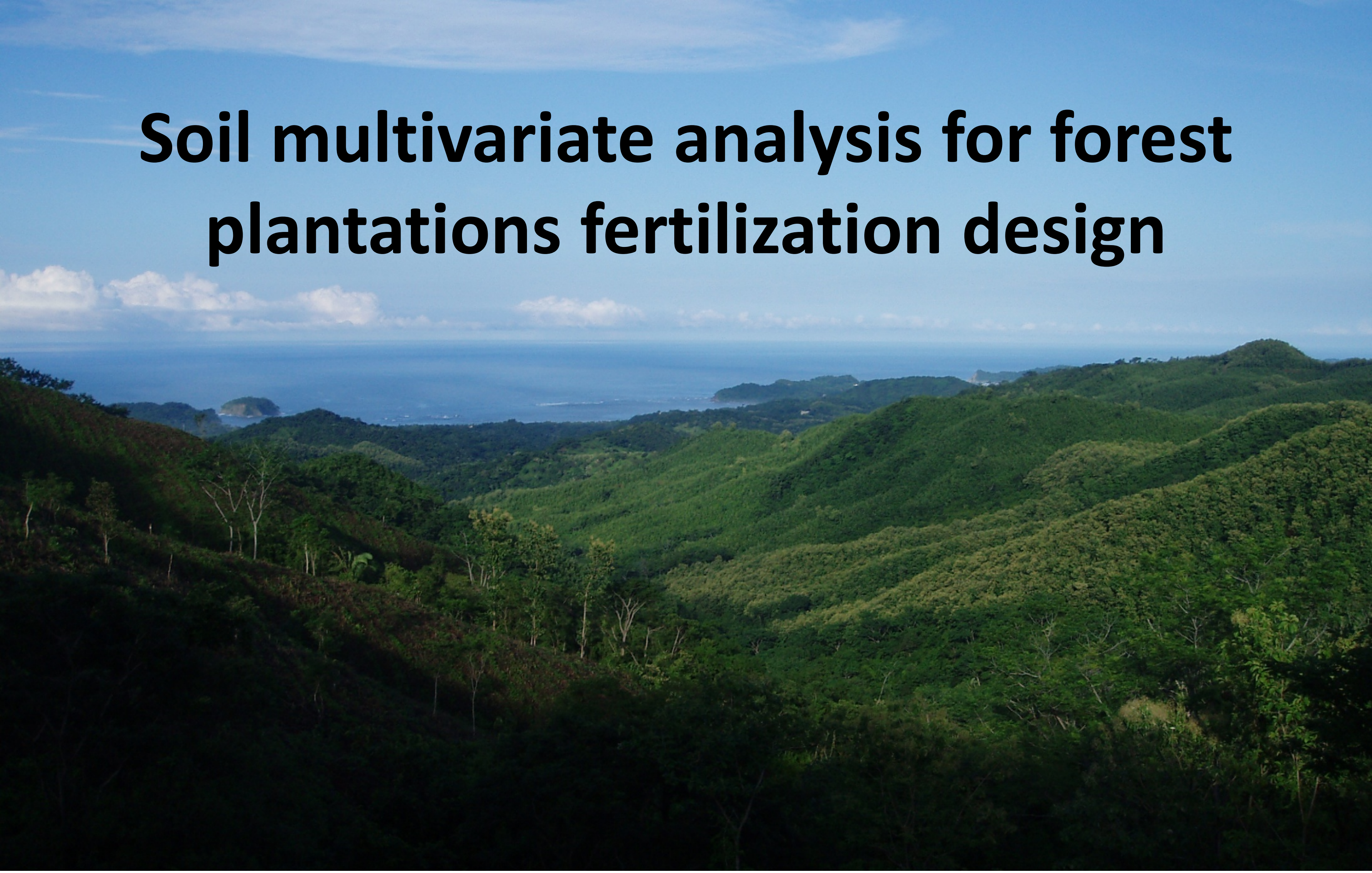
Soil multivariate analysis for forest plantations fertilization design



Nutrient Dynamics of Planted Forests

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CONTENTS

INTRODUCTION

Soil management and forest nutrition

Sustainable timber production (environmental aspects)?

