Detecting Anomalies in Forage Availability and Quality of the Bathurst Caribou Summer Range using Satellite Remote Sensing

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Objectives

Sustainable northern development is a shared goal among governments and northern residents in Canada. The NWT Cumulative Impact Monitoring Program (CIMP) is one of the tools being used to achieve the goal. Caribou and their habitats have been identified by CIMP as one of the key priorities. In this study, we aim to: (1) apply and refine an unbiased and objective method to the Bathurst caribou summer range for monitoring leaf biomass and seasonality changes using satellite remote sensing and field measurement data; and (2) detect anomalies in forage availability and quality by land cover classes within the summer range on the basis of leaf biomass and seasonality monitoring results.

Study area and data sources

The Bathurst summer range study area is located northeast of NWT and southwest of Nunavut (Fig. 1). Data sources of this study include: (1) Landsat-derived land cover maps circa 2000 developed by Olthof et al. (2007); (2) field leaf biomass measurements at 27 sites during the summer of 2005 around the Lupin Gold Mine and Yellowknife; (3) BRDF corrected AVHRR surface reflectance (red and near infrared), cloudiness index, and inter-sensors calibration; (4) Landsat scenes over the Bathurst caribou habitat for leaf biomass map.

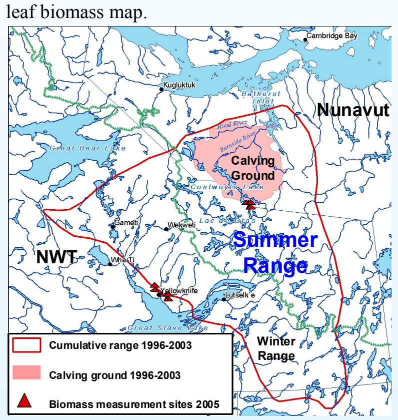

Figure 1. Location of Bathurst caribou summer range (between red boundary line and green tree line) and field leaf biomass measurement sites.

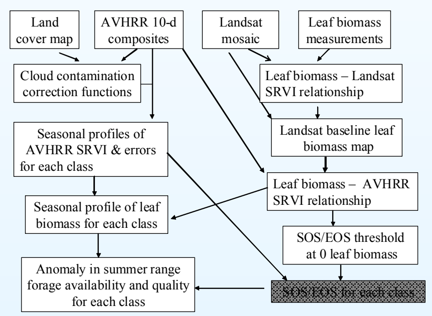

Figure 2. Flow chart showing the steps of an unbiased and objective method for monitoring leaf biomass and seasonality changes in the Arctic.

Methods

An unbiased and objective method for monitoring leaf biomass and seasonality changes in the Arctic has been developed (see details in Chen et al, 2012, a & b). Figure 2 outlines the application and refinement of this method for the summer range of Bathurst caribou herd.

Result 1. Application and refinement of an unbiased and objective method for monitoring leaf biomass and seasonality over the Bathurst summer range

On the basis of the Landsat-derived land cover map (Olthof and Fraser, 2007), we stratified 50% pure 1-km pixels in the Bathurst summer range into 3 broad land cover classes: shrub, herb-shrub, and lichen low vegetation (Table 1).

Table 1. Number of 50% pure AVHRR pixels within a land cover class in the Bathurst summer range

	Combined land cover class			
	Shrub	Herb-shrub	Lichen low veg	Treed
1 Evergreen forest (>75% cover) - old				3
15 Low regenerating to young mixed cover				20
16 Deciduous shrubland (>75% cover)	1			
19 Shrubs-herb-lichen-bare	2			
22 Sparse coniferous (density 10-25%), herb-shrub cover				596
23 Herb-shrub		9774		
24 Shrub-herb-lichen-bare	10			
25 Shrub-herb-lichen-water bodies	19			
26 Lichen-shrubs-herb, bare soil or rock outcrop			15	
28 Low vegetation cover (bare soil, rock outcrop)			72	
35 Lichen barren			1369	
36 Lichen-shrub-herb-bare			3590	
37 Sparse coniferous (density 10-25%), lichens-shrub-herb cover				58
38 Rock outcrop, low vegetation cover			5	
39 Recent burns				2
41 Low vegetation cover			107	
Subtotal	32	9774	5158	679

Relationships between the simple ratio vegetation index (SRVI = near infrared reflectance / red reflectance) of cloud contaminated pixels and clear-sky pixels within a class in the Bathurst summer range were developed (Fig. 3). These relationships were then used to correct cloud contamination and produce unbiased seasonal profiles of AVHRR SRVI for the 3 classes (Fig. 4).

