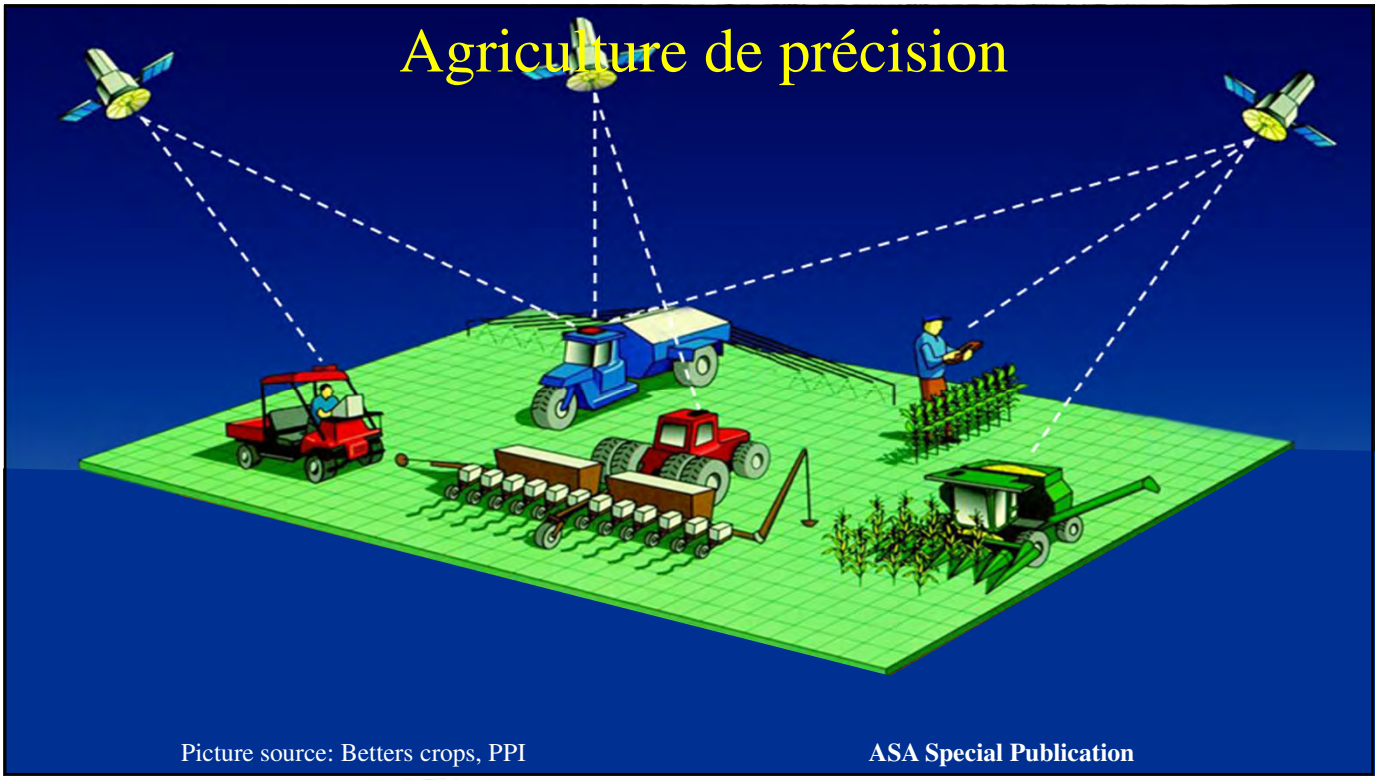
La gestion d'azote : Le passé, le présent, l'avenir

Prof. Raj Khosla
Colorado State University
Robert E. Gardner Professor of Precision Agriculture

Founder and Past President
International Society of Precision Agriculture

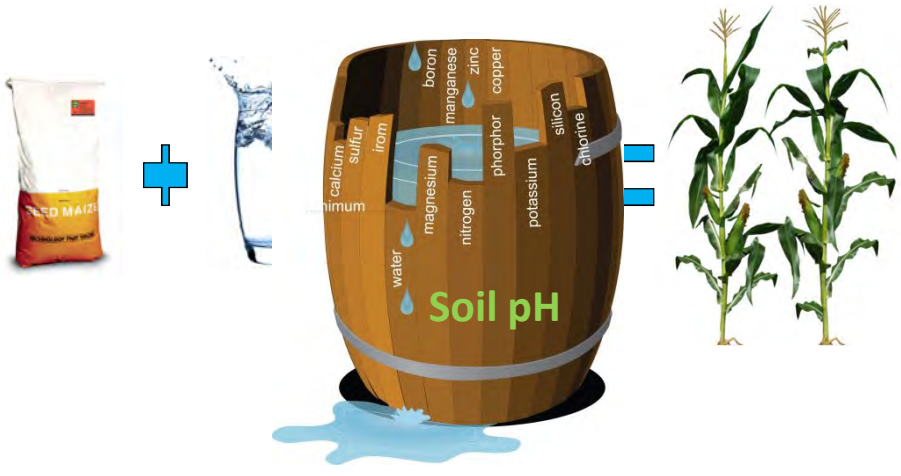


Picture source: Betters crops, PPI

ASA Special Publication

L'agriculture (numérique) de précision …

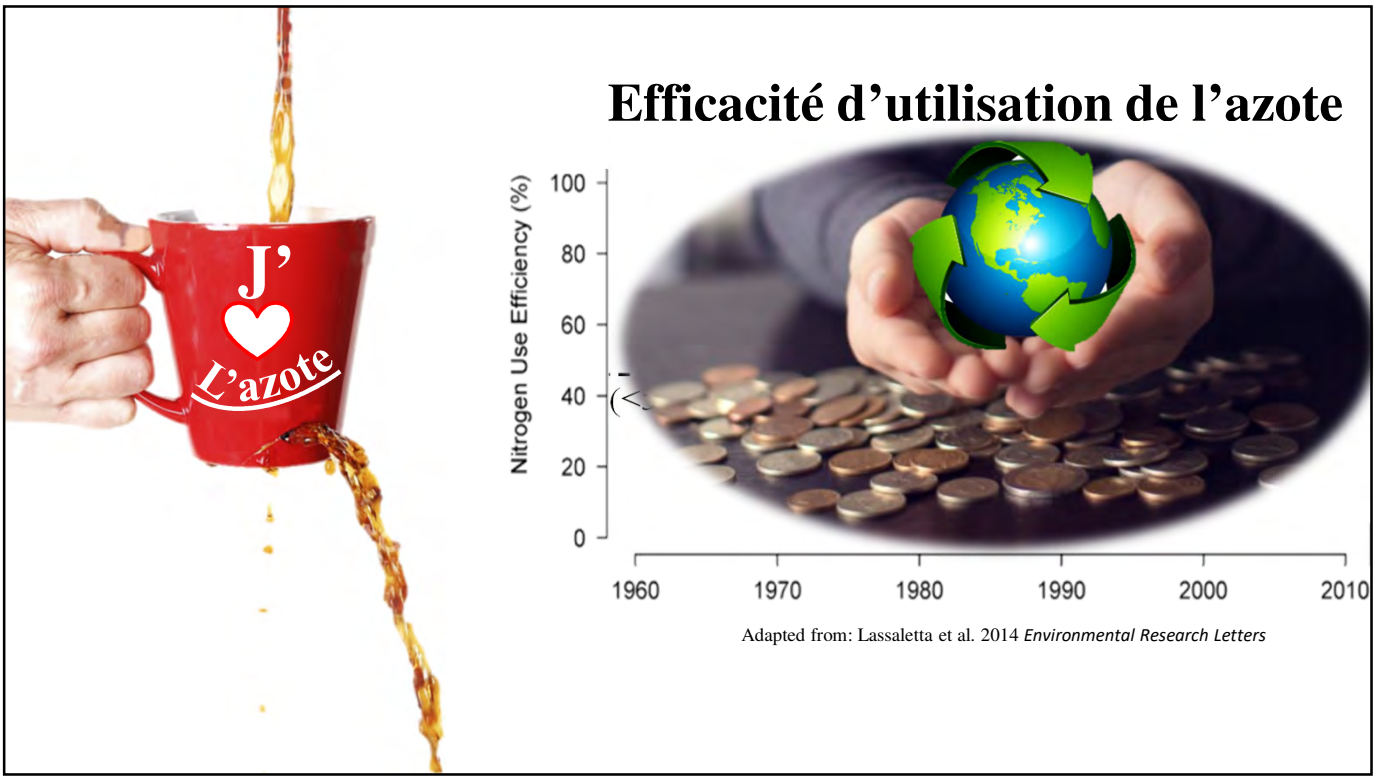
Agronomie de base

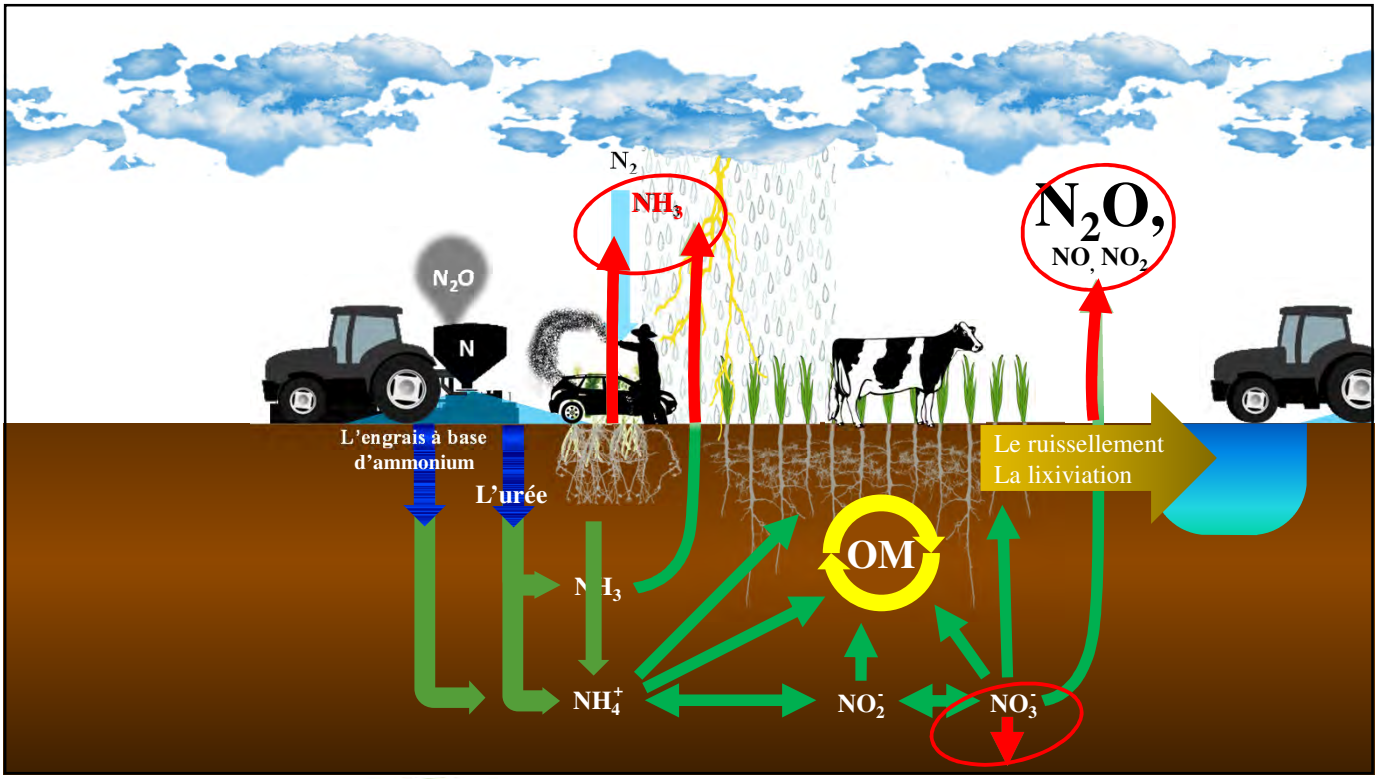


loi des facteurs limitants


HABER-BOSCH PROCESS
Nitrogen
❖ Processus fixant le N dans l'air en ammoniac
❖ L'une des plus grandes inventions du 20e siècle
❖ Responsable de la moitié de la nourriture mondiale d'aujourd'hui
❖ Sans cela, 30 à 40% de la population ne serait pas en vie

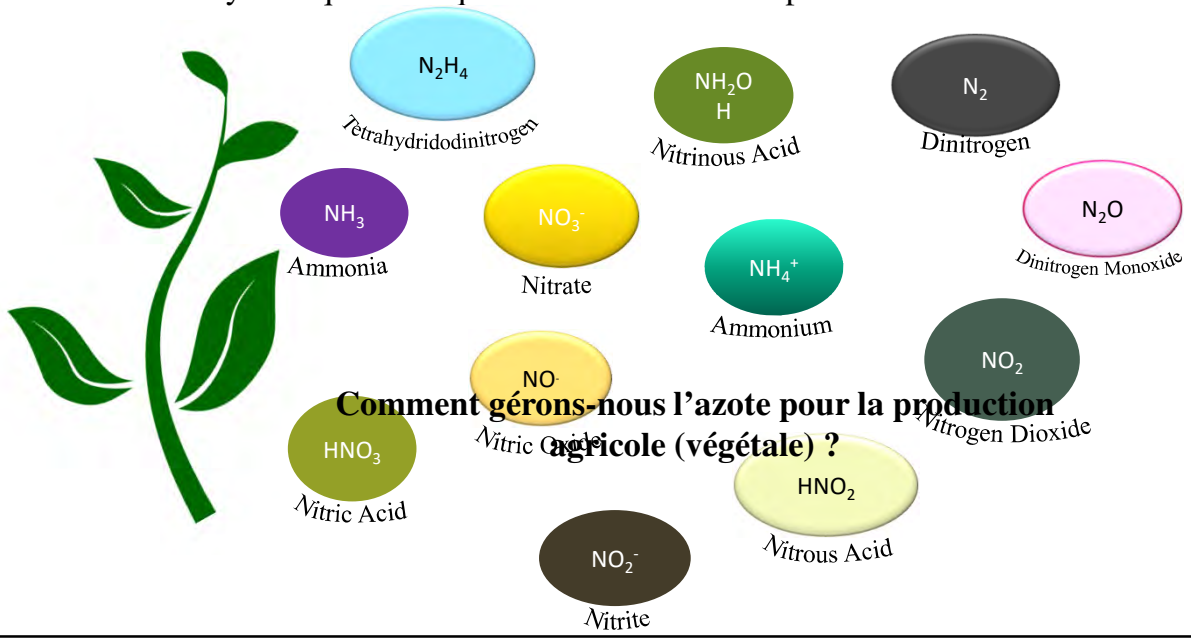

La gestion de l'azote


J'
L'azote
Efficacité d'utilisation de l'azote
Nitrogen Use Efficiency (%)
100
80
60
40
20
0
1960
1970
1980
1990
2000
2010
Adapted from: Lassaletta et al. 2014 Environmental Research Letters

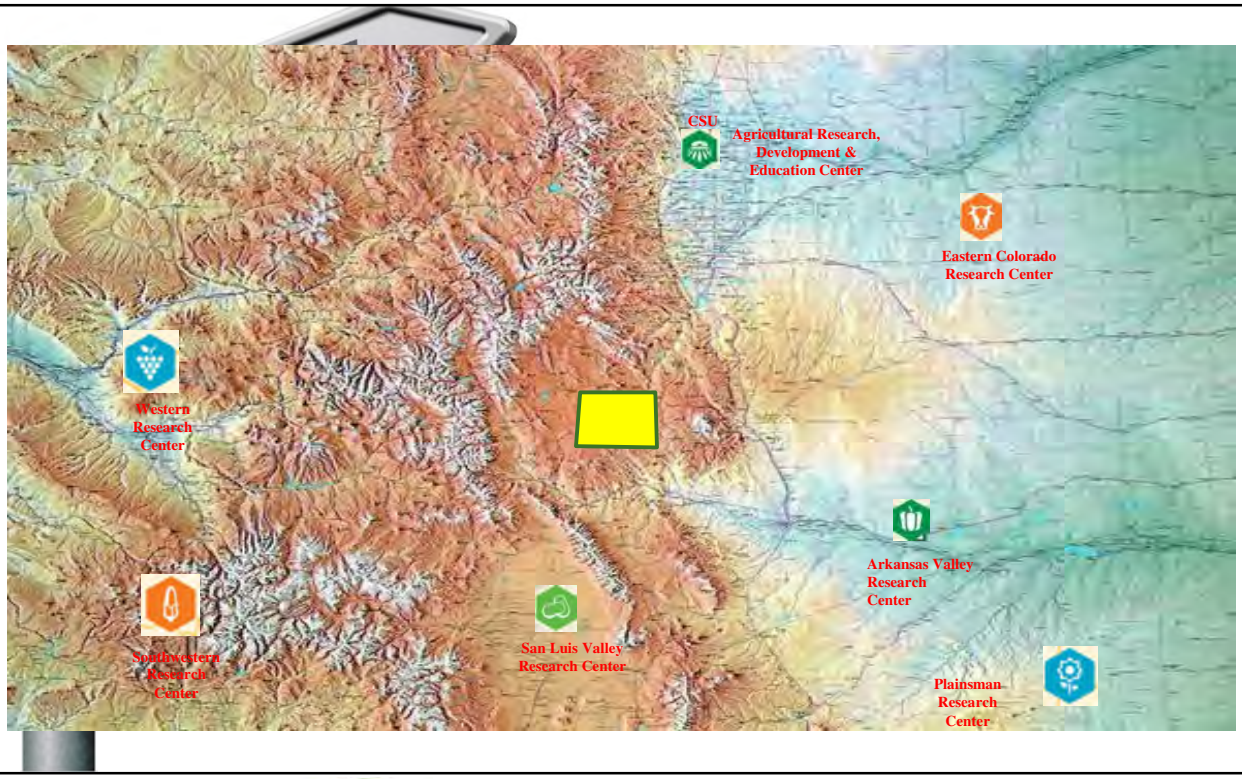

N_2
NH_3
N_2O
N_2O, NO, NO_2
N
L'engrais à base d'ammonium
L'urée
Le ruissellement
La lixiviation
OM
NH_3
NH_4^+
NO_2^-
NO_3^-