Sustain high productivity (second rotation)

Fertilization

Central America

Common in intensively managed plantations

Low dosage (only 100-150 g at ~~establishment~~)

Correct formula? Usually N-P-K

Needs for other nutrients (Mg and micronutrients: B and Zn)

Much lower than nutrient extraction by timber harvest

INTRODUCTION

Precision agriculture → **Precision forestry**

→ Within-fields soil heterogeneity / fertilization application needs

→ Site-specific management (soil heterogeneity) → Individual stands

→ Nutrient management zones (group of sites) → Groups of stands

INTRODUCTION

Objective

Analyze the capability of multivariate analysis to delineate soil fertility classes

Show the usefulness of this methodology aiming a more detailed nutritional management of forest plantations

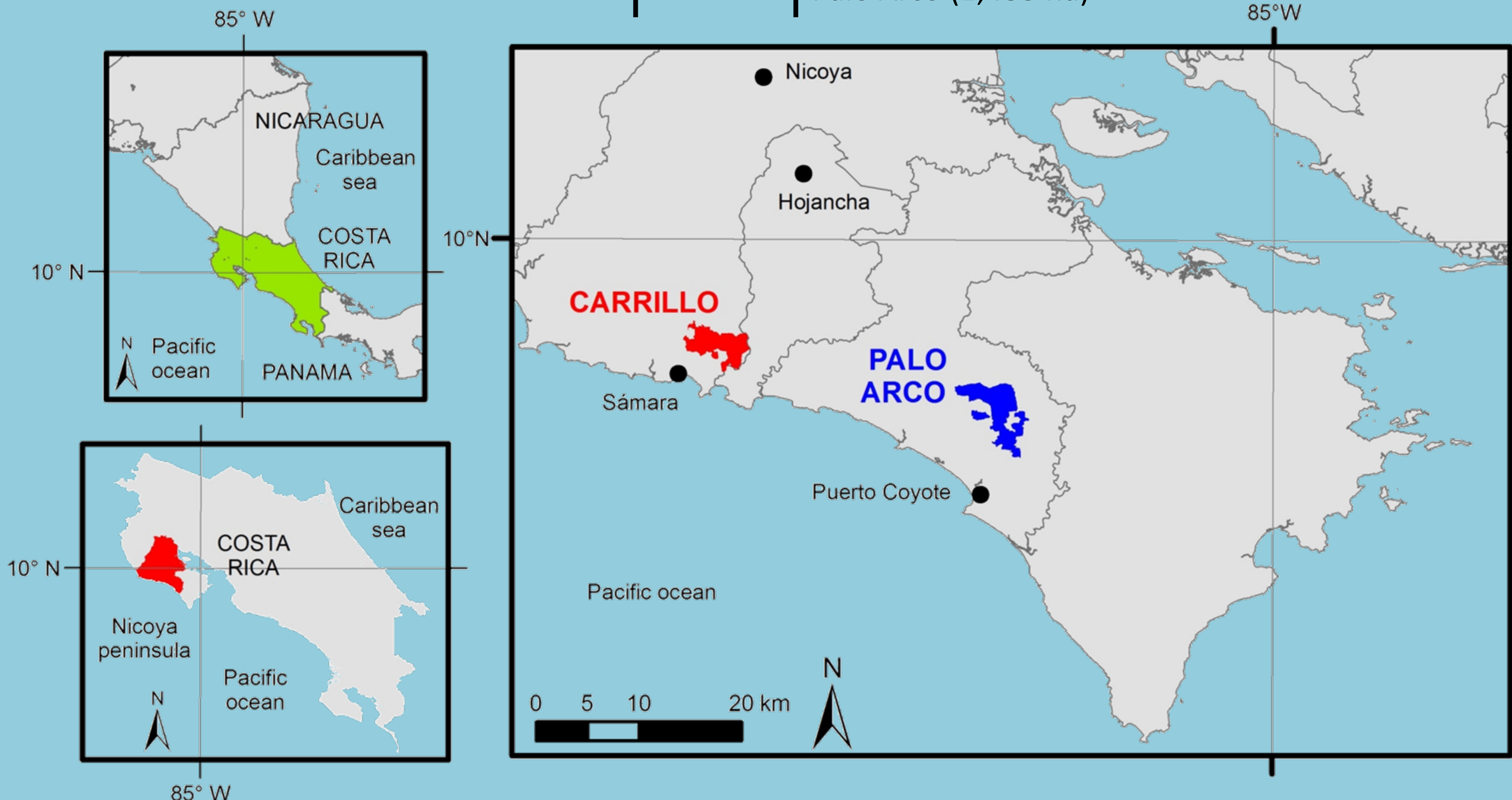
MATERIAL AND METHODS

MATERIAL AND METHODS

Study area

Panamerican Woods Ltd. → Teak (*Tectona grandis* L.f.) plantations

2 fields:
- Carrillo (1,040 ha)
- Palo Arco (1,488 ha)



