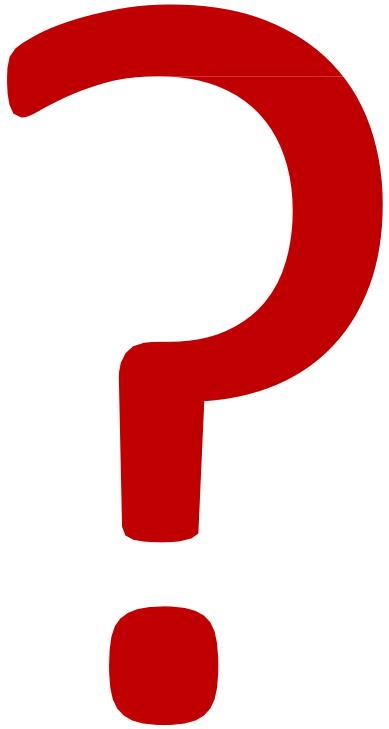
Absorbance, reflectance and transmittance for Ground-Based / Near Ground-Based

Sensing from satellites on different orbits, from an airplane and from a tractor (From Chuvieco and Huete 2010 and from Heege et al. 2008, altered)

Ground-Based / Near Ground-Based

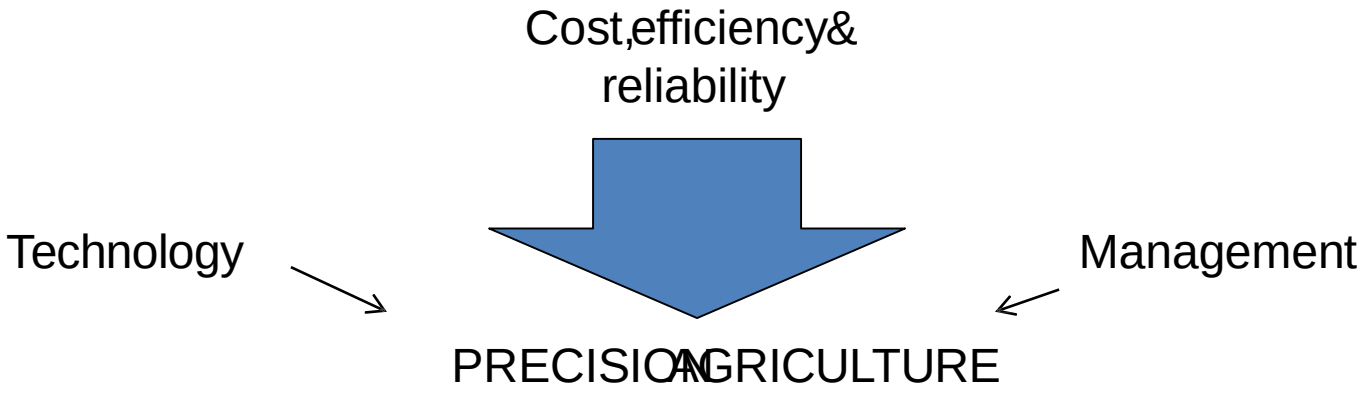
Why] šr[eeded



Ground-Based/ Near Ground-Based

Why] šrequeeded:

- Limitations of Aerial/Satellite/Airborne technologies for commercial use for individual farmer
- high cost of images from airborne,
- hilly hill in the plantation area,
- infrequency of satellite overpasses,
- risk of images being scattered by clouds
- delays between image capture and availability of usable data.
- trees shades



Precision Agriculture (Site-Specific Management) is not a "one-size-fits-all" proposition or universal solution to address spatial variability

- Different field sizes
- Different crops
- Different soils
- Uncertainty about climate and water availability
- Spatial variability in nutrient status
- Availability of field equipment is important
- Implementation might require technical assistance

High yields may not be highly correlated with profitability

Sustainability requires a multi-year analysis

Perceptions - may not be true, but they are in the minds of individuals

Precision Agriculture Perceptions

- I / [too old to learn
- Too expensive
- My fields are uniform
- I / [still farming, so my operation must be sustainable
- Too much risk
- I already demonstrate environmental stewardship
- Technical assistance is not available or is unreliable

Original4-Rs

Appliedat the field scale - - delineatesmanagementzones

RIGHT- Place

Rate

Time

Form

What about the plant environment?

Howto createa better environmentfor plants?

Consider: compaction
nutrient placement
plant competition
weeds

Approaches to Precision Agriculture

Proactive - Plan ahead and lock-in decisions

based on:
- soil texture and water holding capacity
- nutrient information
- anticipated weather
- yield goal

Reactive - Monitor weather and crop vigor to make in-season adjustments (also called "adaptive management")

according to:
- available soil water
- anticipated weather
- estimated nutrient losses thus far in the season
- crop vigor (sensors or remote sensing)
- changes in yield potential

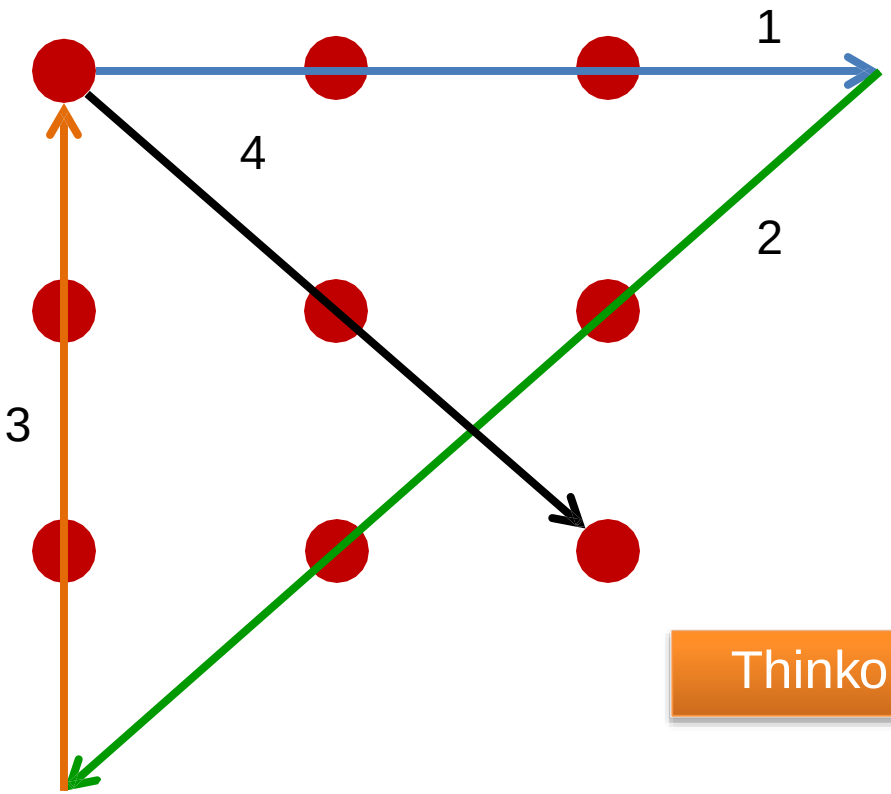
Harnessing Precision Agriculture information is like

making Som-Tam!

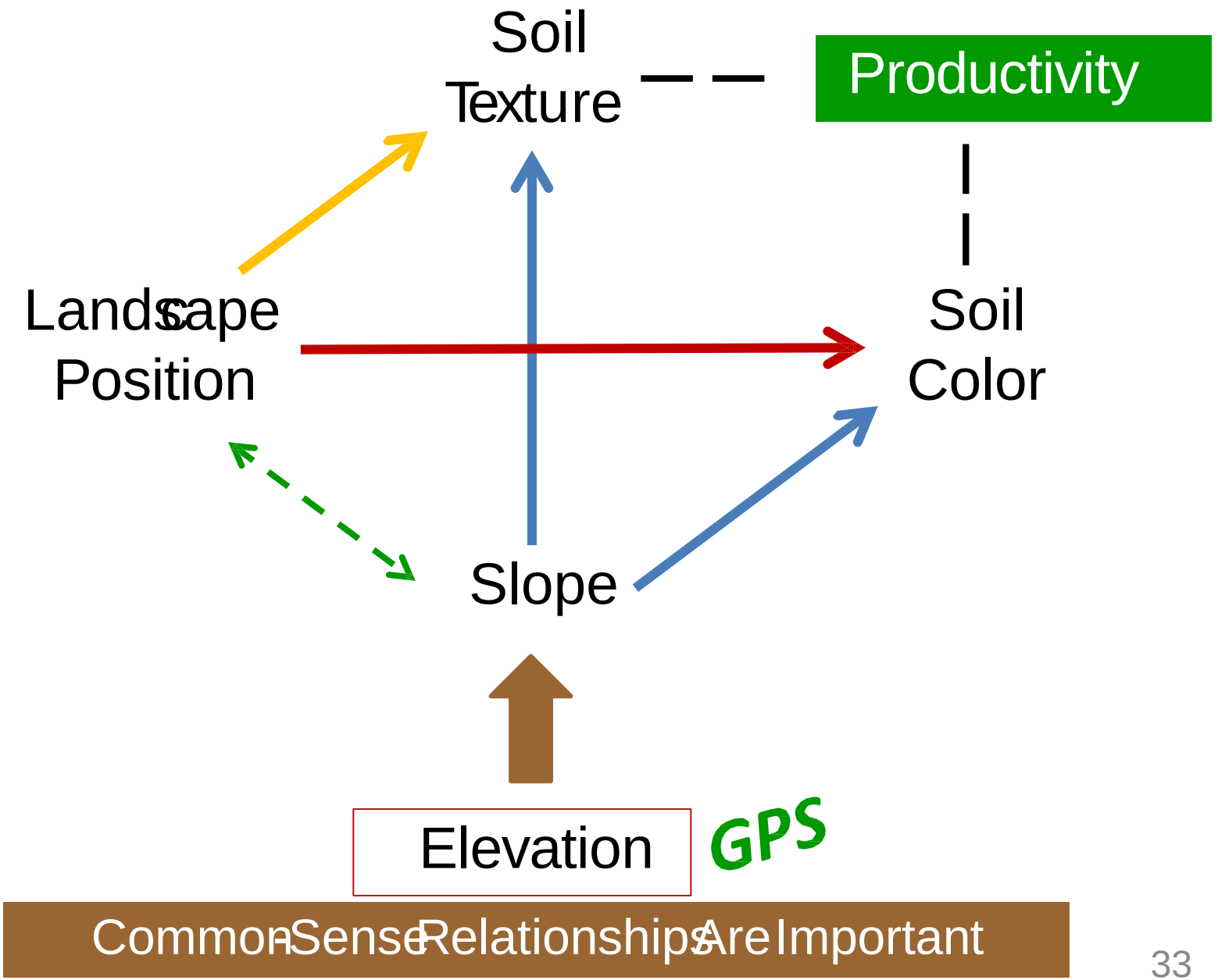
Needs multiple ingredients in the right proportions

Precision Agriculture is about innovation and thinking outside the box

How would you connect these nine points with four continuous lines?



Think outside the box!


Soil Texture
Productivity
Landscape Position
Soil Color
Slope
Elevation
GPS
Common-Sense Relationships Are Important