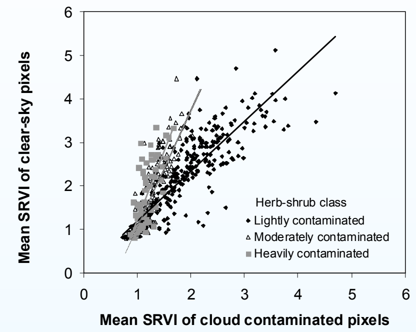

Figure 3. Relationship between cloud contaminated pixels and clear-sky pixels within the herb-shrub class within the Bathurst summer range from 1985-2011.

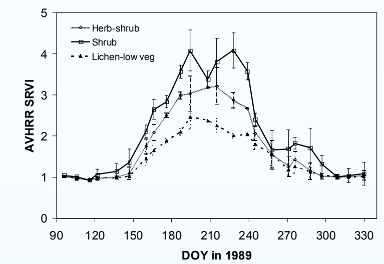

Figure 4. Examples of AVHRR seasonal profiles for the 3 classes in the Bathurst summer range in 1989.

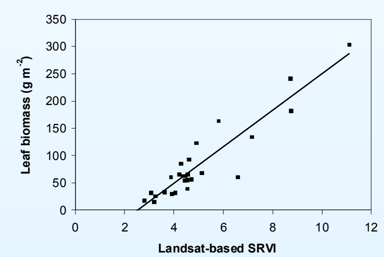

Figure 5. Relationship between Landsat SRVI and leaf biomass measured during the summer of 2005 in and around the Bathurst summer range.

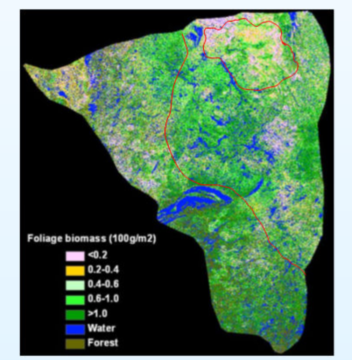

Figure 6. Leaf biomass map derived by applying Landsat SRVI and leaf biomass relationship to a Landsat mosaic.

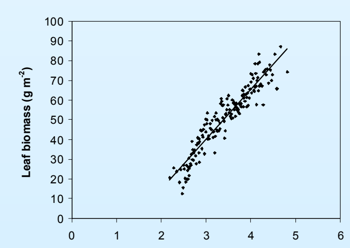

Figure 7. Relationship between AVHRR SRVI and leaf biomass calculated from the Landsat-derived leaf biomass map.

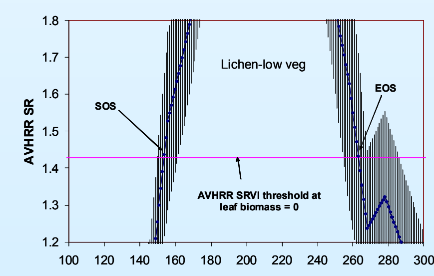

Figure 8. Example showing the quantification of SOS and EOS for the lichen low vegetation class within the Bathurst summer range in 1989.

Using the field leaf biomass measurements and corresponding Landsat SRVI, we developed their relationship (Fig. 5) and applied it to a Landsat mosaic to produce a 30-m land biomass map (Fig. 6). Aggregating the 30-m resolution leaf biomass to 1-km resolution and correlating them with clear-sky AVHRR SRVI, we developed the relationship between AVHRR SRVI and leaf biomass (Fig. 7). From Fig. 7, we can derive AVHRR SRVI threshold (=1.428) for objectively determining the start (or end) date of growing season, namely, SOS (or EOS) for each land cover class in the Bathurst summer range (Fig. 8).

Result 2. Anomalies in forage availability and quality of the Bathurst caribou summer range

Late start date and early end date of green leaf biomass, inadequate leaf biomass, and poor quality of leaf biomass in the summer range are generally believed to be detrimental to caribou growth and pregnancy rates during the summer-fall period and calf:cow ratio in the following year. Therefore, we quantified these summer range forage availability and quality variables using the standard anomalies of the SOS and EOS; of leaf biomass during spring-early summer (11-20/06), early summer (21/06-10/07), mid-summer (11/07-10/08), late summer (11/08-20/09), and late summer-fall (21/09-10/10) on the basis of their seasonal distributions in relation with temperature and precipitation (Fig. 9); and of the leaf N content at the peak leaf biomass (Fig. 10).

