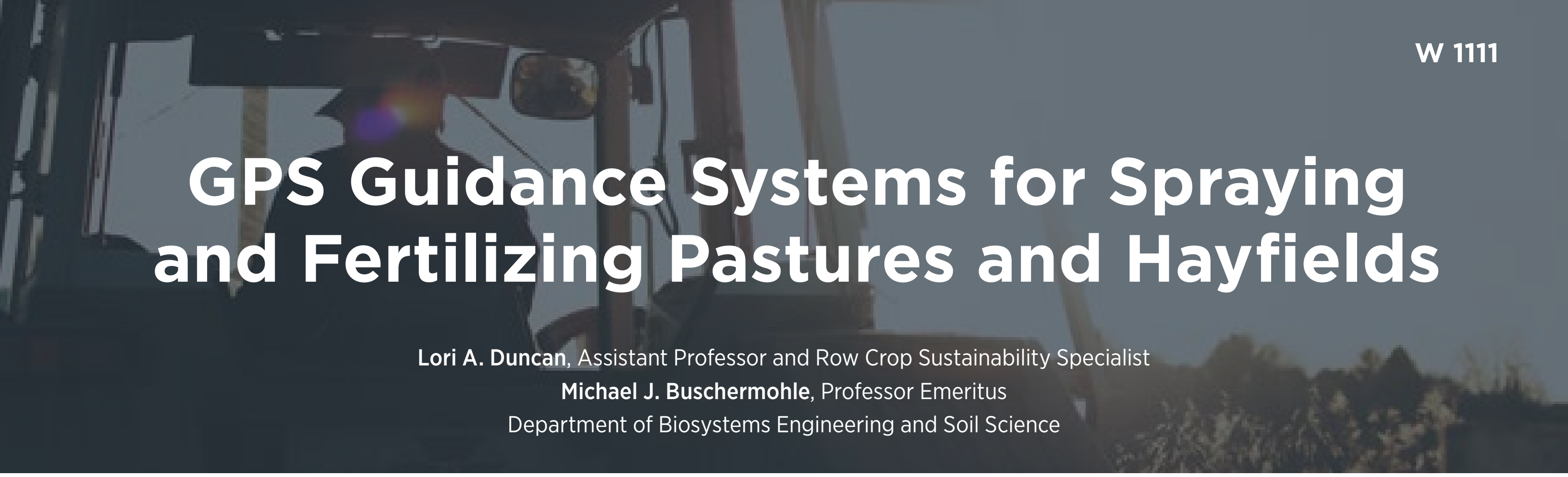

W 1111

GPS Guidance Systems for Spraying and Fertilizing Pastures and Hayfields

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The cost of agricultural chemicals and commercial fertilizer used in pasture and hay production has a major impact on the profitability of livestock operations. With rising input costs as well as the environmental concerns associated with the over-application of chemicals and fertilizer, livestock producers are looking at ways to improve the application of crop inputs such as utilizing global positioning systems, or GPS, guidance systems. GPS guidance systems provide visual feedback to help steer tractors, sprayers, fertilizer applicators and other farm equipment as you travel through the field. GPS guidance with consistent pass-to-pass accuracy results in fewer skips and overlaps that lowers seed, fertilizer, chemical and fuel costs as well as helps save time when spraying or fertilizing pastures and hayfields.

Benefits

Most operators spraying or fertilizing pastures and hayfields tend to overlap passes to prevent skips, leading to higher input costs. Studies have shown that input savings from using GPS guidance systems can range anywhere from 2 to 7 percent depending on field size and shape. Eliminating skips provides better weed control and improved yields. Additional benefits of GPS guidance systems include enabling extended hours of operation, lower operator fatigue and time savings.

What is GPS?

Satellite navigation is based on a global network of satellites that revolve around the Earth in a precise orbit. The satellite constellation most people are familiar with is the United States Global Positioning System (GPS). At the time of this publication, the GPS constellation consists of 31 operational satellites that orbit the earth twice a day. These satellites are positioned so that a user can view at least four satellites from any location on Earth. Each satellite transmits a unique signal and orbital information that enable GPS devices to calculate your location by measuring the time it takes for the signal to travel from the satellite to the GPS receiver. Three other worldwide satellite constellations – BeiDou (China), GLONASS (Russia) and Galileo (European Union) — also transmit similar signals. Together, these constellations are called the Global Navigation Satellite System (GNSS). The terms GPS and GNSS are often used synonymously; the main difference between the two systems is that the GPS receivers can only receive signals from U.S. satellites while the GNSS receivers can receive signals from both the U.S. satellites and other worldwide satellite systems. Most new systems today have both GPS and GNSS capabilities – having the availability to acquire more satellites improves receiver accuracy and reliability.

