Using RTK-based GPS guidance for planting and inverting peanuts

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Abstract

GPS guidance of farm machinery has been adopted by increasingly larger segments of the farming community over the past decade because of the inherent gains in efficiency that it provides. The study was conducted for two consecutive years (2010 and 2011) on a working farm in Georgia, USA. The goal of our study was to quantify the yield benefit of using RTK-based automated steering (auto-steer) to plant and invert peanuts under a variety of terrain conditions. When all data are grouped together, auto-steer outperformed conventional by 579 kg/ha in 2010 and 451 kg/ha in 2011.

Keywords: auto-steer, RTK, planting, inverting, peanuts, yield increase

Introduction

GPS guidance of farm machinery has been adopted by increasingly larger segments of the farming community over the past decade because of the inherent gains in efficiency that it provides. Schimmelpfennig and Ebel (2011) estimated that in 2010, guidance system adoption on areas planted to maize and soybeans in the USA was in the range of 15–35 %. Taylor et al. (2008) and Bergtold et al. (2009) attributed increased crop yields to the use of GPS guidance for strip tillage operations. Bergtold et al. (2009) and Griffin et al. (2008) also reported yield gains when using GPS guidance during planting and for optimum input placement. Schimmelpfennig and Ebel (2011) reported significant reductions in fuel consumption. As a result, it is now quite common to find farmers who own multiple vehicles (tractors, sprayers, and harvesters) equipped with GPS guidance. In many areas of the USA, the most advanced and expensive form of GPS guidance, RTK-based automated steering (auto-steer), is also being quickly adopted by farmers. In the southeastern USA one of the reasons farmers are quick to adopt GPS guidance, and specifically auto-steer, is that it can theoretically result in large yield gains when used to plant and invert peanuts – one of the region's most important crops (Leidner, 2012.)

The peanut, or groundnut (*Arachis hypogaea*), is a low growing crop which produces its fruit under-ground much like the potato. As the peanut plant matures, it produces nuts (fruit) on its tap root but also on vines that extend outwards from the main stem. Much of the yield is found on the vines. Peanut harvesting is a two-step process. First an inverter passes through the field. The inverter undercuts the tap root and flips the plant upside down so that it is laying on the soil with the leaves down and the nuts lying upwards. After a few days of drying in the field, the plants are harvested mechanically. It is very important that the tractor pulling the inverter pass as close as possible over the centerline on which the peanuts were planted otherwise the inverter will cut off sections of the vines and those peanuts will remain in the soil and be lost to the farmer. When

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the peanut plants are mature, their canopy completely covers the soil and it is visually very difficult to identify the centerline on which peanuts were planted. Consequently farmers regularly incur what they call “digging losses” – peanuts lost during inverting. Digging losses are also affected by the tillage system used (conventional versus conservation tillage), soil texture, soil moisture conditions at the time of inversion, and peanut maturity. Digging losses may range from 15 to 30% of the peanut crop’s potential yield (Ortiz et al., 2013).

RTK-based auto-steer offers peanut farmers the potential of being able to follow the planting centerline with both accuracy and precision when inverting their peanuts. Ortiz et al. (2013) used auto-steer to intentionally invert peanuts at increasing distances from the planting centerline and showed that peanut yields decreased with distance. The goal of our study was to quantify the yield benefit of using RTK-based auto-steer to plant and invert peanuts on the farm under a variety of terrain conditions.

Methods

The study was conducted for two consecutive years (2010 and 2011) on a working farm in Georgia, USA. Georgia is the leading peanut-producing state in the USA. During each year a field with sloped land and field rows with varying degrees of curvature

