

Sensoriamento e sensores

(plantas)

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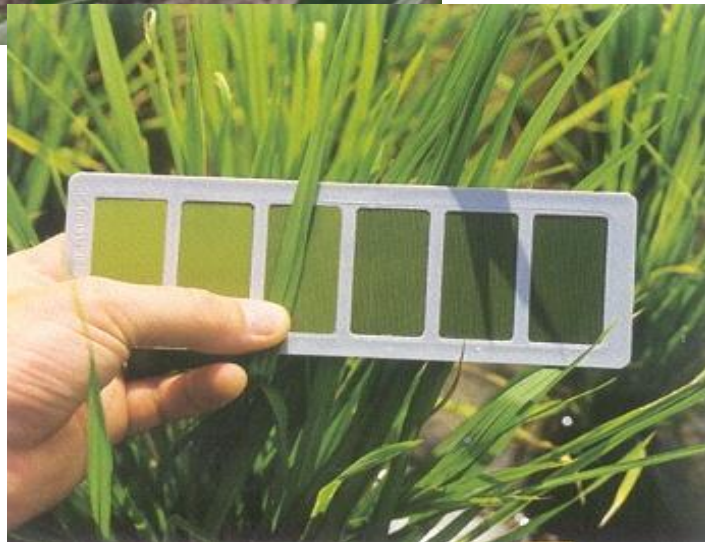


www.agriculturadeprecisao.org.br

Objetivo

Abordar as técnicas relacionadas ao uso de sensores de alvos agrícolas, especialmente solo e plantas, para a obtenção de dados e diagnóstico da variabilidade espacial, visando tratamento localizado via mapas ou em tempo real.

Sensores de plantas



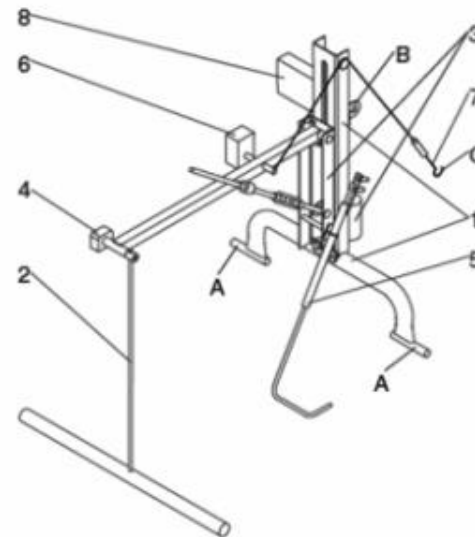
... predominantemente ópticos



Sensores de planta



Ehlert e Dammer, 2006



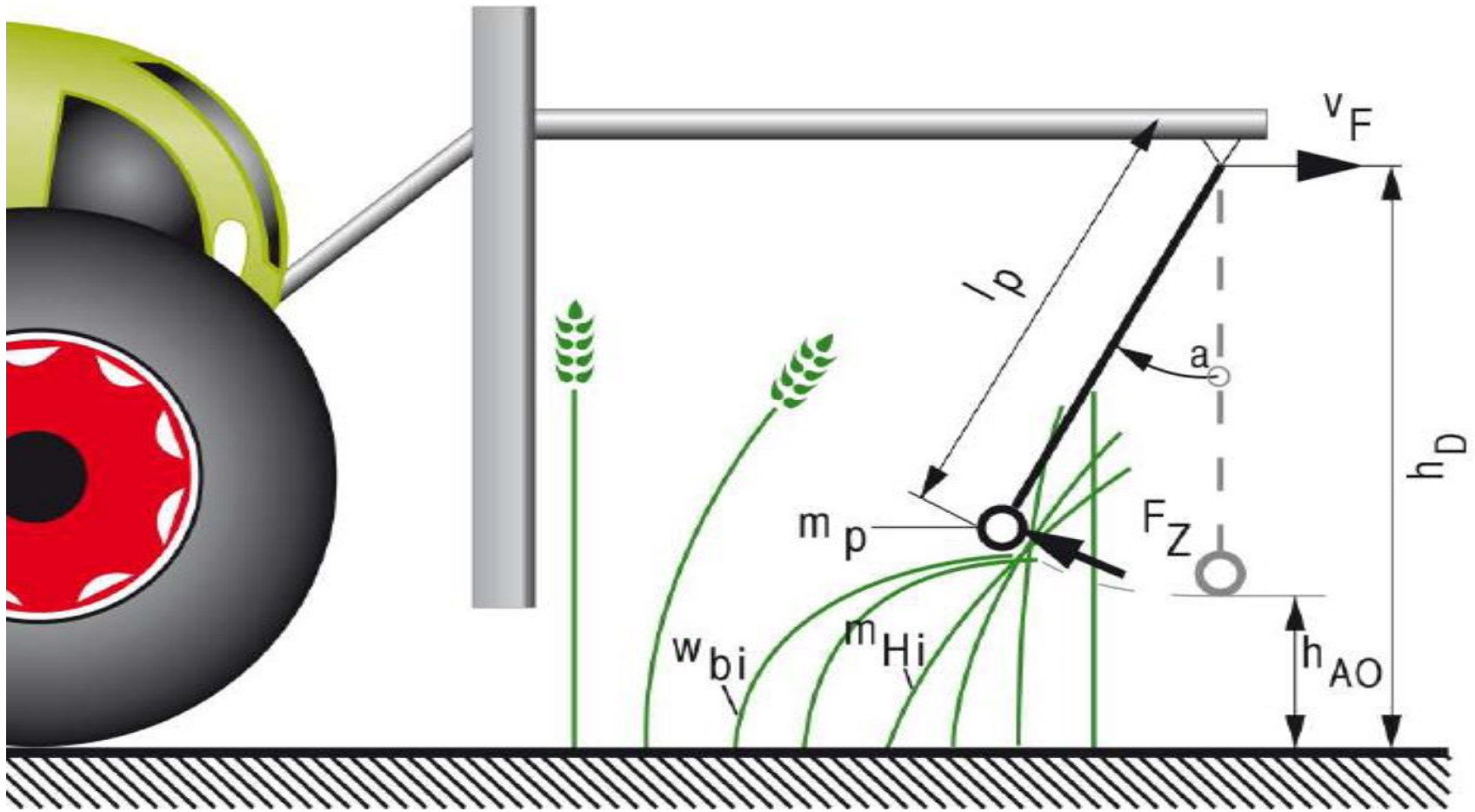
- 1 - Frame
 - 2 - Pendulum body
 - 3 - Depth compensation
 - 4 - Potentiometer
 - 5 - Surface sensor rod
 - 6 - Inclination sensor
 - 7 - Drawing cable
 - 8 - Electronic box
- A,A,B,(C) - Linkage points

Main parameters:

- Complete mass - 40 kg
- Working width - 1.0 m
- Voltage - 12 V -
- Energy consumption - max. 50W

Sensor de densidade de plantas

Princípio de funcionamento



Class, 2009





WERNER, A. (2008)

Sensoriamento sem contato físico (remoto)

(óptica)

Níveis de aquisição de dados – essencialmente estimativa de biomassa



Orbital



Aéreo (avião)



Aéreo (“VANT”)

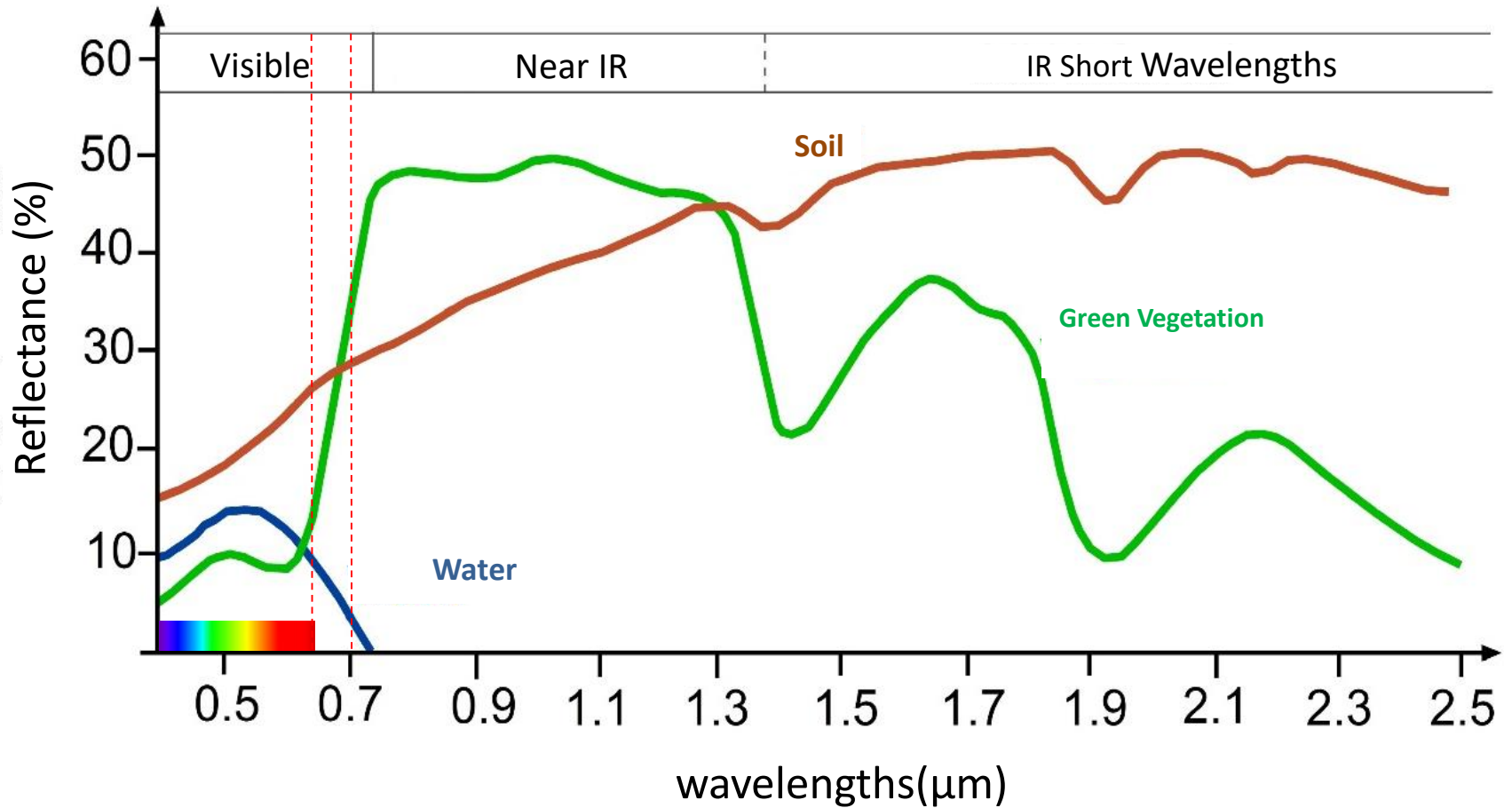


Terrestre

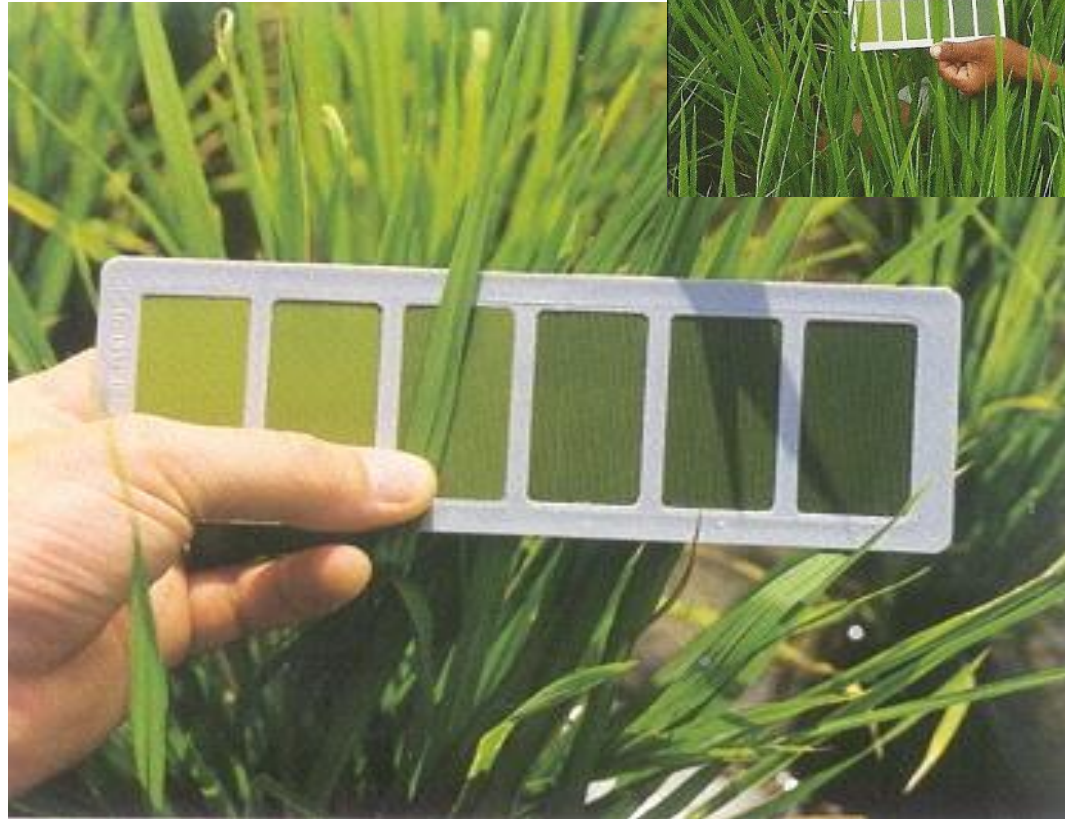
Ativos!

Sensores de plantas

Distribuição do comprimento de ondas eletromagnéticas



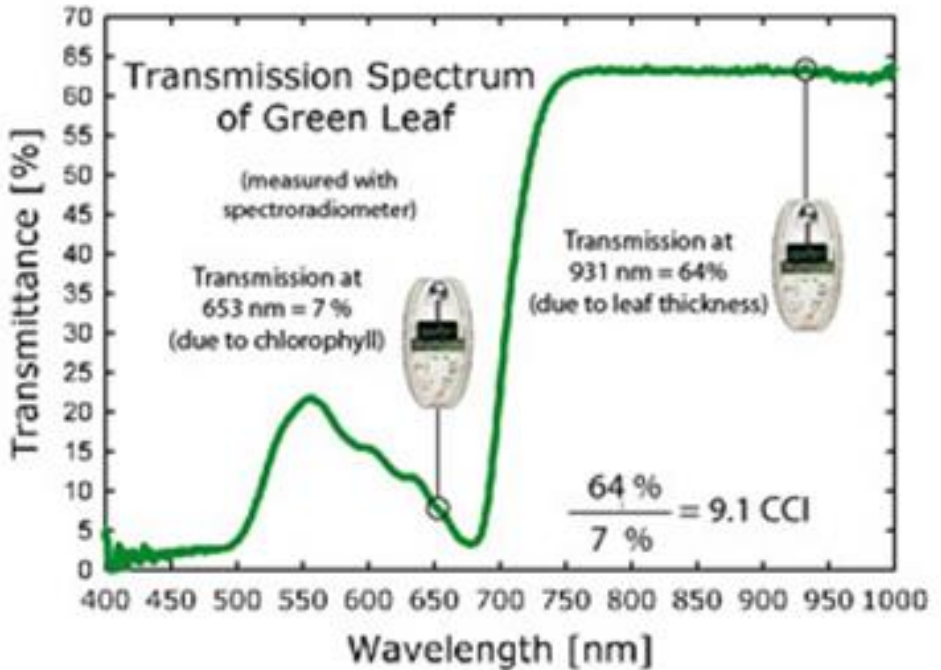
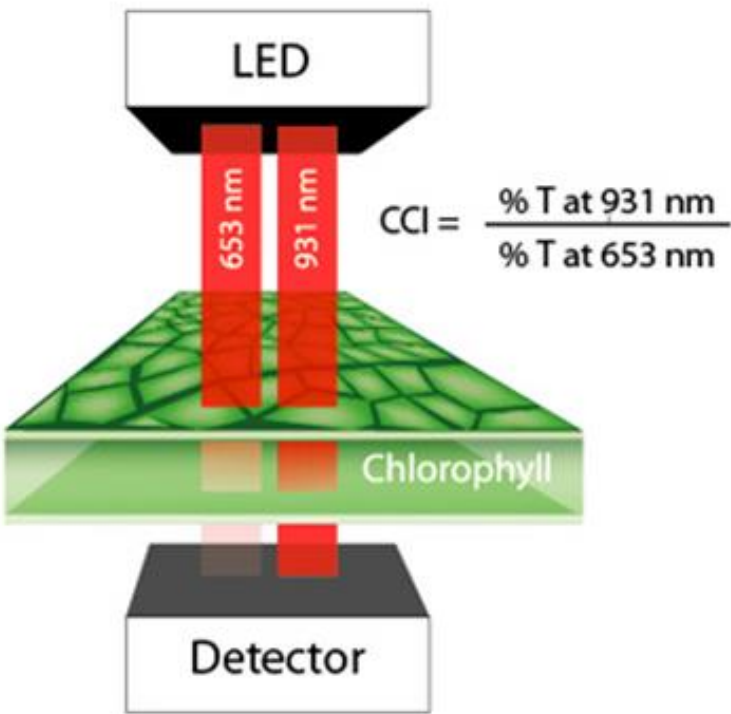
Sensores ópticos (plantas)



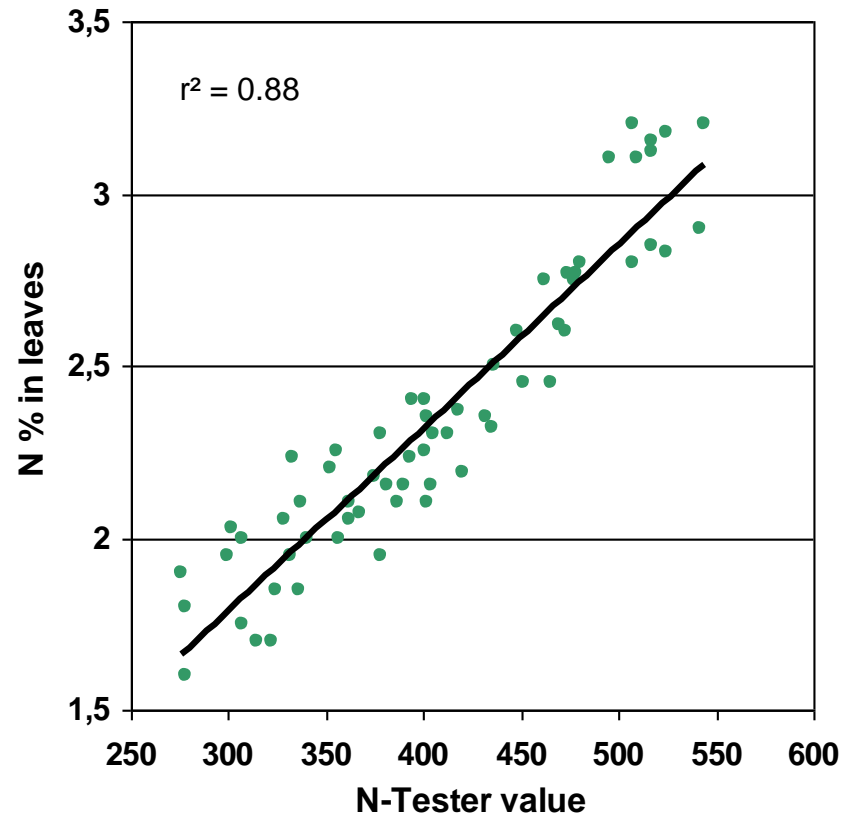
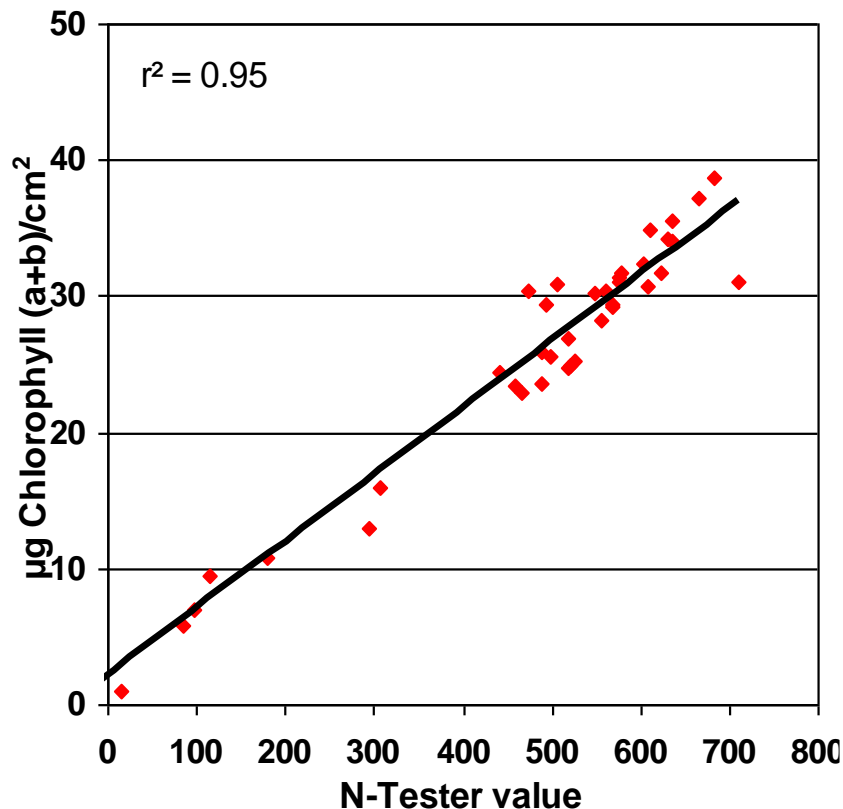
Sensores de clorofila (absorbância e transmitância)



Sensores óticos diretos – transmitância e absorbância (clorofila)



Relação dos medidores com Clorofila e Nitrogênio



Fonte: Yara

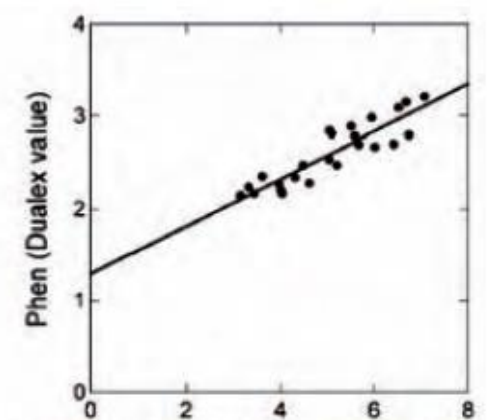
Clorofilômetros



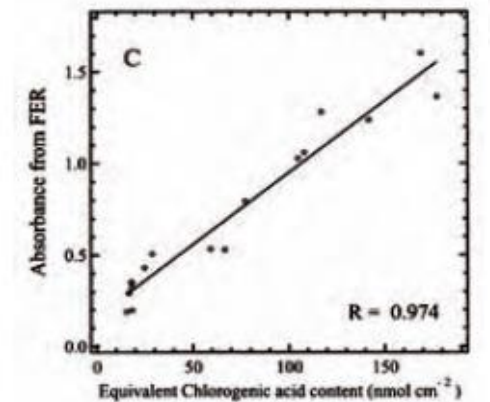
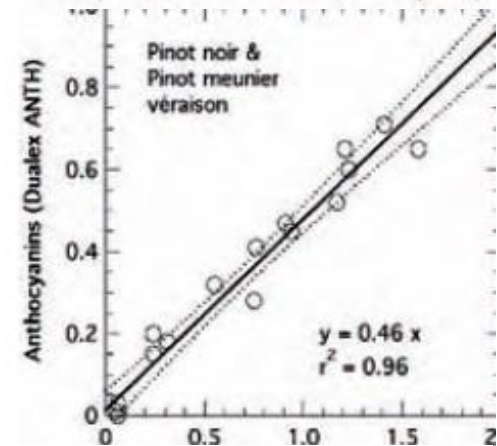
Medição do conteúdo de isoorientina em trigo como indicador de deficiência de N

Medição de conteúdo de antocianina na casca de “berry”

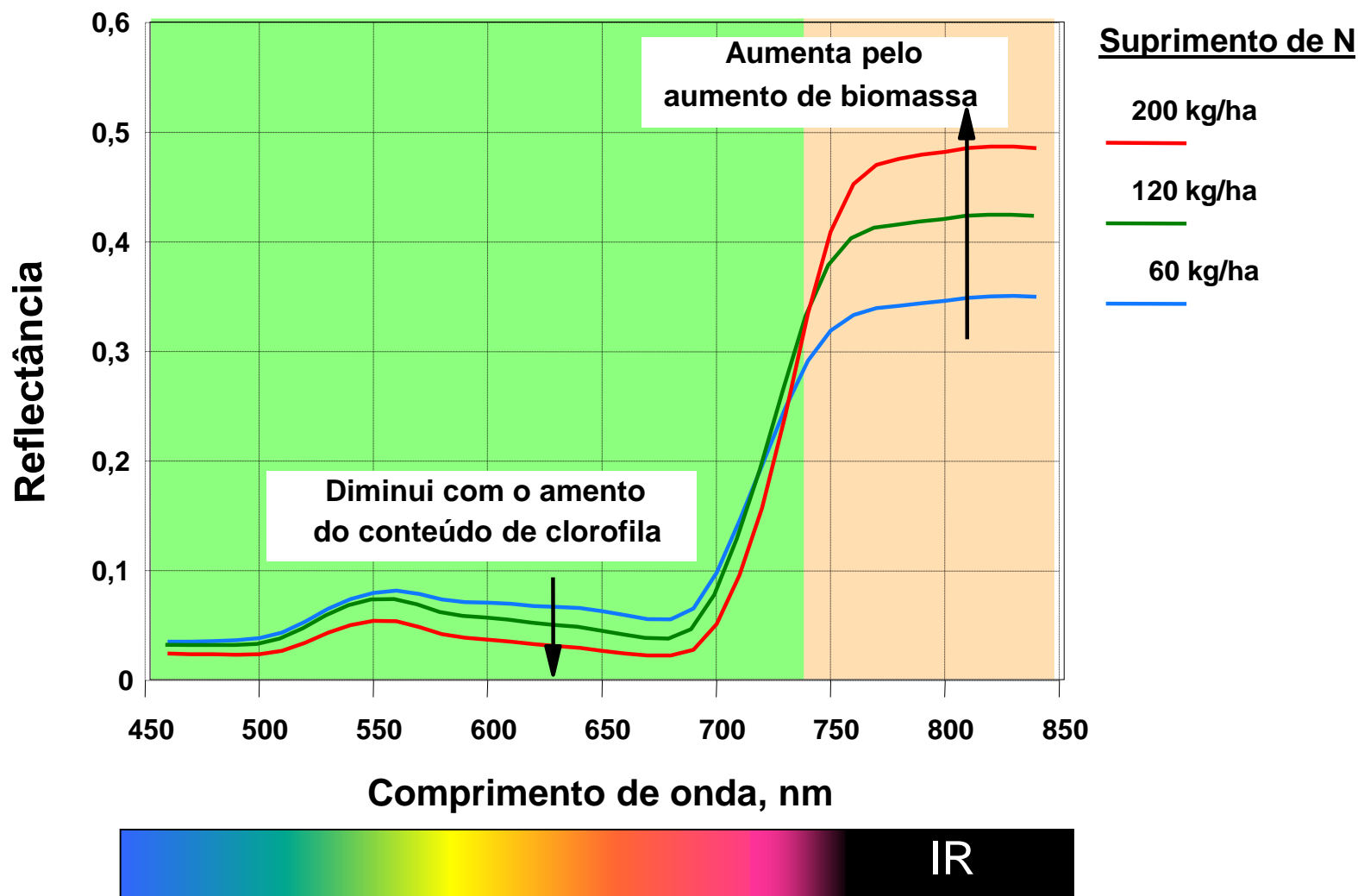
Correlação entre absorbância e conteúdo de ácido clorogênico em folhas de tabaco



Phen (absorbance of the flavone peak)



A utilidade da refletância na agricultura



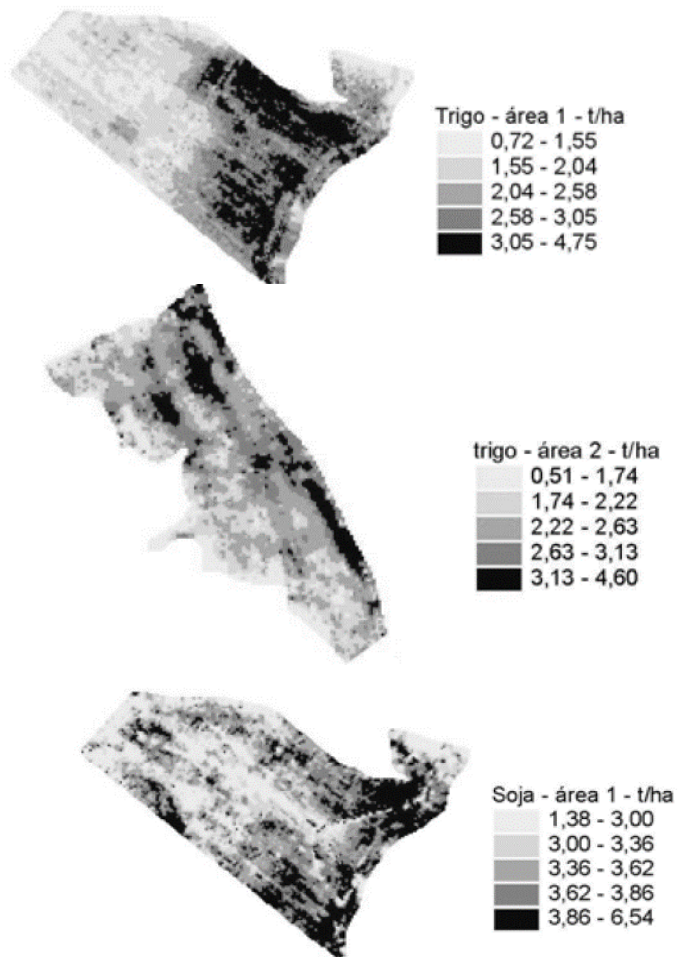
Fonte: Adaptado de Yara N response trial 1994.

