Facultad de Agronomía
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Application of the Forest Reclamation Approach to Establish Nothofagus Forest in Chilean Patagonia

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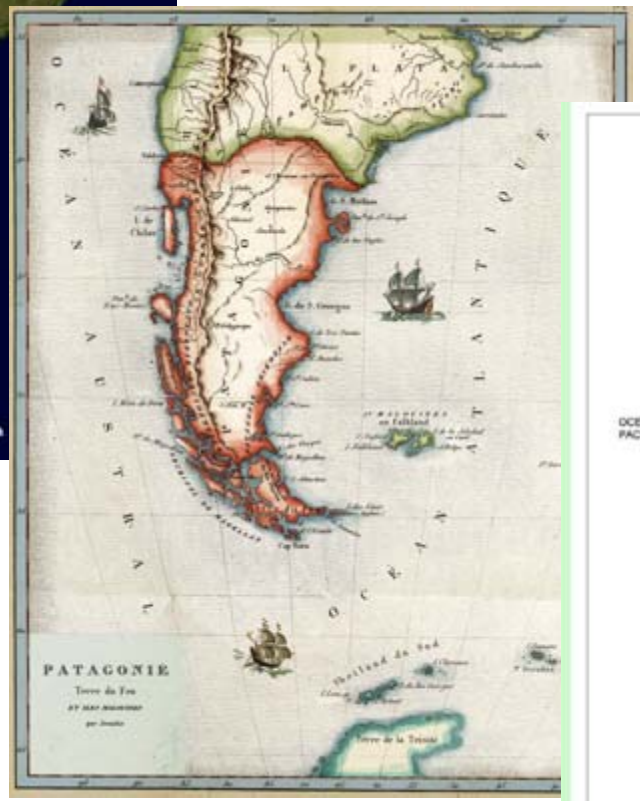
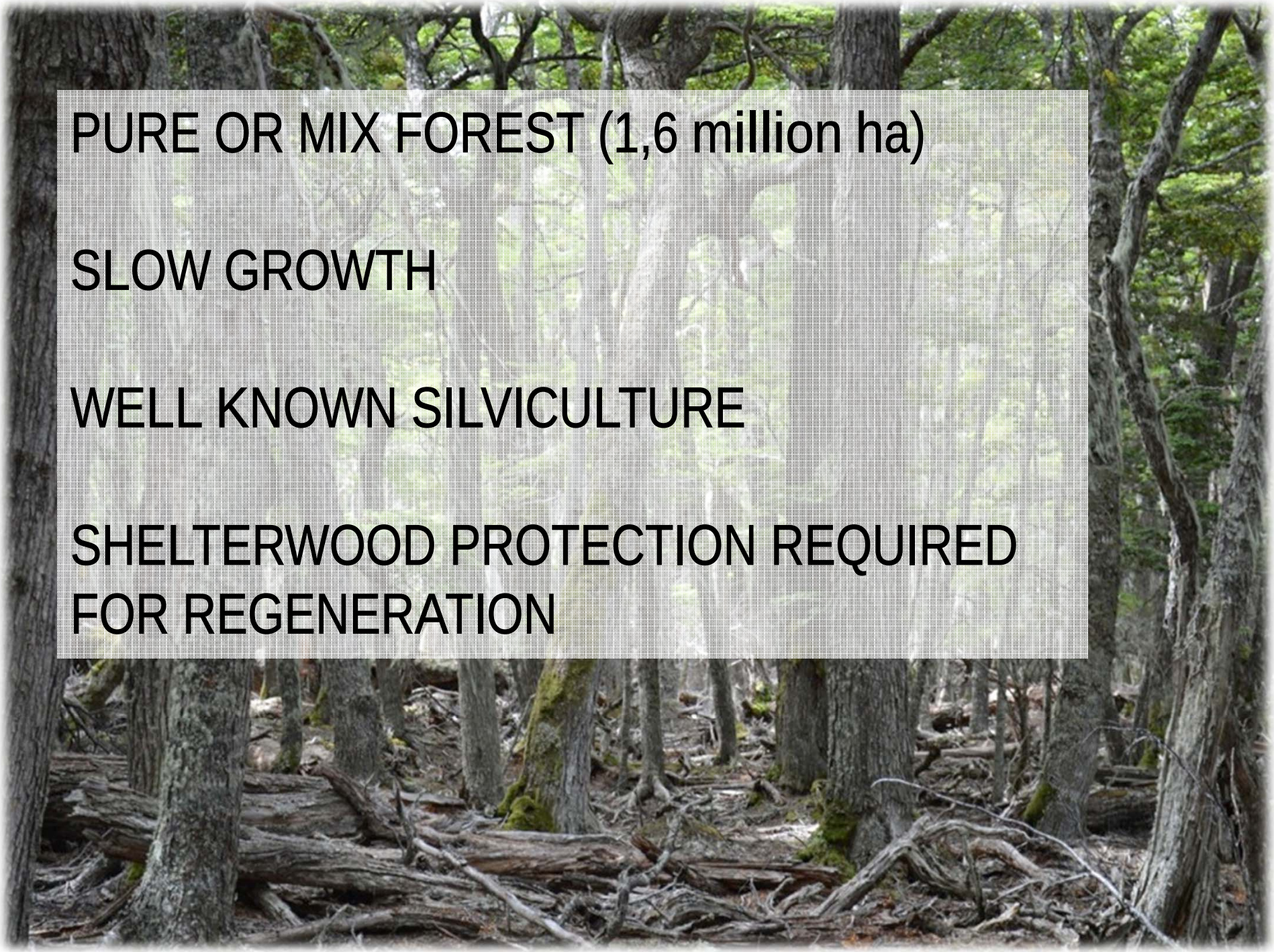
Nothofagus pumilio forest (Lenga)





PURE OR MIX FOREST (1,6 million ha)

