Arrested succession? Quantifying ecological recovery on reclaimed well pads in Alberta's boreal forests

Anne CS McIntosh[1], Randi Lupardus[2][1][2], Janz A[2], Azeria ET[3], Santala K[4], Aubin I[4]. [1] Science Dept, Augustana Campus, University of Alberta, Camrose, Alberta, T4V 2R3, amcintos@ualberta.ca, [2] Alberta Environment and Parks, Environmental Monitoring & Science Division, Edmonton, AB T5J 5C6, Canada (Janz retired), [3]Alberta Biodiversity Monitoring Institute, University of Alberta, Edmonton, AB T6G 2E9, [4]Natural Resources Canada, Great Lakes Forestry Centre, Sault Ste. Marie, ON P6A 2E5

INTRODUCTION

- Site preparation for oil and gas extraction often requires the complete removal of vegetation and surface soil on the well pad.
- Although subsequent reclamation then attempts to restore vegetation and soil properties on the well pad, given the magnitude of the extraction disturbance, the potential to shift its future successional trajectory is high.
- Alberta's forested regions have over 240,000 drilled well pads, including ~25% that have received a reclamation certificate.
- There is a lack of understanding of long-term successional trajectories of reclaimed oil and natural gas well sites in forested lands – including both the plant communities on the well pads and their functional traits.

RESEARCH QUESTIONS

1) Are certified reclaimed wellsites on a positive/directional successional trajectory for recovery (explored for both plant community composition and plant functional traits)?
2) Which above- and below-ground properties are good ecological indicators for recovery of reclaimed well pads?
3) How different are plant traits in young and old reclaimed well pads compared to natural forests?

METHODS

- We sampled plant community composition (% cover by species) and soil attributes on 30 reclaimed well pads and adjacent reference sites in Alberta's boreal forest ranging from 7-48 years post-certification.
- Functional traits: calculated community-weighted trait means (CWM) for each site by weighting species traits by relative species abundance at each site. Traits included fast-resource acquisition traits typical of early successional species that colonize quickly (e.g., annuals, abundant seed production), and traits typical of late-successional species, which are linked to resource conservation (e.g., longevity, shade tolerant)

