Multi-scale study on the effects of harvesting on understory functional diversity in coniferous and mixed wood forests in the Clay Belt region of Quebec and Ontario

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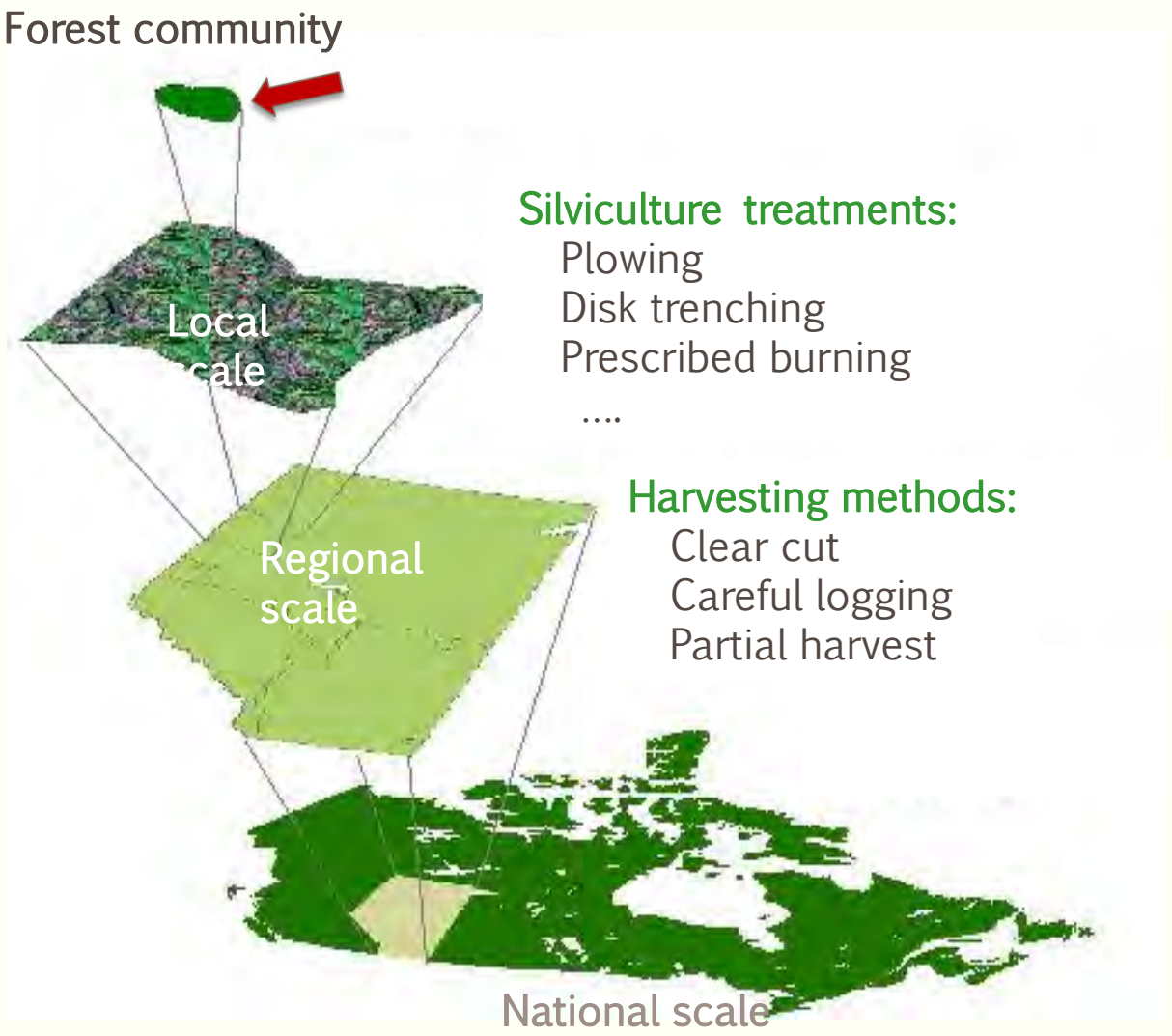
Multi-scale harvesting disturbance



Silviculture treatments:

- Plowing
- Disk trenching
- Prescribed burning
- ....

