Drivers of plant functional traits in understory communities of Italian forests

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1. introduction

- Maintenance of biodiversity among the criteria to measure ecological sustainability, but species richness is not always a good descriptor of disturbance-resilience processes.
- Taxonomic-based measures can be biased when considering different biogeographical regions.

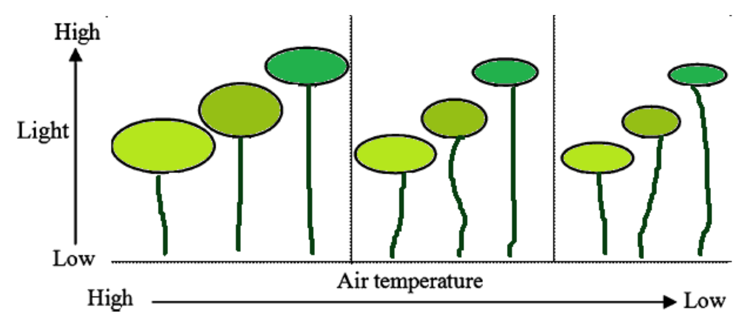
- **Functional traits**
  - sensitive measure of plant diversity, higher comparability
  - influence ecosystem processes and/or respond to environmental conditions

- **Functional diversity** (trait distribution in plant communities/populations):
  - resource type of use and efficiency, functionally diverse communities
  - climate & biotic interactions shape plant community dynamics and functioning

FIRST AID:

Plant trait–environment relationships

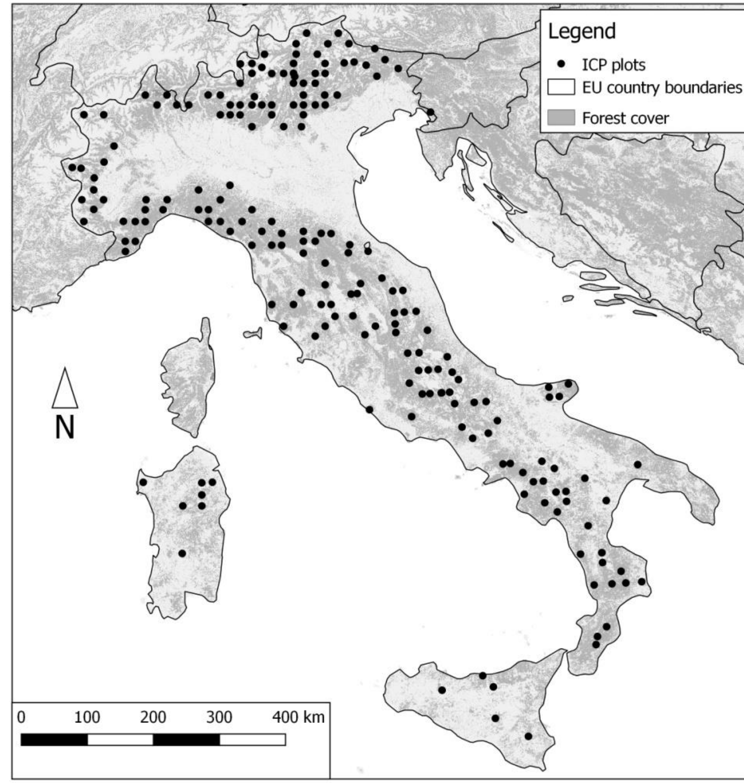
Spatial representative design



2. design & methods

Trait-environment relationships
Italian forests vegetation
explored for drivers of
plant diversity variability

LI representative 201 sites
based on 16x16 km grid



- understory vascular plants p\a and % cover (400 m² sampled surface)
- Biosoil-Biodiversity field protocol, trained & intercalibrated teams
- Selected above-belowground traits; community weighted mean (CWM) by specific relative cover
- a range of variables in relation to climate, soil, structure

→ drivers for plant traits variability

also integrating the effect of some land-use indication

Functional traits representing the major axes of plant strategies both above and belowground
assigned to the species up to cumulative 80% abundance

Group	Variable	Unit	notes
response strategy traits	**specific leaf area (SLA)**	$m^2\ kg^{-1}$	proxy of plant growth and photosynthetic efficence
	plant height (H)	*cm*	related to competitive ability and access to vertical light gradient
	seed mass (SM)	*CV (%)*	indicative of s-t dispersal ability and seedling establishment
clonal traits	**clonal growth organs (CGO)**	*Y|N*	space occupancy, persistence
	belowground clonal growth organs (CGO_below)	*Y|N*	space occupancy, persistence
	long spacers (S_long)	*Y|N (>10 cm)*	space occupancy
	long-term connections (C_long)	*Y|N (>2 yrs)*	space occupancy, persistence on unpredictable sites
	fast lateral spread (Spr_fast)	*Y|N (>0.25 m/yr)*	space occupancy
bud bank traits	**bud protection (B_protect)**	*Y|N*	persistence, response to disturbance
	large bud bank (BB_large)	*Y|N (<10)*	persistence, response to disturbance
	perennial belowground bud bank (Per_BB_below)	*Y|N (>2 yrs)*	persistence, response to disturbance

SOURCES

Seed Information Database Kew RBG

TRY - LEDA Traitbase

CLOPLA

Field integration for missing species (UNICAM papers)