Les formes d'azote

Il n'y en a que deux qui sont accessibles aux plantes : NO3- et NH4+

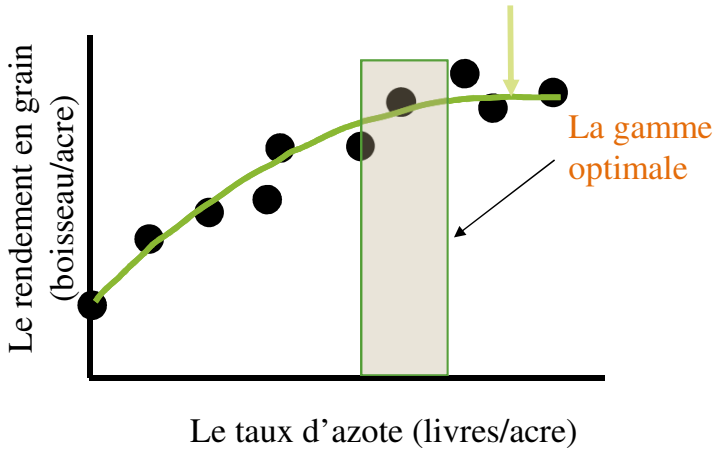


Comment gérons-nous l'azote pour la production agricole (végétale) ?



Calculer le taux optimal d'azote

Le taux d'azote= 35+ (1.2 X EY (bu/ac))



La gestion d'azote

Le taux d'azote recommandé

La gestion d'azote

L'etat	Le taux d'azote recommandé
CO	35+ (1.2 X EY (bu/ac)) – (.8 X Average ppm NO3 N in soil) – (.14 X EY (bu/ac) X %OM)- other N Credits

L'estimation des rendements (EY)

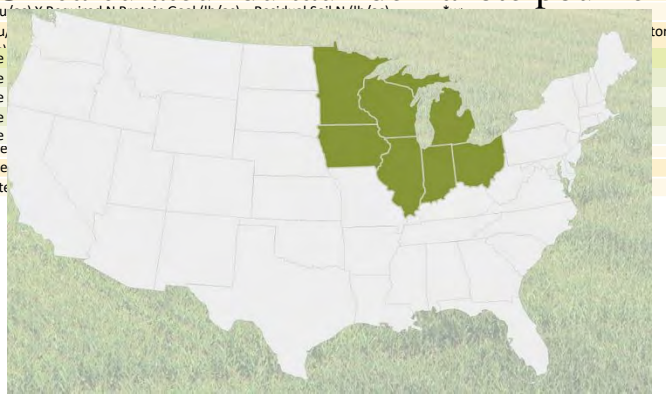
Analyse de l'azote (NO_3^-) du sol

L'azote résiduel dans le sol

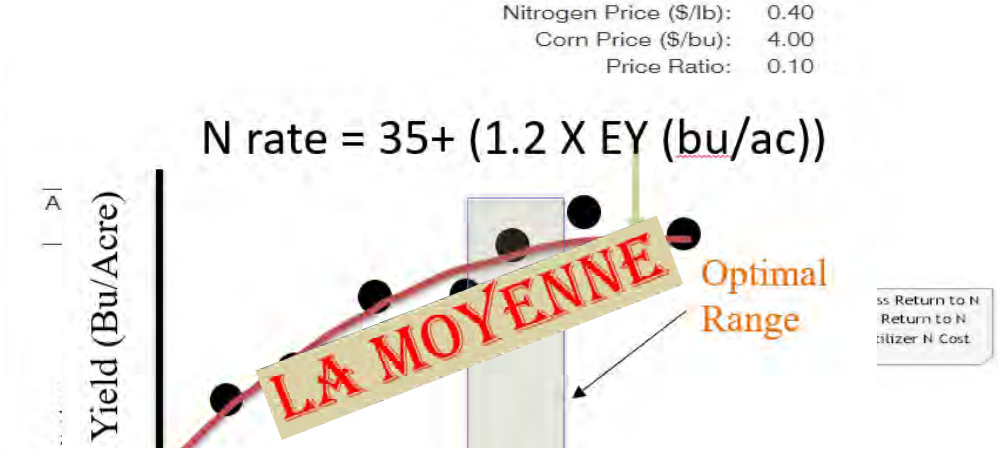
Des applications Web

L'etat	Le taux d'azote recommandé
CO	35+ (1.2 X EY (bu/ac)) – (8 X average ppm NO3 N in soil) – (.14 X EY (bu/ac) X %OM)- other N credits
KS	(1.6X YG (bu/ac))-(%OM X 20) - Priofile N - Legume N- other N Credit
OH	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
IN	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
MI	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
MO	Fertilizer N recommendation (lbs/ac) - preplant N test credits (lbs/ac)
MT	N Fertilizer YG Recommendation (lbs/ac) - PSNT NO_3^- (lbs/ac) *Wheat
ND	Fertilizer N recommendation (lbs/ac)- Soil Nitrate Concentration (lbs/ac)- N Credits (lbs/ac)
NE	35+ [1.2X EY (bu/ac) - (0.14 X average ppm NO3-N in soil X 2) X EY (bu/ac) X %OM] - other N credits
OR	YG (bu/ac) X Required N Protein Goal (lb/ac) - Residual Soil N (lb/ac) *
PA	EY (bu/ac) X Factor (lb/ac)) X Soil Nitrate
IA	N Rate
WI	N Rate
MN	N Rate
IL	N Rate
ND	N Rate
MN	N Rate
IL	N Rate
ND	N Rate

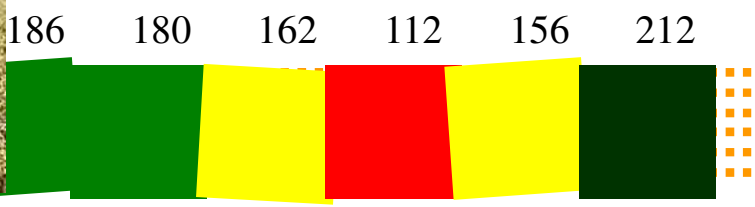
Un calculateur du taux de l'azote pour le maïs



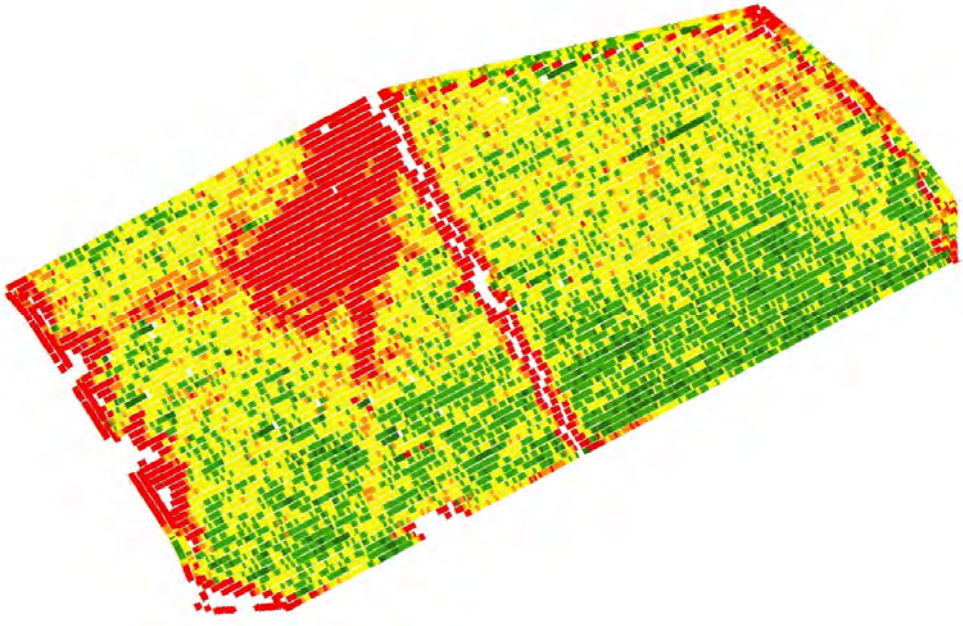
Des applications Web

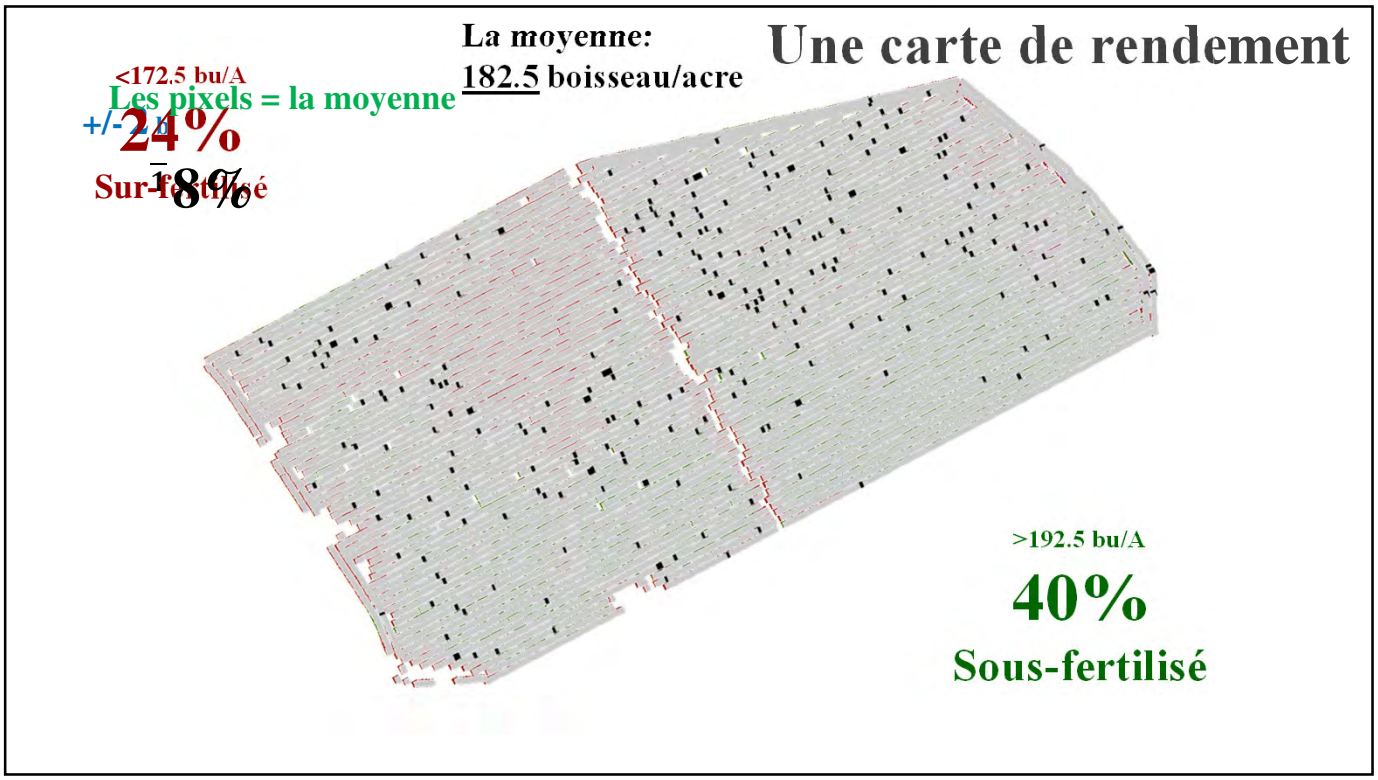


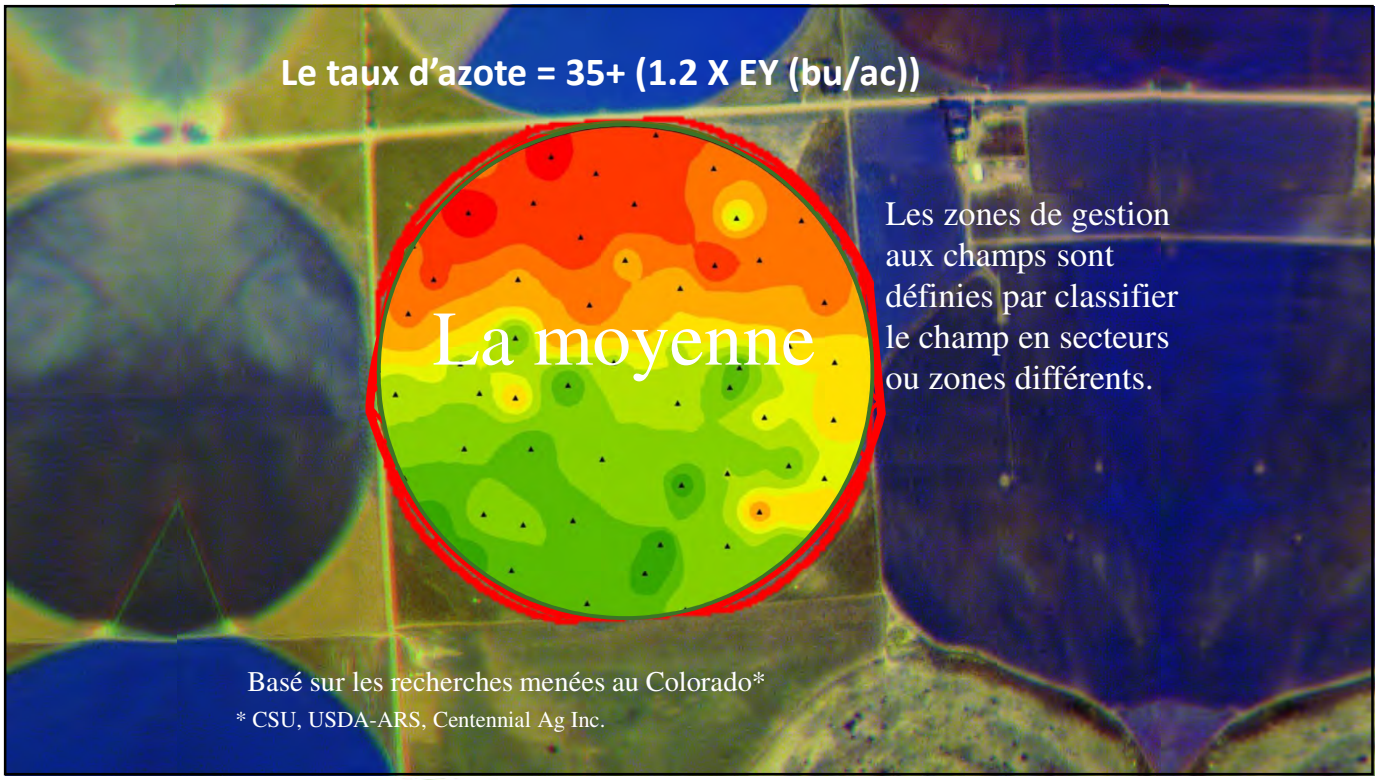
Connaissez-vous des gens qui gèrent encore par la moyenne (de rendement)



