Precision Agriculture

Past - - -

- - - Present - - -

- - - Future

Dr. Jim Schepers or

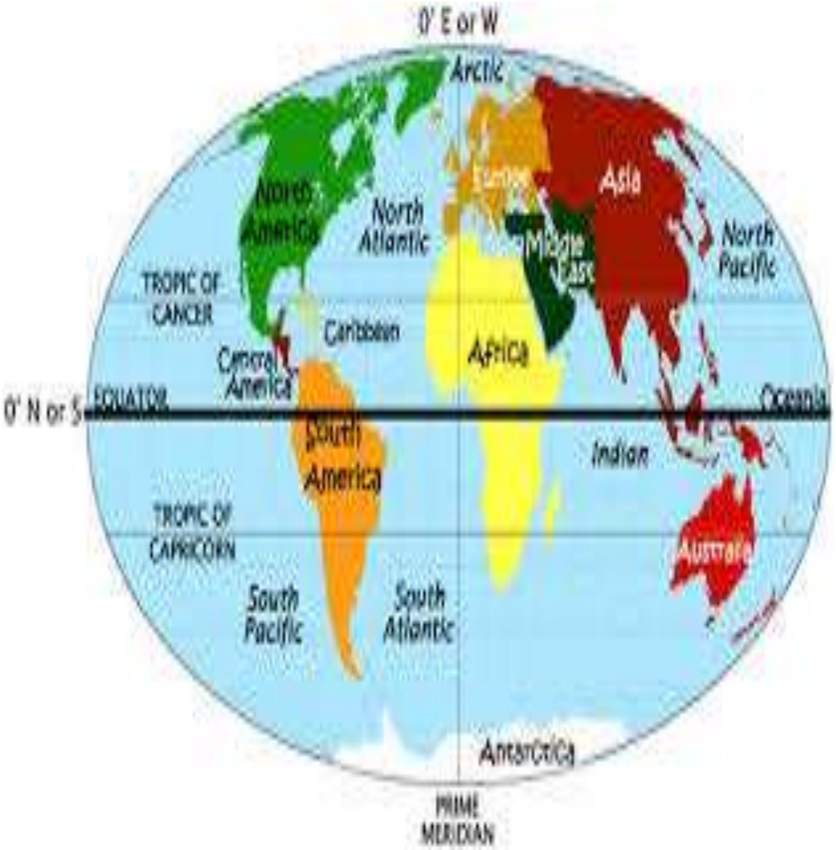
Dr. Dennis Francis

USDA-Agricultural Research Service

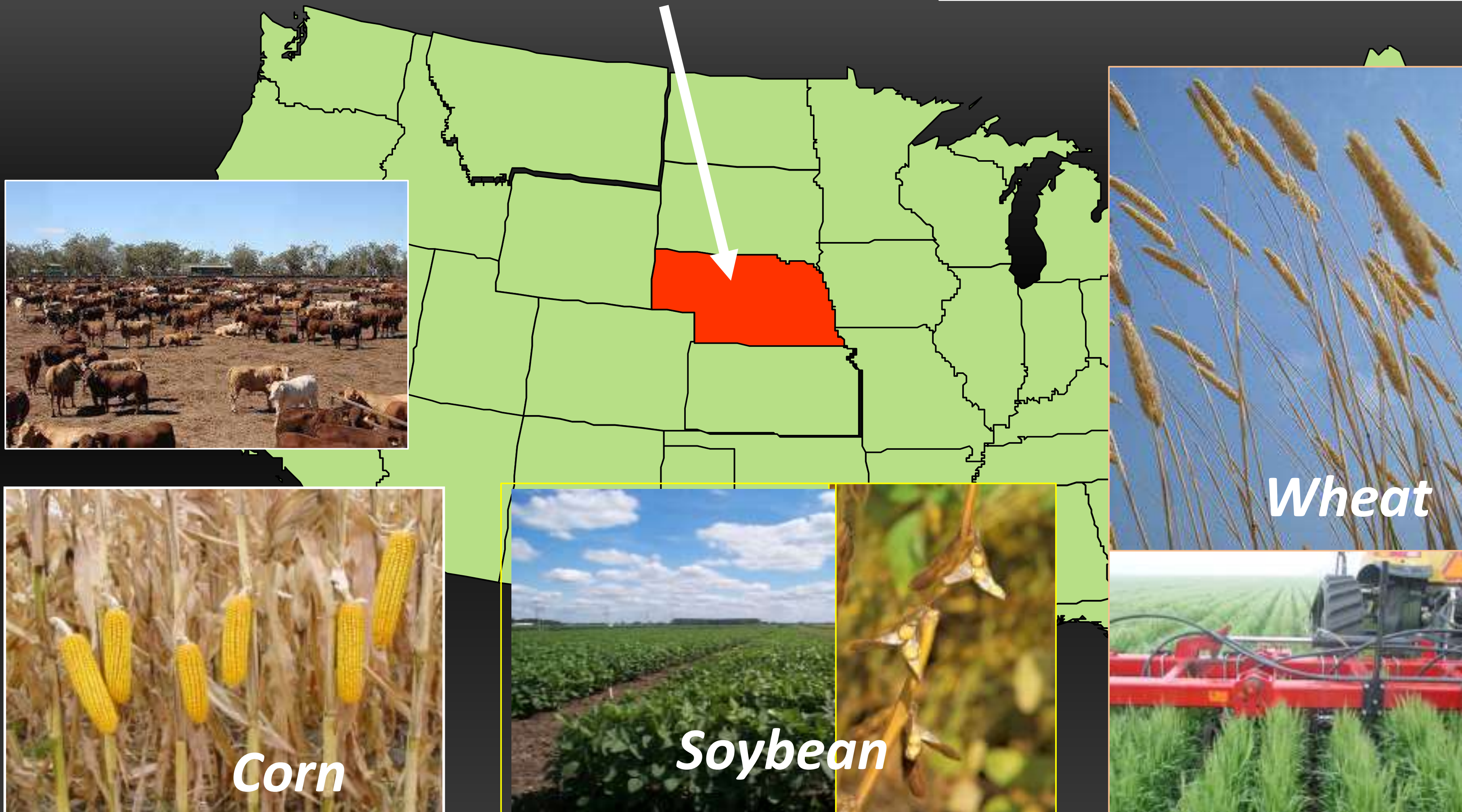
(both happily retired)

Thanks - - for the invitation to the 2014 Precision Agriculture National Symposium

My first trip to Brazil (Sete Lagoas) was in January 1995



Nebraska



Farmers are great observers !