Explanatory variables: not correlated, ecologically relevant, selected by explanatory power [WorldClim, LI CONECOFOR datasets (ICP Forests), and literature]

Group	Variable	Unit	Range	Source, notes	PFT	CLT
Climate	**Total Potential Evapotr. (PET)**	*mm*	370 - 1065	Trabucco & Zomer (2009)	●	
	Isothermality	*%*	23 - 38	Hijmans et al. (2005), WorldClim	●	●
	T seasonality	*CV (%)*	51 - 75	Hijmans et al. (2005), WorldClim	●	
	Max T of the warmest month	*°C*	9.2 – 31.5	Hijmans et al. (2005), WorldClim	●	●
	Min T of the coldest month	*°C*	-10.5 – 7.1	Hijmans et al. (2005), WorldClim		●
	P of the driest month	*mm*	4 – 102	Hijmans et al. (2005), WorldClim		●
	P of the wettest month	*mm*	65 - 155	Hijmans et al. (2005), WorldClim	●	●
	P seasonality	*CV (%)*	7 - 64	Hijmans et al. (2005), WorldClim	●	●
Soil	**Soil pH**	$-log(H^+)$	4 – 8.6	Andreetta et al. (2016)	●	●
	Total N	*g/kg*	1.2 – 16.1	Andreetta et al. (2013)	●	
	N/C	*na*	0.05 – 0.19	Andreetta et al. (2016)	●	●
	Subsoil P	*mg/kg*	55 - 4450	Andreetta et al. (2016)	●	
	Topsoil available K	*cmol+/Kg*	0.01 - 7	Unpublished data	●	●
	Effective soil volume	*cm*	4.5 - 170	Proxy of water holding capacity. Andreetta et al. (2016)	●	●
Structure	**Total vegetation cover**	*%*	40 - 100	Biotic driver of vegetation.	●	●
	Litter cover	*%*	2 - 100	Biotic driver of vegetation.	●	●
	Baresoil cover	*%*	0 - 68	Biotic driver of vegetation.	●	
	Mosses cover	*%*	0 - 72	Biotic driver of vegetation.	●	
	Number of tree layers	*Classes*	1 - 4	1, 2, 3, >3 tree layers; indicator of structural complexity.	●	
	Basal area	m^2/ha	2.8 - 69	Related to total woody biomass.	●	●
	Stem density	*n. stems/ha*	100 - 2000	Related to dynamic state and competition within stand.	●	
Land-use	**Previous land-use**	*Classes*	1 - 5	Forested >300yrs; >100yrs; 25-100yrs; <25yrs; unknown.	●	
	Current land-use	*Classes*	1 - 4	Unmanaged; managed >10yrs; within 10 yrs; unknown.	●	●
	Mean age of dominant storey	*Age classes*	8, 20 yrs each	Age of the dominant storey linked to the last treatment.	●	
	Type of management	*Classes*	1 - 4	High forest; development to high forest; coppice; 4, other.	●	
	Total released deadwood	$m^3/400m^2$	0 - 15	Proxy of disturbance intensity.	●	●
	Deadwood removal	*Classes*	1, 3, 4, 5, 7	1, Yes; 3, no; 4, partly; 5, unknown; 7, accumulated piles.	●	●

3. expected drivers

PFT (Leaf**S**eed**H**eight**)**

(H1) climate and (H2) soil as main abiotic filters for understory plant functional traits at regional scale

(H3) weak effect of land-use (manag.) and vegetation structure, as heterogeneously dispersed and historically rooted

Clonal and **budbank**

(H4) climate affects traits related to clonality and resprouting

(H5) mesic, richer soils forests are relevant for traits related to space occupancy

