Farming with robots

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Harper Adams University

- Founded 1901 by Thomas Harper Adams
- Crops, Animals, Food, Land and Engineering
- *Circa* 2500 students
- Engineering graduates
  - 95% employment rate in 2014
  - 94% in professional and managerial jobs
  - 2nd place in Farming By Satellite prize 2014
  - Shortlisted for the Times Higher award 2014
    - Outstanding Contribution to Innovation and Technology
    - University of the year
- THES Top 50 university in UK 2015

National Center for Precision Farming

- David Cameron (Prime Minister) 2012
  - *"It's great for the UK that Harper Adams is establishing the National Centre for Precision Farming."*
- Liz Truss (The secretary for state for environment, food and rural affairs) Sept 2015
  - *"Shropshire is home to Harper Adams University, the National Centre for Precision Farming, and the mechanical engineering centre, which is a global centre for excellence in terms of modernising farming techniques."*

Farming in the future?

- Identify trends in the past that are true today and carry through to the future
- Identify weaknesses in current system
  - Is big always good? Highest yield gives highest profit? ....
  - Can tractors be twice the size in the next ten years? ....
- Assumptions
  - Sustainable food supply in changing conditions
  - Improve farm economic viability
  - Desire to have less environmental impact
  - Tighter legislation from EU and UK
  - Energy prices increase
  - More volatile weather due to climate change
  - More competition from world food prices
- Crop production must become more flexible and efficient

Current farming system

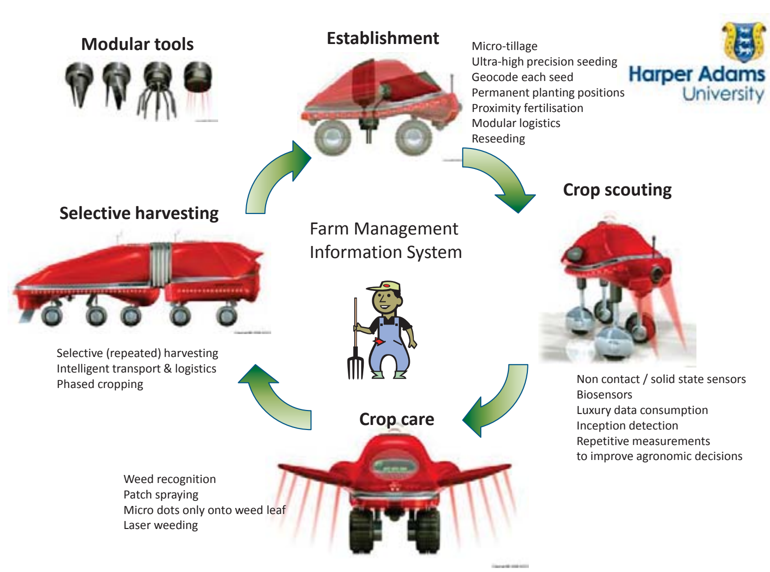
- Industrial production line
  - Maximum crop production after the war
  - Large tractors doing the same work everywhere
  - Cheap energy
- Flexible manufacturing
  - React to changes in real-time based on current conditions
    - Weather, growth, prices, legislation, incentives
    - Information intensive

Current size

- Mechanisation getting bigger all the time
  - Due to driver costs
    - Doubling work rates keeps costs down
  - Reaching maximum size
    - Combines are now at maximum size that can fit inside a railway tunnel for transport
    - Good for large fields
  - Small working window needs a bigger machine but the bigger the machine the smaller the working window.
    - Self fulfilling prophecy
    - Horsepower does not help when weight is the problem
  - We cannot change the weather but we can change the tractor

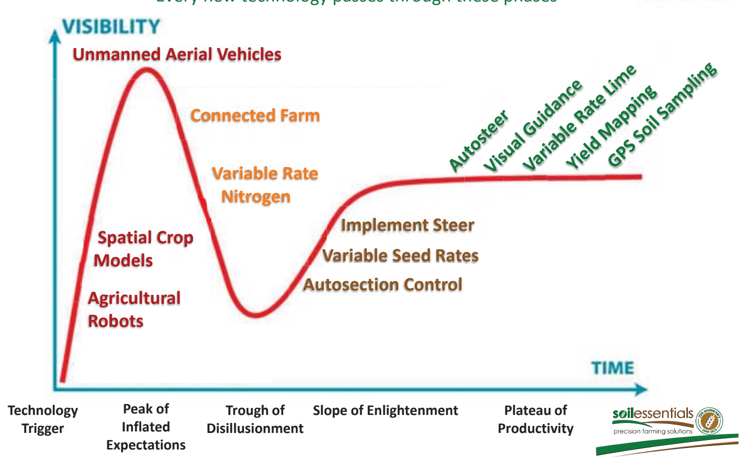
Farming with robots

- Agricultural robotics is a new systems concept to help improve;
  - Food sustainability in a growing population
  - Lowering the cost of food production
  - Reducing the energy needed in agriculture
  - Protect environmental services
  - Making production agriculture significantly more efficient



Gartner Hype Cycle

Every new technology passes through these phases



Web-farming.com

Current system: Compaction

- Up to 90% of the energy going in to cultivation is there to repair the damage caused by large machines
- Up to 96% of the field area compacted by tyres in "random traffic" systems
- If we do not damage the soil in the first place, we do not need to repair it
- Move towards Controlled Traffic Farming and ultra light machines

Robotic seeder

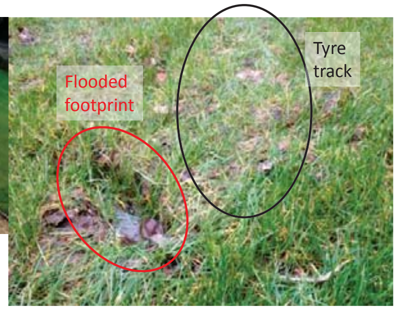
- Ultra light, very low draught force
  - No agronomic compaction
  - Put seed into the ground in any weather
- Micro tillage
  - Cultivate for each individual seed position
- Permanent planting positions
  - Same place each year
- Use vertical or rotary seeding methods
  - Punch planting
- Seeding depth to moisture
  - Improve germination rates

Ultra light seeding robot

Harper Adams University

- Less than 40kPa (6PSI) under the contact patch does no agronomic damage even at field capacity
- Can seed the ground in any weather conditions