Spatial Variability

BUT

May not be able to explain their observations

AS SUCH

Producers welcome scientific information and are eager to learn from the discussion

Initial precision agricultural efforts were driven by industry

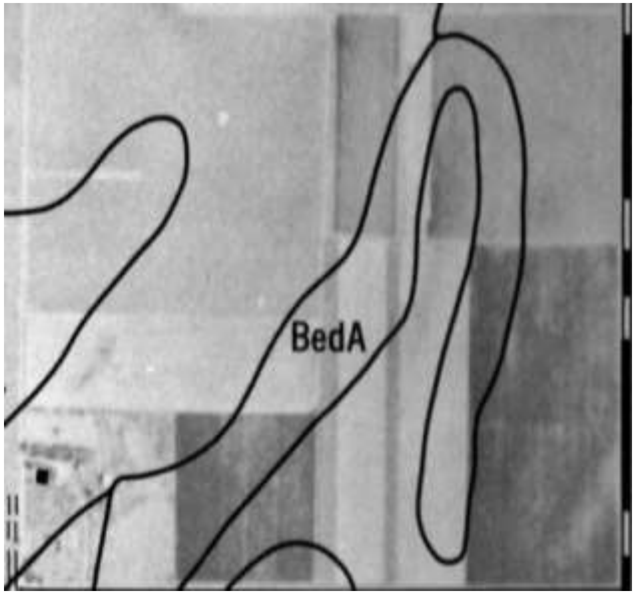
Assumed spatial variability in yield was caused by nutrients deficiencies

Six nutrients

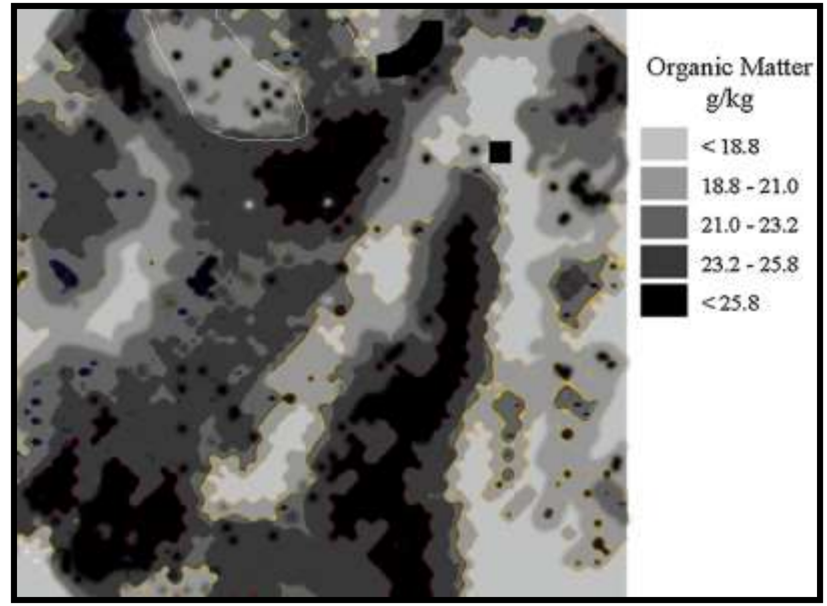
Outcome: Spatial variability in crop vigor and yield was only partially removed

Need: Technologies to quantify yield variability

- Variable-rate multi-nutrient applications were based on soil testing data
- GPS was not available

