Working time requirement of operators and process-related idle time of semi-autonomous field robots

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SIMA
AGRITECH DAY
By AXEMA

Who am I ?

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Eine Einrichtung des Bundesministeriums für
Land- und Forstwirtschaft, Regionen und Wasserwirtschaft

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5th SIMA AgriTech Day by Axema

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FARMING FOR FUTURE

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Mit Unterstützung von Bund, Ländern und Europäischer Union
Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft
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Source: HBLFA Francisco Josephinum


Source: https://www.hatzenbichler.com


Source: https://www.greenbot.nl

Source: HBLFA Francisco Josephinum

Introduction I

- First field robots that work autonomously in the field have been presented in recent years
- Compared to conventional tractor-driven machines, these robots have small working widths.
- In order to be able to process the same area in a timely manner, several robots must be used at the same time and these must continue to work outside of the operator's working hours.

Source: https://www.greenbot.nl

Source: FarmersFuture R&B GmbH

Introduction II

- However, under today's technical and traffic law framework, they are not allowed to change to the next field on public roads autonomously.
- To do this, they must be attached to the three-point hitch of a tractor or loaded onto a transport vehicle.
- This presentation will try to answer two questions:
  - How long is the idle time of the robots in connection with the transfer to the next ?
  - How long can robots continue to work autonomously after the end of the operator's working day?

Source: https://www.greenbot.nl

Source: FarmersFuture R&B GmbH

Materials and Methods

- Based on a job description at the level of sub-operations, the workflow of the robots and the operator for a working day are simulated.
- The calculations bases on data from time studies on robots and comparable conventional machines.
- The breakdown of working time is based on Winkler and Frisch (2014).

Materials and Methods

- In order to be able to examine the effects of the area capacity of the robots on the question:
  - Mowing of grassland is simulated as an operation with a relatively high area capacity
  - Hoeing sugar beets is simulated as an operation with a relatively low area capacity
- In the simulation are varied:
  - operating speed
  - working width
  - turning time
  - driving speed when driving empty in the field
  - time requirement for transferring the robot to the next field
  - number of field robots used
  - number of processed fields at the same time

Materials and Methods

- The first step in the simulation is planning the field-work track of the implement and the operator.
- After that, the required working time is assigned to each track section and the cumulative time of the equipment and operator used is determined parallel.
- Idle times due to work organization and the time required for the individual fields are determined based on the cumulative time.
- The simulations are carried out for the investigated jobs for both robots and conventional tractor-driven implements and the results are then compared.
- The simulation is programmed in Microsoft Excel.

Materials and Methods

- Examined jobs
  - Mowing of grassland

Tractor mower (9 m working width)

Source: HBLFA Francisco Josephinum

Source: https://www.greenbot.nl

Robot (3 m working width)

  - Hoeing of sugar beet

Source: https://www.hatzenbichler.com

Tractor with hoe
(5.4 m working width)

Robot (1.8 m
working width)

