Using Radar Chart Areas to Evaluate the Sensitivity of Electronic Nose Sensors in Detecting Water Stress in Soybean

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Summary

- SHORT RESUME;
- TOPICS INTEREST;
- EMBRAPA INSTRUMENTATION;
- SCIENTIFIC MOTIVATION;
- BASIC PRINCIPLE OF ELECTRONIC NOSE;
- MATERIALS AND METHODS;
- RESULTS AND DISCUSSION;
- CONCLUSION AND FUTURE WORKS

Short Resume

Undergraduate (1982 – 1986)	Electronic Engineer – FEB (BR)	Agronomic electronic scale.
Master Science (1989 – 1993)	Electrical Engineer - EESC/USP (BR)	MW applied to measure Soil Moisture.
Doctorate (1994 – 1998)	Physical Chemistry – IQSC/USP (BR)	Application of AFM in agriculture.
Pos-Doctorate (2002 – 2003)	Chemistry – UPENN (USA)	Affordable Sensors using Conductive Polymers.
Visting Scientist (2012 – 2015)	Plant Science – FZJ – (DE)	New methods and techniques applied to Plant Phenotyping.

Senior Researcher
Embrapa Instrumentation
São Carlos –SP (BR)

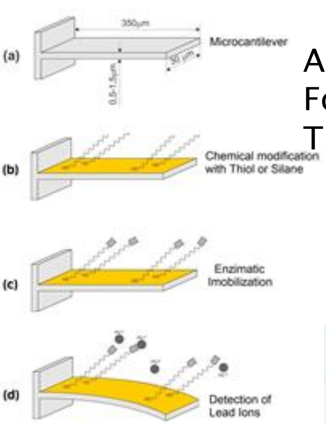
New methods and techniques to plant phenotyping

Electronic Nose

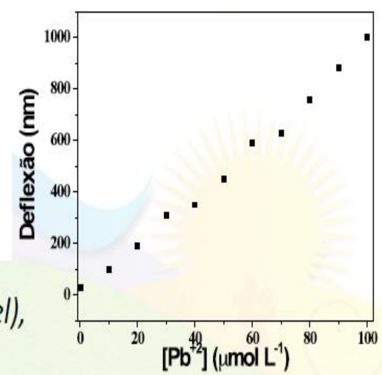
High Sensitive Sensors

Sensor and biosensor developed with microcantilever, applied to VOCs and water quality;

MICROCANTILEVER AS BIOSENSORS

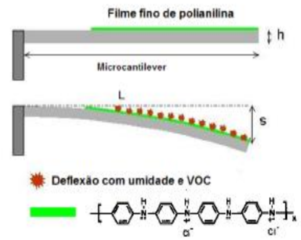


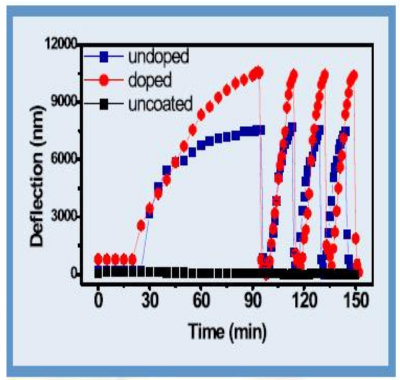
Alcalina Fosfatase Tipo 1



Stefens et al, *Sensors (Basel), (6), 8278-8300, 2012.*

MICROCANTILEVER AS SENSORS





*Margarido et al., **Brazilian Journal of Physics,** v. 52, p.112-114, 2022*

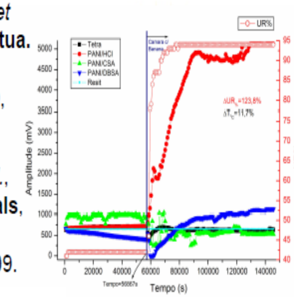
*Steffens et al., **Microelectronic Engineering**, 113, 80-85, 2014*

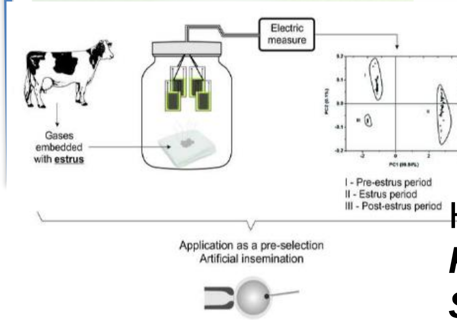
Affordable sensors

Disposable Sensors using LPT: -Paper and plastic Electronic Nose;

E-nose to evaluation the fruit ripeness

- E.C. Venancio *et al.*, **Sens. & Actua. B: Chem.**, 130, Iss.; 2, 723-729, 2008.
- C. Stefens *et al.*, **Synthetic Metals**, v. 159, p. 2329-2332, 2009.