(H6) land-use (management) favor bud bank-resprouting traits

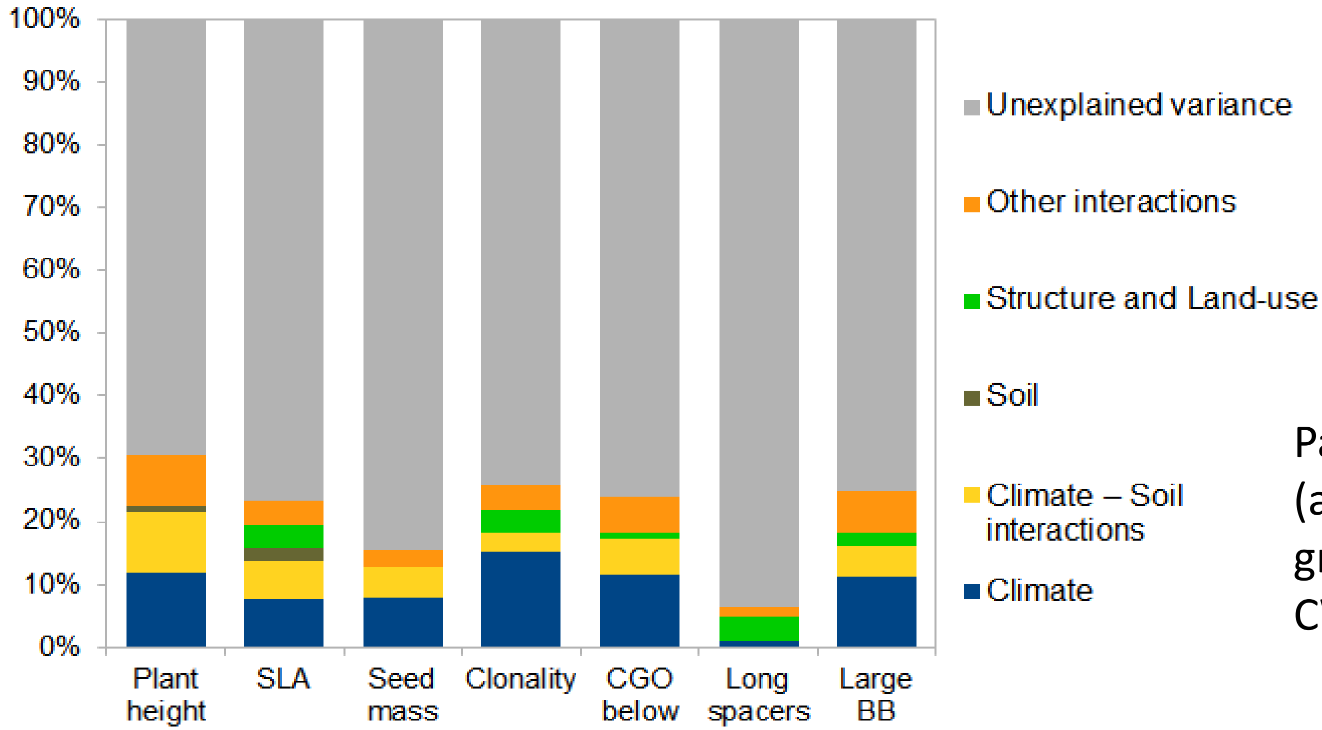
Stepwise forward ordination (parsimonious explanatory variables for each trait)

sign. MonteCarlo randomization

Single best linear correlations by RDA, npar generalized additive models (GAMs)

Variance partitioning (how groups of variables contribute to total explained variation)

4. Results Groups of explanatory variables



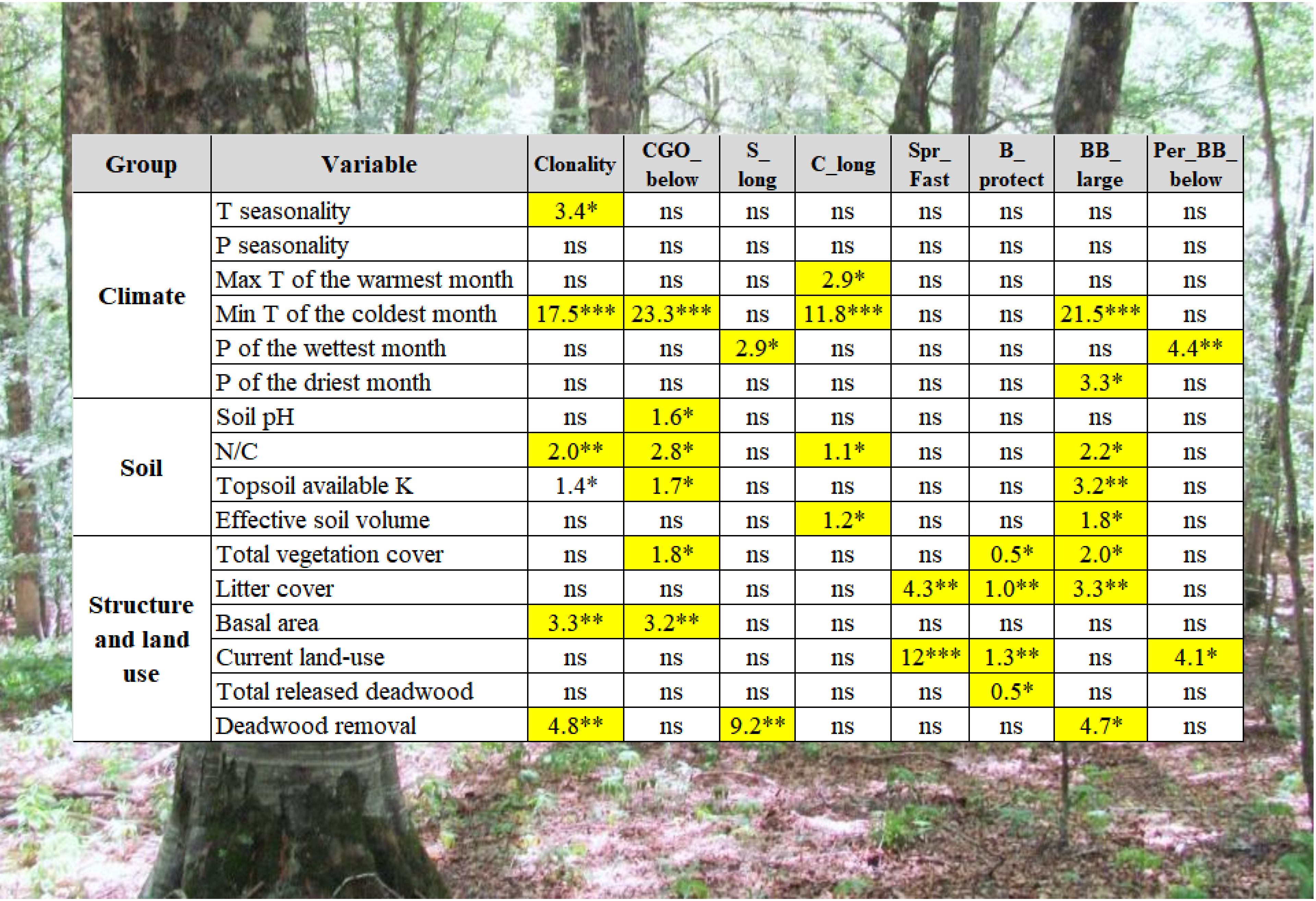
Partition variance (adjusted R^2 %) groups for traits CWM values