Source: HBLFA Francisco Josephinum

Assumptions for the simulation

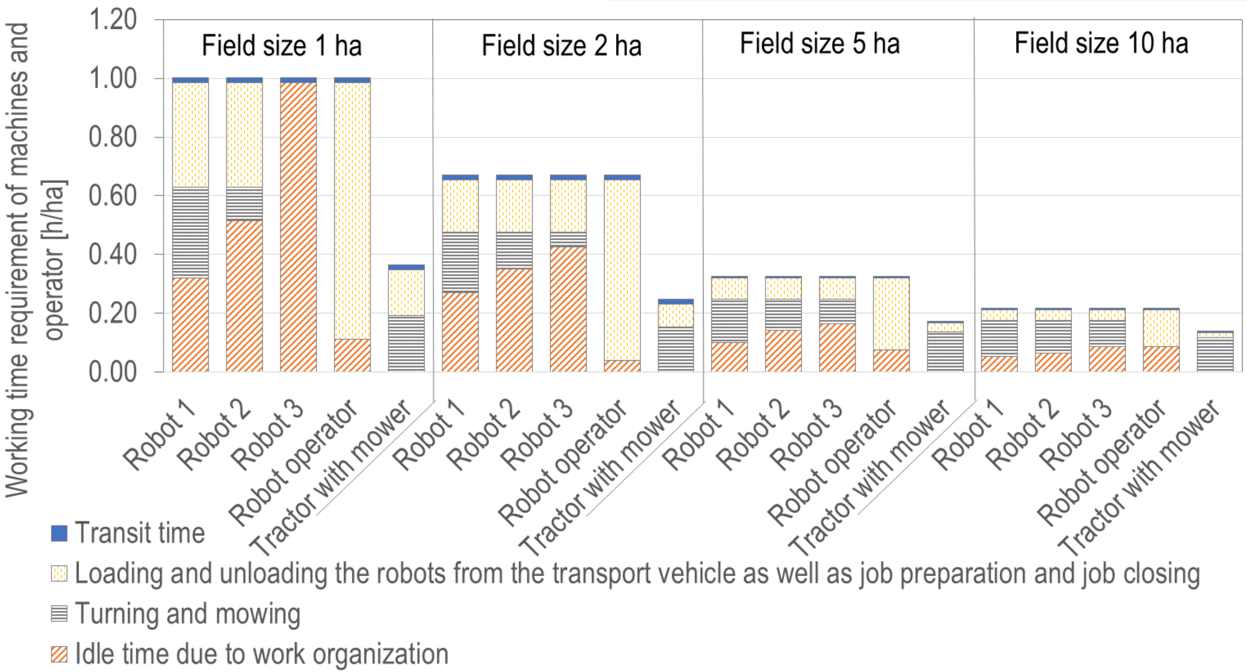
- Length to width ratio of the fields: 4:1.
- Distance from field to field or farm:
  - Field size 1 ha - 0.5 km
  - Field size 2 and 5 ha - 1 km
  - Field size 10 ha - 2 km
- Average driving speed for the transfer between field and field or farm: 30 km/h (for robot as well as tractor mechanization)

Machines and determining factors for mowing

Mechanization	Determining factor	Scenario Non-productive time high	Scenario Non-productive time low
Robot with mower (working width 3 m)	SO1: Preparation of the unloading or loading process [min]	4.34	1.50
	SO2: Unload and get robot ready for use [min]	9.94	3.10
	SO3: Prepare robot for transport and load min]	11.41	3.20
	SO4: Prepare transport vehicle for departure [min]	5.28	2.10
	Operating speed [km/h]	12.0	
	Turning time [min]	0.21	
Tractor with mower (working width 9 m)	Working time per field for job preparation [min]	4.45	
	Working time per field for job closing [min]	4.90	
	Operating speed [km/h]	12.0	
	Turning time [min]	0.21	

