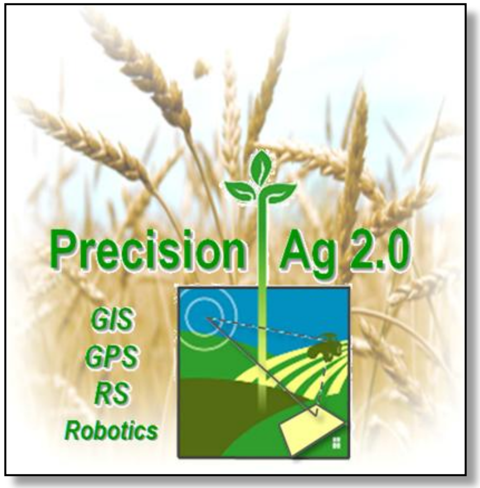
PRECISION AG 2.0 Conference

February 11-12, 2014 — Calgary, Alberta, Canada

Precision Agriculture's Bold New Era:

A Brief History, Current Expression and Radical New Directions



*…this presentation investigates the legacy of **Precision Ag's unique expression of Geotechnology**, its current challenges, and its probable future directions*

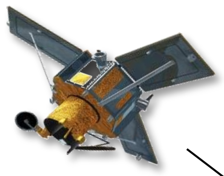
Plenary address by ***Joseph K. Berry***

W. M. Keck Visiting Scholar in Geosciences, Department of Geography, University of Denver
Adjunct Faculty, Warner College of Natural Resources, Colorado State University
Principal, Berry & Associates // Spatial Information Systems
*Email **jberry@innovativegis.com** — Website **www.innovativegis.com/basis/***

*(See **http://www.innovativegis.com/basis/present/PAconf_Calgary2014/** to access support materials including PowerPoint)*

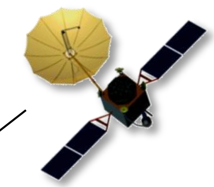
Geotechnology as a Mega-Technology

Geotechnology is one of the three "**mega -technologies**" for the 21st century and promises to <u>forever change how we conceptualize, utilize and visualize</u> spatial relationships in scientific research and commercial applications *(U.S. Department of Labor)*



Remote Sensing
(measure and classify)

Geographic Information Systems ***(map and analyze)***



Global Positioning System ***(location and navigation)***

GPS/GIS/RS

The Spatial Triad

Computer Mapping (70s)
Spatial Database Management (80s)

<u>Technological Tool</u>

Mapping *involves <u>precise placement</u> (delineation) of physical features*

(graphical inventory)

is

<u>Where</u> **<u>What</u>**

Descriptive Mapping

Prescriptive Modeling

<u>Why</u> **<u>So What</u>** and **<u>What If</u>**

Map Analysis (90s)
Multimedia Mapping (00s)

<u>Analytical Tool</u>

Modeling *involves <u>analysis</u> of spatial patterns and relationships*

(map analysis/modeling)

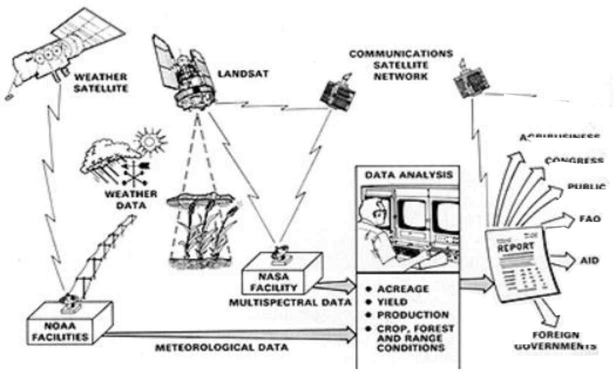
(Berry)

Historical Setting and Evolution of Precision Ag

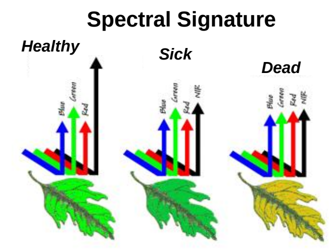
***Precision Agriculture** is a "site-specific management" technology that <u>measures and responds to the spatial and temporal intra-field variations</u> for maximizing crop production while preserving resources.*

*PA's development is closely aligned with **Geotechnology*** *(RS, GIS, GPS)* *and **Robotics*** *(intelligent implements).*

Computer Mapping *(70s **Where**)*

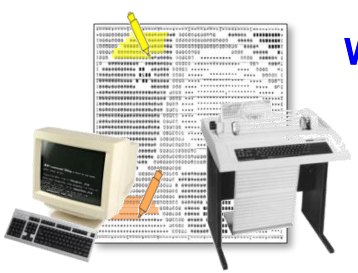


"Automated Image Analysis"



The **Large Area Crop Inventory Experiment (LACIE)** was the first large scale remote sensing project in agriculture demonstrating that improved accuracy in predictions of wheat production can be achieved by the use of <u>satellite imagery</u>. LACIE experimenters used Image analysis techniques to <u>predict with great accuracy</u> the size of the 1977 Soviet wheat crop six weeks prior to harvest.

…<u>foundational research</u> in ***Machine Processing of Remotely Sensed Data***



"PA in Waiting"

Spatial Database Management *(80s **Where is What**)*

The raging debate in GIS at the time was **Discrete Spatial Objects** (*Vector*) vs. **Continuous Map Surfaces** (*Raster*). Since the vector perspective more closely matched manual map-making and applications, it dominated GIS. But vector maps are of little use in farming and GPS was too inaccurate/ unreliable, so <u>Precision Ag was stymied</u>. **Map Algebra** that identified a set of grid-based primitive operations in a GIS allowing two or more geo-registered raster layers to produce a new raster layer using <u>algebraic operations</u> such as addition, subtraction etc. By sequencing these primitives operations, a **Cartographic Modeling** process analogous to solving equations is developed– it's just that the <u>variables are entire map layers composed of thousands of numbers</u>.

…<u>technological advances</u> improving ***Spatial/Temporal Resolution in RS and GPS***

(Berry)

Historical Setting and Evolution of Precision Ag

***Precision Agriculture** is a "site-specific management" technology that <u>measures and responds to the spatial and temporal intra-field variations</u> for maximizing crop production while maintaining good land stewardship.*

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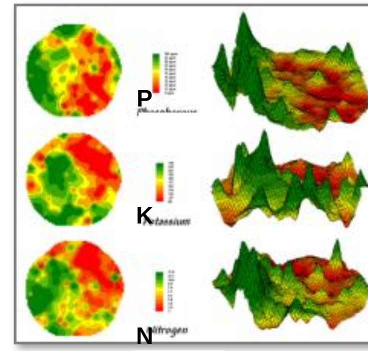
"Farm Maps as Data"



Map Analysis *(90s **Why and So What**)*

Map Algebra concepts were extended by a more rigorous mathematical/statistical framework (**Map Analysis** and **GIS Modeling**) and additional grid-based analytical capabilities were developed. The raging debate in early Precision Ag circles was **Management Zones** (Discrete/Aggregated/Vector) versus **On-the-Fly** (Continuous/Disaggregated/Raster). As GPS, satellite/aerial imaging and image processing became more precise, reliable and available, <u>continuous data and processing approaches won out</u>. With sub-meter positioning, hyperspectral detail and advanced grid analysis tools, Precision Ag moved from a research and innovation dominated field to a promising mega-industry. Networks of high-end workstations and desktop computers replaced old mainframe computers.

…the pieces begin to fall into place and ***Adolescent PA Grows Up***

"All Systems Go"

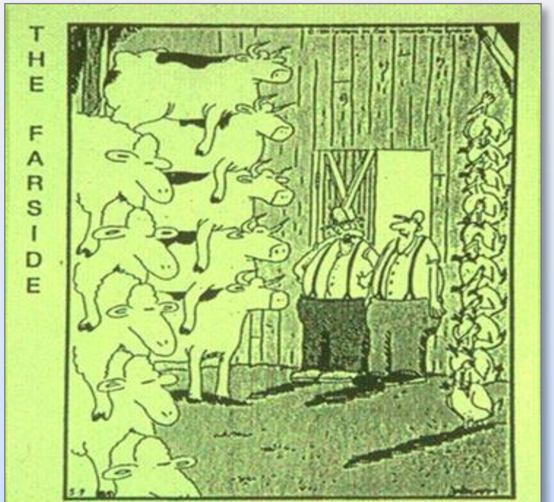
GeoWeb and Mobile Devices *(00s **Wow!!!**)*

The modern computing environment has radically changed from "stay-at-home" computers to <u>powerful portable devices</u> with <u>high speed connectivity</u> (e.g., mobile phones, pads, tablets and notebooks). Cloud storage/computing provides access to vast amounts of GIS and RS data and processing.

*…like a perfect storm, the **Precise Alignment of RS, GIS, GPS, Analytics and Robotics** continues to fuel PA innovation and adoption* ***(Berry)***

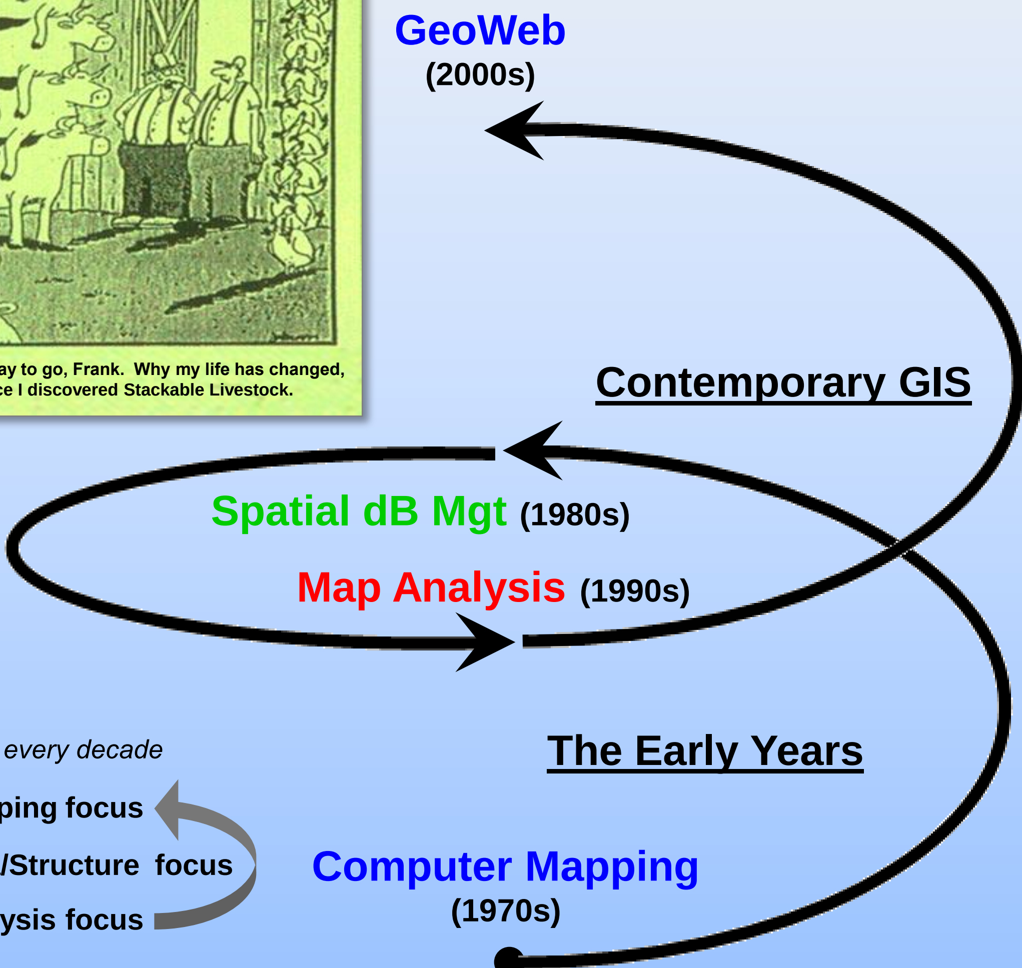
GIS Development Cycle *(…where we've been)*

GIS Evolution



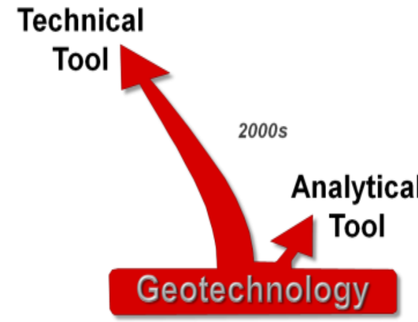
"It's the only way to go, Frank. Why my life has changed, Ever since I discovered Stackable Livestock.

