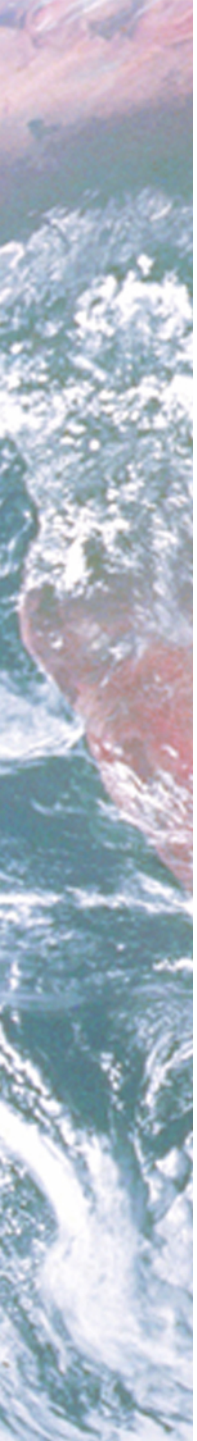

Geospatial Technologies for the Agricultural Sciences

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Outline

- What are the technologies?
- GPS details
  - Improving GPS accuracy/reducing error
  - GPS units
- Integration with GIS
  - GIS software packages, including freeware
  - Geospatial data & imagery
- Applications for agricultural field research

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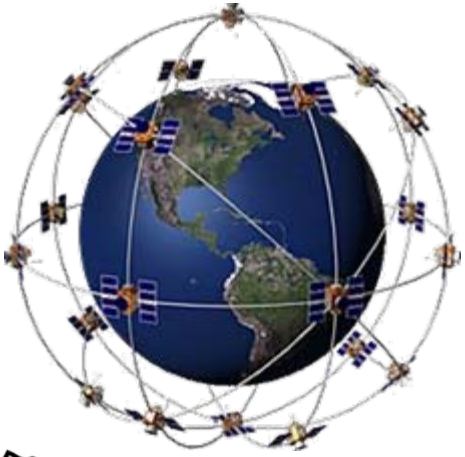
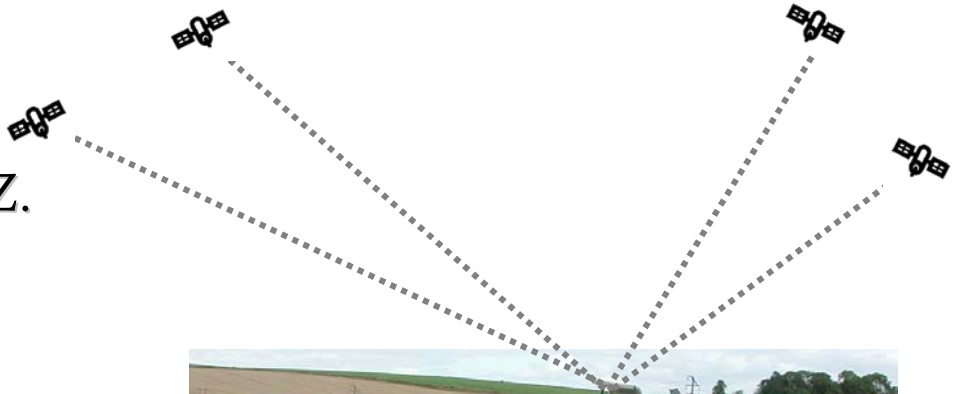
What is GPS?
Global **P**ositioning **S**ystems



- 24 satellites make up civilian GPS
- 6-7 satellites are visible from any spot on Earth
- 4 or more GPS satellites used to compute X, Y, and Z.



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How GPS Works

- Need 4 or more satellites for accurate location!

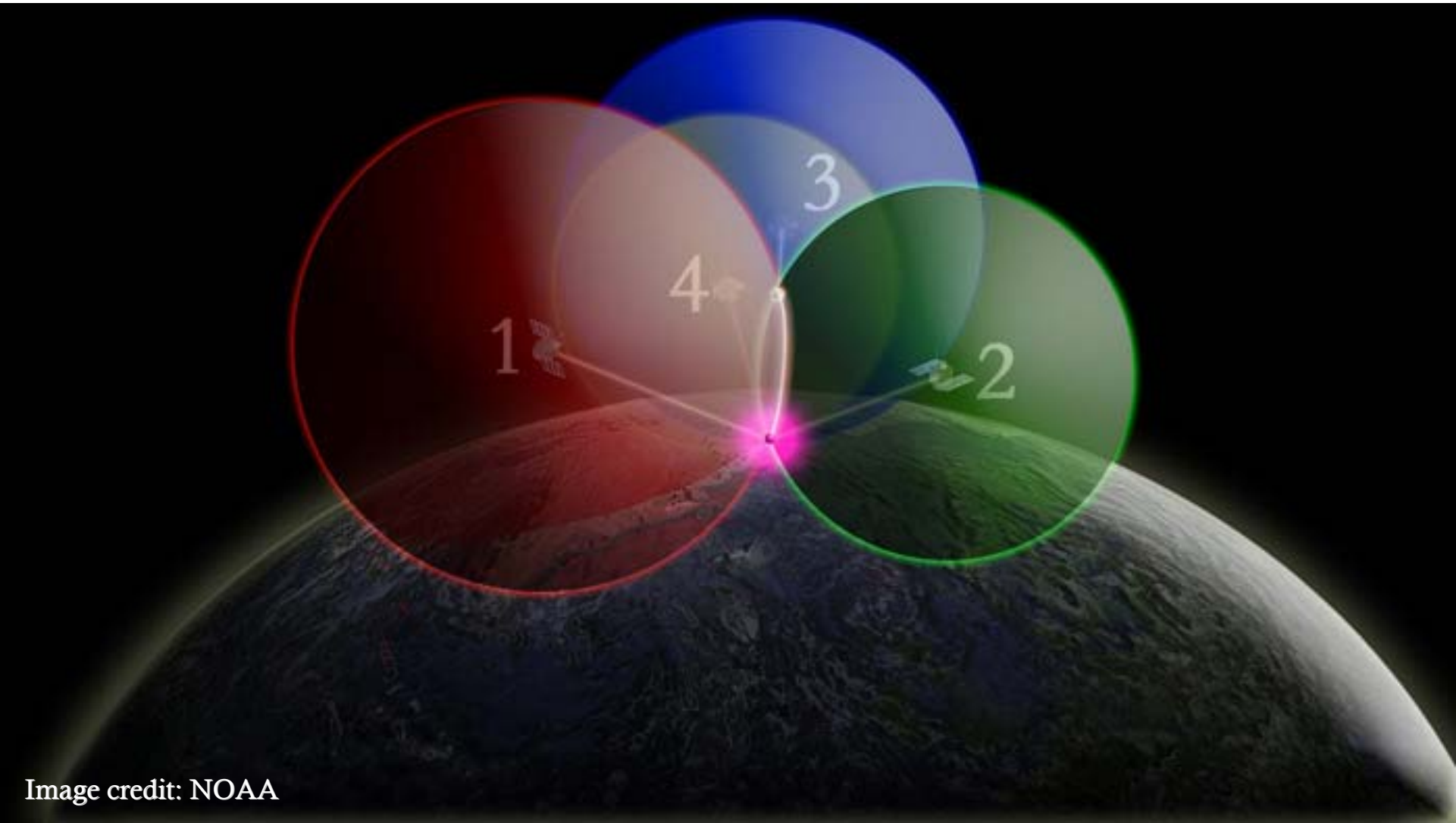


Image credit: NOAA

GPS Accuracy

Accuracy primarily depends on:

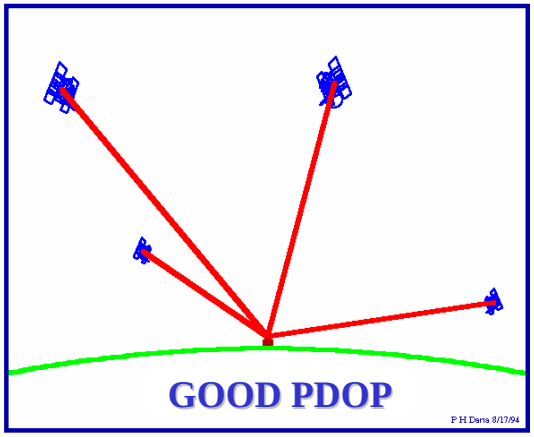
1. Number of satellites used to calculate position

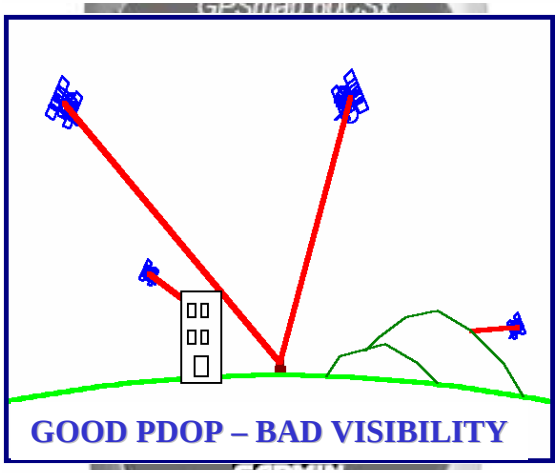
2. Strength of the signal of those satellites

3. Satellite position
   - Positional Dilution of Precision (PDOP)

4. Differential Correction Procedures
   - WAAS (can improve to 2-5m)
   - DGPS (can improve to 0.1-1m)

   (Your GPS unit must be WAAS- or DGPS-compatible!)