PFTs & Clonal traits patterns of understory communities at IT national level linked to a complex combination of variables (8-30% explained).

Climate group - and in interaction with **soil** features, relevant role for all considered plant functional traits (20 to 12 %, say almost 90% of the significant variables) , but spacers → regional filtering

Structural and land-use variables have lower relevance → local based

Group	Variable	H			SLA			SM		
		Est. *df*	*F*	*P*	Est. *df*	*F*	*P*	Est. *df*	*F*	*P*
Climate	PET	1.000	2.913	0.090	1.000	0.896	0.345	1.000	3.858	**0.050**
	Isothermality	1.000	0.890	0.347	2.719	2.020	0.119	3.545	1.030	0.389
	T seasonality	3.208	2.476	**0.047**	1.000	7.252	**0.008**	2.503	0.954	0.429
	Max T warmest month	1.556	0.285	0.716	2.699	0.943	0.380	1.592	1.939	0.169
	P wettest month	1.574	0.974	0.325	1.000	0.004	0.951	3.131	2.755	**0.034**
	P seasonality	2,741	1.565	0.142	1.000	0.194	0.660	1.000	1.983	0.161
Soil	Soil available K	1.000	1.182	0.279	5.718	2.274	**0.035**	1.000	0.102	0.750
	Effective soil volume	1.000	0.036	0.849	1.000	0.517	0.473	1.000	1.094	0.297
	Soil pH	1.000	0.018	0.893	1.000	1.184	0.278	1.000	0.492	0.484
	Subsoil P	1.000	7.749	**0.006**	1.000	1.559	0.214	2.345	1.537	0.271
	Total N	1.000	0.002	0.966	1.178	3.034	0.057	1.000	0.584	0.446
	N/C	1.000	0.000	0.984	1.000	0.993	0.321	1.477	0.418	0.542
Structure	N. of tree layers	c	1.761	0.140	c	0.331	0.857	c	0.469	0.758
	Total vegetation cover	1.000	1.126	0.290	1.427	0.241	0.720	1.000	0.726	0.396
	Litter cover	1.000	0.696	0.405	2.038	1.200	0.341	1.000	0.990	0.321
	Baresoil cover	3.627	2.499	**0.038**	1.000	0.040	0.842	1.379	1.623	0.131
	Mosses cover	1.000	2.151	0.145	5.077	1.513	0.178	2.564	1.208	0.279
	Basal area	1.504	0.314	0.655	1.000	4.639	**0.033**	1.000	0.093	0.760
	Stem density	1.000	0.031	0.861	2.541	0.889	0.411	1.000	0.107	0.744
Land-use	Mean age dom. storey	c	0.572	0.778	c	0.879	0.525	c	2.876	**0.008**
	Type of management	c	0.302	0.824	c	1.738	0.162	c	0.172	0.915
	Previous land-use	c	0.323	0.862	c	0.615	0.652	c	0.376	0.825
	Current land-use	c	1.251	0.293	c	1.466	0.226	c	0.384	0.764
	Deadwood removal	c	3.019	**0.020**	c	0.866	0.486	c	0.388	0.817
	Total deadwood	1.343	0.160	0.797	1.000	0.289	0.591	1.000	1.022	0.314



Group	Variable	Clonality	CGO_ below	S_ long	C_long	Spr_ Fast	B_ protect	BB_ large	Per_BB_ below
Climate	T seasonality	3.4*	ns	ns	ns	ns	ns	ns	ns
	P seasonality	ns	ns	ns	ns	ns	ns	ns	ns
	Max T of the warmest month	ns	ns	ns	2.9*	ns	ns	ns	ns
	Min T of the coldest month	17.5***	23.3***	ns	11.8***	ns	ns	21.5***	ns
	P of the wettest month	ns	ns	2.9*	ns	ns	ns	ns	4.4**
	P of the driest month	ns	ns	ns	ns	ns	ns	3.3*	ns
Soil	Soil pH	ns	1.6*	ns	ns	ns	ns	ns	ns
	N/C	2.0**	2.8*	ns	1.1*	ns	ns	2.2*	ns
	Topsoil available K	1.4*	1.7*	ns	ns	ns	ns	3.2**	ns
	Effective soil volume	ns	ns	ns	1.2*	ns	ns	1.8*	ns
Structure and land use	Total vegetation cover	ns	1.8*	ns	ns	ns	0.5*	2.0*	ns
	Litter cover	ns	ns	ns	ns	4.3**	1.0**	3.3**	ns
	Basal area	3.3**	3.2**	ns	ns	ns	ns	ns	ns
	Current land-use	ns	ns	ns	ns	12***	1.3**	ns	4.1*
	Total released deadwood	ns	ns	ns	ns	ns	0.5*	ns	ns
	Deadwood removal	4.8**	ns	9.2**	ns	ns	ns	4.7*	ns