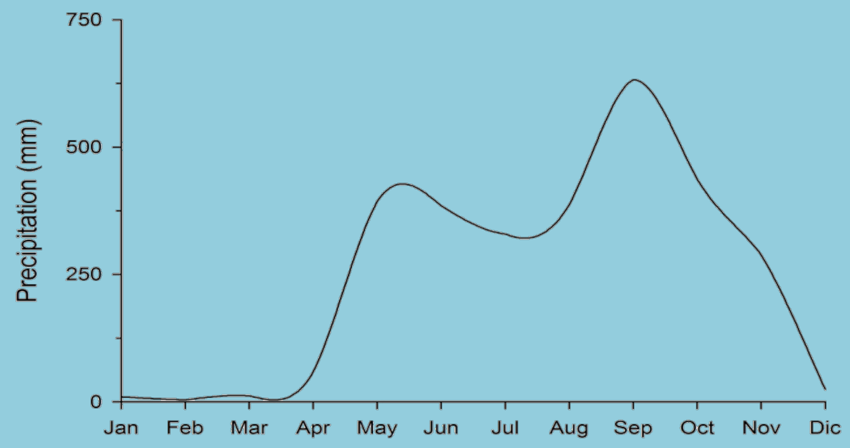
MATERIAL AND METHODS

Study area

Climate → Tropical wet forests

2,500 mm yr^{-1}

4 – 6 dry months



Soil

General: Fertile, reddish and clayey

- Carrillo: Typic Rhodustalfs mixed with Typic Dystrustepts
- Palo Arco: Typic Haploustalfs mixed with Vertic Haploustepts

Panamerican Woods soil database

195 topsoil (0-20 cm) fertility samples across all the different stands

pH, exchangeable Ca, Mg, K, ECEC, P, Fe, Cu, Zn, Mn and acidity (Olsen-KCl method)

MATERIAL AND METHODS

Teak plantations in Central America

150,000 ha in Central and South America
- 55.000 ha in Panama (9th country in the world)
- 31.500 ha in Costa Rica

High growth rates and short rotation period
- Search for high soil fertility sites
- Big investments (big companies)
- Intensive management
- High rates of nutrient extraction by timber harvest

Region	MAI (m^3/ha/yr)		Rotation period (yrs)	
	Min	Max	Min	Max
Africa (7)	3	21	4	60
Asia (5)	2	14	20	80
Caribbean (3)	3	12	20	65
Centr. America (5)	5	30	6	30
Oceania (2)	5	12	20	30
South America (4)	10	27	20	30
World (26)	**2**	**30**	**4**	**80**

MATERIAL AND METHODS

Statistical multivariate analysis

Objective: simplify the data

- Ordination methods: graphic representation of similarities between plot points
  - Principal Component Analysis (PCA)
  - Non-metric MultiDimensional Scaling (NMDS)
- Classification methods: grouping of similar samples into discrete classes
  - Cluster analysis

