nahanni, ParkSPACE or CCVA please contact Paul Zorn, Monitoring Ecologist (paul.zorn@pc.gc.ca).

[1] Parks Canada. 2009. Business case - Parks Canada Agency International Polar Year (IPY) Program. November 1 2009 to March 31, 2010. Natural Resource Conservation. Gatineau, QC.

[2] McLennan, D. 2012. The PCA Terrestrial Ecosystem Classification (PCA TEC). Draft. Natural Resource Conservation. Gatineau, QC.

Data Sources

The ecotype map developed for Nahanni was comprised of five primary data sources (table 1). Chief among these was the SPOT5 imagery (figure 1) which served as the base of the map. The mapping base was derived from a $10m^2$ SPOT5 ortho-rectified mosaic that consisted of 22 scenes that were purchased from BlackBridge Inc. Acquiring 22 scenes that covered the park boundary, represented the peak phonological period, and were cloud / haze free was a challenge. In particular, local weathers systems related to the dramatic topography within the park created a high occurrence of thick clouds or atmospheric haze. In order to create a full park mosaic that was cloud / haze free and within peak phenology, scenes needed to span a series of years (table 2). Most scenes were acquired between 2010 and 2013, however, two scenes were from 2006 and one scene from 2009 (figure 2).

The digital elevation model (DEM) (figure 3) and hydrographic layers (ie, lakes, streams, rivers) were acquired for free from the National Topographic and Canvec databases available from the GeoGratis website hosted by Natural Resources Canada (http://geogratis.gc.ca/site/eng/extraction). The GPS aerial video and GPS ground photos were acquired during field surveys in the park conducted in summer of 2012 (figure 4).

Table 1. Primary data sources used in the development of Nahanni's ecotype map.

Data	Scale	Source
SPOT5 (22 orthorectified scenes)	$10m^2$ multispectral	Blackbridge Inc.
Digital elevation model	$30m^2$	National Topographic Database
Hydrographic layers	1:50,000	Canvec
GPS aerial video	variable	Field surveys 2012
GPS ground photos	variable	Field surveys 2012

Table 2: Acquisition dates for SPOT5 scenes that comprise the mosaic used for mapping.

Scene 1: 2012-07-23	Scene 6: 2012-09-05	Scene 11: 2012-08-25	Scene 17: 2012-07-09
Scene 2: 2010-09-12	Scene 7: 2012-08-15	Scene 12: 2012-09-18	Scene 18: 2006-09-17
Scene 3: 2012-07-22	Scene 8: 2012-08-07	Scene 13: 2012-08-25	Scene 19: 2012-09-18
Scene 4: 2013-09-06	Scene 9: 2012-08-07	Scene 14: 2010-09-07	Scene 20: 2012-08-31
Scene 5: 2011-08-04	Scene 10: 2012-08-30	Scene 15: 2010-09-07	Scene 21: 2009-07-23
		Scene 16: 2012-07-09	Scene 22: 2006-08-23

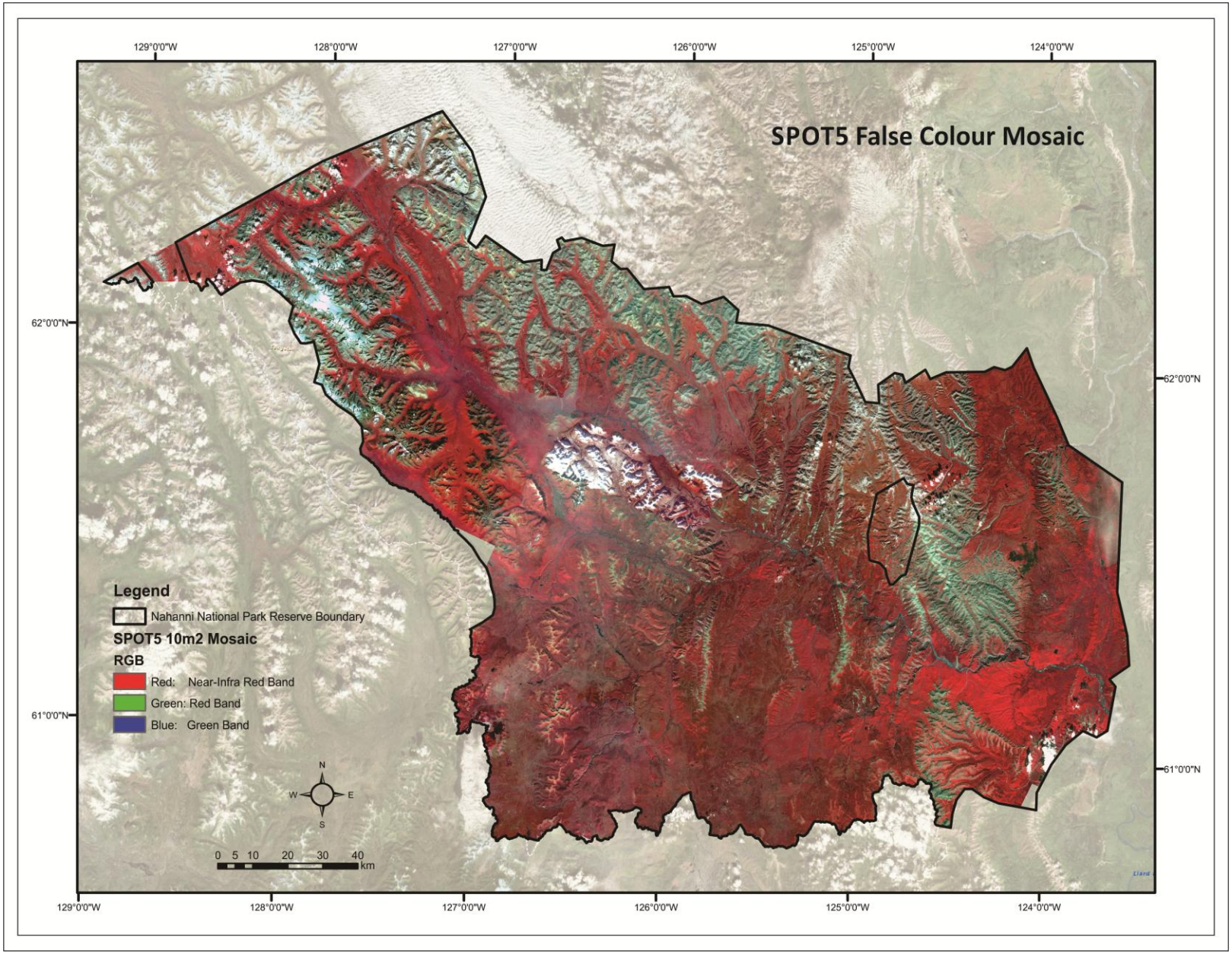


Figure 1. SPOT5 false colour, ortho-rectified mosaic used for ecotype mapping in Nahanni National Park Reserve.

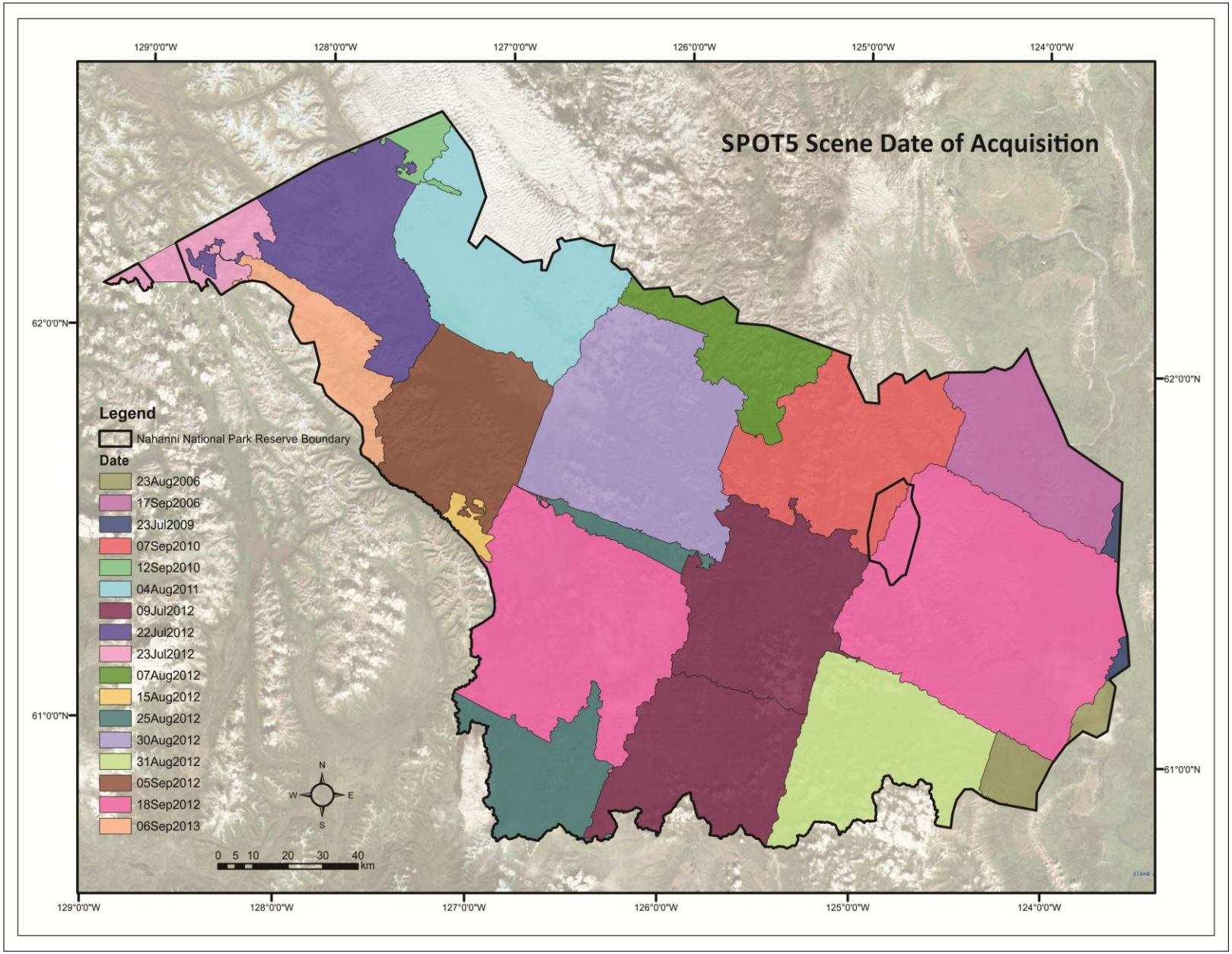


Figure 2. Date of acquisition for SPOT5 scenes used in ecotype map development.

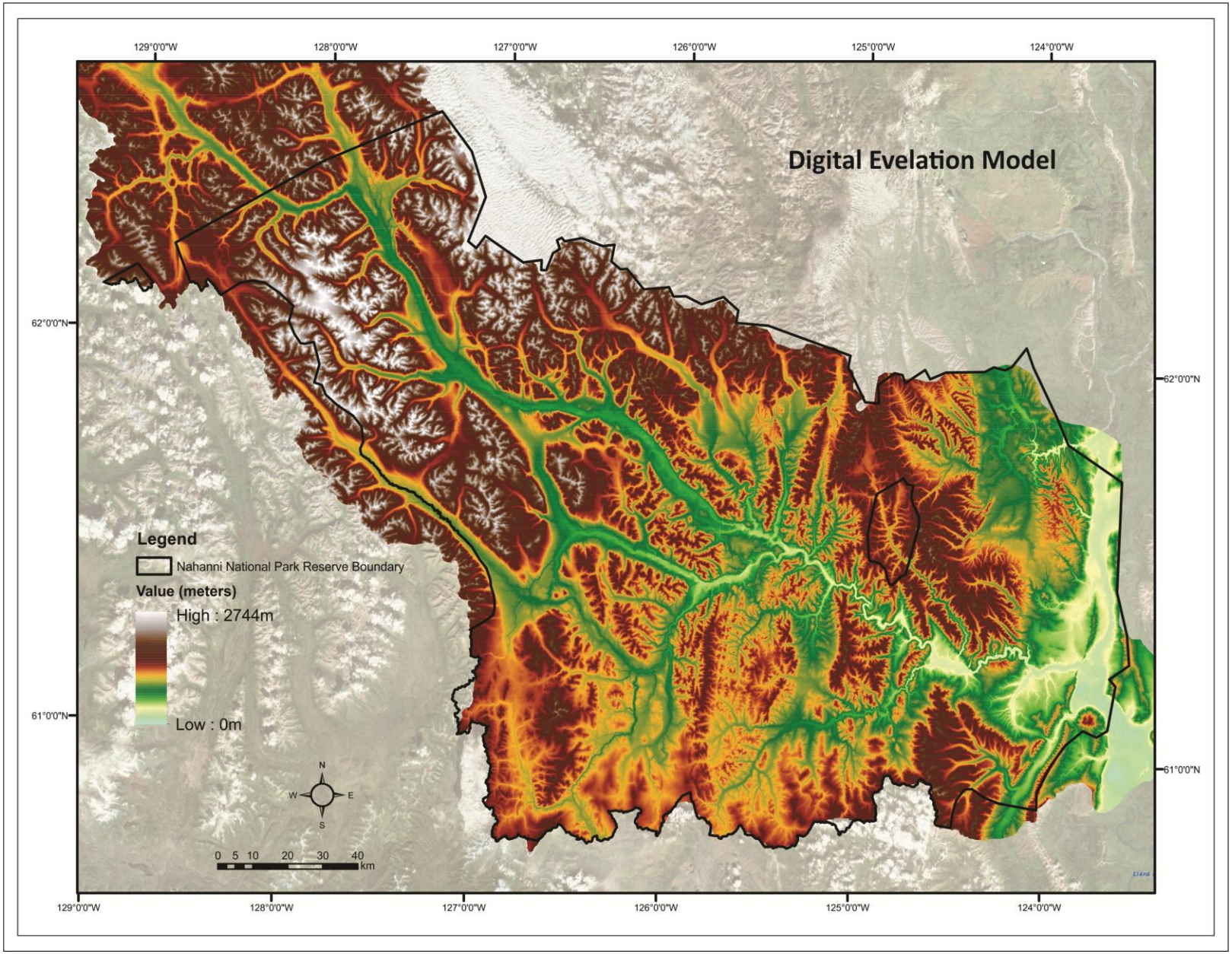


Figure 3. Digital elevation model (30m2) of Nahanni National Park Reserve acquired from GeoGratis.

