LGN5831 - SPECIAL TOPICS IN GENETICS AND PLANT BREEDING

DEVELOPMENT OF SPECTRAL INDEX FOR DETECTION OF COFFEE LEAF MINER IN COFFEE

Research proposal

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Introduction

- Coffe economic chain
  - 154 million bags exports – world wide
  - 160 US/lb – average future price - NY
- Coffee – gross revenue estimates 2017 - R$19.56 bi
- Brazil – coffee leading exporter (estimates 44.83 million bags – 2017)

CONAB, 2017
ICO, 2017

Introduction

Coffee leaf miner

- *Leucoptera coffeella* Guérin-Méneville - lepdopteran
  - 50% production reduction

- Principal control:

neonicotinoids

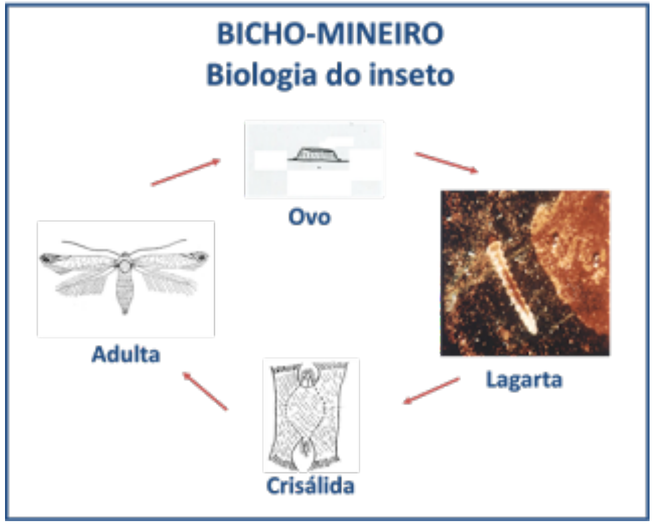
anthranilic diamide

organophosphates

Introduction

Chemical control

- Environmental risk
- Risk to the operator
- Inefficiency of application in rough terrains
- Imbalance in the cycle pest population



Introduction

- Others: resistance cultivars (*Coffea racemosa*)
  - *Mean objective in breeding programs: pests and desease*

- Evaluation
  - Field
  - Green house

Coffee evaluation cycle

Arabica crosses

≈ 9 months

Seed germination

≈ 1 month

Seedlings

- Green house evaluation,
- Early evaluation,
- Evaluation time,

≈ 5 months

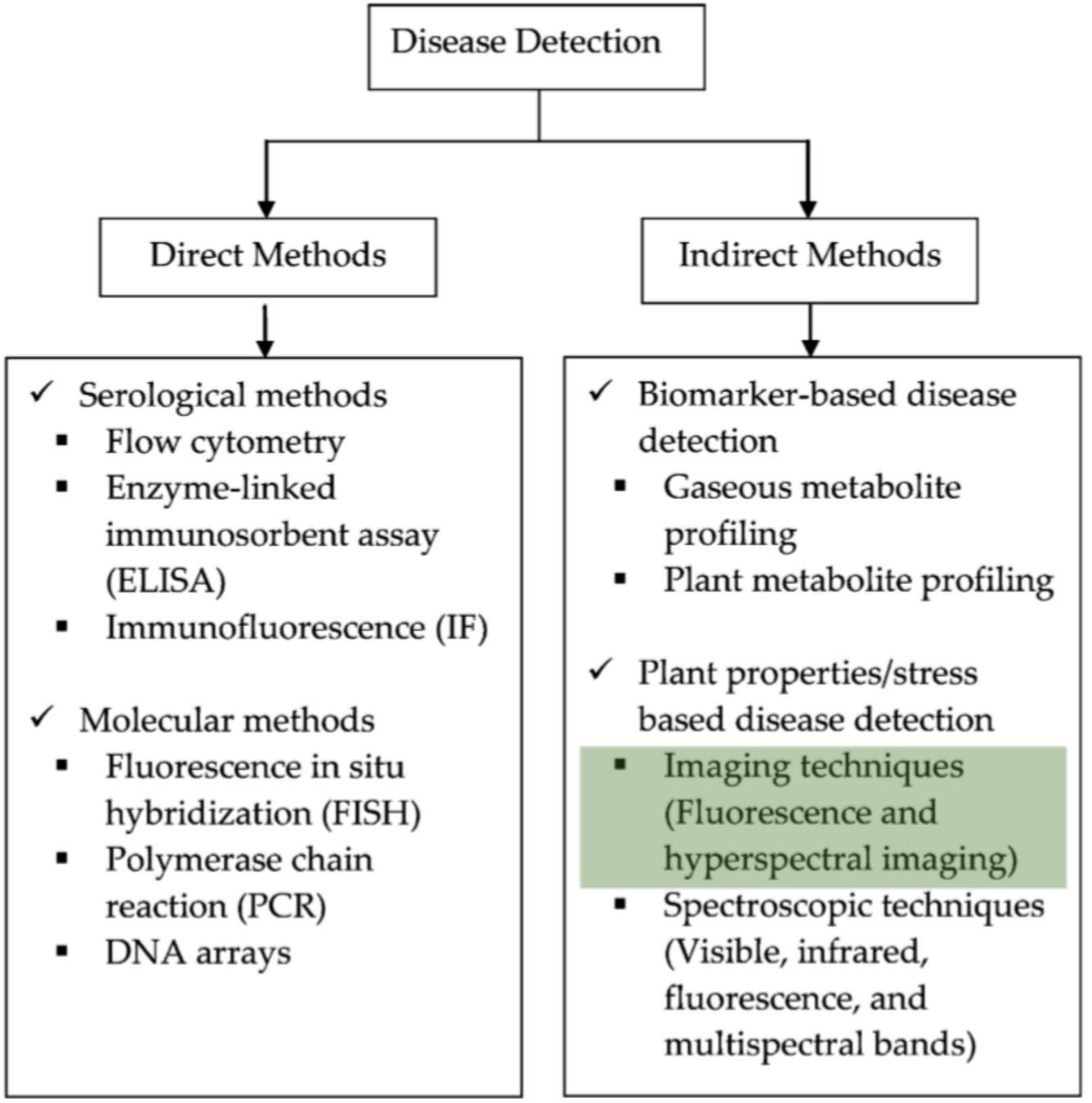
Coffee experimental field

- Best genotypes,
- Ratings after 2 years,
- 5 years of evaluation,
- Agronomic traits,