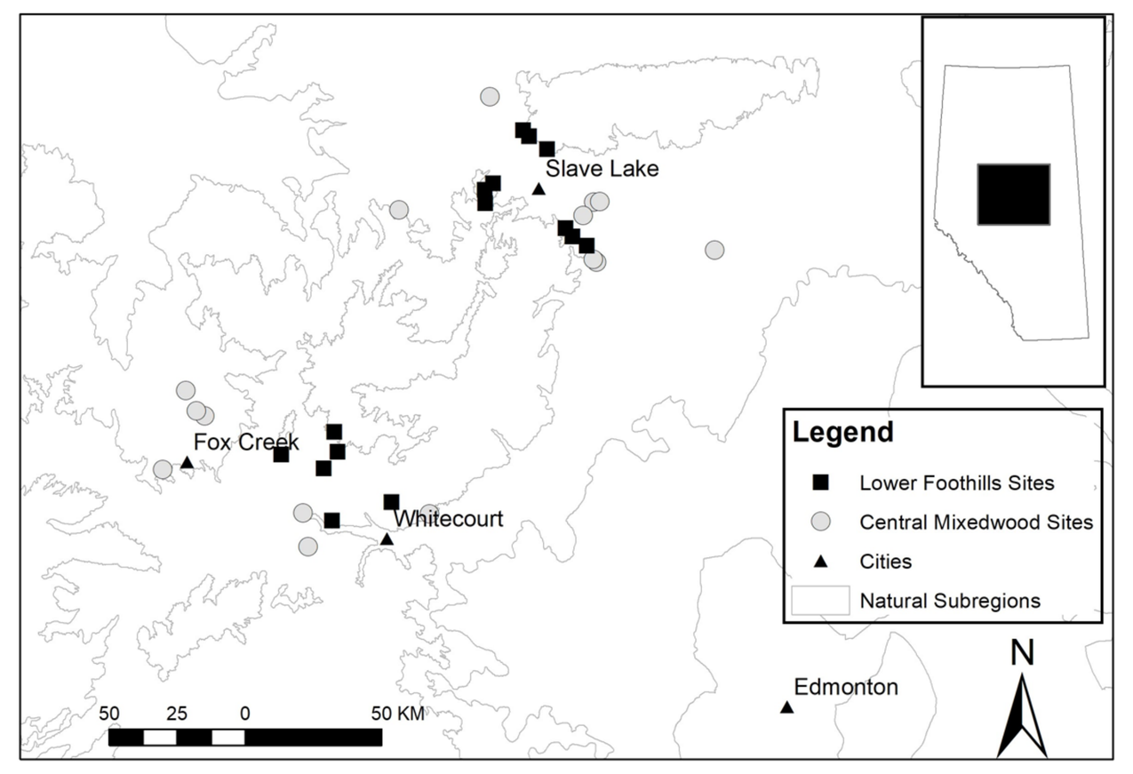


Fig. 1. Study locations units (N=30) in Alberta's Central Mixedwood and Lower Foothills Natural Subregions, with wellsites ranging from 7-48 years post-reclamation certification.