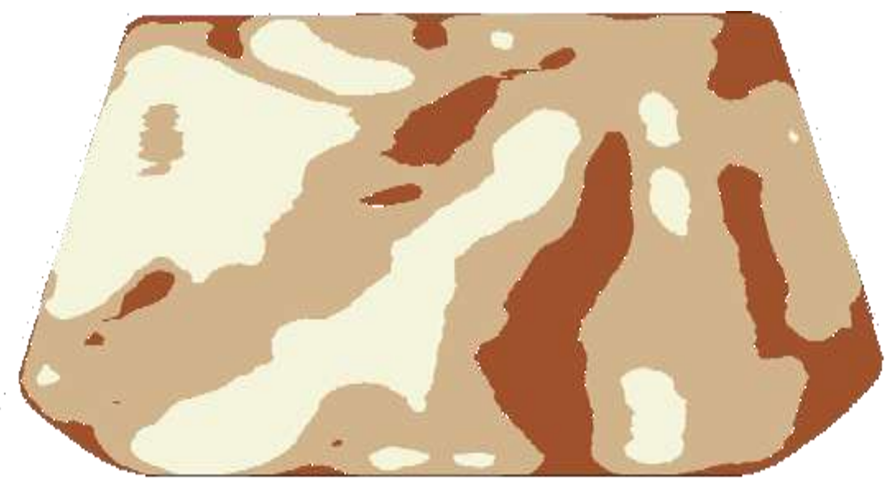


Soil Survey

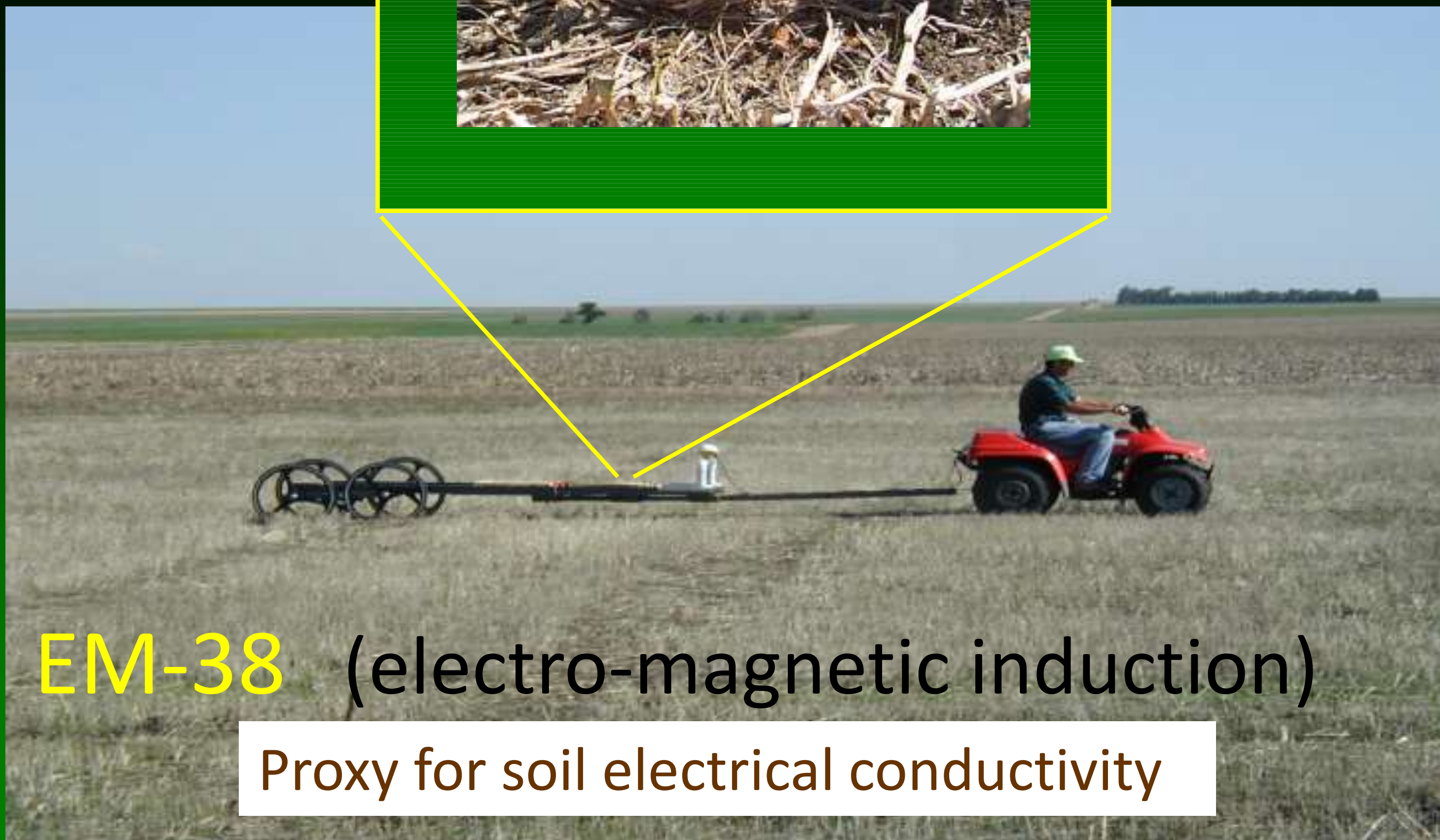


Grid Soil Sampling


Bare Soil Image


Computer Generated Management Zones

Another Tool



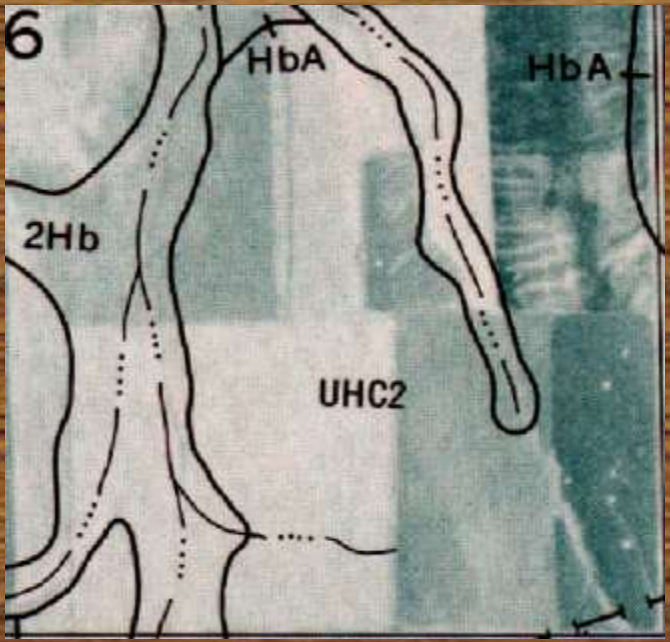
EM-38 (electro-magnetic induction)

Proxy for soil electrical conductivity

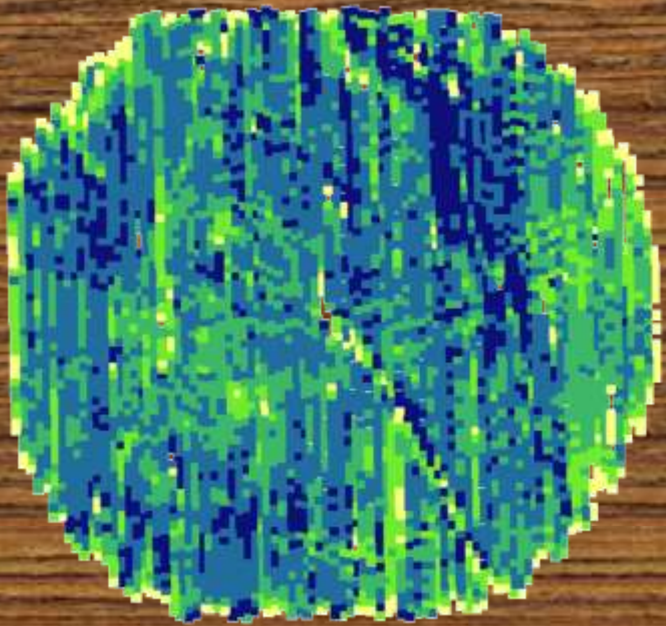
Electrical Conductivity

Veris (electro-magnetic induction)

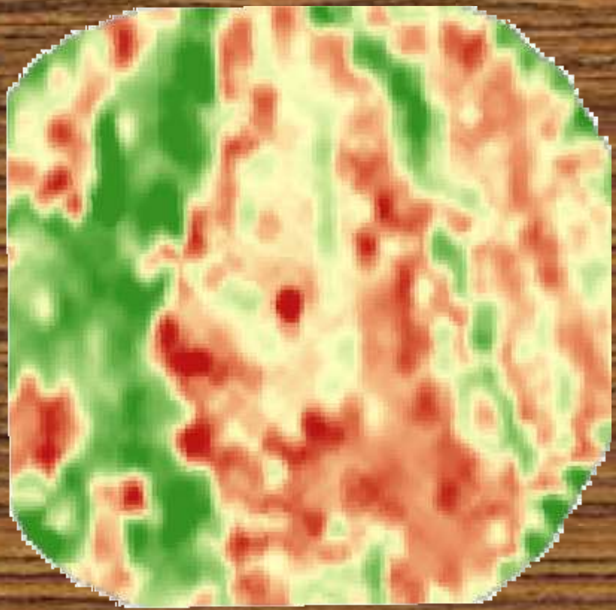
Soil Survey



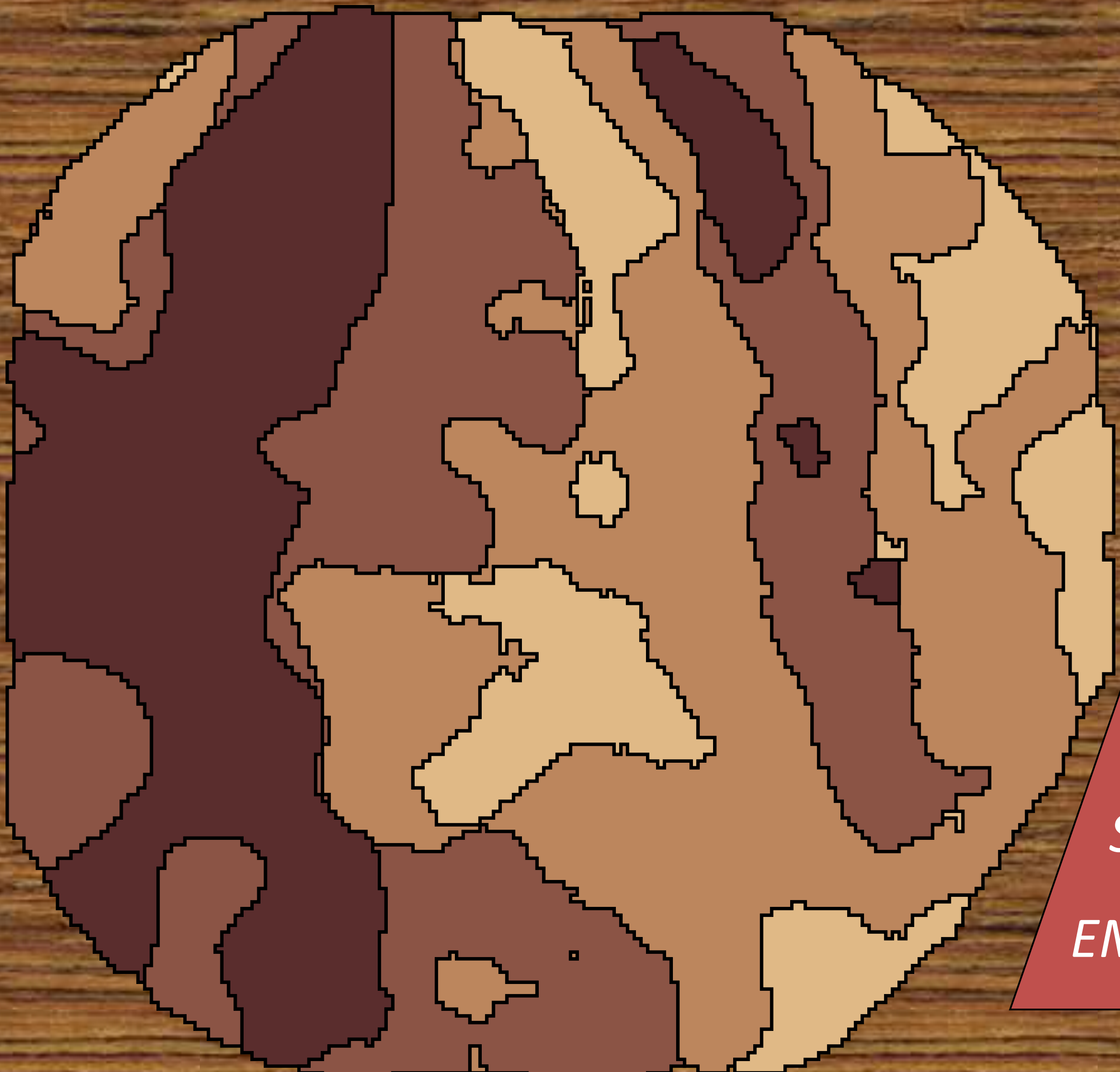
Yield Map
2000



Electrical
Conductivity



Computer Generated Management Zones



Incorporating. . .

