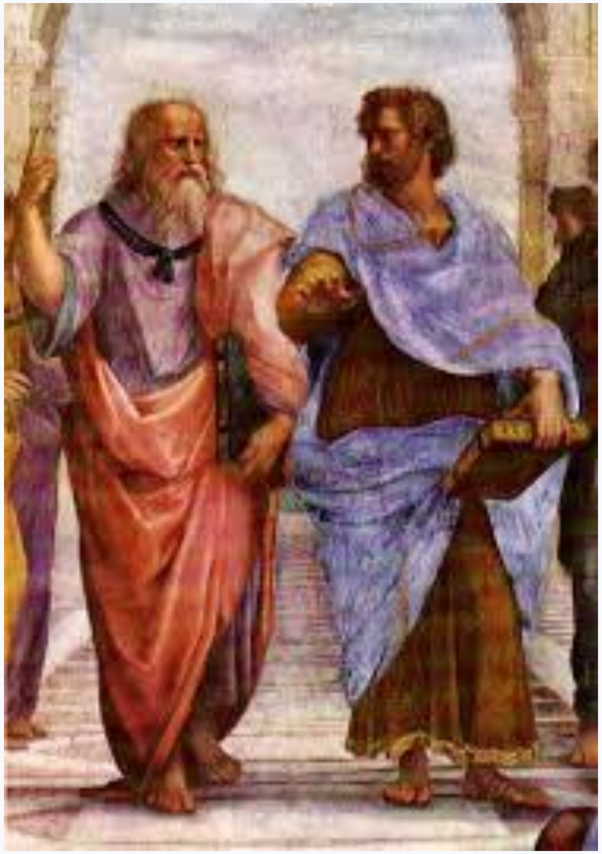
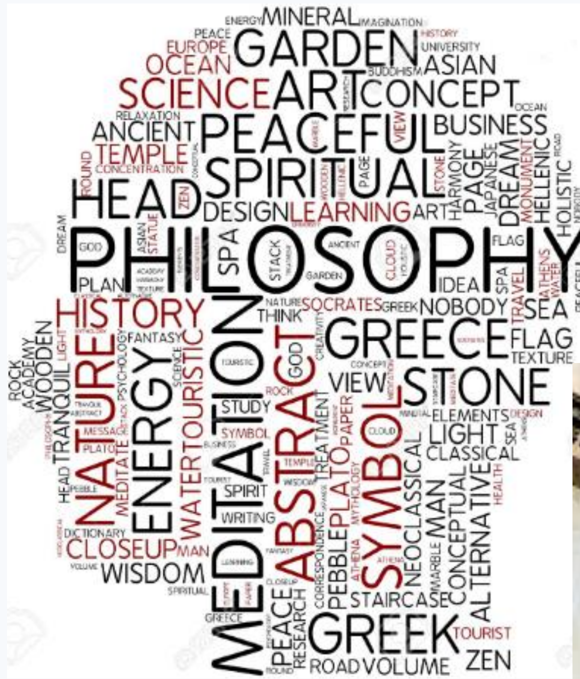
The Tenth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2019

Advanced Sensors and Socio-environmental Policy in Decision Making for Food Production

Paulo E. Cruvinel, Ph.D
Researcher

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PHILOSOPHY
PLAN
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HISTORY
SOCRATES
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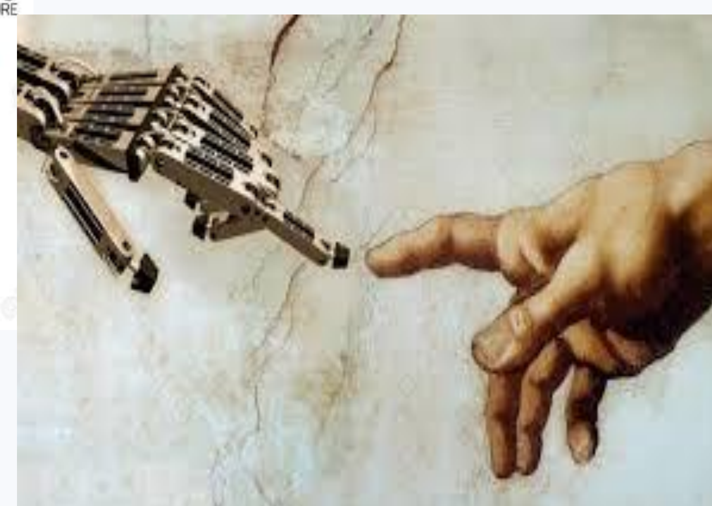


Presentation Outline

1. Social Responsibility and Sustainability.
2. Innovation and Society.
3. Sensors.
4. Solomonoff & Shannon.
5. Decision Making for Food Production.
6. Advanced Sensors in Agriculture.
7. Some Examples.
8. Agricultural Value Chain and Opportunities.
9. Conclusion.

Social Responsibility and Sustainability

Social Responsibility and Sustainability

Social Responsibility

- **Social & Corporative Business**

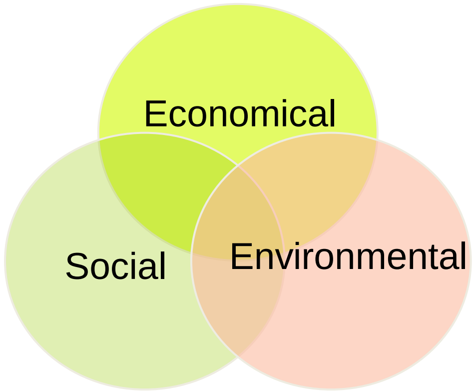
public commitment and productive sector, commercial and management processes based on the company's ethical, transparent and solidary relationships with all the publics affected by its activities.

Source: Ethos Institute

Sustainable Development

- Meet the needs of the present without compromising the ability of future generations to meet their own needs.

Source: UNO, bases on “The Bundtland Report” World Comission on Environment and Development, 1987



Sustainability

Sustainability is the long term continued capacity.

Source: “The Bundtland Report” World Comission on Environment and Development

Innovation and Society

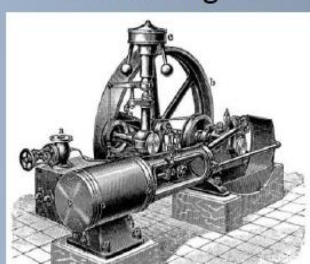
Innovation and impacts on society

Forces & Influences

Quality of life
Engineering & Science

1ª

steam engine



GB

1782

Power Generation - Mechanical Production powered by water and steam.

200 years

Mobility

2ª

conveyor belt

US

1913

Industrialization - Mass production based on division of labor and use of electricity.

60 years

Electronics

3ª

Computer, NC,PLC

US/EU

1954

Electronic Automation - Introduction of electronics, IT and robotics for greater production based on automation.

40 years

ICTs

4ª

Cyber Physical Systems

EU

2015

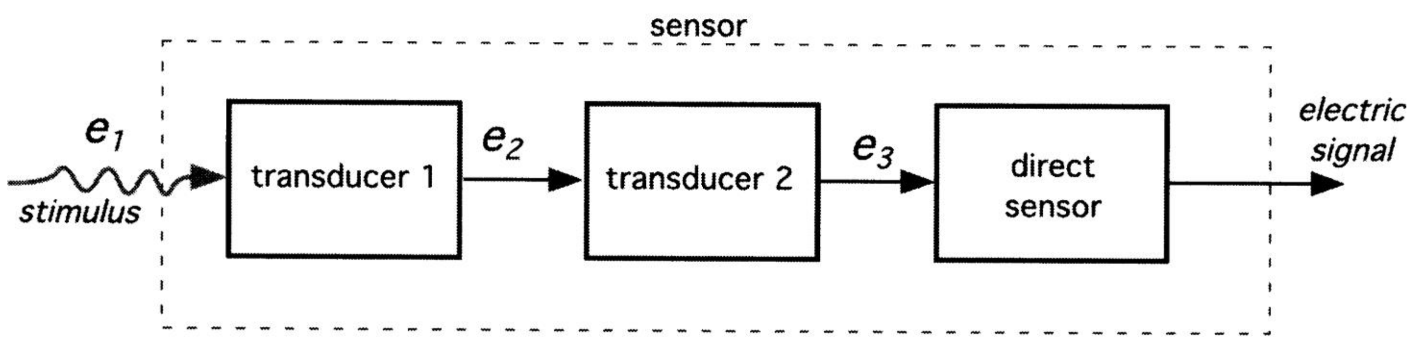
Intelligent Automation - based on cyber-physical production systems

How long it will be present ???

Sensors

Sensors and Bridge with Nature

- A sensor is a device that receives a stimulus and responds with an electrical signal.



- Sound
- Moisture
- Light
- Radiation
- Temperature
- Chemical presence
- Motion, position, displacement
- Velocity and acceleration
- Force, strain
- Pressure
- Flow
- (among others)

The Response is an Electrical Signal

- electrical mean a signal which can be channeled, amplified and modified by electronic devices:
  - Voltage
  - Current
  - Charge

- The voltage, current or charge may be describe by:
  - Amplitude
  - Frequency
  - Phase
  - Digital code

Physical Principles of Sensing

- Charges, fields & potentials
- Capacitance
- Magnetism
- Induction
- Resistance
- Piezoelectric effect

- Peltier effects
- Hall effects
- Thermal properties of materials
- Heat transfer
- Light
- (among others)

Detectable Phenomenon

Stimulus	Quantity
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave Velocity
Biological & Chemical	Fluid Concentrations (Gas or Liquid)
Electric	Charge, Voltage, Current, Electric Field (amplitude, phase, polarization), Conductivity, Permittivity
Magnetic	Magnetic Field (amplitude, phase, polarization), Flux, Permeability
Optical	Refractive Index, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific Heat, Thermal Conductivity
Mechanical	Position, Velocity, Acceleration, Force, Strain, Stress, Pressure, Torque

Types of Sensor

- **Direct**
  - A sensor that can convert a non-electrical stimulus into an electrical signal with intermediate stages.
    - Thermocouple (temperature to voltage)
- **Indirect**
  - A sensor that multiple conversion steps to transform the measured signal into an electrical signal.
    - A fiber-optic displacement sensor:

      Current $\rightarrow$photons $\rightarrow$current

Physical Principles

- **Ampere's Law**
  - A current carrying conductor in a magnetic field experiences a force (e.g. galvanometer)

- **Curie-Weiss Law**
  - There is a transition temperature at which ferromagnetic materials exhibit paramagnetic behavior

- **Faraday's Law of Induction**
  - A coil resist a change in magnetic field by generating an opposing voltage/current (e.g. transformer)

- **Photoconductive Effect**
  - When light strikes certain semiconductor materials, the resistance of the material decreases (e.g. photo-resistor)

- **(among others)!**

Choosing a Sensor

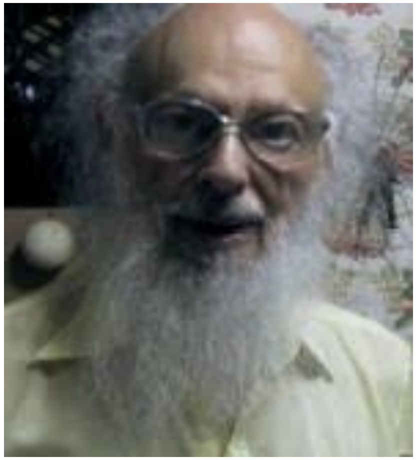
Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Need for Sensors

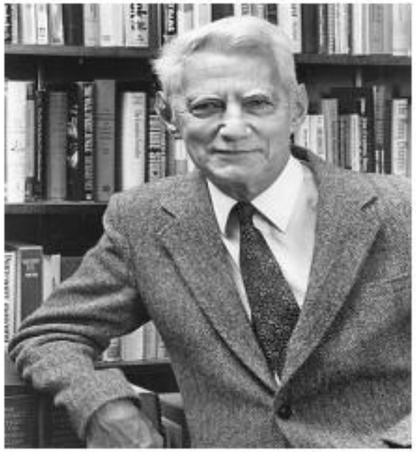
"Without the use of sensors, there would be no data, no information retrieval, no oriented knowledge, as well as no interaction with nature by machines, and of course no automation at all"