February 2014



Crop scouting

- Working with agronomists by giving near-real-time data over the whole farm
- UGVs (Unmanned Ground Vehicle)
  - Phenotyping robots
    - Crop trials to evaluate new genotypes
  - Scouting robots
    - Targeted agronomic measurements
- UAVs (Unmanned Aerial Vehicle)
  - Rapid assessment technique
  - High resolution imagery
    - Visible: Crop cover, growth rates, flooding extent, late emergence, weed patches, rabbit damage, nutrient imbalance
    - Non-visible: NDVI, Thermal, multispectral
    - Sensor limited by weight and power

2nd Generation UAS

- Tethered UAVs
- Self docking
- Automated logistics
- New engines
- Self guided
- Collaborative M2M
- Picocopters to megacopters

Crop scouting; Dionysus robot

Harper Adams University

- Crop scouting robot for vineyards
- Build by Harper Adams MEng students for the University of Athens
- Software Architecture for Agricultural Robots
- Thermal camera for irrigation status
- Multispectral camera for nutrient status
- LIDAR for canopy extent and density

Robotic Weeding

- Mechanical weeding
- Micro droplet spraying
- Laser weeding

Laser weeding

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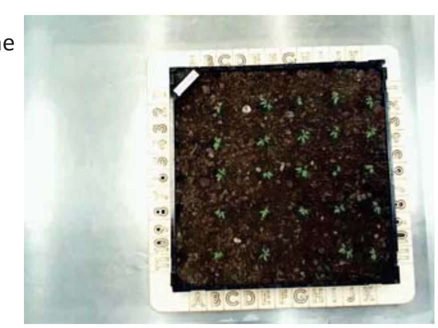
- Machine vision recognises the growing point of the weed
- Laser kills the weed by heating the growing point
- Saving 100% herbicide
- Harper Adams University is now building a real-time robot to laser and microdot weeds
- Funded by a major agrochemical company 2014-2017



The Royal Veterinary and Agricultural University

Intra-row Weeding with a Cycloid Hoe

Denmark, May 2006

Robotti

Harper Adams University

UNIVERSITY OF SOUTHERN DENMARK

Autonomous tractor

Selective harvesting

- Up to 60% of harvested crop is not of saleable quality
- Only harvest that part of the crop which has 100% saleable characteristics
  - Phased harvesting
- Pre harvest quality and quantity assessment
  - Grading / packing / sorting at the point of harvest
    - Add value to products on-farm
  - Grade for quality
    - Size, sweetness, ripeness, shelf life, protein etc
  - Minimise off farm grading and sorting
  - Add value to on-farm products

Conclusions

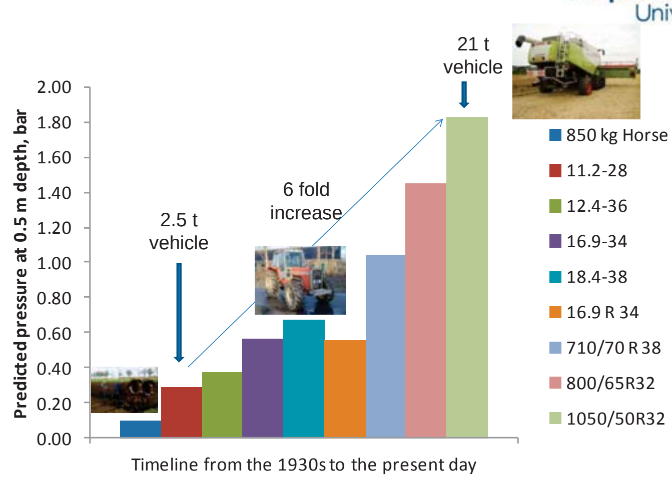
- Mobile robots will be used commercially in the arable and horticultural sectors
- Robots will be very disruptive but will have significant benefits
- We are now designing the new systems and trying to understand the implications
- We are always interested in partnerships

Current Traffic & Tillage System Research @ Harper Adams University

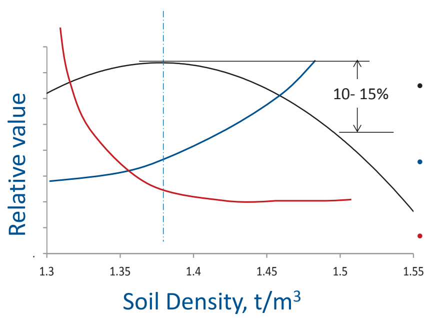
PhD Students: Emily Smith, Joseph Martlew, Anthony Millington, Rayhan Shaheb

Supervisors: Paula Misiewicz, Dick Godwin, David White, Ed Dickin, Simon Woods, Mark Moore, Tony Grift
And many others as shown on slides

Weight Increase



Background
The effects of soil compaction

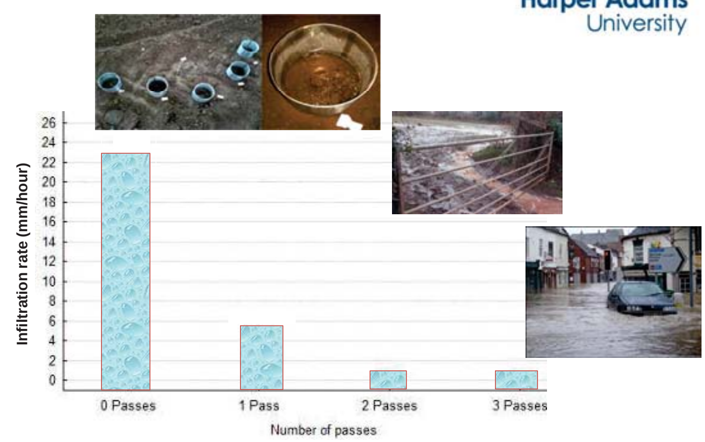


- Reduces crop yield from optimum *(Negi & McKyes, 1978)*
- Increases draught forces *(Godwin, 1974; Chamen et al, 1992)*
- Reduces infiltration rates *(Chamen 2011; Chyba, 2012)*

Economic cost in England and Wales : €1.2 - 1.6bn/annum

(Morris et al –Cranfield University, 2011)

