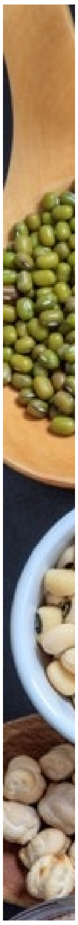
SLUTRAPPORT
GUDP-projekt 01-07-2017 - 31-12-2020.

NutrieRoute



31. MARTS 2020

Af Ole Green
Agro Intelligence ApS

Ministeriet for Fødevarer, Landbrug og Fiskeri
gudp

Grønt Udviklings- og Demonstrationsprogram

Projektet, som er beskrevet i denne rapport, er støttet af Grønt Udviklings- og Demonstrationsprogram, GUDP, som er en erhvervsstøtteordning under Ministeriet for Fødevarer, Landbrug og Fiskeri.

GUDP giver tilskud til projekter, der understøtter grøn og bæredygtig omstilling af fødevareerhvervet, og programmet dækker hele værdikæden fra primærproduktion til forarbejdningsindustri og afsætningsled.

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GUDP-sekretariatet i Landbrugsstyrelsen
Nyrupsgade 30, 1780 København V
Augustenborg Slot 3, 6440 Augustenborg | Tlf.+45 33 95 80 00

Mail: gudp@lbst.dk
Web: www.gudp.dk

Denne slutrapport er godkendt af GUDP, men det er alene rapportens forfatter/projektlederen, som er ansvarlige for indholdet. Rapporten må citeres med kildeangivelse.

END REPORT

NutrieRoute

PURPOSE

NutrieRoute is a GUDP funded project involving Agro Intelligence ApS, SEGES and the University of Aarhus. The project developed an application that supports slurry truck drivers to make complicated decisions. A dynamic multi-criteria route/logistic optimization model for slurry application integrated with an overall optimized fertilization strategy was developed. In order to minimize the driving distance in the field, the application rate can be reduced/increased in each track, while at the same time allowing for varying the slurry application rate, resulting in an optimal sequence of tracks with a specified application rate for each track. This type of application can be compensated by reducing and increasing the application of artificial fertilizers.

This can, for example, be the best possible combination of tracks in relation to the size of the slurry truck or the addition of liquid manure to the slurry which increases the nutrient content of the slurry so that a load can be stretched further. Once the application has taken place, data are processed to give the owner of the field a calculated first year utilization effect of his nutrients. All in all, NutrieRoute can improve the delivery of nutrients and facilitate the work of the driver.

PROJEKTETS RELEVANS

Slurry application is a so-called capacity operation, where not only the machine itself must be handled but also a material flow, here slurry. Optimized logistics and other driving optimizations become extremely important and depend on factors such as machine dimensions, manure nutrient content, field geometry and possibly vulnerable areas in the field where traffic with a fully loaded slurry tanker is not advantageous. There will often be overlap in headlands, which causes over-fertilization, just as inappropriate driving patterns otherwise lead to increased detours, increased time consumption, reduced capacity, etc. Under favourable conditions for slurry application, the field efficiency can be above 80%, while under unfavourable conditions it can easily fall below 60%, so there is a significant optimization potential.

MAIN RESULTS

An optimization and simulation model/tool has been developed to determine an optimized coverage and route plan in order to minimize the driving distance in the field, while at the same time allowing for varying the slurry application rate. This includes the optimal sequence of tracks with a specified application rate for each track. The optimization is based on multiple optimization criteria, like 1) visiting the depots for refilling with empty tank, 2) avoid passing through wet parts of the field unless with empty tank, 3) avoid making turns in the main crop area, 4) limit all turning maneuvers to the headland part of the field, and 5) apply (±%30) tolerance for the slurry application rate. The operations efficiency of the optimized plans generated by the proposed method were compared with conventional non-optimized methods used by farmers, showing a 18.6% and 28.1% reduction in the non-working travelled distance and the non-working time, respectively.

In addition, the slurry model and application are able to recommend how much to fill in the slurry tank and which tracks should be driven in order to reduce soil compaction and reduce the load on the soil.