Bare Soil Image

Elevation

Slope

EM-38

First yield-monitor combines were tested in 1992

Situation: Required ***three*** computers

- Grain flow
- Grain moisture
- GPS (initially scrambled)

- Yield-monitors are common on new combines
- Grain protein content monitors are now available
- Yield maps are not fully utilized

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

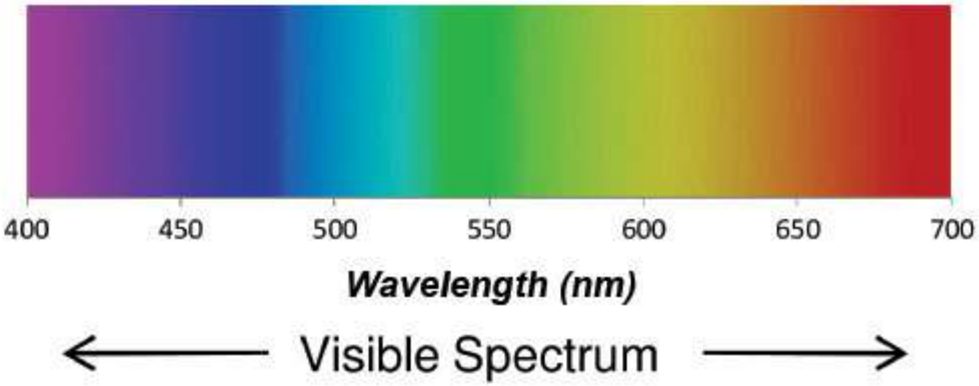
Active sensor research initiated in 1999

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

Most individuals agree that - - "***seeing is believing***",

AND

the human eye is especially sensitive to ***green*** colors



BUT

Humans cannot see near infrared light, which is reflected by living vegetation (***also called biomass***)

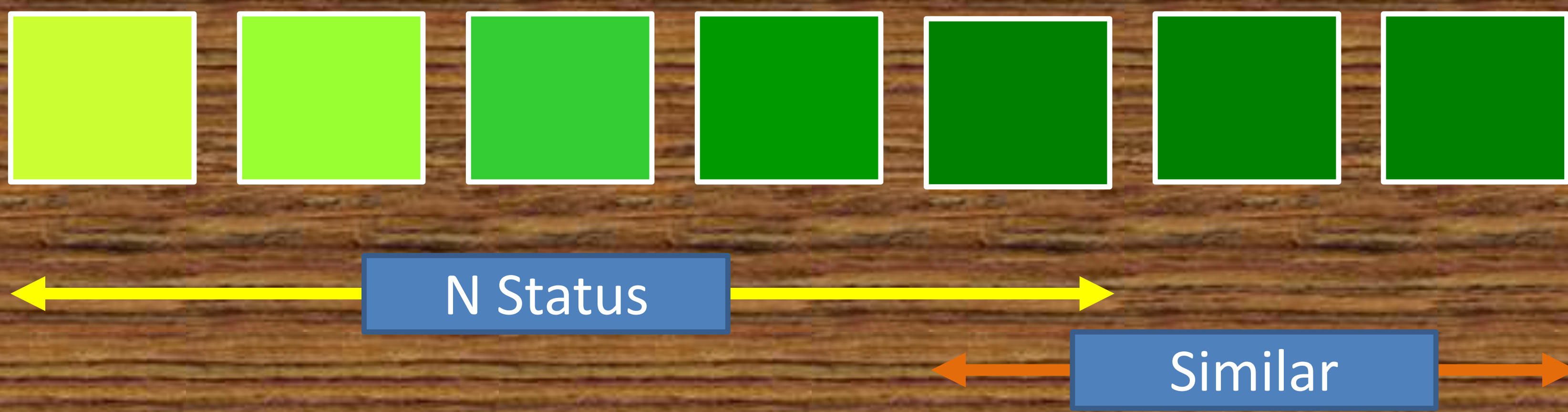
AS SUCH

Farmers largely base their assessment of crop vigor on "***greenness***" (***related to chlorophyll content and nitrogen status***)

Remember - - - -

Canopy sensors respond to ***"living biomass"*** and ***"chlorophyll content"***

Treatments / N-rates



Canopy sensors can not quantify excess N

AND

Soil background reduces sensitivity

Sensors can be designed to be sensitive to ***Greenness*** -
(i.e., chlorophyll and nitrogen status in most cases)

AND TO

near infrared ***(NIR)*** light - ("*living vegetation*" called biomass)

BASICALLY

NIR - size of the factory (cumulative indicator of canopy size)
(number and size of leaves)

Chlorophyll - output potential of leaves via photosynthesis

RESULTING IN

Yield and potential profitability
- - - - ***This why we need to measure chlorophyll and biomass***

Crop Circle ACS-430

or

AgLeader OptRx

Functions **Day** or **Night**

Cotton

Greece 2010

Mexico - White Corn, 2010

Irrigated Corn - Nebraska

Variable-Rate N Injection

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 "REAL" in the minds of individuals

Precision Agriculture Perceptions

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

Original 4-Rs

Applied at the field scale - - *delineates management zones*

RIGHT - **Place**

Rate

Time

Form

What about the plant environment ?

How to create a better environment for 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

Potentially Useful Technologies	United States	Brazil
Variable-rate planting	moderate	______
Multiple-cultivar planting	low	______
Variable-rate lime	high	______
Variable-rate nutrients	moderate	______
Yield mapping	high	
Crop canopy sensors	moderate	
Remote sensing	moderate	______
Climate & growth models	???	______
High-clearance applicators	moderate	______
Crop consultants	moderate ++	______
Auto-guidance	high	______

How would you populate this table ?

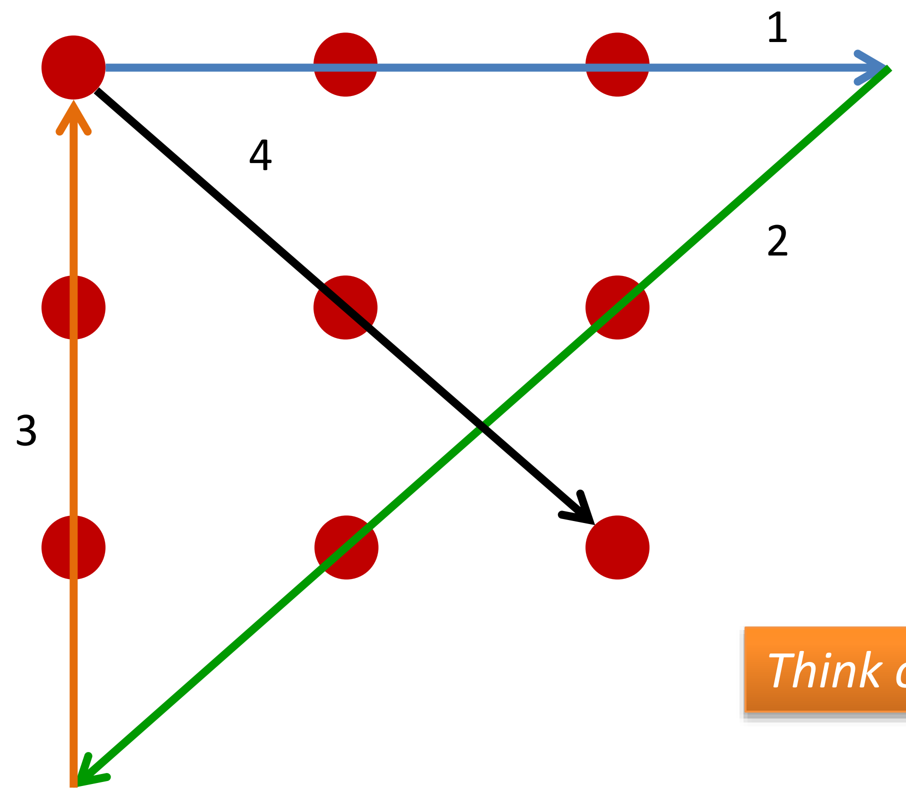
Harnessing ***Precision Agriculture*** information is like

making sausage !