4. Results single explanatory variables

Driving group Climate

T-related variables largely affect traits variation (not the mean values)

T annual variation (T seasonality) and extremes (e.g. Tmin coldest , Tmax warmest month) are especially linked to Clonal & BB traits (clonality, belowground clonal organs, long-term ramet connection, large bud bank)

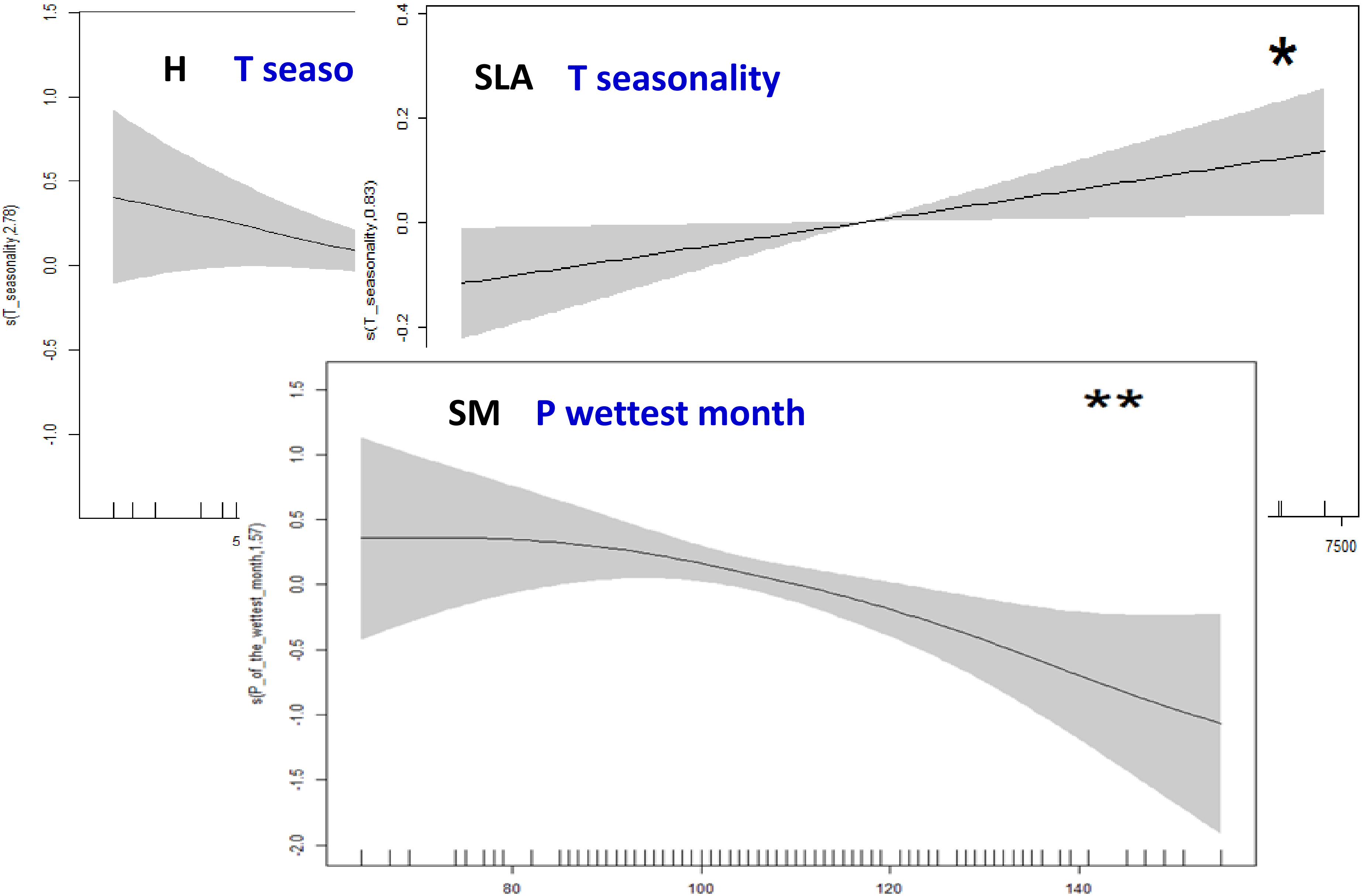
Driving group Soil

Guided by nutrient-related parameters, and – only for belowground clonal traits – water availability