Image analysis

- Evaluations – note scale (Guerreiro-Filho, 1999):
  - Resistance
  - Severity of attack (notes for %)

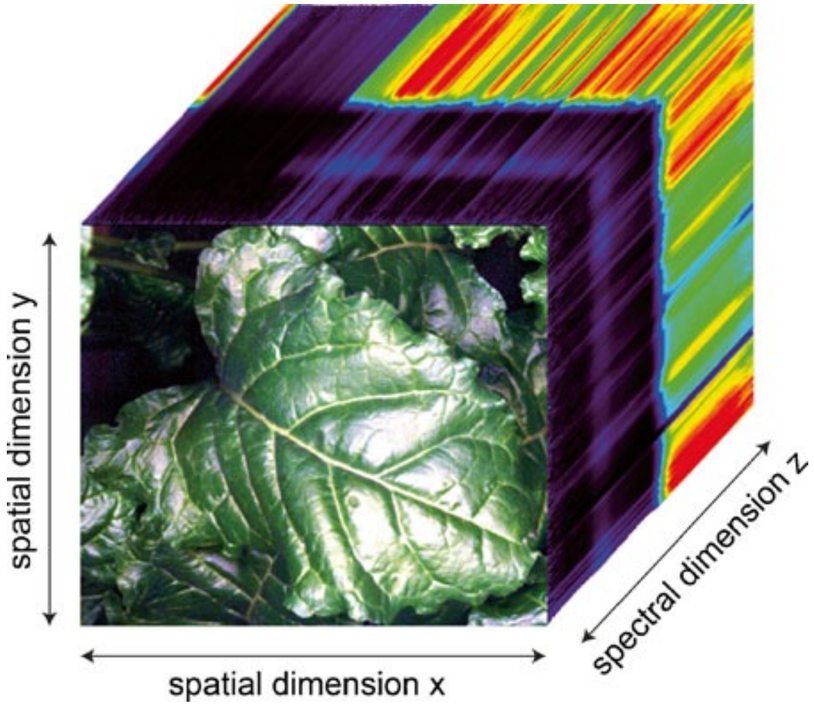
- Note scale
  - Operational facilities
  - Subjectivity
  - Genotype categorization
  - **Rate bias**


Disease Detection
Direct Methods
Indirect Methods
✓ Serological methods
▪ Flow cytometry
▪ Enzyme-linked immunosorbent assay (ELISA)
▪ Immunofluorescence (IF)
✓ Molecular methods
▪ Fluorescence in situ hybridization (FISH)
▪ Polymerase chain reaction (PCR)
▪ DNA arrays
✓ Biomarker-based disease detection
▪ Gaseous metabolite profiling
▪ Plant metabolite profiling
✓ Plant properties/stress based disease detection
▪ Imaging techniques (Fluorescence and hyperspectral imaging)
▪ Spectroscopic techniques (Visible, infrared, fluorescence, and multispectral bands)

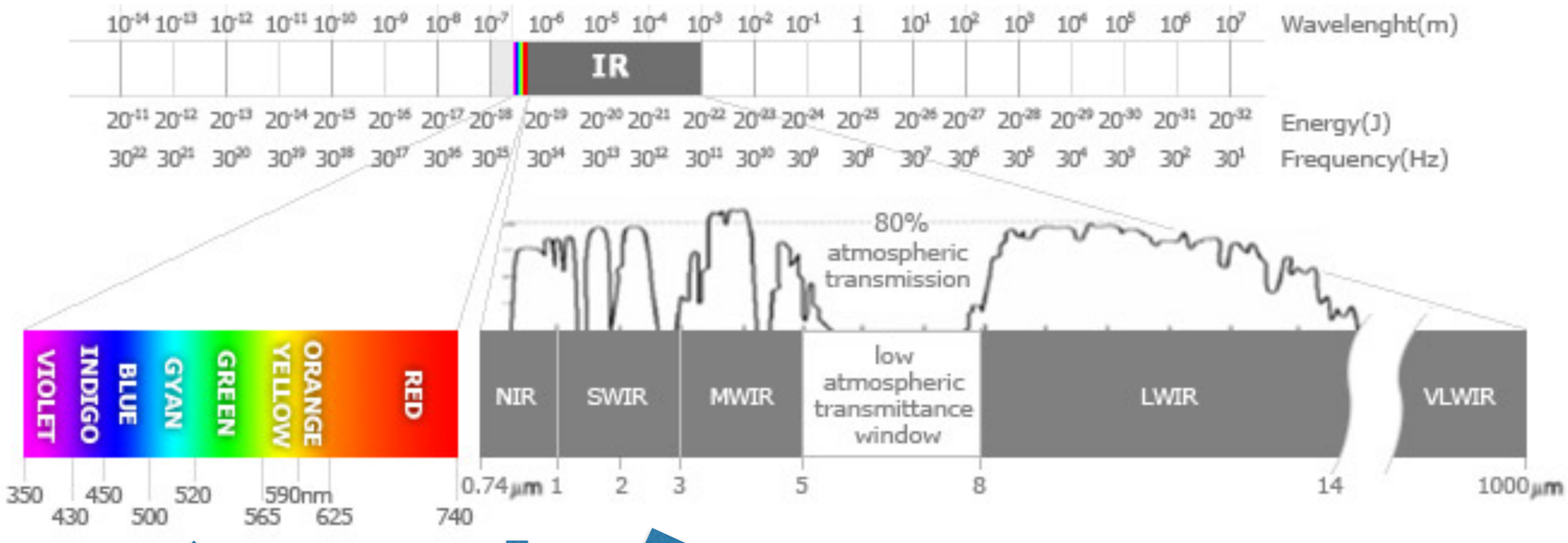
Argumentation

- ***Hyperspectral cameras*** facilitate the detection of both spectral and spatial information of an object:

- Each spatially located pixel of an image contains the full wavelength information



Argumentation



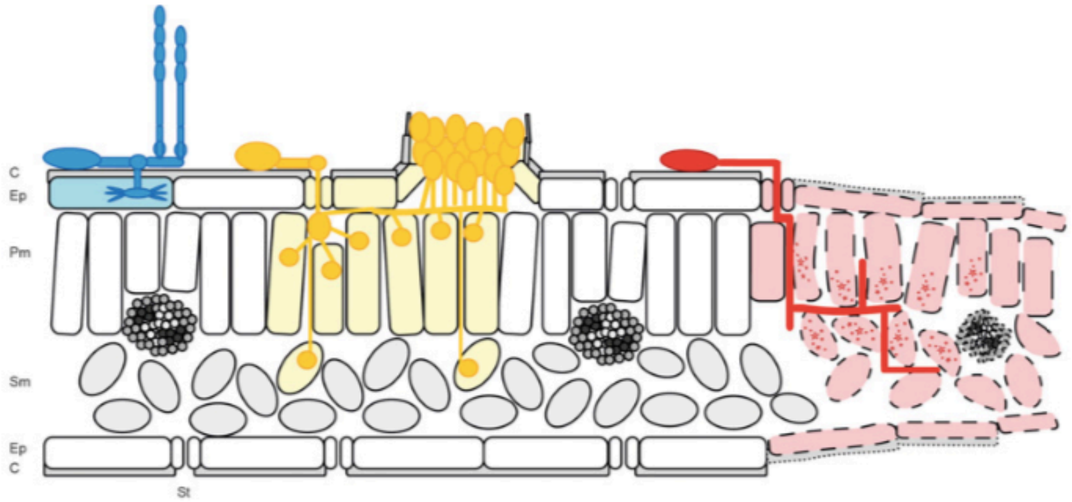
Leaf pigment content

- **Leaf structure**
- **Internal scattering processes**

- **Composition of leaf chemicals**
- **water**

Argumentation

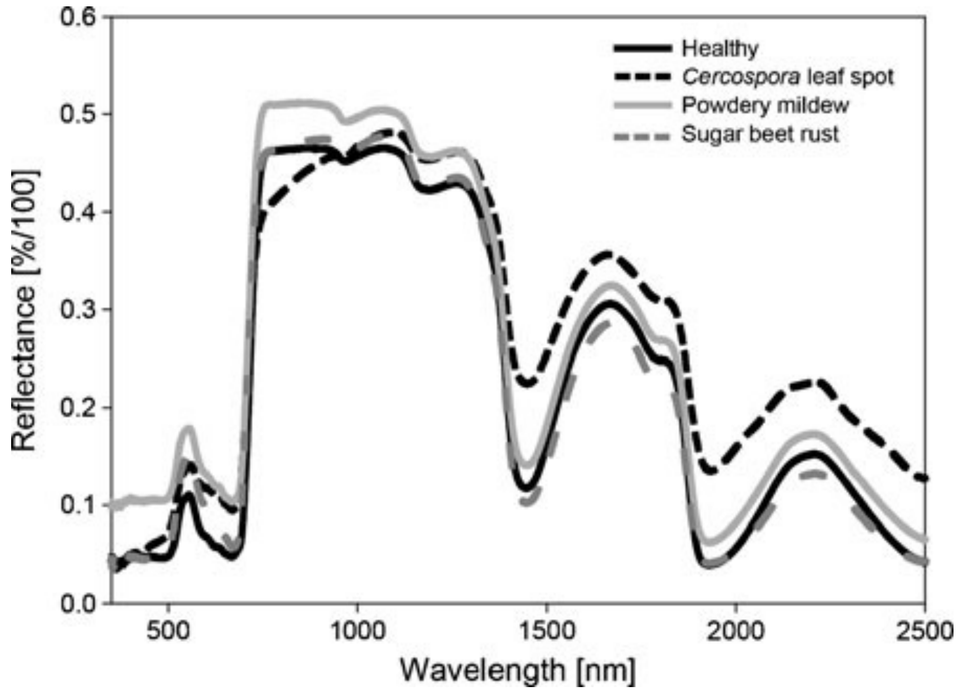
- Changes in reflectance: impairments in the **leaf structure** and **chemical composition** of the tissue that is highly specific.



- These highly complex and unique disease patterns enable an identification of diseases based on the spectral properties of plants.

Argumentation

- Construction of ***spectral signatures***
- Disease-specific symptoms may be detectable



Argumentation

Analysis of sensor data

- Using specific wavelengths of spectral signatures, **spectral algorithms** have been developed to specify different plant parameters
- Benefits and disadvantages
- A combination of different wavelengths **spectral disease indices (SDI)** can be useful to simplify disease detection by spectral sensors