Harvesting methods:

- Clear cut
- Careful logging
- Partial harvest

Site Preparation

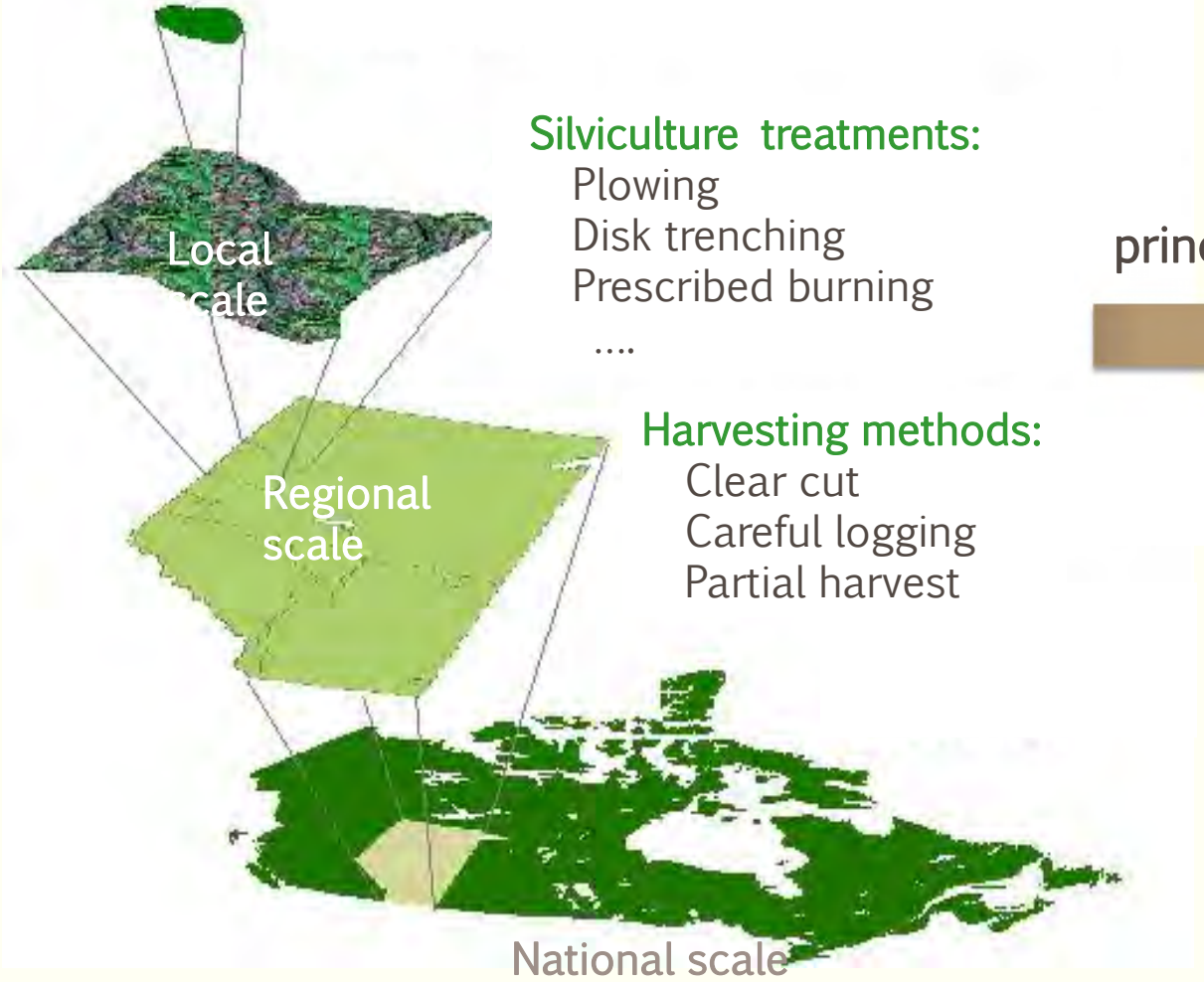
Modify micro-sites by changing:
- Micro-climate
- Plant competition
- Soil condition (temperature, moisture, nutrient)

