Dionysis Bochtis, Ph.D,
Dept. of Engineering, Aarhus University

Systems engineering advances for addressing complexity in bio-production chains

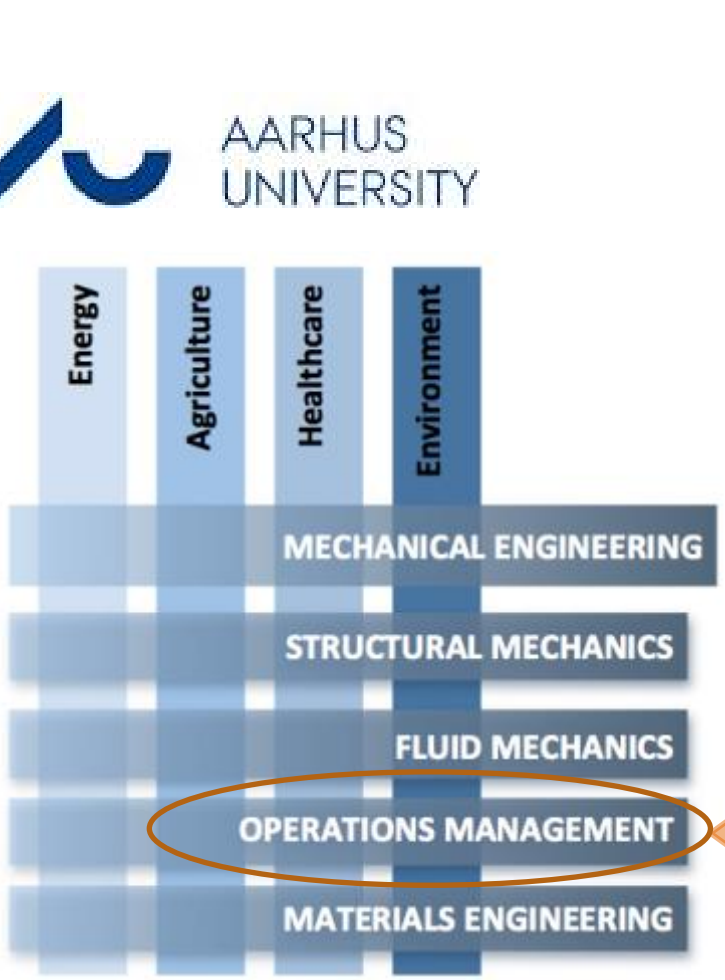
AARHUS
UNIVERSITY

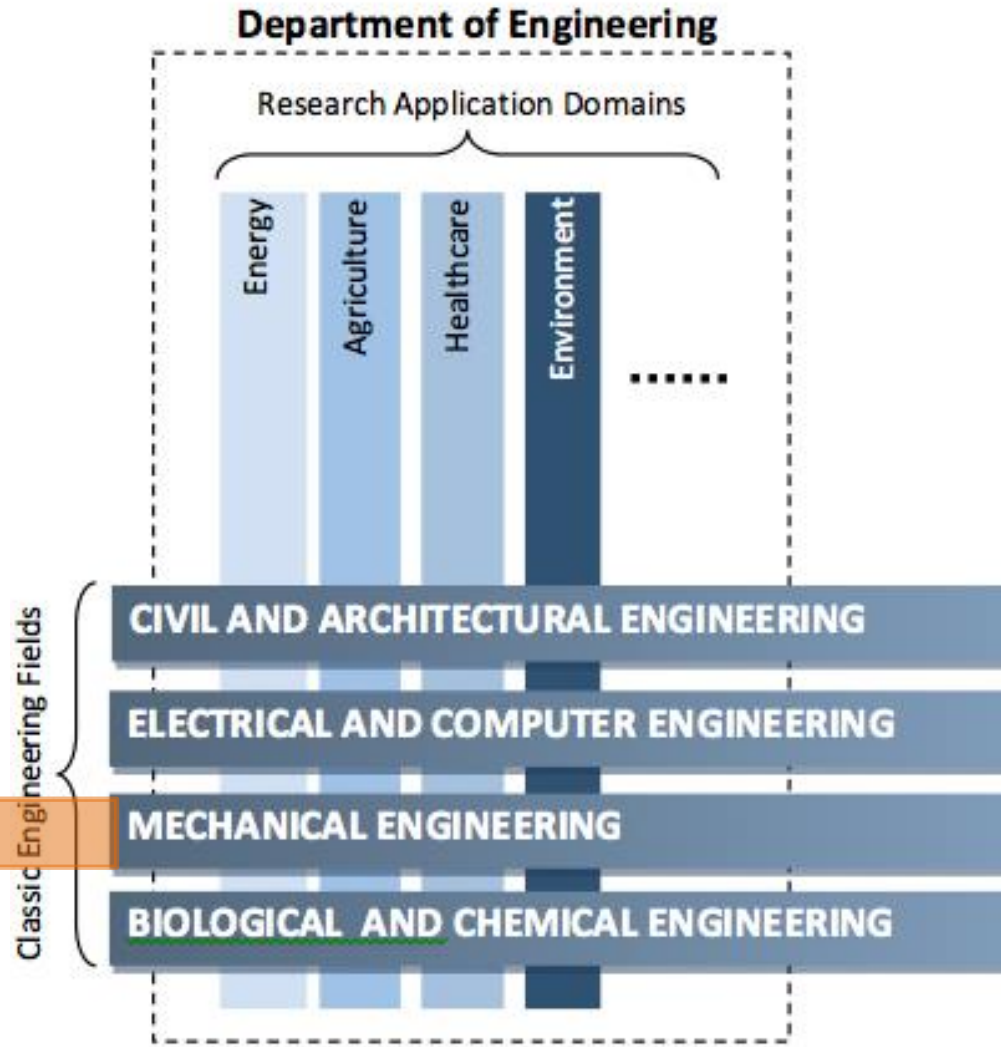
DEPARTMENT OF ENGINEERING

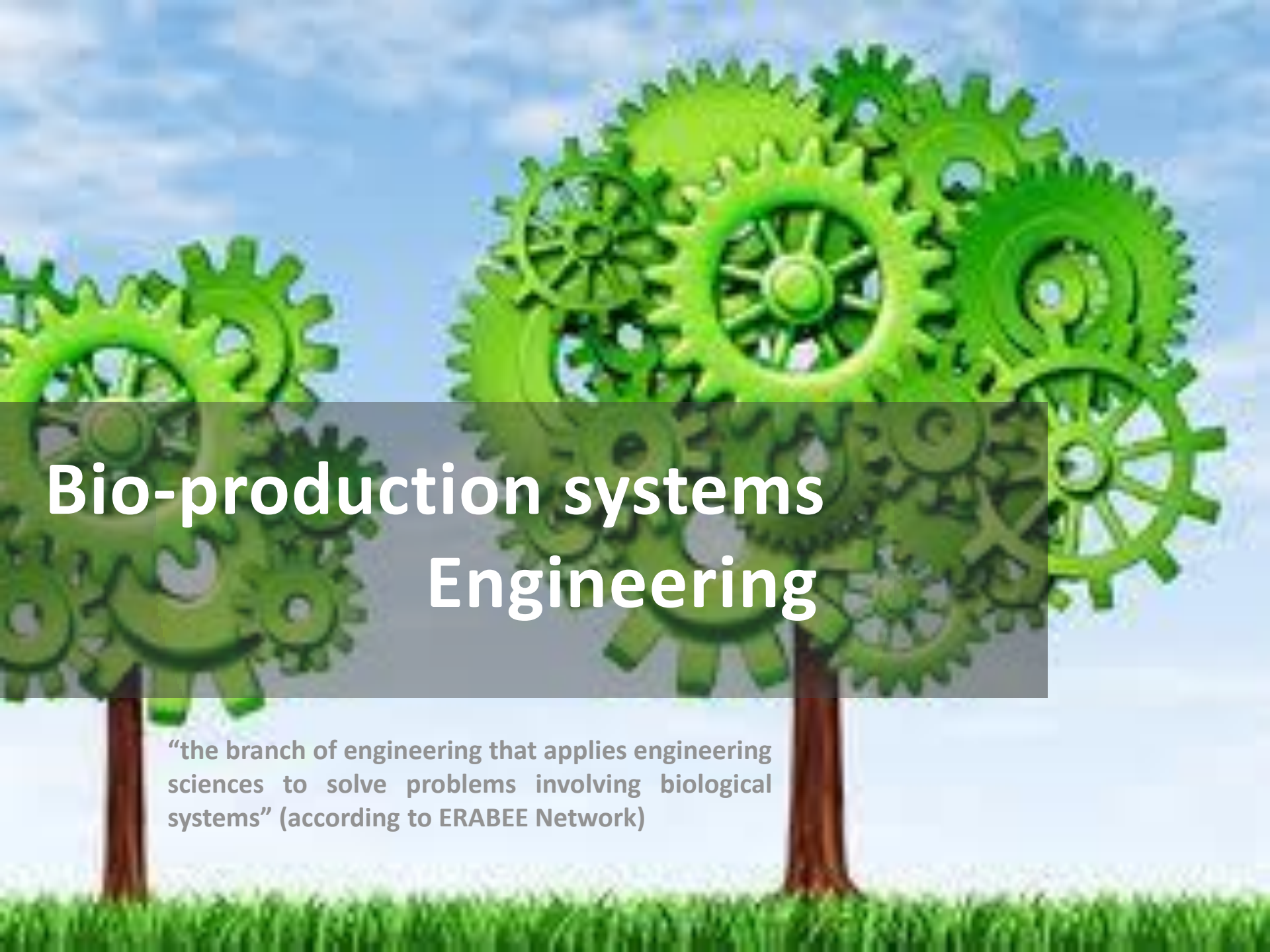




AARHUS UNIVERSITY







Bio-production systems Engineering

"the branch of engineering that applies engineering sciences to solve problems involving biological systems" (according to ERABEE Network)

Bio-production systems Engineering



the phases from the past to today and to the future



1

Mechanisation

Providing human operators with tools and machinery that assists them with the muscular requirements of work (increase productivity)

Past



1 Mechanisation

-Increased work rates
-Economical platforms for the latest technological developments

ECONOMIES of SCALE








1 Mechanisation

-Increased risk for soil damage through ground pressure

ECONOMIES of SCALE











ICT & Automation

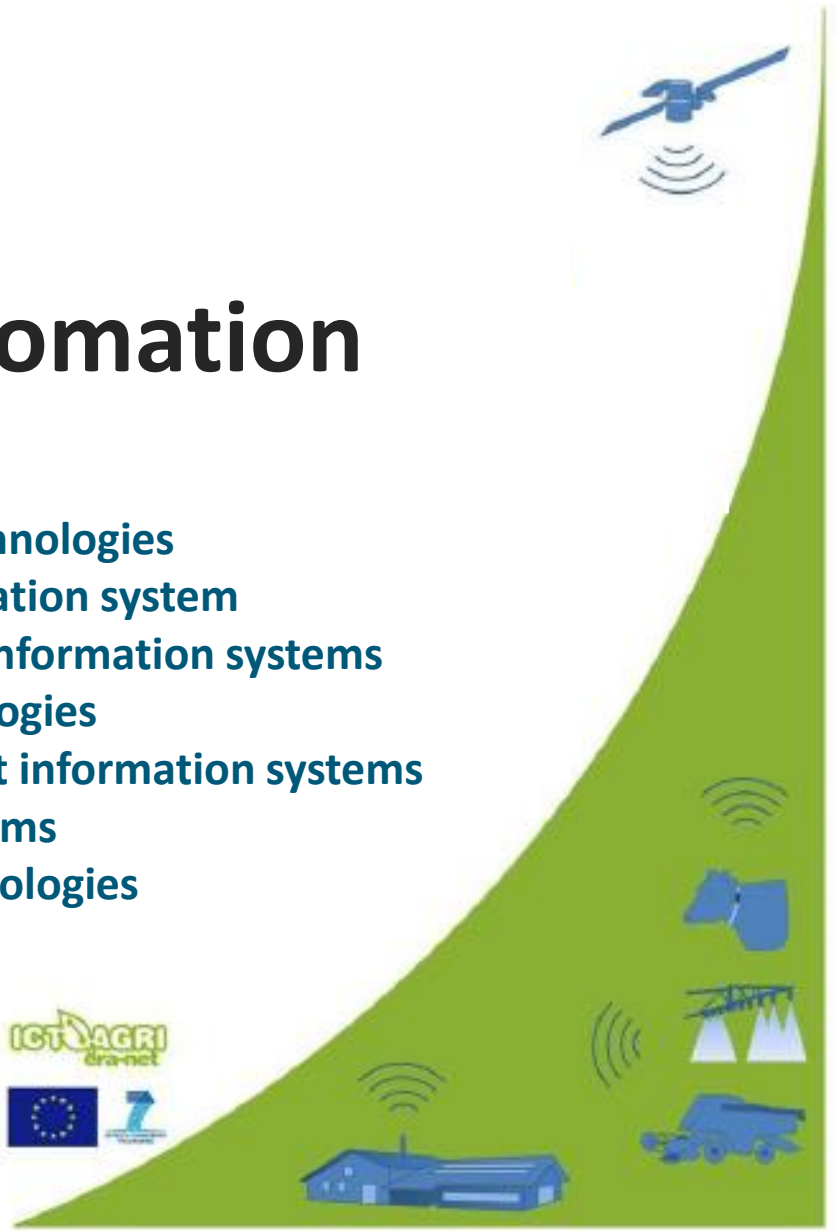
a step beyond mechanization. Automation greatly decreases the need for human sensory and mental requirements while increasing **capacity**, **speed**, and **repeatability**

Present

2

ICT & Automation

- Wireless technologies
- Global navigation system
- Geographic information systems
- RFID technologies
- Management information systems
- Control systems
- Sensor technologies
- ……





Robotics

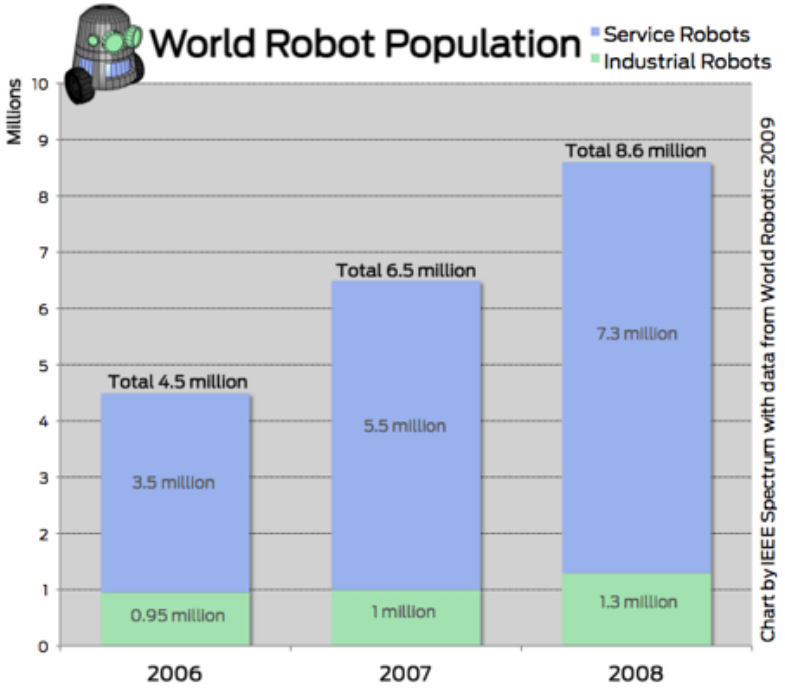
Complex, intelligent and flexible systems (artificial helpers)

18.0 MILLION

ROBOTS WILL POPULATE
THE WORLD IN 2011

6.5 MILLION

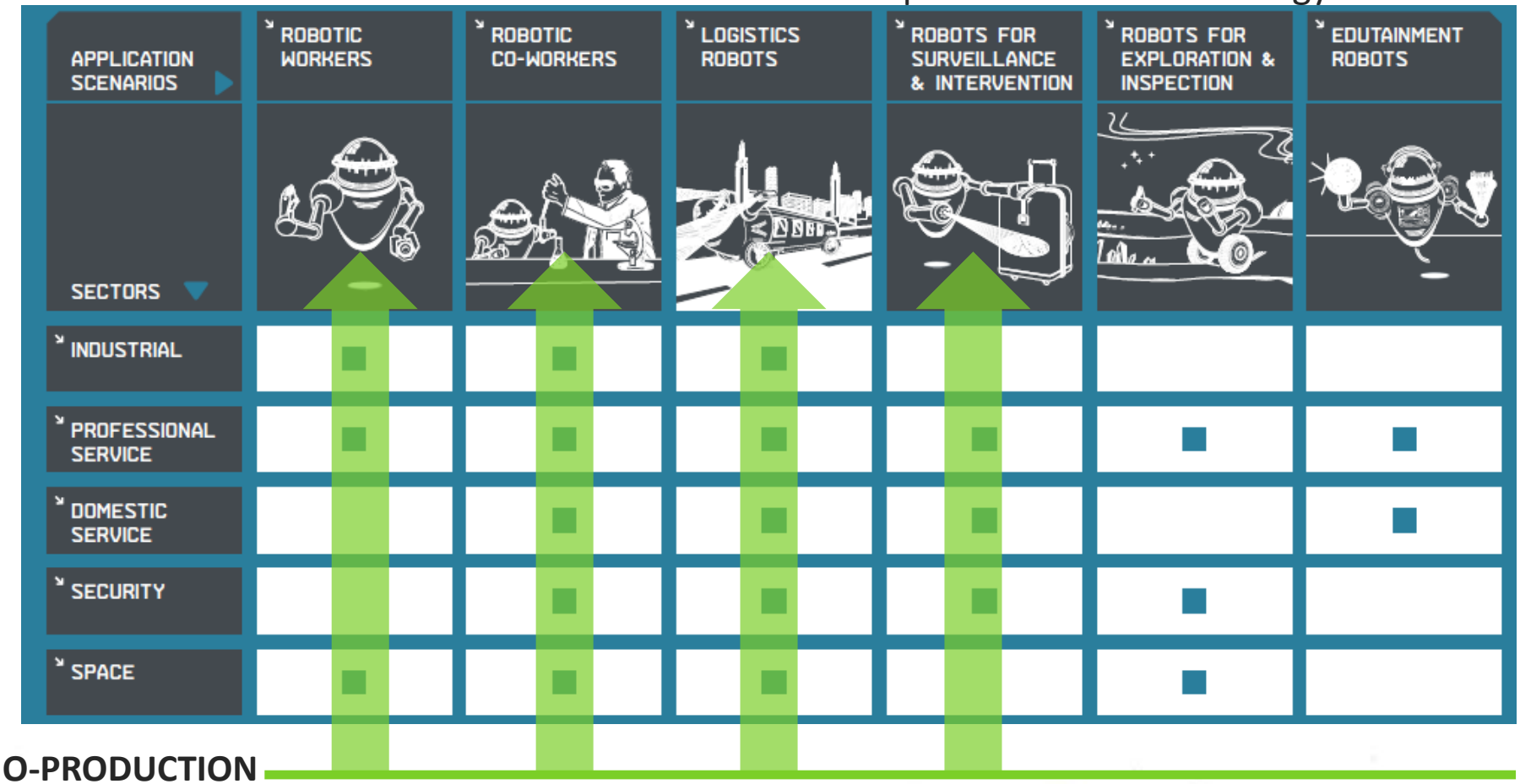
ROBOTS WERE IN OPERATION
WORLDWIDE IN 2007



www.worldrobotics.org

where to place bio-production robotics?