SLOW GROWTH

WELL KNOWN SILVICULTURE

SHELTERWOOD PROTECTION REQUIRED FOR REGENERATION

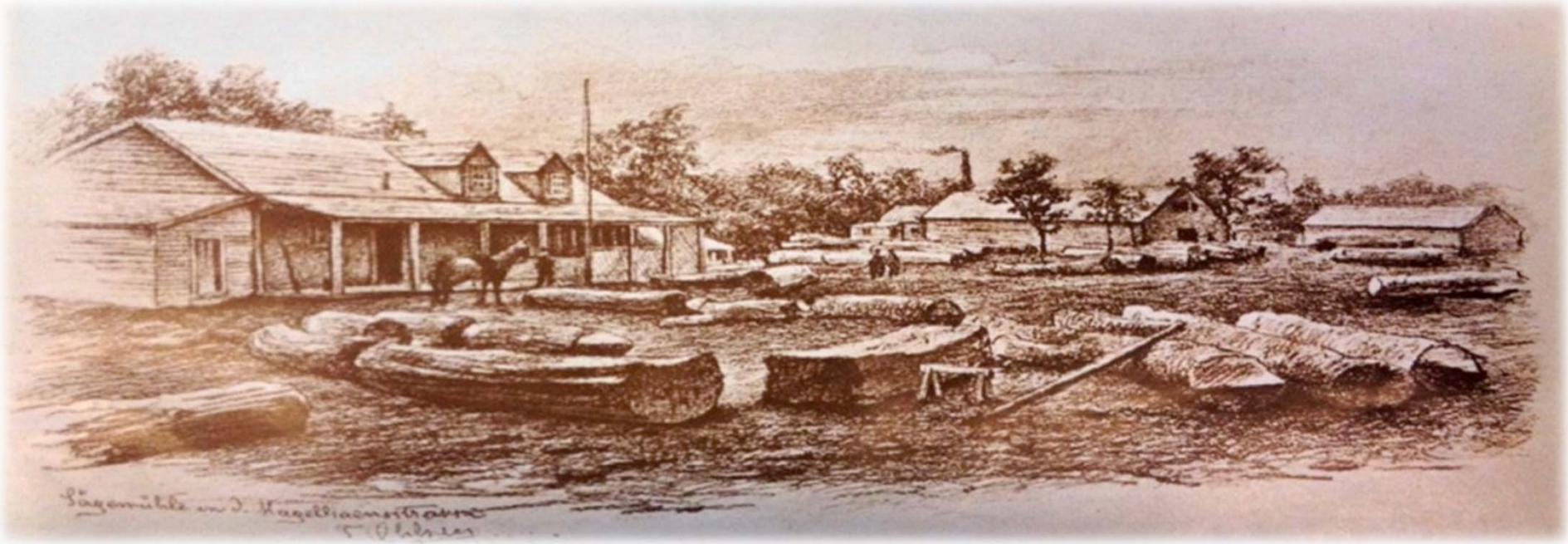
Chilean Patagonia

Agrarian Settlements

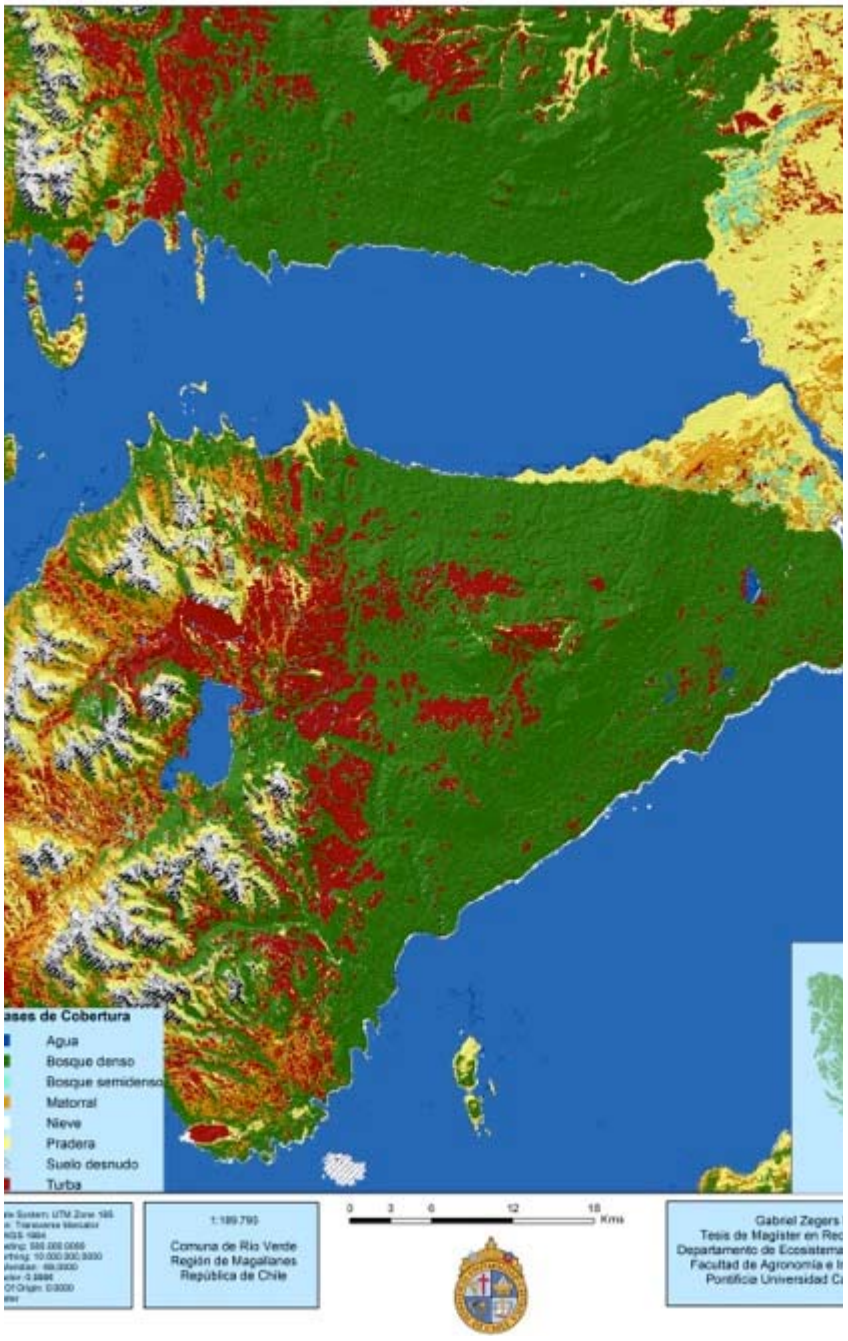
- 1890 – 1905: first land consecions to settlers (small scale farming)
- 1905 – 1910: Start of sistematic selective logging, induced fires and exotic pasture establishment (logging and burning).

European Settlemen

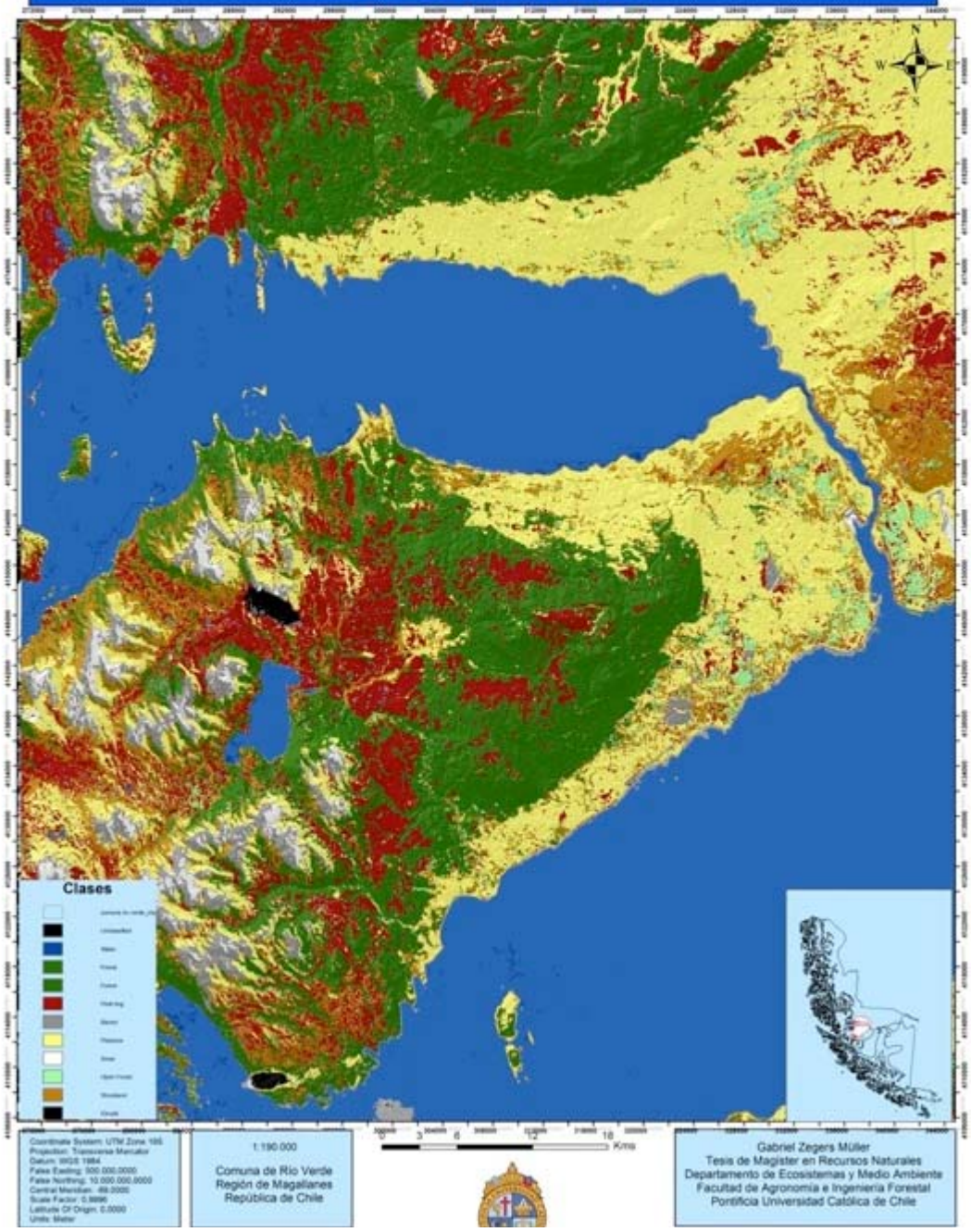
- 1910: First mills in the Region
- 1910-1952: Open the forest to be replace with praire
- 1958: Last big fire in the region



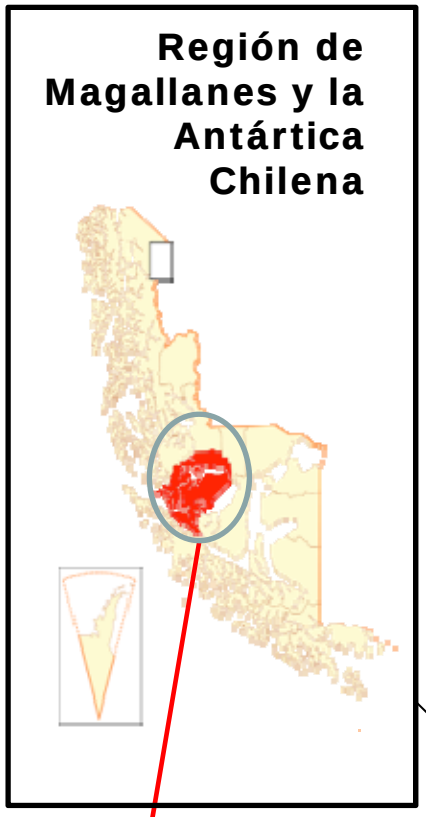
Coberturas Vegetacionales Pre-colonización