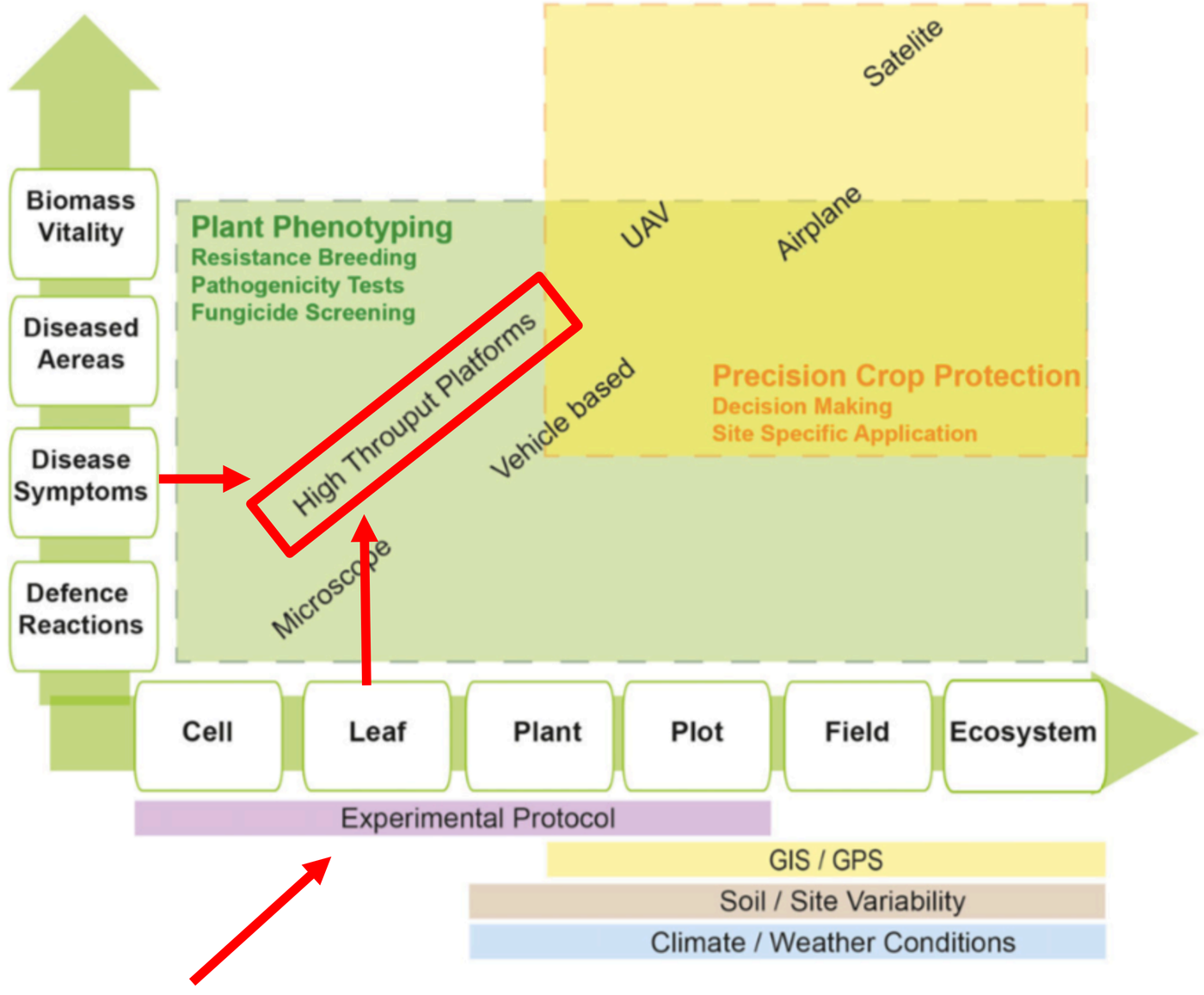
Motivation

- The identification of a disease, its discrimination from other diseases and abiotic stressors, using sensing techniques is still a challenge in vegetation monitoring;

- Interpretation of spectral reflectance data without knowledge on spectral characteristics of leaves and typical symptoms is impossible at present