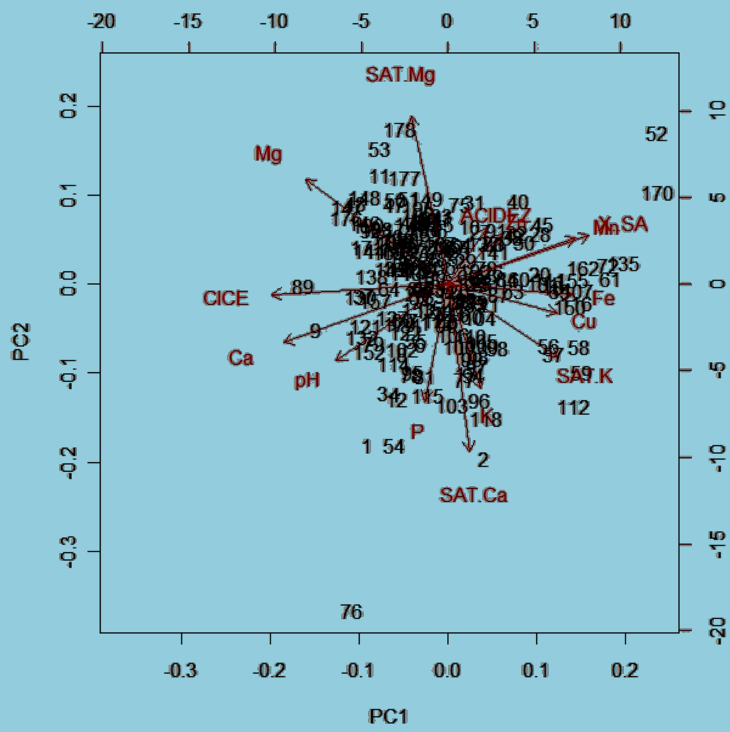
Data transformation

Variables centered with the mean and standardized with the standard deviation

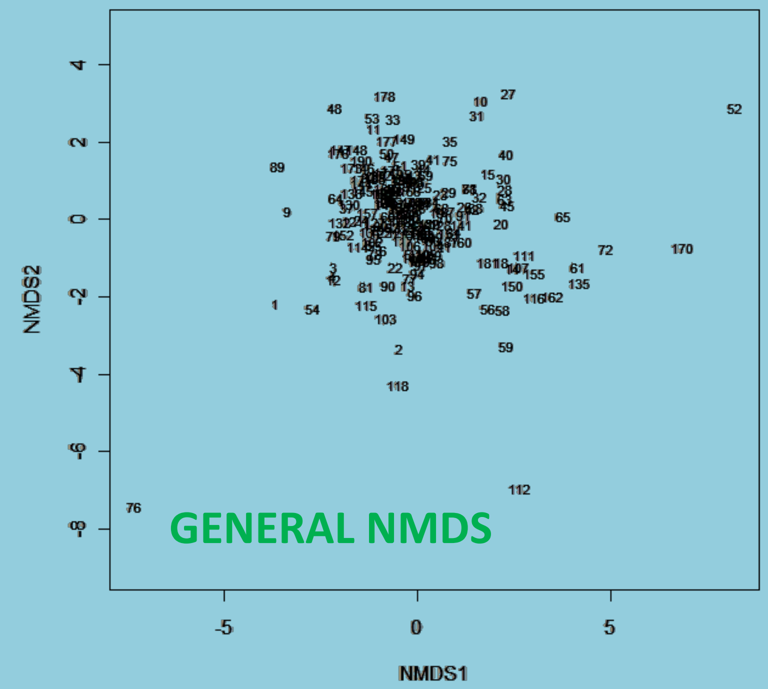
Type of analysis	Origin of the data	Number of samples	Name	Number of groups	Reference for centering
PCA	General	195	G-PCA	—	average
				—	critical value
NMDS	General	195	G-NMDS	—	average
				—	critical value
	Carrillo	75	C-NMDS	—	average
				—	critical value
	Palo Arco	120	PA-NMDS	—	average
				—	critical value
Cluster	General	195	G-2	2	average critical value
			G-3	3	average critical value
			G-4	4	average critical value
			G-5	5	average critical value
			G-6	6	average critical value
	Carrillo	75	C-2	2	average critical value
			C-3	3	average critical value
	Palo Arco	120	PA-2	2	average critical value
			PA-3	3	average critical value