…Precision Ag's expression of Geotechnology involves radically __different technologies__ with extremely __high expectations__



…about every decade

- Mapping focus
- Data/Structure focus
- Analysis focus



The lion's share of growth has been GIS's ever expanding capabilities as a "*__Technical Tool__*"

…corralling vast amounts of spatial data and providing near __instantaneous access__ to remote sensing images, GPS navigation, interactive maps, records management, geo-queries and awesome displays.

But keep in mind—

*…PA is about doing the **right thing** at the **right place** and at the **right time***

*…it **identifies** and **responds** to **variability within a field***

*…it **__augments__ indigenous knowledge***
(__not__ a replacement)

*—that are expressions of GIS as an "__**Analytical Tool**__"*

(Berry)

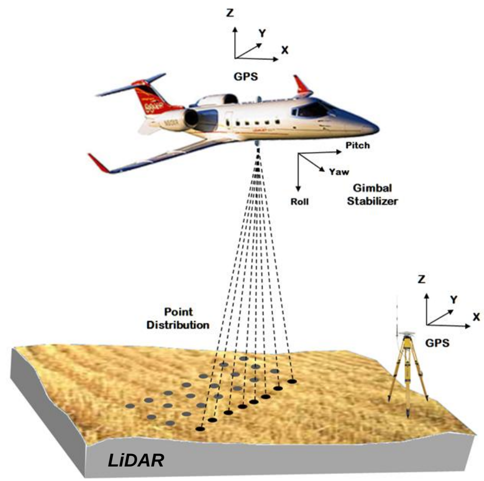
Some Examples of Soaring PA Technology Applications

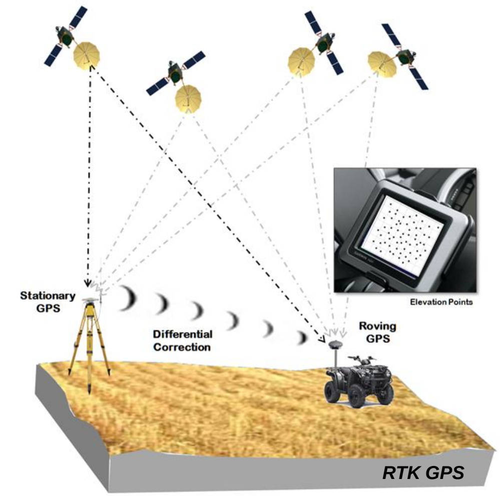
1) **LiDAR Imaging** *vs.* **RTK GPS** *(terrain surface)*

LiDAR *for regional/state-wide surveys*
RTK GPS *for farm-level survey*
LiDAR *and* ***RTK*** *for multistage terrain analysis*

Airborne LiDAR	RTK
Pros • Collected on regional or statewide basis. • High density (≥1 pulse/square meter) • Collected in advance.	**Pros** • Very accurate. • Can collect the exact points required. • Trusted by engineers to be accurate enough for survey data.
Cons • Accuracy is not always recognized as acceptable for design. • Hard to tie into true on-the-ground elevations.	**Cons** • Collected on an "as needed basis." • Not compiled into a seamless layer. • Generally lacks entire watershed data.

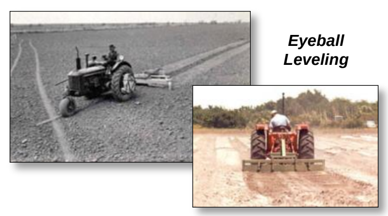
Tom Buman's Precision Conservation blog at **http://precisionconservation.com/**





2) **Automated 3D Machines** *(controlling positioning/hydraulics)*

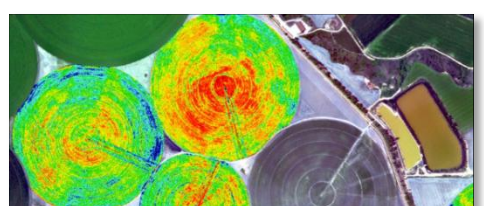
Field Grading *to level a field*
Optimal ***Field Tile*** *placement*
Variable-rate Seeding *(depressions)*



http://www.fao.org/docrep/t0231e/t0231e08.htm/

3) **Remote Sensing Imagery** *and* **Drone Technology**

Remote Sensing:
Satellite *and* ***Hyperspectral Imaging*** *for crop development*



http://www.specterra.com.au/precision_agriculture.html

Drones:
Geometric registration *for Farm/Compliance Mapping*
Spectral analysis *for Field Scouting*
Possibly *for Spot Spraying (Future)*

http://aerialfarmer.blogspot.com/

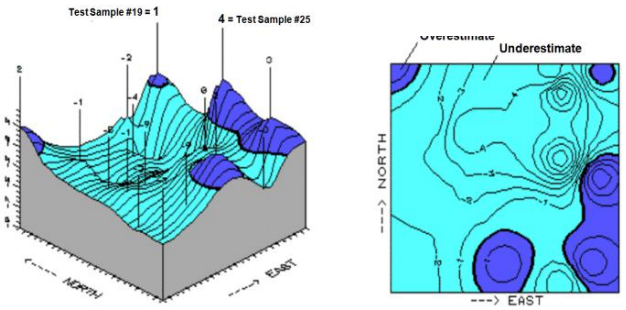
(Berry)

More Examples of Soaring PA Technology Applications

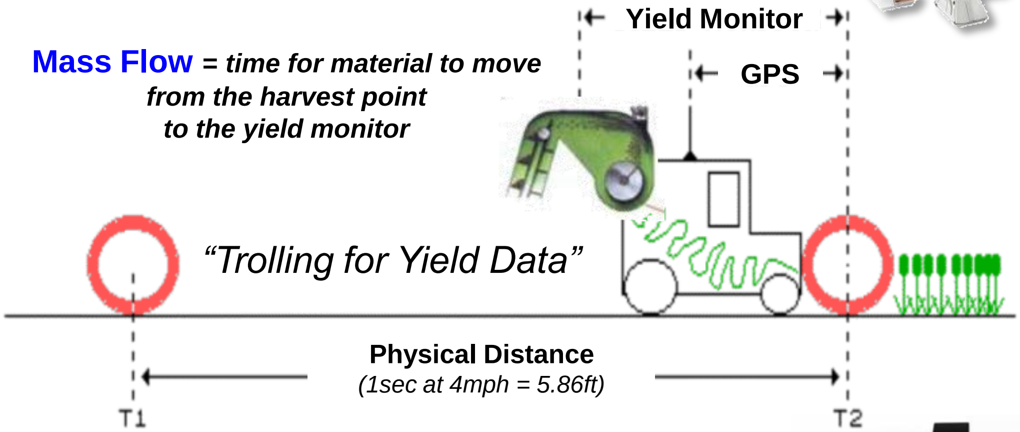
4) Ground Instrumentation *for weather, soil moisture, harvesting*

Farm-based ***Weather Stations*** *for disease, insect and water monitoring*
In-field network of ***Soil Moisture Probes*** *for Evapotranspiration (ET) modeling*
Robotic Machines *that can operate autonomously*
Advances in ***Crop Yield Monitor*** *accuracy*
Advances in ***Field Sampling*** *and*
Map Surface Generation

Mapping the Residuals — Geographic Distribution of Interpolation Error



Interpolation Error

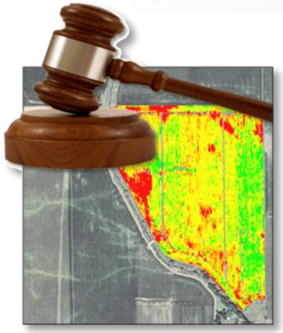


5) New Technology Environment

Faster/Cheaper/Smaller *computers/tablets/phones*
Ubiquitous Connectivity *from farm base to field to cafe*
Cloud Computing *capabilities (more available and accessible)*

6) Evolving Legal, Regulatory, Business and Social Environments

As Applied Mapping *for regulatory compliance and organic/GMO certification*
Data Ownership, Convertibility and Sharing *will become increasingly important*
Integrated Platform Solutions *from a few large companies will replace*
the disparate pieces of a solution from various small companies
Scale, Expense and Cyber-phobia *will continue as entry constraints but diminish*
as the farm community becomes more comfortable with computer technology



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Yield Limiting Factors *(the basis of PA)*

Water
Weather
Topography
Nutrients
Weeds
Pests
Genetics
Seeding Rate
Other…

Candidate factor ***for Precision Agriculture and Site-specific Management***
***if and only if* —**

the factor is a significant driving variable
it has measurable spatial variability
its spatial variation can be explained and spatial relationships established
it exhibits a spatial response to practical management actions

…and results in production gains, increased profitability and/or improved stewardship

(Berry)

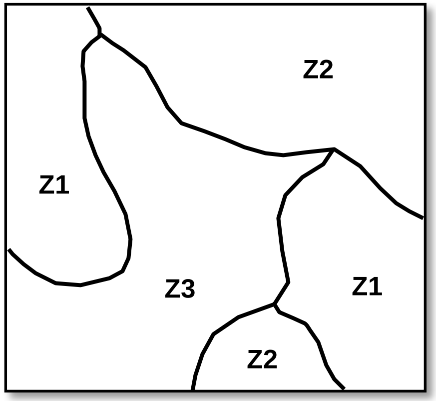
Whole Field vs. Site Specific Management

Aggregated Space

Whole-field *assumes the "average" conditions are the same everywhere within the field (uniform/homogenous)*

*Management action is the **same throughout the field***

Aggregated Space



Discrete Management Zones *break the field into areas of similar conditions (zones)*

*Management action is the **same within each zone***

…manage as a set of small irregular sub-fields

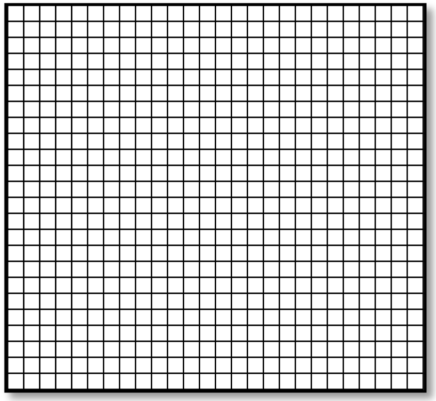
The bulk of agricultural research has been "non-spatial"

(Spatially Aggregated)

…but PA is all about disaggregated spatial relationships/patterns—

Research Opportunity

Disaggregated Space



Continuous Map Surfaces *break the field into small consistent pieces (grid cells) that track specific conditions at each grid location*

*Management action **varies continuously throughout the field***

(Berry)

Data Analysis Perspectives *(Data Space vs. Geographic Space)*

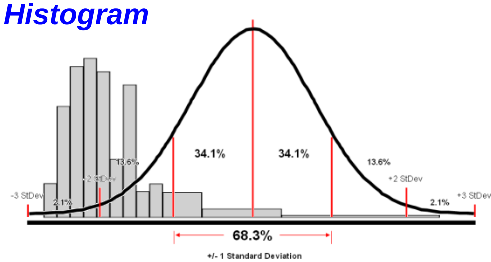
Traditional Analysis

(Data Space — Non-spatial Statistics)

Standard Normal Curve

*fit to the data (**density function**)*

Histogram



Central Tendency

Typical	Average = 22.0
How Typical	StDev = 18.7

Field Data

	A	B	C
1	5	5	4
2	5	10	9
3	5	15	0
4	5	20	0
5	10	5	25
6	10	10	2
7	10	15	4
8	10	20	0
9	15	5	6
10	15	10	22
11	15	15	42
12	15	20	33
13	20	5	16
14	20	10	43
15	20	15	87
16	20	20	68
17			