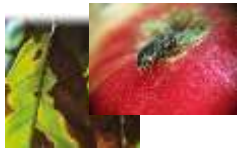
Uncertainty of climate

Water (rain),
Light Intensty

1

3

4



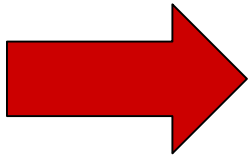
Pests& Diseases

Water
Shortage

No plants
management
Weeds

6

5

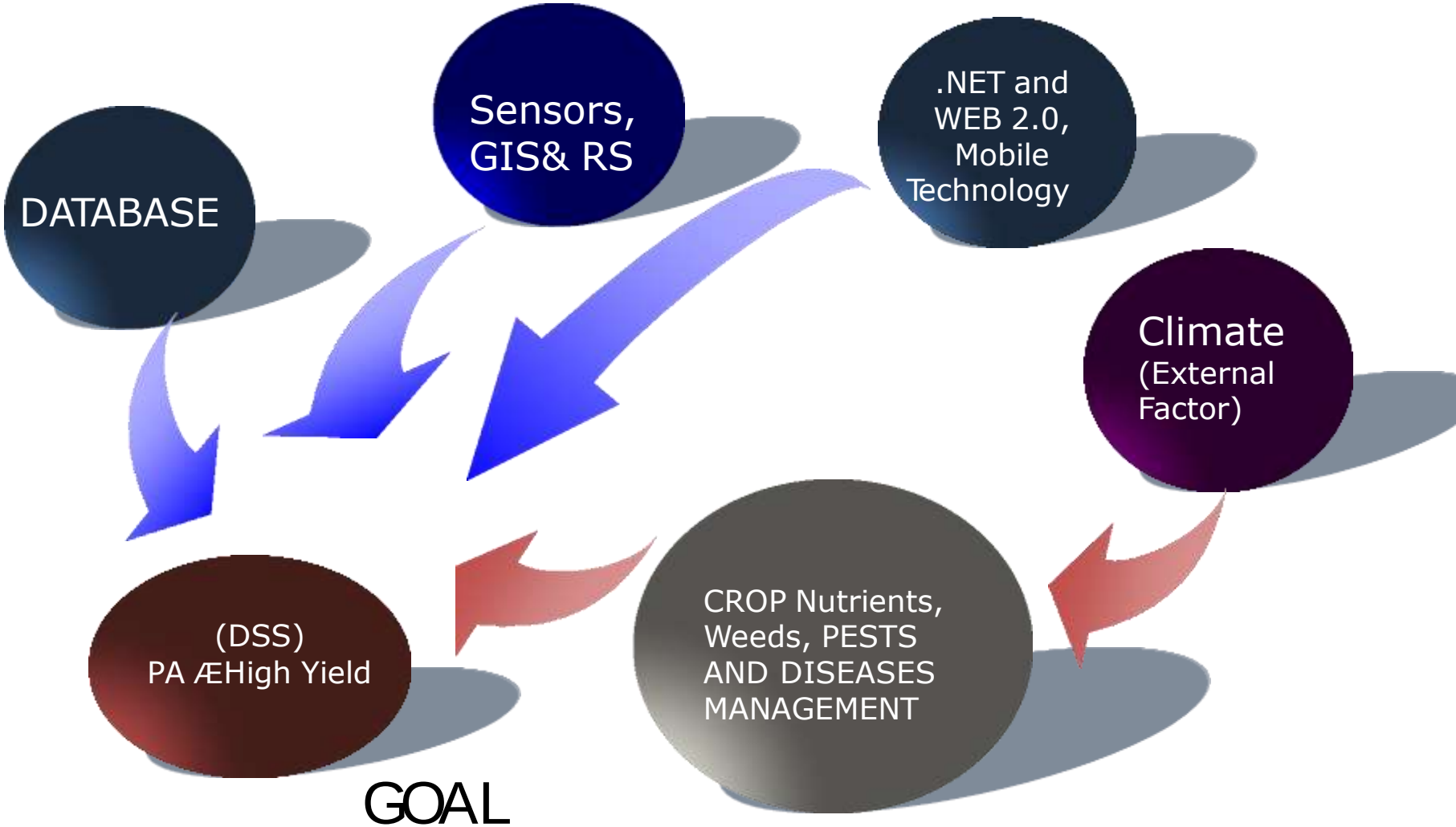


LowQuality&
Quantity
of Commodities

2

inappropriate
dosage

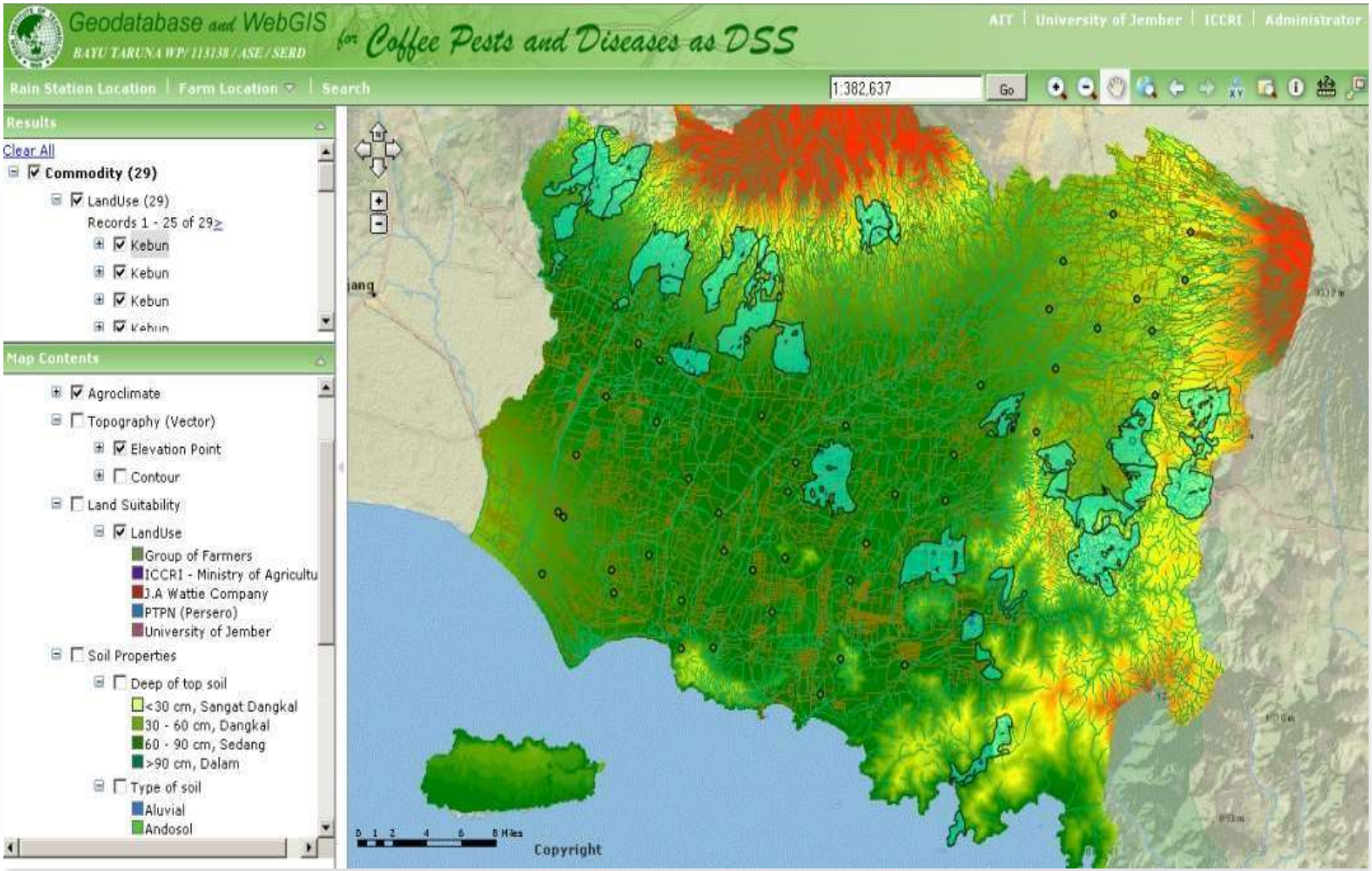
TechnologyUsed



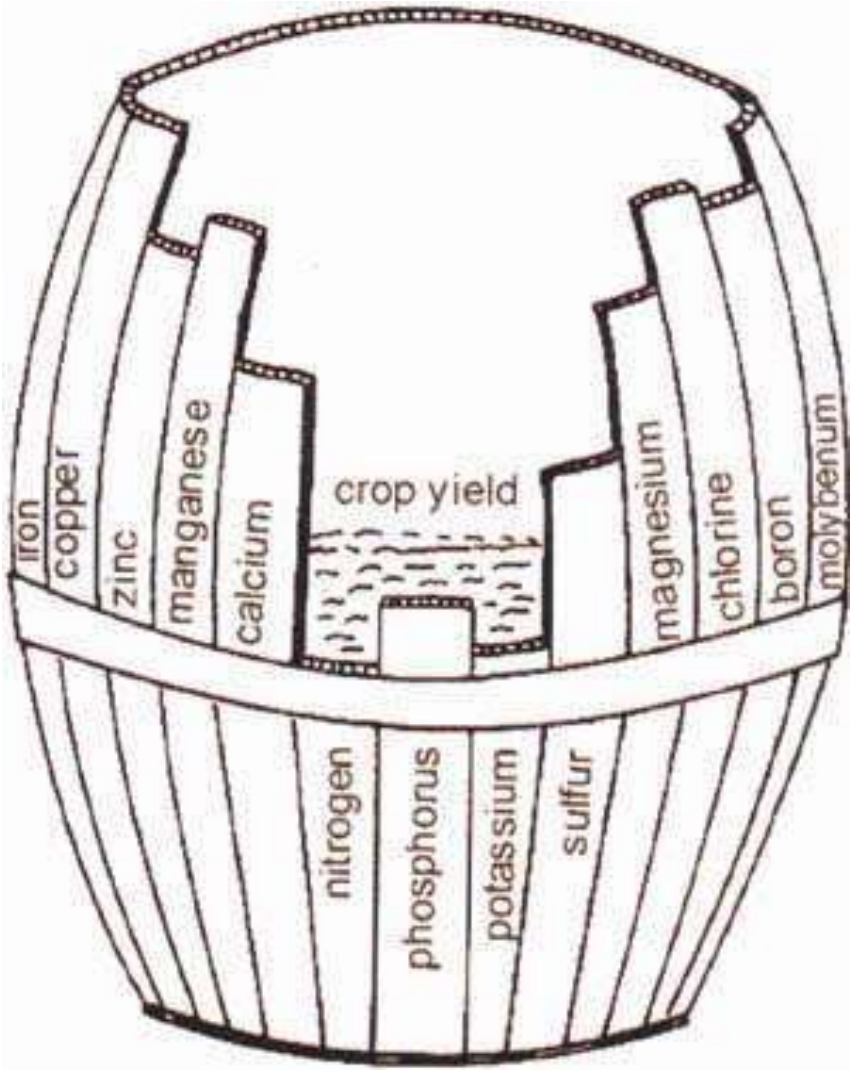
Advanced Technologies

- The growth of non-destructive technologies is very rapid
- Spectral vegetation indices are widely used for monitoring, analyzing, and mapping temporal and spatial variations in vegetation structure as well as certain biophysical parameters
- Such indices enable assessment and monitoring of biophysical properties like soils (Joseph, et al, 2010), pests and diseases and macronutrients (Joseph, et al, 2010; Schlemmer, et al. 2013).
- researchers used the technologies like CropSpec (Vali, et al. 2013), SPAD, Spectrometer (Yao, et al. 2014; Wang, et al. 2012; Min., et al. 2008; Wei., et al. 2012; Elfatih., et al. 2010; Javier, et al . 2014), GreenSeekers (Ali., et al 2015), CropCircle, and LAI meter to analyze the crop-plant in many different parameters.

Weeds, Pests & Diseases Management



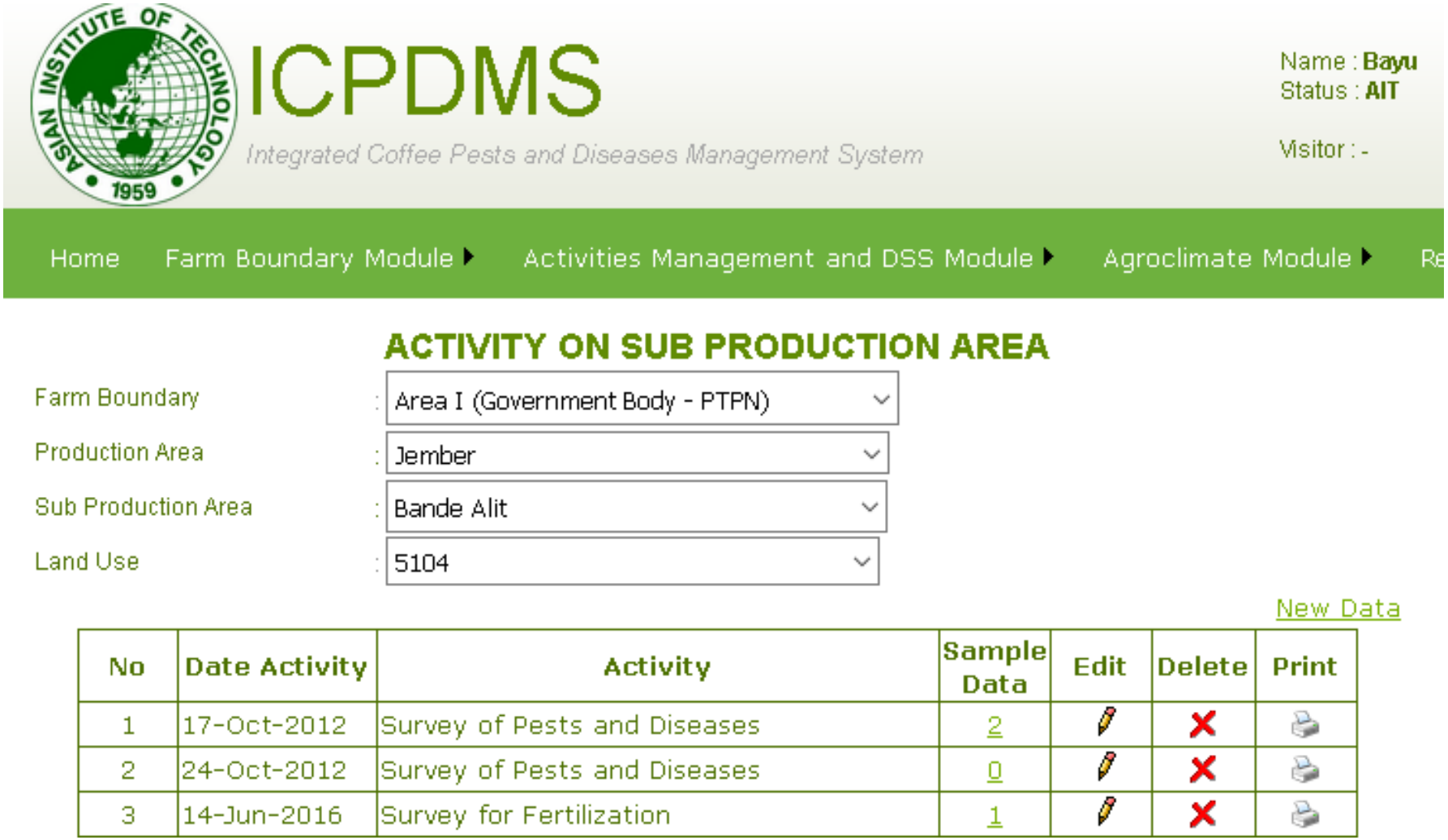
Nutrient Management



'Barrel Analogy' using nitrogen as the least available nutrient

N Nutrient Management

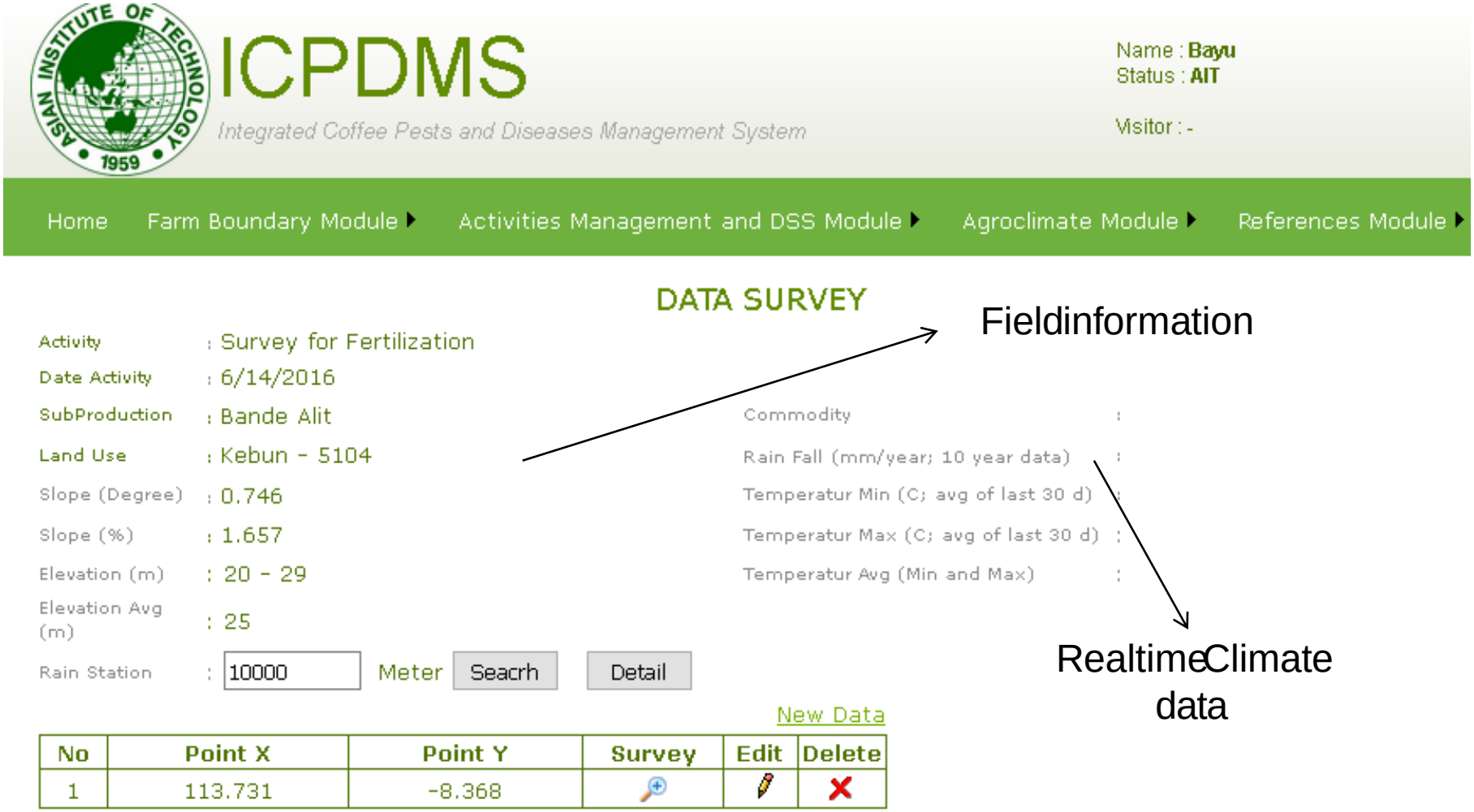
(Decidingthe location and activities)