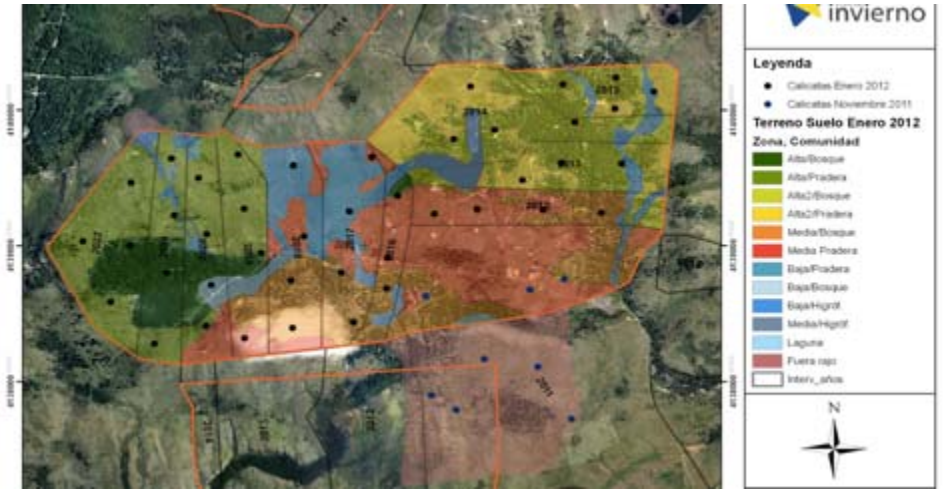


Land Cover Map 2014



MINA INVIERNO
COAL MINE PROJECT

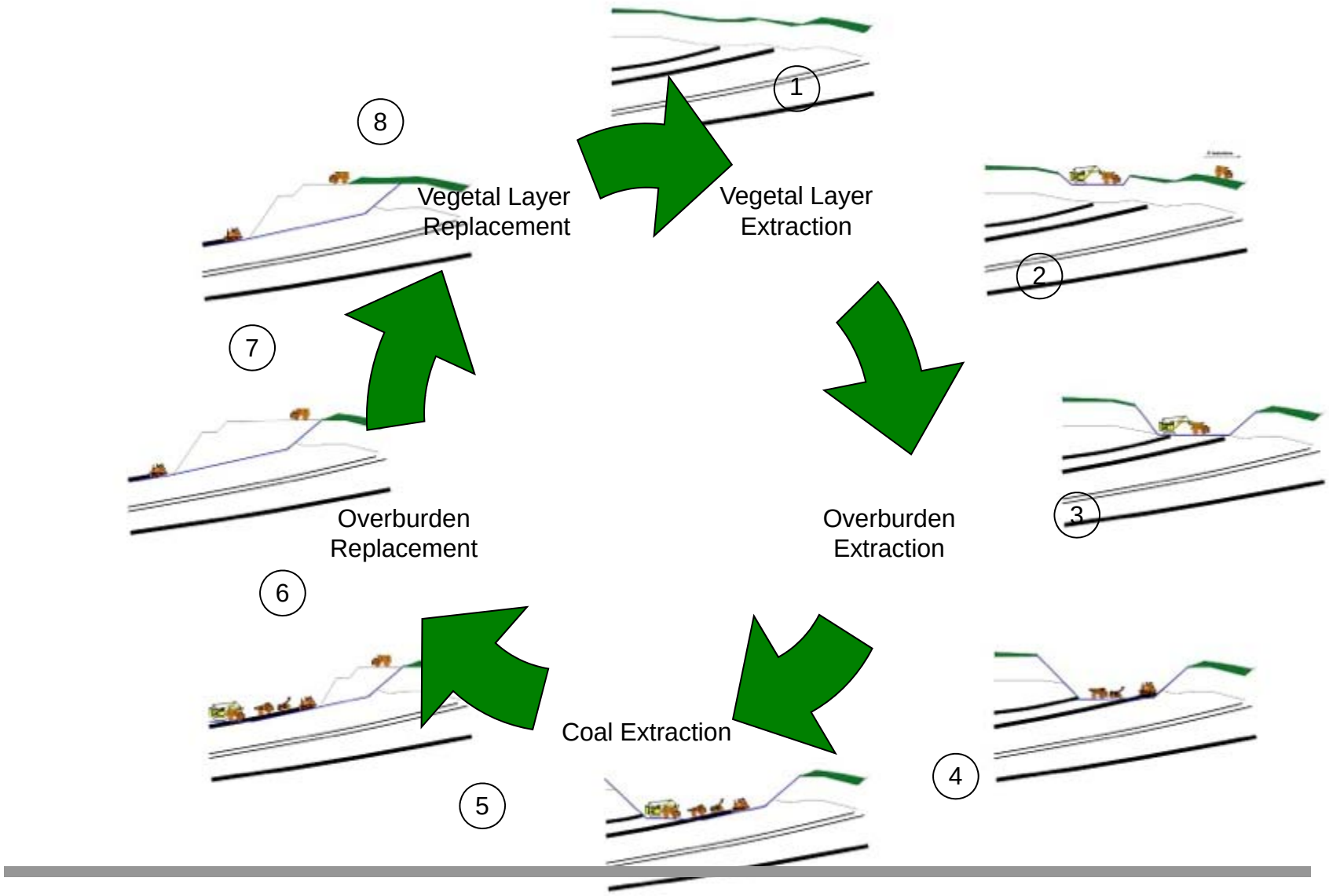




- Previous reclamation practices

- NEW RECLAMATION REGULATIONS
- PROJECT COMMITMENTS

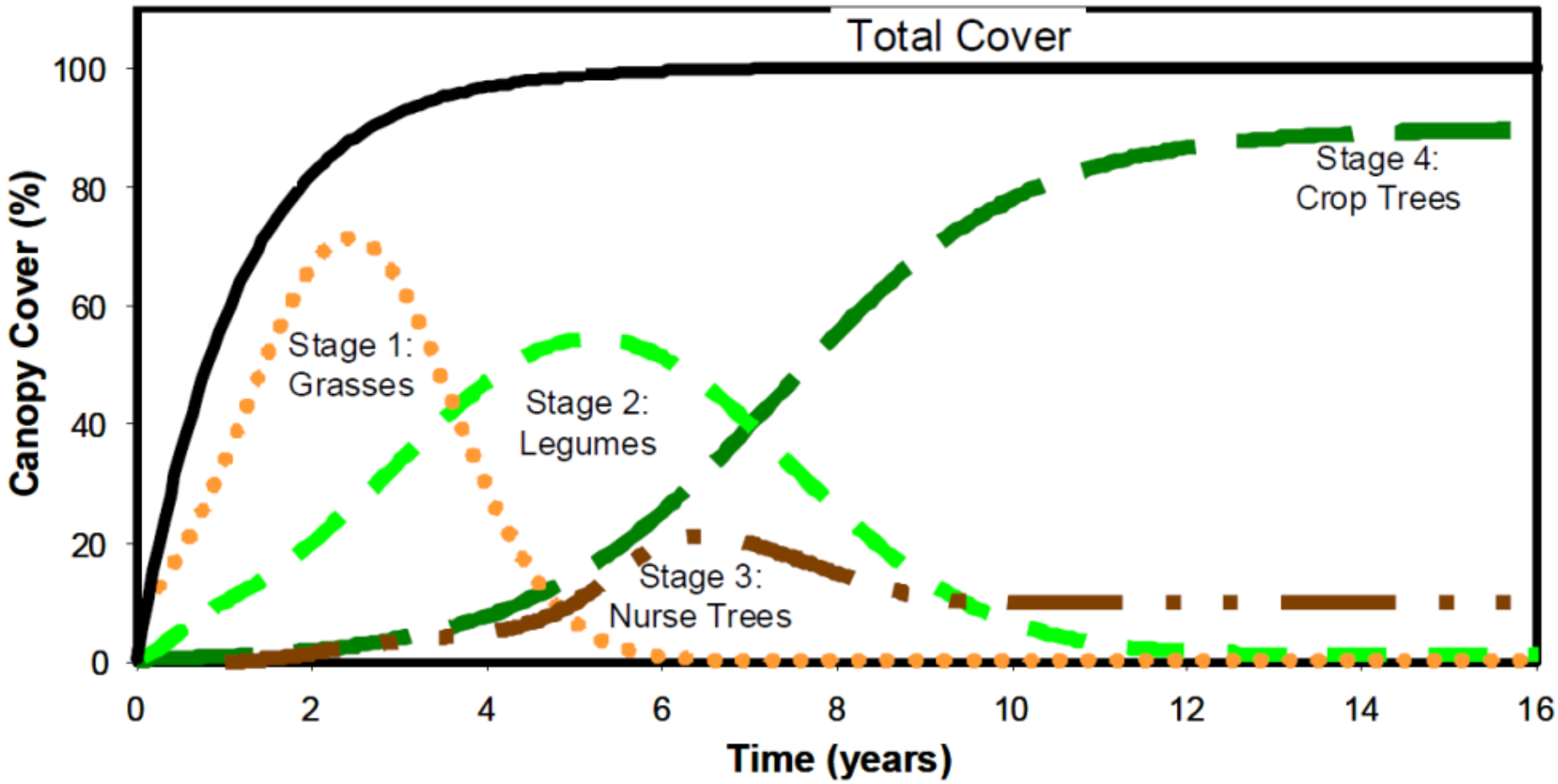
Objective: to develop the reclamation Model



FRA FOR NOTHOFAGUS FOREST

- Develop a new forest mine reclamation approach for Nothofagus pumilio Forest
  - Identify suitable vegetation material
  - Understand top soil variability across the landscape
  - Characterized microsite variability suitable for regeneration

FINAL GOAL: FOREST RECLAMATION APPROACH



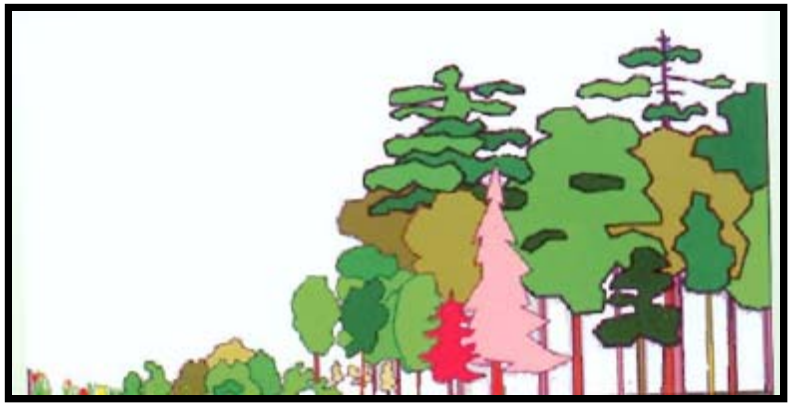
Step 1: Vegetation survey….how things are growing?