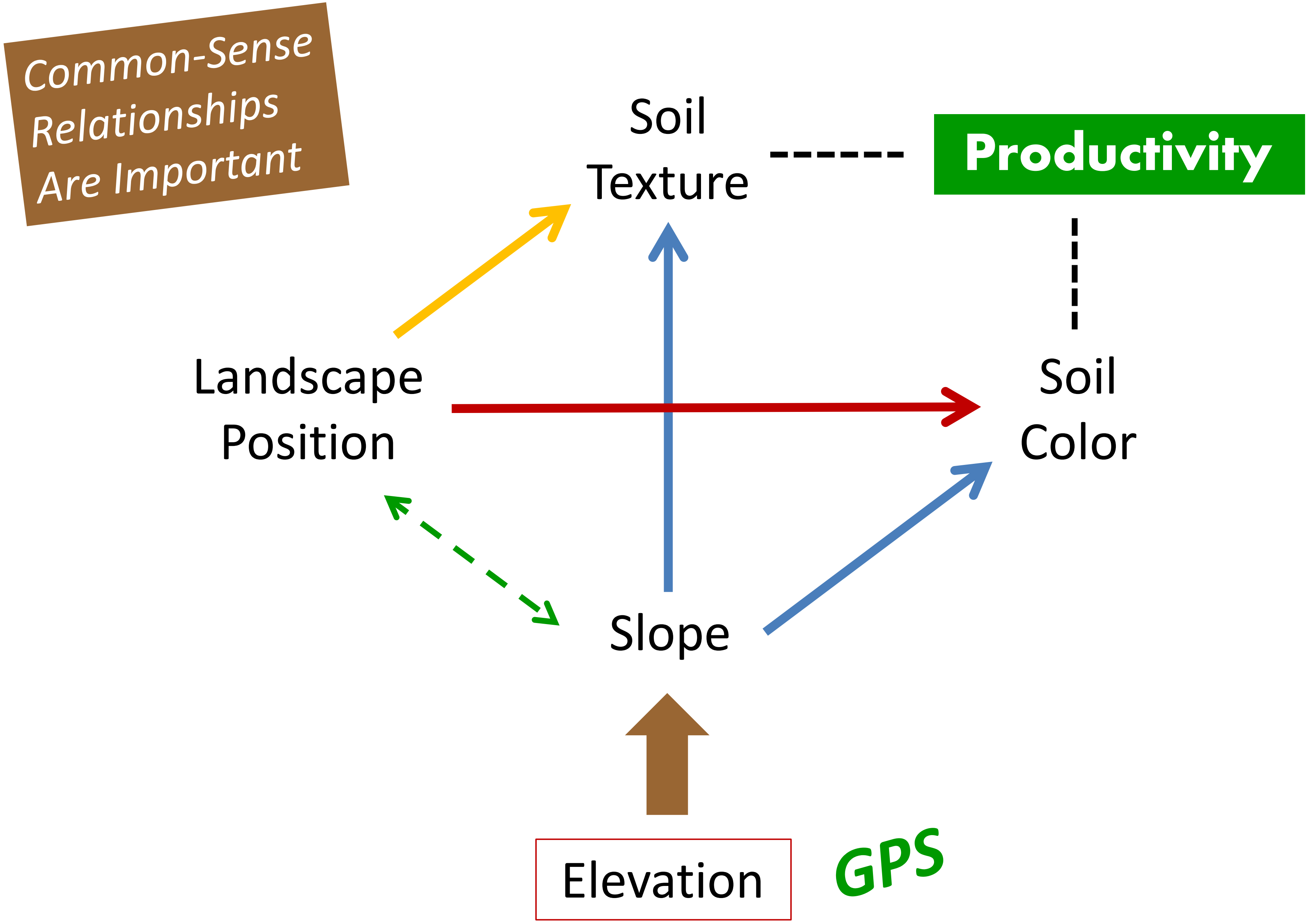
Needs multiple ingredients in the right proportions

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 !



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

So Much for the Concept of Precision Agriculture

How did the Embrapa / USDA-ARS partnership come to be ?

The relationship started in January 1995 - A friend, Walter Baethgen, from Uruguay put me in contact with Goncalo Franca with Embrapa at Sete Lagoas.

A graduate student, scientist with Li-Cor, and Jim Schepers tested prototype passive sensors with the assistance of Goncalo Franca and Evandro Mantovani (*also hosted by Bob Schaffert, Antonio Bahia, and Mauricio Lopes*).

Morethson Resende (water management) and Derli Santana (soil classification) traveled to Nebraska while on sabbatical leave (1995-1997).

A team of nine USDA-ARS scientists visited five Embrapa locations in 1996. Precision agriculture was identified as a discipline of interest for scientific exchanges. This was the beginning of the **LABEX** program.

LABEX Friends who spent time in Nebraska

Ariovaldo Luchiari

Moresthon Resende

Ricardo Inamasu

Evandro Mantovani

Others without Pictures

Scientists

Goncalo Franca
Derli Santana
Frederico Duraes

Jose Molin

Graduate Students

Antonio Coehlo
Jaoa Camargo Neto
Luciano Shiratsuchi

Lucas Amaral

Field Researchers - 2000

Special Thanks

Ricardo Inamasu

Examples of imagination, innovation, determination and execution

Thank You

"It' cold - ***like hell*** - in Nebraska"