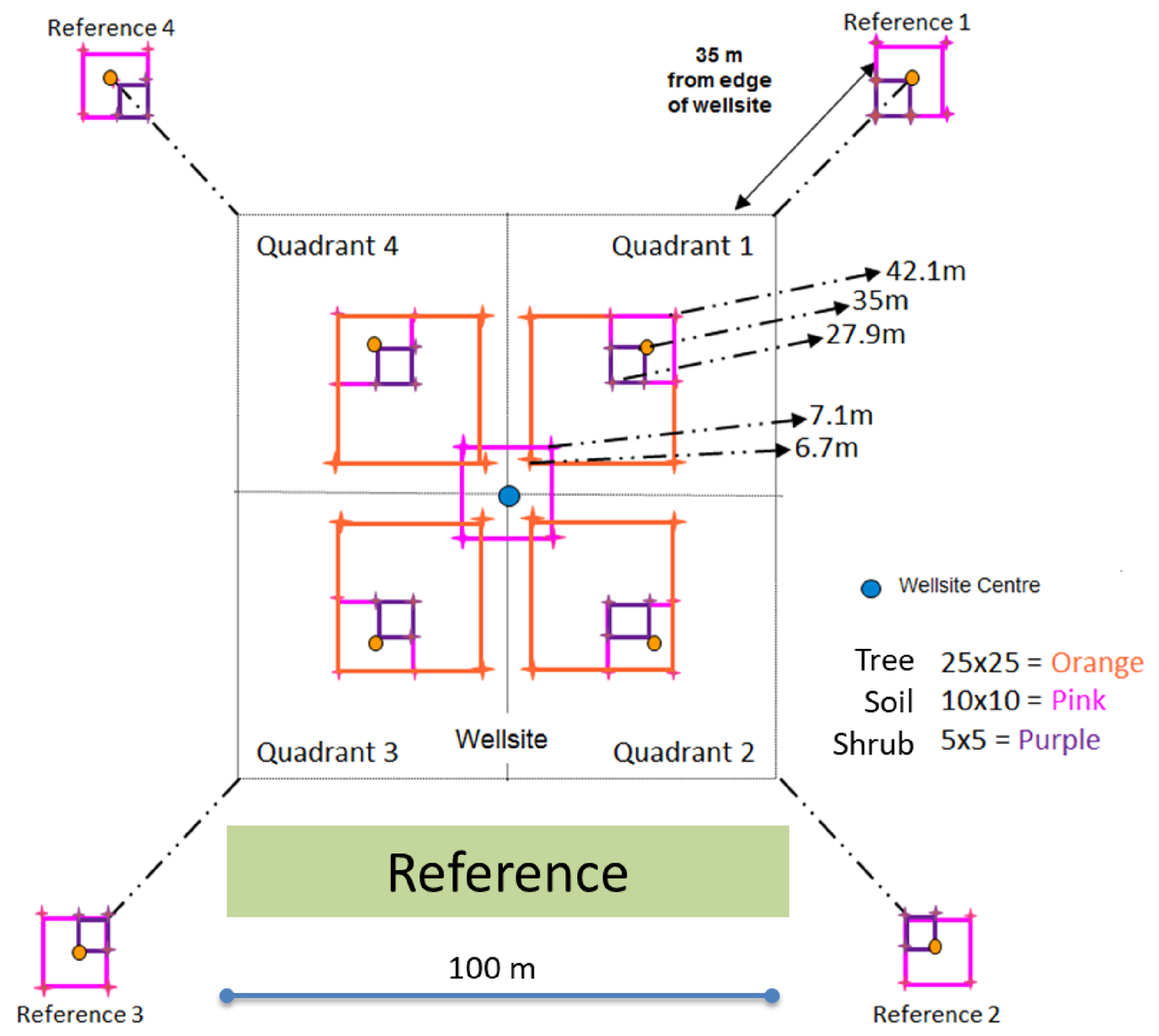
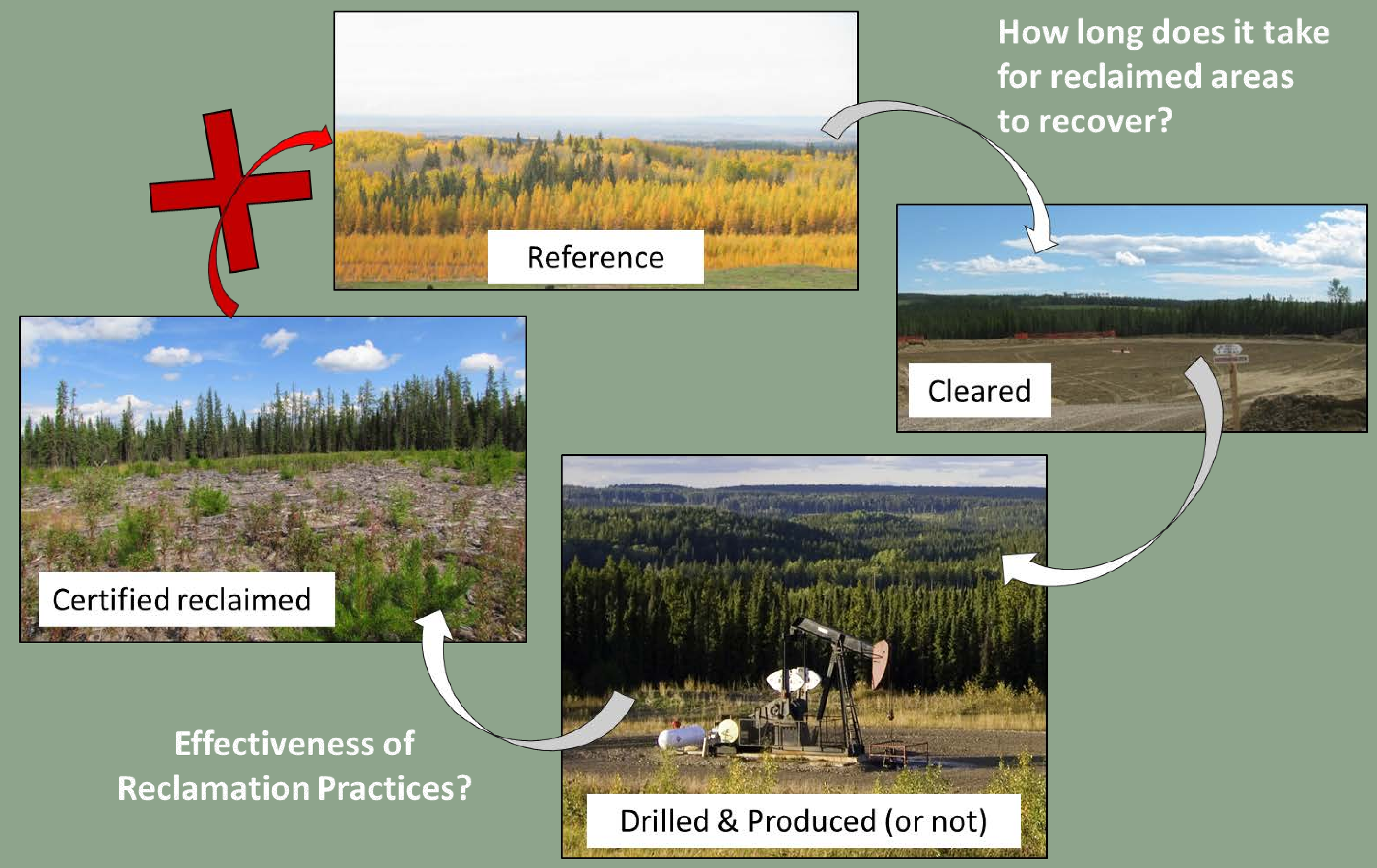


Fig. 2. Sampling design for collection of soil and vegetation properties on reclaimed and adjacent reference sites at each study unit. (McIntosh et al. 2019)

Variety of Multivariate Statistical Analyses Conducted (examples:)

- Non-metric Multidimensional Scaling (NMDS) Ordination
- Indicator Species Analysis
- Multivariate Joint Generalized Estimating Equation (JGEE; location unit was the cluster variable)
- Principal Component Analysis (PCA)
- Permutational multivariate analysis of variance (PERMANOVA)
- Community weighted mean redundancy analysis (CWM-RDA)

Disturbance legacy impacts of reclaimed well pads are long lasting (>40 yrs), potentially flat lining the recovery trajectories of their plant communities, but with slow directional recovery of plant functional traits.