Biomassa x produtividade

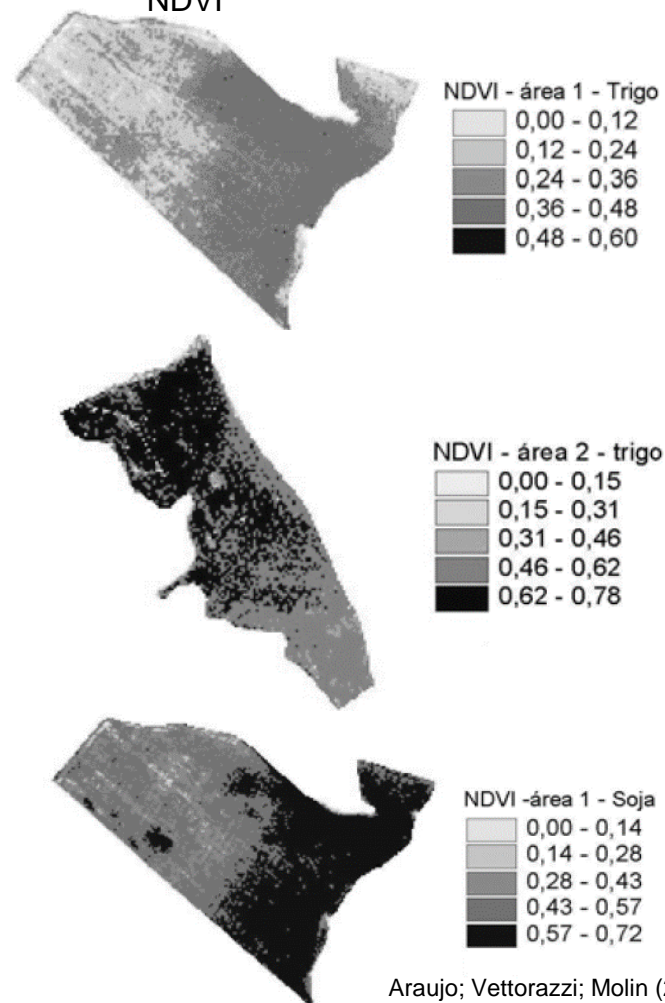
Regressão linear - valores de R²

	Produtividades		
	Soja Área 1	Trigo Área 1	Trigo Área 2
Vermelho	0,420	0,578	0,095
Infravermelho próximo	0,500	0,594	0,103
NDVI	0,539	0,819	0,158

Produtividades



NDVI



Araujo; Vettorazzi; Molin (2005)

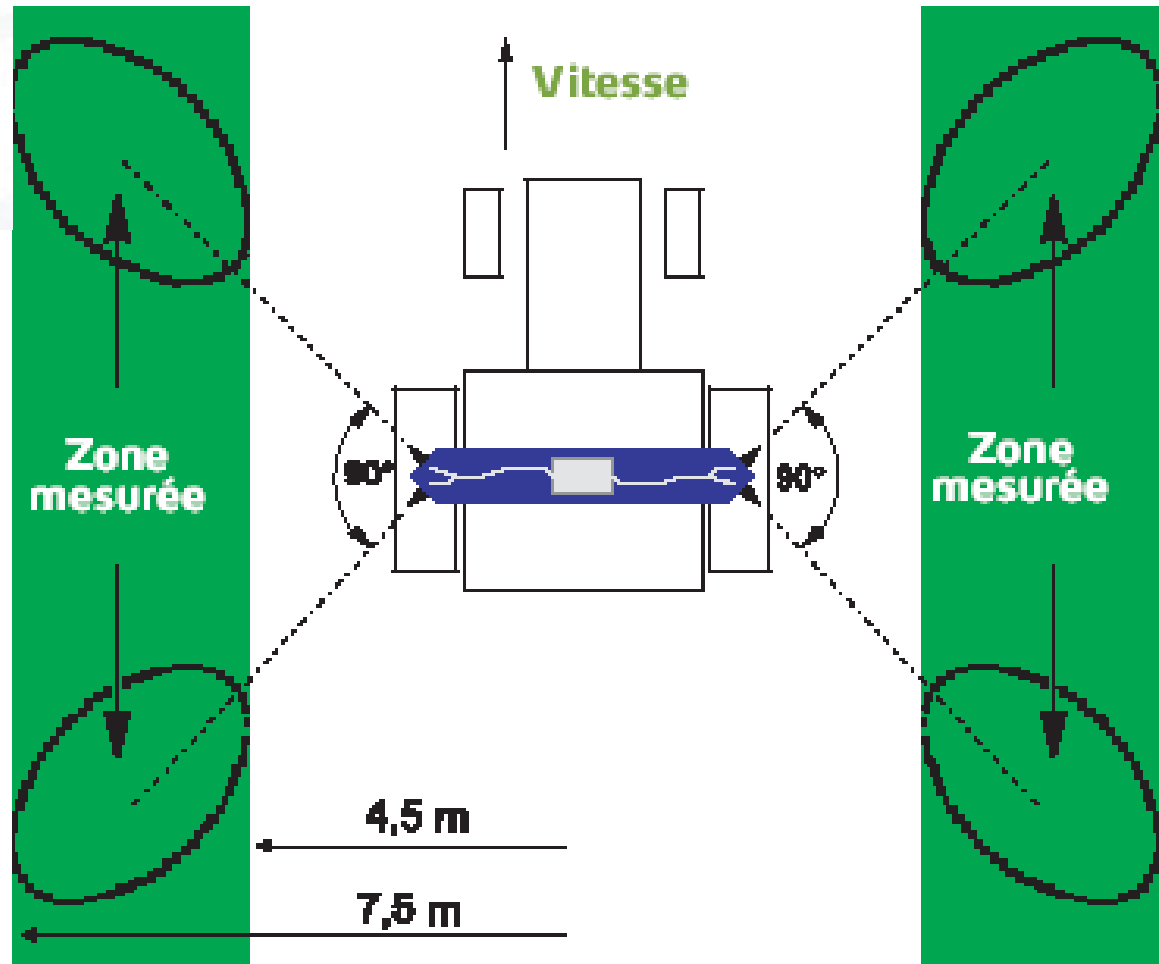
Sensores dedicados

Sensores multiespectrais passivos

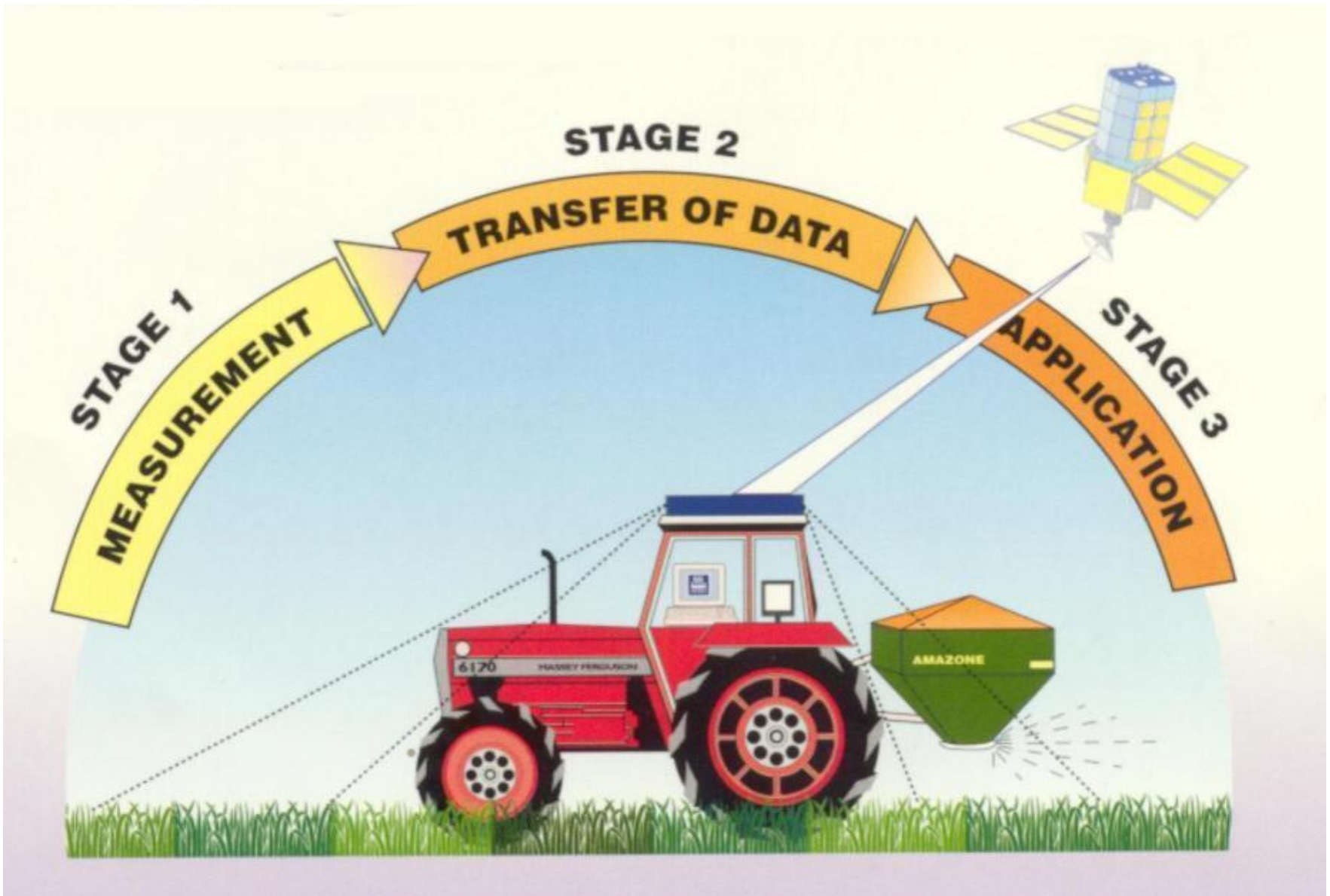
1999!!



WERNER, A. (2008)



Yara N-Sensor



Yara N-Sensor

Sensores multiespectrais

Ativos



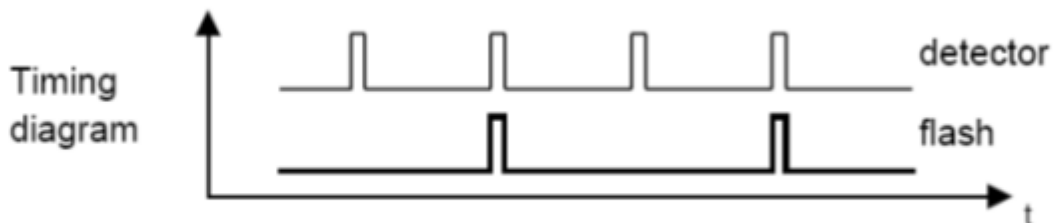
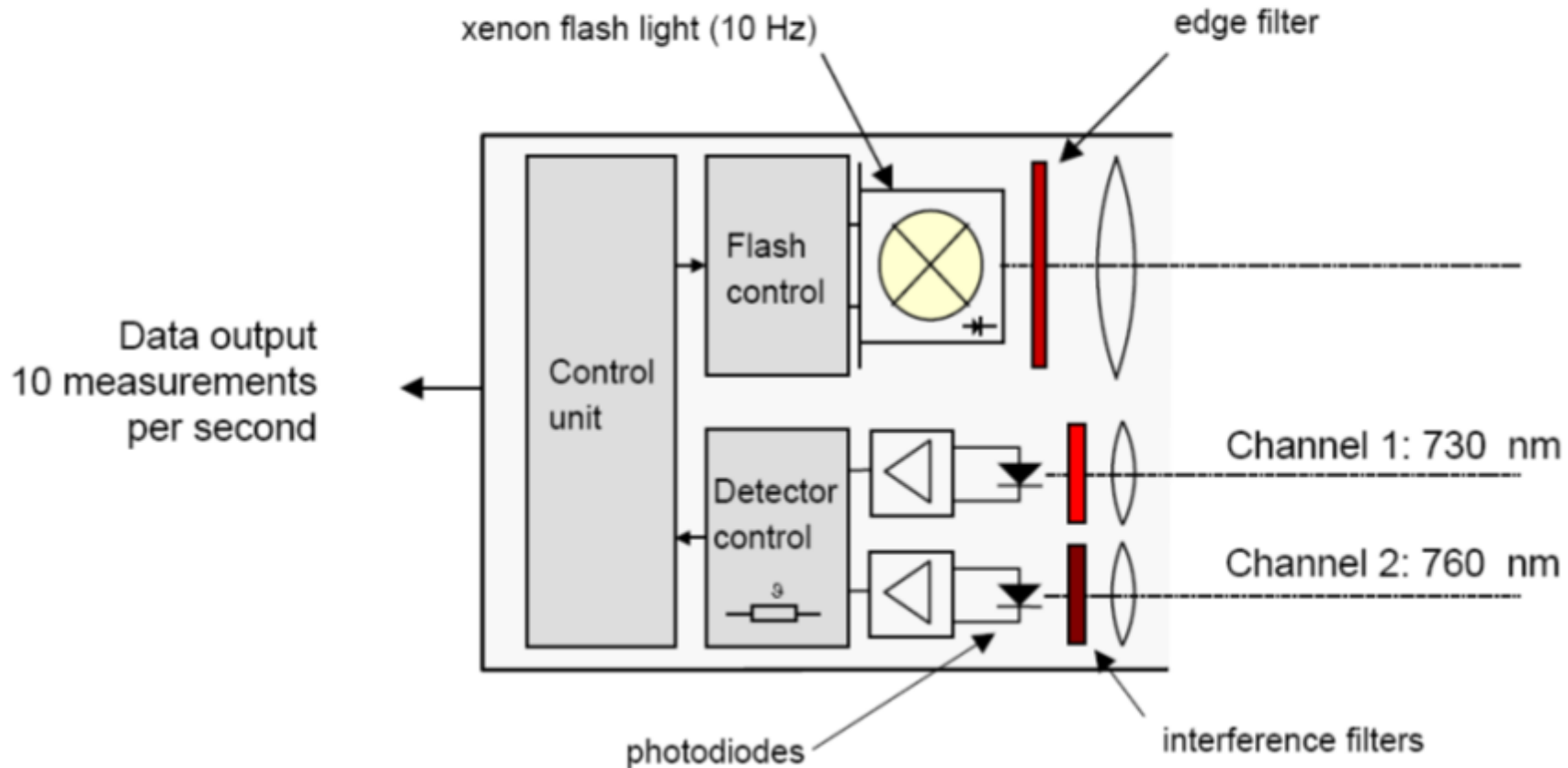
Yara N-Sensor

Sensores multiespectrais ativos



Yara N-Sensor

Active Sensing Head

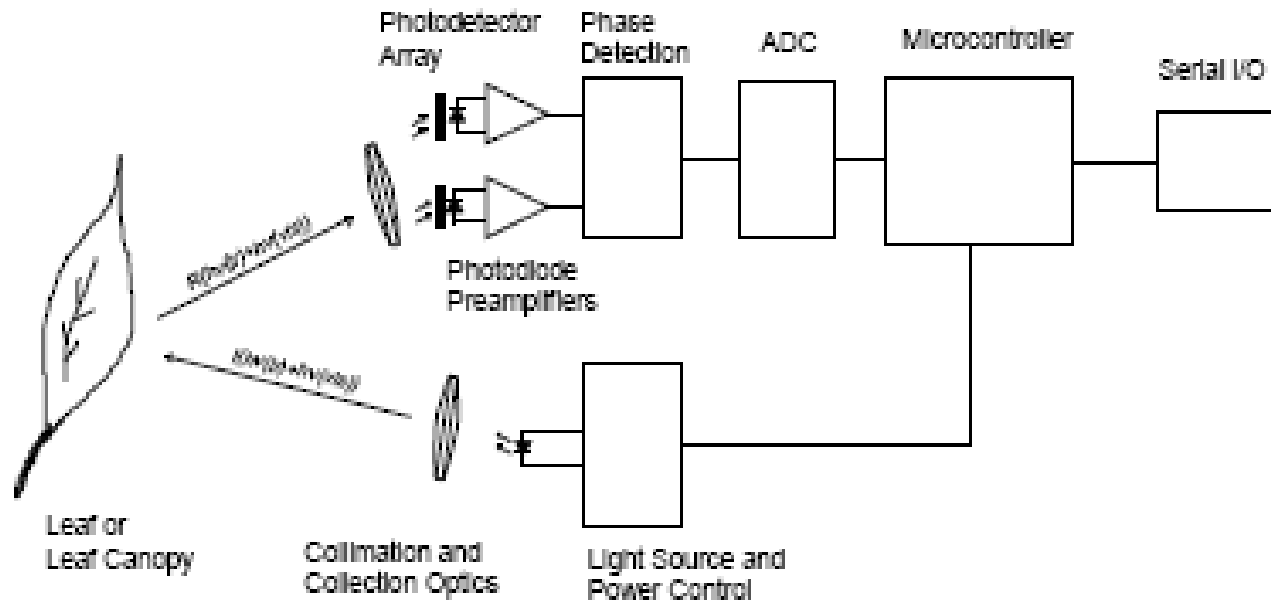


Sensores
multiespectrais

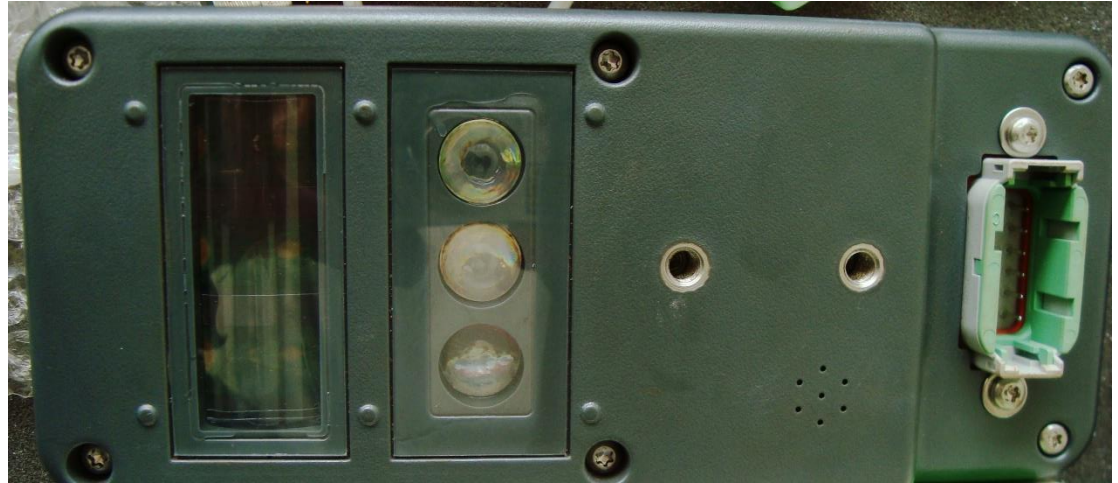
Ativos



Sensores multiespectrais Ativos (Crop Circle)



Holland et al., 2006





**Investigações ESALQ com
sensores ópticos**

25 7 2006

Investigações ESALQ com cana (2006)



N-Sensor

CropCircle

GreenSeeker





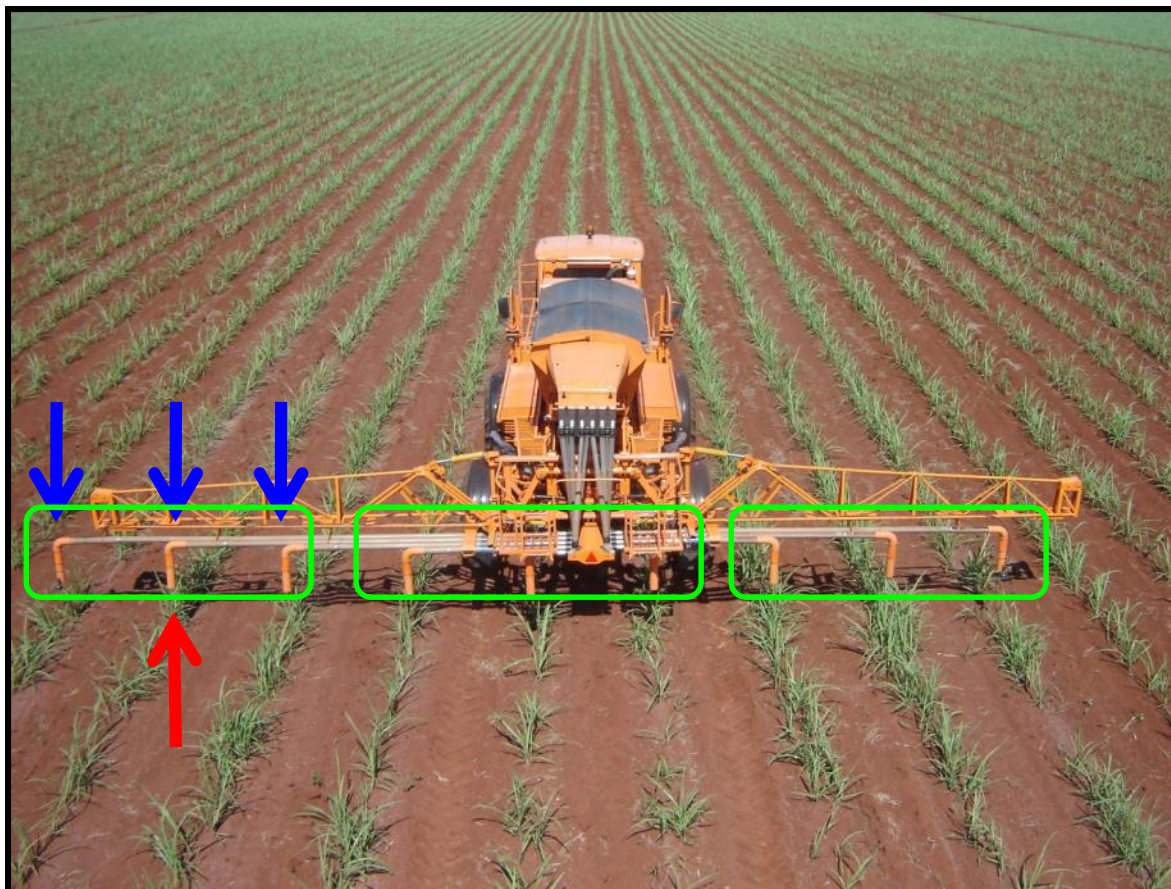




Medição de duas elipses de 3 m cada.







Um sensor por linha?

Um sensor por esteira?