Jim Schepers

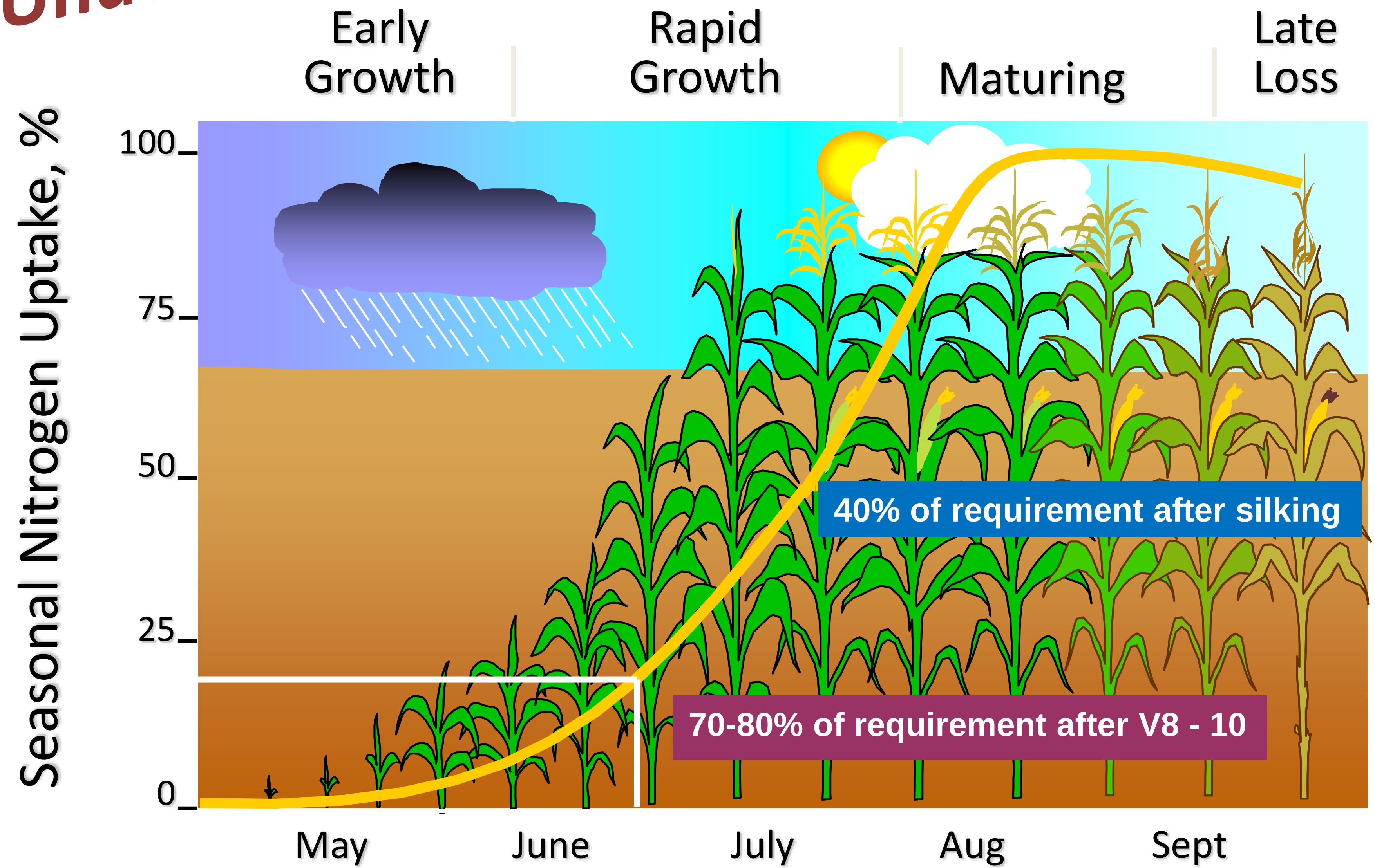
402-310-6150

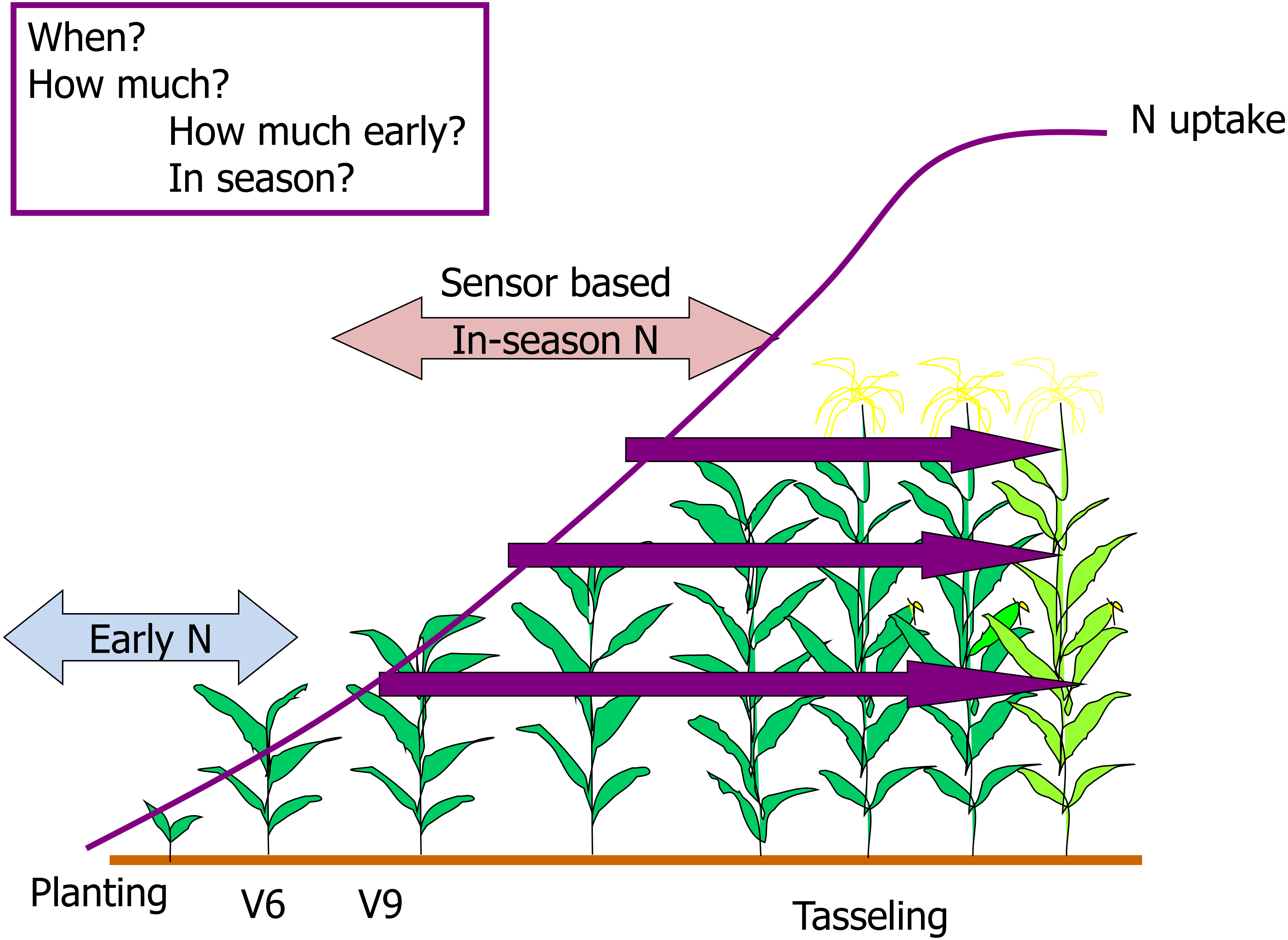
james.schepers@gmail.com

Optimizing In-season Nitrogen Management

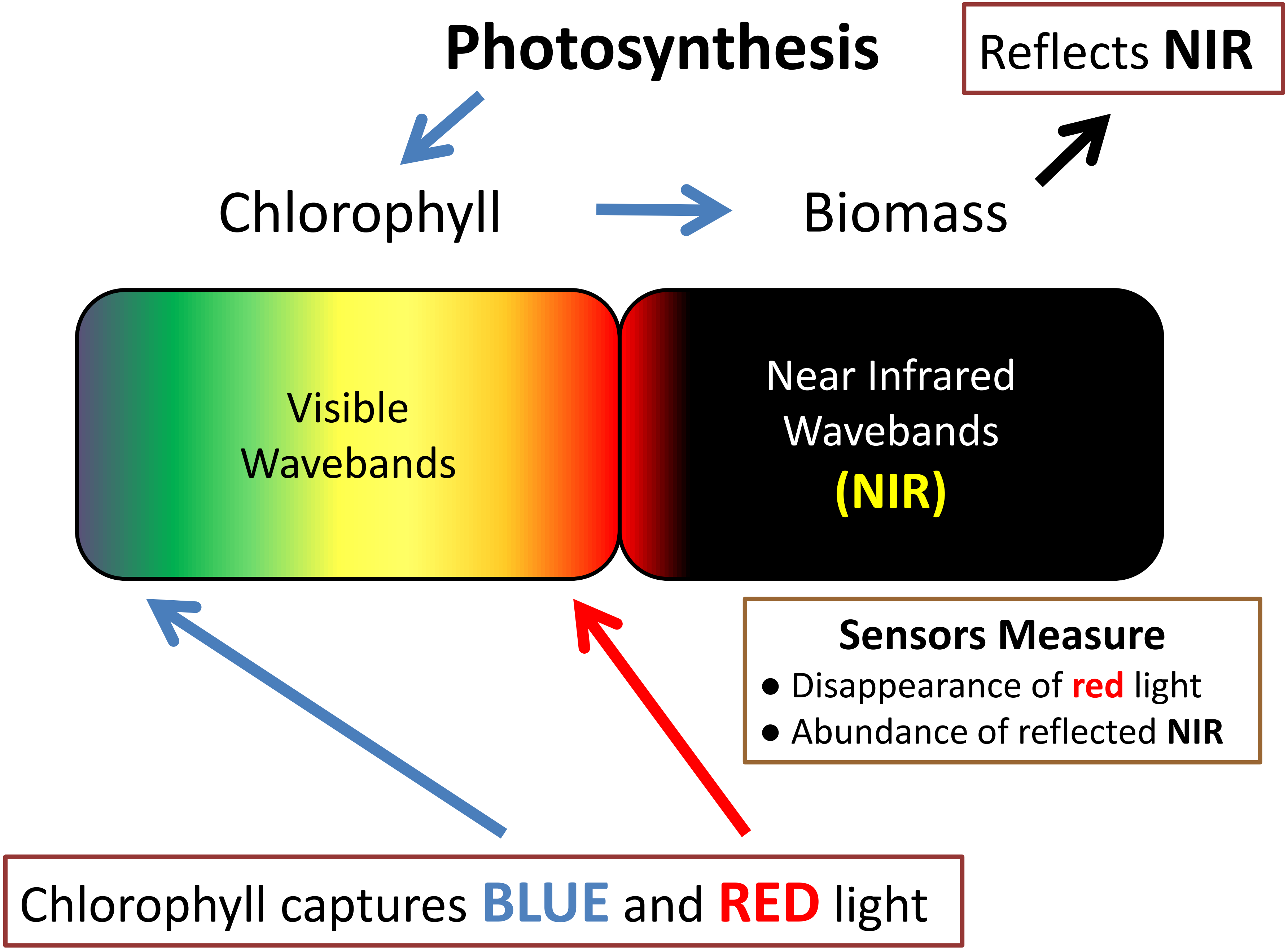
Dennis D. Francis and James S. Schepers

Understanding the Crop





When?
How much?
How much early?
In season?
N uptake
Sensor based
In-season N
Early N
Planting
V6
V9
Tasseling


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

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

$$\text{NDRE} = \frac{(\text{NIR} - \text{Red Edge})}{(\text{NIR} + \text{Red Edge})}$$