Solomonoff & Shannon

The importance of Solomonoff and Shannon



Ray Solomonoff, 1926-2009



Claude Shannon, 1916–2001

"…..about a month and a half ago I worked out a method of devising a machine that would think." (Solomonoff, 1950)

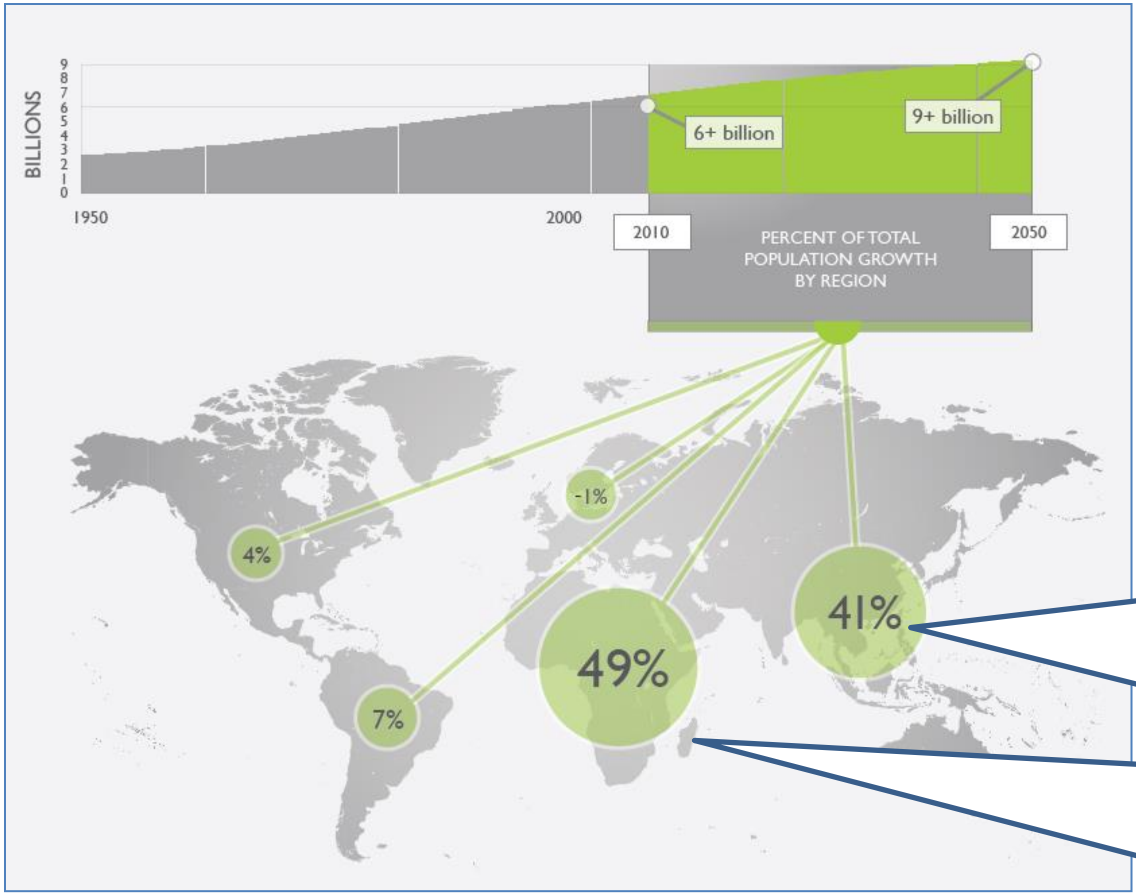
Claude Shannon's work in 1948 and subsequent developments in information theory in the coming years influenced Solomonoff.

Shannon showed that information is something that can be quantified and that the amount of information is related to its probability.

Decision Making for Food Production

The Multiple Agri-Food Challenges

Asymmetries of population growth and food production



Source: *UN data from Global Harvest Initiative GAP Report (2011).*

Expected Population Growth by Region

2010 - 2050

Most population growth is expected in sub-Saharan Africa and Asia.
Low-income areas with relatively low levels of agricultural productivity.

The Multiple Agri-Food Challenges

- Climate change posing a serious threat to food security as arable land becomes less available on the planet;

- Need for greater inclusion of individuals in the citizenship baseline in order to supply elements to fully integrate social and environmental responsibilities and resilience of natural resources;

- Need of data from the complex water-soil-plant-atmosphere ‘system to monitor and manage risks and productivity gains, sensors and decision-aid systems, including demands for intelligent machines for real-time Bigdata management and rural-urban connection.

The Multiple Agri-Food Challenges

- An increasing global population, in combination with climate change, poses a threat to food security as arable land becomes less available;
- **Global population**: Projected to be approaching 9+ Billion People in the 2050s;
- **Food production**: needs to increase more than 60% in food production;
- **Degradation, Water use, Resilience of natural resources, Pest Control**: needs for sustainability based on good practices;
- **Risk Control**: Biggest challenge….

Knowledge Needs, Science, Education and Innovation

As defined by the Food and Agriculture Organization (FAO) of the United Nations:

- Food security "exists when all people at all times have both physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs for an active and healthy life."

Source: Food and Agricultural Organization of the United Nations (2019). Hunger Portal: FAO. Date retrieved: October 12, 2019. Retrieved from: http://www.fao.org/hunger/en/

Food Security...But also Food Safety

RESEARCH ARTICLE OPEN ACCESS

Complexity of the International Agro-Food Trade Network and Its Impact on Food Safety

Article | Metrics | Related Content | Comments: 2

Mária Ercsey-Ravasz[1,2], **Zoltán Toroczkai**[1], **Zoltán Lakner**[3], **József Baranyi**[4*]

1 Interdisciplinary Center for Network Science and Applications (iCeNSA) and Department Physics, University of Notre Dame, Notre Dame, Indiana, United States of America, **2** Faculty of Physics, Babes-Bolyai University, RO-400084 Cluj-Napoca, Romania, **3** Department of Food Sciences, Budapest Corvinus University, Budapest, Hungary, **4** Institute of Food Research, Norwich Research Park, Norwich, United Kingdom

To **add a note**, highlight some text. Hide notes

Make a general comment

Jump to

Abstract Top

With the world's population now in excess of 7 billion, it is vital to ensure the chemical and microbiological safety of our food, while maintaining the sustainability of its production, distribution and trade. Using UN databases, here we show that the international agro-food trade network (IFTN), with nodes and edges representing countries and import-export fluxes, respectively, has evolved into a highly heterogeneous, complex supply-chain network. Seven countries form the core of the IFTN, with high values of betweenness centrality and each trading with over 77% of all the countries in the world. Graph theoretical analysis and a dynamic food flux model show that the IFTN provides a vehicle suitable for the fast distribution of potential contaminants but unsuitable for tracing their origin. In particular, we show that high values of node betweenness and vulnerability correlate well with recorded large food poisoning outbreaks.

http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.phone.0037810

Analysis of the international food-trade network shows great vulnerability to the fast spread of contaminants.

Source: Ercsey-Ravasz M, Toroczkai Z, Lakner Z, Baranyi J (2012) Complexity of the International Agro-Food Trade Network and Its Impact on Food Safety. PLoS ONE 7(5): e37810. doi:10.1371/journal.pone.0037810

Needs for Data, Information, and knowledge (science & innovation)

Sustainability

Advanced Sensors

Agricultural Sensors

Sensors used in farming are known as agricultural sensors.

- These sensors provide data which assist farmers to monitor and optimize crops by adapting to changes in the environmental conditions;

- These sensors are installed on agricultural machinery, weather stations, drones and robots used in the agriculture industry;

- They can be controlled using mobile apps specifically developed for the purpose;

- Based on wireless connectivity either they can be controlled directly using WI-FI or through cellular towers with cellular frequencies with the help of mobile phone applications.

Agricultural Sensors

•**Yield Monitoring** systems are placed on crop harvesting vehicles such as combines and corn harvesters.

•**Yield Mapping** uses spatial coordinate data from GPS sensors mounted on harvesting equipment. Yield monitoring data is combined with the coordinates to create yield maps.

•**Variable Rate Fertilizer** application tools use yield maps and perhaps optical surveys of plant health determined by coloration to control granular, liquid, and gaseous fertilizer materials. Variable rate controllers can either be manually controlled or automatically controlled using an on-board computer guided by real GPS location.

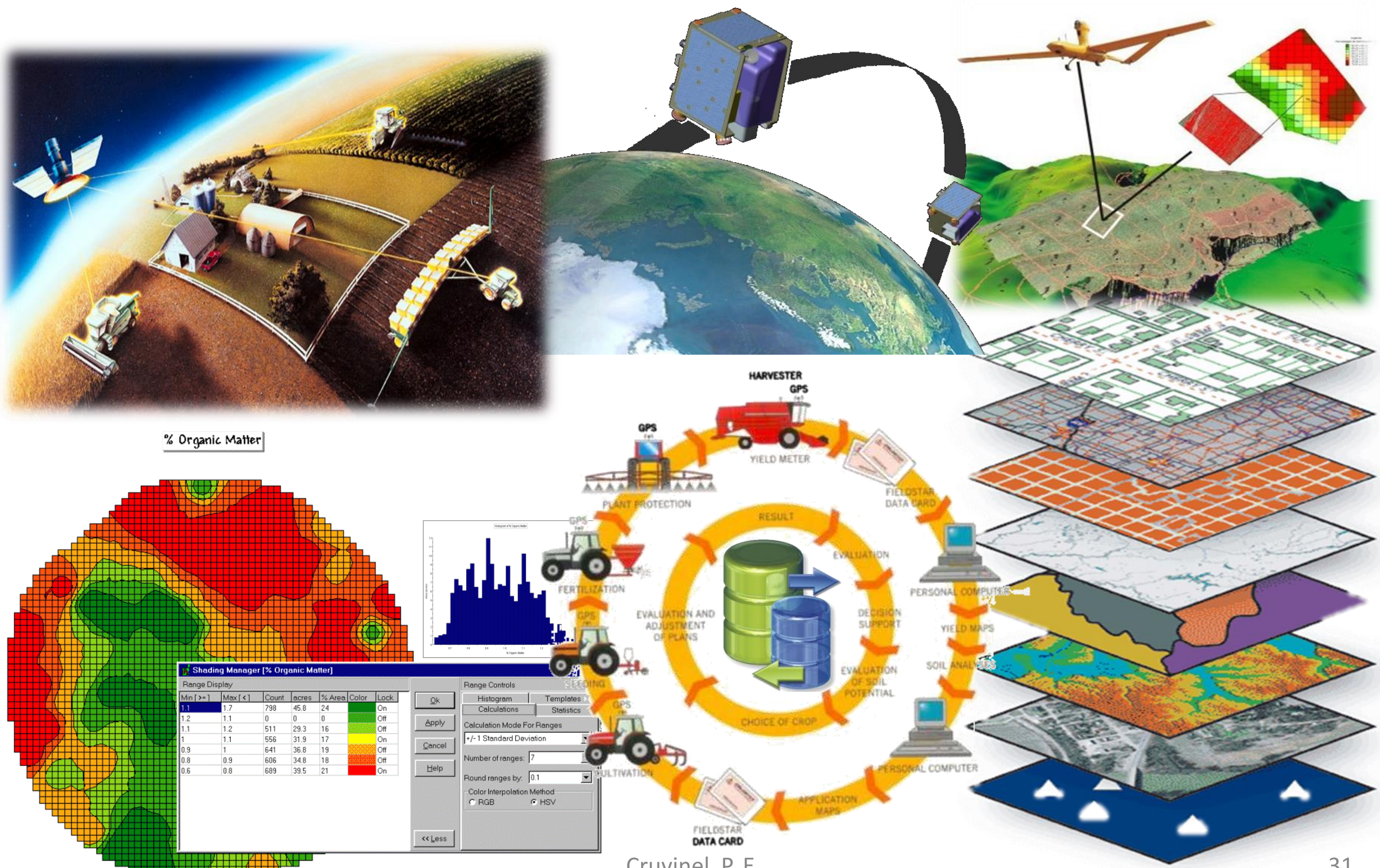
•**Weed Mapping** currently uses operator interpretation and input to generate maps by quickly marking the location with a GPS receiver and datalogger.

