2019 Harvest Area Remote Sensing-Based Spectral Regeneration

Metadata & Technical Documentation

Alberta Biodiversity Monitoring Institute, Geospatial Centre

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ABMI ALBERTA BIODIVERSITY MONITORING INSTITUTE

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1. Overview

1.1. Summary

The Alberta Biodiversity Monitoring Institute's (ABMI's) 2019 harvest area spectral regeneration dataset provides a remote sensing-based characterization of vegetation regrowth in relevant harvest area polygons contained within the ABMI's Human Footprint Inventory (HFI) [1]. Its intent is to represent the status and trends of post-harvest regeneration as seen through changes in spectral signals detected from the Earth's land surface.

1.2. Description

This dataset is provided in the form of a vector layer containing harvest area polygons from the ABMI's HFI 2019, the original attributes that accompany the latter dataset, and an additional series of attributes containing metrics and other information related to remote sensing-based spectral regeneration. These metrics exist for the roughly 57,800 of the harvest areas for which such information could be reliably and confidently extracted (i.e., they were harvested within the appropriate time period, and minimal noise or other interference is present in their spectral signals). The harvest areas possessing spectral regeneration data are distributed widely across Alberta and we believe they present a good representation of the various landscapes and regions of the province. Spectral regeneration data are generated using a multi-decadal time series of Landsat Earth Observation satellite imagery, covering the province of Alberta for the years 1984 through 2019. The imagery is processed and analyzed using the Google's online Earth Engine platform. Further details can be found in Hird et al. [2].

1.3. Credits

This dataset was developed and generated by the ABMI's Geospatial Centre.

1.4. Citation

This product should be cited with this document using the following:

Alberta Biodiversity Monitoring Institute. 2022. "2019 Remotely Sensed Harvest Area Spectral Regeneration – Metadata and Technical Documentation." Edmonton, Alberta, Canada.

1.5. Contact Information

If you have questions or concerns about the data, please contact:

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1.6. Keywords

Alberta, harvest area, forest spectral regeneration, remote sensing, Landsat, time series analysis, LandTrendr, cloud computing, Google Earth Engine

2. Use Limitations

This product was developed and produced using freely-available, open-source Landsat 5, 7 and 8 satellite imagery, and the ABMI Human Footprint Inventory (2019). The 2019 Harvest Area Remote Sensing-Based Spectral Regeneration dataset may be freely used provided it is cited properly (see the Citation section above).

2.1. Open-Sourced Data

This dataset contains data originating from open sources, which has subsequently been enhanced through computer analysis processing. The Open Sourced Data may be reproduced in whole or in part and in any form for educational, data collection or non-profit purposes without special permission from the ABMI provided acknowledgement of the source is made. No use of the Open Sourced Data may be made for resale without prior permission in writing from the ABMI. By accessing the Open Sourced Data, you agree to indemnify and hold harmless the ABMI and the ABMI's subsidiaries, affiliates, related parties, officers, directors, employees, agents, independent contractors, advertisers, partners, co-branders, and Open Sourced Data sources from any and all actions, proceedings, claims, demands, liabilities, losses, damages, and expenses which may be brought against or suffered by the ABMI or which it may sustain, pay or incur, arising or resulting from your violation of this clause. The Open Sourced Data is provided on an "As Is" and "As Available" basis and the ABMI does not guarantee that the Open Sourced Data will be suitable for your purposes or requirements. The ABMI further states that the Open Sourced Data is subject to change, and the ABMI gives no guarantee that the content is complete, accurate, error or virus free, or up to date. The ABMI disclaims all warranties, conditions, and other terms of any kind, whether express or implied, whether in contract, tort (including liability for negligence) or otherwise, including, but not limited to any implied term of satisfactory quality, fitness for a particular purpose, and any standard of reasonable care and skill.

