
Food and Agriculture Organization of the United Nations
GLOSOLAN
Soil spectroscopy training workshops
The Brazilian Soil Spectral Library Experience from Scientific to Society Services
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Geocis Group
Online webinars
BRAZIL
2021
GLOBAL SOIL PARTNERSHIP

A: Contextualization

A1: Science and Food Production

Prof. José Luiz Demattê, Pedologist
University of São Paulo (Retired)

Along his life, the base for productivity was to know soil types

Inside this complex, the main Engine is mineralogy

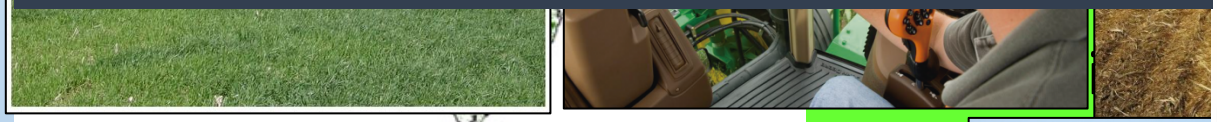
His Merit, was to Put Pedology for soil management and Food Production

Evolution
From Pedology-Pedometrics-Spectroscopy
For Food Production

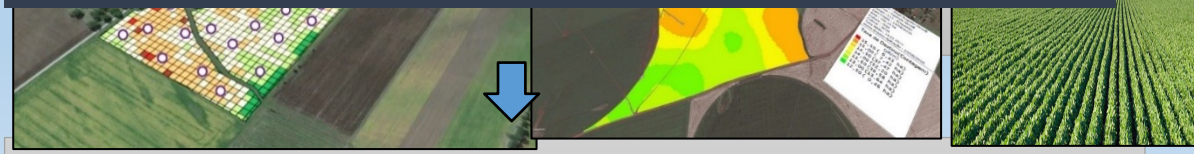
Basic Information
Soils analysis!

Ask for Soil nutrient analysis…….

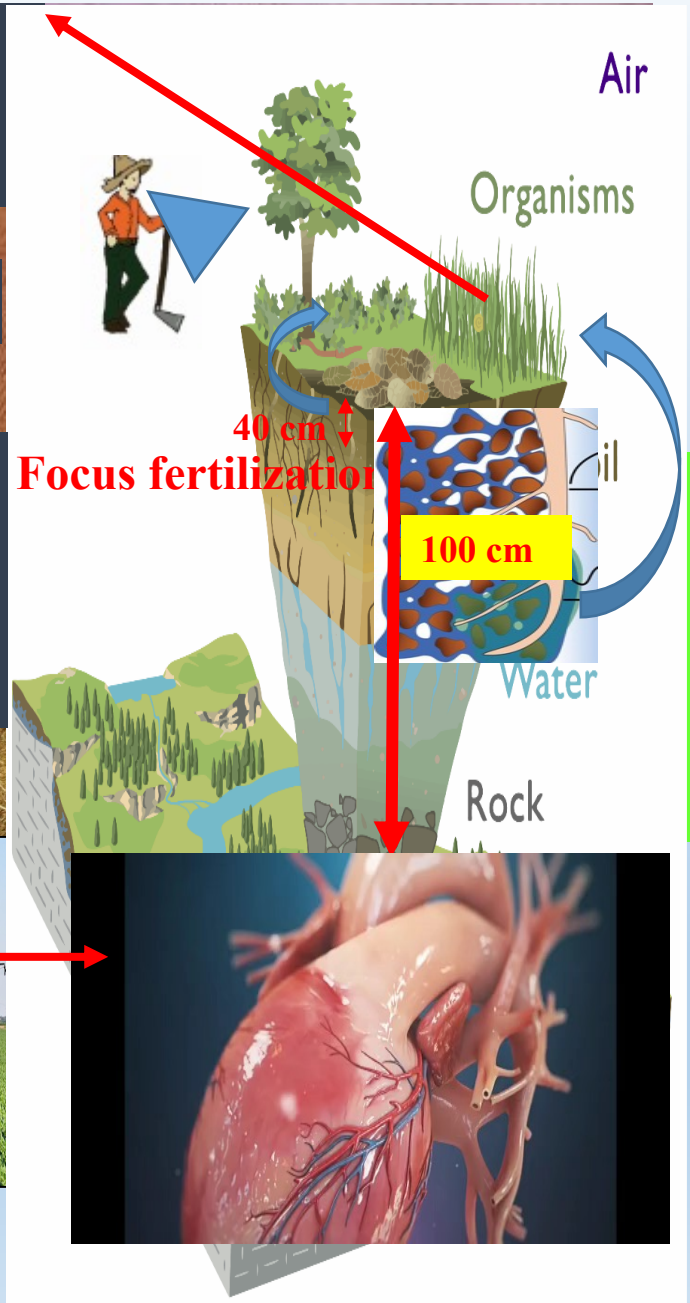
Its dynamics needs texture, carbon, mineralogy and depth to be understood……



In fact, Soil function as a complex organism

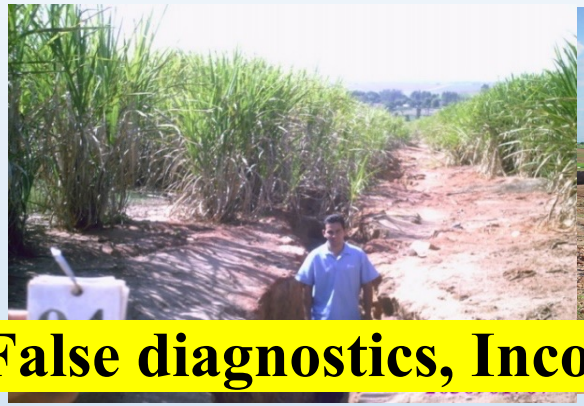


Numbers indicate that, to help to sustain the worlds needs, Brazil will have to produce 20% more after all area be used



A3: The consequence when user do not know how soil function

Why do still keep focus on fertilizer?



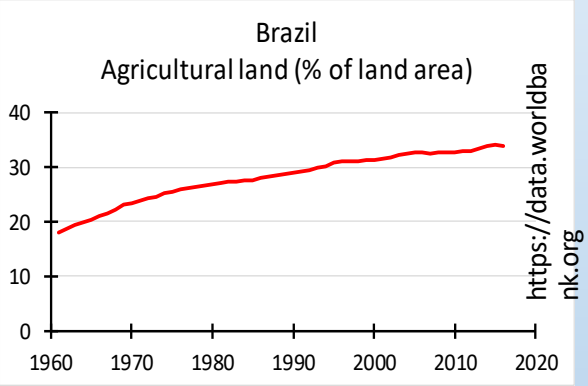
Degradation = False diagnostics, Incorrect management

A4: The basic information: Soil Analysis

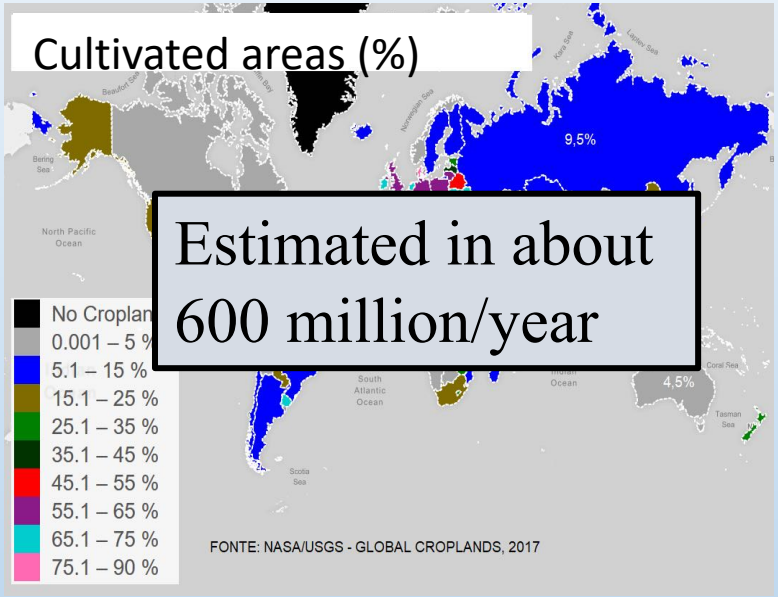
Number of Soil Analysis

Brazil

Estimated in about
6.000.000 per year



World Demand?



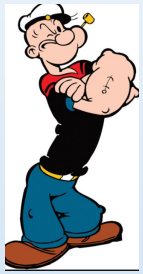
Estimated in about
600 million/year

Can we keep the demand with enrironmental quality?

Will we have the natural resources for wet analysis?