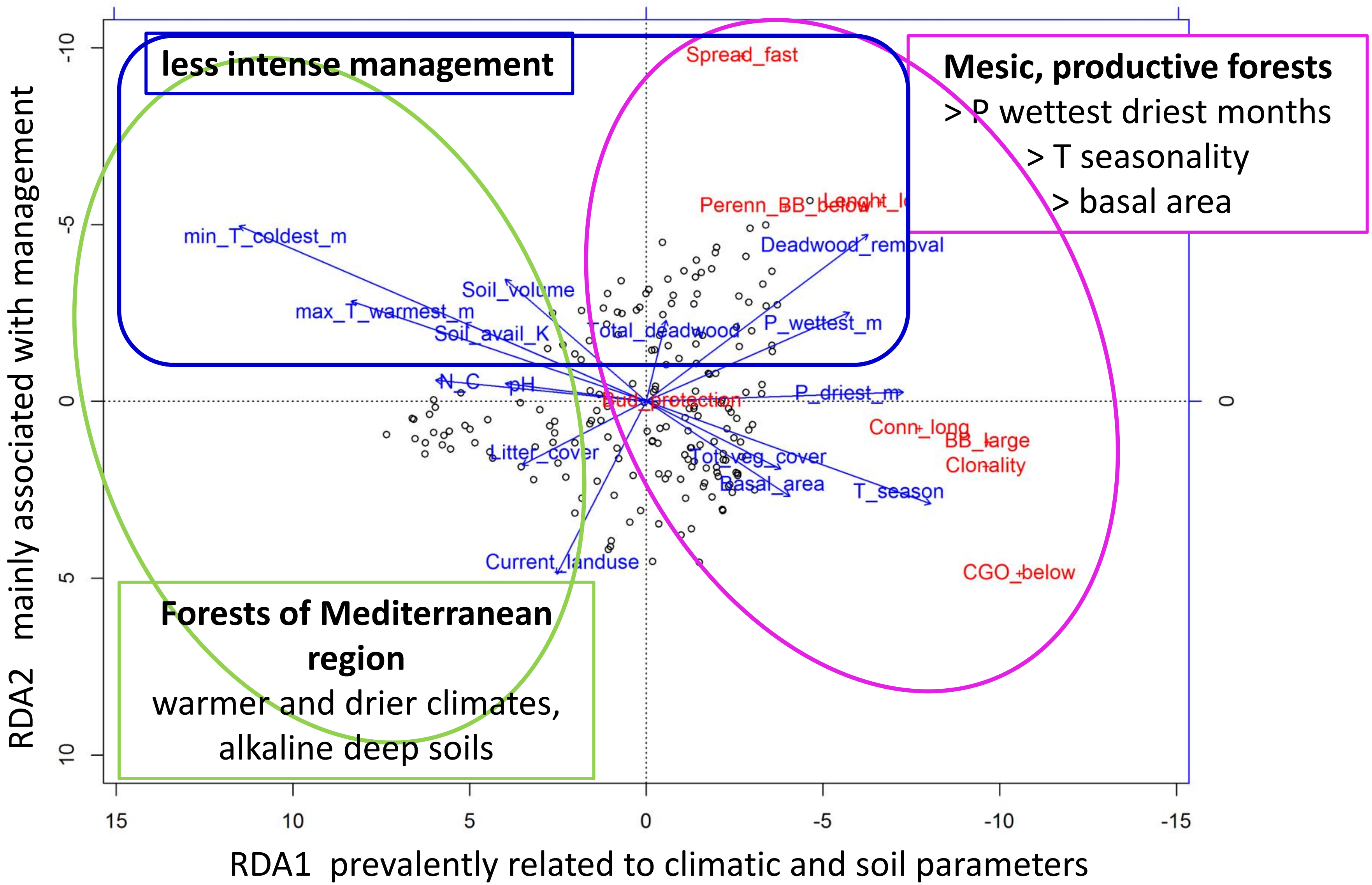
Forest structure and management

Few descriptors, related to Clonal and Bud bank traits

Estimated smoothers generalized additive models (GAMs) CI 95%



4. Results RDA Σ 25% of variance



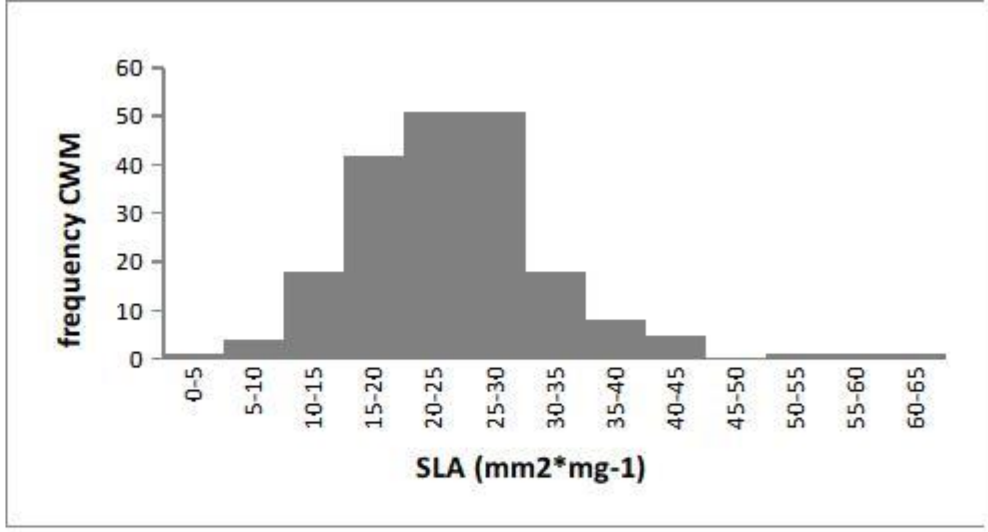
5. Forest plant functional diversity: Italian patterns