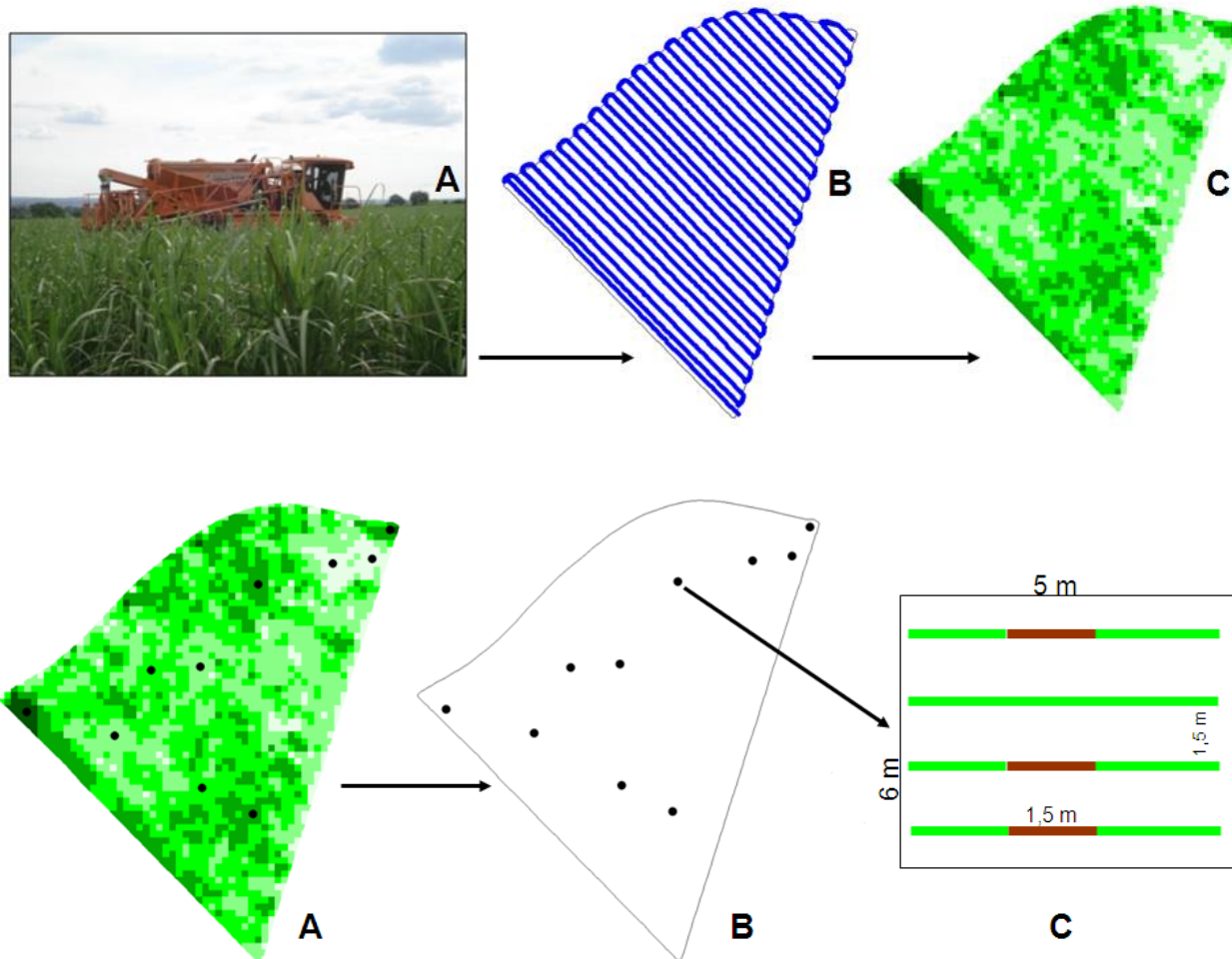
3 esteiras independentes

AMARAL, 2014

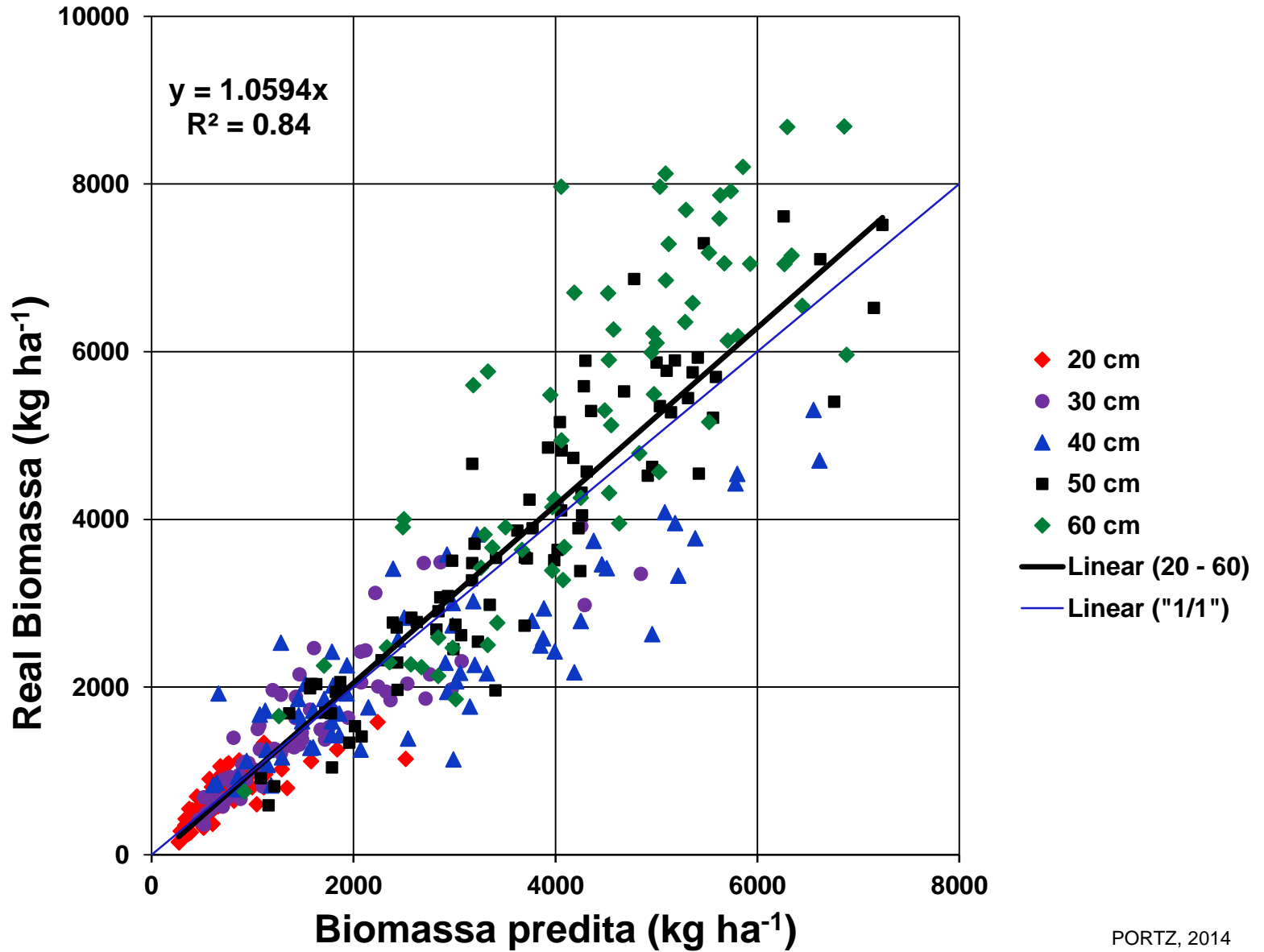




Como construir o modelo

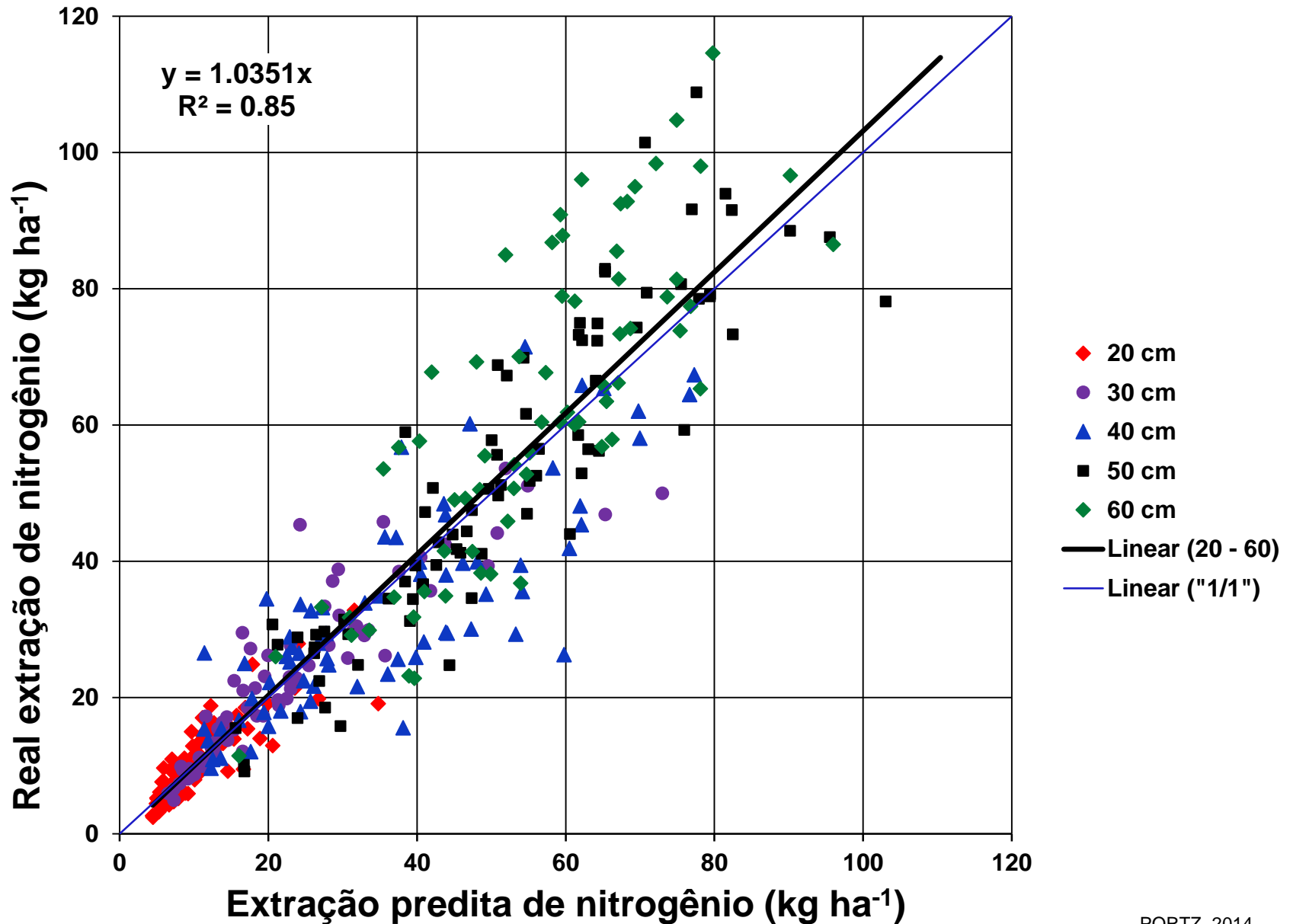


Biomassa predita versus real para 2009/10 e 2010/11



PORTZ, 2014

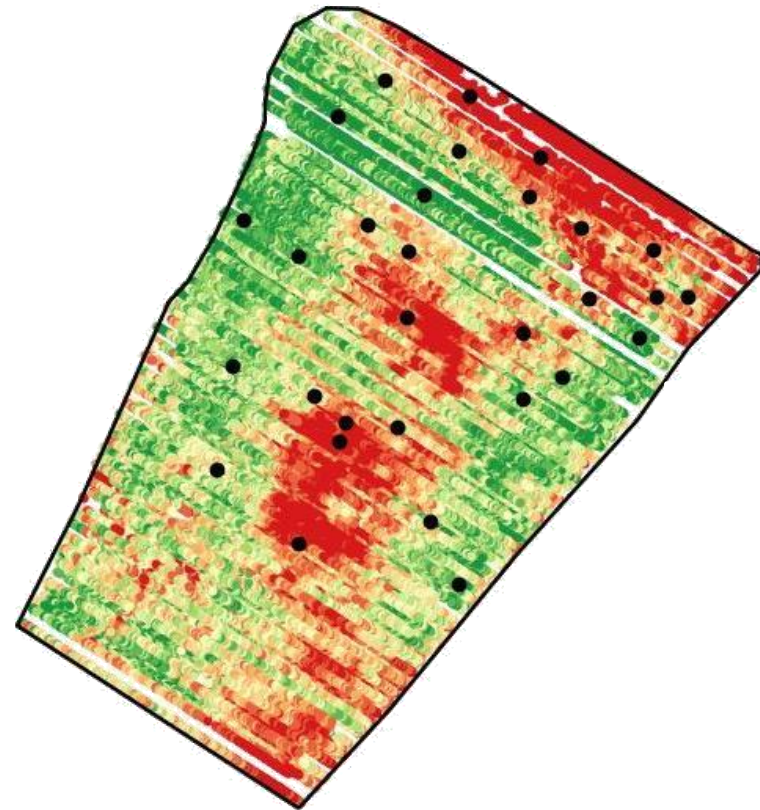
Nitrogênio predito versus real para 2009/10 e 2010/11

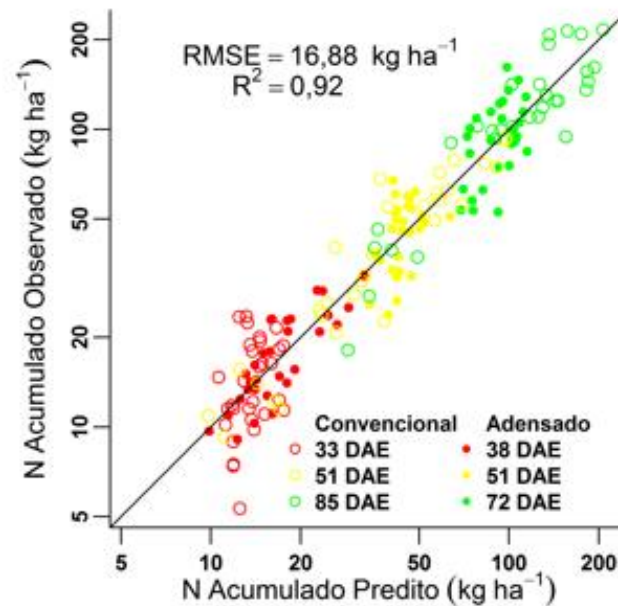
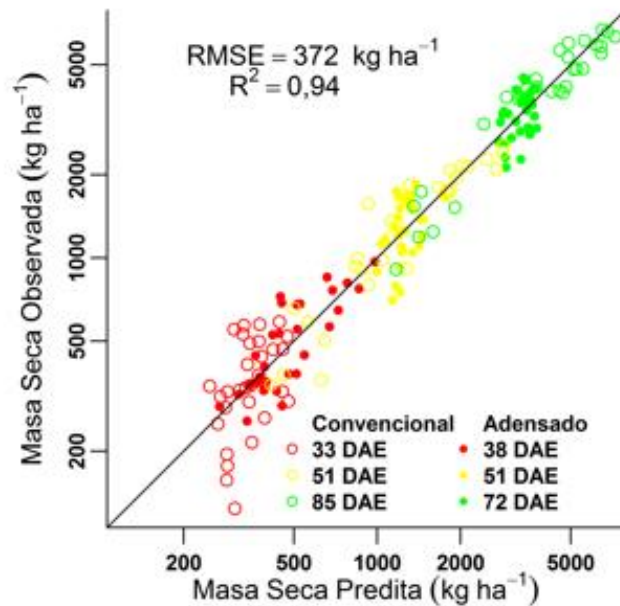
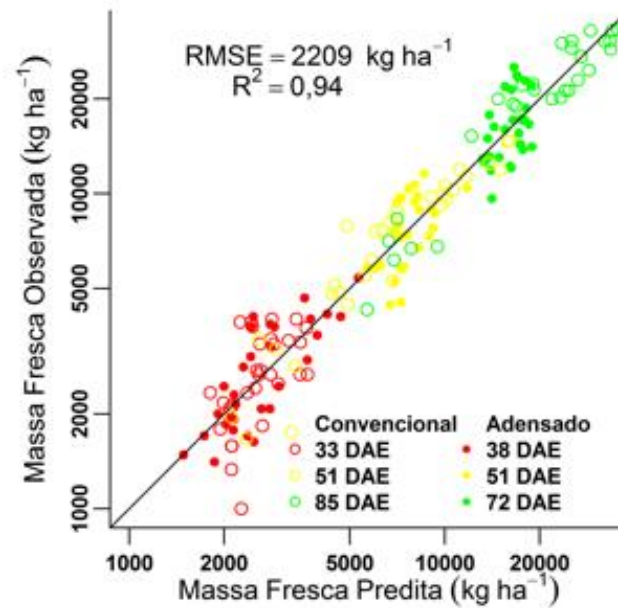
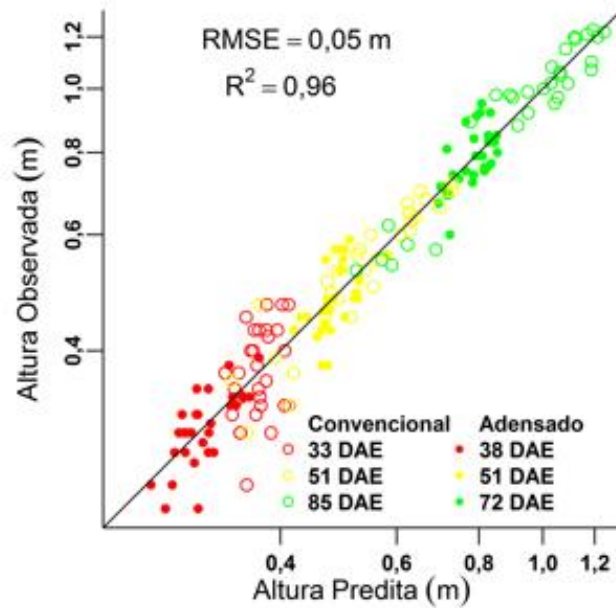


PORTZ, 2014

Como construir o modelo

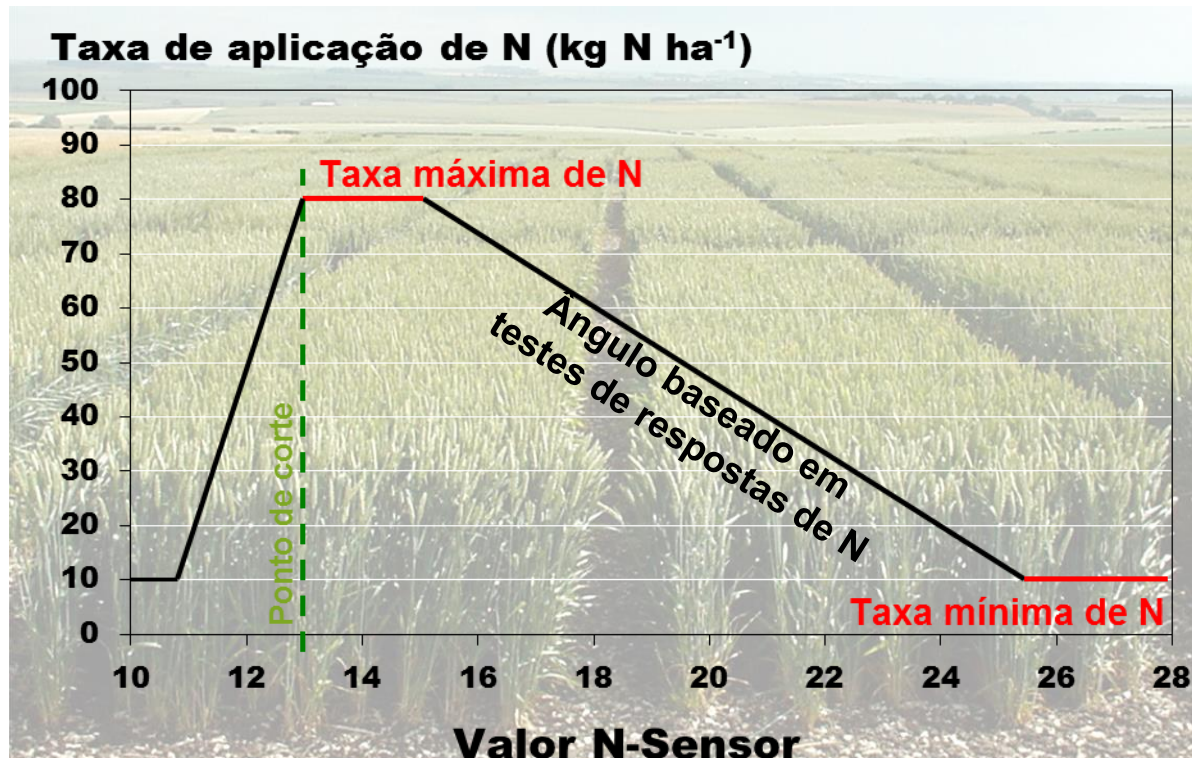
- Coleta das amostras:
 - 30 pontos de amostragem
 - Locais escolhidos com base nos mapas dos sensores a fim de aproveitar toda a amplitude da variabilidade do talhão





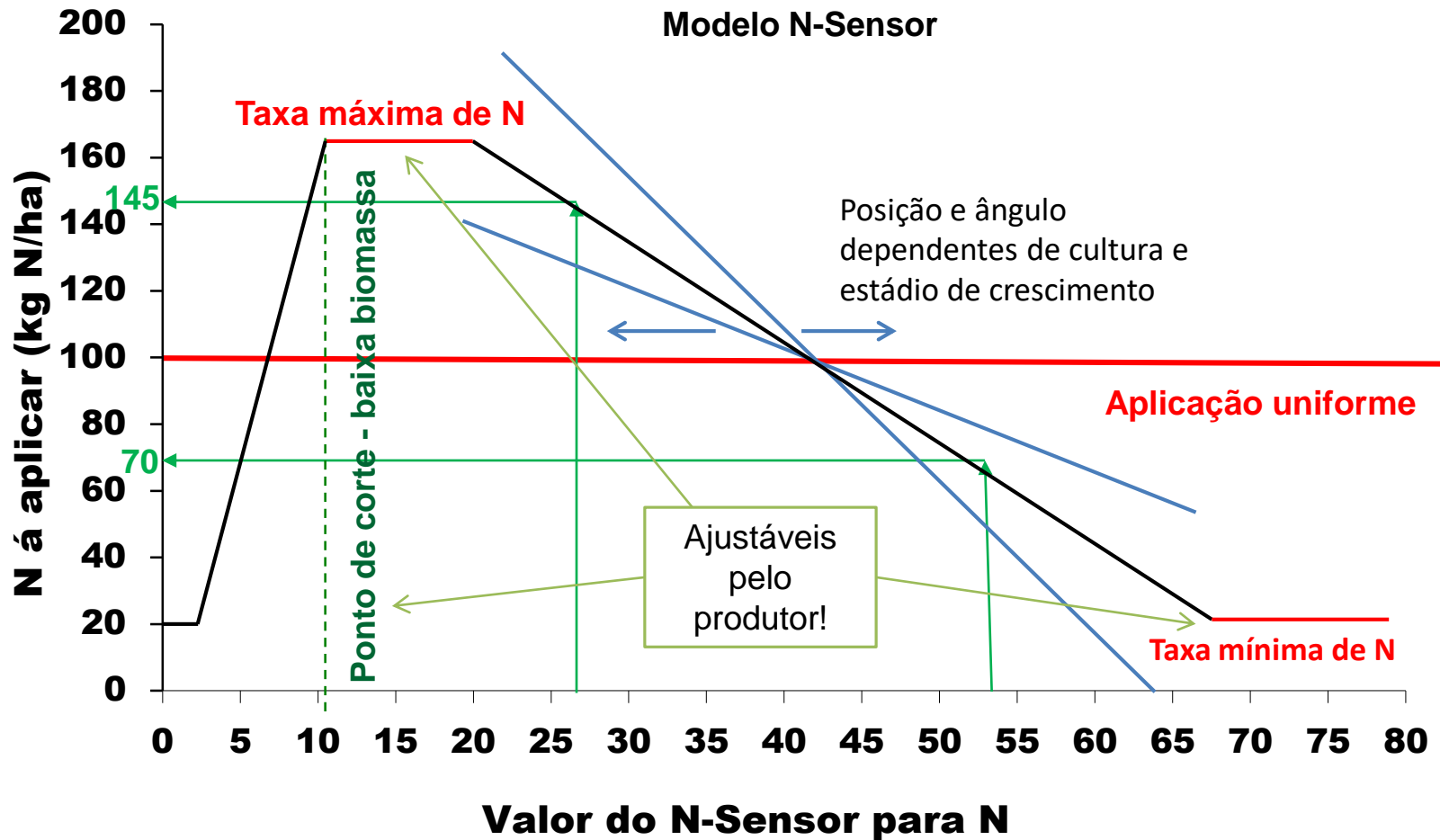
Modelo genérico de calibração agronômica

- Testes de respostas de N são conduzidas para investigar a relação entre valores do sensor e taxas de N ótimas
- Conversão de medições de reflectância na recomendação de fertilizantes



Existe uma relação específica para cada cultivo e estágio de crescimento, com uma inclinação de aplicação que está implementada no Software do N-Sensor

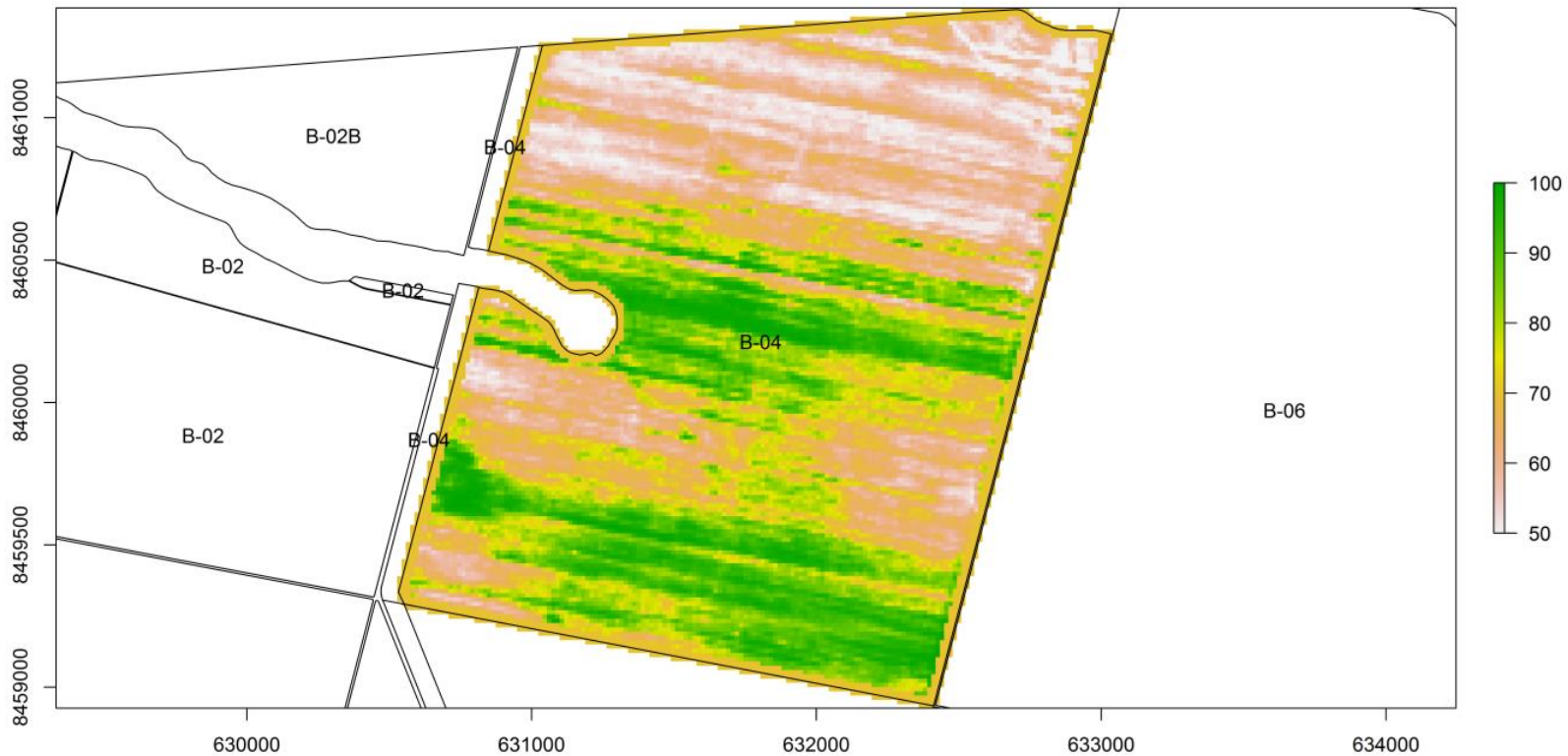
Modelo genérico de calibração agronômica; ex: cereais