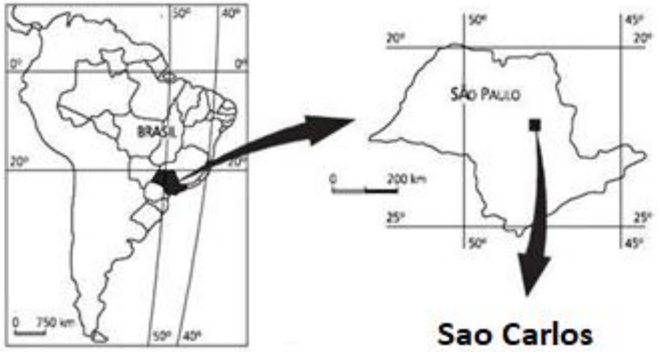
Manzoli *et al.* **Sens & Actua. B: Chem**, 282, 609-616, 2019

Herrmann *et al.*, ***Frontiers in Plant Science***, 2024

Embrapa Instrumentation

Sao Carlos (SP) – BRAZIL

One of 43 Embrapa units spread out in Brazil.



Scientific Motivation

- Land vegetation contributes 90% of the global VOC emissions[1];
- Plants have been shown to emit volatile organic compounds (VOCs) when they are affected by stress[2,3];
- The promising outlook of VOC phenotyping as a fast and non-invasive measure of phenotypic dynamics[4];
- Potential applications of E-Nose as affordable plant gas detection[5];.
- Establishing a method of data visualization and analysis using an area radar chart.

1- Kindler-Scharr et al. **Nature**, 416, 17, 381-384, 2009;

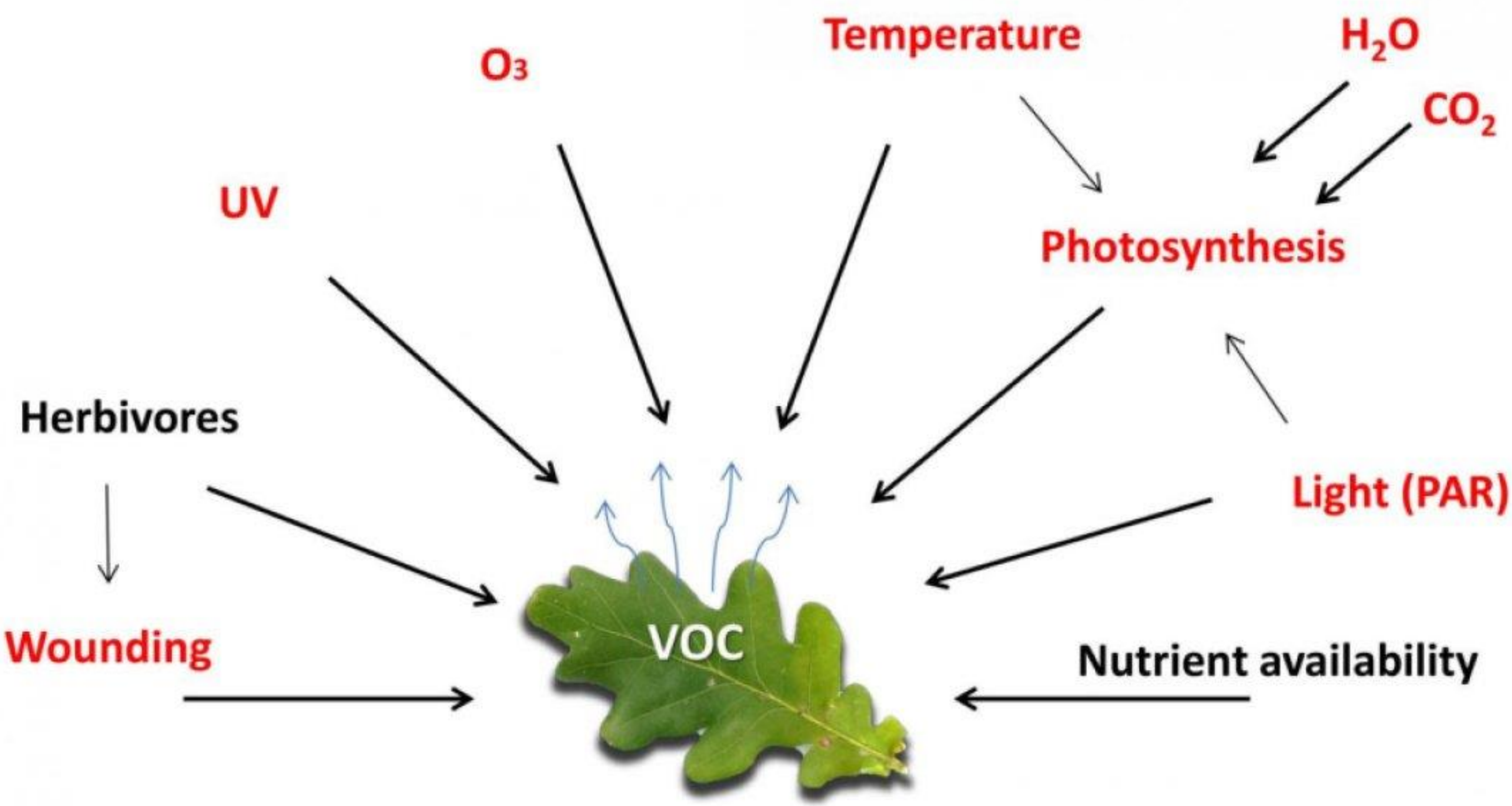
2 - Jansen et al. **Annual Review of Phytopalogy**, 49, 157-174, 2011.