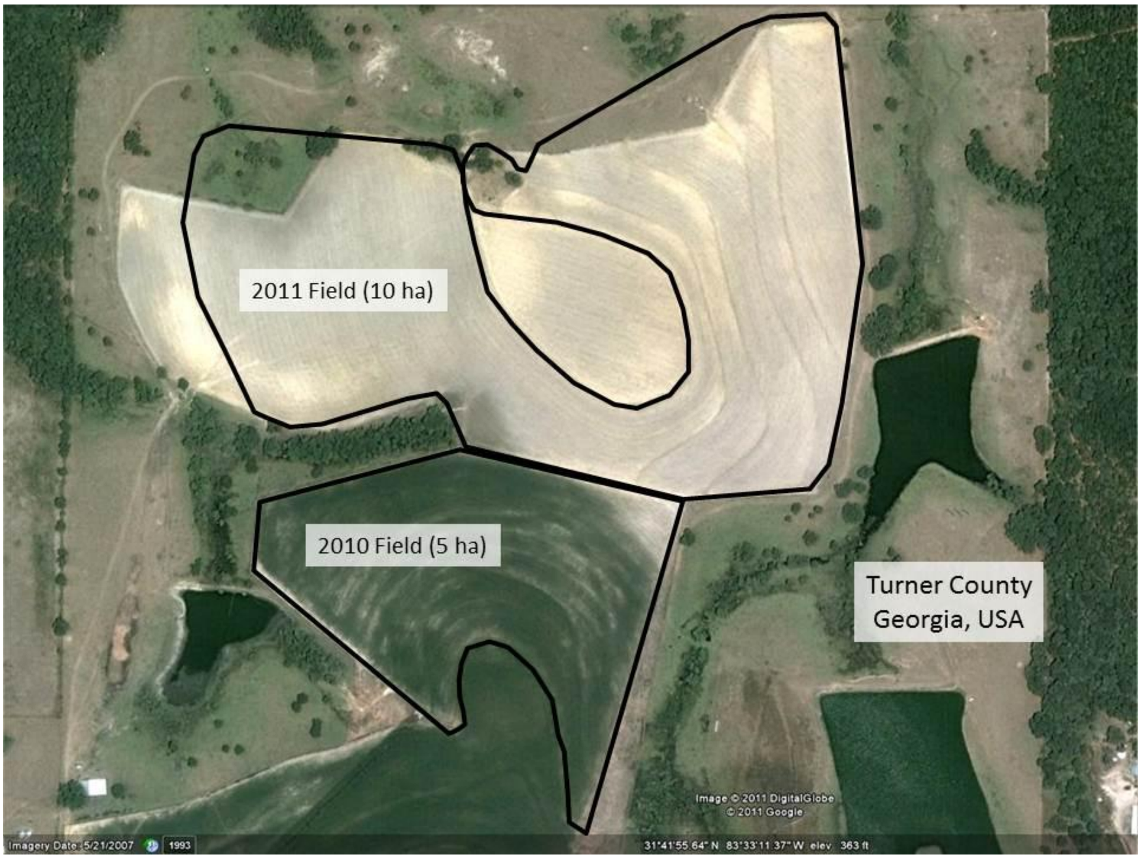

Figure 1. Google Earth image of the two fields used in the study. The field used in 2011 was expanded to the black boundaries shown in the figure to accommodate a new center pivot irrigation system. The tear drop-shaped area in the middle of the field was not used for the study. Non-parallel earthen terraces used to control erosion are clearly seen in the 2011 field but existed in the 2010 field as well.