Careful logging

Partial harvest VR

Multi-scale harvesting disturbance

Forest community



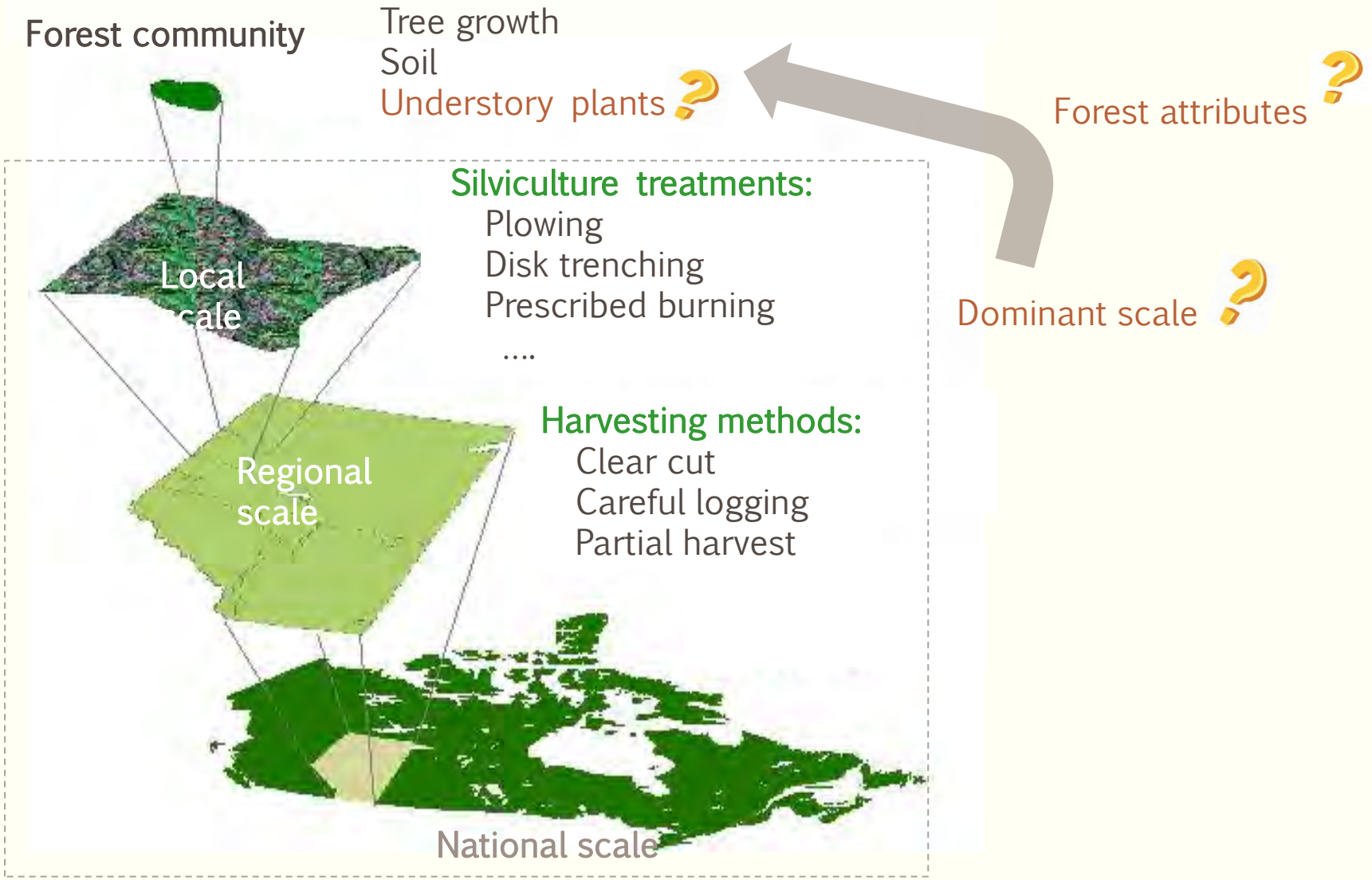
Silviculture treatments:
- Plowing
- Disk trenching
- Prescribed burning
- ....

Harvesting methods:
- Clear cut
- Careful logging
- Partial harvest

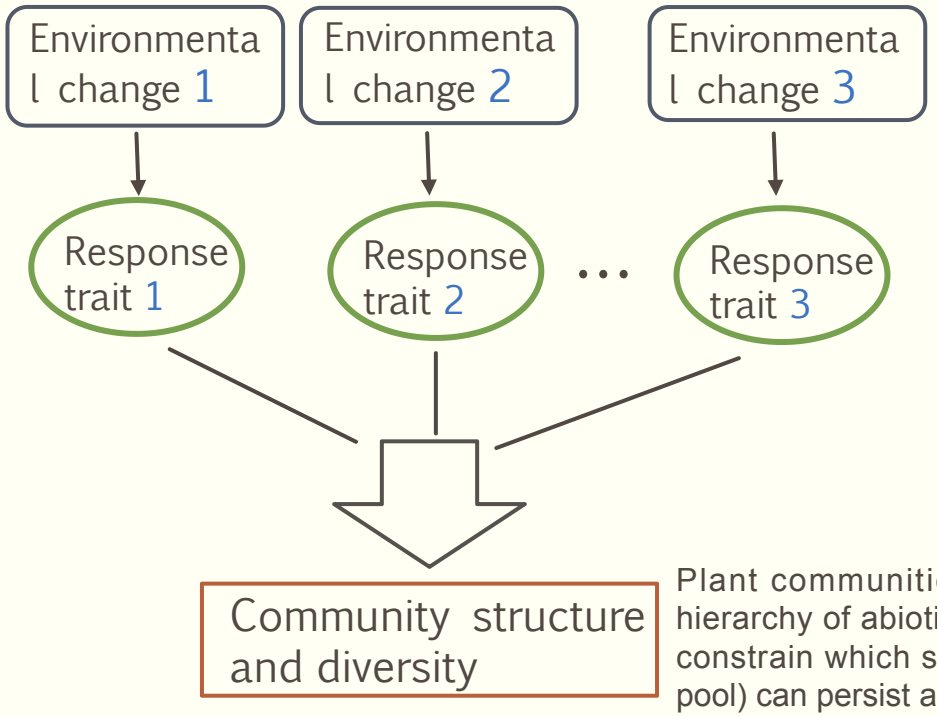
principal aim

Sustainable timber production

Multi-scale harvesting disturbance



Functional traits



Plant communities can be seen as the result of a hierarchy of abiotic and biotic filters that successively constrain which species and traits (from the regional pool) can persist at a site.