No	Date Activity	Activity	Sample Data	Edit	Delete	Print
1	17-Oct-2012	Survey of Pests and Diseases	2			
2	24-Oct-2012	Survey of Pests and Diseases	0			
3	14-Jun-2016	Survey for Fertilization	1			

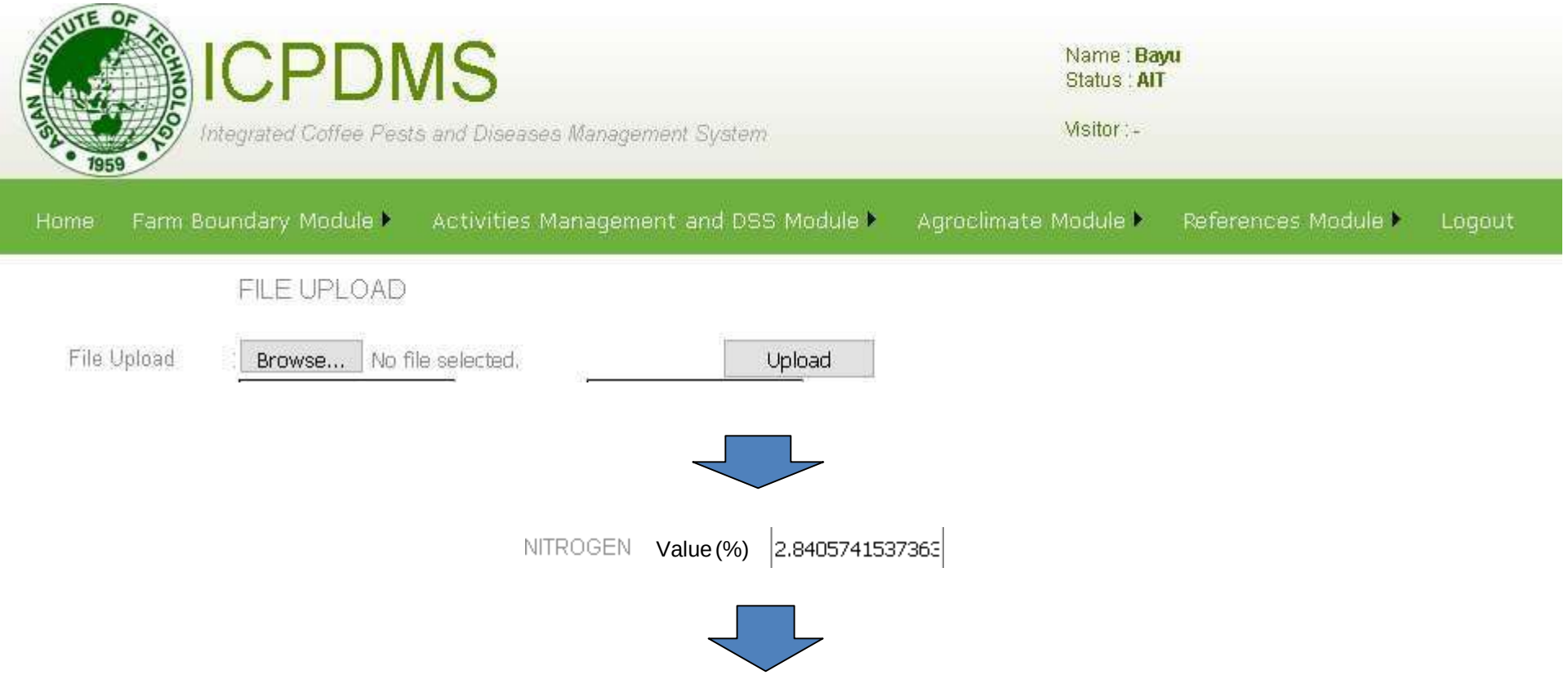
N Nutrient Management

(Input Plantposition inside fieldarea)



N Nutrient Management

(Image analysis and DSS via Online)



Nitrogen Recommendation for individual Coffee Plant

Source: Bay (2016)

SENSORS

INTRODUCTION (*Background*)

Active Nitrogen Sensor (CropSpec)

GNSS

CropSpec Algorithm:

S1= 100* (R t 1)

Where

R= NIR/RedEdge

Compared to

NDVI= (R- 1) / (R+ 1)

$$S1\ \text{value ratio} = \frac{S1\ \text{value of an interest area}}{S1\ \text{value of the nitrogen strip}}$$

S1CAL= 47 * S1/ S1REF

S1 Left
cropspec

RedEdge

NIR

S1 Average

R is simple ratio of NIR reflectance (800-810 nm) to RedEdge (730-740nm)

Active Nitrogen Sensors

Specifications	GreenSeeker®	CropCircle®	CropSpec®
Manufacturer	N Tech Indus. Inc.	Holland Scientific	Topcon
Model	RT200	ACS-470	IP67
Datalogger	RT Commander	GeoSCOUT GLS-400	X20
Light Source	LED	Modulated polychromatic LED array	Lasers
Power	12 VDC	10 to 17 VDC	10-32 VDC
Operational Wavebands	660/15 (Red) and 770/15 (NIR)	670/20 (Red) and 760/LWP (NIR)	730/10 nm (Red) and 800/10 nm (NIR)
Footprint/ Field of view	5 × 60 cm	15 × 57 cm (changes with height)	2-3 meters
Viewing angle	32 °	32/6 °	45-55 °
Operating Height	0.86 meters	0.6-1.2 meters	2-4 meters
Mount	Handheld or Sprayer boom	Handheld or Sprayer boom	Tractor cab

Source McVeagh et al. (2012).

Crop Circle ACS-430

or

AgLeader OptRx

Functions Day or Night

Variable-Rate N Injection

Topcon

HollandScientific

(AgLeader)

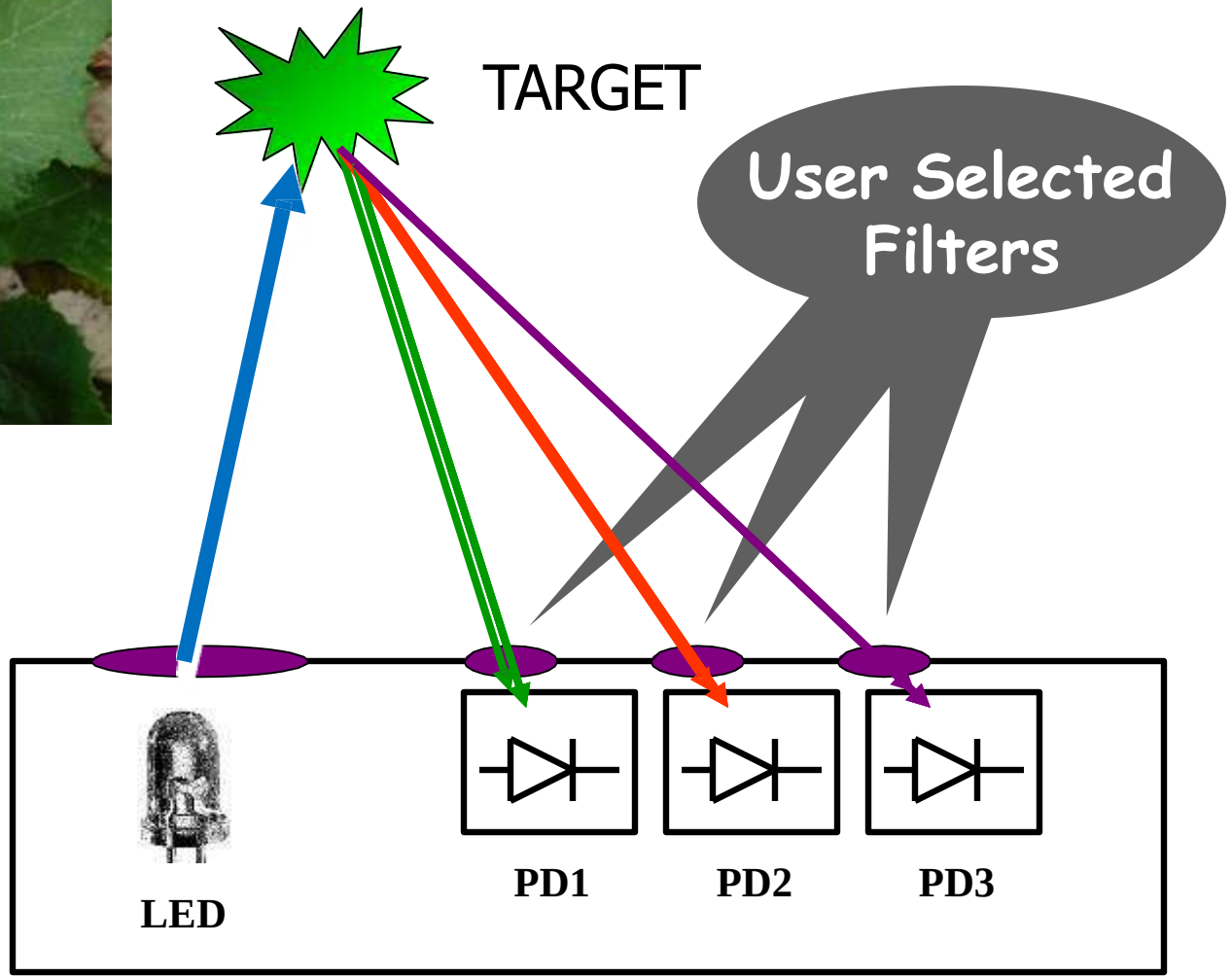
NTechIndustries

(Trimble)

Foot-print changes with plant height

Modulation/Demodulation Using Polychromatic LEDs

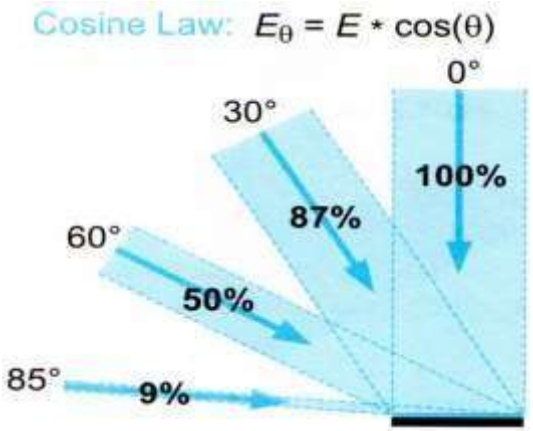
ACS-470



Spectrometer

Mini spectrometer and its components (a. spectrometer; b. light source; c. cosine adapter ; d. fiber probe)

we tested ASEQINSTRUMENTmini spectrometerwhich can provide spectraldata within the rangeof 300-1000nm (~USD1,500)



LIGHTMEASUREMENT(COSINEADAPTER)

REFLECTANCEMEASUREMENT

$$\%\ R\ (sample) = \frac{D(sample) - D\ (dark)}{D\ (Spectralon) - D\ (dark)} * 100$$

Leafchlorophyllmeters(SPAD)

it is exposedto two light sources:(1) ared- (640nm) and(2) an infrared light (940nm) positionedjust abovethe leaf

Cameras as Passive Sensors

Traditional CCD and CMOS sensors

- CCD – Charge Coupled Device
- CMOS – Complimentary Metal Oxide Semiconductor

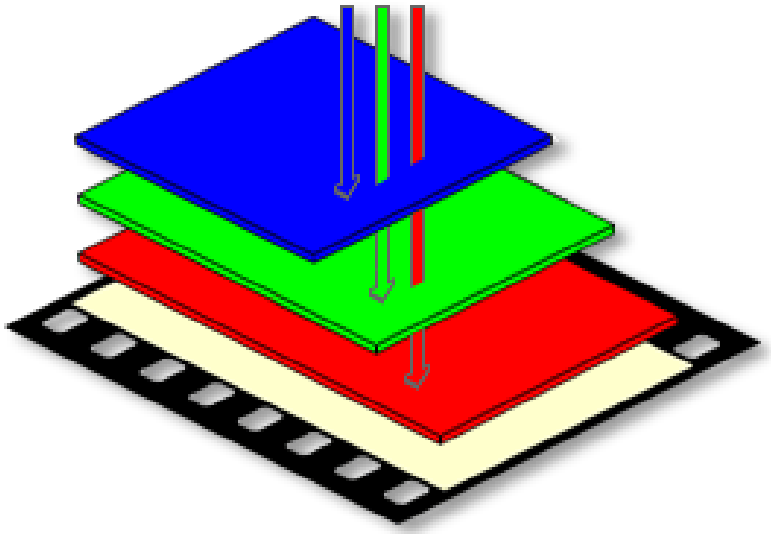
- CMOS sensors offer higher performance capabilities, and are commonly found in ultra-high frame rate videography
- CCDs are more common in consumer camera applications due to lower cost of development

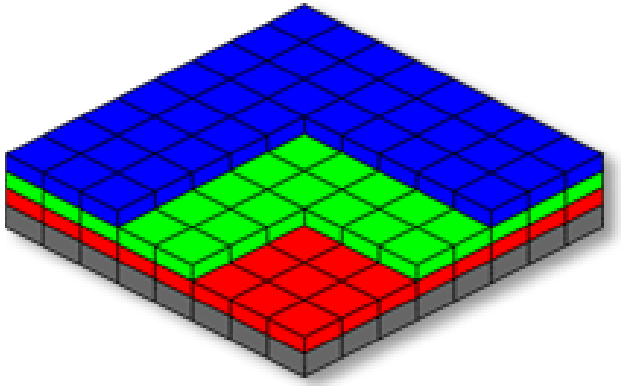
CCD vs. CMOS

	CCD	CMOS
Signal from Pixel	Electron packet	voltage
Relative R&D cost	Low	High
Cost to Manufacture	Higher	Lower
Dynamic range	High	Moderate
Speed	Moderately fast	Very fast
Relative power consumption	Moderate	Very low