Especie	Forest	Transition	Grassland
Berberis darwinii	s/r	s/r	s/r
Berberis ilicifolia	0,90 ± 0,50	s/r	s/r
Berberis microphylla	1,50 ± 1,39	9,47 ± 3,15	2,05 ± 0,98
Empetrum rubrum	s/r	s/r	s/r
Gaultheria mucronata	s/r	s/r	s/r
Gaultheria pumilia	s/r	0,18 ± 0,17	0,05 ± 0,05
Maytenus magellanica	s/r	s/r	s/r
Nothofagus antarctica	s/r	s/r	s/r
Nothofagus betuloide	0,20 ± 0,20	0,06 ± 0,08	0,09 ± 0,06
Nothofagus pumilio	2,00 ± 1,58	1,18 ± 0,72	0,09 ± 0,06

Step 1: Understand the microsites and forest regeneration

Comunity	Microsite condition	Species		
		N. pumilio	*N. betuloides*	*N. antartica*
Forest	Open site	1,20 ± 0,55	0,10± 010	s/r
Forest	Shrubs	1,60 ± 0,60	0,30± 0,21	s/r
Forest	Wod.-Debr	1,70 ± 0,37	1,00± 0,39*	s/r
Transition	Open site	1,35± 0,31*	0,24± 0,14	s/r
Transition	Shrub	2,77± 0,38	0,77± 0,24	s/r
Transition	Wod-Debr.	3,00± 0,42	0,71± 0,28	s/r
Grassland	Open site	0,14± 0,10*	0,18± 0,14	s/r
Grassland	Shrubs	0,55± 0,17	0,09± 0,09	s/r
Grassland	Wod-Debr.	0,64± 0,19	0,23± 0,19	s/r

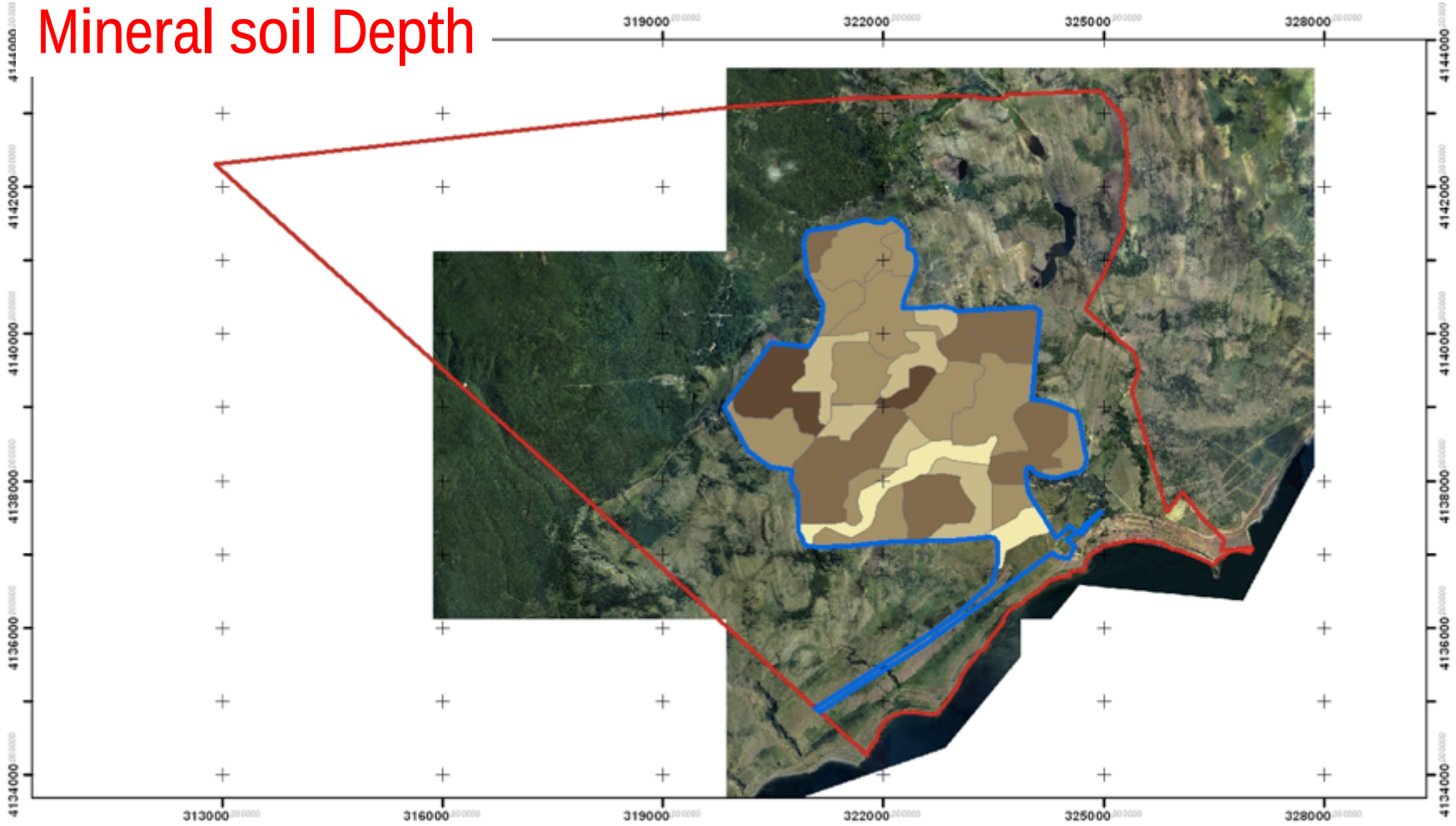
Regeneration strategies



Step 2: Surface soil material selection

Step 2: Surface soil material selection

Mineral soil Depth



ISLARIESCO MINERA

0 1,5 3
Kilometers

Profundidad de las estratas superficiales

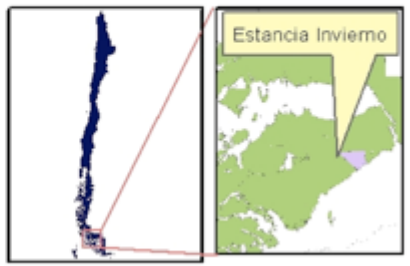
Simbología

- Área de Intervención
- Estancia Invierno

Profundidad (cm)

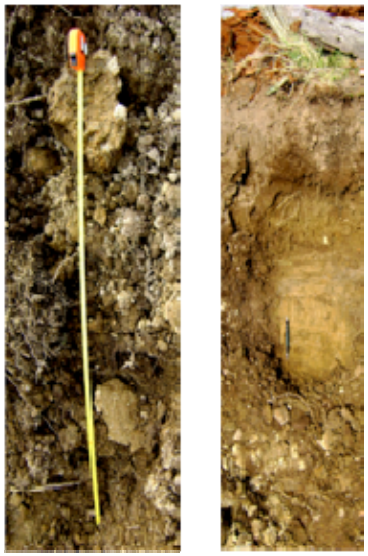
- N/D
- 1 - 35
- 36 - 70
- 71 - 105
- 106 - 180

N
W E
S



Additions for the FRA model

- **Top soil removal to a depth of 1.5 to 2.0**
- **Mix woody debris, branches and no competitive herbaceous cover to avoid soil erosion and promote soil recovery**
- **Avoid competitive exotic herbs.**
- **Facilitators such as native shrubs and trees**