SEGES has developed a webservice to exchange data with the Danish Field Database and other collaborators. (https://plantapi.seges.dk/)

The purpose of the webservice is, among other things, developed to exchange data with machines. The service communicates pending tasks, created in the Farm management information system (FMIS) Mark Online, as well as required field geometry available to farming equipment. This enables Robotti or similar machines to fetch information about tasks such as fertilizer application for a specific field.

An authorization hierarchy has been implemented to ensure that each machine or user, only has access to the data needed in order to perform its tasks.

Each task has a unique identifier which enables machines to ensure that data is linked to the correct task in the database. When a task is executed by the machine, the machine can use the webservice to send data to Danish Field Database, thereby submitting information about the specific nutrient content applied during that specific task.

SEGES, together with AgroIntelli, has performed a Proof of Concept which clearly shows that AgroIntelli, using this webservice, have access to the required data and that the machine can send data back to Danish Field Database.

Furthermore, the data from the machine is used to calculate the first-year nutrient use efficiency using the GylleIT-model, developed outside this project.
When data has been sent to Danish Field Database, several automated routines are run:

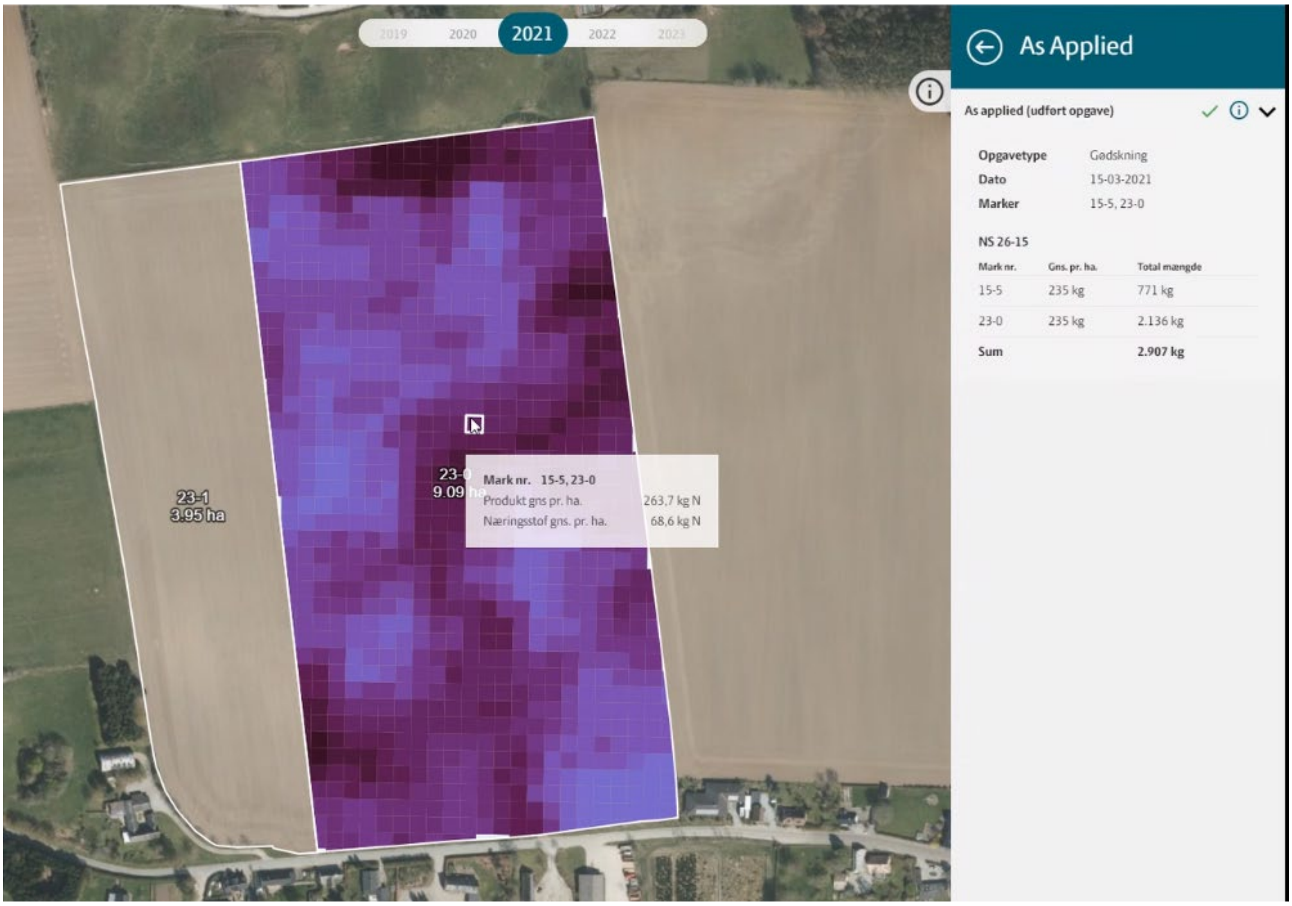
- The task is enriched with details about total amounts applied.
- The task is enriched with amount applied by hectare.
- The task is enriched with the calculated first year nutrient use efficiency.
- The task is updated with the precise date and time of completion.
- ...and the task is marked as complete.