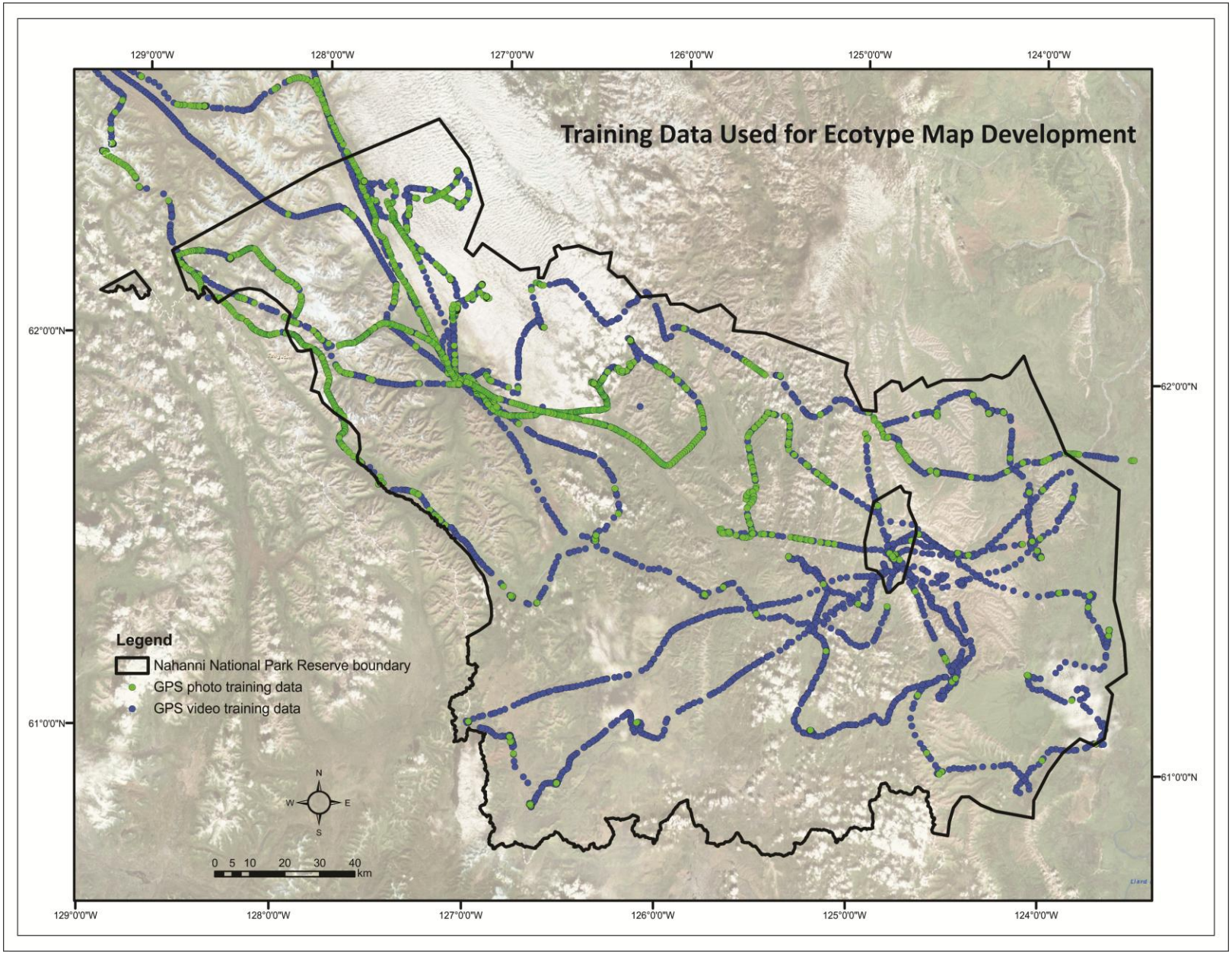


Figure 4. Locations of GPS video and GPS ground photo locations taken throughout Nahanni National Park Reserve during summer 2012.

Methods

Methods associated with the development of the ecotype map for Nahanni can be described in two major steps each of which having several components. These major steps are entitled: Image Processing and Hybrid Hierarchical Spatial Modelling.

Image Processing

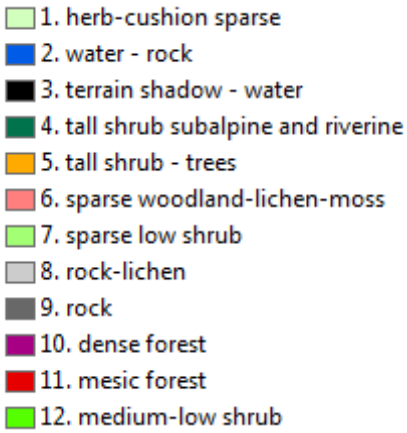
Archived and newly tasked SPOT5 images were acquired over Nahanni between July to September with cloud cover 10% or less. Scenes were available for the entire park that met these criteria; however, the resulting scenes were often covered with significant atmospheric haze. Raw SPOT5 scenes were geo-referenced and ortho-rectified by the image provider, BlackBridge Inc. Individual panchromatic and multispectral scenes were then colour balanced and mosaiced to create a complete coverage of the park. Both ortho-rectified scenes and the final ortho-rectified mosaic were delivered to Parks Canada.

Hybrid Hierarchical Spatial Modelling

The methods used for ecotype map development can be described as a hybrid hierarchical spatial modelling approach. The term “hybrid” is used because the approach combines unsupervised classification, supervised classification, and post-model expert rules. The approach is “hierarchical” because the process begins with a coarse scale classification across the entire park. This coarse classification was used to provide a stratification of the park. Within each strata separate models were then created that fine tuned the classification and added detail and texture to the map. Finally, post-model expert rules were applied to improve map accuracy or to better define ecotype polygons that were difficult to distinguish from spectral characteristics but were discernible from a topographical context (ie, rules to discriminate subalpine areas based on a combination of spectral values and elevation).

Initially, an overall 255 class unsupervised classification was applied to the SPOT5 mosaic using PCI Geomatica 2013[3]. These 255 clusters were then labelled based on a majority rule into the following classes:

[3] PCI Geomatics. 2013. Geomatica Professional remote sensing software. http://www.pcigeomatics.com/



Each of these initial 12 classes represented strata within each another smaller scale unsupervised classification was generated. Field-based GPS video and ground photos were used to interpret and label these smaller scale clusters to create an updated map version. The next stage involved developing cloud, shadow and haze masks. Original SPOT5 scenes were inspected to determine if clear imagery was available to in-fill some of the cloud, shadow or haze areas. Where imagery was available, the ecotype map was extended into these new areas using a random forest supervised classification model using R3.2.0[4] and the randomForest package 4.6-10[5]. The results of the random forest models were integrated into the last iteration from the unsupervised classifications. This integration was accomplished using object-based methods from eCognition[6]. eCognition objects were derived from the SPOT5 mosaic in order to create "natural" cut-lines so that random forest output could become seamlessly stamped into the ecotype map without creating edge-matching errors. This version of the map was then inspected and, where necessary to improve model accuracy, a series of post-model expert rules were applied in ArcGIS 10.2[7] (post-model rules available in appendix 1).

[4] R Core Team. 2014. R: A Language and Environment for Statistical Computing. Version R3.2.0. R Foundation for Statistical Computing. Vienna, Austria.

[5] Breiman, L. et al. 2015. Package "randomForest"- Breiman and Cutler's random forests for classification and regression. Version 4.6-10.

[6] Nussbaum, S. and G. Menz. 2008. eCognition Image analysis Software. Springer. Netherlands.

[7] ESRI 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute. Redlands, CA.

Results

Ecotype Map

The ecotype map for Nahanni National Park Reserve is shown in figure 5. The final map contains 26 classes with 15 vegetation classes (table 3). Some class labels contain more than one descriptor (ie, rock / water, terrain shadow / water, mixed forest, mainly deciduous / tall shrub). In these cases ground conditions were not spectrally separable or the ground conditions represented a mosaic of multiple classes at the scale of a pixel. In these instances, the order of class name represents the relative dominance of each class within a pixel. For pixels labelled "rock / water", therefore, rock represents a greater proportion of the pixel than water. Detailed descriptions of each vegetated ecotype class are provided in a set of Fact Sheets found in appendix 2.

Detailed descriptions of each legend item in the ecotype map are provided in the Fact Sheets in Appendix 2. Each Fact Sheet contains photographic examples and information pertaining to associated vegetation communities, soil moisture and soil nutrient regime.

Table 3. Summary metadata for Nahanni ecotype map.

Image source	SPOT5
Total number of satellite scenes	22
Spatial resolution	$10m^2$
Date of imagery	Mid to late summer. Majority of scenes between 2010 – 2012. Four of 22 scenes beyond this range.
Total number of map classes	26
Total number of vegetated classes	15
Positional accuracy	+/-5m
Overall classification accuracy	79.03%
Data projection	UTM 10N. NAD 1983.
Date of classification	September 2014

A number of challenges arose during the mapping process as a consequence of the quality of the SPOT5 imagery. In particular, the mountainous terrain within Nahanni created local weather systems that result in a high prevalence of cloud and atmospheric haze. Where possible, alternate SPOT5 scenes from a similar phenological period but in a different year were used to in-fill cloudy or hazy areas. Unfortunately, there were some areas within the park for which no high quality scenes existed. In these instances we used the highest quality imagery available even though they contained areas of cloud or haze. The effect of haze in the ecotype classification is that it "decreases" the amount of vegetation in a pixel (ie, reduces the estimated vegetation biomass from multi-spectral signatures) such that more productive ecotype classes are predicted to be less productive classes (figure 6). For example, forest can be predicted as shrubland, shrubland can be predicted as tundra, etc. Where possible the effect was minimized by random forest modelling and post-model expert rules.

Differences in phenology among SPOT5 scenes were also an issue. In some instances, in order to find cloud-free images, scenes adjacent to each other were from different phenological periods (ie, July

versus September). These differences in phenology affect the spectral signature of pixels which may lead to misclassifications.

Successional stage related to fire history was another issue that was addressed during mapping. Recently burnt forest (less than 25 years) only was labelled as “burnt” whereas older burns where classified as forest, typically deciduous, mixed or coniferous. Finally, burnt forest pixels were spectrally similar to terrain or cloud shadow which may lead to confusion among these classes. Terrain and cloud shadow masking was used to identify these situations, however, these classification errors may exist in small areas.

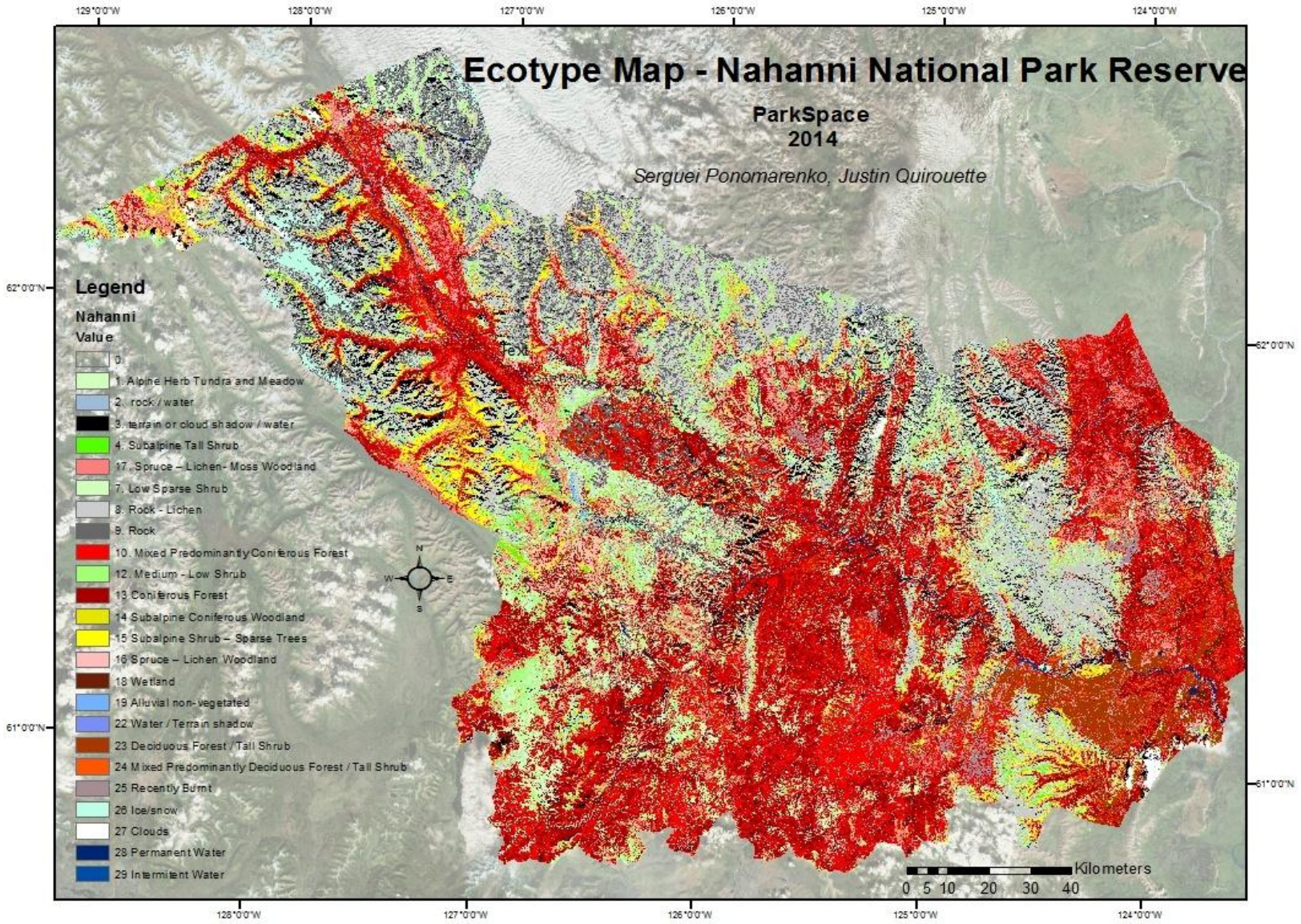


Figure 5. Ecotype map of Nahanni National Park Reserve.

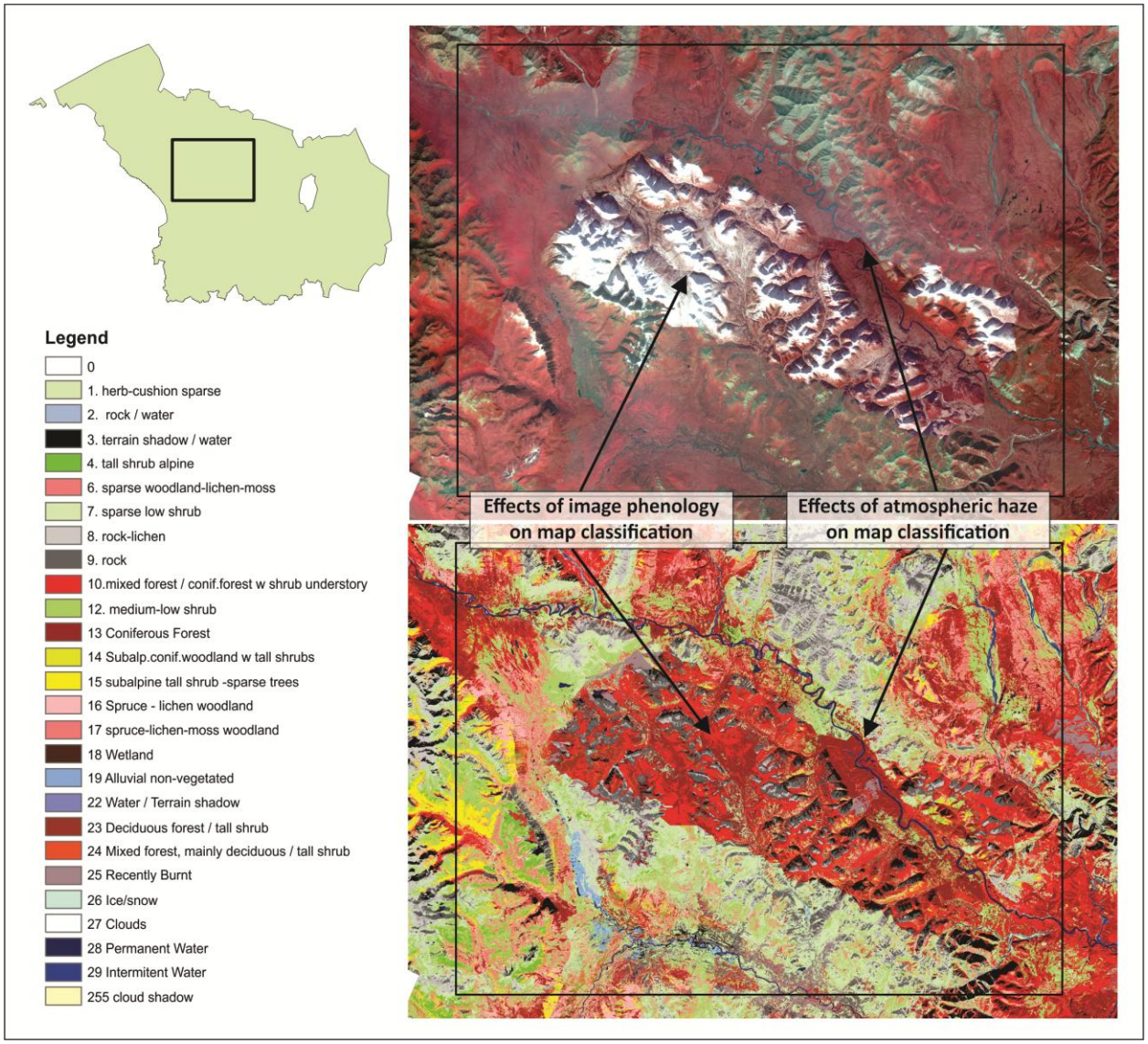


Figure 6. Effect of atmospheric haze and differences in image phenology on ecotype map classification. This example shows both kinds of effects. Edges between haze and non-haze areas can create artificial boundaries between ecotypes. Differences in image phenology required in-filling of separate spatial models that accounted for snow and ice cover.

