LOWER COST OPTIONS FOR AS-APPLIED MAPPING AND VARIABLE RATE APPLICATIONS OF MANURE

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ABSTRACT. *EPA regulations under the Clean Water Act (33 US Code (USC) 1251(a)) and Concentrated Animal Feeding Operations (68 Federal Registry (FR) 7176:FEB 2003) are driving the need for improved record keeping and accountability of manure applications. Current commercial systems to collect as-applied maps and automated variable-rate applications are cost prohibitive for most applicators.*

To address these issues, University of Illinois faculty and extension educators have conducted research/demonstration projects on the capabilities and accuracy of consumer grade hand-held GPS receivers and pocket PC's for on-farm applications.

Based on initial results, an on-farm system was developed to collect as-applied maps utilizing readily available components including: GPS receiver, pocket/portable PC, commercial software, and existing flow meter. The system allowed visual representation of field aerial maps, non-application zones, and swath tracking. In addition, operator controlled variable rate application data was recorded. With additional development, this system has the potential to automate the flow for variable rate application and non-application zones from preloaded data. This producer driven, innovative research will be continued through the fall application season.

Keywords. *GPS, manure application, GIS, hand-held GPS, pocket/portable PC*

Introduction

EPA regulations under the Clean Water Act (33 US Code (USC) 1251(a)) and Concentrated Animal Feeding Operations (68 Federal Registry (FR) 7176:FEB 2003) are driving the need for improved record keeping and accountability of manure applications. Currently, producers and custom applicators create hand-drawn or computer drawn maps showing setbacks and non-application zones over an aerial photograph. This method demonstrates knowledge, but not observance, of the non-application zones. Current commercial systems to collect as-applied maps and automated variable-rate applications are cost prohibitive for most applicators.

In recent years, researchers have been evaluating commercial-grade and consumer-grade global positioning system (GPS) receivers for agricultural application. Taylor (2004) evaluated the parallel swathing and linear repeatability of differential GPS (DGPS) receivers. Shannon et al. (2001 & 2002) compared yield data collected simultaneously with a “low-cost” GPS receiver and a DGPS receiver. From examination of the yield maps and management zones created from the data, the difference in performance between two low-cost GPS receivers and the more expensive DGPS receiver was difficult to discern. Lee et al. (2003) concluded a (consumer grade) wide area augmented system (WAAS) corrected GPS receiver would be adequate for tracking a traveling gun wastewater application system.

OBJECTIVES

The goals of the project were twofold:

- Evaluate the accuracy and precision of several WAAS-corrected GPS receivers recently purchased by University of Illinois extension educators.
- Develop an as-applied manure mapping system, based on one or more of these GPS receivers, to automate the collection of geo-referenced flow rate and display the data in real-time.

MATERIALS AND METHODS

The consumer grade receivers used in the first phase included: MAP 330 (Magellan Cooperation, San Dimas, CA), Pocket Xtrack (Fortuna Electronic Corp., Taipei City, Taiwan), Legend (Garmin International, Olatha, KS), Navman GPS i Series (Navman NZ Ltd, New Zealand), Clip-On Bluetooth

(Fortuna Electronic Corp.), and two D157N Receivers (SST Development Group, Inc., Stillwater, OK)[1]. These units were evaluated in static and dynamic tests for accuracy and precision.

The GPS receivers were arranged in an open field on a 3.05 m (10 ft) grid pattern, for the static test. A US Geologic Survey weather station with known coordinates was used as a corner reference point. Two DGPS Trimble AgGPS122 (Trimble Navigation Limited, Sunnyvale, CA) receivers were placed at the diagonal corners of the rectangular layout, opposite the weather station, as references to "ground-truth" the grid pattern. Data points were logged every 60 seconds over a 2 ½ hour time period. A Circular Error Probability (CEP) extension for ArcView 3.3 (ESRI, Redlands, CA) was used to evaluate the static test data. The extension, "DNR Garmin Extension for ArcView," was downloaded from the Minnesota Department of Natural Resources website. CEP values were calculated for both the average location and estimated true location.