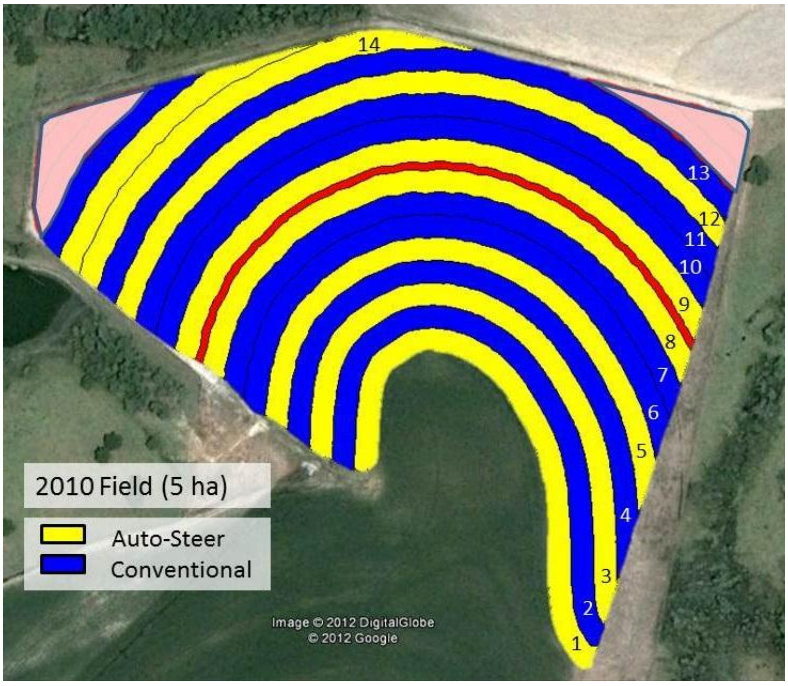

Figure 2. Experimental design used in 2010. Each replicate (colored strip) = 12 rows of peanuts or three 4-row passes

ranging from extreme to mild was selected for the study. In addition, both fields contained steep earthen terraces installed decades ago to reduce erosion. These terraces were not parallel to each other nor were they parallel to the row pattern currently used by the farmer. As a result, the tractor and implement was required to cross these terraces at various angles during all field operations. The fields were adjacent to each other (Figure 1). Field size was 5 ha in 2010 and 10 ha in 2011. The fields were divided into alternating strips representing treatments.

<u>Treatments</u>

In 2010 there were two treatments – manual and auto-steer (Figure 2). In 2011 there were three treatments – manual, auto-steer, and auto-steer with passive implement guidance (Figure 3). Each strip consisted of three passes of four row equipment (12 rows, 4 rows per pass). The same farm equipment (tractor, planter, and inverter) was used for all treatments – the auto-steer was either engaged or not engaged depending on the treatment. The tractor belonged to the University of Georgia (UGA) Precision Agriculture Team while the implements belonged to the cooperating farmer. Manual treatments were planted and inverted conventionally (no GPS guidance). Auto-steer treatments were planted and inverted using a Trimble AgGPS Autopilot™ auto-steer system. The auto-steer with passive implement guidance treatments were planted and inverted using the Trimble AgGPS Autopilot™ auto-steer system with AgGPS Trueguide™ implement guidance. A single A-B line created prior to planting along the innermost curve of the field (Figures 2 and 3) was used for all subsequent auto-steer passes during planting and inverting.

The Trueguide™ system is a "passive" guidance system that attempts to affect the position of the implement. It uses the AgGPS Autopilot™ automated steering system to adjust the direction of travel of the tractor in order to place the implement on the centerline because tworking implement behind the tractor is where precision is most important. Implement guidance is particularly useful when working sloped lands with curvature where the implement tends to drift off the centerline. To be fully effective, the Trueguide™ system requires the implement to be towed rather than mounted. This allows the tractor's longitudinal axis to be in a different orientation from that of the implement's and allows the AgGPS Autopilot™ automated steering system to adjust the direction of travel of the tractor in order to place the implement on the centerline. In our