•**Variable Spraying** controllers turn herbicide spray booms on and off, and customize the amount (and blend) of the spray applied. Once weed locations are identified and mapped, the volume and mix of the spray can be determined.

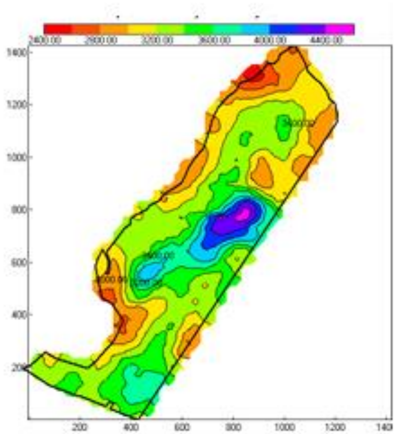
•**Guidance Systems** can accurately position a moving vehicle within 30cm or less using GPS. Guidance systems replace conventional equipment for spraying or seeding. Autonomous vehicles are currently under development and will likely be put into use in the very near future.

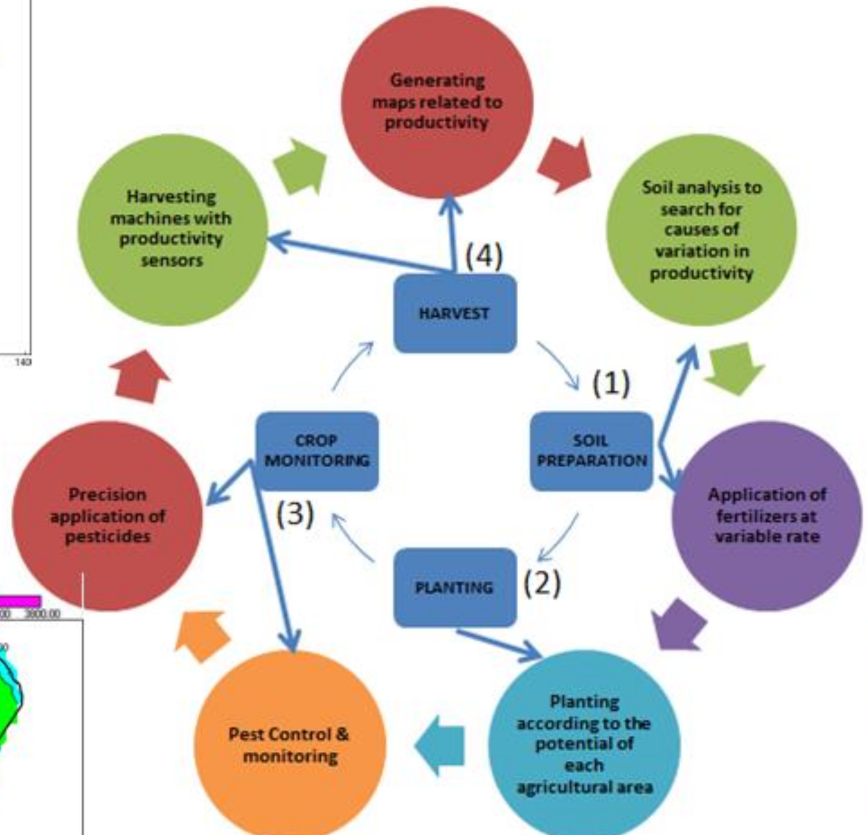
Agriculture Sensors	Functional description
Location Sensors	These sensors determine latitude, longitude and altitude of any position within required area. They take help of GPS satellites for this purpose.
Optical Sensors	These sensors use light in order to measure properties of the soil. They are installed on satellites, drones or robots to determine clay, organic matter and moisture contents of the soil.
Electro-Chemical Sensors	These sensors help in gathering chemical data of the soils by detecting specific ions in the soil. They provide information's in the form of pH and soil nutrient levels, or even electrical conductivity in pesticides, among others.
Mechanical Sensors	These sensors are used to measure soil compaction or mechanical resistance.
Dielectric Soil Moisture Sensors	These sensors measure moisture levels by measuring dielectric constant of the soil.
Air Flow Sensors	These sensors are used to measure air permeability.

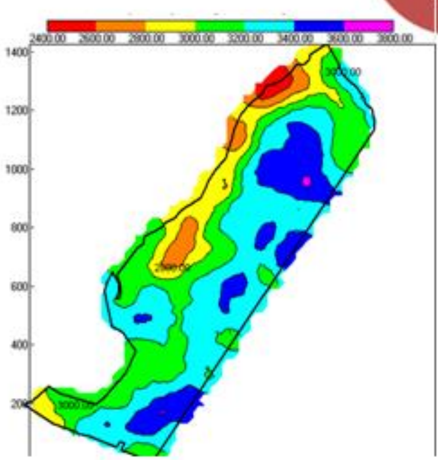
Agriculture based on data, information, and knowledge



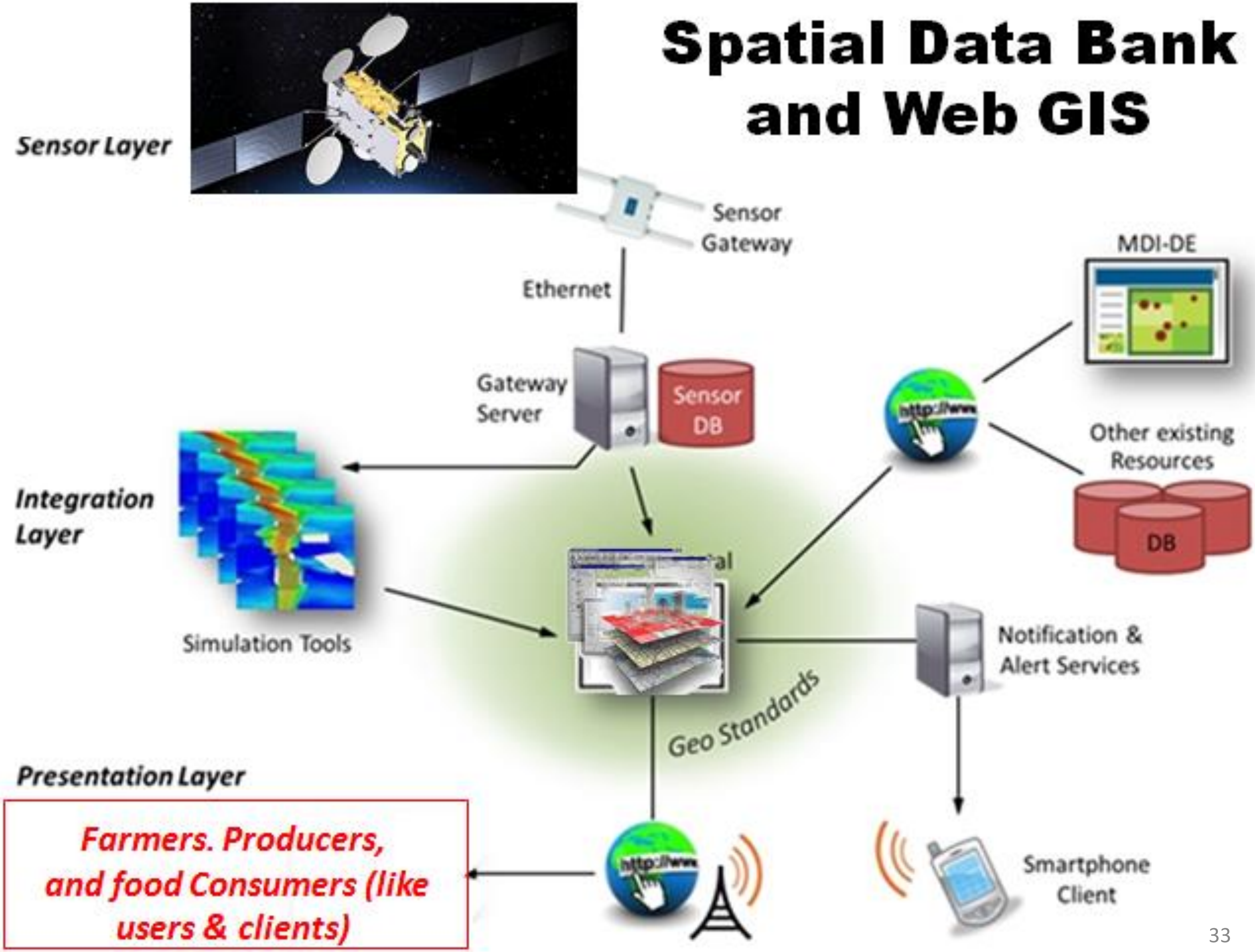
Sensors, Real-Time Critical Embedded Systems & Agricultural Automation