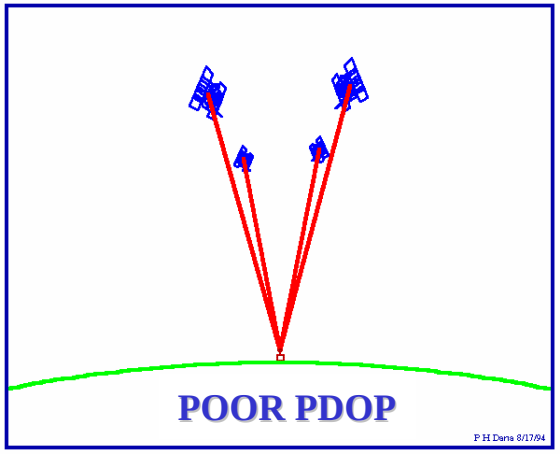
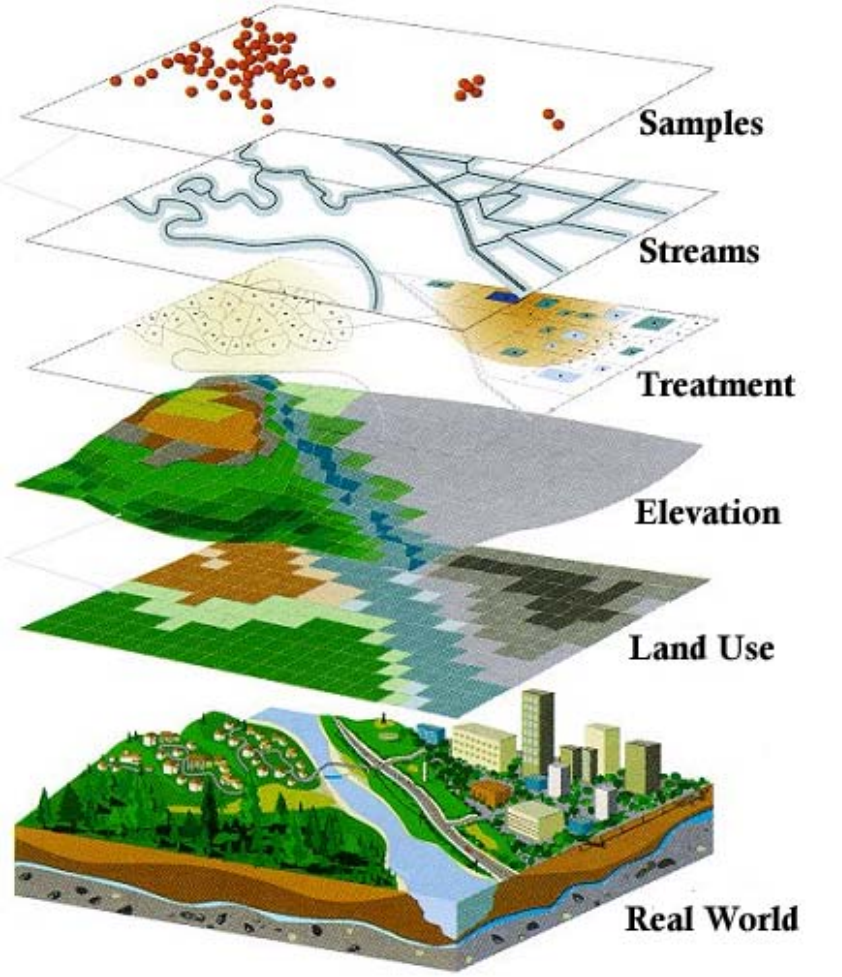


Image credit: P.H. Dana, Garmin

What is GIS?
Geographic **I**nformation **S**ystems

- Entry, editing, storage, query and retrieval, transformation, analysis, and display & printing of spatial data.
- GIS integrates spatial data from many sources, scales, and formats.
- *Key point*: All data in a GIS is **georeferenced**, i.e. located by means of geographical coordinates with respect to some reference system.



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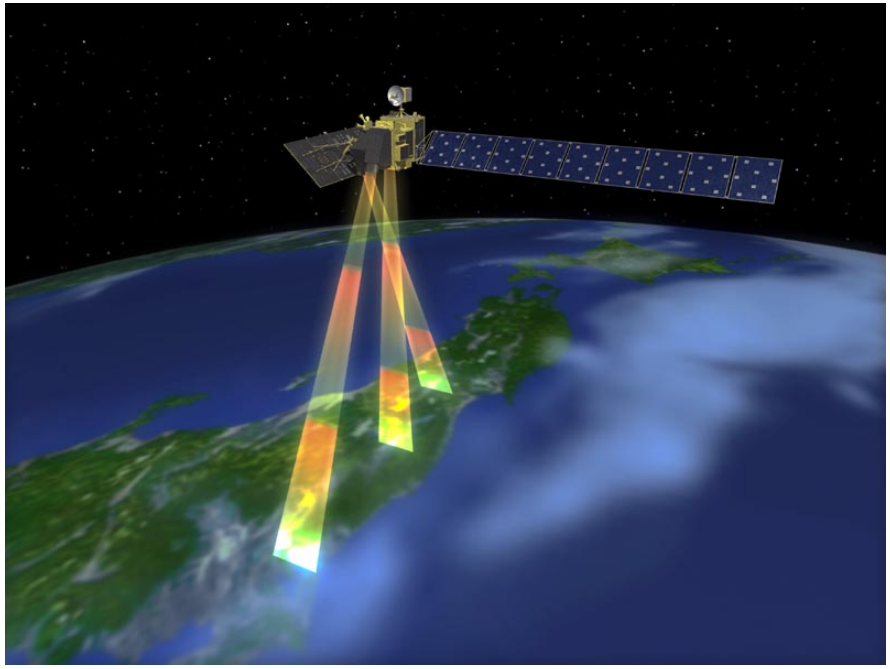
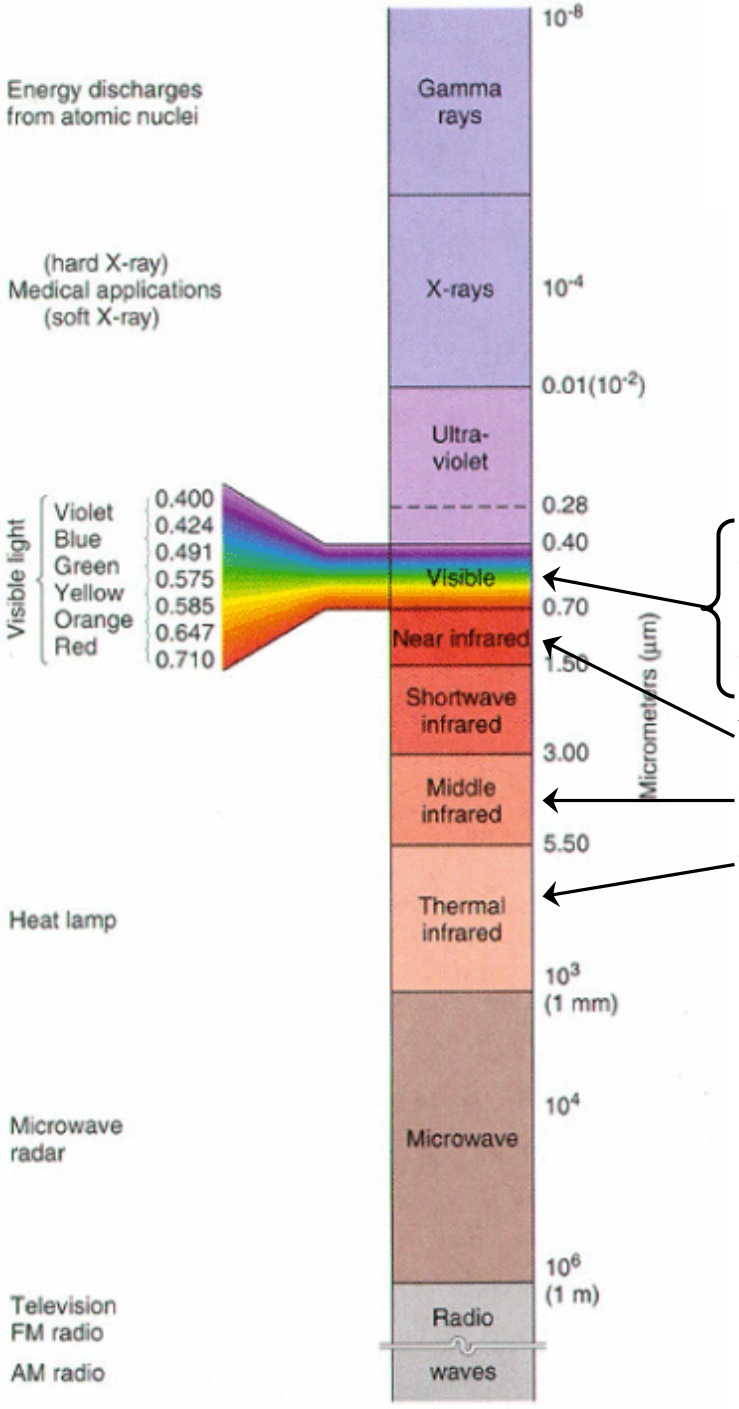
What is remote sensing?