Une carte de rendement



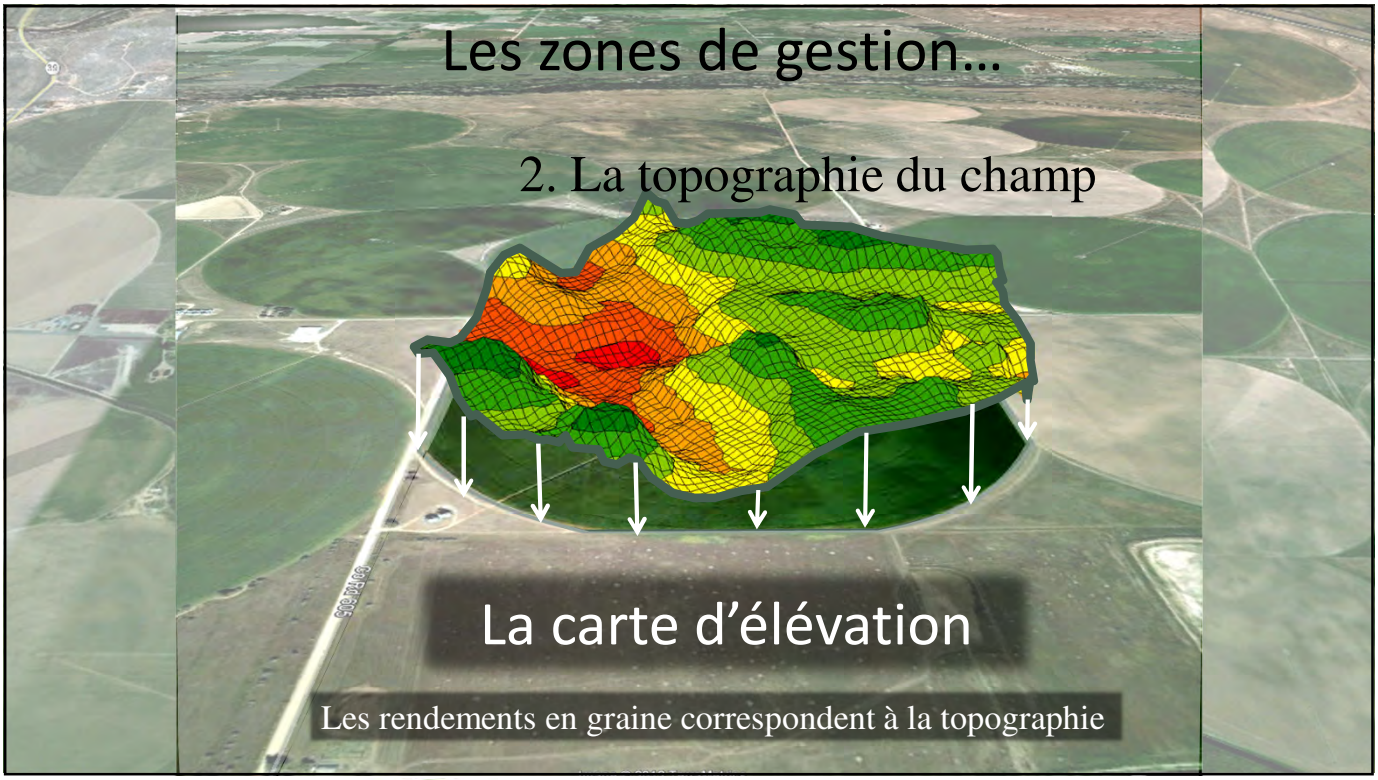

Une carte de rendement
La moyenne:
182.5 boisseau/acre
<172.5 bu/A
Les pixels = la moyenne
+/- 2.5
24%
Sur-fertilisé
18%
>192.5 bu/A
40%
Sous-fertilisé

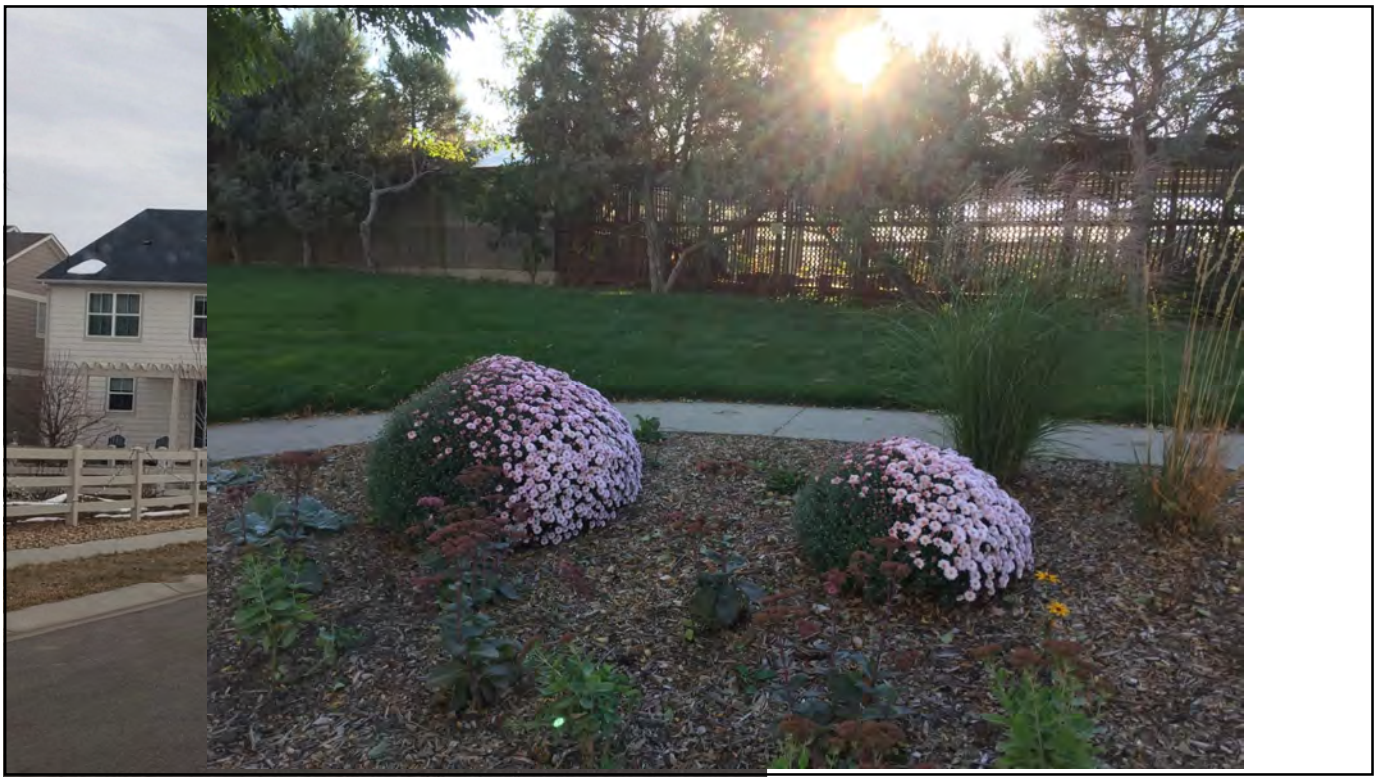

Le taux d'azote = 35+ (1.2 X EY (bu/ac))
La moyenne
Les zones de gestion aux champs sont définies par classifier le champ en secteurs ou zones différents.
Basé sur les recherches menées au Colorado*
* CSU, USDA-ARS, Centennial Ag Inc.

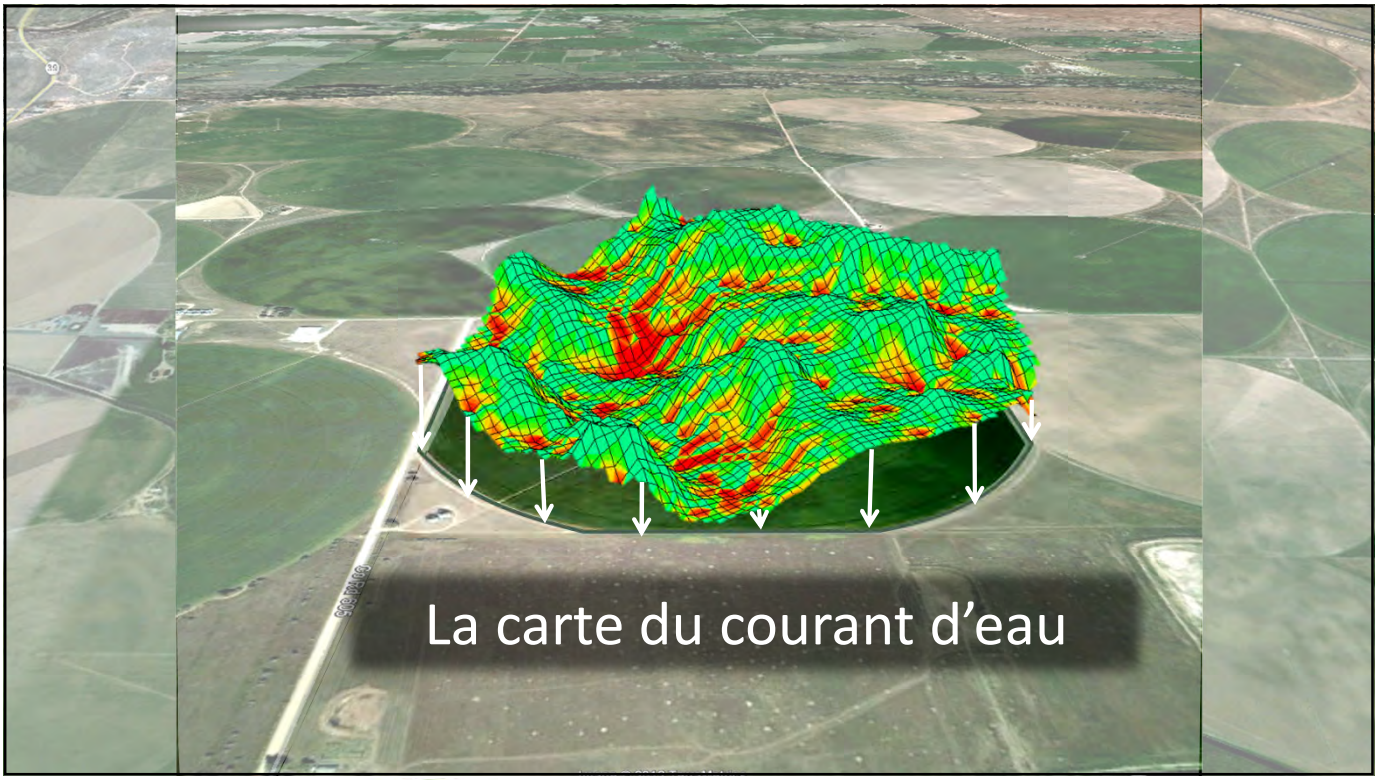
Les zones de gestion

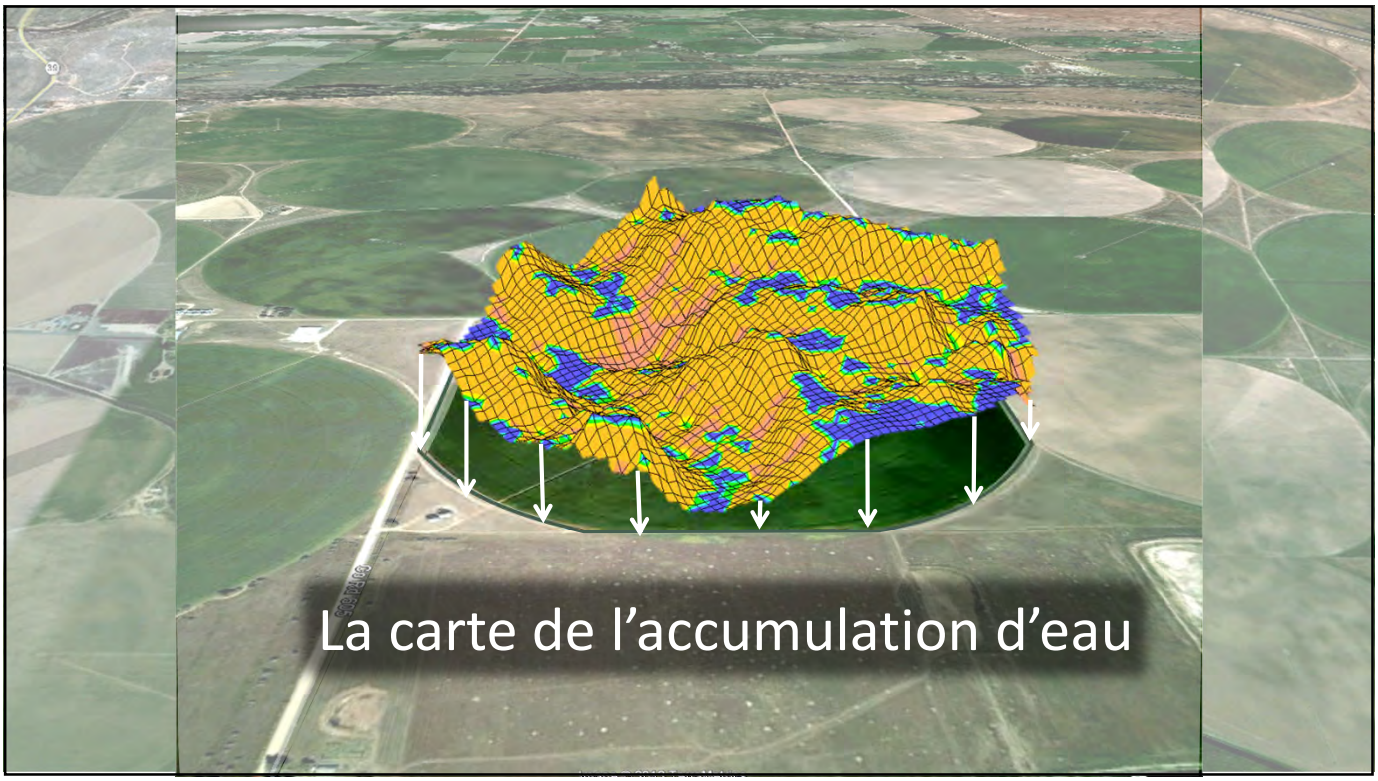
"Une sous-région du champ qui exprime une combinaison homogène des facteurs limitants du rendement"

Au Colorado, on a développé quatre techniques pour définir les zones de gestion


Les zones de gestion…
2. La topographie du champ
La carte d'élévation
Les rendements en graine correspondent à la topographie




La carte du courant d’eau


La carte de l'accumulation d'eau


Les zones de gestion…
3. L'expérience de l'ag
HIGH
LOW

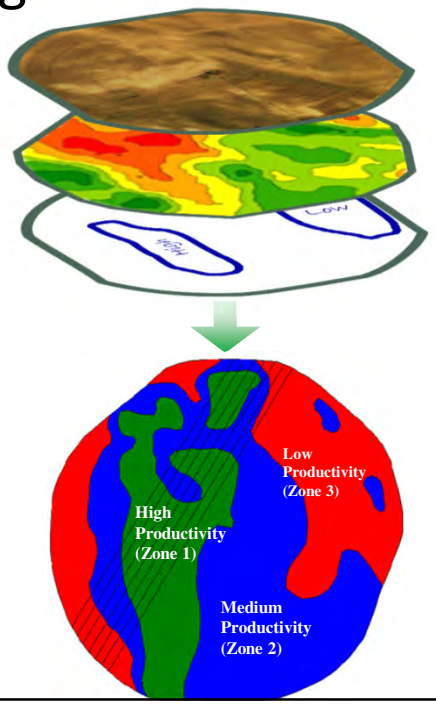
Les zones de gestion…

Les trois couches de données

- ✓ Les images aériennes
- ✓ La topographie
- ✓ L'expérience de l'agriculteur(trice)

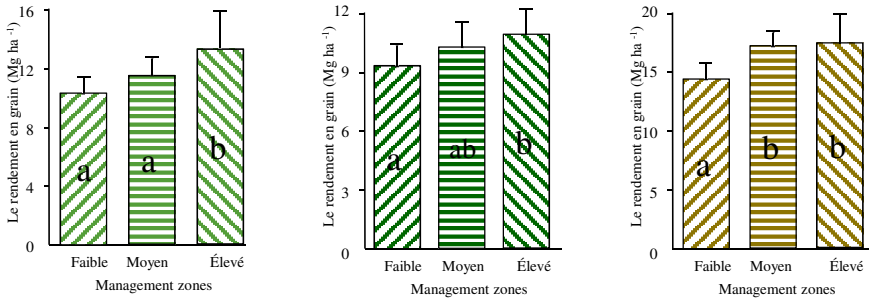
sont empilées (superposées) comme couches de SIG pour distinguer la zone

Des traits comme une couleur foncé, une basse topographie, et un rendement historiquement élevé permettent de désigner une zone potentiellement plus productive ou une zone élevée



Les zones de gestion…

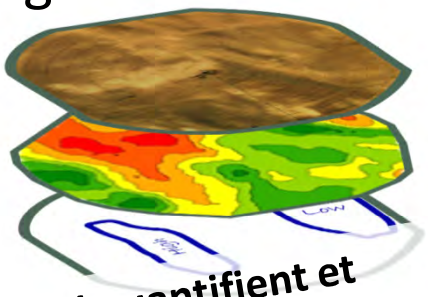
La moyenne de rendement en grain à travers les zones de gestion



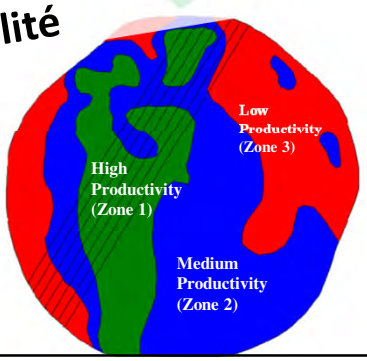
Up to 46% reduction in N loadings without impairing grain yields