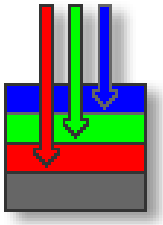
Traditional Film and Foveon Sensors

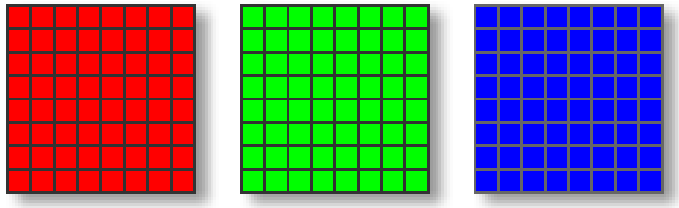
35 mm Color Film



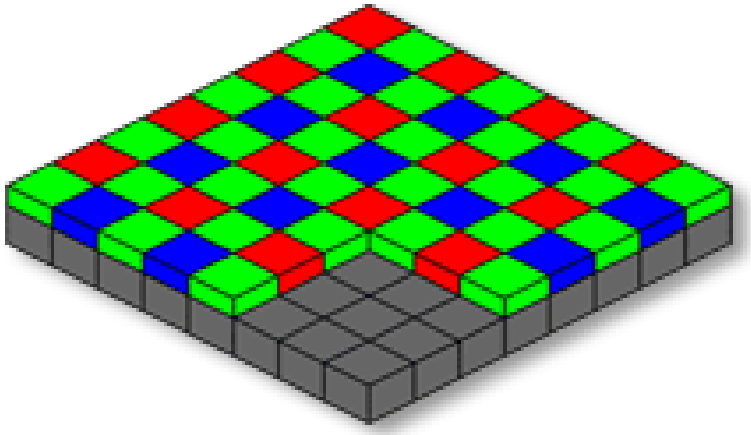


Foveon Sensor

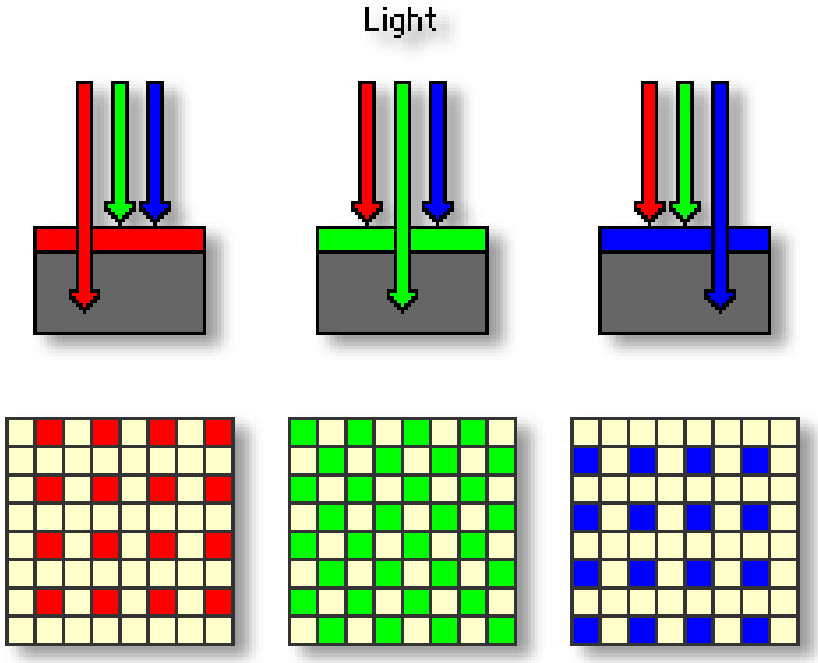




The Bayer Array Sensor

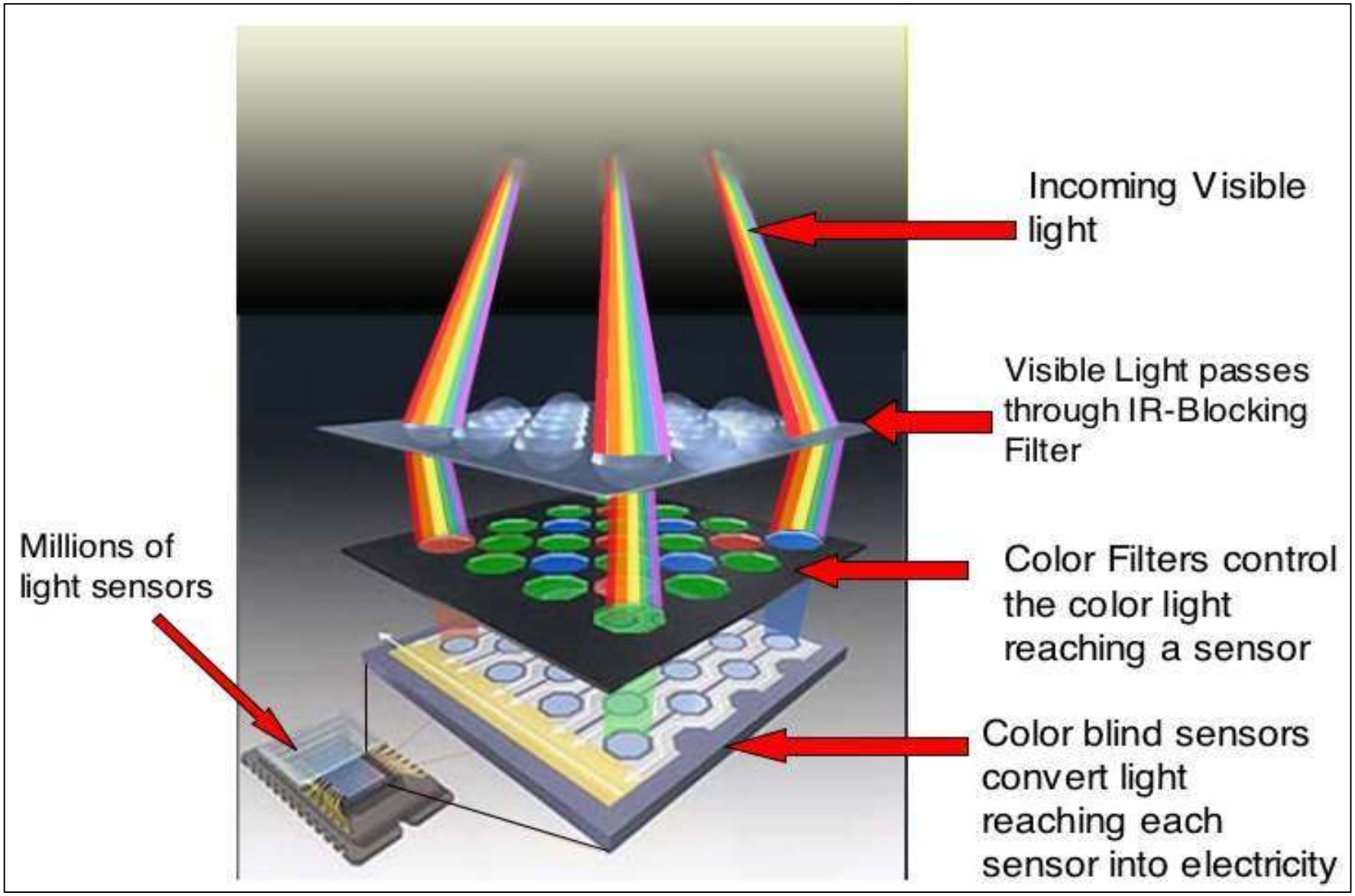


Color Filter Array Sensor



- Extrapolates color data from adjacent pixels
- Cannot reproduce colors to extreme accuracy without moving a camera to three positions
- Less expensive to produce than Foveon sensors

Working of an RGB CCD sensor



So, how do they produce images?

- Photons strike the sensor, and are converted into electrical charges
- Charges of pixels are read
  - CCDs transport the charge across the chip to be read at one corner of the array
  - CMOS sensors can read charge at each individual pixel.
- Analog-to-digital conversion of voltages to digital values

- Most consumer cameras utilize 8-bit pixels
  - ± ^] š ‰ šrefers to a • v • } sensitivity to grey scale depth.
  - 8 bits per pixel, 3 channels (RGB), $2^8 = 256$ discrete colors

What does it mean?

- This information is sent to a post-processing system, which continues to process incoming data.
- Post-processing uses numerous algorithms to de-mosaic, reduce image noise, and enhance edges.
- Images are compressed and saved into their respective format on a hard disk.

CAMERAS AND TOOLS

Footprint 20x20cm

Modified Camera
(Removed the Hot Mirror)

Nikon D70 with Internal Filter RG665

External Filter

Gray Card: 18% Reflectance

Prodisk II & 24 Colors card

JPEG & Pre-processing WB

RGB Standard
(Unmodified)

ASUS ZENFONE 5

5 Bands
RGB, Red Edge and NIR

CAMERAÆANDIRFILTER

Modified Camera;
Footprint 20x20cm

THB3000

Unmodified Camera (canon IXUS 160)

THB3000

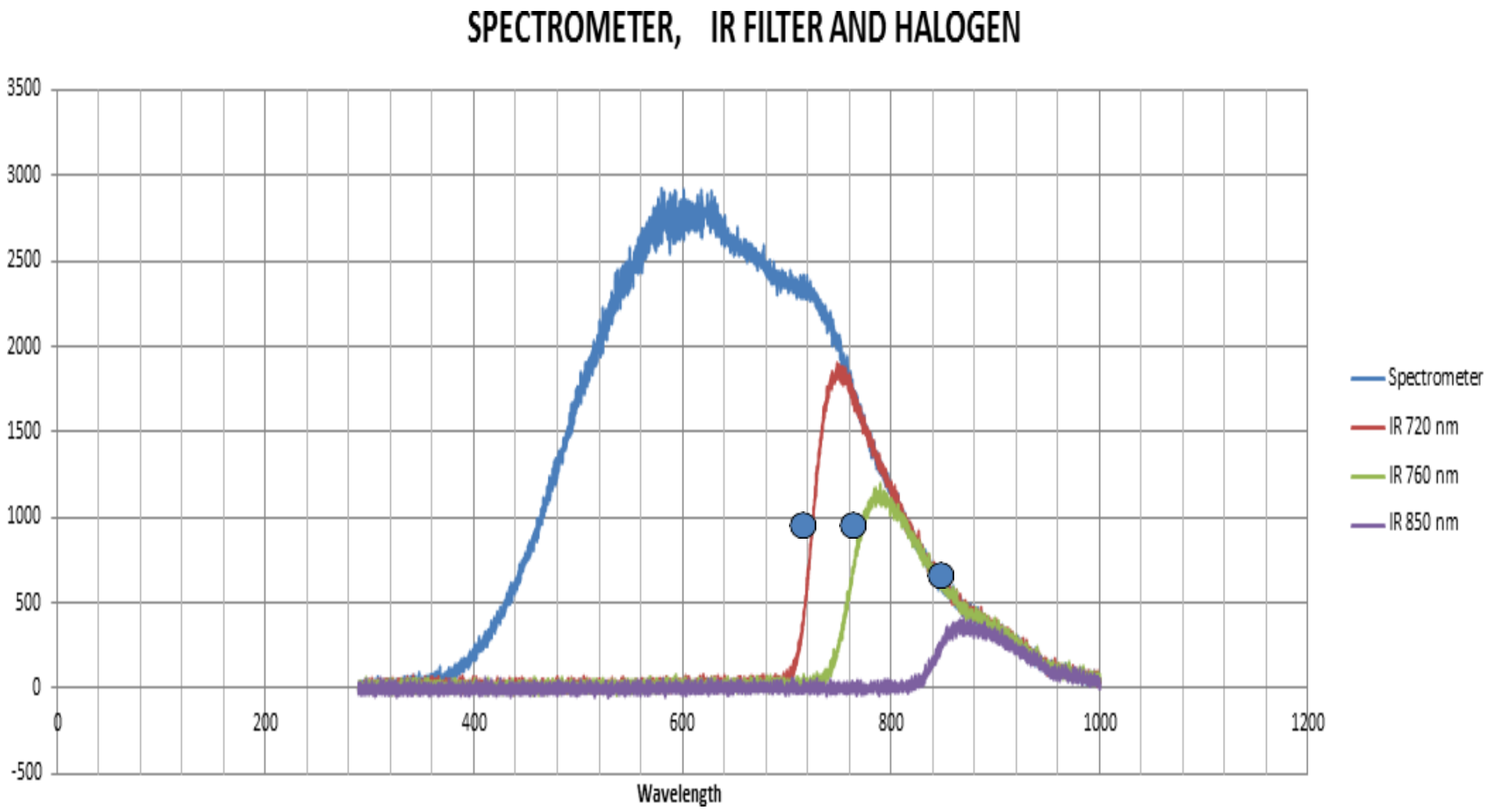
ASUS ZENFONE 5

Nikon D70 with Internal Filter 590 long pass (life pixel)