The value of the standard anomaly = (current year value – long-term mean)/long-term standard deviation). We indexed the overall summer range forage availability and quality as the mean of the eight standard anomalies (i.e., summer range mean anomaly, or SRMA). Note here the anomaly for late SOS is signed as negative, so that a negative SRMA indicates poor overall forage availability and quality. Note that while it is possible that the negative anomaly for one forage availability/quality variable had a more significant impact on caribou demographic variables than that for another forage availability/quality variable, we don't have enough information to assign different weights to them. Therefore, a simple average is used to calculate SRMA.

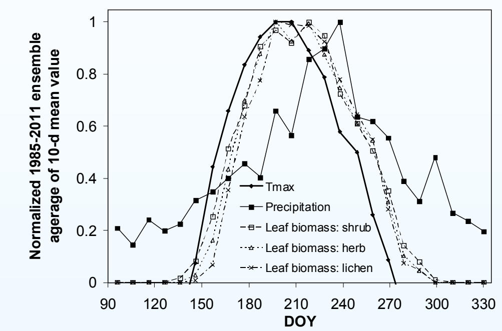

Figure 9. Normalized 1985-2011 ensemble average of 10-d leaf biomass for the 3 classes, 10-d mean maximum temperature (T_{max}) and 10-d cumulative precipitation for the Bathurst summer range.

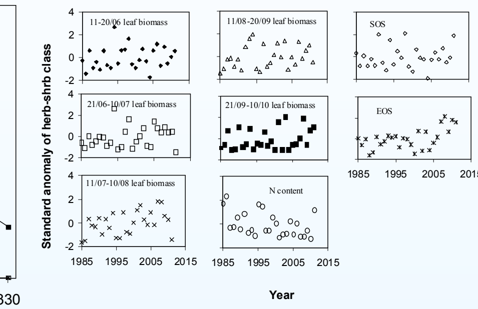

Figure 10. Standard anomalies of leaf biomass (periods 11-20/06, 21/06-10/07, 11/07-10/08, 11/08-20/09, and 21/09-10/10), N content, SOS, and EOS for the herb-shrub class during 1985-2011.

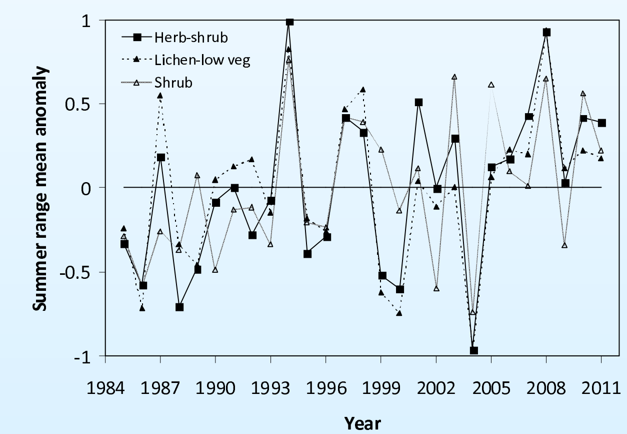

Figure 11. Inter-annual variations in the Bathurst summer range mean anomaly (SRMA) of the three land cover classes from 1985-2011.

For the herb-shrub class, which makes up 62.4% of the Bathurst caribou summer range, the lowest SRMA was detected to be in 2004, followed by that in 1988 and 2000 (Fig. 11). Similarly, the lowest three SRA years were 2004, 2000, and 1986 for the lichen-low vegetation class and 2004, 2002, and 1986, for the shrub class. The lichen-low veg class and shrub class make up 33% and 0.2 % of summer range respectively. Late SOS, early EOS, low leaf biomass during 11/06-10/10, except mid-summer (11/07-10/08) resulted the lowest SRA in 2004 for the herb-shrub class and Lichen low-vegetation class. The same can be said for the shrub class except nearly normal leaf biomass in periods 21/06-10/07, and 11/07-10/08.

Conclusion

(1) Using the field measurements of leaf biomass, we applied and refined an unbiased and objective method for monitoring leaf biomass and seasonality change to the Bathurst summer range

(2) Large inter-annual variations in the summer range mean anomalies were found for all three classes. Year 2004 was found to have the lowest SRMA for all 3 classes, while year 2000 the 2nd lowest for lichen low vegetation class and 3rd for herb-shrub.

Reference

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