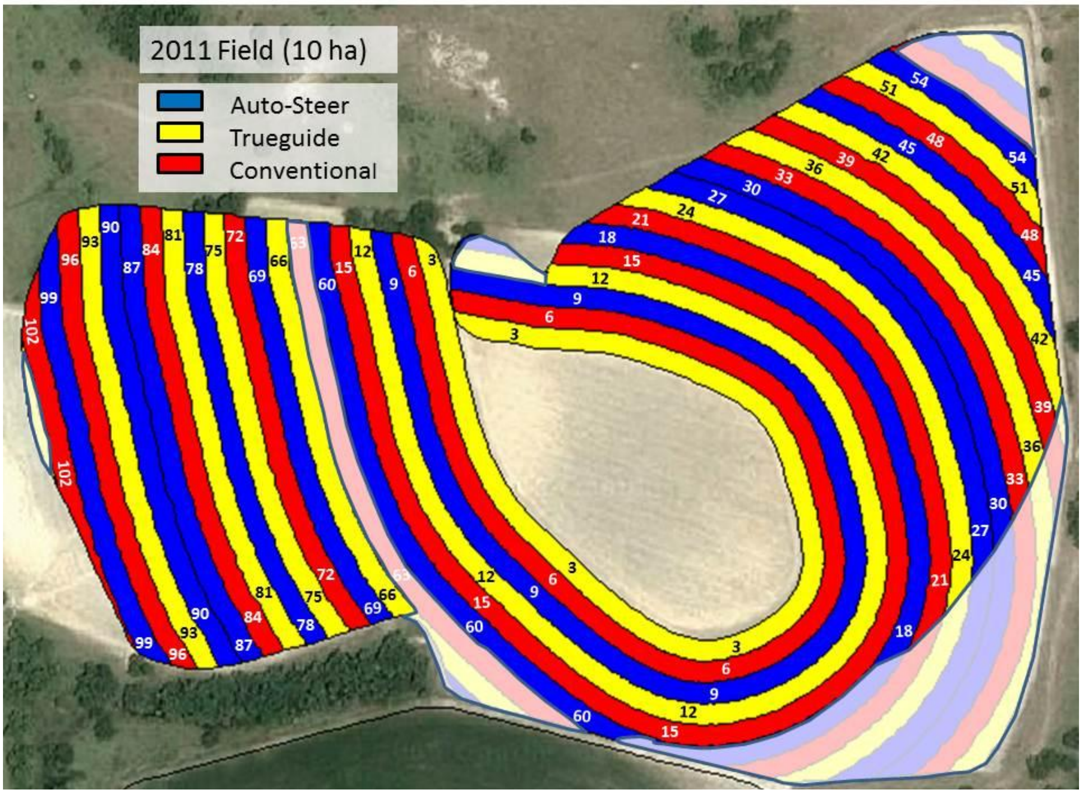

Figure 3. Experimental design used in 2011. Each replicate (colored strip) = 12 rows of peanuts or three 4-row passes

study, both implements (planter, inverter) were mounted to the tractor with a 3-point hitch which limited the effectiveness of the Trueguide™ system.

<u>Planting and harvest</u>

Peanuts were planted using strip tillage. Tillage and planting was done as a single operation. The Georgia-06G peanut cultivar was used during both years. Peanuts were inverted (Figure 4) and allowed to dry for two to three days before harvest. During the 2010 harvest, the "middle" pass of each strip within each treatment was harvested individually. The two "outside" passes in each strip were considered buffer passes and not harvested individually. The peanuts harvested from the middle pass were emptied by the harvester into a peanut wagon mounted on four load

Figure 4. Inverting peanuts with a 4-row KMC peanut inverter pulled by the UGA tractor equipped with a Trimble® AgGPS Autopilot™ auto-steer system.

Figure 5. Peanut harvester emptying a load of peanuts into a peanut wagon (left) and load scales used to record weight of peanuts harvested from a pass (right). A load scale is located under each wheel of the wagon.

scales and the mass of peanuts recorded (Figure 5). During 2011, all three passes in each strip were harvested individually and their yield recorded individually.

Data analysis

The experimental design was entered into the Farm Works™ software. The software was used to measure and verify strip length and area. In addition, the strips were grouped into low, medium, and high curvature rows. The 2010 field contained only medium and high curvature rows (Figure 6) while the 2011 field contained low, medium, and high curvature rows (Figure 7).

The measured mass of peanuts was corrected for foreign material content and moisture content using information provided by the United States Department of Agriculture grading office at the buying point to which the cooperating farmer sold his peanuts.

Data were analyzed two different ways: 1) they were grouped together by treatment and compared, and 2) they were grouped by curvature of the rows harvested and treatment and compared. To be consistent with 2010, only data from the middle pass in 2011 was used for comparisons.

