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Coal Mine Reclamation Performance Assessment using Time-Series Landsat Data

Introduction

The Alberta Energy Regulator/Alberta Geological Survey is investigating the potential of Earth Observation (EO) data to enhance the auditing process by identifying sites-at-risk for ground assessment and tracking reclamation progression over time. The criteria for evaluating site-at-risk include vegetation type and vegetation health considering the surrounding land cover type as well as the undisturbed land condition prior to coal mining. Vegetation health is considered as a key site-at-risk indicator as it reflects if the soil is capable of sustaining life. Landsat time-series datasets were tested to assess the coal mine reclamation with the extraction of progression of coal mine disturbances and vegetation recovery from 1972 to 2016. The study area includes Gregg River, Luscar, and Cheviot coal mines located south of Hinton, Alberta (Figure 1).

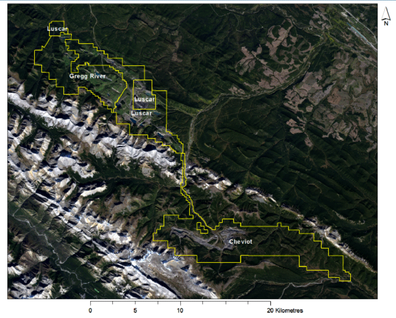

Figure 1. Study area with coal mines shown on Sept 15, 2016 Landsat-8 scene.

Method

Chronology of coal mining disturbances and vegetation recoveries were extracted based on multi-temporal changes in the Normalized Difference Vegetation Index (NDVI) using Landsat data from1972 to 2016 collected in summer (Figure 2). A land use/land cover classification was produced using 2016 Landsat-8 data with Maximum Likelihoodclassifier, where training datasets were selected from the unchanged areas of 2000's Alberta Ground Cover Classification (AGCC) data. Types of vegetation recovery and coal mining related land disturbances at current state and pre-disturbance state were addressed based on the classification maps. Accuracy assessment of change detection results were conducted using land change data from the Natural Resources Canada/Pacific Forestry Centre (PFC). In addition, AGCC data was used for accuracy assessment of classification results.

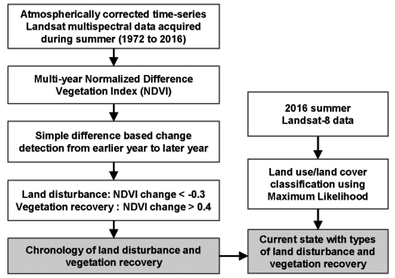

Figure 2. Processing steps for extracting land disturbance and vegetation recovery.

Results

Vegetation recovery was observed on 59 %, 27 %, and 8 % areas of the Gregg River, Luscar, and Cheviot coal mines, respectively (Figures 3-5). For the Gregg River coal mine, the highest disturbance occurred in1995 - 2000 (37 %) and the highest recovery occurred in 2000 - 2005 (43 %). For the Luscar coal mine, the highest disturbance occurred in 1995 - 2000 (26 %) and the highest recovery occurred in 1985 - 1990 (23 %). For the Cheviot coal mine, the highest disturbance occurred in 2010 - 2015 (34 %) and the highest recovery occurred in 2010 - 2015 (78 %). For all three coal mines, 90 % vegetation recovery includes grass/shrub/short vegetation and the remaining includes trees/coniferous forest. Coal mine disturbance prior to 1972 was visually assessed using an aerial photo from 1950 (Figures 4 a, 5 c, f, and i). An average accuracy of 84 % was observed for land change detection and land use/land cover classification results (Tables 1 and 2).

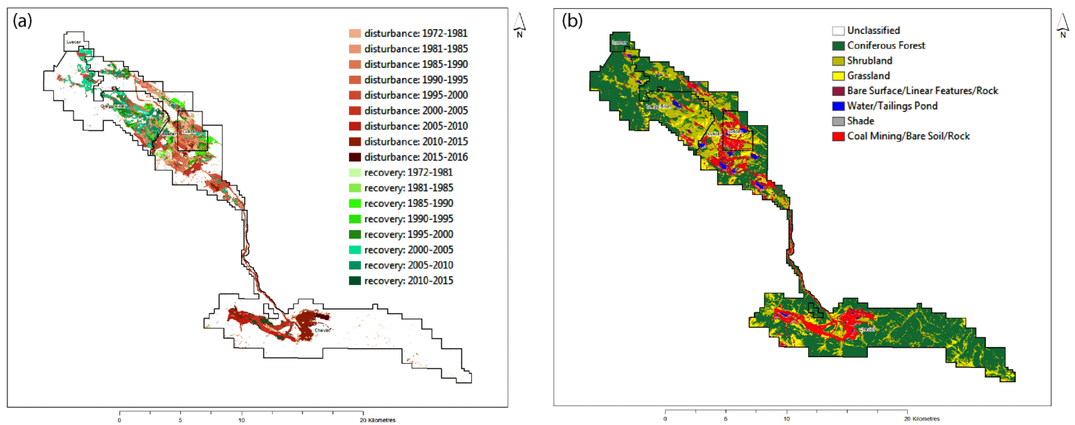

Figure 3. (a) Traces of historical land changes in 2016 with (b) 2016 land use/land cover types extracted from Landsat data.

