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Precision Farming and Agricultural Engineering for the 21st Century:

How to make production agriculture more efficient

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www.unibots.com
Project Manager of FutureFarm
www.FutureFarm.eu

UniBots.com

FutureFarm

About me

- Grew up on a small farm in South Wales
- Worked on relief services around the UK
- Voluntary Service Overseas in Nigeria
- United Nations Volunteer in Lesotho
- Studied Agricultural Engineering at Silsoe College
- *Project Engineer in Sierra Leone*
- 14 years as lecturer in ICT & PF at Silsoe College
- Professor of Ag Eng at KVL in Denmark
- Manager of European FutureFarm project in Greece
- Professor of Ag Eng at Harper Adams

Countries visited

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Professorships

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- Founded 1901 by Thomas Harper Adams
- University College of the Year 2008 -2012
- Crops, Animals, Food, Land and Engineering
- *Circa* 2500 students
- 1st in the UK for graduate employment 2012
- 3rd in the UK for teaching excellence 2012
  - OU, Cambridge, Harper Adams, Oxford, …
- 5th in the UK for student satisfaction 2012

Engineering Department

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- Two unique degree courses in the UK
  - Agricultural Engineering
  - Off-Road Vehicle Design
- FdSc / BSc / BEng / MEng / MRes / Mphil / PhD
- 27 staff, 300+ students
- Workshop with 7 full time staff
- 90m x 30m Soil hall
- 50+ tractors and vehicles
- New MScs in 2013
  - Precision Farming
  - Applied Automation Engineering
- Teaching links with China and Brazil
- Funding from
  - Claas Stiftung
  - Douglas Bomford Trust

Agricultural Engineers

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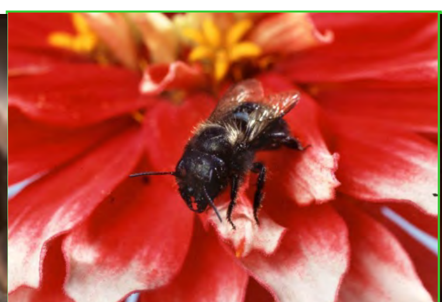
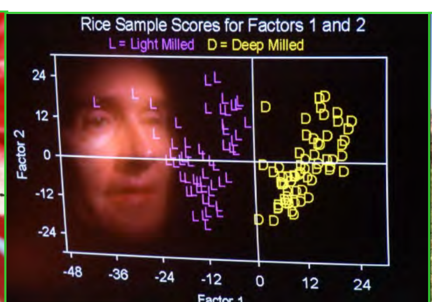
- Devise practical, efficient solutions for producing, storing, transporting, processing, and packaging agricultural products
- Solve problems related to systems, processes, and machines that interact with humans, plants, animals, microorganisms, and biological materials
- Develop solutions for responsible, alternative uses of agricultural products, by-products and wastes and of our natural resources - soil, water, air, and energy





World food problems

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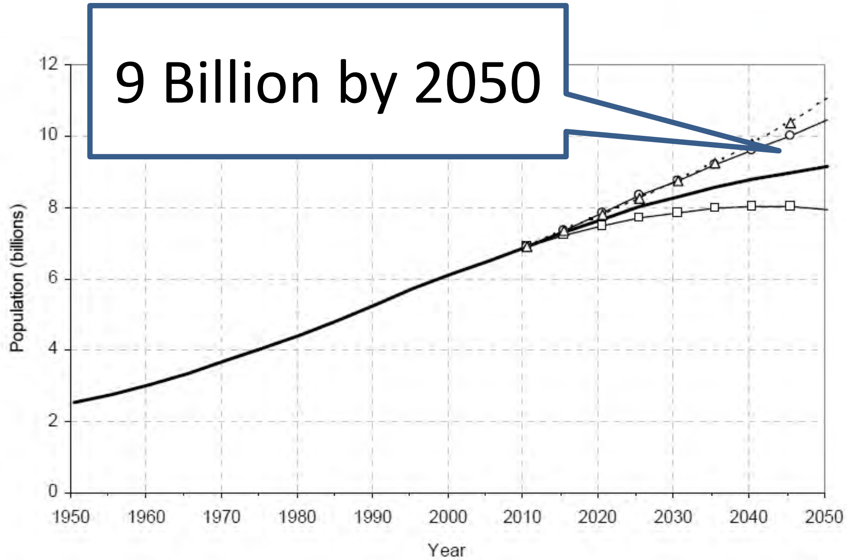
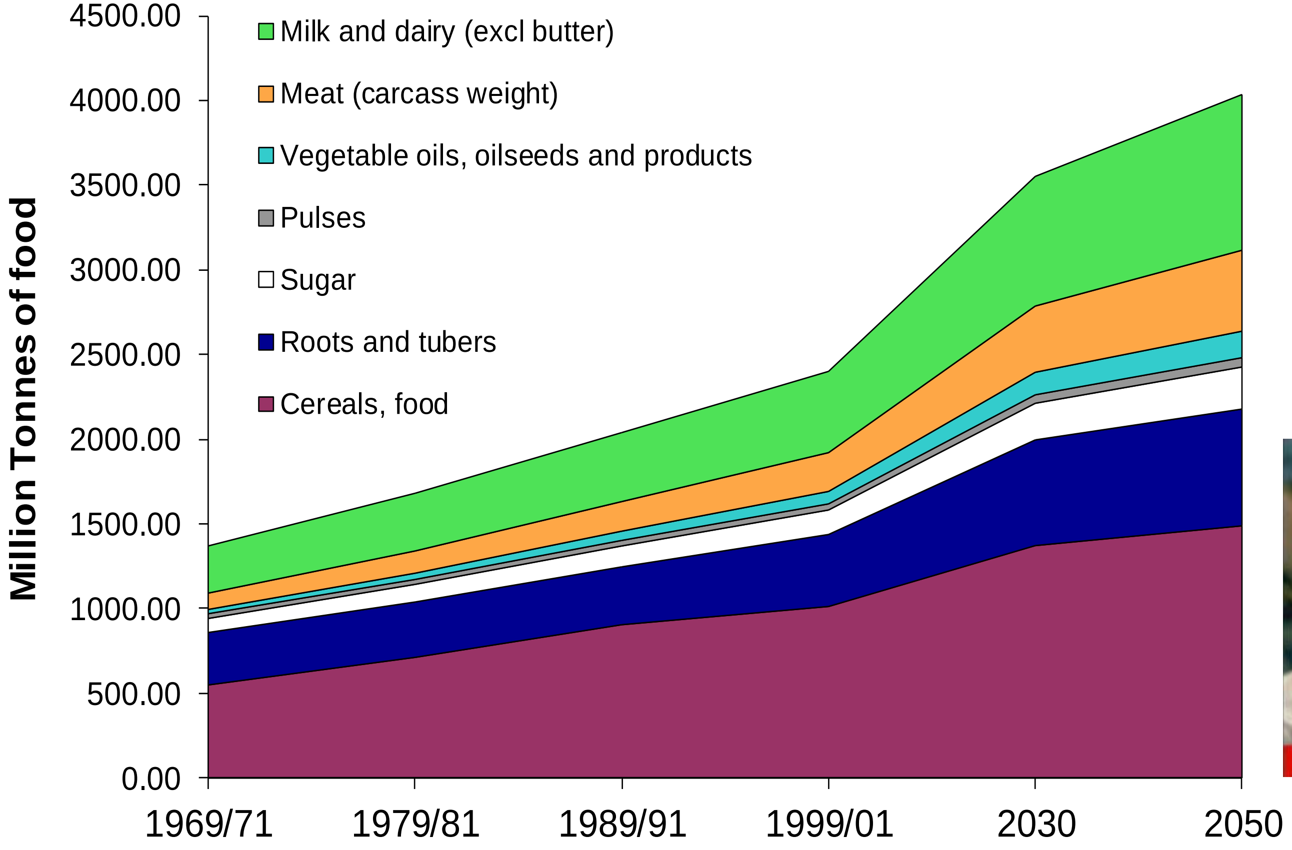
- Population growth ↑
- Protein consumption ↑
- Global warming ↑
- Energy crops ↑
- Food prices ↑
- Land & soil quality ↓
- Available land & water ↓
- % Rural population ↓



