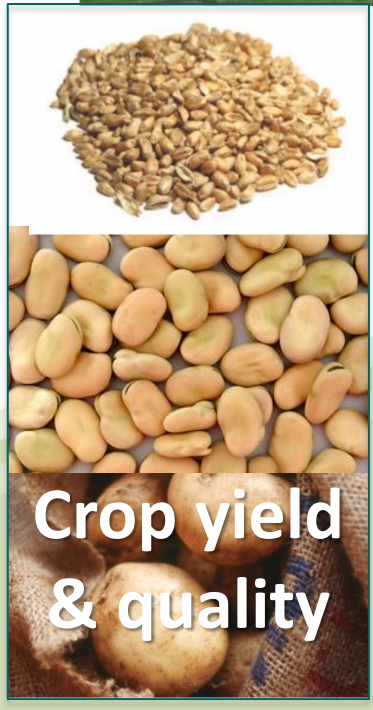
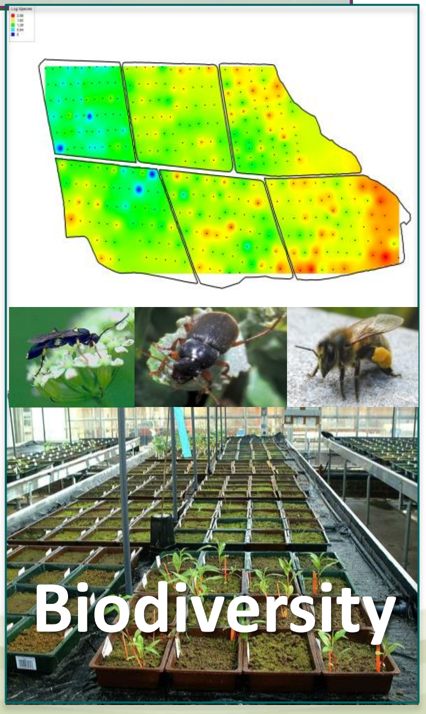
The Centre for Sustainable Cropping

The James Hutton Institute

A whole-systems approach for optimising crop production and environmental health for long term food security.





Objectives

- Design a “sustainable” cropping system (management and crop varieties) to optimise:

Inputs & Yield Vs Environmental health, Biodiversity & Ecosystem processes

- Compare this system against conventional management

- System defined according to 3 categories:
  - Ecological (biodiversity for ecosystem services)
  - Environmental (reduced environmental footprint)
  - Economic (maintain yield with less non-renewable inputs)

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Management options

	Ecosystem function/service	Management change
1. Ecological	• Diverse weeds and foodwebs • Regulation of pests and disease • Pollination • Decomposition and nutrient cycling	• Reduced herbicide to achieve 5-10% cover of dicots • Threshold crop protection to minimise non-target effects • Conservation headlands & margins for natural enemy and pollinator resource supply
2. Environmental	• Soil physical structure for optimal plant rooting and erosion control • Enhancing water quality by reducing losses to soil water • Air pollution mitigation. • Reducing carbon footprint	• Non-inversion tillage • Stubble, compost incorporation • Cover cropping • Variable rate agrochemical inputs • Engineered riparian buffers and multifunctional margins
3. Economic	• Primary productivity - efficient conversion of resource to harvestable yield	• Alternative sources of plant nutrients, e.g. BNF to compensate for reduced N • IPM to compensate for reduced agrochem inputs • Environmental management (2) to enhance production efficiency

Indicators for monitoring impact

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	Ecosystem function/service	Indicator
1. Ecological	• Diverse weeds and foodwebs. • Regulation of pests and disease. • Pollination. • Decomposition and nutrient cycling.	• Arable weed seedbank • Emerged weed and margin flora diversity • Surface active invertebrates (pitfalls) • Epigeal invertebrate diversity (vortis) • Crop pests and diseases • Pollinators and pollination rates • Earthworms and litter decomposition
2. Environmental	• Soil physical structure for optimal plant rooting and erosion control. • Enhancing water quality by reducing losses to soil water. • Air pollution mitigation. • Reducing carbon footprint.	• Soil strength, carbon content, water holding capacity, • Soil nutrient supply • Sediment loss and run-off • N and P conc in soil water • GHG emissions • Carbon footprint
3. Economic	• Primary productivity - efficient conversion of resource to harvestable product.	• Crop yield, health and product quality • Production efficiency and financial margins (calculated from input costs against sale price)

The CSC platform

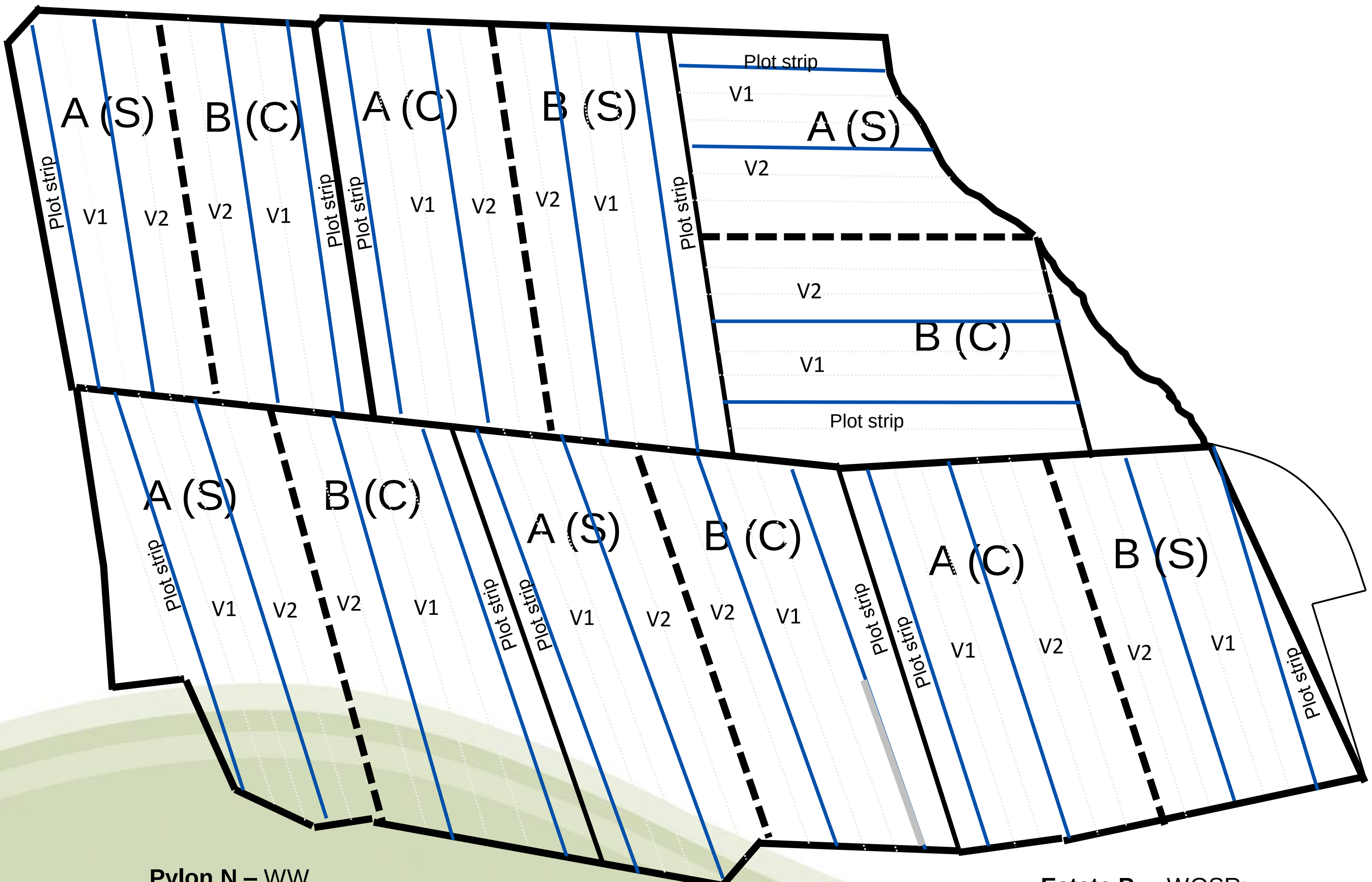
- Six course rotation:

Potato – Winter wheat – Winter barley – Winter oilseed – Beans – Spring barley

- 42 ha, 6 fields
- Split field design

Field layout from autumn 2016

Road K - Potato **Middle East L–** SB **Den South M -** Beans



Pylon N – WW
PS: Myriad or Consort
V1: Viscount
V2: Leeds

Kennels O – WB
PS: Retriever
V1: Infinity
V2: Bazooka

Estate P – WOSR:
PS: Harnass
V1: Cracker
V2: Anastasia

The Sustainable Cropping System

- Non-inversion tillage (10cm)
- Tied-ridging (potatoes to reduce erosion)
- Clover undersowing (additional N input in SB)
- Compost addition (10t/ha before sowing)
- Straw incorporation (economic vs environmental benefit of cereal straw to be assessed)
- Reduced mineral fertiliser (75%, to be replaced with alternative sources of nutrients)
- Reduced herbicide (aiming for 5-10% cover of dicot weeds)
- Pesticides/fungicides (threshold levels – use HGCA dose response curves)
- Cover cropping (oil radish)

- Variable rate liming, fertiliser
- Controlled traffic
- IPM strategies
- Direct drilling
- Intercropping

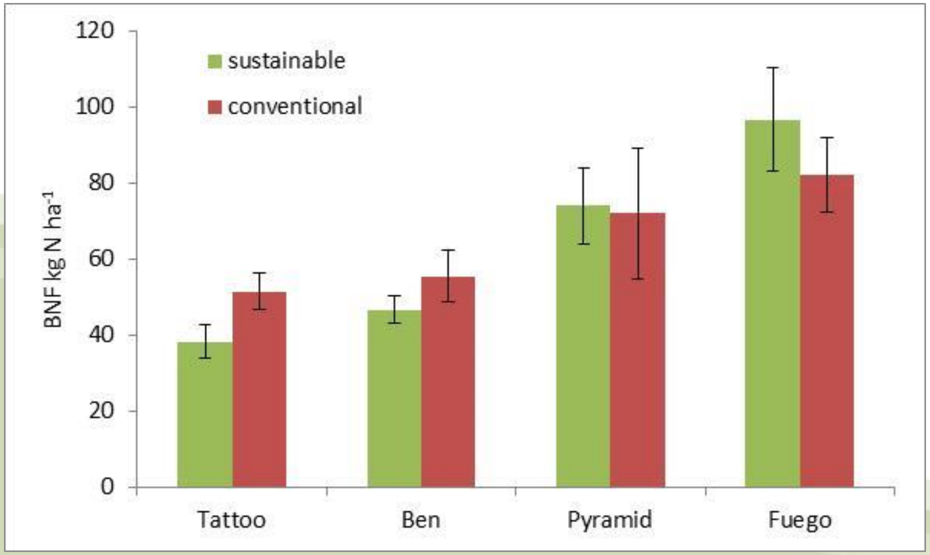
Preliminary findings

Effect of the “sustainable” cropping on three system components:

- Environmental (renewable sources of nutrients, reducing losses from the system: soil properties, leaching/runoff, GHG emissions)
- Ecological (biodiversity for ecosystem services: decomposition, pollination and predation)
- Economic (financial margins, yields)

Environmental: alternative sources of N

- BNF by Faba bean and undersown clover (EU Legume Futures, Genomia, RESAS 2.1 – novel crops)
- ^{15}N-based field studies have shown Faba bean to fix 73-335 kg shoot N ha^{-1} yr^{-1} (Jensen et al. 2010)
- $\delta^{15}N$ values of faba beans from the CSC indicated N fixation rates of over 200 kg ha^{-1} yr^{-1}
- 50 kg ha^{-1} yr^{-1} residual in soil after harvest = net gain



Contact: Pete Iannetta

Environmental: GHG emissions and leaching

- Cover boxes and lysimeters sampled every 4 weeks through growing season
- Analysis for CH_4, CO_2, N_2O (gas) NO_2, NO_3 (soil water)
- Soil samples to 25cm for NO_2, NO_3, pH, N and C, moisture content, temperature, conductivity
- Data for nitrogen loss model developed as an accounting tool for nitrogen in arable crops (RESAS 2.3 and EU AMIGA)

Nitrogen losses from arable systems across Europe estimated at:

- Soil erosion - 60 kg N ha^{-1} yr^{-1}
- Leaching /runoff - 36 kg N ha^{-1} yr^{-1}
- Gaseous emissions - 52.5 kg N ha^{-1} yr^{-1}
- Harvested material - 135 kg N ha^{-1} yr^{-1}

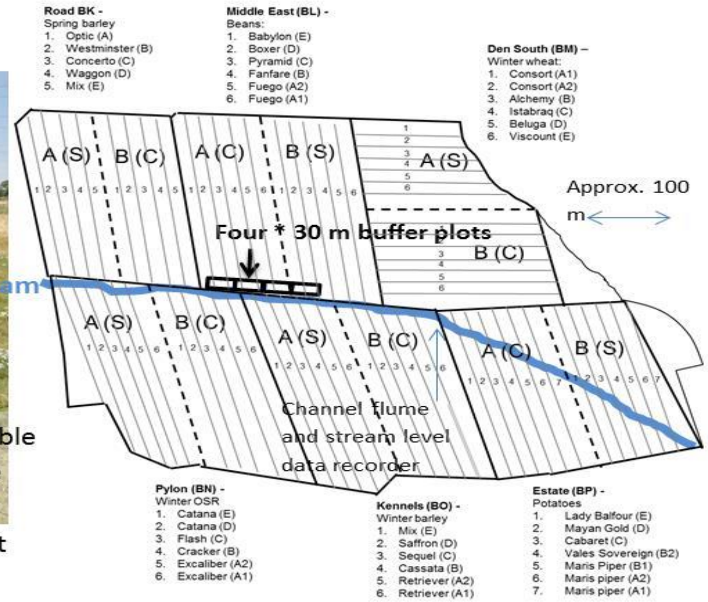
(Leip et al 2008)