PERIOD2

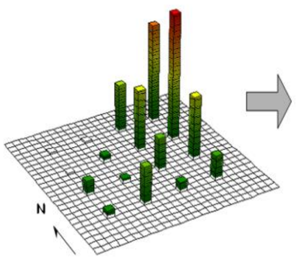
Map Analysis

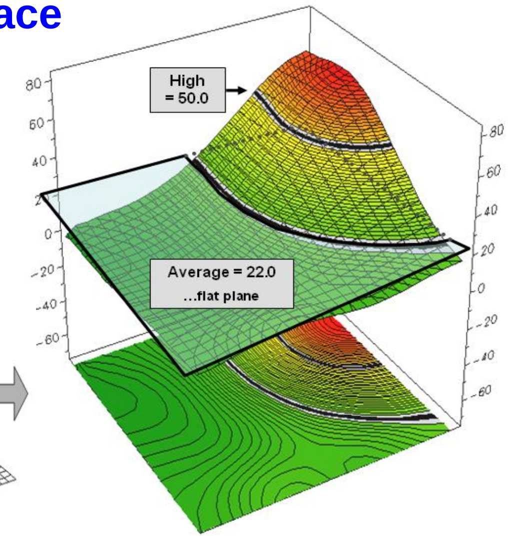
(Geographic Space — Spatial Statistics)

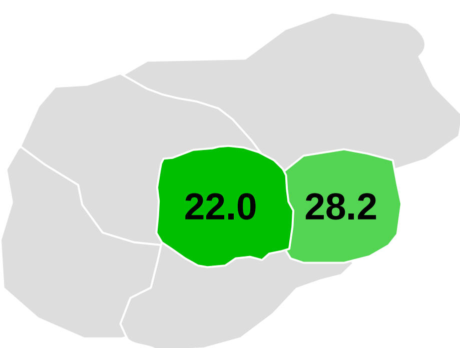
Interpolated Surface

*fit to the data (**density function**)*

Point Data Plot

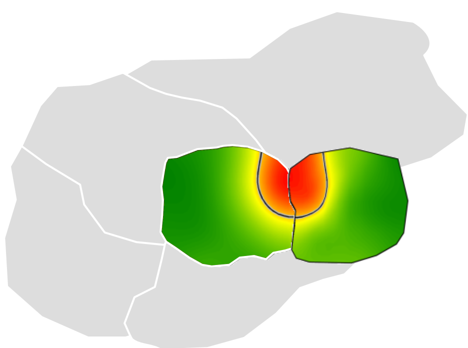






Discrete
Spatial Object
(Generalized)
"Single Value"

Continuous
Spatial Distribution
(Detailed)
"Thousands of Values"



Identifies the Typical Value

Maps the Variance

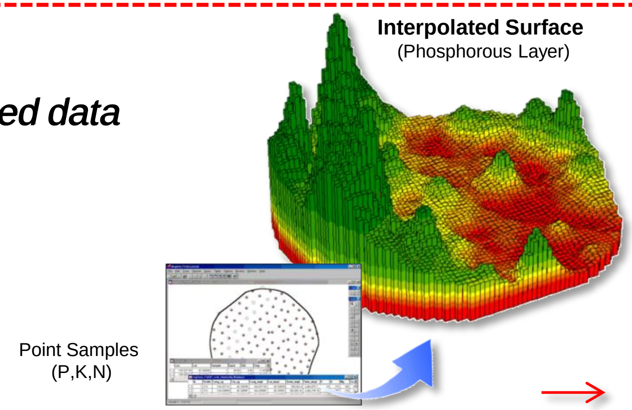
(Berry)

Grid-based Map Analysis Approaches

Map Analysis *involves three broad types of "Analytical Tools"—*

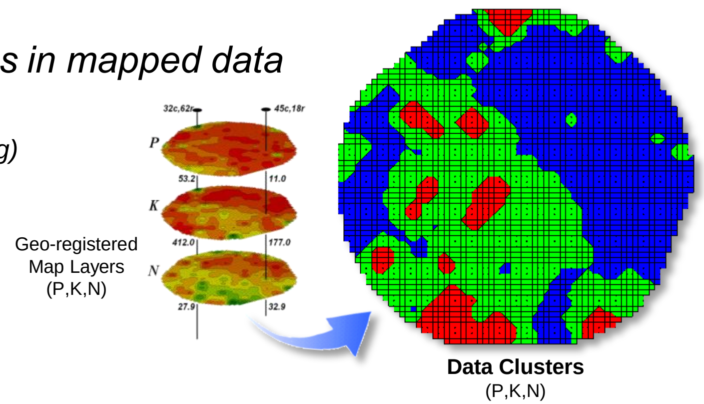
Surface Modeling *maps the spatial distribution of point-sampled data*

- **Map Generalization**— *characterizes spatial trends* ***(e.g., tilted plane)***
- **Spatial Interpolation**— *continuous spatial distribution* ***(e.g., IDW, Krig)***
- **Other**— *roving windows and facets* ***(e.g., density surface, tessellation)***



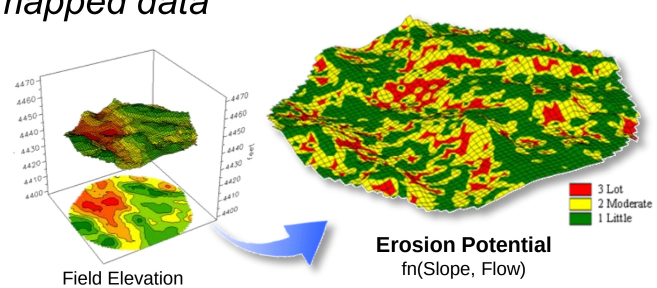
Spatial Statistics *investigates the "numerical" relationships in mapped data*

- **Descriptive**— *aggregate statistics (e.g., average, stdev, similarity, clustering)*
- **Predictive**— *relationships among map layers (e.g., regression)*
- **Prescription**— *appropriate actions (e.g., decision rules, optimization)*



Spatial Analysis *investigates the "contextual" relationships in mapped data*

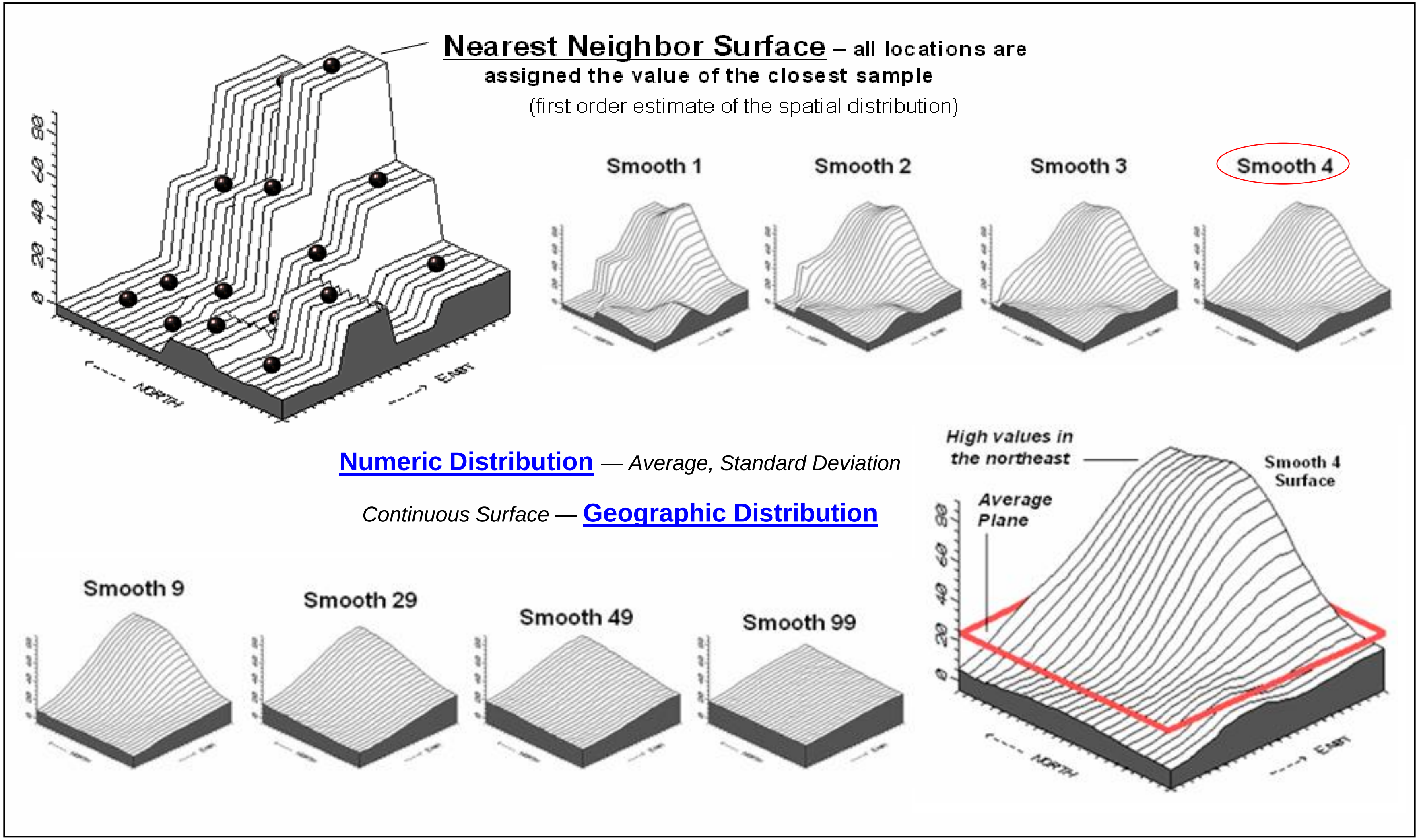
- **Reclassify**— *reassigns map values (e.g., position, value, shape, contiguity)*
- **Overlay**— *map layer coincidence (e.g., point-by-point, region-wide, map-wide)*
- **Distance**— *proximity and connection (e.g., movement, optimal paths, visibility)*
- **Neighbors**— *roving windows (e.g., slope, aspect, diversity, anomaly)*



(Berry)

Geographic Distribution *(Mapping the Variance)*

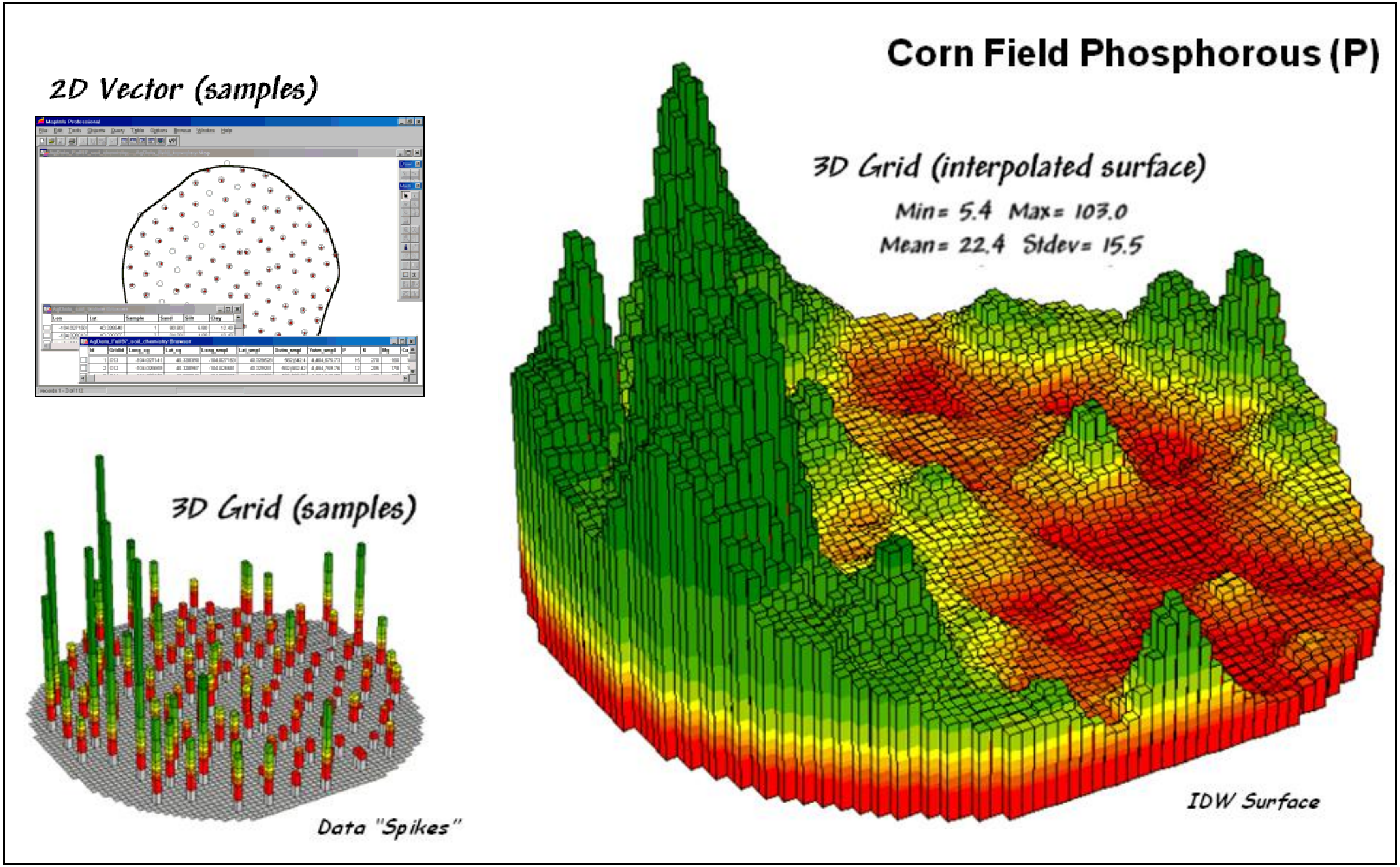
The "iterative smoothing" process is similar to slapping a chunk of modeler's clay over the "data spikes," then taking a knife and cutting away the excess (successive smoothing) to leave a ***continuous surface*** *that encapsulates the peaks and valleys implied in the field samples*