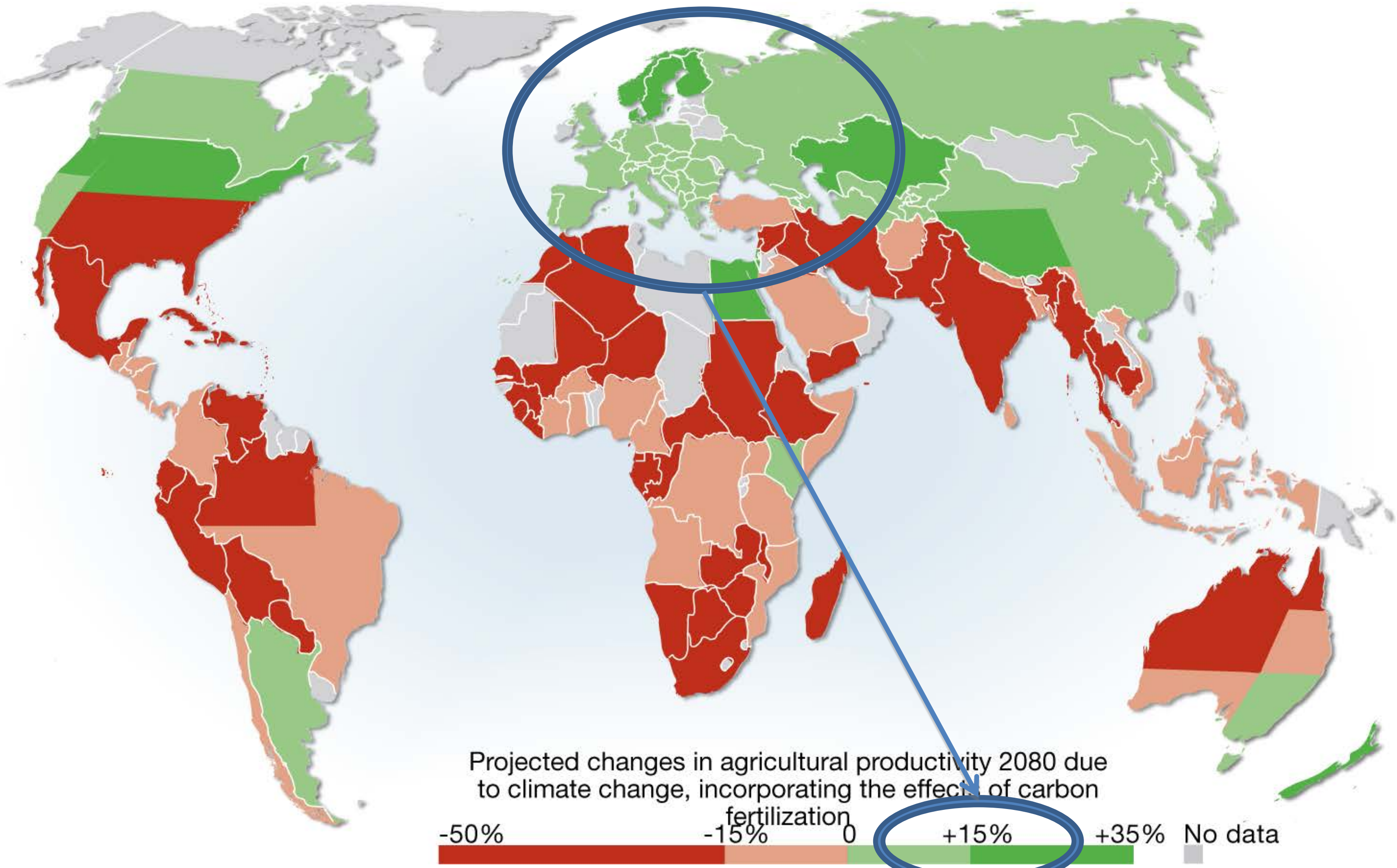
Increased demand for food worldwide



World food production must rise by **50 % by 2030** to meet increasing demand *UN 2008*

Source – FAO/UN

Global warming gives Europe production potential



Source: Cline 2007,.
Global Warming and Agriculture: Impact Estimates by Country. Washington D.C., USA: Peterson Institute

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The Future of Food and Farming

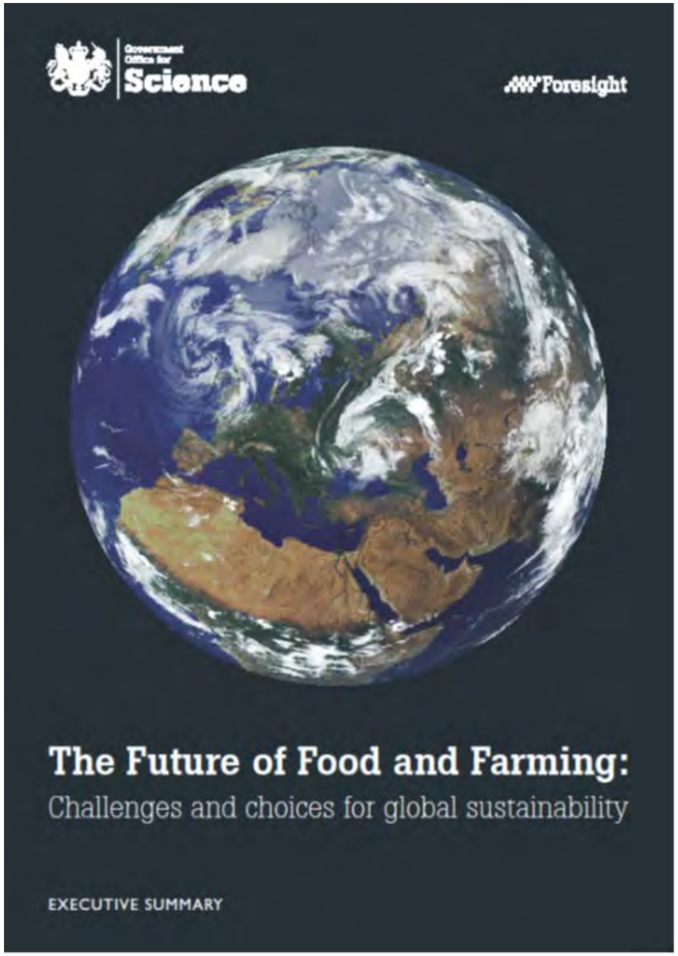
A. Balancing future demand and supply sustainably – to ensure that food supplies are affordable.

B. Ensuring that there is adequate stability in food supplies – and protecting the most vulnerable from the volatility that does occur.

C. Achieving global access to food and ending hunger. This recognises that producing enough food in the world so that everyone can potentially be fed is not the same thing as ensuring food security for all.