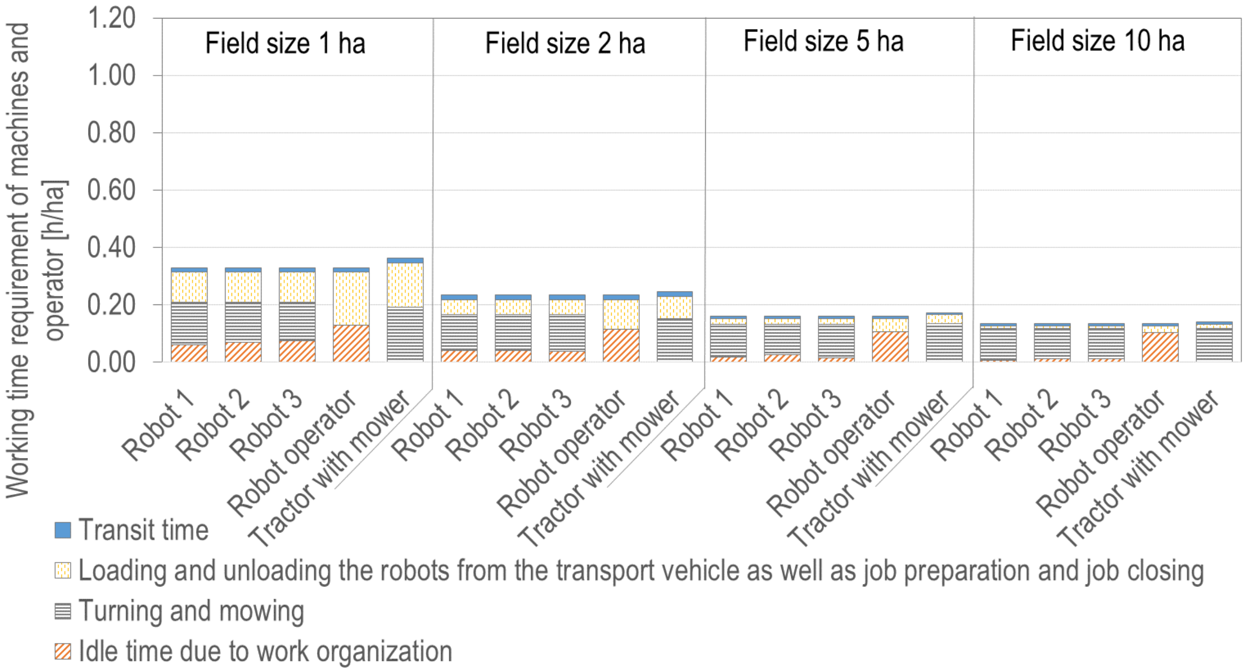
Results mowing

- Scenario Non-productive time high
- Robots work on the same field
- One robot after the other is loaded or unloaded from the transport vehicle by the operator



Results mowing

- Scenario Non-productive time low
- Robots work on the same field
- Robots drive autonomously onto the transport vehicle and leave it autonomously



Materials and Methods

- Examined jobs
  - Mowing of grassland

  - Hoeing of sugar beet

Tractor with hoe
(5.4 m working width)

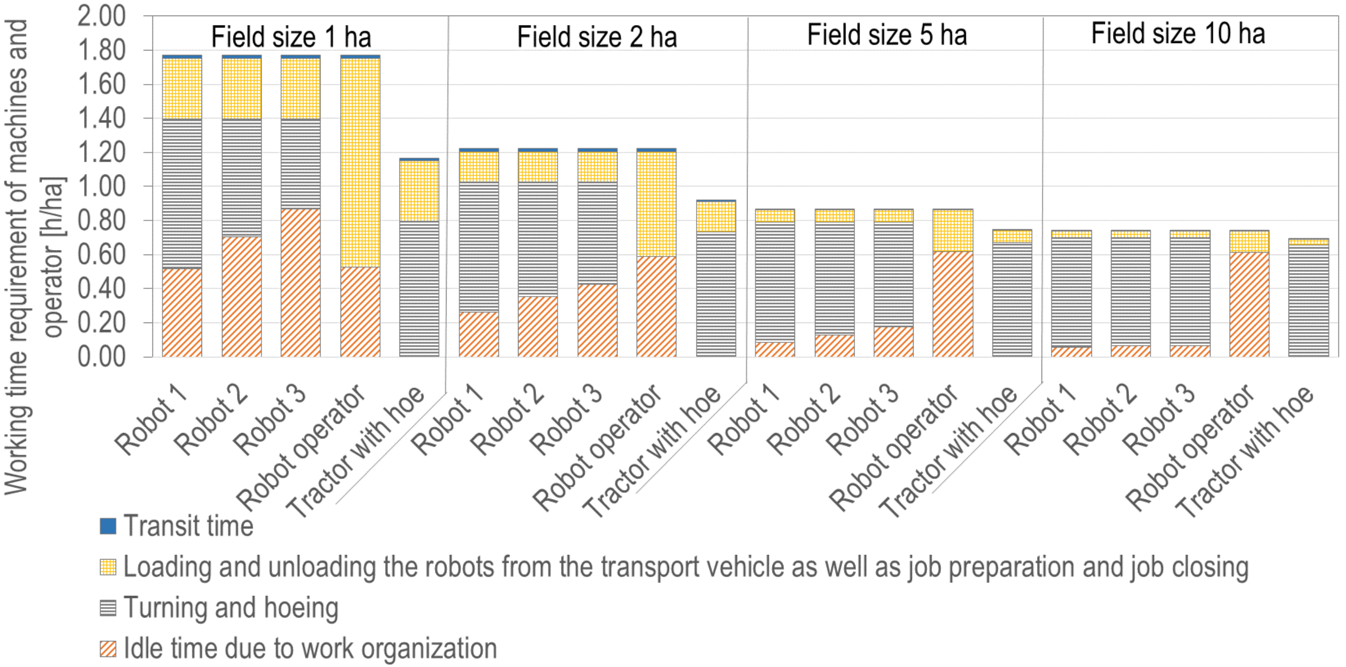
Robot (1.8 m
working width)