A5: The Solution = Spectroscopy

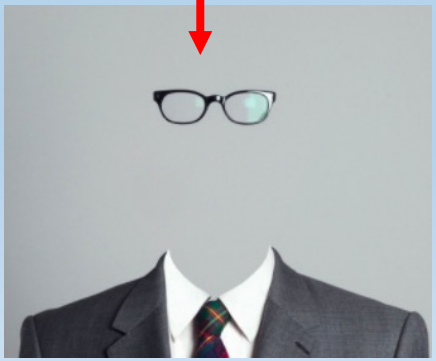
Spectroscopy is a Quick, easy and clean method for soil analysis



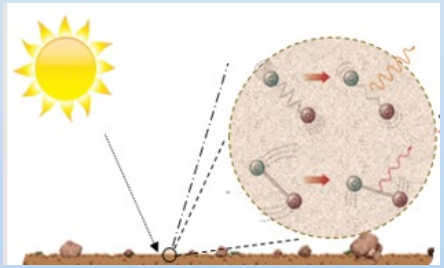
It is a Physical detection
Strong scientific background

But it is ´An Invisible Information´
(Spectroscopy Technique)

You cannot see



How to explain?



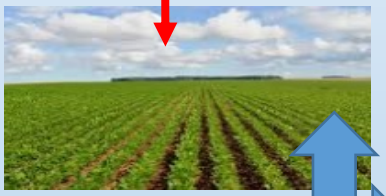
This you can see!

A6: Make it visible:
Reaching Spectroscopy From Field Experience


















Human Learning

Human Decision

Machine Learning

Soil spectroscopy

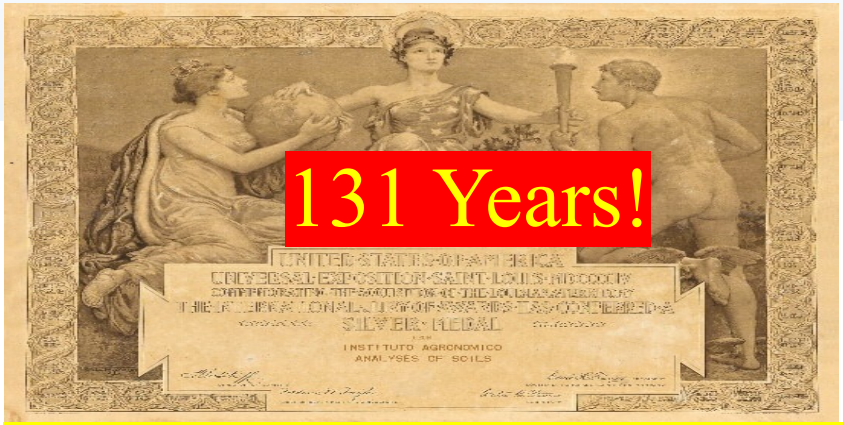
Goal:

Develop the first Brazilian Soil Spectral Library (BSSL) and show its relationship with soil properties

- ✓ Point: Despite the technique present Strong background it Still remains in the scientific field

Why?

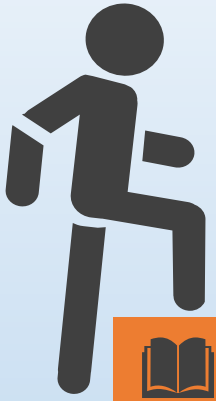
B2: Detect who were the key Regulators



First document Brazil on soil analysis was in 1889

Wet laboratories Experience

B3: Plan-Three Steps to reach society (took 25 years..rsrsrs)



Demonstration

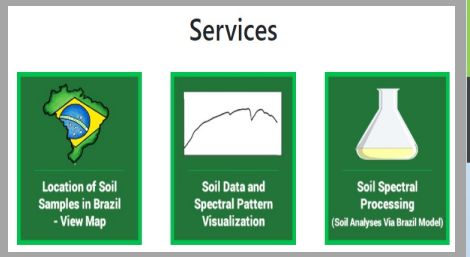
1995-2013

For scientists

Teaching

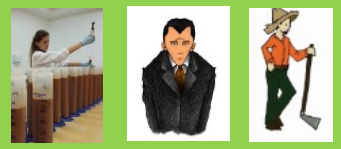
2017-2021

Service-Practice



2021-2023

Real Use



2023-

For regulators (Show the previous Paper): It works!

Scientists

Society (Users)

B4: Convince scientists to participate on the BSSL

Describe the importance by boletins, papers, lectures, mails, phone calls! This is new!

Show what we already did since 1993!

The Pedologists were the most critical Communities:

Action! I invited a retired awarded respected Pedologist, Igo Lepch, to be part of the team. He stould 1 year and saw in close. Afterwards helped to spread the knowledge!

and Soil Nutrition, Precision Agriculture,

The Scientific Fertility Community:
I promised a course to normalize noise

Support of The Brazilian Digital Soil Mapping Group (Dra. Maria de Lourdes Mendonça)

B5: Put to work!

Make it simple

No contract, no institutional participation, only the main researchers

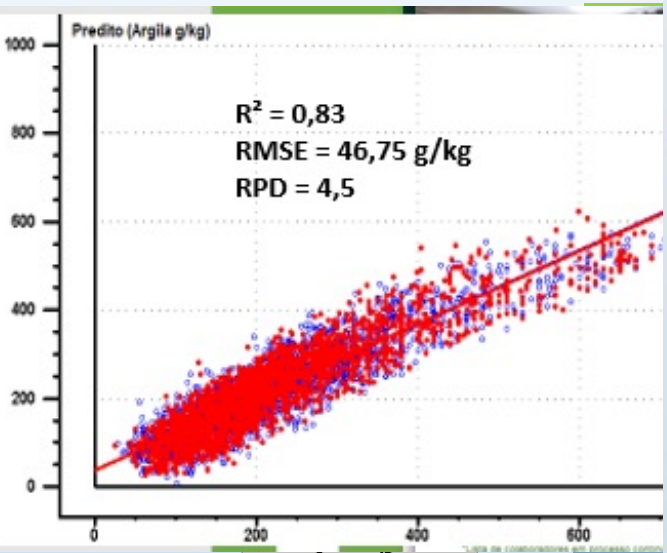
Key = Trust + low cost + you give you gain all gain

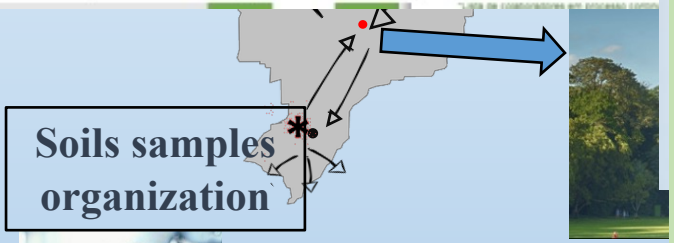
1- Put the Key persons to spread the BSSL around the country!

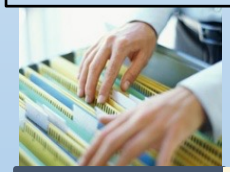
2- Almost nobody had equipment! We make all spectroscopy for you!

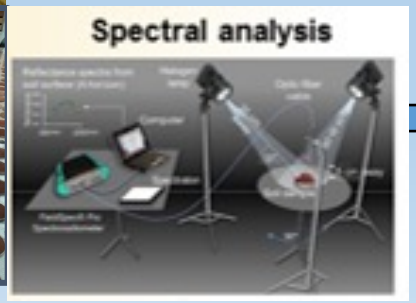
3- You can send students and we teach them!

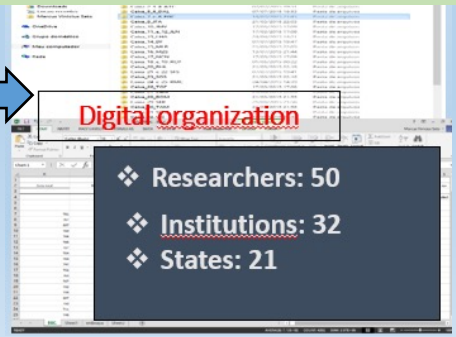
B6: BSSL flowchart and impacts











Impact

1-New groups were created

2-Without disclose data, Encourage effective participation

3- External Users can get in contact and reach the dataset

4- Young students got on-board…..Pedologists as well

B7: History of Teaching for Society

- Traditional labs have years of experience and domain of the users
- Although, society starts pressure along use of residues mostly for organic matter which will be prohibited

Regulators

840,000 kg of dichromate and ammonium Fe sulfate

toxic chemical

Annual expenditure of US$ 2.5 million

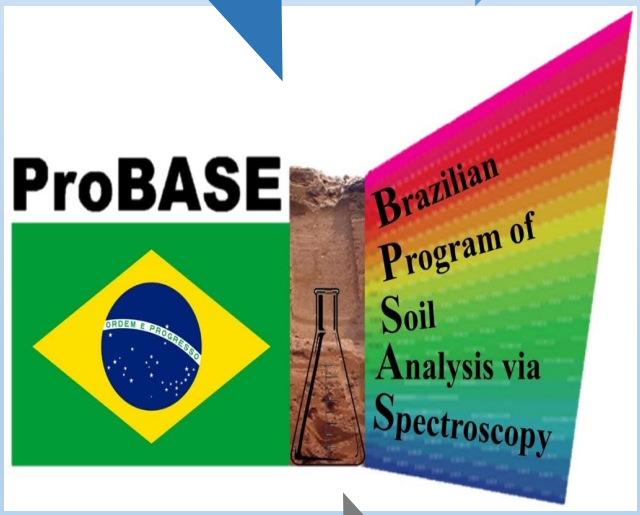
Traditional analysis OM cost (US$ 5.00 per sample)

- Along 2016, some companies inserted in the market sensors to make soil analysis
- The promise: would analyse sand, silt, clay, CEC, pH, OM, Ca, Mg, K, P, Na..micronutrients
- This shocked traditional wet laboratory community (About 400). Is it our end????? What should I do?
- Farmers and researchers were also surprised
- To normalize communication using science, we created the Brazilian Program of Soil Analysis via Spectroscopy

Rule: Only Wet Laboratories, the seed!