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3. Data Specifications

3.1. Processing Environment

The Google Earth Engine online code editor [3]; ESRI ArcGIS Desktop 10.7.1; R 4.2.0; Rstudio Version 2022.02.3, Build 492

3.2. Extents

Latitude and Longitude
- West: -120
- East: -110
- South: 49
- North: 60

Projection: Alberta Environment & Parks 10TM, NAD83, ‘Forest’
- North: 6650732.874 metres (m)
- South: 5425911.945 m
- East: 850578.966 m
- West: 179312.099 m

3.3. Spatial Reference

Projected Coordinate System: NAD_1983_10TM_AEP_Forest
WKID: 3400; Authority: EPSG
Projection: Transverse Mercator
False Easting: 500000.00000000
False Northing: 0.00000000
Central Meridian: -115.00000000
Scale Factor: 0.99920000
Latitude of Origin: 0.00000000
Linear Unit: Meter
Geographic Coordinate System: GCS_North_American_1983

Prime Meridian: Greenwich
Angular Unit: Degree
Datum: D_North_American_1983
Spheroid: GRS_1980
Semi-major Axis: 6378137.0
Semi-minor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

3.4. Data Format

These data are provided as an ESRI Shapefile (.shp), containing relevant ABMI 2019 HFI harvest area polygons and associated attributes, with the addition of a set of spectrally-based, regeneration-related attributes.

3.5. Lineage

This dataset is an updated version, to the year 2019, of the first publicly available spectral regeneration dataset provided by the ABMI (previous version: to 2018) and accessible through the ABMI website (www.abmi.ca). The dataset may be further updated or replaced with a new version in future where relevant (e.g., when important changes, improvements, or additions are made to the data).

3.6. Attribute Fields

Table 1 summarizes the list of attributes/fields found in the ABMI 2019 harvest area spectral regeneration dataset (provided in ESRI's Shapefile format). For detailed information regarding the generation of the regeneration attributes, see the Methods section below. For detailed information on HFI feature attributes, refer to the HFI 2018 metadata documentation [1].

Table 1. List of attribute fields found within the 2019 Harvest Area Spectral Regeneration dataset. For further details, see Section 3 (Methods) below.

Field	Possible Values	Description
HFI feature attributes		
OBJECTID	1 to 300000	Unique polygon object identification number; specific to this 2019 dataset
SOURCE	See [1]	ABMI's original source for a harvest area polygon [1]
HFI_ID	See [1]	ABMI's unique identifier for this polygon feature [1]
FEATURE_TY	See [1]	ABMI HFI feature type (e.g., harvest area) [1]
YEAR	See [1]	Year the feature appeared in the HFI, according to the feature's source [1]

Field	Possible Values	Description
SECTOR_HFI	See [1]	Indicates the industry that created the footprint [1]
Modifier_Y	See [1]	Whether the feature changed or is new from the previous 2018 HFI [1]
Spectral regeneration metric attributes		
regnAnlyYN	Y (Yes), N (No)	Indicates whether this harvest area polygon was included in analyses (does not indicate whether spectral regeneration metrics were reliably or appropriately extracted)
regnMetsYN	Y, N	Indicates whether spectral regeneration metrics were reliably and appropriately extracted for this harvest area
AnlysID	1 to 300000	Unique identifier used in analyses of harvest area polygons, for all harvest area polygons analyzed
preNBR_m	-1000.0 to 1000.0	Pre-harvest spectral vegetation index (SVI) value (mean*). Scaled by 1000.
preNBR_s	-1000.0 to 1000.0	Pre-harvest spectral SVI value (standard deviation (sd)**)
hrvYr_m	1989.0 to 2013.0	Year in which the harvest event is detected (mean)
hrvYr_s	0 to 3.0	Year in which the harvest event is detected (sd)
lnDstb_m	1.0 to 24.0	Length of time (years) between the detected harvest event and the beginning of regeneration (mean)
lnDstb_sd	0 to 10.0	Length of time (years) between the detected harvest event and the beginning of regeneration (sd)
regStYr_m	1990.0 to 2013.0	Year in which detectable post-harvest spectral regeneration begins (mean)
regStYr_s	0 to 10.0	Year in which detectable post-harvest spectral regeneration begins (sd)
nbrDstb_m	0 to 2000.0	Total detected change in SVI values detected at harvest event (mean)
nbrDstb_s	0 to 300.0	Total detected change in SVI values detected at harvest event (sd)
reg5yr_m	0 to 100.0+	Percent spectral regeneration 5 years after regeneration has begun (mean)
reg5yr_s	0 to 50.0	Percent spectral regeneration 5 years after regeneration has begun (sd)
y2reg80_m	0 to 30.0	Length (years) of time required to reach 80% spectral regeneration (mean)
y2reg80_s	0 to 15.0	Length (years) of time required to reach 80% spectral regeneration (sd)
reg2019_m	0 to 100.0+	Current (to 2019) level of percent spectral regeneration (mean)
reg2019_s	0 to 90.0	Current (to 2019) level of percent spectral regeneration (sd)
totPolyPix	>= 0	Total number of Landsat 30 m pixels representing