1.3 mt

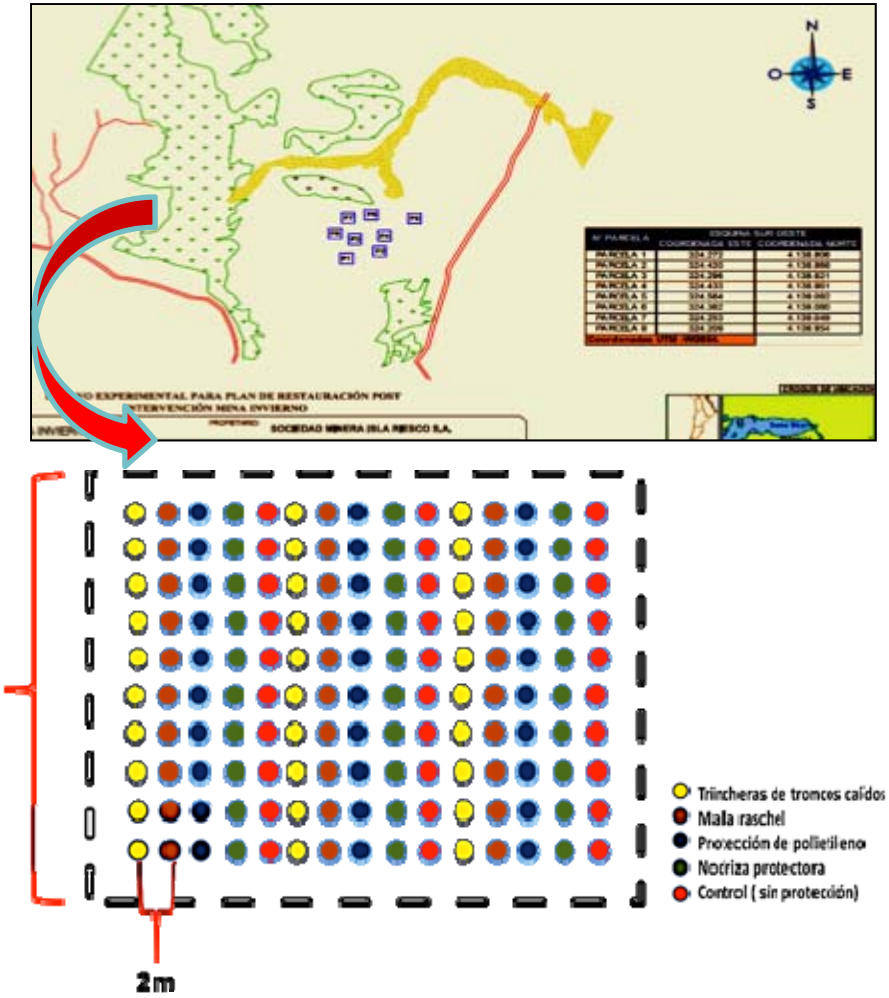
Top soil removal

Top soil replacement

STEP 3: REFORESTATION PRACTICES

LEVEL 1: TOP SOIL REMOVAL vs PRAIRE

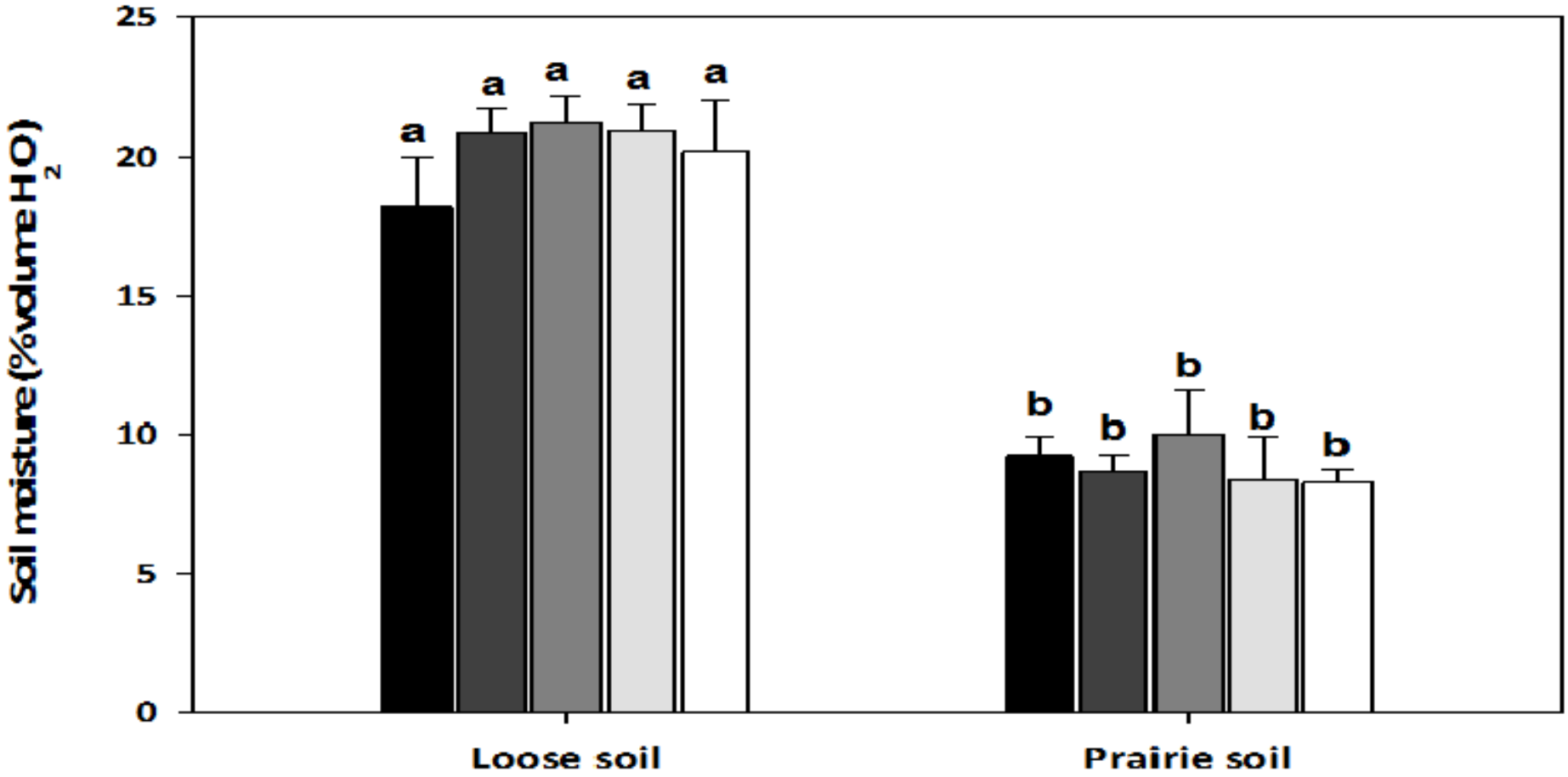
LEVEL 2: 4 PROTECTION SYSTEM + CONTROL

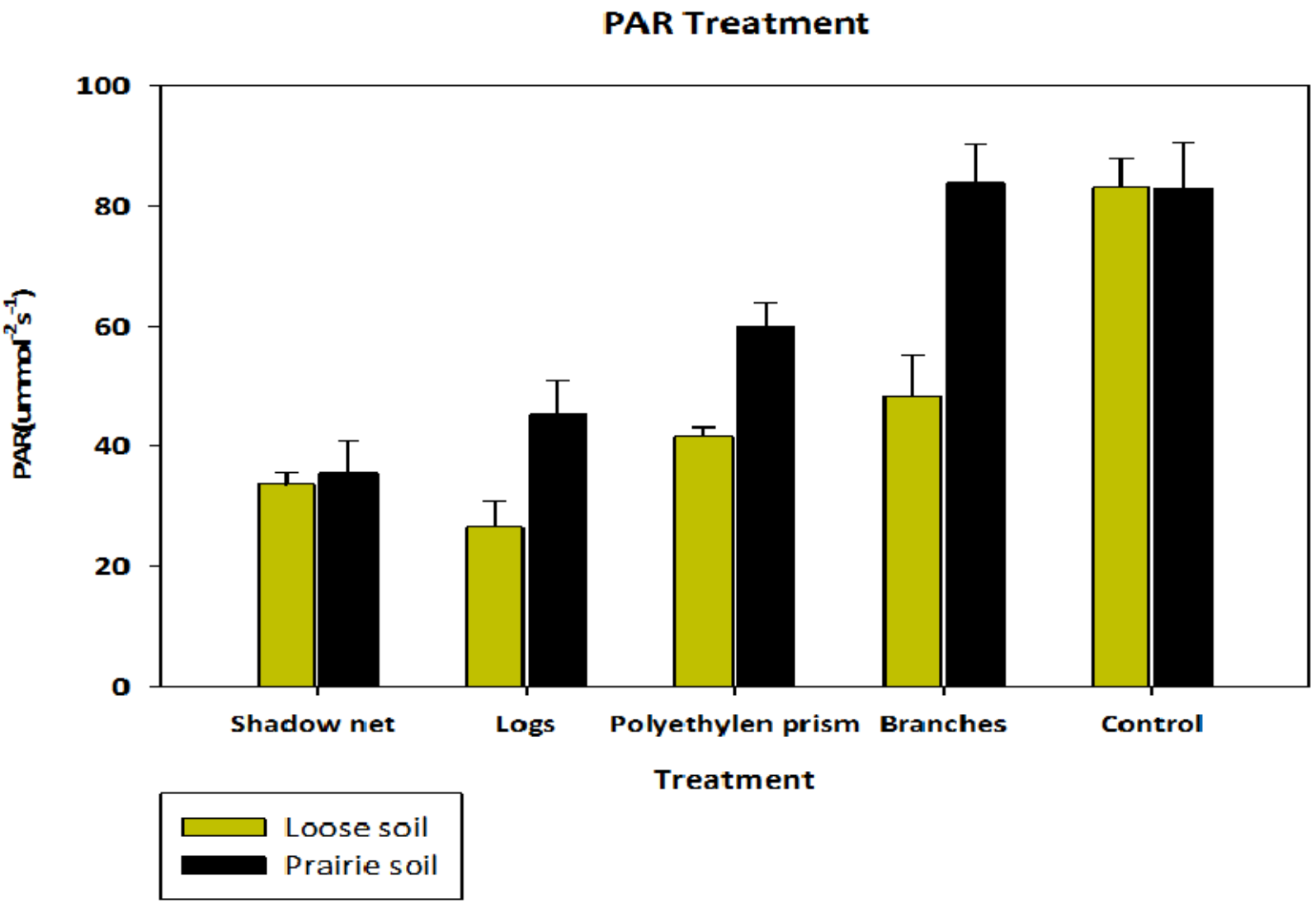


STUDY

TOP SOIL REMOVAL

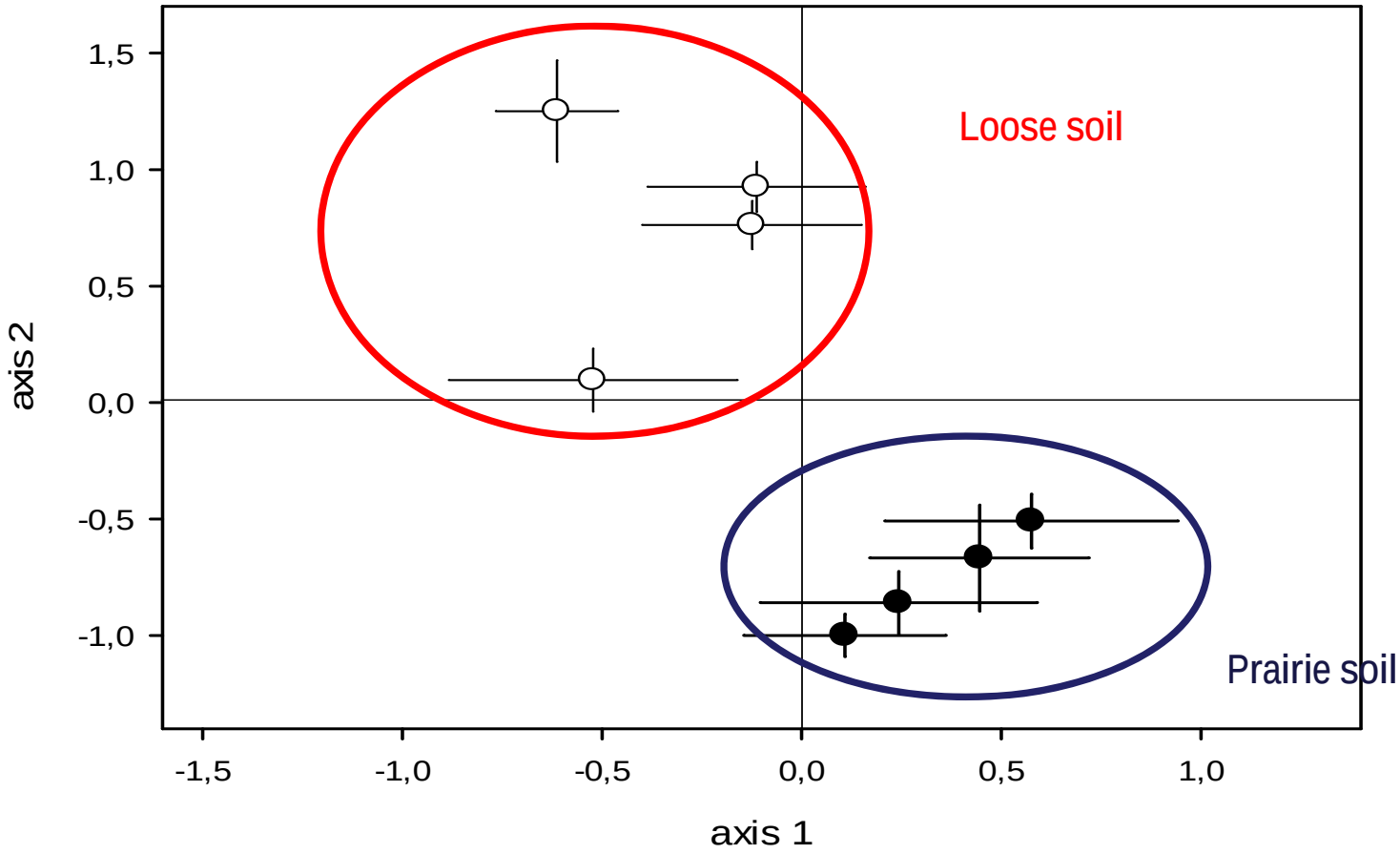
PRAIRE


Soil moisture (%volume H_2O)
25
20
15
10
5
0
a
a
a
a
a
b
b
b
b
b
Loose soil
Prairie soil


PAR Treatment
100
80
60
40
20
0
PAR(ummol-2s-1)
Shadow net
Logs
Polyethylen prism
Branches