Three all terrain vehicles (ATV) were driven around the parameter of an open parking lot during the dynamic test. Three receivers were mounted on each ATV maintaining approximately 1.8 m (6 ft) of separation between receivers. Data points were recorded every second or 0.9 m (3 ft) of movement and saved as boundaries (polygons). The AgGPS 122 receivers were used as the "standard" for the dynamic test.

Based on the preliminary test, an as-applied mapping system for manure application was developed to automate the collection of GPS reference flow rate and to display the data on an onboard computer in real time. The owner of a large pork production facility offered an opportunity to field-test the concept utilizing his existing equipment: tractor equipped with an AFS GPS receiver (Case IH, Racine, WI), laptop computer, and flow meter (Krohne, Inc. Peabody, MA). Some of the additional items used to complete the system were: FarmWorks Site Pro software (CTN Data Service, Inc., Hamilton, IN), external USB port extender, analog-to-digital counter (DGH Corporation, Manchester, NH), and cabling.

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[1] Mention of trade names is for illustrative purposes and does not imply endorsement by the authors.

Two field trials of the as-applied mapping systems were conducted using water as the application material during the summer of 2004. The site had several non-application (buffer) zones around a pond, buildings, and property boundaries. The operator manually controlled the flow based on visual observation of the preloaded application/non-application map viewed on the onboard computer. The application rate is calculated from the flow rate, distance between data points, and implement width collected for each data point.

RESULTS AND DISCUSSION

The static CEP (estimated true location) at 95% was within 4.5 m (15 ft) for all the receivers with four receivers less than 2.8 m (9.2 ft) (Table 1). The CEP (point averaged location) at 95% was within 4.4 m (14.5 ft) with four receivers less than 2.44 m (8 ft) (Table 2). The graphically measured distance between the estimated true location and the point averaged location for each receiver is shown in Table 3. The results were comparable to the information provided in the product literature for the receivers.

The dynamic test provided more information about the usefulness of the GPS receivers for on-farm applications. Only minor differences could be visually detected when overlaying the polygons of the various receivers. The test field calculated area from the Trimble receiver data was 0.71 ha (1.75 ac). Area calculations for all receivers were within 0.004 ha (0.07 ac) of the Trimble.

The first field trial of the as-applied mapping system successfully recorded the travel path of the equipment, geo-referenced flow rate, total fluid applied, and calculated geo-referenced application rate (Figure 1). The application rate variation due to changes in pump speed and tractor travel speed during the test was displayed as a color gradient of the track. The second trial provided very similar results. Total gallons logged by the system were within 69 gallons of the Krohne data logger for an application in excess of 75700 liters (20000 gal) total. Testing of the system during fall manure application operations was planned.

Table 1 The Circular Error Probability calculated based on the estimated true location.

Circular Error Probability from estimated true location					
50%			95%		
	m	(ft)		m	(ft)
Trimble (R)	0.37	(1.2)	Trimble (R)	0.67	(2.2)
Trimble (G)	0.79	(2.6)	Trimble (G)	1.37	(4.5)
Navman	1.04	(3.4)	Navman	2.41	(7.9)
Pocket Xtrack	1.65	(5.4)	MAP330	2.47	(8.1)
Legend	1.74	(5.7)	SST (S)	2.74	(9.0)
SST (S)	1.80	(5.9)	Pocket Xtrack	2.77	(9.1)
SST (F)	1.86	(6.1)	Legend	3.32	(10.9)
Clip-On Bluetooth	1.89	(6.2)	Clip-On Bluetooth	3.63	(11.9)
MAP 330	2.47	(8.1)	SST (F)	4.36	(14.3)

Table 2 Circular Error Probability calculated based on the averaged center point.

Circular Error Probability from averaged center point					
50%			95%		
	m	(ft)		m	(ft)
MAP 330	0.24	(0.8)	Trimble (R)	0.67	(2.2)
Trimble (G)	0.34	(1.1)	MAP 330	0.79	(2.6)
Trimble (R)	0.37	(1.2)	Trimble (G)	1.04	(3.4)
Legend	0.67	(2.2)	Legend	1.62	(5.3)
Navman	1.07	(3.5)	Navman	2.26	(7.4)
Pocket Xtrack	1.10	(3.6)	Pocket Xtrack	2.35	(7.7)
Clip-On Bluetooth	1.13	(3.7)	Clip-On Bluetooth	2.65	(8.7)
SST (S)	1.16	(3.8)	SST (S)	3.05	(10.0)
SST (F)	1.74	(5.7)	SST (F)	4.42	(14.5)

Table 3 The linear distance between the estimated true location and the point averaged location for each receiver.

