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Path planning in advance to help with agricultural emissions and time management

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Regardless of the job, the saying 'well planned is half done' holds true. It is well known that in Finland, the agricultural season in spring and autumn is short and there is no extra time to spare. Therefore, it is good to prepare and plan the work in advance. Autopilot has been available for work machines for about ten years, but route planning programs are just making their entrance. Autopilot in itself does not save time unless it is more precise than a human or follows a faster route. With RTK correction, centimeter-accurate steering is achieved, which eliminates overlapping driving, but the routes can still be suboptimal. In the Smart Agriculture project in Tarvaala, we compared how much time is saved by pre-optimized driving routes compared to manually driven ones. The routes were created in the spring, outside the season, and on the conventional side, the same paths as always were driven, meaning the longest possible swath. The work phase was sowing and fertilization, and the plot was a rectangular 8-hectare block belonging to the project. The work phases were recorded in a task file, and from both halves, all breaks over 30 seconds, which we assumed were due to human reasons such as breaks and machine checks, were removed. The experiment revealed that the time saved by pre-created routes was 17% compared to the traditional way of driving. The field was familiar to the driver in advance. Even if one considers the time spent creating the routes, about 10 minutes, the savings are regained the following year when the routes do not change, as long as the field remains the same shape. Different routes can, of course, be created for different work phases, such as sowing routes at a 45-degree angle to the sowing tillage. Temporal savings also bring other benefits such as lower emissions through reduced total consumption and improved driver well-being through reduced working hours.

Keywords: path planning, routes, smartfarming, compaction, optimizing

Introduction

This investigation constituted a component of the broader "Älymaatila" project, which was operational from 2021 to 2023 in the central Finnish locale of Saarijärvi. The project's objective was to evaluate the efficacy of advanced smart farming technologies, classified at a Technology Readiness Level (TRL) of 7 or above, in contrast to traditional agricultural practices on a typical Finnish field. To facilitate this comparison, the field under study was bifurcated into two sections of comparable dimensions and configurations. The segment to the left was designated for the application of smart farming apparatuses, whereas the right portion remained subject to conventional farming methods. It was determined that the division of the field would remain constant throughout the project's duration, with adjustments made only to the sequence of agricultural operations to prevent any bias towards either section. On the smart farming section, the fertilizer application was modified for areas identified as underperforming in terms of yield, despite these adjustments not impacting the overall time or fuel consumption associated with these interventions. This research in continued in the ongoing Finnish Future Farm project.

Material and methods

In the conducted research, the agricultural machinery employed comprised a 2023 Valtra N175 tractor (121 kW) and seeder was Tume Super Nova Combi 3000 (Fig. 1). Both the tractor and the seeder were equipped with ISOBUS technology, facilitating the subsequent collection of data derived from the operational tasks executed. Furthermore, the tractor was augmented with a Real-Time Kinematic (RTK) correction signal, enhancing its positioning accuracy, while the seeder was outfitted with two 1.5-meter Section Controls (SC). These SC units were strategically configured to ensure a 50% overlap with previously sown areas, given the available options of 0%, 50%, or 100%. This methodological choice was predicated on the objective of minimizing both the redundancy of seed coverage and the occurrence of unsown patches, which could potentially foster weed proliferation.

Fig. 1. Tractor and implement used in the tests

The path planning for the agricultural operations was facilitated by the use of Geo-bird software, which, at the time of the study, was in its beta development phase. Consequently, the software's capabilities were limited to the planning of direct traversal paths, with the functionality to design headland routes not yet implemented. The routes were optimized for 3m wide seeder going on average 10kmh and going around any possible obstacles such as islets three times. This way we would ensure that the following paths would be straighter. Headland width was 21m because of the width of the sprayer which is very typical width (Fig. 2)

Fig. 2. Planned driving paths on the left side of the test field

For the cultivation plan the FMIS (Farm Management Information System) used was Mtceh minunmaantilani. For this operating system we could not affect since it is really hard to change for the farm during season. The FMIS would have not affected on the end results since we only created the seeding and fertilizer maps with it and the same maps could have been created with any other FMIS. Whether other operating system would have created the maps differently is debatable and still it would have not affected on the driving paths. Since the amount of sowing seed was constant throughout the field we varied the fertilizer (Fig. 3) based on the results from last year.

The fertilizer used was standard Yaramila Y 25 (25N-3P-6K) and the amount varied 230 kg ha^{-1} to 300 kg ha^{-1} corresponding of 57.5 kg N ha^{-1} to 75 kg N ha^{-1} depending on the soil type and last years harvest map. The areas where nitrogen fertilizer was left to less were more organic to avoid grain from rotting or were on dry headland area shaded by trees.