Field	Possible Values	Description
		the pre-processed (i.e., buffered, simplified) harvest area polygon
Data quality flag attributes		
perRelvPix	0 to 100.0	Percent of total intersecting pixels that were appropriate, relevant, and retained for use in metric calculations
perOutRng	0 to 100.0	Percent of intersecting pixels flagged for 'out of date range'
perNoRegn	0 to 100.0	Percent of intersecting pixels flagged for 'no regeneration detected'
perMltDstb	0 to 100.0	Percent of intersecting pixels flagged for 'multiple disturbances detected'
perNoHrv	0 to 100.0	Percent of intersecting pixels flagged for 'no harvest events detected'
Confidence score attributes ŧ		
confSz	0 to 6	Confidence score based on size of harvest area polygon (greater confidence is given to larger harvest areas as they are represented by a larger sample of pixels)
confRelvPx	0 to 6	Confidence score based on percentage of representative pixels used in metric calculations (i.e., not flagged and removed from analyses)
confCntgPx	0 to 6	Confidence score based on the number of contiguous pixels used in metric calculations
confHrvYr	0 to 6	Confidence score based on within-polygon variability in the detected year of harvest event
confLnDstb	0 to 6	Confidence score based on within-polygon variability in the length of time between the detected harvest event and detected beginning of regeneration
confNBRchg	0 to 6	Confidence score based on within-polygon variability in SVI total disturbance values
confRegn	0 to 6	Confidence score based on within-polygon variability in current levels of percent spectral regeneration
confY2R80	0 to 6	Confidence score based on within-polygon variability in the years required to reach 80% spectral regeneration
conf5yReg	0 to 6	Confidence score based on within-polygon variability in 5-year post-harvest spectral regeneration
confTotSum	0 to 54	Overall confidence score; a sum of all calculated confidence scores

* Mean: mean of metric values from all relevant/appropriate pixels intersecting the harvest area polygon of interest

** Standard deviation: mean of metric values from all relevant/appropriate pixels intersecting the harvest area polygon of interest

ŧ Confidence scores range from 0 (very low) to 6 (very high)

3.7. No Data Values

No Data or Null values are filled with a value of -9999 where a particular metric or attribute was not calculable. This is the case for those harvest area polygons for which metrics were calculated and are provided, or for those that were analyzed but not appropriate for reporting spectral regeneration. For instance, where all relevant pixels representing a harvest area contained the same year of harvest event, the standard deviation of these values is not calculable, and is given a value of -9999. As another example, where spectral signals did not reach 80% spectral regeneration, these metrics are given a no data value of -9999.

Metric and related attributes for harvest areas that were not analyzed are given a value of zero.

4. Methods

The following provides a brief summary of the methods used to produce the harvest area spectral regeneration dataset. These are described further in the peer-reviewed paper published by Hird et al. [2].