- The capture of information about the Earth's surface from a distance, usually an airplane or satellite.



Electromagnetic Spectrum



source: Christopherson (2000) *Geosystems*

Blue: soil, plants, roads, water

Green: vegetation type differences, roads

Red: vegetation type differences & man-made features

Near infrared: biomass, veg types, soil moisture

Middle infrared: moisture in veg and soils, rocks

Thermal infrared: vegetation stress, soil moisture, relative heat

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Applications for Agricultural Field Research

- Precision agriculture includes the use of GPS, GIS, and remote sensing to manage practices in variable field conditions.

- Map, monitor, and manage:
  - Crop Production
    - Crop Pattern
    - Crop Yield (using NIR bands)
  - Irrigation
  - Moisture, Water stress (using Thermal bands)
  - Soil Management
    - Moisture (using Thermal bands)
    - Nutrients
  - Pests detection and monitoring
    - Spray applications

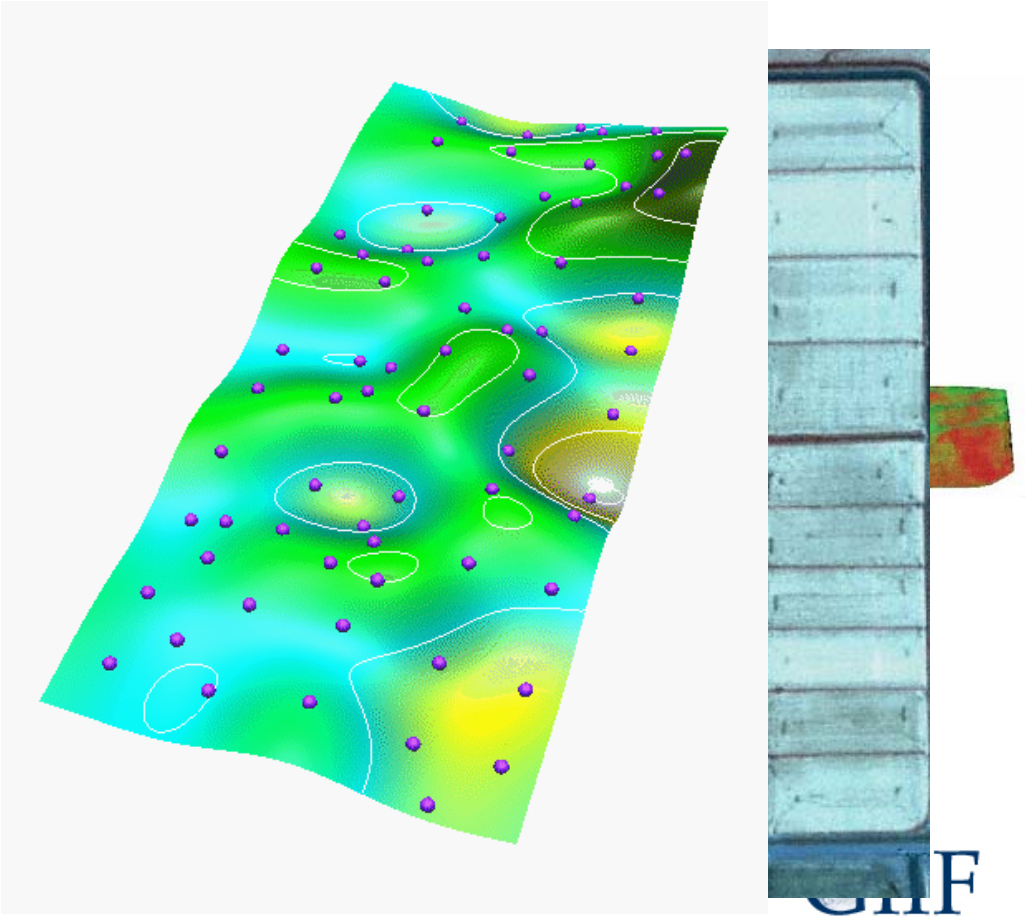

Image credits: http://www.gisrs.com/Agric.html

GPS Options for Field Research

- **Garmin w/ field notes**
  - Handheld GPS
  - Field notebook
  - PROS
    - Simple, light-weight, and inexpensive
  - CONS
    - Only gives GPS coordinates
    - Restricted to lower accuracy (2-15 m error)

- **Field PDA system**
  - PDA
  - GPS
  - Software
  - PROS
    - Collects data electronically
    - Uses custom programs and forms
    - Overlay GPS points on imagery in the field
    - Improved accuracy (up to 10 cm)
  - CONS
    - Expensive
    - Sometimes NOT user-friendly
    - Less light-weight

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Handheld GPS Units

- Accuracy is usually 5-15m; can be as much as 50m due under heavy canopy, PDOP, etc.
- Cannot set PDOP threshold
- Some have WAAS differential correction to improve accuracy to 2-5m.

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Guide to the Handheld Garmin models

- C – Color display
- S – Electronic compass and barometric altimeter
- X – Expandable memory, new SiRF chip

Garmin
GPSmap 76 C

Garmin
GPSmap 60 CSx

Garmin
eTrex Vista Cx

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Field PDA+GPS:

What You Need

- PDA:

- GPS (if needed):

- Software

ArcPad

Trimble TerraSync

Trimble GPS Pathfinder Office

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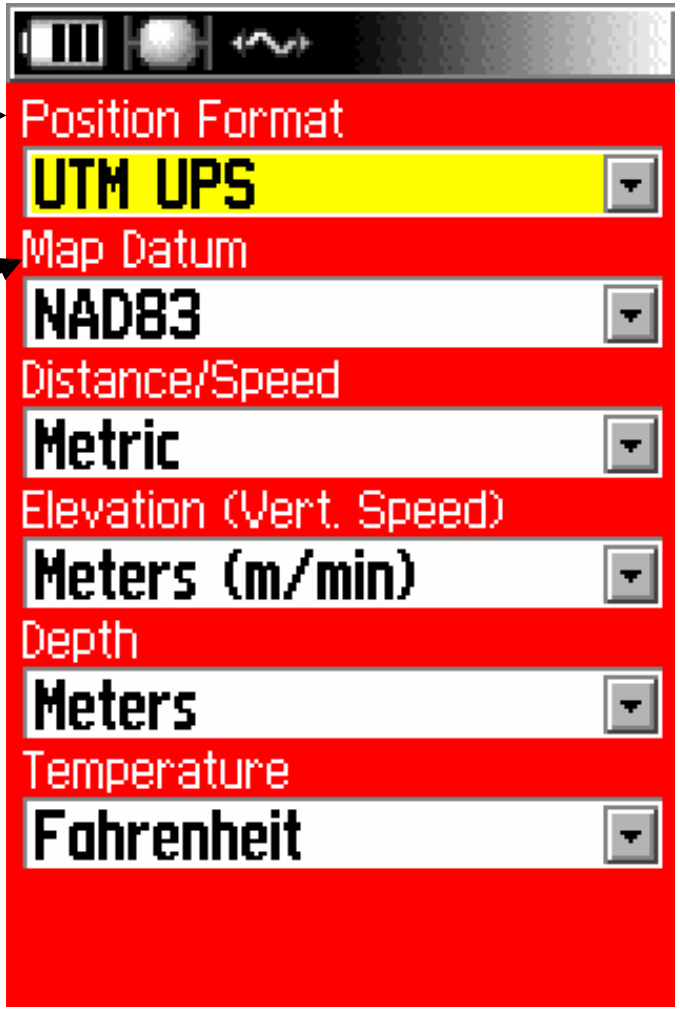
GPS for Agricultural Field Research

- What are your accuracy needs?
  - 2-15 m …handheld units are okay
  - <2 m …mapping-grade units are needed
- GPS good for mapping points, lines, and polygons of relatively small areas
  - Very large areas should be mapped/digitized using imagery in a GIS.
- How much data will you collect?
  - Points, lines, AND polygons?
  - Extensive field note taking?