- **Plant traits variation linked to complex combination of different variables significantly explaining max 30% of variance**
- **Climate-soil interaction controls SLA, SM, H variation (H1) (H2)**
- **Climate (H4), secondly Soil (H5) influence Clonal and BB traits**
- **Land-use & structure weakly shape SLA ~~(H3)~~ and clonal traits (H6)**
- **Plant communities of mesic, productive forests show species with low H, SM, high SLA values, clonal and resprouting abilities. Mostly, this corresponds to forest specialist species under smooth disturbance regimes.**
- **The opposite scenario can be linked to forest species living under stress conditions (e.g. drought, intensive management)**

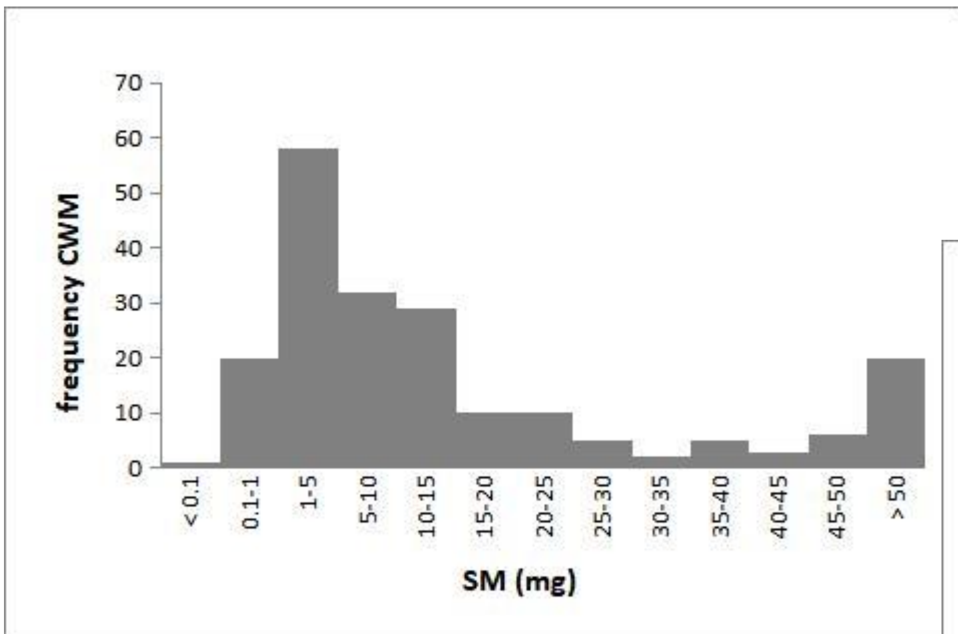
next outlook?

- **Scale matters: multiscalar studies to deepen processes and mechanisms and disclose plant-standwise disturbance relationships**
- **Plant traits variations along time on representative design to reveal adaptive ability of plant communities in face of global changes**
- **Extend at continental level (provided plant presence/absence& cover)**
- **Plant functional patterns of biogeographic regions and main forest types more comparable and sensitive respect to taxonomic based**
- **Resampling LI to enlighten community-level trait changes**
- **Modeling using future climatic scenarios can take advantage of this approach (considering traits sensitivity to climate)**
- **Species specific traits must take into account intraspecific variability**

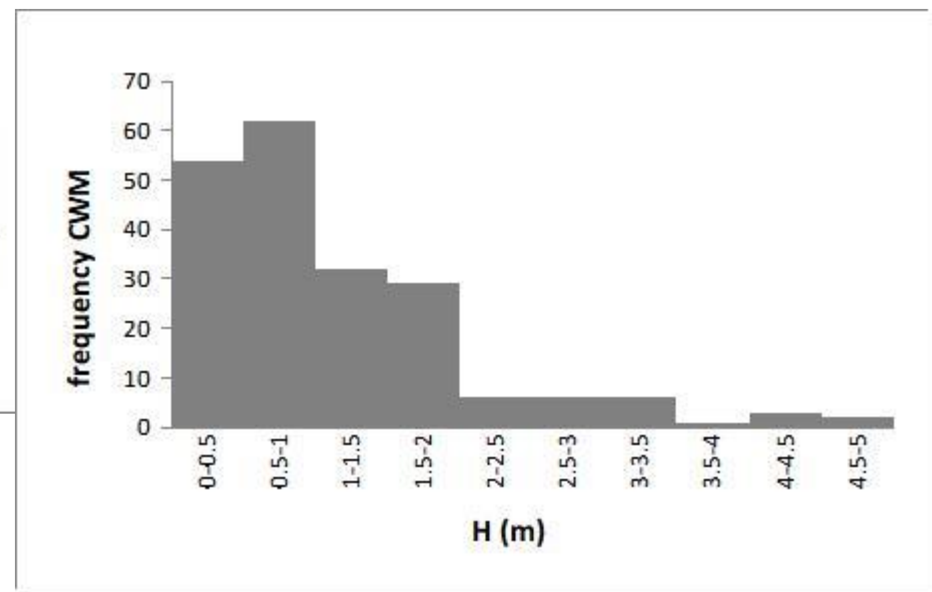

Thanks for your kind attention



frequency CWM
60
50
40
30
20
10
0
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
SLA (mm2*mg-1)



frequency CWM
70
60
50
40
30
20
10
0
< 0.1
0.1-1
1-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
> 50
SM (mg)