Lavorel and Garnier, 2002

Research questions

Harvesting disturbance

- Harvest scale
- Method scale
- Treatment scale

Understory functional trait

Q1: Best disturbance scale?

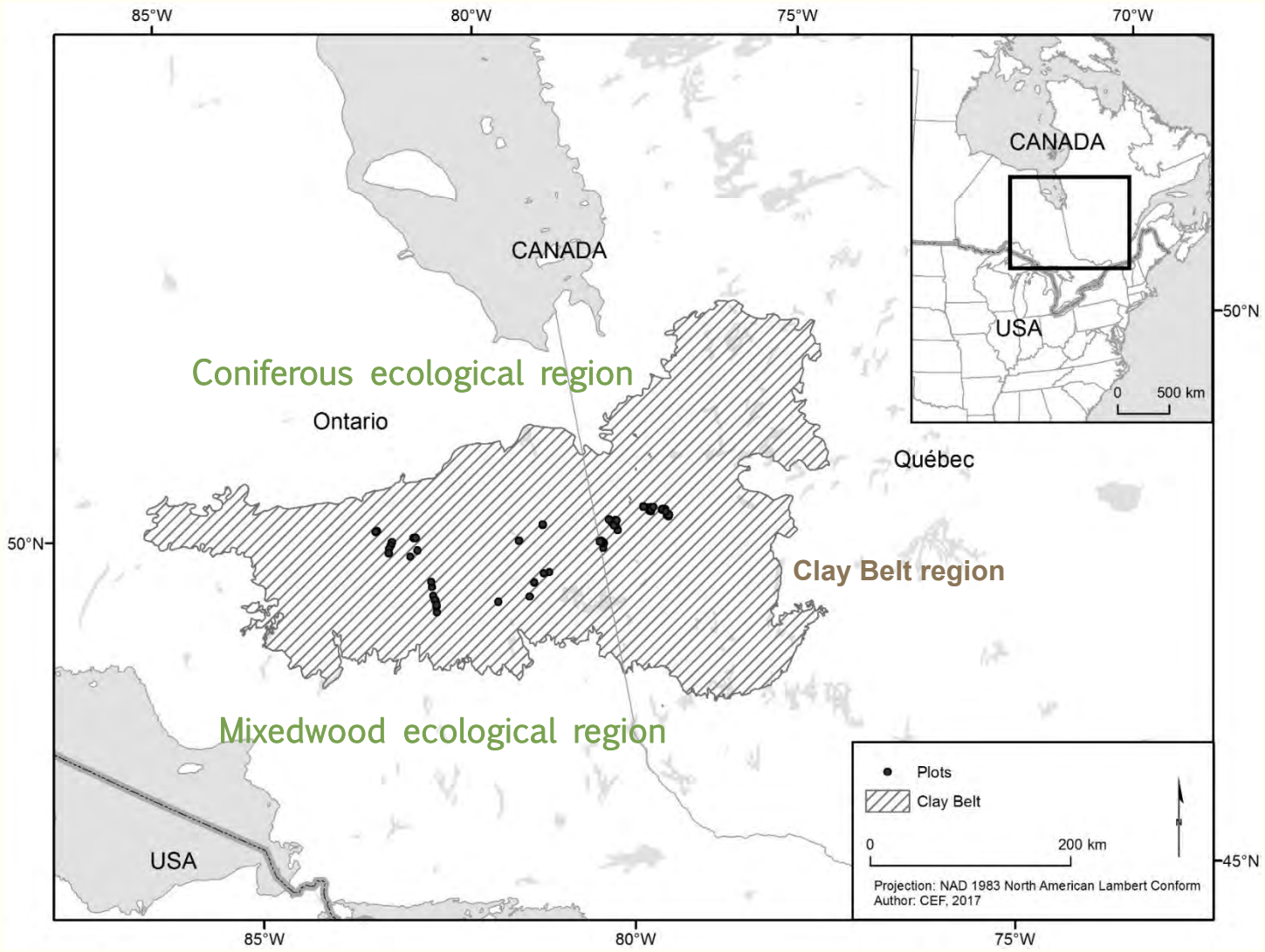
Q2: Relationship between disturbance and trait at the best scale?

Q3: the role of forest attributes in affecting trait-disturbance relationship?