Estratégia Yara com o uso do N-Sensor para aplicação de N

Dose média: 70 kg/ha

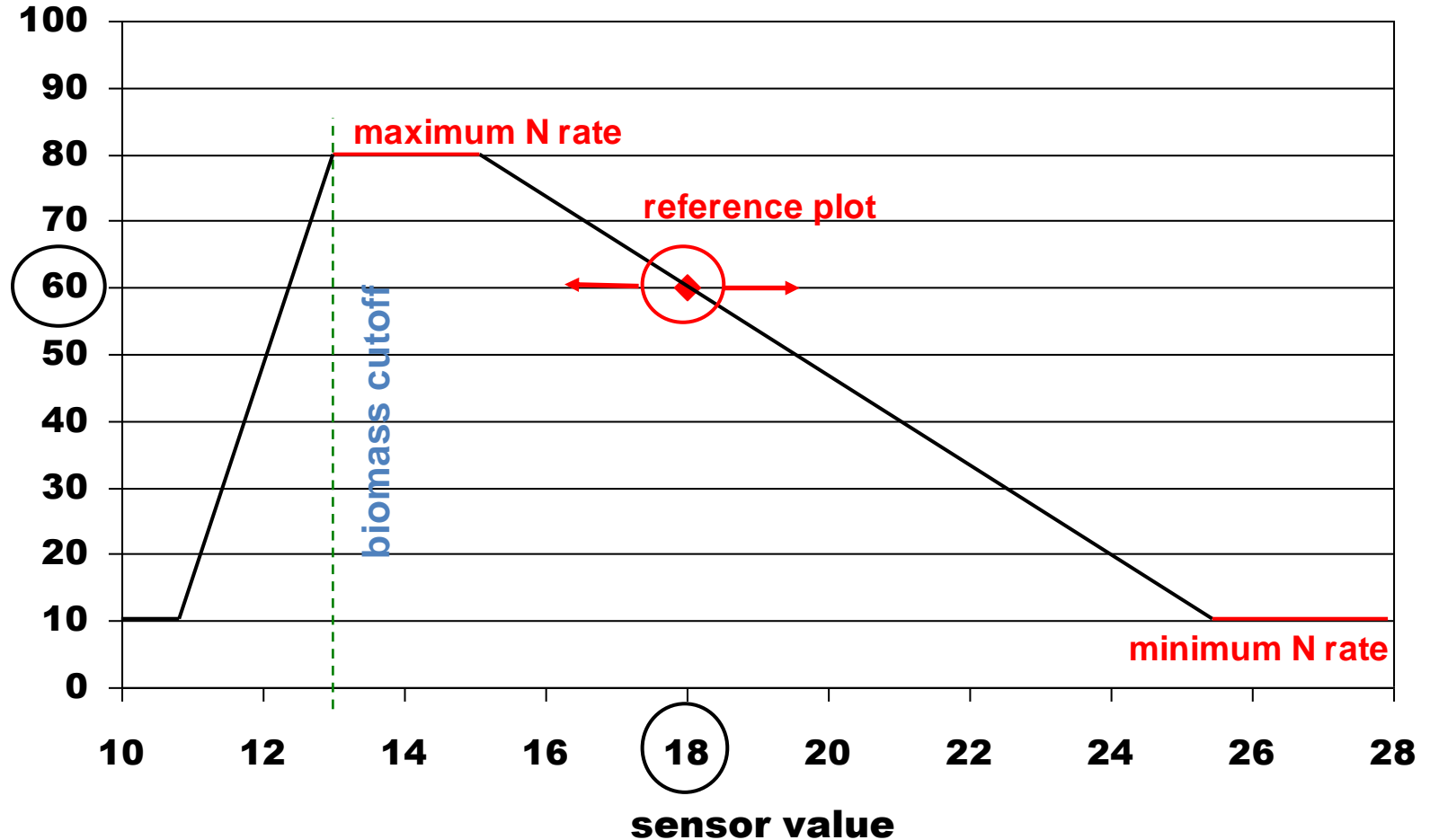


Área: 429.06 ha

SmartAgri, 2018

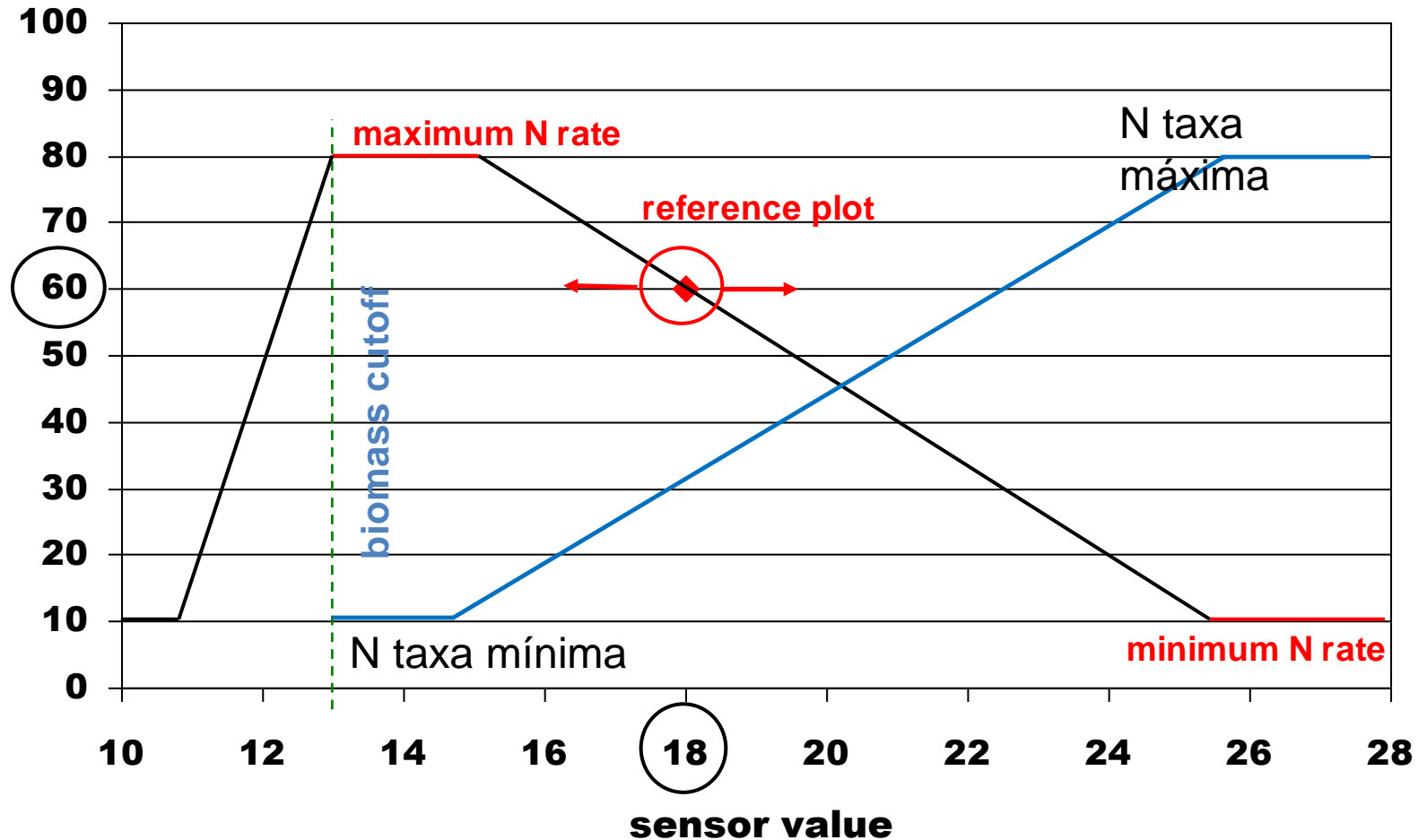
Objetivo final

N application rate (kg N/ha)

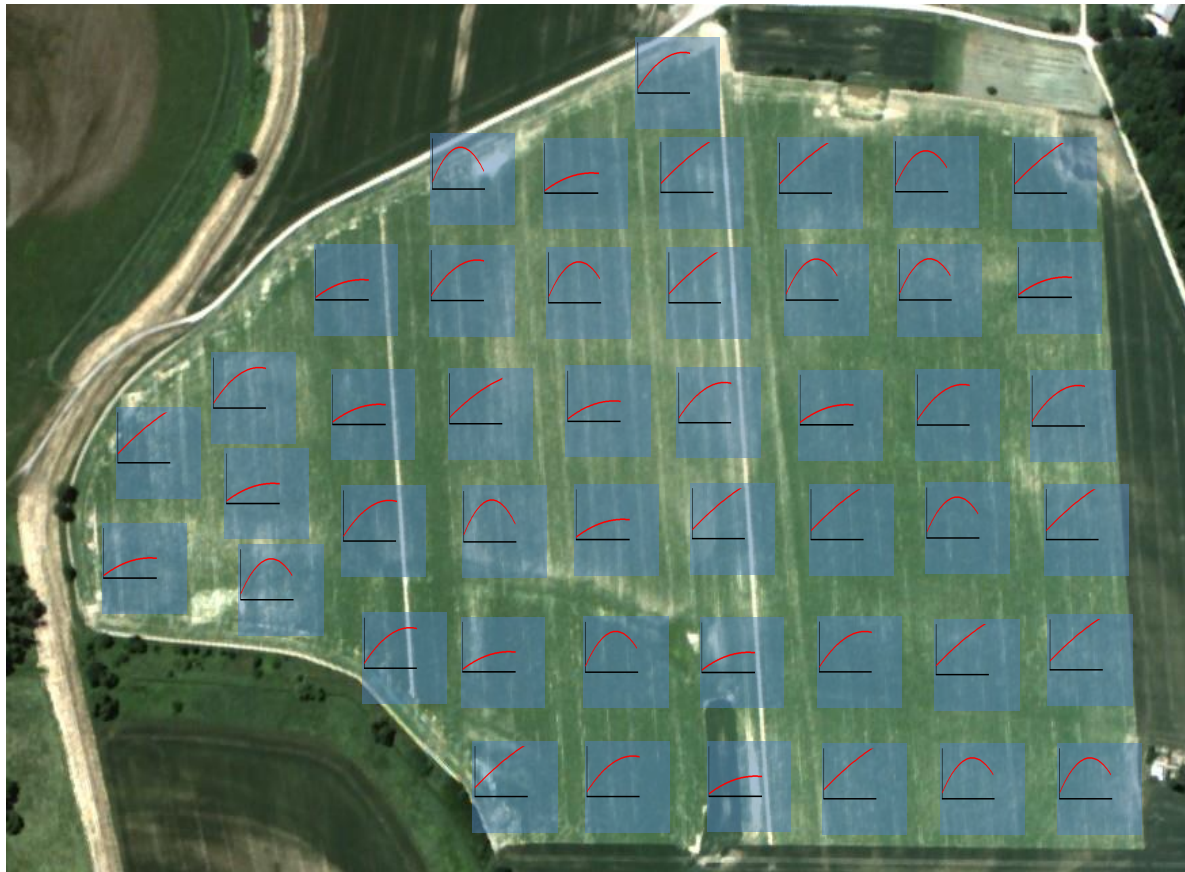


Objetivo final

N application rate (kg N/ha)

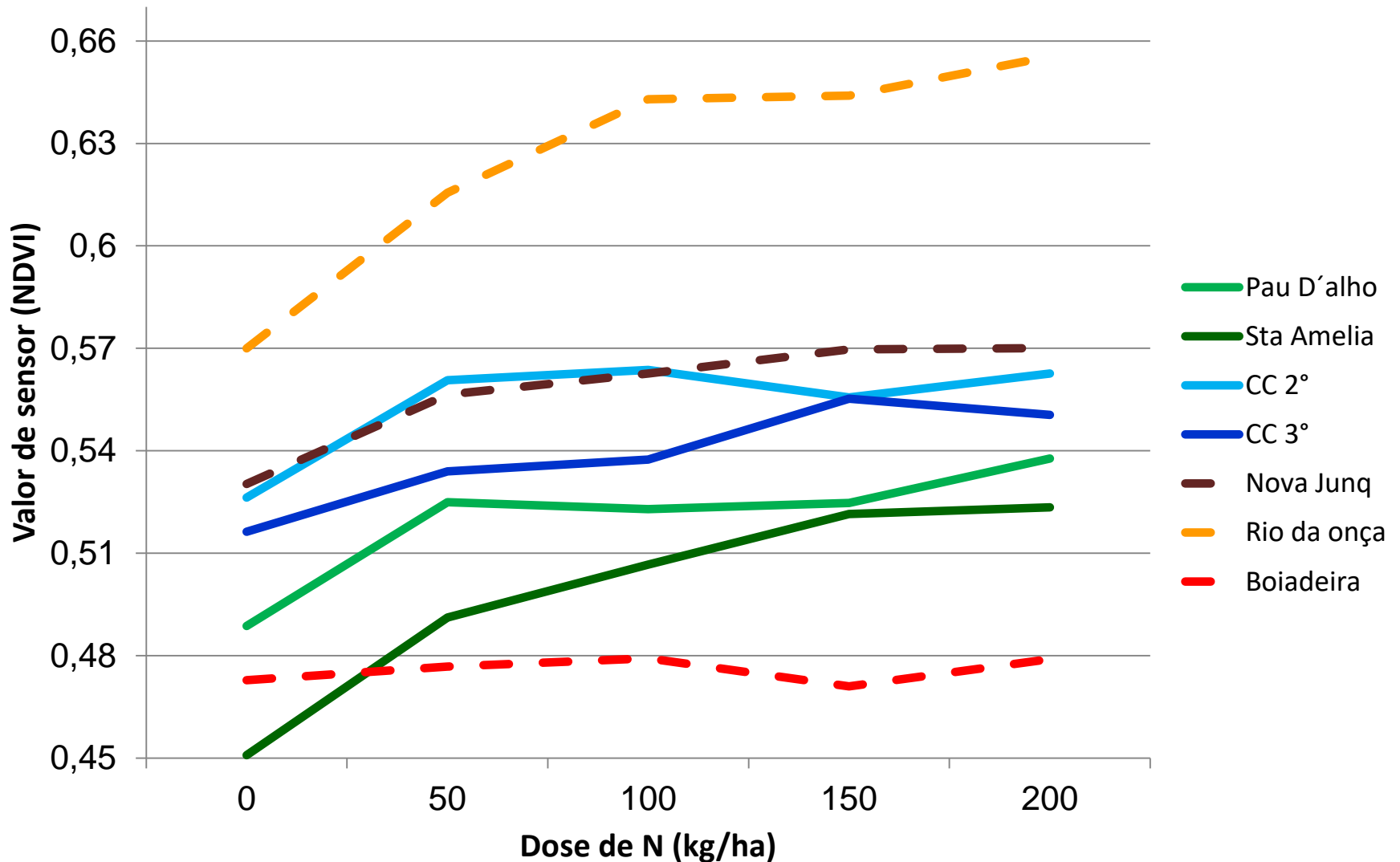


Se as lavouras são heterogêneas, a fertilização nitrogenada em taxa variável é a consequência lógica



Curvas de resposta de N tem variação espacial

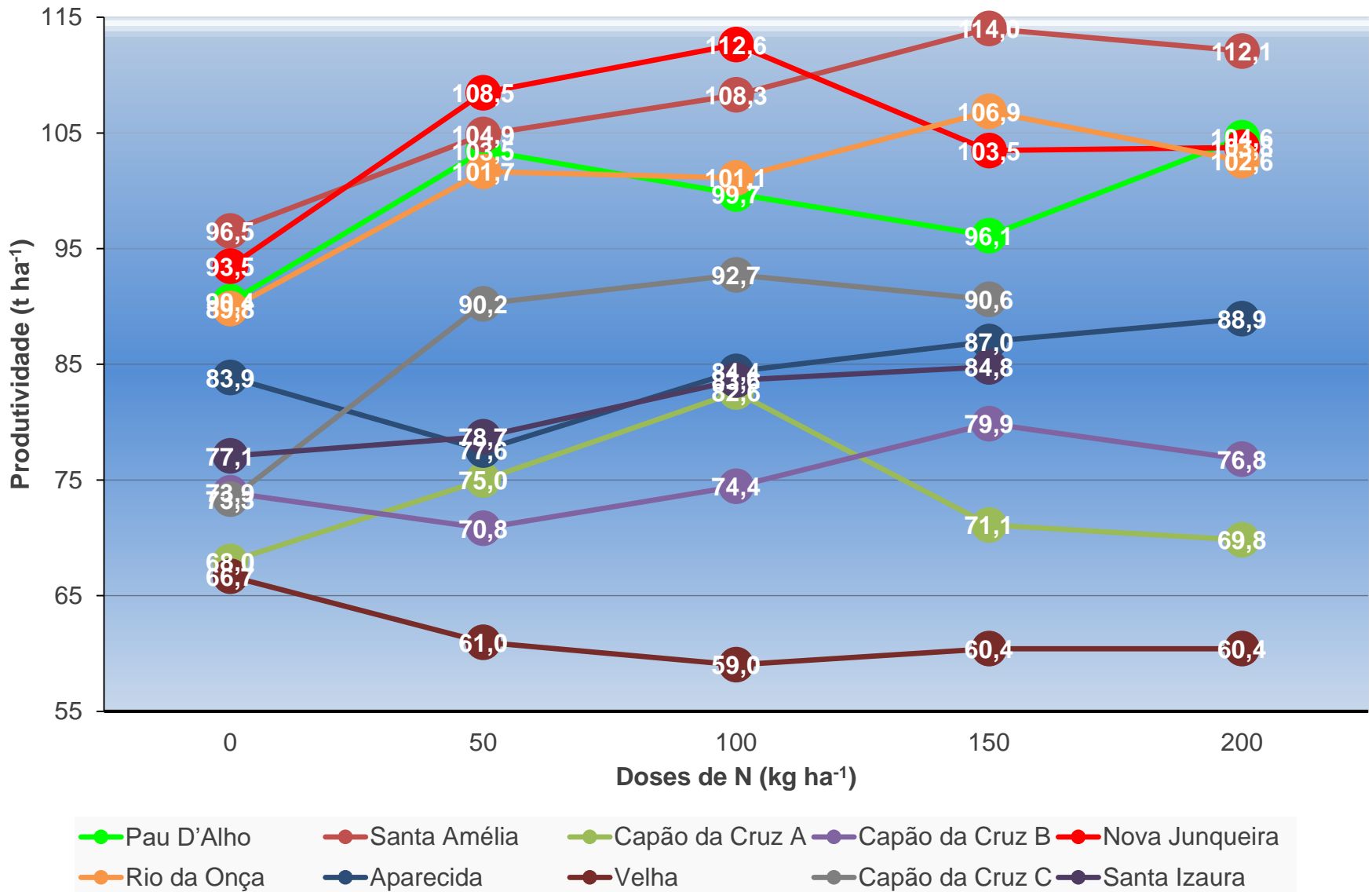
Outra abordagem para construir o modelo



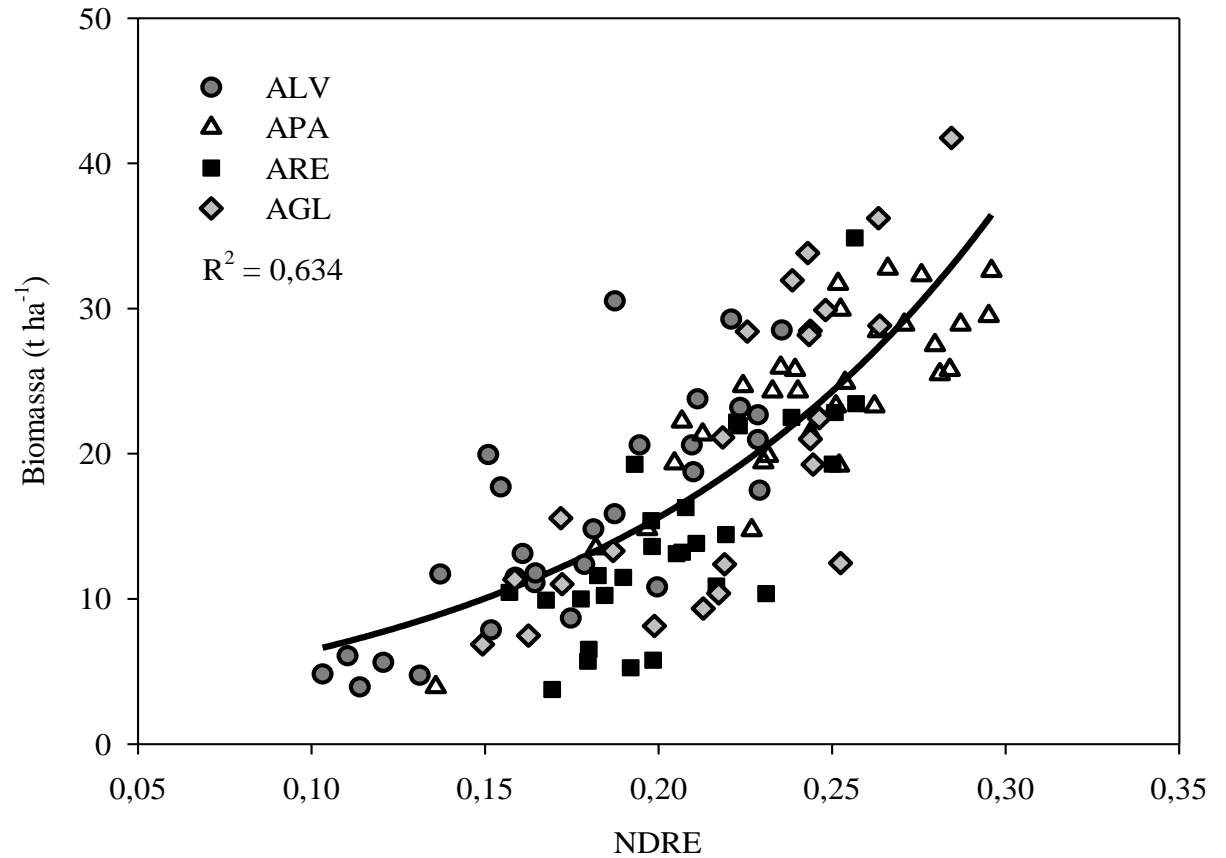
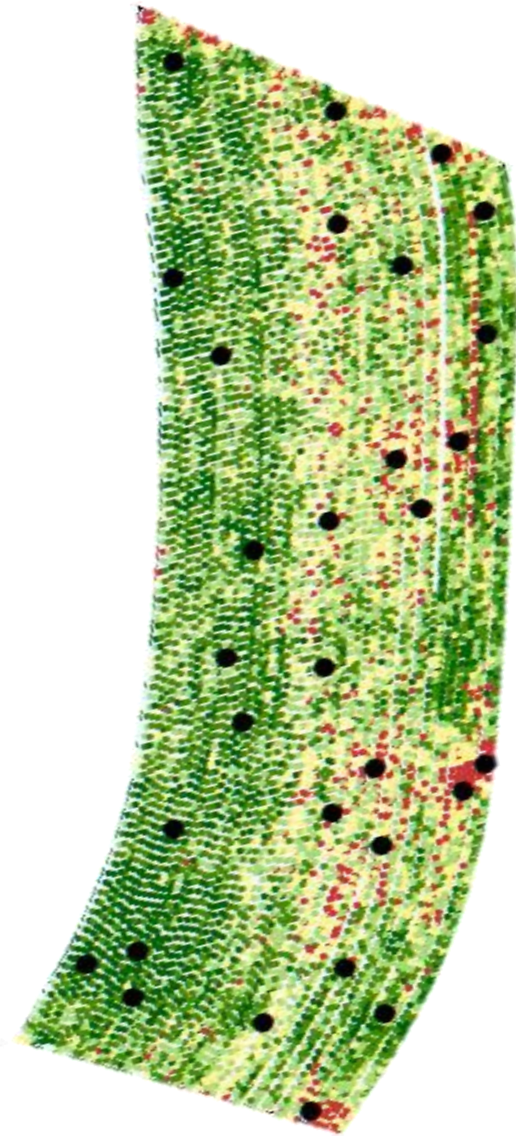
Amaral & Molin, 2015



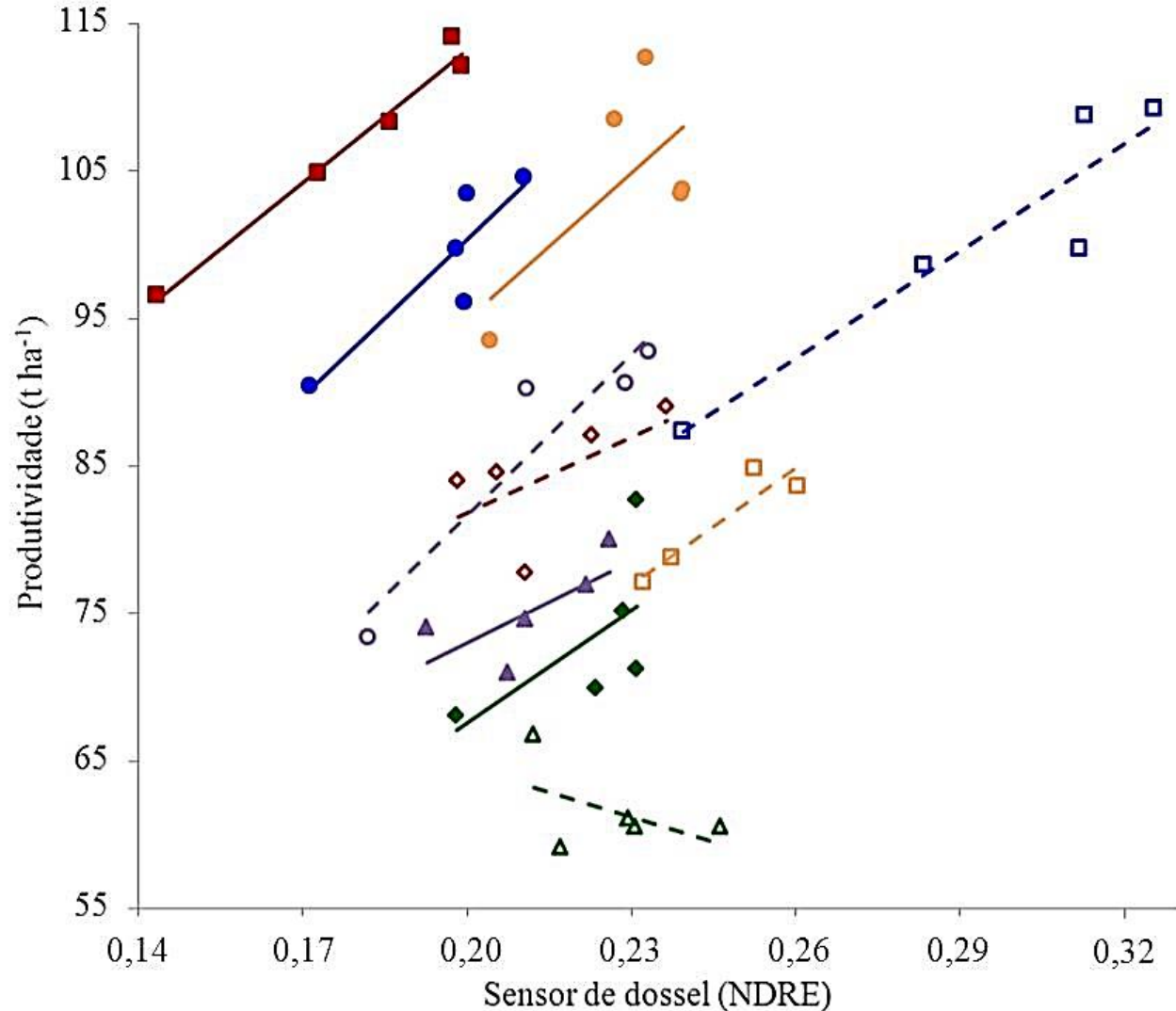
Resultados dos experimentos com doses de N