The ABMI 2019 HFI harvest area polygons were pre-processed before being brought into the Google Earth Engine (GEE) analysis environment. They were first negatively buffered by 30 m (i.e., the outer 30 metres of each polygon was removed), so as to minimize edge effects resulting from any misalignment between the polygons themselves and the satellite imagery that has a 30 m spatial resolution.

These outlines were then simplified (with a maximum change tolerance of 15 m, or half the pixel width of the satellite imagery used in this workflow). This enabled efficient uploading of the polygon features into the analysis environment. Finally, those individual polygons < 900 m^2 in size – the size of one Landsat image pixel (30 m x 30 m) – were removed. This pertained to both polygons that represented a single harvest area feature, and those that represented a disjointed piece of a larger harvest area feature (e.g., that resulted from negative buffering).

4.1. Landsat Data Processing

Figure 1 illustrates the workflow implemented to generate this dataset. The majority of the methodology is undertaken with the GEE online platform, using a customized script written with the help of the JavaScript-based GEE code editing application programming interface.

Tier 1 processed surface reflectance imagery from Landsat 5 Thematic Mapper, 7 Enhanced Thematic Mapper +, and 8 Operational Land Imager are first calibrated and masked for cloud and cloud shadow using provided quality flags (see the GEE Data Catalog for more information: https://developers.google.com/earth-engine/datasets). They are then integrated into a single time series stack of growing-season images (i.e., June through September) covering 1984 to 2019. This image stack is processed to produce yearly best pixel composites using per-pixel median compositing. Per-pixel time series of a calculated spectral vegetation index (SVI) derived from this composited dataset form the foundation of the ABMI's remotely-sensed characterization of post-harvest spectral regeneration.

Equation (1) shows the calculation used for the SVI employed here (an index commonly referred to as the Normalized Burn Ratio), which has been shown in published research to work well for detecting and characterizing forest vegetation disturbances and regeneration.

$$SVI = \frac{NIR_{reflectance} - S \qquad _{reflectance}}{NIR_{reflectance} + SWIR_{reflectance}} \tag{1}$$

where *NIR* is near infrared, and *SWIR* is shortwave infrared [4]. The equation results in unitless values ranging from -1 to 1 which are often scaled up by 1000 for data handling.

Per-pixel time series of annual, growing-season SVI values are processed using the LandTrendr algorithm – a temporal segmentation method designed to extract changes in surface vegetation conditions from time series of remotely-sensed spectral values using a series of linear trend segments fit to a time series [5]. The resulting segmented time series are then ready for extracting information related to detectable harvest events and spectral regeneration.