Source: Koch, Khosla, et al. 2004

Les zones de gestion…



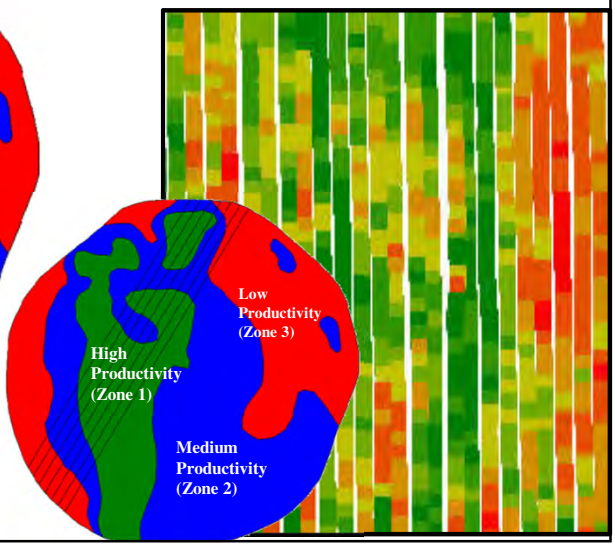
Les zones basées sur le sol quantifient et gèrent la macro-variabilité



Gestion basée sur le sol

Macrovariabilité

Microvariabilité

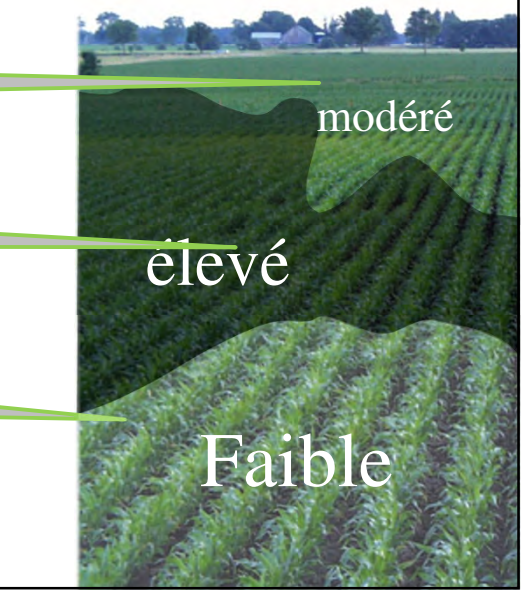


Associer les zones de gestion aux détecteurs proximaux

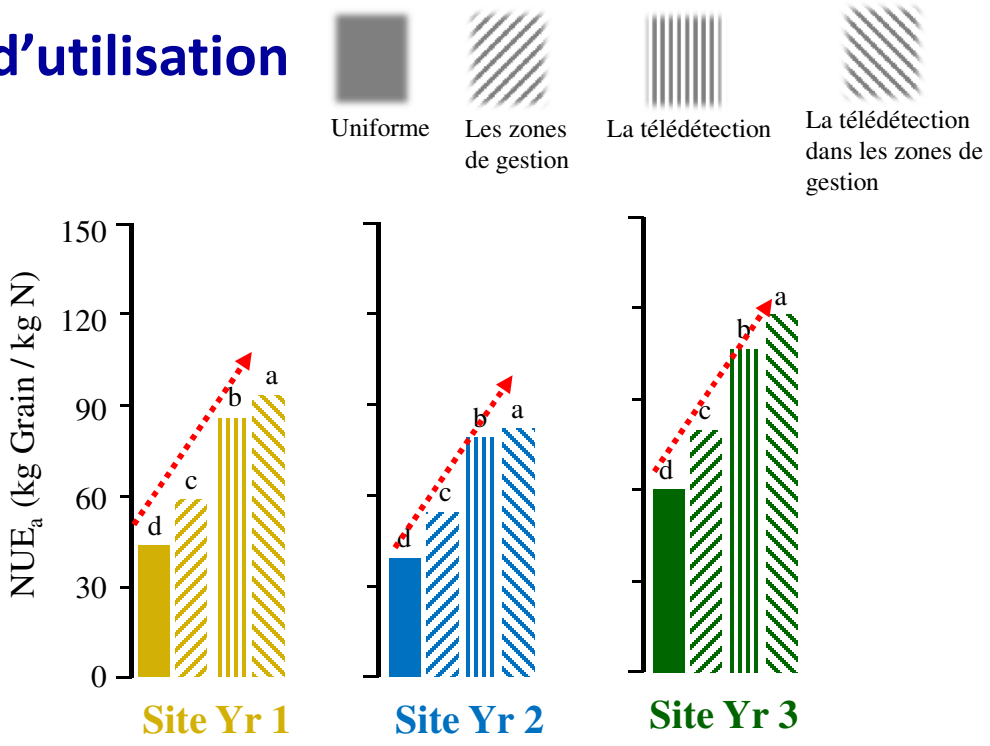
Le taux d'azote (kg ha^{-1}) = (135.3 x (NDVI$_{Ref.}$ / NDVI$_{Target}$)^2) – (134.8 x (NDVI$_{Ref.}$ / NDVI$_{Target}$)) + 1

Associer les zones de gestion aux détecteurs proximaux

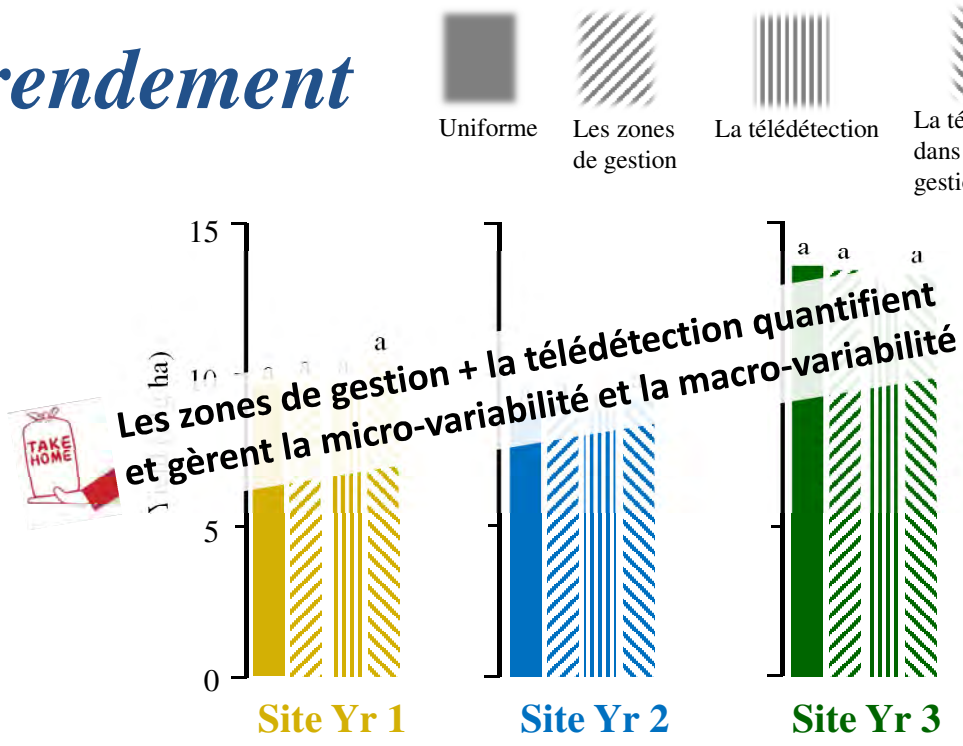
Le taux d'azote (kg ha^{-1}) = (135.3 x (NDVI$_{Ref.}$ / NDVI$_{Target}$)^2) – (134.8 x (NDVI$_{Ref.}$ / NDVI$_{Target}$)) + 1



L'efficacité d'utilisation de l'azote ?



Le rendement

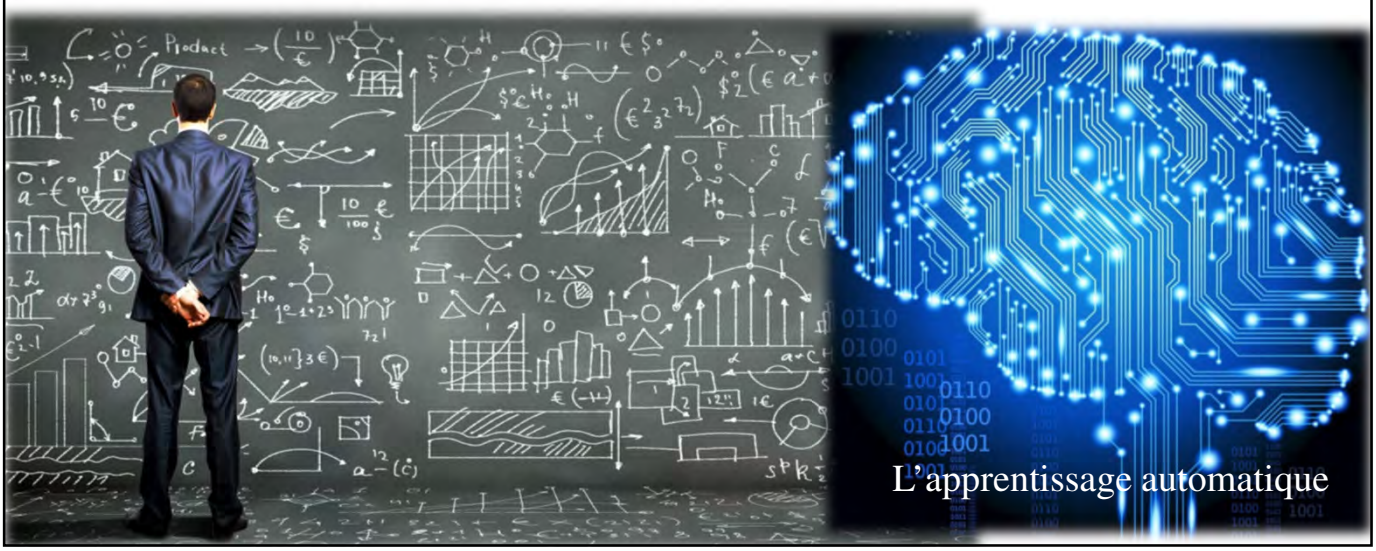


Les zones de gestion + la télédétection quantifient et gèrent la micro-variabilité et la macro-variabilité

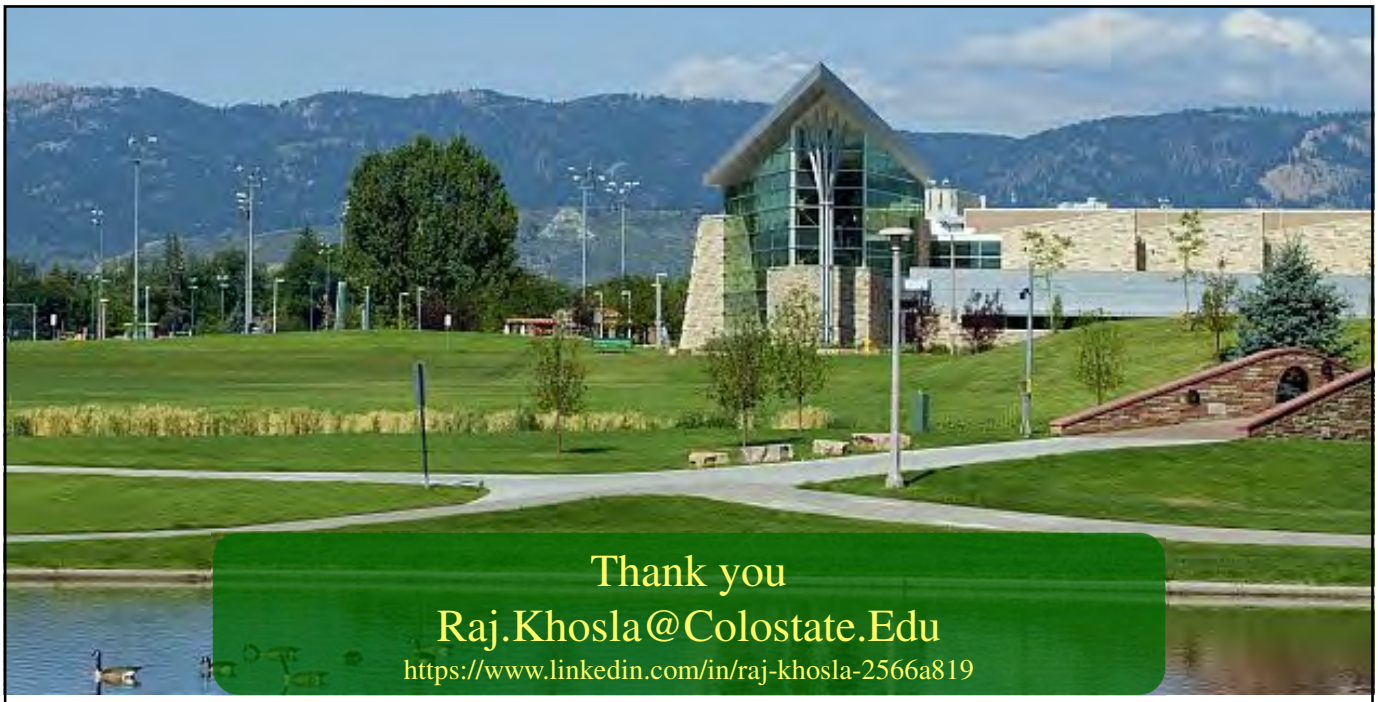
A Way Forward

La voie de l'avenir

Il y aura encore plus de modèles de sol et de la culture qui englobent plusieurs d'autres paramètres sensibles



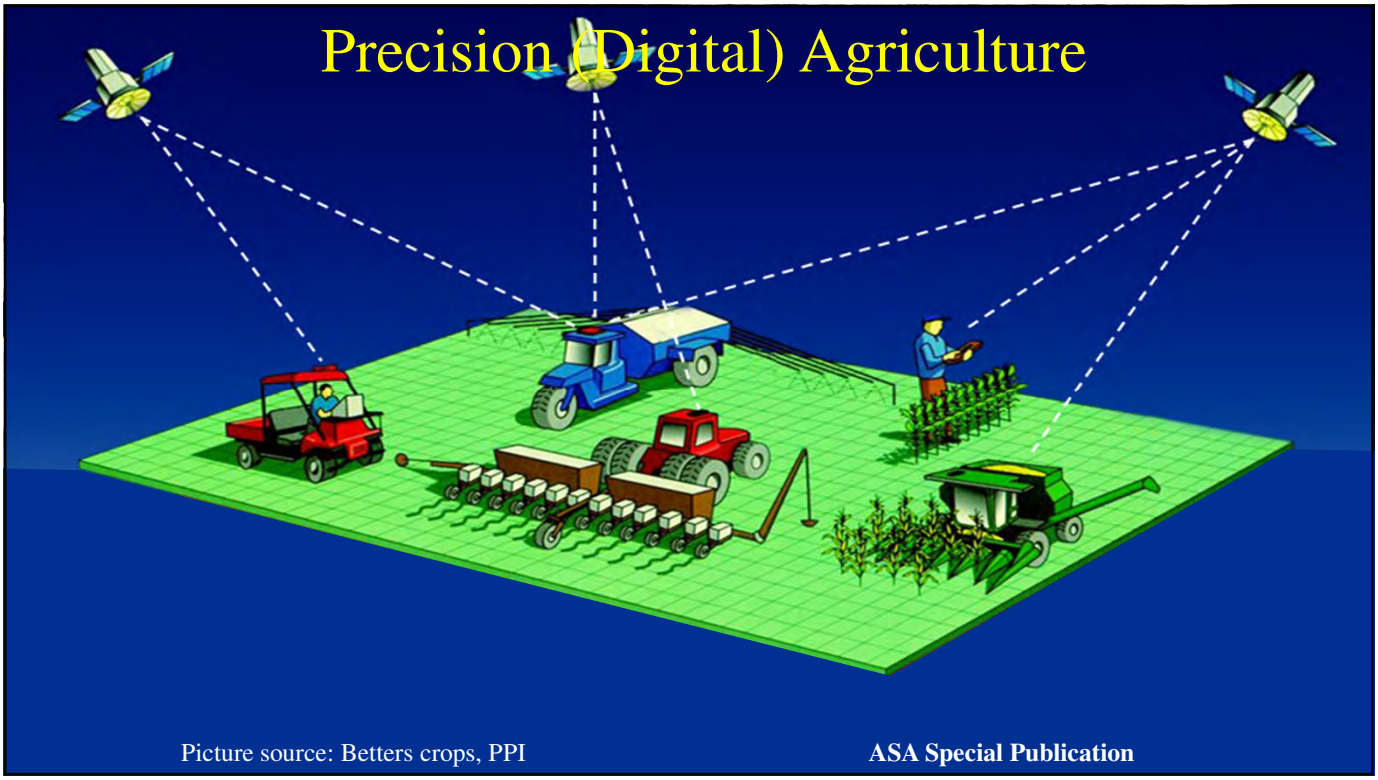
L'apprentissage automatique


Thank you
Raj.Khosla@Colostate.Edu
https://www.linkedin.com/in/raj-khosla-2566a819