Relação de sensor com biomassa



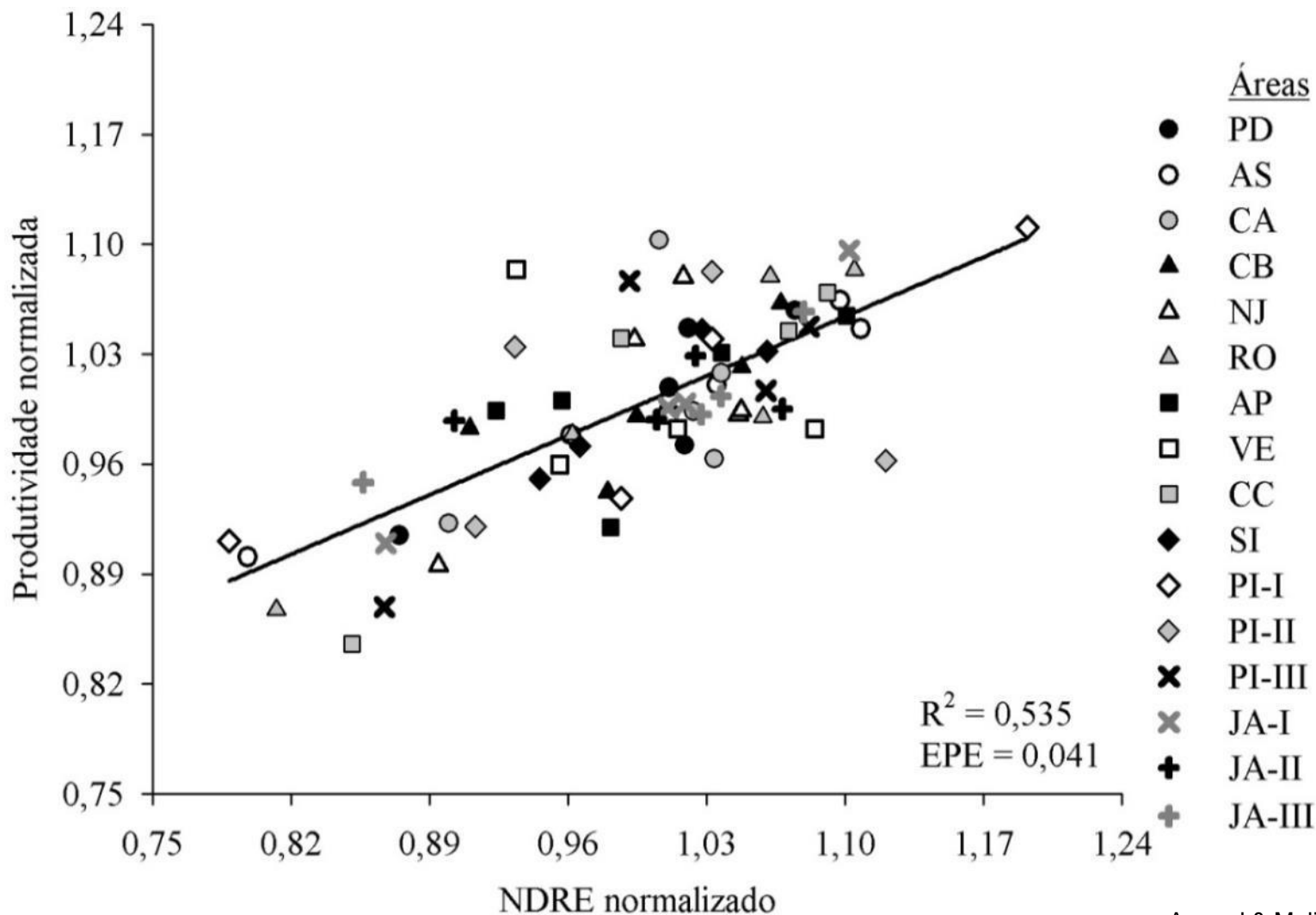
Relação das leituras do sensor com a produtividade da cana



● PA	$y = 353,7x + 29,5$; $R^2 = 0,80$	□ RO	$y = 242,2x + 29,4$; $R^2 = 0,87$
■ AS	$y = 299,2x + 53,4$; $R^2 = 0,98$	◆ AP	$y = 171,7x + 47,5$; $R^2 = 0,36$
◆ CA	$y = 248,7x + 17,3$; $R^2 = 0,35$	▲ VE	$y = -110,1x + 86,5$; $R^2 = 0,24$
▲ CB	$y = 184,9x + 36,0$; $R^2 = 0,51$	○ CC	$y = 362,3x + 9,2$; $R^2 = 0,89$
● NJ	$y = 264,1x + 16,7$; $R^2 = 0,86$	□ SI	$y = 331,2x + 28,7$; $R^2 = 0,44$

Amaral & Molin, 2015

Possibilidade de estimar a produtividade localizadamente através de valores normalizados



Amaral & Molin, 2015

O algoritmo

$$N_{apl} = \left[0.41 + \frac{NDRE_{pt}}{NDRE_{md}} \times 0.585 \right] \times P_{est} \times N_{kt} \times \left(1 - \frac{N_{ex}}{100} \right)$$

Valor de NDRE obtido para cada leitura do sensor

Produtividade média estimada para o canavial

Porcentagem de N já acumulado pela cultura em relação ao total demandado para o ciclo da cultura

Dose de N recomendada para cada leitura do sensor de dossel

Valor médio do NDRE para todo o canavial

Recomendação de N para a produção de colmos esperada (kg t⁻¹)

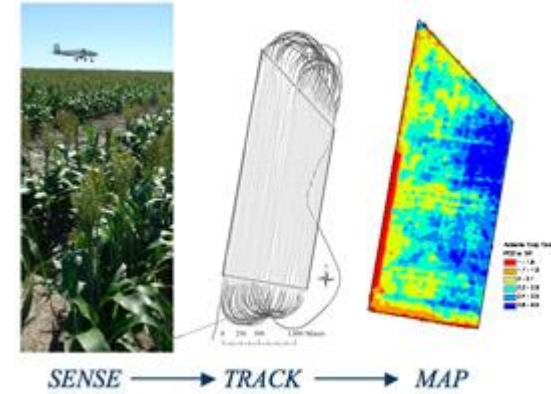
O princípio:

- ✓ Aplicar mais N onde existem menos fatores limitando a produtividade;
- ✓ Obtém-se maior chance do N aplicado ser absorvido;
- ✓ Possibilidade de melhorar a produção onde as condições estão mais adequadas.

Equipamentos disponíveis no mercado

Holland Scientifics:

- CropCircle (ACS-430)
- CropCircle (ACS-470)
- Raptor ACS-225LR



AgLeader:

- OptRx



Trimble:

- GreenSeeker

Yara:

- N-Sensor



Topcon

- CropSpec



Falker

- Flexum

Fritzmeier:

- Isaria



ForceA

- Multiplex



(b)



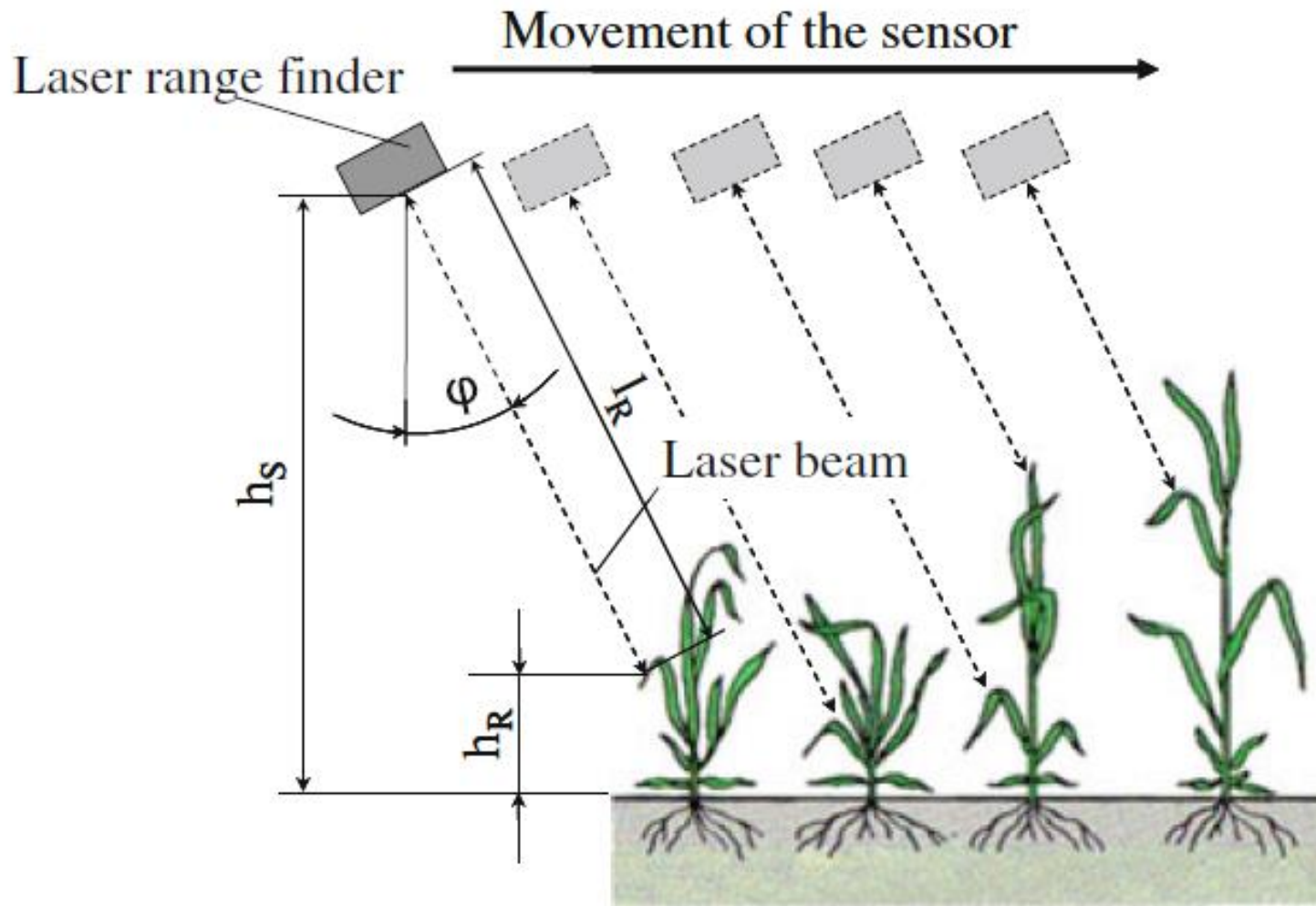
4 fontes de luz (LED): 373 nm (UV), 470 nm (B), 516 nm (G) e 635 nm (R)
 3 detectores =>Fluorescência: Amarelo (YF), vermelho (RF) e vermelho-extremo (FRF).

Experimentos ESALQ com trigo (2006)





Sensores de distância (altura/volume de plantas)