Step 1: Understanding fundamental on Vis-NIR and discuss results

Predict attributes



Via Spectroscopy

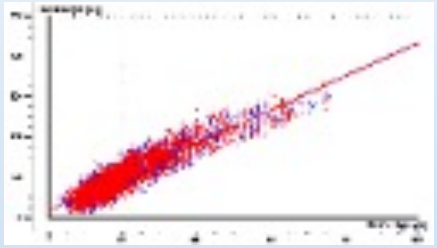
Step 2: All types of ranges

Step 3: Make the link with remote sensing and Agriculture applications

B8: The ProBASE (Brazilian Program on Soil Analysis via Spectroscopy)

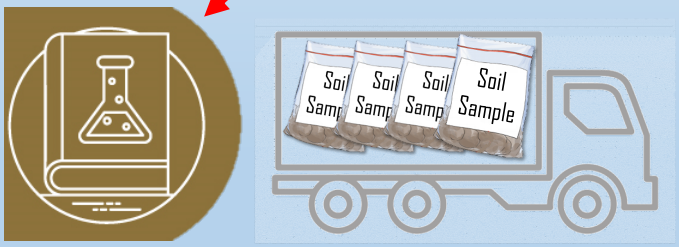
Russia

- GeoCiS contacted LABORATORIES (via telephone, conferences, lectures in centers of excellence, BSSL presentation)



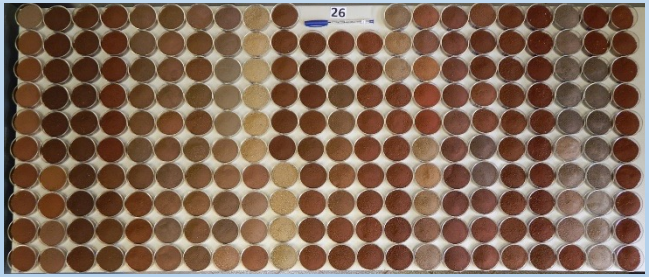
-Obtention of prediction models:
i) by laboratory (200 samples)
ii) All population (7200 samples)

-Samples scanned with NIR, MIR and FRX



-Each LAB sent (in September 2018) ~200 air-dried soil samples

-Samples arrived at ESALQ



-Each LAB receives a code (from 1 to 36)
-Samples organized by LAB and stored at GeoCiS.

Brazilian Program of Soil Analysis via Spectroscopy (ProBASE)

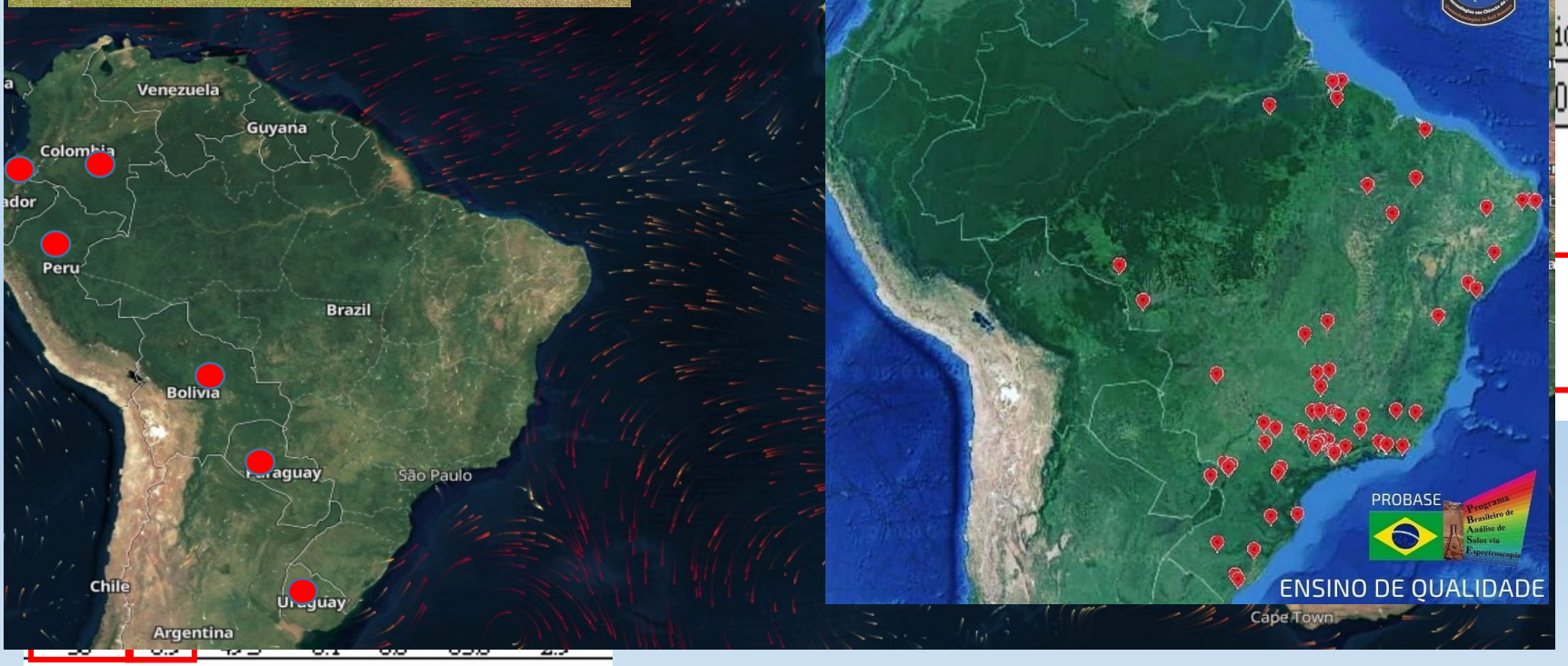
(1) 5 months later LAB's came to USP to participate in theoretical and practical classes.

(2) The data were presented and they met a spectral laboratory

Brazilian Program of Soil Analysis via Spectroscopy (ProBASE)

The results were presented showing only the laboratory code.

Local models were



	idation set	
	0.5 - 0.8	> 0.8
	25	50
	25	0
	50	25
	0	0

Brazilian Program of Soil Analysis via Spectroscopy (ProBASE)

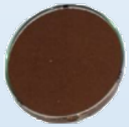
Impact

- The community's first impact on the exposure of sensor equipment launched on a national chain that would replace laboratory analyzes was now normalized
- After the course, there was a complete demystification of magic spectroscopy and we were able to concentrate on real and documented data
- They understood that spectroscopy is laboratory-dependent
- Now they are going through the questioning process to understand and insert spectroscopy into the traditional laboratory system
- The main Regional Soil Quality Regulators started to insert the spectroscopy discipline

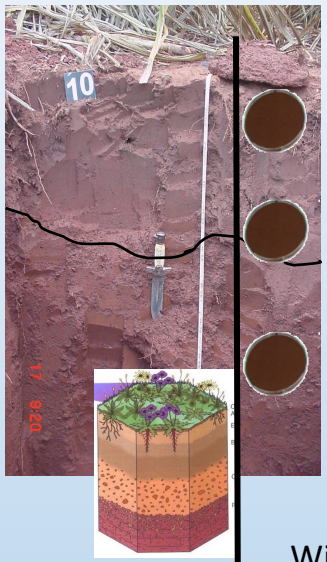
C: Step 3: The online Service - Brazilian Experience