Relationship between compaction and infiltration rate



After: Chyba, 2012

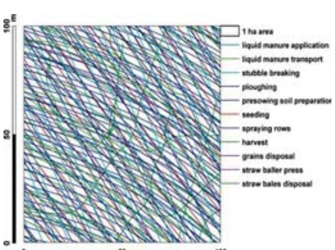
1.42 1.58 1.62 1.62
Soil Density g/cc

Random Traffic Problems

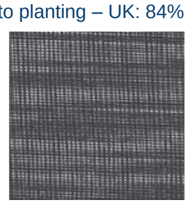
Extensive areas of the field are exposed to trafficking

- Random Traffic + plough = 85% covered
- Minimum Tillage = 65% covered
- Direct Drilling = 45% covered

Winter wheat – Czech Republic *Kroulik et al., 2009*

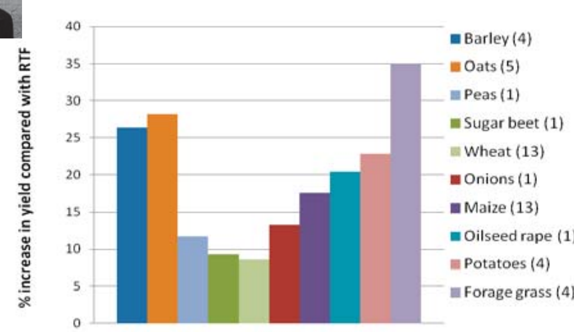


Potato planting – UK: 84% cover



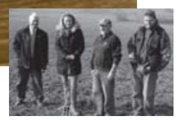
Kroulik , Misiewicz, White and Godwin, 2012

Average yield benefit from CTF



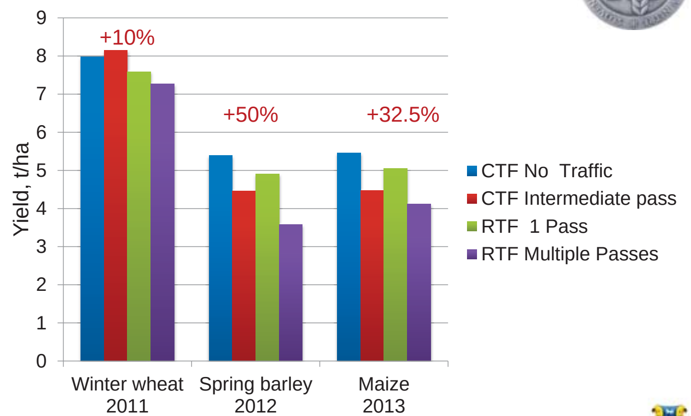
The average yield benefit from CTF compared with random traffic farming. Numbers in parenthesis indicate the number of studies reported.
(After: Chamen, 2011)

Field Scale Studies: Slovakia



After: Galambosova, Rataj, Macak, Chamen and Godwin, 2012

Grain yield (t/ha)



After: Galambosova et al., 2015

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HAU Research Sites

Traffic and Tillage Systems Study

Harper Adams University

Aim: To compare the effects of alternative traffic and tillage systems on crop yield, energy and economics, water holding and infiltration rates over an extended period circa 10 years.

2011 - 12: Winter Wheat (normalisation year)
2012 - 13: Winter Wheat
2013 - 14: Winter Barley
2014 - 15: Winter Barley
2015 - 16: Cover crop & Spring Oats
2016 - 17: Cover crop & Spring Wheat

3 x 3 factorial design

9 treatments replicated in 4 blocks
= 36 plots in total (each 4m wide)

Traffic / Tillage	Random Traffic Farming	Low Ground Pressure	Controlled Traffic Farming
Deep tillage	250mm	250mm	250mm
Shallow tillage	100mm	100mm	100mm
Zero tillage	0mm	0mm	0mm

After: Smith, Misiewicz, Chaney, White and Godwin, 2013/2014

Harper Adams University

Tillage and Traffic Systems Study

Harper Adams University

Year 1 (2011- 2012)
- Site normalisation to investigate the variability of the field after drain installation and subsoiling with a winter wheat crop using CTF

Years 2 – 5 + (2012 – 2017++)
- Plot trials
- 3 Traffic X 3 Tillage treatments

Smith et al., 2013/2014

Soil Uniformity

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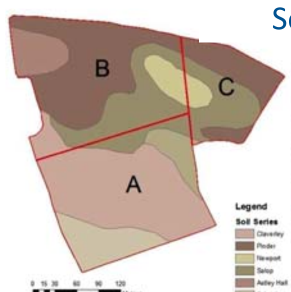
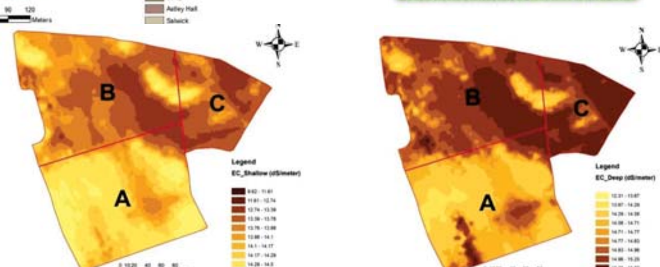
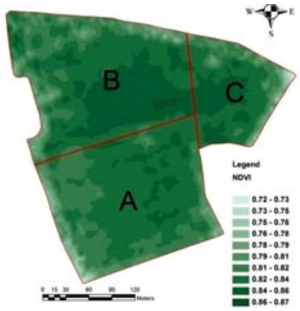




After: Kristof et al. 2012

Crop uniformity - 2012



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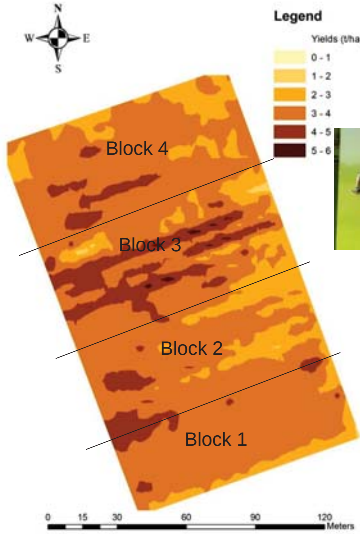
After: Kristof et al. 2012

Crop Uniformity (t/ha)



