QUANTIFYING THE TRAFFIC FOOTPRINT OF ZERO-TILLAGE SYSTEMS

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Abstract
This work was conducted to determine the area of a field trafficked by farm machinery over a cropping season. The case-study field had been established to wheat and managed under zero-tillage for over 10 years, and the soil type was a Typic Argiudoll. Measurements showed that the total wheeled area was 12-ha, representing 68% of the 19-ha field used for the study. Given that operating and track gauge widths of different the machinery did not match, and field traffic was random, the total area of the field affected by traffic over the rotation cycle could be greater than the area reported in this study (single-season). Adoption of controlled traffic farming, with fully matched machinery, could reduce the area affected by traffic from current 68% to less than 20% depending upon the design of the system, which will help optimize field efficiency and logistics, reduce fuel-use and labour, and lift productivity.

Key words: *controlled traffic farming; no-tillage; random traffic; soil compaction; wheeled soil.*

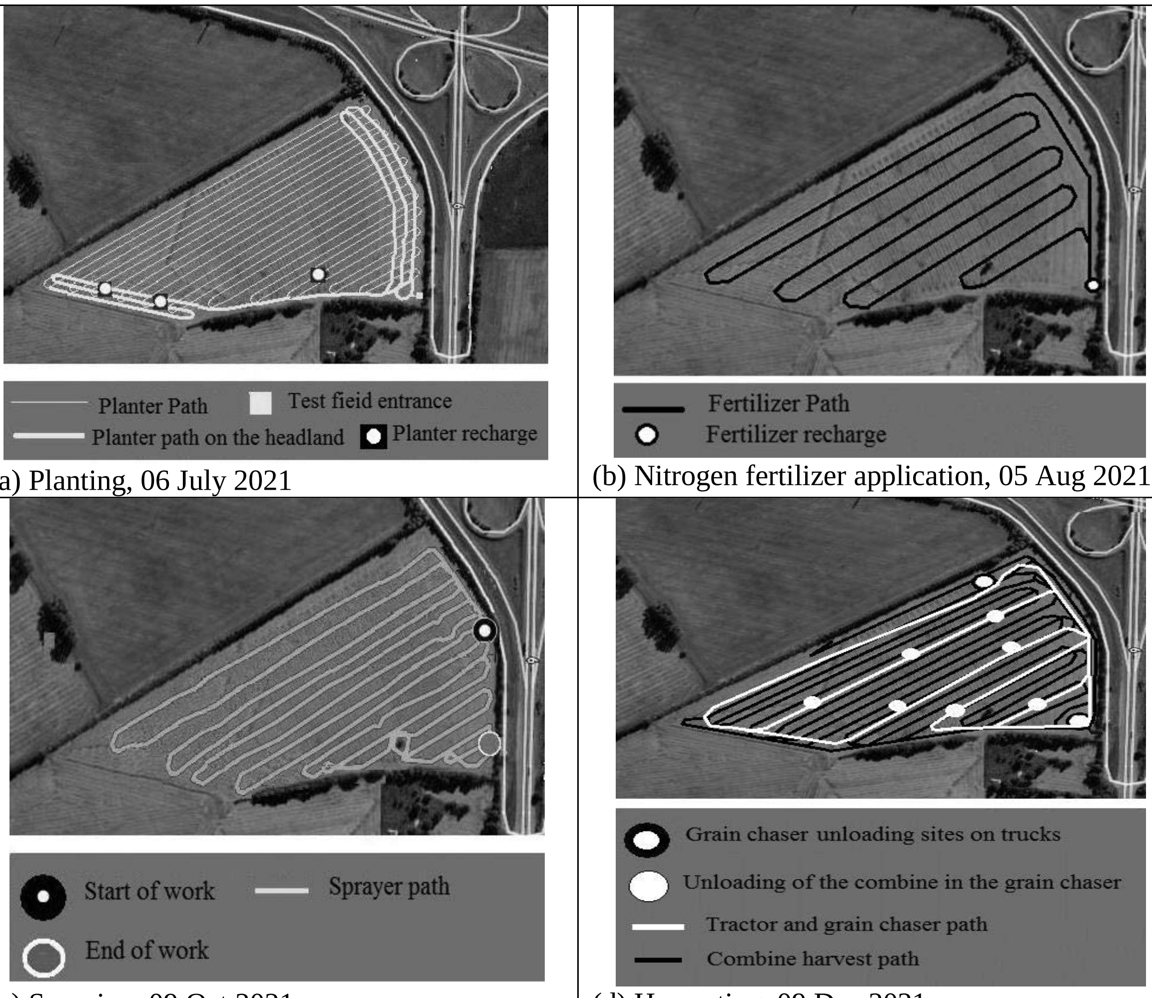
INTRODUCTION

The arable land area established to wheat in Argentina is estimated to be approximately 7 M ha per year, and more than 90% of this area is managed under permanent zero-tillage (ZT). The soils in the main wheat-growing region of Argentina are susceptible to compaction, and the risk of compaction occurring is exacerbated by the timing of field operations, and the combined effects of vehicle mass and wheel configuration, with most mechanization systems managed without controlled traffic. Previous studies in Argentina (e.g., *Botta et al., 2007*) have shown that traffic intensities in ZT cropping systems can be as high as 40 Mg km^{-1} ha^{-1} and given typical rotation cycles (e.g., wheat/soybean, 12 months), the opportunities for alleviation of such compaction through natural processes are therefore limited. The adverse effects of compaction on the soil physical and hydraulic properties are well documented, and affect crop yield and therefore the profitability and sustainability of farming (*Soane et al., 1982*). In rainfed agriculture, the effect of compaction on yield is can be more significant in dry years (*Hussein et al., 2021a-b*). Whilst adoption of zero- and reduced tillage systems has enabled field traffic to be significantly reduced compared with conventional tillage systems that require primary and secondary tillage operations for crop establishment, the overall traffic footprint measured as a percentage of field-cropped area can be still large (e.g., 40-60%), as shown by several studies outside Argentina (e.g., *Chamen, 2015*). Such traffic footprints mean that the benefits of ZT may not be fully realized (*Antille et al., 2015*). The objective of this work was to estimate the total area of a field wheeled over a single cropping season. The work was conducted on a commercial field that had been managed under ZT and without controlled traffic for more than 10 years. Results derived from this work may be used to increase awareness of the extent and potential impact of field traffic on soil and encourage farmers in Argentina to consider options for converting to controlled traffic farming.

MATERIALS AND METHODS

The study was conducted on a commercial farm located near Lujan (Buenos Aires, Argentina) during the 2021 winter season (Figure 1). The soil at the site is a Typic Argiudoll with 22% clay, 73% silt and 5% sand in the top 0-200 mm depth interval. The 19 ha field had been managed under continuous zero-tillage for more than ten years. The crops typically grown at the site are wheat (Triticum aestivum L.), established in late June to early July and harvested in December, followed by soybean (Glycine max L.), established immediately after wheat and harvested mid-May. The specifications of the equipment used in the study are presented in Table 1.

Fig. 1 Aerial view and GPS coordinates of the commercial field used for the study



(a) Planting, 06 July 2021
(b) Nitrogen fertilizer application, 05 Aug 2021