Development of spectral index for detection of coffee leaf miner in coffee

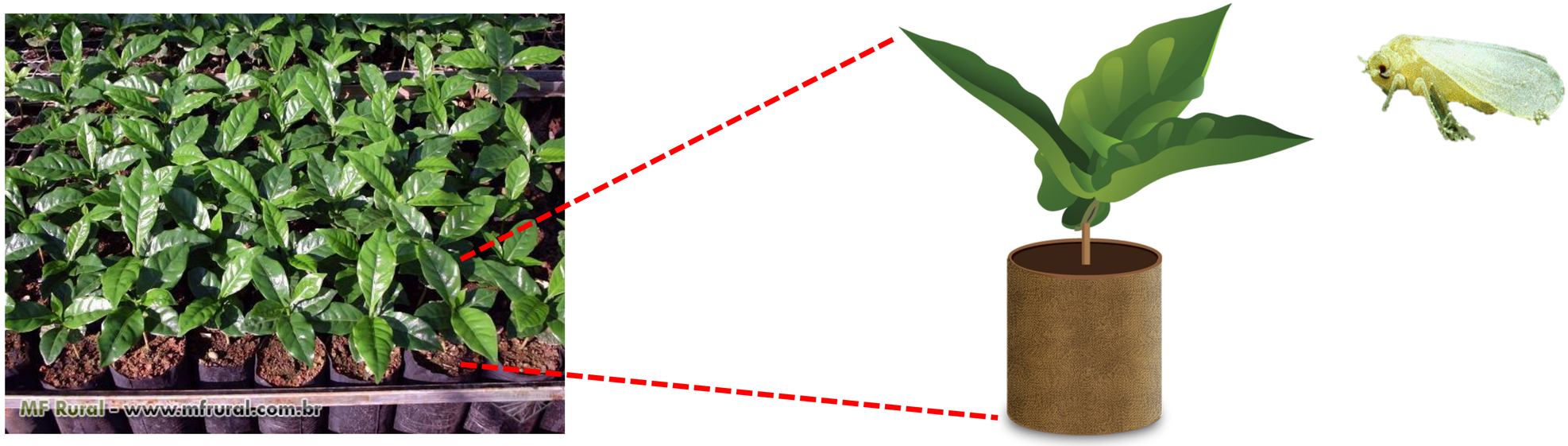
Methodology



Methodology

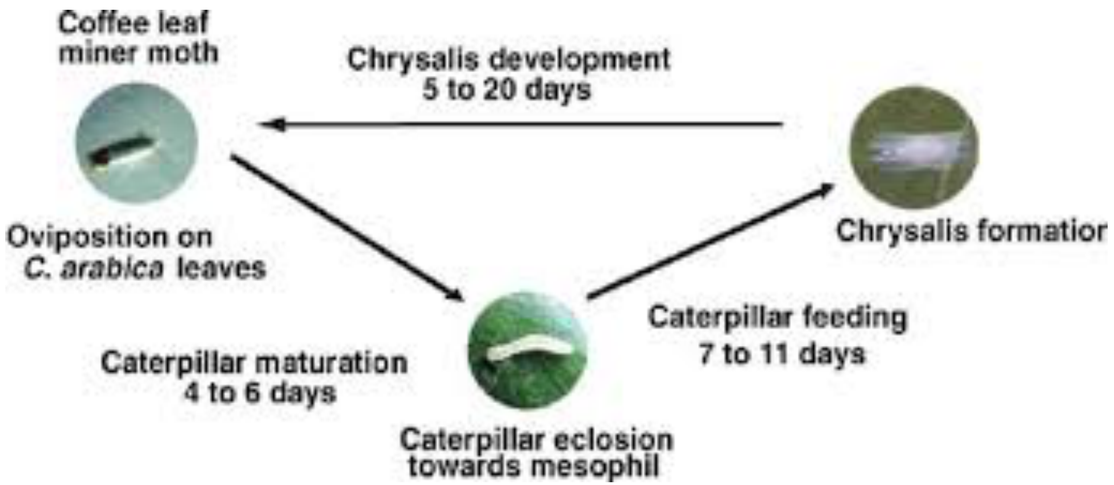
Experimental setup

- Use a data set of spectral signatures from healthy coffee leaves and from coffee leaves infested with LM



Methodology

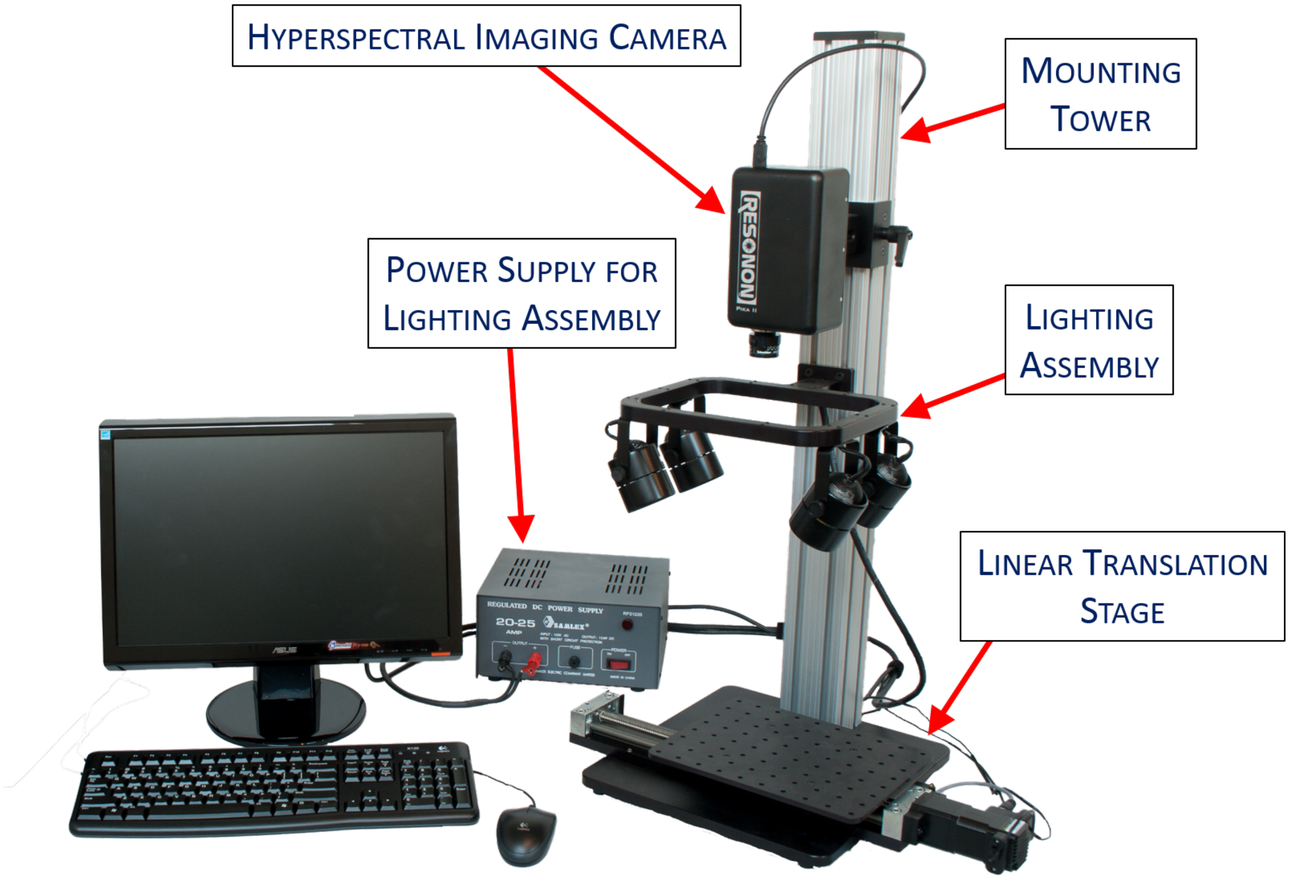
Experimental setup



- Controlled conditions
  - Isolated stressor
  - Lightening and background pattern
- Two experiments