Contact: Mark Young

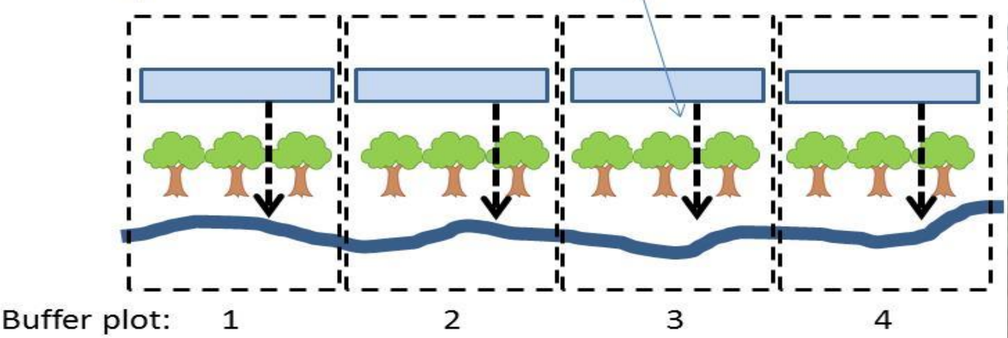
Environmental: engineered buffer zones for reducing losses (Danish Gov BufferTech)

Spill pipe with variable outlet height device between ditch and stream for each plot

Hillslope with 10 ha catchment



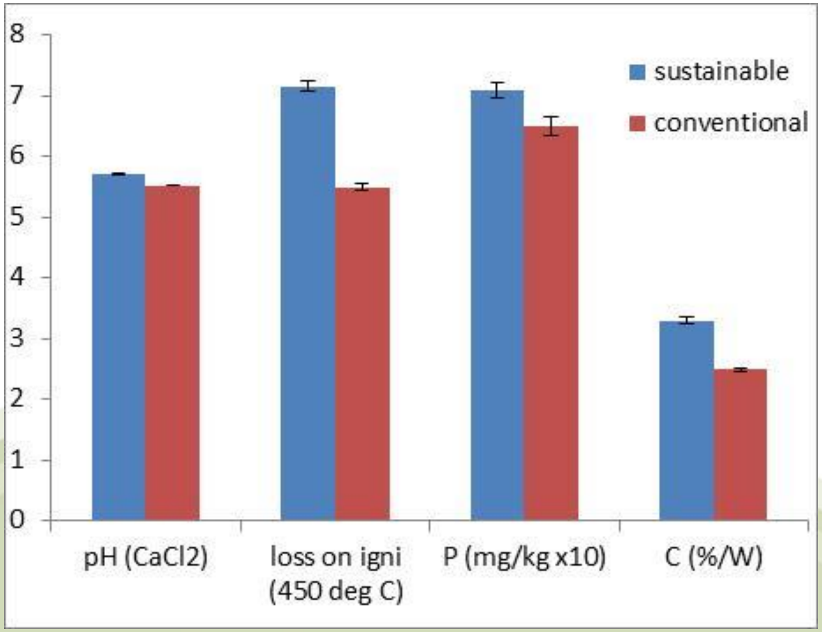
- Lysimeters (leaching into soil water)
- Run-off and sediment loss into ditches