Quality Assessment

Table 4 displays a confusion matrix and the estimated classification accuracy of the ecotype map. These values are derived from partitioning available training data into a 80% training and 20% testing set. The training set was used to develop a random forest model that predicted class associations based on spectral values from SPOT5. The independent test set was then used to assess model accuracy. This accuracy assessment is considered to be conservative as it tests the accuracy of model results only and does not incorporate the post-model expert rules. For example, the user's accuracy for wetland (18), alluvial non-vegetated (19), recently burnt (25) and intermittent water (29) are relatively low. As a consequence all of these classes were further improved by post-model rules that utilized data sets beyond SPOT5 (see appendix 1 for post model rules). The accuracy assessment does not consider these post-model improvements.

The per-class accuracy within the confusion matrix is useful to highlight which classes tend to be confused with each other. For example, Low Sparse Shrub (7) is predicted with 74% accuracy. However, the majority of incorrect predictions confuse Low Sparse Shrub (7) with Medium-Low Shrub (12). This confusion is understandable as shrub density is a gradient and, on the ground, low sparse shrub naturally transitions to more productive medium-low shrub communities as soil nutrient and moisture conditions improve. Applying discreet classes to communities that form a natural gradient is a common source of "error" found in any land cover map. Such instances are not necessarily errors *per se* but are rather a simple function of placing hard class boundaries around vegetation transition zones.

Another example of common confusion is Coniferous Forest (13) with Recently Burnt (25). Where classification errors occur with coniferous forest the mis-classification most often tends to be predicting these pixels as Recently Burnt. This is understandable as both are dominated by trees and can have very similar spectral values from satellite imagery. To reduce this error post-model rules were created that apply recent fire mapping produced by Darrel Zell[8]. These products were used as a stamp to further discriminate between these two classes.

Overall, the per class accuracy values are considered to be an under estimate, however, the relative patterns within the confusion matrix should still be accurate. Classes with higher estimated accuracy tend to be those with more distinct spectral signatures and can be more easily discriminated with SPOT5 imagery alone. Classes with lower accuracy are those that typically are not unique based on their spectral characteristics and were subsequently improved with post-model rules. Those classes that tend to be confused with each other are those that share similar spectral values and/or are ecologically similar.

[8] Zell, Darrel. 2014. Fire Mapping of Nahanni National Park Reserve. Data files accessed in September 2014. Parks Canada.

Table 4. Confusion matrix assessment of overall and relative class accuracy of the ecotype map for Nahanni National Park Reserve.

	Reference																							*User's Accuracy*
Prediction	1	2	3	4	7	8	9	10	12	13	14	15	16	17	18	19	22	23	24	25	26	28	29	
1. Alpine Herb-Grass-Cushion Shrub	**172**	0	0	0	9	4	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	*0.92*
2. Rock / water	0	**27**	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	*0.84*
3. Terrain or cloud shadow / water	0	0	**151**	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	18	2	10	0	*0.81*
4. Subalpine Tall Shrub	0	0	0	**182**	1	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	*0.97*
7. Low Sparse Shrub	6	0	1	0	**138**	7	3	1	22	0	1	0	0	4	1	2	0	0	1	0	0	0	0	*0.74*
8. Rock - Lichen	10	0	1	1	7	**143**	21	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	*0.76*
9. Rock	0	3	8	0	1	7	**140**	0	0	0	0	0	0	3	0	4	0	0	1	7	6	2	5	*0.75*
10. Mixed Predominantly Coniferous Forest / Conif. Forest with Shrub Understory	1	0	0	0	1	0	0	**150**	4	7	0	0	4	1	3	0	0	0	14	1	1	0	0	*0.80*
12. Medium - Low Shrub	2	0	0	2	10	2	0	1	**161**	0	0	0	3	2	0	0	0	0	4	0	0	0	0	*0.86*
13. Coniferous Forest	0	0	4	0	3	0	0	10	1	**114**	0	0	0	6	1	0	0	0	5	42	0	1	0	*0.61*
14. Subalpine Coniferous Woodland	0	0	0	1	0	0	0	0	0	0	**101**	2	1	0	0	0	0	0	1	0	0	0	0	*0.95*
15. Subalpine Shrub – Sparse Trees	0	0	0	6	1	0	0	0	5	0	2	**165**	4	3	0	0	0	0	1	0	0	0	0	*0.88*
16. Spruce – Lichen Woodland	1	0	0	0	0	0	0	0	1	0	4	2	**159**	8	5	0	0	5	2	0	0	0	0	*0.85*
17. Spruce – Lichen- Moss Woodland	1	0	0	0	1	2	0	4	14	2	0	12	11	**136**	1	0	0	0	0	3	0	0	0	*0.73*
18. Wetland	2	0	0	0	3	0	0	10	1	3	0	0	13	16	**35**	0	0	1	3	1	0	0	1	*0.39*
19. Alluvial Non-Vegetated	0	0	2	0	0	4	8	0	0	0	0	0	0	0	0	**28**	0	0	0	1	0	4	12	*0.47*
22. Water / Terrain Shadow	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	**19**	0	0	1	0	4	0	*0.73*
23. Deciduous Forest / Tall Shrub	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**172**	13	0	0	0	0	*0.92*
24. Mixed Predominantly Deciduous Forest / Tall Shrub	0	0	0	0	1	0	0	4	5	0	3	0	6	2	4	1	0	8	**152**	0	1	0	0	*0.81*
25. Recently Burnt	0	0	20	0	0	2	2	0	0	40	0	0	0	0	0	0	1	0	0	**115**	0	4	3	*0.61*
26. Ice/Snow	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	**184**	0	0	*0.98*
28. Permanent Water	0	2	13	0	0	3	0	0	0	4	0	0	0	0	0	3	2	0	0	7	0	**141**	12	*0.75*
29. Intermittent Water	3	2	1	0	0	6	7	0	1	2	0	0	0	0	0	8	0	0	2	1	0	17	**65**	*0.57*
Producer's Accuracy	*0.86*	*0.79*	*0.75*	*0.94*	*0.78*	*0.79*	*0.75*	*0.83*	*0.75*	*0.65*	*0.91*	*0.90*	*0.79*	*0.75*	*0.70*	*0.57*	*0.83*	*0.91*	*0.76*	*0.58*	*0.95*	*0.77*	*0.65*	

Overall Accuracy = 0.79 (95%CI: 0.7767, 0.8035)

Map Comparison

Another way in which the ecotype map can be assessed is by comparing it to existing land cover maps for Nahanni. Figure 7 shows the existing land cover map from Stow and Wilson[9]. Figure 8 provides a direct visual comparison of the northern end of the park between the Stow and Wilson map and the ecotype map. For this comparison the palette used in the original Stow and Wilson map was adjusted to match the ecotype map.

The quality of the ecotype map is best assessed through a combination of quantitative accuracy assessment and qualitative comparisons with existing mapping products. The quantitative accuracy assessment is conservative as it does not incorporate post model improvements made through the application of "expert rules". The qualitative map comparison between the ecotype and Stow & Wilson maps show an ecotype map with similar landscape pattern but with improved spatial and thematic resolution. These two assessments, taken together, highlight an ecotype map that accurately describes land cover at the scale of the park and provides a product that will be useful for a range of park management applications.

Overall, the two maps display similar spatial patterns in land cover. However, the ecotype map shows improved spatial and thematic resolution. These differences can be primarily attributed to the differences between Landsat TM imagery (used in the Stow and Wilson map) versus SPOT5 imagery (used in the ecotype map). The improved spatial resolution in the ecotype map is able to discern more landscape texture and more detailed patterns. This increased resolution, in conjunction with the hybrid hierarchical modelling approach, provides the ecotype map with improved thematic resolution as the ecotype map contains a total of 26 classes compared to 16 classes in the Stow and Wilson map.

[9] Stow, N., and P. Wilson. 2006. Aggregated landcover map for the Greater Nahanni Ecosystem. Report to the Parks Canada Agency. Ottawa, Ontario, Canada.

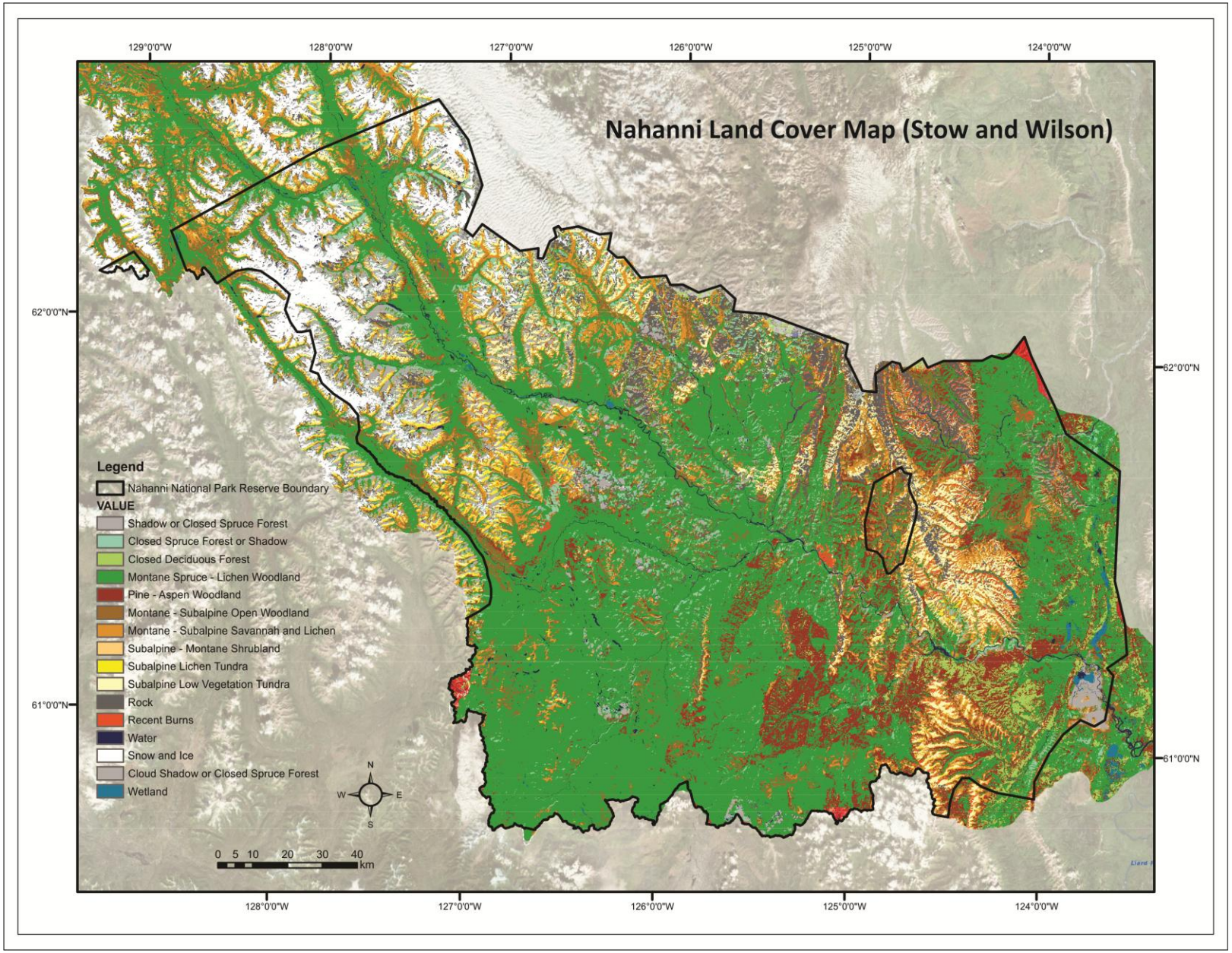


Figure 7. Landcover map from Stow and Wilson (2006).

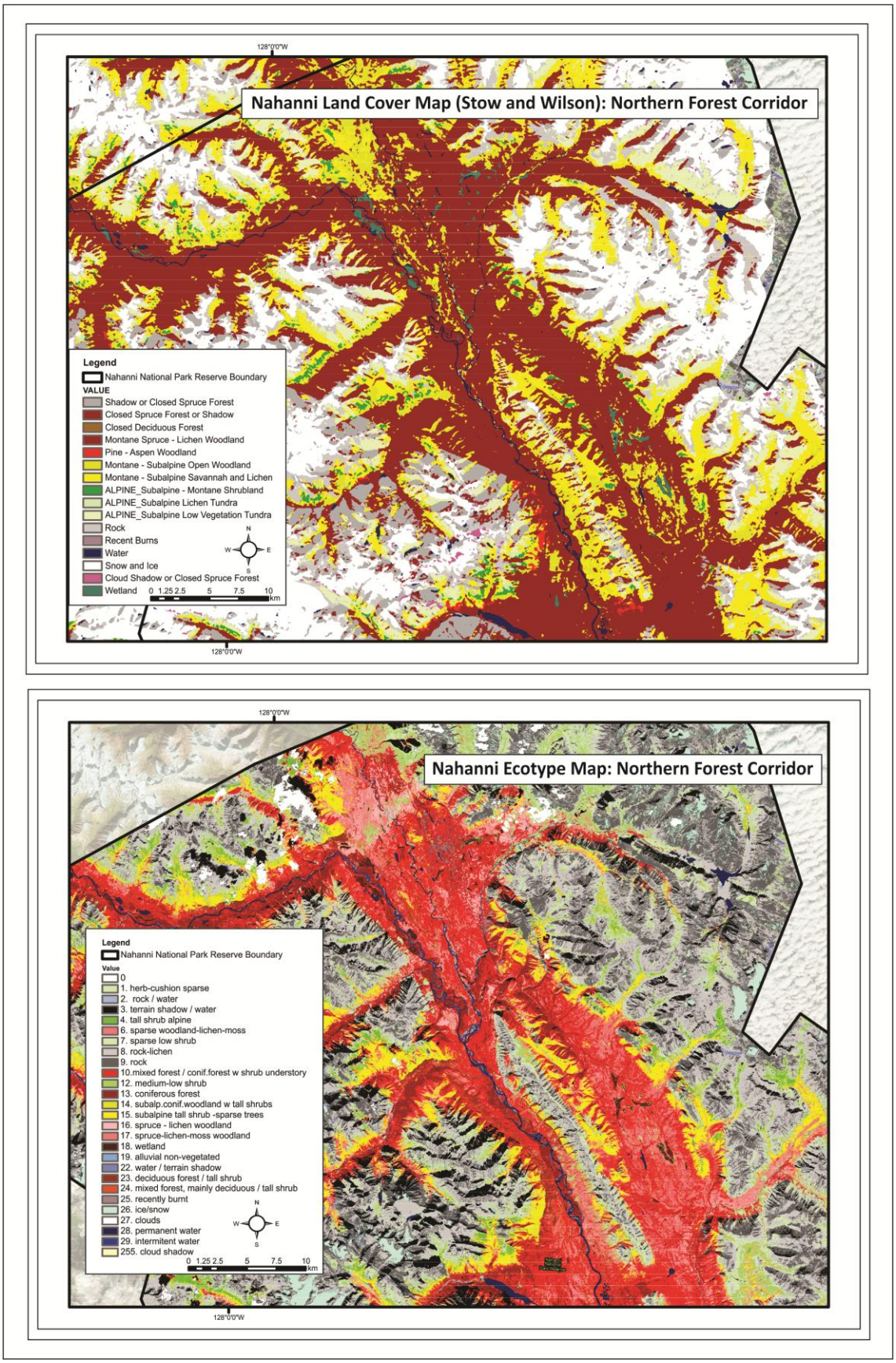


Figure 8. Comparison of the ecotype map and Stow & Wilson landcover map in the northern forest corridor region of Nahanni.