(Berry)

Spatial Interpolation *(soil nutrient levels)*

Spatial Interpolation *maps the* ***geographic distribution*** *inherent in data sets*



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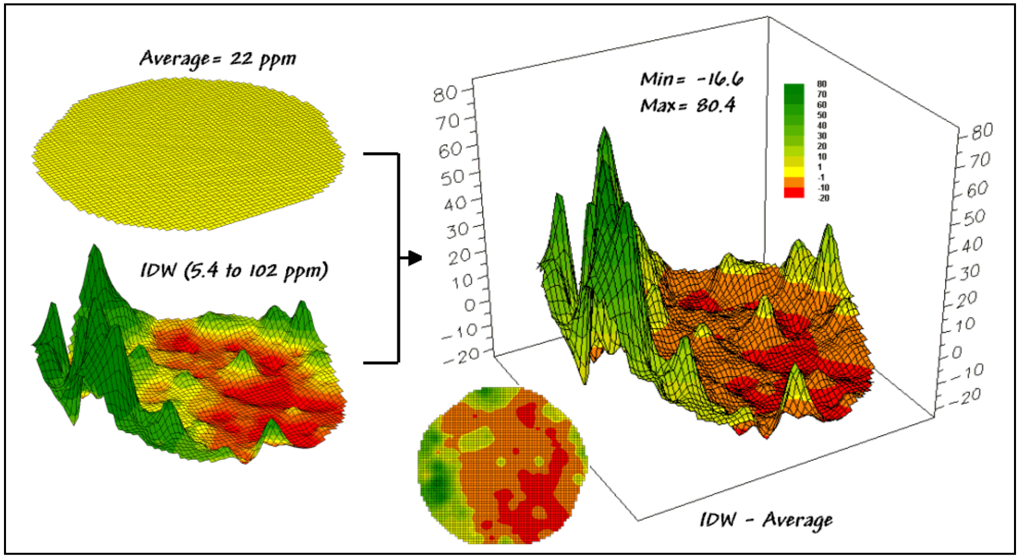
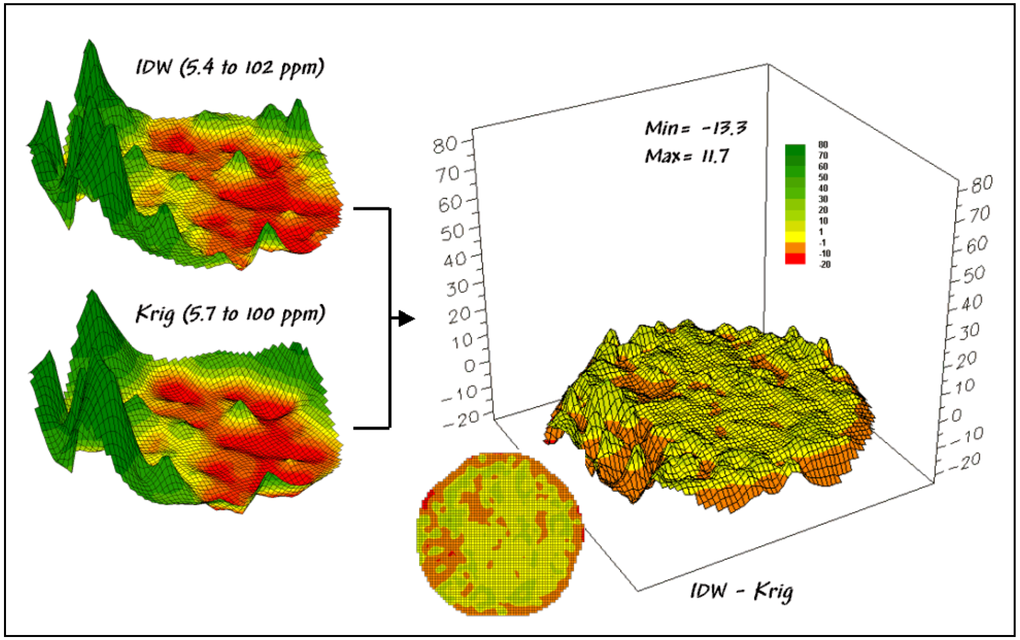
Comparing Spatial Interpolation Results



Comparison of the
***IDW** interpolated surface*
to the
*whole field **Average***
*shows **large differences***
in localized estimates
(-16.6 to 80.4 ppm)



Comparison of the
***IDW** interpolated surface*
to the
***Krig** interpolated surface shows*
small differences
in localized estimates
(-13.3 to 11.7 ppm)

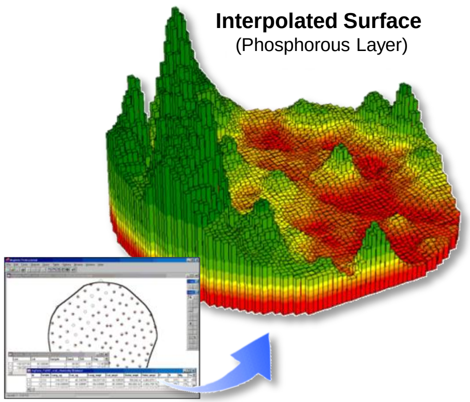
(Berry)

Grid-based Map Analysis Approaches

Map Analysis *involves three broad types of "Analytical Tools"—*

Surface Modeling *maps the spatial distribution of point-sampled data*

- **Map Generalization**— *characterizes spatial trends (e.g., tilted plane)*
- **Spatial Interpolation**— *derives a continuous spatial distribution (e.g., IDW, Krig)*
- **Other**— *roving windows and facets (e.g., density surface, tessellation)*



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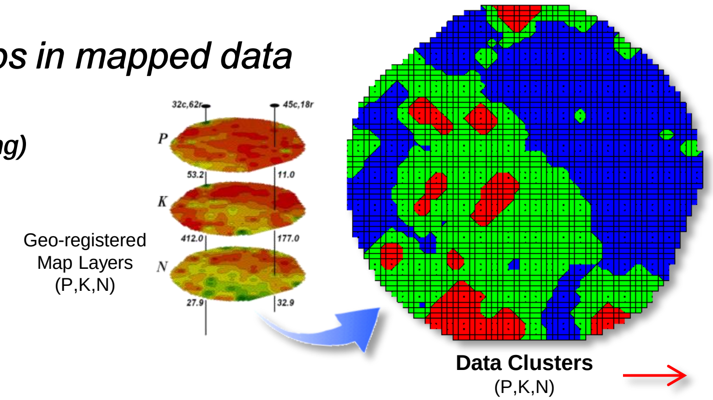

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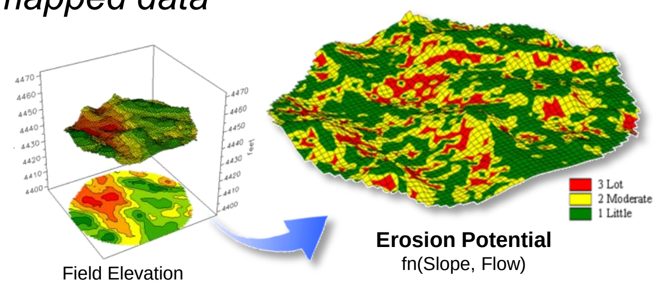

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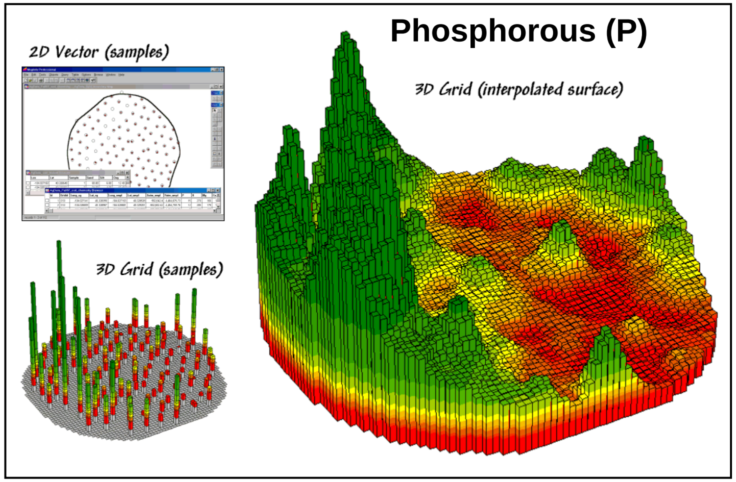
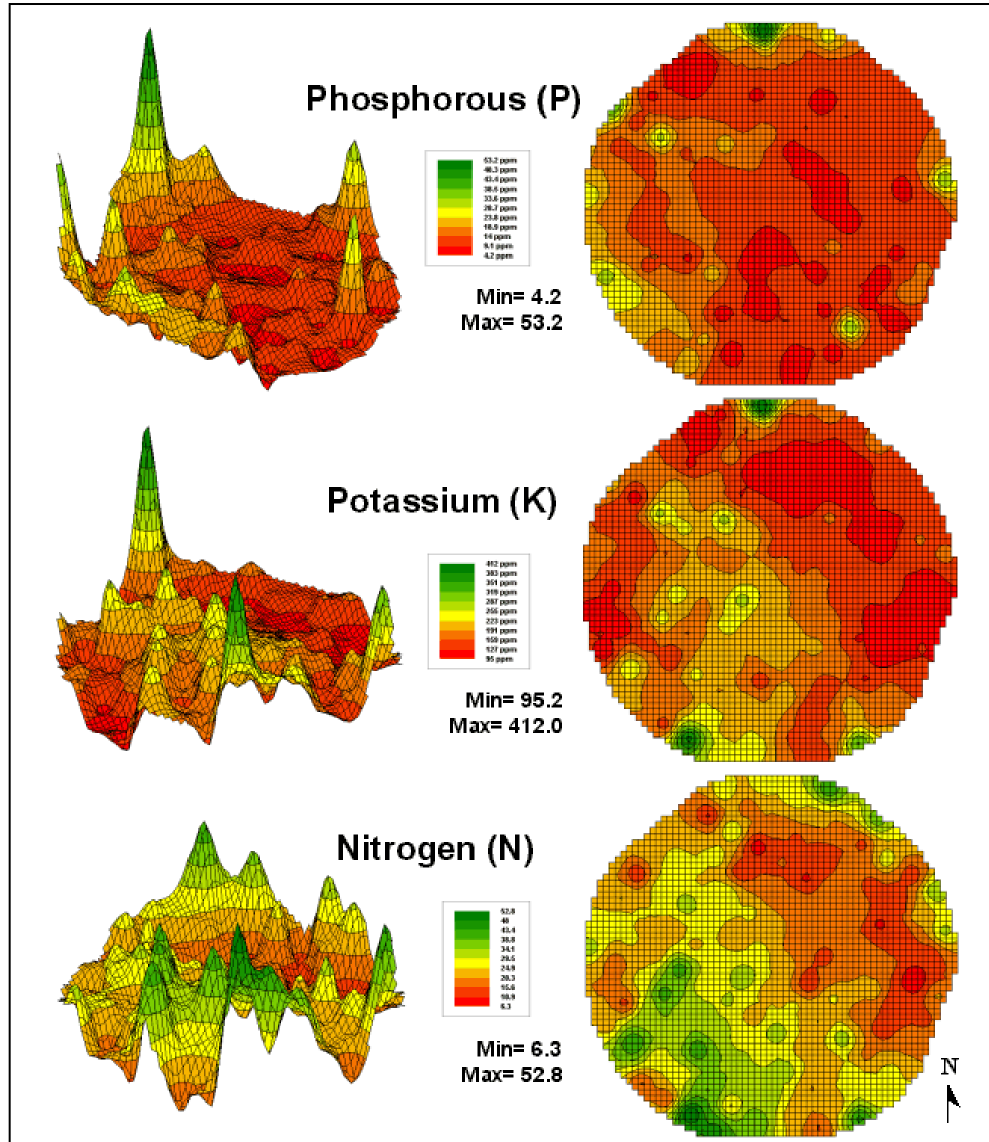
Visualizing Spatial Relationships

Interpolated Spatial Distribution





What spatial relationships do you see?