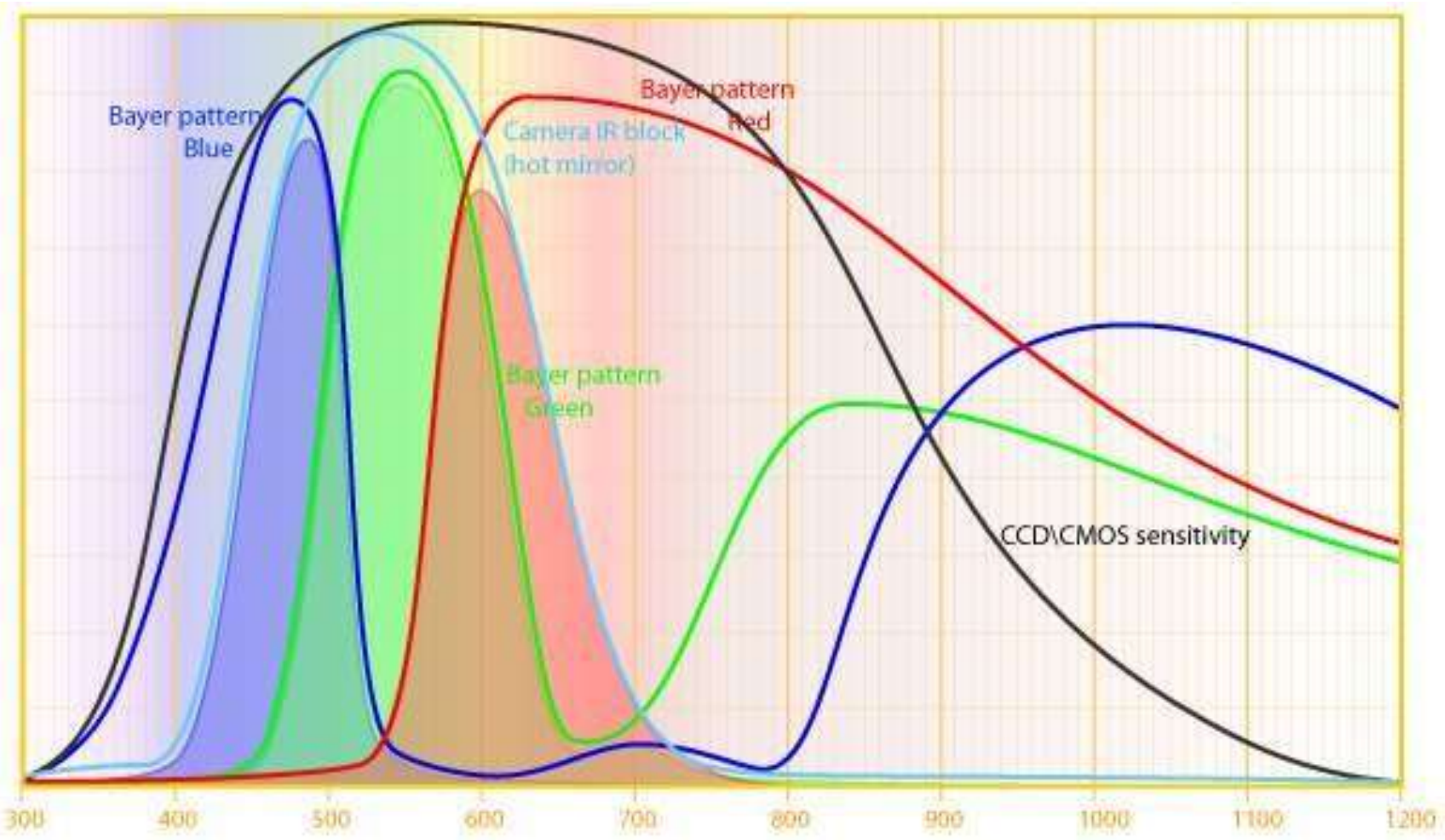
External Filter

- ZOME (680nm, 720nm, 760nm and 850nm) ÆCHINA (THB3000)
- SCHOOTT RG665 ÆUSA (USD80)
- Dual band Pass Filter (715nm and 815nm) ÆUSA (USD140)
- Red transparent paper (plastic) ÆBook Store AIT (USD0.15/ THB5)
- Roll Film (negative)

IRFILTER(Zomei720,760,850)

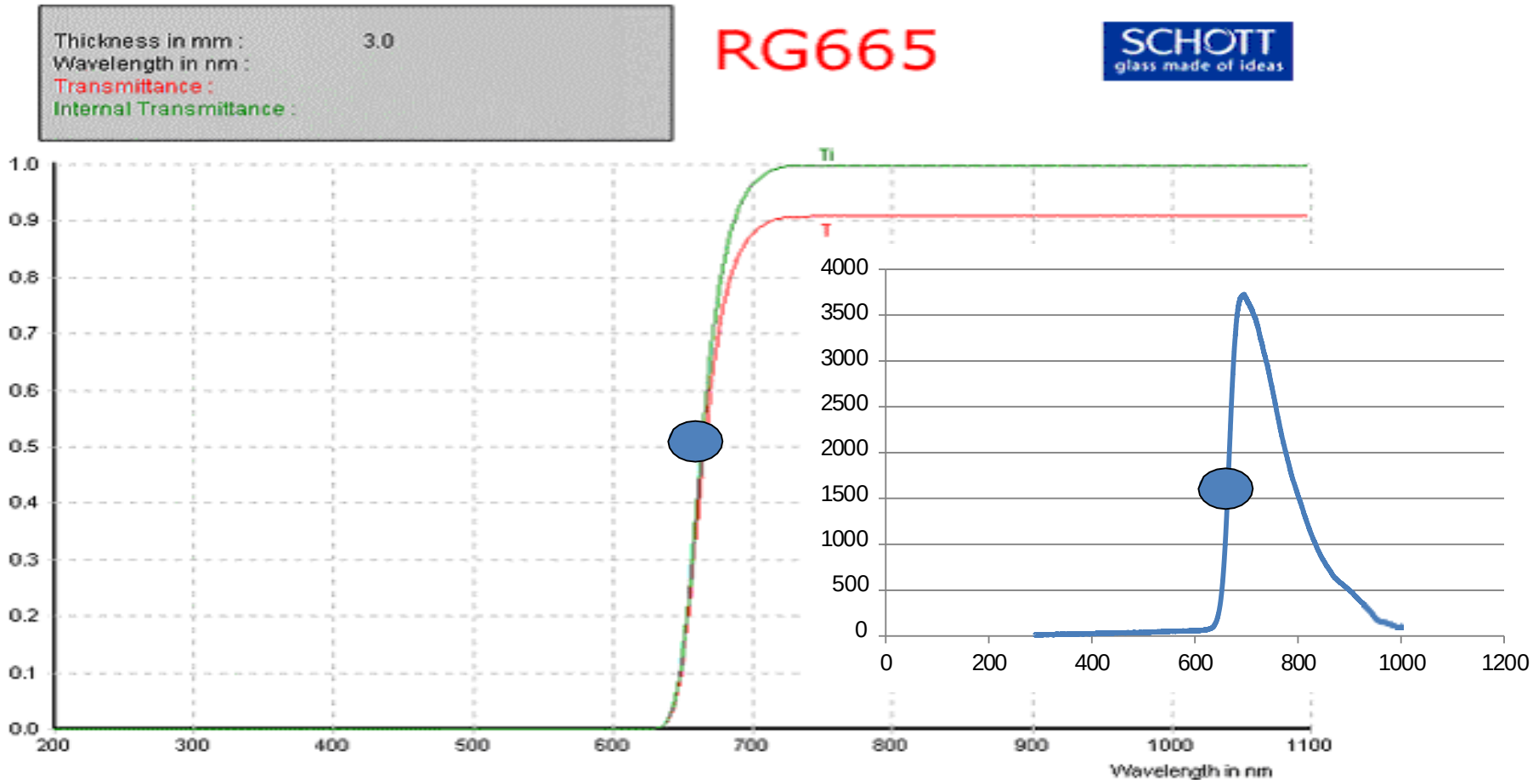


CCD SENSOR

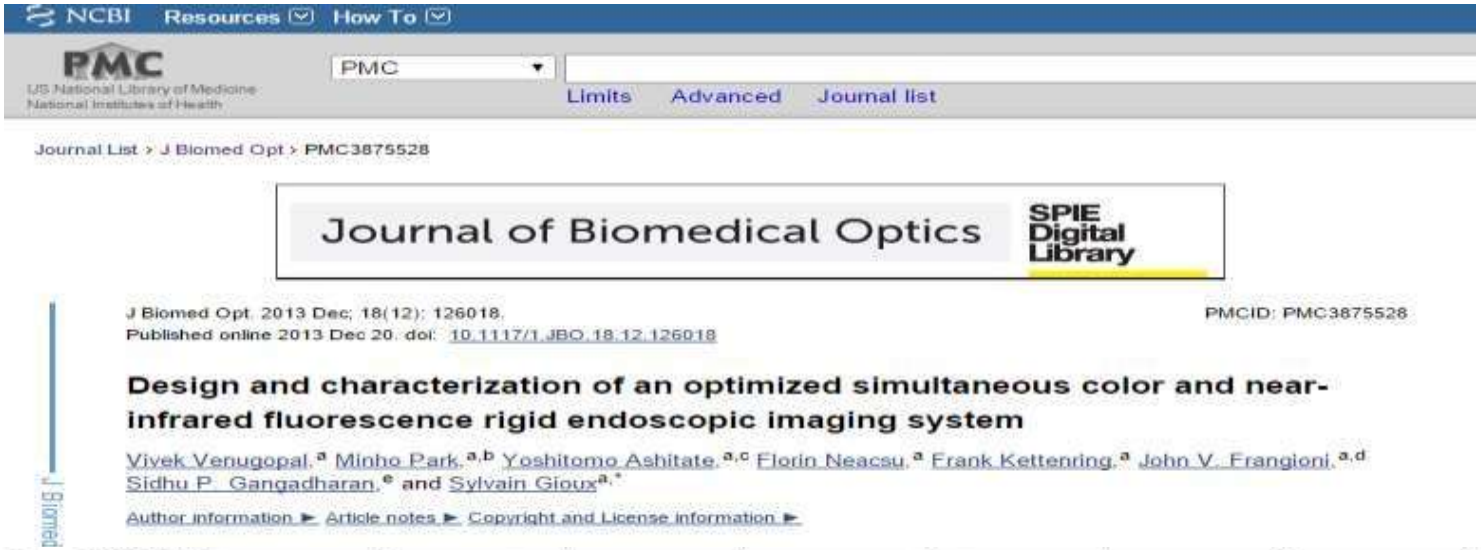


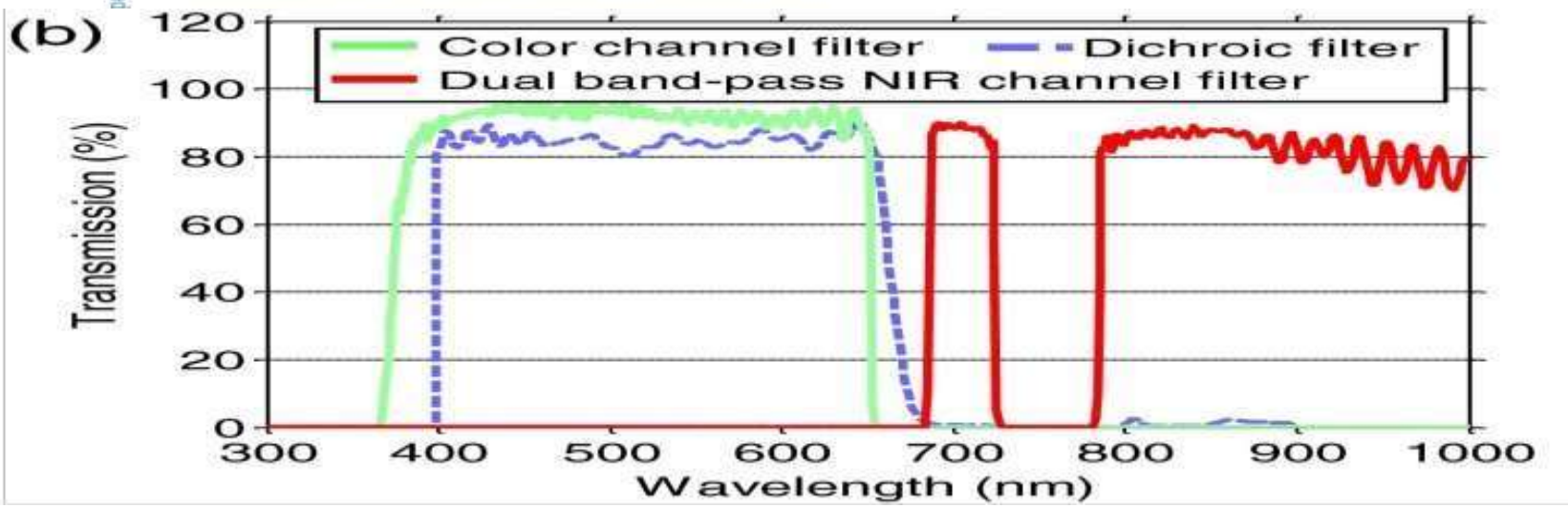
(Nijland,2012)

IRFILTER(SCHOTTRG665)

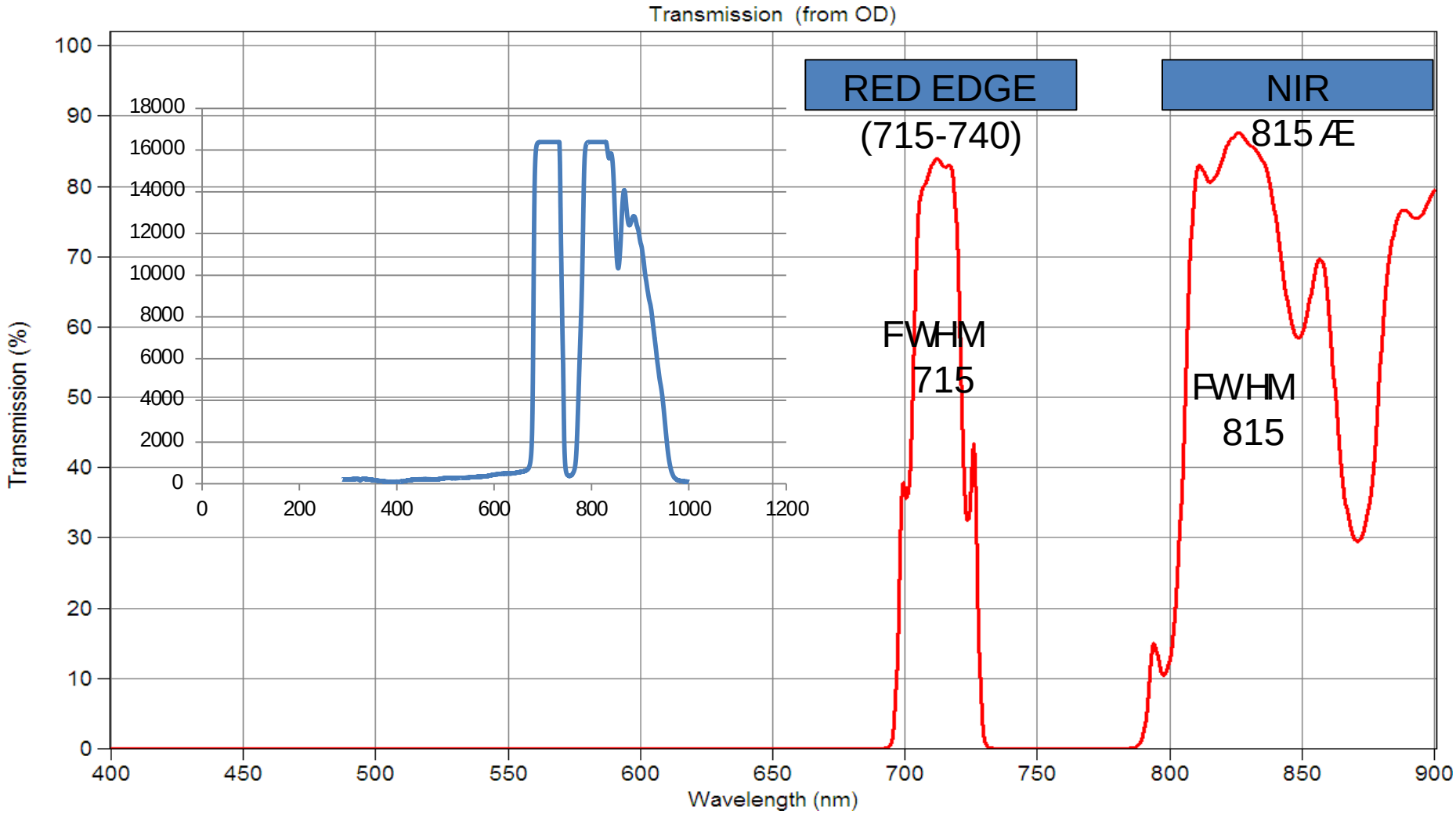


IR FILTER (DUAL NIR BANDPASS FILTER) Microscope (25,4mm)