Data supplied by Robotti includes large amounts of site-specific details using the standardized format, ISOXML. By integration with the Gylle-IT model, the data is used to calculate the first-year nutrient use efficiency, by taking in to account local weather data from DMI, crop type, development stage and slurry nutrient content. The farmer has access to the resulting information through Mark Online, Crop-Manager or using the app FarmTracking.

A feature which visualizes the as-applied details for a task, has been implemented in CropManager. This feature supports tasks, which have a variable application rate. The feature currently can show tasks, which applied mineral fertilizer using a Bogballe spreader, or tasks which have applied slurry us-ing Robotti from AgroIntelli. There is an ongoing effort to integrate with additional machine suppliers as well as additional data types.

The feature functions as an archive of geospatially referenced data about applied slurry and other types of tasks. This can be used for compliance with regulations, and as a valuable source of insight when analyzing crop development.

The feature includes a function to download the As-Applied maps which can be used as a data source to generate other variable rate application maps in other applications such as AgroGIS, which is also a pro-gram offered by SEGES. Using the information gathered from the As-Applied map, CropManager can help the users create custom maps for future crop management, which considers the already ap-plied nutrients.



Example of an As-applied map in CropManager.

PROJECT AND EXPERIENCES

Data was collected to find out what in the process of the slurry operation could be optimized. Fill times, preparing the slurry boom for application, in-field transport while empty, in field transport while full, applying slurry time, transport driving to and from refill station, and distance were recorded and analyzed. Data from almost 3000 slurry loads were collected and analyzed.

