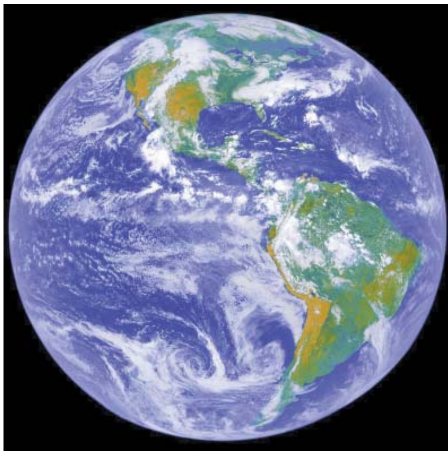


GPS and Surveying of Weed Populations
Equipment and Costs

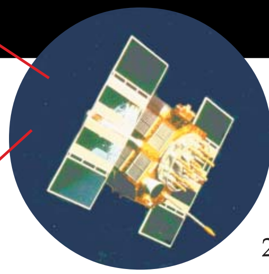
By: Pat Akers, Integrated Pest Control Branch, California Dept. of Food and Agriculture

Scott Park uses a GPS unit to measure a *Lygodium* infestation in the Big Cypress Seminole Indian Reservation in Florida. Photo by John Volin.

Nowadays most people are probably aware of the existence of the Global Positioning System, better known as GPS. Many know that it's useful for surveying, agriculture, mining, geology, navigating and locating objects on the earth. In fact, GPS has found many important uses in natural resource management, including the mapping of weed populations. This article describes the selection of GPS equipment for the mapping and management of weeds.

A Primer on How it Works

GPS has three major components. The first component is the GPS unit, which gives us access to the system. A GPS unit is a specialized radio receiver combined with electronics for



filtering and calculations. The second major component is a set of 24 specialized satellites that the GPS receiver uses for calculating its position. The third component is a set of ground stations for tracking the satellites. Each satellite broadcasts several different sets of information, of which three are most important to our discussion: 1) a time signal, 2) information on the satellites' positions, and 3) a unique binary sequence code (C/A). By receiving the satellite signals, the GPS receiver can triangulate its position by calculating its distance from each satellite. *For an expanded description of different sets of information see www.cdfa.ca.gov/gps.*

Effects of the System on the Field User

The characteristics of the system have at least four major effects on its use in the field: 1) Ninety-five percent of the time, the system (itself) will estimate a position within about 22 meters of the true position. The Department of Defense adds an additional error signal to the system, degrading its accuracy to about 100 meters. This makes the accuracy of an expensive GPS about the same as a low-end model. 2)The receiver has to be able to lock onto at least four satellites in order to determine a position in three dimensions. 3) Trees, hills or buildings can obscure the satellite signals. 4) At times, the satellites will be clustered in one small part of the sky. Such an arrangement can seriously degrade the accuracy of the position calculations. Some GPS units will stop collecting data under such conditions, and all you can do is wait 20-40 minutes until the satellites move into a better arrangement.

Choosing a GPS Unit: Juggling Needs

The selection of a GPS unit will strongly depend on the needs of the user. Examples of common user needs are:

1) Accuracy for navigation.
2) Accuracy for detailed mapping (with 2-3 meter accuracy being adequate).
3) Accuracy without having to remain on a single location for more than 1 second.
4) The GPS data must be easily transferred to a mapping program (Geographic Information System or GIS).
5) The ability to record specific descriptive information along with the positional data.
6) The unit should be as convenient to use as possible.
7) Costs should be kept as low as possible. Meeting different requirements affects the cost of the GPS solution.

Low-end Systems - The absolutely lowest cost option is one of the many sportsman GPS models on the market. Many of these units are highly sophisticated, very portable, offer a number of convenient bells and whistles, and cost less than $300, sometimes as little as $200. For example, both Garmin and Eagle manufacture 12-parallel-channel GPS units which have received good reviews from users. These systems are limited to 100 meter accuracy unless differentially corrected. Although many of these units describe themselves as "DGPS ready," an antenna and receiver for the correction data must be added separately. They also have limited capabilities to store GPS position information, especially descriptive data.