D. Managing the contribution of the food system to the mitigation of climate change.

E. Maintaining biodiversity and ecosystem services while feeding the world.



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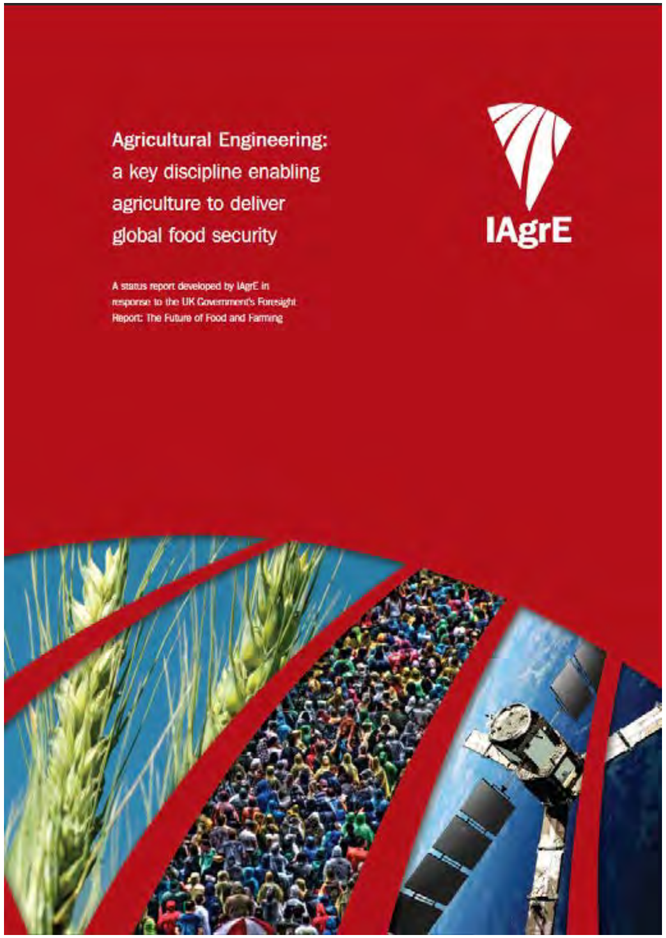
Agricultural Engineering:

a key discipline enabling agriculture to deliver global food security

		Precision Farming
A.	**'Balancing future demand and supply sustainably'** - precision management of inputs, detection of disease and control of production systems, and more efficient use of key resources such as irrigation water to deliver sustainable intensification.	✓
B.	**'Addressing the threat of future volatility in the food system'** - farm systems models and operational research to understand more clearly how interventions are likely to affect farming practice and outputs, and investment of skills and management advances into storage regimes and facilities to buffer food supply chains against local or regional disruption.	✓
C.	**'Ending hunger'** - translation of agricultural engineering approaches in sympathy with local conditions as a strong basis for development, strengthening local infrastructure and supply chains, facilitating appropriate mechanisation and postharvest systems that can link poor and smallholder farmers to the market.	✗
D.	**'Meeting the challenges of a low emissions world'** - understanding and tools to improve efficiency of resource use, optimising the management of crops and animals so emissions can be minimised per unit of food delivered, and reducing the energy demands of vehicles and processes.	✓
E.	**'Maintaining biodiversity and ecosystem services while feeding the world'** - coupling understanding of the biological system and natural environment with the approach to production management: e.g. better methods of targeting pesticides to preserve ecosystems and biodiversity as production intensifies; and soil management machines and methods to sustain production, maintain soil quality, and minimise pollution and flooding risk.	✓



Institution of Agricultural Engineers (IAgrE)
www.IAgrE.org

My world view

- These are big problems that cannot be solved by individuals or single states
- Agricultural Engineers can play their part in lessening the impact
- Develop new systems that can make production cropping more efficient
- Teach people how best to ‘engineer’ solutions
- Put these concepts into practice with farmers

My UK view

- Agricultural Engineering has been ignored by policy makers for too long
- Currently very good political and commercial support
  - Creation and funding of NCPF
  - IAgrE report for government Chief Scientist
  - DEFRA funding of USER-PA project
  - BIS consultation on Agri-Tech strategy for UK
  - Novel clean, efficient technologies supported by UK sustainability guru
  - Commercial growers and suppliers asking for solutions

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National Center for Precision Farming

- *“It's great for the UK that Harper Adams is establishing the National Centre for Precision Farming. "*
- Launched in Westminster Feb 2012
- New NCPF building
  - £1.5m Raised privately
    - Douglas Bomford Trust
    - Eric Lea Charitable Trust
  - £1.5m Government Catalyst fund
  - Started building Nov 2012
  - Finished by end of 2013

The Prime Minister welcomed the investment in precision farming facilities

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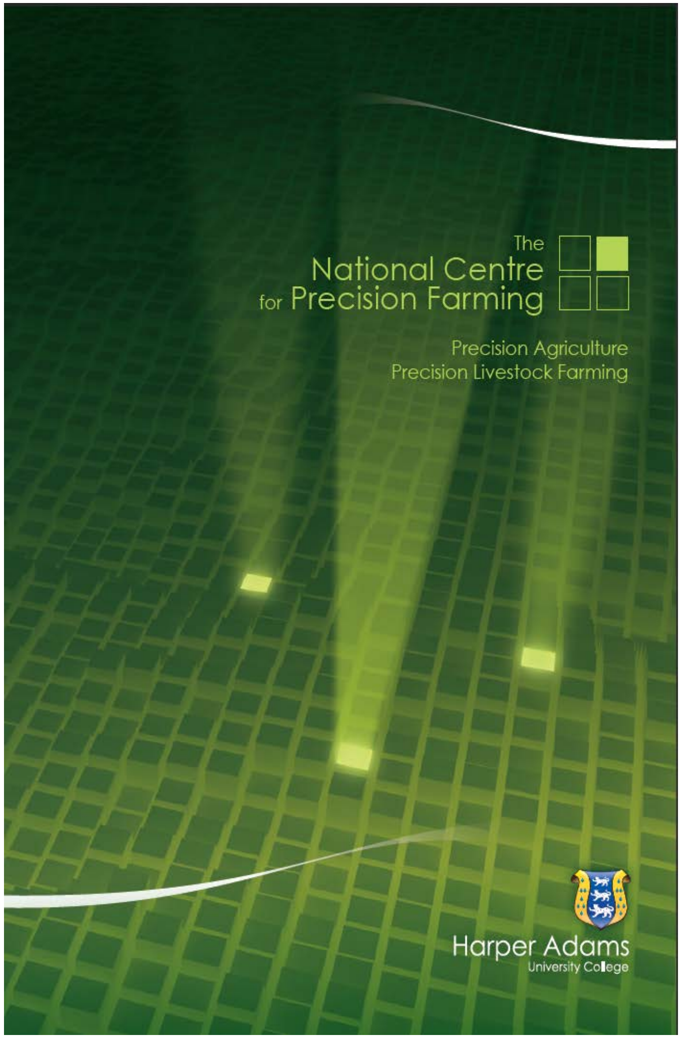
National Centre for Precision Farming



- The Centre is an inclusive, non-competitive networking hub used for passing on information and bringing people together.
- The outcome is to help farmers meet today's political, economic and environmental needs by using smarter systems
- The NCPF will introduce short courses, technical days and conferences
- Paid membership for added services
- www.harper-adams.ac.uk/NCPF