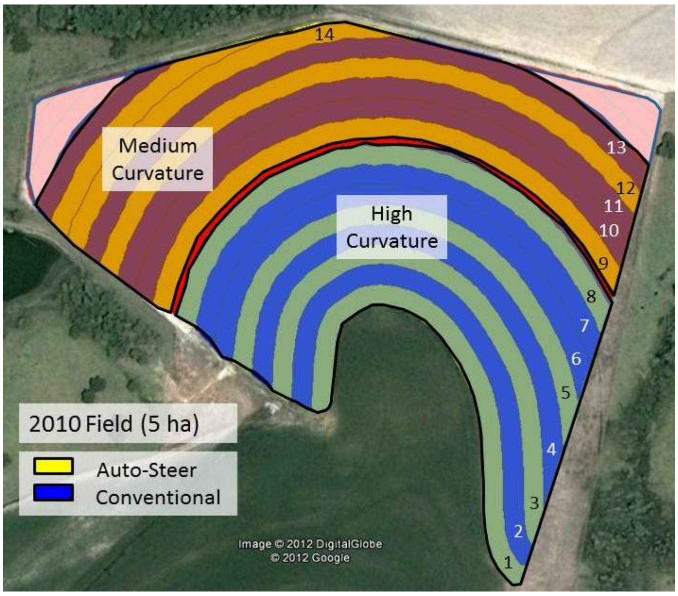

Figure 6. The 2010 field was divided into high and medium curvature areas.

Results and Discussion

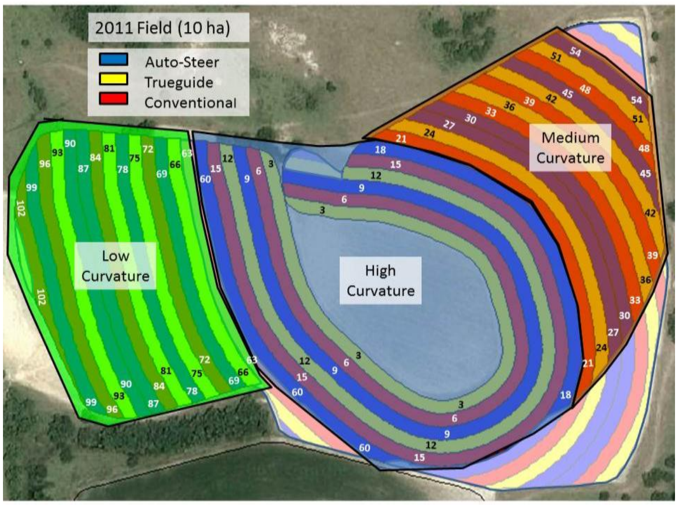

Figure 7. The 2011 field was divided into high, medium, and low curvature areas.

When all data were grouped together, auto-steer out-performed conventional by 579 kg/ha in 2010 and 451 kg/ha in 2011 (Table 1). In 2010, auto-steer outperformed conventional by 338 and 745 kg/ha in high curvature and medium curvature rows, respectively (there were no low curvature rows in the 2010 field).

In 2011, auto-steer outperformed conventional by 175, 502, and 642 kg/ha in high curvature, medium curvature, and low curvature rows, respectively. Table 1 summarizes the comparison between conventional and auto-steer.

Auto-steer outperformed conventional much more under medium and low curvature conditions than under high curvature conditions. This observation was somewhat surprising at first because all involved with this project expected the opposite result. In retrospect however, this result is logical. It was originally assumed that under low curvature conditions, a human operator would be able to follow the centerline well. In fact, the solid green peanut canopy encountered when inverting peanuts makes it difficult for the human operator to align the tractor with the planting centerline whereas the auto-steer system can place the tractor within 2.5 cm of the centerline. When coupled with better performance of the auto-steer system itself under low curvature conditions than under high curvature conditions, this results in much higher yields for planting and inverting with auto-steer under low to medium curvature conditions.

Table 1. Comparison between the effect of conventional and auto-steer on peanut yield during the 2010 and 2011 studies.