Precision Nitrogen Management: Past, Present, and the Future

Prof. Raj Khosla
Colorado State University
Robert E. Gardner Professor of Precision Agriculture

Founder and Past President
International Society of Precision Agriculture

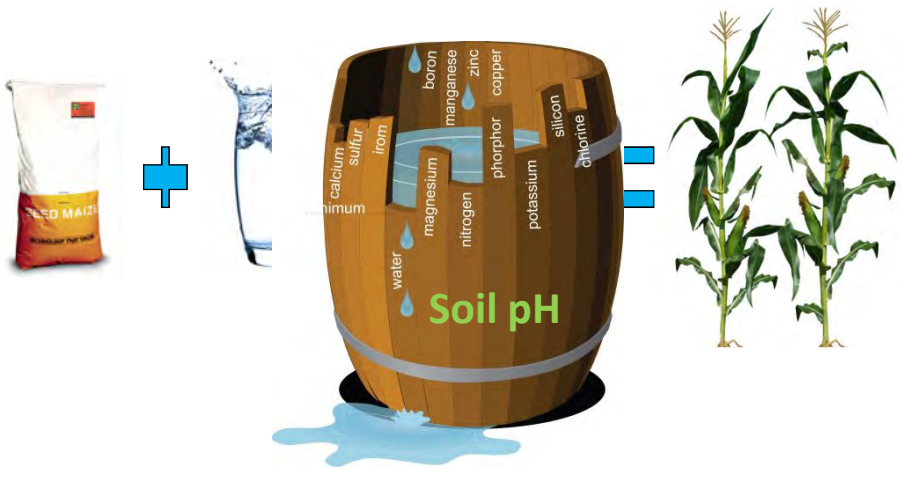


Picture source: Betters crops, PPI

ASA Special Publication

Precision (Digital) Agriculture…

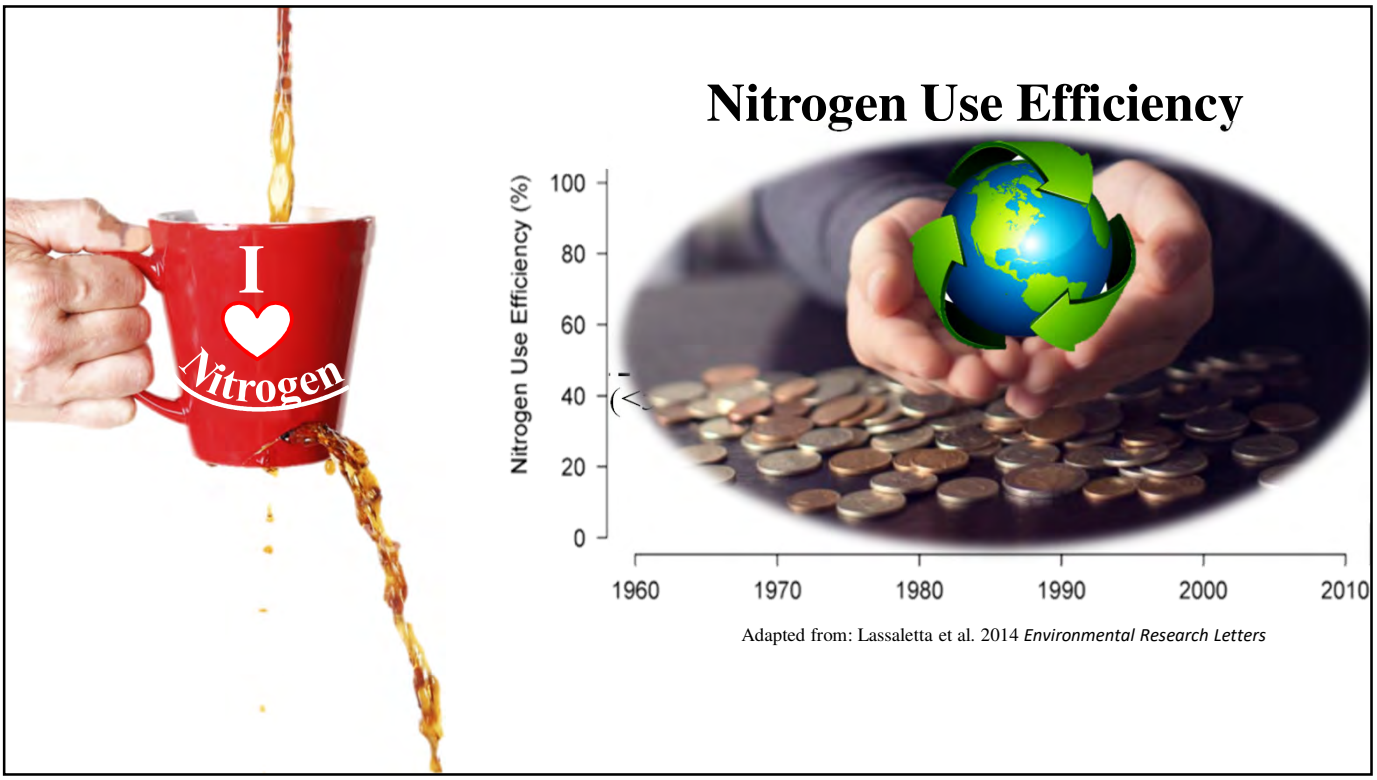
Basic agronomy



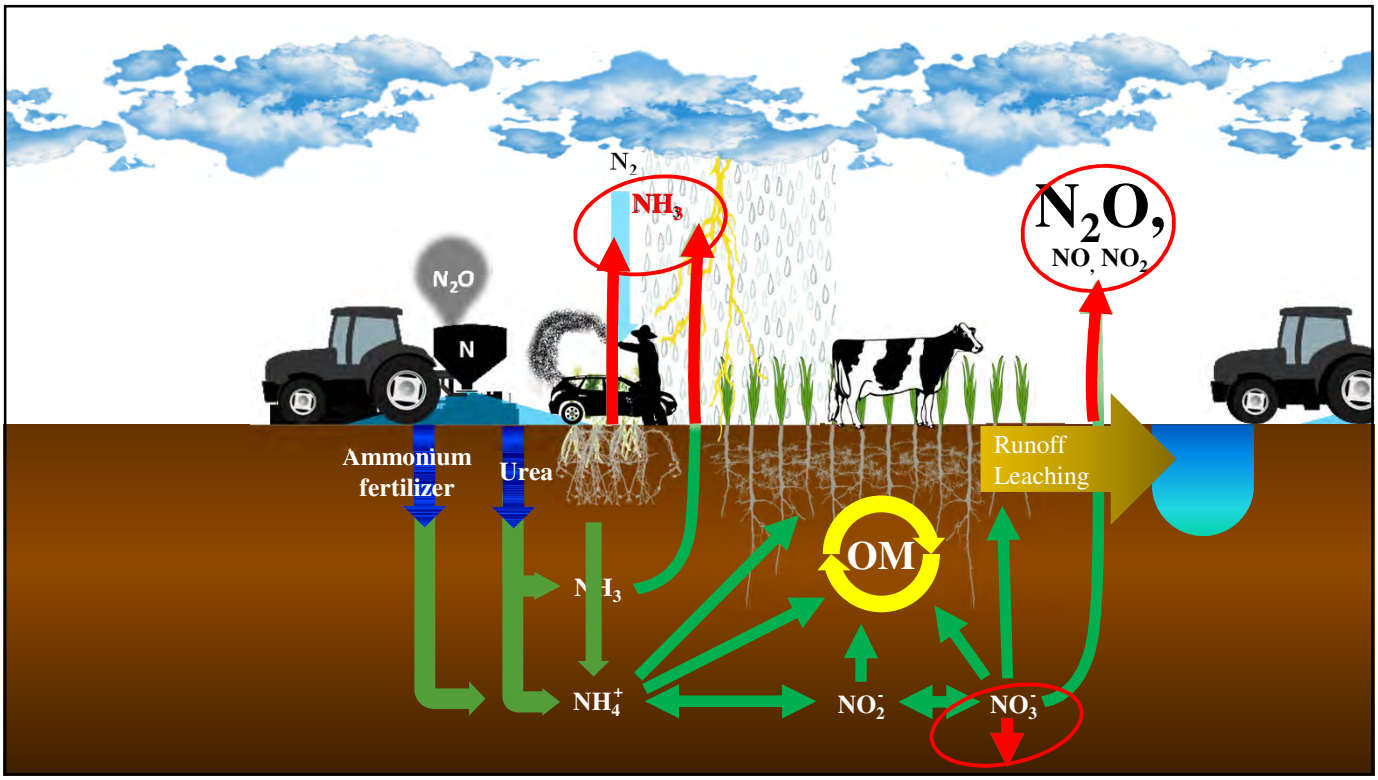
Law of limiting factors

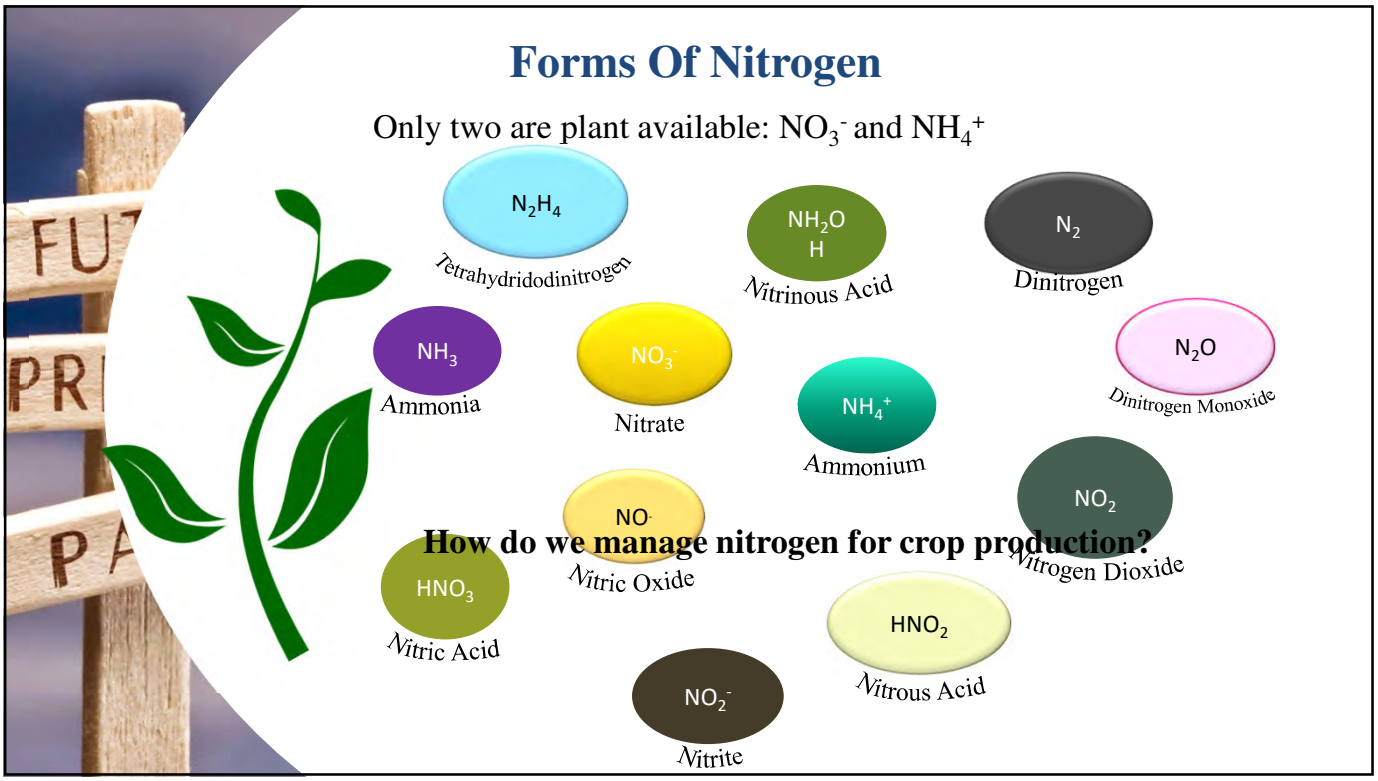

HABER-BOSCH PROCESS
Nitrogen
❖ Process fixing N in the air into ammonia
❖ One of the greatest inventions of the 20th century
❖ Responsible for half of today's world food
❖ Without it, 30-40% of population would not be alive

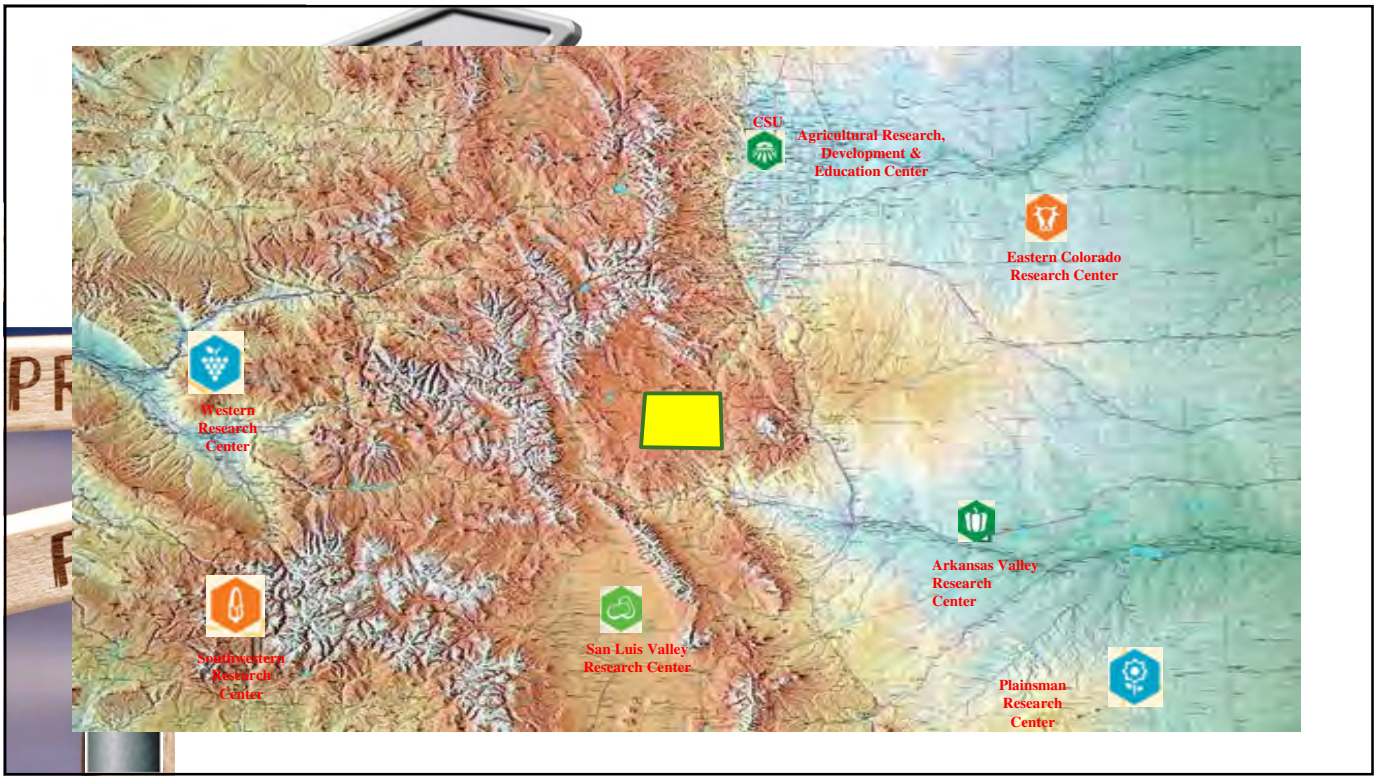

Nitrogen management



Adapted from: Lassaletta et al. 2014 *Environmental Research Letters*

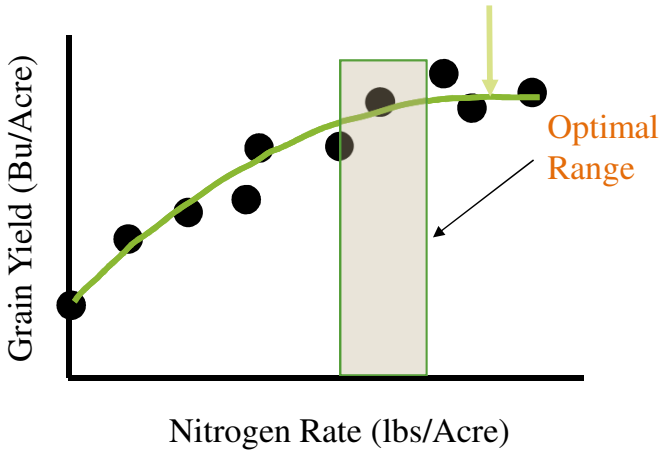



Forms Of Nitrogen
Only two are plant available: NO_3^- and NH_4^+
N_2H_4
Tetrahydridodinitrogen
NH_2OH
Nitrinous Acid
N_2
Dinitrogen
NH_3
Ammonia
NO_3^-
Nitrate
N_2O
Dinitrogen Monoxide
NH_4^+
Ammonium
NO
Nitric Oxide
NO_2
Nitrogen Dioxide
How do we manage nitrogen for crop production?
HNO_3
Nitric Acid
HNO_2
Nitrous Acid
NO_2^-
Nitrite