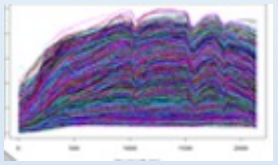
Inside the Box

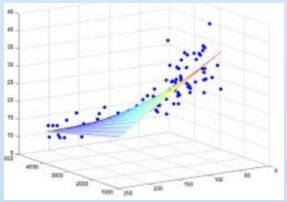
Backend



A single sample indicating the depth







With soil classification

Front end

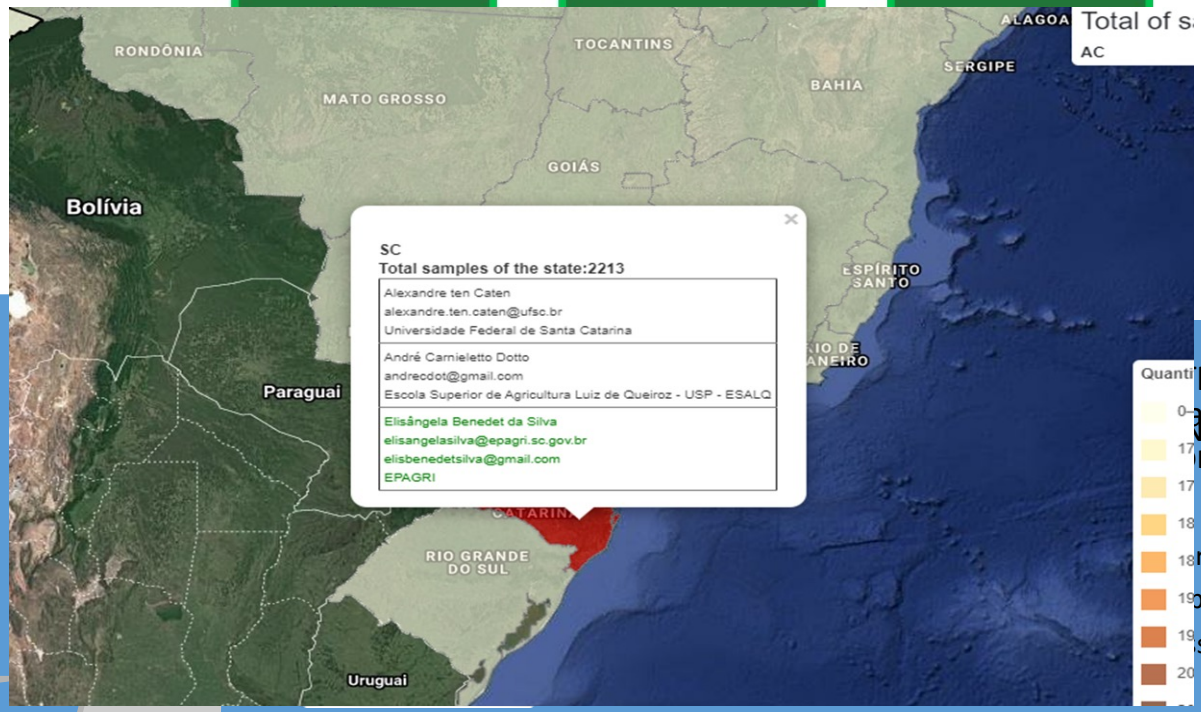
Options to see spectra

SERVER Besbbr.com.br

The on-line Map of collaborators Soil Spectral Library

Services

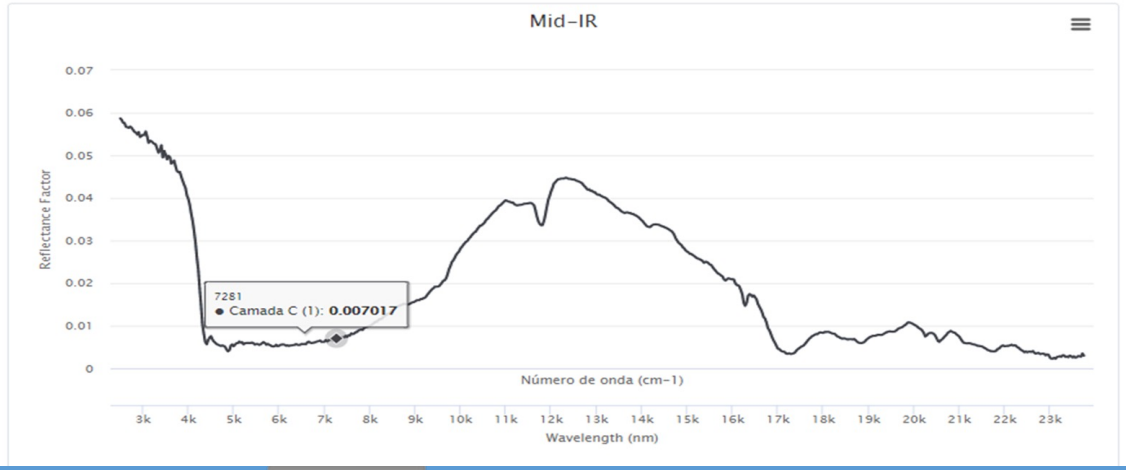
Data can be depict by contacting the researcher and make joint works!



Vis-NIR and MIR Library

Analysis

State: **Rio de Janeiro**; Layer: **C**; Texture: **Sandy loam**



cation
fication

- Texture

Food and Agriculture Organization of the United Nations

GLOSOLAN
Soil spectroscopy training workshops

SOIL ANALYSIS REPORT

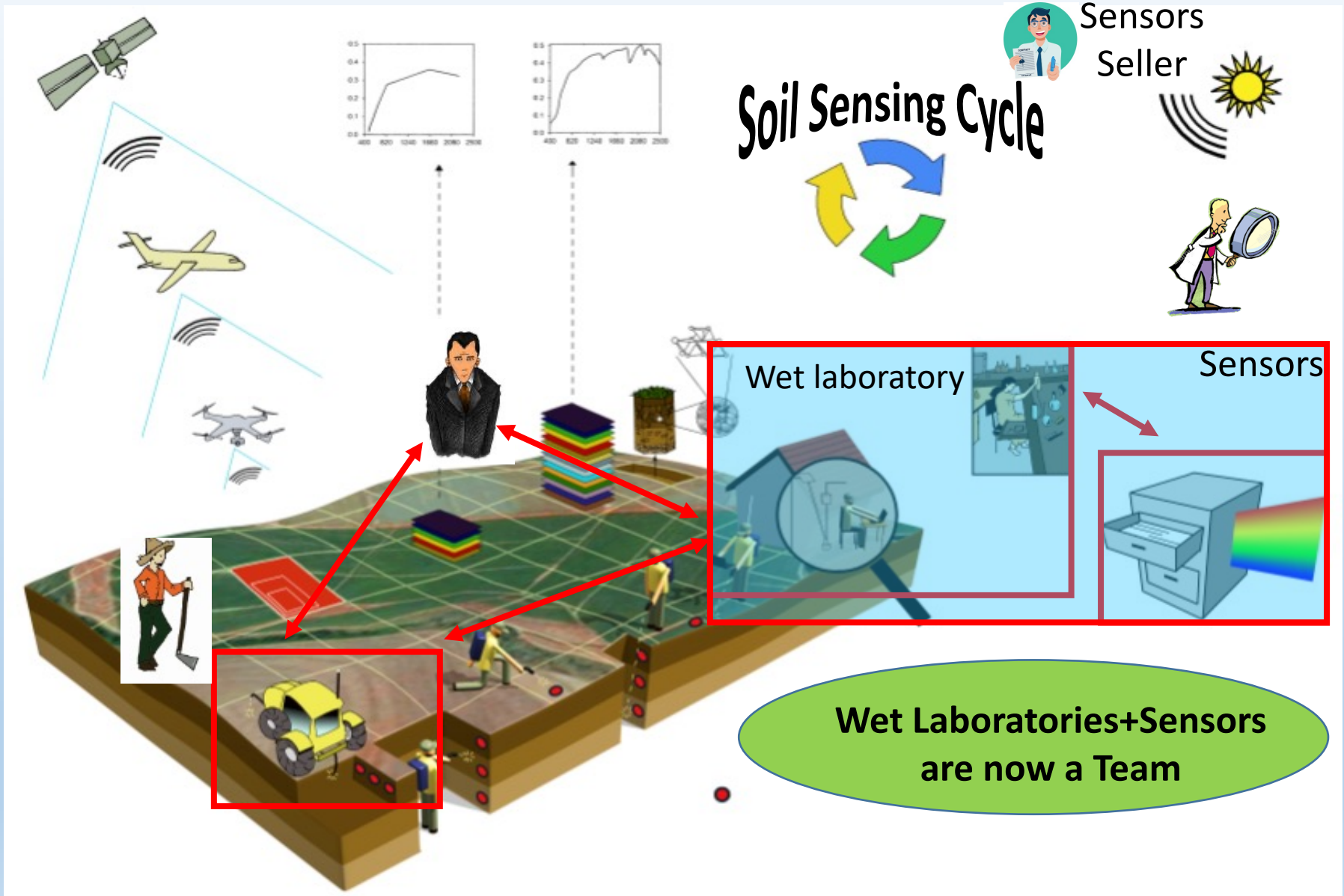
Local: Department of Soil Science, Luiz de Queiroz College of Agriculture, University of São Paulo.
Address: Pádua Dias Avenue, 11, Piracicaba, São Paulo, Brazil