EUROP: European Robotics Technology Platform



THE CHALLENGES

The challenges

Global food security

Higher global demand for food

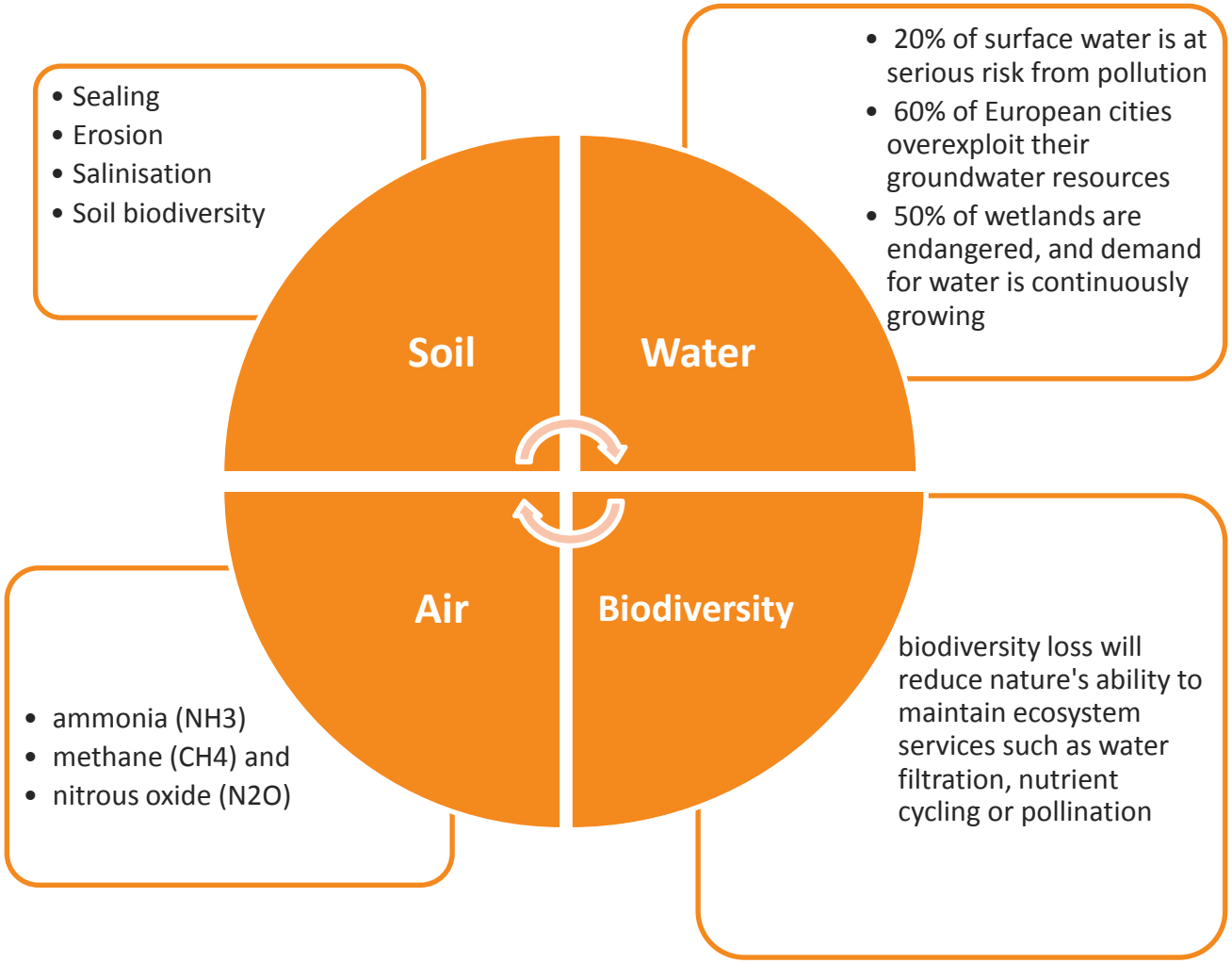
- Population increase
- Changes in global demographics
- Swift towards meat consumption in food preferences of developing countries

Degradation of natural recourses

FAO 2009, ESF/COST 2009; Boden *et al.* 2010

The challenges

Sustainable management of natural resources



EEA (2010) / WFD (2010) / The World Bank (2009)

The challenges

Energy consumption

The facts

Worldwide energy demand is projected to grow by 44% between 2006 and 2030

In 2030 energy imports of EU will account of nearly 70% of energy needs

EU will highly dependent on fossil energy from non-European countries

EIA (2009) / EC (2009)

Food safety

The EU integrated approach to food safety aims to ensure

- **high level of food safety,**
- **animal health,**
- **animal welfare and**
- **plant health**

through systematic farm-to-fork measures and adequate monitoring.

The challenges

Climate change

The impact of agriculture

(CO2) accounts for 63%, NH4 accounts for 19% of man-made global warming

1 t NH4 has about 33 times the warming effect of 1t CO2

Agriculture is a significant source of methane

The impact on agriculture

New crop diseases

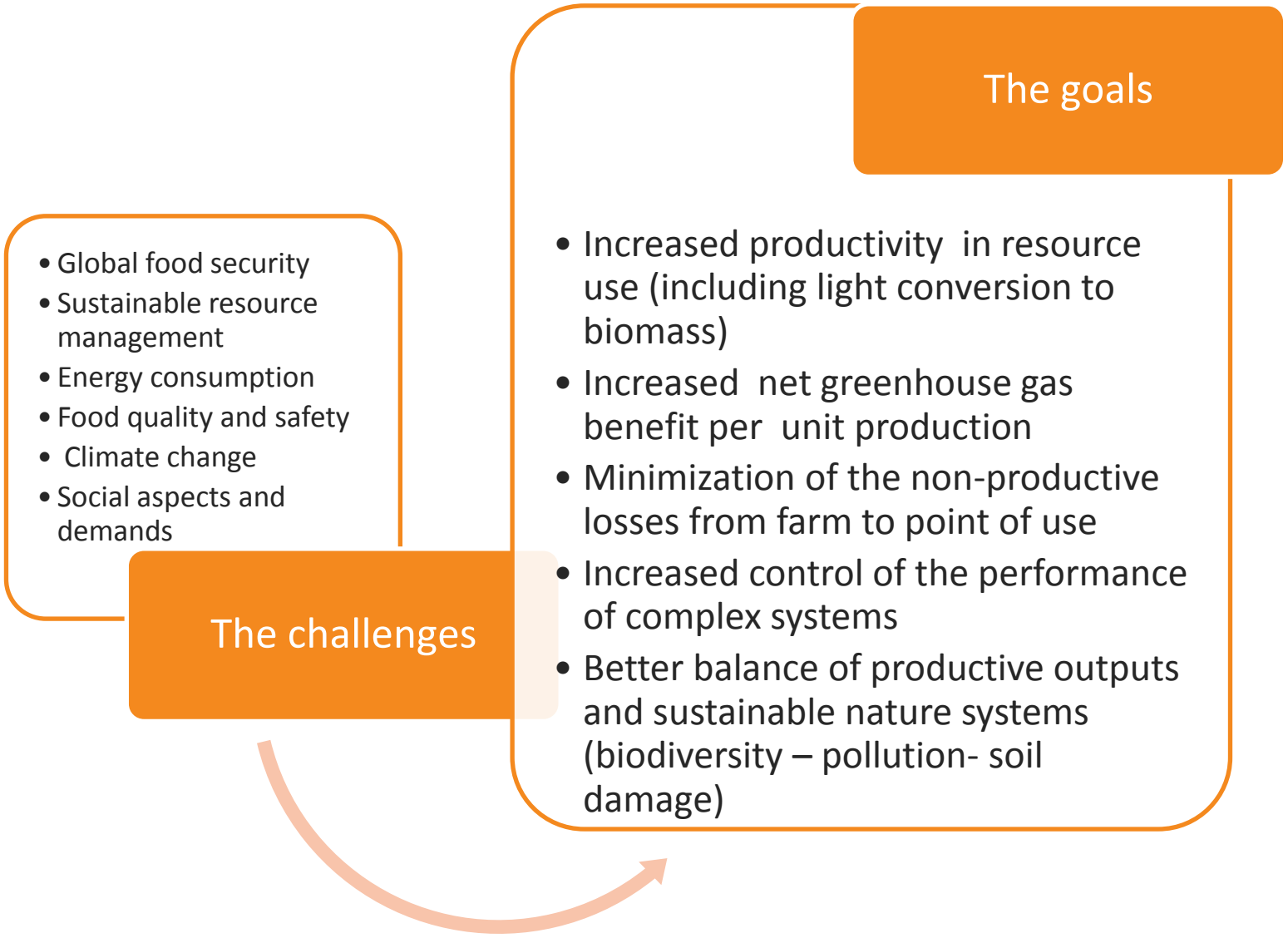
Effects on productivity

Water scarcity

The demand for agricultural water increases by 6 to 10% for each increase in temperature of 1° C

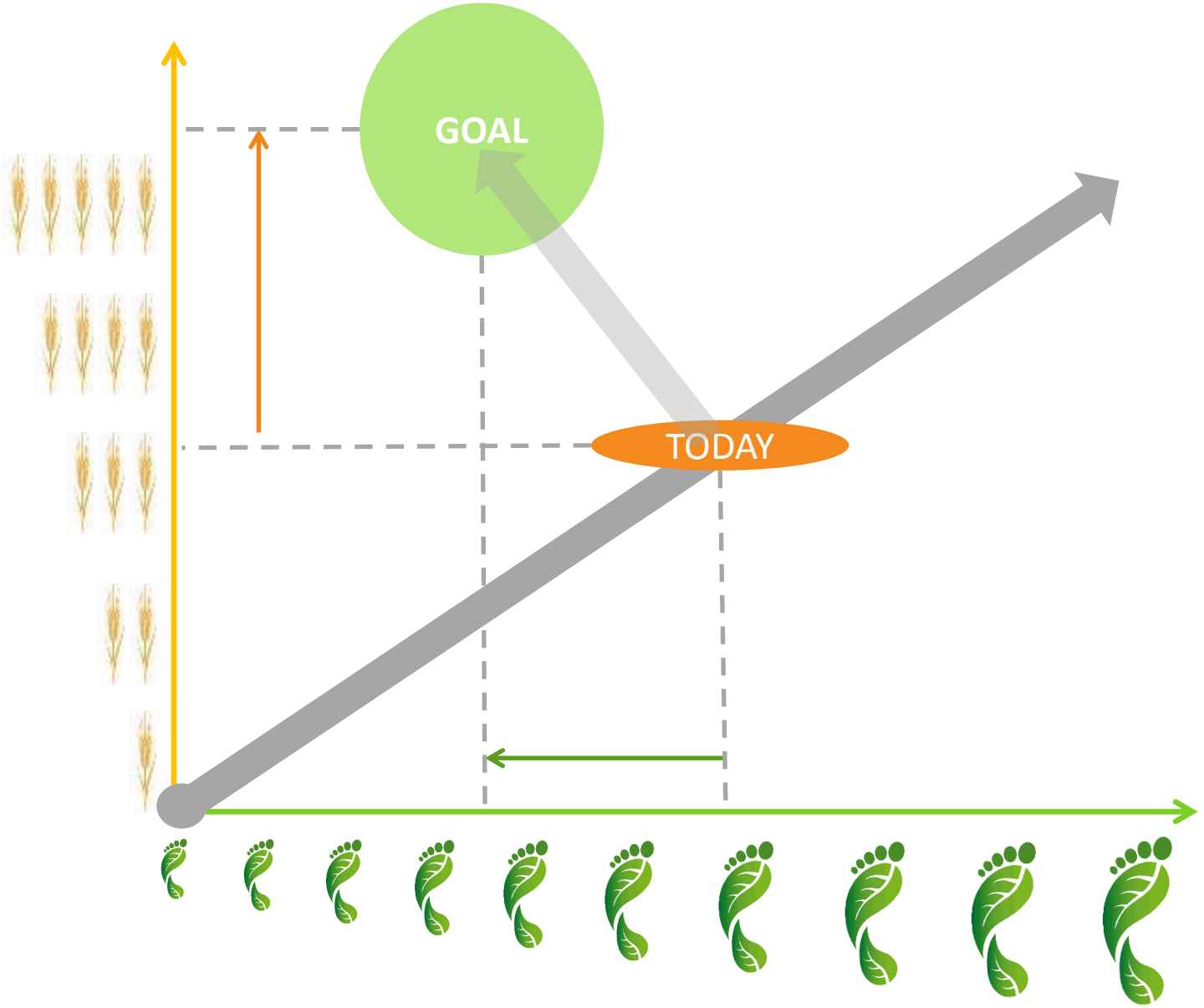
FAO (2011)

The Goals



ICT-AGRI Strategic Research Agenda (2012); Day (2011)