Recommendations

The primary constraint to the development of the ecotype map for Nahanni was the quality of available SPOT imagery. High prevalence of clouds and atmospheric haze create a situation where acquiring consistent clean imagery for the entire park, during the same period of peak phenology, was very difficult. To acquire clean imagery, therefore, scenes from different times within a year, or across different years, were necessary. In order to improve the quality of the ecotype map areas of intense clouds, haze, and large phenological differences among scenes, needs to be identified and delineated. Within these delineated areas the ecotype map should be opportunistically updated with clean imagery as it becomes available. Landsat8 should be the focus for acquiring clean imagery because it is free and, if multi-spectral bands are pan-fused, have a spatial resolution of $15m^2$ which is similar to SPOT5.

The recommended process for in-filling delineated areas with an updated ecotype model is summarized below:

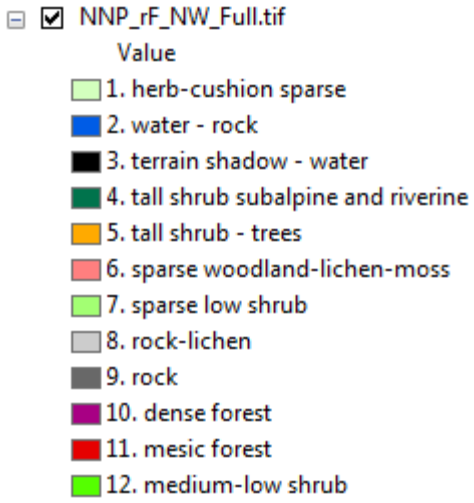
- Use eCognition to create "natural" cutlines from the original ecotype map that delineate areas of low image quality. These areas are to be identified through visual inspection of the SPOT5 mosaic used to create the ecotype map. The SPOT5 mosaic is available on the FTP site at: ftp://external@ftp.pcan2.ca/CCVA/Nahanni.
- Search USGS Glovis (http://glovis.usgs.gov/) on a periodic basis for new, clean Landsat8 imagery that cover the delineated areas, are cloud free, represent peak phenology (July or August), and do not appear to contain atmospheric haze. Download Landsat8 scenes that meet these criteria.
- Once new Landsat8 data are acquired that cover all of the delineated areas then create a new random forest model with this new imagery to in-fill the areas with new ecotype map segments.
- To create the random forest model, spatial predictors should be derived from the Landsat8 imagery. These predictors should include, at a minimum, the raw spectral bands and NDVI.
- Training data for the random forest model should represent randomly selected pixels from the original ecotype map from areas that are in close proximity to the delineated areas. Partition these training data into a 80% training set and a 20% testing set.
- Develop the model using the 80% training set. Conduct an accuracy assessment of this new model using the independent 20% testing set. If accuracy is sufficient then spatially extrapolate this model using the Landsat8 predictors to cover the delineated areas. Use the natural cutlines from eCognition as a mask to burn-in the random forest model results thereby creating an updated ecotype map for the park.

For more information about this process, contact Paul Zorn, Monitoring Ecologist at National Office (paul.zorn@pc.gc.ca).

Appendix 1—Post-Model Expert Rules (Serguei Ponomarenko)

After mosaic is done.

1. Unsupervised classification of image 255 classes.
2. Identifying each unsupervised class to the initial legend items based on majority rule.
3. Produce map variant 1 with 12 ecotype classes.



4. Musk out all the classes but one and do unsupervised classification of each of them.
5. Further subdivide each initial class based on reviewing video training data.
6. Rules 1 to 11 developed and applied.

Divide Class 10 Moist_Forest - Rule 1 and 2.

Z:\IPY data\exchange\Nahanni\Unsupervised_Classes\Nahanni_2004-2012_MOSAIC_Moist_Forest_UNSUP.tif

1.Classes 1 to 152 - Coniferous Forest. (NEW class 13).

2. Classes 153 to 255 -Mixed Forest or Coniferous Forest with shrub understory.

(REPLACE class 10)

Divide Class 5. Tall Shrubs - Trees

Z:\IPY data\exchange\Nahanni\Unsupervised_Classes\Nahanni_2004-2012_MOSAIC_Tall_Shrubs_UNSUP.tif

on
3. cloud shadow - #5. (NEW class 255)
4. Subalpine conif. woodland with tall shrubs - #1-4, 6-51. (NEW class 14)
5. Subalpine tall shrubs with sparse conif.trees ## 52-255. (NEW class 15)
6.other classes #0.

Divide Class 11 Mesic_Forest
Z:\IPY data\exchange\Nahanni\Unsupervised_Classes\Nahanni_2004-2012_MOSAIC_Tall_Shrubs_UNSUP.tif

7.other classes #0.
8. Mixed Forest or Coniferous Forest with shrub understory - ##1-90
9. Coniferous Forest. - ##91-99, 254,255.
10. Spruce - Lichen Woodland - ##100-127, 142,143,154,211,229, (NEW class 16)

11. Spruce - Lichen - Moss Woodland - ##128-141,144-153,155-210,212-228,230-253. (NEW class 17)

7. Develop flat areas model.

8. Rule 12. Flat areas that are occupied by # 6,16,17 and 12 and below 900 m should be classified as #18. Fen.
9. Rule 13. Flat areas #3 and 2 should be water (less 10% slope).
10. Rule 14. Flat areas adjacent to water and occupied by #8 and 9 should be "Alluvial Non-vegetated.

Rule 15. Out of unsupervised classification of :
Class **10** : Z:\IPY data\exchange\Nahanni\Unsupervised_Classes\Nahanni_2004-2012_MOSAIC_**Moist_Forest**_UNSUP.tif
classes 41,56,59 and 75 should be new class Marsh/shallow water if they have less 10 degrees slope.
Rule 16: do unsupervised classification(256) within classes 2 to 5 of "clip_MRVBF.img" (flatter areas) intersecting with classes ##2,3,8,9 of Nahanni_2014_ExpertRules_1_11.tif. and below 900 m.

Rule 17. do unsupervised classification(256) within classes 2 to 5 of "clip_MRVBF.img" (flatter areas) intersecting with all classes but not ##2,3,8,9 of Nahanni_2014_ExpertRules_1_11.tif and below 900m.

Rules 18 and 19 as step 16 and 17 but above 900m.

Rule X. Stamp Ice and Snow.
Stump Water and Shallow Water.
Stump Rock

Rule X. Create class “Mixed, mainly deciduous forest” from the training data of “Nahanni corridor clip”.
Rule X1. Class 15 below 900 m should be “Deciduous forest / tall shrub.
Rule X2. Class 14 below 900 m should be “Mixed forest, mainly deciduous / tall shrub.
Unsupervised classif. of burnt areas

Cloud shadow can be confused with Spruce Forest
Within burnt areas severely burnt areas can be mistaken for water or shadow.
Edge of clouds are often wrongly classified.
The snow in shade can be represented as Rock or Rock-Lichen.
In hazy areas

Recently burnt areas were mapped exclusively within available fire polygons younger than 35 years. The portions of those polygons that does not show a significant regeneration were mapped as “Recently Burnt”. This class can be confused with Terrain and Cloud Shadows, dark colored rock outcrops and old Spruce forest. According to our observations a good portion of recently burnt areas was not included in the polygons of the National Forest Database and the updated version of it received from Darrel Zell. Their inclusion requires additional work and can be done at the later time.

In hazy areas the spectral signal gets weakened and some misinterpretation can have place. The following misinterpretation in hazy areas is common:
Deciduous or Mixed Forests can be misinterpreted as Spruce – Lichen Woodland or Spruce – Lichen – Moss Woodland.
Wetlands can be misinterpreted as Spruce – Lichen Woodland or Spruce – Lichen – Moss Woodland.

Forested and Subalpine classes can be misinterpreted as Alpine classes.

At lower elevations alpine ecotypes (Herb-Grass-Cushion Shrub, Medium-Low Shrub and Sparse Low Shrub) often represent Wetlands as they share the same physiognomy.

Class Terrain "Shadow / Cloud shadow / Water" in the majority cases represents Terrain Shadow in the minority cases represents Cloud Shadow and even a smaller part of it represents Water. This class can be confused with ``Recently Burnt`` class.

Appendix 2—Ecotype Map Fact Sheets

Nahanni Ecotype Classification

Scientific and Common name: Alpine Herb Tundra and Meadow; Herb-Grass-Cushion Shrub

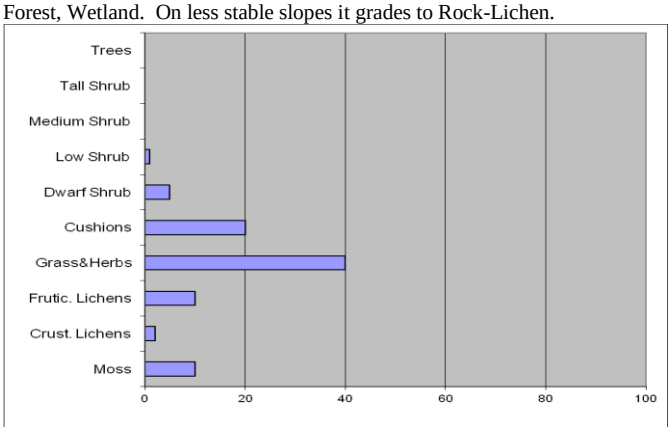
Concept: Communities of the alpine zone dominated by herbs, grasses and cushion shrubs. The climate usually is too cold to allow growth of shrubs and trees. Water regime is from submesic to subhygric. Snow accumulation during winter is normal or less than normal. It can occur on all aspects, although at the northern aspects tends to occur at lower elevations. The permafrost is commonly present; cryoturbation processes are not very active. It can also occur as a successional community at lower elevations.

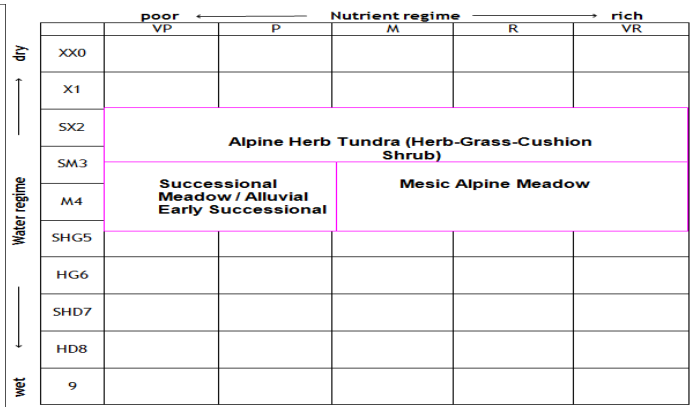
Components: A number of communities are included both on acidic and calcareous substrates. All these communities share physiognomic similarity. Mesic Alpine Meadow, Herb-Grass-Cushion Shrub Tundra, successional meadows in Subalpine and Boreal zones. As a minor component, it includes Alluvial Early successional communities.

Zones: dominant in the alpine zone and can occur in Subalpine and Boreal zones.

Vegetation: A part of the surface might not vegetated. Sparse layer of low shrubs (*Salix sp., Potentilla fruticosa*) may or may not be present. Cushion shrubs and sometimes dwarf shrubs are well expressed in alpine/tundra communities. Among cushion shrubs most common are *Salix reticulata, Dryas integrifolia, Silene acaule. Oxytropis nigrescens, Potentilla uniflora* and *Saxifraga oppositifolia*. Dwarf shrubs include *Rhododendron lapponicum , Cassiope tetragona* and *Vaccinium uliginosum*. Herbs and grasses is a dominant layer. Common herbs and grasses include *Festuca altaica, Carex scirpoidea, Anemone parviflora, Calamagrostis canadensis, Aconitum delphiniifolium, Delphinium brachycentrum, Lupinus alpine, Hedysarum alpinum, Gentianella propinqua, Senecio lugens* and *Senecio atropurpurea*. Mosses and lichens are common and might be prominent. Common species are: *Cetraria cucullata, Hylocomium splendens, Tomenthypnum nitens*. In successional meadows grasses and herbs are dominant and cushion shrub are commonly absent.

Similar communities: Due to it heterogeneity it can grade to a variety of other types such as Low Sparse Shrub, Subalpine Coniferous Woodland, Deciduous Forest, Wetland. On less stable slopes it grades to Rock-Lichen.





Author and Date: Serguei Ponomarenko, 2015-03-10.

Nahanni Ecotype Classification

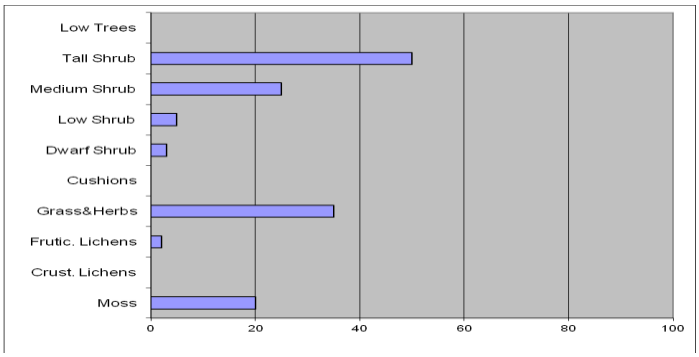
Scientific and Common name: Subalpine Tall Shrub
Concept: This is a late successional community in the subalpine zone on mesic and Subhygric sites. Commonly it is at higher altitudes than Subalpine Shrub – Sparse Trees but due to the heterogeneity of the landscape it is often occur intermittently with it.

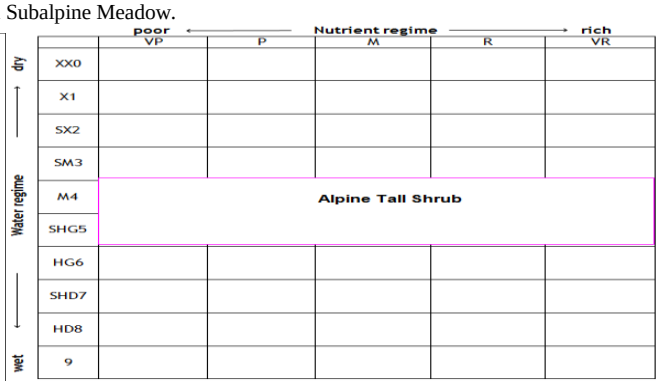
Components: There are acidic and calcareous variants of this community. Main component is Subalpine Tall Shrub. A minor component is Wetland Tall Shrub.

Zones: main – Subalpine.