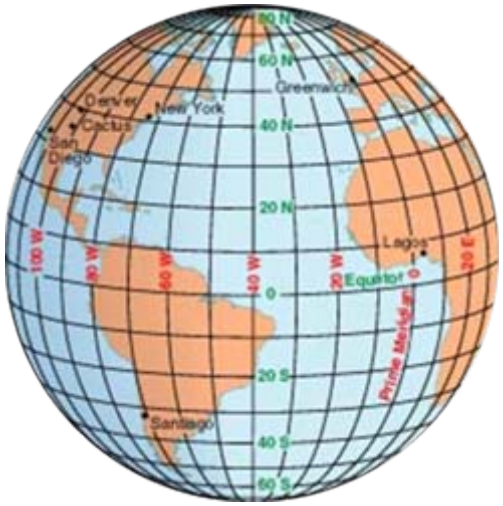
GPS Standardization

- Position Format
  - How 3-D earth is mapped on a 2-D surface
  - Same thing as "projection"
- Map Datum
  - Mathematical model that fits the earth to an ellipsoid



GPS Standardization

- Latitude/longitude is OK, but…
  - Lat/long is not consistent across Earth.
  - Misinterpretation of the three different formats (degrees-minutes-seconds, degrees-decimal minutes, and decimal degrees) can cause error.
  - Rounding lat/long numbers can cause error.



- Use UTM
  - Numbers represent meters, so each integer is a meter.
  - Split into zones so there are never negative numbers

- Most important thing is to <u>be consistent</u> and <u>document</u> what you do!

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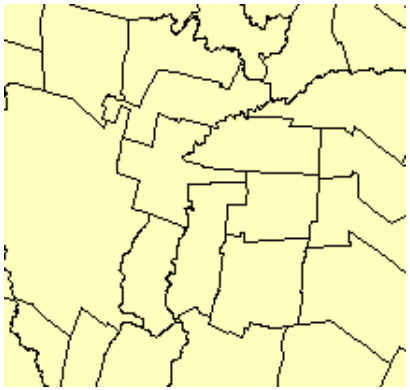
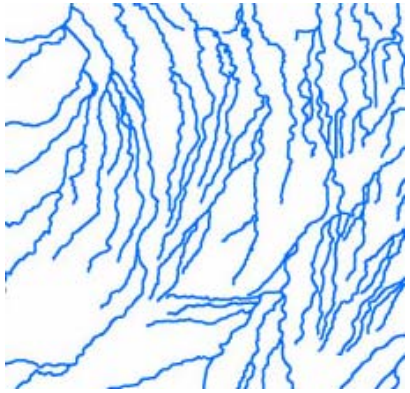
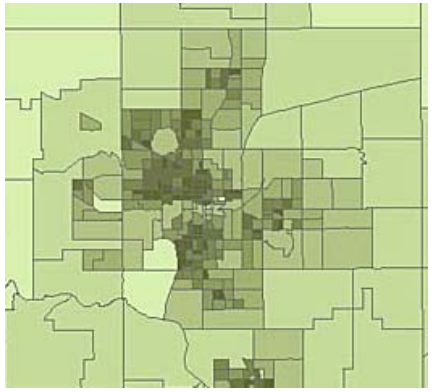
Geospatial Data Examples



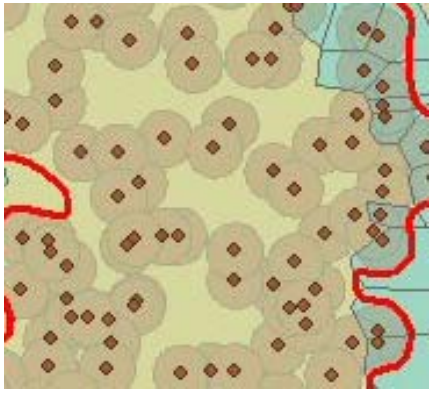
Counties



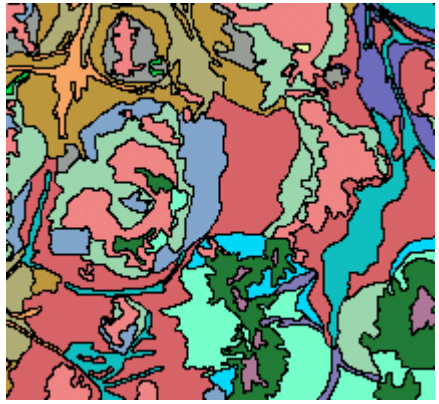
Rivers



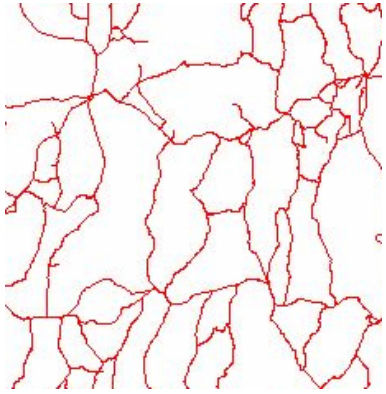
Census data



GPS data



Soil type



Roads

Habitat boundaries

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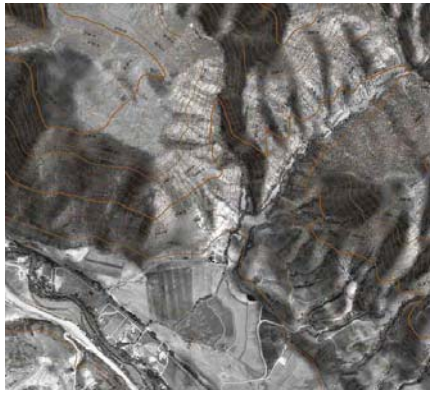
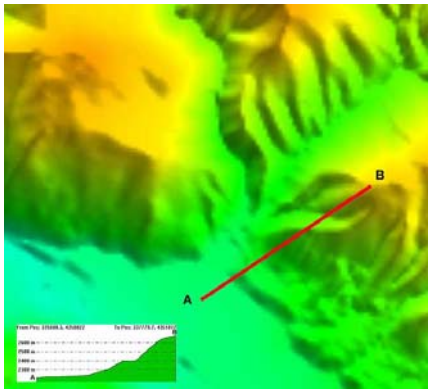
Geospatial Data Examples