3 – Fisher et al., **Science,** 360, 739, 2018;

4 – Niederbacher et al., **Journal of Experimental Botany**, 66, 18, 5403–5416, 2015;

5 - Herrmann *et al.*, **Frontiers in Plant Science,** 2024

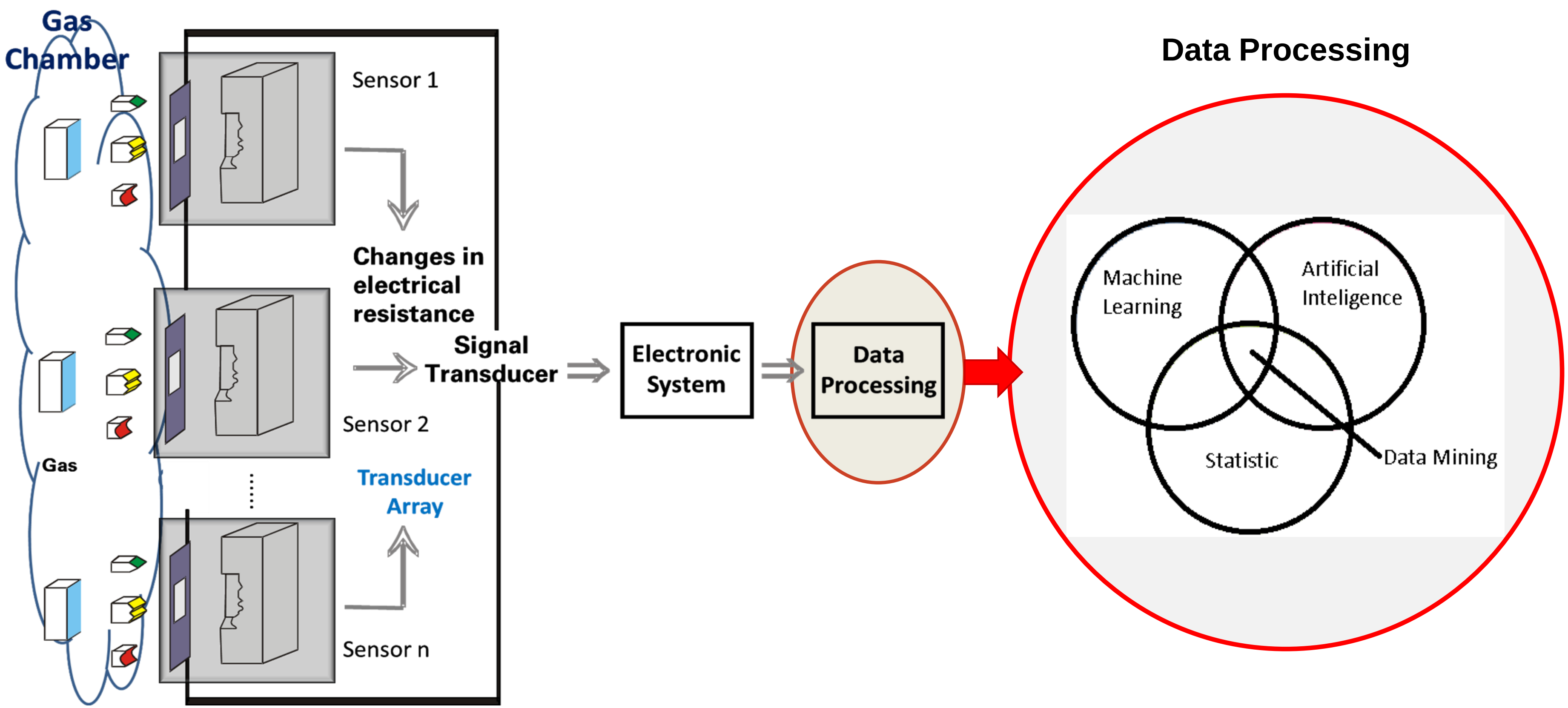
Impact of abiotic and biotic factors on plant VOC emission



