**METADATA & BACKGROUND INFORMATION**

**Name:** Arrested succession? Assessing plant community recovery on reclaimed oil and natural gas well pads in Alberta's boreal forests.

**Source of data:** Lupardus R, McIntosh ACS, Janz A, Farr D. 2019. Succession after reclamation: Identifying and assessing ecological indicators of forest recovery on reclaimed oil and natural gas well pads. Ecological Indicators. 106, 105515.

**Type of community studied**: Plant community

**Type of habitat studied:** Boreal Forest and Reclaimed Well pads within the Boreal Forest

**Beginning year of study:** 2014

**End year of study:** 2014

**Methods**

**Study Area:**

The study area was located in both the Central Mixedwood (conifer & deciduous; n=15) Natural Subregion within the Boreal Natural Region and Lower Foothills (n=15) Natural Subregion within the Foothills Natural Region (The Natural Regions Committee, 2006). The area is characterized by deciduous, coniferous and mixedwood forested landscapes, with varying topographical, hydrological and ecological regimes.

**Study Design (Experimental or Observational – if experimental – randomized? Blocked, etc.? (hint: is there a blocking variable in the second matrix)**

We stratified sampling to select a subregion within each of Alberta’s two Natural Regions that are dominated by forest. This is an observational study.

**Description of Groups (observational)/Treatments (experimental)**

Groups include reference and wellsite locations. The system that we have adopted sampled two paired sites within a single study unit: the ~ 100 x 100 m (1 ha) reclaimed wellsite, and a 1 ha adjacent reference site that did not have a footprint of human disturbance.

**Data Collection**

Detailed field sampling methods can be found in McIntosh et al. (2019). Here we briefly summarize the data collection and processing:

When the field crew arrives onsite, the first step is to identify the wellsite centre, which will be the centre point for the reclamation wellsite 1 ha plot too. This center is located as precisely as possible using a hand-held GPS with an accuracy of < 7 m (GPS coordinates were identified from the maps and GIS investigation prior to the site visit). A permanent metal marker (or metal magnet) was inserted in the sample hole at wellsite centre after soil sampling is completed so that the location can be readily identified with a metal detector during future visits to the site. If the site is on private land, approval for the insertion of these permanent markers was obtained. Four sub-ordinal transects were then laid out which were oriented to the four corners of the wellsite (e.g., if the wellsite is square in cardinal directions, then the bearings of the 4 transects would be northeast 45°, southeast 135°, southwest 225°, northwest 315° – if not cardinal then it is adapted to the directions of the four transects to angles so they intersect the four corners of the wellsite). Each quadrant was then assigned a letter code (wellsite = B, C, D, E; reference = F, G, H, I). The bearings for the wellsite corners and GPS coordinates for the center of each 10 x 10 m plot was also recorded. Transects were then established, by using a 100-m tape attached to the wellsite centre pigtail and laying it out along the bearing of the sub-ordinal transect.

**Vegetation sampling**

We systematically selected sampling points both on the wellsite and in the adjacent reference. We purposely relocated sampled reference sites to avoid areas impacted by old roads, harvest areas, residential areas, canals, railways, reservoirs, transmission lines, cultivation, insect kill, seismic lines, pipelines, and other disturbances. A series of eight 5-m x 5-m vegetation plots were laid out at each well site – four of which were systematically placed on the wellpad itself (i.e., the area cleared for well construction), and four of which were distributed within the nearby, undisturbed (i.e., natural) forested landscape so as to capture the local, natural vegetative state to which the reclaimed, disturbed area would ideally return. This is referred to as the *reference condition*. It should be noted that the four undisturbed vegetation plots were repositioned in the field if their intended location coincided with or were close to any anthropogenic disturbances such as a road.

Firstly, two-dimensional herb/forb and shrub vegetation cover was estimated at three separate height strata for each 5-m x 5-m plot: (i) < 0.5 m, (ii) 0.5 m to 2 m, and (iii) 2 m to 5 m. Herbs and forbs were identified as non-woody vascular plants, whereas shrubs were defined as non-tree, vascular plants with woody stems. Small trees < 1.3 m in height were included in estimates of shrub cover. When trees were present at a 5-m x 5-m plot, both top height (m) and diameter at breast height (DBH: 1.3 m above ground; measured in cm) were measured for each individual tree. All live trees ≥ 1.3 m in height, as well as dead trees ≥ 1.3 m in height, and not leaning > 45° from vertical were measured, with the exception of *Alnus* (alder) or *Salix* (willow) species. Height was measured using a vertex hypsometer, and DBH was measured using DBH tape. Given that shrub and herb/forb cover were estimated at the 5-m x 5-m plot level, and individual tree locations were not recorded in the field, we used the plot as the unit of analysis (i.e., our sample unit) in order to maintain consistency in our investigation. Therefore, tree heights and DBH measurements were summarized for each 5-m x 5-m plot using basic descriptive statistics (mean, standard deviation, minimum, maximum, and range) before being included in our statistical analysis (Hird et al. 2017)

**Soil sampling**

One composite sample per depth made up of 5 cores from each of the 10 x 10 m plots.