#	Areia	Silte	Argila	Carbono Orgânico	Ph	Ca	Mg	K	Al	H	Soma de Bases	CTC	Saturação por bases	Saturação por Al	P	Fe_2O_3	Al_2O_3	SiO_2	TiO_2	MnO	ki	Matiz	Matiz2	Valor	Croma
Unidade	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	H_2O	mmolc.kg^{-1}	mmolc.kg^{-1}	mmolc.kg^{-1}	mmolc.kg^{-1}	mmolc.kg^{-1}	mmolc.kg^{-1}	mmolc.kg^{-1}	%	%	mg.kg	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}					
R^2	0.79	0.63	0.80	0.58	0.17	0.42	0.43	0.06	0.28	0.62	0.26	0.66	0.44	0.46	0.16	0.79	0.73	0.75	0.72	0.72	0.26				
RMSE	120.45	75.05	93.64	7.28	0.61	26.61	9.09	5.86	7.12	15.78	55.61	34.69	18.18	20.76	20.54	38.3	39.69	36.71	8.71	0.36	2.01				
1	350.9	321.6	327.5	12.6	5.8	47.8	13.9	2.1	4.7	29.0	86.9	89.1	65.0	3.4	12.7	65.6	50.7	101.2	4.6	1.0	2.4	6.67	"Y"	6.1	5.1
2	362.2	317.8	319.9	10.3	5.9	55.2	19.9	2.3	6.6	23.1	87.9	98.1	67.2	3.0	9.2	55.6	44.5	99.4	3.1	0.6	1.9	7	"Y"	6.3	5.3
3	359.4	315.0	325.4	12.3	5.8	42.0	11.2							3.3	10.2	52.4	35.9	75.9	2.2	0.7	1.5	7.07	"Y"	6	5.3
4	393.2	329.6	277.1	18.0	6.1	81.5								2.2		86.1	53.4	125.6	6.4	1.3	3.4	6.63	"Y"	6.4	5.3
5	431.9	330.1	237.9	21.9	6.1	82.4										81.6	51.3	125.5	6.8	1.3	3.4	6.72	"Y"	6.4	5.3
6	369.3	325.0	305.6	15.0	6.0	53.2									10.6	81.5	55.6	118.5	5.9	1.3	3.2	6.67	"Y"	6.2	5.3
7	418.6	308.4	272.9	10.9	5.8	65.0	18.9	2.9						0.5	12.0	59.1	32.9	92.2	3.6	0.8	2.2	6.21	"Y"	6.1	5.1
8	362.7	252.6	384.7	16.4	6.2	61.8	10.5	1.6	11.7	2.7	60.5	92.2	72.4	4.1	9.3	51.3	9.2	53.2	2.3	0.7	4.0	6.71	"Y"	5.6	5.5
9	327.3	353.1	319.4	11.1	6.0	56.9	19.8	2.2	5.7	17.9	96.3	98.6	67.9	1.3	10.2	60.6	52.6	115.1	4.4	0.6	2.5	7.44	"Y"	6.2	5
10	286.5	330.2	383.2	11.2	5.8	49.3	15.0	2.2	10.1	25.6	94.9	100.4	63.4	5.5	8.5	69.8	42.6	123.8	6.1	0.8	1.9	6.98	"Y"	5.8	5
11	281.2	314.5	404.2	10.8	5.9	52.4	20.6	2.3	10.5	23.2	92.4	103.2	64.1	4.3	14.0	73.7	52.8	143.5	6.0	0.8	3.7	6.76	"Y"	6	5.1
12	276.6	332.3	391.0	12.8	5.9	53.5	14.2	2.1	10.8	20.1	62.9	87.5	60.0	5.5	13.2	77.7	39.8	106.0	5.5	0.8	5.2	6.86	"Y"	5.7	5.2
13	280.8	331.2	387.9	11.0	5.8	51.6	14.2	2.2	10.9	19.8	87.6	77.9	59.0	5.0	8.0	69.8	50.0	118.0	4.7	0.8	2.0	6.93	"Y"	6.1	5.2
14	406.5	314.4	279.0	19.1	6.0	64.0	12.6	2.0	3.3	21.3	88.6	74.7	72.0	2.1	11.2	84.0	50.7	120.5	6.2	1.3	3.4	6.72	"Y"	6.3	5.3
15	371.3	332.3	296.2	11.1	6.0	75.0	25.5	2.3	4.8	13.4	88.9	112.7	75.1	0.7	12.5	62.3	52.5	117.1	4.2	0.5	2.3	7.11	"Y"	6.3	4.9

Summary: ´If you cannot measure, you cannot manage it´

- Statistics: R2, RMSE, RPIQs.

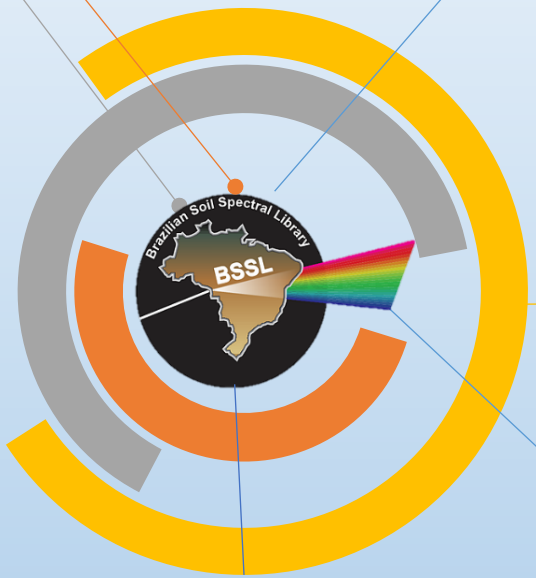
Impact on the chain of Market



C1: Important Events BSSL - time line

2020
First On line platform = Service

1993-95 PhD
(knowledge pedology vs spectroscopy)



2019 – First Teaching Program

2018
First paper

2018 – First RS Symposium In the World Congress of Soil Science

2015 –First Workshop on Soil Spectroscopy From Ground to space

Consideration Regarding the technology and Brazilian Experience

The near future on soil analysis: The Hybrid Laboratory

Definition

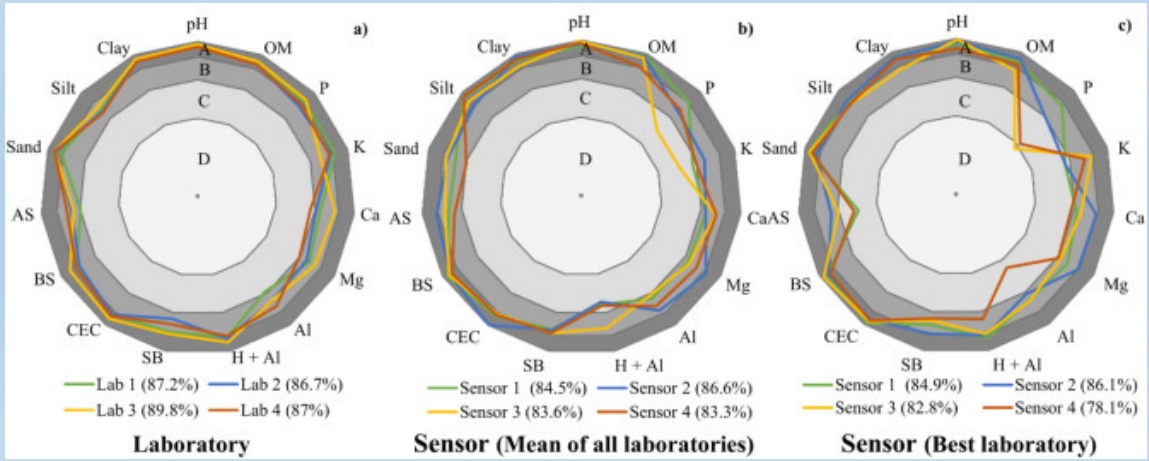
Wet soil analysis works together with spectroscopy to reach the best quality, low cost, clean and quick analysis, going from laboratory to field as well

ELSEVIER

GEODERMA

Soil analytical quality control by traditional and spectroscopy techniques: Constructing the future of a hybrid laboratory for low environmental impact