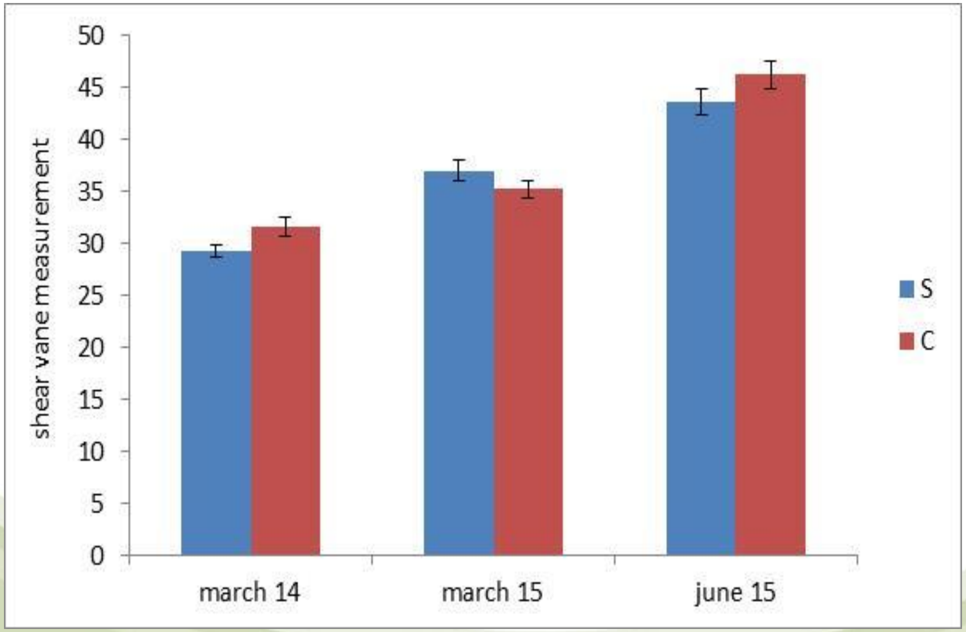


Contact: Marc Stutter

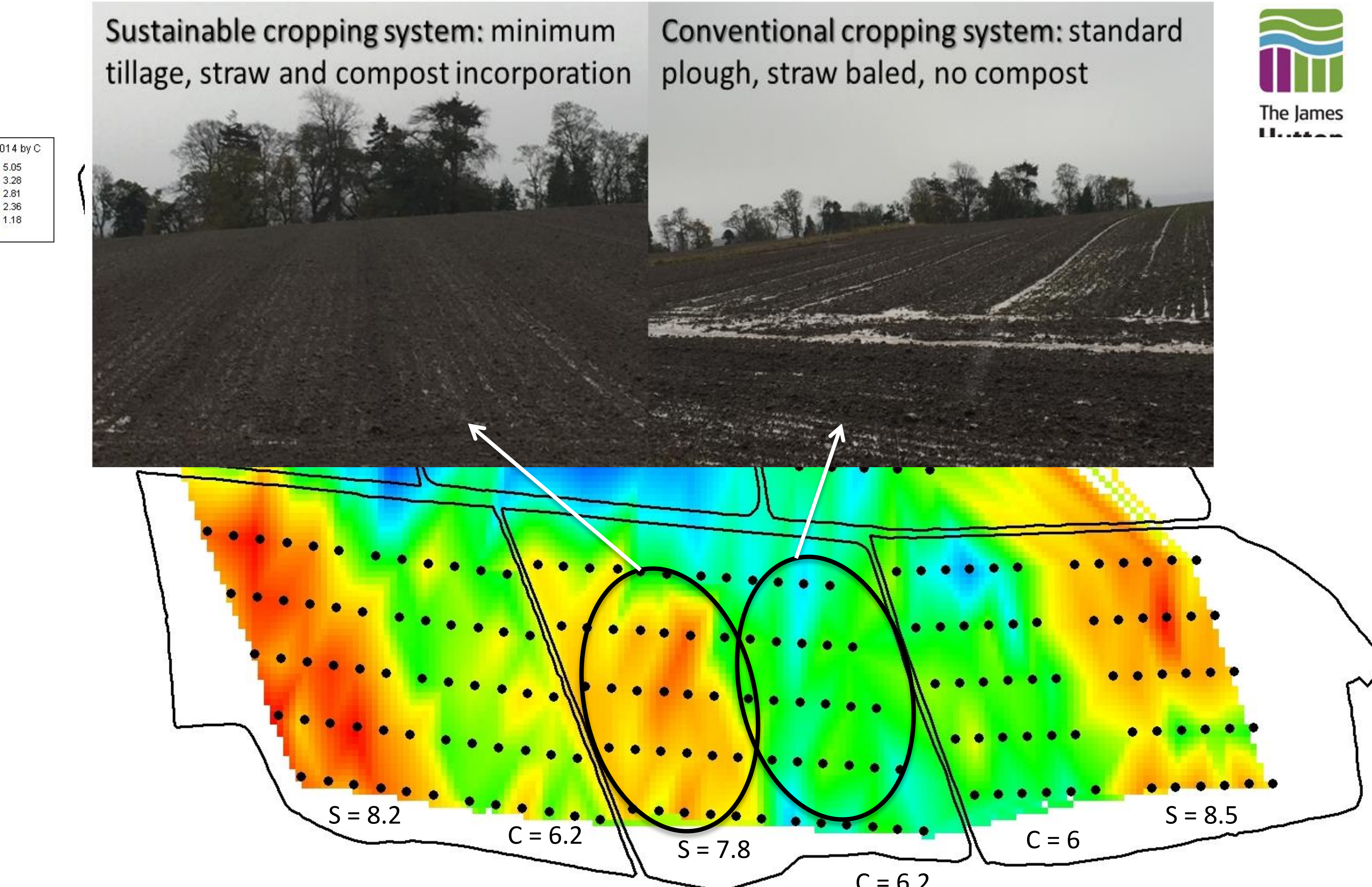
Environmental: soil properties

- Straw incorporation, compost addition, cover crops, reduced tillage, tied ridging
- Higher pH, soil organic matter and carbon, phosphorus
- No difference in soil strength between treatments