My vision

- Help farmers make better decisions
  - Develop Farm Management Information Systems
  - Identify good strategies and practices
  - Support decision making through better real-time information
- Use ICT to improve production efficiency
  - Improve current machines to assist operators
  - Smart machines and systems

Smart machines & systems

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- Agricultural robots
  - System to meet today's needs
- Energetic efficiency
  - Reduction, closed on-farm systems, energy harvesting
- Controlled traffic farming
  - Route planning, minimal tillage, reduced energy, increased infiltration
- Smart drains (Nano materials)
  - Drainage / irrigation, filter N or pollutants
- Novel sensing systems
  - Non contact solid state, Biosensors, UAVs, …
- Integrated management information systems
  - Government policy, guidelines, legislation, cross compliance, on-farm real-time data

FutureFarm

"Bert, I don't want to depress you, but your governor's just bought one of those new tractors that don't need a driver"

Daily Express, July 7th, 1964

Current trend for mechanisation to get bigger

- Advantages
  - Current system very effective
  - Reduced labour cost/ha
  - High work rates/hour
  - Good for large farms & fields
  - Economies of scale

- Disadvantages
  - High cost of operator
  - High capital expense
  - Reduced flexibility
  - Subsoil compaction?
  - Cannot be used on wet soil



New mechanisation system requirements

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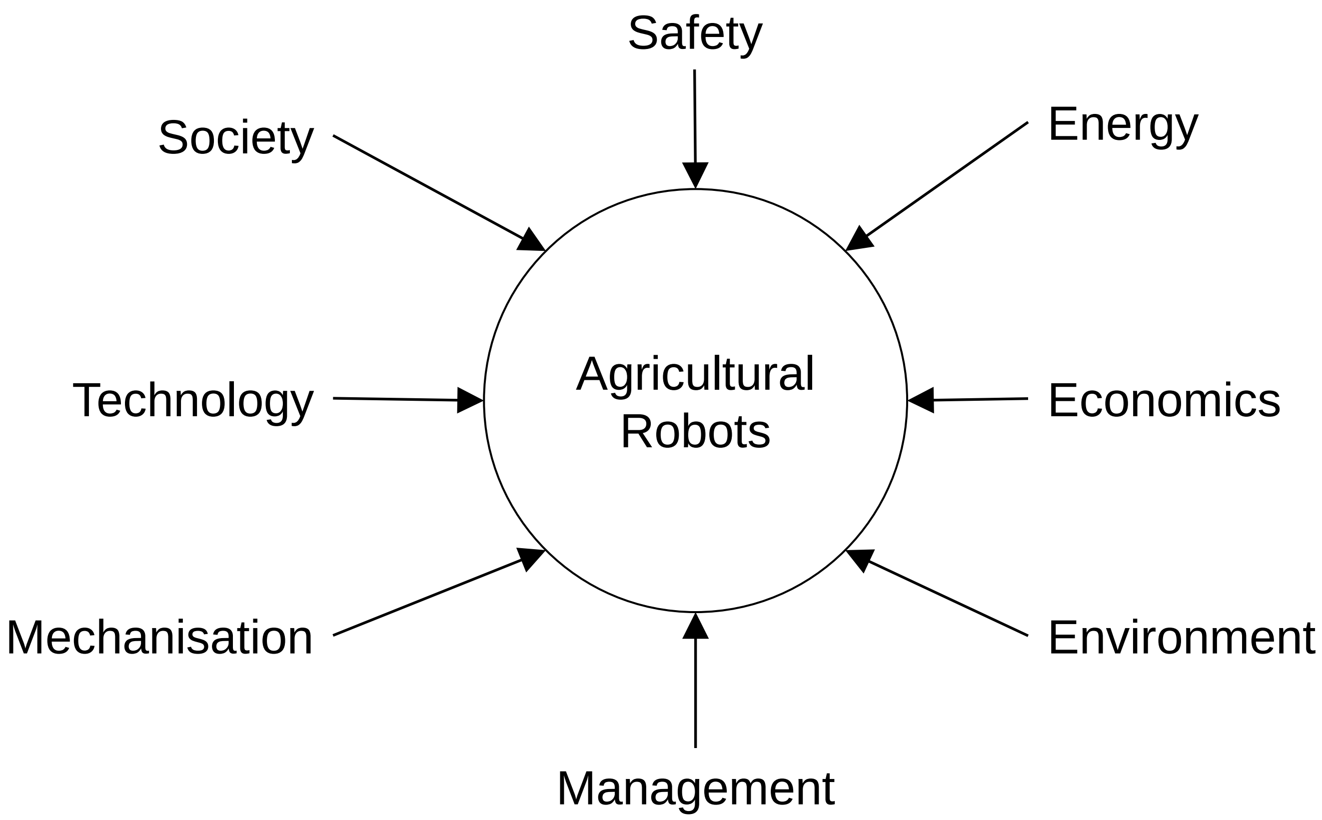
- Develop new generation of machinery based on plant needs
- Allow us to do operations we cannot do now, or find too expensive or time consuming
- Low energy, intelligently targeted inputs
- Small area or plant scale operations
- Very low compaction
- Modular and scalable
- Cost effective
- Integrated real-time fleet management