Forest attributes:

- Forest type
- Time since last fire
- Time since disturbance

Study area



1) Data sets:

DeGrandpré et al, 1993
Bescond et al., 2011
Kpodo, 2014
Lafleur et al., 2010
Renard et al., 2016
Higelin, unpublished

2) Vegetation Sampling

105 sites
986 plots (400 m^2)
4 subplots (1m^2) per plot

The percent cover of all vascular plant species present (including woody and herbaceous species with height < 2 m)

Data base

Three disturbance scales:

Harvest scale : harvested vs unharvested
Method scale : careful logging, partial harvest and clear cut
Treatment scale : 10 silviculture treatments

Forest attributes:

Forest type
Time since last fire
Time since disturbance

15 traits represent:

Morphology
Regeneration strategy
Resource utilization

Ecological variables – effect variables

Harvesting disturbance

Variable	Levels	Description
Harvest	Unharv	Pre-harvested or un-harvested forests
	Harv	Harvested forests
Method	CPRS	Cut with protection of regeneration and soils
	PAR	Partial harvest
	CC	Clear cut
Treatment	CPRSol	CPRS without treatment
	CPRSpl	Plowing after CPRS
	CPRSdt	Disk trenching after CPRS
	CPRSsa	CPRS with small agglomerations of tree retention
	CL	Careful logging in Ontario
	$PAR_{33.66}$	33% to 66% forests harvested
	PARms	Partial cut with protection of small merchantable stems
	PARvr	Partial Cut with conservation of canopy cover (variable retention)
	CCol	Clear cut without treatment
	CCpb	Prescribed burning after clear cut

Forest attributes

Variable	Description	Levels
STP	Stand type	bS
		Mixed
TSF	Time since fire	≤100 yr
		>100 yr
TSD	Time since disturbance	≤15 yr
		>15 yr

Functional trait groups

Category	Trait	Trait group
Morphology	Raunkiaer life Form	**1) Rauk.cha 2) Rauk.geo 3) Rauk.hem 4) Rauk.mcpha 5) Rauk.mgpha**
	Lateral extension	**1) Clone.compact 2) Clone.phalanx 3) Clone.guerilla**
	Vegetative propagation	**1) Rhizome 2) Non-rhizome**
	Maximum height (cm)	
	Root depth (cm)	
	Stem specific density (mg/mm^3)	
	Specific leaf area (mm^2/mg)	
Regeneration and dispersion	Mode of reproduction	**1) Repro.veg 2) Repro.mse**
	Flowering phenology	**1) Flower.sp 2) Flower.Su**
	Seed dispersal vector	**1) Disper.ani 2) Disper.wow**
	Seed persistence	**1) Seed.short 2) Seed.semi-permanent 3) Seed.permanent**
	Seed weight (mg)	
Resource utilization	Humidity preference	**1) Humid 2) Xeric 3) Broad.humid**
	Light requirement	**1) Shad.int 2) Shad.mid 3) Shad.tol**
	Habitat	**1) MForest 2) PForest 3) NForest**

Data analysis

Community-level approach > A good overview of the community structure

- **Functional diversity indices**

  Functional Richness (FRic)
  Evenness (FEve)
  Divergence (FDiv)

- **Generalized linear mixed models (GLMMs, Quasi-Poisson "family")**

  Model selection based on QAICc

  Fric (FEve, FDiv) ~ Null model
  Harvest
  Method
  Treatment
  Forest type
  Time since fire
  Time since disturbance

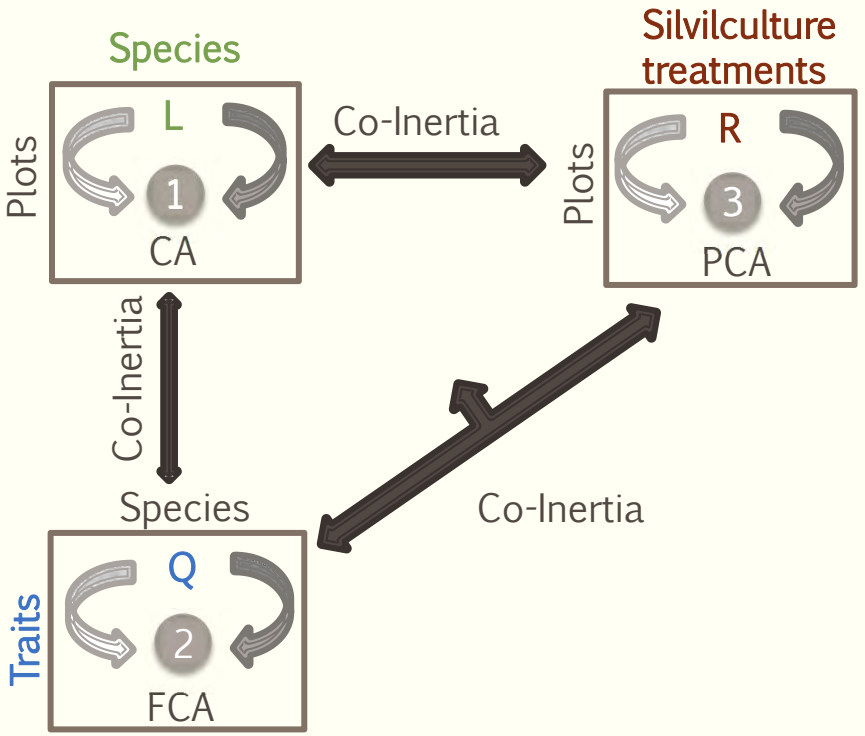
  Two random effects: "sites" and "plots"