For soil bulk density measurements of 5 core samples were collected at the depth 0 to 15 cm. For pH, total organic carbon, and total nitrogen 5 core samples were collected at the depth 15 to 30 cm. All these measurements were determined using the core method (when coarse fragments occupy less than 25% by volume (Maynard and Curran 2006)). In the field, a double-cylinder, drop-hammer sampler with a liner core was used to collect an undisturbed soil sample. The samples were then stored in a polyethylene bag in a cooler for transport to the laboratory.

Organic matter is defined as the LFH layer of the soil horizon. LFH horizon depth was measured, and was determined by the typically dark colour, and coarse and fibrous (containing rooting systems) characteristics. LFH does not include live vegetation on the surface. The thickness of the organic layer was measured at each of the five sampling points within each 10 x10 m square plot where the soil core is collected from.

**Data Processing**

To determine bulk density, the weight of the sampled soil core was determined after drying the sample in an oven at 105°C for 24 hours. For chemistry measurements, the soils were removed from the polyethylene bags and air dried in line trays at 37.5 °C. The samples were then crushed and grinded through a 2 mm sieve and any rocks were screened out (that were >2mm in diameter). The 5 core samples were then thoroughly mixed and were subsampled for soil organic carbon (SOC), total nitrogen (TN) and pH analysis.

The data that were collected in this study have been separated into two separate .csv files. The first file – primarydataset.csv contains the percent cover data from the understory quadrats that were measured in each plot. The second .csv file is the seconddataset.csv file where all of the other attributes (e.g., soil properties, aggregate cover values) and categorical variables that are used to classify the data are recorded.

**PrimaryDataset.csv Entity-level Metadata**

Table 1. Primarydataset.csv Column Descriptors

|  |  |  |  |
| --- | --- | --- | --- |
| Column identifier | Type | Units | Description |
| ID | Primary Key | n/a | Unique identifier that indicates the sampling unit that was measured – it is a combination of the Site\_ID and the WellorRef fields so there is one row and one unique identifier for each of the 60 sampling units (30 sites \* 2 locations within each site – wellsite (well) or adjacent reference (ref) |
| ABIBAL – VIOREN: (Species codes) | Quantitative | percent | Each of these columns are the species codes for each of the 106 understory plant species that were sampled within the 0.25 m2 quadrats. The value reported here is the mean percent cover value for all of the quadrats that were sampled within a wellsite or reference within a given study unit that was sampled. The species codes and the species names that they refer to are highlighted in Table 2. |

Table 2. Species list scientific names and common names. Visit plants.usda.gov to get more information on individual plant species.