$$\text{Chl Index} = \frac{(\text{NIR} - \text{Red})}{(\text{Red Edge} - \text{Red})} \quad \textit{OR} \quad \frac{(\text{NIR})}{(\text{Red Edge})} - 1$$

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

\- Many factors can influence leaf chlorophyll content -

Algorithm Comparison

"Why not compare nitrogen recommendations using a common data set ?"

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

patents

Topcon

Holland Scientific

(Ag Leader)

NTech Industries

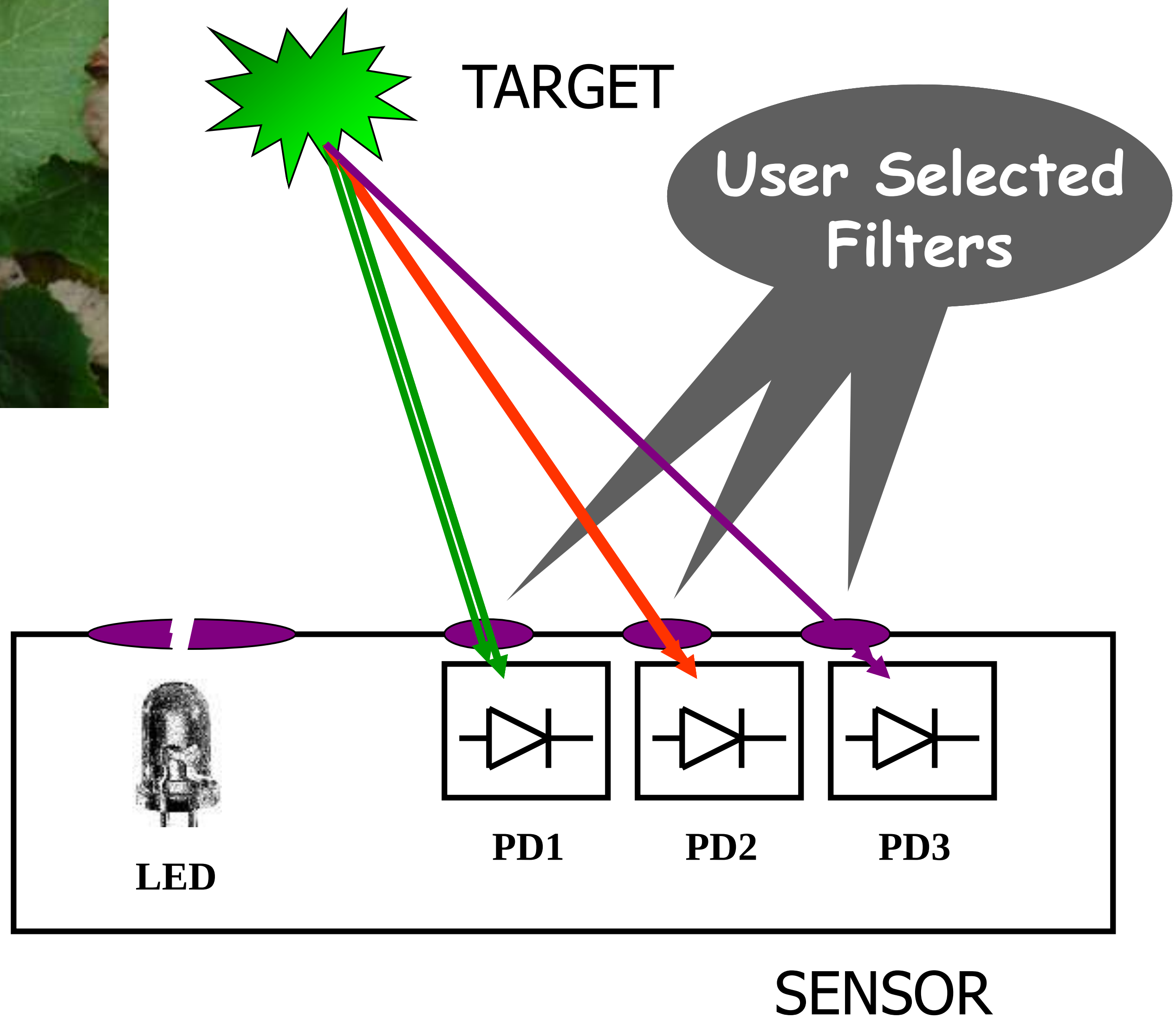
(Trimble)

Crop Spec

Foot-print changes with plant height

Modulation/Demodulation Using Polychromatic LEDs

ACS-470



Sufficiency Index

Relative "**Vigor**"
(i.e., 92% adequate)