(c) Spraying, 09 Oct 2021
(d) Harvesting, 09 Dec 2021

Fig. 2 Vehicle's trajectories

Tab. 1 Specifications of the farm equipment used in the study

Equipment	Brand/Model	Rear tires	Front tires	Width, m	Load, kN
FWA Tractor	CASE 200	710/70 R38	600/45 R28	-	74.67
FWA Tractor	JD6600	23.1-30	16.9/14-24	-	45.57
Combine harvester	CASE 2388	19.5-24	800/65 R32	9	93.10
Sprayer	Metalfor 7030	320/85 R36 (all tires)		28	90.16
Fertiliser applicator	Fertec	12.4-36 (all tires)		28	68.60
Planter	Crucianelli 3520	400/60-18 (all tires)		7	111.23
Chaser bin	AGROMEC	21L30 (single axle)		-	137.20

All vehicles used in the field from planting to harvest were equipped with a DGPS signal receiver, which enabled trajectories within the field to be mapped. Wheeled areas were subsequently estimated by multiplying the total distance travelled by each vehicle by two times the section width of the tires fitted to corresponding vehicle. For the two tractors, the section width was given by the wider (rear) tires; this was possible because the tires fitted on the front and rear axles are aligned. Field trajectories were drawn for each operation conducted in the field and super-imposed to the aerial image of the field. The area affected by traffic was estimated for each operation as percentage of the field cropped area; the sum of which returned the traffic footprint across all operations performed during the season.

RESULTS DISCUSSION

Vehicle's trajectories are shown in Figures 2a-d for each operation performed between, and including, planting and harvesting. Table 2 shows the calculated wheeled areas for each operation.

Tab. 2 Wheel tracked areas for all field operations (ha), and expressed as a percentage of the field-cropped area

Field operation	Area, ha	% of field-cropped area
Planting	6.69	35.20
Fertilizer application	0.36	1.89
Spraying	0.54	2.85
Harvesting	5.36	28.20
Total	12.95	68.14

The total area affected by traffic was greater than that reported in other studies in Europe (e.g., *Galambošová et al., 2017*), Australia (e.g., *Tullberg et al., 2007; Antille et al., 2019*) and Argentina (e.g., *Botta et al., 2007, 2022*) for ZT systems, which was attributed to the configuration of the equipment used in this study. The total wheeled area estimated by this study could be reduced to less than 20% through the adoption of controlled traffic farming (CTF). This would require modification of the farm equipment to fit a common track gauge width that matches that of the combine harvester (3-m wheel spacing, single tire configuration), and by enabling all equipment to operate in modules that have; for example, a 3:1 ratio (that is, sprayer/fertilizer applicator-to-planter/combine harvester). For the equipment listed in Table 1, this means that the planter should be 9-m wide to match the cutter front of the combine harvester. The operating width of the sprayer and fertilizer applicator would need to be reduced from 28 to 27 m. Conversion from the current unmatched mechanization system to a fully matched CTF system should be considered as part of the machinery replacement program over a timeframe that is economical and compatible with the farming enterprise.

CONCLUSIONS

The total wheeled area estimated in this study over a single cropping season represented approximately two-thirds of the field-cropped area. This wheeled area could be reduced to less than 20% with careful planning and modification of the equipment to meet the specifications of a fully matched controlled traffic farming (CTF) system operated at 3-m center and 9-m base module with a 3:1 ratio (planter/combine harvester-to-sprayer rig/fertilizer applicator). Conversion to a fully matched CTF system needs to be considered as part of the machinery replacement program over a timeframe that is economical and compatible with the farming enterprise. Based on other studies in Argentina, adoption of CTF could lift productivity by a conservative 12%-15%, while reducing inter-annual yield variability and improving fuel-use efficiency and the timelines of field operations.

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