GPS and GNSS systems are comprised of three major segments: the space segment (satellites), the ground segment (ground control stations), and the user segment (GNSS or GPS receivers). GPS and GNSS receivers are continuously receiving radio signals from the satellites orbiting the earth. The ground control stations continuously track these satellites and transmit updated position information back to the satellite.

Components of a GPS Guidance Systems

The main components of a GPS guidance systems include a differential GPS (DGPS) receiver and antenna, a computer or microprocessor, and an LCD graphics display that provides easy-to-use guidance patterns and real-time "as-applied" coverage mapping (Figure 1). The GPS antenna is used to receive signals from satellites orbiting the earth. The location of the antenna is critical to the performance of the guidance system; GPS antennas should be mounted on top of a tractor, sprayer or spreader truck along the centerline to ensure the antenna has a direct line of sight to satellites. With mounting hardware such as Ram mounts, magnets or suction cups, the GPS antenna and display can be easily moved from vehicle to vehicle. The DGPS receiver, which is built into the GPS antenna or the onboard computer, determines the location of the equipment and sends that information to the computer or microprocessor to create an accurate navigation path. The LCD graphical display allows users to input critical application information and shows a two-dimensional image of the centerline of vehicle and the intended navigation path that the operator uses to accurately steer the vehicle.

Figure 1. *GPS guidance system*, teejet

GPS Guidance System Set-Up

There are just a few simple steps in setting up a field to spray or fertilize using a GPS guidance system. First, you enter the width of the sprayer or the throw distance of the fertilizer applicator along with some other basic setup information into the guidance system's computer. Next, you must establish an A-B line. The A-B line is an imaginary reference line the guidance system uses to determine parallel navigation paths across the field. To establish the A-B line, you drive to where you want to start the first pass and hit the "set A" button then drive to the other end of the field as you are making the first pass and hit the "set B" button. The guidance system computer records the GPS position at both the starting (A) and ending (B) locations. Using the sprayer width or fertilizer spread swath entered by the user, the guidance system's computer calculates subsequent parallel passes across the field and displays them on the LCD display. The two most popular patterns for ground application are parallel swathing and contour paths (Figure 2). The turns are not shown on the LCD display, so you must make the turn at the end of the pass and position the vehicle along the next parallel navigation pass. The monitor shows the real-time position of the vehicle in relation to the desired navigation path. Any deviation from the current navigation path is displayed on the monitor so you know which way to steer the vehicle to maintain the desired path. As you travel along the desired path, the monitor generates a coverage map, sometimes called an as-applied map (Figure 3). This coverage map highlights the areas in the field that have been sprayed or fertilized as well as shows areas that have been either overlapped

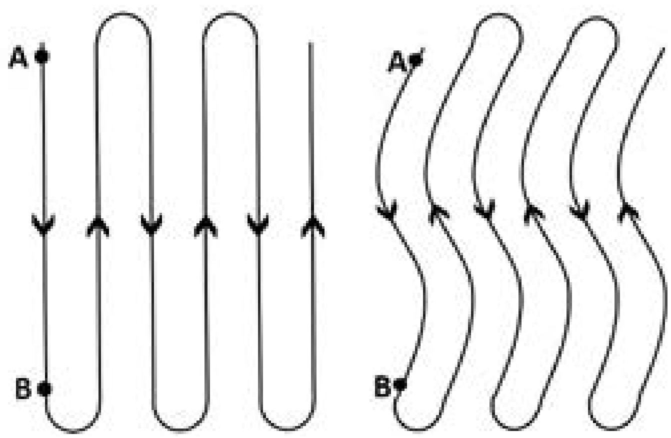

Figure 2. *Parallel and contour swathing*

Figure 3. *As-Applied Map,* raven

or skipped. Most GPS guidance systems can generate field boundaries and calculate the total area covered by the sprayer or fertilizer applicator. This information is very useful for keeping farm records.

Getting a GPS Fix

GPS devices must acquire signals from three satellites to determine a two-dimensional position (X,Y) on the Earth. This is called a GPS lock or fix. Acquiring a fourth satellite signal is needed to get a two-dimensional position and altitude (X,Y,Z). GPS antenna require a direct line of sight to the satellite signals. Barns, buildings, tree canopies, terrain features and the interior of tractor cabs can prevent GPS satellite signals from reaching the antenna. It is important to locate your GPS antenna where it has a clear and unobstructed view of a large portion of the sky.