DISTANCE FROM ESTIMATED TRUE LOCATION TO POINT AVERAGED LOCATION					
	m	(ft)		m	(ft)
Trimble (R)	0.15	(0.5)	Pocket Xtrack	1.19	(3.9)
Navman	0.37	(1.2)	Clip-On Bluetooth	1.58	(5.2)
Trimble (G)	0.67	(2.2)	Legend	1.86	(6.1)
SST (F)	0.82	(2.7)	MAP 330	1.89	(6.2)
SST (S)	0.88	(2.9)			

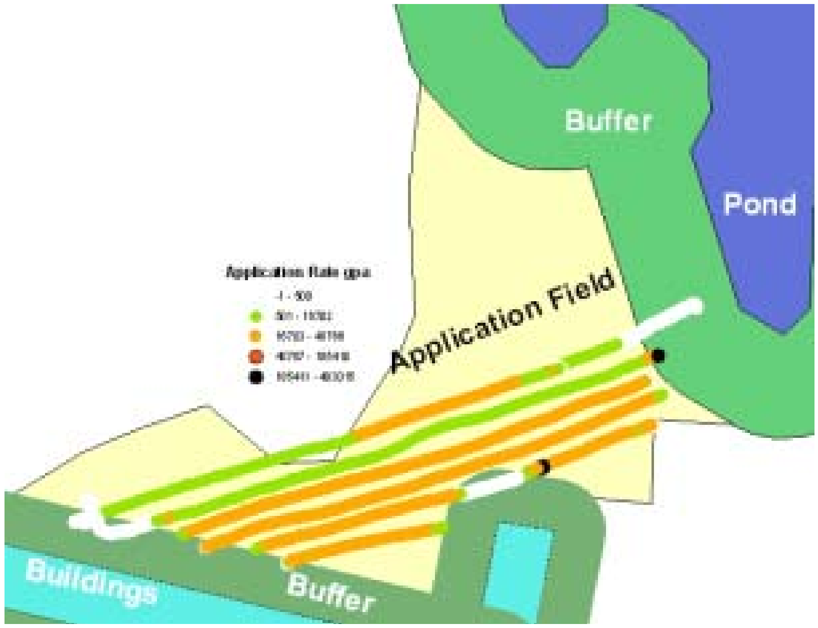

Figure 1. As-applied map for the first trial with water includes the variation in application rate due to tractor speed and flow rate.

CONCLUSION

The potential to use newer consumer-grade GPS receivers for as-applied mapping was verified through static and dynamic test. The static test results indicate the receivers are within 4.5 m (15 ft) of a known location 95% of the time. Four receivers were less than 2.8 m (9.2 ft) from the known location 95% of the time. The dynamic test demonstrated the ability of all the receivers to provide useful path and area data. The boundaries collected over-laid each other with minor visible variation. All the receivers recorded areas within 0.004 ha (0.07 ac) of the 0.71 ha (1.75 ac) test area calculated from the Trimble AgGPS122 receiver data.

The as-applied mapping was installed on a pork producer's manure application equipment and tested with water application during the summer of 2004. The system successfully recorded the travel path of the equipment, geo-referenced flow rate, total fluid applied, and calculated geo-referenced application rate. Operator controlled variable-rate application was achieved by changing tractor speed or pumping rate. Due to wet weather, data from manure applications with the system has been limited.

The demonstrated design offers Midwest livestock producers and commercial applicators a lower cost, automated system to provide as-applied mapping for accountability to regulators and the public. While the industry has been reluctant to spend large sums for technology, producers/commercial applicators from Illinois, Michigan, and Wisconsin have expressed interest in a lower cost option. The next step will be to use new technologies such as: manure flow control valves, infinitely variable speed tractor transmissions, and other automated tractor control systems to develop automated, variable-rate manure application systems based on preloaded base maps.

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