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RESULTS (from Lupardus et al. 2019, Azeria et al. 2020)

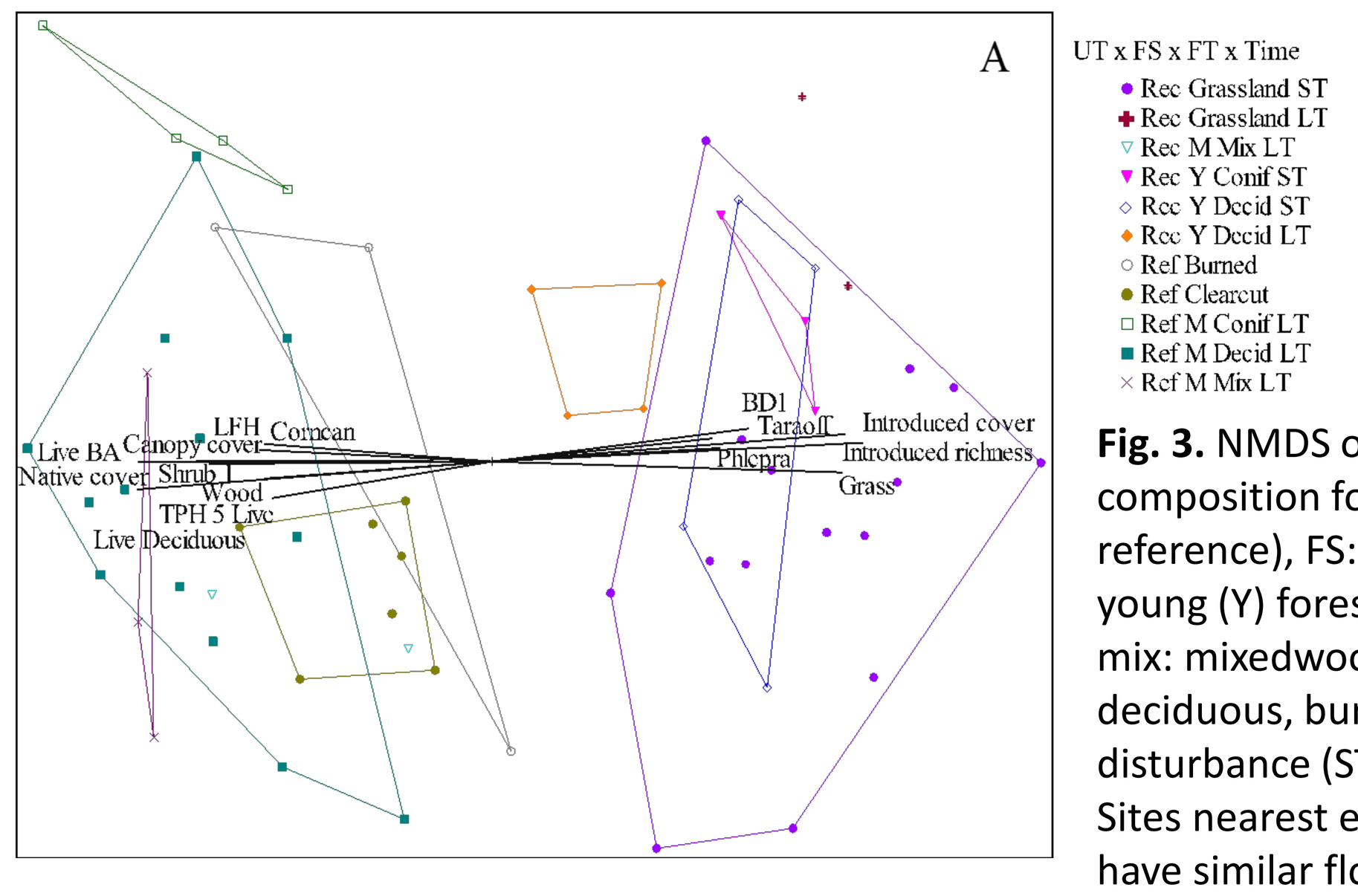

Fig. 3. NMDS of vegetation species composition for UT: unit type (reclaimed vs reference), FS: forest stage (mature (M) vs young (Y) forest), FT: forest type (grassland, mix: mixedwood, conif: coniferous, decid: deciduous, burned, clearcut), and time since disturbance (ST= 7-34 yrs, LT 35 to 48 yrs). Sites nearest each other in ordination space have similar floristic assemblages. A) vectors indicate environmental, vegetation, soil, and diversity variables which had an $R^2 \geq 0.4$. Vector direction and length reflect the strength of correlation with the first two axes.