Why Does GPS Sometimes Show Me in The Wrong Place?

GPS receivers calculate their position by measuring the time it takes for the signal to travel from the satellites to the receiver. Satellite signals travel at the speed of light, which is about 186,000 miles per second. The distance between the GPS antenna and the satellite can be calculated by multiplying the speed of light by the time it takes the signal to travel from the satellite to the antenna. While GPS systems have been designed to be as accurate as possible, there are still errors encountered when using GPS systems. The major sources of GPS positional error are:

- Atmospheric interference
- Clock errors
- Multi-path effects
- Satellite signal blockage due to buildings, mountains, trees, etc.

As the GPS signals travel from the satellites toward Earth, the atmospheric layers around the earth deflect and slightly delay the signals. These delays are especially prevalent within the ionosphere and troposphere layers. This delay causes the speed of the GPS signal to be slower traveling through the ionosphere than the speed of the GPS signal traveling through space. Therefore, the distance calculated from “signal speed x time” will be different when the signal passes through the ionosphere and troposphere versus passing through space. Satellites and GPS receivers have built-in atomic clocks to measure time. While atomic clocks maintain a high level of accuracy, there will always be a slight variation in clock rates. This drift causes errors in the distance calculation. Ideally, GPS signals travel directly from satellites to GPS receivers. Oftentimes, GPS receivers must distinguish between signals received directly from satellites and other signals that have been reflected from surrounding objects, such as buildings, trees, hilly terrain and even the ground. GPS antennas are designed to minimize interference from signals reflected from below the antenna, but signals reflected from above are more difficult to eliminate. One technique for minimizing multipath errors is to set the mask angle to only track those satellites that are at least 15 degrees above the horizon – this can be entered by the user during the initial GPS and display setup.

Improving GPS Accuracy

The accuracy of a GPS guidance system is critical for achieving proper guidance when spraying and fertilizing pastures and hayfields. Although GPS guidance systems have been designed to be as accurate as possible, the GPS signal must be combined with a correction or augmentation signal to achieve the positional accuracy needed for guidance. The type of GPS receiver determines which correction signals are used by the system and how these correction signals are processed by the guidance system to improve its accuracy. There are three types of correction signals used by GPS receivers: public augmentation services, subscription augmentation services and real-time kinematic (RTK) systems.

Many of the low-cost GPS receivers available in the U.S. utilize the Wide Area Augmentation System (WAAS). The WAAS is maintained by the U.S. Federal Aviation Administration and provides a free public correction service for GPS receivers. The WAAS utilizes a combination of ground base stations and satellites to broadcast differentially-corrected signals at the same frequency as the GPS signal. Several equipment manufacturers also provide free correction signals such as John Deere’s SF1 and Case IH’s AFS1. These systems provide a position accuracy of 1-3m, but a pass-to-pass accuracy of less than 1 foot.

Subscription augmentation services use ground-based cellular towers or satellites to broadcast their correction signal. The level of accuracy (less than 1 inch to 12 inches) that can be achieved by these systems varies depending on the service you choose. These are fee-based systems, and the yearly subscription cost varies depending on which service you use. Several different subscription services are available on the market, including Trimble RTX, OmniStar, John Deere (SF2) and Case IH (AFS2).

RTK systems are comprised of a base station and a GPS receiver located on a tractor, sprayer or any other piece of equipment. This GPS receiver is often called the rover. The base station is in a precisely known location close to the rover and receives signals from the GPS satellites to create a correction factor that can be used to increase location accuracy and reduce errors. The base station broadcasts its location and these correction signals to the rover receiver(s). The rover utilizes this information along with the satellite signals it is receiving to precisely estimate its location relative to the base station. Although RTK guidance systems are the most accurate and can achieve pass-to-pass accuracies of less than 1 inch with year-to-year repeatability, they are also relatively expensive as compared to the WAAS-based guidance systems.

Cost

The cost of GPS guidance systems varies depending on the GPS receiver and the LCD display. Increasing the GPS accuracy of the system also increases its cost. Entry-level guidance systems that use the free WAAS correction service are suitable for spraying and fertilizing pastures and hayfields. There are numerous entry-level GPS guidance systems on the market that cost below $3,000. Cost share is also available through the Tennessee Department of Agriculture's Agricultural Enhancement Livestock Equipment Program. When comparing costs, make sure you have all the necessary components and cables to make the system fully functional.

Entry Level Guidance System Manufacturers

An entry level guidance system can be purchased from your local farm supply store, or directly from the manufacturers below.

Raven

TeeJet

Trimble

AgLeader

Topcon

Outback

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