José Alexandre M. Demattê*,[1], Andre Carnieletto Dotto, Luis Gustavo Bedin, Veridiana Maria Sayão, Arnaldo Barros e Souza



There exist larger variation between wet laboratories than sensors laboratories

The best model was dependent on the best wet soil quality analysis

Example/Suggestion of an Hybrid Laboratory

PHASE 1: Basic

Spectral Sector

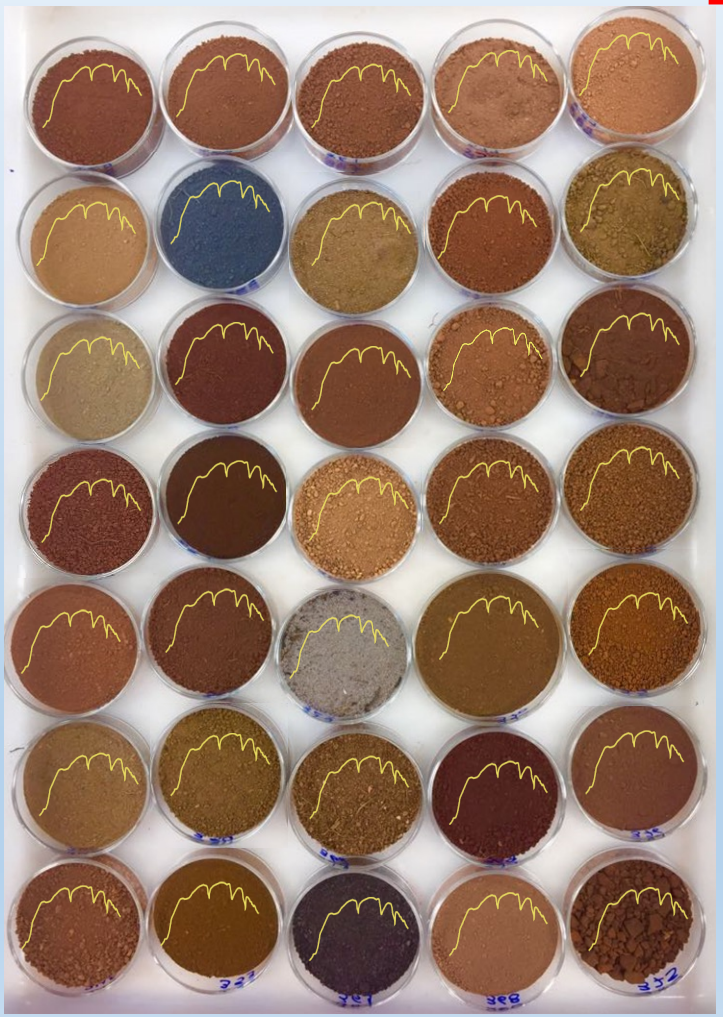
Step 1: adcquire spectra of all samples before soil analysis

Chemometrics Sector

Setp 2: Select main representative Soil samples based on spectra

Wet Laboratory sector

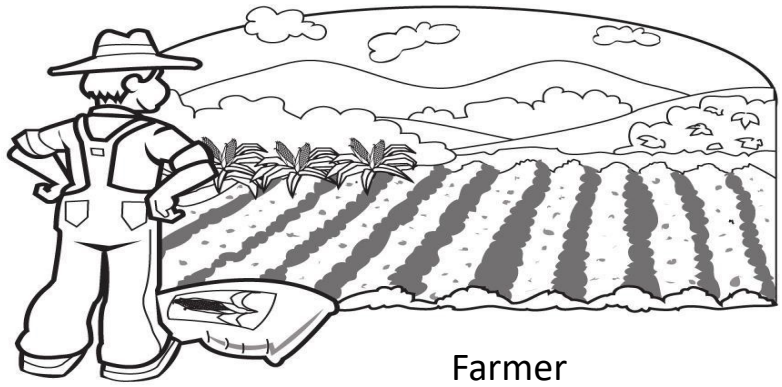
Make tradicional analysis



Chemometrics: Modelling and quantification of the soil attribute

Soil analyses report

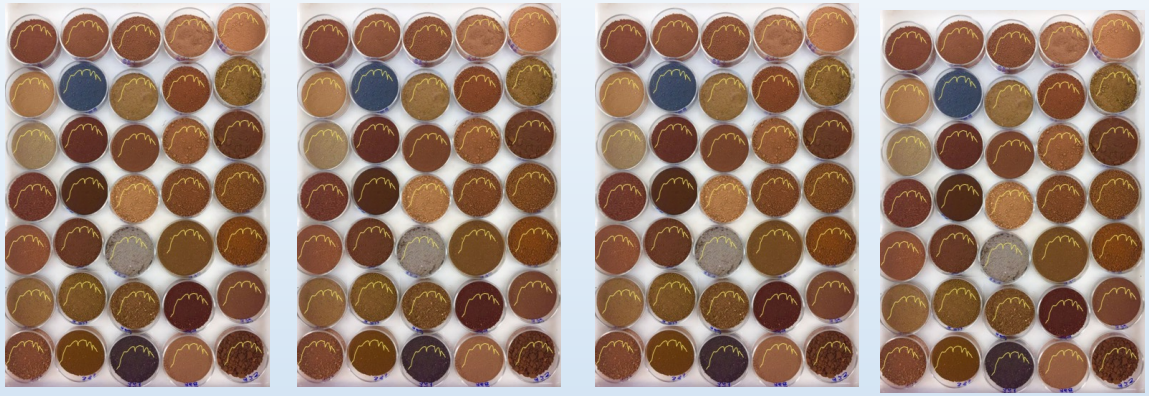
Nº LAB.	AMOSTRA	pH		P	K	K	Ca	Mg	Al	H + Al	M.O.	Argila	Silte	Areia
		Água	$CaCl_2$	mg/dm³		cmolc/dm³					g/dm³	g/dm³		
4807	L 01	5,35	4,29	1,6	50,8	0,13	1,10	0,87	1,36	4,95	16,3	285	60	655
4808	L 02	5,47	4,30	1,2	53,8	0,14	1,09	0,78	1,34	4,41	14,0	240	90	670
4809	L 03	5,32	4,29	1,1	43,0	0,11	0,91	0,75	1,65	5,06	14,6	245	105	650
4810	L 04	5,56	4,47	0,9	65,5	0,17	1,13	0,98	0,85	3,42	13,6	200	95	705
4811	L 05	5,33	4,28	1,0	39,1	0,10	1,10	0,85	1,68	4,95	15,9	260	100	640
4812	L 06	5,18	4,04	1,1	38,1	0,10	0,31	0,24	2,17	5,22	11,9	200	80	720
4813	L 07	5,19	4,06	1,0	39,1	0,10	0,31	0,25	2,18	5,56	14,0	250	90	660
4814	L 08	5,28	4,16	1,0	37,1	0,10	0,65	0,51	1,81	4,95	13,6	270	60	670
4815	L 09	5,52	4,62	0,9	45,0	0,11	1,27	1,04	0,13	3,35	17,5	275	55	670



Farmer

PHASE 1: Advanced

Client 1 Client 2 Client 3 Client 4

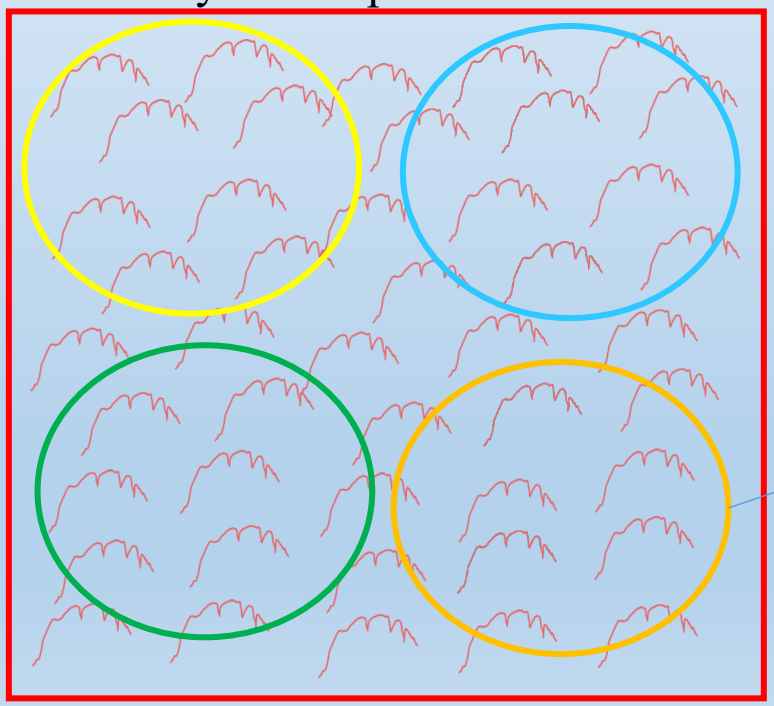


Reception

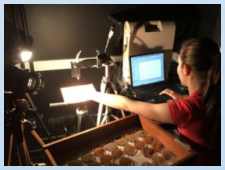
New client bring
Only ONE sample

Client recieves
soil analysis

Laboratory has a Spectral Dataset



Take Spectra



Chemometrics will see the population

And will indicate in which the unknown spectra fits, using its model

Or, if does not fit go to tradicional and agregate to the dataset

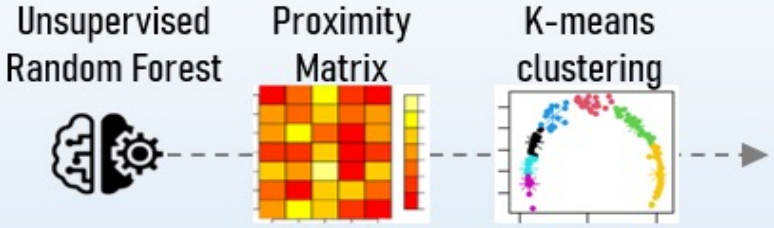
Spectroscopy for wet laboratory quality evaluation: A Qualitative view