CSU
Agricultural Research, Development & Education Center
Eastern Colorado Research Center
Western Research Center
Arkansas Valley Research Center
San Luis Valley Research Center
Plainsman Research Center

Calculating the Optimal N Rate

N rate = 35+ (1.2 X EY (bu/ac))



N Management

N Rate Recommendation

N Management

State	N Rate Recommendation
CO	35+ (1.2 X EY (bu/ac)) – (.8 X Average ppm NO3 N in soil) – (.14 X EY (bu/ac) X %OM)- other N Credits

Estimated Yield (EY)

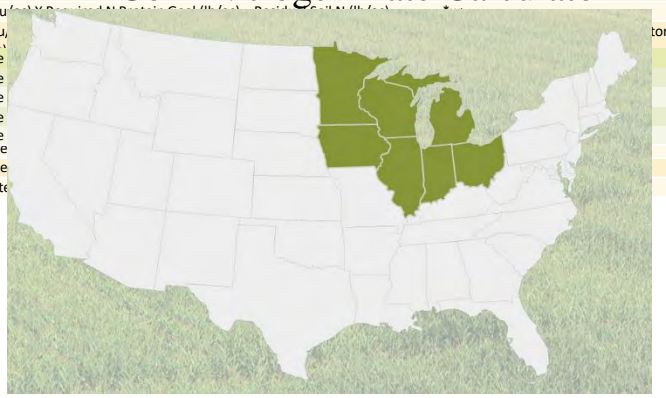
Soil N Test

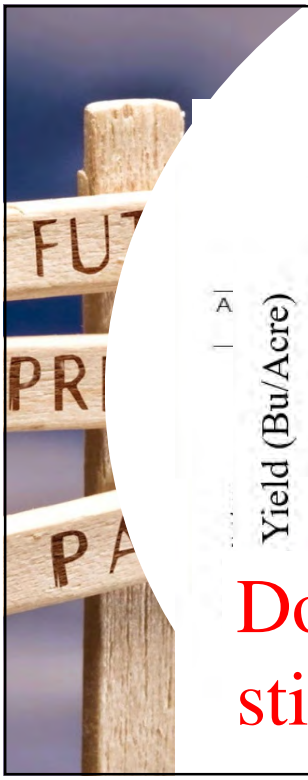
N Credits

Web Applications

State	N Rate Recommendation
CO	35+ (1.2 X EY (bu/ac)) – (8 X average ppm NO3 N in soil) – (.14 X EY (bu/ac) X %OM)- other N credits
KS	(1.6X YG (bu/ac))-(%OM X 20) - Priofile N - Legume N- other N Credit
OH	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
IN	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
MI	-27 + (1.36 X Yield Potential (bu/ac) -100) – N credit (lb/ac) or 110 + [1.36 X (Yield potential (bu/ac) -100)] – N credit (lb/ac)
MO	Fertilizer N recommendation (lbs/ac) - preplant N test credits (lbs/ac)
MT	N Fertilizer YG Recommendation (lbs/ac) - PSNT NO_3^- (lbs/ac) *Wheat
ND	Fertilizer N recommendation (lbs/ac)- Soil Nitrate Concentration (lbs/ac)- N Credits (lbs/ac)
NE	35+ [1.2 X EY (bu/ac)] – (8 X average ppm [illegible] X %OM)- other N credits
OR	YG (bu [illegible]
PA	EY (bu [illegible] tor (lb/ac)) X Soil Nitrate
IA	N Rate
WI	N Rate
MN	N Rate
IL	N Rate
ND	N Rate
MN	N Rate
IL	N Rate
ND	N Rate

Corn Nitrogen Rate Calculator

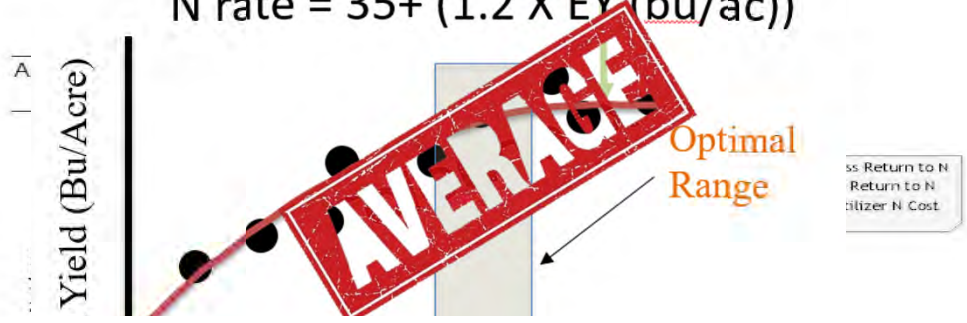




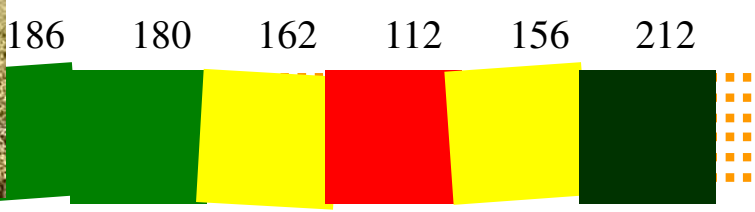
Web Application

Nitrogen Price ($/lb): 0.40
Corn Price ($/bu): 4.00
Price Ratio: 0.10

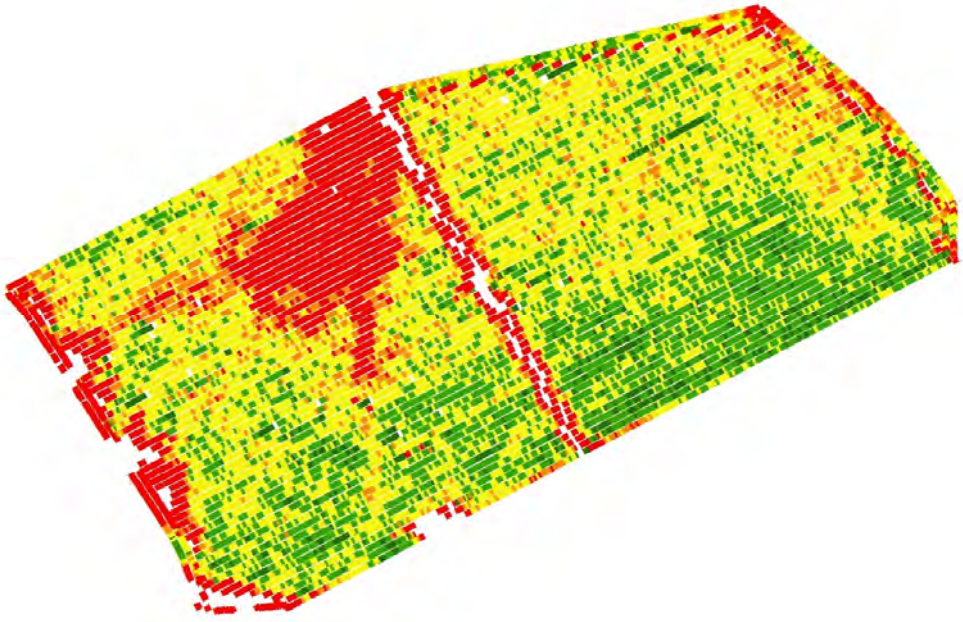
N rate = 35+ (1.2 X EY (bu/ac))

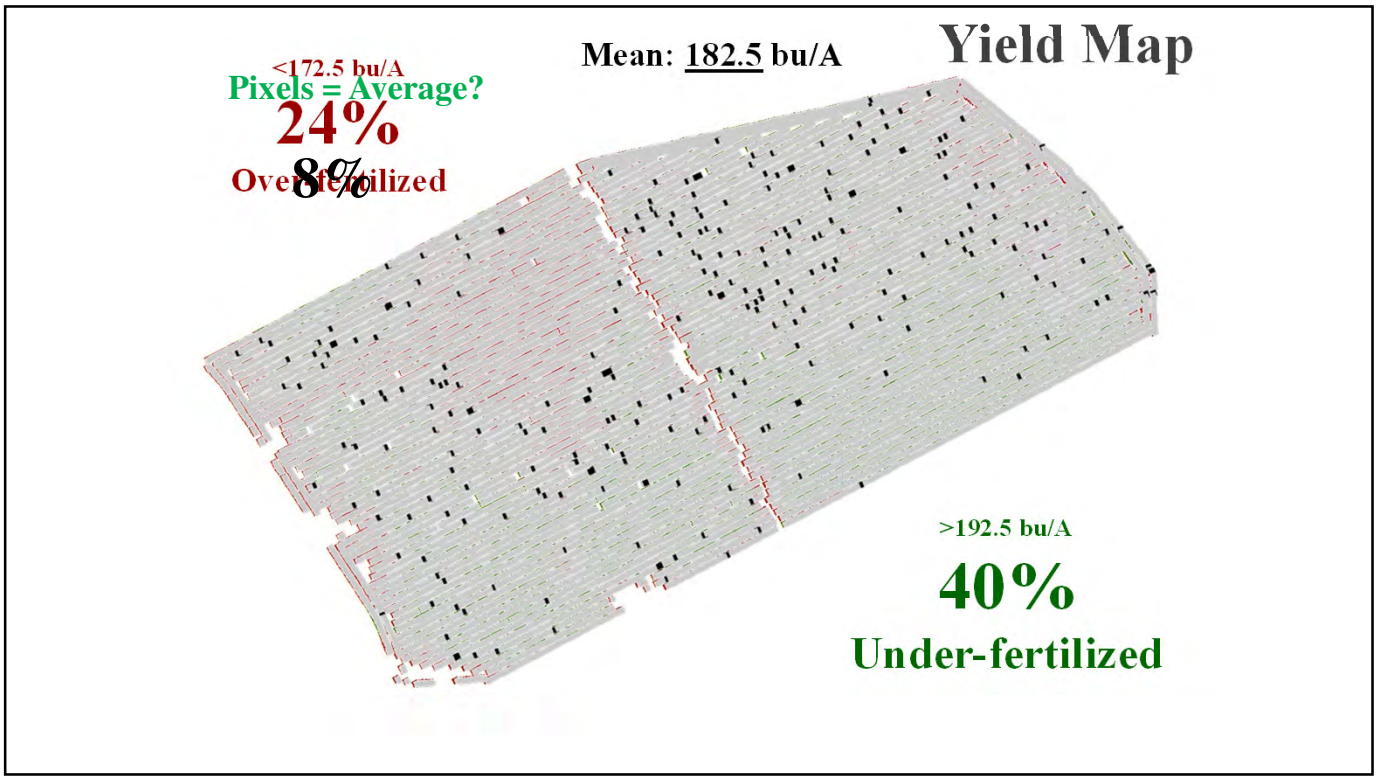


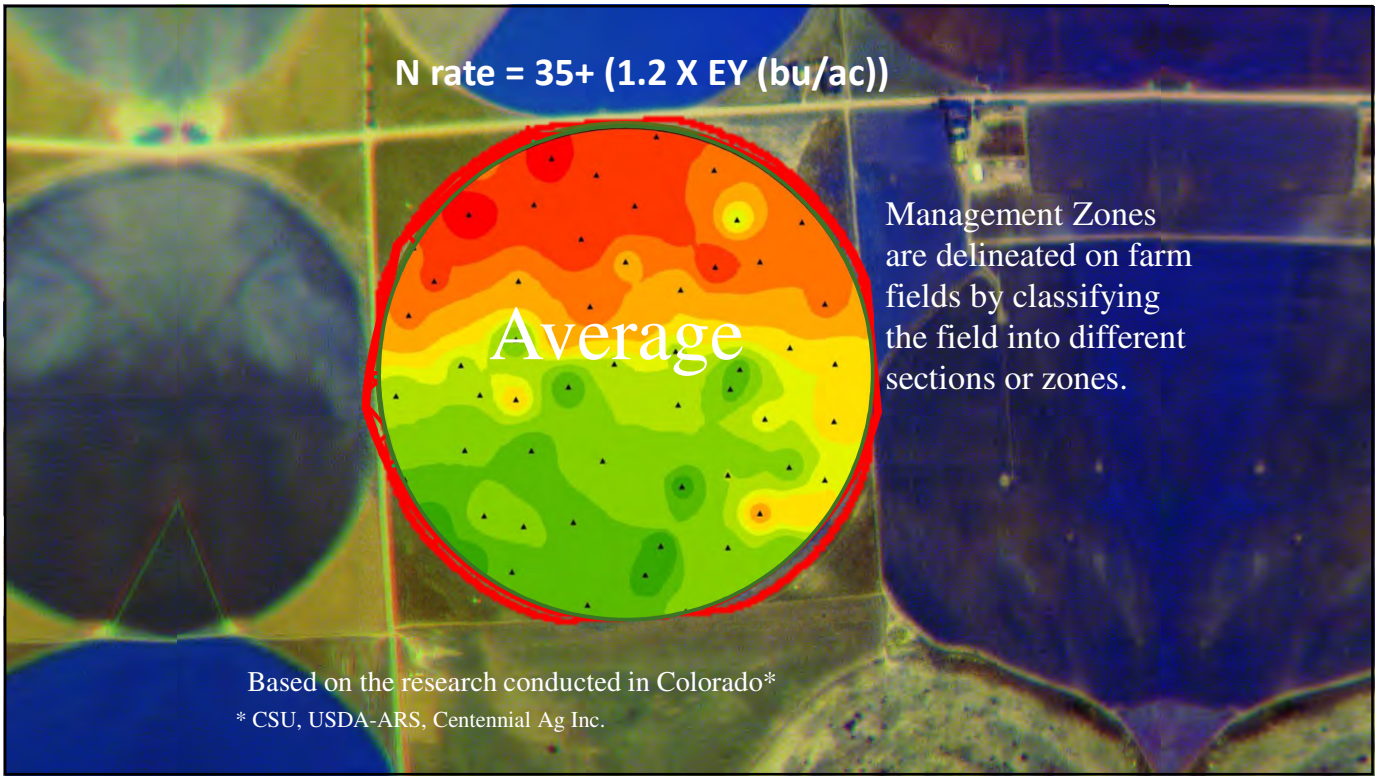
Do you know folks who are still managing the average?



Yield Map




Yield Map
Mean: 182.5 bu/A
<172.5 bu/A
Pixels = Average?
24%
8%
Over-fertilized
>192.5 bu/A
40%
Under-fertilized


N rate = 35+ (1.2 X EY (bu/ac))
Average
Management Zones are delineated on farm fields by classifying the field into different sections or zones.
Based on the research conducted in Colorado*
* CSU, USDA-ARS, Centennial Ag Inc.