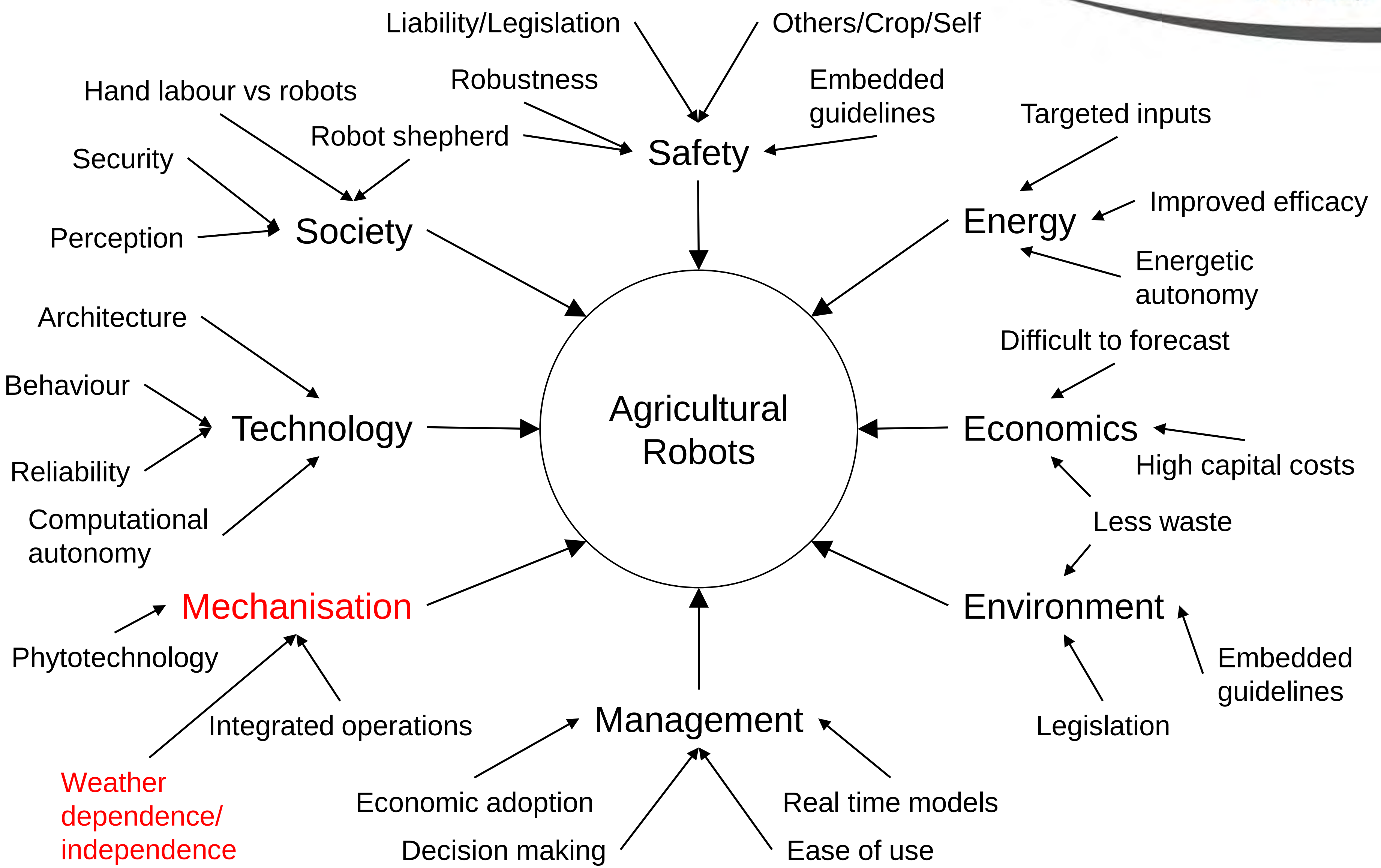
Design factors

- Safe and reliable
- Light weight
- Small and autonomous
- Easy to manage
- Computational (and energetic) autonomy
- Weather independence / dependence
- Redundant system architecture
- Graceful degradation
- Communication
- Identifiable behaviour
- Self awareness
- Work at night
- Systemic design

Systemic design:
Eight perspectives of agricultural robots



Complex part model



Farmers Weekly

Friday 23 November 2012

- Half of Scottish growers have yet to finish drilling cereals this autumn following weeks of "relentless" wet weather, a survey from NFU Scotland shows.
- One in five growers still have more than 10% of their cereals, maize or potatoes to harvest.
- And a staggering one in 10 arable respondents still had 50% or more of their cereals and maize in the field
- *Is this the wrong sort of weather or the wrong sort of tractor?*

Robotic agriculture highlights

- Cultivation and seeding
  - Soil compaction
  - Trafficability
  - Seeding
- Scouting and crop care
  - 3 generations of crop scouts
  - Weather dependent spraying
  - Microdot spraying
  - Laser weeding
- Selective harvesting

Soil compaction

- Large tractors cause significant soil compaction that results in up to 90% of the energy being used in cultivation, to repair the damage caused by the machinery in the first place
- *Low ground pressure tyres*
- *Controlled Traffic Farming (CTF) & route planning*
- *Can we develop a system that does what we want without causing compaction problems?*
  - *Ultra light machines, micro tillage, zero draft force*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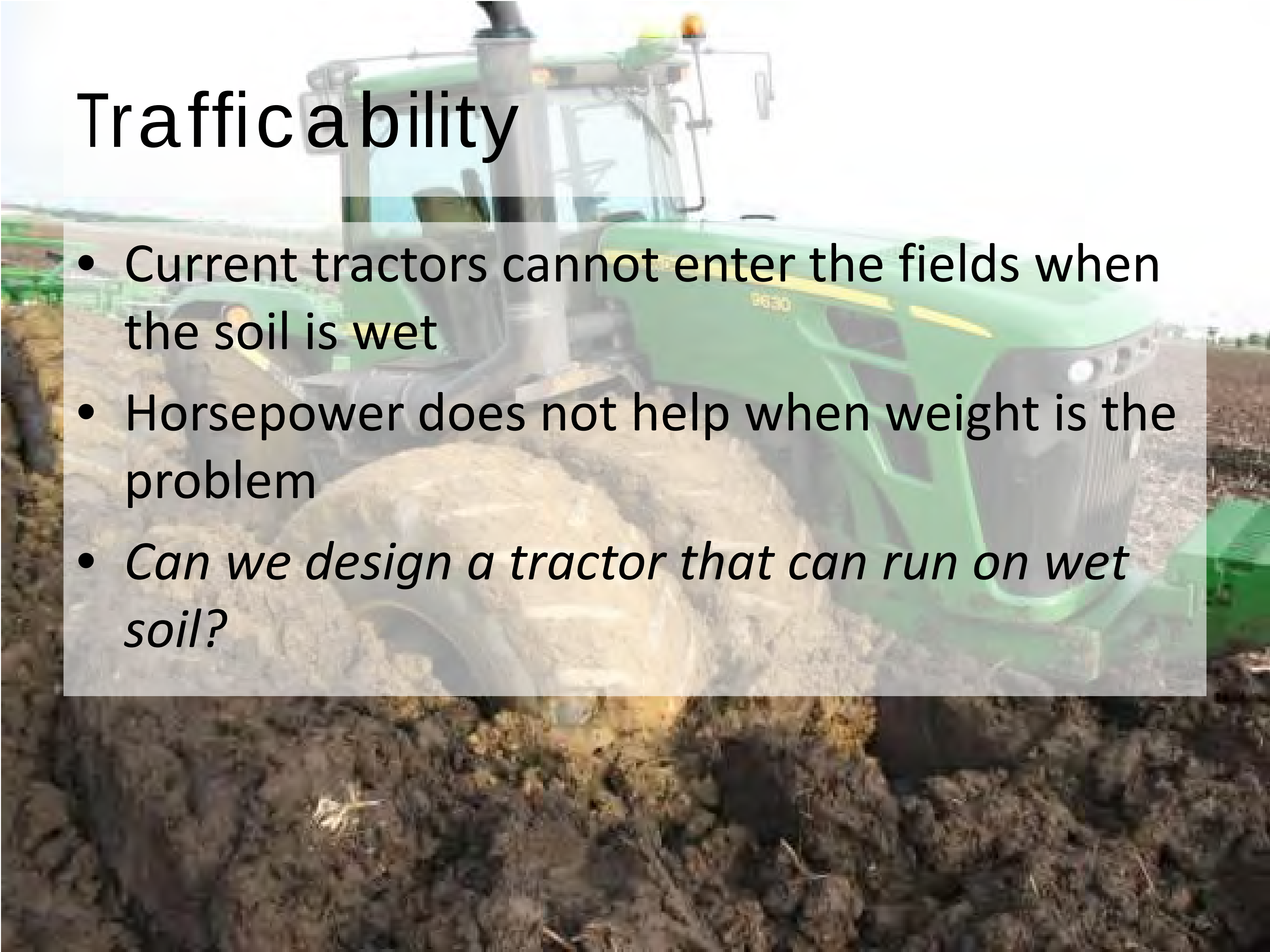

Trafficability

- Current tractors cannot enter the fields when the soil is wet
- Horsepower does not help when weight is the problem
- *Can we design a tractor that can run on wet soil?*


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Seeding

- Most seed only guarantees 80% germination
- Seeders produce void areas
- Intra row competition between plants
- Can we develop a ‘reseeder’?
- Can we control seed depth for moisture?
- Can we orient seeds to reduce competition?