Satellite imagery

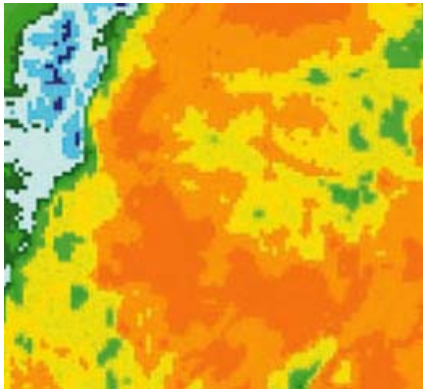


Elevation



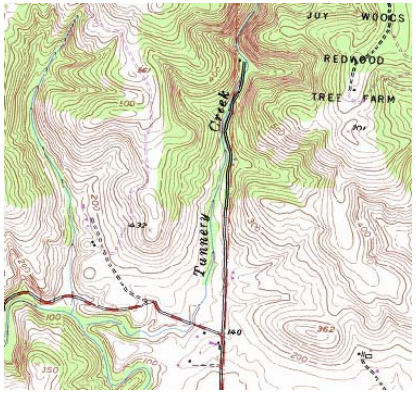
Temperature

Landcover/landuse



Precipitation

Aerial photography



Digital USGS topo map

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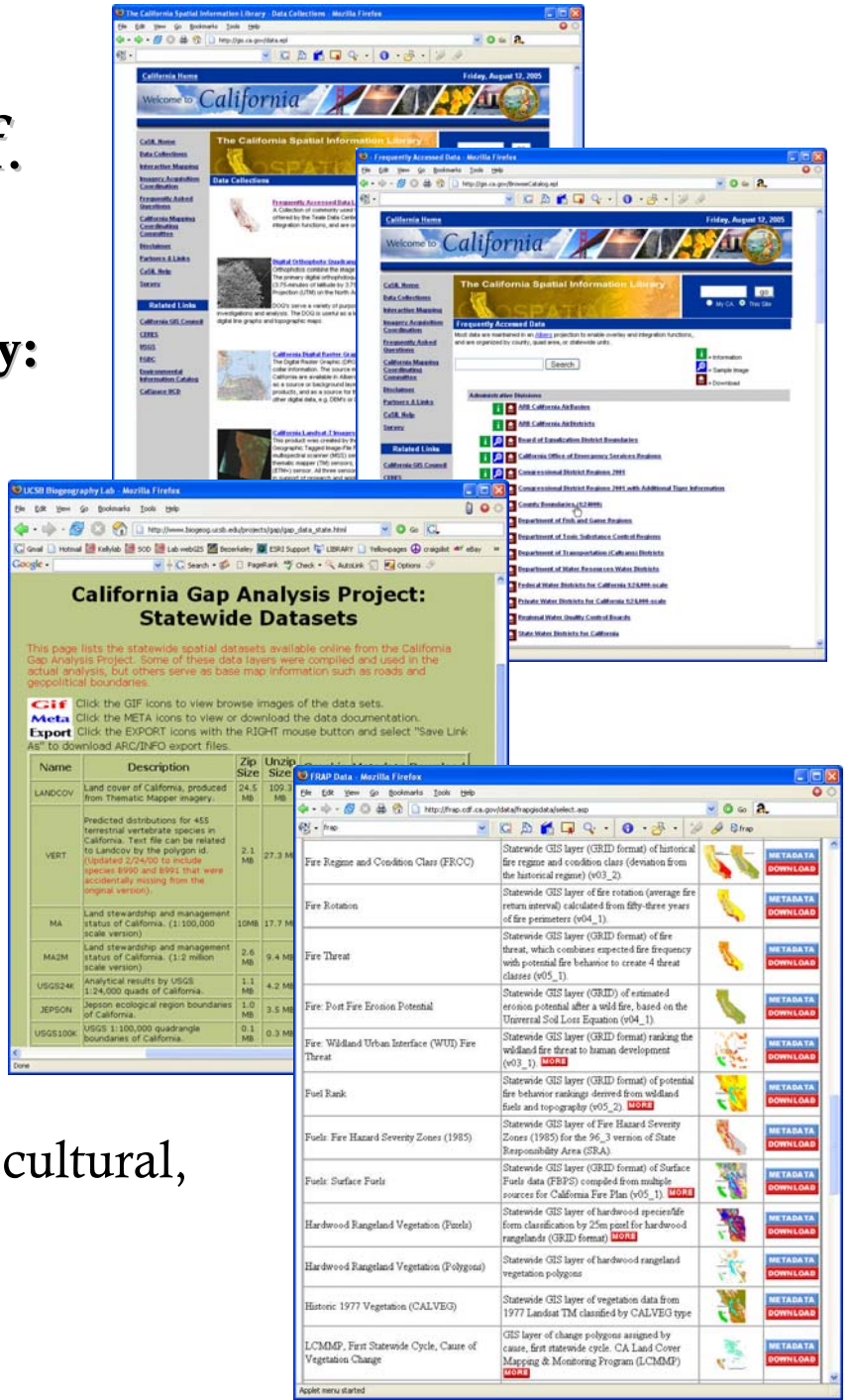
Free Geospatial Data for Calif.

- **California Spatial Information Library:**
  http://gis.ca.gov/data.epl

- **Cal GAP Project:**
  http://www.biogeog.ucsb.edu/projects/gap/gap_data2.html

- **CDF FRAP:**
  http://frap.cdf.ca.gov/infocenter.html



Includes geospatial data, such as political, cultural, and physical data.
Also includes some imagery!

Imagery

- **National Agriculture Imagery Program (NAIP)** – free!
  http://new.casil.ucdavis.edu/casil/remote_sensing/naip_2005/
  Annual true-color aerial photography for the entire state of CA (1m)
  Near-infrared flown but not yet available.
- **USGS:** http://seamless.usgs.gov/ - free!
  Aerial photography of urban areas flown in 2002 (60cm) & in 2004 (1m) – not of entire state though!
- **NextMap California:** http://www.intermap.com/corporate/california.cfm
  Elevation and imagery of the entire state (1m)
- Satellite imagery? …can be very expensive.
- Fly your own aerial photography? …useful but can be expensive.

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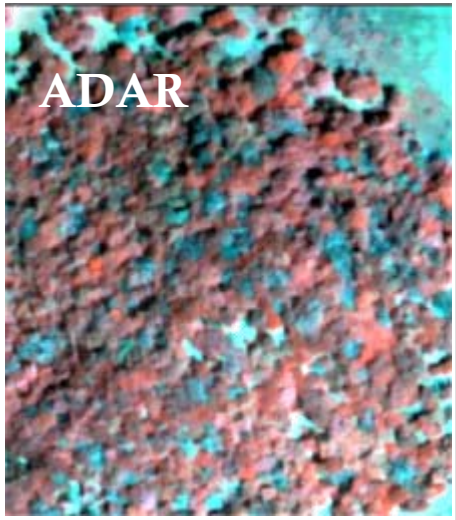
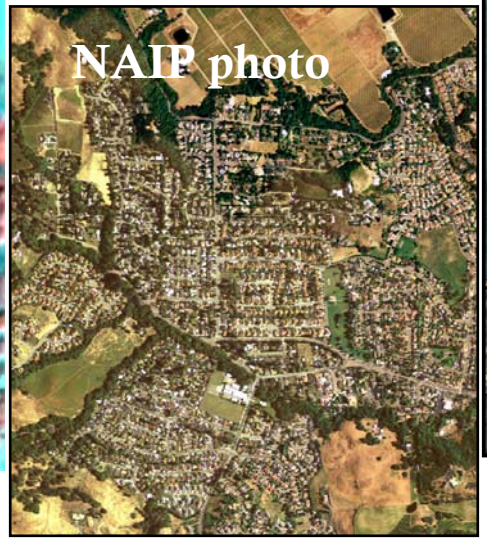
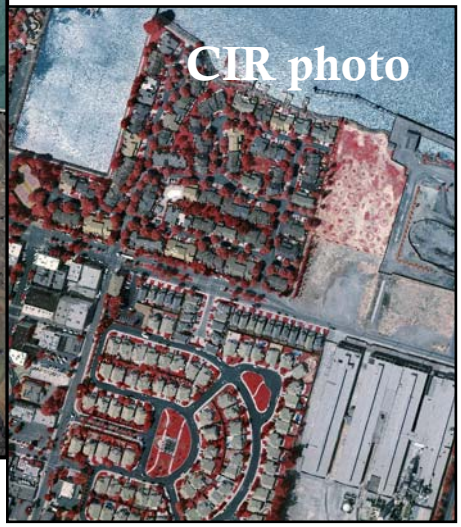
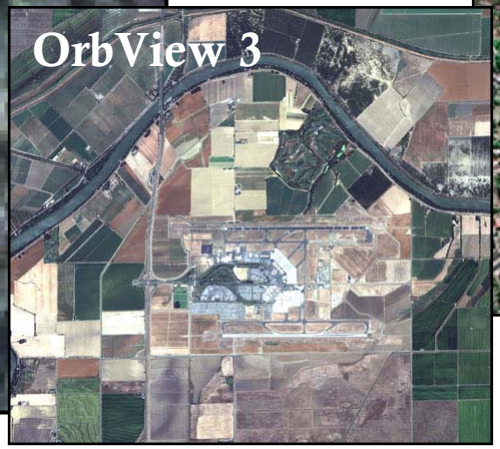
High Resolution Imagery









GIS Software:
Visualizing your geospatial data

Google Earth Plus
($20/yr)