The Goal



ENGINEERING ADVANCES

SATELLITE-BASED NAVIGATION

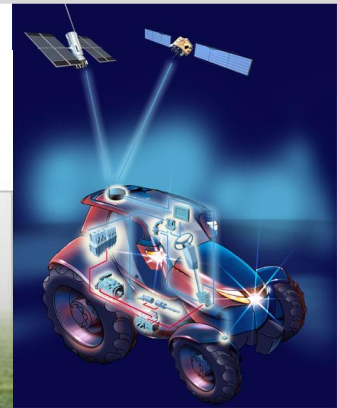




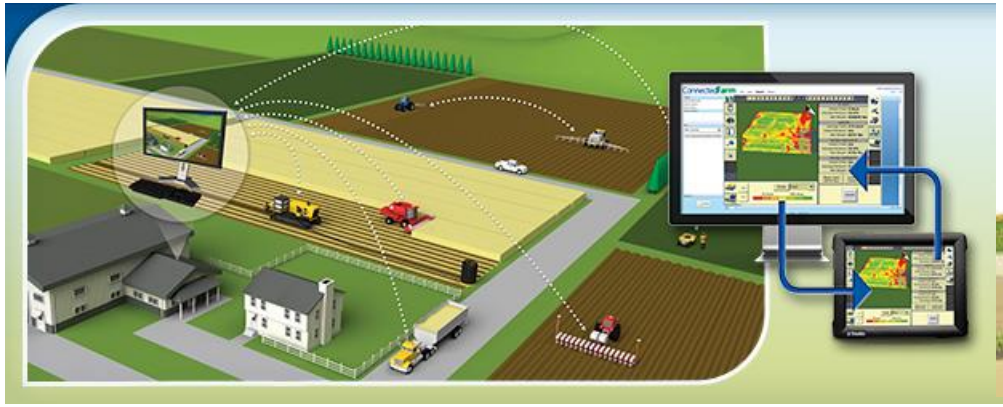


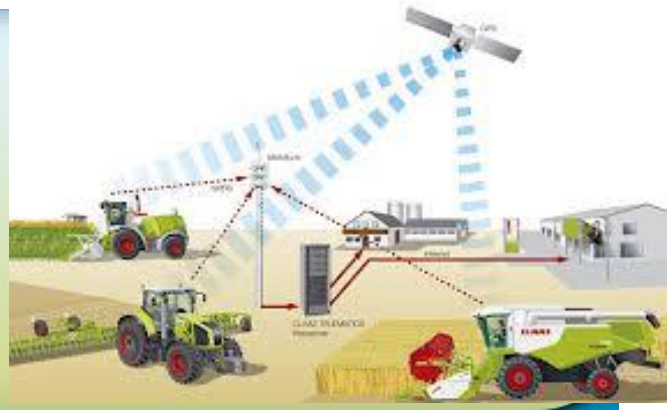






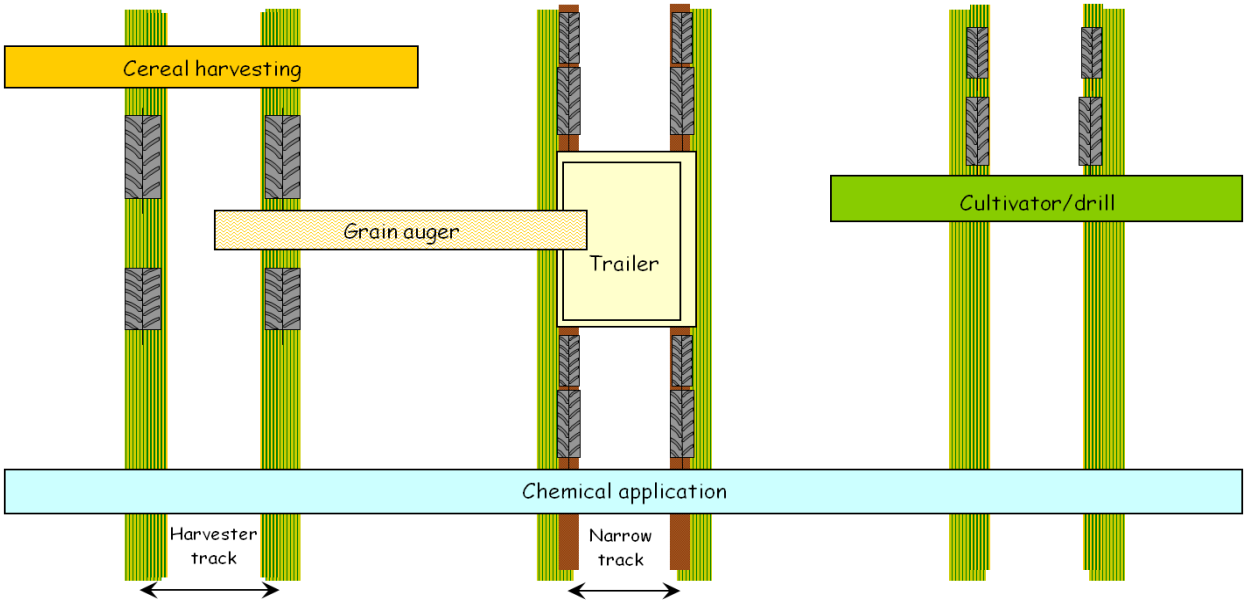
TELEMATIC SYSTEMS





CONTROLLED TRAFFIC FARMING

The principle

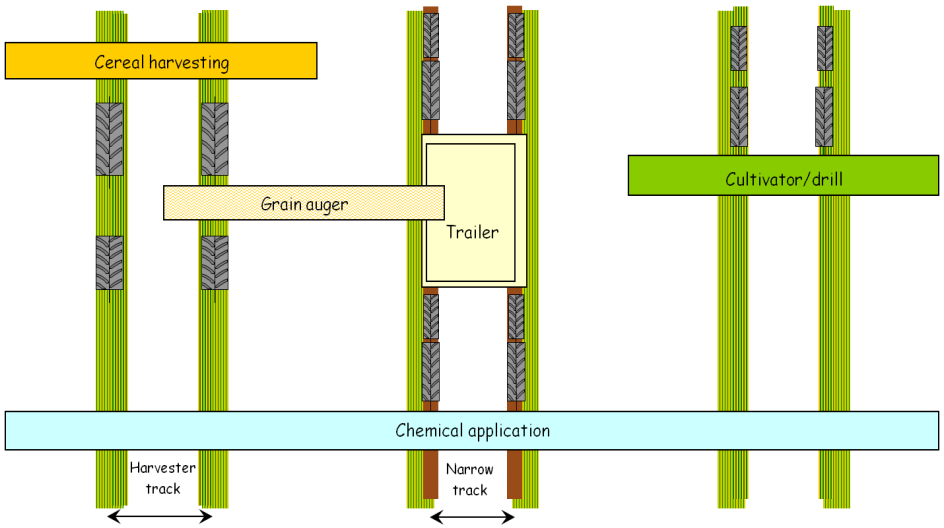


Tim Chamen, CTF Europe. Ltd

Permanent wheel tracks

CONTROLLED TRAFFIC FARMING

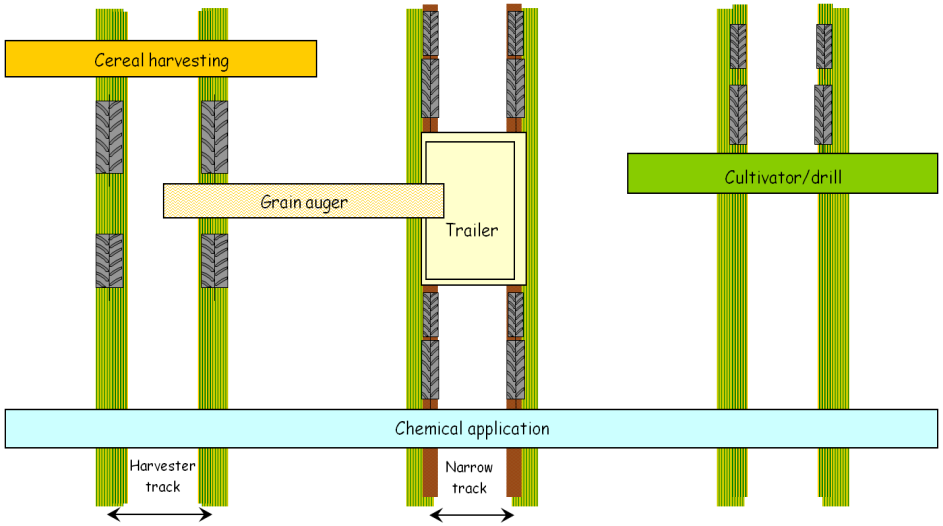
The benefits



- Increased yield
- Energy savings
- Reduced loss of CO2
- Reduced loss of H2O

Permanent wheel tracks

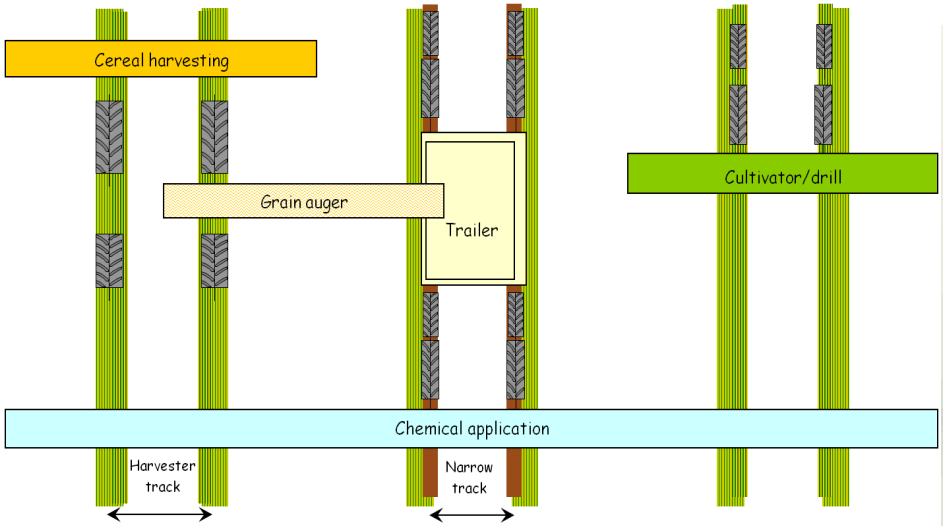
CONTROLLED TRAFFIC FARMING





Modifications of existing machinery

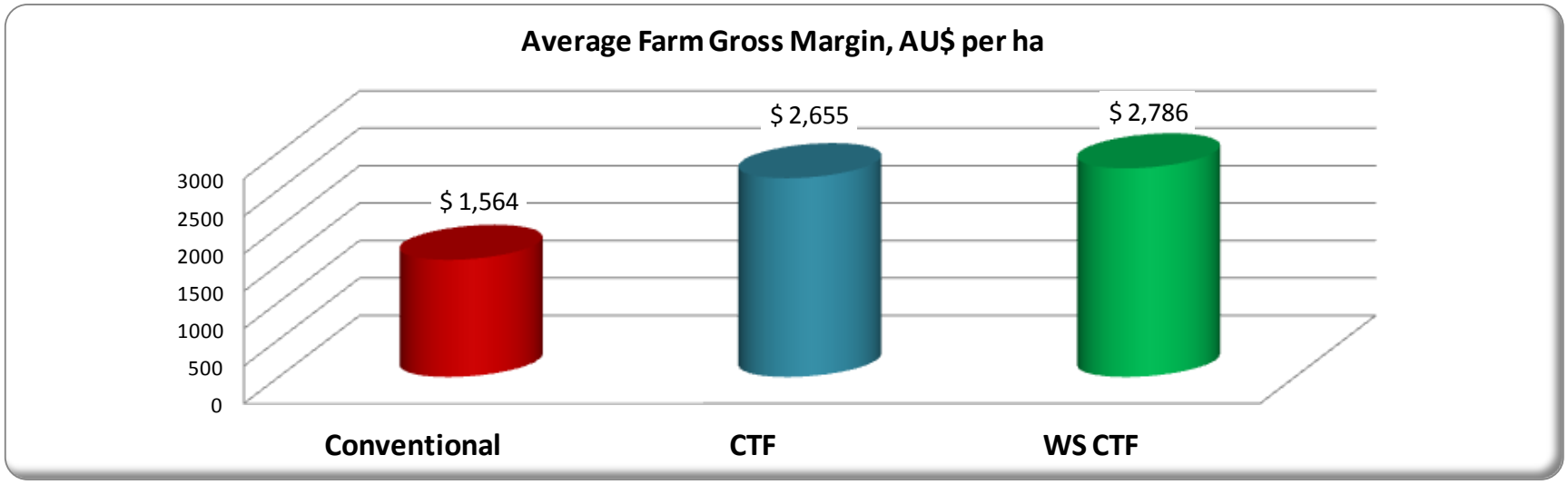
CONTROLLED TRAFFIC FARMING

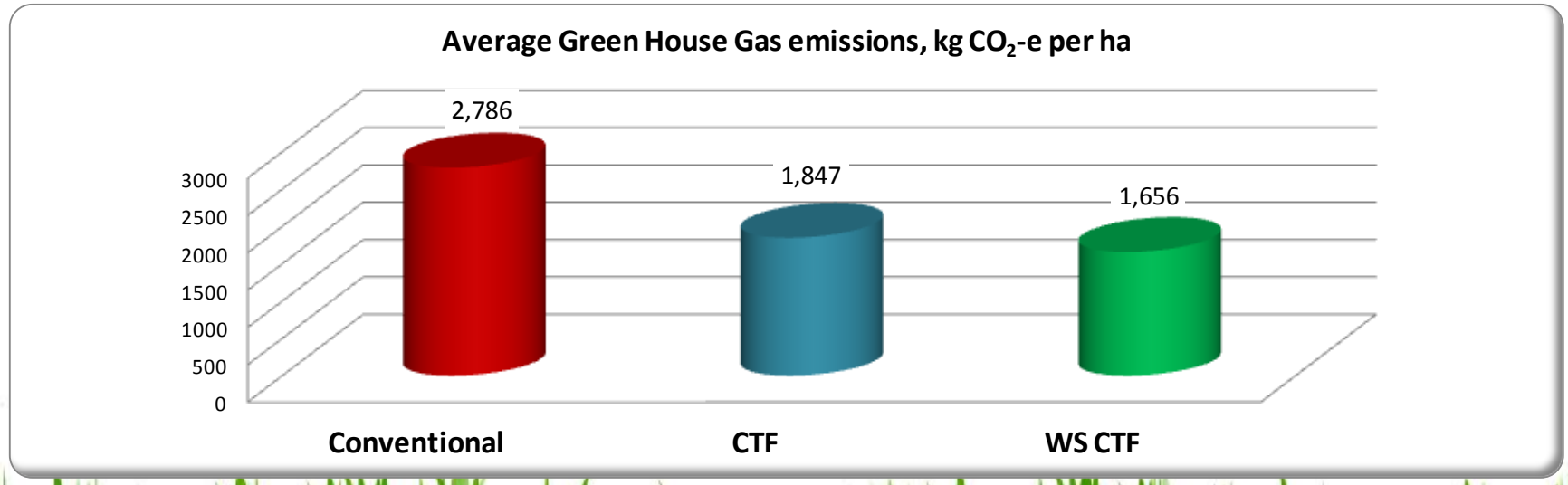




Completely new systems

CONTROLLED TRAFFIC FARMING

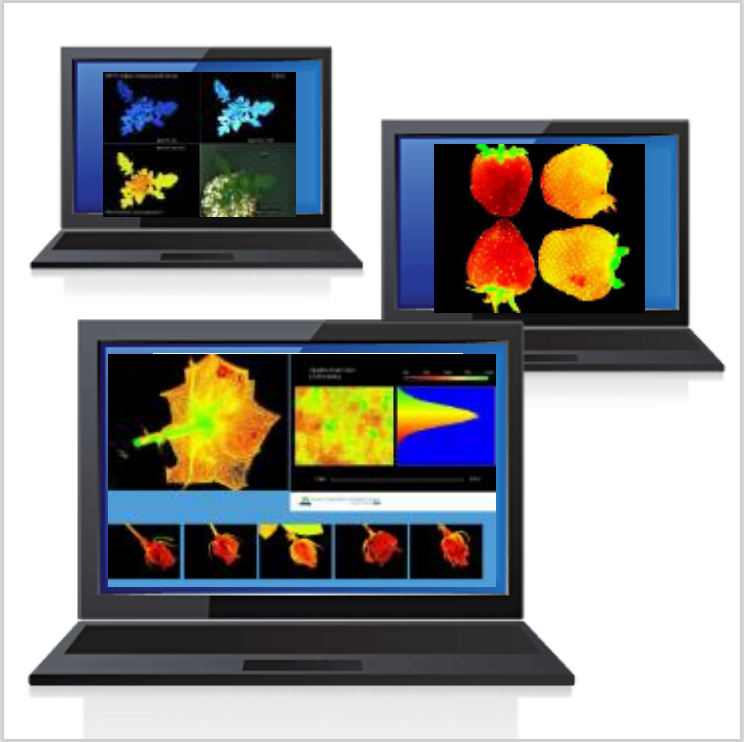




Pedersen et al (work in progress)

SENSOR TECHNOLOGIES

- **Machine Vision**
- **Sensor networks**
- **On-the-go sensors**
- **…**



Source : Pekkeriet, E.J. , Campen, J.B. , Henten, E.J. van (2012)

ROBOTICS

- Controlled environment (Arable farming)
- Semi-controlled (Specialty crops)
- Un-controlled environment (Greenhouse)



PRECISION FARMING







BUT…the concept is still in the process of translation from a **vision** to **practical approaches**

PRECISION FARMING

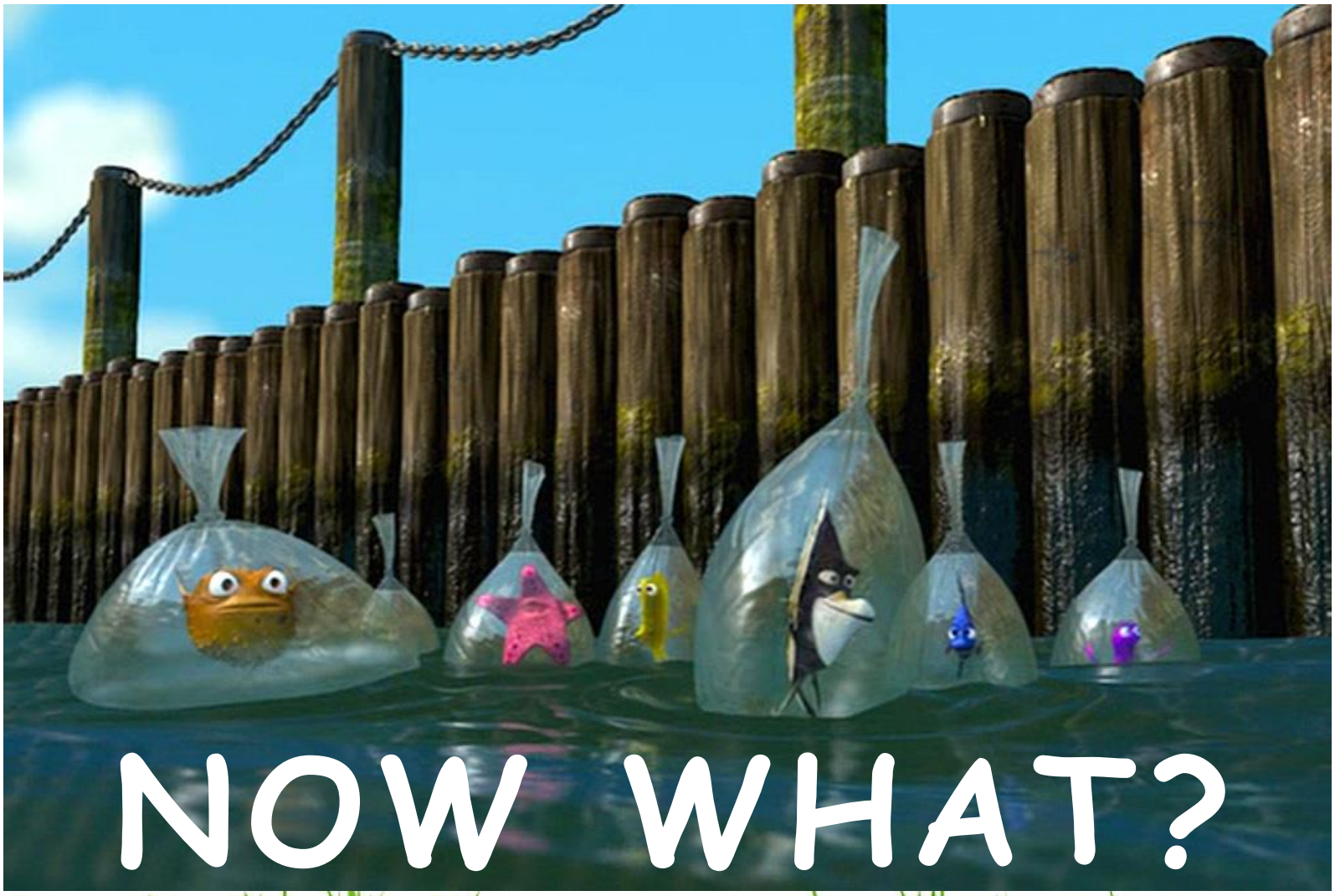


HOWEVER,…the basic tenet still holds true:

Managing inputs uniformly across whole fields has only limited logic

Zang et al., (2002); Day (2011)

SYSTEMS ENGINEERING
within the solution domain


NOW WHAT?





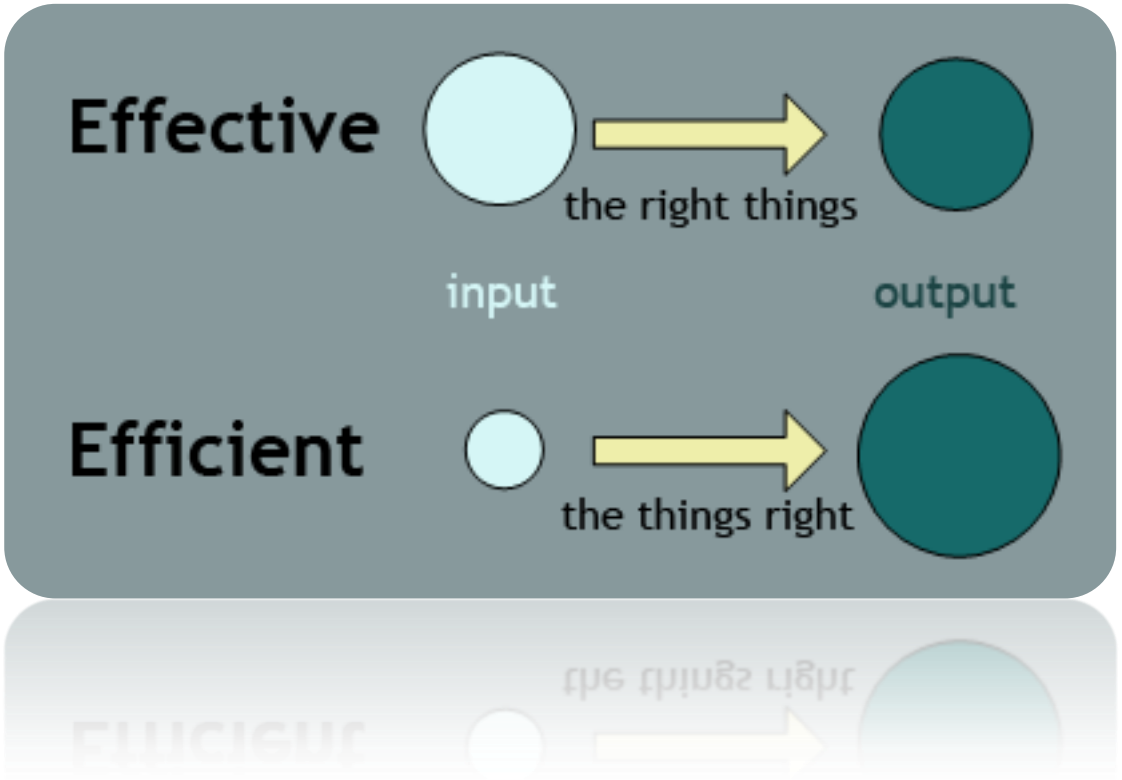


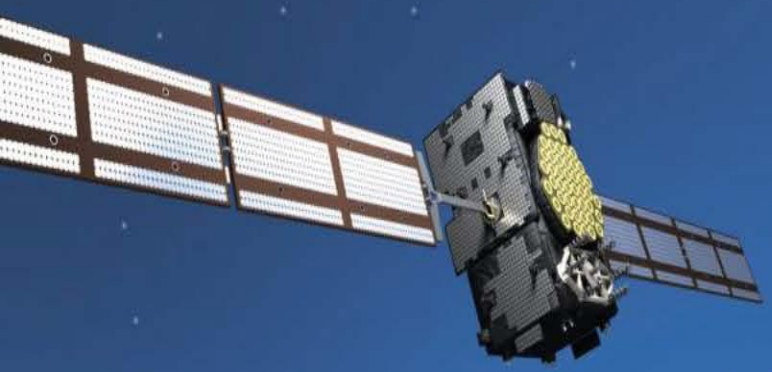





NOW WHAT?