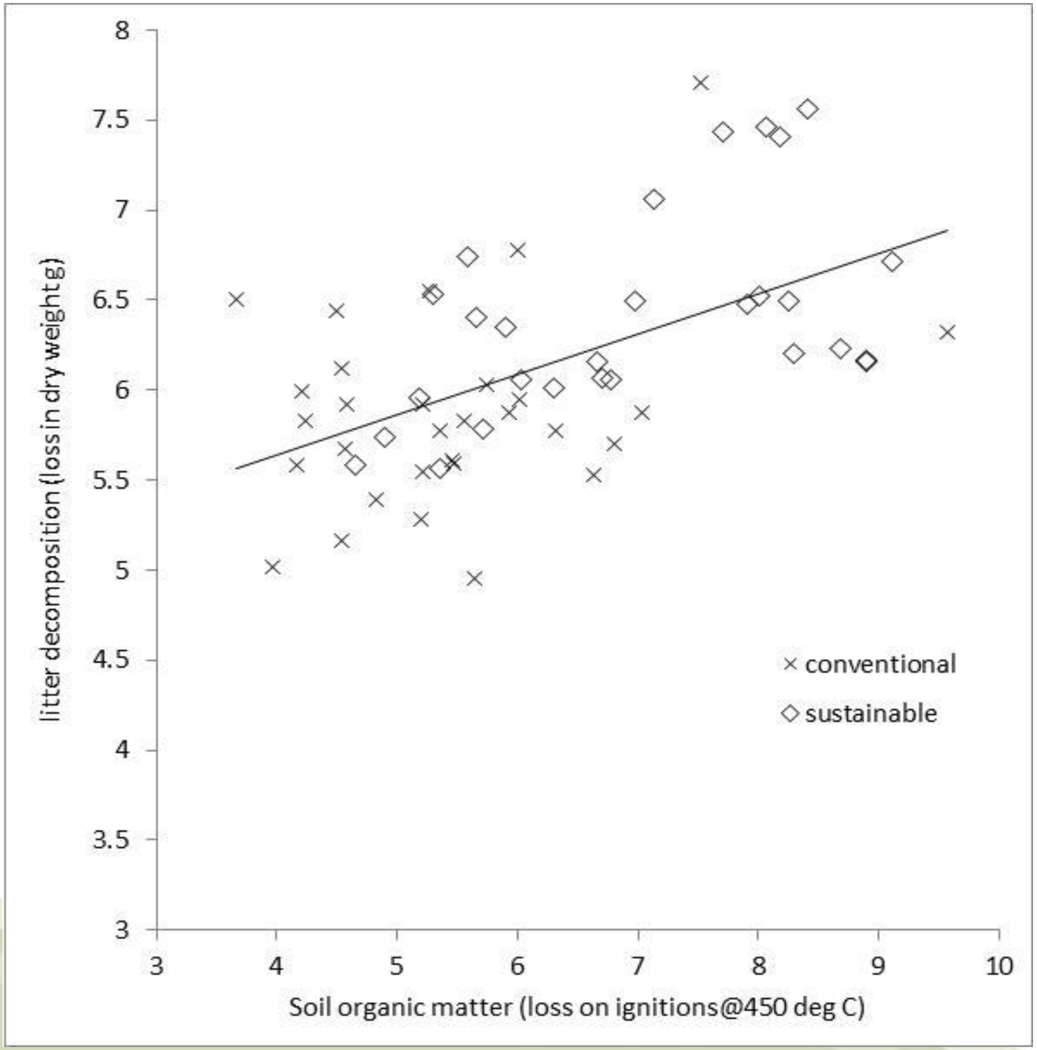


Contact: Cathy Hawes



Contact: Cathy Hawes

Ecological: biodiversity for ecosystem services

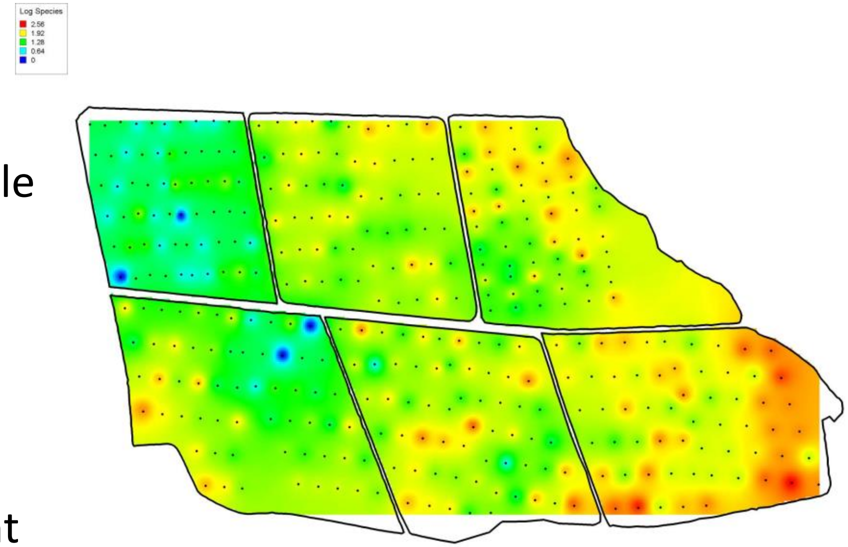


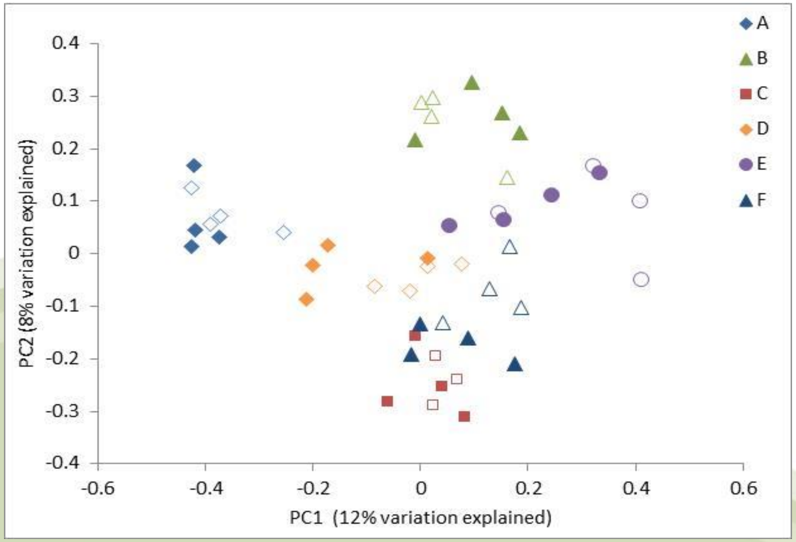
Soil carbon, litter decomposition and soil biodiversity

Contact: Cathy Hawes

Ecological: biodiversity for ecosystem services

- Soil seedbank composition assessed by seedling emergence over a permanent sampling grid
- More weeds and greater biodiversity in sustainable crops (esp spring sown)
- No direct effect of weeds on yields (within-field scale)
- Field effect stronger than within season treatment effect or previous years crop





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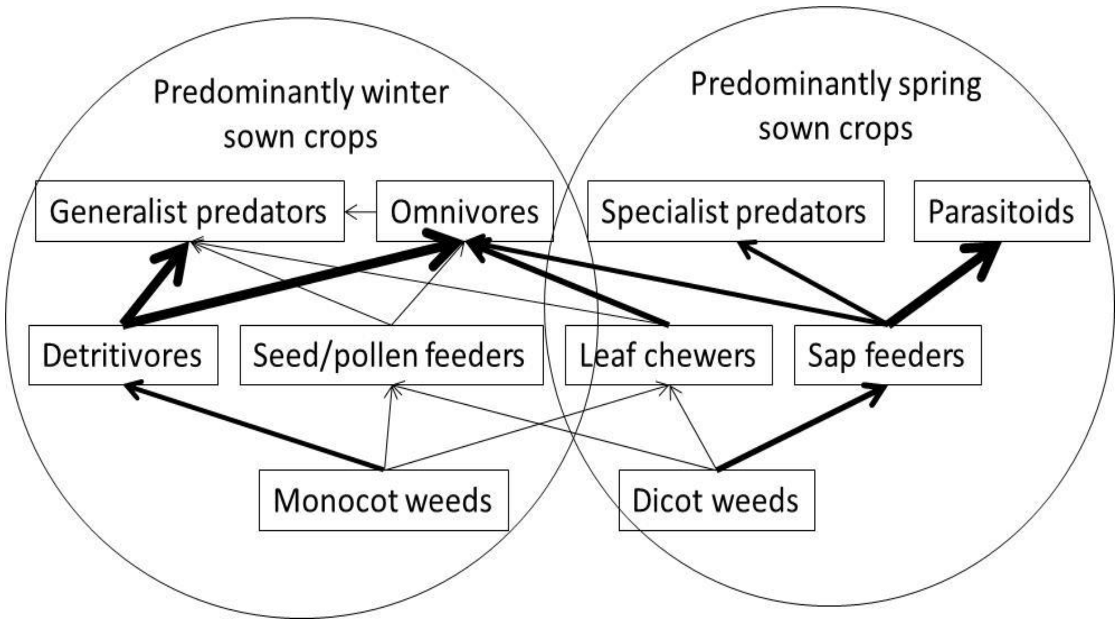
Ecological: biodiversity for ecosystem services



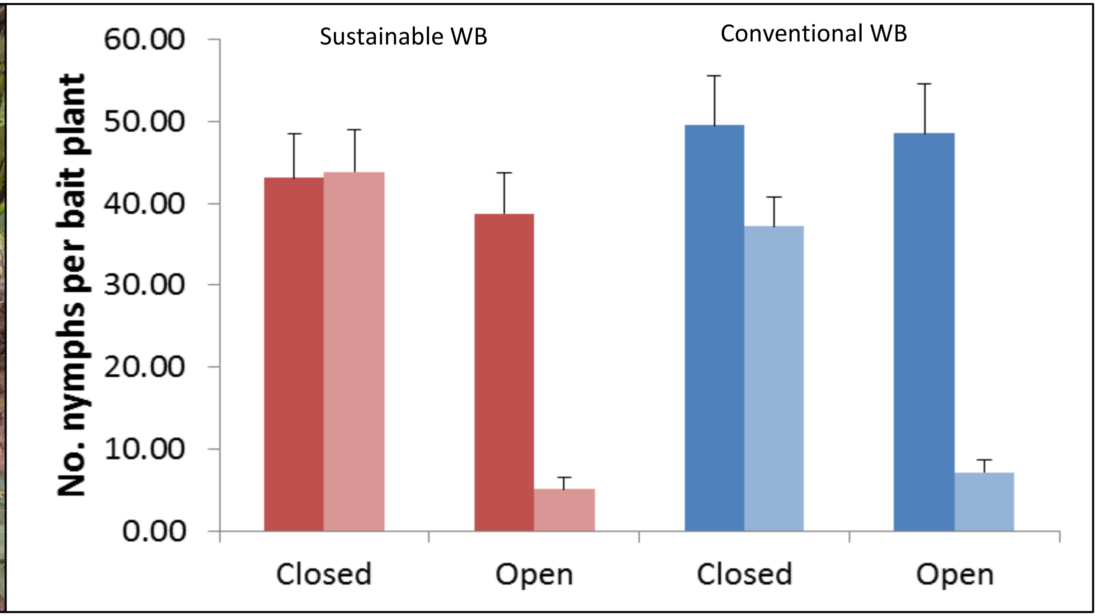
Vortis sampling, pitfall trapping and pollinator transects for:

- arable foodwebs
- pollination
- natural enemy control of crop pests

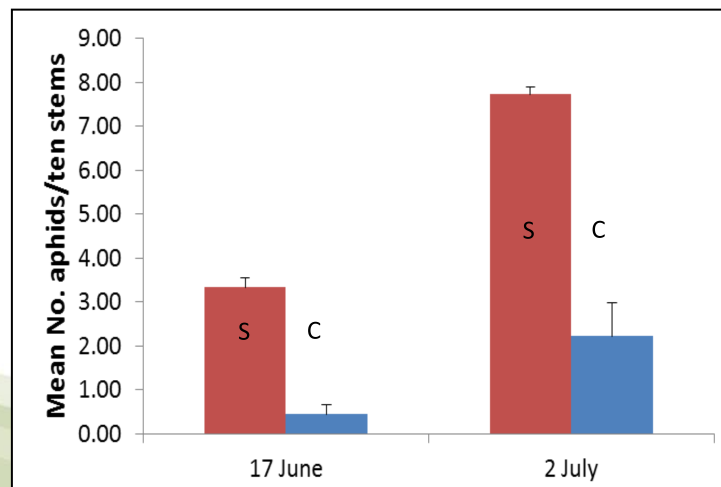
Contact: Cathy Hawes

Ecological: biodiversity for ecosystem services

Insect pest regulation by natural enemies



- Reduced aphid abundance on bait plants exposed to natural enemies
- Highest parasitoid abundance and % parasitism in sustainable potato
- Reduced aphid abundance sustainable winter cereals
- Possibly due to lower plant N content rather than natural enemies

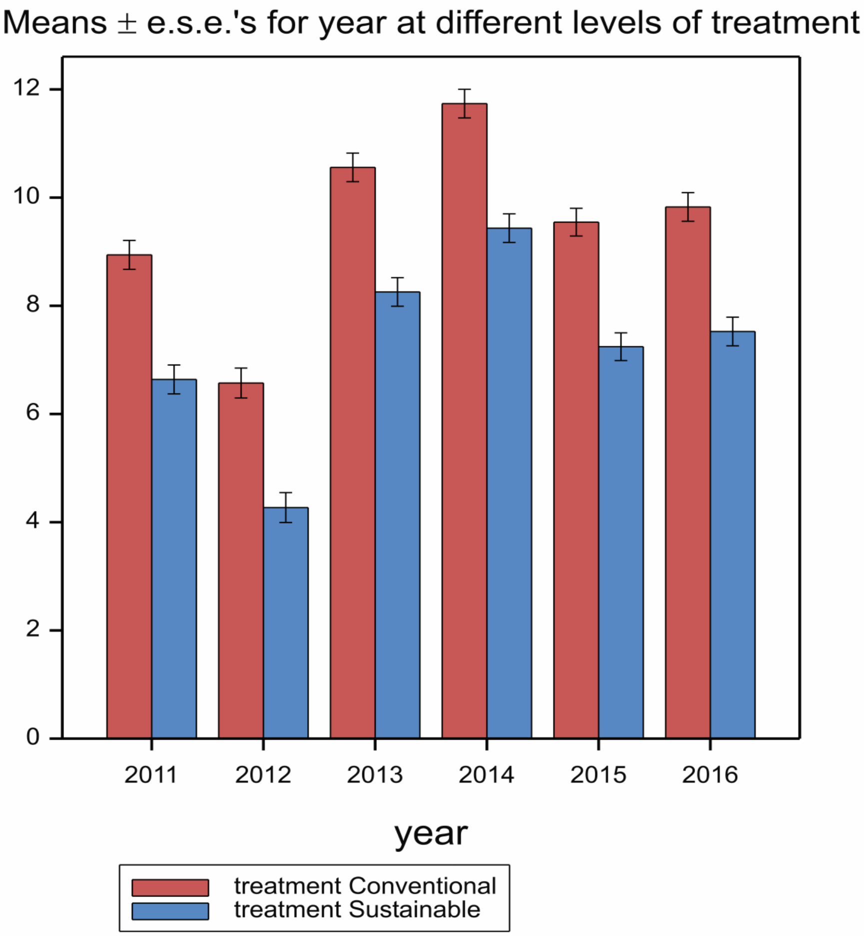


Contact: Ali Karley

Economics

- Gross margins to be estimated from
  - Product sale prices (harvested material, straw bales etc)
  - Input costs (seed, agrochemicals, compost)
  - Tractor time and fuel use
- Data being collated for final year of rotation (socio-economics group in Aberdeen)
- Yield data can be reported….

Economics: winter wheat yield



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	2.77	52.0	0.036
treatment	44.24	5.0	0.001
variety.tmt	4.40	52.3	0.004

Sustainable management:

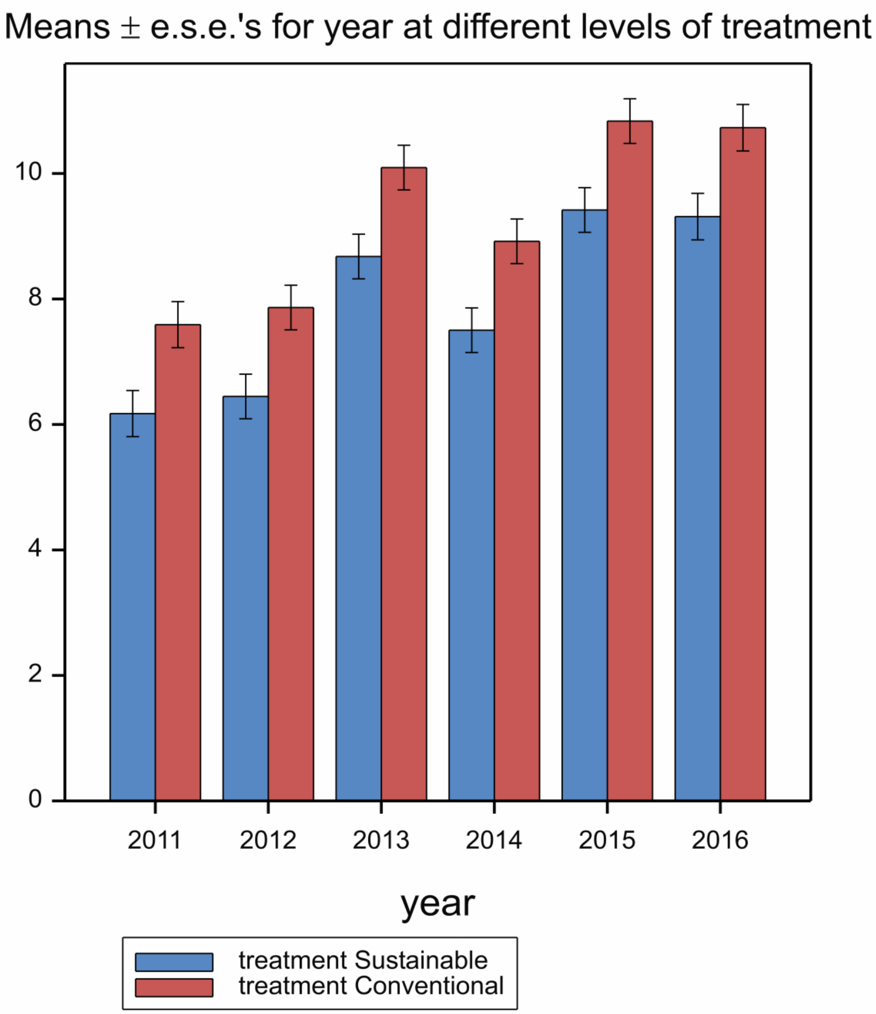
- min-till
- 35 t ha^{-1} compost + straw incorporation
- 200 kg ha^{-1} N
- 0.5 dose herbicide
- threshold fungicide