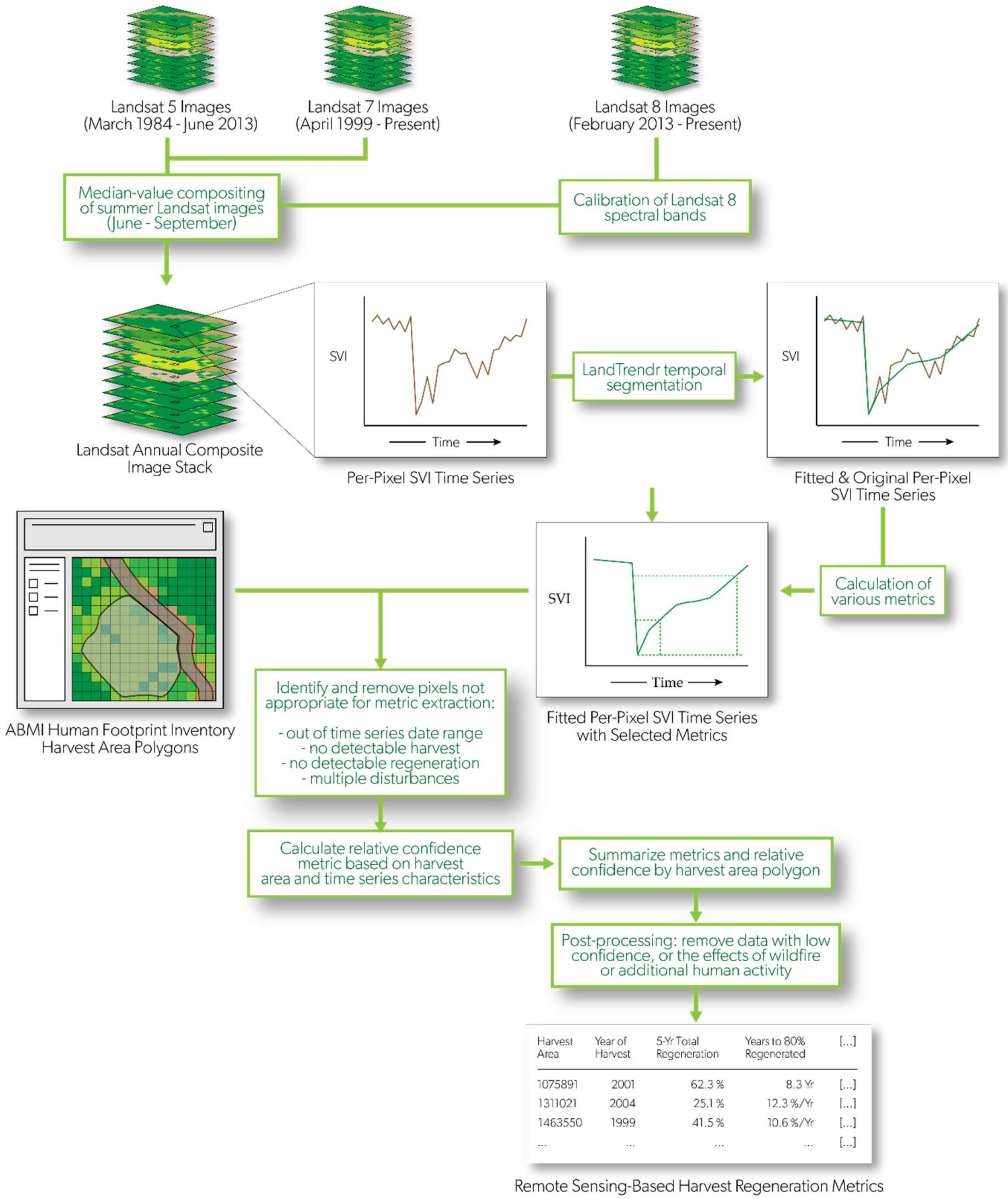

Figure 1. General workflow used for generating per-harvest area polygon metrics related to remotely-sensed spectral regeneration.

4.2. Characterizing Post-Harvest Spectral Regeneration

Table 1 in section 3.6 (Attribute Fields) describes the metrics contained within the harvest area spectral regeneration dataset. It should be noted that these were identified as most relevant from those tested during development, based on information contained in the scientific literature, as well as personal observations of the data. Alongside these metrics, related quality information extracted for each corresponding harvest area polygon are provided. Regeneration-specific metrics are generally given as percent spectral regeneration, which refers to the percent of the total drop in SVI values (occurring with the detected harvest event) that has been regained – i.e., the percent of the spectral signature that has returned. Figure 2 illustrates how these metrics are calculated.