Fig. 3. Planned and implemented seed fertilization

Results

The implementation of pre-planned driving routes engendered a notable reduction in both the distance traversed on the field, by 19%, and in fuel consumption, by 17% (Fig. 4). The principal factors contributing to the efficiency gains, particularly on the left side of the field, were attributed to an increase in driving speed within the headland areas, coupled with the establishment of longer and straighter driving paths which facilitated enhanced driving velocities. Driving accuracy indirectly affected the total time by reducing overlapping driving. The increased time and fuel consumption caused by the field island located on the right sight of the field was countered by replacing the values of it's surroundings by the average values of a segment of straight level field from the northern part of the right side. The time taken to create the driving paths are not presented in the Figure 3. because they were made out of season, it took marginal time to make them which would have not affected the results and the time costs can be divided over the next years because the field boundaries do not change.

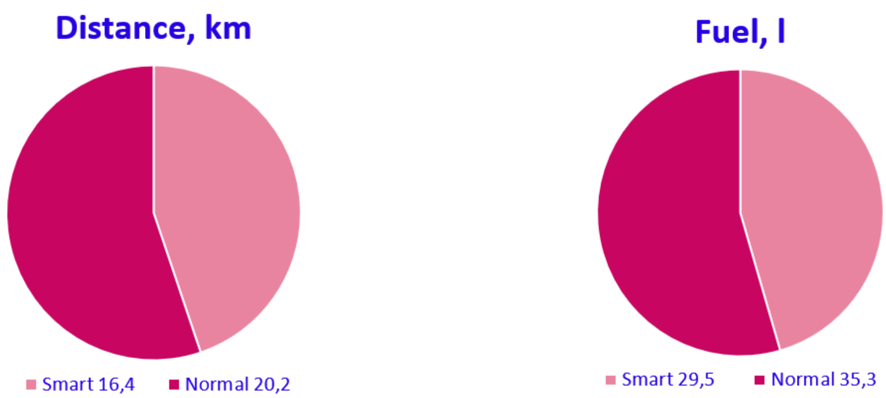

Fig. 4. Distance and fuel results

It is noteworthy to observe the variations in driving paths between the years 2022 and 2023. The factors contributing to these discrepancies include the unavailability of the geo bird in the initial year, followed by the introduction of a different operator in the subsequent year, albeit with identical qualifications, machinery, and software. This scenario presents a compelling avenue for future research, specifically in comparing the efficacy and deviations of various driving methodologies against pre-established trajectories. Figure 5 elucidates the differential aspects between the years through visual representation.

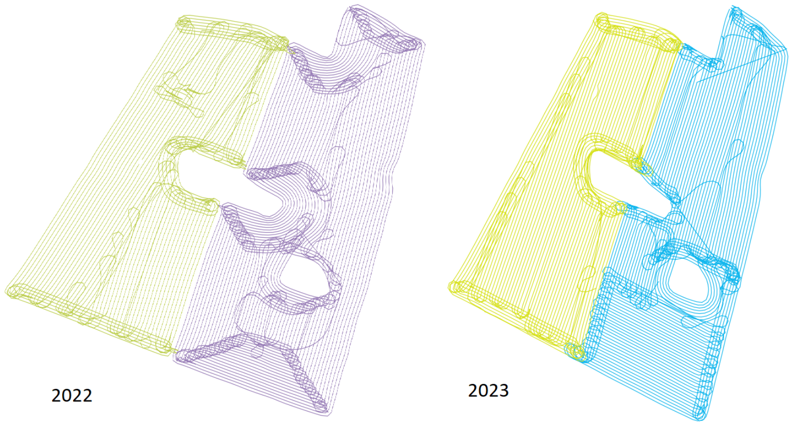

Fig. 5. Driving paths on two different years

Discussion

Based on trials in two years and two different but seasoned drivers the teaching they had have a big role on how they drive and choose paths. The path planning program is independent and advantages new and experienced drivers as well. The problems which we luckily didn't have occur when the tractors has to avoid a unexpected areas on the field such as wet spot, rock or birds nest. Those can have an impact on the rest of the lines and cause major overlapping, but same challenges appear without the program.

In real life circumstances it is also challenging to avoid humane brakes and erros which might occure more often on the other side of the field. These can be removed up to certain point but after that they can distort the results. It would also be more consistent to use the same driver but they tend to graduate and for the academy it is better to utilizer different students.

Conclusions

In scenarios characterized by uniform field conditions, the pre-creation and optimization of driving paths emerge as highly advantageous strategies from an economic standpoint. This approach predicates on two fundamental assumptions: firstly, that the tractor is equipped with an appropriate steering and guidance system, and secondly, that it is compatible with the path planning software. These preconditions are essential for ensuring the effective implementation of the planned paths. The versatility of this method allows for the customization of paths according to the specific dimensions or operational speeds of various implements, thereby making it applicable across diverse field layouts and agricultural tasks. They can also be sent OTA (Over the Air) or via USB (Universal Serial Bus).

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