From effectiveness to efficiency





GEOPAL

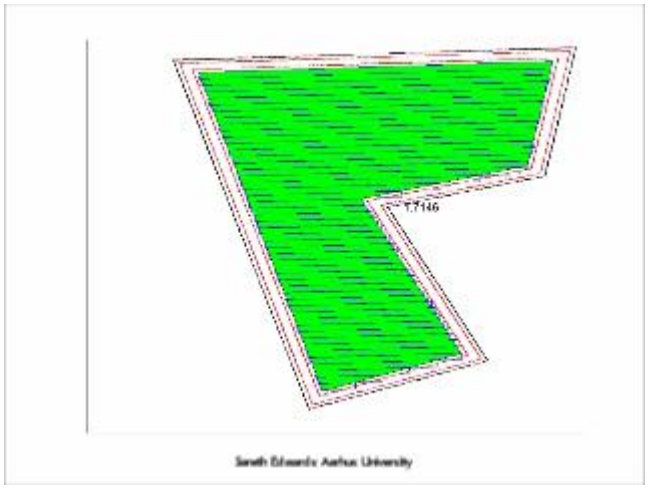
NAVIGATION

GSA

SEVENTH FRAMEWORK PROGRAMME

GEOPAL NAVIGATION

Route Planning System



Central Web-Server



Mobile Units

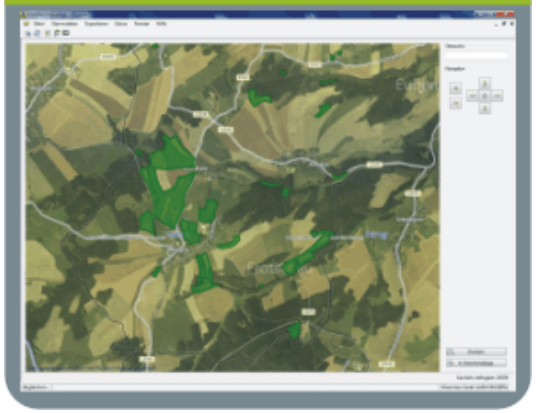


FP7 PROJECT GNSS-based Planning system for Agricultural Logistics

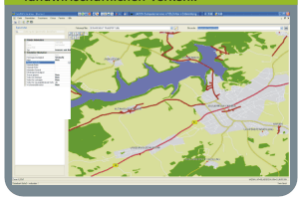
GEOPAL
NAVIGATION



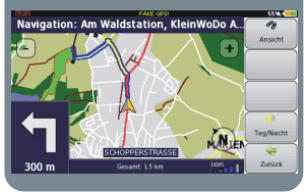
Integration von Schlaggrenzen durch Import von kml oder Shp Dateien. Auch das einzeichnen von Zielen ist kein Problem.



Sie reagieren bei der Routenplanung aktiv z.B. auf Straßensperrung für den landwirtschaftlichen Verkehr.



Vermeidung von Fehlfahrten durch sichere Navigation zum Ziel



FP7 PROJECT GNSS-based Planning system for Agricultural Logistics

GSA

SEVENTH FRAMEWORK PROGRAMME

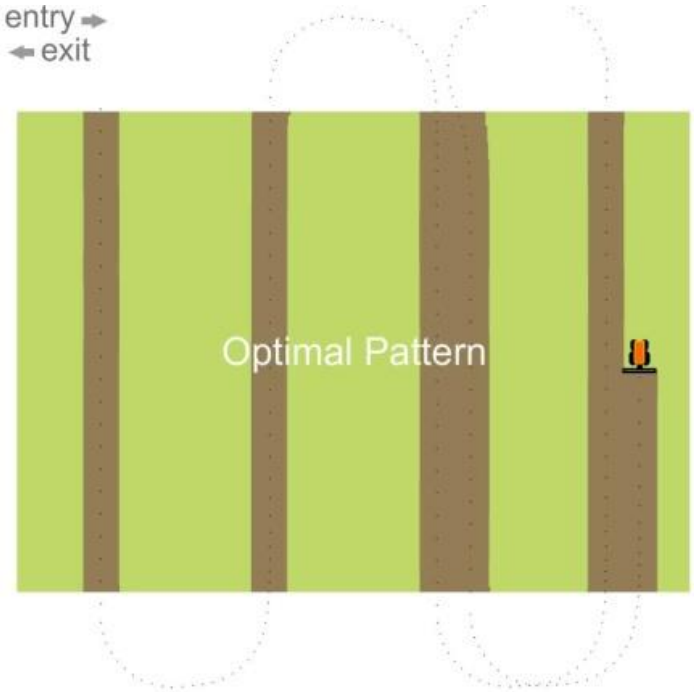


area coverage planning

B-patterns

A simple example:

Optimal pattern for a simple 20 tracks field and a given combination of inputs:







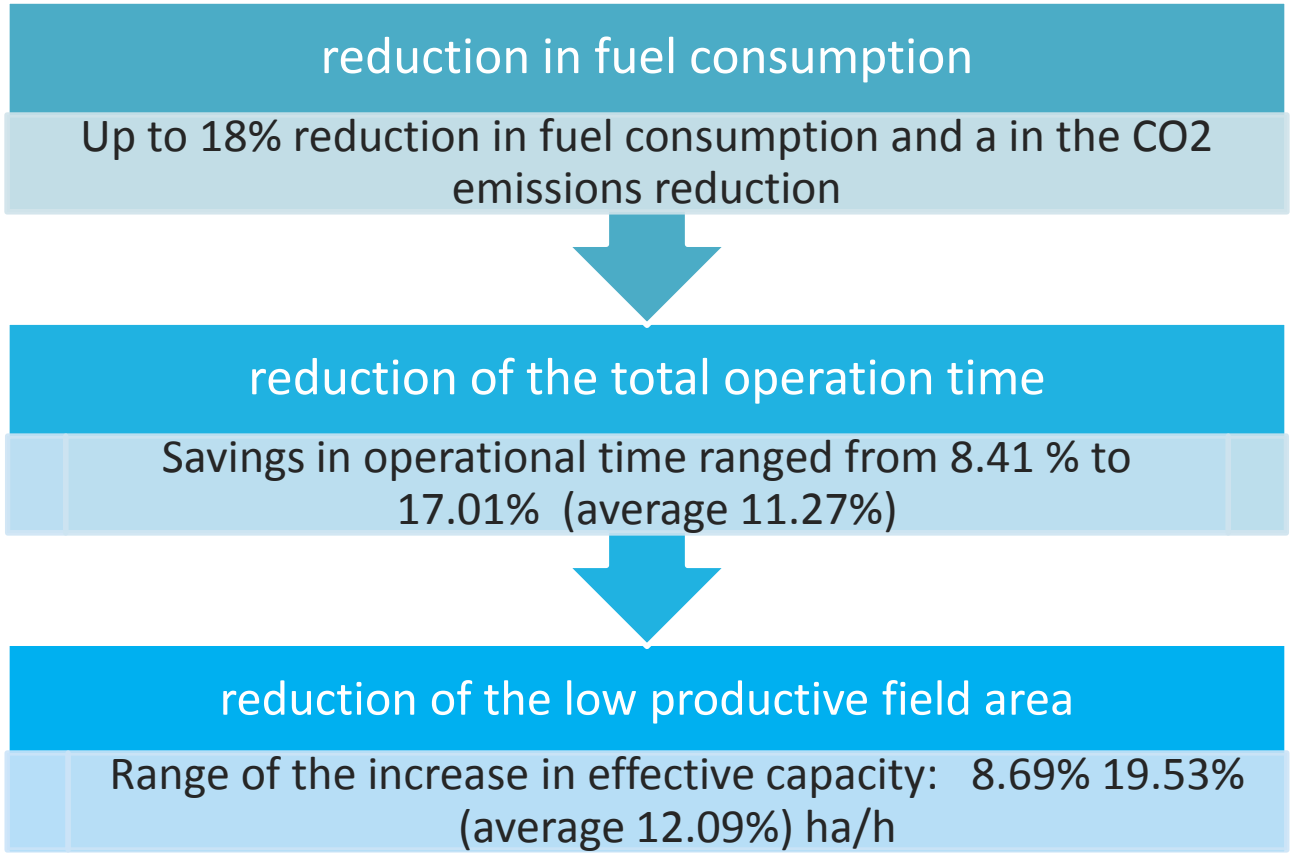






Assessment

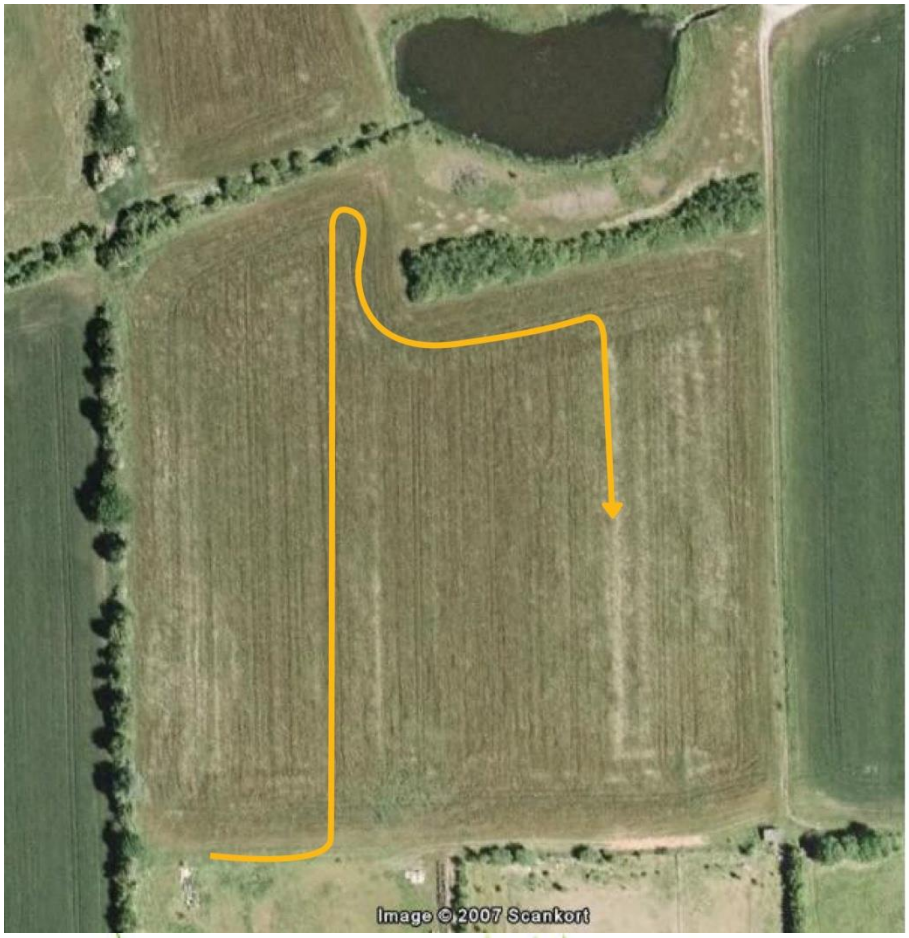
advantages

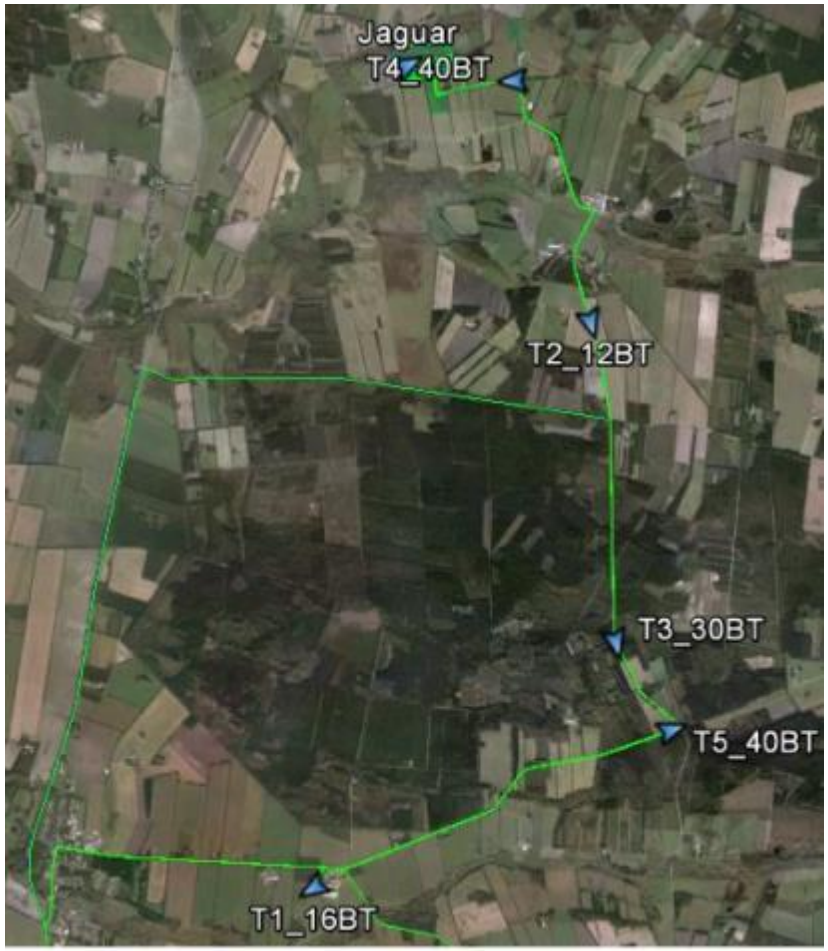




navigation tool for service units

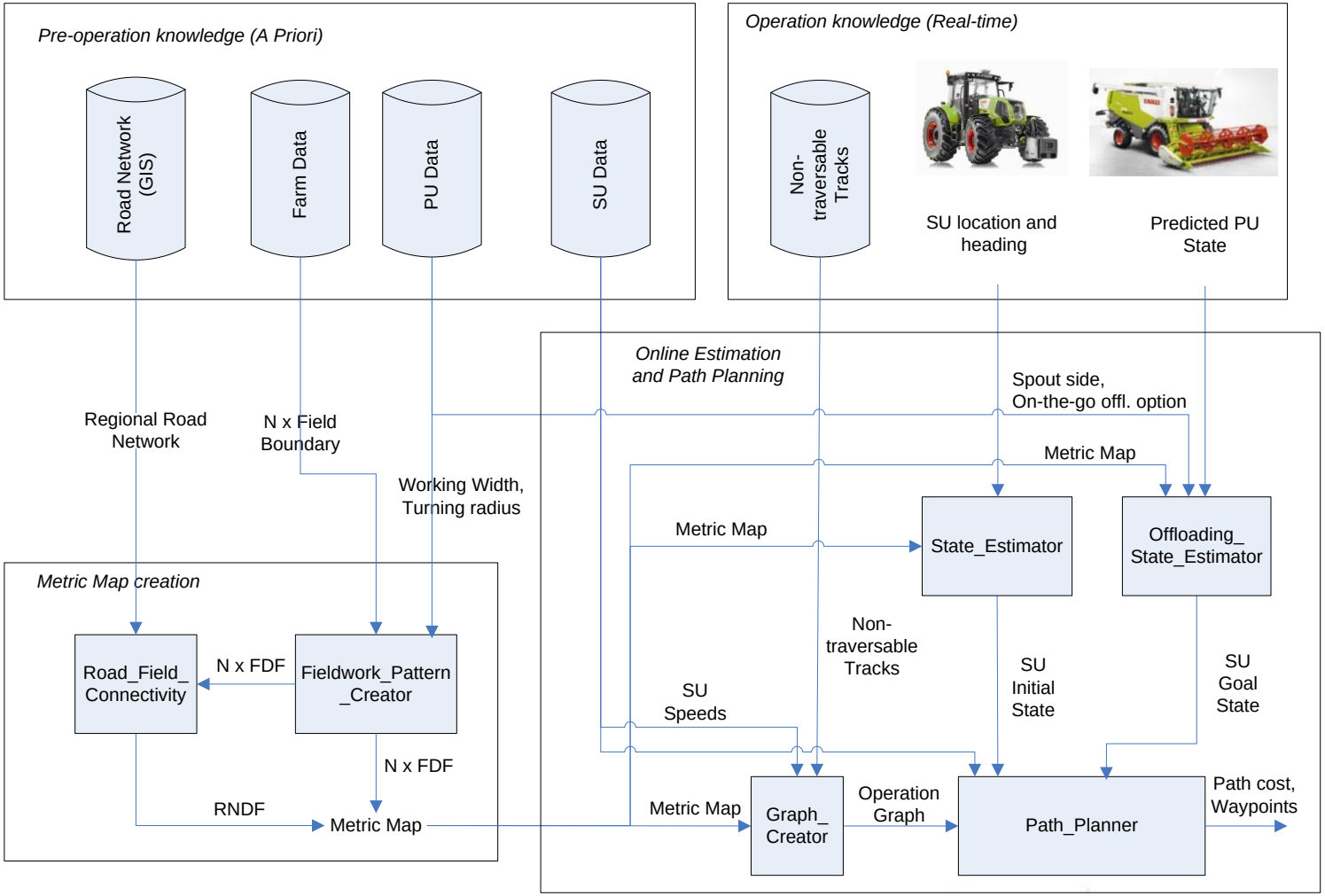
Planning for service units





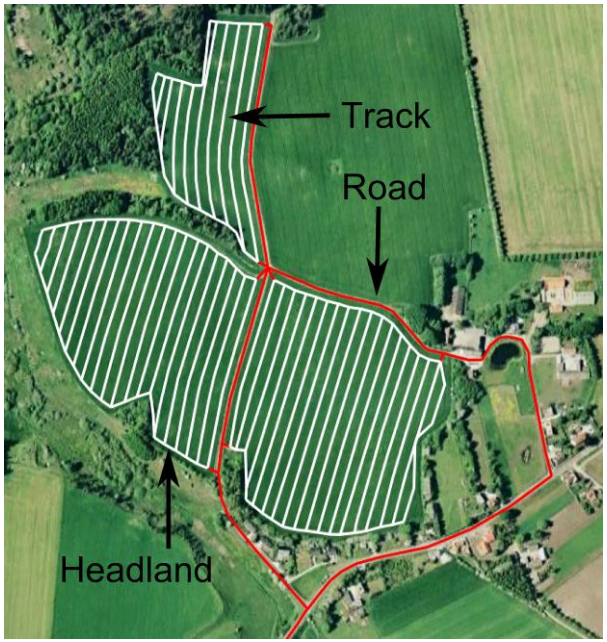
Jensen et al., 2013)