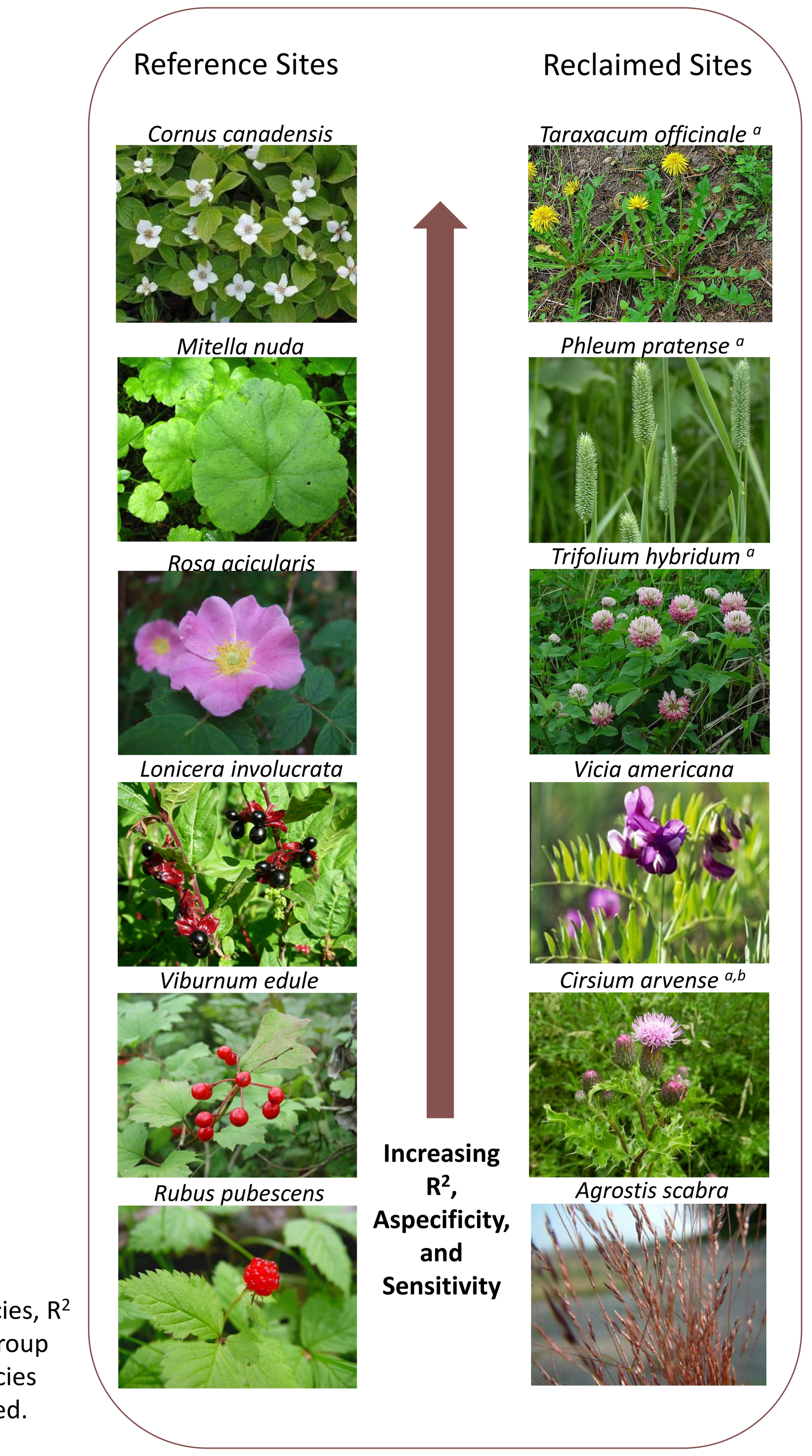

Fig. 4. Indicator Species Analysis. [a]Introduced species, [b]noxious species, R^2 = correlation between species & group (reclaimed or reference), only species with $R^2 \geq 0.7$ and $p \leq 0.001$ reported.