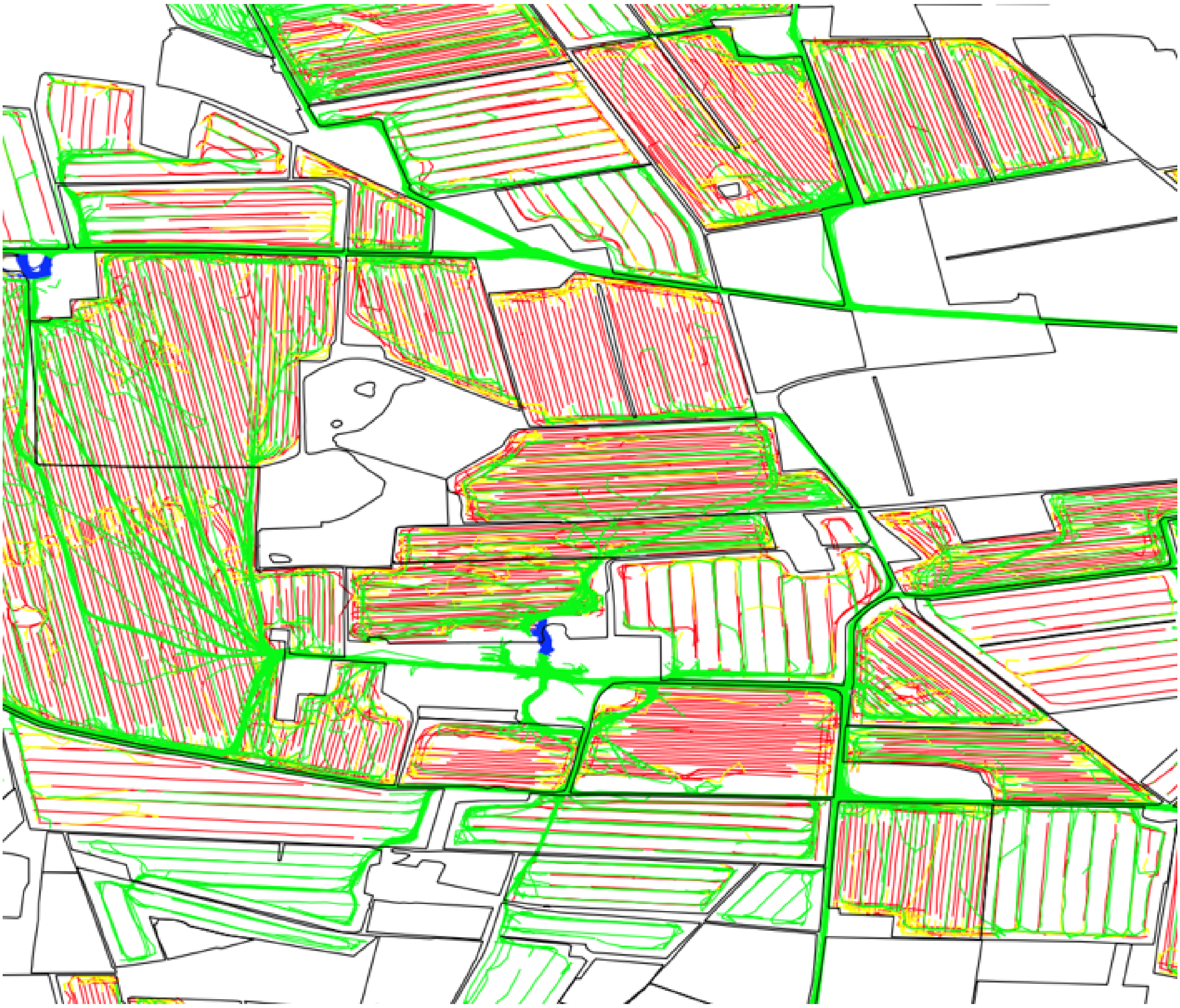


Figure 1: Green lines show the movement of the tractor and slurry wagons to and from the fields and also in field driving.

Slurry wagon utilization (m^3/hour)

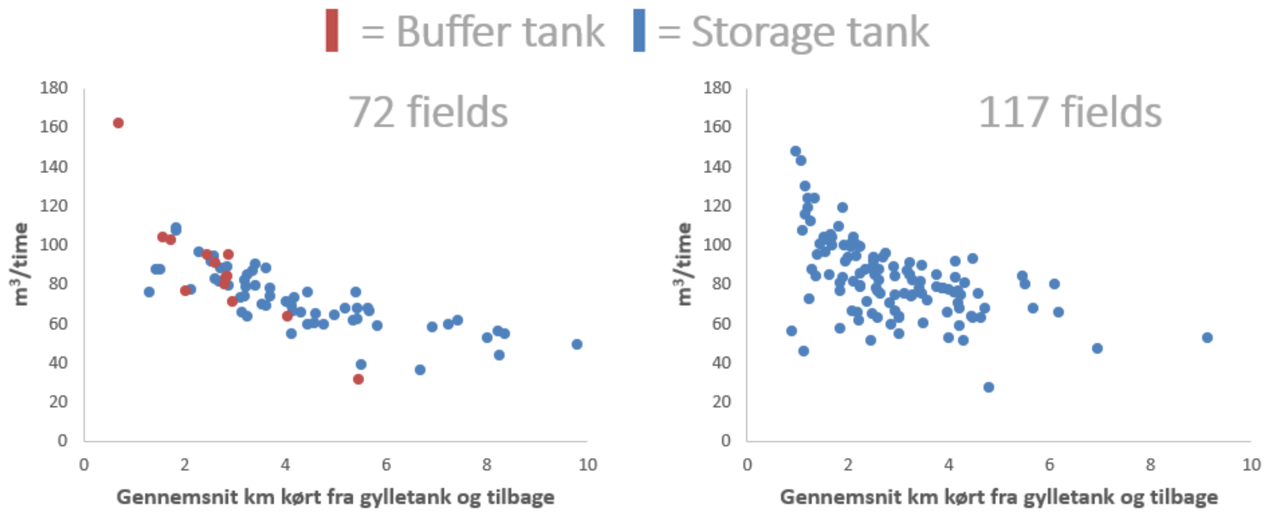


Figure 2: Data collected from 72 and 117 fields for the average km driven from the slurry tank and back to the field.