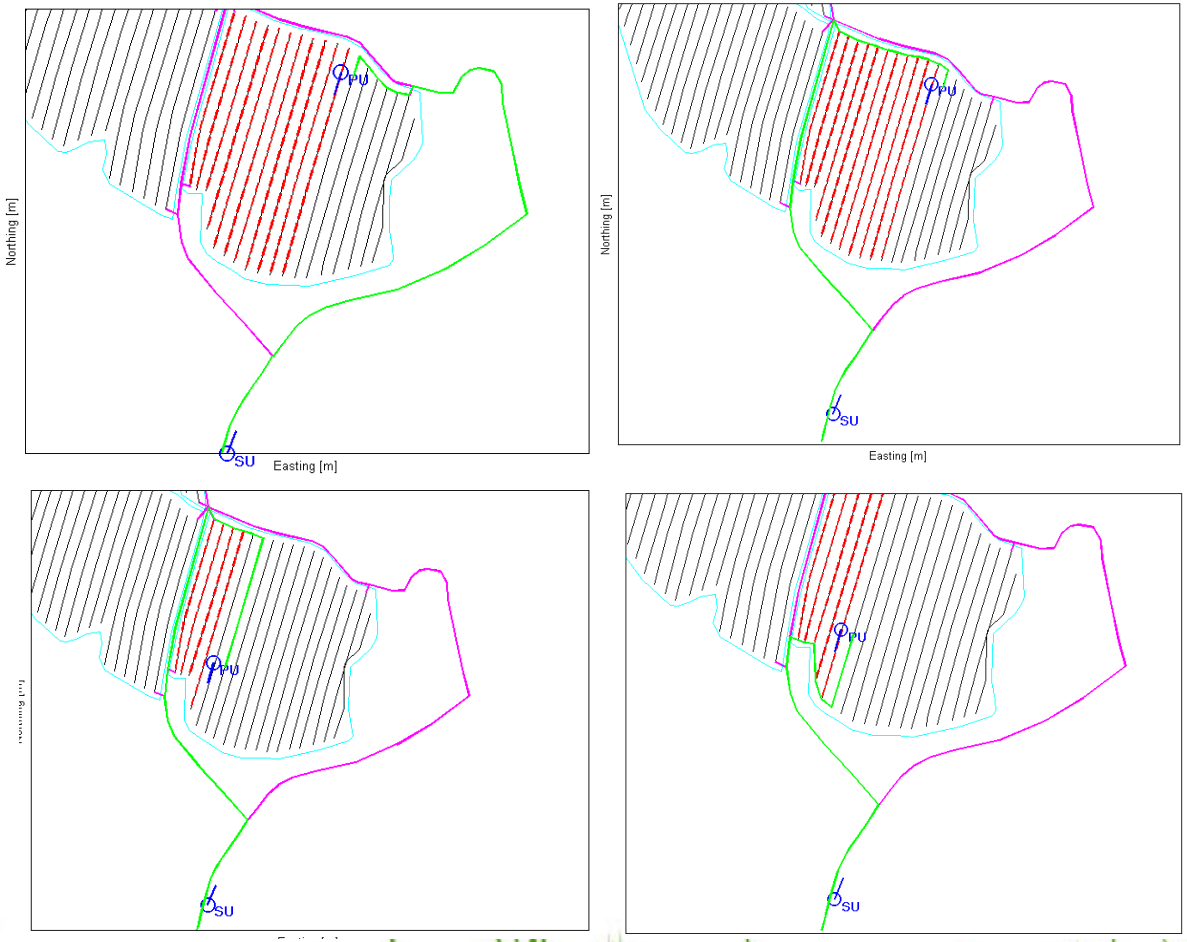
Planning for service units



Jensen et al., 2013)

Planning for service units





Jensen et al., 2013)



on-line machinery co-ordination

On-line machinery coordination

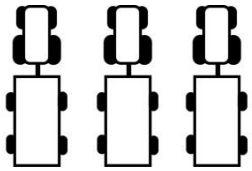
complex operational system



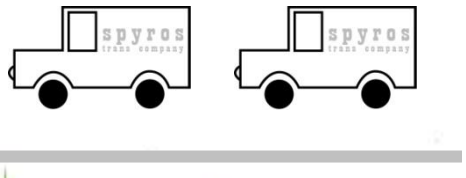
- fleet of harvesters



- fleet of unloading carts

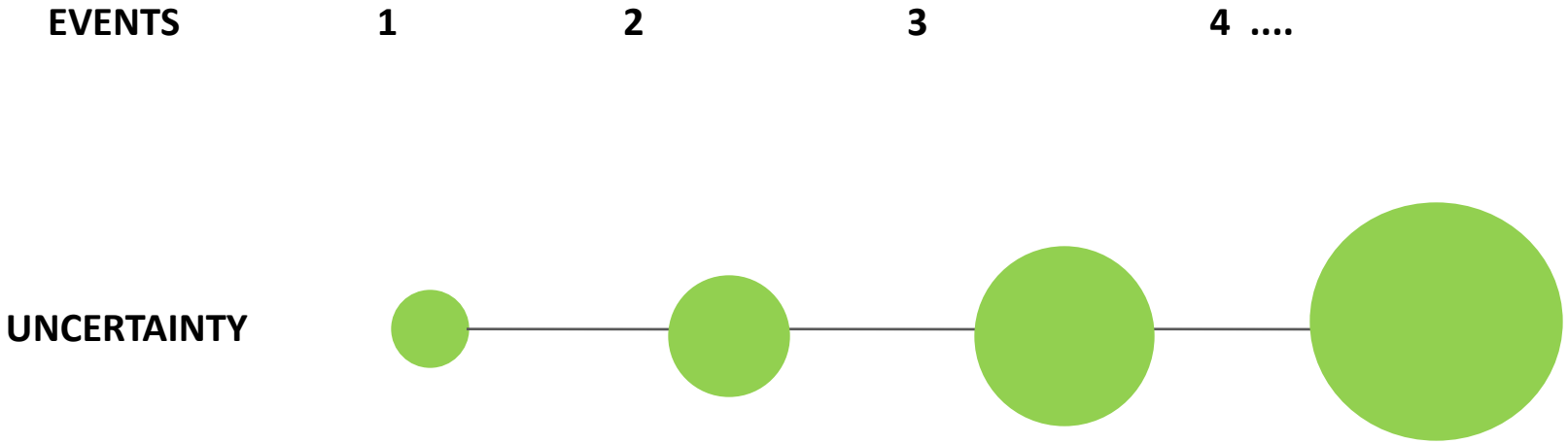


- geographically dispersed silos
- cycle time

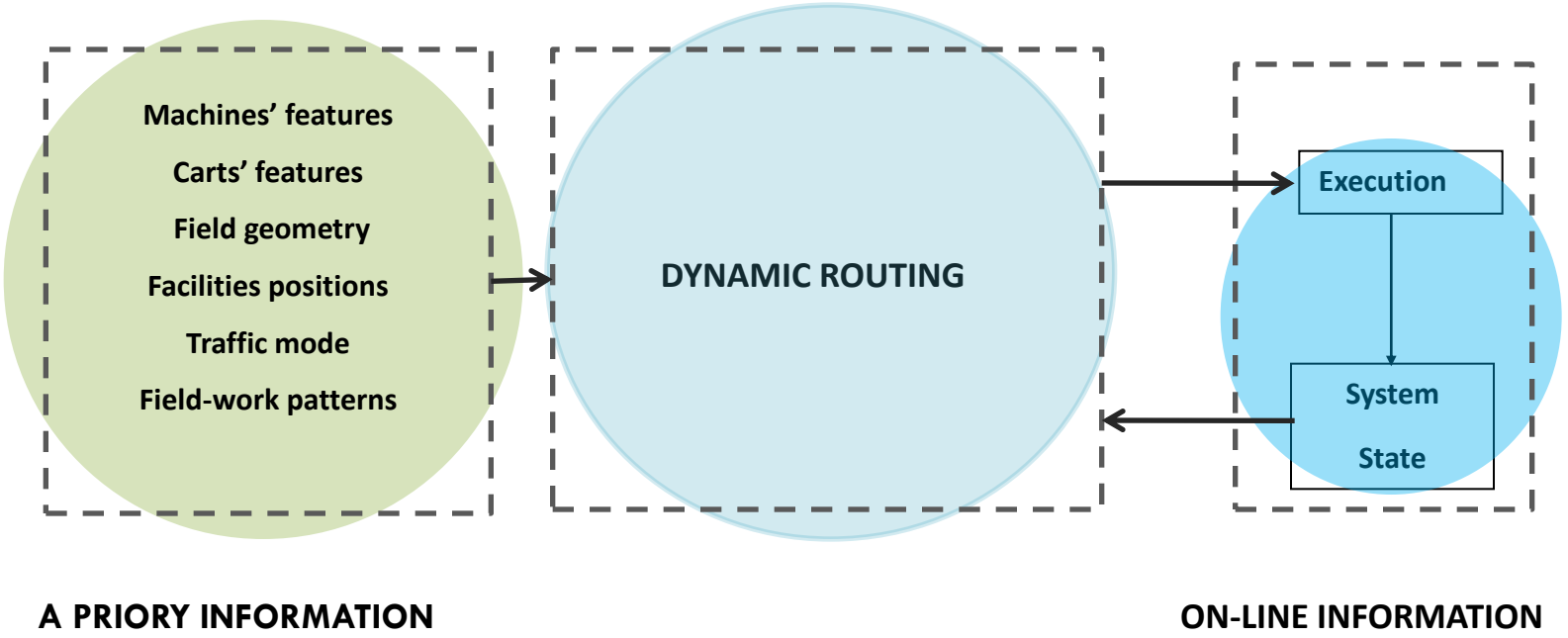


On-line machinery coordination

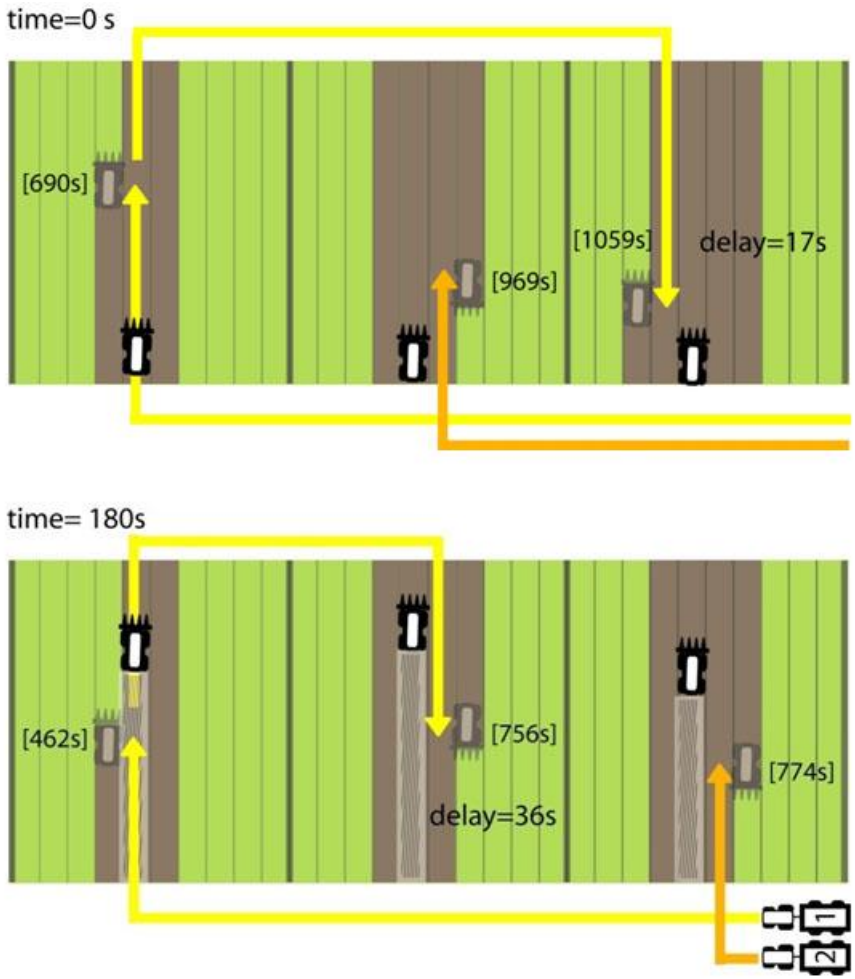
a priory information based optimization methods can not used due to unknown **yield spatial distribution**



On-line machinery coordination



On-line machinery coordination



estimated harvested area

un-harvested area

harvested area

cart 1 route

cart 2 route

harvester current potision

estimated unloading potision

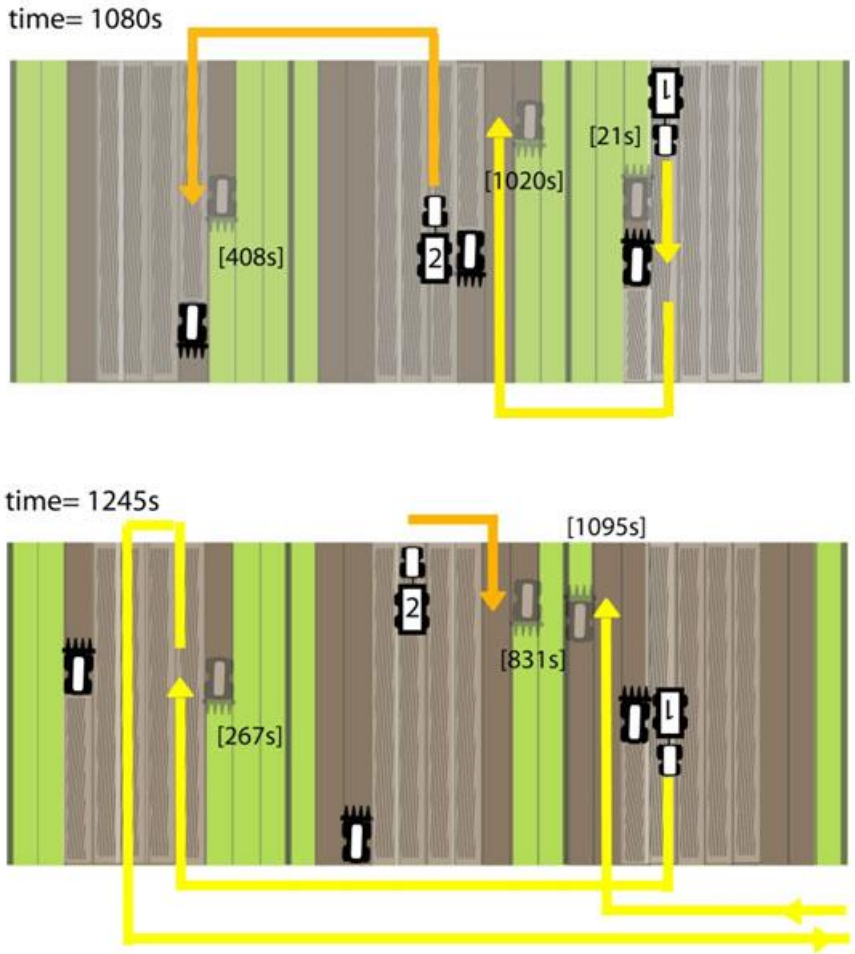
un-loading cart current potision

time= .....s current time (sec)

[.....s] time until unloading (sec)

delay=.....s estimated delay time (sec)

On-line machinery coordination



estimated harvested area

un-harvested area

harvested area

cart 1 route

cart 2 route

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estimated unloading potision

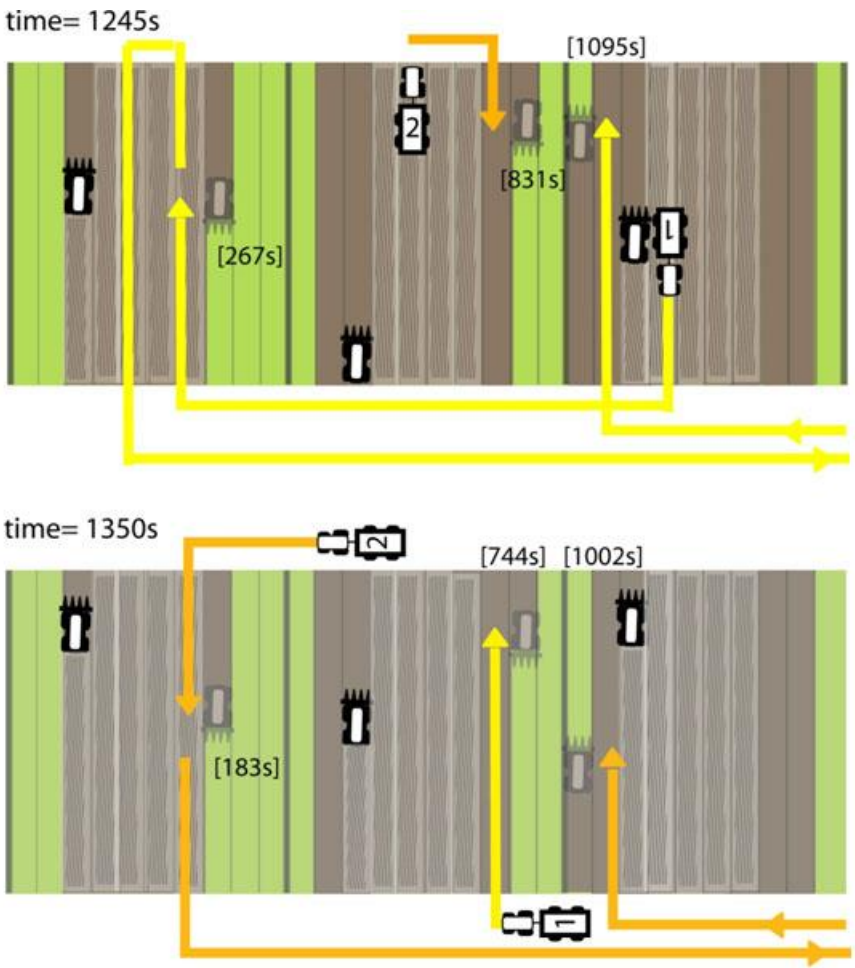
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time= .....s current time (sec)