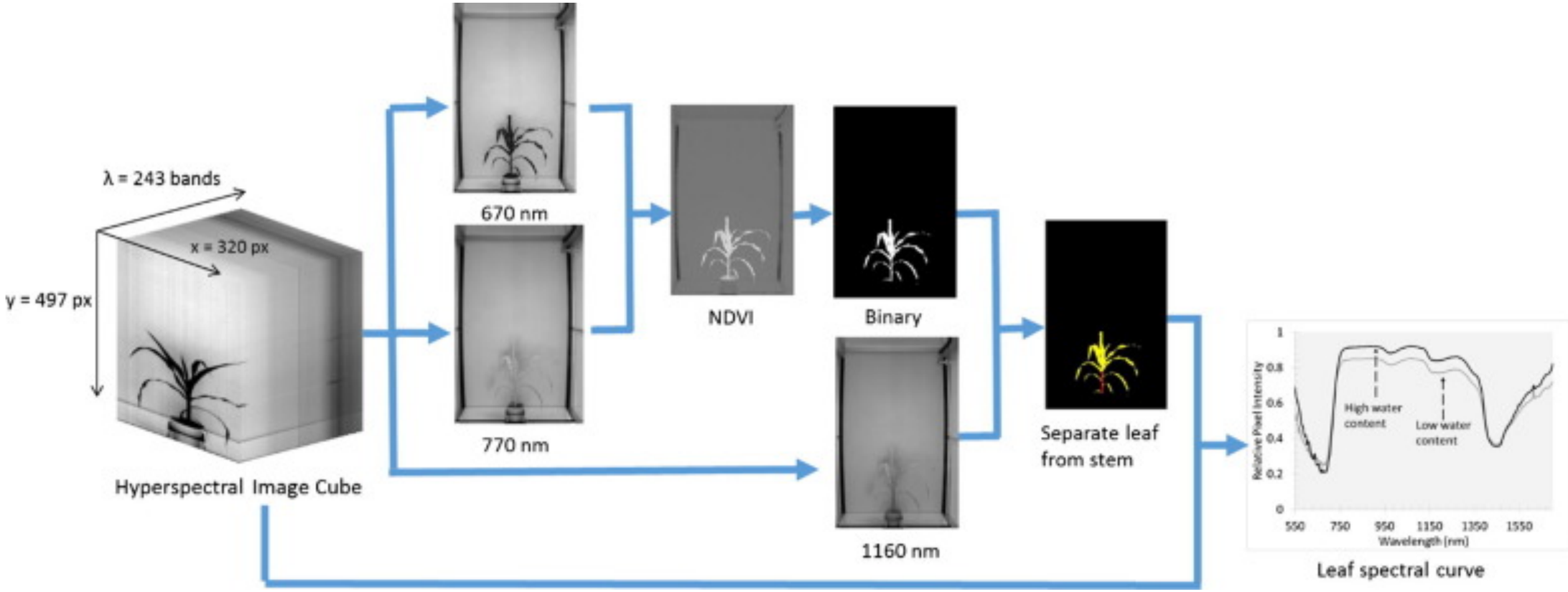
Methodology

Measurement of leaf reflectance



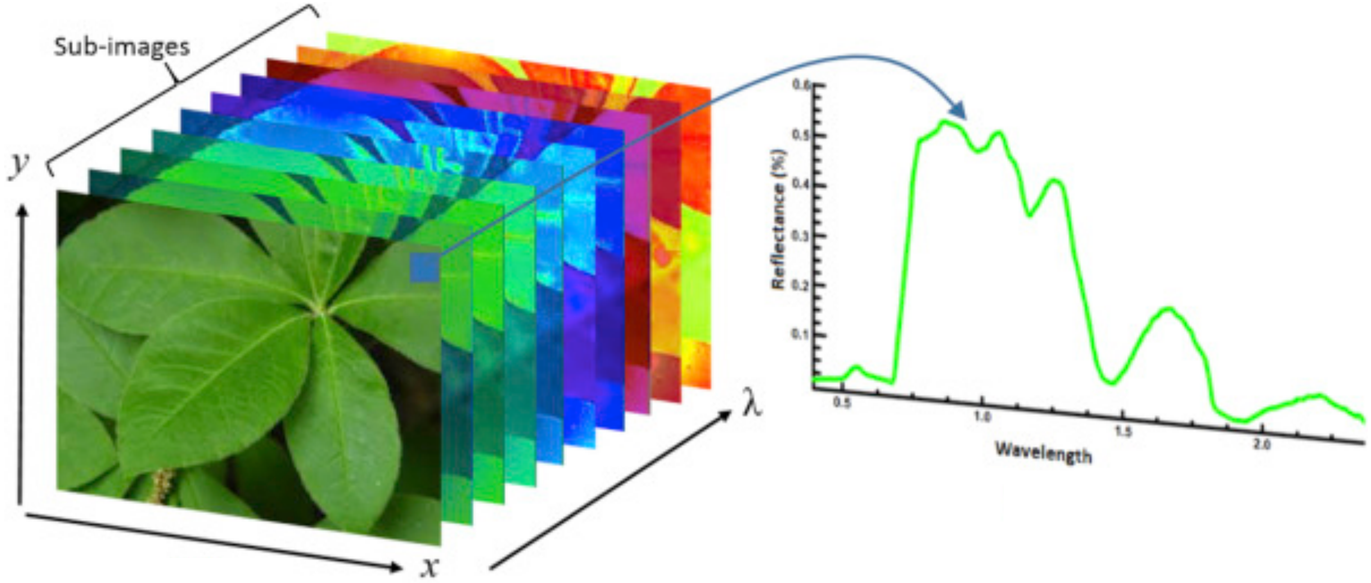
Methodology

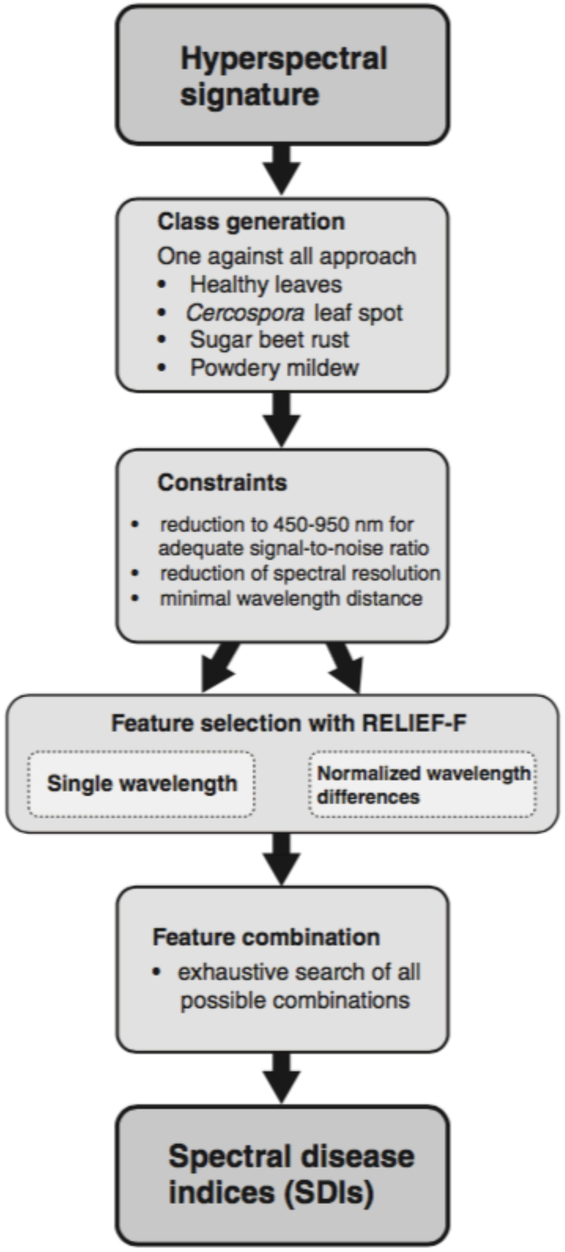
Measurement of leaf reflectance



Methodology

Construction of SDI





Methodology

Construction of SDI

- RELIEF-F algorithm: most relevant single wavelengths and wavelength differences
  - estimates the relevance of wavelength according to their goodness to separate samples of both classes which are near to each other.

$$Healthy - index\,(HI) : \frac{R534 - R698}{R534 + R698} - \frac{1}{2} \cdot R704$$