The next important improvement is the addition of differential correction capability. There are a lot of options, with lots of trade-offs. However, the issue is further complicated because Trimble's "mapping-quality" GPS units all provide essentially a complete mapping package, including the ability to differentially correct data using PPDGPS. Since there is almost a qualitative divide between them and other GPS systems, I will treat Trimble products separately.

Trimble vs. Everybody Else: "Mapping Grade" GPS systems - Trimble mapping products are expensive, but they provide mapping data with 0.5-3 meter accuracy, using a standard computer and Internet connection. Their system includes software (Pathfinder Office) that runs on the PC computer and provides a powerful and easy PPDGPS facility. The package provides reasonably flexible data entry capabilities, the ability to record information on line-type or area-type objects (instead of just points), and flexible integration with GIS systems.

Trimble has essentially two lines that depend on PPDGPS. 1) *Trimble's GeoExplorer* is a hand-held GPS that costs about $3500 with the battery pack. It provides 1-3 meter accuracy, differentially corrected. It has a fairly flexible data entry capability and it's controlled through a series of menus, but it has only 8 buttons on the keypad. Text data is entered by scrolling through the entire alphanumeric character set, which can be quite tedious. Fortunately, the data entry screens allow the creation of menus, which can often minimize the need to enter text. 2) *Trimble's Pathfinder Pro XL* has the GPS receiver mounted in a backpack, attached to a handheld datalogger, and its 8- or 12-channel GPS engine provides accuracy to less than a meter. Trimble no longer manufactures it, but it can often be found used. The updated versions of the ProXL are the ProXR and ProXRS, which integrate RTDGPS capability and provide accuracy down to 0.5 meters. They cost $9,000 to $12,000. The "ProX" line dataloggers provides better information about the GPS status than the GeoExplorer and they have full alphanumeric keypads. *For further discussion see www.cdfa.ca.gov/gps.*

And for Everybody Else: Real Time Differential GPS (RTDGPS) - RTDGPS has one big advantage over Post-Processed Differential GPS (PPDGPS): the corrected, high-accuracy results are available immediately in the field. This makes RTDGPS extremely useful for navigation, as its accuracy is 1-20 meters, depending on the quality of the receiver and the reference data. The major disadvantage of RTDGPS relative to PPDGPS is that the accurate results depend on remaining in contact with the reference station. Any locations recorded while out of contact will

USDA researchers use GPS technology to track the progress of the country's first melaleuca biocontrol agent, *Oxyops vitiosa* in Florida.

have only 100 meter accuracy, and there will be no way to improve that accuracy, either in the field or the office (unless you also have PPDGPS capability, or want to stay on one location for an extended period of time so you can average the results). PPDGPS does not depend on remaining in contact with a reference station. RTDGPS is also somewhat less accurate than PPDGPS, but the difference is generally negligible for all but the most demanding applications. In the past, RTDGPS had other disadvantages having to do with the complexity and expense of implementing RTDGPS relative to PPDGPS, especially for implementing the most dependable solutions. However, as with most emerging technologies, costs continue to drop and performance improves. In the last year or so RTDGPS solutions have begun to appear that approach the cost-effectiveness and dependability of Trimble units.

The major variable in the cost vs. dependability equation of RTDGPS is the choice of the source for the differential correction data. For most of us, there are three major sources for correction data: 1) commercial broadcasts on FM wavelengths, using transmission facilities of normal commercial radio, 2) commercial broadcasts from geosynchronous satellites, and 3) government broadcasts from specialized Coast Guard DGPS transmitters called "Beacons." As you might expect, there are trade-offs between cost, convenience, and capability for these different options. *For a more complete discussion of sources for data correction see www.cdfa.ca.gov/gps*