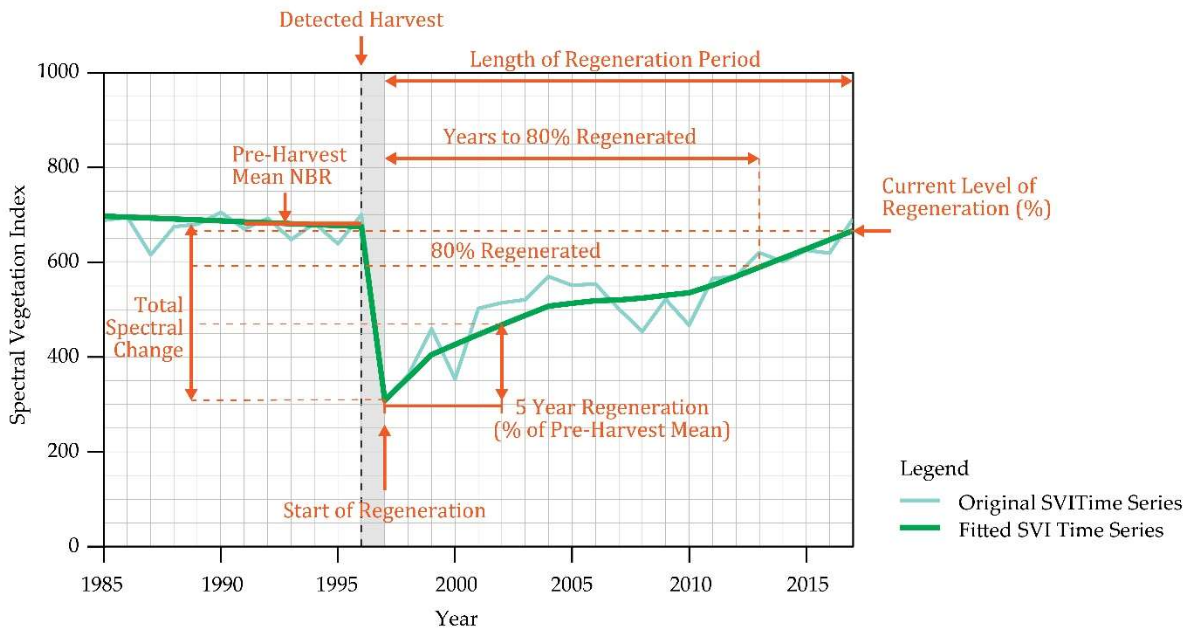

Figure 2. Graphic illustrating how various metrics and information related to post-harvest spectral regeneration are extracted from a per-pixel spectral vegetation index time series.

The pre-processed 2019 HFI harvest area polygons are brought into the GEE environment, and per-polygon metric statistical summaries (mean and standard deviation) are calculated for each harvest area. As indicated in Table 1, pixels for which extracting regeneration metrics is either infeasible or inappropriate are flagged and removed from further analysis. That is, these flagged pixels are not included in per-polygon summaries. The conditions under which a pixel is flagged and subsequently removed are detailed in Table 2.

Table 2. Description of conditions under which pixels are flagged for removal from further processing.

Flag	Description
No harvest	No inter-annual drop in SVI values beyond a certain magnitude is detected,

Flag	Description
	indicating notable vegetation removal did not occur (e.g., pixels where retention during harvest was practiced)
Multiple disturbances	More than one inter-annual drop in SVI beyond a certain magnitude is detected, and separated by more than 3 years (indicating separate events)
Out of date range	A harvest was detected, but occurred too early or late in the time series for proper metric calculations; the current workflow requires data be available 5 years before harvest and 5 years after regeneration for calculations
No regeneration	A harvest or disturbance was detected, but SVI values do not increase post-disturbance, indicating no regeneration is occurring

4.3. Post-Processing

Harvest area polygons wherein > 50% of the pixels intersecting that polygon are flagged and removed, or where fewer than 9 pixels in total remain for metric calculations, are removed from the dataset. These are judged to offer insufficiently reliable representations of spectral regeneration within the harvested area. The threshold of 9 pixels was used as it represents, under ideal conditions, a situation in which a block of pixels wherein the centre pixel is surrounded by other pixels representing the same spectral signatures. This will in theory help further minimize any remaining edge effects from areas adjacent to the harvest area polygon.