Time usage inside the field (Drag hoses)

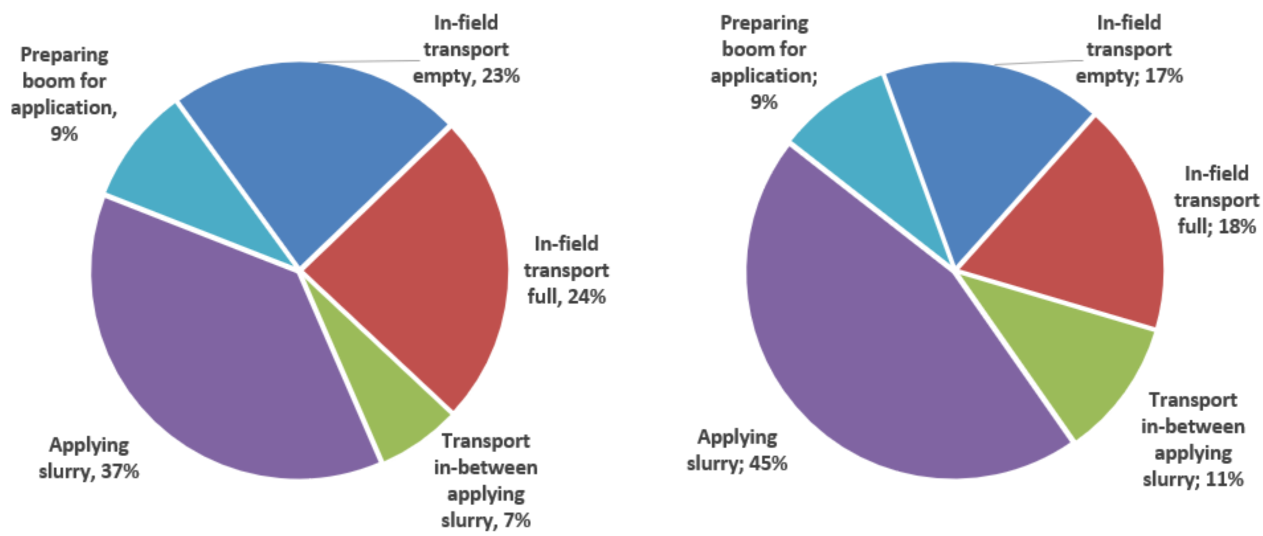


Figure 3: The time used once the slurry wagon arrives in the field.