LIDAR



Sensor a ultrassom



Suporte para
sensores a
ultrassom

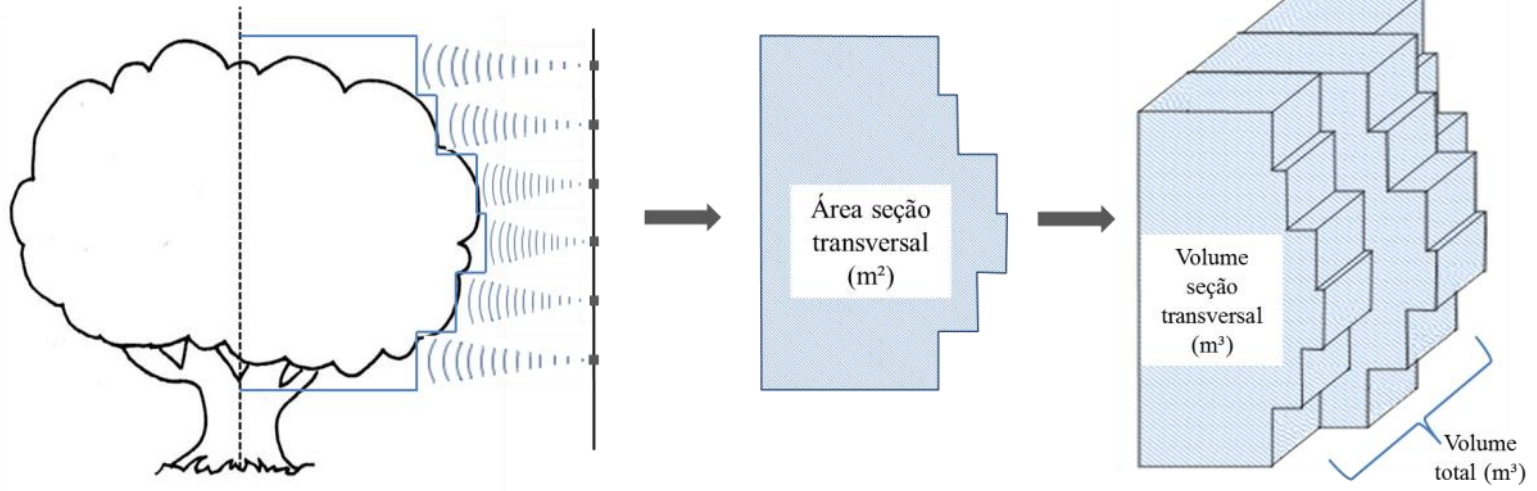


Receptor GNSS

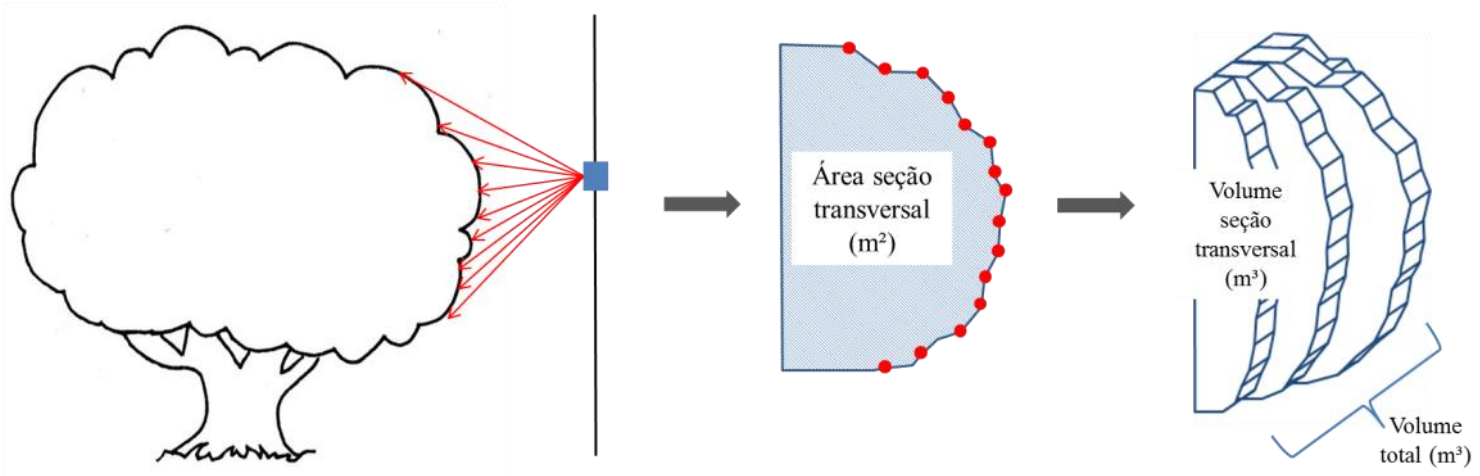
LIDAR

Colaço, 2015

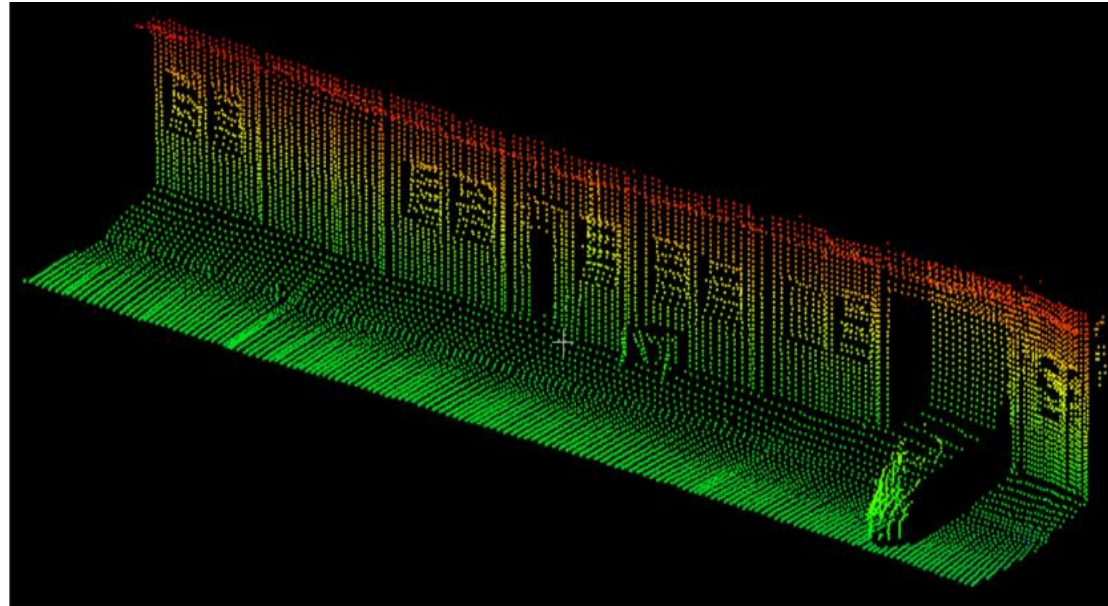
Ultrassom



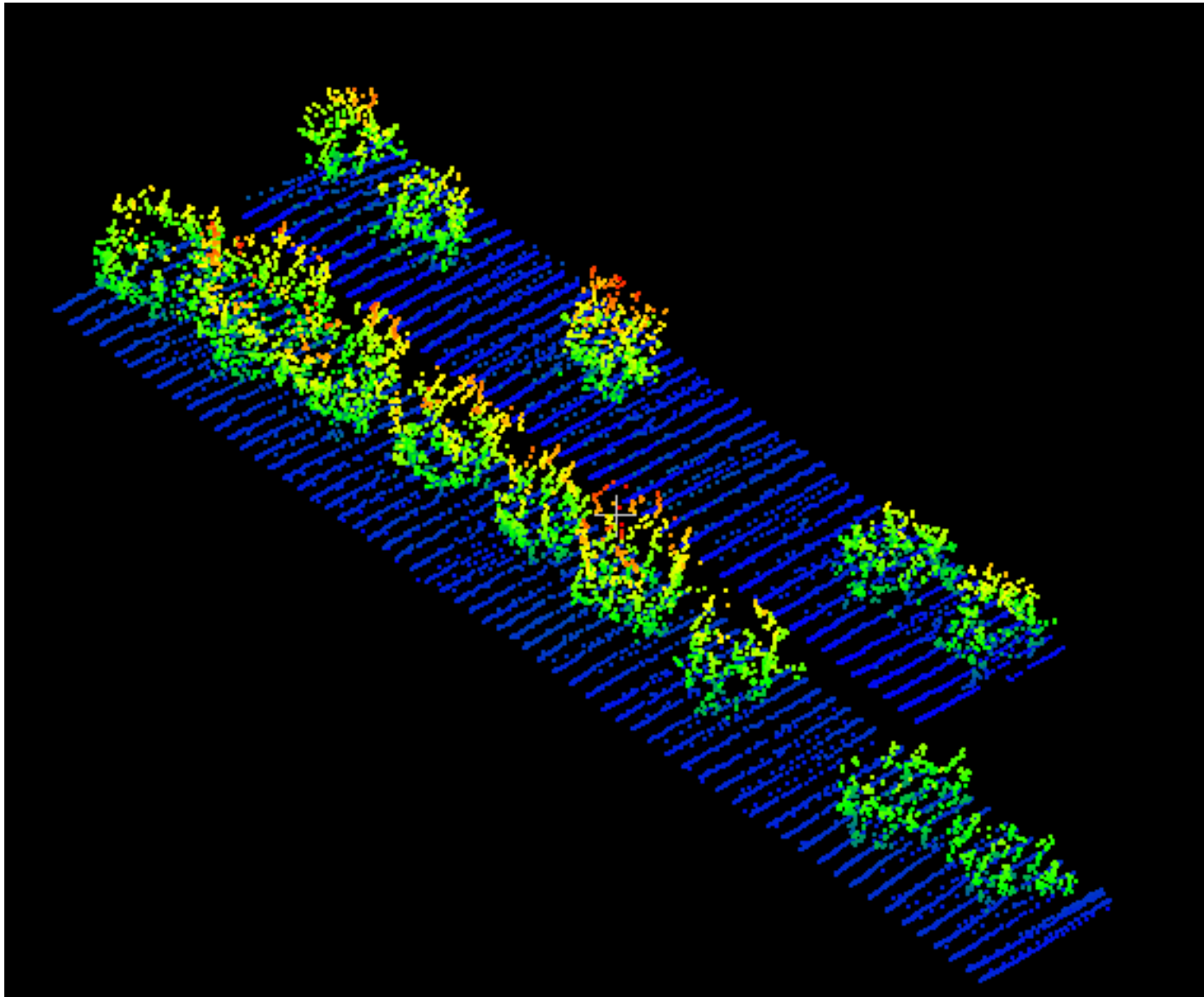
LIDAR



Colaço, 2015

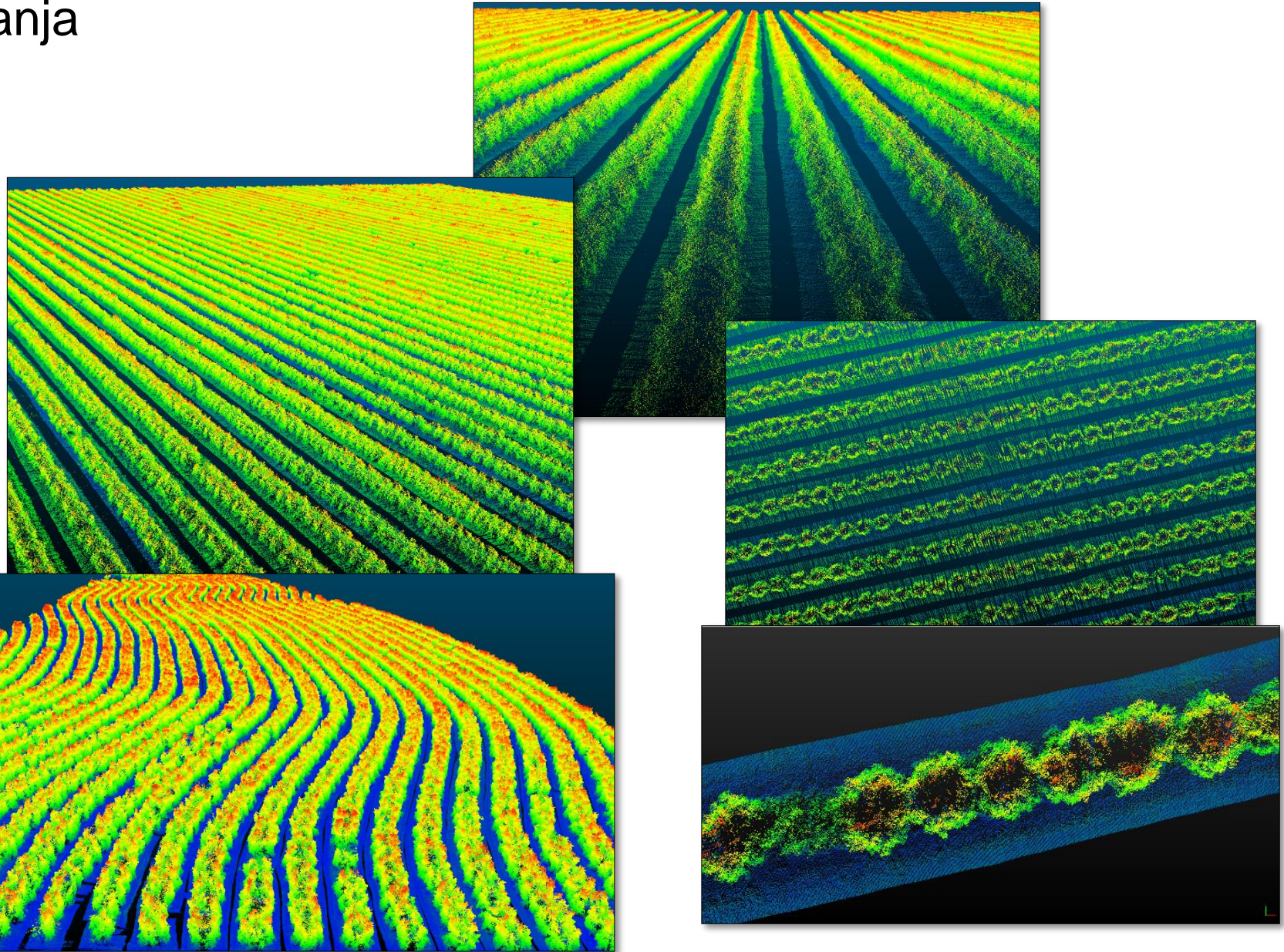


Colaço, 2015

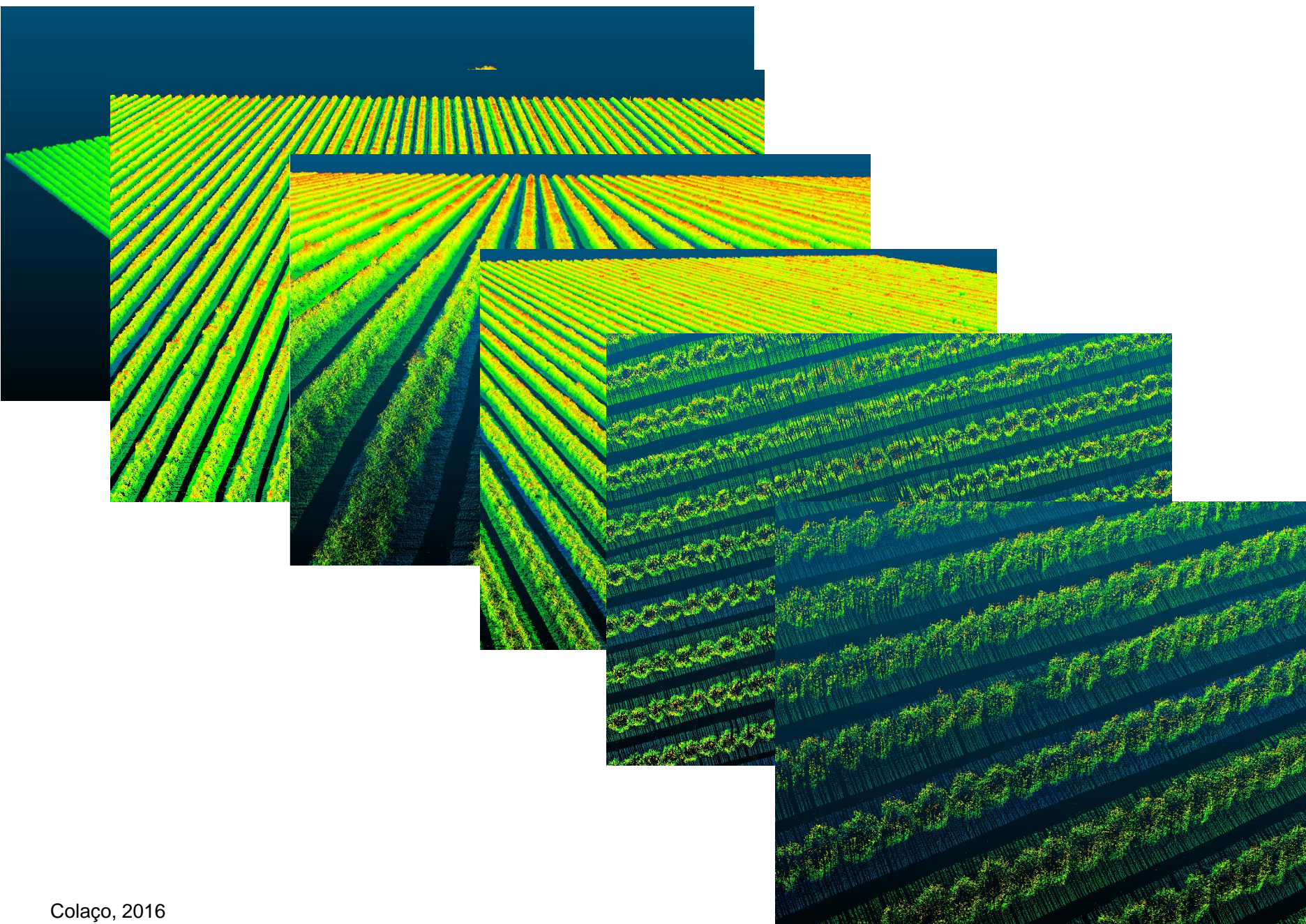


Colaço, 2015

Laranja

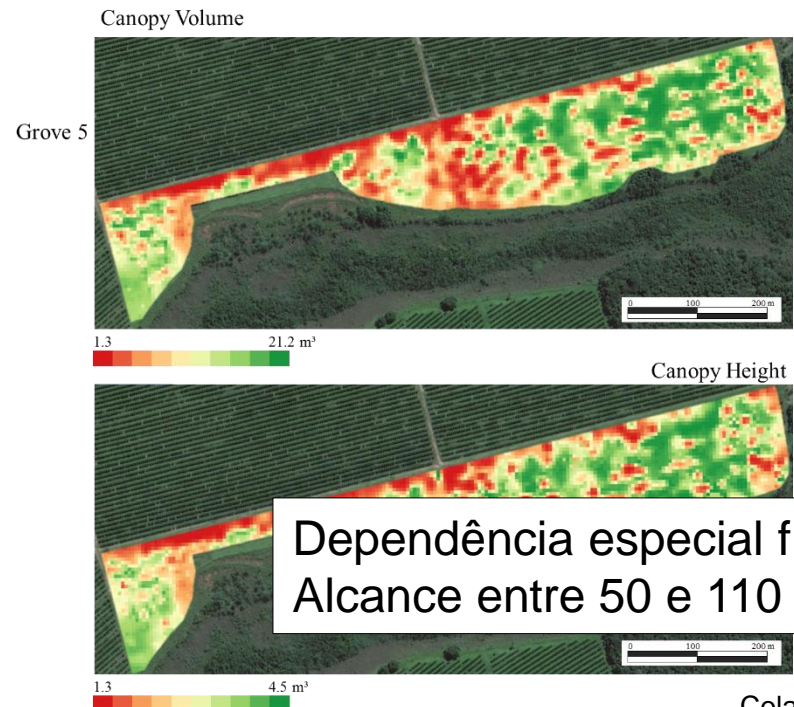
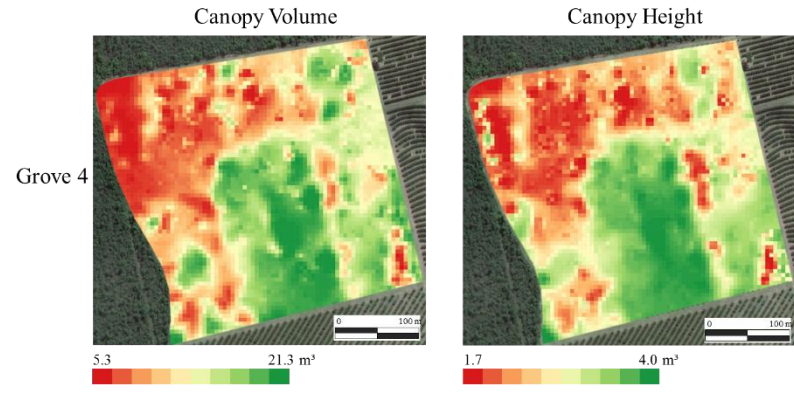
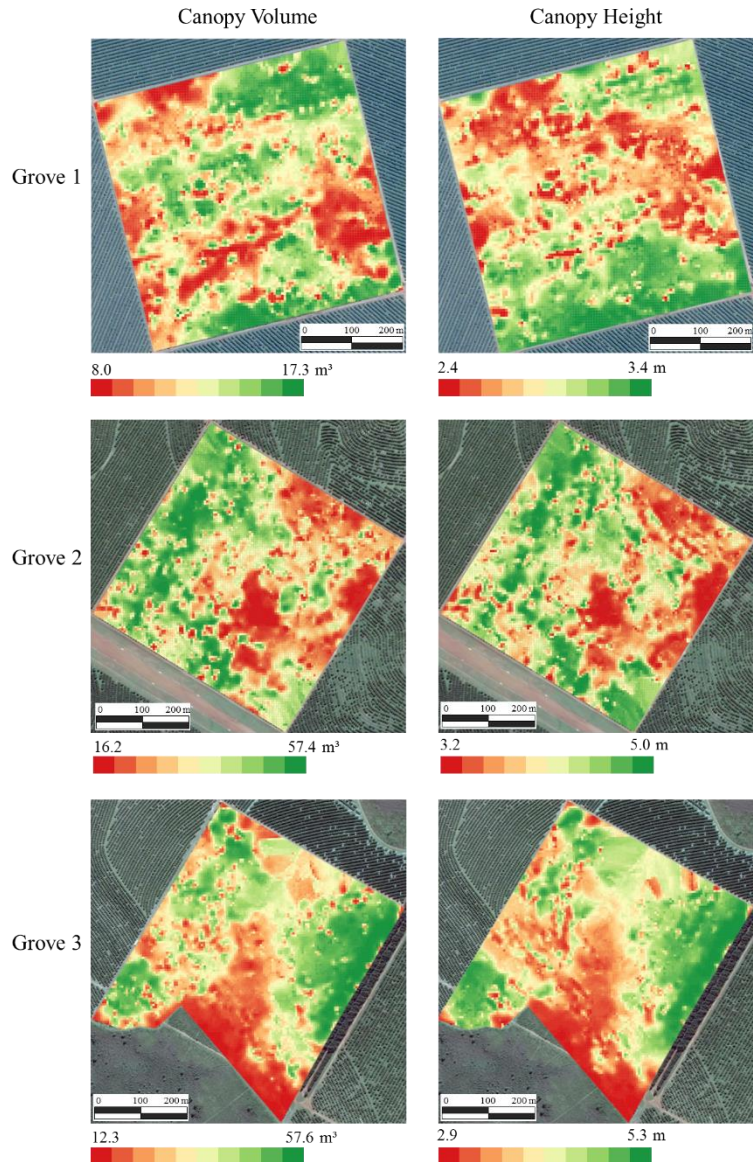


Colaço, 2016



Colaço, 2016

Canopy volume and height spatial variability and site-specific applications in commercial orange groves

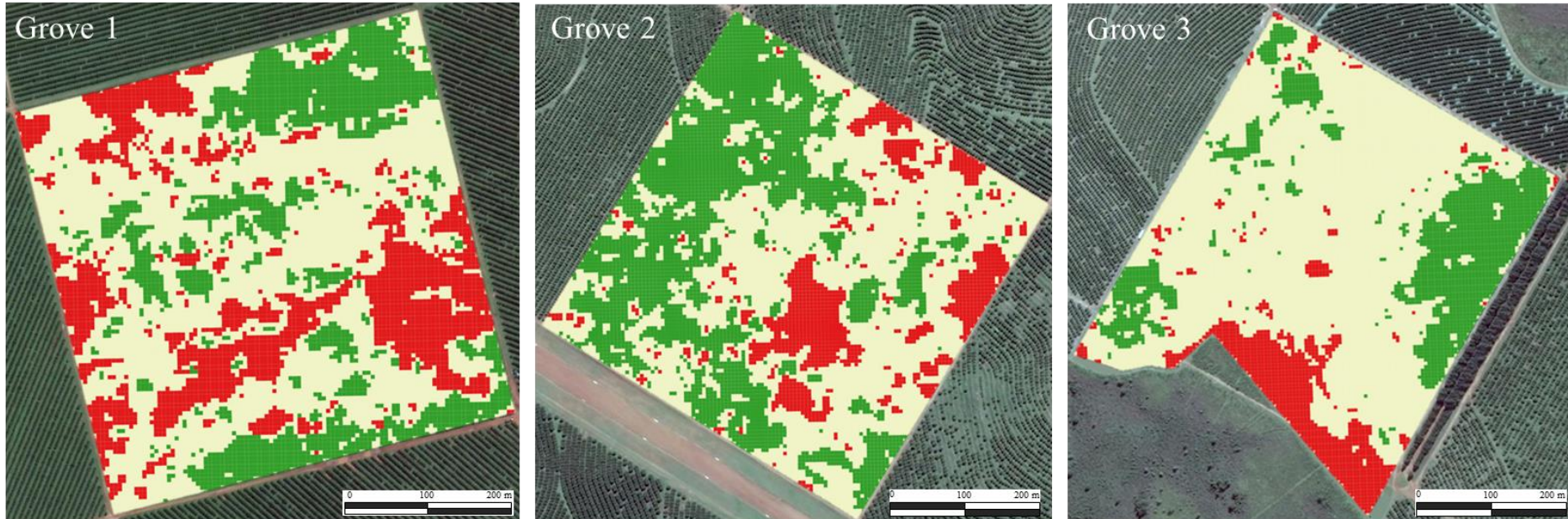





Dependência especial fraca;
Alcance entre 50 e 110 m

Colaço, 2016

Canopy volume and height spatial variability and site-specific applications in commercial orange groves

Classification of orange groves into different tree size zones



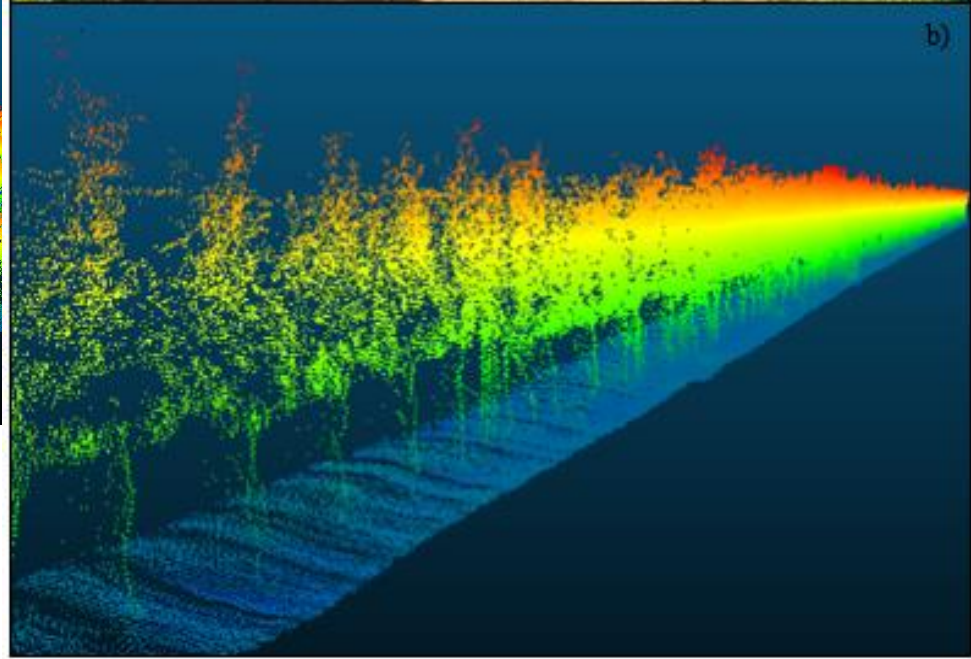
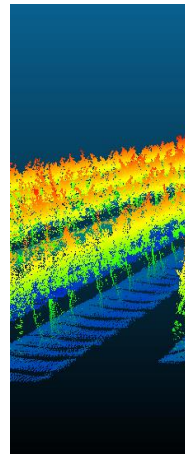
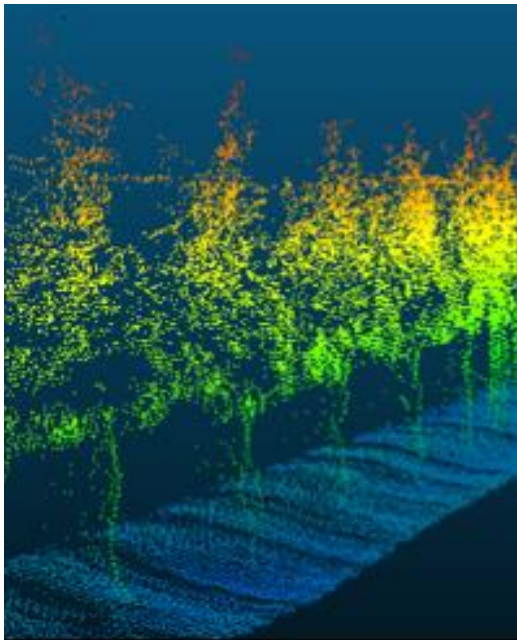
-  Small trees zone
-  Medium trees zone
-  Large trees zone

Colaço, 2016

Uva

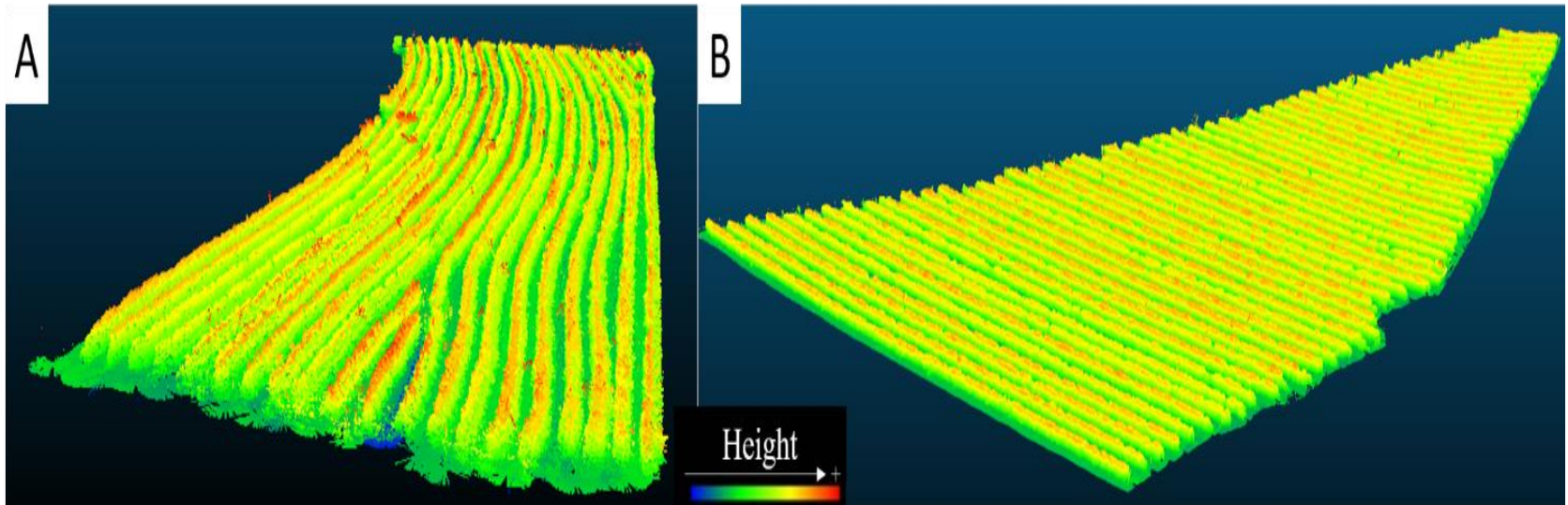
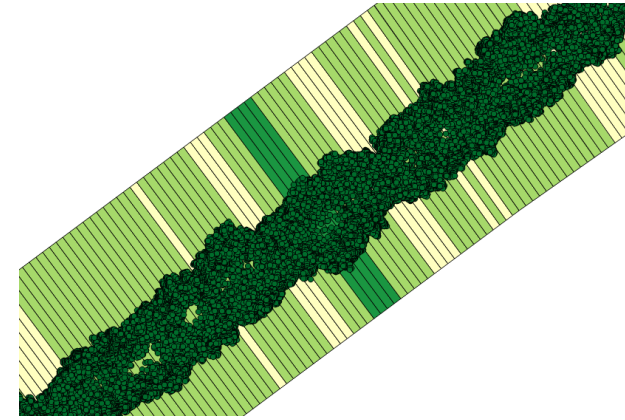
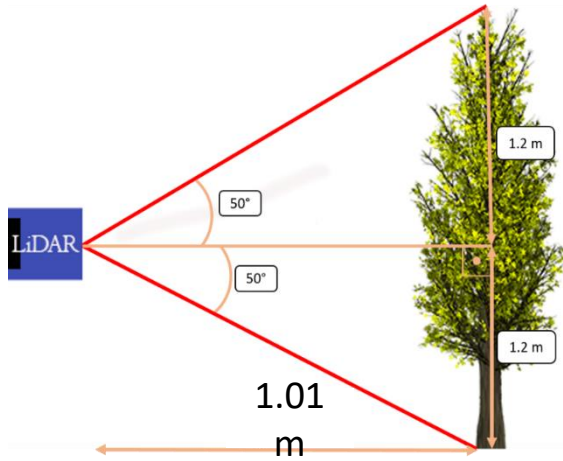


	A	B
1	Hora	Latitude
2	1,61E+19	-2,358.483.400.000.000.000
3	1,61E+19	-2,358.483.400.000.000.000
4	1,61E+19	-2,358.483.400.000.000.000
5	1,61E+19	-2,358.483.400.000.000.000
6	1,61E+19	-2,358.483.400.000.000.000
7	1,61E+19	-2,358.483.400.000.000.000
8	1,61E+19	-2,358.483.400.000.000.000
9	1,61E+19	-2,358.483.400.000.000.000
10	1,61E+19	-2,358.483.400.000.000.000
11	1,61E+19	-2,358.483.400.000.000.000
12	1,61E+19	-2,358.483.400.000.000.000
13	1,61E+19	-2,358.483.400.000.000.000
14	1,61E+19	-2,358.483.400.000.000.000
15	1,61E+19	-2,358.483.400.000.000.000
16	1,61E+19	-2,358.483.400.000.000.000
17	1,61E+19	-2,358.483.400.000.000.000
18	1,61E+19	-2,358.483.400.000.000.000
19	1,61E+19	-2,358.483.400.000.000.000
20	1,61E+19	-2,358.483.400.000.000.000
21	1,61E+19	-2,358.483.400.000.000.000
22	1,61E+19	-2,358.483.400.000.000.000
23	1,61E+19	-2,358.483.400.000.000.000
24	1,61E+19	-2,358.483.400.000.000.000
25	1,61E+19	-2,358.483.400.000.000.000
26	1,61E+19	-2,358.483.400.000.000.000
27	1,61E+19	-2,358.483.400.000.000.000
28	1,61E+19	-2,358.483.400.000.000.000
29	1,61E+19	-2,358.483.400.000.000.000
30	1,61E+19	-2,358.483.400.000.000.000
31	1,61E+19	-2,358.483.400.000.000.000
32	1,61E+19	-2,358.483.400.000.000.000
33	1,61E+19	-2,358.483.400.000.000.000
34	1,61E+19	-2,358.483.400.000.000.000
35	1,61E+19	-2,358.483.400.000.000.000
36	1,61E+19	-2,358.483.400.000.000.000
37	1,61E+19	-2,358.483.400.000.000.000
38	1,61E+19	-2,358.483.400.000.000.000
39	1,61E+19	-2,358.483.400.000.000.000
40	1,61E+19	-2,358.483.400.000.000.000
41	1,61E+19	-2,358.483.400.000.000.000
42	1,61E+19	-2,358.483.400.000.000.000
43	1,61E+19	-2,358.483.400.000.000.000
44	1,61E+19	-2,358.483.400.000.000.000
45	1,61E+19	-2,358.483.400.000.000.000
46	1,61E+19	-2,358.483.400.000.000.000
47	1,61E+19	-2,358.483.400.000.000.000
48	1,61E+19	-2,358.483.400.000.000.000
49	1,61E+19	-2,358.483.400.000.000.000
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51	1,61E+19	-2,358.483.400.000.000.000
52	1,61E+19	-2,358.483.400.000.000.000
53	1,61E+19	-2,358.483.400.000.000.000
54	1,61E+19	-2,358.483.400.000.000.000
55	1,61E+19	-2,358.483.400.000.000.000
56	1,61E+19	-2,358.483.400.000.000.000
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59	1,61E+19	-2,358.483.400.000.000.000
60	1,61E+19	-2,358.483.400.000.000.000
61	1,61E+19	-2,358.483.400.000.000.000
62	1,61E+19	-2,358.483.400.000.000.000
63	1,61E+19	-2,358.483.400.000.000.000
64	1,61E+19	-2,358.483.400.000.000.000
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66	1,61E+19	-2,358.483.400.000.000.000
67	1,61E+19	-2,358.483.400.000.000.000
68	1,61E+19	-2,358.483.400.000.000.000
69	1,61E+19	-2,358.483.400.000.000.000
70	1,61E+19	-2,358.483.400.000.000.000
71	1,61E+19	-2,358.483.400.000.000.000
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76	1,61E+19	-2,358.483.400.000.000.000
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78	1,61E+19	-2,358.483.400.000.000.000
79	1,61E+19	-2,358.483.400.000.000.000
80	1,61E+19	-2,358.483.400.000.000.000
81	1,61E+19	-2,358.483.400.000.000.000
82	1,61E+19	-2,358.483.400.000.000.000
83	1,61E+19	-2,358.483.400.000.000.000
84	1,61E+19	-2,358.483.400.000.000.000
85	1,61E+19	-2,358.483.400.000.000.000
86	1,61E+19	-2,358.483.400.000.000.000
87	1,61E+19	-2,358.483.400.000.000.000
88	1,61E+19	-2,358.483.400.000.000.000
89	1,61E+19	-2,358.483.400.000.000.000
90	1,61E+19	-2,358.483.400.000.000.000
91	1,61E+19	-2,358.483.400.000.000.000
92	1,61E+19	-2,358.483.400.000.000.000
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98	1,61E+19	-2,358.483.400.000.000.000
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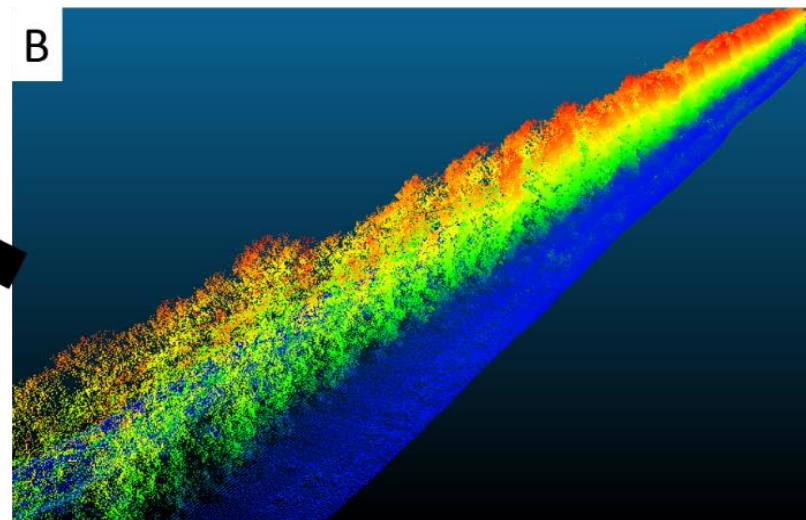
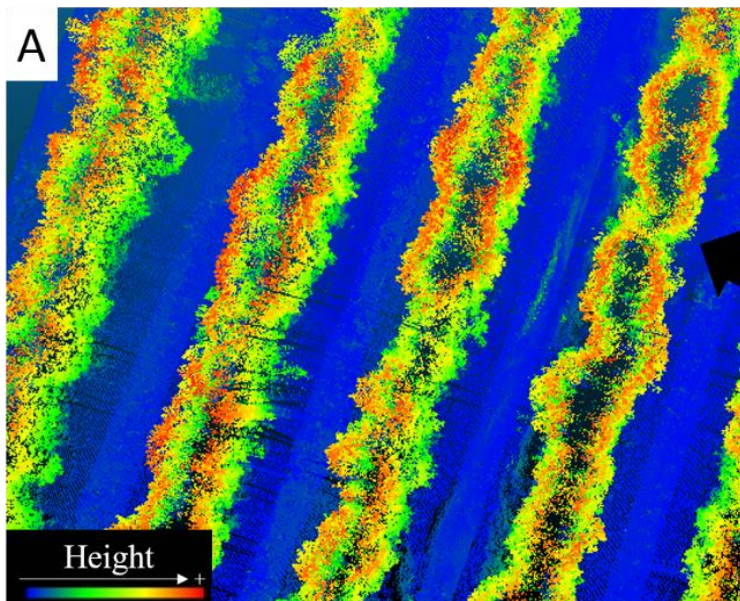