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On-line machinery coordination



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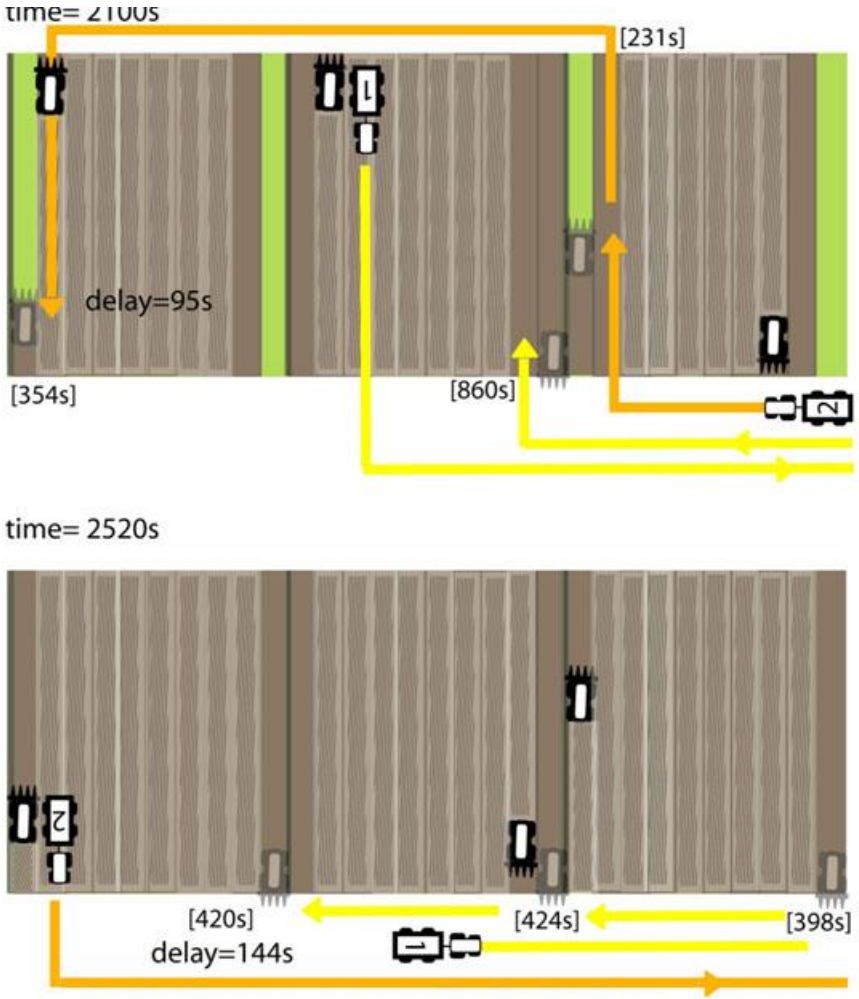
un-loading cart current potision

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On-line machinery coordination



estimated harvested area

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un-loading cart current potision

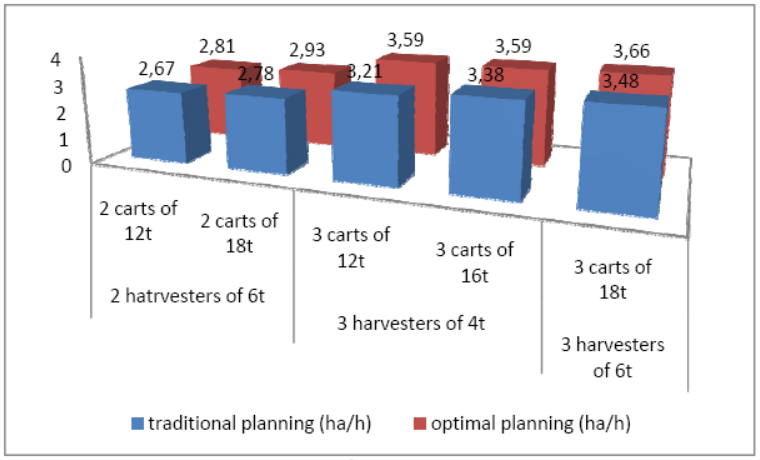
time= .....s current time (sec)

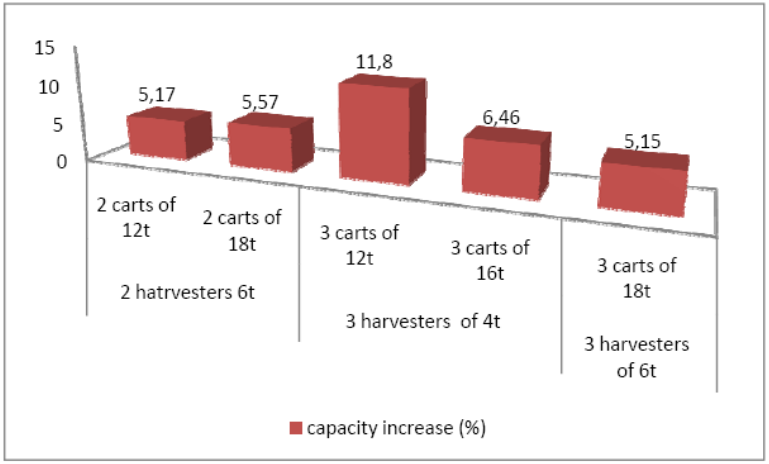
[.....s] time until unloading (sec)

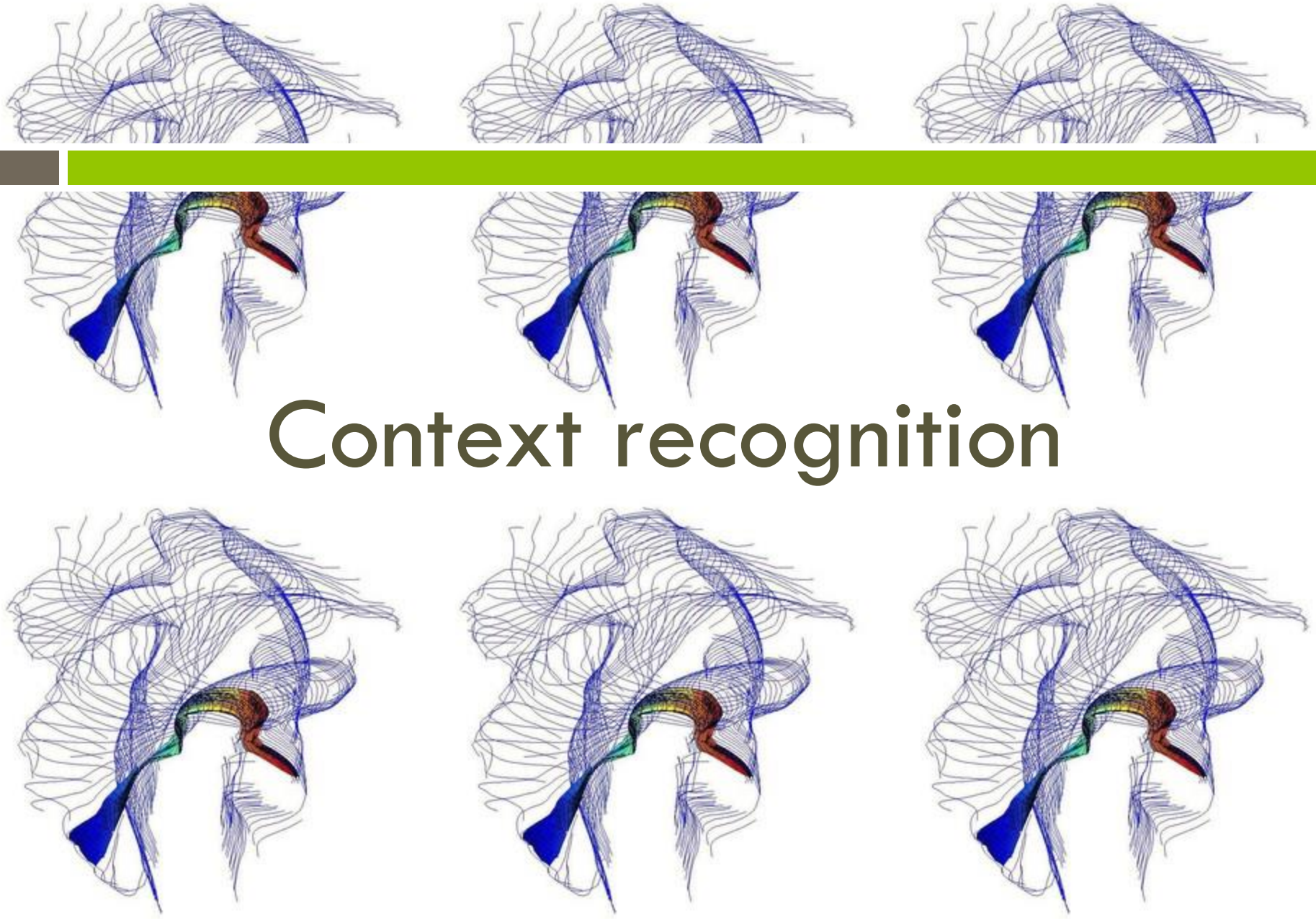
delay=.....s estimated delay time (sec)

On-line machinery coordination

Evaluation based on theoretical analysis (FP7: Future farm)

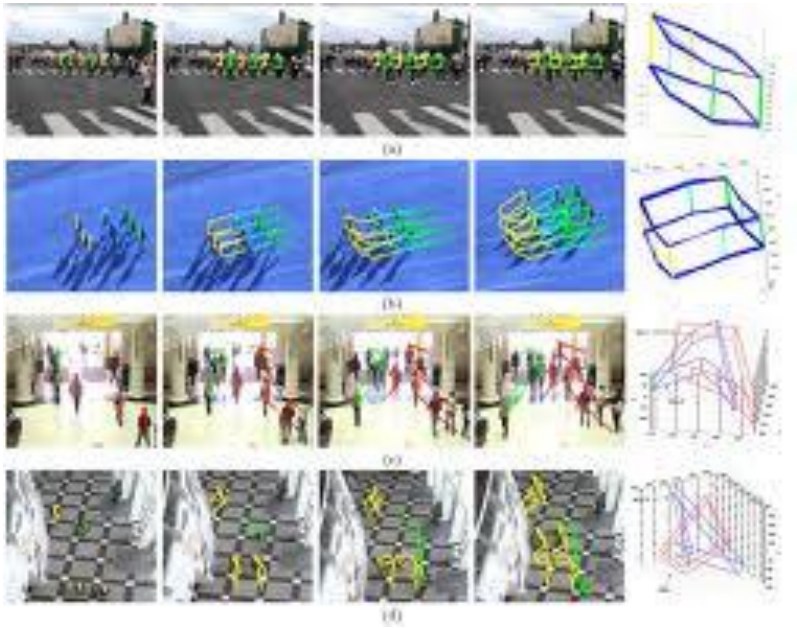


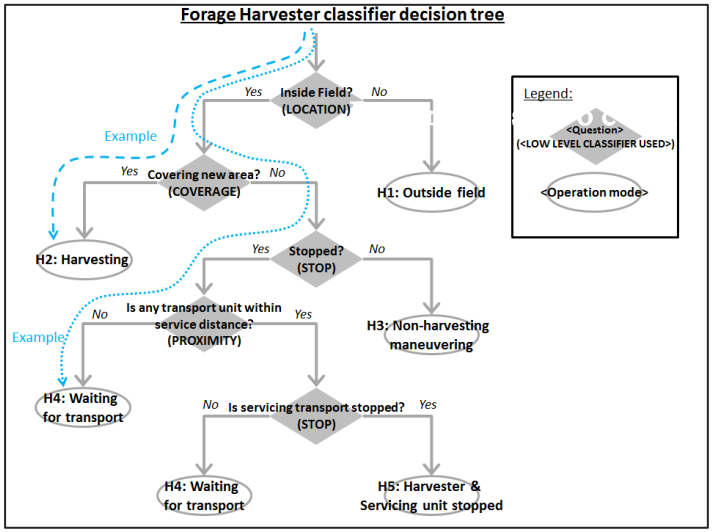


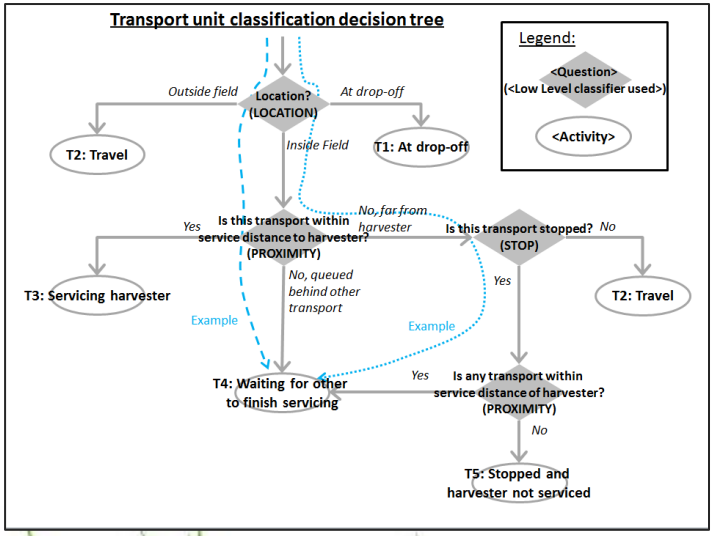


Context recognition

Context recognition

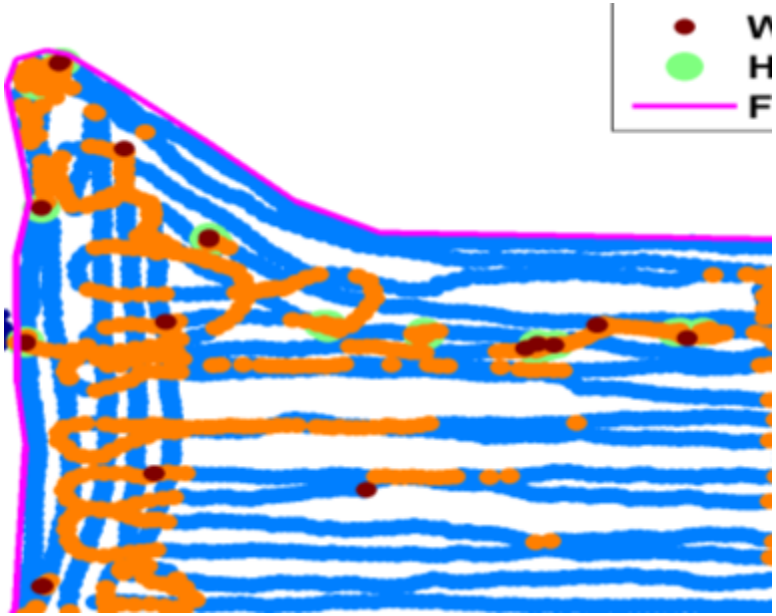


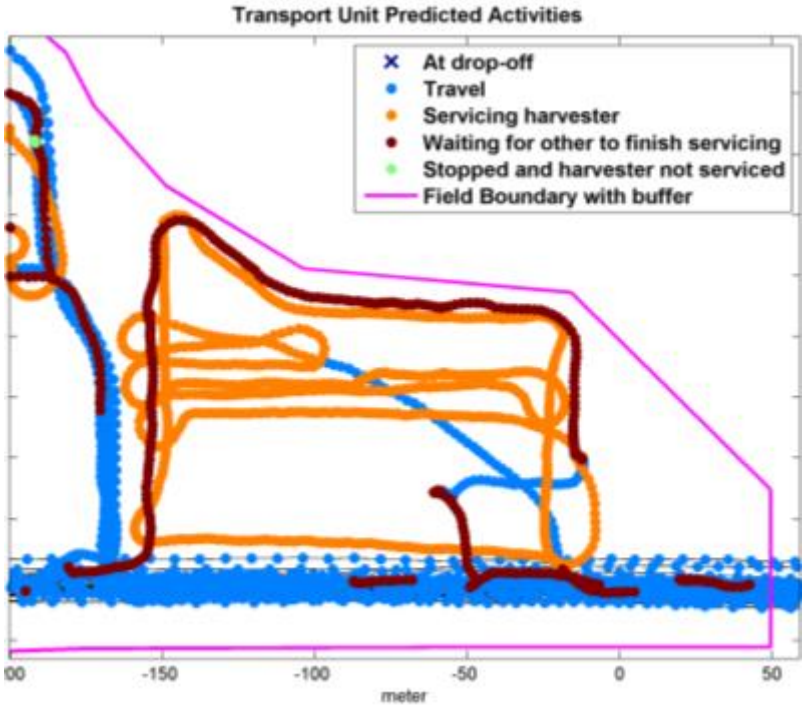




Jensen et al. Under review

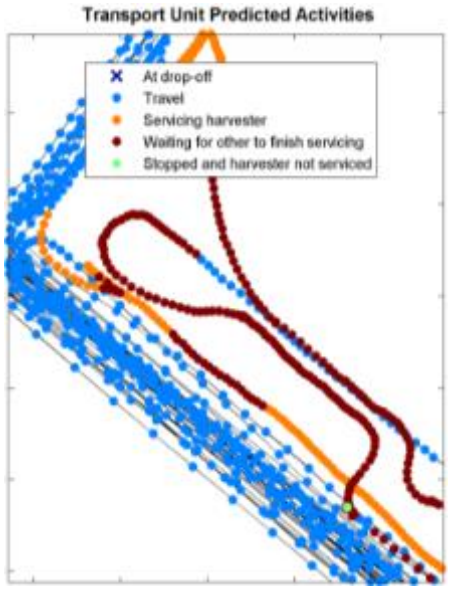
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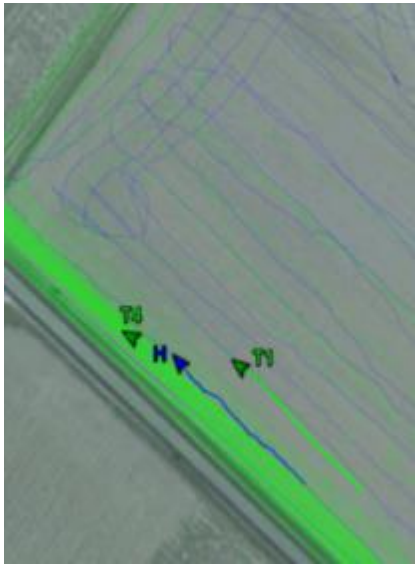