…do relatively high levels of P often occur with high levels of K and N?

…how often?

…where?

<u>Humans</u> can only "see" broad

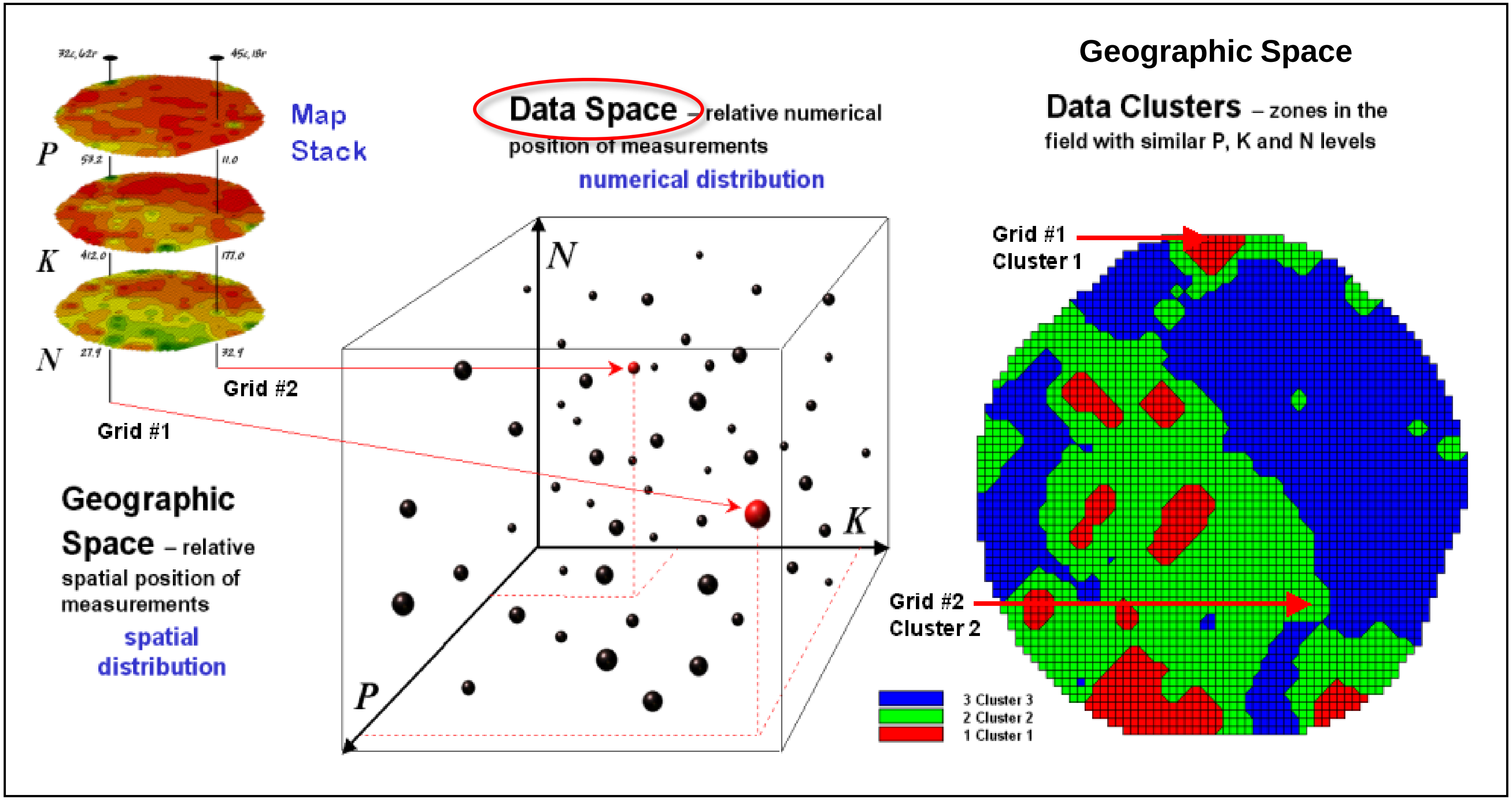
<u>Generalized Patterns</u>

in a <u>single</u> map variable…

(Berry)

Clustering Maps for Data Zones

…but *computers* can "see" ***detailed patterns*** *in multiple map variables (using* ***Data Space)***



…groups of "floating balls" in data space identify locations in the field with similar data patterns– ***Data Zones*** *(Data Clusters)*

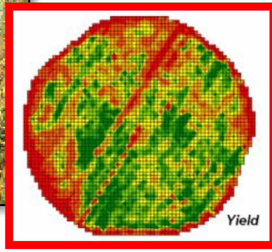
…or a ***Continuous Equation*** *precisely identifying the right action for each grid cell*

(Berry)

The Precision Ag Process *(Fertility example)*

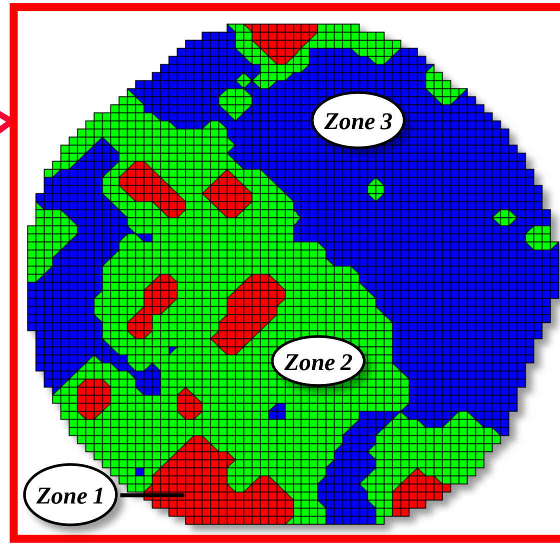
*…there are <u>four fundamental steps</u> in the **Precision Ag Process**—*

Dependent Map Variable



Yield Map ***On-the-Fly***

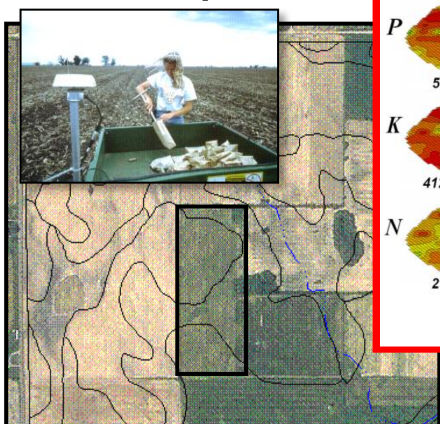
Prescription Map

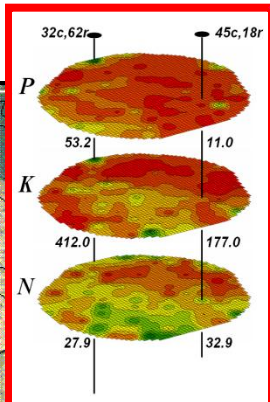


"Intelligent Implements"

Variable Rate Application

Nutrient Maps ***Derived***





Independent Map Variables

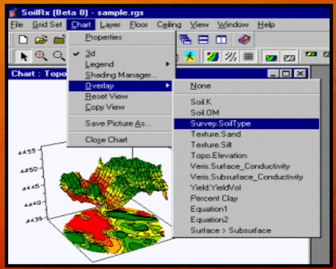
1) ***Data Collection*** → *2)* ***Data Analysis*** → *3)* ***Modeling*** → *4)* ***Management Action***

…the process is more generally termed ***<u>Spatial Data Mining</u>*** and is used in a host of applications from *Geo-business* to *Epidemiology* to *Infrastructure Routing* to *Wildfire Risk Modeling* …etc.

and is analogous to non-spatial "***Quantitative Data Analysis***"— but uses "***Map Variables***"

(Berry)

So Where Are We in Precision Ag?



Yield Mapping *…done deal for many crops*

Soil Nutrient Mapping *…procedures need validation*

Mgt Zone Mapping *…alternative approaches need study & validation*

Map Analysis and Modeling

The Full Precision Farming Process *…a fair piece to go*

IF <*condition*> THEN <*action*> *…based on spatial relationship "rules"*

– ***Description*** *(Where is What)* *…coming on line (Mapping)*

– ***Prediction*** *(Why and So What)* *…needs lots of work (Inference)*

– ***Prescription*** *(Do What Where)* *…barely on the research radar (Optimization)*

PA Research Nugget (Science)

– ***Action*** *(Precisely Here)* *…done deal for many farm inputs (location aware Robotics)*

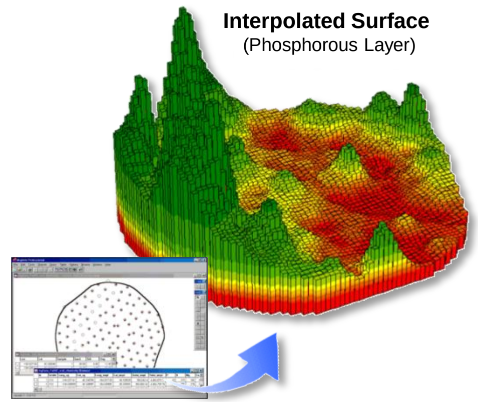
(Berry)

Grid-based Map Analysis Approaches

Map Analysis *involves three broad types of "Analytical Tools"—*

Surface Modeling *maps the spatial distribution of point-sampled data*

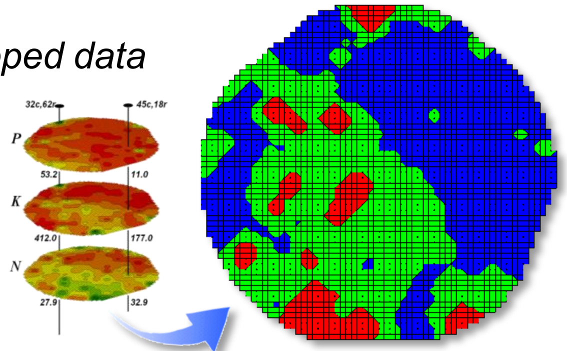
- **Map Generalization**— *characterizes spatial trends (e.g., tilted plane)*
- **Spatial Interpolation**— *derives a continuous spatial distribution (e.g., IDW, Krig)*
- **Other**— *roving windows and facets (e.g., density surface, tessellation)*



Spatial Statistics *investigates the "numerical" relationships in mapped data*

- **Descriptive**— *aggregate statistics (e.g., average, stdev, similarity, clustering)*
- **Predictive**— *relationships among map layers (e.g., regression)*
- **Prescription**— *appropriate actions (e.g., decision rules, optimization)*