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Smith et al., 2013

RDS Ceres 8000i

Finalised plot design

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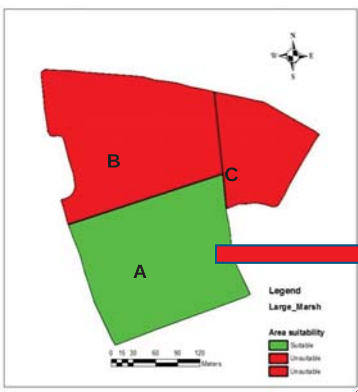
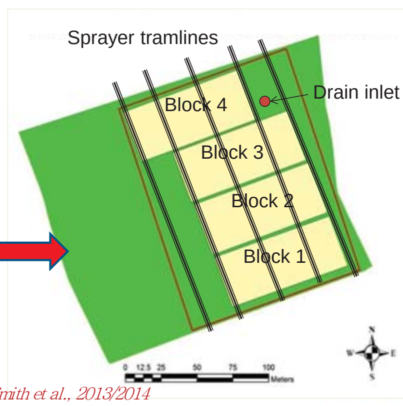
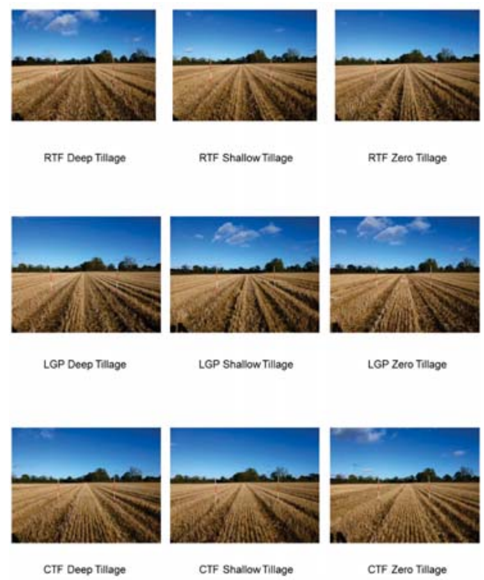




Smith et al., 2013/2014



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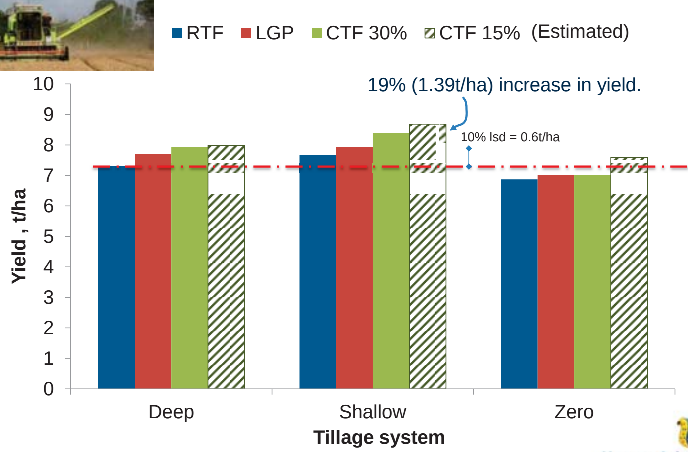
Traffic wheel patterns in October 2012

Smith et al., 2013/2014

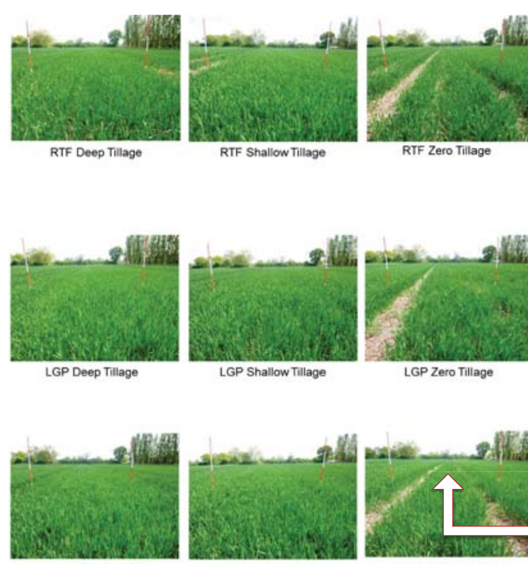
Winter wheat yield - 2013

Combine Harvester Results



Smith et al., 2014

Harper Adams University



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Crop condition on 29th May 2013

Zero tillage has a problem in wheel marks in all traffic systems

Smith et al., 2014

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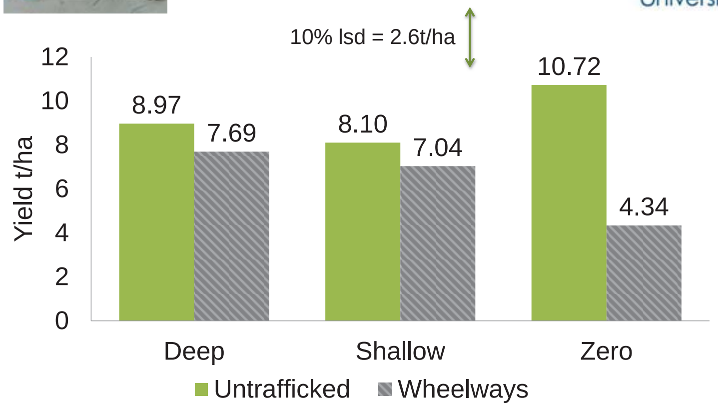
Winter Wheat Yield - 2013

Hand Sample Results



Untrafficked yields significantly higher than Wheelways (p<0.05)

Smith et al., 2014

Draught force and fuel consumption



Treatment	Tillage draught force, kN	Drilling draught force, kN	Fuel consumption for Tillage + Drilling, l/ha
Deep Tillage - 250mm	64.9	15.9	22.16
Shallow Tillage -100mm	21.3	16.7	16.42
Zero- Till	0	16.5	8.82

No difference from the effect of traffic systems

After: Arslan et al 2014

Less of a problem with Zero-till in May 2014

Winter barley

Smith et al., 2014

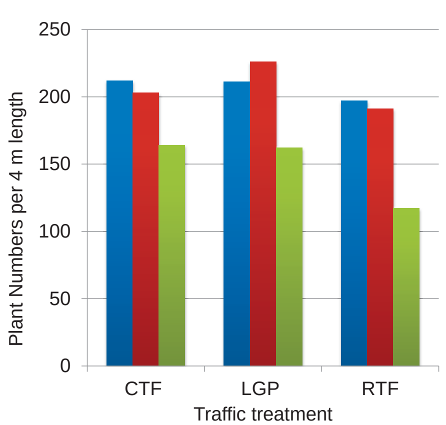
Less of a problem with Zero-till in May 2015