Data analysis

Species-level approach

Which traits predict species response to harvesting disturbance

- Basic RLQ analysis



Hausner et al., 2003

- Partial RLQ analysis

To identify and remove the potentially confounding effects of stand attributes

RLQ_{covSTP}
RLQ_{covTSF}
RLQ_{covTSD}

Best disturbance scale

Differences in QAICc values between the different ecological models and the null model for functional diversity indices

		Functional diversity indices		
	Models	**FRic**	**FEve**	**FDiv**
Harvesting disturbance scales	Harvest	-171.72	-202.02	-17.03
	Method	-211.98	-214.10	-79.47
	Treatment	-484.69	-188.03	-183.43
Forest attributes	Forest type	-5.51	-2.87	-34.17
	Time since disturbance	-94.02	-55.33	-39.61
	Time since fire	-197.25	-12.99	-144.48

The smaller the QAICc, the better the model with respect to the others.

Effects of treatments on functional diversity

Disturbance directly on trees

Disturbance directly on trees and soil

Response variable	Explanatory variable	Estimate	SE	*P*	
FRic	Unharv (Intercept)	-1.26	0.04	< 2e-16	***
	CCol	0.18	0.10	0.08	
	CCpb	**0.45**	**0.18**	**0.01**	*
	CPRSag	**0.75**	**0.18**	**0.00**	***
	CPRSdt	**-0.65**	**0.22**	**0.00**	**
	CPRSol	0.11	0.07	0.13	
	CPRSpl	**-0.38**	**0.18**	**0.04**	*
	CPRSsa	0.16	0.26	0.54	
	PAR33.66	-0.22	0.23	0.34	
	PARms	**0.25**	**0.11**	**0.02**	*
	PARvr	**0.28**	**0.09**	**0.00**	**
FDiv	Unharv (Intercept)	-0.30	0.02	< 2e-16	***
	CCol	0.11	0.07	0.09	
	CCpb	0.05	0.14	0.73	
	CPRSag	0.12	0.15	0.45	
	CPRSdt	**-0.41**	**0.12**	**0.00**	***
	CPRSol	0.00	0.05	0.91	
	CPRSpl	**-0.21**	**0.11**	**0.04**	*
	CPRSsa	0.08	0.17	0.64	
	PAR33.66	-0.08	0.13	0.55	
	PARms	0.06	0.07	0.43	
	PARvr	0.05	0.06	0.39	

Eigenvalues, percentage and cumulative percentage of variance explained by the first two axes of the basic RLQ and the partial RLQ at the treatment and method scales

	Axis 1		Axis 2		
	Eigenvalues	%	Eigenvalues	%	Cum.%
a) Treatment					
Basic RLQ	0.37	61.19	0.12	19.62	80.81
RLQ_{covSTP}	0.14	50.35	0.05	18.20	68.55
RLQ_{covTSF}	0.39	64.03	0.12	19.93	83.96
RLQ_{covTSD}	0.09	43.60	0.05	24.14	67.74
b) Method					
Basic RLQ	0.64	91.50	0.05	7.66	99.16
RLQ_{covSTP}	0.06	67.25	0.03	27.60	94.85
RLQ_{covTSF}	0.68	92.06	0.05	7.33	99.36
RLQ_{covTSD}	0.19	90.12	0.01	8.73	98.85