factors are affected by any plant enclosure.

Bruhn *et al., 2015*

Basic Principle of the E-Nose and Machine Learning



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MATERIALS AND METHODS

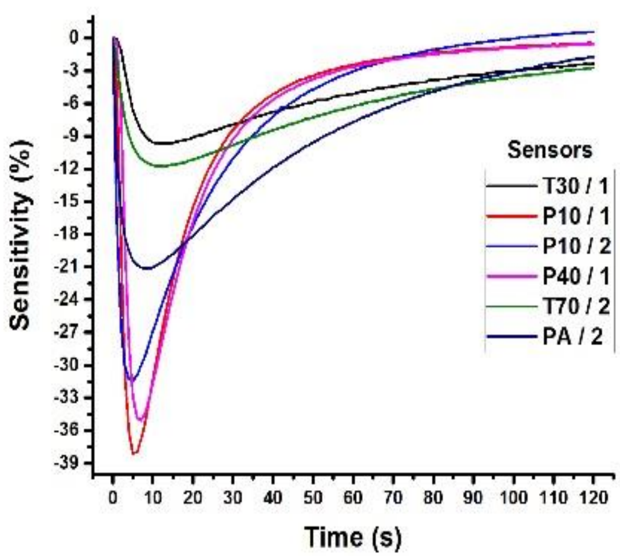
TABLE I. THE SENSORS INSTALLED IN THE E-NOSE ARE [6]:

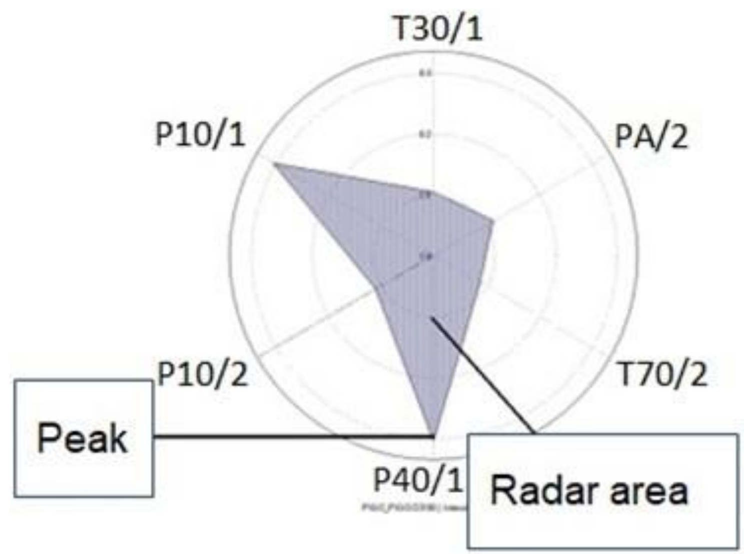
No.	Sensor	Sensitivity property	Reference Materials
S1	T30/1	Organic compounds	Organic compounds
S2	P10/1	Combustible gas	hydrocarbon
S3	P10/2	Inflammable gas	methane
S4	P40/1	Oxidizing gas	fluorine
S5	T70/2	Aromatic compounds	Methyl benzene, xylene
S6	PA/2	Organic compounds and toxic gas	Ammonia, amines, ethyl alcohol

$$S(\%) = \left(\frac{R - R_0}{R_0}\right) x100 \qquad (\%) \qquad\qquad (1)$$

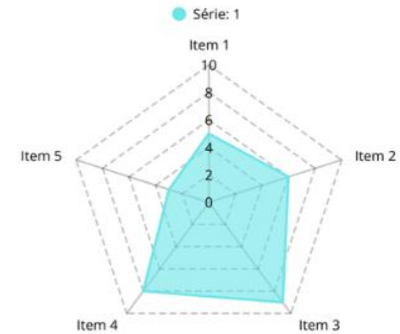
R_0 – Initial electrical resistance (Ω);