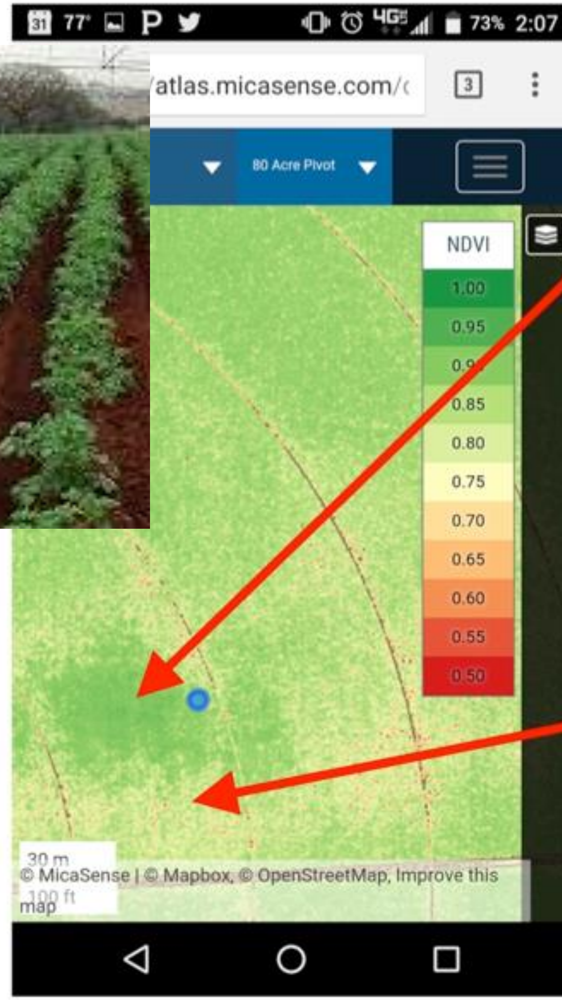


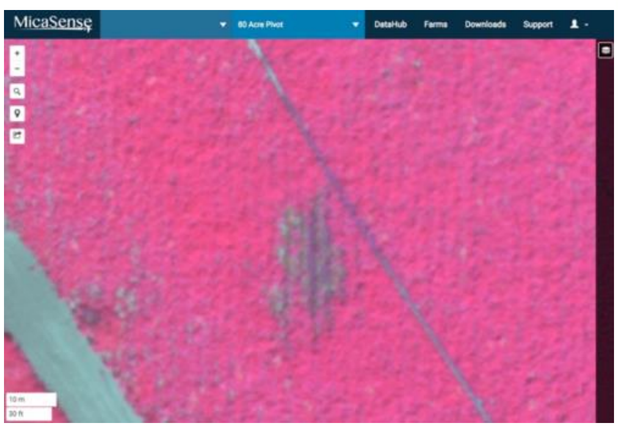
Spatial Data Bank and Web GIS



Some Examples of Application

Mapping and analysis of vegetation cover, and other features

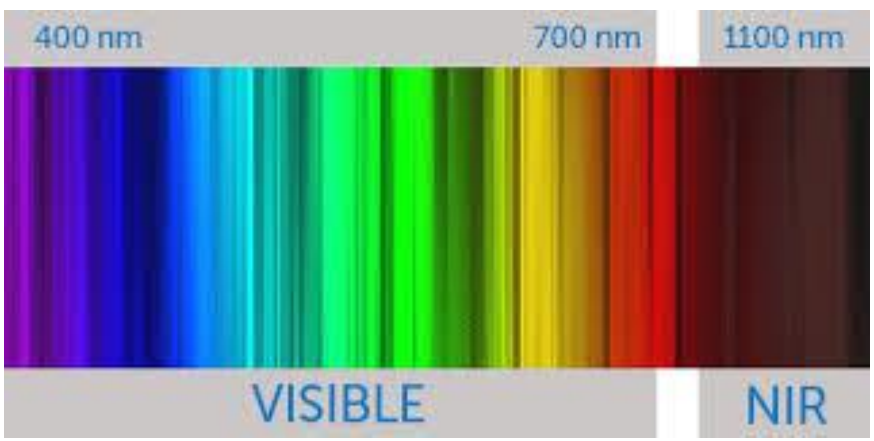


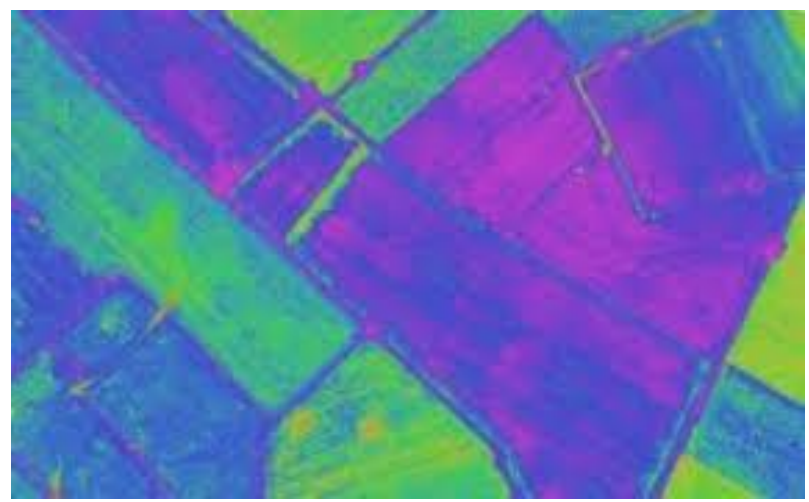


Broadleaf weed showing a high NDVI on an evaluation map.

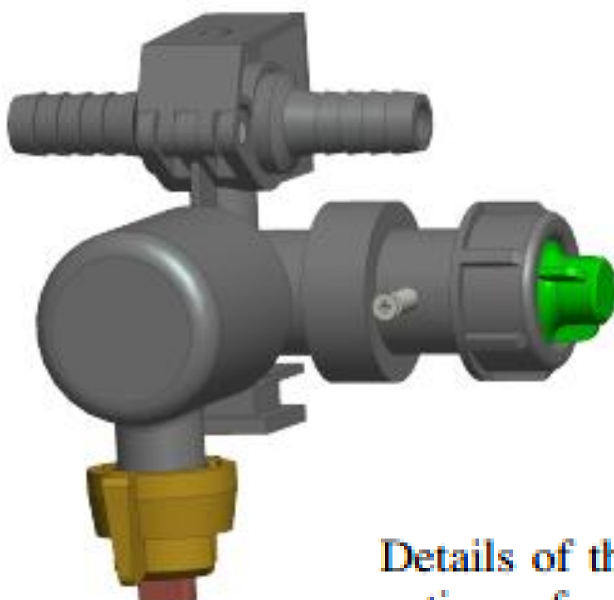
One could interpret it as an undeveloped plant, which is actually a weed.

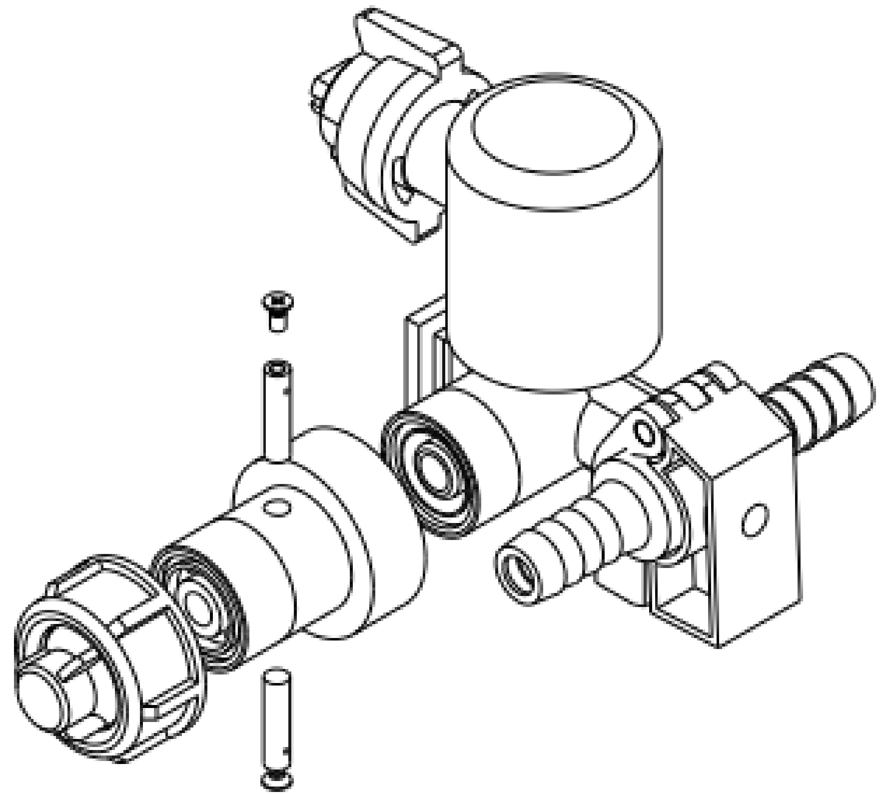
Mapping and analysis of vegetation cover, and other features



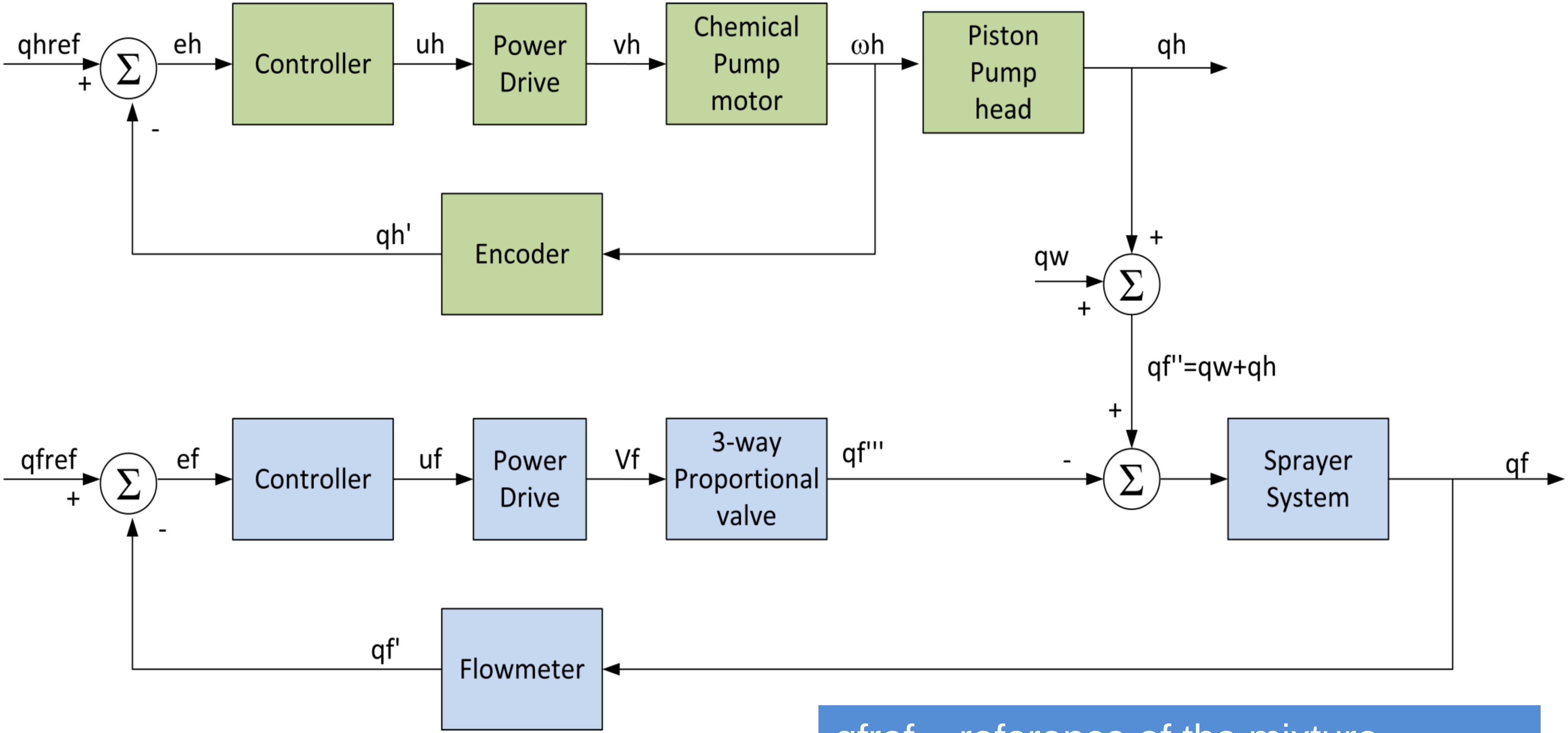


An Intelligent and Customized Electrical Conductivity Sensor to Evaluate the Response Time of a Direct Injection System





Details of the smart sensor customized to measure the response time of a system of direct injection of pesticides.

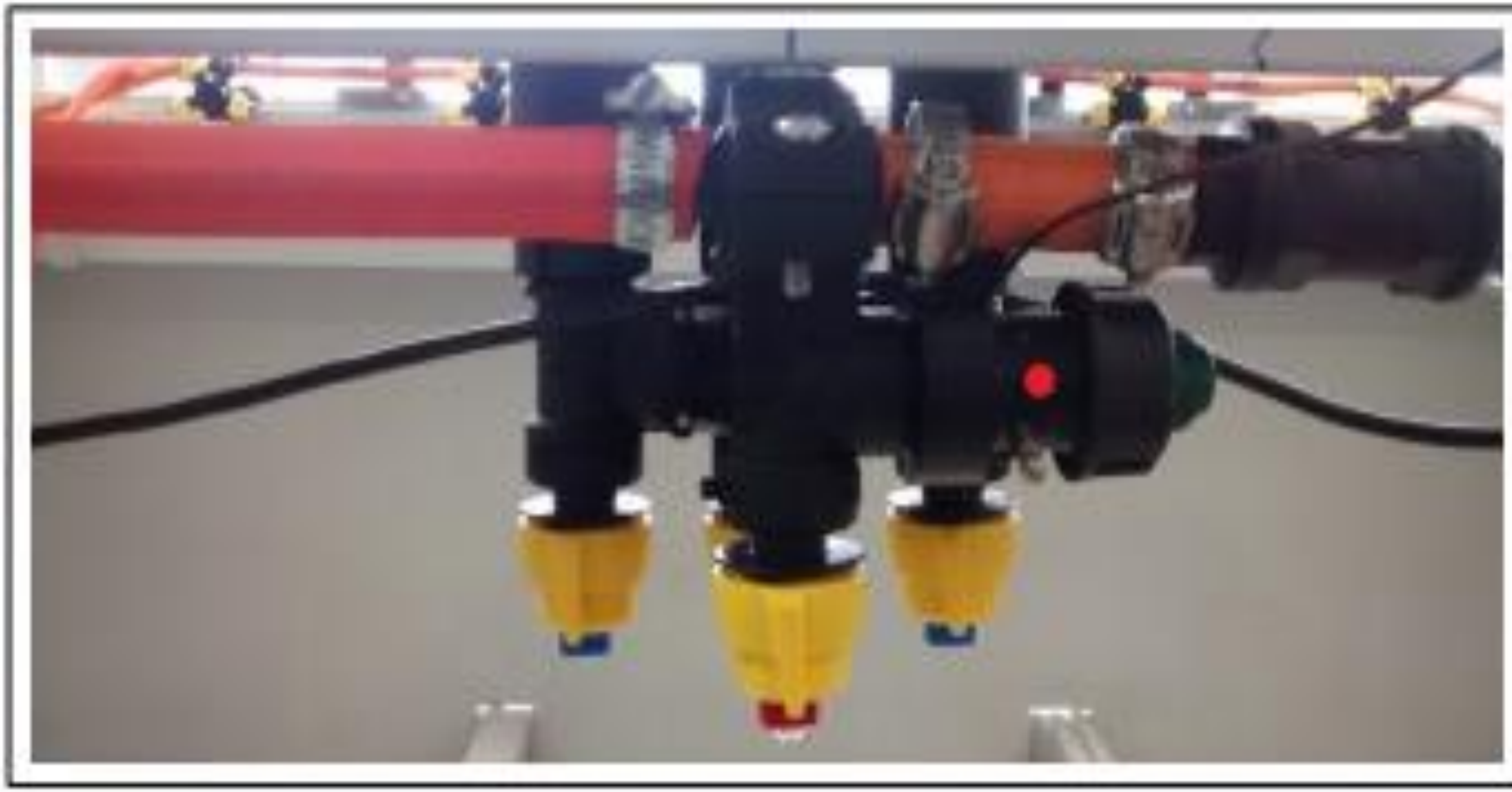


qhref – chemical reference
eh – chemical error
uh – control action
vh – chemical pump motor (Voltage)
ωh – motor speed
qh – chemical flow
qh' – estimated chemical flow