RESULTS AND DISCUSSION

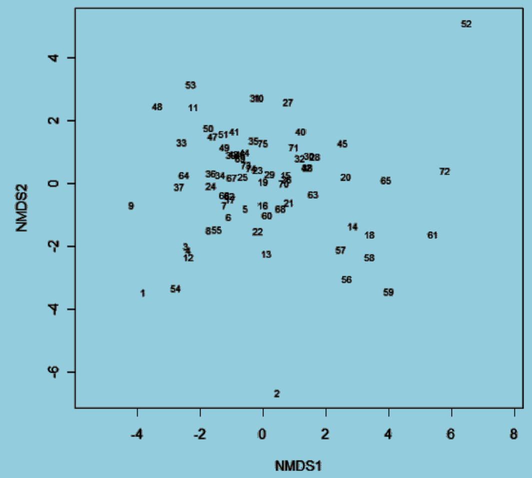
	Group	Average CV (%)	Δ average CV (%)	Number of soil samples in the group
Null hypothesis (no-grouping)		66.8	----	195
Grouping by plantation	Carrillo	66.5	-0.4	75
	Palo Arco	58.3	-12.7	120
G-2	Group 1	60.2	-10.5	158
	Group 2	56.2	-9.7	37
G-3	Group 1	55.8	-14.1	157
	Group 2	56.2	-9.7	37
	Group 3	---	---	1
G-4	Group 1	60.2	-10.5	157
	Group 2	52.3	-17.4	35
	Group 3	51.8	-22.5*	2
	Group 4	---	---	1
G-5	Group 1	60.2	-10.5	157
	Group 2	40.2	**-40.9****	19
	Group 3	38.2	**-36.6****	16
	Group 4	51.8	-22.5*	2
	Group 5	---	---	1
G-6	Group 1	35.7	**-45.5****	5
	Group 2	40.2	**-40.9****	19
	Group 3	55.0	-17.7	152
	Group 4	38.2	**-36.6****	16
	Group 5	51.8	-22.5*	2
	Group 6	---	---	1
C-2	Group 1	-2.8	-2.7	74
	Group 2	---	---	1
C-3	Group 1	-19.2	-16.3	42
	Group 2	-17.9	-21.4*	32
	Group 3	---	---	1
PA-2	Group 1	-14.0	-26.8*	110
	Group 2	-13.3	-29.0*	10
PA-3	Group 1	---	---	1
	Group 2	-17.4	-31.4*	109
	Group 3	-13.3	-29.0*	10