R – Electrical resistance varying over time (Ω)





Calculating the Area of a Radar Chart



The method of radar chart for Multidimensional Data:

X = {X_1, $X_2 X_j$, ⋯ X_n} is a multi-dimensional data set, and X_i {x_{i1}, x_{i2}, $x_{i3} x_{iN}$} is a N-dimensional vector. Use the radar chart when N⩾3 (Liu et al., 2008).

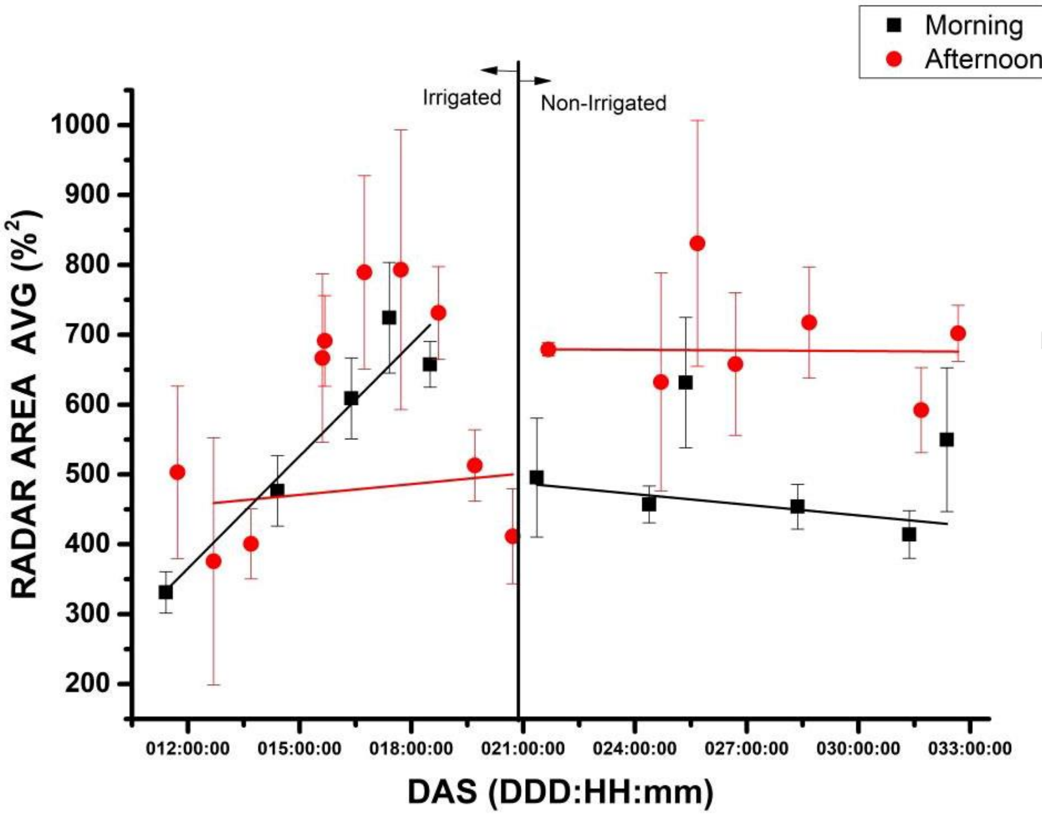
A method for evaluating the accessibility of a facility location using the area of a radar chart was provided by Takenaka and collaborators (Takenaka et al., 2018). The authors argue that the area of a radar chart is a more stable measure of accessibility than other measures.

The Area of the Radar (A_n) was calculated with the Shoelace equation (2) where X_i = S_i {S1(%), S2(%), S3(%), S4(%), S5(%), S6(%)}.