| Species Code | Genus | Species | Common |
| --- | --- | --- | --- |
| Abiebal | *Abies* | *balsamea* | Balsam Fir |
| Achimill | *Achillea* | *millefolium* | Common Yarrow |
| Agrosca | *Agropyron* | *scabra* | Tickle Grass |
| Agrotra | *Agropyron* | *trachycaulum* | Slender Wheatgrass |
| Alnucri | *Alnus* | *crispa* | Green Alder |
| Alnurug | *Alnus* | *rugosa* |  |
| Amelaln | *Amelanchier* | *alnifolia* | Saskatoon |
| Apocand | *Apocynum* | *androsaemifolium* | Spreading Dogbane |
| Aquican | *Aquilegia* | *canadensis* | Canada Columbine |
| Aralnud | *Aralia* | *nudicaulis* | Wild Sarsparilla |
| Arnicor | *Arnica* | *cordifolia* | Heart-Leafed Arnica |
| Astecil | *Aster* | *ciliolatus* | Lindley's Aster |
| Astecon | *Aster* | *conspicuus* | Showy Aster |
| Betupap | *Betula* | *papyrifera* | Paper Birch |
| Botrvir | *Botrychium* | *virginianum* | Virginia Grape Fern |
| Bracsal | *Brachythecium* | *salebrosum* | Golden Ragged Moss |
| Bromcil | *Bromus* | *ciliatus* | Fringed Brome |
| Bromine | *Bromus* | *inermis* | Smooth Brome |
| Brompum | *Bromus* | *pumpellianus* | Pumpelly brome |
| Calacan | *Calamagrostis* | *canadensis* | Bluejoint |
| Carespp | *Carex* | *Spp* | Upland Carex Spp |
| Castmin | *Castilleja* | *miniata* | Red Indian Paintbrush |
| Chamang | *Chamerion* | *angustifolium* | Fireweed |
| Circalp | *Circaea* | *alpina* | Small Enchanter's-Nightshade |
| Cirsarv | *Cirsium* | *arvense* | Canada Thistle |
| Cladspp | *Cladonia* | *spp* |  |
| Corncan | *Cornus* | *canadensis* | Bunchberry |
| Cornsto | *Cornus* | *stolonifera* | Dogwood |
| Desccae | *Deschampsia* | *caespitosa* | Tufted Hairgrass |
| Dicrsco | *Dicranum* | *scoparium* | Broom Moss |
| Dryoaus | *Dryopteris* | *austriaca* | Spinulose Shield Fern |
| Elymspp | *Elymus* |  |  |
| Equiarv | *Equisetum* | *arvense* | Common Horsetail |
| Equipra | *Equisetum* | *pratense* | Meadow Horsetail |
| Equisyl | *Equisetum* | *sylvaticum* | Woodland Horsetail |
| Eurhpul | *Eurhynchium* | *pulchellum* | Common Beaked Moss |
| Evermes | *Evernia* | *mesomorpha* | Spruce Moss |
| Fragves | *Fragaria* | *vesca* | Woodland Strawberry |
| Fragvir | *Fragaria* | *virginiana* | Wild Strawberry |
| Galetet | *Galeopsis* | *tetrahit* | Hemp-Nettle |
| Galibor | *Galium* | *boreale* | Northern Bedstraw |
| Galitri | *Galium* | *triflorum* | Sweet-scented Bedstraw |
| Geumale | *Geum* | *aleppicum* | Yellow Avens |
| Gymndry | *Gymnocarpium* | *dryopteris* | Common Oak Fern |
| Habehyp | *Habenaria* | *hyperborea* | Northern Green Orchid |
| Haledef | *Halenia* | *deflexa* | Spurred Gentian |
| Heralan | *Heracleum* | *lanatum* | Cow-Parsnip |
| Hierumb | *Hieracium* | *umbellatum* | Narrow-leaved Hawkweed |
| Hylospl | *Hylocomium* | *splendens* | Stairstep Moss |
| Impacap | *Impatiens* | *capensis* | Spotted Touch-Me-Not |
| Ledugro | *Ledum* | *groenlandicum* | Labrador Tea |
| Leyminn | *Leymus* | *innovatus* | Hairy Wild Rye Grass |
| Linnbor | *Linnaeus* | *borealis* | Twinflower |
| Loniinv | *Lonicera* | *involucrata* | Bracted Honeysuckle |
| Lycoann | *Lycopodium* | *annotinum* | Stiff Club-moss |
| Maiacan | *Maianthemum* | *canadense* | Wild Lily-of-the-valley |
| Melioff | *Melilotus* | *officinalis* | Yellow Sweet Clover |
| Mertpan | *Mertensia* | *paniculata* | Tall Lungwort |
| Mitenud | *Mitella* | *nuda* | Bishop's Cap |
| Orthsec | *Orthilia* | *secunda* | One-sided Wintergreen |
| Oryzasp | *Oryzopsis* | *asperifolia* | Rough-Leaved Ricegrass |
| Peltcan | *Peltigera* | *canina* | Dog Lichen |
| Petapal | *Petasites* | *palmatus* | Palmate-Leaved Coltsfoot |
| Petasag | *Petasites* | *sagitatus* | Arrow Leaved Coltsfoot |
| Phalaru | *Phalaris* | *arundinacea* | Reed Canary Grass |
| Phlepra | *Phleum* | *pratense* | Timothy |
| Picegla | *Picea* | *glauca* | White Spruce |
| Picemar | *Picea* | *mariana* | Black Spruce |
| Plagcus | *Plagiomnium* | *cuspidatum* | Woodsy Leafy Moss |
| Platyrep | *Platygyrium* | *repens* | common flat-brocade moss |
| Pleusch | *Pleurozium* | *schreberei* | Big Red Stem |
| Poapal | *Poa* | *palustris* | Fowl Bluegrass |
| Pohlnut | *Pohlia* | *nutans* | Copper Wire Moss |
| Polyjun | *Polytrichum* | *juniperinum* | Juniper Hair-Cap |
| Popubal | *Populus* | *balsamifera* | Balsam Poplar |
| Poputre | *Populus* | *tremuloides* | Trembling Aspen |
| Ptilcri | *Ptilium* | *crista-castrensis* | Knight's Plume |
| Pyroasa | *Pyrola* | *asarifolia* | Common Pink wintergreen |
| Rhinbor | *Rhinanthus* | *borealis* | Yellow Rattle |
| Ribelac | *Ribes* | *lacustre* | Black Gooseberry |
| Ribeoxy | *Ribes* | *oxycanthoides* | Canadian gooseberry |
| Ribetri | *Ribes* | *triste* | Wild Red Currant |
| Rosaaci | *Rosa* | *acicularis* | Prickly Rose |
| Rubucha | *Rubus* | *chamaemorus* | Cloudberry |
| Rubuida | *Rubus* | *idaeus* | Raspberry |
| Rubupub | *Rubus* | *pubescens* | Dewberry |
| salix | *Salix* | *Spp* |  |
| Scirmic | *Scirpus* | *microcarpus* | Small-Fruited Bulrush |
| Shepcan | *Shepherdia* | *canadensis* | Canada buffaloberry |
| Smileste | *Smilacina* | *stellata* | false Solomon's seal |
| Solican | *Solidago* | *canadensis* | Canada Goldenrod |
| Soncarv | *Sonchus* | *arvensis* | Perennial Sow-thistle |
| Soncasp | *Sonchus* | *asper* | Spiny Annual Sow-thistle |
| Stelspp | *Stellaria* | *Spp* | Chickweed Spp |
| Sympalb | *Symphoricarpos* | *albus* | Common Snowberry |
| Sympcil | *Symphyotrichum* | *ciliolatum* |  |
| Sympocc | *Symphoricarpos* | *occidentalis* | Buckbrush |
| Taraoff | *Taraxacum* | *officinale* | Common Dandelion |
| Thuiabi | *Thuidium* | *abietinum* | Wiry Fern Moss |
| Triebor | *Trientalis* | *borealis* | Northern Starflower |
| Trifhyb | *Trifolium* | *hybridum* | Alsike Clover |
| Trifpra | *Trifolium* | *pratense* | Red Clover |
| Urtidio | *Urtica* | *dioica* | Stinging Nettle |
| Vacccae | *Vaccinium* | *caespitosum* | Dwarf Bilberry |
| Vaccmyr | *Vaccinium* | *myrtilloides* | Common Blueberry |
| Vaccvit | *Vaccinium* | *vitis-idaea* | Lingonberry |
| Vibuedu | *Viburnum* | *edule* | Mooseberry |
| Viciame | *Vicia* | *americana* | American Vetch |
| Violcan | *Viola* | *canadensis* | Canadian white violet |
| Violren | *Viola* | *renifolia* | Kidneyleaf Violet |