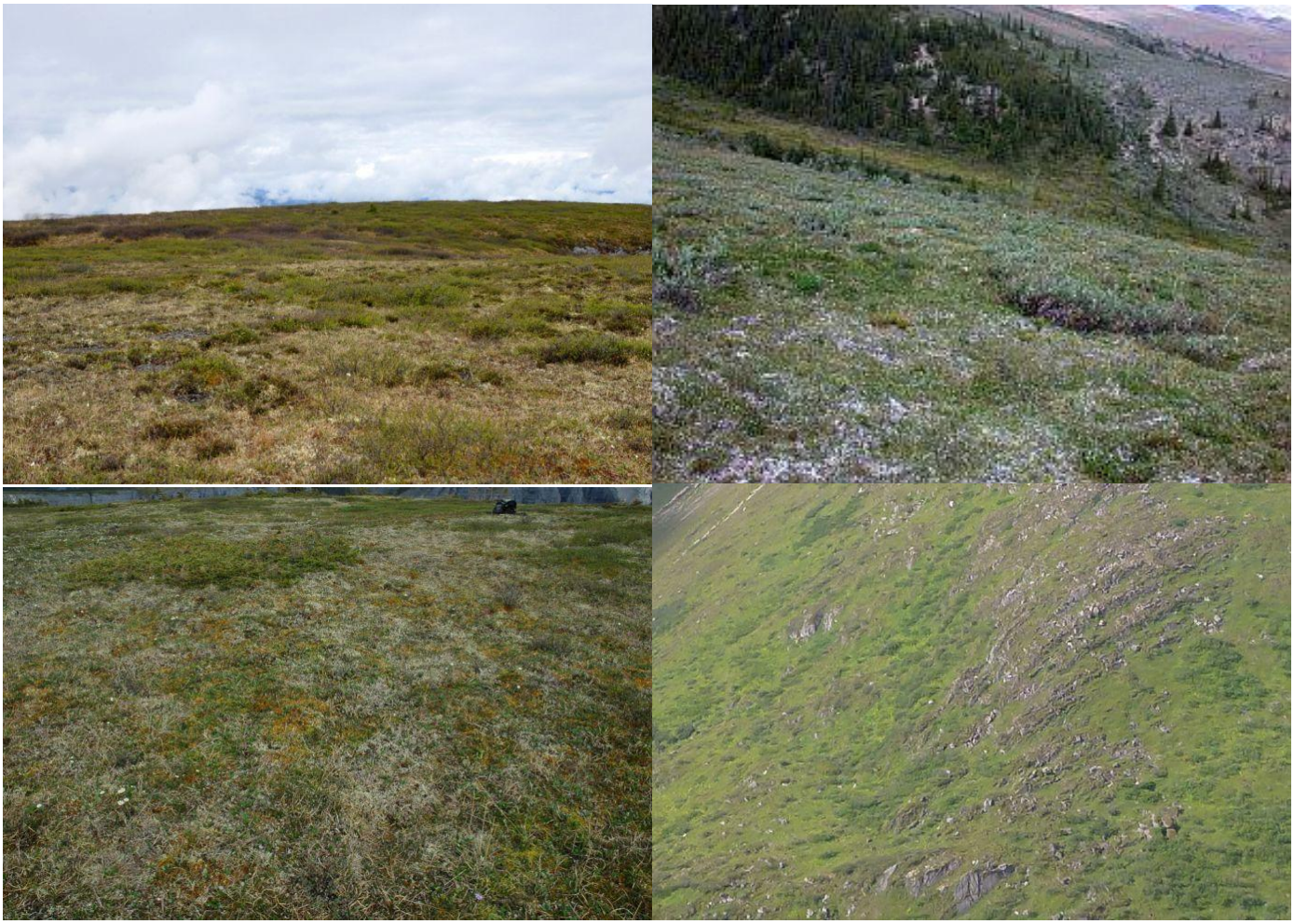
Vegetation: Tree layer is absent or very sparse. Tall and medium shrubs of *Salix arbusculoides, Salix glauca, Betula glandulosa* and *Alnus crispa* constitute the dominant layer. Tree species such as *Populus balsamifera* can also be found in this ecotype. Meadow herbs and grasses or heath species constitute lower layers.

Similar communities. This community is very similar and grades to Subalpine Tall Shrubs –Sparse Trees at lower elevations. At higher elevations or it grades to Medium – Low Shrub. After disturbance this community can be replaces with Subalpine Meadow.





Author and Date: Serguei Ponomarenko, 2015-03-06.



Nahanni Ecotype Classification

Scientific and Common name: Low Sparse Shrub

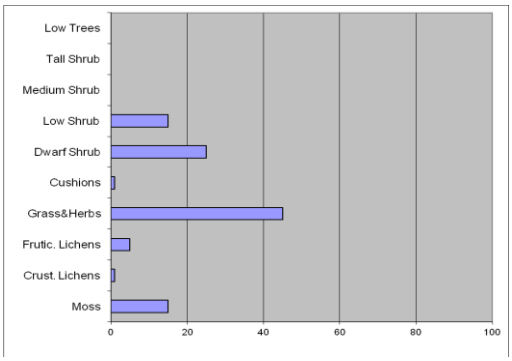
Concept: This is a late successional community in the alpine zone on submesic, mesic and subhygric sites. Commonly it is at higher altitudes than Alpine Medium-Low Shrub but due to the heterogeneity of the landscape it is often occur intermittently with it. It can also be a mid-successional community in boreal and subalpine zone after disturbance. Low Sparse Shrub can also be a part of Wetland group of communities.

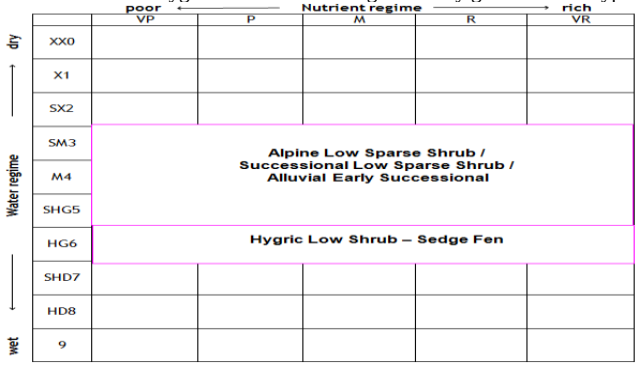
Components: main component is Alpine Low Sparse Shrub, Not often this ecotype can have a sparse layer of krumholtz *Picea glauca. A*dditional components are: Successional Low Sparse Shrub, Hygric Low Shrub – Sedge Fen. As a minor component, it includes Alluvial Early successional communities.

Zones: main - Alpine, additional : Subalpine, Boreal.

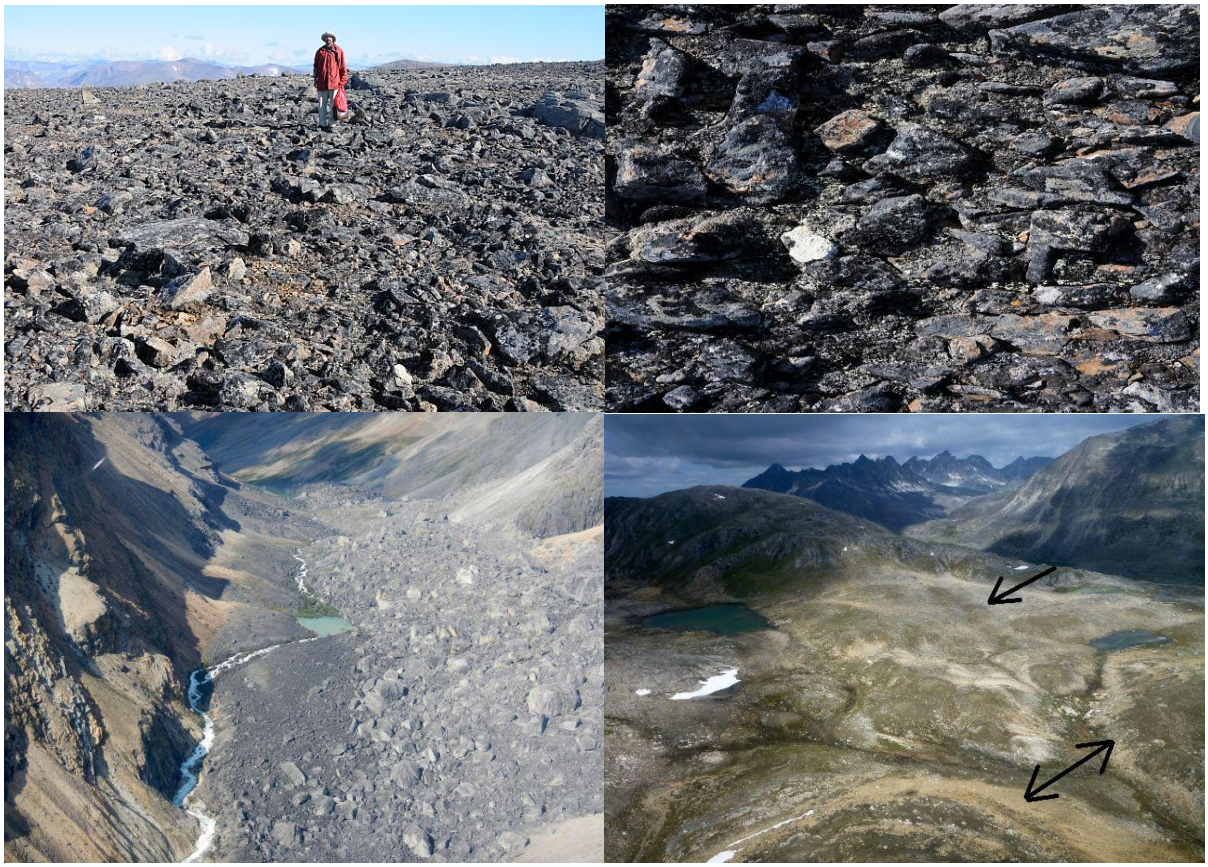
Vegetation: Tree layer is absent. Dominant layers are dwarf shrubs and herbs. Low shrubs of *Betula glandulosa* and willows (*Salix barrattiana*, *Salix arbusculoides)* constitute a sparse upper layer. Herbs and grasses most often is a dominant layer. Lichen and bryophytes can be well represented or be a minor component.

Similar communities. This group of communities may grade to Alpine Medium-Low Shrub at lower elevations and to Herb Tundra at higher elevations. The successional variant may grade to Spruce or Deciduous Forest or Woodland. Hygric Low Shrub – Sedge Fen may grade to other types of Wetlands.





Author and Date: Serguei Ponomarenko, 2015-03-16.



Nahanni Ecotype Classification

Scientific and Common name: Rock - Lichen

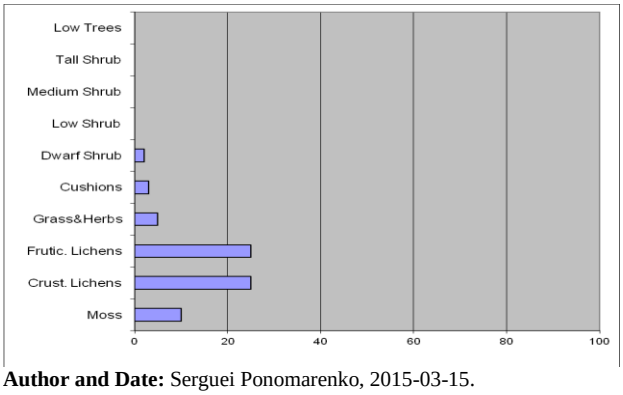
Concept: This community is present in all altitudinal zones but occupy a wider diversity of site types at higher elevations. In all zones it occupies rock outcrops with no soil and boulder / fragmented rock fields of different origin. At higher elevation it can also occupy areas with some finer soil material at the surface. In this later case the soil material is frequently cryoturbated. This can be a pioneer community on recently exposed rock surfaces or be thousand years old in the nival zone. It is spread on excessively drained to well drained flat and sloped sites that are not receiving surface seepage for a prolonged period of time. The sites may experience intensive cryoturbation. Other sites may be very stable. In winter this community often does not have normal snow accumulation due to wind erosion, can have normal snow accumulation or can have excessive snow accumulation that does not melt until late in the summer. The soil material may not be present or is a mixture of cobbles and boulders, sometimes with some finer fractions.

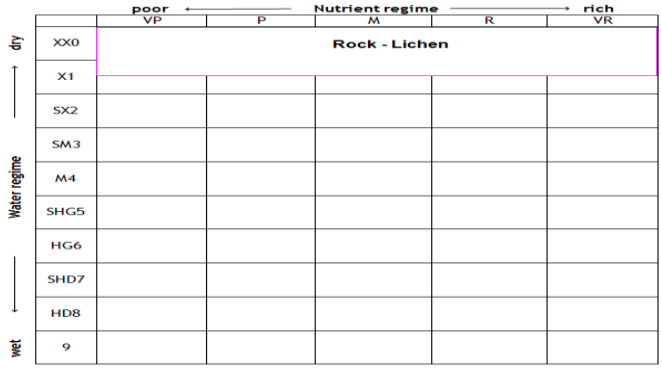
Components: not divided.

Zones: most common in the Nival and Alpine zones; occurs in Subalpine and Boreal.

Vegetation: The dominant life forms in this community are crustose lichens; the fruticose and foliose lichens are present with smaller cover. Can occupy from very few percent to 80% cover with average height between less than a millimetre to 2-3 cm. Common species of lichens include *Rhizocarpon geographicum*, *Stereocaulon glaucescens*, *Bryoria nitidula*, *Umbilicaria spp.*, *Alectoria nigricans* and others. Vascular species cover is less than few percent, often less than 1%.

Close communities: This community is often represented as a small-patch component in other alpine communities. It grades to Rock on the higher disturbance rock surfaces and to Alluvial Non-Vegetated.





Author and Date: Serguei Ponomarenko, 2015-03-15.

Nahanni Ecotype Classification

Scientific and Common name: Mixed Predominantly Coniferous Forest

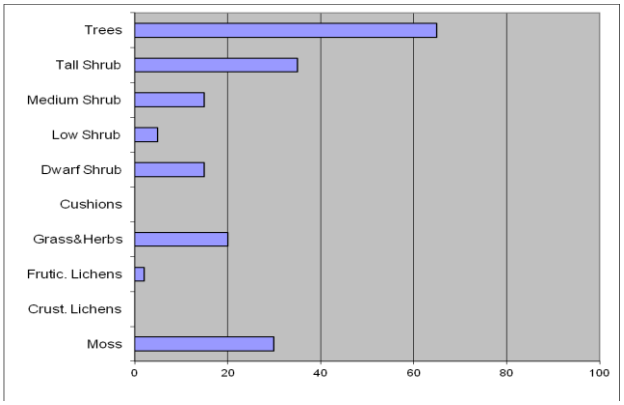
Concept: Mid seral large group of communities on submesic to subhygric sites. Nutrient regime is medium or rich. Often represents a post-fire successional stage. In winter this community group has normal snow accumulation.

Components: This group of communities consists of a number of mixed communities including coniferous woodlands with thick shrub understory.

Zones: Boreal zone.

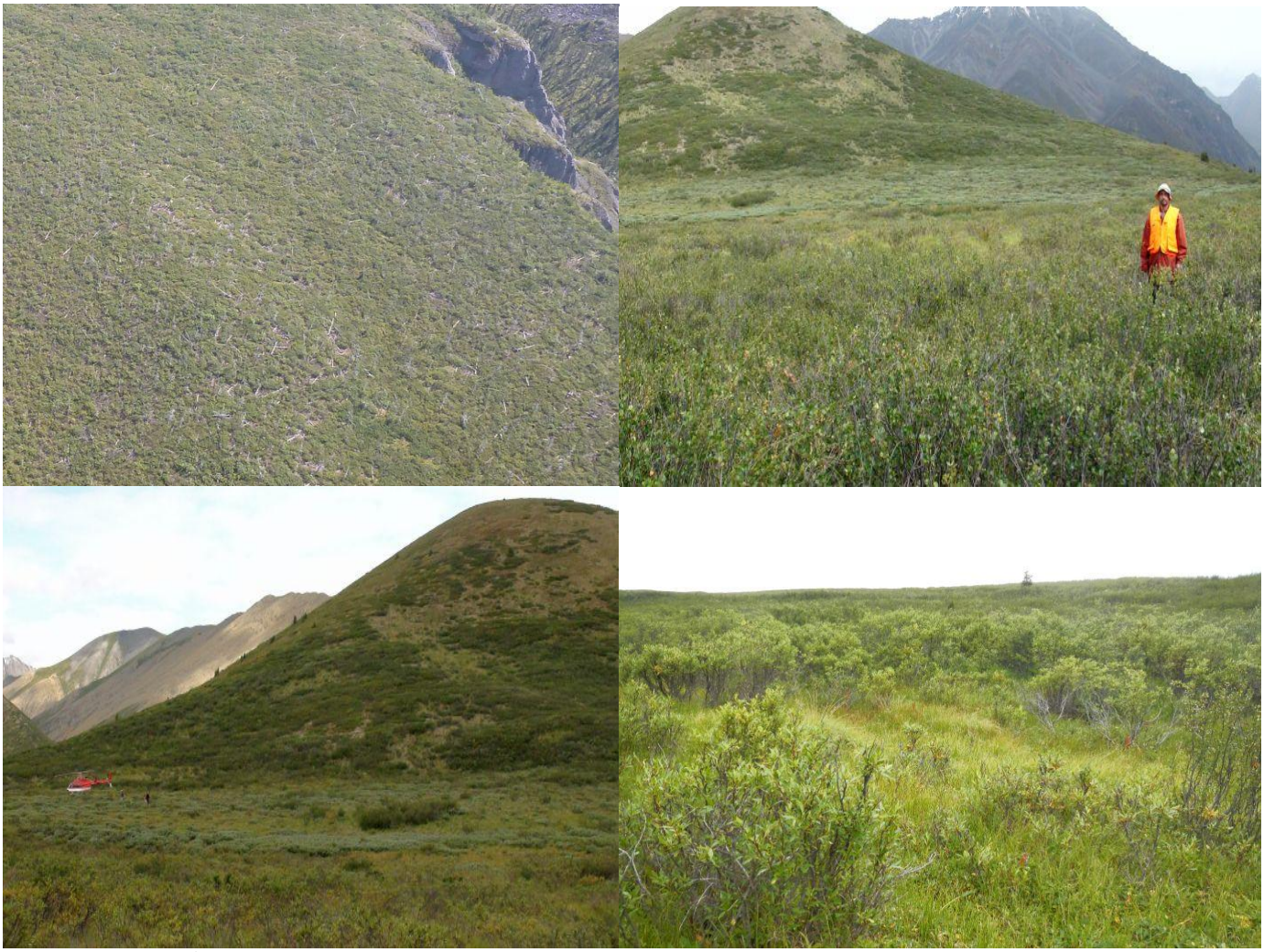
Vegetation: *Picea glauca* and/or *Picea mariana* or much more rare *Pinus contorta* constitute a moderately dense to sparse tree layer. *Populus tremuloides* and less commonly *Betula papyrifera* can be present in canopy. Shrub layer is well developed and commonly have *Betula glandulosa, Alnus crispa, Alnus incana ssp. rugosa, Shepherdia canadensis, Cornus sericea, Amelanchier alnifolia, Viburnum edule* and often willows *(Salix bebbiana, Salix scouleriana, Salix glauca, Salix niphoclada*). In low shrubs common are *Rosa acicularis, Ledum groenlandicum.* The dwarf shrub layer can be well developed or sparse and includes *Vaccinium uliginosum, Vaccimnium vitis-idae*. The herb layer can be rich or poor. Bryophytes are dominat in D layer (*Pleurozium schreberi, Ptilium crista-castrensis, Tomenhypnum nitens, Hylocomnium splendens and Sphagnum sp.*

Similar communities. With time this ecotype can get replaced with Coniferous Forest. In cooler and humid conditions, this community grades into Spruce – Lichen Woodland or Spruce – Lichen – Moss Woodland. At higher elevations it grades to Subalpine Shrub – Sparse Trees. In wetter sites it grades to the Wetland groups of communities.