Machines and determining factors for hoeing

Mechanization	Determining factor	Scenario Non-productive time high	Scenario Non-productive time low
Robot with hoe (4 rows, working width 1.8 m)	SO1: Preparation of the unloading or loading process [min]	4.34	1.50
	SO2: Unload and get robot ready for use [min]	9.94	3.10
	SO3: Prepare robot for transport and load min]	11.41	3.20
	SO4: Prepare transport vehicle for departure [min]	5.28	2.10
	Operating speed [km/h]	3.0	
	Turning time [min]	0.31	
Tractor with 12-row hoe (working width 5.4 m)	Working time per field for job preparation [min]	3.09	
	Working time per field for job closing [min]	3.22	
	Operating speed [km/h]	3.0	
	Turning time [min]	0.31	

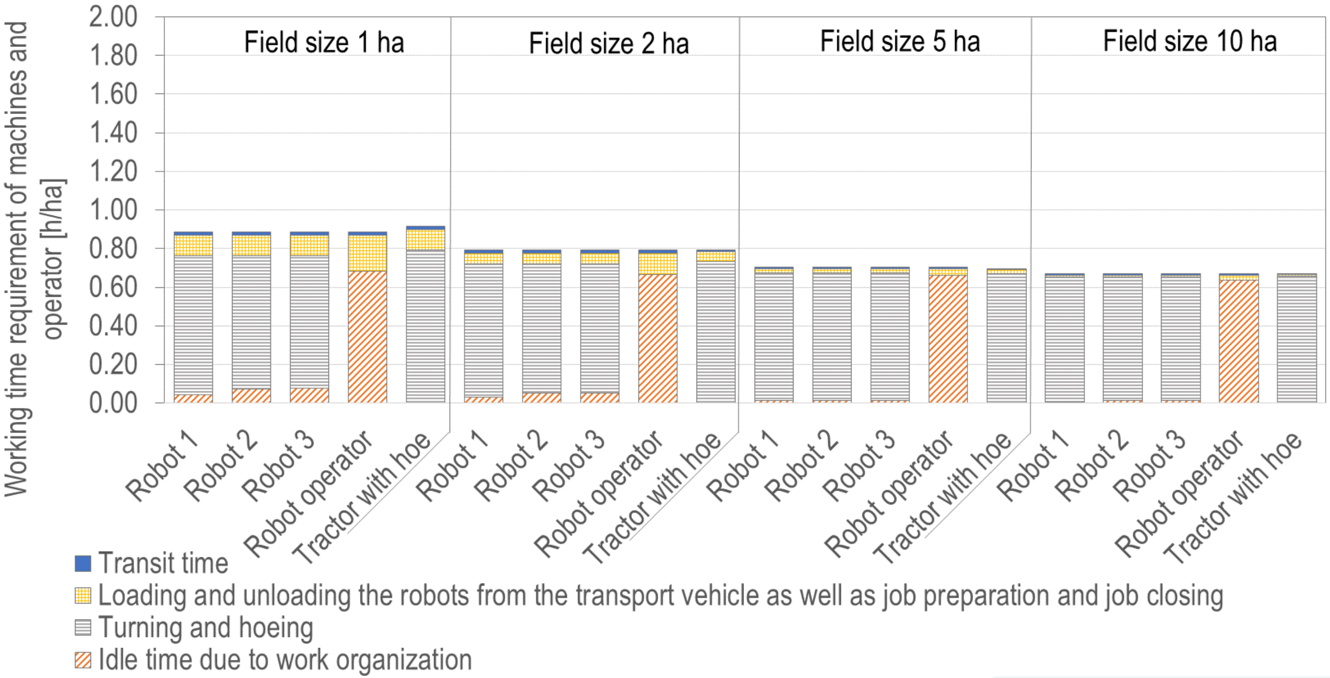
Ergebnisse Hacken

- Scenario Non-productive time high
- Robots work on the same field
- One robot after the other is loaded or unloaded from the transport vehicle by the operator



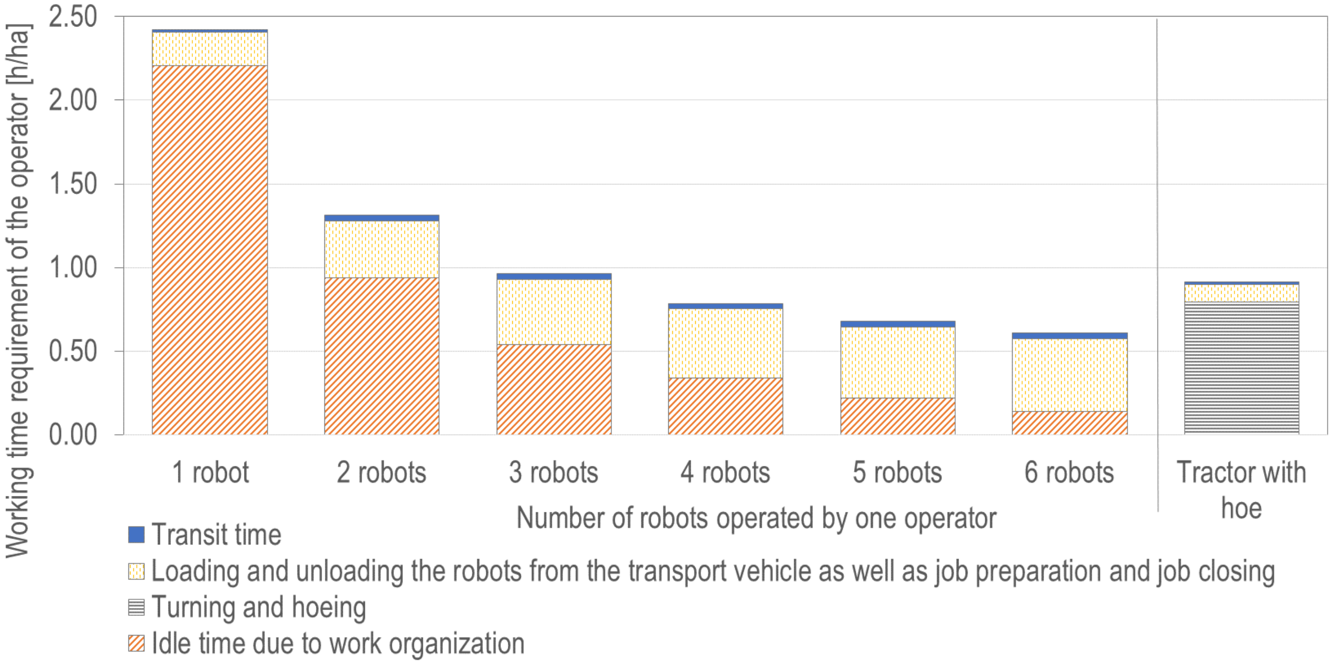
Results hoeing

- Scenario Non-productive time low
- Robots work on the same field
- Robots drive autonomously onto the transport vehicle and leave it autonomously



Working time requirement of the robots' operator for hoeing sugar beets

- Scenario Non-productive time low
- Robots work on different fields
- Robots drive autonomously onto the transport vehicle and leave it autonomously
- Field size 1 ha