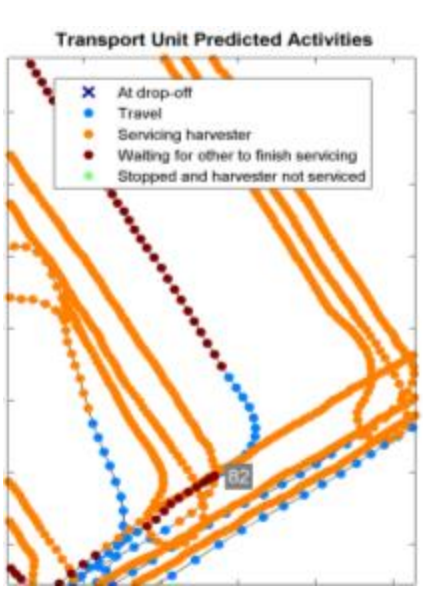


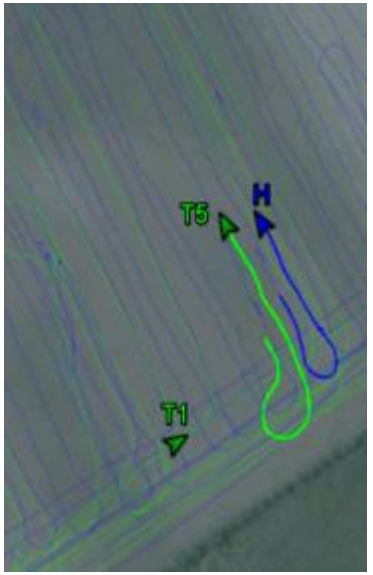
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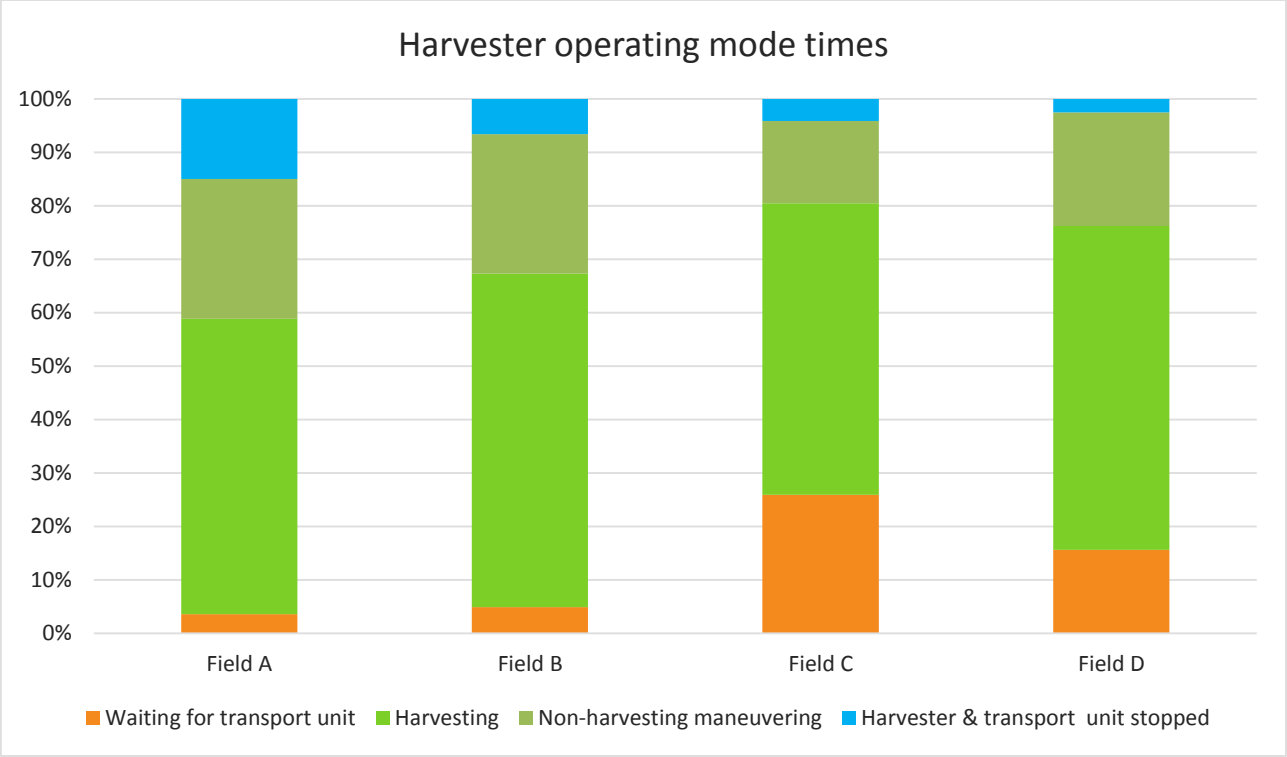




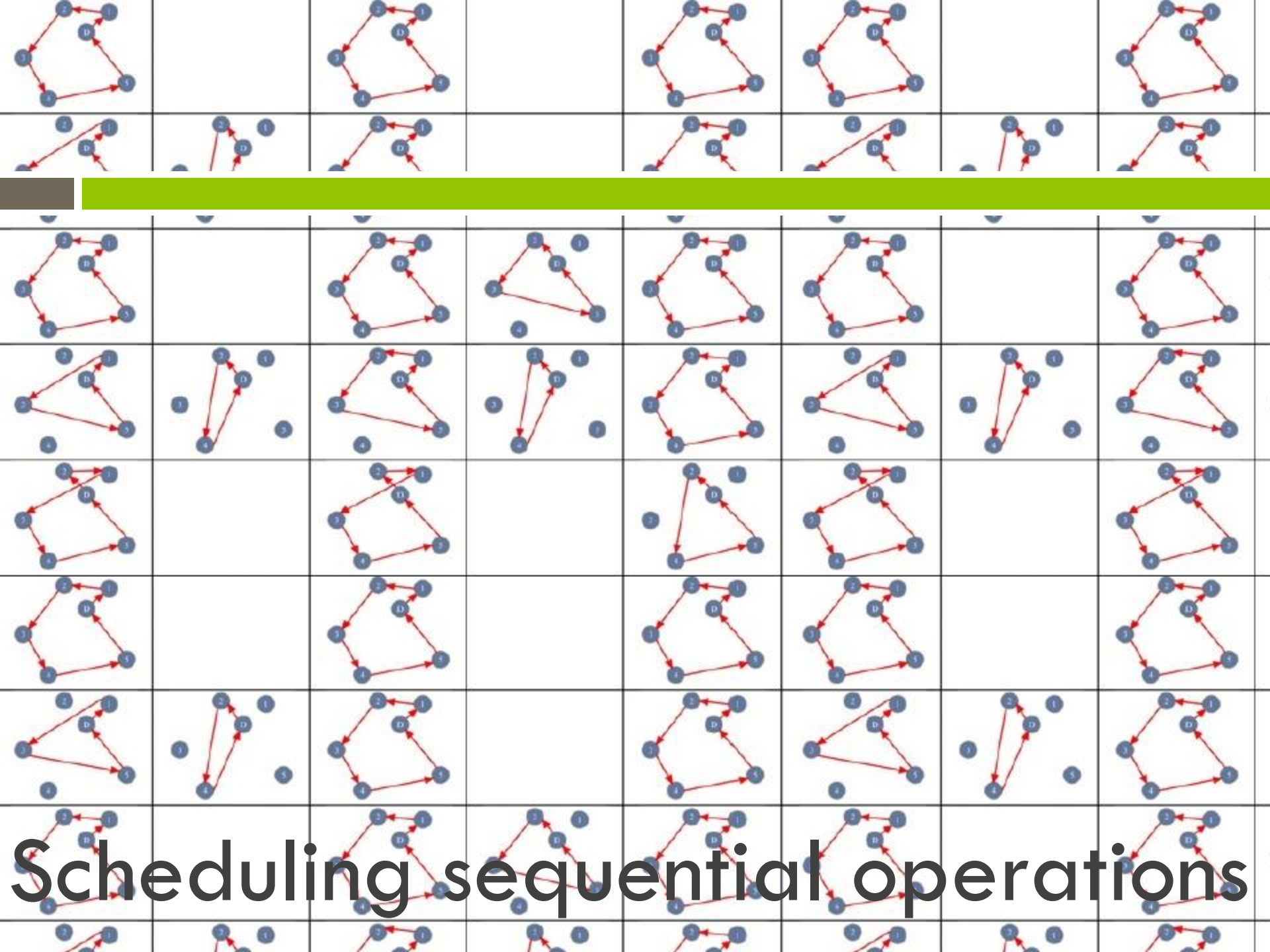


Jensen et al. Under review

Context recognition



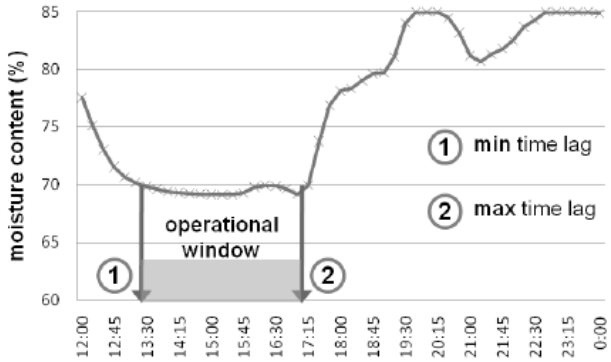
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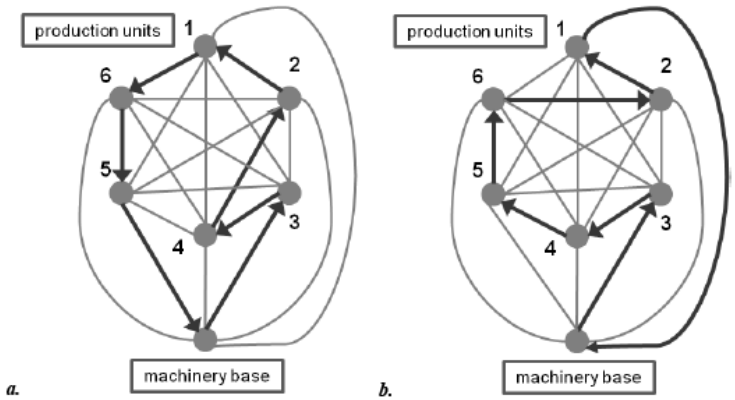


Scheduling sequential operations

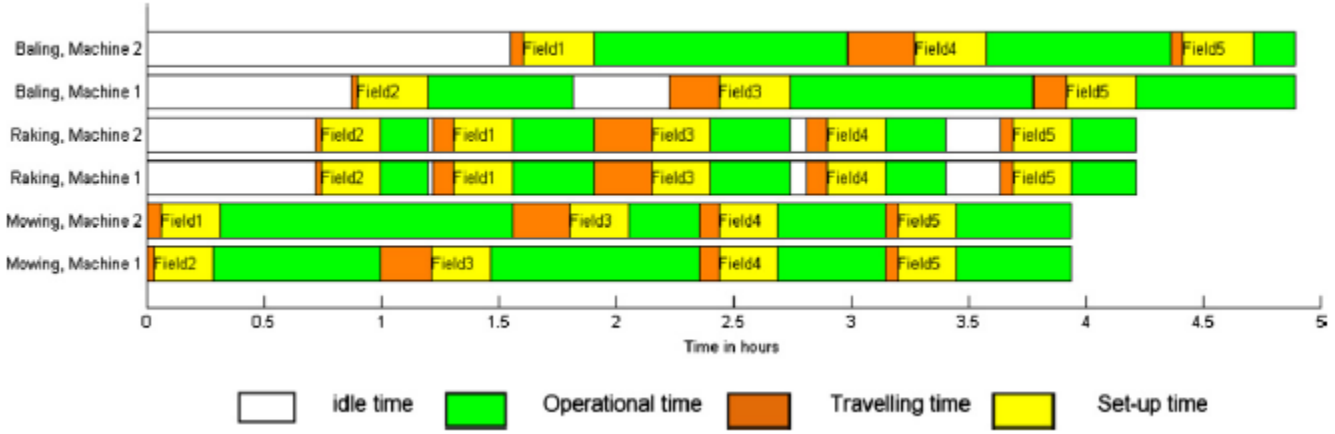
Scheduling sequential operations

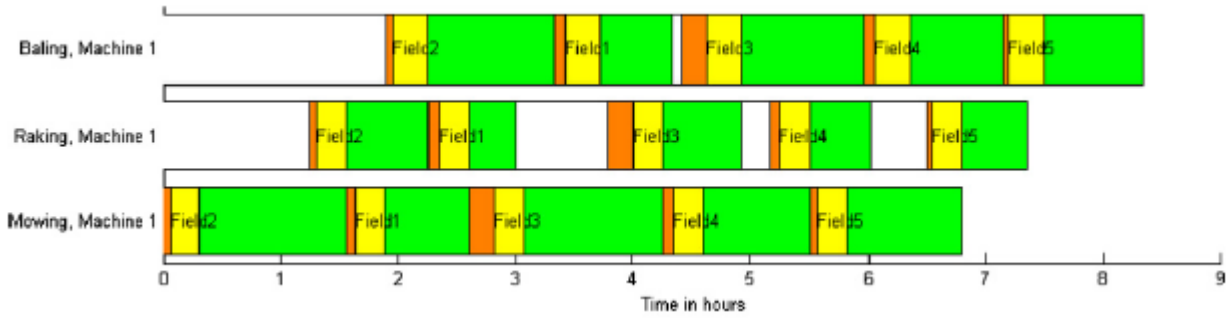




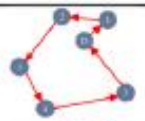
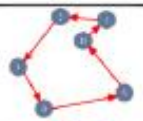
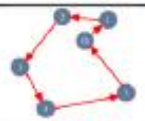
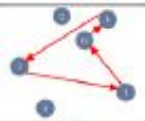
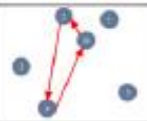
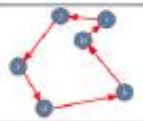
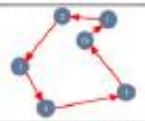
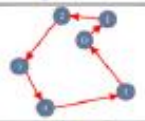
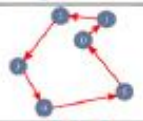
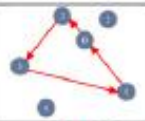
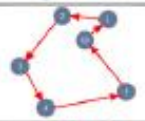
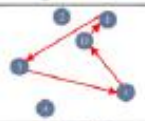
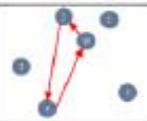
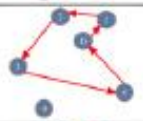
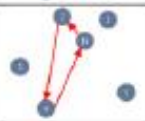
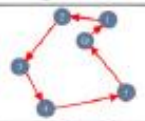
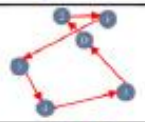
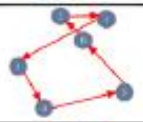
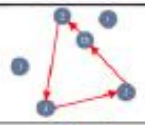
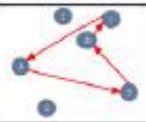
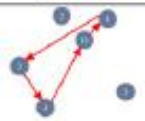
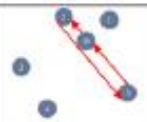
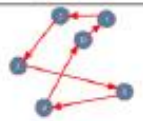
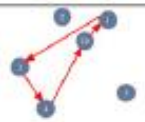
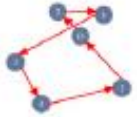
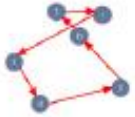
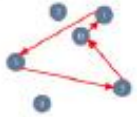
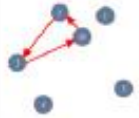
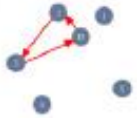
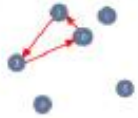