Curvature	Treatment	2010			2011		
		Avg. Yield (kg/ha)	Diff.[1] (kg/ha)	Econ. Gain[2] (USD)	Avg. Yield (kg/ha)	Diff.[1] (kg/ha)	Econ. Gain[2] (USD)
All	Auto-Steer	5748	579	27,851	6145	451	34,350
	Conventional	5169			5694		
High	Auto-Steer	5804	338	16,274	6185	175	13,324
	Conventional	5466			6011		
Medium	Auto-Steer	5518	745	35,821	6280	502	38,219
	Conventional	4773			5778		
Low	Auto-Steer	N/A			6013	642	48,889
	Conventional	N/A			5371		

[1]Difference = Auto-steer – Conventional

[2]Economic Gain is calculated using peanut prices of 660 USD/tonne in 2010 and 1045 USD/tonne in 2011.

Trueguide™ compared to auto-steer and conventional

The Trueguide™ system performed poorly under high curvature conditions yielding 146 kg/ha less than conventional and 321 kg/ha less than auto-steer. This was expected based on the observed performance of the system during planting and inverting. Because of the 3-point hitch, the AgGPS Autopilot™ automated steering system was unable to adjust the direction of travel of the tractor to place the implement over the centerline of the sharply curved rows – when the tractor's longitudinal axis changed direction so did the implement's. As a result, the system was constantly under-correcting or over-correcting without being able to properly adjust to the conditions.
In contrast, under low curvature conditions, the system was able to outperform conventional and auto-steer by 896 kg/ha and 255 kg/ha, respectively. This is likely because even with the 3-point hitch, the less demanding terrain (low curvature and lower slope) allowed the system to better place the implement over the centerline. Although the Trueguide™ system shows impressive benefits under low-curvature, low-slope conditions, it cannot be used to its maximum potential when the implement is mounted to the tractor rather than towed by the tractor.

Effect of auto-steer on digging losses

As mentioned earlier, digging losses in peanuts may range from 15 to 30% of the crop's potential yield. When peanuts are grown with strip tillage on finer-textured, less friable soils as was done in this study, digging losses may approach the upper end of this range. For example, Jackson et al. (2011) measured digging losses of 26% in strip tillage peanuts planted and inverted without auto-steer at a location in southern Georgia with similar soils. If we assume similar digging losses for the overall average conventional yields measured in this study (5169 and 5694 kg/ha for 2010 and 2011, respectively – Table 1), then the potential yields for 2010 and 2011 would be 6985 and 7694 kg/ha, respectively. At 26%, the theoretical digging losses would then be 1816 kg/ha in 2010 and 2000 kg/ha in 2011. By using auto-steer, digging losses were reduced by 579 kg/ha (32%) in 2010 and 451 kg/ha (23%) in 2011. In other words, estimated digging losses for all curvatures combined were reduced to 18% in 2010 and 20% in 2011. Digging losses were further reduced in the medium and low curvatures.

Economic returns from using auto-steer

Table 1 also includes the economic benefit resulting from applying the measured yield gains to the average area planted to peanuts each year by the cooperating farmer (73 ha). Using the yield gain resulting from auto-steer under all curvature conditions (579 kg/ha in 2010 and 451 kg/ha in 2011), the farmer would have realized an economic gain of USD 27,851 in 2010 and USD 34,350 in 2011. The large difference in economic return between 2010 and 2011 is caused by the large difference in peanut prices between the two years. In 2010, the farmer sold his peanuts for 660 USD/tonne while in 2011 he sold his crop for 1045 USD /tonne. Considering that installation of an RTK-based auto-steer system on a tractor costs between USD 22,000 and USD 25,000 (depending on the manufacturer) and requires an annual RTK correction subscription of between USD 800 to USD 1000, investing in an auto-steer system is a good economic decision as the system can easily pay for itself in short order. Few studies have addressed the economic returns gained by using auto-steer but Griffin (2009) showed that auto-steer becomes more profitable as farm size increases.

Conclusions

The experiment reported here conclusively shows that using RTK-based auto-steer to plant and invert peanuts results in substantial yield gains and associated economic returns. When added to the other efficiency gains resulting from consistently using auto-steer for farm operations such as spraying, tillage, etc., investing in auto-steer appears to be a sound investment for many farmers. Because of this, peanut industry observers report that auto-steer is quickly becoming an essential tool for farmers in the southeastern USA who include peanuts in their crop rotation (Leidner, 2012).

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