Mix and Match - There are two other trends that can affect the choice of a system. First, RTDGPS has such overpowering advantages that manufacturers are integrating RTDGPS receivers with GPS receivers in their higher-end systems. For example, *Trimble's ProXL* has been replaced by the ProXR, which incorporates a Beacon receiver, and the ProXRS, which incorporates both a Beacon and satellite receiver. The other trend is to turn a computer or other equipment into a GPS system. For instance, TeleType produces a small GPS sensor, without any readout whatsoever, that can plug into the PC port of a laptop computer and turn it into a GPS unit. Including software to allow viewing of the results against a background map, it costs about $850. At CDFA, we are about to evaluate a similar system. It combines a Racal Navigator 2-meter accuracy DGPS sensor (which is a Trimble 8-channel GPS receiver integrated with Racal's DGPS correction receiver), a handheld Windows CE computer, and datalogging/GPS/mapping software to create a complete datalogging RTDGPS system, which should also provide a moving map for navigation purposes. The sensor costs about $2800, the handheld computer about $600, the software about $700, and various costs for cables, battery, and pack bring the total cost to $4500, which includes one year of the satellite DGPS subscription service. This competes in cost with the GeoExplorer, yet provides real-time differential GPS in the field for excellent navigation (especially with the moving map), robust satellite service, and a very convenient and flexible data entry system.

What's a Poor Mapper to Do?

If you are trying to get into GPS mapping of weeds, the first step is to

XenoNET

General GPS Web Sites

www.navcen.uscg.mil/dgps –The Coast Guard site for DGPS
www.fs.fed.us/database/gps/ USFS -GPS Page, especially good for access to Trimble Base Station sites
ftp://ftp.trimble.com/pub/cbsfiles/-Trimble's base station files from Sunnyvale, CA
www.fs.fed.us/database/gps/eureka.htm -USFS Eureka, California GPS base station
www.cnde.iastate.edu/staff/swormley/gps/dgps.html -Sam Wormley's DGPS explanations
www.qualityeng.co.uk/gpstutor -GPS Tutor: fairly detailed treatment
vancouver-webpages.com/pub/peter/index.html - Peter Bennett's GPS and NMEA Site
www.geo.swt.edu/reference/Gps.html -GPS LINKS
www.gislinx.com/GPS_Sites/ - Gateway site for links to many GPS and GIS issues
www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html –GPS overview
www.trimble.com/gps/index.htm –Trimble GPS overview

GPS "General Stores"

www.navtechgps.com -Navtech GPS Store
www.cansel.ca –Cansel: sales and rentals GPS and surveying equipment
www.geowarehouse.com -Geowarehouse
www.nvlt.com/index.html -NVLT GPS Receivers and Satellite Communication Products

Mapping and Surveying Grade GPS Manufacturers

www.trimble.com -Trimble GPS Solutions
www.cmtinc.com-Corvallis Microtechnology, Inc
www.satloc.com/index.stm -Satloc: especially for agricultural applications, but also mapping
www.ashtech.com -Ashtech, now merged with Magellan
www.topcon.com –Topcon, mostly surveying

Consumer-grade GPS Manufacturers (including Beacon RTDGPS receivers)

www.eaglegps.com -Eagle Electronics
www.garmin.com -Garmin GPS products
www.magellangps.com -Magellan GPS products

Vendors of FM RTDGPS receivers and services

www.accqpoint.com -ACCQPOINT Communications Corporation
www.dgps.com -DCI's DGPS and TMC Services

Vendors of Satellite RTDGPS receivers and services

www.omnistar.com -OmniStar
www.racal-landstar-usa.com
www.racal-landstar.com -Racal LandStar

Post-Processing DGPS Software

www.geotronics.se:81/gpssoft.shtml - Geotracer System 2000 establish your priorities, including cost. Your budget will determine whether you can afford differential correction and flexible data entry and manipulation. Also consider where you work. If you work within range of the Coast Guard Beacons, this is definitely an option to consider carefully. A simple sportsman model GPS with an added consumer-level Beacon receiver (accurate to 4-12 meters) would not cost much more than $600 total. For another $1100-1500 you could add flexible data entry, by interfacing a Beacon-based RTDGPS sensor with a consumer handheld computer and appropriate software. If you work beyond the range of the Beacons but have a higher budget, *Trimble's GeoExplorer* provides data entry flexibility, good accuracy for mapping via PPDGPS, and no continuing subscription costs. If you can afford an additional $800 per year above the cost of a GeoExplorer, then a handheld computer system interfaced with a satellite-based RTDGPS will give you accurate navigation, very convenient data entry, and the freedom of satellite RTDGPS. If you cannot afford differential correction, probably greater overall accuracy can be achieved with careful marking of 7.5 min USGS topographic quads in the field, rather than GPS. Finally, remember that GPS is an emerging technology. If you can't afford what you want now, in a year or two it might be available.