Result
Clay content 106 gkg^{-1}
Sandy soil

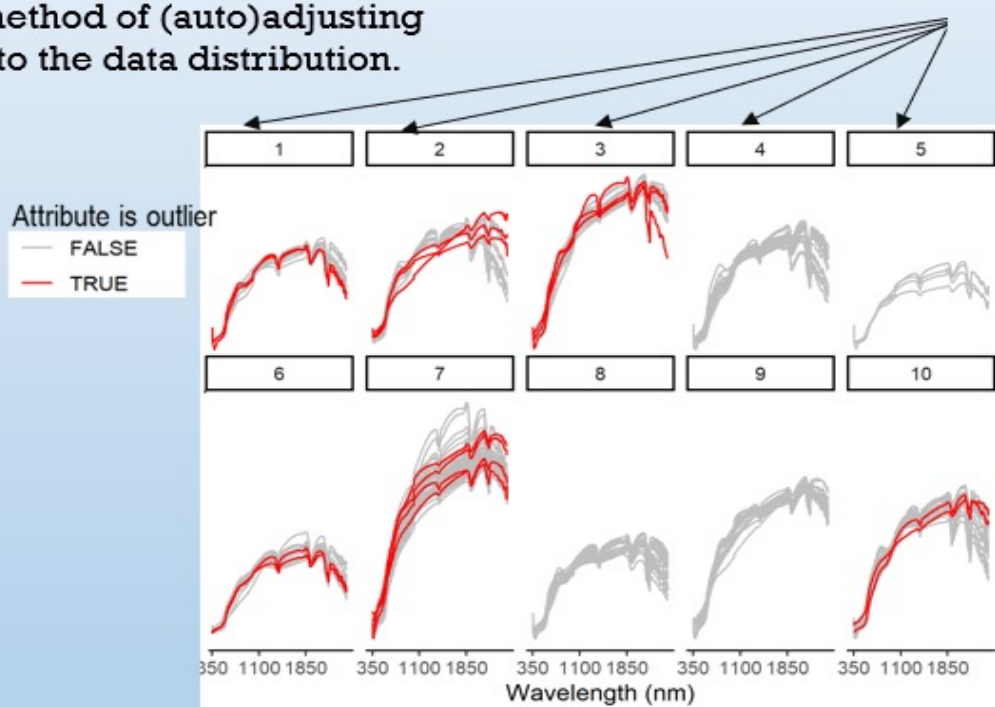
Are they OK?

A systematic Spectroscopy Quality Evaluation

Unsupervised Random Forest → Proximity Matrix → K-means clustering → Spectral Clusters



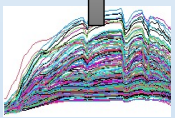
Outlier detection using a method of (auto)adjusting to the data distribution.



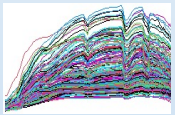
Spectroscopy to see your cost and optimize soil analysis $

Cost reduction

36 Laboratories from Brazil and Paraguay

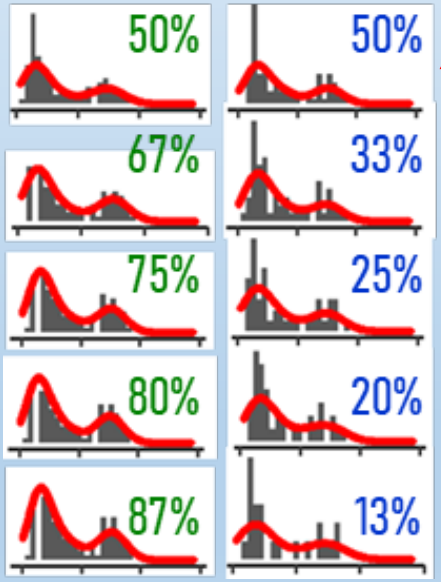


Training



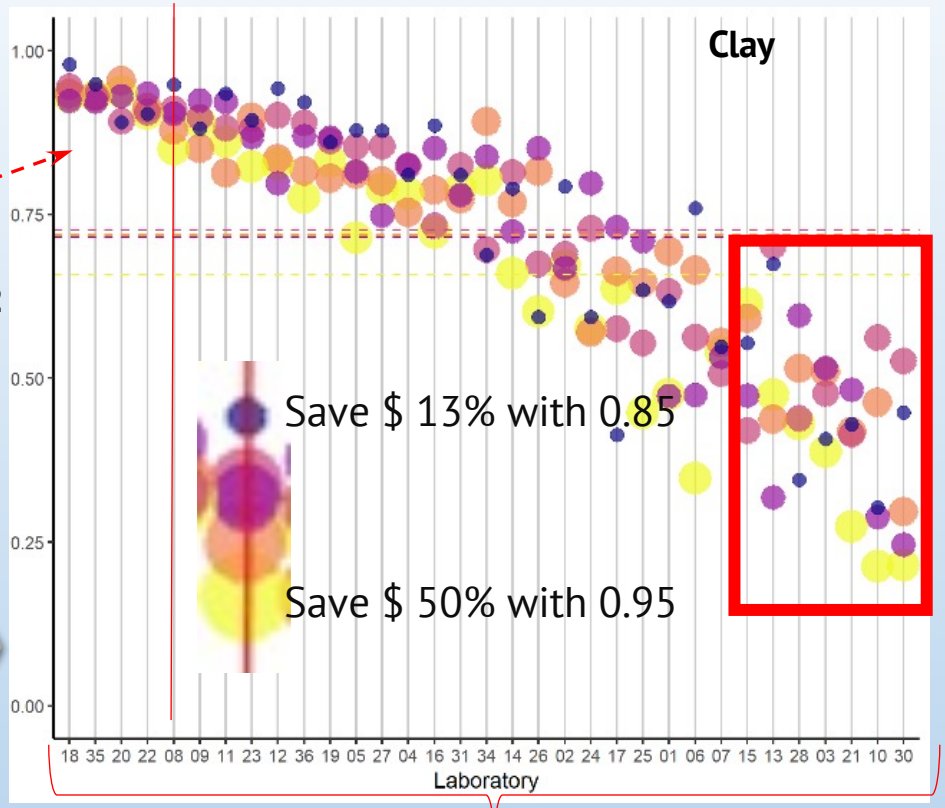
Testing

https://esalqgeocis.wixsite.com/geocis/probase



Nearly 7,000 samples analyzed

R^2



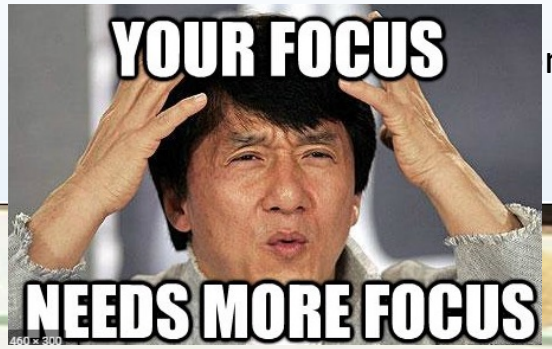
Laboratories

Test set size (%)

13
20
25
33
50

Poppiel et al. (not published)

Soil analysis and Productivity: What are we missing?