" Target "		"Managed Crop"		
Reference	=	"Happy Crop"	=	**S I**

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

Reference Value Determination

German	Not used *"Walk in the field"*
Missouri	"…we filter off values *<u>from an N-rich area</u>* that would represent poor or no stand and then take the ***mean*** of what remained". *(Newell Kitchen)*
Oklahoma	"Reference values are tied to the readings we collect from the N-rich strip (producers and research). " *(Bill Raun)* *Earlier used highest 3-consecutive second value (30-point running average)*
Holland	"Virtual reference" - 95-percentile value (2 Std. Dev. units above the mean) for histogram of vegetation index values from field strip receiving modest preplant N application. *(~1/3 recommended rate)* *"Drive-and-Apply" - Automatically updated virtual reference when starting in average to above-average part of the field.*

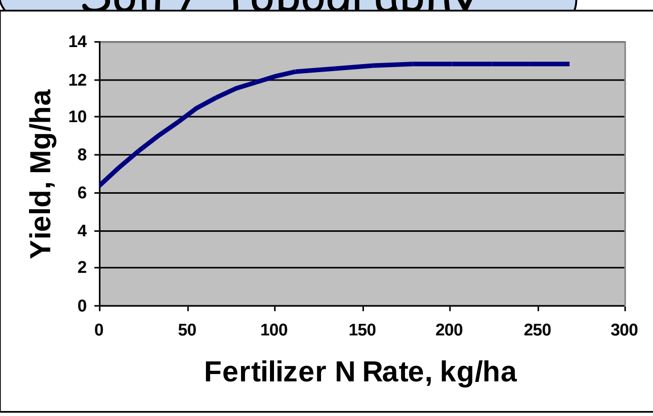
N Credits
Preplant N

EONR
Producer Optimum

Field
Reference

Sufficiency Index

Spatial
Soil / Topography



Algorithm

N Accumulation
(based on growth stage)

Back-Off Strategy
SI to start cutback
SI to cut-off

German Algorithm

- N-Sensor

- *Producer identifies poor part of the field and assigns the desired N rate.*
- *Similarly, the producer identifies a good part of the field and assigns the preferred N rate.*
- *Sensor readings are taken from each area.*
- *Linear regression algorithm is developed for variable rate application.*

Developed for small grains **with** multiple applications.

Oklahoma Algorithm

- GreenSeeker specific
- Crop specific

Assess crop growth and vigor via sensor readings:

- Record growing degree days (GDD) since planting
- Calculate potential yield based on NDVI / GDD data **vs.** yields from past years and locations
- Back calculate the difference in grain N content between reference and target plants
- Adjust for NUE

New Approach

- Use reference NDVI and yield data from multiple locations and years to generate sigmoid-shaped growth function
- Predict yield potential from NDVI using sigmoid function

Missouri Algorithm

- By sensor
- By growth stage

Crop Sensor Stage Missouri N rate equation

Corn GreenSeeker	V6-7 (12" to knee high)	(220 x ratio*) - 170
Corn GreenSeeker	V8-10 (waist high)	(170 x ratio) - 120
Corn GreenSeeker	V11+ (chest high or taller)	(160 x ratio) - 130
Corn Crop Circle 210	V6-7	(330 x ratio) - 270
Corn Crop Circle 210	V8-10	(250 x ratio) - 200
Corn Crop Circle 210	V11+	(240 x ratio) - 210

Ratio = (Target visible/near-infrared) / (High-N visible/near-infrared)

" SI "

- Calibrated using field studies
- Minimum N-rate of 30 – 60 lb/acre regardless of sensor reading

Source: "Managing Nitrogen with Crop Sensors: WHY and HOW" (Scharf)

Holland / Schepers Algorithm

- Universal

Based on the mathematical derivation from an ***N-rate*** *vs.* ***yield*** *response function (quadratic component)*

$$N\ Rec = (N_{opt} - N_{credits}) \times \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

Farmer's optimum rate or EONR

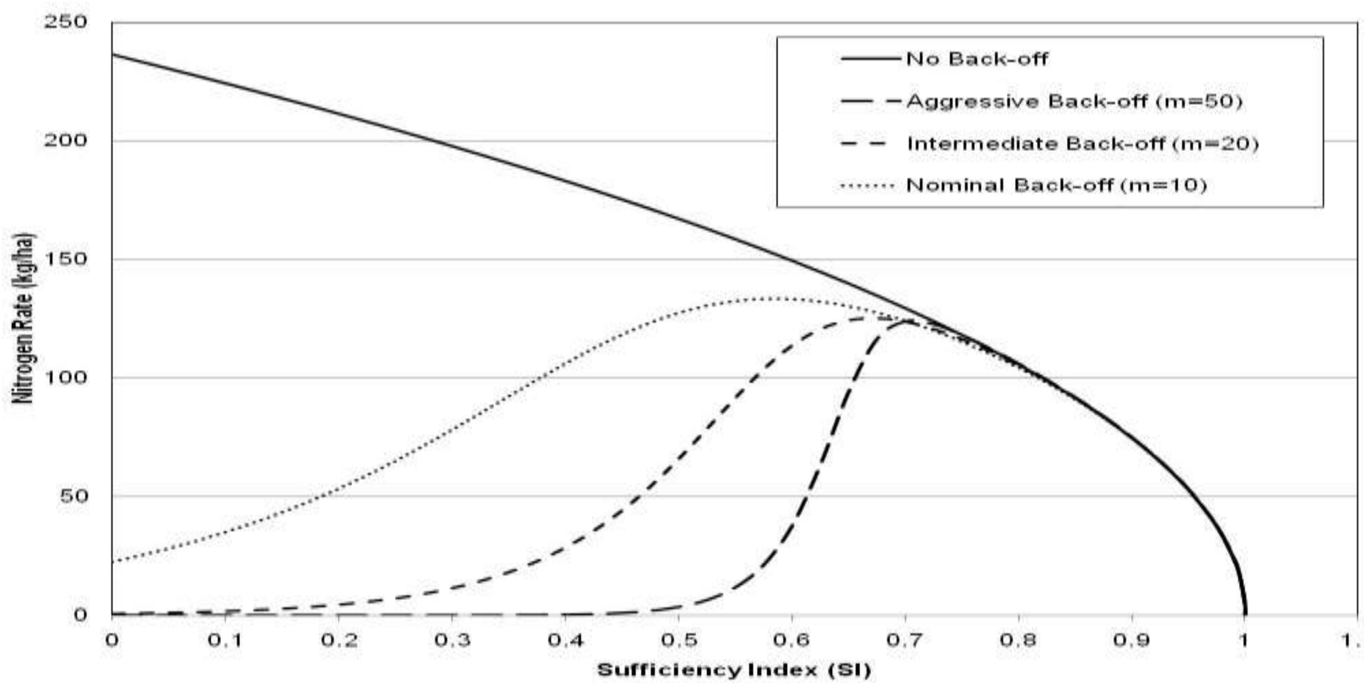
Source: "Derivation of a Variable Rate Nitrogen Application Model for In-Season Fertilization of Corn" (Holland and Schepers, Agron. J. 102:1415–1424 (2010)

*Holland-Schepers Generalized N-Rate Model:

$$N_{APP} = MZ_i \cdot \left(N_{OPT} - \sum N_{CRD} \right) \cdot \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

Zone Scaling — Management Inputs and Credits — Sensor Data

"Back-off" Function



***Reference**

Holland, K. H., & Schepers, J. S. (2010). Derivation of a variable rate nitrogen application model for in-season fertilization of corn. *Agronomy Journal 102*:1415-1424.

Other Features

	N Credits	Cut-Back Feature	Yield Prediction	Management Zones	Genetic Potential
German	No	No	No	No	No
Missouri	No	No	No	No	No
Oklahoma	No	**Yes / No**	**Yes**	No	No
Holland	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Thank You