Control
Treatment
Loose soil
Prairie soil

RESULTS

-PAR (umolm^{-2}s^{-1})
-Soil Moisture (%vol de H_2O)
-Wind Protection (m/s)

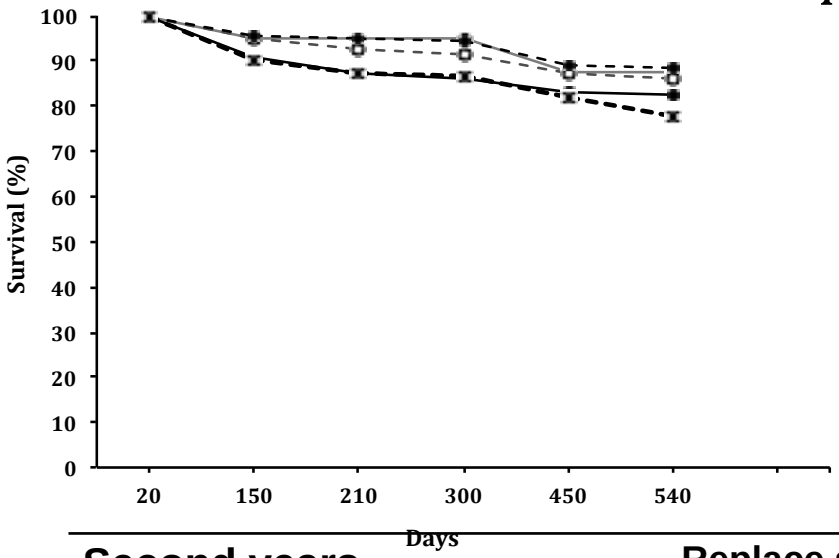


GENERAL SOIL PROPERTIES

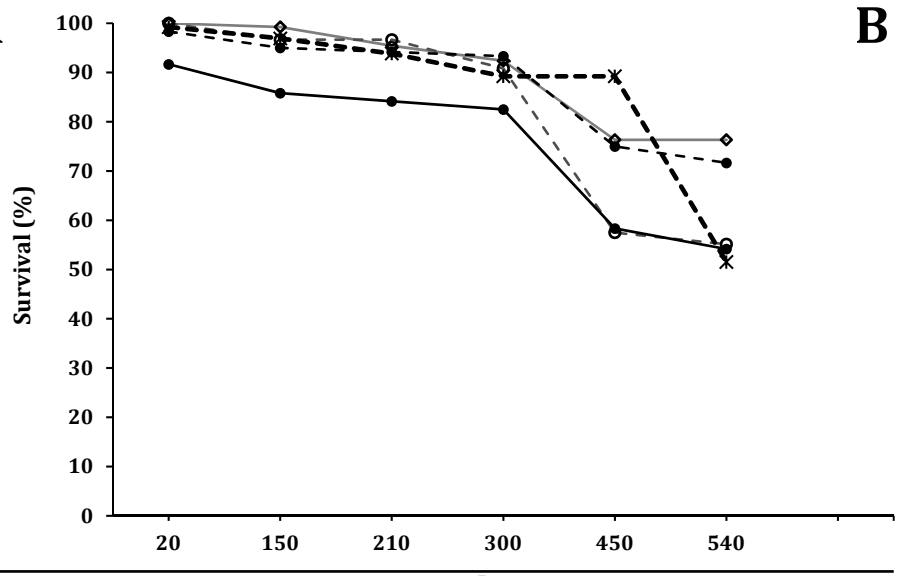
	REFERENCE FOREST	REPLACE SOIL (LS)	Prairie soil (PS)	*P*<0,05
Soil Properties				
K(cm/seg)	0,03(±0,01)	0,008(±0,001)	0,91(±0,01)	0,01*
Compactation (Mpa)	0,44 (±0,060)	0,69 (±0,05)	1,01(±0,078)	**$9{,}77e^{-05}$*** **
Bulk density (gr/cm^3)	0,02(±0.012)	0,08 (±0.025)	0,18 (±0.053)	**$1{,}851e^{-11}$** **