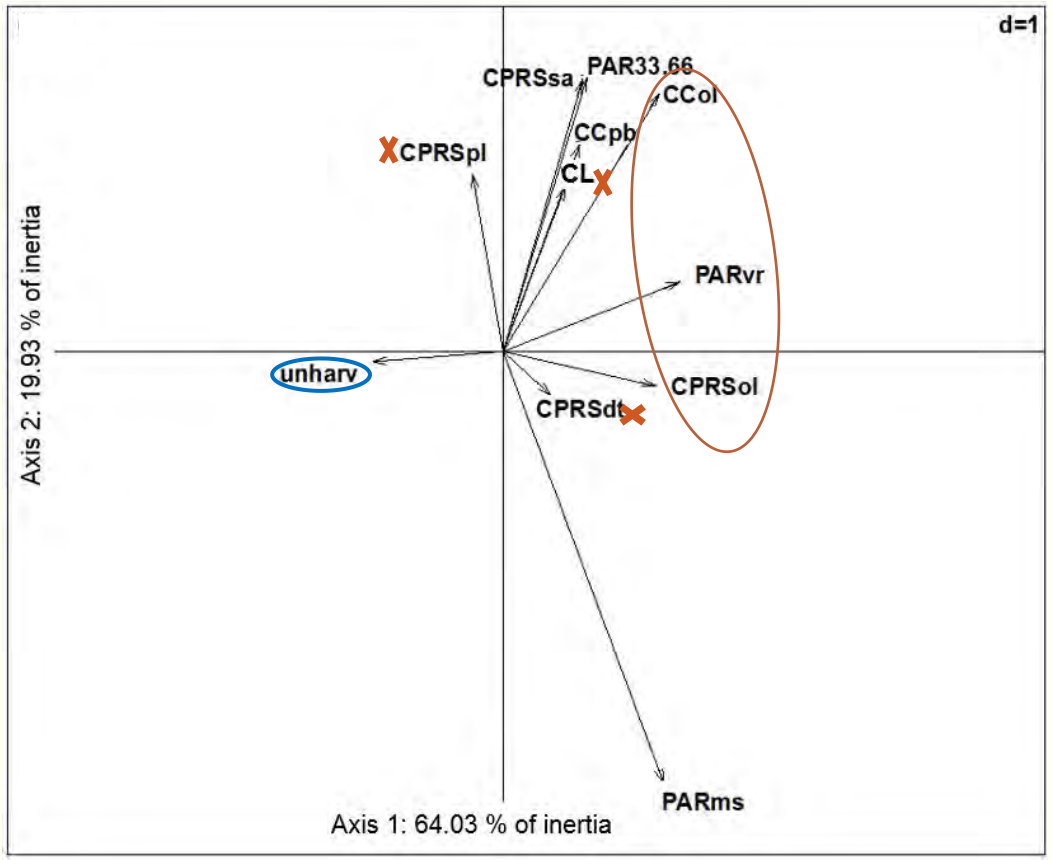
highest

highest

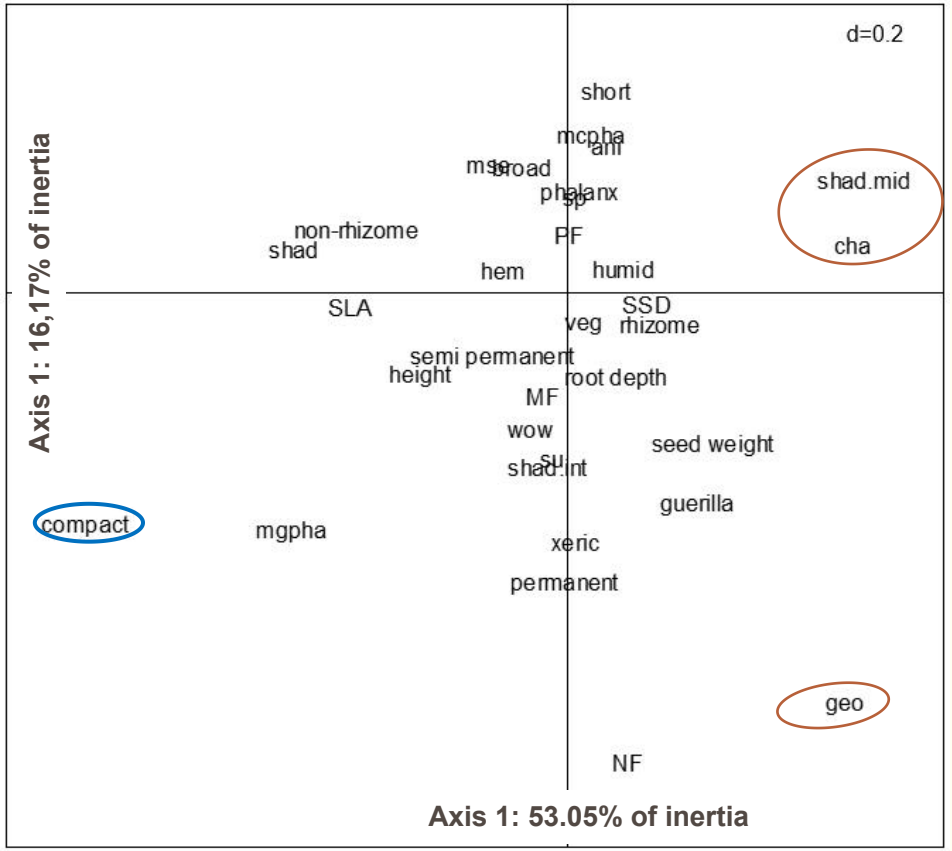
"RLQcovSTP", "RLQcovTSF" or "RLQcovTSD" Respectively means partial RLQ analysis using STP, TSF or TSD as co-variable.