Water regime	Nutrient regime: poor ← VP	P	M	R	→ rich VR
dry ↑	XX0				
	X1				
	SX2				
	SM3	Mixed Predominantly Coniferous Forest			
	M4				
	SHG5				
	HG6				
↓	SHD7				
	HD8				
wet	9				

Author and Date: Serguei Ponomarenko, 2015-03-16.



Nahanni Ecotype Classification

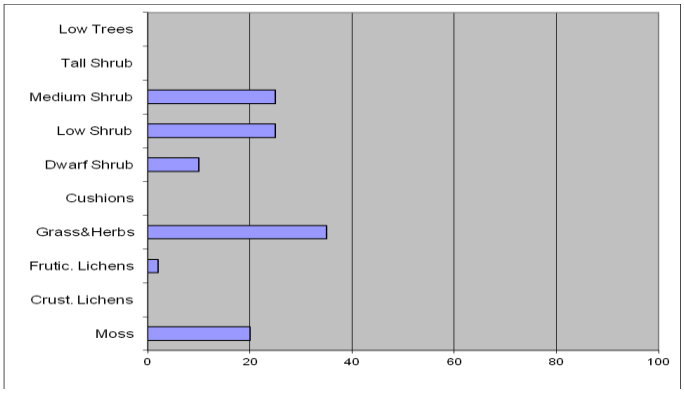
Scientific and Common name: Medium - Low Shrub
Concept: This is a late successional community in the alpine zone on mesic and subhygric sites. Commonly it is at higher altitudes than Subalpine Tall Shrub but due to the heterogeneity of the landscape it is often occur intermittently with it. It can also be a mid-successional community in boreal and subalpine zone after disturbance (most commonly after fire). Medium - Low Shrub can also be a part of Wetland group of communities.

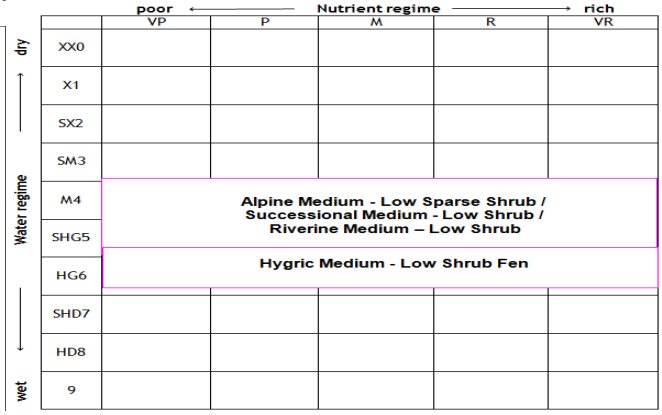
Components: Main - Alpine-Subalpine Medium-Low Shrub; additional - Successional Medium-Low Shrub, Hygric Medium-Low Shrub, Riverine Medium-Low Shrub.

Zones: Alpine, Subalpine, Boreal.

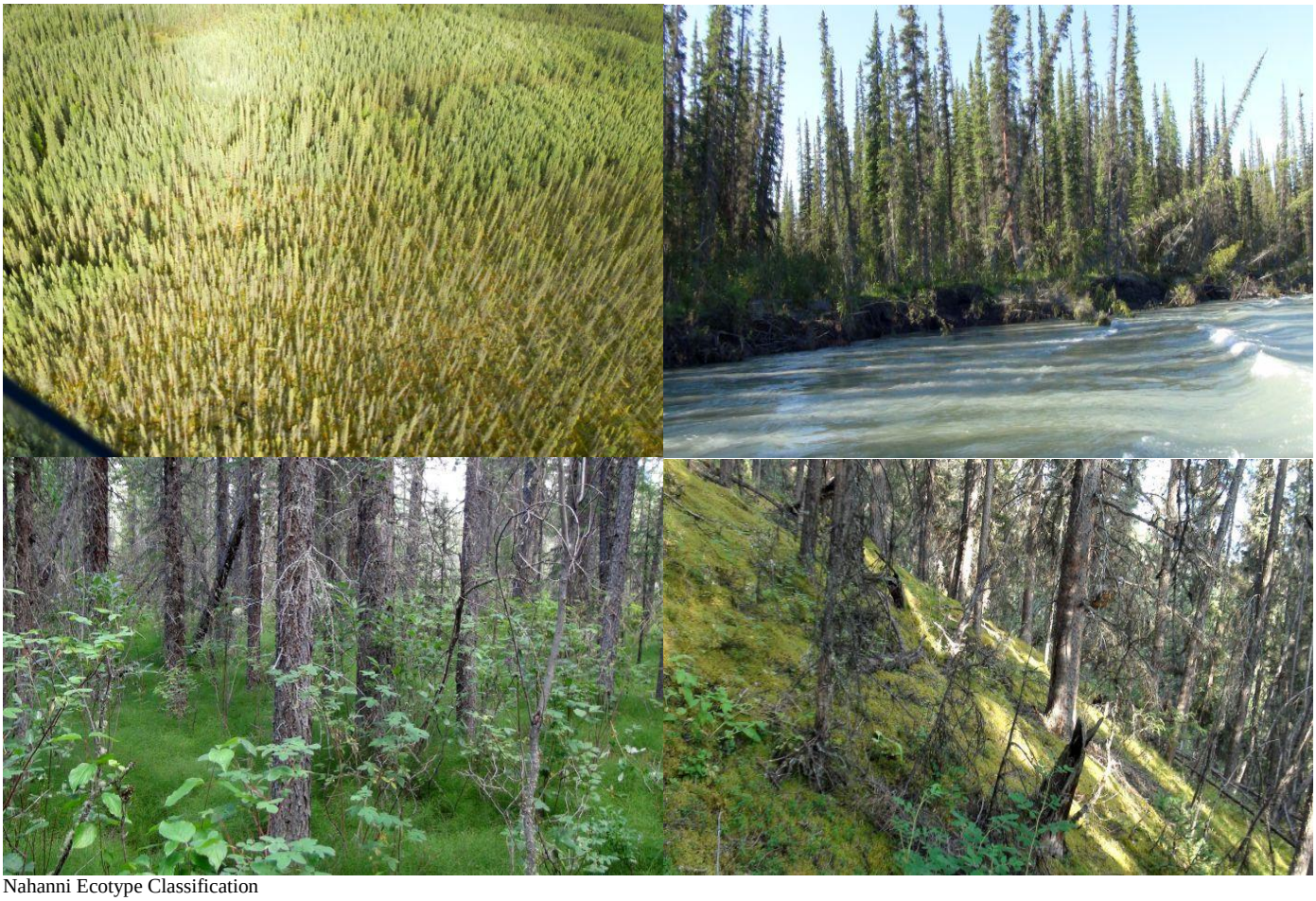
Vegetation: Tree layer is absent. Medium shrubs of *Salix myrtillifolia*, *Salix arbusculoides*, *Salix glauca*, *Betula glandulosa* and *Potentilla fruticosa* constitute the dominant layer. Meadow herbs and grasses or heath species form the lower layer.

Similar communities. This group of communities may grade to Subalpine Tall Shrubs at lower elevations or to Low Sparse Shrub at higher elevations. The successional variant may grade to Spruce or Deciduous Forest or Woodland. Hygric Medium-Low Shrub may grade to other types of Wetlands.





Author and Date: Serguei Ponomarenko, 2015-03-09.



Nahanni Ecotype Classification

Scientific and common name: Coniferous Forest

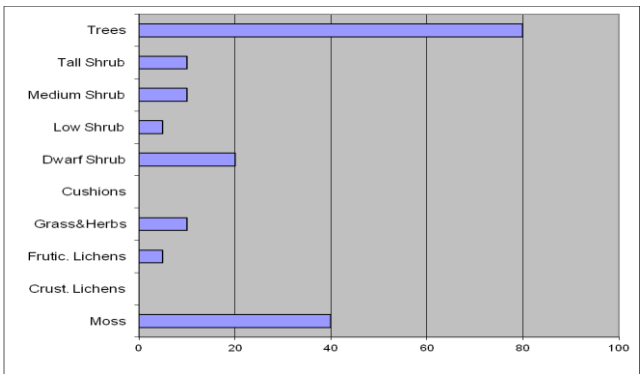
Concept: Late seral large group of communities on submesic, mesic and subhygric sites. Nutrient regime is poor, medium or rich. Permafrost is absent. Soils are commonly with an organic mor/moder layer. In winter this community group has normal snow accumulation.

Components: This group of communities consists of: Riparian White Spruce - Equisetum sp. Forest, White Spruce – Herb –Rich Subhygric Forest, White spruce – Shrub Woodland and Black Spruce Sphagnum sp. Subhygric-Hygric Woodland and Successinal Lodgepole Pine Forest..

Zones: dominant group of communities in the Boreal zone.

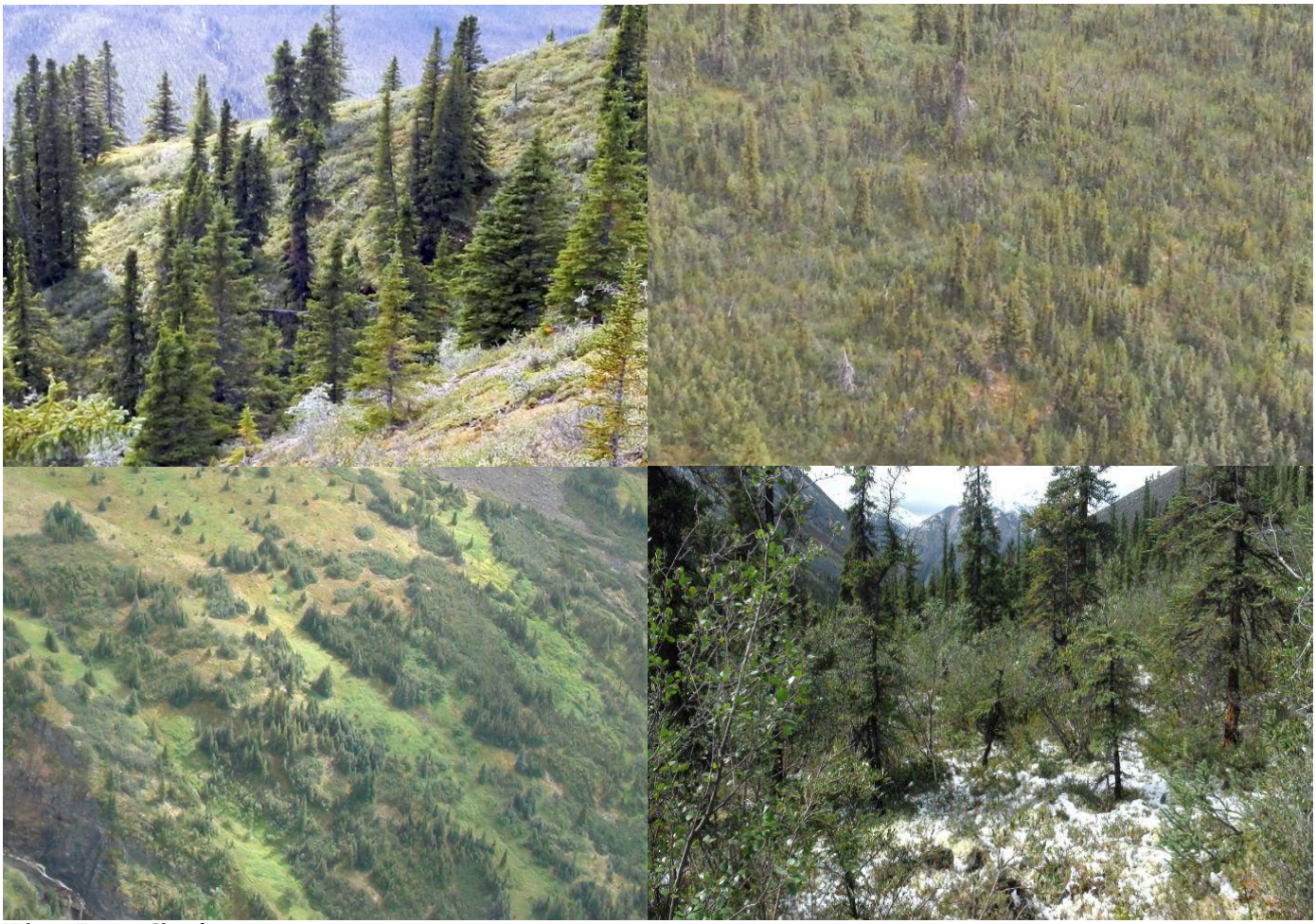
Vegetation: *Picea glauca* and/or *Picea mariana* or much more rare *Pinus contorta* constitute a moderately dense to dense tree layer. In medium shrub layer common are *Betula glandulosa, Alnus crispa, Shepherdia canadensis, Cornus sericea* and often willows *(Salix glauca, Salix niphoclada*). In low shrubs common are *Rosa acicularis, Ledum groenlandicum.* The dwarf shrub layer is commonly well developed and includes *Vaccinium uliginosum, Vaccimnium vitis-idae.* The herb layer can be rich or poor. Bryophytes are dominant in D layer (*Pleurozium schreberi, Ptilium crista-castrensis*, Tomenhypnum *nitens, Hylocomnium splendens and Sphagnum sp.)*

Similar communities: In cooler and air-humid conditions, this community grades into Spruce – Lichen Woodland or Spruce – Lichen – Moss Woodland. At higher elevations it grades to Subalpine Coniferous Woodland. In wetter sites it grades to the Wetland groups of communities.



Water regime	poor ← Nutrient regime → rich				
	VP	P	M	R	VR
dry	XX0				
	X1				
	SX2				
	SM3	Coniferous Forest			
	M4				
	SHG5				
	HG6				
	SHD7				
	HD8				
wet	9				

Author and Date: Serguei Ponomarenko, 2015-03-16.