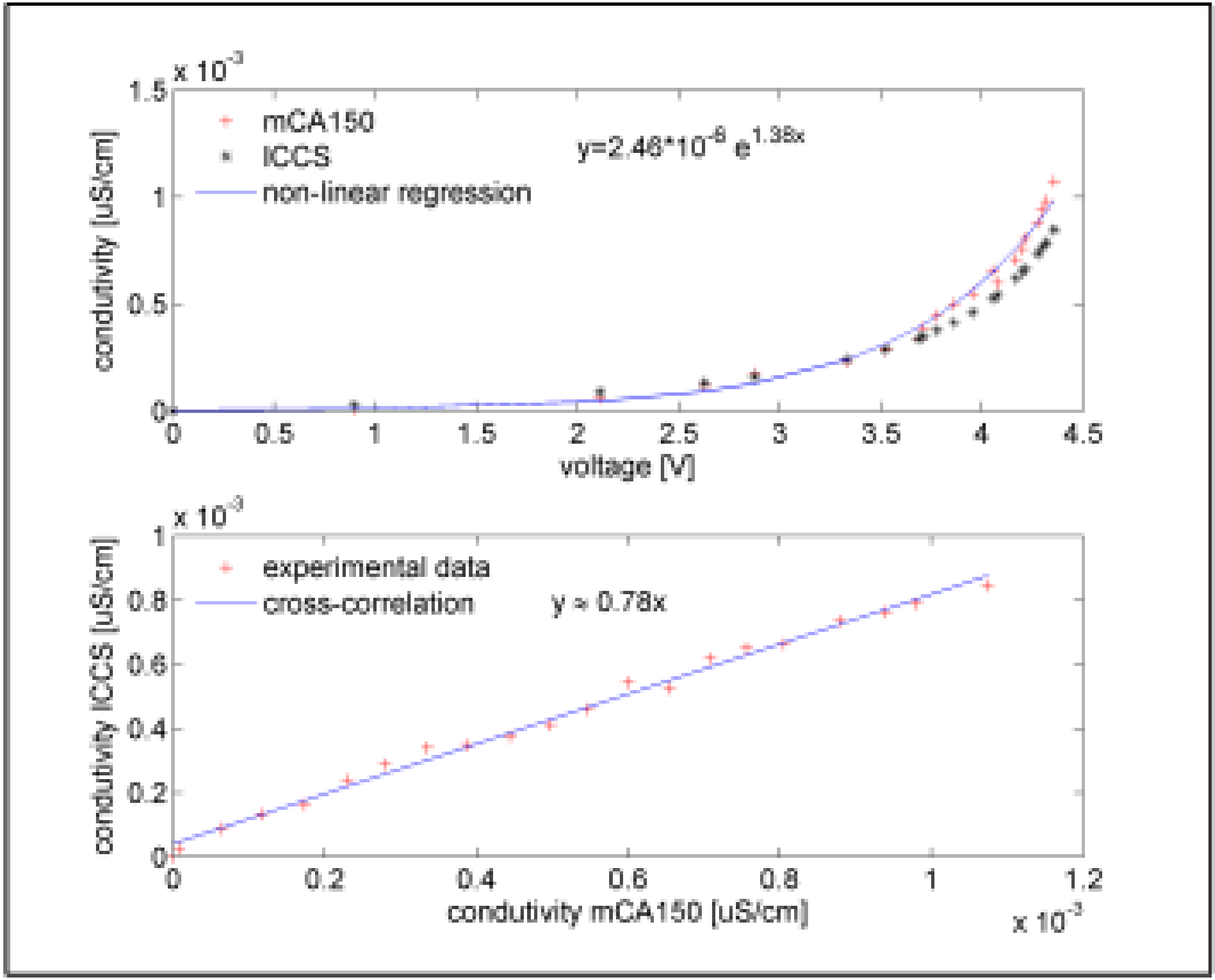
qfref – reference of the mixture
ef – mixture error
uf – controller action
vf – proportional valve (Voltage)
qf – desirable mixture flow
qf' – measure of the mixture flow
qf'' – chemical flow plus the water flow
qf''' – mixture flow after control
qw – water flow

Pseudo-code of the algorithm for self-assessment and self-diagnostic

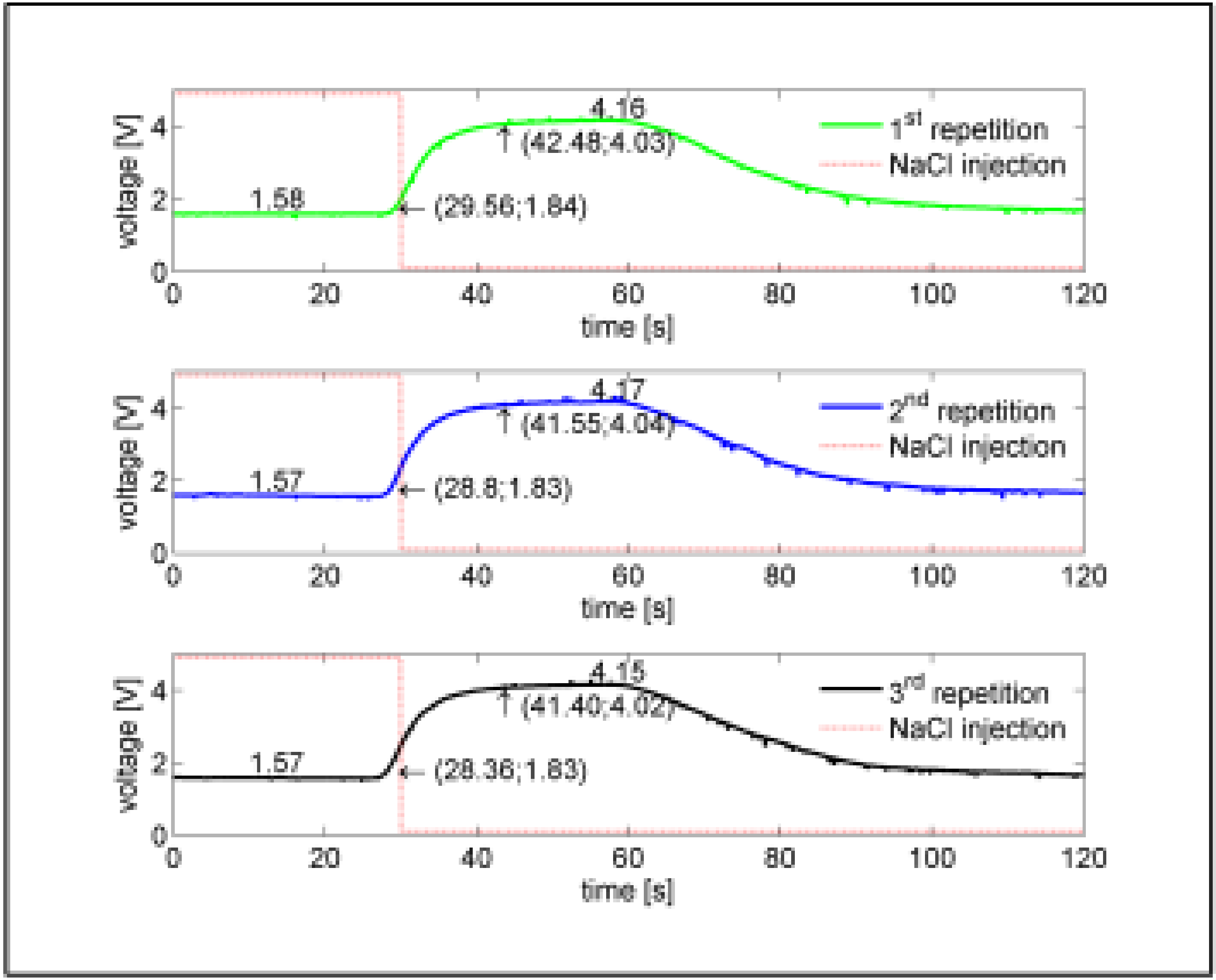
```
Initialization (TIMER, SERIAL, ADC);
if 0.50V < V_ICCS ≤ 4.90V then
  | data valid flag = true;
else
  | data valid flag = false;
end
while true do
  | if data valid flag == true then
  |   | read temperature ADC;
  |   | read conductivity ADC;
  |   | calculate CONDUCTIVITY;
  |   | send CONDUCTIVITY to SERIAL;
  | else
  |   | send ERROR to SERIAL;
  | end
end
```



Instrumental arrangement for validation of the intelligent sensor to measure response time of a direct injection sprayer with TeeJet® QJS Multiple Nozzle Bodies e-ChemSaver.



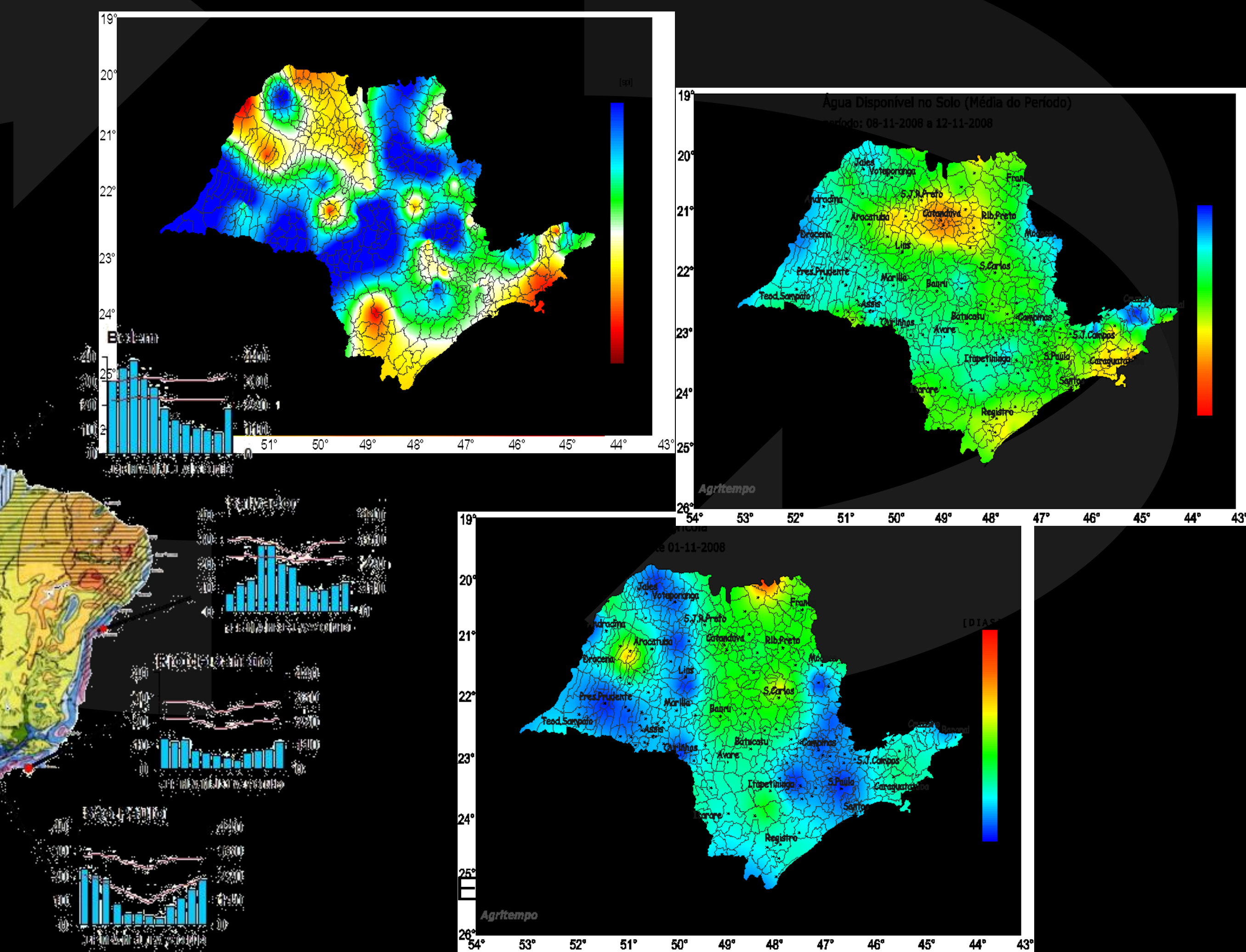
Calibration curves and comparison of measurements of the electrical conductivity from experimental solutions obtained with the intelligent and customized sensor with cell constant of $0.255\,\mathrm{cm}^{-1}$.

