GLOBAL POSITIONING SYSTEM (GPS): CURRENT STATUS AND POSSIBLE NURSERY USES

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The GPS (Global Positioning System) is a worldwide satellite-positioning system that was funded, installed, and continues to be operated by the U.S. Department of Defense. The navigation signals are provided free and can be used by anyone who has the equipment necessary to receive them.

The Missoula Technology and Development Center (MTDC) became involved with GPS technology in August of 1983 when the Timber and Engineering Department, the program's main sponsors, recognized the potential of GPS for resource management activities. The USDA Forest Service's Washington Office assigned the project. Over the years, new sponsors have joined the program, which now includes the departments of Engineering, Timber Management, Fire and Aviation Management, Forest Health Protection, Recreation, Law Enforcement and Investigation, and Research, Lands, and Wildlife.

In October 1987 MTDC evaluated a GPS unit at a GPS test and training facility the MTDC had developed at the University of Montana's Lubrecht Experimental Forest. The performance of the GPS unit was impressive, especially for digitizing a road for mapping purposes. However, that evaluation pointed out a problem with the tree canopy attenuating the signal and reducing horizontal accuracy. A report was issued covering the overall evaluation of the unit.

Other test sites were established: 1 in the eastern hardwood forests of Indiana and 1 in a typical west coast Douglas-fir forest in Oregon. The additional sites allowed the Center to test GPS receivers under a variety of field conditions. The test site on the Hoosier National Forest near Bedford, IN, was established in April 1991. This site has a 7-point polygon under a mixed oak/hickory/beech canopy typical of old-growth central hardwoods. The west coast test site was set up in 1995 on the Clackamas District of the Mount Hood National Forest. The course consists of a 13-point polygon. It is under a heavy canopy of Douglas-fir and western hemlock overstory (24 to 40 inches in d.b.h.) with a vine maple and red alder understory. In 1998 a Northeastern test site was established at Ridley Creek State Park in Pennsylvania. It consists of a 12-point polygon under a poplar, oak, maple, and beech canopy.

Position control for all of these test sites was brought in with GPS. Conventional survey equipment was used to survey in the test sites under the canopy. The test sites allow us to evaluate GPS equipment under a variety of canopy conditions typical of those encountered by Forest Service users. Users can select the GPS receiver best suited for their job based on tests conducted in conditions similar to those they will encounter while working.

The GPS navigation signal has two parts: a Standard Positioning Service (SPS) using a Coarse Acquisition (C/A) or civilian code on the L1 frequency and a Precise Positioning Service (PPS) using the P(Y) code or military signal, available on the L1 and L2 frequencies. The PPS signal is only available to the military and authorized United States Government agencies. The C/A code is intentionally degraded. Its accuracy is only guaranteed to be within 100 meters 95% of the time and within 300 meters 99% of the time. This intentional inaccuracy is called Selective Availability (SA). The PPS receivers have encryption devices that remove selective availability. These receivers provide autonomous accuracy on the order of 9 to 10 meters under the canopy.

A procedure known as differential correction was developed to improve the accuracy of the C/A signal and remove the selective availability. A second receiver is placed over a known point, or a base station is used and positions are recorded there while the roving second receiver is recording positions in the field. Because the base station receiver is on a known point, the difference between its recorded position and the known value is calculated. Position data from the roving receiver can be corrected using these values. Corrections can be made in real time if the correction signal is radioed back to the roving receiver. Otherwise, corrections can be made later by postprocessing the data.

In May 1994 the Forest Service Annex to the Memorandum of Agreement between the Department of Defense and the Department of Agriculture was signed. This agreement authorized the Forest Service and other agencies that signed annexes to use GPS receivers. Figure 1 shows some typical accuracies that can be obtained with PPS receivers and C/A code receivers.

NEW OPPORTUNITIES IN GPS

Satellite Broadcast of Differential Signal

In the past, local services (usually an FM radio station) had to be available to broadcast the differential correction signal to the remote GPS receiver. Another method was to set up a base station over a known point and relay that correction signal to the remote GPS receiver. Now a satellite service is available to relay the differential correction signal to GPS receivers that are equipped to receive them. The satellite providing this service is in a geosynchronous orbit near the equator. In the northern United States, this signal is hard to receive under a dense forest canopy.

Dual-Frequency Capability

If a receiver is capable of tracking both the L1 and L2 frequencies, it can compare these signals and reduce the amount of error caused by conditions in the ionosphere. This capability will be more common when new satellites become available with the second and third frequencies.