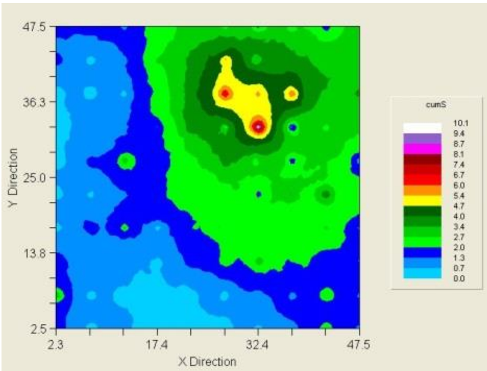


frequency CWM
70
60
50
40
30
20
10
0
0-0.5
0.5-1
1-1.5
1.5-2
2-2.5
2.5-3
3-3.5
3.5-4
4-4.5
4.5-5
H (m)

Italy, CONECOFOR: 1999-2011 (50x50 cm)

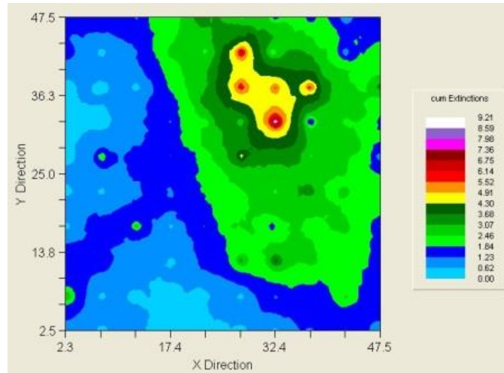
Trends or plasticity? (plant *traits* associated to nutrients)

ABR1



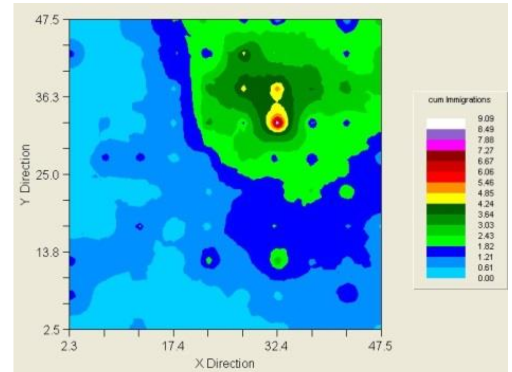
Cummulative species richness

20 spp.



Cummulative extinction

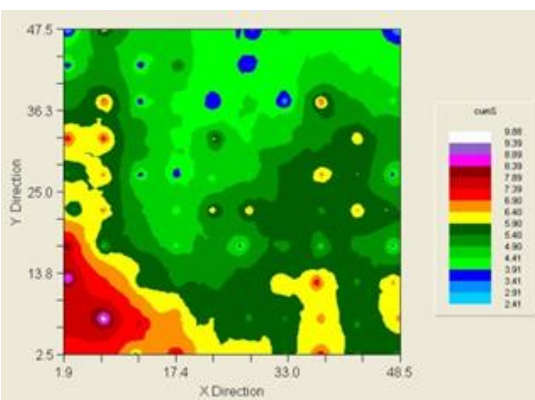
13 spp.



Cummulative immigration

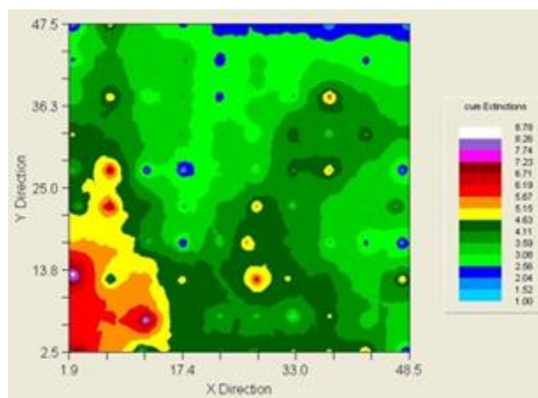
13 spp.

CAM1



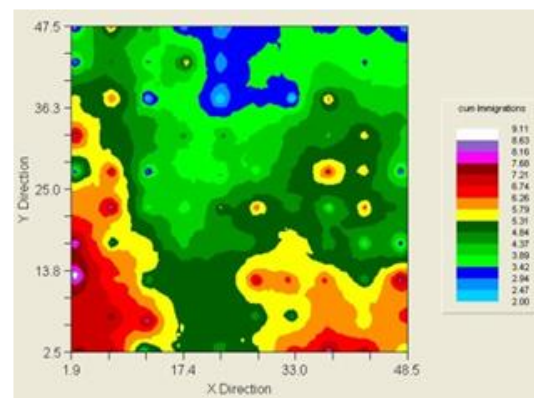
Cummulative species richness

35 spp.



Cummulative extinction

22 spp.



Cummulative immigration

25 spp.