Number of robots that can be operated by one operator I

- Winkler and Frisch (2014) classified the time for agricultural work in three main categories:
  - Operation time (t1)
  - Fault time (t2)
  - Non-productive time (t3)
  - Process time = Operation time (t1) + Fault time (t2)
  - Total time = Operation time (t1) + Fault time (t2) + Non-productive time (t3)

Number of robots that can be operated by one operator II

- Classification of the time for agricultural work (Winkler and Frisch (2014) :

Operation time (t1)

- **Execution time (t11)**
  time for executing the work task
- **Turning time (t12)**
  time for changing the working direction
- **Loading and unloading time (t13)**
  time for loading/unloading equipment
- **Inherent delay time (t14)**
  time for unavoidable delay of the work
- **Adjustment time (t15)**
  time for adjusting working equipment or further adjustment of work processes
- **Relaxation time (t16)**
  time for mandatory relaxation due to work load

Fault time (t2)

- **Functional and technical fault time (t21)** time for putting work equipment into operation again
- **Fault time due to work organization (t22)**
- **Fault time due to weather (t23)**
- **Contingency time (t24)**
  time for fulfilling human rights

Non-productive time (t3)

- **Supply time (t31)**
  time for filling or unloading equipment
- **Job preparation time (t32)**
  time for bringing equipment into the correct working position
- **Job closing time (t33)**
  time for returning equipment to its initial position
- **Transit time (t34)**
  time for travelling a specified distance
- **Servicing time (t35)**
  time for preventive maintenance of working equipment

Number of robots that can be operated by one operator III

- Number of robots that can be operated by one operator increases, if
  - Execution time (t11) per field increases (field size, shape of the field, working width and operation speed of the robot)
  - Turning time (t12) per field increases (time per turning, number of turnings per field)
- Number of robots that can be operated by one operator decreases, if
  - Adjustment time (t15) per field increases
  - Job preparation time (t32) or Job closing time (t33) per field increase
  - Transit time (t34) per field increases

Number of robots that can be operated by one operator IV

- If no fault time are taken into account, the number of robots (a_r) can be estimated using the following formula:

$$\lfloor a_r \rfloor = \frac{t12 + t22}{t15 + t32 + t33 + t34}$$

Results - Period of time that robots can work while operator's end of working day

Robot with ..	Field size [ha]			
	1	2	5	10
.. mower (working width 3 m, operating speed 12 km/h)	0.4 h	0.6 h	1.4 h	2.6 h
.. 6-row hoe (working width 3 m, operating speed 750 m/h)	5.4 h	10.2 h	24.4 h	48.1 h
.. 4-row hoe (working width 1,8 m, operating speed 750 m/h)	9.0 h	16.7 h	40.7 h	80.7 h

- Available field work time outside of the operator's working hours can be better utilized,
  - the lower the area capacity of the job is
  - the larger the fields are
  - when each robot works alone on a field

Conclusions I

- If several relatively small robots shall replace a more powerful implement attached to the tractor, the transfer of the robots from field to field must be designed in a time-efficient manner. If this is not the case, the working time requirement per hectare for the robot operator is significantly higher than that of the tractor driver. In this context, small fields are particularly critical for operations with a high area capacity, such as mowing grassland.

- The maximum number of robots that can be operated by one operator without idle time for the robots depends on:
  - Field size
  - Area capacity
  - Working time required to transfer the robots to the next field (Time for loading and unloading onto the transport vehicle influences the efficiency significantly.)

Conclusions II

- If several robots work at the same time, the strategy of using them on different fields results in higher working time requirement for the operator and higher area capacity of the robots.
- Robots with a high area capacity can autonomously work while operator’s end of working day only on large fields for a long period because they need the operator for changing to the next field. Several small robots with low area capacity working on different fields are advantageous in this context.
- In order to avoid idle time of the robots, the field size and area capacity of the robots must be taken into account when planning the time for the operator's breaks.

Thank you for your attention!

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