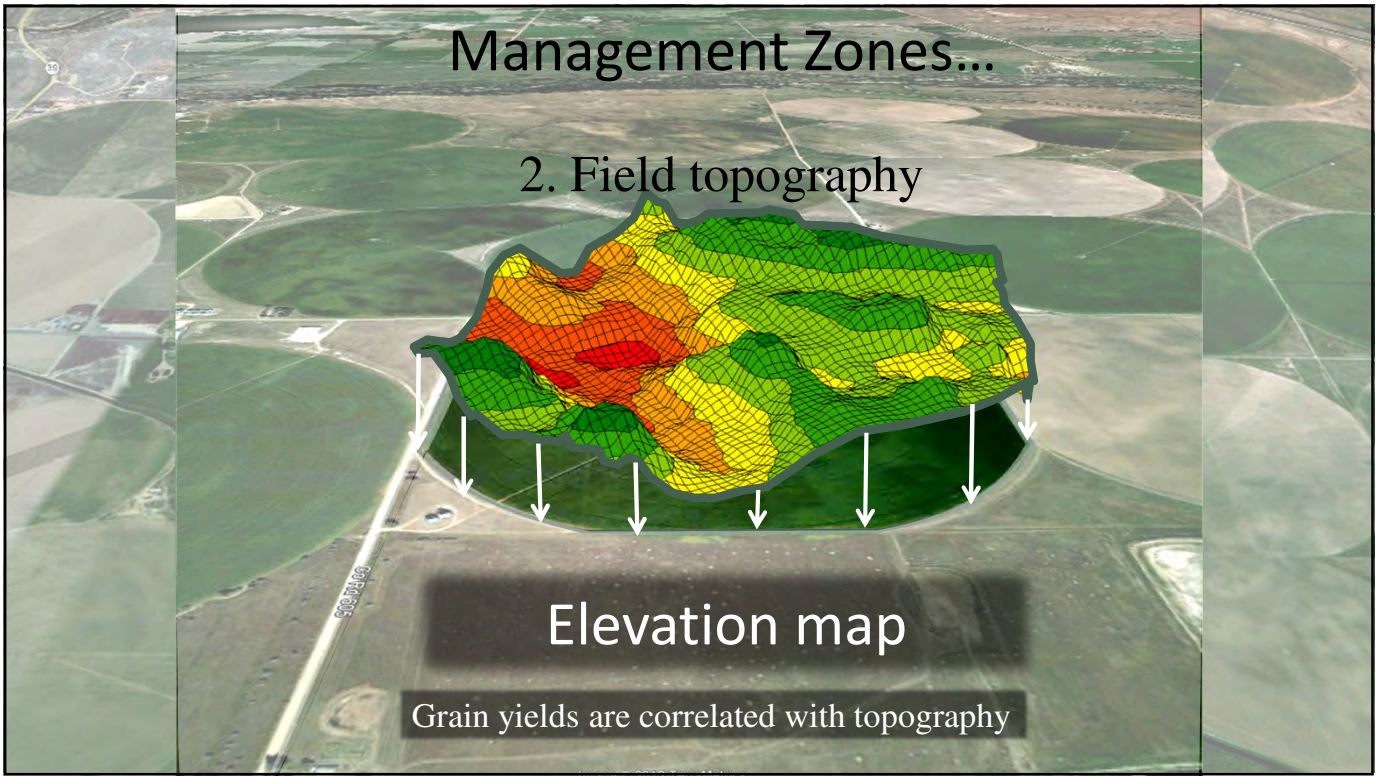
Management Zones

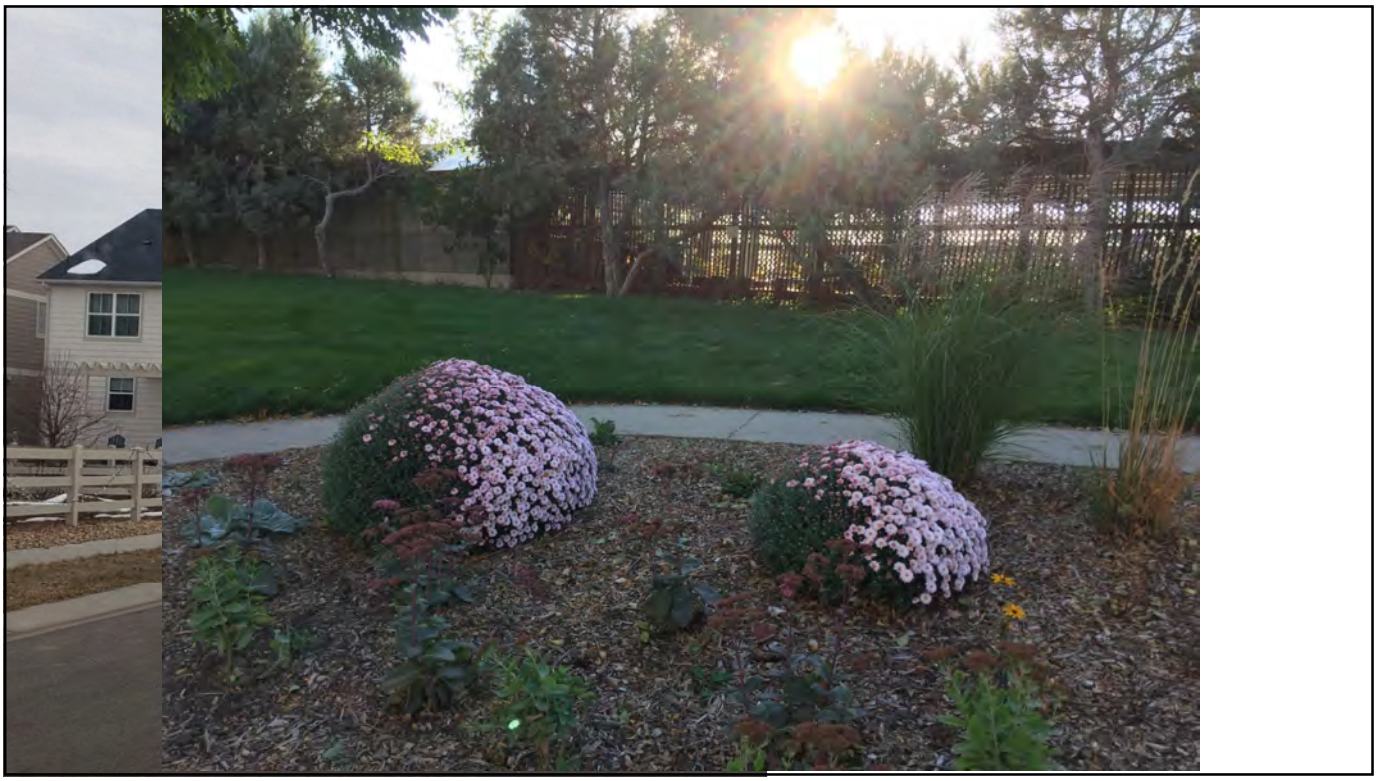
"A sub-region of a field that expresses a homogeneous combination of yield limiting factors"

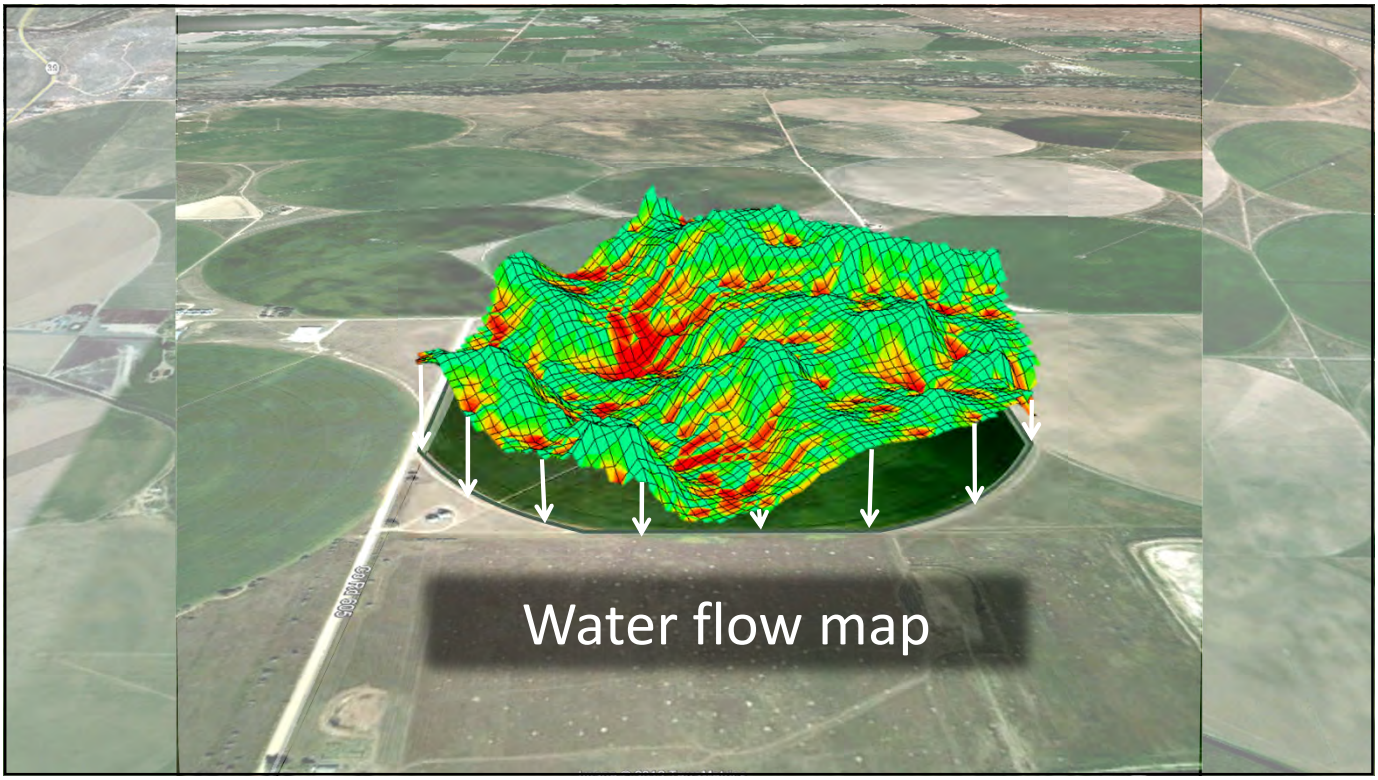
In Colorado, we have developed four techniques of delineating management zones

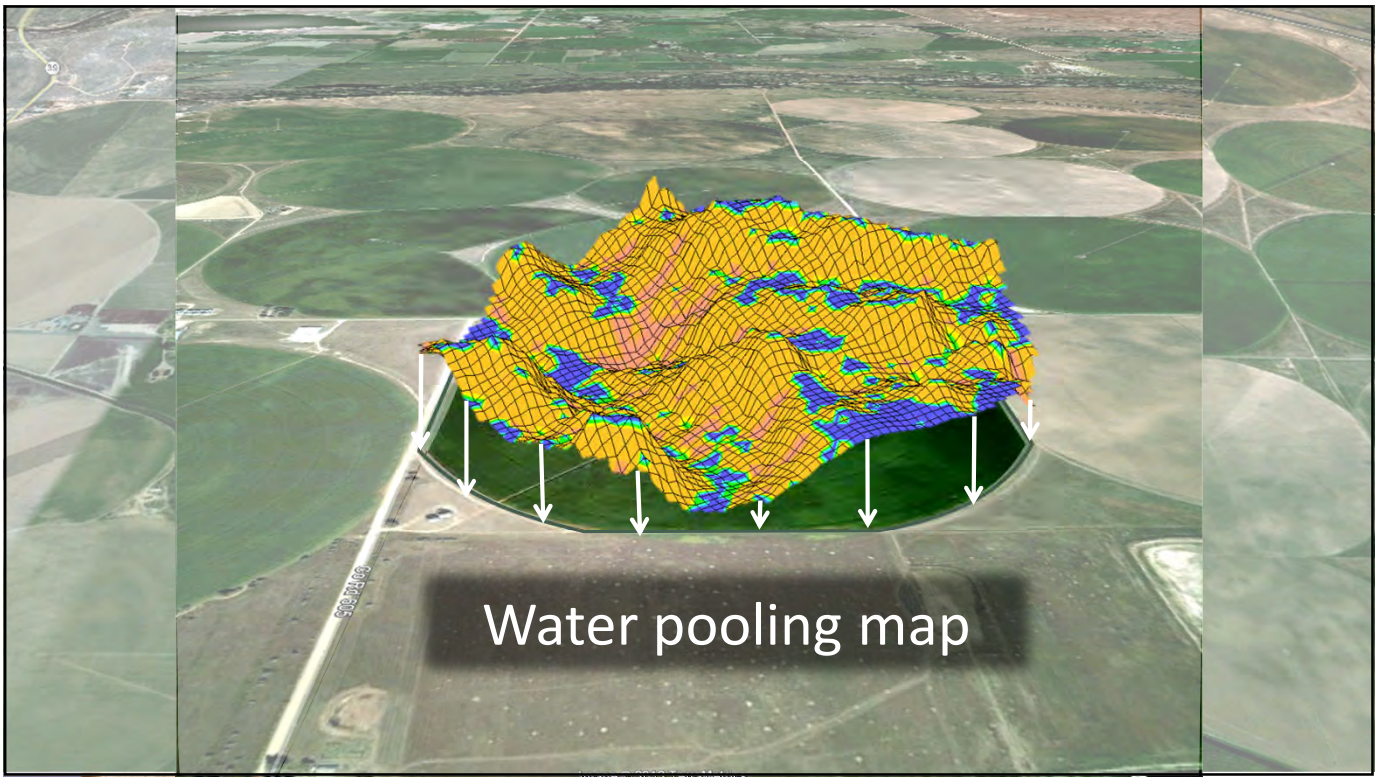
USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

NASA


Management Zones…
2. Field topography
Elevation map
Grain yields are correlated with topography




Water flow map


Water pooling map


Management Zones…
3. Farmer's experience
HIGH
LOW

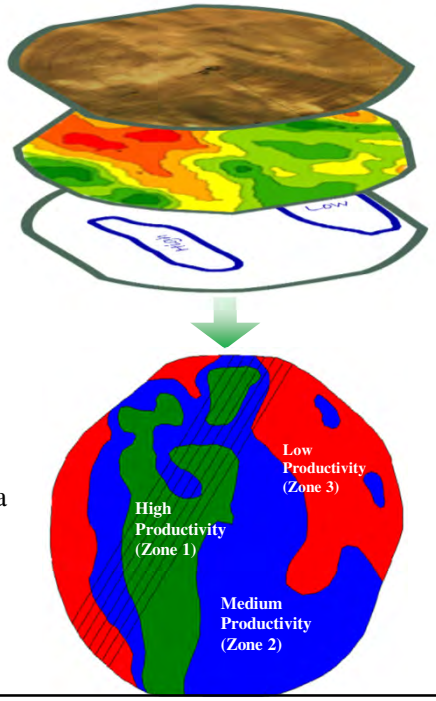
Management Zones…

The three data layers

- ✓ Aerial Imagery
- ✓ Topography
- ✓ Farmer's experience

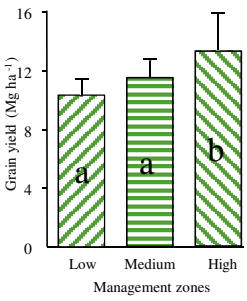
are stacked as GIS layers to delineate the zone

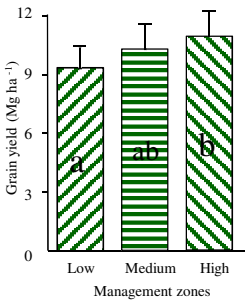
Traits such as dark color, low-lying topography, and historic high yields were designated as a zone of potentially high productivity or high zone