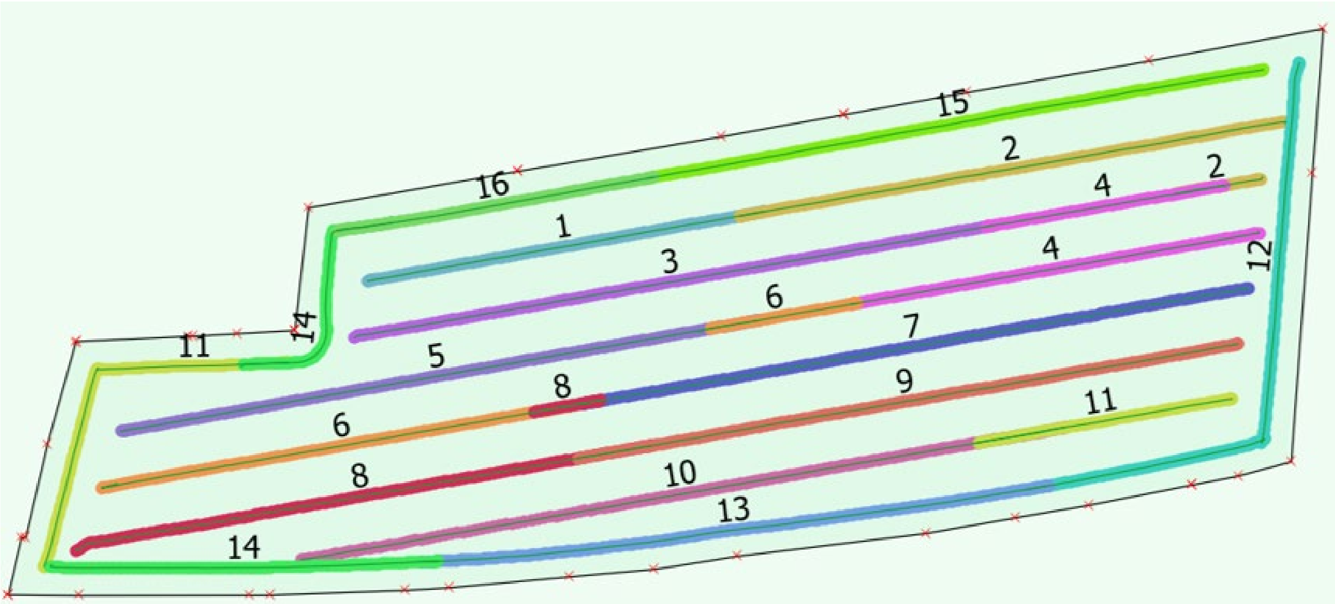


Figure 4: Fields were analyzed. This shows where the slurry was applied in one of the analyzed fields. It also shows that there are several tracks where the driver would need to drive over the same area 3 times.

From the analysis of the data collected, it was decided to create a model using the slurry wagon volume, working width, number of loads of slurry, total amount of slurry in each load, field area, amount of distance to the slurry station, and amount of time working.

Different solution methods to the multi-criteria optimization has been tested and validated, resulting in finding an optimal coverage plan, casted as a capacitated vehicle routing problem (CVRP), followed by the second part of the problem casted as knapsack problem in order to find an optimal application rate for each work area of the field, and finally, the optimal traversal sequence will be found by applying novel meta-heuristic algorithm Simulated Annealing (SA) methods to the discrete search space involving the above mentioned constraints. The key innovation and optimisation kernel is the multi-objective optimization for the route planning system, which complicates the optimization as compared with single constraints, like single task time or non-working distance.

Resultat	
2018:	3040sek, 5.5km
Optimeret:	3036sek, 5.4km

Figure 5: A field that was observed an analyzed in 2018. It was possible to reduce the distance driven by 0.1 km. See table 1, below.

2018, June: From station to field: 5 Amount of slurry: 148m3 Slurry/trip: 29.6m3 Distance/trip: 1.1km Time/trip: 608sek Working/not working: 248/360sek	2018, June: (simulated optimization) From station to field: 6 Amount of slurry: 159m3 Slurry/trip: 26.6m3 Distance/trip: 0.9km Time/trip: 506sek Working/not working: 250/256sek

Table 1: Comparing the data from analyzed field and from the results of the model (simulated optimization).

An application was design and developed to aid the farmer in applying the slurry.