Second and Third Civil Frequencies

By 2005, two additional civil frequencies will be added to the replacement satellites for the GPS constellation. This system will be operational around the year 2010. There is some talk about moving the schedule up if Congress approves additional funding. With these additional frequencies a new military code will be added that will make the SA unnecessary. A vice-presidential order says that Selective Availability will be turned off by year 2006 if the military has an alternate method of ensuring national security. When Selective Availability is turned off, the position accuracy of standard handheld GPS receivers will be in the 8- to 10-meters range.

Differential GPS (DGPS) Continuous Coverage

The National Geodetic Survey is installing broadcast stations across the United States that will provide double-coverage broadcasting of the differential correctional signal anywhere in the United States. When the system is completed, receivers will be able to use differential correction for real-time accuracy in the order of 2 to 3 meters in the open and 5 to 8 meters under a forest canopy. The latest schedule for completion of these broadcast stations is the year 2003.

Embedded Chips

Electronic chips and boards with embedded GPS receivers are becoming commonplace. GPS will soon be widely used for navigation purposes in personal vehicles. Receivers are getting smaller (some are the size of a postage stamp), and they are becoming more sensitive.

New Techniques

Just as differential correction of the GPS signal has increased its accuracy, other techniques will be developed that will further increase accuracy and reduce the effects of multipath signals (those that bounce off objects such as cliffs). Techniques may be developed for increasing the signal accuracy under the forest canopy.

PRECISION AGRICULTURE

Precision agriculture uses GPS technology to record locations on agricultural fields and Geographic Information System, GIS, technology to store information about those locations to increase agricultural yields, precisely apply fertilizers and pesticides, and fine tune other agricultural practices. Precision agriculture allows farmers and ranchers to manage land by the square meter instead of the square mile.

The Components of Precision Agriculture

Observation-This takes place throughout the year. Tasks such as soil mapping, weed mapping, pest mapping, and recording crop growth, rainfall, and other unique conditions fall into this category. These observations need to be added to the database.

Analysis The database of observed events needs to be put in a GIS. This information is updated periodically to keep the database current.

Timely and Precise Response to Fine-Scale Variation With the use of variable rate technology, different parts of a field can receive different rates of spray or fertilizer. Matching the needs with the product is one of the benefits of precision agriculture.

Assessment-A harvest-yield monitor allows the field's productivity to be determined. Because the yield in different parts of the field is known, a manager can see if variable rate application produced the desired results. By reviewing all the information, better management decisions can be made. The return on investment can be determined in dollars per acre rather than on total production costs.

Uses of Precision Agriculture in the Agricultural System

Land preparation-GPS can be used to provide more accurate leveling of the seedbed for floodirrigated lands. It can be used to provide more accurate control of agricultural machinery, reducing overlap and requiring fewer passes to perform a field operation.

Crop Monitoring, Pest Management, and Irrigation Water Management-At different times during the growing cycle, the crop can be monitored for moisture stress, insect infestation, and weeds. Tasks such as irrigation, spraying, and cultivation can be performed only on the areas of a field that require them.

Soil and Nutrient Monitoring After soil fertility has been tested across a field, a GIS map can show the fertility of the soil, the soil type, and nutrient deficiency at different areas in the field. Soil amendments such as sulfur, lime or organic material and fertilizer can be applied only to areas that need them. When crop yields are compared with soil and nutrient information for specific areas, it may be possible to determine that certain crops are more suited to different soil types and would do better in fields with those soil types.

Conservation Practices GIS information concerning soil productivity and erodibility could be used to control implements so the soil is not tilled in highly erodible areas.

POSSIBLE USES OF PRECISION AGRICULTURE TECHNIQUES FOR NURSERIES

Some precision agriculture techniques may not apply to nurseries because nurseries are much smaller than the typical farm. The nursery manager has a much better idea of the fertility of seedbeds, irrigation needs, and pest invasions than the typical farmer would have. Seedling lots are usually small. Hand markers can be placed to marl different lots. However, some possibilities do exist for use of precision agriculture techniques in nurseries.

Monitoring Source for Tree Seed-The seed source fox seedlings should be located near the area where the seedlings are to be planted after they are taken from a nursery. The GPS position of the seed source would provide a manager information on where the seed was harvested. A database could be built recording potential seed sources and their positions for future use.

Outplacing Seedlings-It would be valuable to know where lots of different seedlings are placed in the forest. If different growing practices have been used for various seedlings, an easy way of monitoring seedling performance would be to observe their growth in the location where they were planted.

REFERENCES

The following sources of information are not intended to be complete, nor do they represent any form of endorsement. Each source is easily available through the Internet and *may* offer additional links to other information. The Internet can be a valuable tool for gathering information, but the information should be used with discretion. Sites were valid as of July 1999.

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