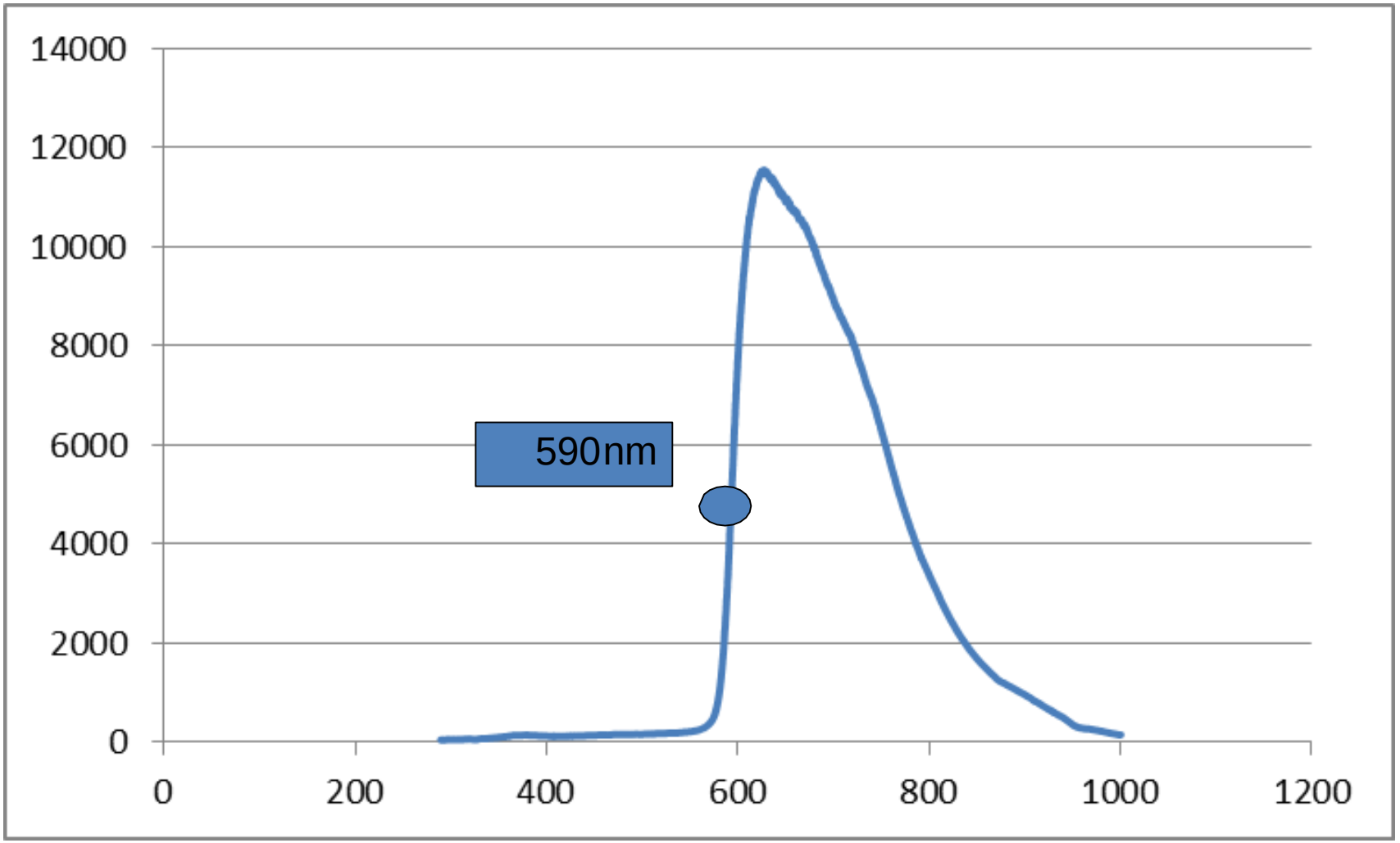




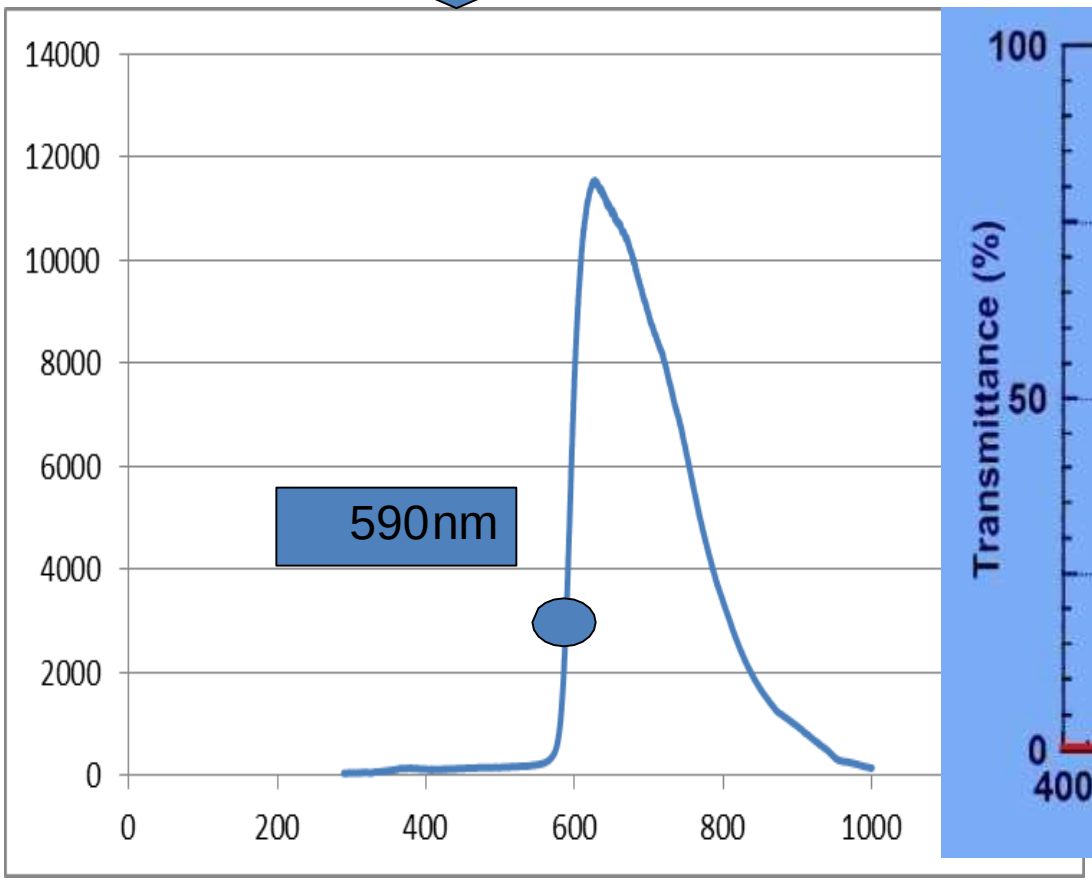
IRFILTER(DUALNIRBANDPASSFILTER)ÆMicroscope(25,4mm)

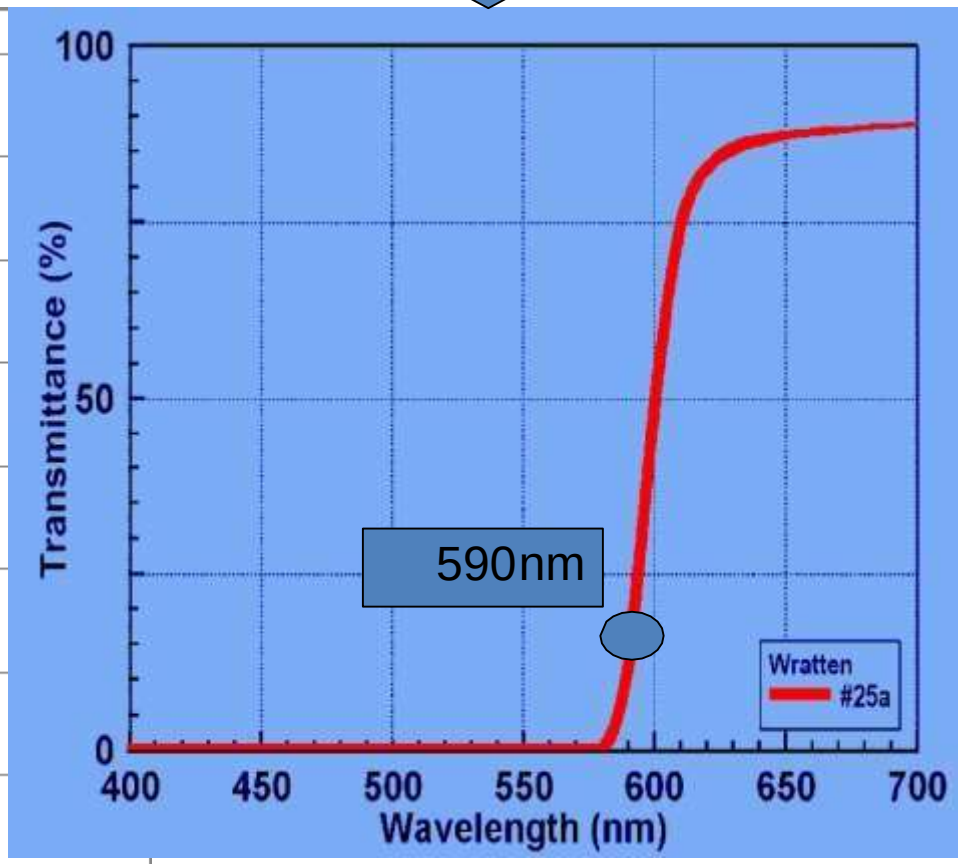


RED TRANSPARENT PAPER (PLASTIC) BOOKSTORE



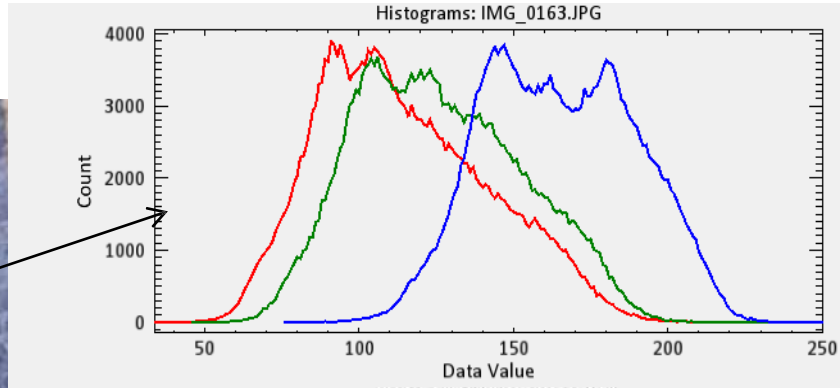
RED TRANSPARENT PAPER V.S LIFEPIXEL 590nm USA (USD 230)/Wratten 25a

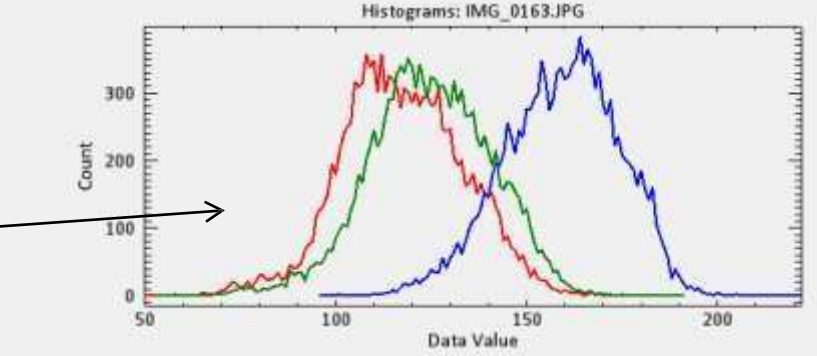


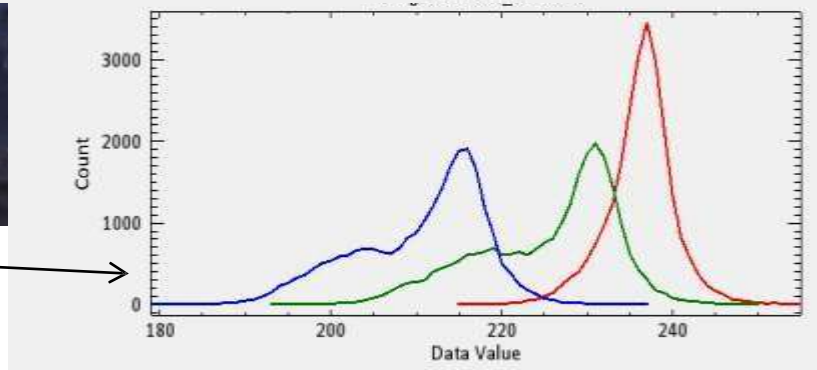


Source: astronomy.activeboard.com (2012)