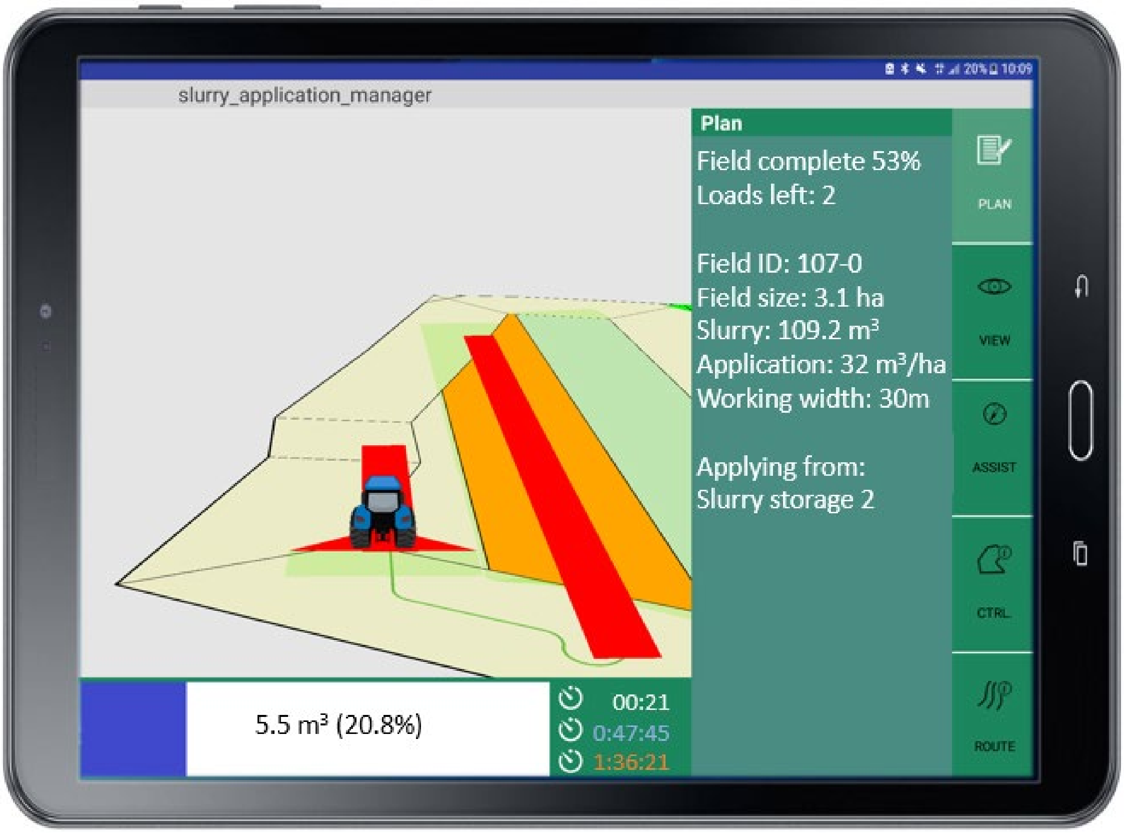


Figure 6: An application was developed using the NutrieRoute model.

CONCLUSION AND PERSPECTIVES

A tool for determining an optimized coverage plan in order to minimize the driving distance in the field, while at the same time allowing for varying the slurry application rate has been developed. Results showed that applying this new method causes 18.6% and 28.1% reduction in the non-working travelled distance and the non-working time, respectively, and in this way, corresponding fuel and CO2 are saved in comparison with conventional methods. Additionally, it was shown that by exploiting the optimal headland patterns, apart from the reduction of non-working distance (followed by the reduction of the fuel consumption and the non-productive time), a reduction of soil compaction in the headland area will also be achieved.

The project has proved the feasibility of multi-criteria optimization in terms of route planning and laid out the perspective for including extra criteria as for example soil information. The experience from this challenge will be used to further develop/adapt the routing optimization algorithm to the soil compaction mitigation problem.

PUBLICATIONS

Mahdi Vahdanjoo, Kun Zhou, and Claus G. Sørensen 2020. **Route Planning for Agricultural Machines with Multiple depots. Case: Manure Application.** Agronomy 2020, 10, 1608; doi:10.3390/agronomy10101608

https://www.mdpi.com/2073-4395/10/10/1608/review_report

Mahdi Vahdanjoo, Christian T. Madsen, and Claus G. Sørensen 2020. **Novel route planning system for machinery selection. Case: slurry application**. AgriEngineering 2020, 2, 408–429; doi:10.3390/agriengineering2030028
https://www.mdpi.com/2624-7402/2/3/28

Mahdi Vahdanjoo, Claus G. Sørensen 2021. **Novel Route Planning method to improve the operational efficiency of capacitated operations. Case: application of organic fertilizer** (submitted to Agronomy)

Sørensen, C. 2019. **Agricultural Technologies for a Sustainable Future**. Invited speaker, China Agricultural University, October 28, 2019, Bejing, China

Sørensen, C. **Precision Agriculture Technologies for a Sustainable Future: Current Trends and Perspectives**, Invited speaker, Namık Kemal Üniversitesi, Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, Tekirdağ, Turkey, February 25th, 2019

Læs mere om GUDP´s projekter på www.gudp.dk