$$Cercospora\ leaf\ spot - index\,(CLS) : \frac{R698 - R570}{R698 + R570} - R734$$

$$Sugar\ beet\ rust - index\,(SBRI) : \frac{R570 - R513}{R570 + R513} + \frac{1}{2} \cdot R704$$

$$Powdery\ mildew - index\,(PMI) : \frac{R520 - R584}{R520 + R584} + R724$$

Mahlein et al. 2013

Methodology

Discriminant analysis of LM symptoms level

0 - 30%

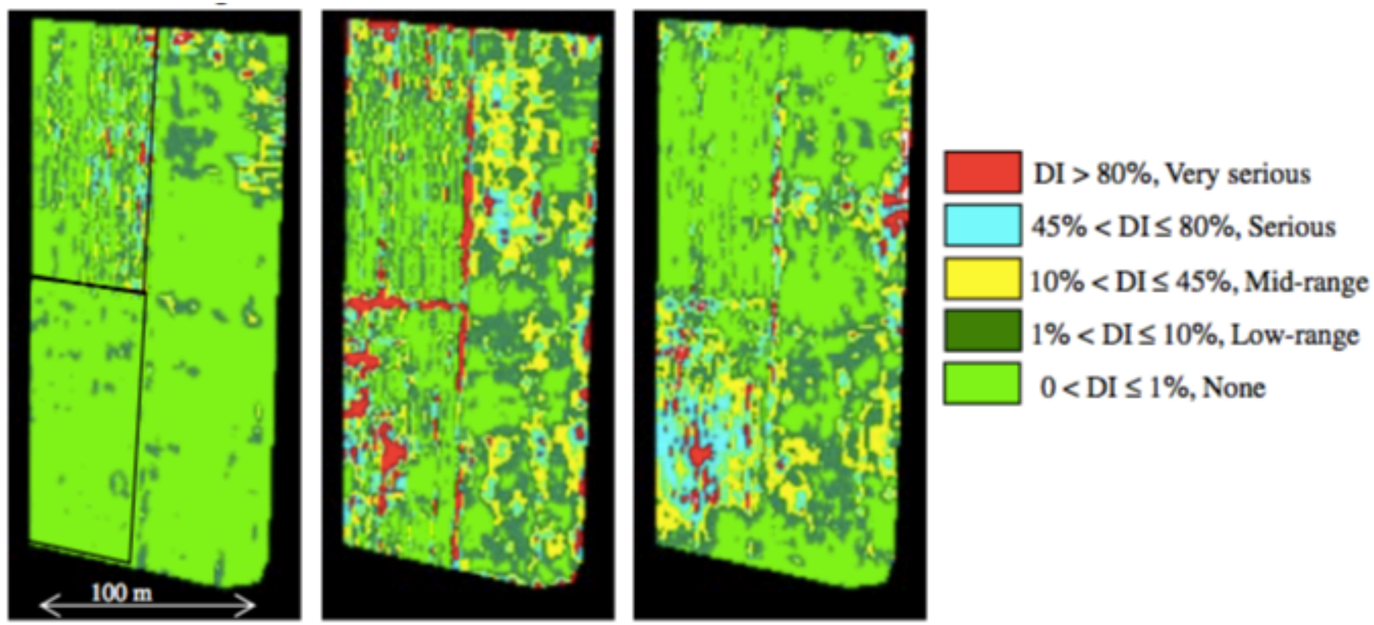
30 - 60%

60 - 100%

Methodology

Discriminant analysis of LM level

- Supervisioned ML
  - SVM (Singh et al. 2016)
  - PLS-DA (Chemura et al. 2017)
  - K-means (Kaur et al. 2016)