Winter barley

Millington et al., 2015

Winter Barley – Plant Numbers

May 2015



	Tillage Mean
Deep Tillage	207
Shallow Tillage	206
Zero-Till	148

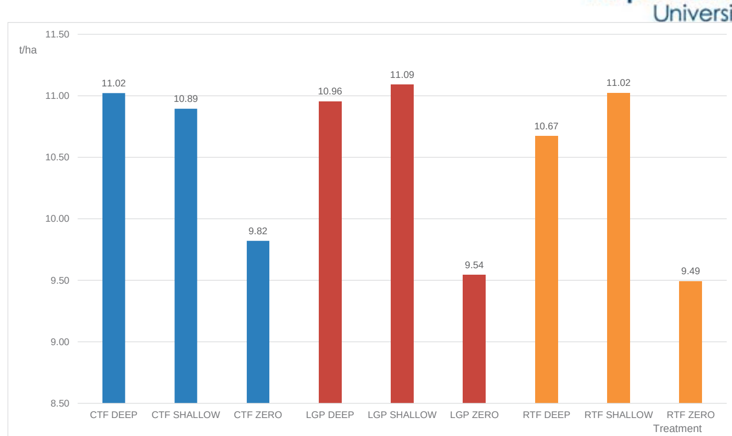
= + 40%

Traffic Mean 193 200 168 = +19%

Millington et al., 2015

Winter Barley – Combine Harvest

August 2015



A significant effect of tillage (p=<0.05).

Studies of 3 Tillage x 3 Traffic systems in Zambia

Conventional | Conservation | Zero/No - till

A significant (22.73%) reduction (p=<0.05) in crop emergence between trafficked and un-trafficked treatments. However, the differences between individual traffic and tillage treatments were insignificant (p=>0.05) for 1st season.

Martlew et al., 2015

Studies of 3 Tillage x 2 Traffic systems at the University of Illinois

Effect of tyre inflation pressure on soil conditions and crop yield for 3 tillage systems in corn/soya bean rotations

Conclusions

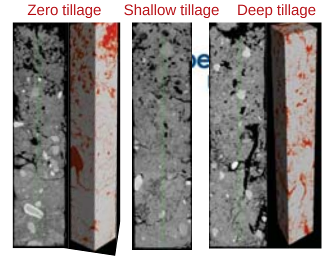
- The data show that in comparison to "conventional farming practice" numerous studies have shown benefits from alternative traffic management practices.
- In particular in the Tillage x Traffic Study at Harper Adams shows: -
  - The CTF/Shallow tillage treatment with a 30% traffic lane area showed a significant (p<0.10) 15% (1.1t/ha) increase in winter wheat yield, and
  - The estimated CTF/Shallow tillage with a 15% traffic lane area showed a 19% (1.39t/ha) increase in winter wheat yield.
  - The Low Ground Pressure/Shallow tillage treatment showed a significant (p<0.10) 9% (0.64t/ha) increase in winter wheat yield.
  - In a good year crops might be able to "cope" with soil compaction.
- Managing traffic lanes is critical especially with Zero-tillage in wet conditions.
- CTF and Zero Tillage should be good companions.
- Guidance and navigation systems need to be reliable and compatible.

Further work

1. Further improve reliability and compatibility of PA systems.
2. Further improve the equipment for fully integrated mechanization.
3. Evaluate the soil conditions that provide optimal crop development.
4. Consider the use of lower tyre inflation pressure options.
5. Additional work is needed for grass and forage production.

X Ray Computer Tomography

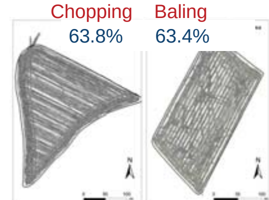
Zero tillage | Shallow tillage | Deep tillage



After: Mooney, University of Nottingham

2 Studies 1. SRUC and Harper Adams in Scotland
2. BOKU in Austria

Chopping 63.8% | Baling 63.4%



Kroulik , Misiewicz, White and Godwin, 2012

Thank you for your attention
and
the support of our sponsors

Final reflection

"Man has only a thin layer of soil between him and starvation".
Anonymous

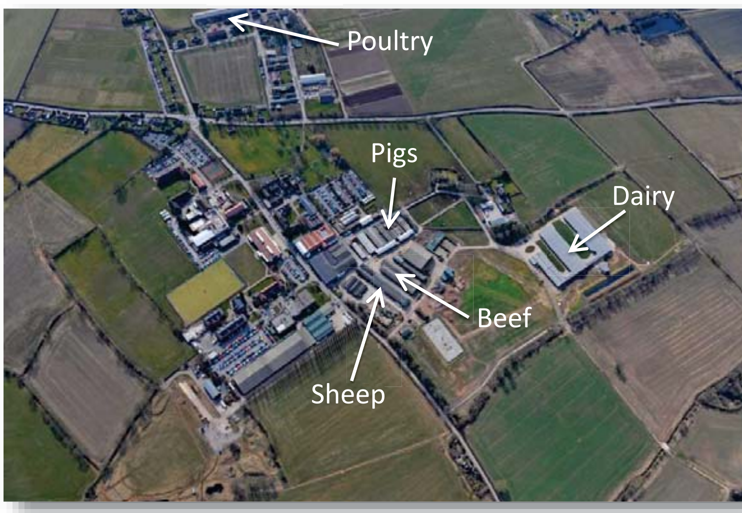
Harper Adams University

Precision Livestock

Dr Mark Rutter
Reader in Applied Animal Behaviour
Head of Precision Livestock, NCPF

Animal Science Resources

- 400 cow dairy unit
- 240 sow pig unit
- Intensive beef unit
- 200 ewe early lambing flock
- Grass finishing beef and lamb
- Intensive poultry systems
- Laboratories
- Food science labs



Precision dairy technologies

- Range of precision technologies being used on our existing dairy unit:

Precision feed mixing

Behaviour monitoring

Intake monitoring

Partners:

iCEROBOTiCS
Harper Adams University
Kingshay INDEPENDENT DAIRY SPECIALISTS
DAIRY CREST