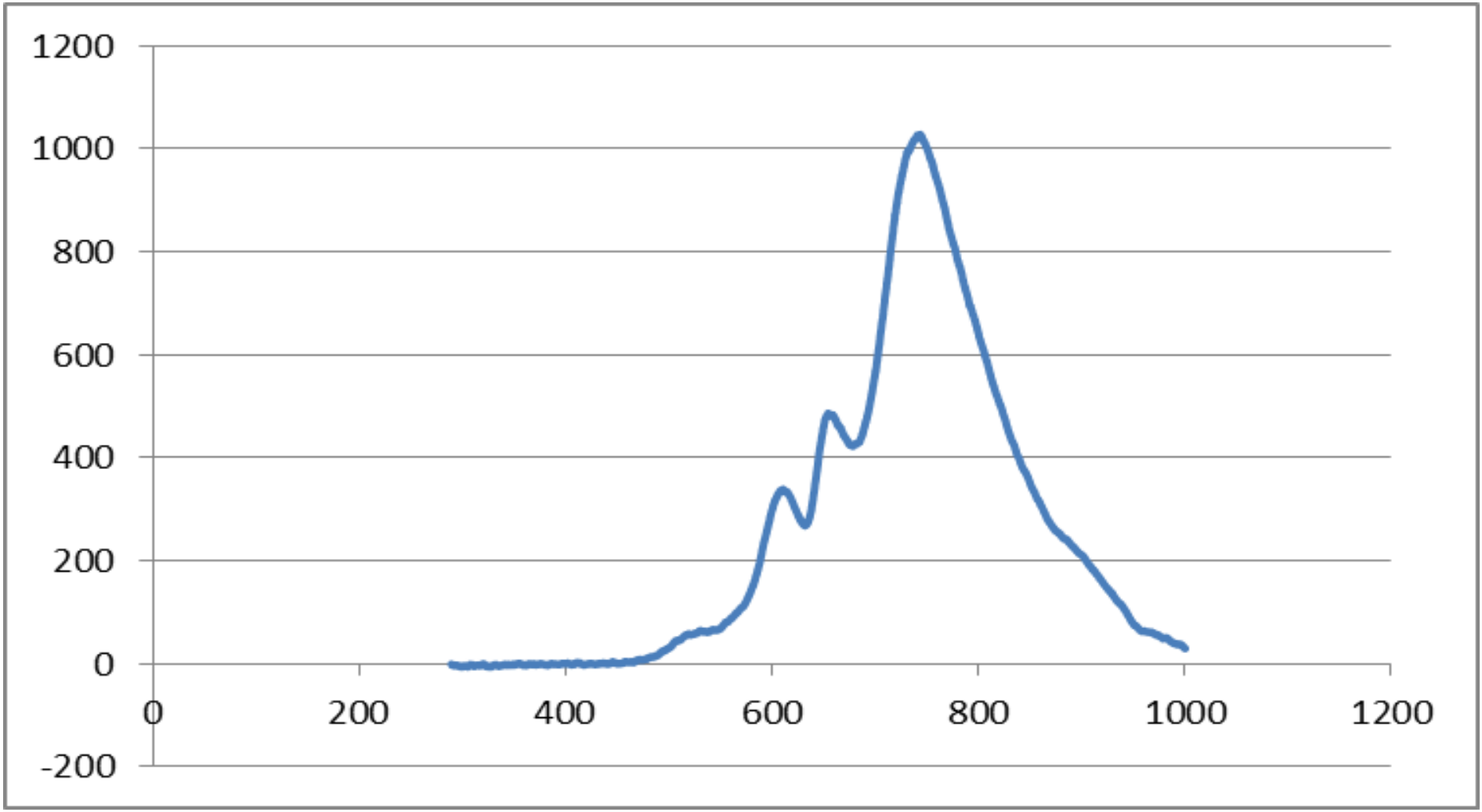
REDTRANSPARENTPAPER



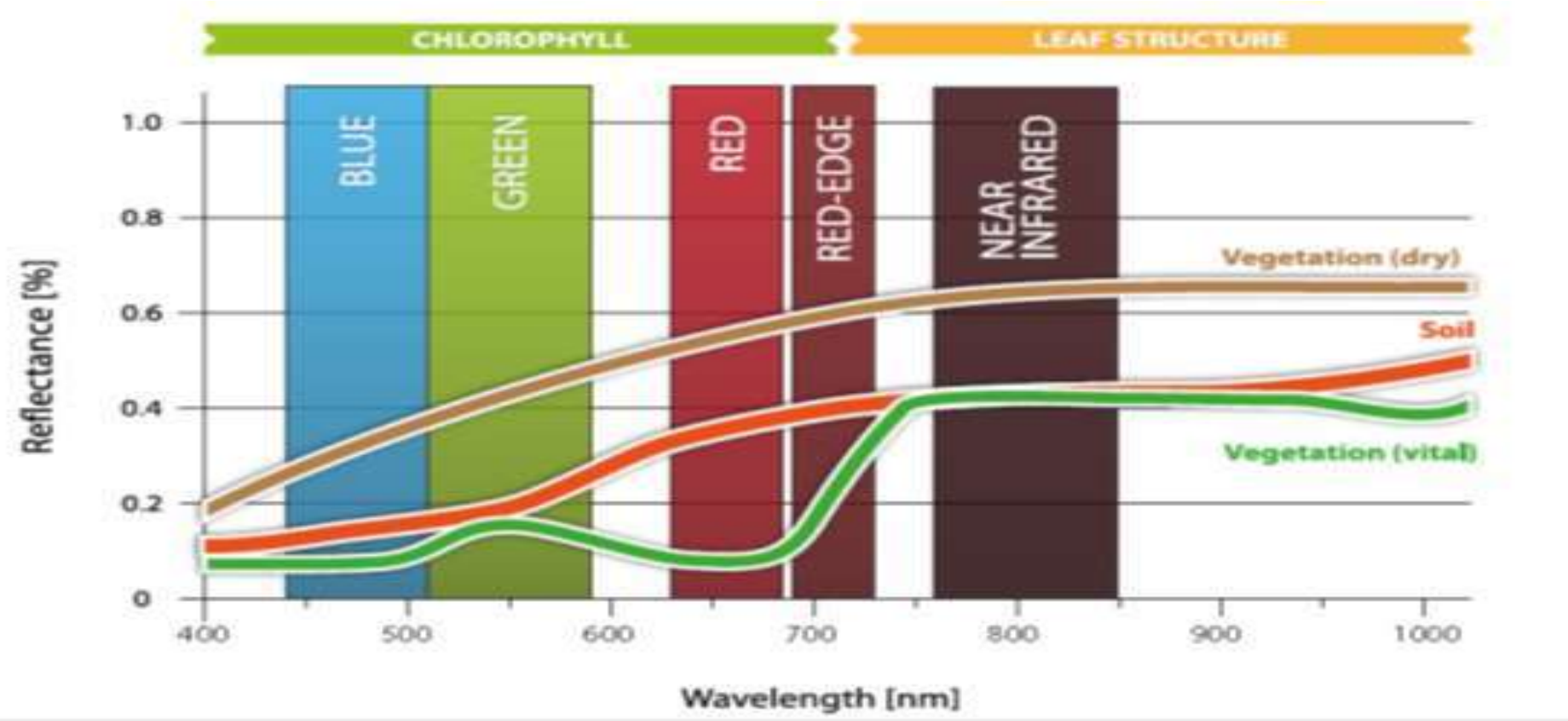




ROLL FILM (NEGATIVE FILM)



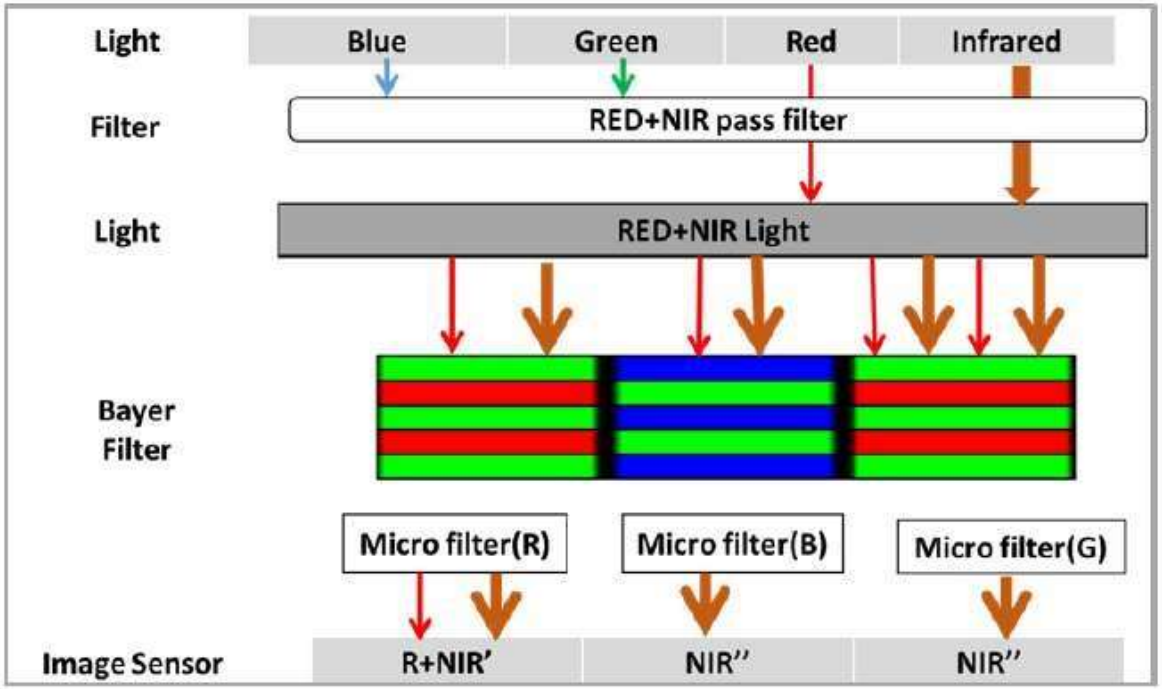
Spectrum



Image(camera)
Reflectance

$$\mathbf{R}(\boldsymbol{Image}) = \frac{\mathbf{DN}\ (\boldsymbol{Image}) \ * \ \mathbf{R}\ (\boldsymbol{Gray\ Card})}{\mathbf{DN}\ (\boldsymbol{Gray\ Card})}$$

Camera(Modified camera Æ singleChipfilter)



(Poudel et al., 2013)

$$NDVI = \frac{NIR - R}{NIR + R} \rightarrow NDVI_{CMOS} = \frac{(B+G) - R}{R}$$

(Dworak., et al, 2013)

$$eNDVI_{CMOS} = \frac{(B+G) - R}{R} \cdot \left\{\frac{B+G}{2}\right\}$$

(Dworak., et al, 2013)

LIGHT SOURCE
HALOGEN 12V 50W

NIR CAMERA & PAPER FILTER (Longpass filter 590nm) ISO 200

NIR CAMERA & DUALBAND PASS FILTER OMEGAOPTICS (720 & 815nm) ISO 100

NIR CAMERA & PAPER FILTER (Longpass filter SCHOTT 665nm) ISO 200

RGB CAMERA & AUTO ISO

NIR CAMERA & PAPER FILTER (Longpass filter 590nm) ISO 200

NIR CAMERA & DUALBAND PASS FILTER OMEGAOPTICS(715 & 815nm) ISO 100

NIR CAMERA & PAPER FILTER (Longpass filter SCHOTT 665nm) ISO 200

RGB CAMERA & AUTO ISO

Potentialuseof the CAMERA

Chlorophyll ÆColor (NIR/ RGB)
Nitrogen ÆColor (NIR/ RGB)
Phosporus ÆColor & Size (NIR/RGB)
Potasium ÆColor& Size(NIR/RGB)
Water Stress ÆColor (NIR/ RGB)
Pests and Diseases ÆColor& Shape(NIR/ RGB)
Sulphur ÆColor(NIR/ RGB)
Zn, Fe ÆSize
PAR, LAI

CANOPY MEASUREMENT

Crop canopy sensor research was initiated in 1993

Situation: Chlorophyll meters worked well for research purposes, but are not practical for commercial fields

Therefore: Need for mobile devices to provide information related to crop biomass (size of the factory) and canopy chlorophyll content (photosynthesis)

Introduced in 1990

First crop canopy sensors used natural lighting (known as passive sensors)

Problems:
- clouds
- shadows
- changes in brightness during the day

Chance to be Solved

Active sensor research initiated in 1999

Attributes:
- generated modulated light
- no affect of shadows
- operational any time of the day
- can be used to facilitate "on-the-Fly" nutrient applications

(Theuseof CropSpe& Camera)

(Theuseof CropSpec& Camera)