Crop scouting

- Laborious
- Difficult to find qualified staff at appropriate time
- Data must be transcribed
- Low levels of repeatability
- Weather dependant
- Expensive
- Trials limited by expensive data capture!
- *Can we design a system to phenotype plants automatically?*


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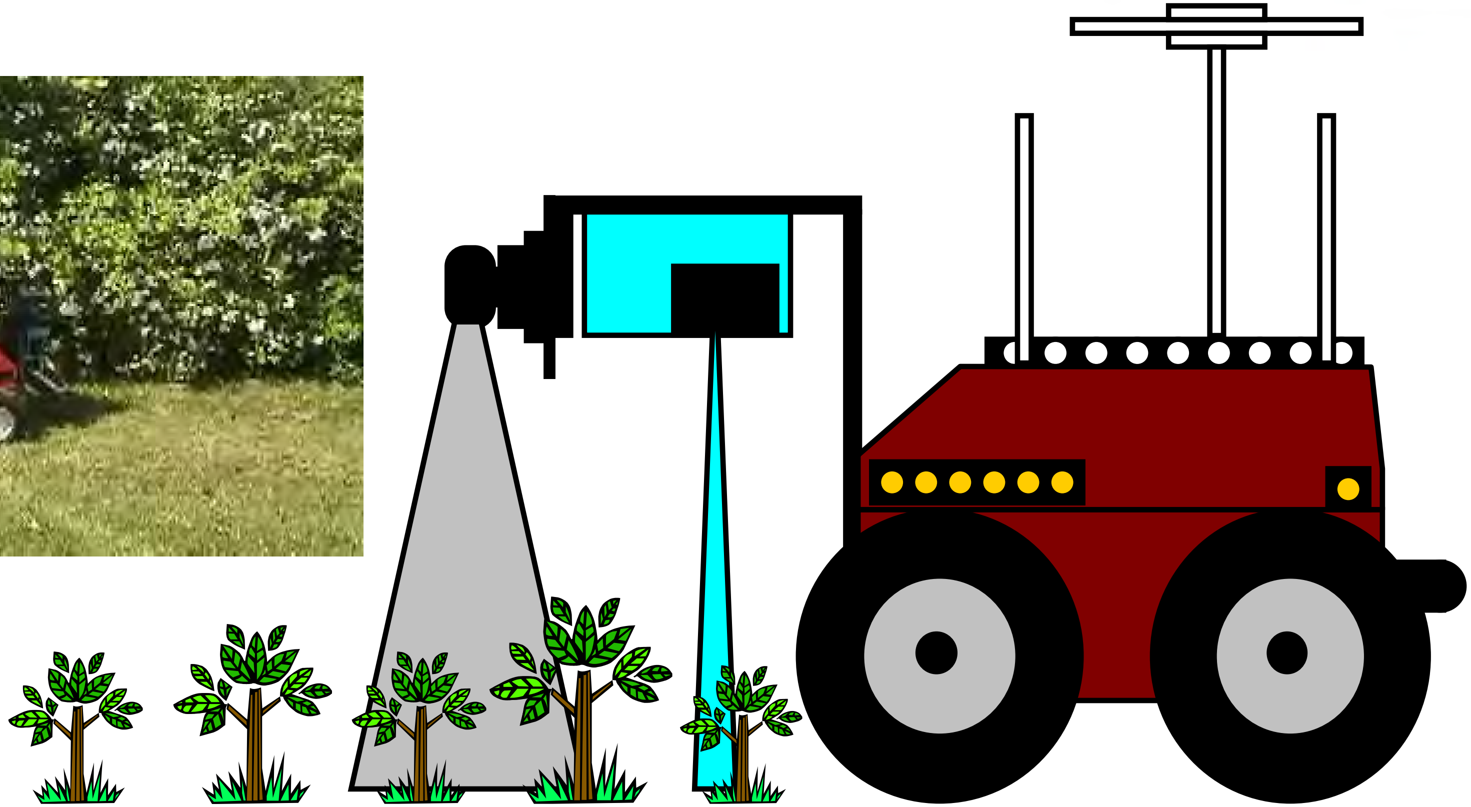
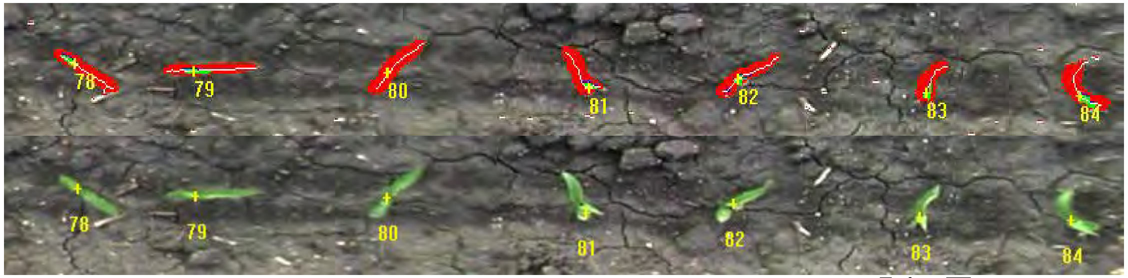
1st Generation crop scout ATRV





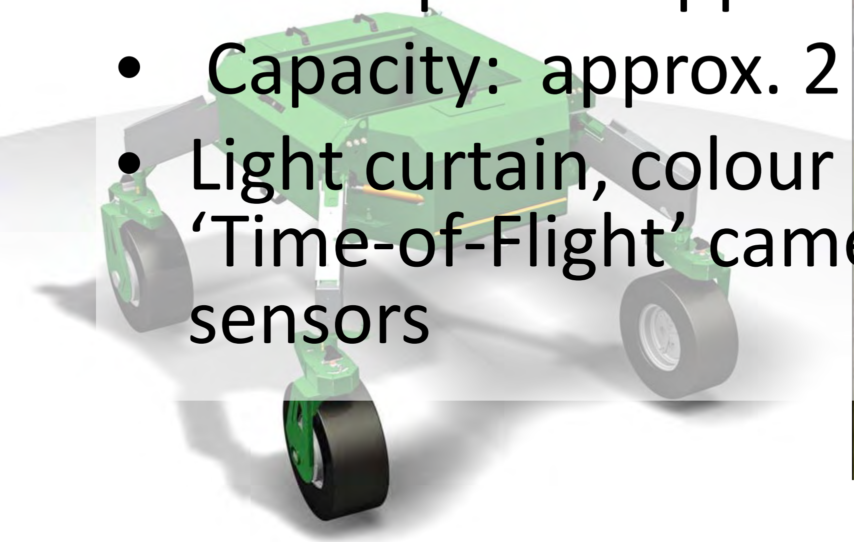
Lie Tang

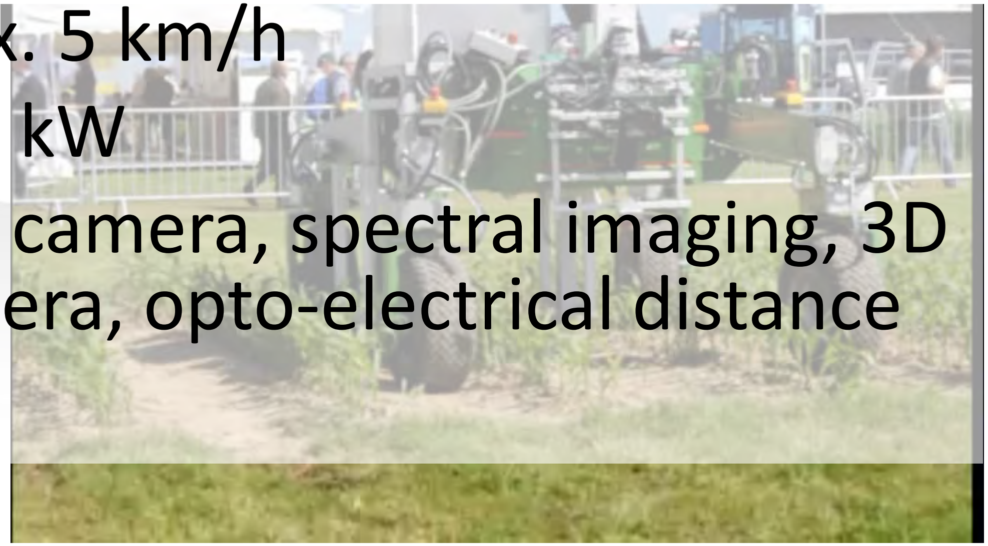
1st Generation crop scout API

- API – Autonomous Plant Inspection platform
- MSc student project at DTU Copenhagen
- Adapted at Aarhus University
- Sensors
  - RTK GPS, Hyperspectral, machine vision, …
- Repeat 250 plots each day