Co-funded by: Innovate UK Technology Strategy Board

DASIE Project

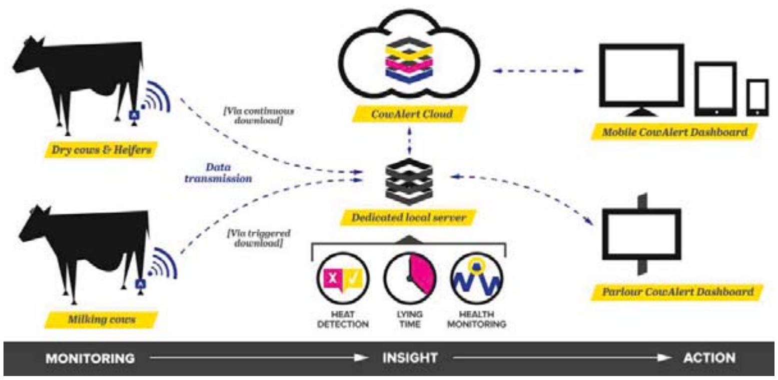
- DASIE is designed to explore how behaviour-monitoring technology can be used to help farmers manage their business more efficiently while simultaneously improving animal health and welfare
- The project involves:
  - field testing on research farms
  - economic validation on commercial herds
  - communication with the dairy farming community

DASIE Project

DASIE Project

- The project is exploring integration with existing farm systems and equipment such as milk meters and feed dispensers, maximising the systems farmers already have:
  - Systems integration
  - Optimised alerting
  - Economic validation

DASIE Project



UK Agri-tech Strategy

- Launched 22 July 2013
- "Aims to improve the translation of research into practical application for agriculture and related industries in UK and overseas"
- £160M government investment over 5yrs:
  - Agri-tech Catalyst (£70M)
  - Centres for Agricultural Innovation (£90M)

Department for Business Innovation & Skills

Department for Environment Food & Rural Affairs

Department for International Development

Animal ~~Engineering~~ focus

Domestication history

- Since their domestication, cattle have usually spent at least part of the year at **pasture**
- Increasing numbers now being **continuously housed**…
- …although some Scandinavian countries now require cows to spend part of the year at pasture

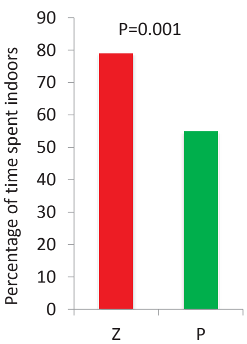
But what do the cows prefer?

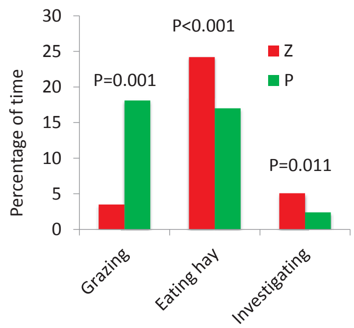
- But do the cows **prefer** to be at pasture?
- And what **factors** influence their preference?
- A series of experiments have been conducted at Harper Adams over the last 8 years

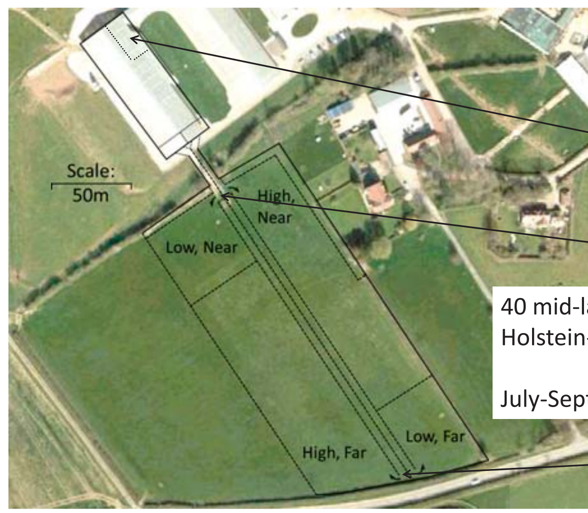
Effects of previous experience

- Holstein Friesian heifers reared in two groups, either:
  - **P**: with **maximum** exposure to pasture
  - **Z**: with **no** exposure to pasture
- Tested their preference (n=24) for pasture at approx. 16 months

Effects of previous experience







Continuously housed cows

Near 38 m

40 mid-late lactation Holstein-Friesians

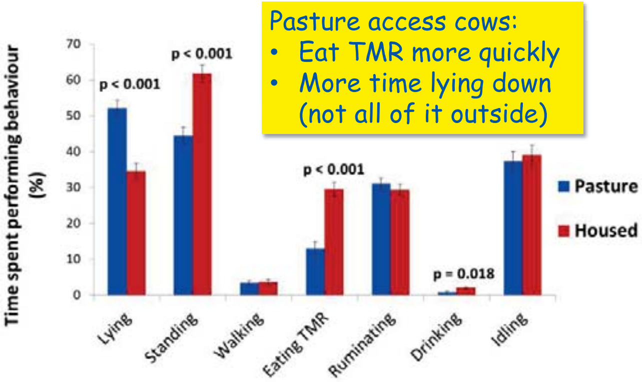
July-September 2011

Far 254 m

Harper Adams University

Continuous housing vs pasture access

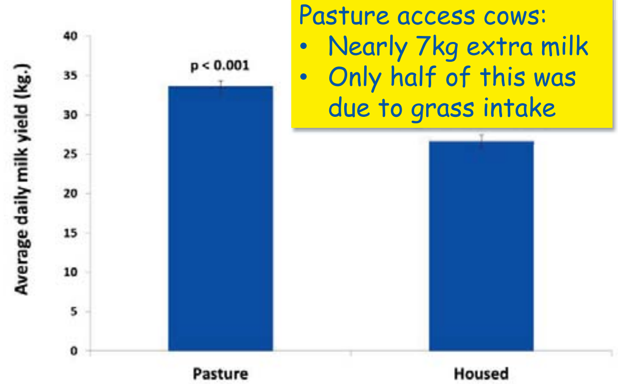
Harper Adams University



Pasture access cows:
- Eat TMR more quickly
- More time lying down (not all of it outside)

Continuous housing vs pasture access

Harper Adams University



Pasture access cows:
- Nearly 7kg extra milk
- Only half of this was due to grass intake