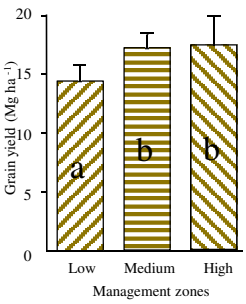


Management zones…

Mean grain yield across MZs

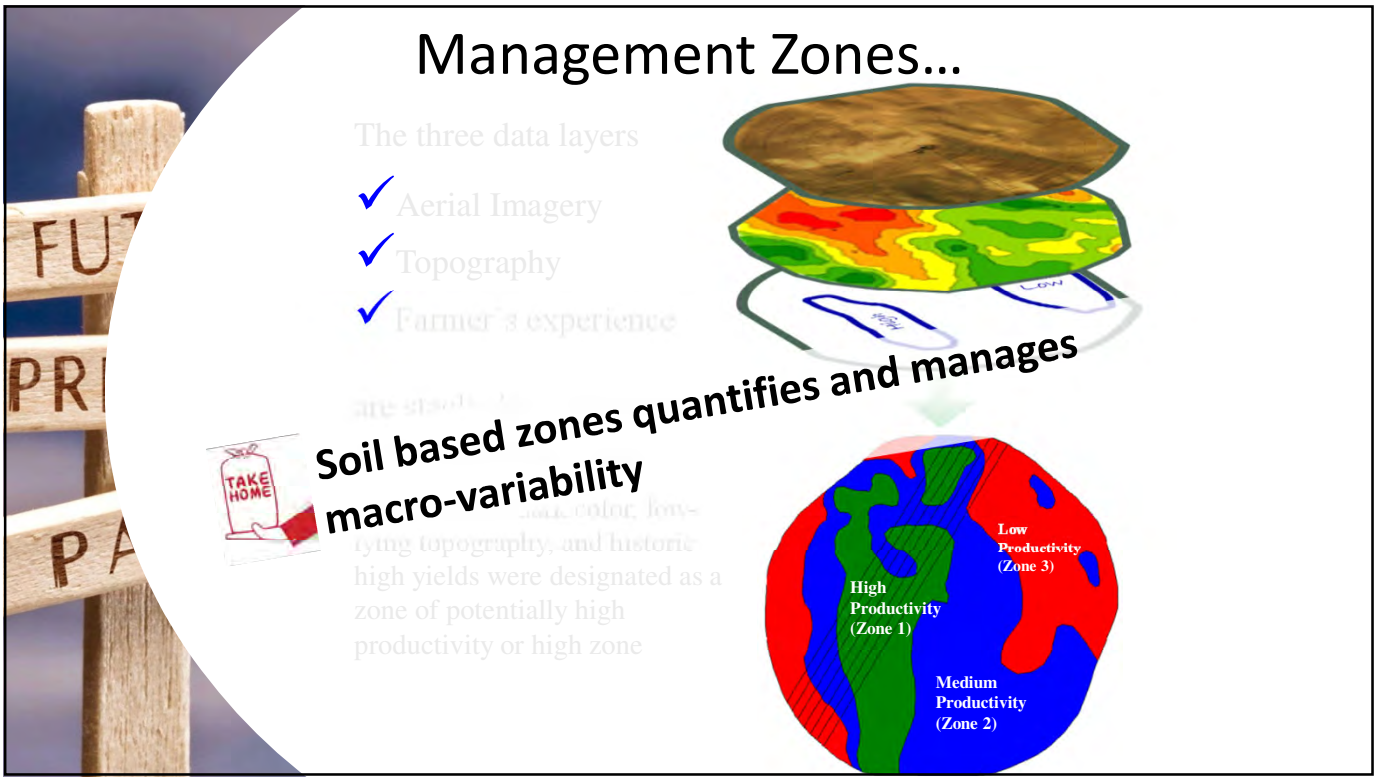


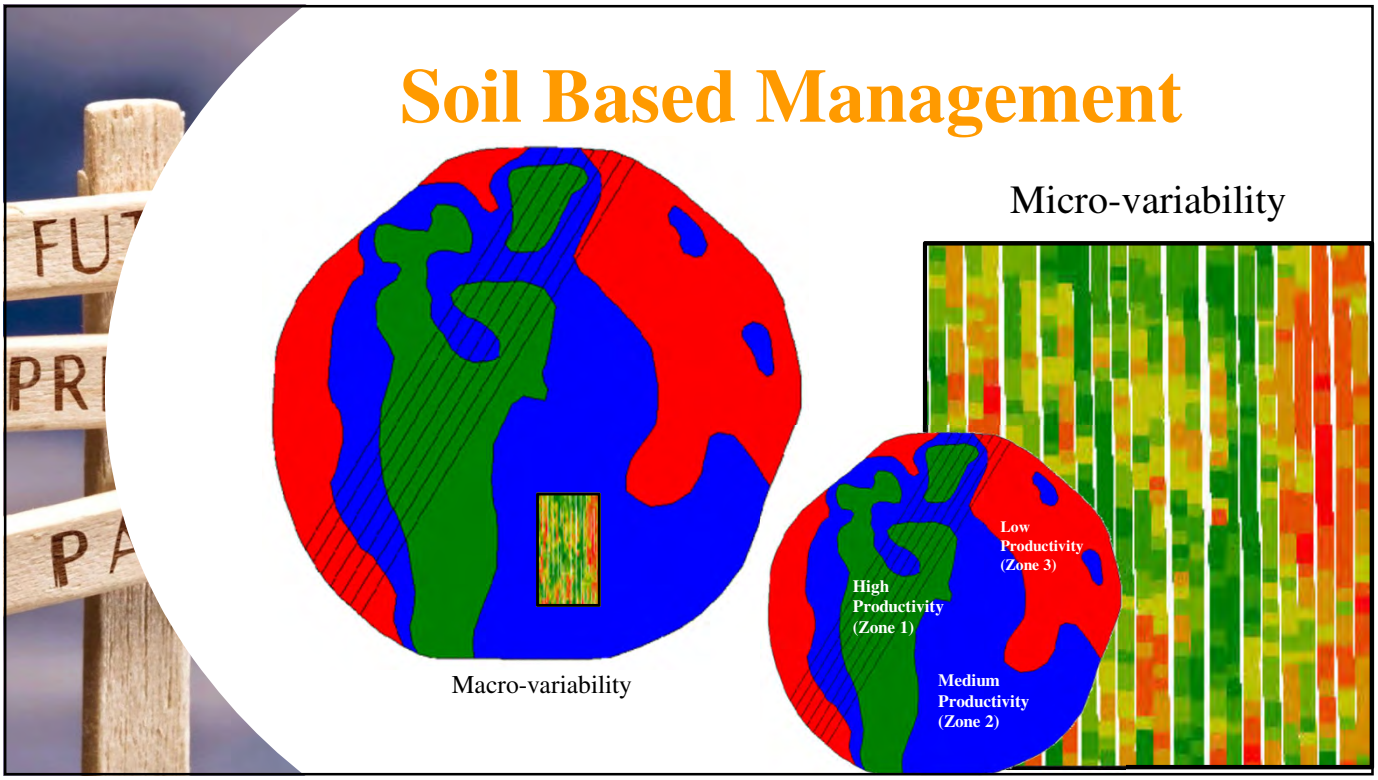




Up to 46% reduction in N loadings without impairing grain yields

Source: Koch, Khosla, et al. 2004


Management Zones…
The three data layers
✓ Aerial Imagery
✓ Topography
✓ Farmer's experience
Soil based zones quantifies and manages macro-variability
TAKE HOME
Low Productivity (Zone 3)
High Productivity (Zone 1)
Medium Productivity (Zone 2)


Soil Based Management
Micro-variability
Macro-variability
Low Productivity (Zone 3)
High Productivity (Zone 1)
Medium Productivity (Zone 2)

Proximal Sensing: Crop Based Management

$$\text{N Rate (kg ha}^{-1}) = (135.3 \times (NDVI_{Ref.} / NDVI_{Target})^2) - (134.8 \times (NDVI_{Ref.} / NDVI_{Target})) + 1$$

~96 lb/a — NDVI 0.41

~96 lb/a — NDVI 0.41

~96 lb/a — NDVI 0.41

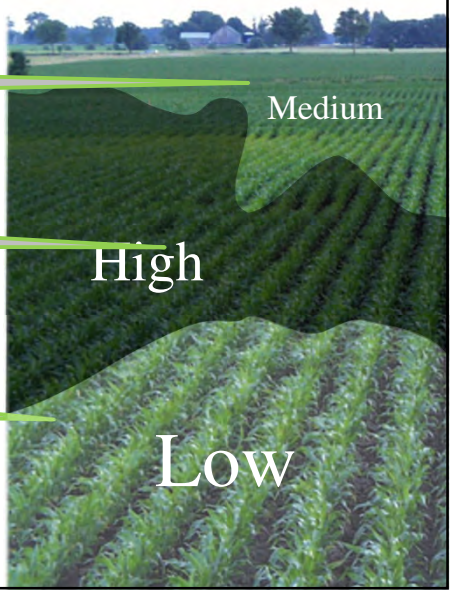
Proximal Sensing: Crop Based Management

$$\text{N Rate (kg ha}^{-1}) = (135.3 \times (NDVI_{Ref.} / NDVI_{Target})^2) - (134.8 \times (NDVI_{Ref.} / NDVI_{Target})) + 1$$

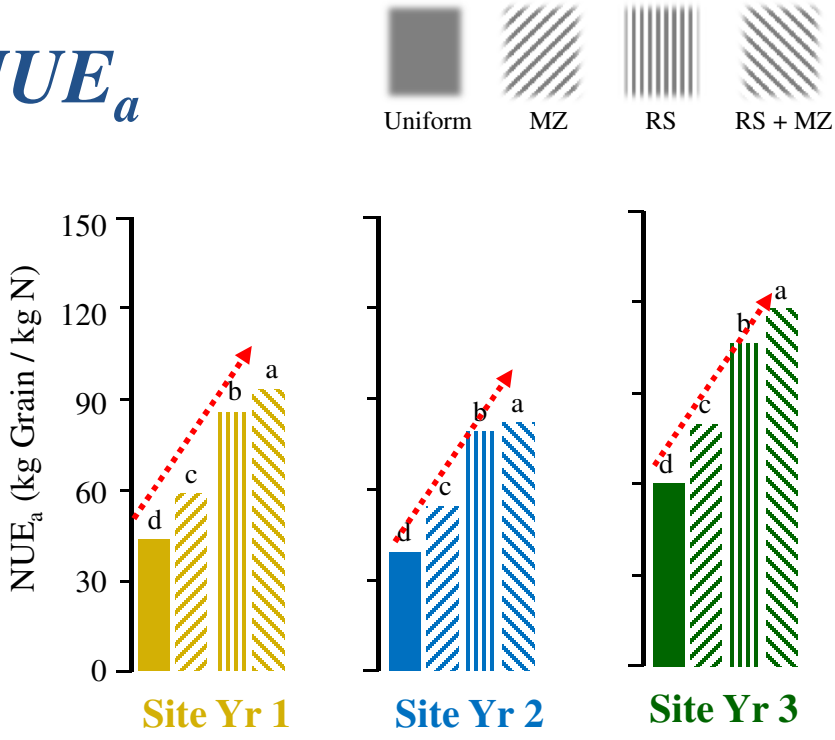
~92 lb/a — NDVI 0.41

~144 lb/a — NDVI 0.41

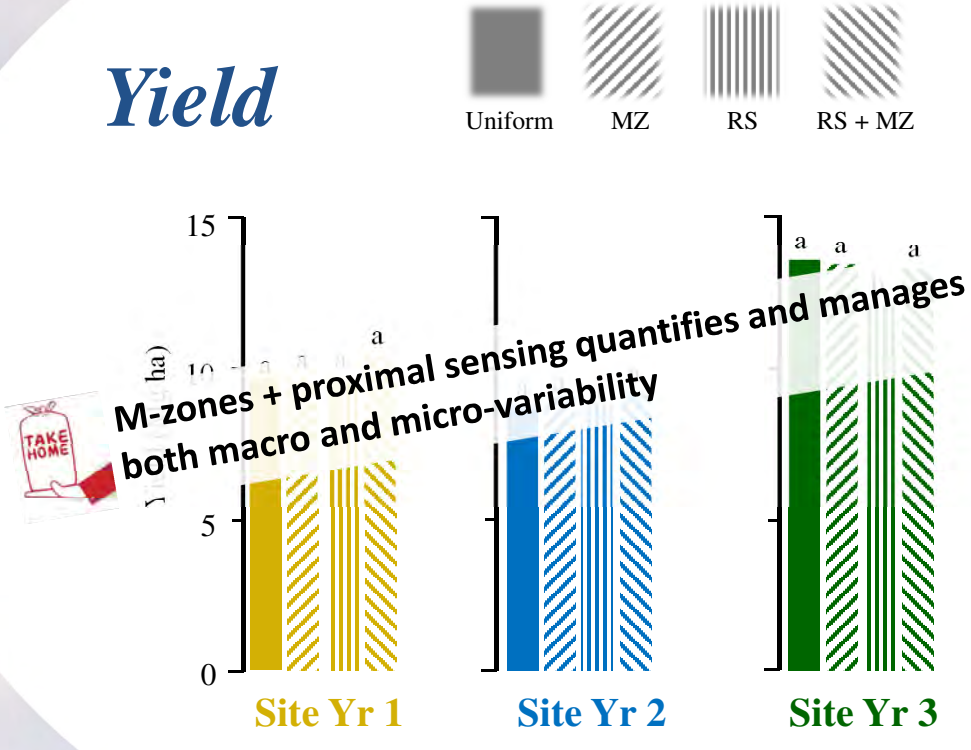
~37 lb/a — NDVI 0.41



NUE_a



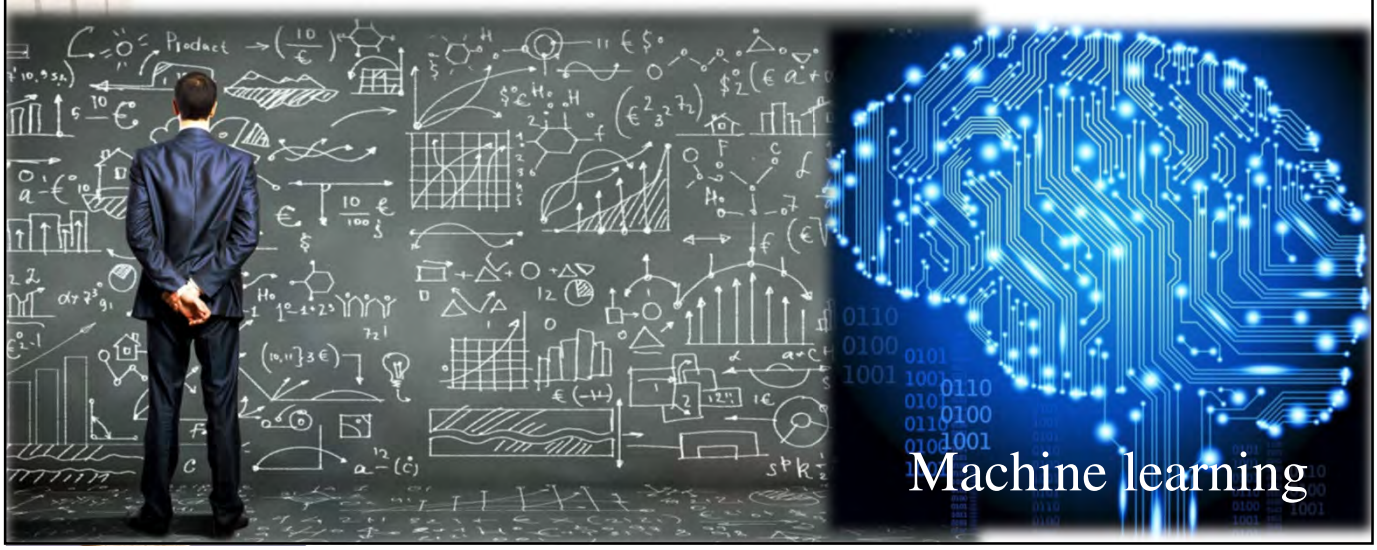
Yield

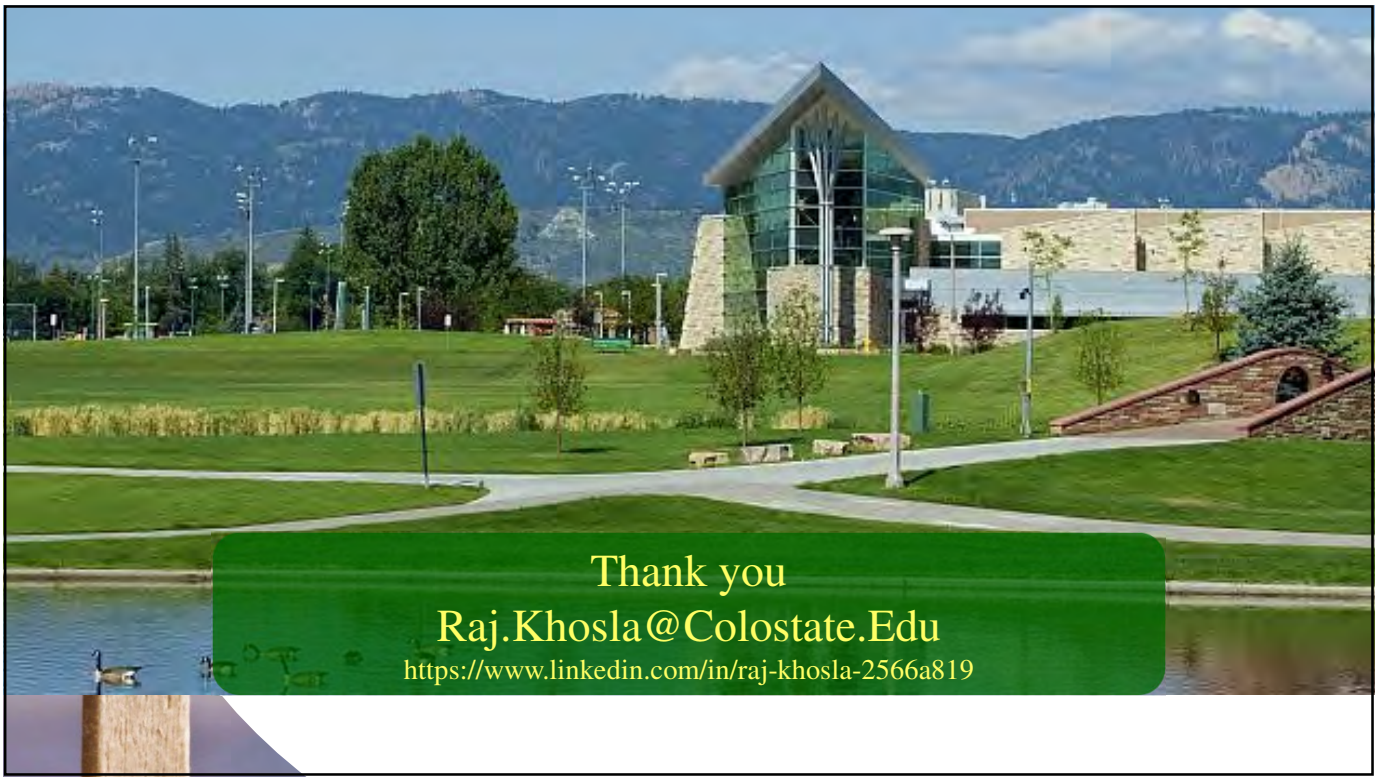


M-zones + proximal sensing quantifies and manages both macro and micro-variability

A Way Forward

There will be even more complex soil and crop models that encompass many other sensitive parameters




Thank you
Raj.Khosla@Colostate.Edu
https://www.linkedin.com/in/raj-khosla-2566a819