SURVIVAL AFTER 2 YEARS

REPLACE SOIL

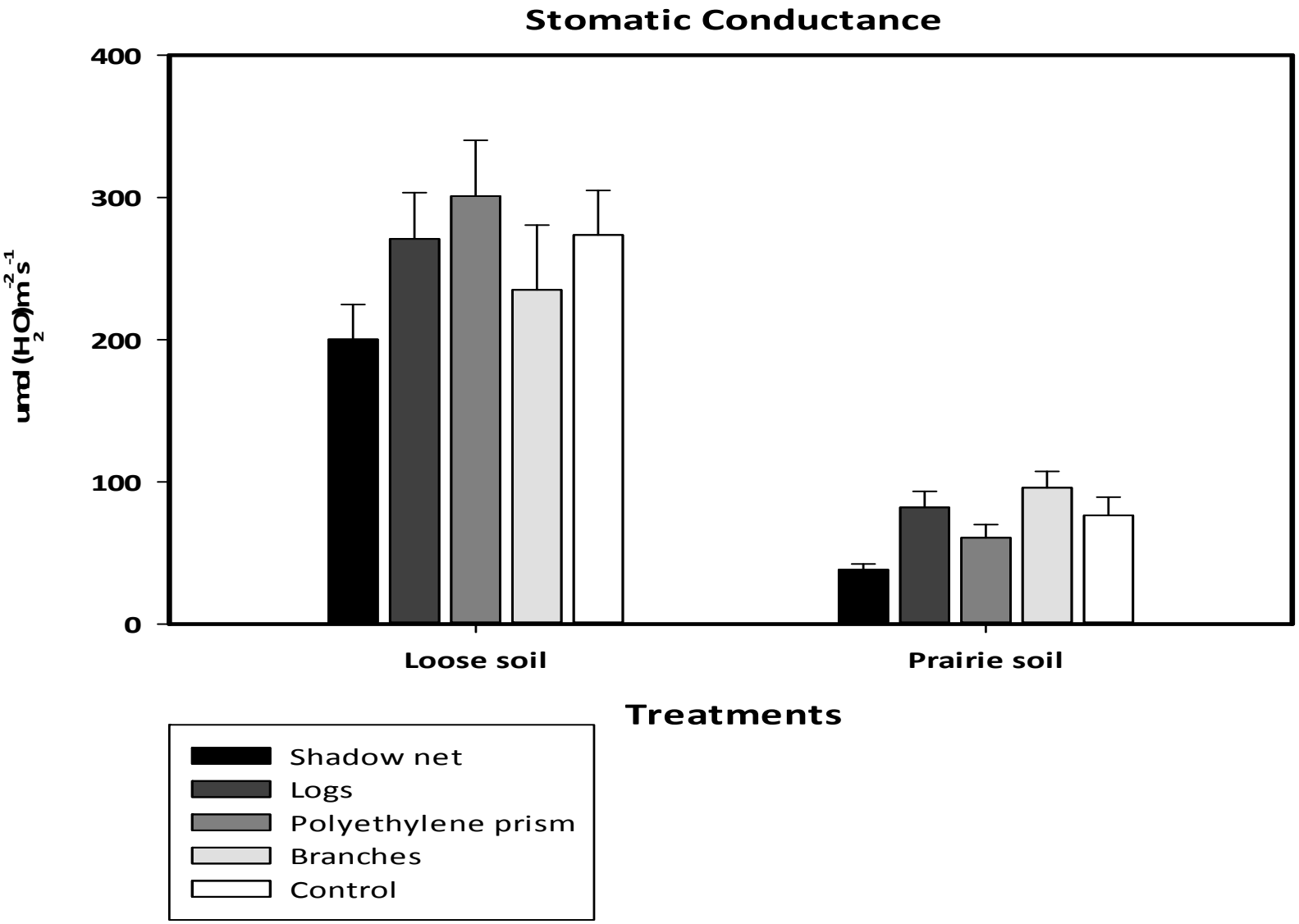


PRAIRE

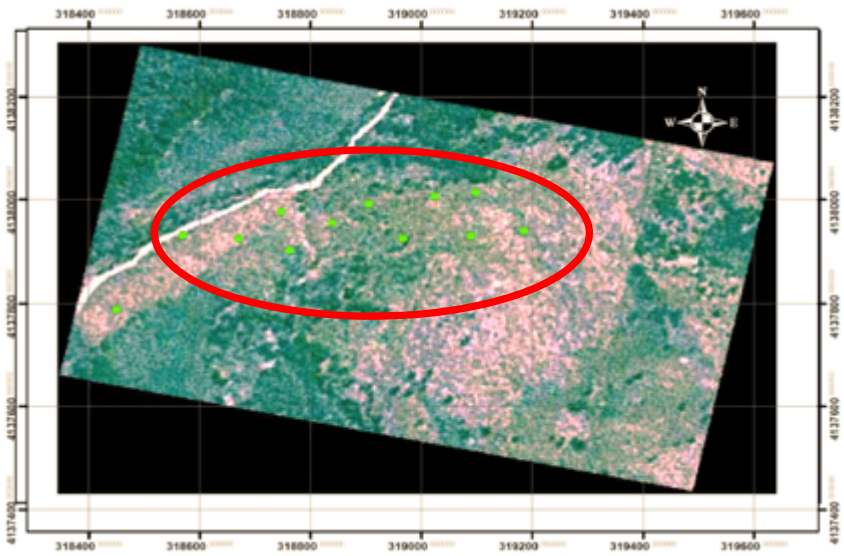


Second years	Replace soil (LS)		Prairie soil (PR)	
	Survival (%)	Mortality (%)	Survival (%)	Mortality (%)
Mesh(M)	86,67	13,33	50,89	49,59
Logs (TR)	89,17	10,83	74,14	25,86
Prism Polyethylene Prism(T)	87,50	12,50	67,09	32,06
Branch(R)	82,50	17,50	59,09	40,91
Control(C)	78,51	21,49	51,94	48,06