Pasture preference conclusions

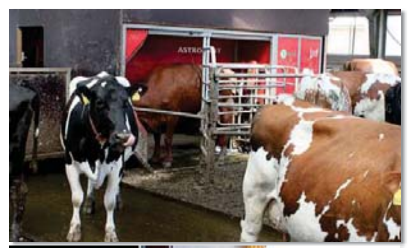
- **Many factors** affect cow preference for pasture:
  - Cows prefer indoors when it is **wet** and/or **cold**
  - Cows are more motivated for pasture at **night**
  - **Grazing** does not appear to be a major factor influencing the preference of high-yielding cows for pasture
  - Pasture access increases **lying times**, as pasture may be more comfortable than cubicles
  - Pasture access gives **higher milk yields**, possibly due to **increased comfort**
  - **Previous experience** has a big effect on preference for pasture, and grazing appears to be **learned** and not innate

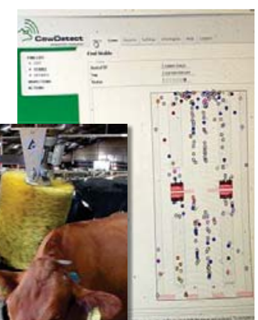
A new approach to 'housing'?

- Cows need (and want!) to be housed for part of the year
- Use a 'preference' approach to help us redesign cow housing and management
- Use 'smart' technologies to help facilitate cow choice
- e.g. adaptive ventilation responding to cow movement in the building
- Bring the best of 'outdoors' to indoors such that the new environment meets the needs of cows 365d/yr
- Cow Oriented Management for Improved Efficiency (COMFIE)

Are precision farming technologies only applicable to intensive farms?

Danish organic dairy farm





Now GEA 'CowView'

Ice-free land use

Pasture makes up:
¼ of ice-free land
⅔ agricultural land

- Pasture
- Crops
- Other
- Undeveloped

Precision grassland management

- The precision 'arable' approach is applicable to grassland management…
- …but only when the herbage is **mechanically** harvested (i.e. when we can map yield)
- So what about when grassland is **grazed**?
- Can we use a precision approach to manage grazed grasslands?

Grazing management

- Measure the available herbage (kgDM Ha^{-1})
- Match this to the intake requirement of the animals to be grazed
- Control access e.g. using strip grazing

Herbage measurement ⇔ Measuring grazing and intake ⇔ Control grass access

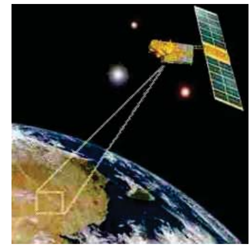
"You can't manage what you can't measure"

Herbage measurement

- Technology is already helping farmers to measure herbage mass:

Rising plate meter

Vehicle-based 'Pasture Meter'



'Pastures from Space'

Control grass access

- Technology is also available to help automate controlled access to grass:

Electronic gates

Timed release gates

Robotic fences

- Virtual fencing

Grazing management

Herbage measurement ✓ ⇔ Measuring grazing and intake ? ⇔ Control grass access ✓

- Can techniques developed by **researchers** to study grazing behaviour be adapted for use on-farm?

Bioacoustics

Microphone → Radio transmitter → Radio receiver connected to video camera i.e. the sound you will hear in the video is transmitted from the cows head

Noseband → 'IGER' Behaviour Recorder

Bioacoustics

Head up

Mainly chew-bites

Chews

Herbage availability

High herbage availability → Low herbage availability

Few bites : **Many chews** → **Many bites** : Few chews

A bioacoustic problem

- The microphone can pick up the sound of conspecifics grazing alongside the subject…
- …so may need to be combined with other sensors e.g. accelerometers

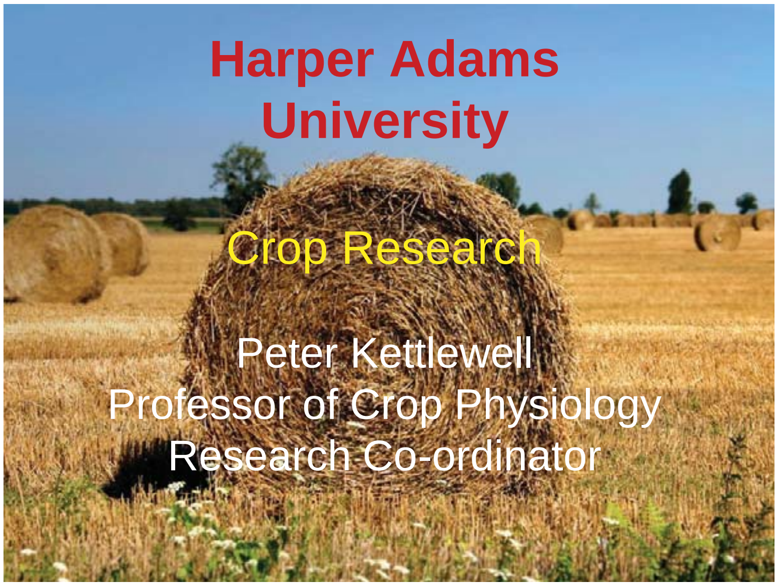
Bioacoustics potential

- Originally needed the human ear to detect bites and chews, but algorithms have been developed to do this **automatically**
- Research has shown the energy density of chewing sound is proportional to bite mass, so has the potential to monitor **intake**
- Has the potential to detect different **plant species** and differences in **herbage quality**

Precision Livestock Farming

Common misconception: Precision farming is all about the further **intensification** of farming

- The principles of precision can be applied to **extensive farming**
- Indeed, precision farming can bring the monitoring and control usually associated with intensive farming to free-ranging animals
- i.e. improve the **efficiency** of extensive systems


Harper Adams
University
Crop Research
Peter Kettlewell
Professor of Crop Physiology
Research Co-ordinator