**Second Dataset Entity-level Metadata**

Table 3. Seconddataset.csv Column Descriptors

|  |  |  |  |
| --- | --- | --- | --- |
| Column identifier | Type | Units | Description |
| ID | Primary Key | n/a | Unique identifier that indicates the sampling unit that was measured – it is a combination of the Site\_ID and the WellorRef fields so there is one row and one unique identifier for each of the 60 sampling units (30 sites \* 2 locations within each site) |
| Site\_ID | Categorical | n/a | Identification of wellsite (There are 30 total, with 15 in the Boreal Natural region (Bor1-15) and 15 in the Foothills Natural region (Foot1-15). |
| WellorRef | Categorical | n/a | Whether it is the wellsite (Well) or adjacent reference (Ref) site that was sampled in that row |
| Bor1Foot2 | Categorical | n/a | Natural subregion within the Boreal or Foothills Natural Regions: 1 = Central Mixedwood Boreal Natural Subregion; 2 = Lower Foothills Natural Subregion |
| Age\_postcert | Quantitative | yrs | The number of years that has passed between when the reclamation certificate was issued after the wellsite was decommissioned and when the wellsite was sampled. |
| LFHmean\_mm | Quantitative | mm | LFH soil horizon depth (organic layer) |
| BD\_0-15cmdepth\_cm | Quantitative | g/cm3 | Bulk density of the soil - 0-15 cm depth |
| pH\_0 | Quantitative | n/a | measured pH of the soil - 0-15 cm depth |
| TOC\_0 | Quantitative | % | Total organic carbon in the soil - 0-15 cm depth |
| TN\_0 | Quantitative | % | Total nitrogen in the soil - 0-15 cm depth |
| CNratio\_0 | Quantitative | n/a | Carbon to nitrogen ratio of the soil - 0-15 cm depth |
| tph\_total | Quantitative | #/ha | Number of live and dead trees/ha |
| LiveBA\_m2/ha | Quantitative | m2/ha | Live basal area (BA; m2/ha) for all trees combined. |
| DeadBA\_m2/ha | Quantitative | m2/ha | Dead basal area (BA; m2/ha) for all trees combined. |
| herb\_cover | Quantitative | % | Percent herb cover |
| shrub\_cover | Quantitative | % | Percent shrub cover |
| graminoid\_cover | Quantitative | % | Percent graminoid cover |
| lichen\_cover | Quantitative | % | Percent lichen cover |
| clubmoss\_cover | Quantitative | % | Percent clubmoss cover |
| fern\_cover | Quantitative | % | Percent fern cover |
| non\_native\_cover | Quantitative | % | Percent non-native vegetation cover |

**References**

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