Those harvest areas overlapping other HFI human footprint features (e.g., mines, wellsites, cultivation), wherein this overlap constitutes more than 20% of their area, were also removed from the dataset so as to minimize the risk that spectral signals have been affected by other anthropogenic activities post-harvest. Visual inspection showed those harvest areas overlapped by other HFI features by less than 20%, were often overlapped by roads or wellsites – features we assume are not captured in our metric calculations due to the use of the previously-discussed flagging system.

The effects of wildfire on post-harvest spectral regeneration metrics were also minimized in post-processing. We removed harvest areas that were overlapped by wildfires in the Government of Alberta's most recent Wildfire Perimeter database (available at: https://wildfire.alberta.ca/resources/historical-data/spatial-wildfire-data.aspx), which had occurred within the 20 years prior to the detected harvest date or any time after the harvest date, and which occupied more than 10% of the harvest area feature's area. The 20-year threshold was chosen because in the majority of cases we observed spectral signals to have returned completely to pre-disturbance levels by this time after a single disturbance event (i.e., the spectral signal has generally saturated after 20 years).

Confidence scores designed to reflect various characteristics of per-harvest area polygon calculations were calculated and used to identify and either evaluate or further remove remaining polygon data that is judged to be of low confidence. Table 3 describes the set of confidence scores calculated for each harvest area polygon.

Table 3. Descriptions and thresholds used for confidence scores calculated for each harvest area polygon for which metrics were generated.

Confidence Factor	Description	Score	Confidence Level
Total pixel count	<1 pixels	0	Very Low
	>=1 & <11 pixels	1	Low
	>=11 & <20 pixels	2	Medium-Low
	>=20 & <30 pixels	3	Medium
	>=30 < 100 pixels	4	Medium-High
	>=100 & <200 pixels	5	High
	>=200 pixels	6	Very High
Percent of pixels available for use in calculations	<50% available	0	Very Low
	>=50% & <60% available	1	Low
	>=60% & <70% available	2	Medium-Low
	>=70% & <80% available	3	Medium
	>=80% & <90% available	4	Medium-High
	>=90% & <100% available	5	High
	100% available	6	Very High
Number of contiguous (i.e., adjacent) pixels available for use in calculations	= 0 contiguous pixels	0	Very Low
	> 0 & <= 2 contiguous pixels	1	Low
	>2 & <=4 contiguous pixels	2	Medium-Low
	>4 & <=6 contiguous pixels	3	Medium
	>6 & <=8 contiguous pixels	4	Medium-High
	>8 & <=10 contiguous pixels	5	High
	>= 11 contiguous pixels	6	Very High
Within-polygon variability* in detected year of harvest	>=3 standard deviation (sd) of within-polygon year of detected harvest (YOH)	0	Very Low
	>=2.5 & <3 YOH sd	1	Low
	>=2 & <2.5 YOH sd	2	Medium-Low
	>=1.5 & <2 YOH sd	3	Medium
	>=1 & <1.5 YOH sd	4	Medium-High
	>=0.5 & <1 YOH sd	5	High
	<0.5 YOH sd	6	Very High
Within-polygon variability in length of time (years) between initial detected harvest and detected beginning of regeneration	>=3 standard deviation (sd) of within-polygon length of disturbance period	0	Very Low
	>= 2 & <3 disturbance length sd	1	Low
	>=1.5 & <2 disturbance length sd	2	Medium-Low
	>=1 & <1.5 disturbance length sd	3	Medium