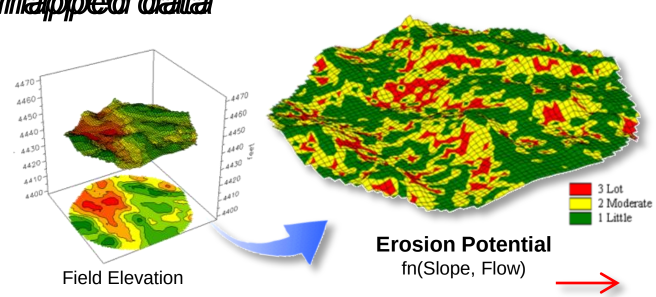
Geo-registered
Map Layers
(P,K,N)



Data Clusters
(P,K,N)

Spatial Analysis *investigates the "contextual" relationships in mapped data*

- **Reclassify**— *reassigns map values (e.g., position, value, shape, contiguity)*
- **Overlay**— *map layer coincidence (e.g., point-by-point, region-wide, map-wide)*
- **Distance**— *proximity and connection (e.g., movement, optimal paths, visibility)*
- **Neighbors**— *roving windows (e.g., slope, aspect, diversity, anomaly)*



(Berry)

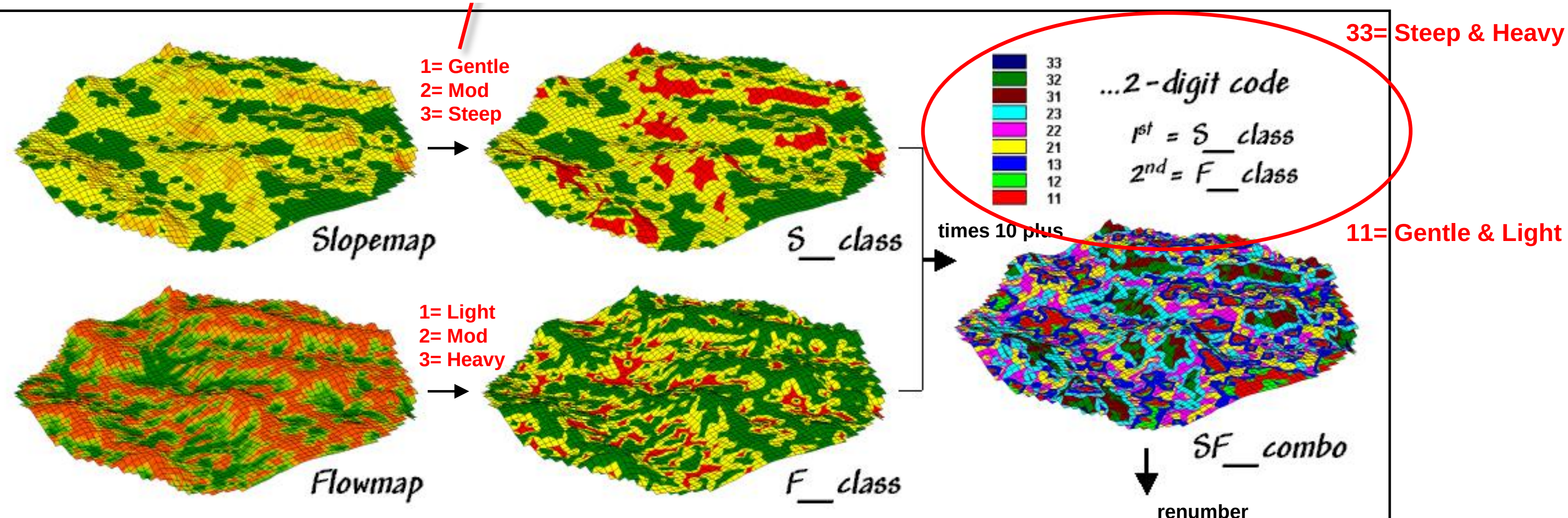
Micro Terrain Analysis *(a simple field erosion/pooling model)*

*Determining **Erosion/PoolingPotential**:*

***Slope** classes (1= Gentle, 2=Moderate, 3= Steep)*

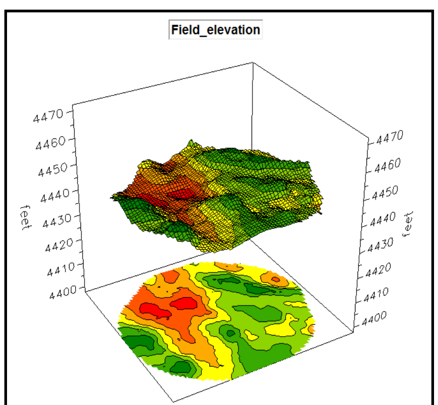
*and **Flow** classes (1= Light, 2=Moderate, 3= Heavy Flows)*

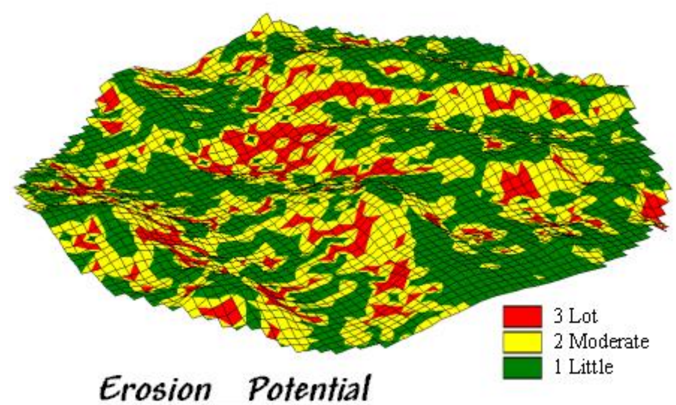
…are combined into a single map identifying erosion/pooling potential



Field Elevation *is formed by assigning an elevation value to each cell in an analysis grid*

(1cm Lidar)





…map of the

Effective Movement

(surface flow)

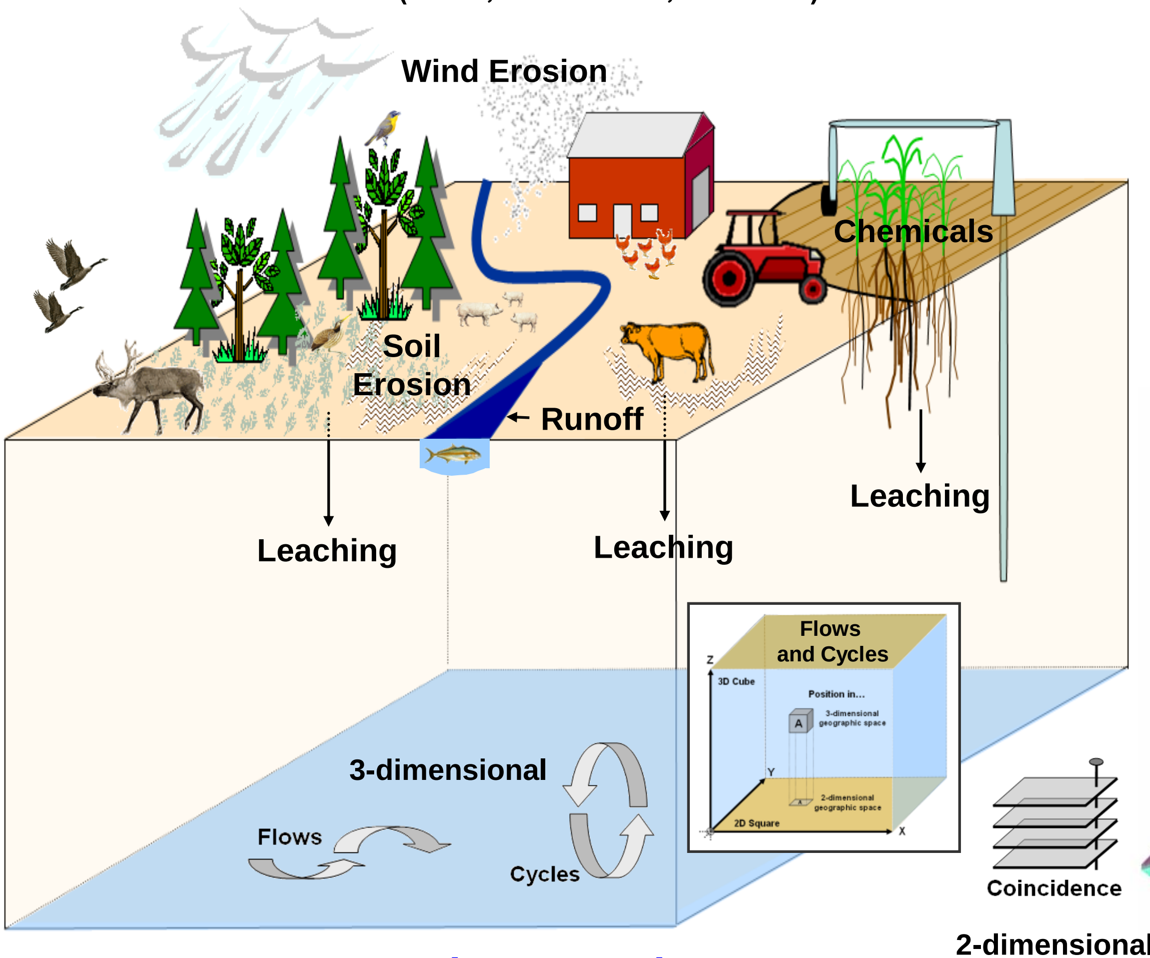
of water, fine particles and organic matter within a field

(Berry)

Precision Conservation *(compared to Precision Ag)*

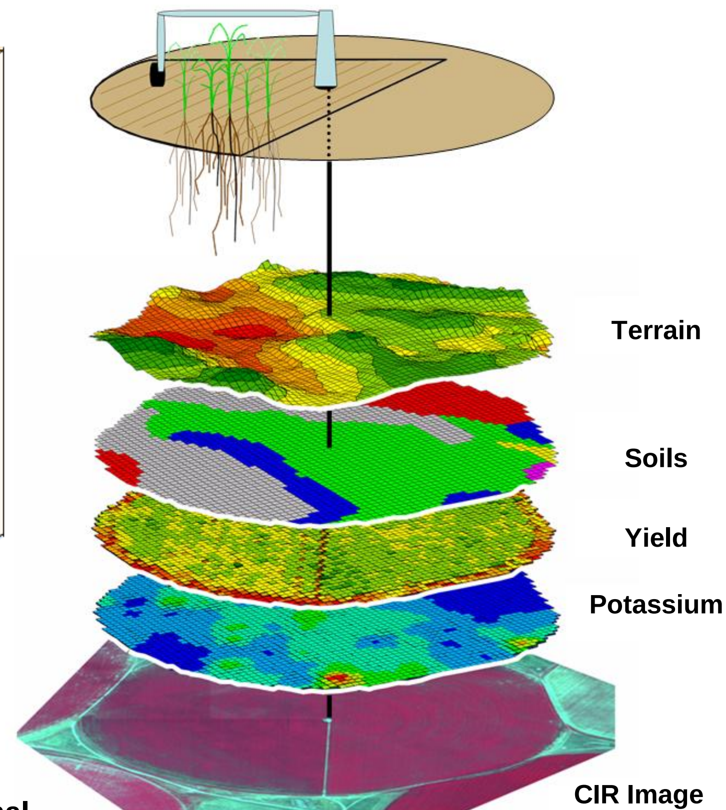
Precision Conservation

(Farm, Watershed,… Focus)



Precision Ag

(Individual Field Focus)



Interconnected Perspective

(Ecological emphasis)