Silva, 2018

Café



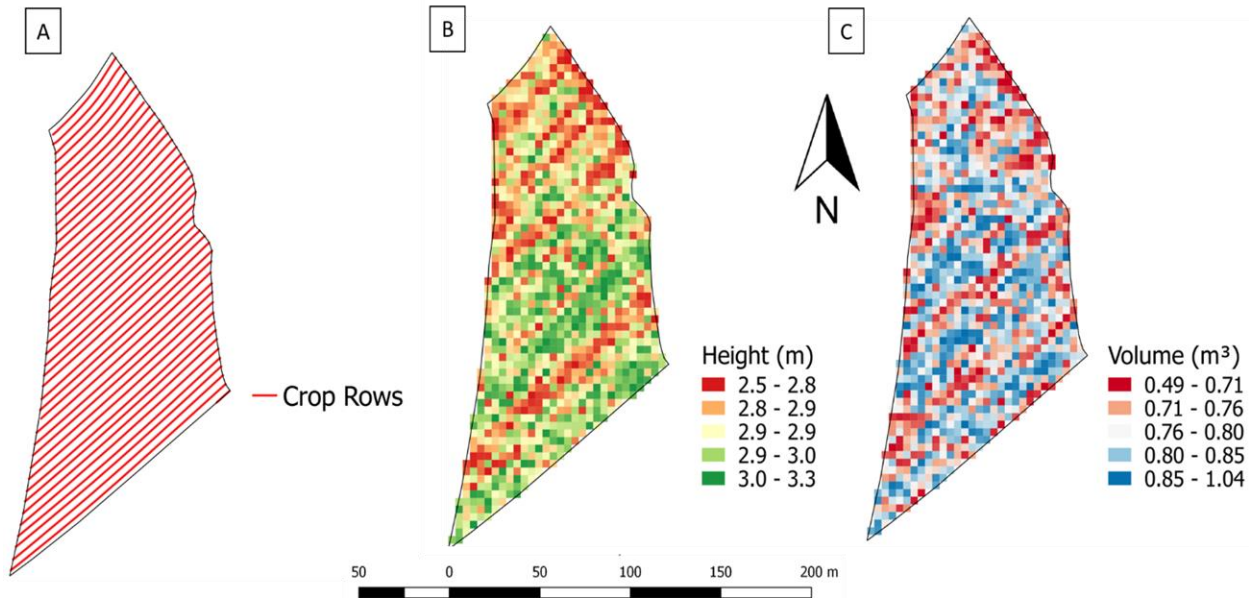
Karp et al., 2018



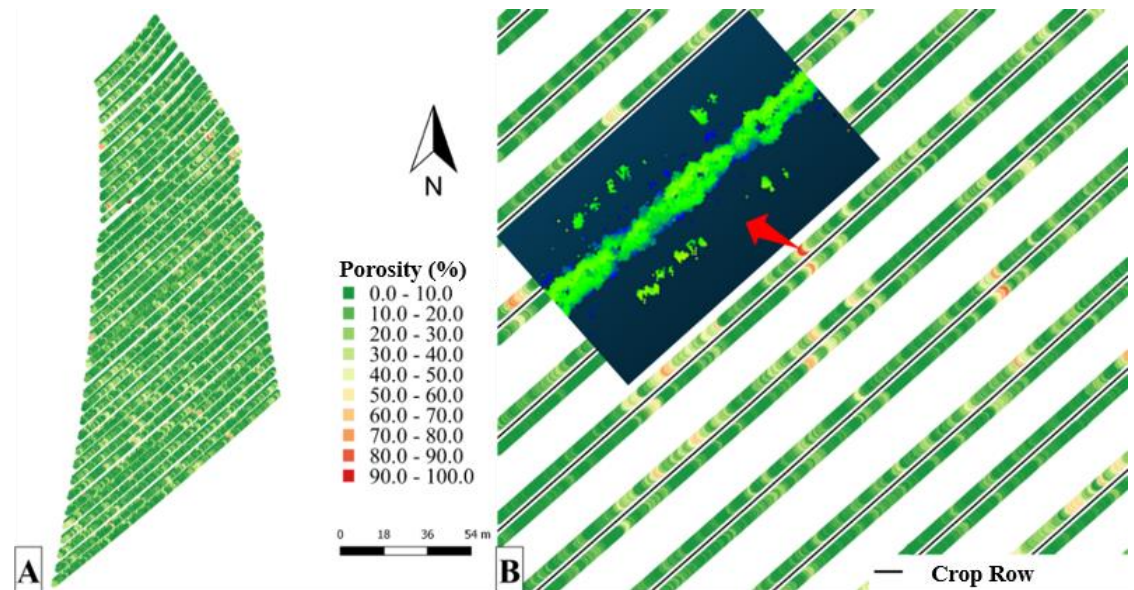
Descriptive statistic of volume and height for Field 2

Variables	Mean	Standard Deviation	Median	Minimum	Maximum	C.V.(%)*
	----- m ³ (volume) or m (height) -----					
Height	2.91	0.19	2.92	2.41	3.37	6.55
Volume	0.78	0.12	0.79	0.48	1.06	15.77

Canopy Geometric Parameters – Field 2

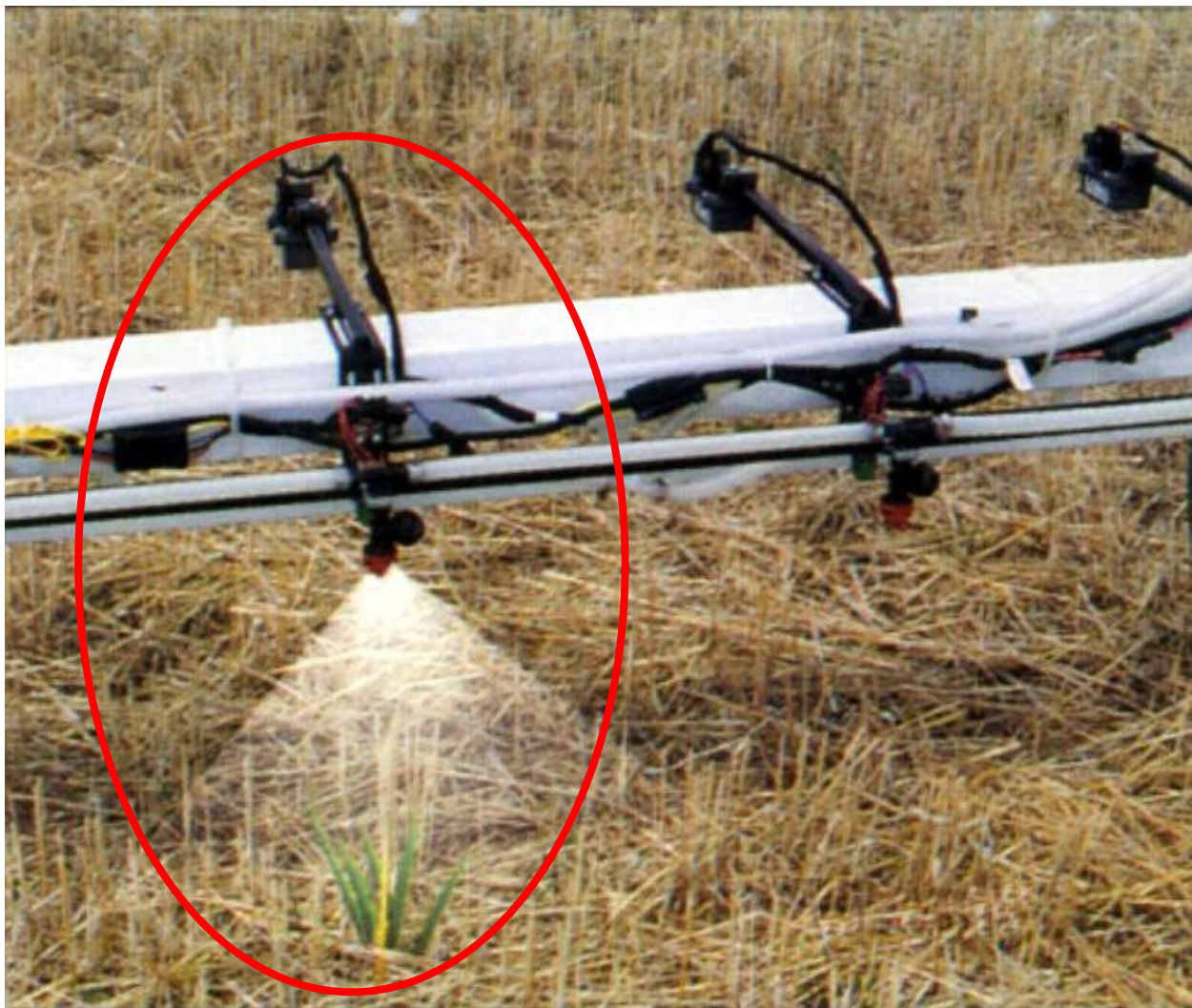


Plants porosity



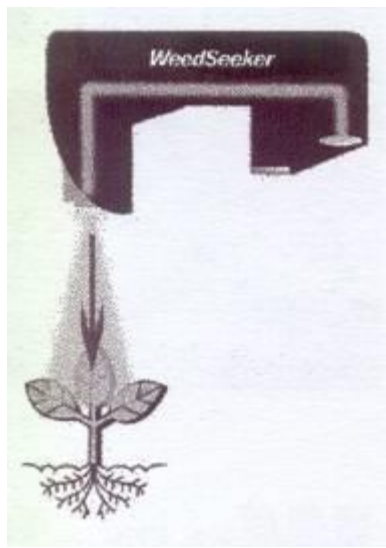
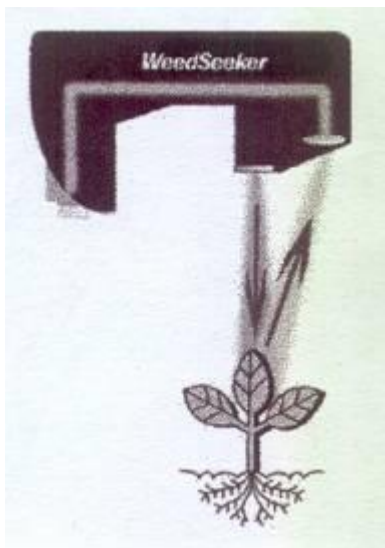
Karp et al., 2018

Sensores para detecção de verde – herbicida!





Sensor de "Verde"



Localiza

Aplica





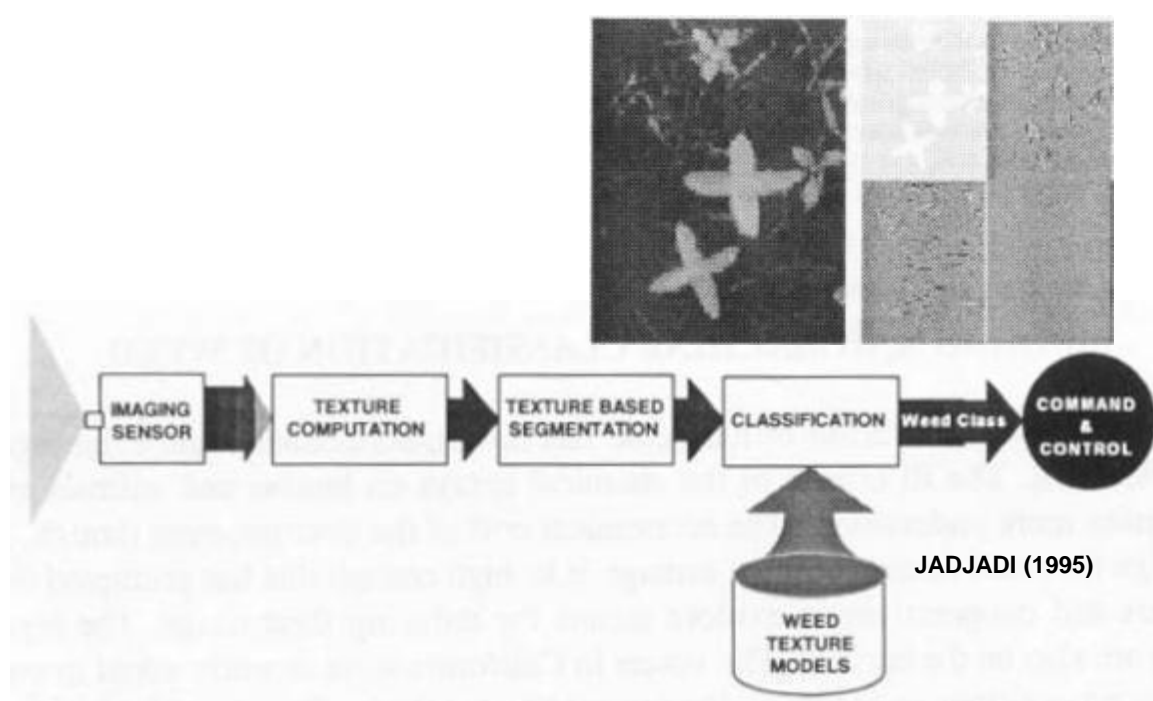
Folheto Herbicat





WeedIt

Visão artificial



Câmera com frequência de 24 imagens/s para velocidades de até 1,43 m/s e pixels de pulverização de 10,5 x 10 mm (de impressora de jato de tinta)

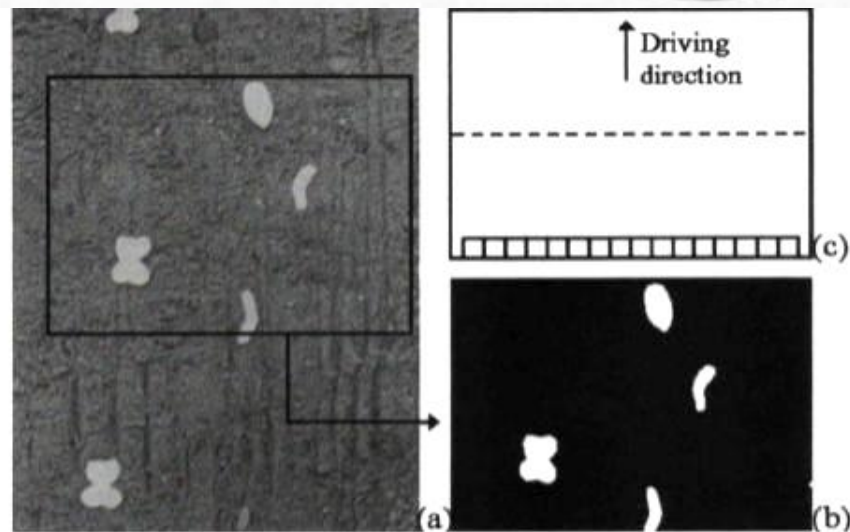
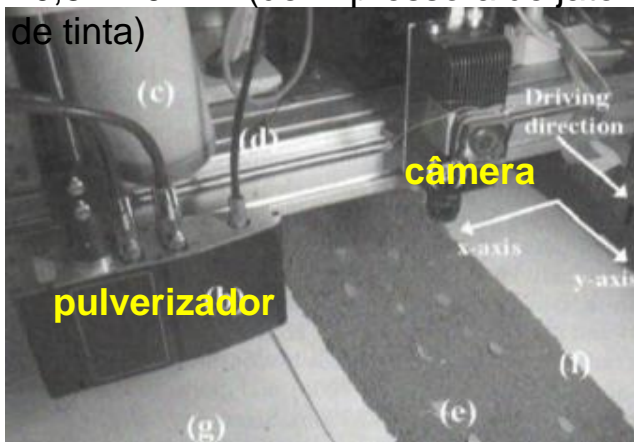
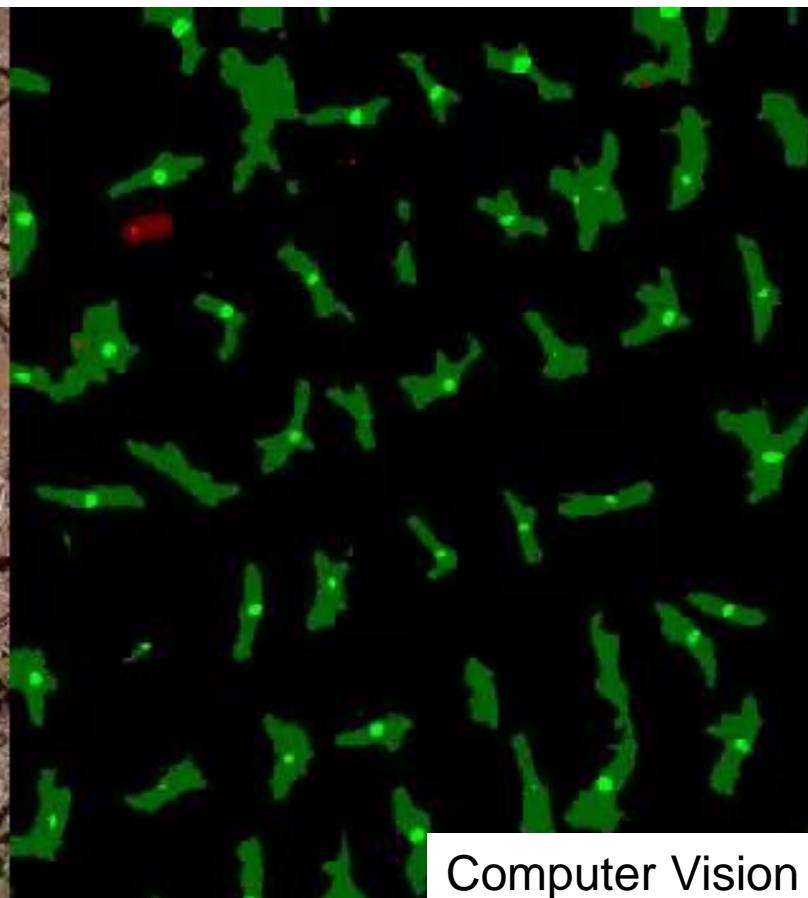


Figure 3. Illustration of the image processing and virtual borders for triggering the dot-sprayer valves. (a) cut-out image of the band of soil with green objects; (b) binary image of the FOV in (a); (c) the 16 virtual squares of size 10.5 mm × 10 mm and centre line of image (dotted line).

NORREMARK, et al., 2009

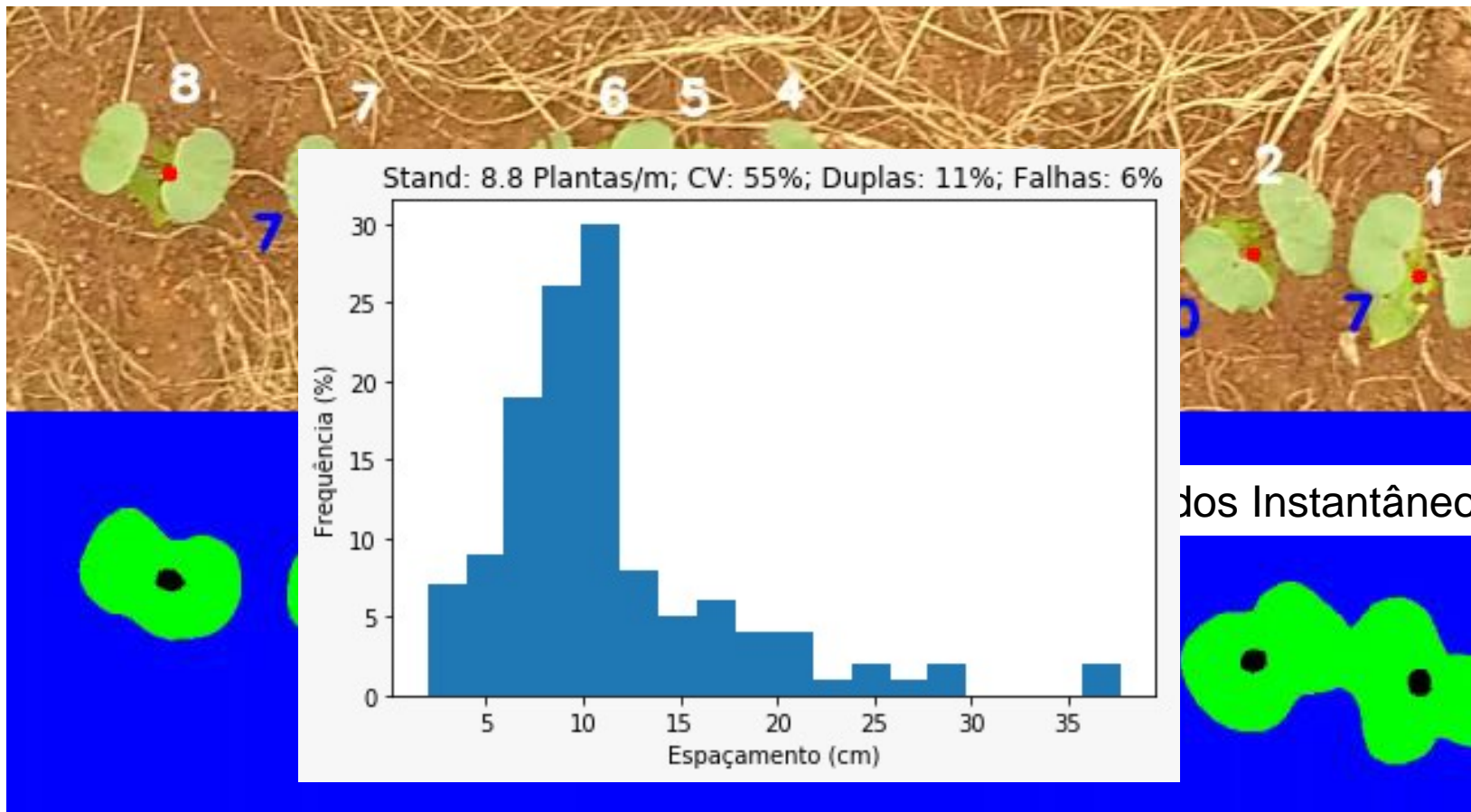


Real image



Computer Vision





dos Instantâneos

On board cameras that takes pictures of the ground and automatically counts the number of grains that were lost during harvest;



Grain identification and counting



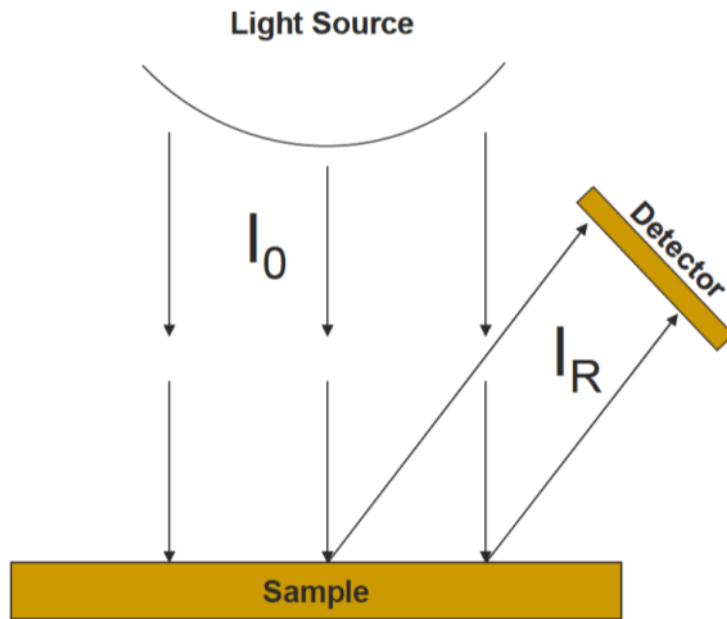
Cameras installed behind harvester platform



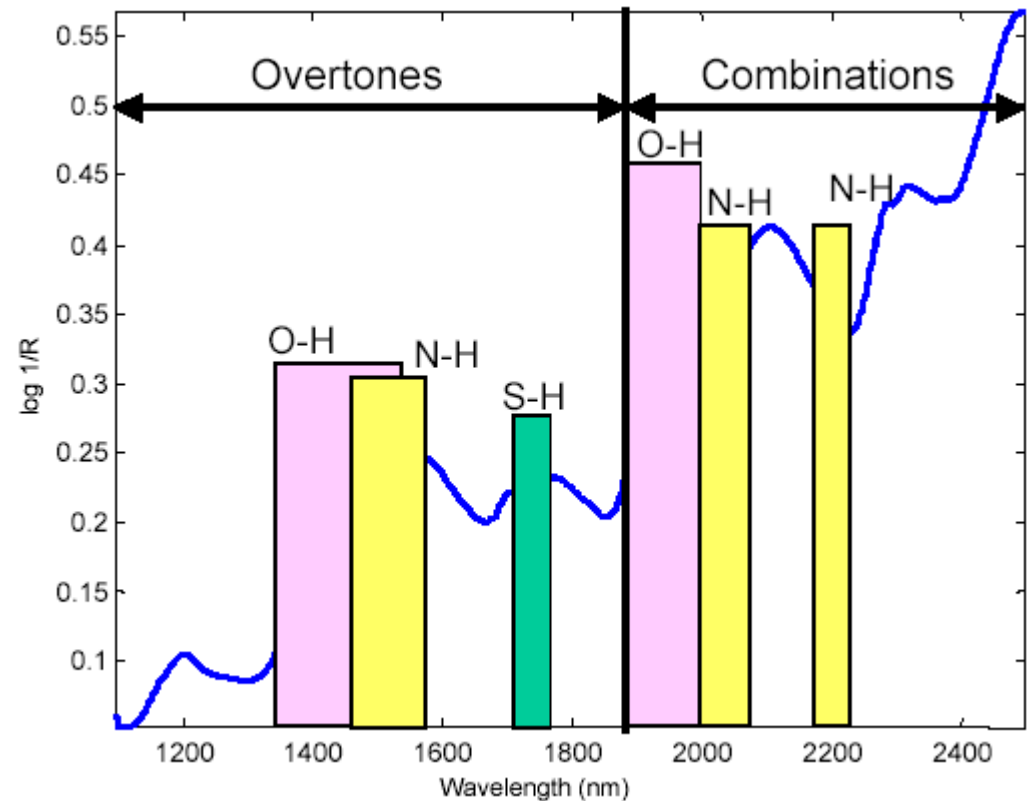
Sensores que tem o produto como alvo

... investigação e
monitoramento da qualidade

Princípio de funcionamento



Bandas do NIR normalmente utilizadas



Digman & Shinnars (2011)

Medidor de umidade do material por NIR (espectroscopia)

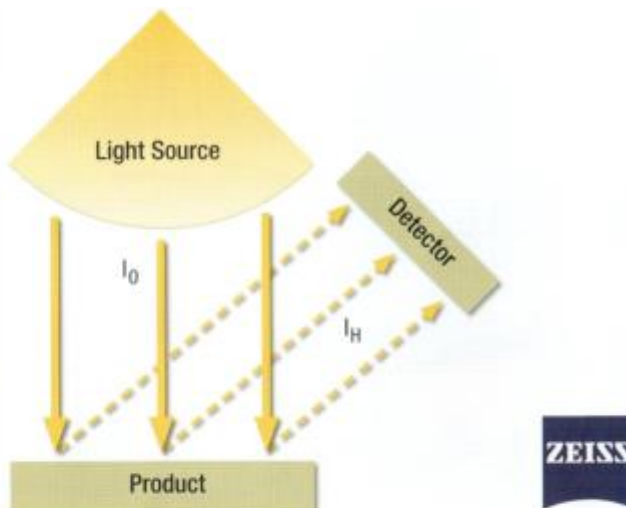
HarvestLab Sensor



In the field, HarvestLab doesn't require calibration and can measure crop quality at material speeds of up to 40 m/sec. Thousands of measurements – on average one analysis per 50 kg of fresh silage – make readings more representative and accurate than with traditional methods.