Nahanni Ecotype Classification

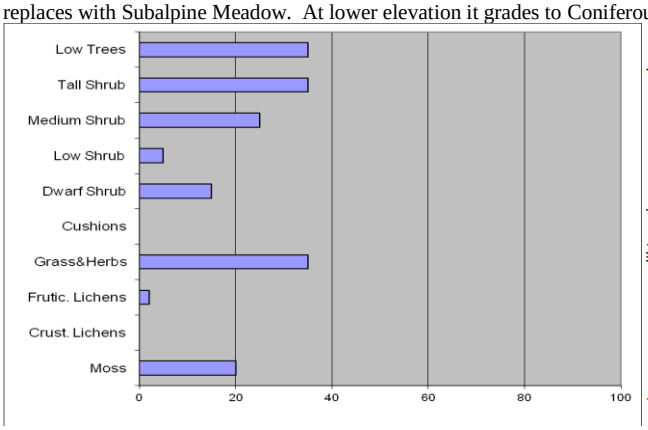
Scientific and Common name: Subalpine Coniferous Woodland
Concept: This is a late successional community in the subalpine zone on mesic and subhygric sites. Commonly it is at lower altitudes than Subalpine Shrub – Sparse Trees and higher than Coniferous, Mixed and Deciduous Forests.

Components: There are acidic and calcareous variants of this community.

Zones: Subalpine.

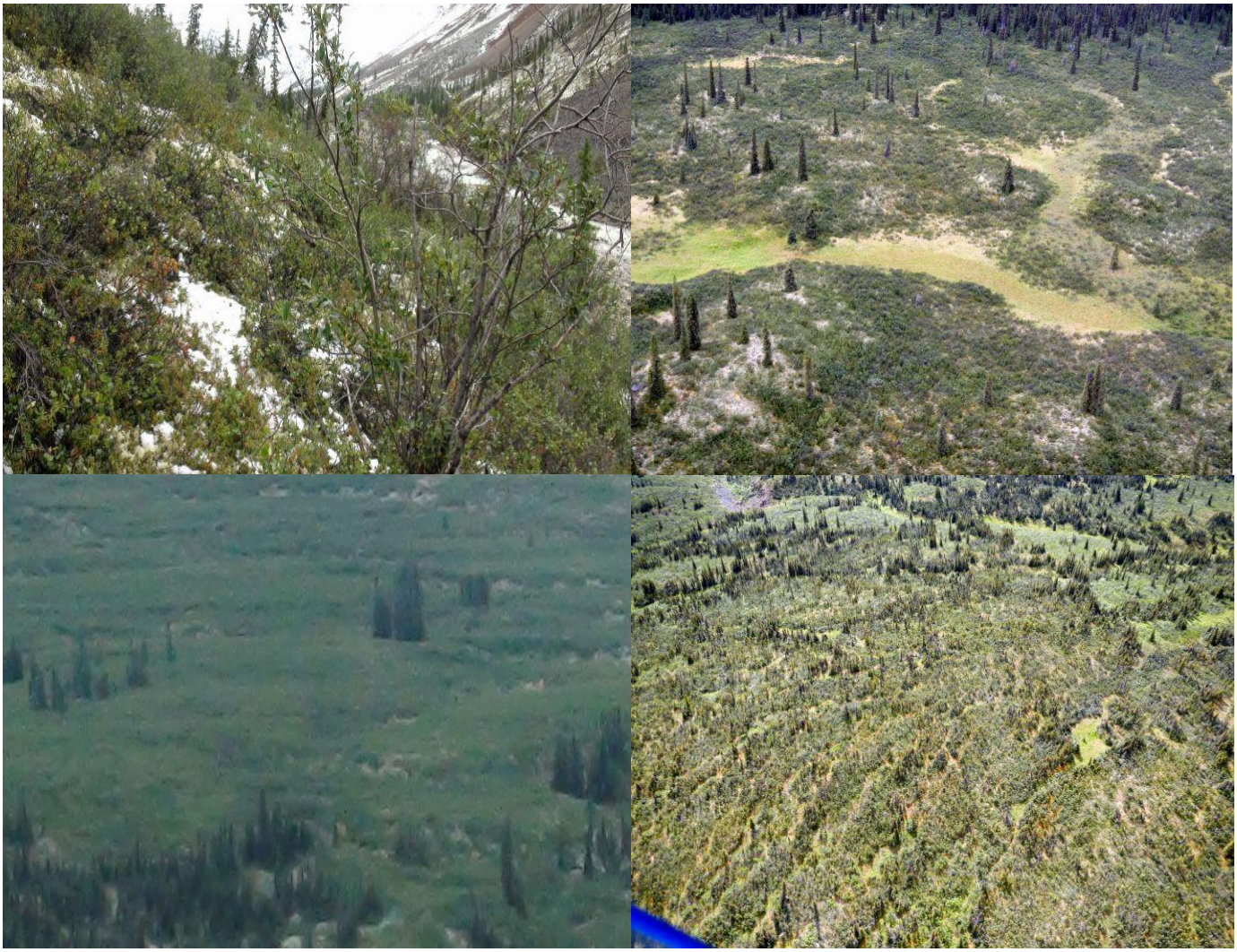
Vegetation: In Subalpine Coniferous Woodland *Picea glauca* and *Abies lasiocarpa* constitutes a sparse to moderately dense tree layer. Trees can be denser in some locations and sparser in others. Tall and medium shrubs of *Salix arbusculoides*, *Salix glauca*, *Betula glandulosa* and *Alnus crispa* are filling the gaps between trees.

Similar communities. With trees getting sparser this community grades to Subalpine Tall Shrubs –Sparse Trees. After disturbance this community can be replaces with Subalpine Meadow. At lower elevation it grades to Coniferous, Mixed or Deciduous Forests.



Water regime	poor ← Nutrient regime → rich				
	VP	P	M	R	VR
dry	XX0					
	X1					
	SX2					
	SM3					
	M4	Subalpine Coniferous Woodland			
	SHG5					
	HG6					
	SHD7					
	HD8					
wet	9					

Author and Date: Serguei Ponomarenko, 2015-03-12.



Nahanni Ecotype Classification

Scientific and common name: Subalpine Shrub – Sparse Trees

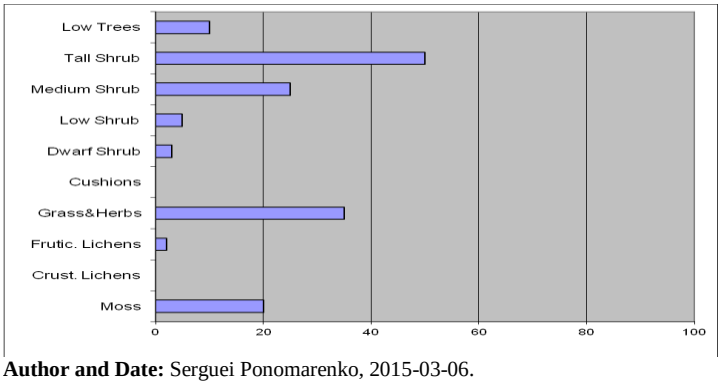
Concept: This is a late successional community in the subalpine zone on mesic and Subhygric sites. Commonly it is at higher altitudes than Subalpine Spruce Woodland and lower than Subalpine Tall Shrub but due to the heterogeneity of the landscape it is often occur intermittently with it.

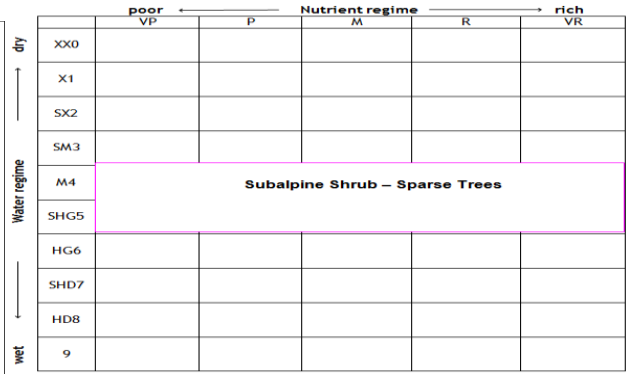
Components: There are acidic and calcareous variants of this community. Wetland Shrub – Sparse Trees is also included in this group as a minor component.

Zones: main - Subalpine.

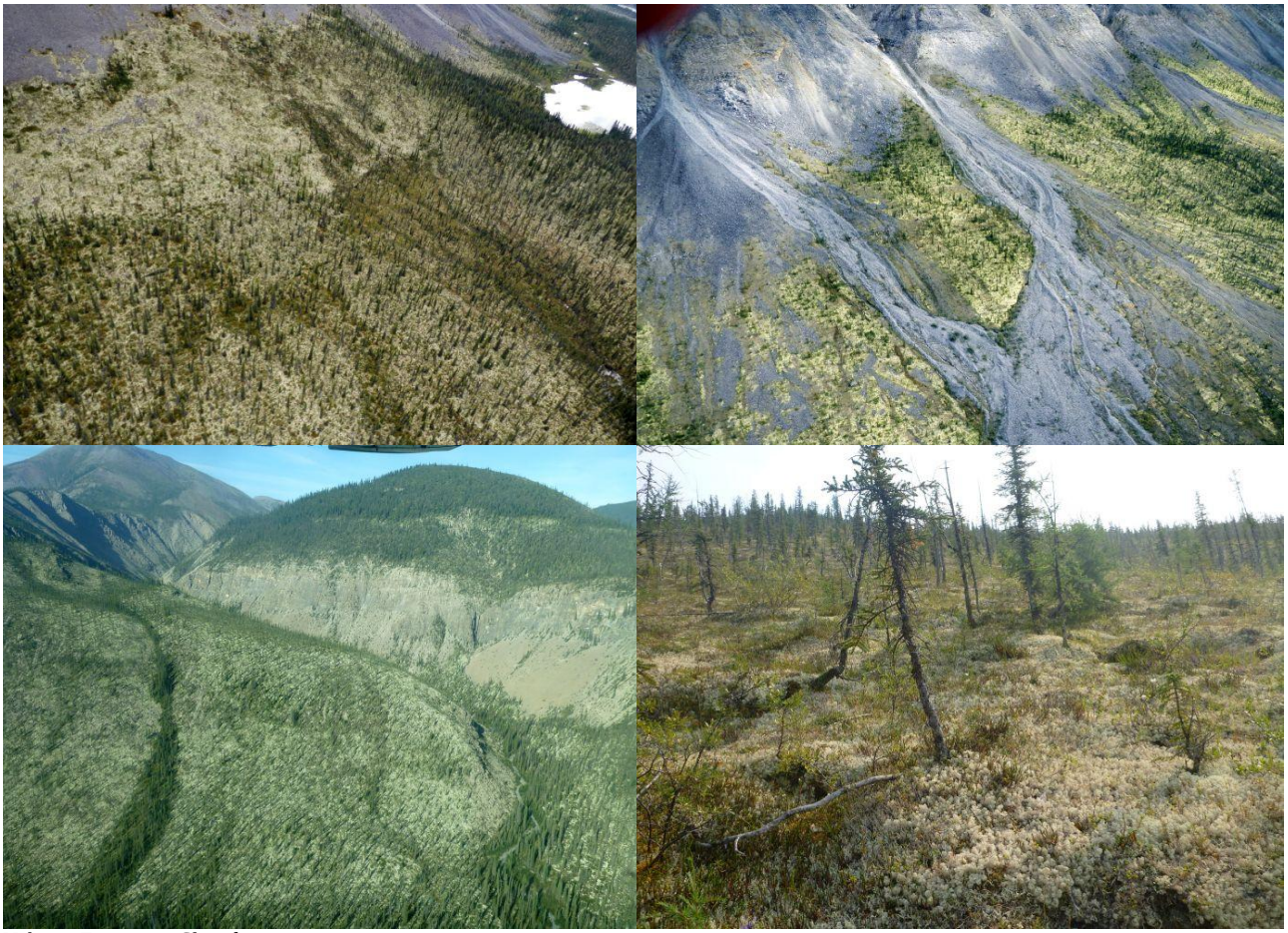
Vegetation: *Picea glauca* and *Abies lasiocarpa* constitutes a very sparse tree layer. Tall and medium shrubs of *Salix arbusculoides, Salix glauca, Betula glandulosa* and *Alnus crispa* are filling the gaps between trees.

Similar communities. With disappearing trees this community grades to Tall Shrubs. After disturbance this community can be replaces with Subalpine Meadow. At lower elevation it grades to Spruce Subalpine Coniferous Woodland.





Author and Date: Serguei Ponomarenko, 2015-03-06.



Nahanni Ecosystem Classification

Scientific name: Picea sp. – Lichen Woodland
Common name: Spruce – Lichen Woodland

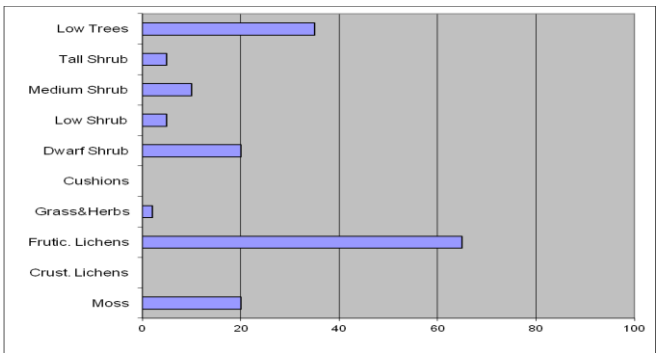
Concept: Late seral group of communities on submesic to mesic sites with poor to nutrient regime and with no active cryoturbation processes. Most commonly occupies slopes of northern aspects that receive little sun light and therefore relatively cold during summer. Biological processes are slow and mor organic accumulates on the surface. Less frequently it occupies flat surfaces with poor nutrient regime but with good drainage.

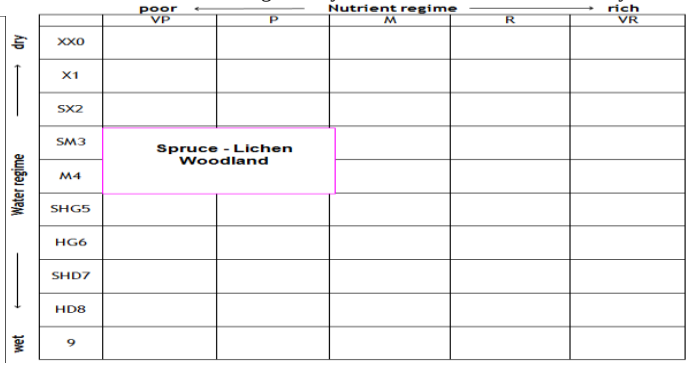
Components: This group of communities consists of: Black Spruce – Lichen Woodland, White Spruce – Lichen Woodland and White Spruce – Lichen Forest.

Zones: Common in the Boreal and Subalpine zones.