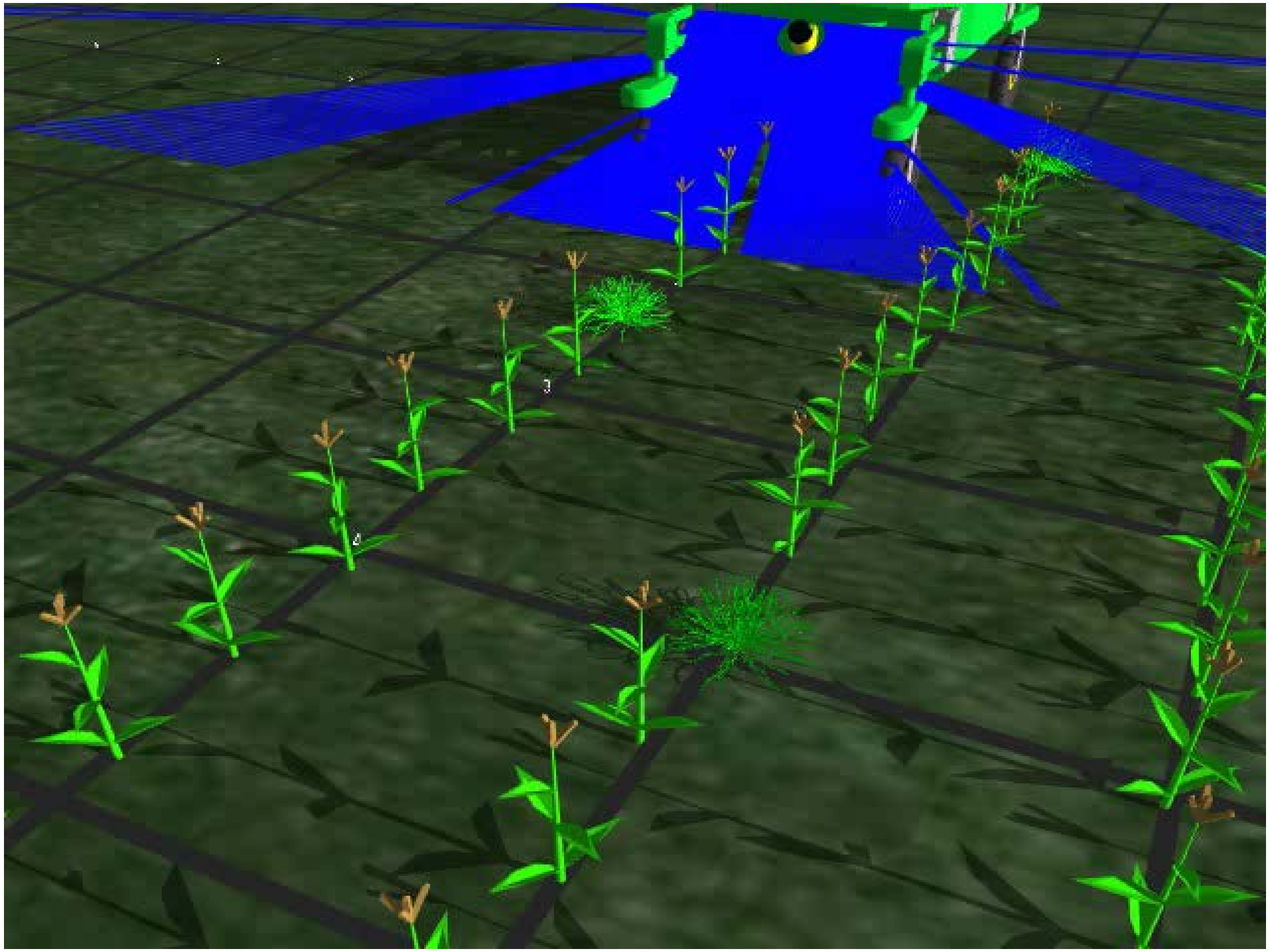
2nd generation crop scout Bonirob

- Bonirob - ‘Bonitur’ German for rating
- Vehicle dimension: 200 cm x 120 cm x 100 cm
- Track width: 75 – 200 cm (variable)
- Ground clearance: 40 – 80 cm (variable)
- Total weight: approx. 600 kg
- Max. speed: approx. 5 km/h
- Capacity: approx. 2 kW
- Light curtain, colour camera, spectral imaging, 3D ‘Time-of-Flight’ camera, opto-electrical distance sensors





3D modelling using LIDAR



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Fachhochschule Osnabrück University of Applied Sciences

3rd generation crop scout Scamp

- Scamp scout:
  - Weed & crop mapping with machine vision
  - Crop stress through Ethylene detection
  - Insect infestation through VoC detection
  - Crop growth rates through crop height
  - Crop nutrient status through multi spectral response
  - Crop quality and quantity estimation before harvest
  - Autonomous phenotyping and 3D canopy models

3D canopy models give context

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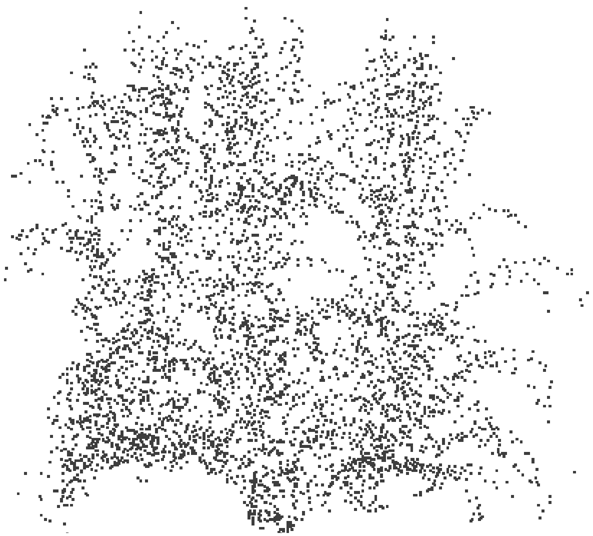