Estimated costs

Features	Price (R$)
Experiment installation	300.00
Camera acquisition	17,000.00
Imagery structure	200.00
TOTAL	**17,500.00**

SOC710

Commercial name	Chemical class	Dosage	Average Price	Price/ha
Actara (250WG)	Neonicotinoids	1kg/ ha	R$ 293/kg	R$293,00
Altacor	Anthranilic diamide	90g/ha	R$ 840/pct 450g	R$168,00
Sabre	Organophosphates	2L/ha	R$ 176/5L	R$70,4

Expected results

Current LM monitoring

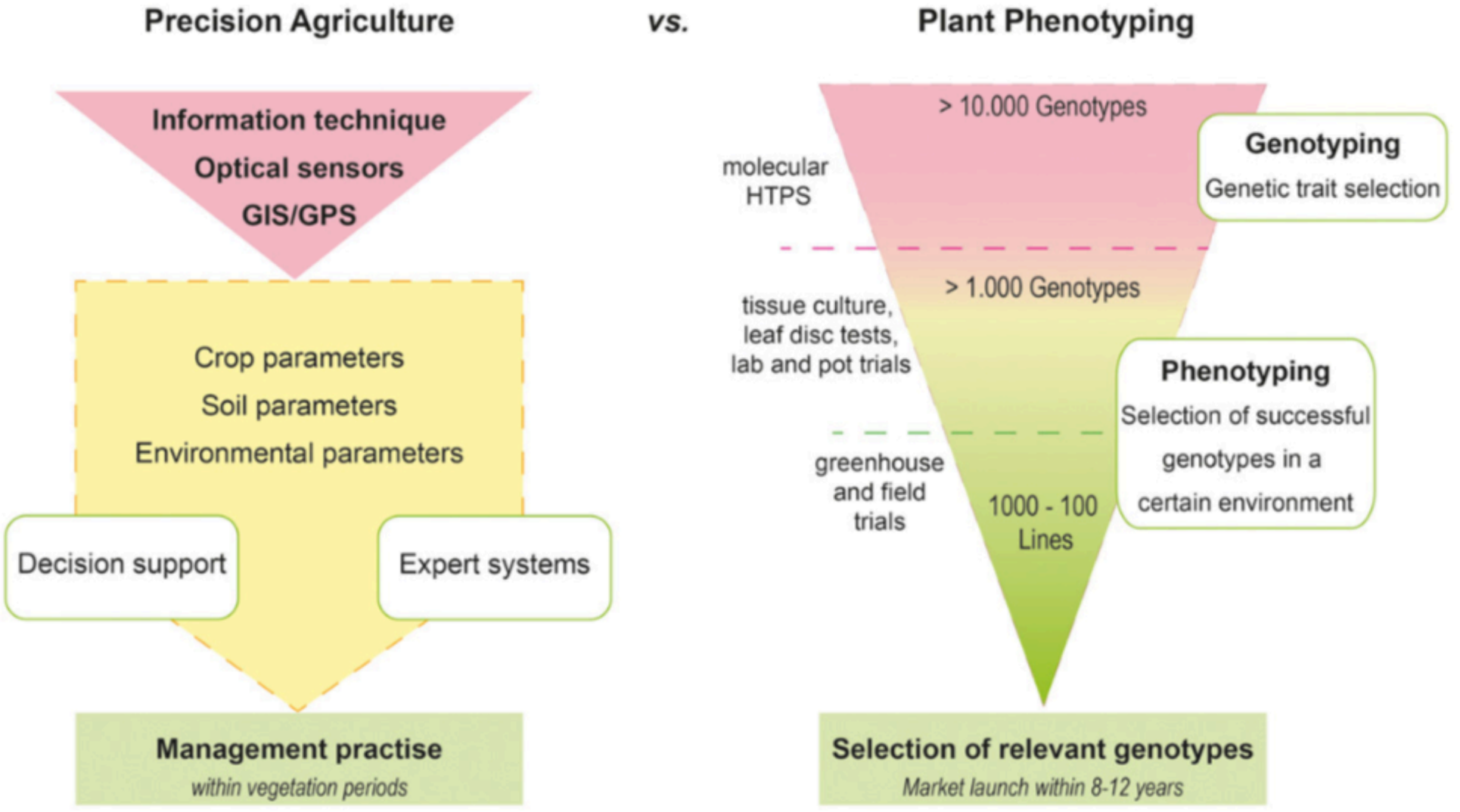
- Occasional field surveys
  - teams of specially trained and experienced personnel;
  - strenuous especially for large coffee plantations;
  - subjective.

Proposed LM monitoring

- Proximal/remote sensing
  - timely and spatially assessment of plant condition;
  - throughout the growing season;
  - non-invasive;
  - provision of accurate information.

Expected Results

- Hyperspectral techniques, alone and in combinations with sensor fusion approaches can highlight host-pathogen interactions at an **early stage**
- Management of the complexity of an identification and quantification of different kinds of stressors
- Decrease of yield loss by LM
- Sustainable impact
- **Potential to be extended to detecting and monitoring under field conditions**
- **Detection of resistant genotypes in due course (plus genomic data)**


Precision Agriculture
vs.
Plant Phenotyping
Information technique
Optical sensors
GIS/GPS
Crop parameters
Soil parameters
Environmental parameters
Decision support
Expert systems
Management practise
within vegetation periods
> 10.000 Genotypes
molecular
HTPS
Genotyping
Genetic trait selection
> 1.000 Genotypes
tissue culture,
leaf disc tests,
lab and pot trials
Phenotyping
Selection of successful
genotypes in a
certain environment
greenhouse
and field
trials
1000 - 100
Lines
Selection of relevant genotypes
Market launch within 8-12 years


THANK YOU!