SEEDLING STRESS



MICROSITE APPROACH FOR PLANTING



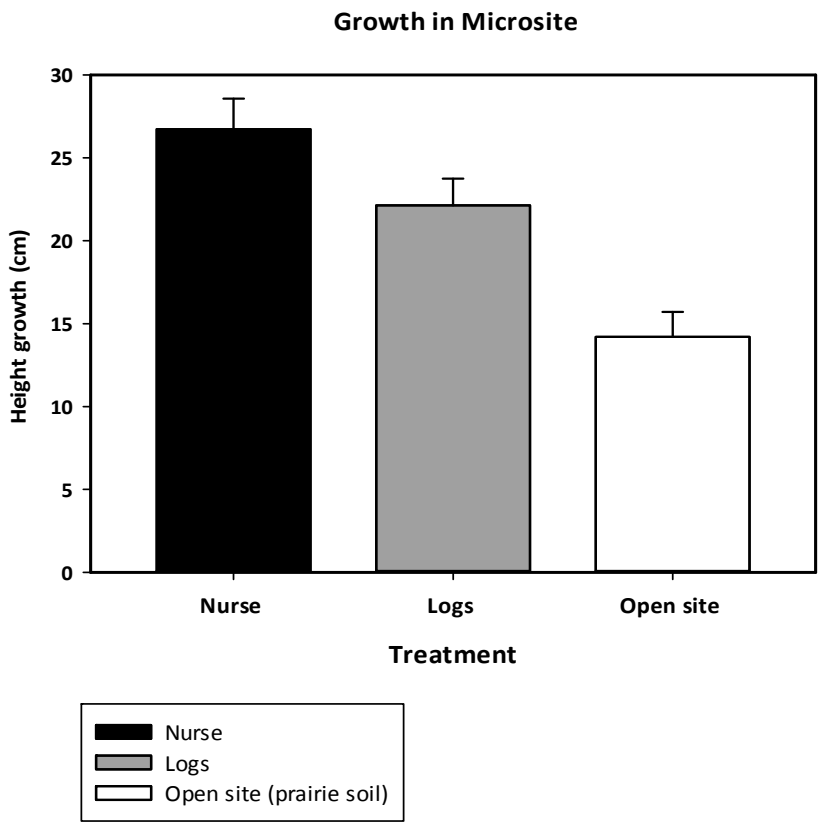
Micrositios

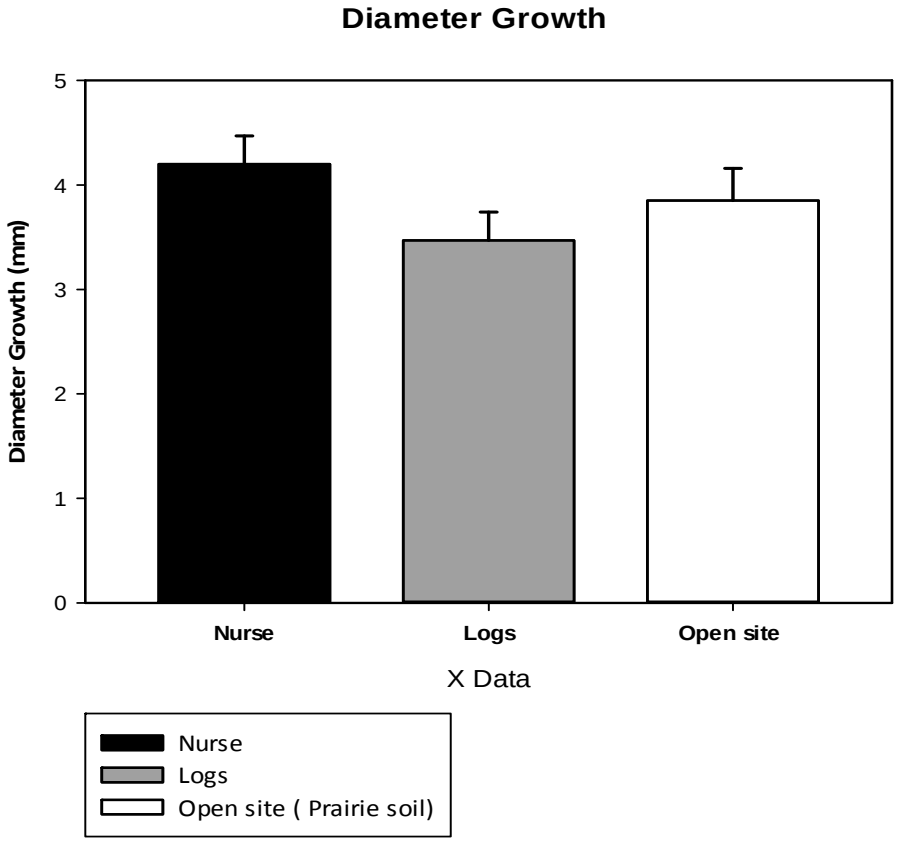
Woody Debris

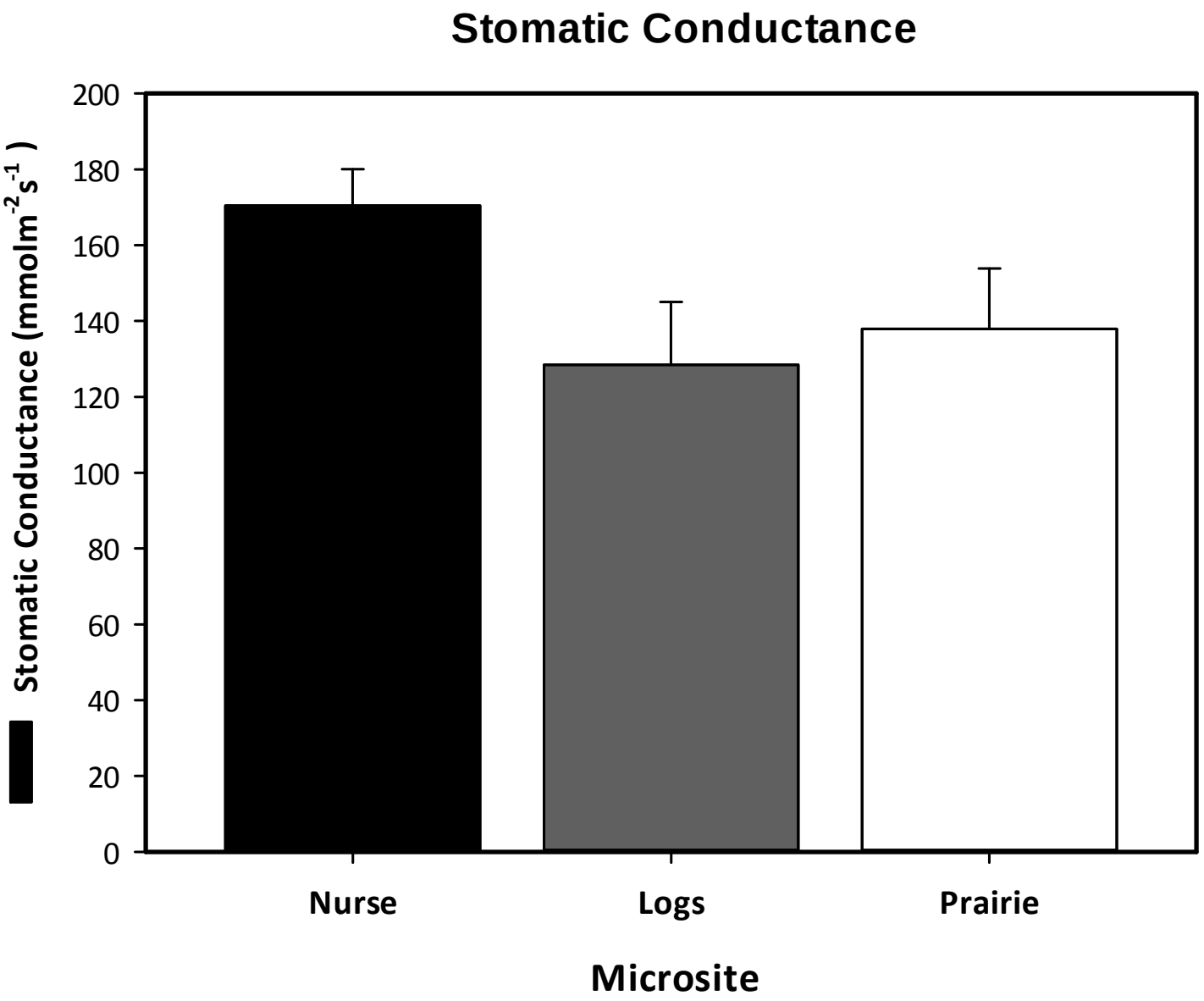
Open areas

Nurse by shrubs

Percentage (%)	Live seedling plant	Death seedlings plant
Nurse	98,43	1,50
Logs	95,8	4,1
Open site (prairie)	81,4	18,6

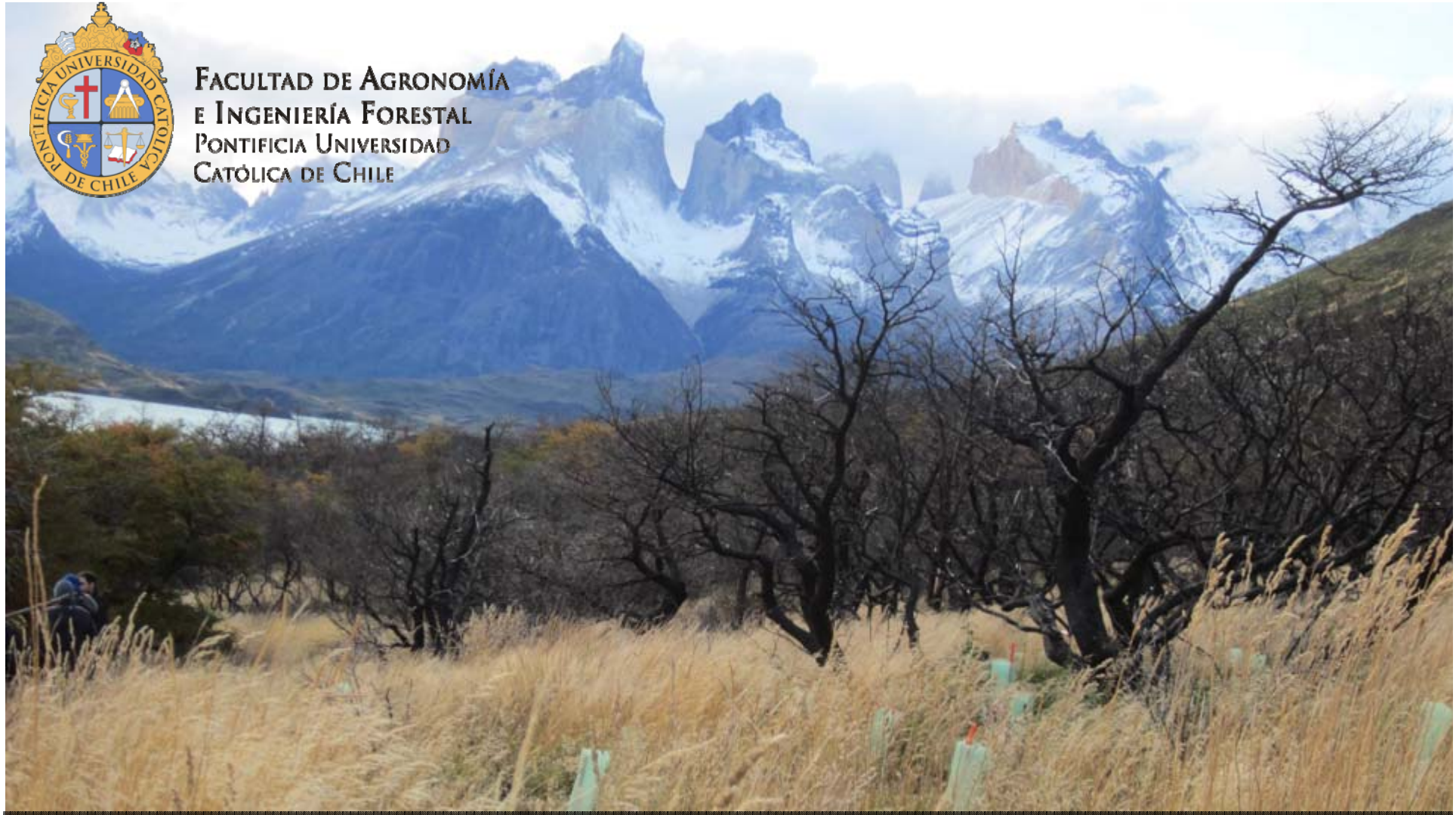





Stomatic Conductance
Stomatic Conductance (mmolm-2s-1)
200
180
160
140
120
100
80
60
40
20
0
Nurse
Logs
Prairie
Microsite

SUMMARY

- The FRA Principales are aplicable for Nothofagus forest in Patagonia
- Top soil replacement increase the chances to reclame coal mine
- Seedlings need to be planted considering the microsite variability
- Soil moisture stress is the key element for reforestation success
- Forest structure and functionality need to be improve



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