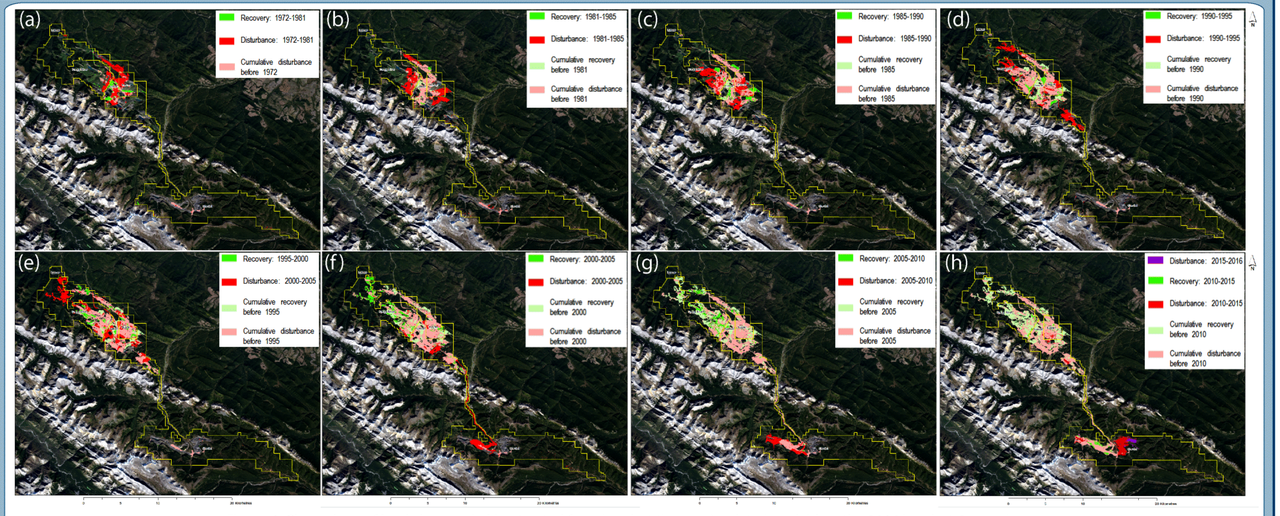

Figure 4. Chronology of land changes (a-h) extracted from Landsat time-series data (overlaid on the 2016 Landsat-8 scene).

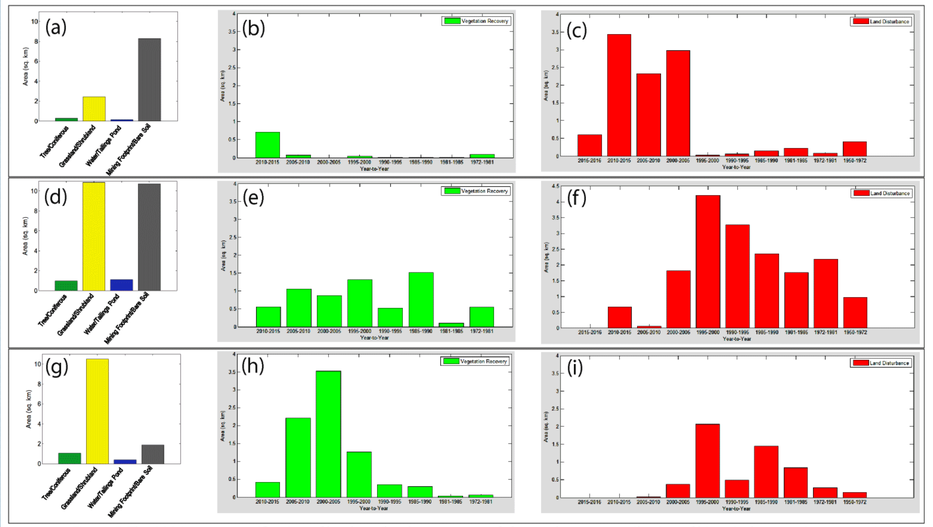

Figure 5. The 2016 state quantification of land use/land cover types of changed areas, contribution of historical vegetation recoveries and land disturbances of Cheviot (a-c), Luscar (d-f), and Gregg River (g-i) coal mines.

Table 1. Accuracy assessment of classification results using AGCC ground-reference data.

Overall Accuracy = 85.29 % Kappa Coefficient = 0.67				
Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Coniferous forest	93.20	87.55	377927 /405494	377927 /431679
Grassland/ shrubland	59.54	79.71	87168 /146395	87168 /109353
Coal mining footprints	100.00	77.86	38178 /38180	38178 /49037

Table 2. Accuracy assessment of change detection results using PFC ground-reference data.

Overall Accuracy = 83.07 % Kappa Coefficient = 0.78				
Changes	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
1985 - 1990	82.96	87.28	5502/6632	5502/6304
1990 - 1995	78.50	82.81	5681/7237	5681/6860
1995 - 2000	89.42	81.32	7525/8415	7525/9254
2000 - 2005	80.08	79.77	4490/5607	4490/5629
2005 - 2010	82.10	86.49	2528/3079	2528/2923

Conclusions

This study demonstrates an application of historical Landsat data for coal mine reclamation assessment to quantify the chronological sequence of disturbance and recovery with current state assessment of land use and land cover. This helps improving the auditing process for numerous industry submissions in-cluding validation of industry submitted information to obtain the reclamation certificate as well as to implement an efficient and transparent land-use plan to support sustainable development.

Reference

Subir Chowdhury, Dennis K. Chao, Todd C. Shipman & Michael A. Wulder (2017): Utilization of Landsat data to quantify land-use and land-cover changes related to oil and gas activities in West-Central Alberta from 2005 to 2013, GIScience & Remote Sensing, DOI: 10.1080/15481603.2017.1317453

Acknowledgments

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