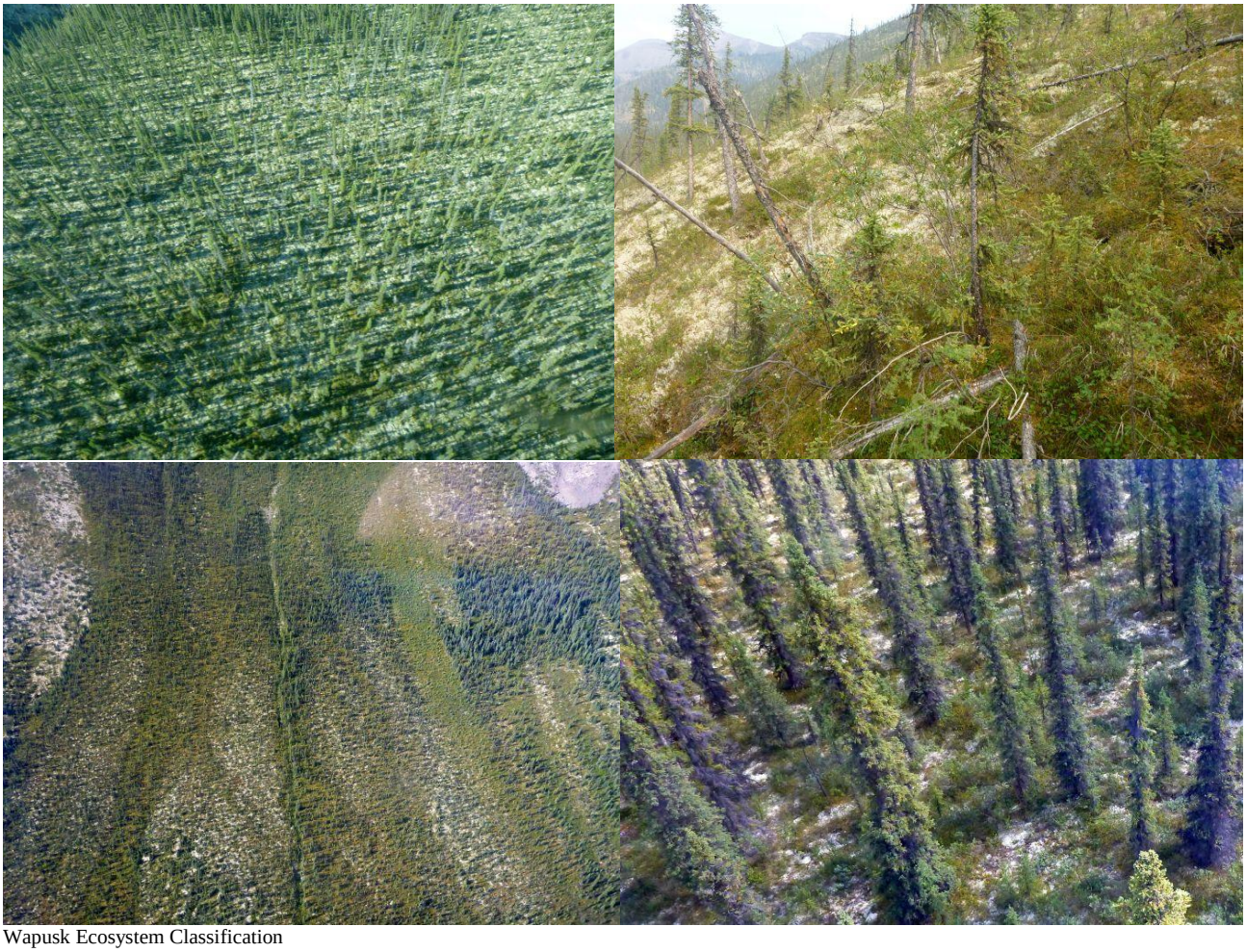
Vegetation: *Picea glauca* or *Picea mariana* constitute a sparse to dense tree to tall shrub layer. *Larix laricina* can be present in the same layers. In medium shrub layer common but sparse is *Betula glandulosa*. In low shrubs dominant is *Ledum groenlandicum.* Dwarf shrubs are always present and often prominent (*Vaccinium uliginosum, Vaccinium vitis-idae, Empetrum nigrum*). Herbs and grasses are very sparse, *Festuca altaica* being most prominent of them. Fruticose lichens are dominant in D (*Cladonia spp., Cladina spp., Cetraria spp.* and *Peltigera sp.*)., Mosses are always present but with lower cover ; most common of them are *Hylocomnium splendens, Pleurozium schreberi* and *Tomenhypnum nitens*.

Similar communities. In subhygric or/and slightly richer conditions, this community grades into Spruce – Lichen – Moss Woodland. In warmer sites it grades into the Coniferous Forest group of communities. After a fire it turns to successional Medium –Low Shrub that gradually succeeds back to this community.





Author and Date: Serguei Ponomarenko, 2015-03-13.



Wapusk Ecosystem Classification

Scientific name: Picea sp. – Lichen- Moss Woodland
Common name: Spruce – Lichen- Moss Woodland

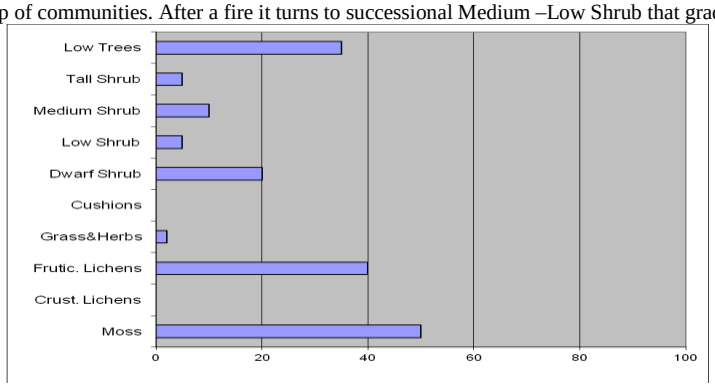
Concept: Late seral group of communities on mesic to Subhygric sites with poor to nutrient regime and with no active cryoturbation processes. Most commonly occupies wide subsurface drainage channels on slopes of northern aspects that receive little sun light and therefore relatively cold during summer. Biological processes are slow and mor organic accumulates on the surface. Less frequently it occupies flat surfaces with poor nutrient regime and slightly restricted drainage.

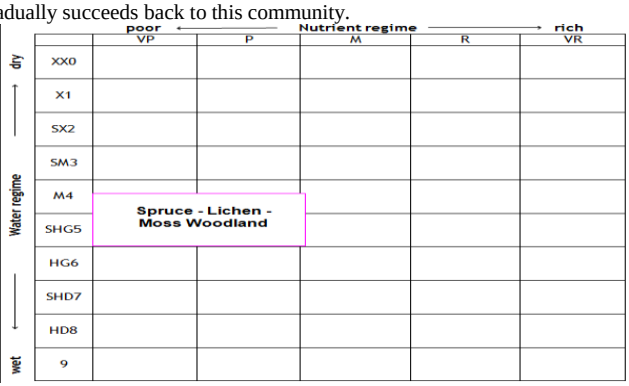
Components: This group of communities consists of: Black Spruce – Lichen -Moss Woodland, White Spruce – Lichen – Moss Woodland and White Spruce – Lichen – Moss Forest.

Zones: Common in the Boreal and Subalpine zones.

Vegetation: *Picea glauca* or *Picea mariana* constitute a sparse to dense tree to tall shrub layer. In medium shrub layer common but sparse is *Betula glandulosa*. In low shrubs dominant is *Ledum groenlandicum.* Dwarf shrubs are always present and often prominent (*Vaccinium uliginosum, Vaccinium vitis-idae, Empetrum nigrum*). Herbs and grasses are very sparse, *Festuca altaica* being most prominent of them. Fruticose lichens (*Cladonia spp., Cladina spp., Cetraria spp.* and *Peltigera sp.*) and bryophytes (*Hylocomnium splendens, Tomenhypnum nitens, Aulacomnium palustre and Sphagnum sp.)* are co-dominant in D or mosses dominate.

Similar communities. In drier conditions, this community grades into Spruce – Lichen Woodland. In warmer sites it grades into the Mesic Spruce Forest group of communities. After a fire it turns to successional Medium –Low Shrub that gradually succeeds back to this community.





Author and Date: Serguei Ponomarenko, 2015-03-13.

Nahanni Ecotype Classification

Scientific and Common name: Wetland
Concept: This is a heterogeneous group sharing hygric to hydric water regime. Physiognomically, it can be grassland (Sedge Fen), Shrubland or Woodland. Water regime can be permanently saturated or water table can fluctuate during the vegetation season. The nutrient regime is from very rich to poor.

Components: Sedge Fen, Shrub Fen, Shrub Swamp, Open Bog, Treed Bog, Marsh.

Zones: Alpine, Subalpine, Boreal.

Vegetation: All species share adaptation to water-logged soils. Among tree species common are *Picea mariana and Larix laricina*. In shrubs common are species of *Salix sp.* and *Alnus rugosa*. In the herb layer common are species of *Carex sp*. For the moss layer typical are *Sphagnum spp*. and *Aulacomnium palustre*.

Similar communities. Spectrally it is very heterogeneous group of communities. That is why components of the Wetland group can be mapped as other ecotypes (see the corresponding fact-sheets). Most often borders on the ground are sharp, less often they are gradual. The physiognomic chart for this community is absent due to heterogeneity of this group.

Water regime	Nutrient regime: poor ← VP	P	M	R	→ rich VR
dry	XX0					
	X1					
	SX2					
	SM3					
	M4					
	SHG5					
	HG6					
	SHD7	Wetland				
	HD8					
wet	9					

Author and Date: Serguei Ponomarenko, 2015-03-20.

Nahanni Ecotype Classification

Scientific and Common name: Deciduous Forest

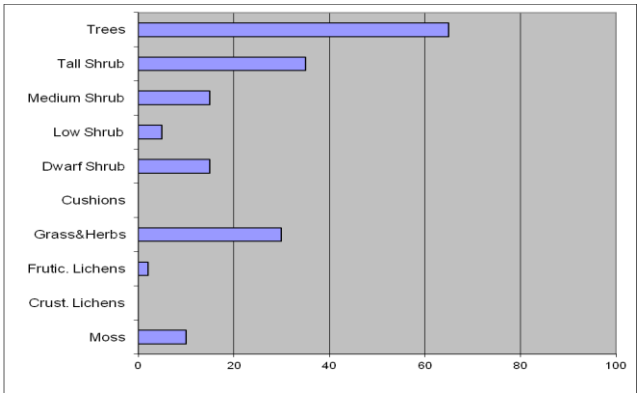
Concept: Early and mid seral large group of communities on submesic to subhygric sites. Nutrient regime is medium or rich. Often represents a post-fire successional stage. In winter this community group has normal snow accumulation.

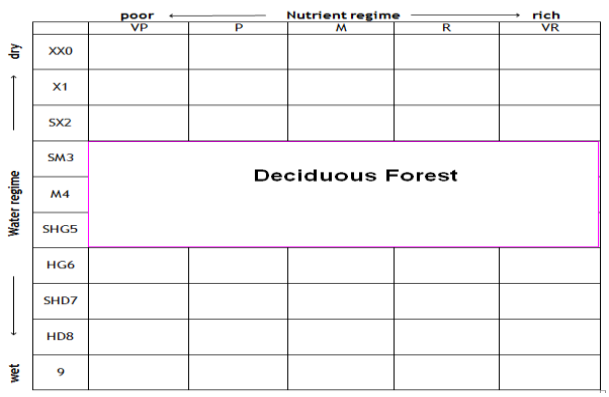
Components: This group of communities consists of a number of deciduous communities. It also includes post-fire tall shrub communities.

Zones: Boreal zone.

Vegetation: *Populus tremuloides* is most commonly a dominant species in the tree layer. Other common tree species in canopy or/and subcanopy is *Betula papyrifera*. In tall and medium shrub layers common are *Betula glandulosa, Alnus crispa, Alnus incana ssp. rugosa, Shepherdia canadensis, Cornus sericea, Amelanchier alnifolia, Viburnum edule* and often willows *(Salix bebbiana, Salix scouleriana, Salix glauca, Salix niphoclada*). In low shrubs common are *Rosa acicularis, Ledum groenlandicum.* The dwarf shrub layer can be well developed and includes *Vaccinium uliginosum, Vaccimnium vitis-idae* and *Arctostaphylos uva-ursi*. The herb layer can be rich or poor. Bryophytes are dominant in D layer (*Pleurozium schreberi, Ptilium crista-castrensis, Hylocomnium splendens and Sphagnum sp.*

Similar communities: With time this ecotype gets replaced with Mixed Forest and then Coniferous Forest. In wetter sites it grades to the Wetland groups of communities.





Author and Date: Serguei Ponomarenko, 2015-03-18.


Nahanni Ecotype Classification

Scientific and Common name: Mixed Predominantly Deciduous Forest

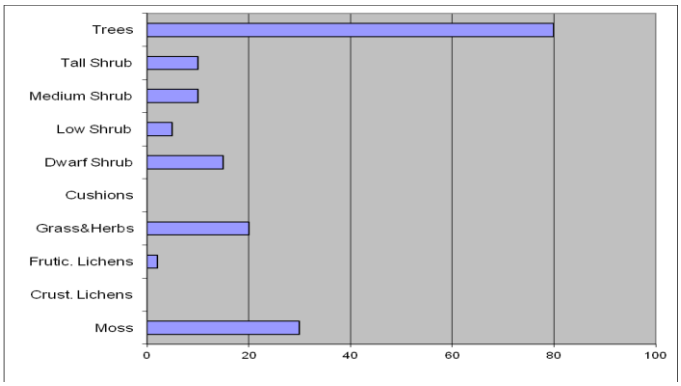
Concept: Mid seral large group of communities on submesic to subhygric sites. Nutrient regime is medium or rich. Often represents an early post-fire successional stage. In winter this community group has normal snow accumulation.

Components: This group of communities consists of a number of mixwood communities.

Zones: Boreal zone.

Vegetation: *Populus tremuloides* is commonly the dominant species in the tree layer. Other common tree species in canopy or/and subcanopy are *Betula papyrifera* and *Picea glauca*. In medium shrub layer common are *Betula glandulosa, Alnus crispa, Shepherdia canadensis, Cornus sericea* and often willows *(Salix glauca, Salix niphoclada*). In low shrubs common are *Rosa acicularis, Ledum groenlandicum*. The dwarf shrub layer is commonly well developed and include *Vaccinium uliginosum, Vaccimnium vitis-idae*. The herb layer can be rich or poor. Bryophytes are dominat in D layer (*Pleurozium schreberi, Ptilium crista-castrensis, Tomenhypnum nitens, Hylocomnium splendens and Sphagnum sp.*

Similar communities. With time this ecotype gets replaced first with Mixed Predominantly Coniferous Forest and then with Spruce Forest. At higher elevations it grades to Subalpine Shrub – Sparse Trees or to Subalpine Tall Shrub. In wetter sites it grades to the Wetland groups of communities (Deciduous Swamp).



Water regime	Nutrient regime: poor ← VP	P	M	R	VR → rich
dry	XX0					
	X1					
	SX2					
	SM3	Mixed Predominantly Deciduous Forest				
	M4					
	SHG5					
	HG6					
	SHD7					
	HD8					
wet	9					

Author and Date: Serguei Ponomarenko, 2015-03-16.

Nahanni Ecotype Classification

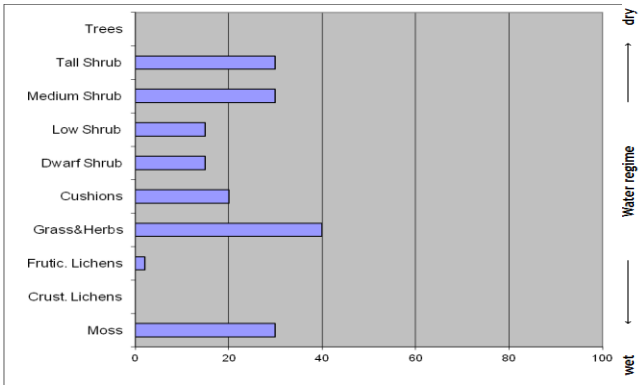
Scientific and Common name: Recently Burnt
Concept: This is a heterogeneous group of early Successinal communities regenerating after a forest fire. The water regime can be from submesic to subhygric (rarely – hygric). The nutrient regime is from very rich to poor.

Components: mostly shrub communities, sometimes dwarf shrubs or bryophytes can be dominant.

Zones: Subalpine, Boreal.

Vegetation: *Populus tremuloides* or *Betula papyrifera* or *Picea glauca* can be regenerating soon after fire. In most cases, *Alnus crispa and Salix sp*. create a shrub layer in which tree species germinate within several years. In other cases, low shrub *Ledum groenlandicum* and/or moss *Polytrichum commune* can be dominant vegetation at the first stage. Sedges and grasses can be prominent in subhygric situations.

Similar communities: This group of communities can grade to Tall Shrubs and Deciduous Forests. Less commonly it succeeds to Coniferous Forest.



	poor ← Nutrient regime → rich				
	VP	P	M	R	VR
XX0					
X1					
SX2					
SM3			Recently Burnt		
M4					
SHG5					
HG6					
SHD7					
HD8					
9					

Author and Date: Serguei Ponomarenko, 2015-03-20.