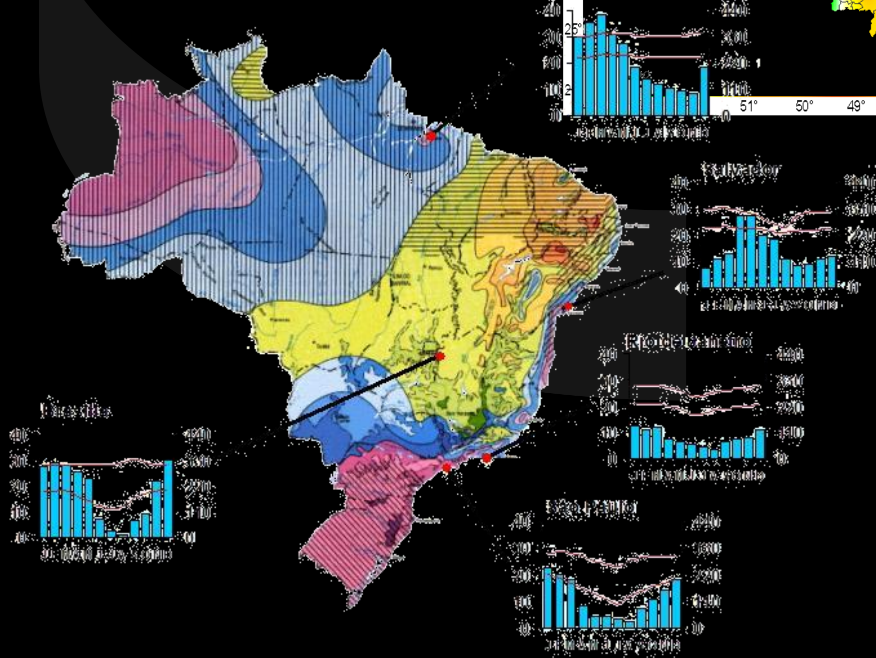


Transients and transport delay times of the sprayer with the conductivity sensor assembled in an actual spraying system with water-NaCl solution flow of 16 l/min and pressure equal to 200 kPa.

Agri-food industry based on use of Advanced Sensors, Bigdata, AI, Advanced Statistics and Decision Making

Sensor network for environmental monitoring and agricultural zoning support





Agricultural research based on geospatial/sensing knowledge to support Public Policies

Zoning of Climatic Risks

Regionalization of climatic claims to minimize losses in agricultural production, risks reducing from the rainfall regimes

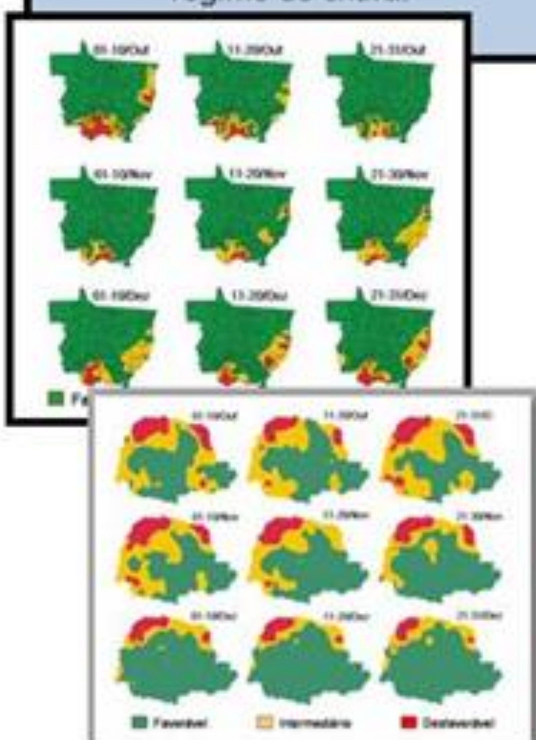
regime de chuva.

Agroecological Zoning of Sugarcane

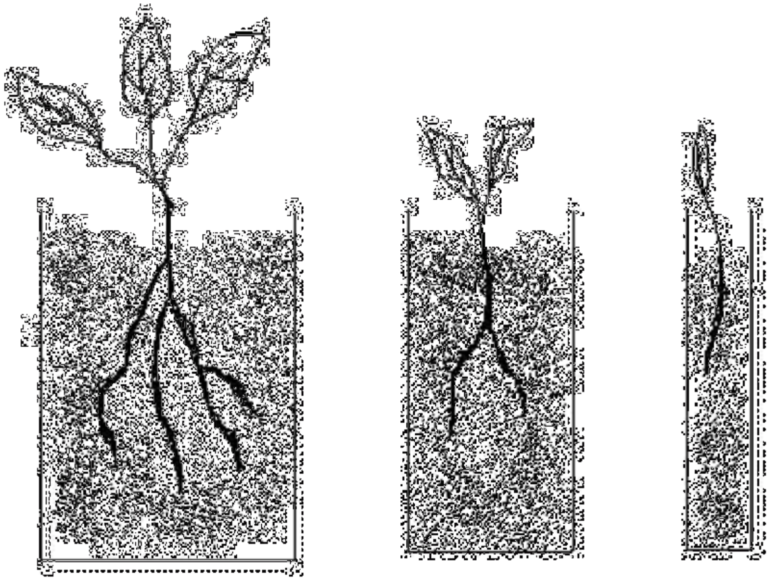
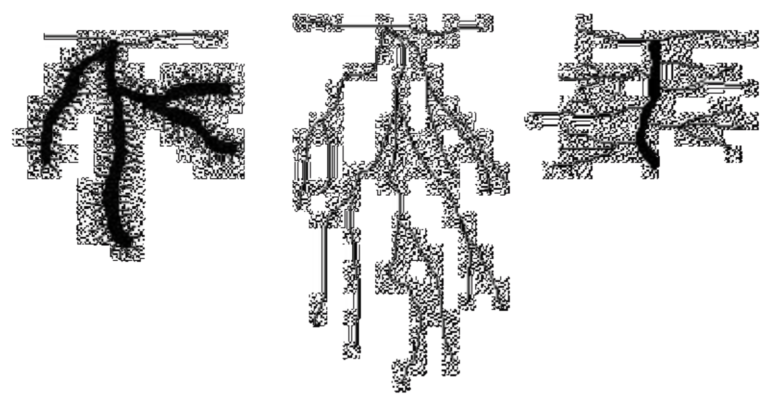
It defines suitable areas and exclusion zones for the cultivation of sugar cane in Brazil. Directs the policy of expansion and bioethanol production

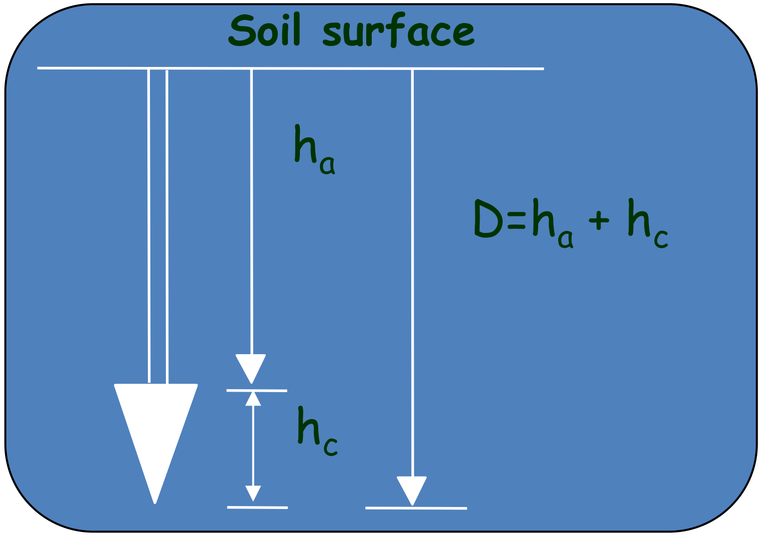
Low Carbon Agriculture ABC Plan

Decarbonization of the agriculture processes by the incorporation of practices of low emission of greenhouse gases



Intelligent sensor to facilitate decision making in the evaluation of soil resistance to root penetration



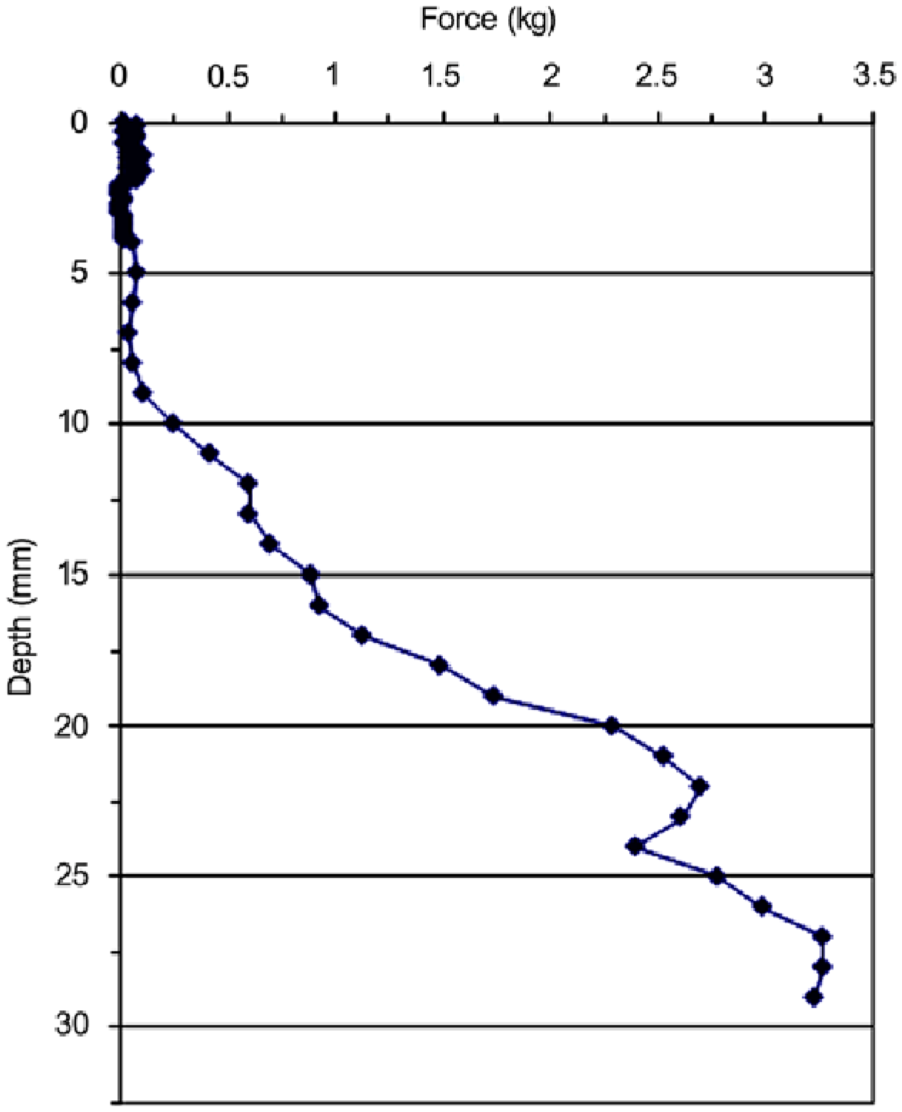
$$RSP = g(\sigma_n, \mu, c_a, RP, \rho, \theta)$$

$$RSP = 6{,}98\rho^2 + \left[-1{,}62x10^{-1} + 1{,}36x10^{-3}\left(h_a + R_c\left(\frac{RP-\sigma_n}{(\mu\sigma_n)+c_a}\right)\right)\right]\rho$$