- $$A_n \equiv \frac{1}{2} \sin \frac{2\pi}{n} \sum_{i=1}^{n} (x_i y_{i+1} - x_{i+1} y_i) \quad (\%^2) \qquad (2)$$

$x_{n+1} = x_1$ and $y_{n+1} = y_1$ to complete the loop.

Results



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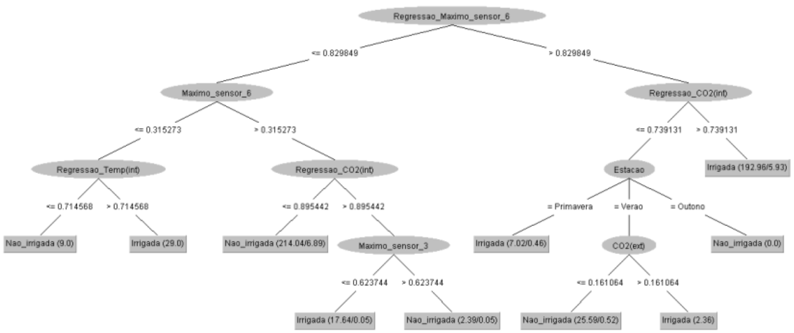
Decision Tree Learning



434 samples

	Decision Tree		**KNN**	
	Irrigated	**Non irrigated**	**Irrigated**	**Non irrigated**
Irrigated	92,7%	7,3%	77,4%	22,6%
Non irrigated	5,7%	94,4%	16,1%	83,9%

Outcomes

Benefit

- Faster Analysis in Some Applications;
- Identification of Complex Mixtures;
- Potential for More Selective Sensors;
- Enhanced Discrimination Capability;
- Information about Exposure Duration;

Drawback

- Sensor Dependence and Variability;
- Calibration Challenges;
- Area calculation being influenced by the shape and the scaling of the axes.

CONCLUSIONS

Area radar charts

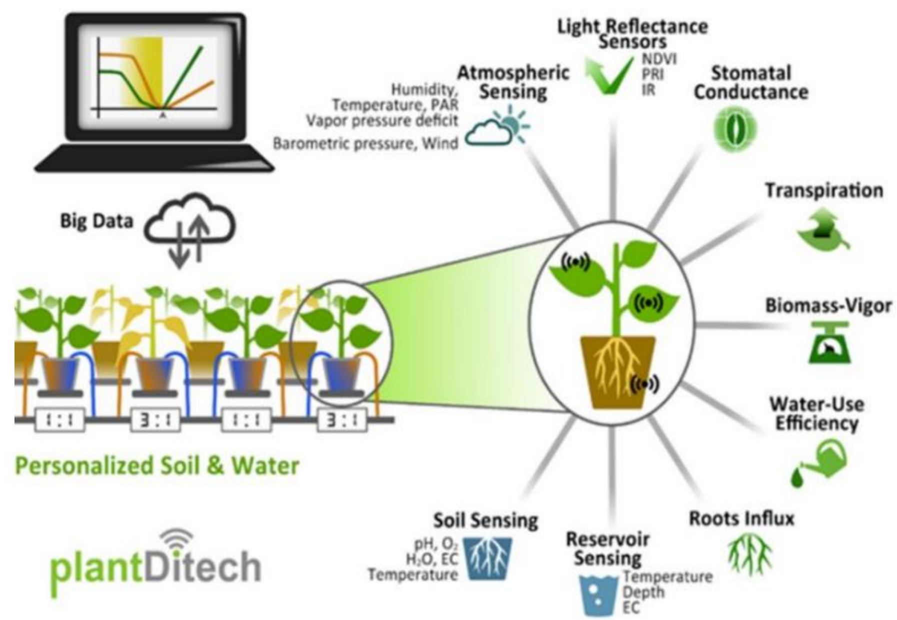
- Valuable tools when analyzing and comparing the overall performance of distinct data groups;
- Presenting complex data in a clear and intuitive manner;
- Facilitate better decision-making and insights;
- Allowing stakeholders to quickly grasp relationships and trends within the data.

Future Work

- Integrate method with equipment in a mobile unit to facilitate field use;
- Incorporate a models with AI;
- Apply the methodology to study thermal and water stress.

“Center for Integration of Enabling Technologies to Increase the Resilience of Agriculture to the Effects of Climate Change.”

CHAMADA PÚBLICA MCTI/FINEP/FNDCT/CENTROS TEMÁTICOS 2023



PlantArray
plantDitech

Acknowledgments

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Thank You!

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