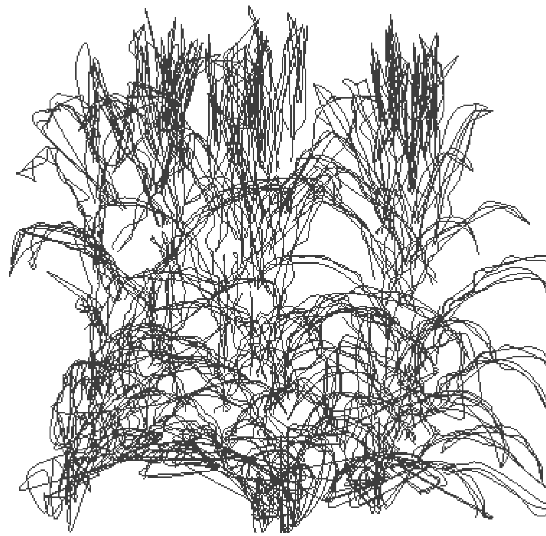

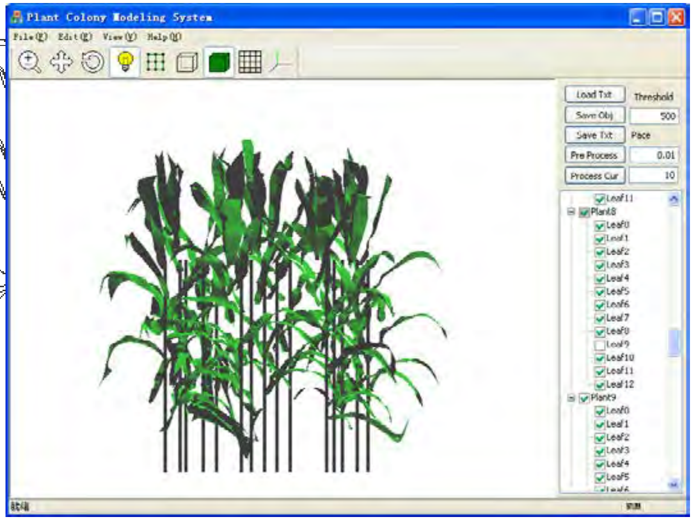

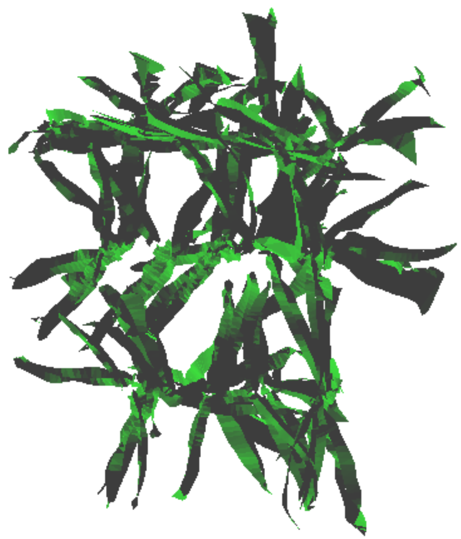

Weather dependent spraying

- When spraying a driver will go home after the wind gets up
- *Can we build a machine that can wait for the wind to die down and continue?*


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MASSEY FERGUSON

MicroDot spraying

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- Smart sprayer saving 99.99% herbicide

UNIVERSITY OF SOUTHERN DENMARK

Laser weeding

- Machine vision recognises the growing point of the weed
- Laser kills the weed by heating the growing point
- Saving 100% herbicide

The Royal Veterinary and Agricultural University

Intra-row Weeding with a Cycloid Hoe

Denmark, May 2006

Selective harvesting

- Expensive 'cheap' labour
- Difficult to support large labour force
- Whole crop harvested and graded
  - Up to 40% not of saleable quality
- *Can we design a selective harvester that only harvests crop of 100% saleable quality?*


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Conclusions

- Agricultural Engineering and Precision Farming can make the bioproduction process more efficient
- Will have a major beneficial impact on food sustainability in UK, Europe and perhaps the world
- New technology systems are ready to be developed and commercialised in the UK

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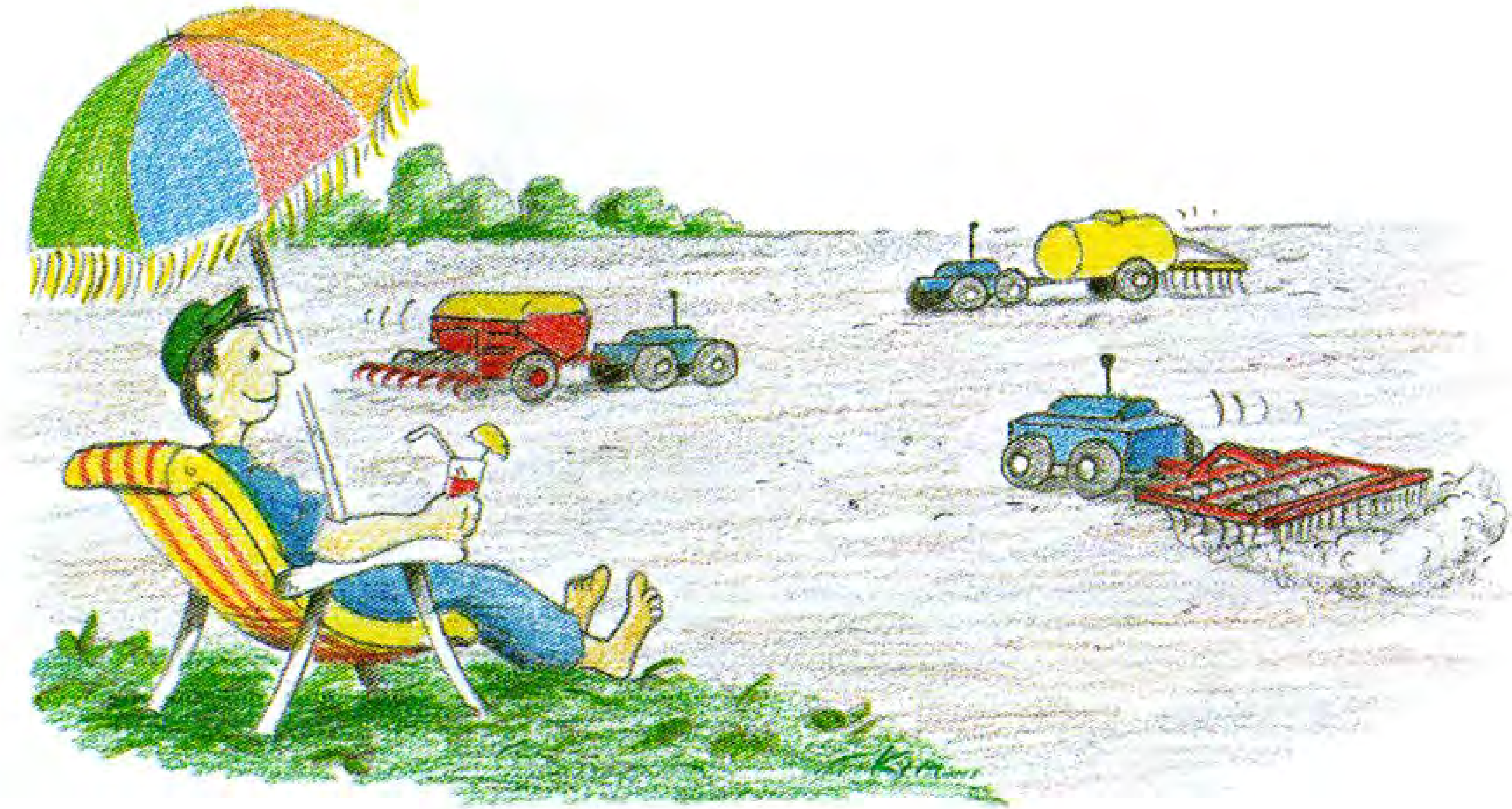


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