Imagefrom the canopy

Camera$Platform

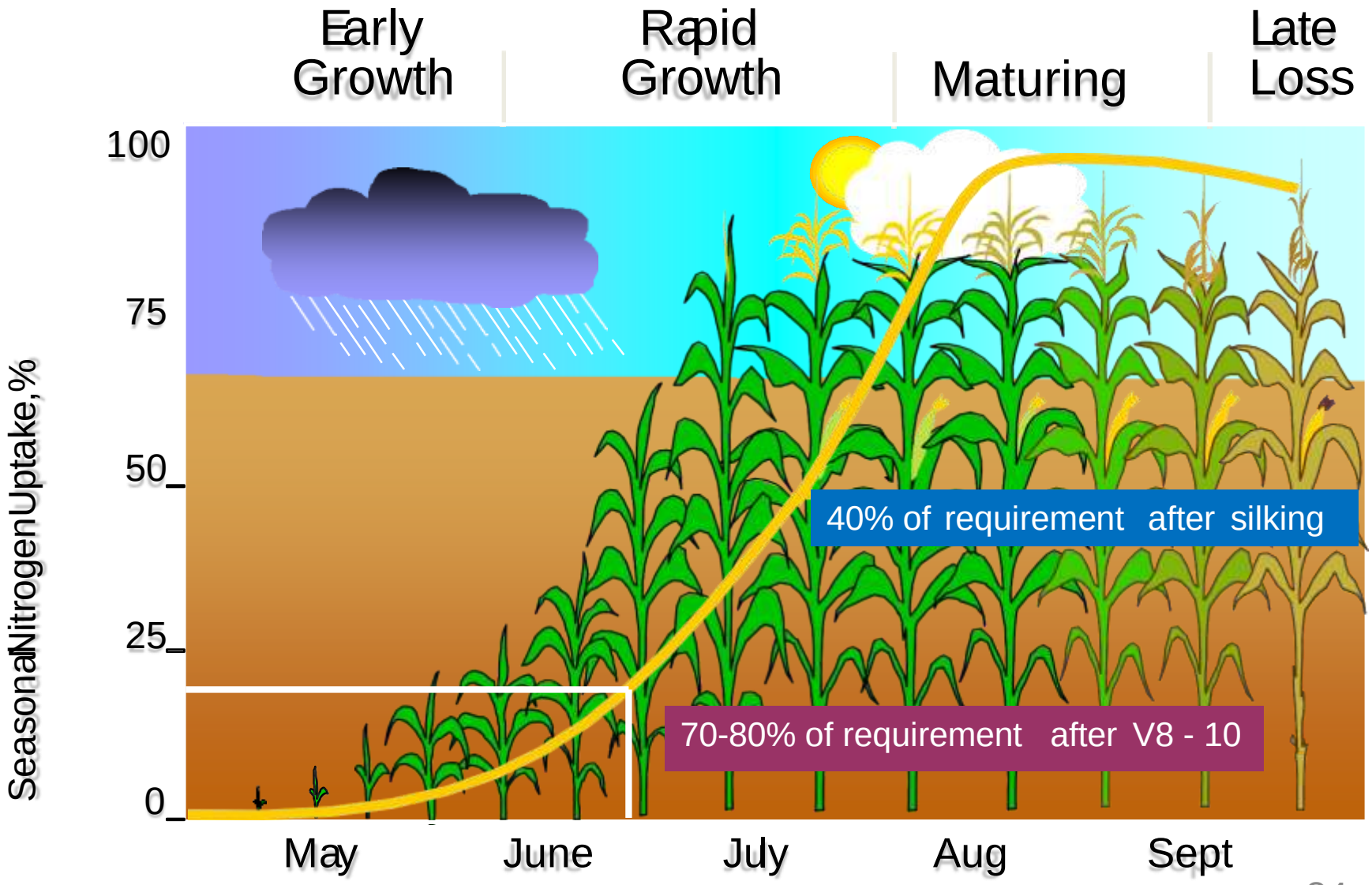
LEAVES MEASUREMENT

Theuseof Spectrometer

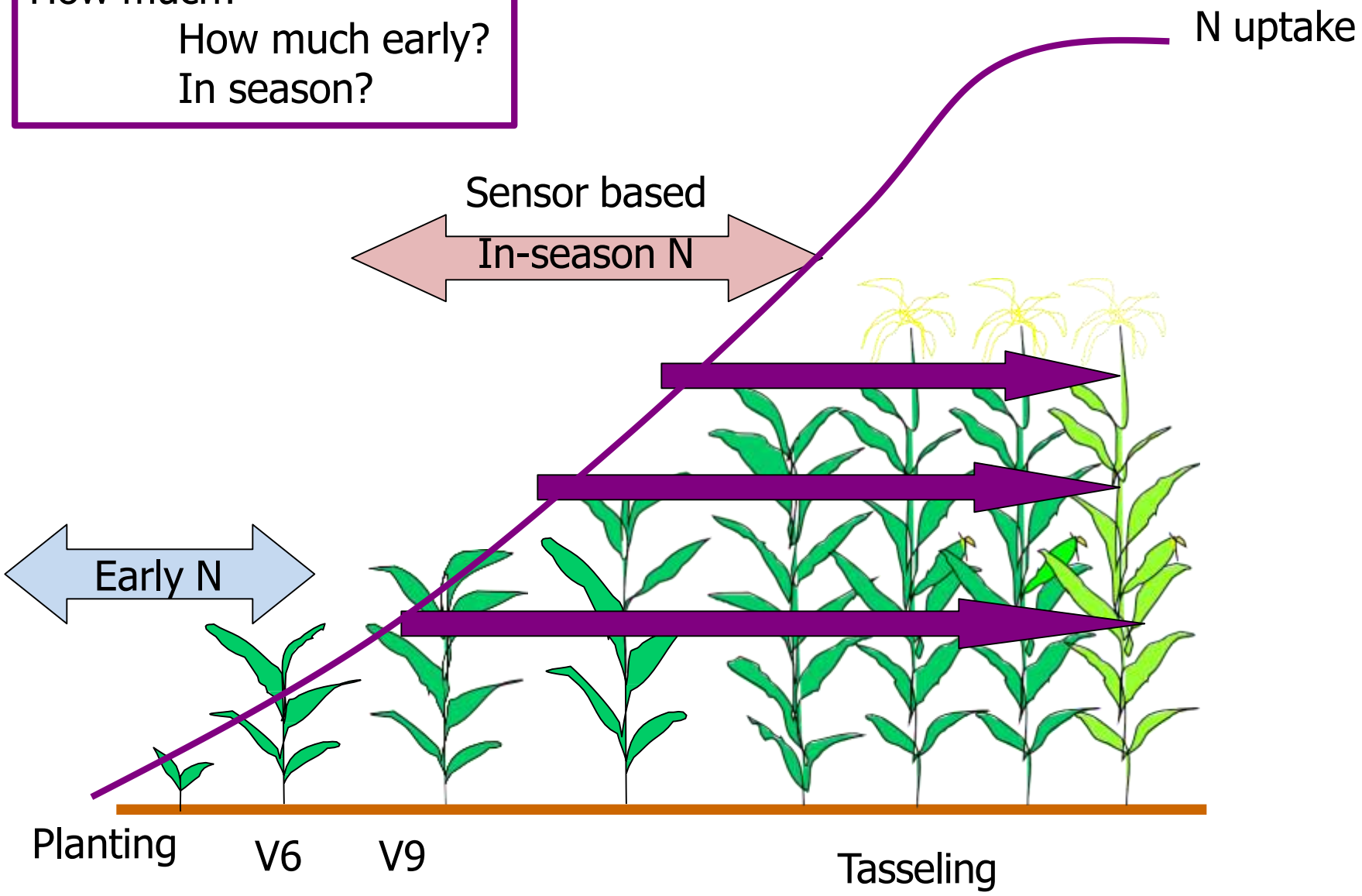
- Spectral measurement the coffee leavesby usingspectrometer
- Measuredthe 15 leaveslabeled
- Measurethe left and right sideof the vein
- Eachside measure10 times and get average

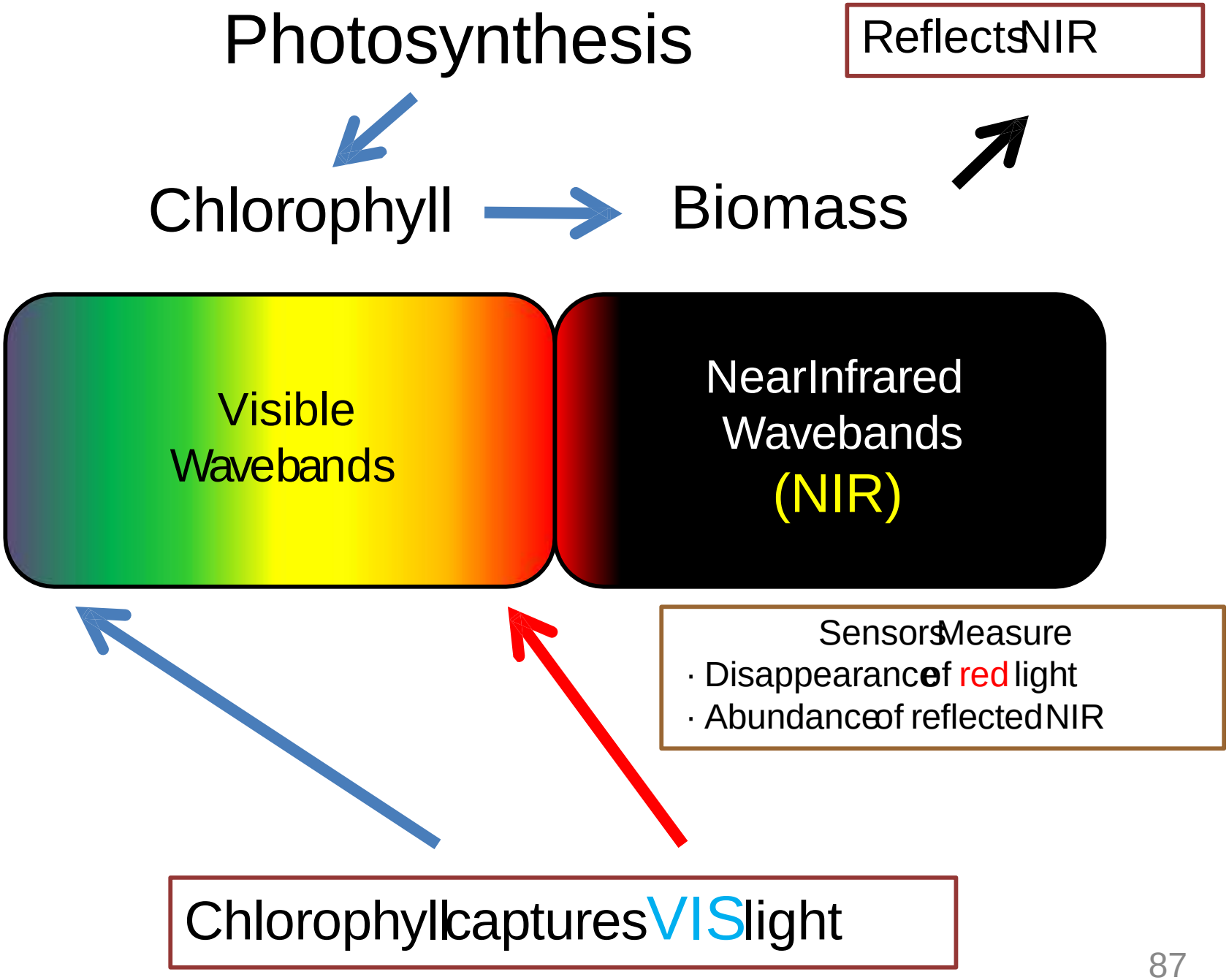
In-season Nitrogen Management

Understanding the Crop



When?
How much?
How much early?
In season?




Photosynthesis
Reflects NIR
Chlorophyll
Biomass
Visible Wavebands
Near Infrared Wavebands (NIR)
Sensors Measure
· Disappearance of red light
· Abundance of reflected NIR
Chlorophyll captures VIS light

Normalize Vegetation Index Values to remove "field effects"

This Means

Compare all data to "Healthy Plants" that have the same:

Growth stage
Cultivar (variety)
Previous crop
Water management
Soil properties - - - except nutrients

If one assumes all nutrients are adequate except for N, for example:

- - - - - - - - - - - - - - - - - -

Differences in crop vigor are probably related to plant N status

Common Vegetation Indices

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

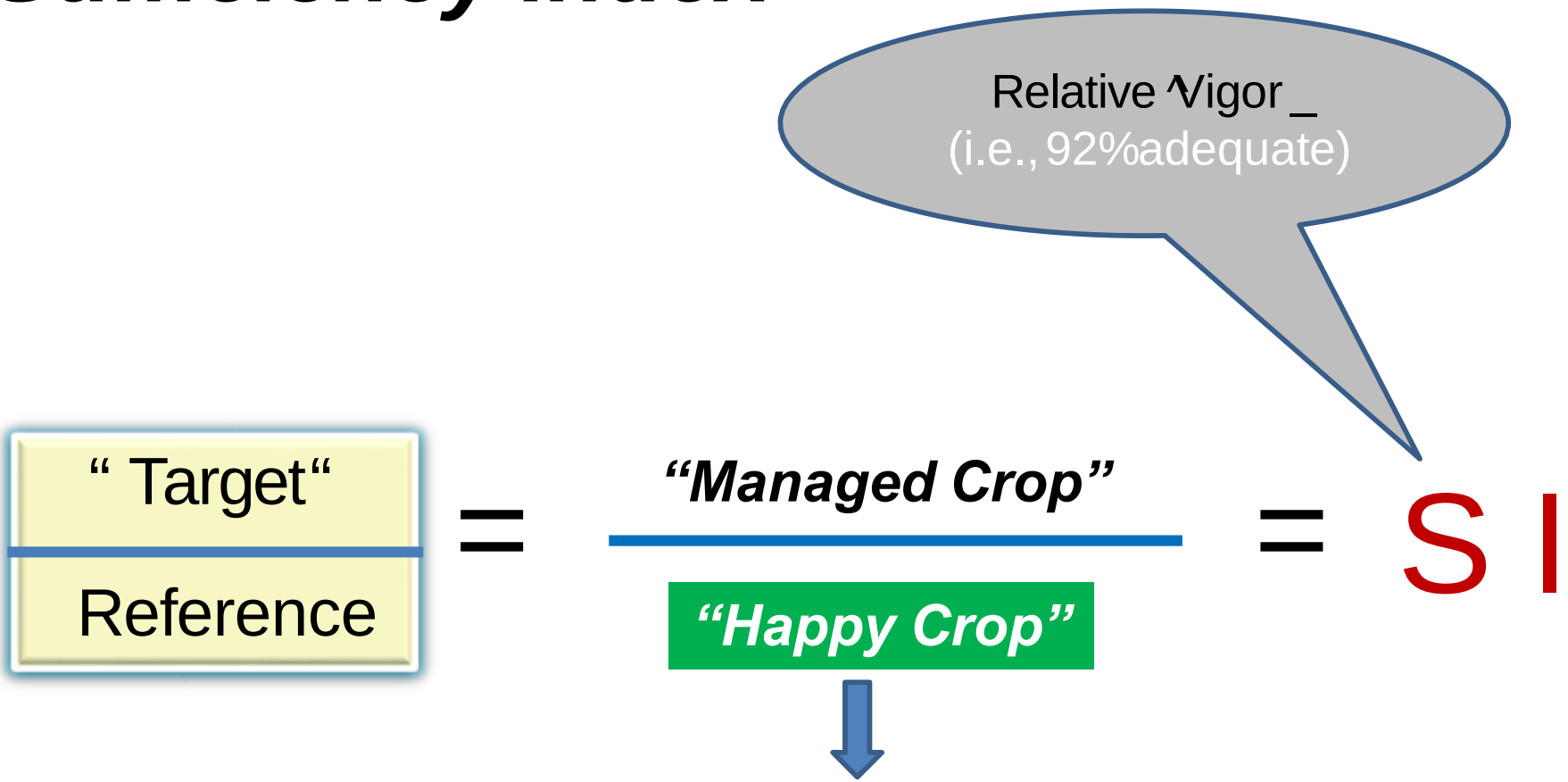
$$NDRE = \frac{(NIR - RedEdge)}{(NIR + RedEdge)}$$

$$Chl\ Index = \frac{(NIR - Red)}{(RedEdge - Red)}$$

$$Visible / NIR = \frac{(Red)}{(NIR)}$$

See: Existing Vegetation Indices 100 VIs

Sufficiency Index



- N-rich (highest 3 consecutive seconds) GreenSeeker
- N-rich (average) Missouri
- Virtual reference from field with modest preplant N Holland

Sensors only Measure Bulk Reflectance

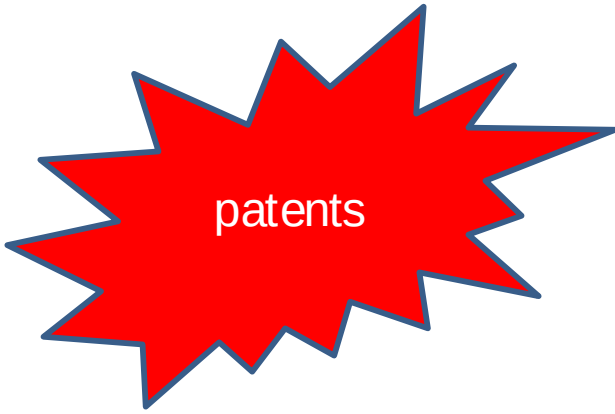
- Many factors can influence leaf chlorophyll content -

Algorithm Comparison

^ t Z ĝot compare nitrogen recommendations using a common data set M _

Algorithms have been developed using specific sensors that are associated with recommended agronomic practices

- Wave-band differences
- Reference Strategy (normalization)
- Opportunity for producer input
- Preplant N differences
- Yield (relative, predicted, not used)
- NUE input



PRACTICAL Session

1. Use Spectrometer, SPAD, CROPSPEC
2. Use CAMERA with different filters (Handheld and DRONE) and EXTRACT RGB from PICTURES
3. Apply to appropriate VIs (provided 100 more VIs)
4. Statistical Analysis (SPECTROMETER, SPAD, or CROPSPEC will be as dependent variable), and CAMERA data will be as Independent variable

Thank You !