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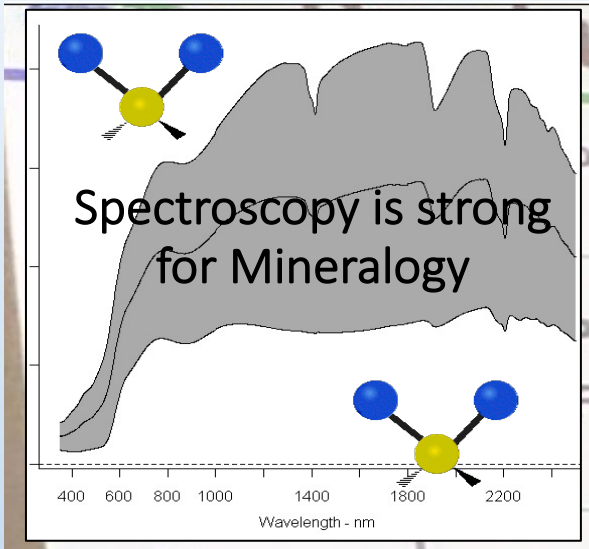
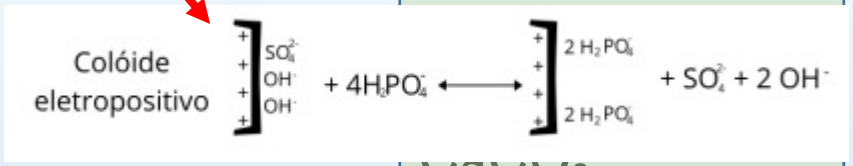


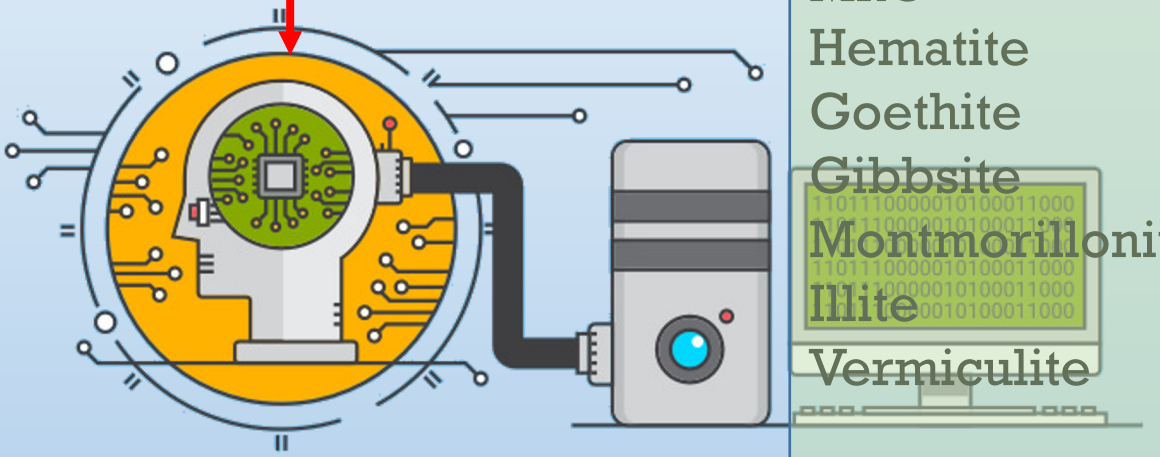
The Machine Era!
And its Limitations

Challenge:
Explain the new era

This you can see!



You cannot see



Machine learning

Population and models dependent

Some cases not scientific explained

Clay
Sand
$CaCO_3$
Fe_2O_3
TiO_2
MnO
Hematite
Goethite
Gibbsite
Montmorillonite
Illite
Vermiculite

CEC

pH

P, Ca, Mg, K, N

Hue, Value, Chroma

SPECTRAL LABORATORY AS A DRIVER FOR SATELLITE APPLICATION IN SOIL ANALYSIS (THE BRAZILIAN GEOSPATIAL SOIL SENSING SYSTEM, GEOS3)

PhD STUDENT: JORGE TADEU FIM ROSAS

COORDINATOR: PROF. JOSÉ ALEXANDRE MELO DEMATTE

USP ESALQ

SOLOS ESALQ • USP

GeoCS

What can be done?

a. Users do not want to understand nor make modelling. We have to make a platform where the user choose the population and the system makes the modelling and deliver the result

b. Advanced level: allow to do its own processing (more for research and advanced users)

c. Spectral libraries can be made for the world, continental, regional or to a farmer. The level chosen will be the users choice regarding accuracy, scale and others. The type to use will be country structure dependent.

d. Teaching courses at different levels (scientific, laboratories, consulters, farmers) have to start immediately to spread the technology, and normalize advantages and limitations.

Final Remarks
Spectroscopy for Soils

Advantage

- Quick
- Simple preparation
- One measurement, several soil components
- Environmental friendly
- Can bring mineralogy elements back to the game
- Great for texture, CEC and OM
- Easier to transfer to field
- Will increase popullarization of soil analysis

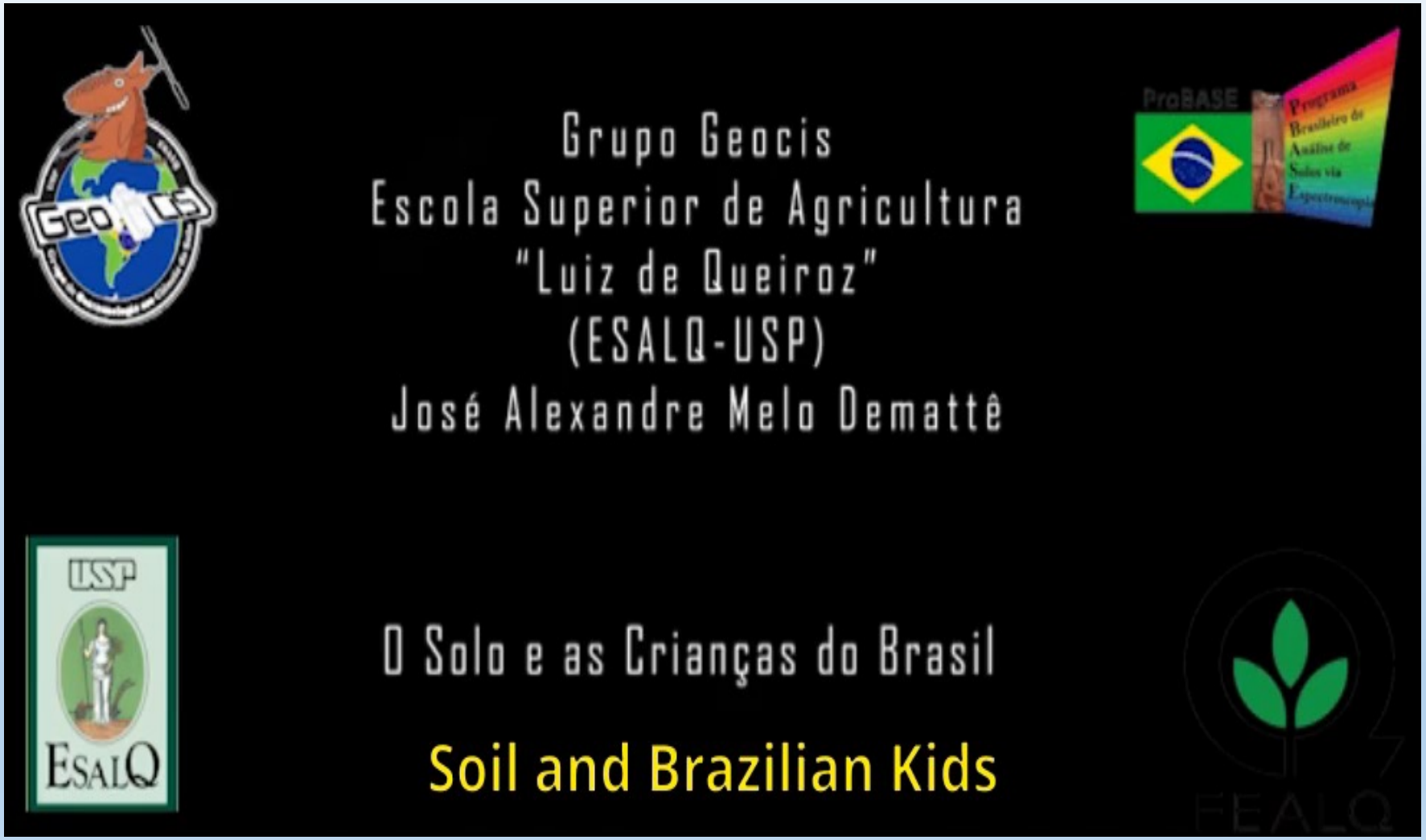
Limitation

- Cost of equipments?
- Good for some elements?

Challenge

- Determine models and populations
- Determine standards and protocols
- Spectral libraries
- Determine agronomic elements (P, Ca, K, Na, Mg...)
- Capacity (of traditional soil laboratories) in spectral methods
- Professionals with expertise in chemometrics + chemistry

New generation deserve a better place



Thank You
Obrigado