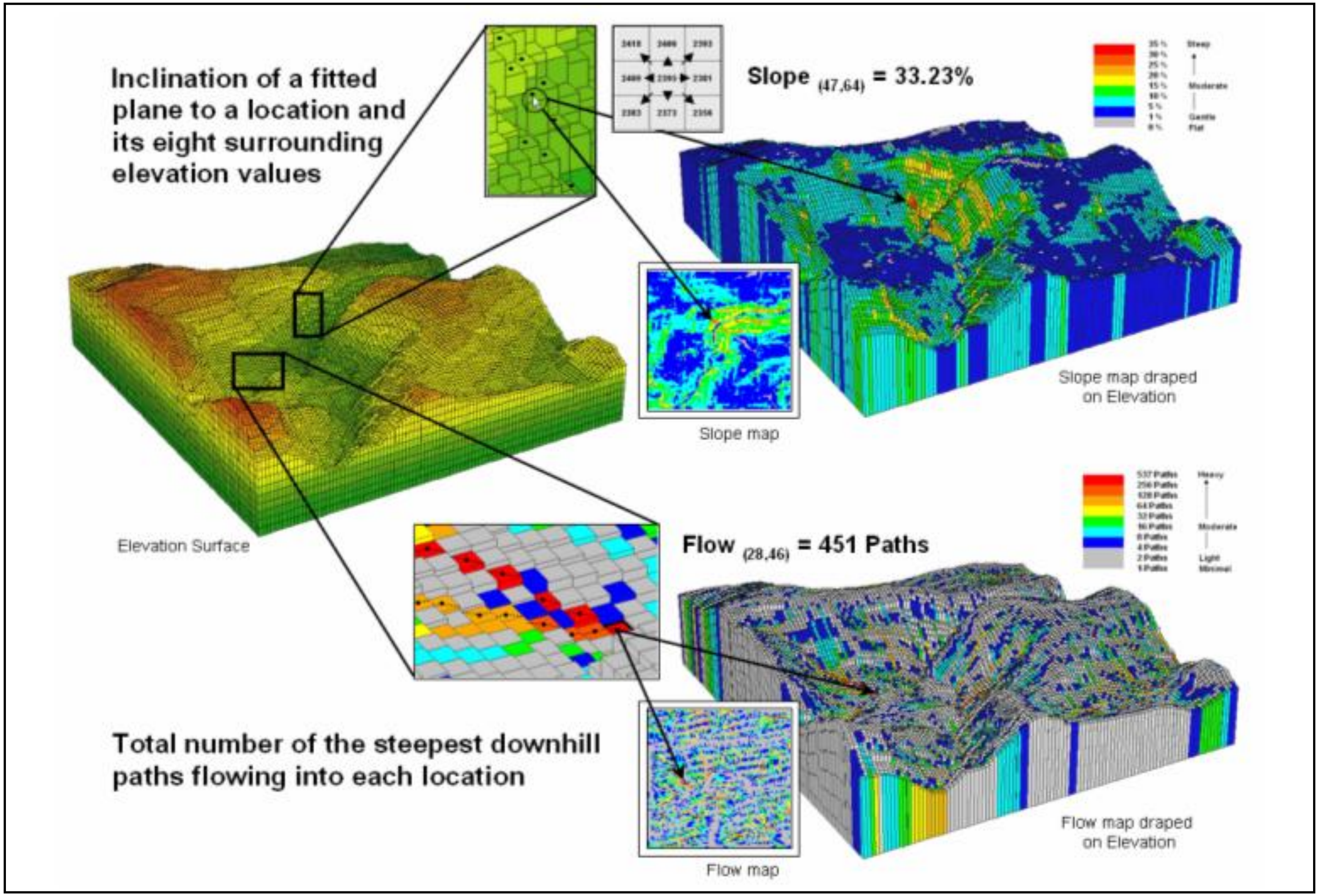
Field Perspective

(Production Emphasis)

(Berry)

Deriving Erosion Potential *(regional scale)*

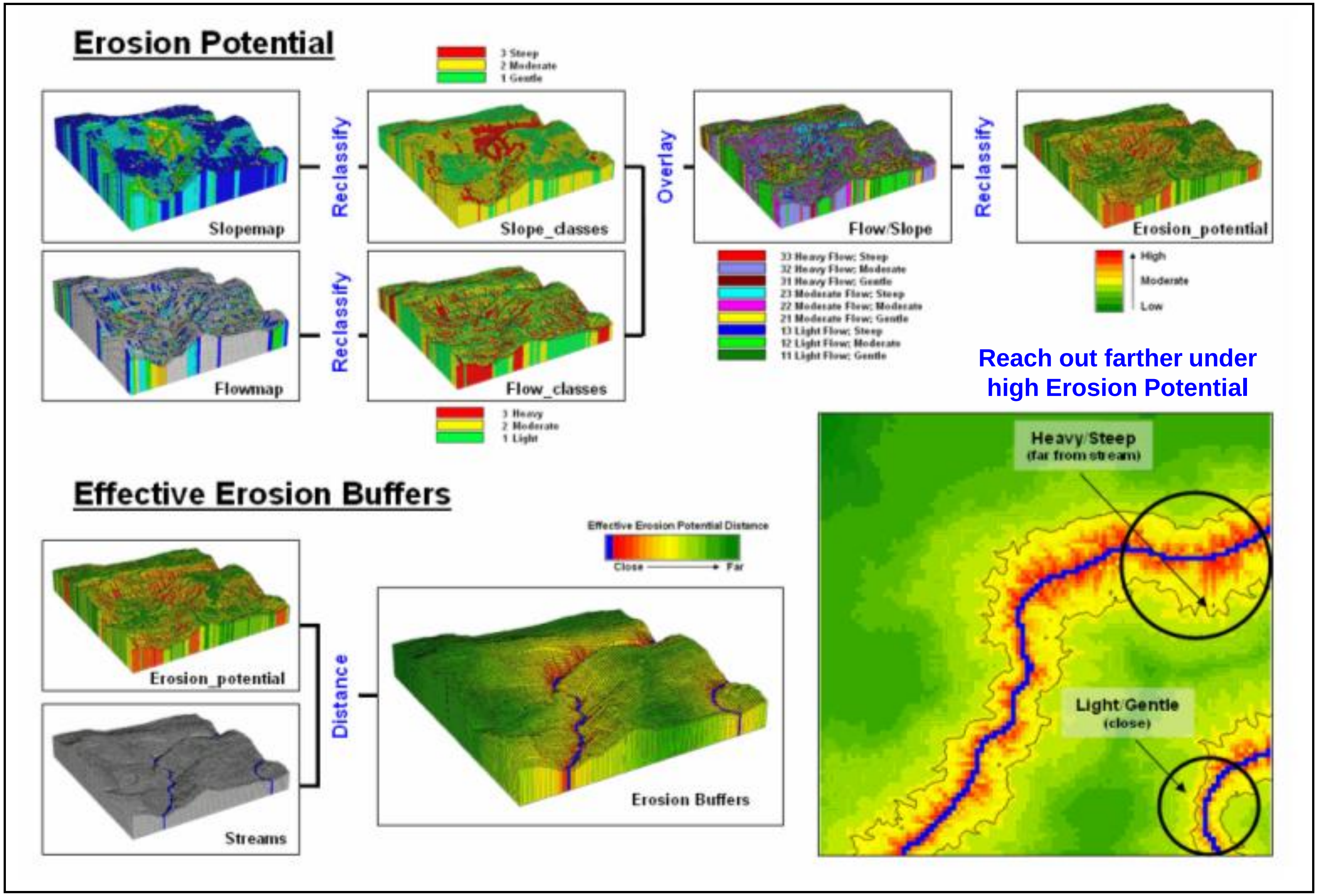
*Maps of surface **Flow** confluence and **Slope** steepness are calculated by considering relative elevation differences throughout a project area*



(Berry)

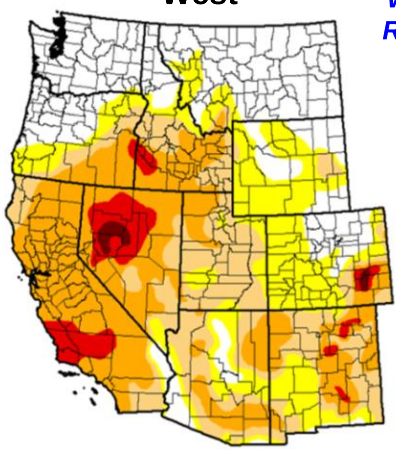
Calculating Effective Distance *(variable-width buffers)*

Effective erosion buffers *around a stream expand and contract depending on the erosion potential of the intervening terrain*

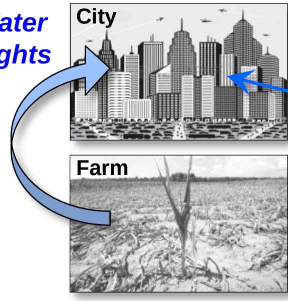


Water Conservation Modeling *(Conservation = "wise use")*

US Drought Monitor
West



Water Rights

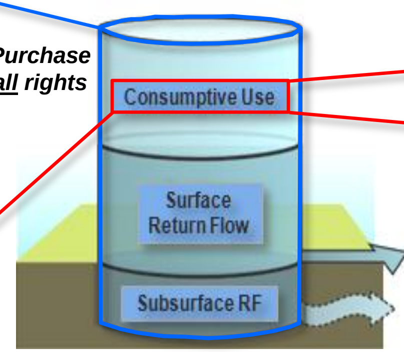


"Buy** and **Dry"

Temporary Monitored Transfers

Purchase <u>all</u> rights

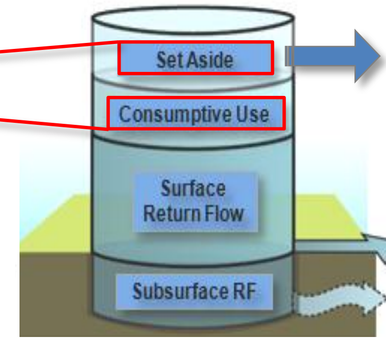
Historic
Crop Water Allocation



To River

Farmland

Alternative Water Budget
Crop Water Allocation



To River

Farmland

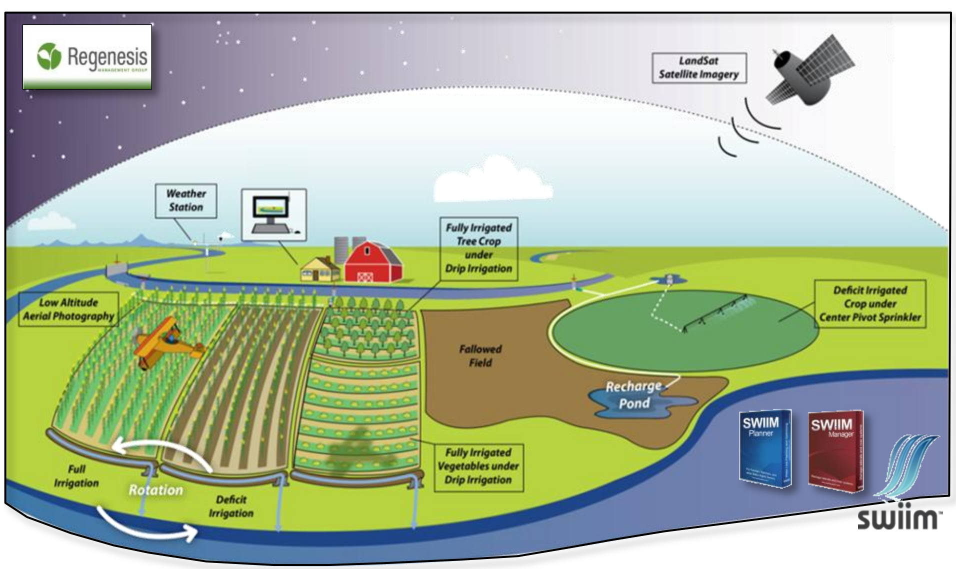
Crops

Farm Income **City Water**

"Win-Win"

Grid-based ***<u>Map Analysis/Modeling</u>*** of consumptive water needs and optimization to increase farm revenue based on ***<u>New/Expanded Instrumentation</u>***:

Water Flow Measurements — Evapotranspiration Monitoring — Soil Moisture Measurements — Remote Sensing