The HarvestLab sensor can easily be converted into a counter-top storage analysis lab with just a few components.



Exclusive Cooperation between John Deere and Carl Zeiss

John Deere and Carl Zeiss developed the HarvestLab near-infrared reflectance sensor because you cannot afford to wait over 24 hours while a sample of your crop is tested in a drying oven!

Carl Zeiss is the German specialist in lenses, optical devices and sensors. The near-infrared reflectance technology used in HarvestLab is the same that many professional laboratories use to analyse crop moisture to an accuracy of $\pm 2\%$.

Near-infrared light is reflected from the moving crop, towards a sensitive detector inside the HarvestLab unit. Silage of different dry matter reflects the NIR light at varying intensities, from which the moisture of the crop is accurately determined.

Na colhedora de forragem



No galpão



John Deere

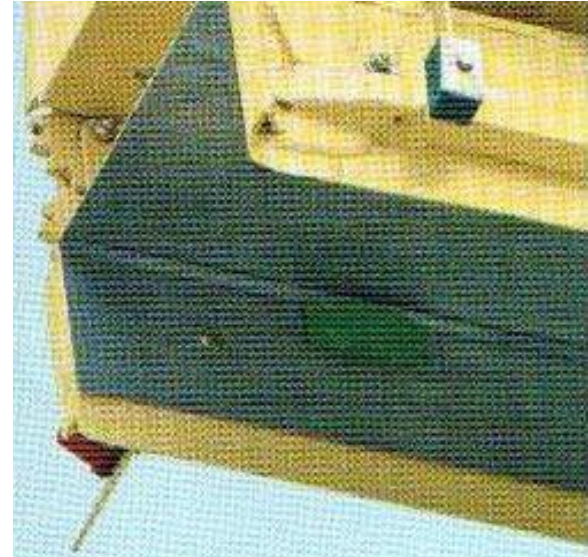
Sensor NIR de bancada



Outros semelhantes:

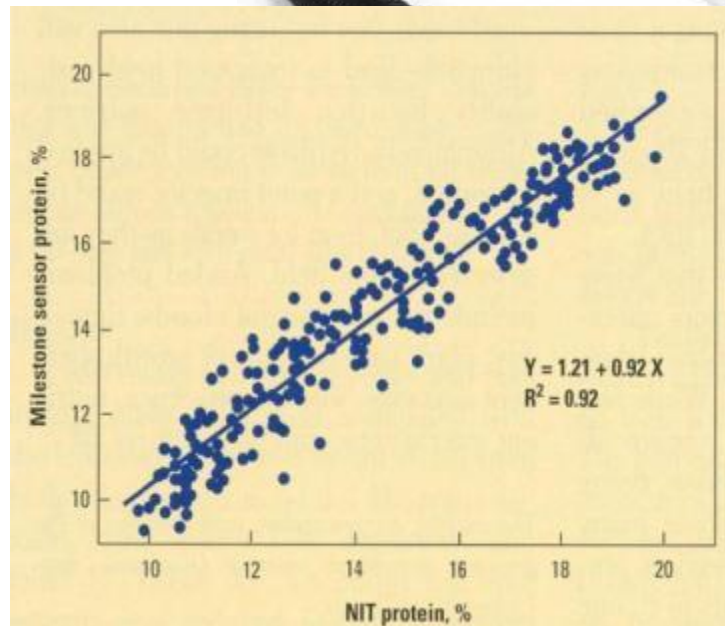
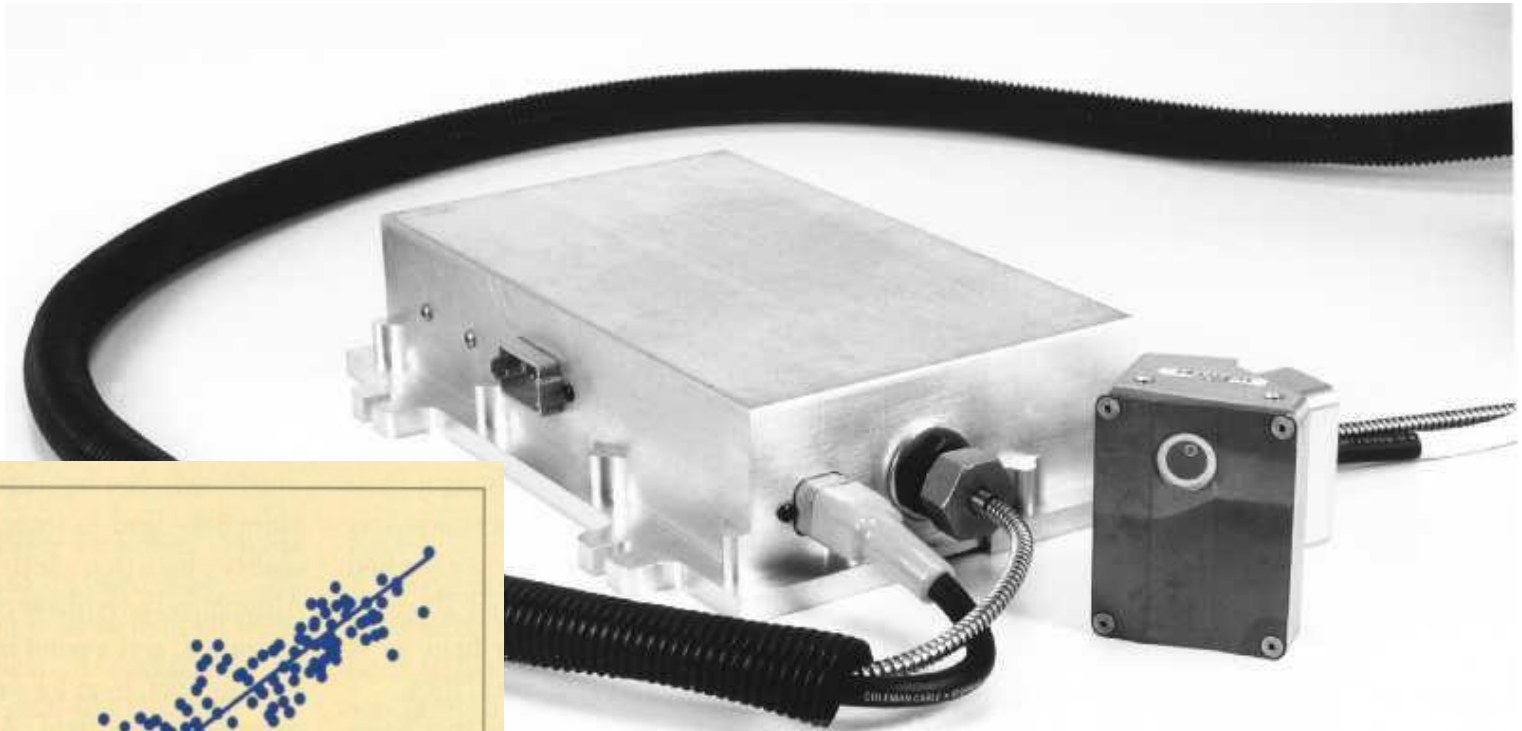


Class – mede por
eletrocondutividade
mais temperatura

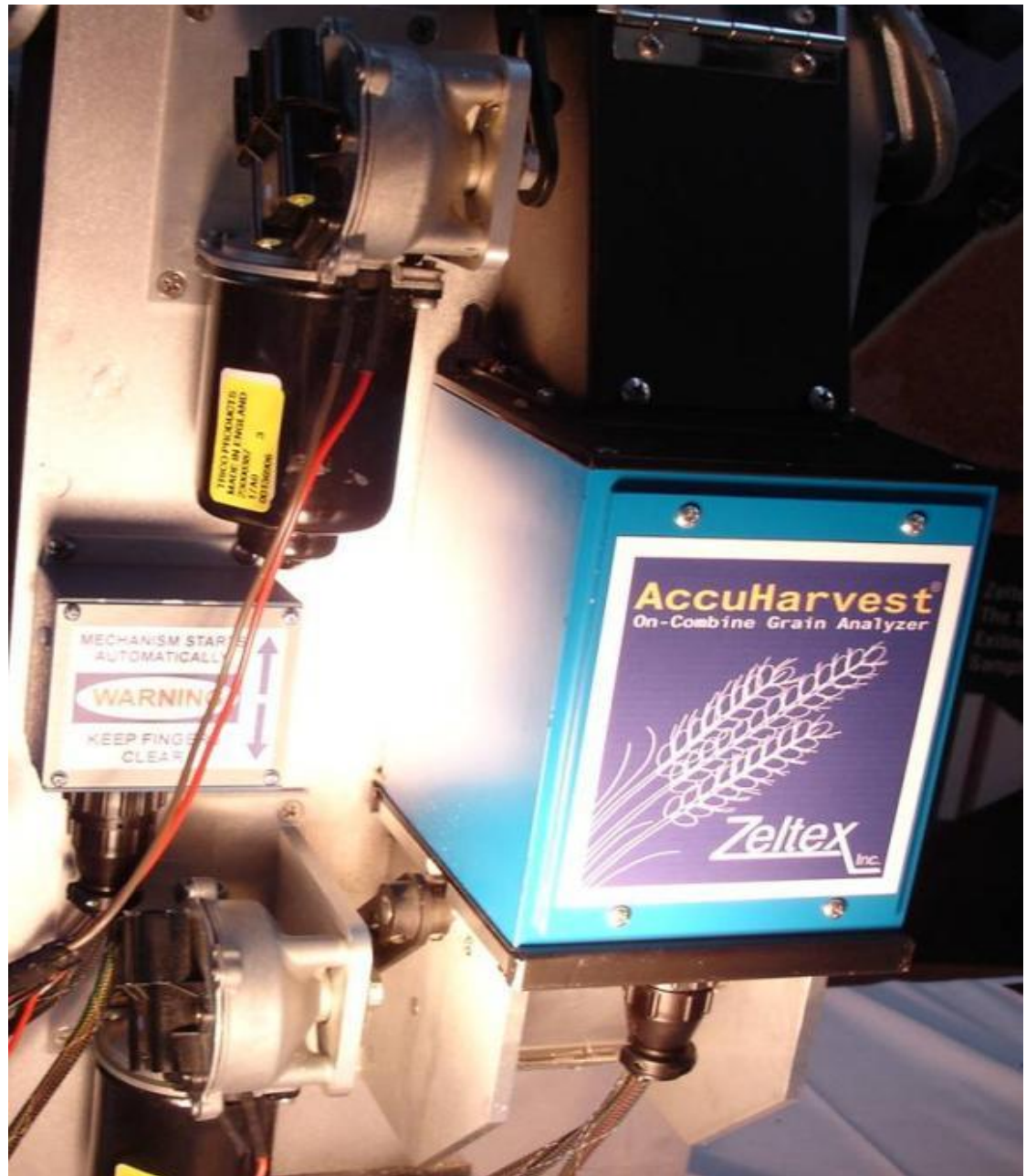


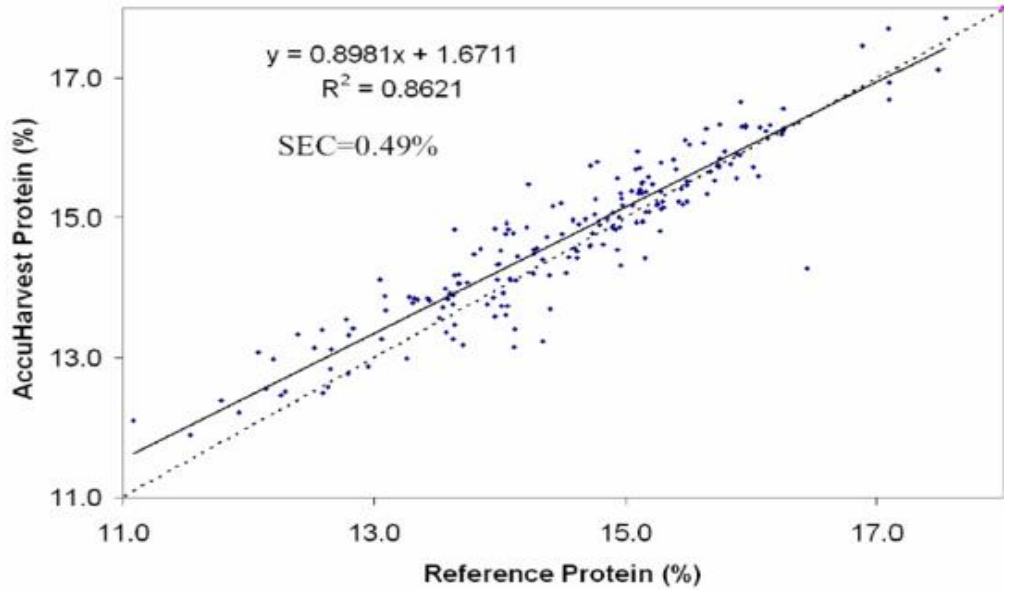
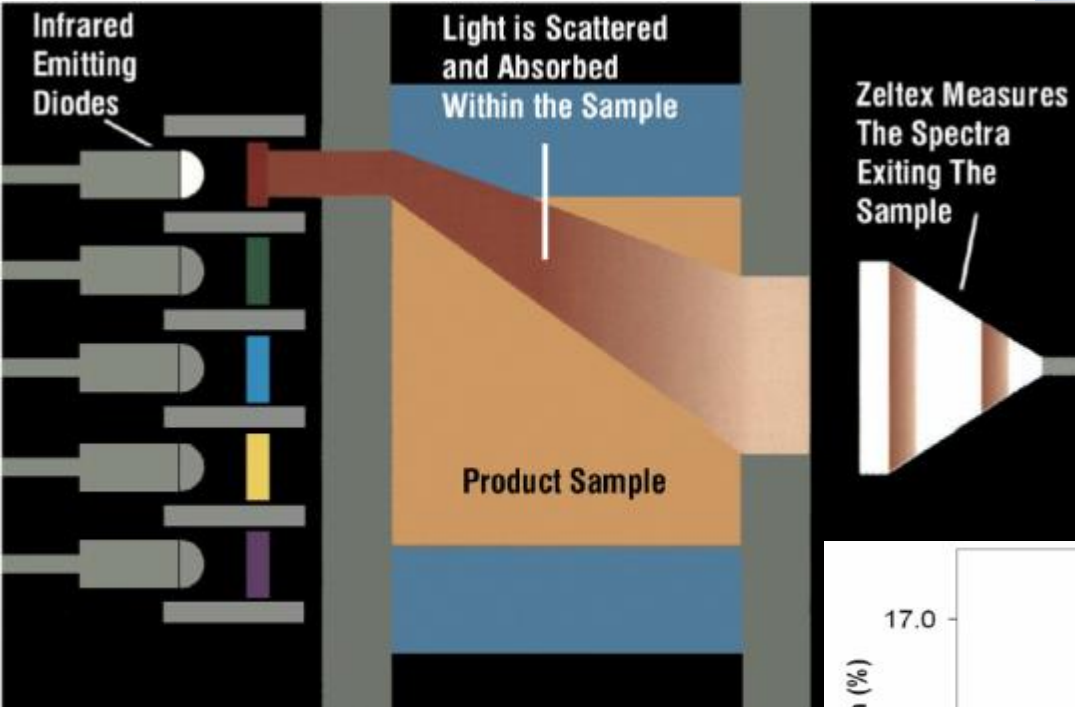
Krone - mede por
eletrocondutividade

Monitor da qualidade dos grãos – teor de proteína

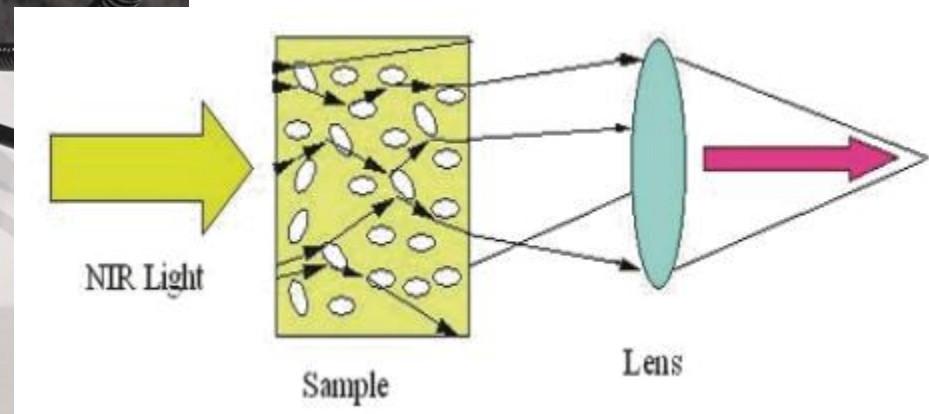


Sensor de proteína em grãos



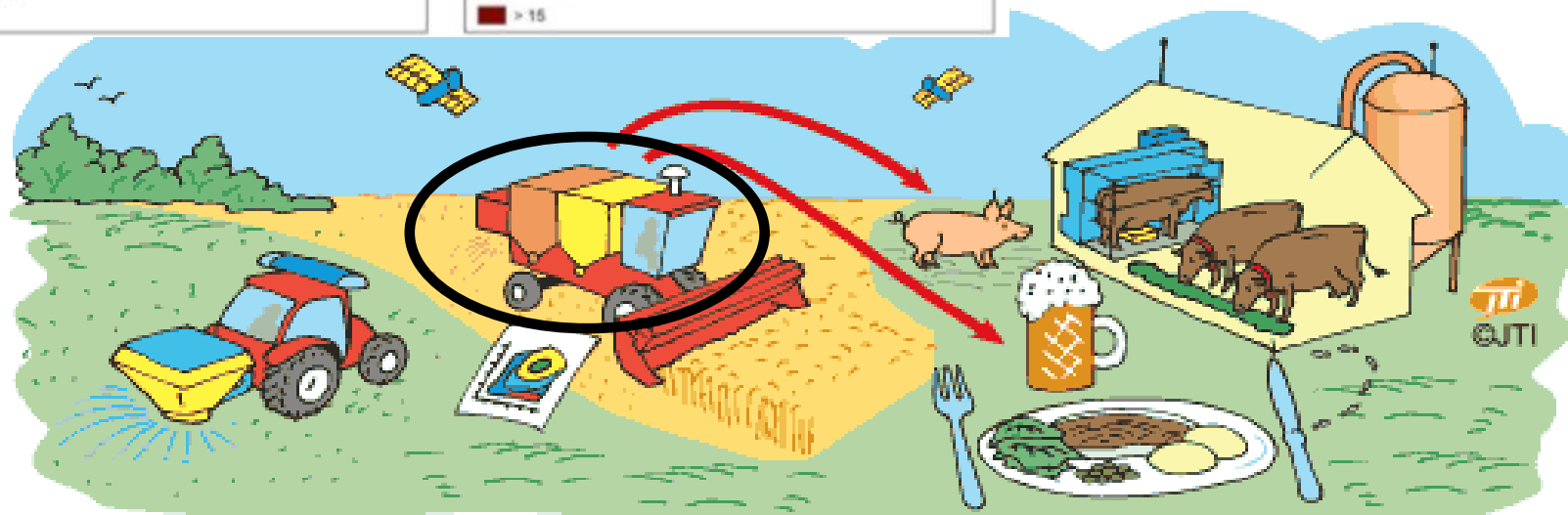
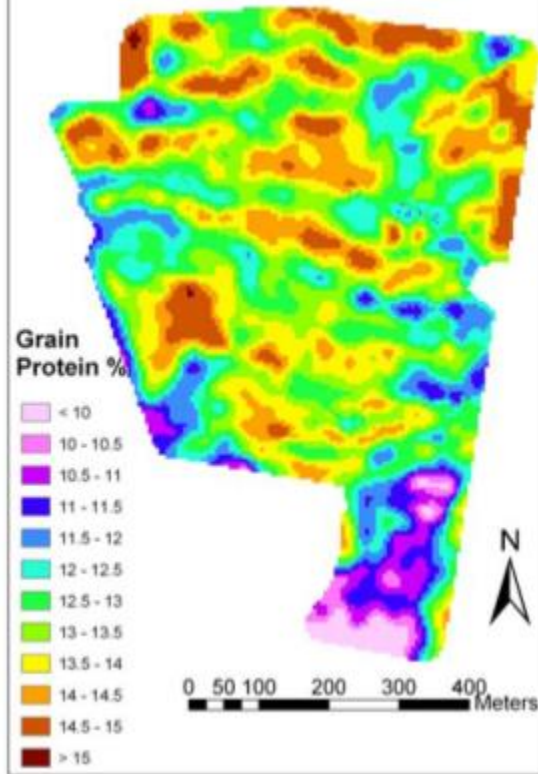
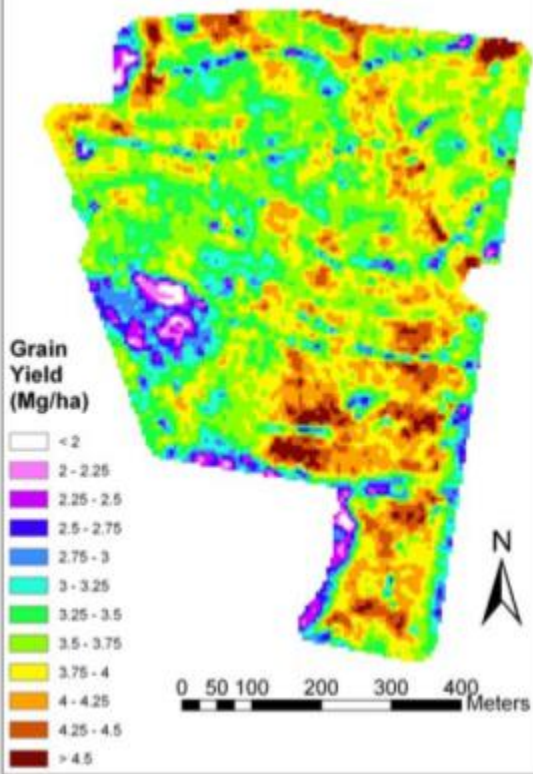


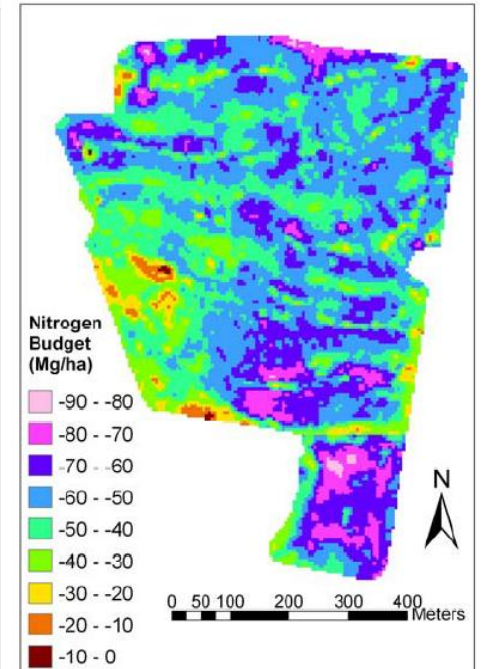
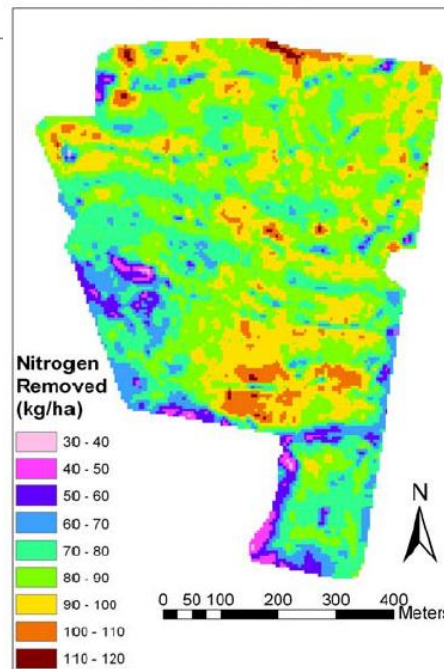
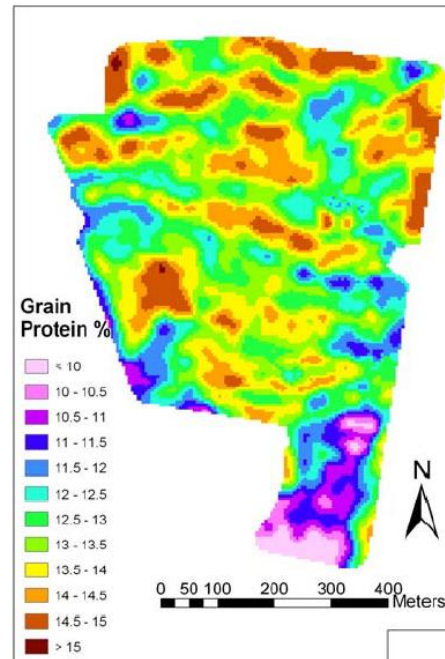
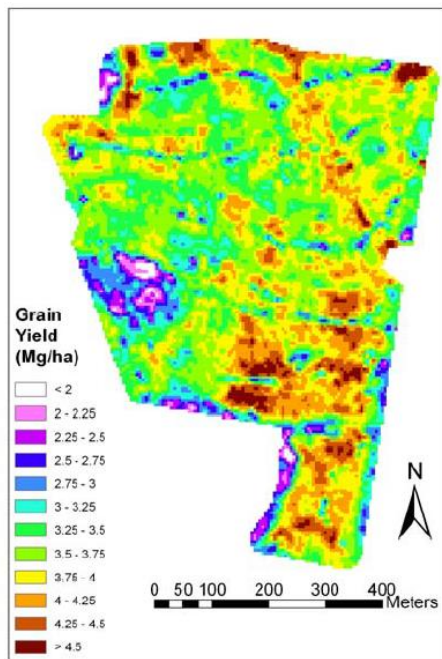
Sensor de proteína em grãos





CASE IH





Taylor et al., 2005