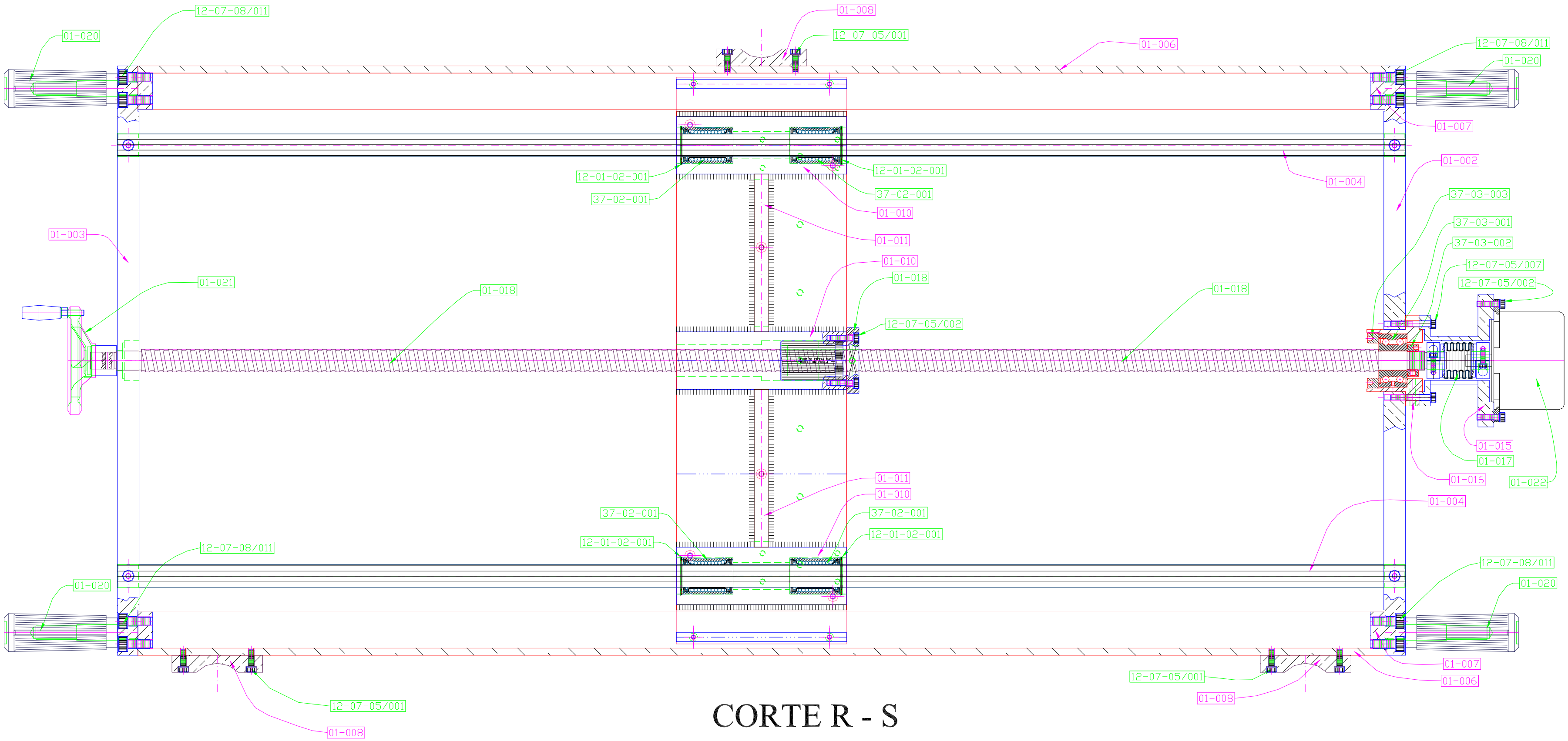
$$+\left[1{,}98x10^{-1} - 9{,}20x10^{-3}\left(h_a + R_c\left(\frac{RP-\sigma_n}{(\mu\sigma_n)+c_a}\right)\right)\right](\theta\rho)$$

$$+9{,}80x10^{-2}\left[h_a + R_c\left(\frac{RP-\sigma_n}{(\mu\sigma_n)+c_a}\right)\right] - 2{,}00x10^{-3}\left[h_a + R_c\left(\frac{RP-\sigma_n}{(\mu\sigma_n)+c_a}\right)\right]^2$$

$$-10{,}44x10^{-3}$$



Soil resistance variations to the root penetration in function of depth Z and coordinates X and Y.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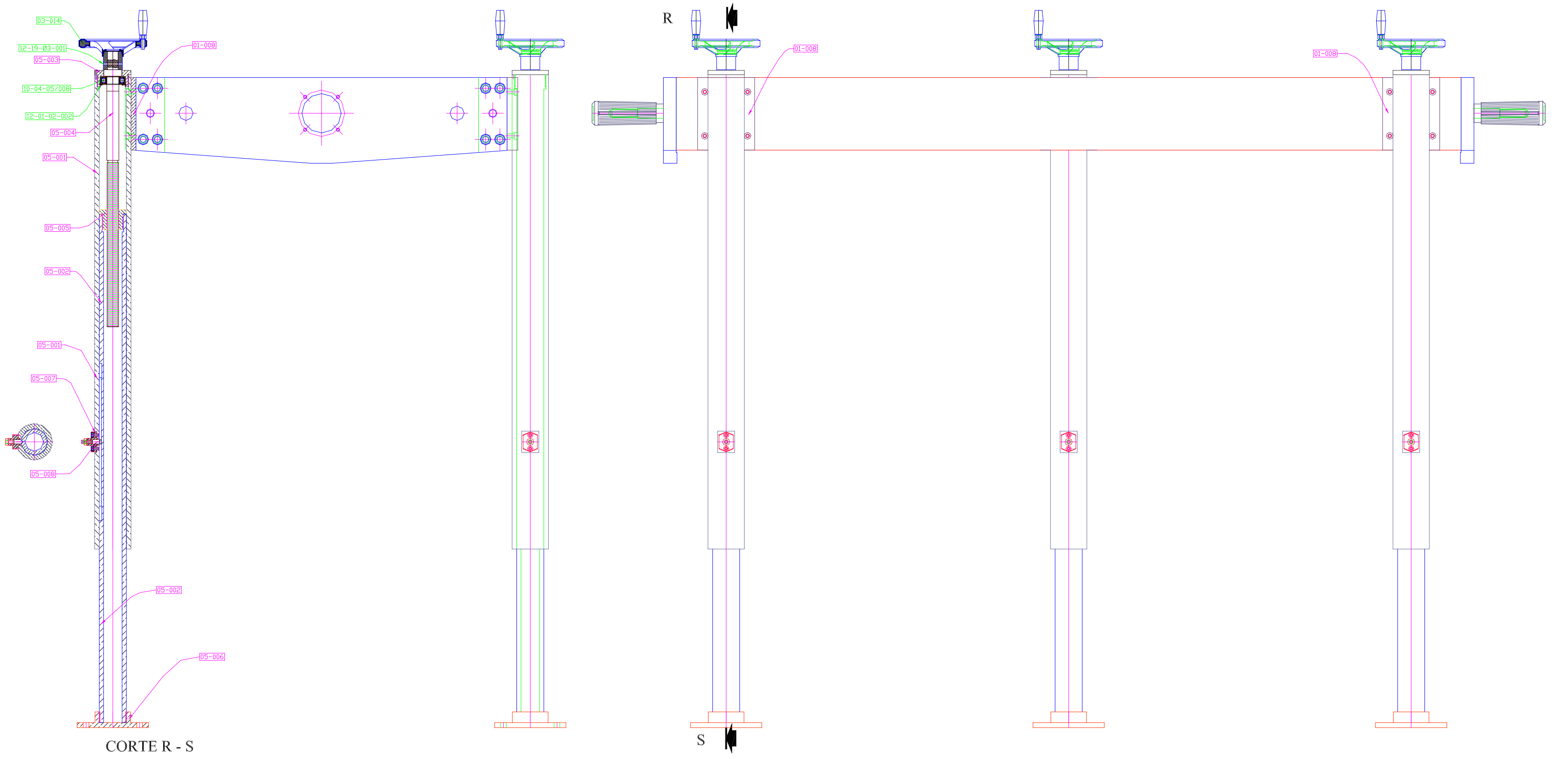
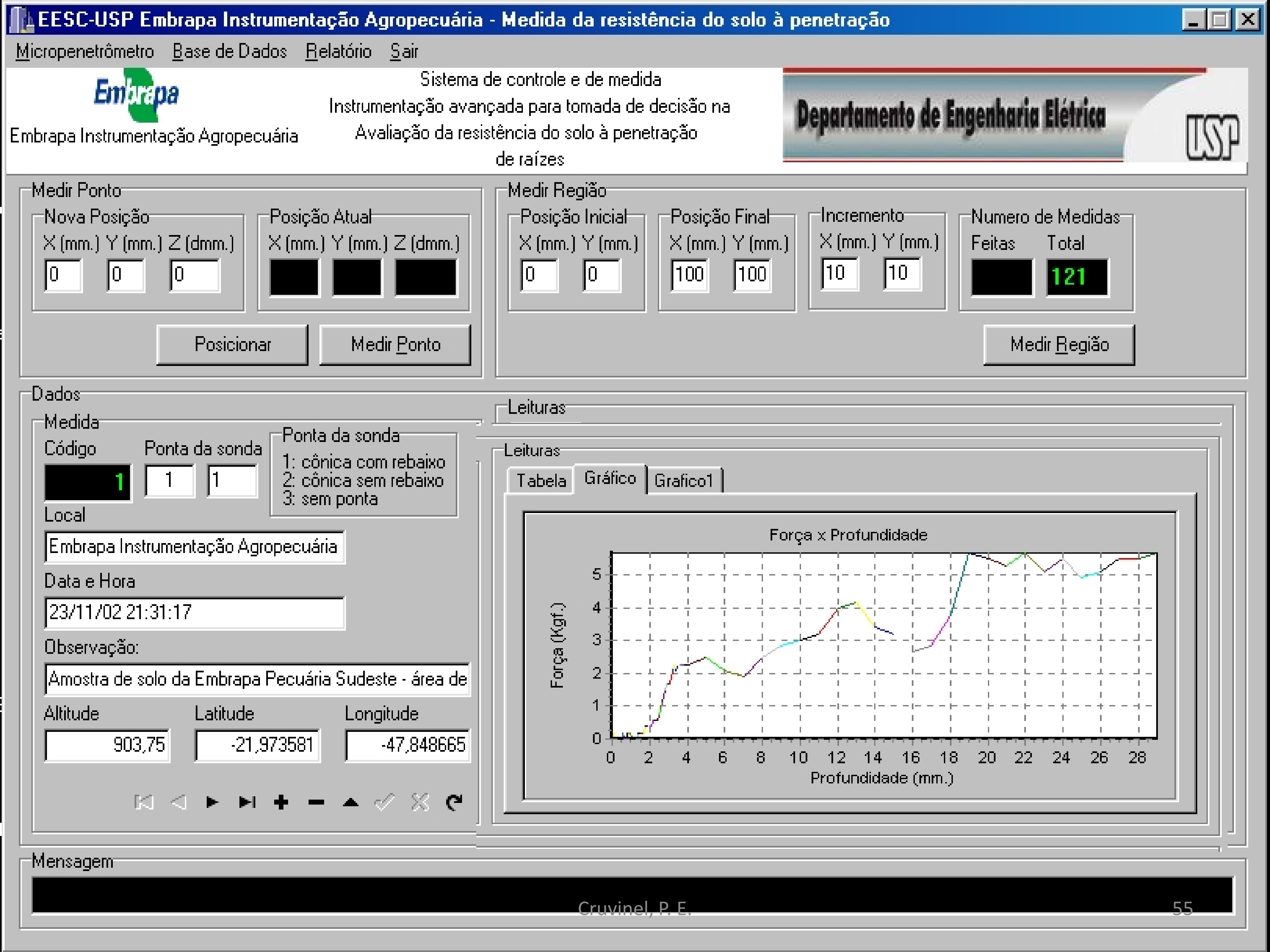
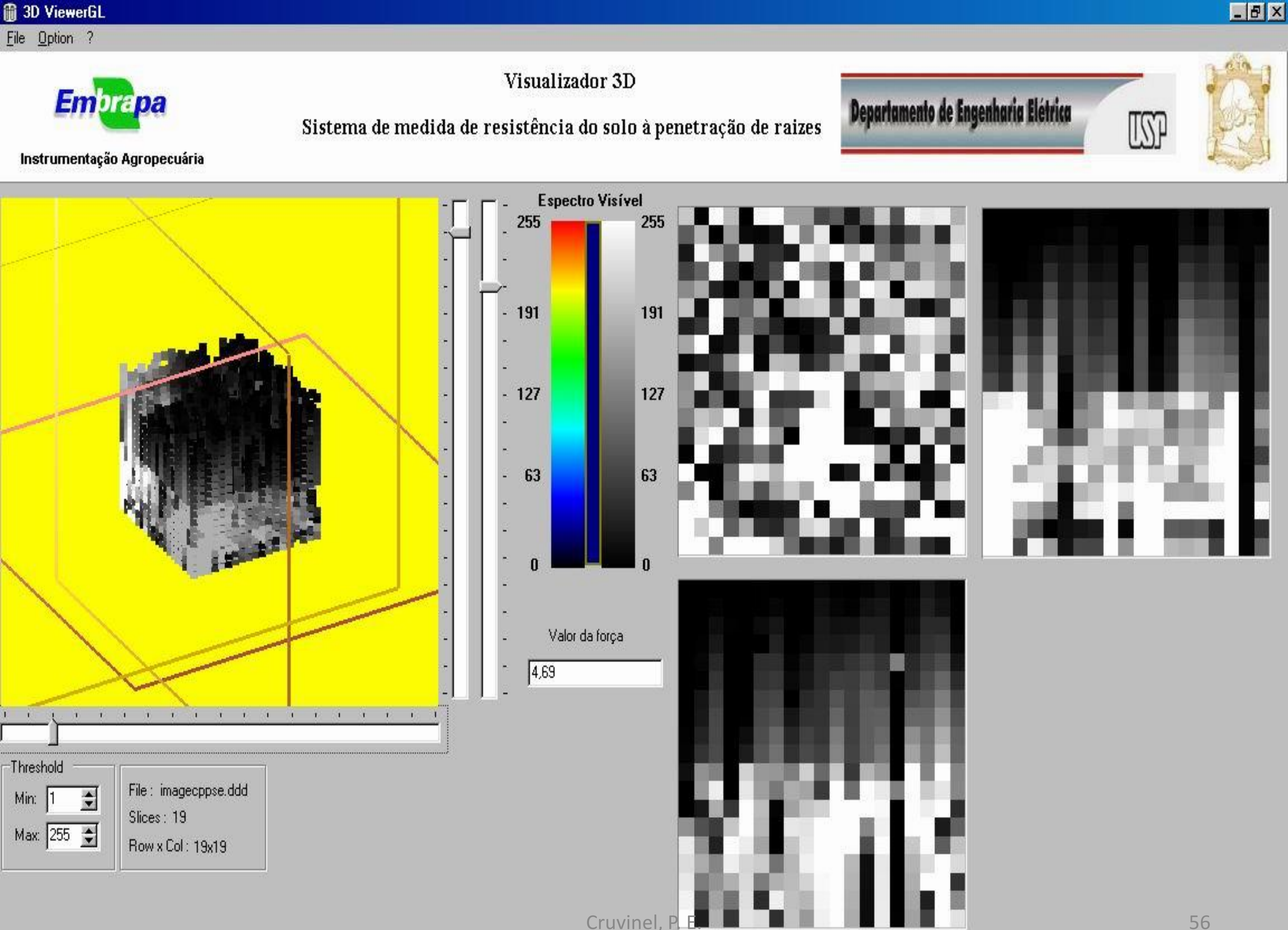