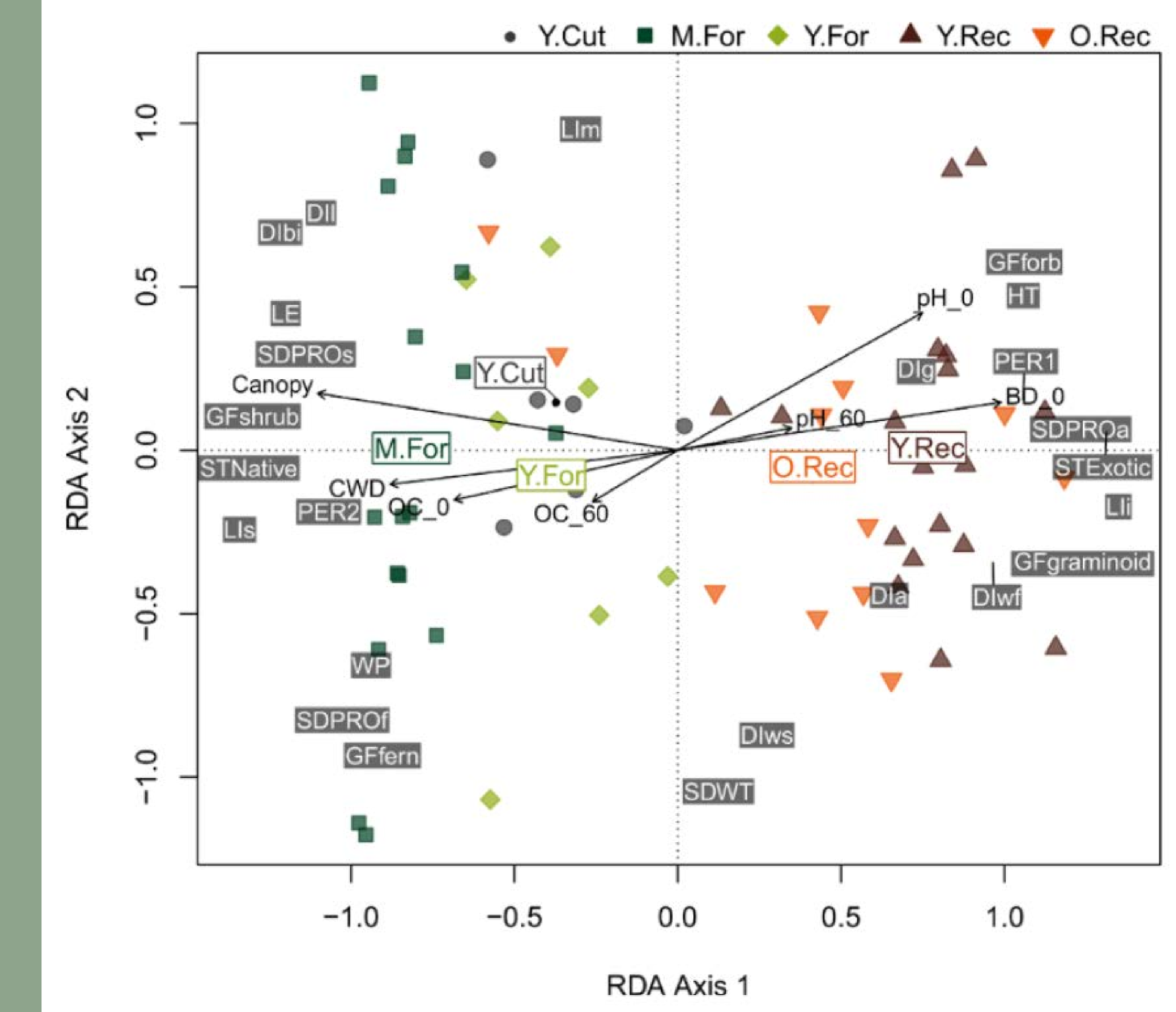

Fig. 5. Redundancy analysis model of trait community weighted mean (CWM). First two axes explained 62.3% of CWM trait variance. Points are study sites, and site type centroids are indicated in boxed labels. Environmental variables are indicated by red arrow, white text in grey boxes are short names for traits (see Table 1[4]). Environmental variables are surface bulk density (BD_0), surface and deep pH and organic carbon (pH_0, pH_60, OC_0, OC_60), canopy cover (canopy), coarse woody debris (CWD). Y.Cut=Young harvest; Y.For=Young forest; M.For=Mature forest ; Y.Rec=Young reclaimed; O.Rec = Old reclaimed

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