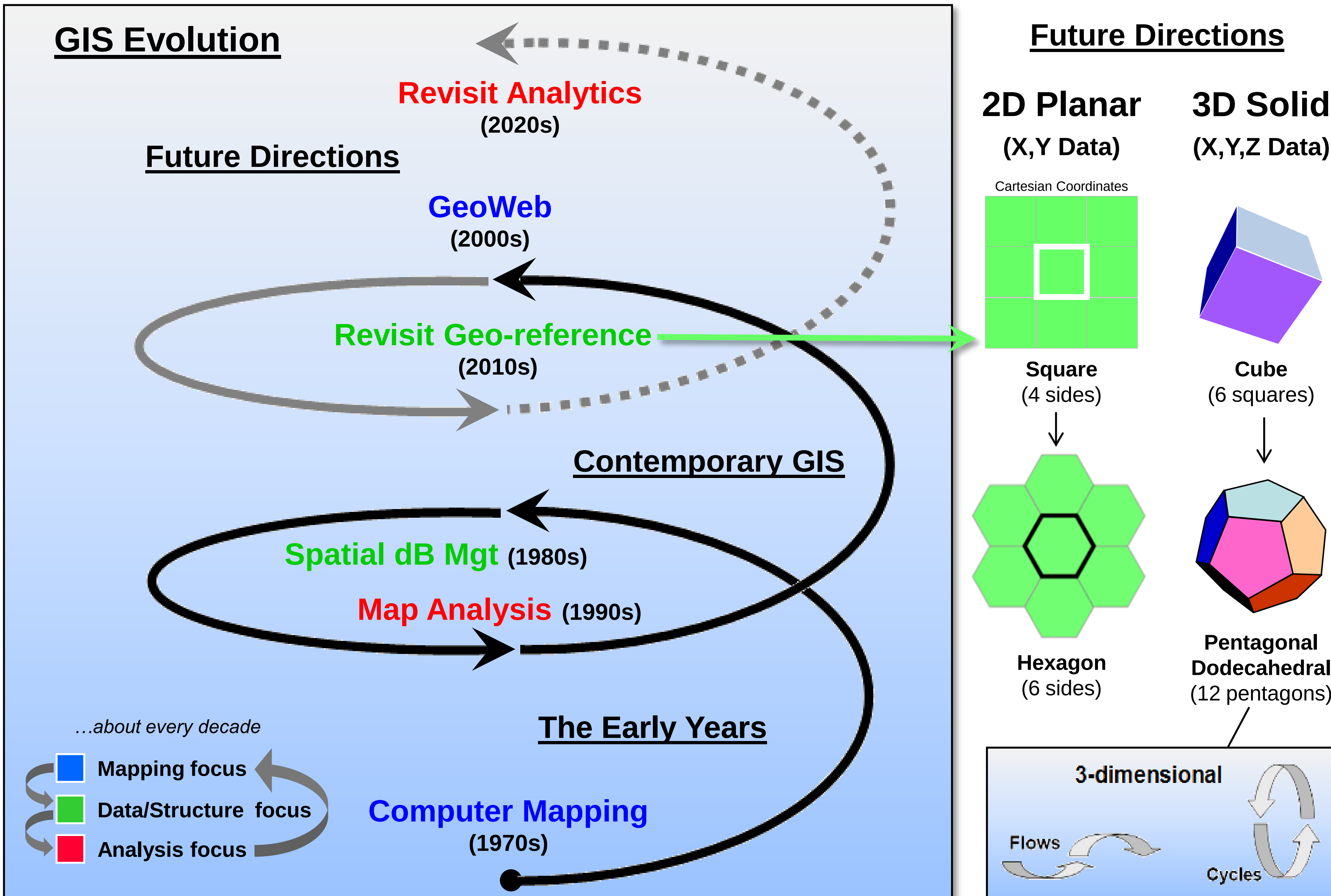


http://www.regenmg.com/Home.aspx

Sustainable Water and Innovative Irrigation Management *(SWIIM)*

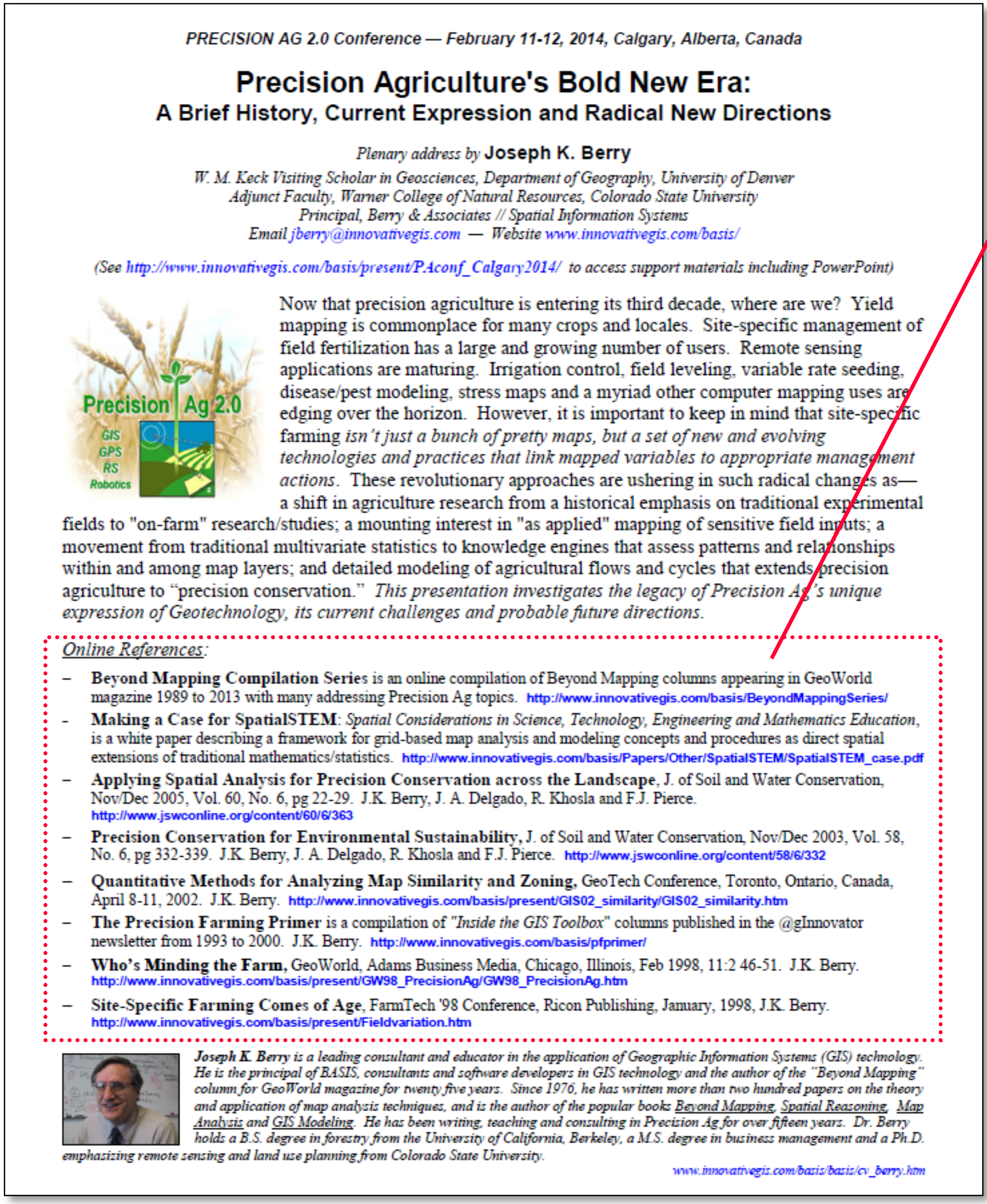
(Berry)

GIS Development Cycle *(…where we're heading)*



(Berry)

Where To Go From Here…



PRECISION AG 2.0 Conference — February 11-12, 2014, Calgary, Alberta, Canada

Precision Agriculture's Bold New Era:
A Brief History, Current Expression and Radical New Directions

Plenary address by **Joseph K. Berry**
W. M. Keck Visiting Scholar in Geosciences, Department of Geography, University of Denver
Adjunct Faculty, Warner College of Natural Resources, Colorado State University
Principal, Berry & Associates // Spatial Information Systems
Email jberry@innovativegis.com — Website www.innovativegis.com/basis/

(See http://www.innovativegis.com/basis/present/PAconf_Calgary2014/ to access support materials including PowerPoint)

Now that precision agriculture is entering its third decade, where are we? Yield mapping is commonplace for many crops and locales. Site-specific management of field fertilization has a large and growing number of users. Remote sensing applications are maturing. Irrigation control, field leveling, variable rate seeding, disease/pest modeling, stress maps and a myriad other computer mapping uses are edging over the horizon. However, it is important to keep in mind that site-specific farming *isn't just a bunch of pretty maps, but a set of new and evolving technologies and practices that link mapped variables to appropriate management actions*. These revolutionary approaches are ushering in such radical changes as— a shift in agriculture research from a historical emphasis on traditional experimental fields to "on-farm" research/studies; a mounting interest in "as applied" mapping of sensitive field inputs; a movement from traditional multivariate statistics to knowledge engines that assess patterns and relationships within and among map layers; and detailed modeling of agricultural flows and cycles that extends precision agriculture to "precision conservation." *This presentation investigates the legacy of Precision Ag's unique expression of Geotechnology, its current challenges and probable future directions.*

Online References:

- **Beyond Mapping Compilation Series** is an online compilation of Beyond Mapping columns appearing in GeoWorld magazine 1989 to 2013 with many addressing Precision Ag topics. http://www.innovativegis.com/basis/BeyondMappingSeries/
- **Making a Case for SpatialSTEM**: *Spatial Considerations in Science, Technology, Engineering and Mathematics Education*, is a white paper describing a framework for grid-based map analysis and modeling concepts and procedures as direct spatial extensions of traditional mathematics/statistics. http://www.innovativegis.com/basis/Papers/Other/SpatialSTEM/SpatialSTEM_case.pdf
- **Applying Spatial Analysis for Precision Conservation across the Landscape**, J. of Soil and Water Conservation, Nov/Dec 2005, Vol. 60, No. 6, pg 22-29. J.K. Berry, J. A. Delgado, R. Khosla and F.J. Pierce. http://www.jswconline.org/content/60/6/363
- **Precision Conservation for Environmental Sustainability**, J. of Soil and Water Conservation, Nov/Dec 2003, Vol. 58, No. 6, pg 332-339. J.K. Berry, J. A. Delgado, R. Khosla and F.J. Pierce. http://www.jswconline.org/content/58/6/332
- **Quantitative Methods for Analyzing Map Similarity and Zoning**, GeoTech Conference, Toronto, Ontario, Canada, April 8-11, 2002. J.K. Berry. http://www.innovativegis.com/basis/present/GIS02_similarity/GIS02_similarity.htm
- **The Precision Farming Primer** is a compilation of "*Inside the GIS Toolbox*" columns published in the @gInnovator newsletter from 1993 to 2000. J.K. Berry. http://www.innovativegis.com/basis/pfprimer/
- **Who's Minding the Farm**, GeoWorld, Adams Business Media, Chicago, Illinois, Feb 1998, 11:2 46-51. J.K. Berry. http://www.innovativegis.com/basis/present/GW98_PrecisionAg/GW98_PrecisionAg.htm
- **Site-Specific Farming Comes of Age**, FarmTech '98 Conference, Ricon Publishing, January, 1998, J.K. Berry. http://www.innovativegis.com/basis/present/Fieldvariation.htm

Joseph K. Berry is a leading consultant and educator in the application of Geographic Information Systems (GIS) technology. He is the principal of BASIS, consultants and software developers in GIS technology and the author of the "Beyond Mapping" column for GeoWorld magazine for twenty five years. Since 1976, he has written more than two hundred papers on the theory and application of map analysis techniques, and is the author of the popular books Beyond Mapping, Spatial Reasoning, Map Analysis and GIS Modeling. He has been writing, teaching and consulting in Precision Ag for over fifteen years. Dr. Berry holds a B.S. degree in forestry from the University of California, Berkeley, a M.S. degree in business management and a Ph.D. emphasizing remote sensing and land use planning from Colorado State University.

www.innovativegis.com/basis/basis/cv_berry.htm

Presentation handout

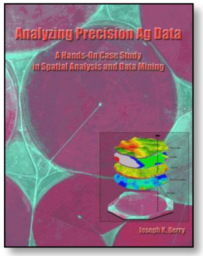
www.innovativegis.com/basis/

Online References

Breakout Session

Returning the Scientific Horse to in Front of the Technical Cart
…a math/stat framework for Map Analysis

Analyzing Precision Ag Data
…downloadable book with hands-on exercises



Beyond Mapping Compilation Series
…Beyond Mapping columns appearing in GeoWorld magazine from March 1989 through December 2013 Organized into four downloadable books