03-014
12-19-Ø3-001
05-003
10-04-05/008
12-01-02-002
05-004
05-001
05-005
05-002
05-001
05-007
05-008
01-008
05-002
05-006
CORTE R - S
R
S
01-008
01-008


EESC-USP Embrapa Instrumentação Agropecuária - Medida da resistência do solo à penetração
Micropenetrômetro
Base de Dados
Relatório
Sair
Embrapa
Embrapa Instrumentação Agropecuária
Sistema de controle e de medida
Instrumentação avançada para tomada de decisão na
Avaliação da resistência do solo à penetração
de raízes
Departamento de Engenharia Elétrica
USP
Medir Ponto
Nova Posição
X (mm.) Y (mm.) Z (dmm.)
0 0 0
Posição Atual
X (mm.) Y (mm.) Z (dmm.)
Posicionar
Medir Ponto
Medir Região
Posição Inicial
X (mm.) Y (mm.)
0 0
Posição Final
X (mm.) Y (mm.)
100 100
Incremento
X (mm.) Y (mm.)
10 10
Numero de Medidas
Feitas
Total
121
Medir Região
Dados
Medida
Código
1
Ponta da sonda
1 1
Ponta da sonda
1: cônica com rebaixo
2: cônica sem rebaixo
3: sem ponta
Local
Embrapa Instrumentação Agropecuária
Data e Hora
23/11/02 21:31:17
Observação:
Amostra de solo da Embrapa Pecuária Sudeste - área de
Altitude
903,75
Latitude
-21,973581
Longitude
-47,848665
Leituras
Leituras
Tabela
Gráfico
Grafico1
Força x Profundidade
Força (Kgf.)
0 1 2 3 4 5
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Profundidade (mm.)
Mensagem

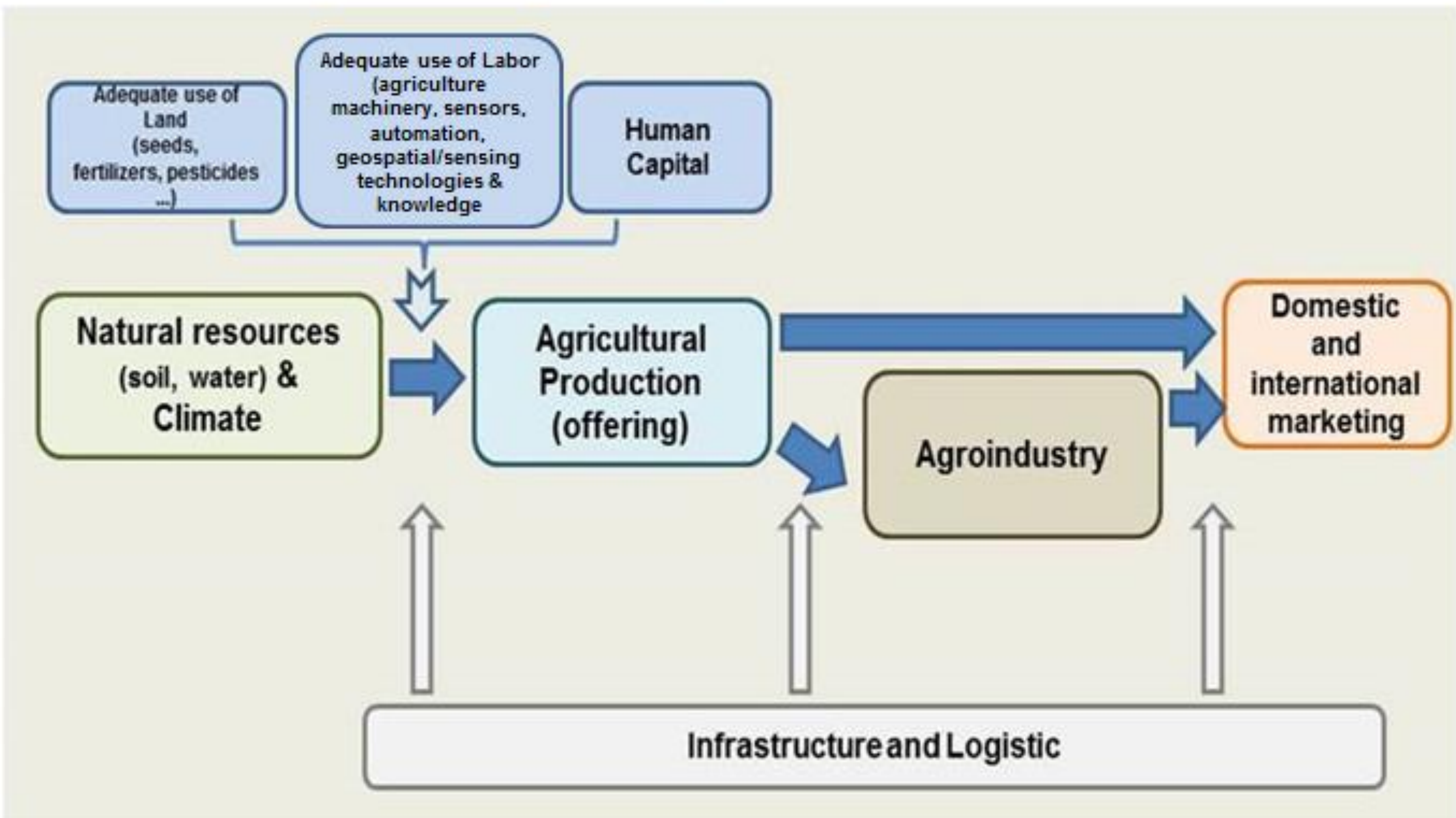

3D ViewerGL
File Option ?
Embrapa
Instrumentação Agropecuária
Visualizador 3D
Sistema de medida de resistência do solo à penetração de raizes
Departamento de Engenharia Elétrica
USP
Espectro Visível
255
191
127
63
0
Valor da força
4,69
Threshold
Min: 1
Max: 255
File : imagecppse.ddd
Slices : 19
Row x Col : 19x19

Agricultural Value Chain and Opportunities

How many Bytes of Data?

- ✓ Google processes about 23 PBytes of data / day;
- ✓ Facebook has about 2.5 PBytes of user data and processes about 15 TBytes of data / day;
- ✓ Wayback Machine has about 3 PBytes of user data and processes about 100 Tbytes of data / month;
- ✓ eBay has about 6.5 Pbytes of user data and processes about 50 TBytes of data / day;
- ✓ CERN and its large Hadron collider generates about 15 Pbytes of data / year.

How many Bytes involved in the Agricultural Value Chains?



Conclusions

Conclusion

Daily requirements for food will soon be reaching its highest peak. There is a great need to seek new methods and new ways for food production associated with people ‘education to fully meet this potential demand.

The use of advanced sensors makes room in crop selection, input selection, agricultural risk management and decision support systems, as well as in providing training to farmers and rural managers.

Agricultural automation based on these new paradigms, including Bigdata analytics and complexity may help humanity, however technological development should be accompanied by social and environmental public policies that seek to ensure the resilience of natural systems and the sustainability of life on the planet.

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Paulo E. Cruvinel
Research Scientist
+5516 997810411
paulo.cruvinel@embrapa.br
http://www.embrapa.br