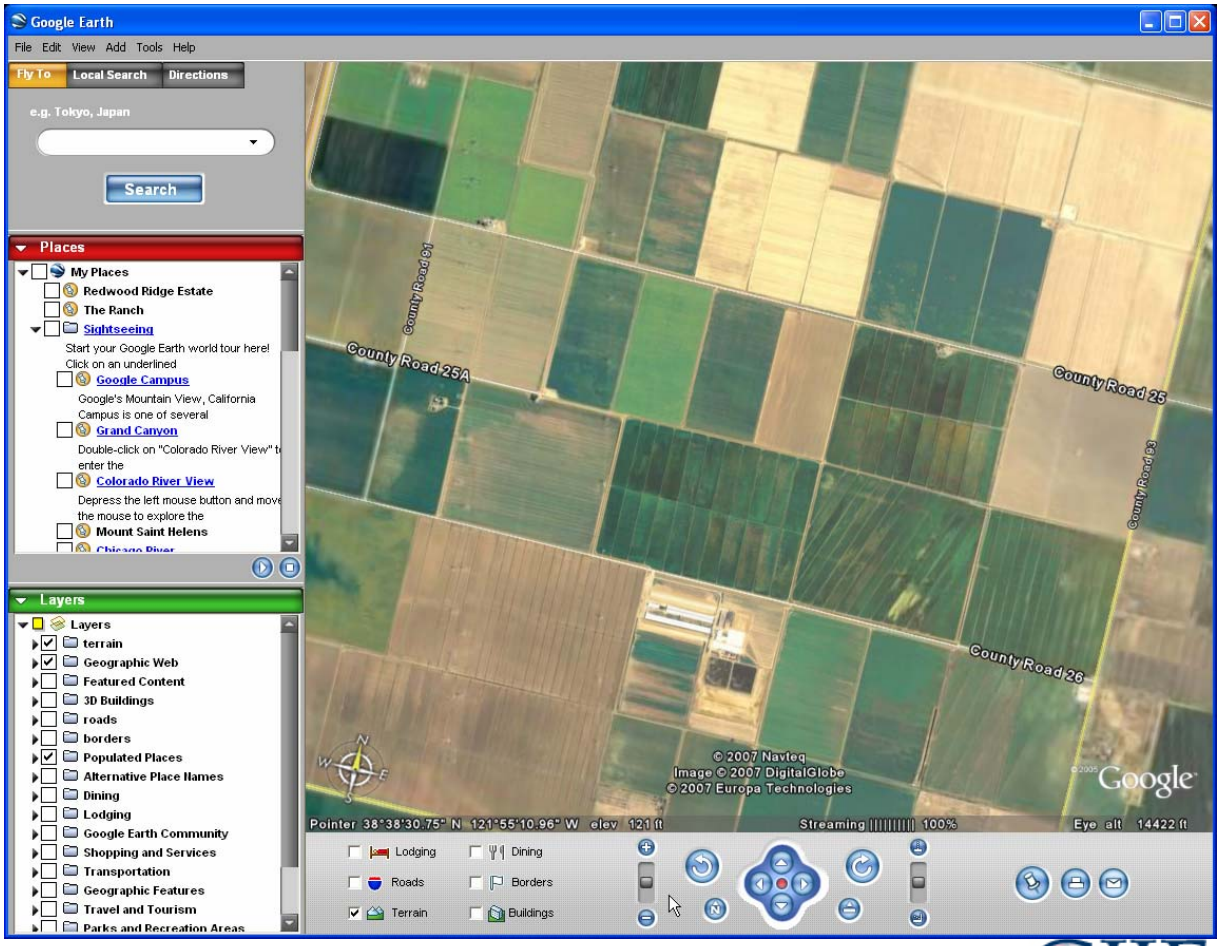
Google Earth Pro
($400/yr)

Pros:

- Easily integrate your GPS data
- Add geospatial data
- Use Google's huge database of imagery

Cons:

- Imagery might not be good for your site
- No spatial analyses



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GIS Software:
Make maps

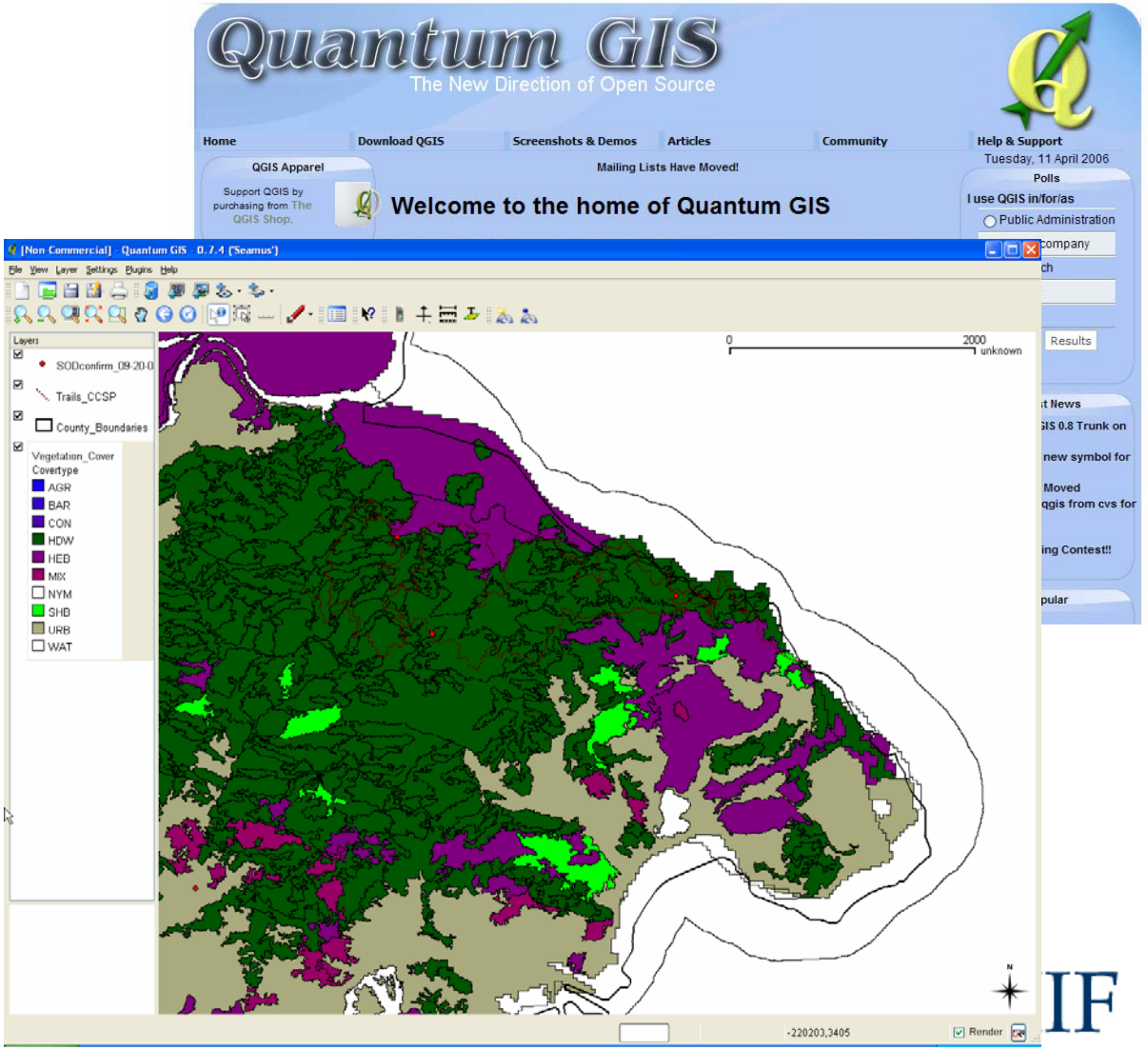
Quantum GIS (QGIS)
(free)

Pros:

- Add geospatial data
- Transfer your GPS points, after some setup
- Runs on PC and Mac

Cons:

- Sometimes finicky
- No spatial analyses
- Projection & datum must be the same



GIS Software:
Analyzing your geospatial data

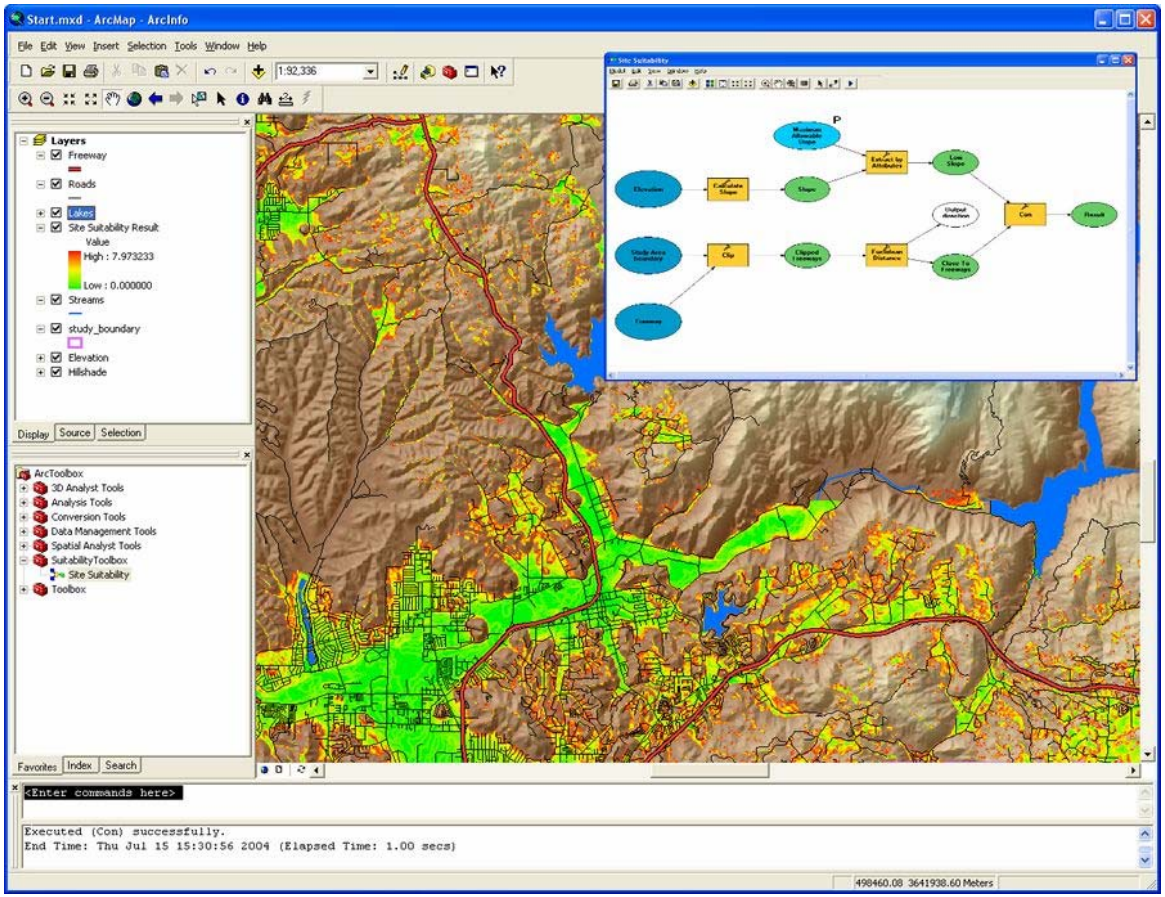
ArcGIS

Pros:

- Extremely powerful spatial analyses
- The sky is the limit!
- Projection on-the-fly

Cons:

- Steep learning curve for performing analyses
  - What to do?
  - Where to find the tool?
  - How to prepare the data?)



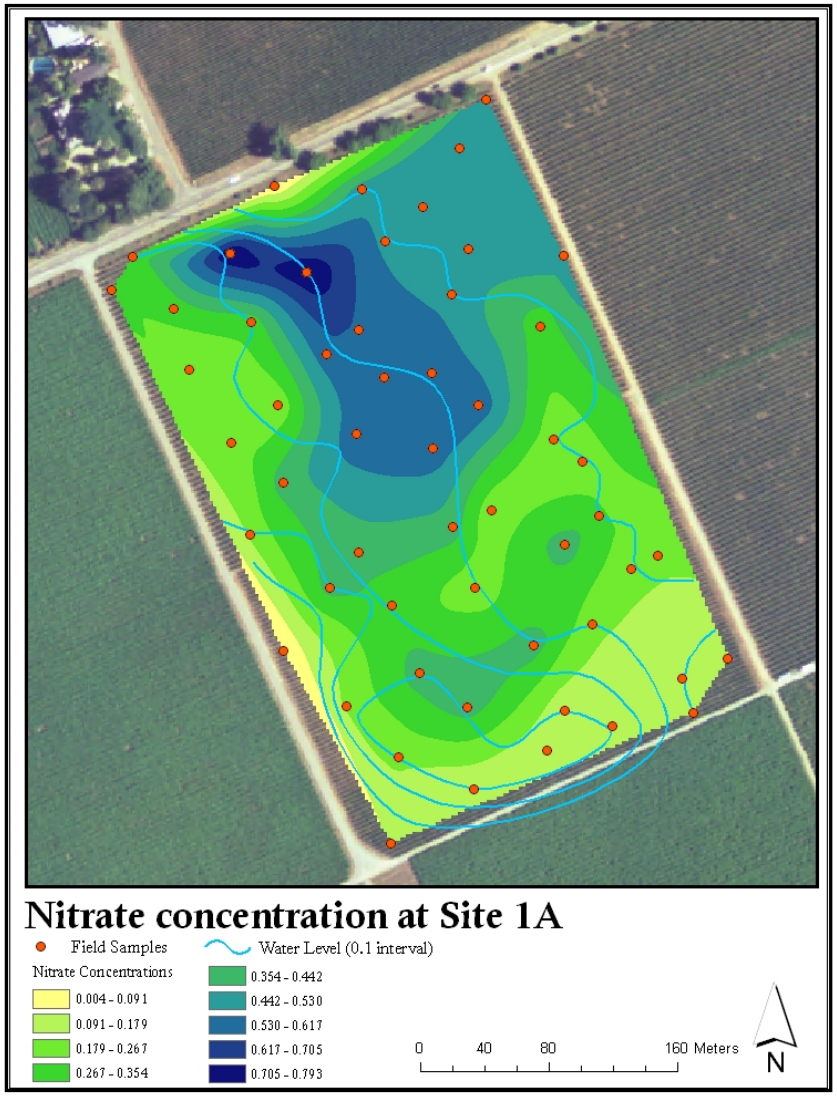
Spatial Analysis Example

You have GPS point samples

- Water level
- Nitrate

You can:

- Download NAIP imagery of your site,
- Plot your GPS points (with water level and nitrate as *attributes*),
- Interpolate contours of water level,
- Interpolate surface of nitrate concentration, and
- Make a map for distribution!



GIIF Workshops for UCCE

- Introduction to GPS & GIS
  - Wednesday, May 23
  - Wednesday, June 13
- Intermediate/Advanced GIS
  - Thursday, July 5th
  - Tuesday, July 24th
  - Tuesday, August 14th
  - Wednesday, September 5th

Tentative dates: Check website!

- Email Karin (karin@nature.berkeley.edu) to register!
- Visit http://GIIF.cnr.berkeley.edu/RREA/ for more info!

Funded by Renewable Resources Extension Act (RREA)

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Handouts for Further Reference

Handheld GPS Buyer's Guide:

What you need to know to buy the best handhe

Global Positioning Systems (GPS) is a common way to co
and natural resources. It is made up of a constellation of 2
accurately determine your location (X,Y,Z) in any weathe

There are several choices of GPS units, all of which differ
units are separated into three categories: recreation-grade,
guide is for recreational and basic mapping units only (wit
2-30m). For more information about higher-grade mapping
http://giif.cnr.berkeley.edu/gps.html.

There are several things you should consider when buying
research:

Waypoint capacity
How many waypoints, or GPS points, will the unit need to hold for the duration of the field visit?
Many Garmin units hold 1,000 waypoints, but some older models hold only 500. You must also factor in tracks, which are made up of waypoints, as part of the waypoint capacity. For most fieldwork, it is recommended to buy a unit with at least 1,000 waypoints.

Built-in electronic compass
Do you need an electronic compass? Electronic compasses
Some fieldwork needs electronic compasses more than others. If it is easy to move around in the field quickly and with relatively little effort (e.g., urban areas, low-lying grasslands, oak woodlands), then you may not need an electronic compass. However, fieldwork in areas where it is dense forest

Memory
What will you be putting on your GPS unit in the future?
Many GPS units now have a lot of internal memory (up to 128MB), but many also now allow for additional memory using removable microSD data cards, of up to 1GB or more. If you plan to buy MapSource road software or topographical datamaps to load into your GPS unit, it is a good idea to buy a unit with expandable memory. All units with an "x" in their model name have expandable memories. Warning: these units will have a much higher price tag!

Receiver
New receiver offers better satellite reception, but costs more.
Newer GPS models offer the SiRF chip, a high-sensitivity GPS receiver, which offers (1) faster GPS

1/5/2007
Image credits: Garmin.com

Buyer's Guide for Field PDAs:

What you need to know to buy the best PDA + GPS unit for your field work

Do you need a PDA for your fieldwork?
It can be a big decision (and often expensive) to go from a simple handheld
tem like a PDA for your fieldwork. There are things to consider when decidi

Use a handheld GPS if you…
- Only need GPS coordinates and prefer to use paper/note book to record field data,
- Want a simple and light-weight device,
- Are concerned with price.