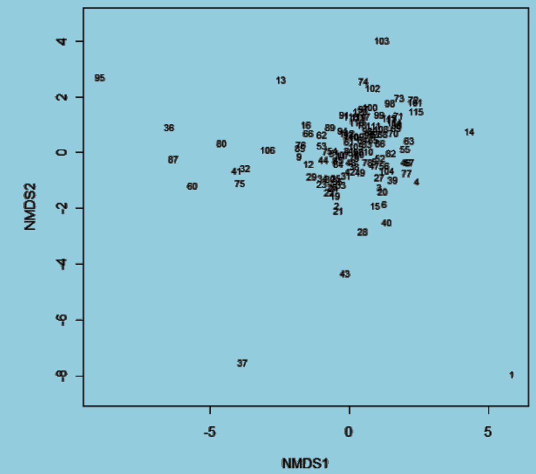
GENERAL PCA

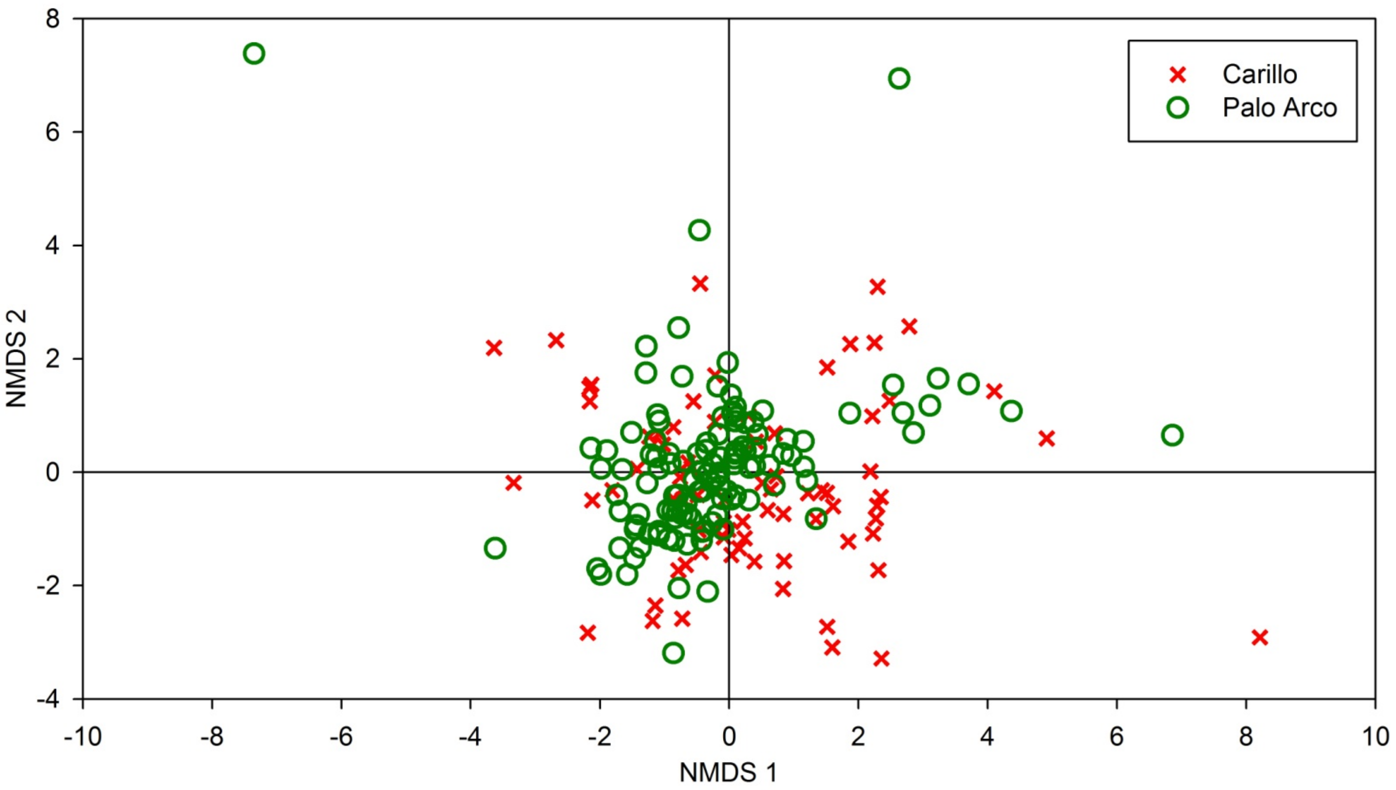


CARRILLO

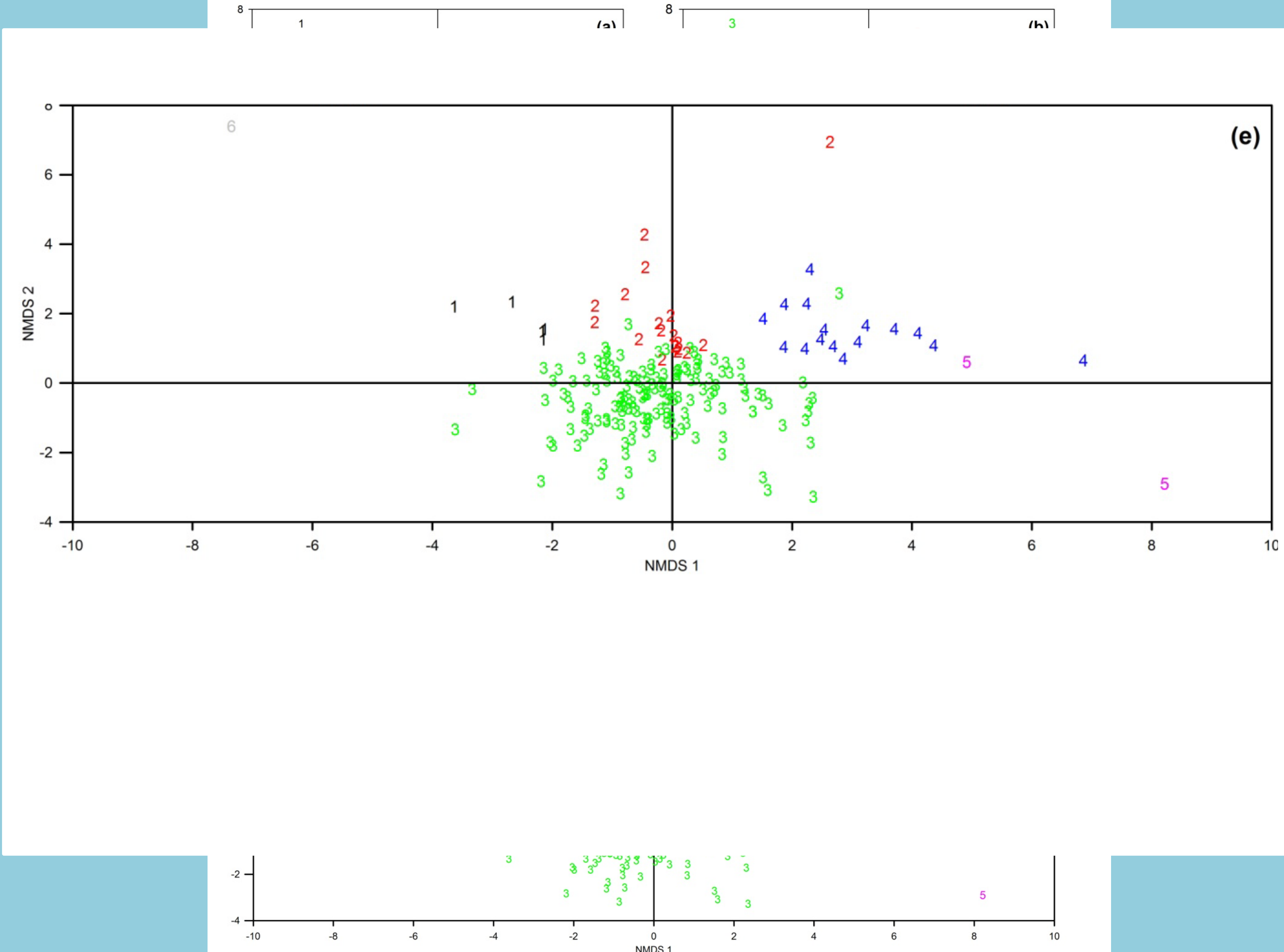


PALO ARCO





8
6
4
2
0
-2
-4
NMDS 2
-10
-8
-6
-4
-2
0
2
4
6
8
10
NMDS 1
Carillo
Palo Arco


(a)
(b)
(e)
NMDS 2
NMDS 1

Mean soil data → P deficiency

Multivariate analysis of soil data

Deficiencies

Group 1 → P, K, Fe and Zn

Groups 4 & 5 → P and K (low pH)

Group 3 → P and K

Group 6 → No deficiencies

Group 2 → P

CONCLUSIONS

Cluster analysis → **Grouping soil samples (soil fertility classes)** → design a fertilization plan for each group of stands of relatively homogeneous soil fertility

NMDS → useful complementary tool for graphically exploring

- similarities within groups of soil samples
- differences between those sample groups

Multivariate analysis provides forest nutrition and soil fertility managers with techniques to classify soil groups by integrating a large number of variables, such as micronutrient concentration values, from across a large number of soil samples.

By designing forest fertilization plans for groups of stands, where each group comprises stands with homogeneous soil fertility properties, fertilizer deployment can therefore be implemented with much greater efficiency and productivity

Other related works and research lines

Soil multivariate analysis for forest plantations fertilization design

Nutrient concentration age dynamics of teak plantations in Central America

Nutrient accumulation and export in teak plantations in Central America

Seasonal variation of nutrient concentration in timber of teak plantations: implications sustainable forest management

Fertilization of teak planted forests along a 11 years chronosequence in Costa Rica

Response of 20 year old teak plantations to fertilization

Nutrition of teak plantations in Panama: critical reference values for foliar nutrient concentrations

Use of machine learning techniques to establish a methodology for land evaluation and site selection for teak plantations in Central America

Effects of teak plantations over soil hydrological properties

- Erosion
- Soil hydraulics (Ksat, porosity, infiltration)

FOREST NUTRITION IN PLANTATIONS WITH OTHER SPECIES

Nutrient concentration, accumulation and export in *Termianlia amazonia* (J.F. Gmel.) Exell] plantations

Nutrient concentration, accumulation and export plantations of other native species

USE OF NEW TECHNOLGIES TO EVALUATE AND MANAGE SOIL RESOURCES IN FOREST PLANTATIONS

At the moment: multivariate statistics and tree-regression (machine learning)

Use of remote sensing to evaluate forest nutrition

Use of geostatistics and digital soil mapping techniques for land evaluation and site selection for forest plantations


Thank you very much
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