Improving the Accuracy of the GPS System: Differential Correction

Most of us would probably wish to locate a weed to better than 100 meters, or even 20 meters. There are several ways of improving the accuracy of the GPS system, but the one that presently offers the best combination of speed, convenience, cost, and dependability is called differential correction, or differential GPS (DGPS). It is not the most accurate, but will provide 0.5 -10 meter accuracy with one second of data, depending on the quality of the GPS receiver. Even the better sportsman models routinely provide 2-5 meter accuracy using differential correction. One to three meters of accuracy has proved adequate for our needs at CDFA, and DGPS has so many other advantages over more accurate approaches that we have never implemented them.

DGPS works on a simple principle. One unit is stationary, at a known location, and acts as a reference base station. The base station unit knows its true location, but continues to calculate its position according to the information it receives from the GPS satellites. The difference between the calculated position and the true position provides an accurate estimate of the errors in the calculated measurement, at the time of the measurement. This estimate of the error can then be applied to the position calculations made at the same time by any GPS unit nearby (called the mobile or rover unit), even if it is moving. For many applications, "nearby" can be anywhere up to 200 miles.

There are two major methods whereby differential corrections can be applied to the measurements made by a mobile unit. 1) **Post-Processed DGPS (PPDGPS):** The position measurements are stored in the mobile GPS and later downloaded to a computer. The correction measurements from the reference GPS are also downloaded into the computer, and then specialized software applies the corrections to the measurements made by the mobile unit. 2) **Real-Time DGPS (RTDGPS):** The correction measurements from the reference GPS are sent to the mobile GPS (almost always by radio), and the corrections are applied to the position measurements a split second after they are made. The mobile GPS unit must have the necessary software and circuitry to apply the corrections to the mobile GPS position measurements, but this capability is now common in modern GPS units, even many sportsman models. Such models use phrases such as "DGPS ready" to describe themselves. A separate antenna and receiver must be added to the GPS unit so it can receive the broadcasts from the reference station. In addition, in many cases access to the reference station signals is sold as a separate service. In high-end professional GPS units, integrated receivers for the reference stations are becoming more common.

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NAEPPC Meets at Natural Areas Association Conference

Brian Bowen,
SE-EPPC Coordinator

The National Association of the Exotic Pest Plant Council met on October 13 in conjunction with the 26th Annual Natural Areas Conference in Tucson, AZ. The meeting was well-attended with representatives from CalEPPC, FLEPPC, TN-EPPC, KY-EPPC (forming) and Mid Atlantic-EPPC (MA-EPPC). The Pacific Northwest EPPC was unable to attend. A brief overview was given by Brian Bowen regarding the history of NAEPPC. There was a discussion of the MOU signed by FLEPPC, CALEPPC, PACNWEPPC, and TN-EPPC at Asilomar, California in 1995 which established NAEPPC. Brian Bowen of TN-EPPC, John Randall and Nelroy Jackson, both of CALEPPC who were present a this meeting, also helped draft the 1995 MOU. John Randall suggested that the MOU be updated. Nelroy Jackson, who was the original transcriber, agreed to work on updating it. Brian and John agreed to review the changes. The MOU will then be sent to all of the respective EPPC boards for approval.

Some noteworthy changes include updating the MOU to add the newly-formed Councils. This may also include organizations interested in participating in the NAEPPC even though they are not an EPPC formally by name, ie., the New York Invasive Plant Council. All participating organizations however will be required to subscribe to the EPPC mission and its goals. The MOU will clearly state that EPPC's purpose pertains to natural area and wildland weed issues. It was