Scheduling sequential operations

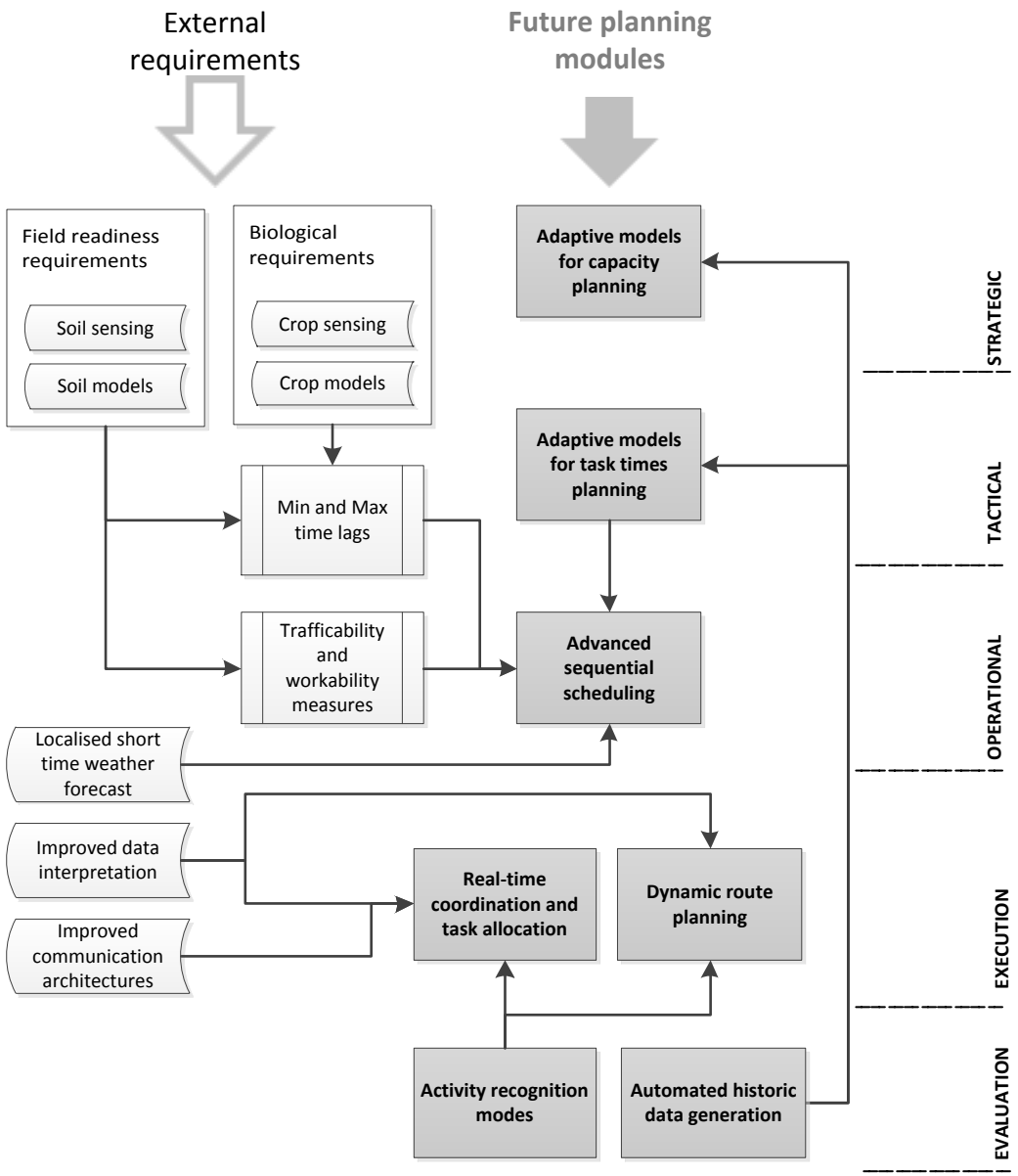




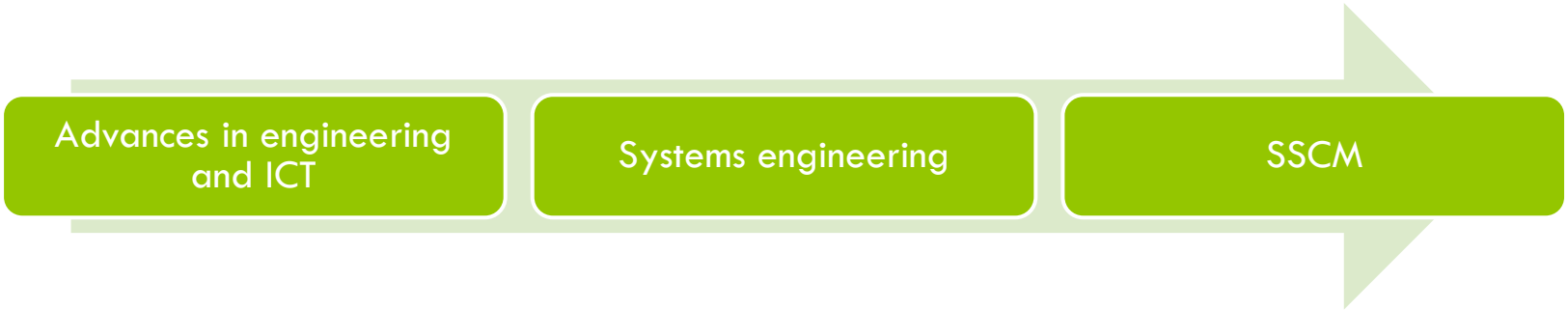
Scheduling sequential operations

	Mowing		Raking		Baling		Total Time (h)	Total Cost (€)
Combination	Machine 1	Machine 2 (if available)	Machine 1	Machine 2 (if available)	Machine 1	Machine 2 (if available)		
1-1-1							8.34	1,078
2-1-1							7.34	1,106
1-2-1							8.01	1,244
2-2-1							6.98	1,196
1-1-2							7.75	1,234
2-1-2							5.59	1,187
1-2-2							7.49	1,356
2-2-2							4.89	1,201

Future requirements



The challenge

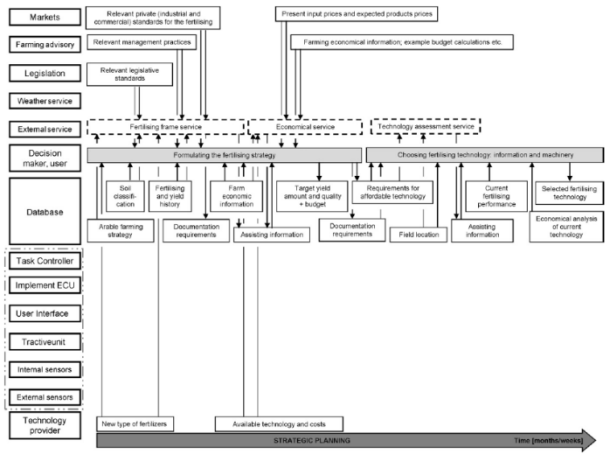


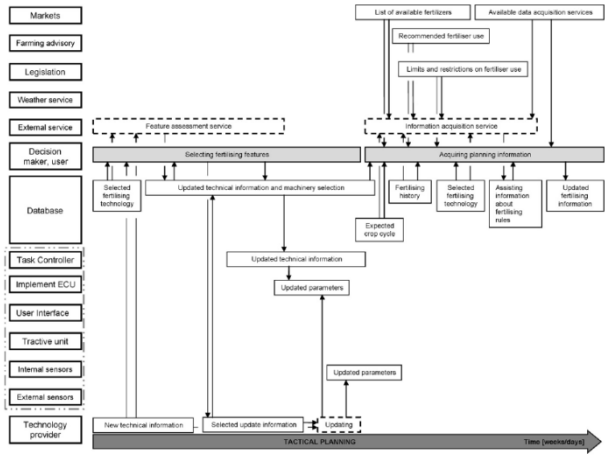
The challenge

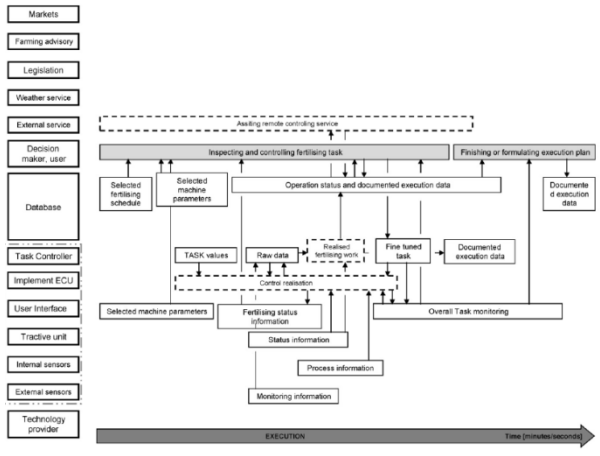
Advances in engineering and ICT

Systems Engineering

SSCM





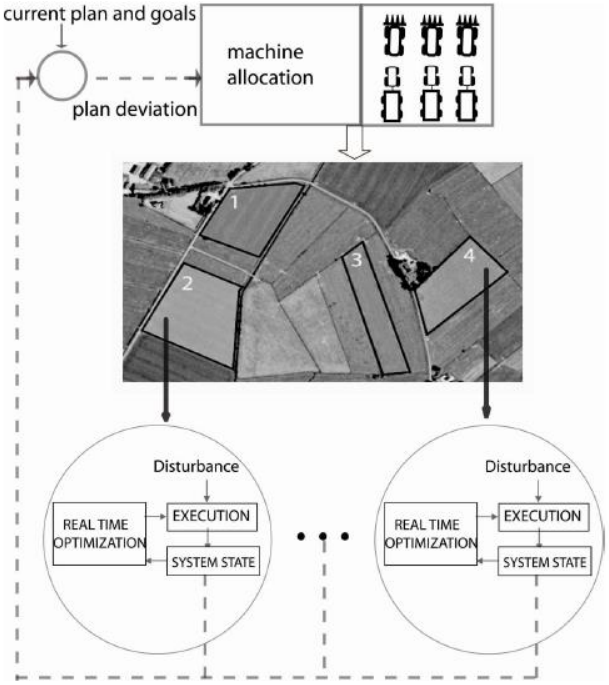


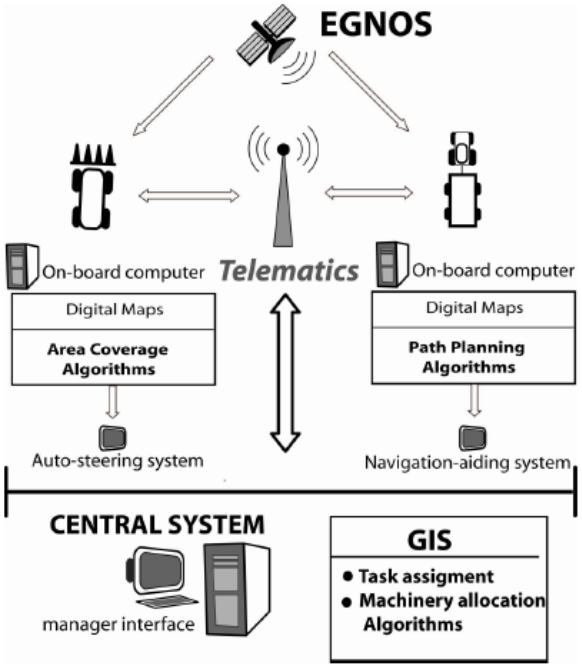
The challenge

Advances in engineering and ICT

Systems engineering

SSCM



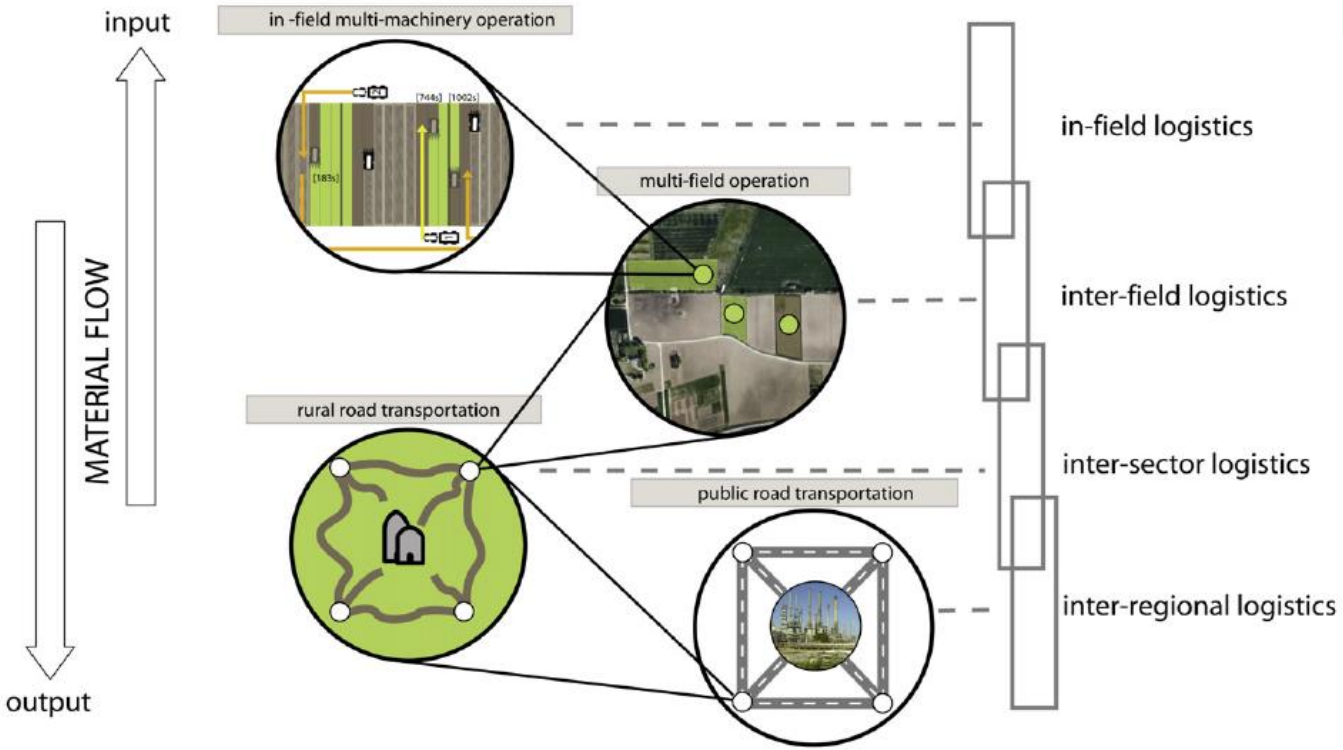


The challenge

Advances in engineering and ICT

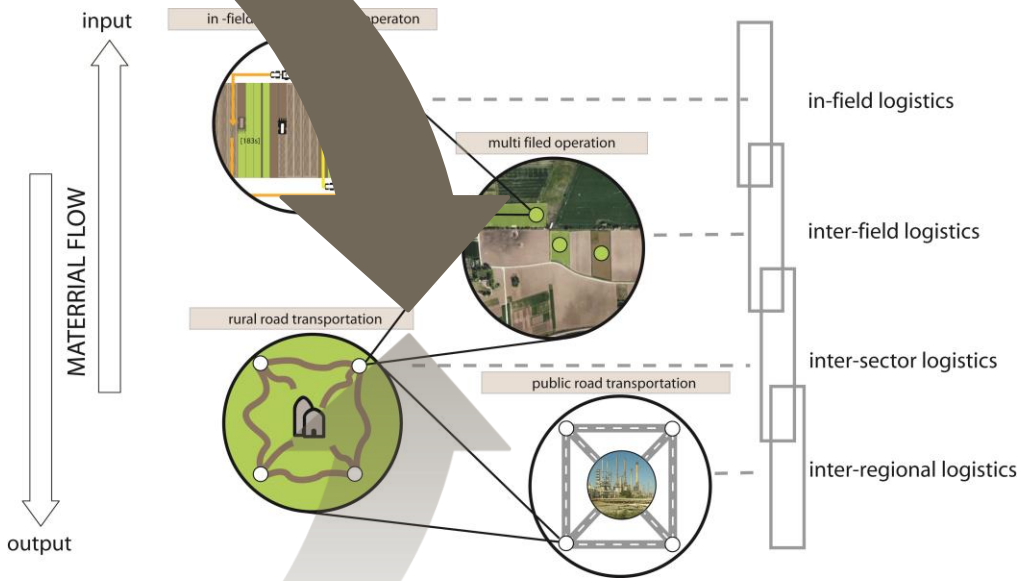
Systems engineering

SSCM

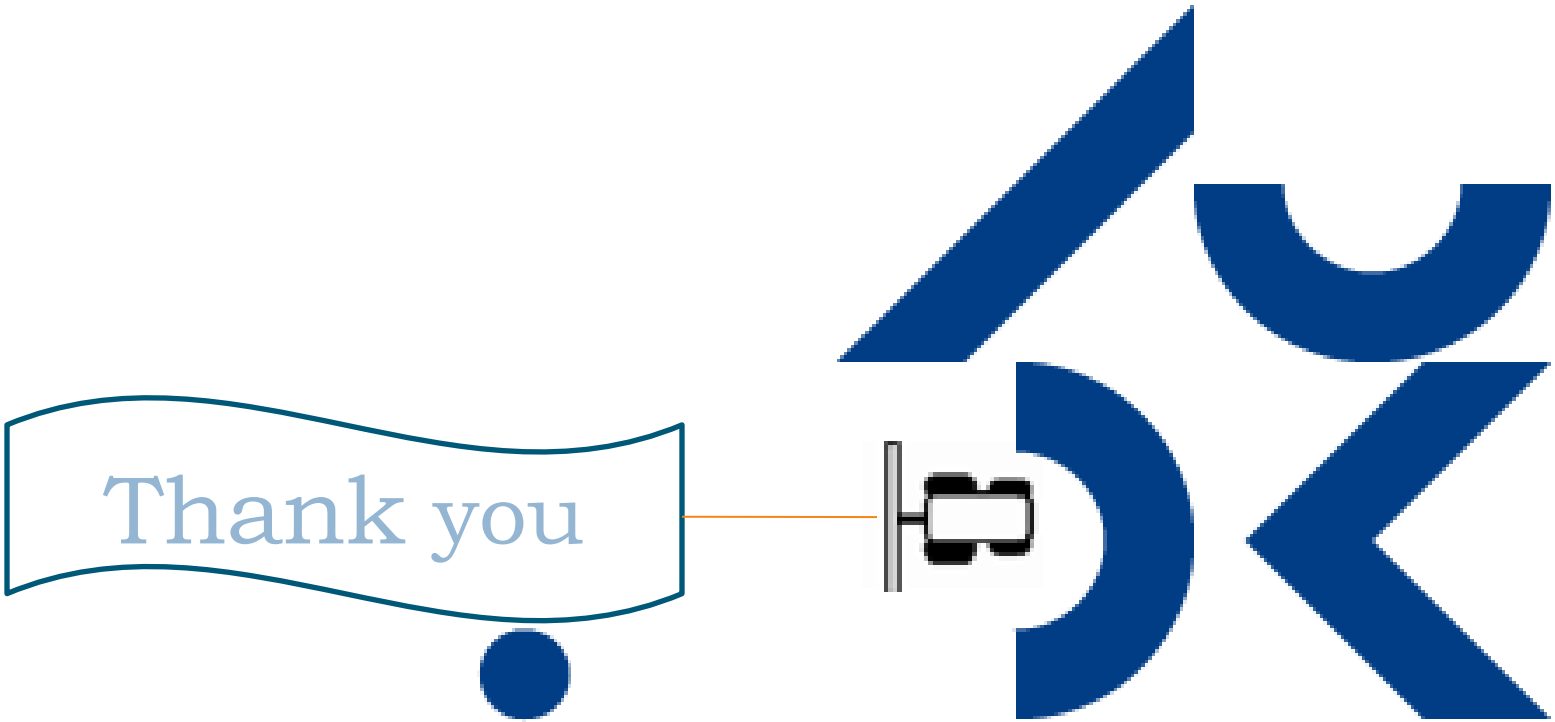


The challenge

- Precision agr re
- Specialise ting
- Automati d control
- Satellite technologies
- Decision Support Systems







Dionysis Bochtis, Ph.D.

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