RLQ analysis

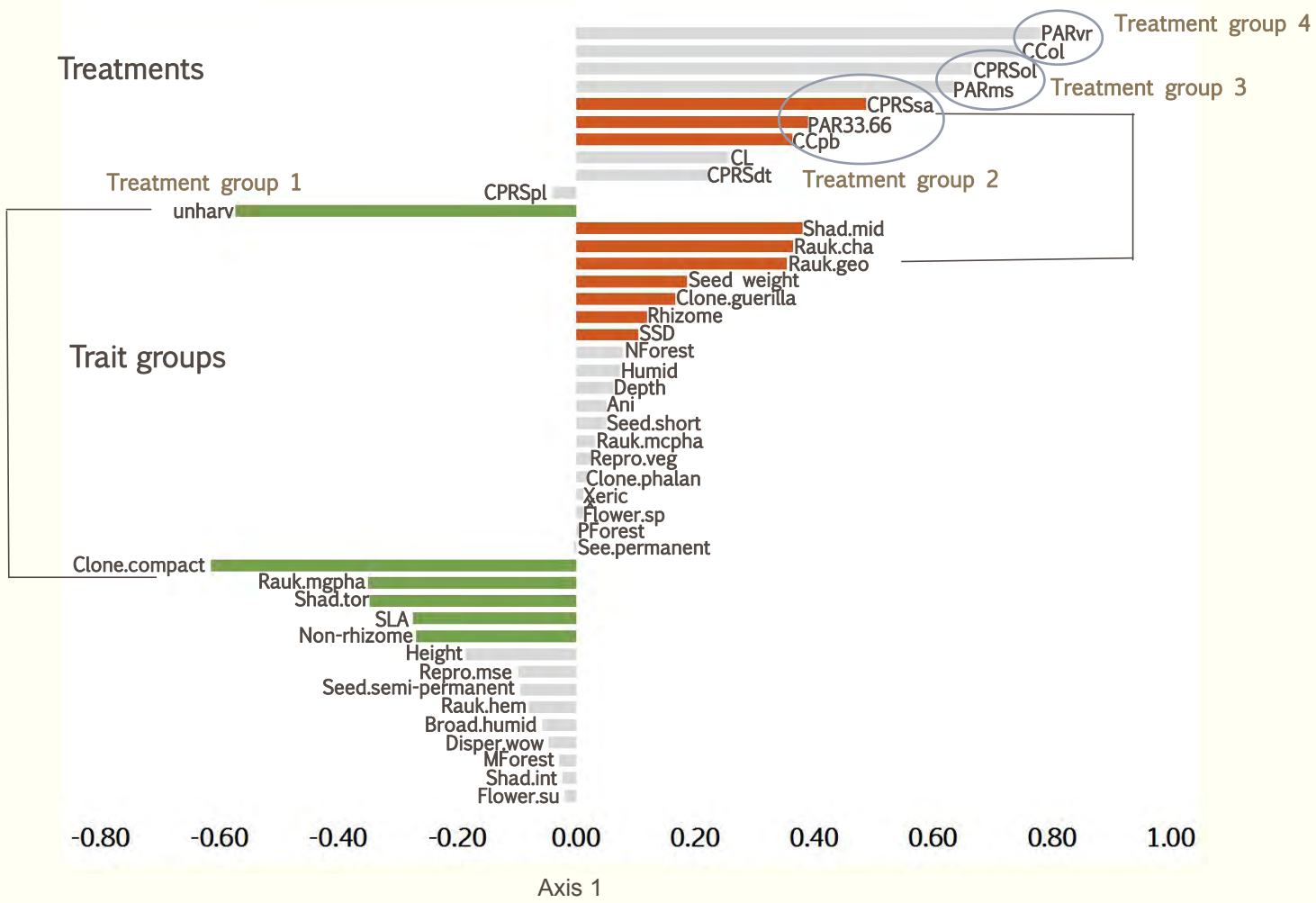
Treatments



Functional trait groups



Relationship between treatments and trait groups on the RLQ Axis 1



1. The details of silvicultural treatments were necessary for explaining patterns in functional diversity.

2. The relationship between silvicultural treatments and patterns of functional traits is:
   - Completely different response of unharvested to harvested despite the age range in unharvested stands.
   - Unharv and three treatments - CCpb, PAR33.66 and CPRSsa were found to be indicated by trait and by more than one trait group. The three treatments had totally the same indicator trait groups.

3. Forest attributes did not play dominant roles in determining functional diversity, only TSF slightly affected the trait-treatment relationship.

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