Use a PDA if you…
- Want to collect fi
- Need a keyboard that is both fast ar
- Want to use custo
- Want to use custo
- Want to use more drop to your GPS

See the "Handheld GPS Buyer's Guide" for more info.

If you decide to purchase a PDA system for fieldwork, there are a few
- ✓ PDA
- ✓ GPS receiver (if you want GPS positioning)
- ✓ Software

PDAs

What's important for fieldwork?

Ruggedness & weather resistance
Rugged units are more expensive than lighter-weight ones, but the investment is worth it if your fieldwork includes moderate to extreme rugged terrain and environments. PDAs designed primarily for business or navigation applications (i.e. HP iPaq, Dell Axim) are not very water resistant, something to consider when you're in environments where it might rain or your water bottle/CamelBak might leak onto the unit in your field pack. It is also a good idea to buy a protective, water-proof case like the one pictured *above* made by DryPak (GPS works through the plastic!). The Trimble Recon (*below*) is rugged enough to work in freezing, muddy, and wet environments.

Operating system (OS)
The programs you want to run on your device will have a huge impact on the operating system (OS) you choose. Common OSs include: Windows Mobile (also known as Windows Mobile for Pocket PC or Pocket PC, etc.), Palm OS, and the new Mac OS X for iPhone. ESRI's ArcPad only runs on Windows Mobile operating systems. Since each PDA device runs only one OS, this will narrow down your choices for which device to buy.

Processor
The faster processor, th
ArcPad will run. With
background imagery w
Try to buy a processor
ARM-based processors
Samsung, Texas Instru
Since each PDA device
this will narrow down
you won't use ArcPad,
processor speed (MHz

Memory
The more memory ("R
programs, like ArcPad
minimum of 64 MB of
or more) is optimal. M
ditional $100-300.

GPS receiver: Integrat
A big decision is wheth
integrated GPS (like th
Mio 168RS, *right*), or w
need to buy a separate
handheld you already h
the expansion s
add a memor
data. Depe
GPS can be
necessarily
connection.
Compact Fl
See the desc

January 2007

GPS Field Protocol:

What you need to know when using your GPS unit for fieldwork

Global Positioning Systems (GPS) is a common way to collect location data for agricultural, u
and natural resources. It is made up of a constellation of 24 satellites used for civilian GPS, w
accurately determine your location (X, Y, Z) in any weather, day or night, anywhere on Earth
GPS unit uses four or more satellites to triangulate your position on Earth. For this reason, yo
four or more satellites! GPS satellite signals travel by line of sight, and will pass through cloud
glass, & plastic, but NOT through most solid objects, such as buildings & mountains.

Your GPS accuracy depends on:

The type of GPS unit you have
If you have a handheld GPS unit (e.g. Garmin), the highest attainable horizontal accuracy is about 3 m. More accurate units like Trimble's GeoXH, will give you accuracy of < 3 m, sometimes sub-meter accuracy under good conditions or with additional antennas. More expensive units are not *always* the most accurate – many have reported that Garmin handhelds give better accuracy under heavy canopy than do more advanced Trimble units.
Recommendation: buy the most affordable (and dependable) GPS that best suits your accuracy requirements!

Number of satellites visible to your receiver
Buildings, terrain, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. Also, signal multi-path might happen if a signal from a satellite is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, causing errors.
Recommendation: The more satellites, the better – but you must have four or more before you record a point! If you cannot get four or more, wait a few minutes for the satellites to move/adjust, or move to an area with better reception and make note of distance and direction moved from the desired point.

Strength of satellite signals
While many GPS units do not give you a measurement of satellite signal strength, you can get an idea of it by viewing the satellite screen on most GPS units, which depicts signal strength with bar graphs for each visibly satellite.
Recommendation: The stronger the signals, the better – just make sure you have four or more satellite signals before you record a point!

Geometric positioning of the satellites in the s
Ideal satellite geometry exists when the satellite located at wide angles relative to each other in s which improves triangulation and thus reduces While Trimble units give a measurement for sat geometry ("PDOP," "HDOP," or "GDOP"), h units do not give a measurement for it – it is a g to be aware that accuracy will improve when sa are distributed in different areas of the sky.
Recommendation: Aim for the satellites to be wid distributed across the skyplot on your GPS unit

Differential correction procedures
Wide-Area Augmentation System (WAAS) is a on many GPS units (see "Handheld GPS Buyer Guide" for more info), and on all Trimble recei WAAS can improve GPS accuracy to within 2 compatible handheld GPS units, and to less tha with Trimble units. However, it's only available North America, and you need an unobstructed the southern horizon, so it's ideal for open land open agricultural crops) and marine application know you are receiving WAAS signal if you are receiving signals from satellites with ID numbe higher (in the skyplot). Differential GPS (DGPS available for Trimble units (a PDAs with ArcPad and GPS software) and can improve ac to about 1 cm.
Recommendation: Only enable if you have an open view of th southern horizon – if you hav WAAS enabled without a cle your accuracy will be reduced the GPS unit is constantly try find the WAAS satellites. As DGPS, use it if you have acce DGPS correction (either real- post-processed), and you wan meter accuracy.

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Pictured here is a Garmin GPSmap 60CSx as an example of the satellite screen, which all GPS devices contain.
Image credit: Garmin.com

GPS Field Protocol
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Geospatial Resources for Agricultural Field Research

Helpful resources and links for using geospatial tools for agricultural research

Basic GIS software
- ESRI ArcGIS (version 9.2 is most recent) – Windows-based GIS program for beginning-to-advanced GIS analysis (available to UCCE through UC Davis)
- ESRI ArcView GIS (version 3.3 is most recent) – Windows-based GIS program for beginning-to-advanced GIS analysis (available to UCCE through UC Davis)
- Google Earth – a Windows- and Mac-based program that allows viewing of imagery and information from local to global scales. The Plus version costs $20/year and allows you to add your GPS points from your GPS unit. The Pro version costs $400/year and allows you add your GIS data (all types) and your GPS points from your GPS unit (http://earth.google.com/).
- Quantum GIS (QGIS) – a Windows- and Mac-based free GIS program for beginning-to-intermediate GIS analysis (http://www.qgis.org/).

Programs and extensions for transferring GPS data between your GPS device and your computer
- Minnesota's Dept. of Natural Resources Garmin applications: http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html Works only with Garmin handheld units. Allows integration with ArcGIS – you can save as a shapefile and automatically add to ArcMap.
- Garmin's Trip and Waypoint Application (comes with all Garmin GPS units): http://www.garmin.com
- MxGPS - ArcMap Extension : http://www.mxgeo.com/
- GPS Utility: http://www.gpsu.co.uk/
- AV Garmin extension for ArcView GIS 3.x: http://arcscripts.esri.com/details.asp?dbid=-962379091 Works only with ArcView GIS 3.x and Garmin handheld units.
- Waypoint+: http://www.taer.org/~kb7z/Waypoint/

How do I get more information on GPS and GIS?

Good GIS websites:
- ✓ GIS.com: http://www.gis.com/
- ✓ Wikipedia: http://en.wikipedia.org/wiki/Geographic_information_system
- ✓ GIIF website: http://giif.cnr.berkeley.edu/gis.html

Good GPS websites:
- ✓ Trimble's GPS Tutorial: All About GPS: http://www.trimble.com/gps/
- ✓ University of Texas, Austin GPS information: http://www.colorado.Edu/geography/gcraft/notes/gps/gps_f.html
- ✓ History of GPS: http://www.beyonddiscovery.org/content/view.page.asp?I=464
- ✓ Trimble GPS training: http://www.gps-trainer.com/
- ✓ GIIF website: http://giif.cnr.berkeley.edu/gps.html

How do I get more training in GPS and GIS?
- The GIIF is hosting GPS and GIS workshops in 2007 specially designed for Cooperative Extension advisors and specialists, with funding from RREA 2006/07. The workshops are free to Cooperative Extension colleagues. Visit http://giif.cnr.berkeley.edu/RREA/ to sign up for a course!
- The Bay Area Automated Mapping Association website lists colleges and universities around the Bay Area-Delta Region which offer GIS instruction. Visit http://www.baama.org/education/ for more information.
- ESRI hosts a virtual campus at their website: http://campus.esri.com/, where you can take courses online or in-person with an instructor, for any of the software.
- Many websites exist online for GPS and GIS training. One example is http://www.gps-trainer.com/

1/5/2007

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http://GIIF.cnr.berkeley.edu

GIIF