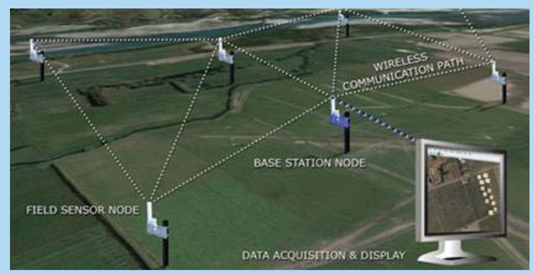

Fitotron


1
2


POT
SPRAYER

Precision Irrigation Research
Tom Norton, Ivan Grove, Sven Peets

wireless sensor networks for optimised irrigation scheduling

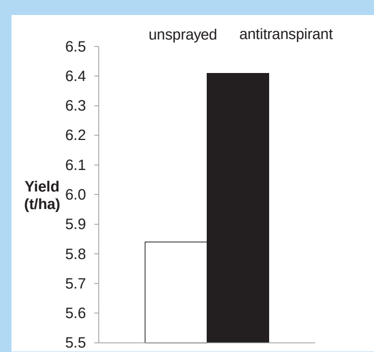


Drought tolerant crops
Ivan Grove

Quantifying water use parameters of quinoa -
a developing crop in the UK

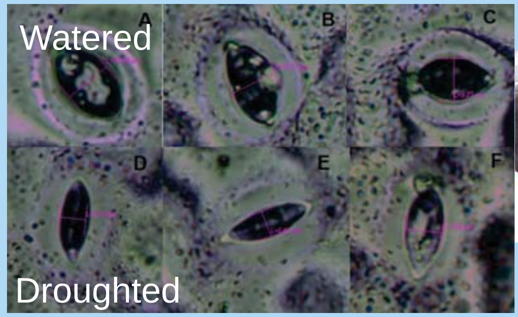
Drought Protection
Peter Kettlewell

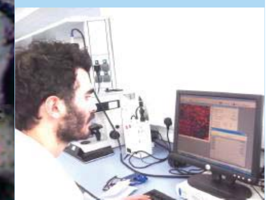
Waterproof the leaves with
film antitranspirant spray at GS 33



Drought damage - wheat 2011

Stomata (pores) on canola (*Brassica napus)* leaves – need to detect stomatal closure





Potato Cyst Nematode

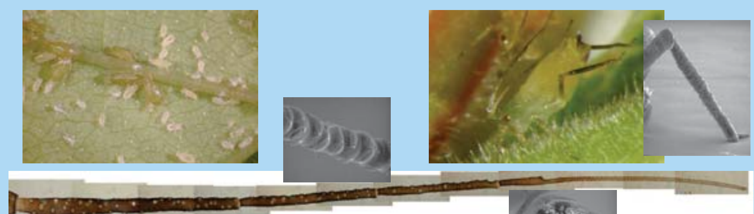
Ivan Grove

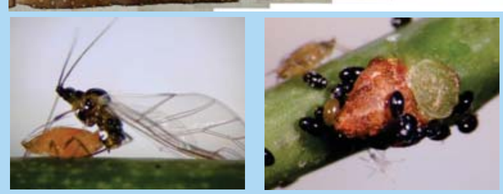
Hyperspectral sensing on aircraft successfully discriminated early stage damage

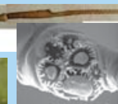
Aphid Biology

Simon Leather

Key agricultural and horticultural pests:



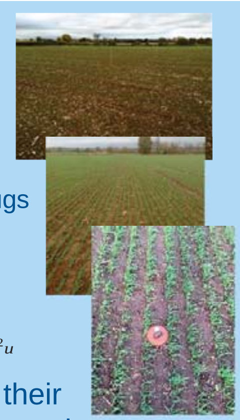




Photos illustrating different stages of aphid life cycles and morphological features involved in pheromone production and odour detection

Slug Research

Keith Walters



- Field investigation to establish:
  - Within-field spatial dynamics of slugs
  - Within-patch dynamics
- Modelling of patch dynamics

$$\frac{\partial u(\mathbf{r},t)}{\partial t} = D\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) = D\nabla^2 u$$

- Characterisation of factors (and their interaction) determining patch formation
- Investigation of relevant slug biology behaviour to inform patch formation/ stability (Lab & field)

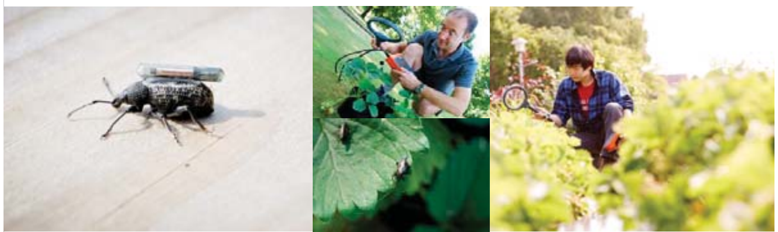
Slug Biology/Behaviour

Provides mechanistic understanding of drivers of spatial/patch dynamics

- RFID tagging: Extent/drivers of in-field dispersal
  - Tag insertion technique established
  - First use of technology on slugs in Europe
    - Little impact of tag on survival or behaviour (feeding, movement, etc.)
    - “3-d” (vertical/horizontal) movement study in field underway

Vine Weevil electronic tagging
Biocontrol agent application
Tom Pope

Harper Adams University



Reducing mycotoxin risk from fusarium disease

Simon Edwards

PhD student: Tijana Stancic

Lodging and Plant Growth Regulators

Mitch Crook

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CANADA-UK FOUNDATION

Rick Bastiani
Project Administrator
rick@canadaukfoundation.org

AWARDS FOR TRAVEL TO CANADA IN 2016

ACADEMIC STAFF AND DOCTORAL STUDENTS OF UK UNIVERSITIES

APPLICATION DEADLINE MARCH 15, 2016

Foundation Travel Awards of £1000 are available to assist faculty and doctoral students pursuing Canadianist research in UK universities to make a research visit to Canada, lasting a minimum of at least one week.

How to apply

1. Completed application forms, downloadable from the Foundation web-site www.canadaukfoundation.org should be sent as email attachments, clearly labeled with the applicant's name, to rick@canadaukfoundation.org. A signed hard copy version must also be submitted to: Rick Bastiani, Project Administrator for the Canada-UK Foundation, 34 Grange Avenue, Luton, Bedfordshire, LU4 9AT.

2.In addition to their application, applicants must arrange for one reference to be sent by email, separately and in confidence, by the appropriate deadline date, to Rick Bastiani rick@canadaukfoundation.org . Referees should be familiar with the work driving the visit to Canada, and able to confirm the relevance of the Canadian visit to the applicant's research and the attainability of the proposed outcomes. They should in addition confirm the institutional status of the applicant- as a contracted, salaried member of staff at a UK university (faculty), as a registered postgraduate at a UK university (doctoral student).