Confidence Factor	Description	Score	Confidence Level
	>=0.75 & <1 disturbance length sd	4	Medium-High
	>=0.25 & <0.75 disturbance length sd	5	High
	<0.25 disturbance length sd	6	Very High
Within-polygon variability in total SVI spectral disturbance detected	>=200 standard deviation (sd) of total spectral	0	Very Low
	>=150 & <200 total disturbance sd	1	Low
	>=125 & <150 total disturbance sd	2	Medium-Low
	>=115 & <125 total disturbance sd	3	Medium
	>=100 & <115 total disturbance sd	4	Medium-High
	>=75 & <100 total disturbance sd	5	High
	<75 total disturbance sd	6	Very High
Within-polygon variability in current levels of spectral regeneration	>= 30 standard deviation (sd) current spectral regeneration	0	Very Low
	>=25 & <30 current regeneration sd	1	Low
	>=20 & <25 current regeneration sd	2	Medium-Low
	>=15 & <20 current regeneration sd	3	Medium
	>=10 & <14 current regeneration sd	4	Medium-High
	>=6 & <10 current regeneration sd	5	High
	<6 TSR current regeneration sd	6	Very High
Within-polygon variability in years required to reach 80% spectral regeneration	>=3.5 standard deviation (sd) of years required to reach 80% spectral regeneration	0	Very Low
	>=3 & < 3.5 sd years to 80% regeneration	1	Low
	>=2.5 & < 3 sd years to 80% regeneration	2	Medium-Low
	>=2 & < 2.5 sd years to 80% regeneration	3	Medium
	>=1.5 & < 2 sd years to 80% regeneration	4	Medium-High
	>=0.5 & < 1.5 sd years to 80% regeneration	5	High
	< 0.5 sd years to 80% regeneration	6	Very High
Within-polygon variability in percent spectral regeneration at 5 years post-harvest	>= 30 standard deviation (sd) of percent spectral regeneration at 5 years	0	Very Low
	>=25 & < 30 sd 5-year regeneration	1	Low
	>=20 & < 25 sd 5-year regeneration	2	Medium-Low
	>=15 & < 20 sd 5-year regeneration	3	Medium
	>=10 & < 15 sd 5-year regeneration	4	Medium-High
	>=5 & < 10 sd 5-year regeneration	5	High

Confidence Factor	Description	Score	Confidence Level
	< 5 sd 5-year regeneration	6	Very High

*Variability is evaluated using the within-polygon standard deviation of the metric in question

The confidence scores described in Table 3 were summed together into an overall confidence score for each harvest area polygon (up to a maximum score of 54). The total confidence score mean and standard deviation for the full, post-processed 2019 harvest area spectral regeneration dataset were calculated, and those polygons with a total confidence score three or more standard deviations below the mean were removed from the dataset. Those polygons with a harvest event year confidence score below 4 were also removed, as this suggests the pixels representing this polygon do not reflect a single, unified harvest event.

4.4. A Note Regarding the 2018 vs. 2019 Datasets

As described in section 3.5 (Lineage) above, this dataset replaces a 2018 version. It is important to note that while the methods used to generate the current 2019 Harvest Area Spectral Regeneration dataset are the same as those used to generate the previous 2018 version, there are harvest areas where spectral regeneration metrics are available for a particular polygon in one of these versions but not the other. This is largely the result of fluctuations found toward the end (most recent years) of the temporally segmented Landsat NBR time series, which can reflect remaining atmospheric effects (e.g., particularly cloudy seasons) or an actual change in land surface conditions (e.g., further disturbance). For instance, a sudden drop in spectral signals in 2019 due to wildfire would be flagged as a second disturbance for an area where only one disturbance is detected in the 2018 dataset, which would lead to its removal from further analyses in the more recent version of the dataset despite showing spectral regeneration metrics in the earlier version. Conversely, a harvest area where the detected harvest event occurred in 2014 would have been too recent for metrics to be captured in the 2018 dataset (i.e., 5 years have not elapsed in order to capture spectral regeneration), but can be captured in the current 2019 dataset.

A comparison of the 2018 and 2019 Harvest Area Spectral Regeneration datasets shows that approximately 13% of the harvest areas that are present in both datasets show this inconsistency in their metrics between the 2018 and 2019 versions of the dataset. Future improvements to the dataset will be aimed at addressing this inconsistency more rigorously.

5. References

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