Conventional management:

- standard plough
- no compost, straw baled
- 270 kg ha^{-1} N
- full recommended dose herbicide
- standard fungicide applications

Contact: Cathy Hawes

Economics: winter barley yield



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	6.78	48.1	<0.001
treatment	6.04	5.0	0.058
variety.tmt	1.49	48.3	0.220

Sustainable management:

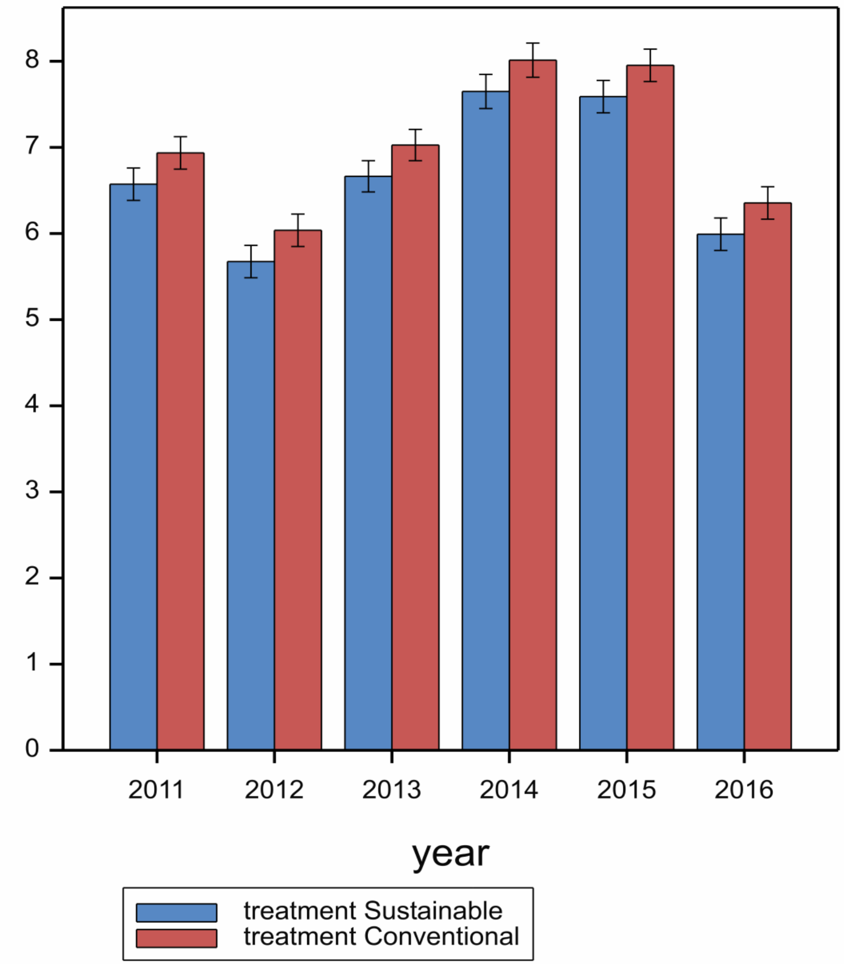
- min-till
- 35 t ha^{-1} compost + straw incorporation
- 130 kg ha^{-1} N
- 0.5 dose herbicide
- threshold fungicide

Conventional management:

- standard plough
- no compost, straw baled
- 170 kg ha^{-1} N
- full recommended dose herbicide
- standard fungicide applications

Economics: spring barley yield

Means ± e.s.e.'s for year at different levels of treatment



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	5.83	51.8	<0.001
treatment	2.82	4.8	0.157
variety.tmt	0.73	52.0	0.576

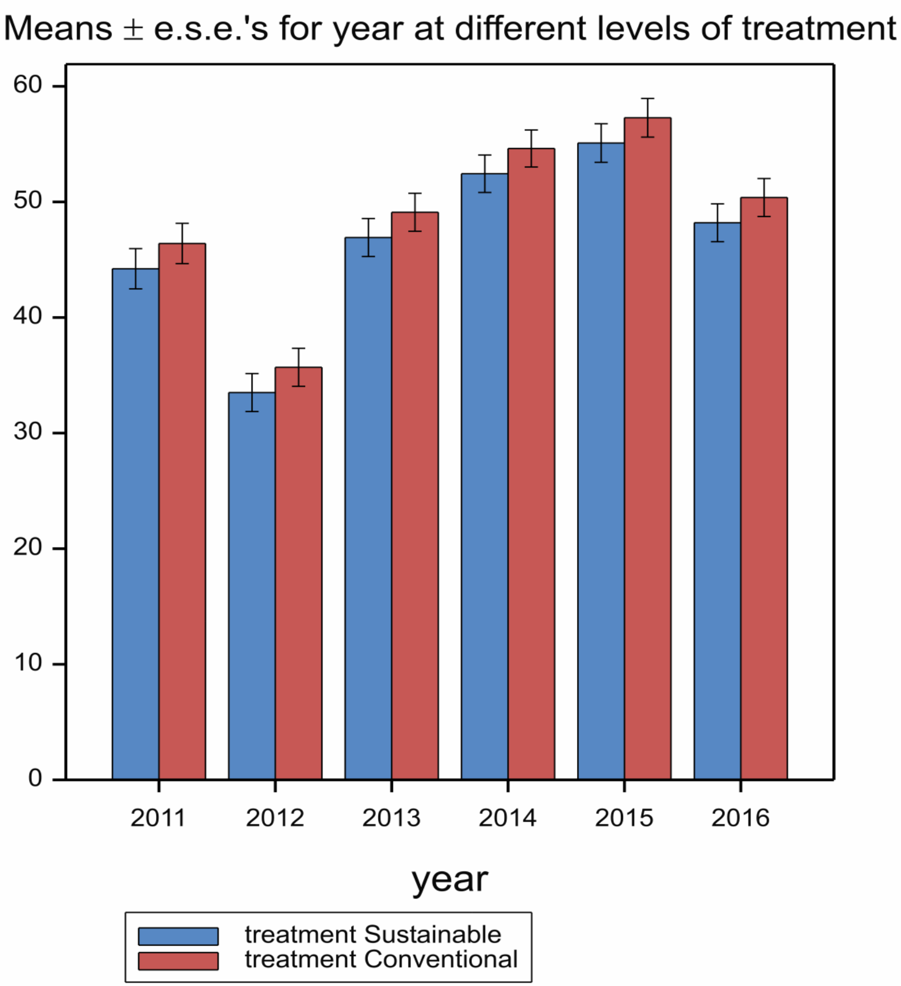
Sustainable management:

- min-till
- 35 t ha^{-1} compost + straw incorporation
- clover undersowing
- 80 kg ha^{-1} N
- alternative herbicide applied after clover establishment
- threshold fungicide

Conventional management:

- standard plough
- no compost, straw baled
- no clover
- 110 kg ha^{-1} N
- full recommended dose herbicide
- standard fungicide applications

Economics: potato yield



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	13.61	51.2	<0.001
treatment	1.25	5.0	0.314
variety.tmt	0.54	51.8	0.704

Sustainable management:

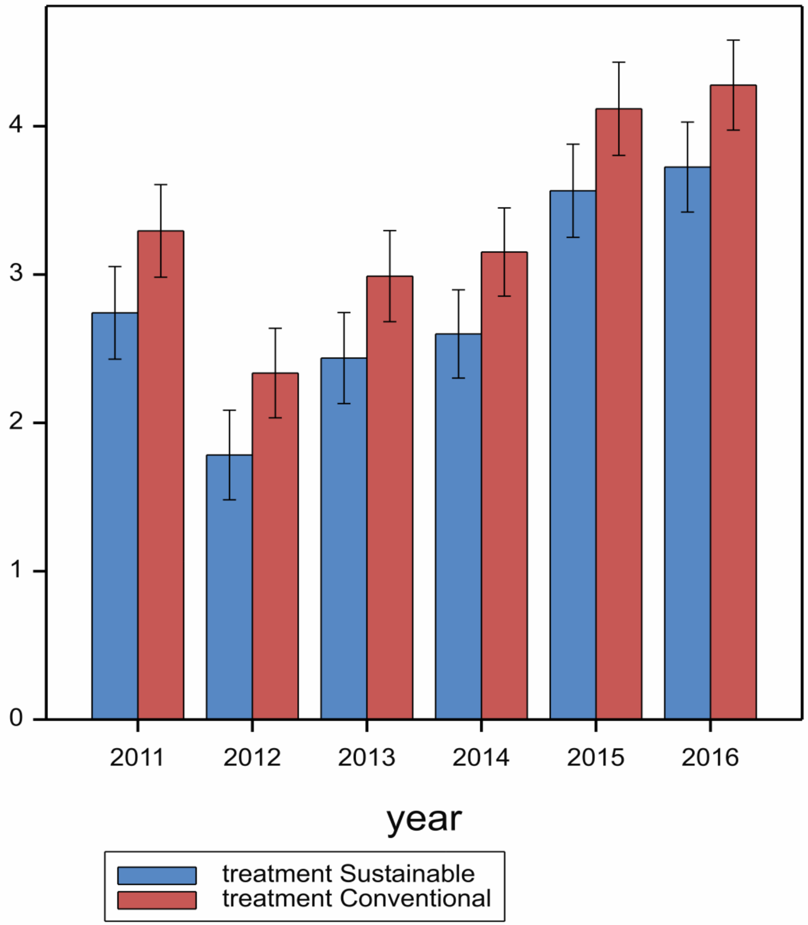
- 35 t ha^{-1} compost + cover crop
- 147 kg ha^{-1} N
- alternative herbicide
- tied ridging

Conventional management:

- standard plough
- no compost or cover crop
- 196 kg ha^{-1} N
- full recommended dose herbicide

Economics: winter oilseed rape yield

Means ± e.s.e.'s for year at different levels of treatment



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	4.80	44.7	0.001
treatment	1.34	4.6	0.303
variety.tmt	0.20	45.4	0.961

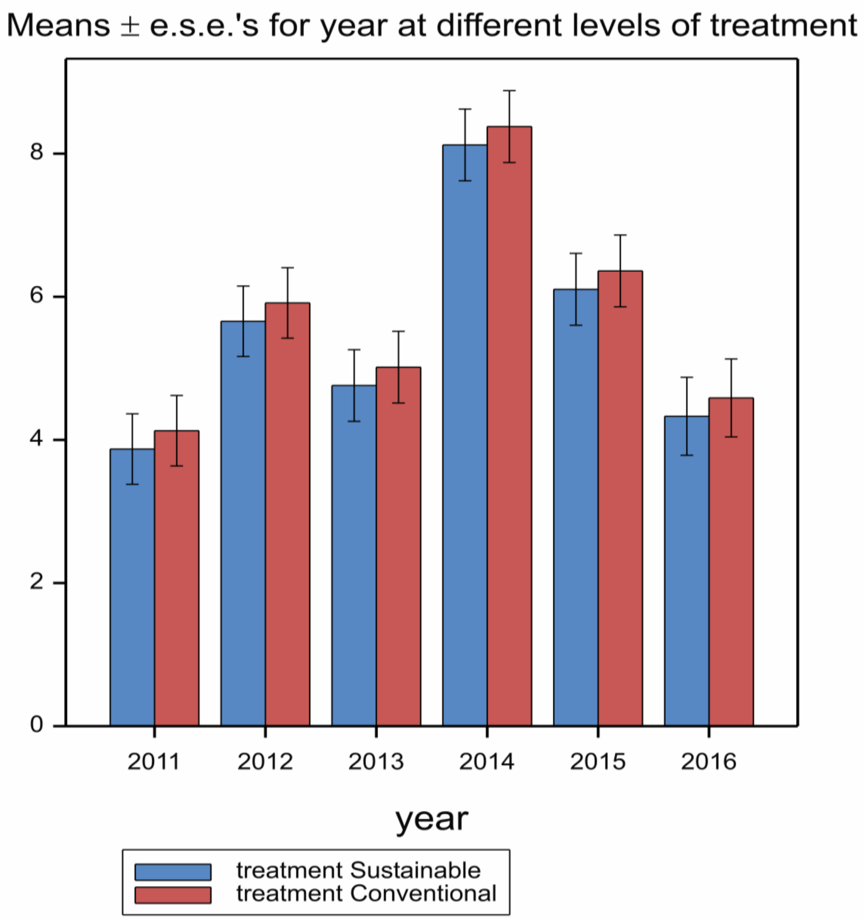
Sustainable management:

- minimum tillage
- 35 t ha^{-1} compost + clover from previous
- 162 kg ha^{-1} N
- reduced herbicide

Conventional management:

- standard plough
- no compost or clover
- 216 kg ha^{-1} N
- full recommended dose herbicide

Economics: bean yield



REML variance components analysis.
Tests for fixed effects; sequentially adding terms to fixed model

Fixed term	F statistic	d.d.f.	F pr
variety	1.76	46.7	0.119
treatment	0.24	4.9	0.647
variety.tmt	0.57	47.6	0.776

Sustainable management:

- minimum tillage
- 35 t ha^{-1} compost
- 0 kg ha^{-1} N
- reduced herbicide

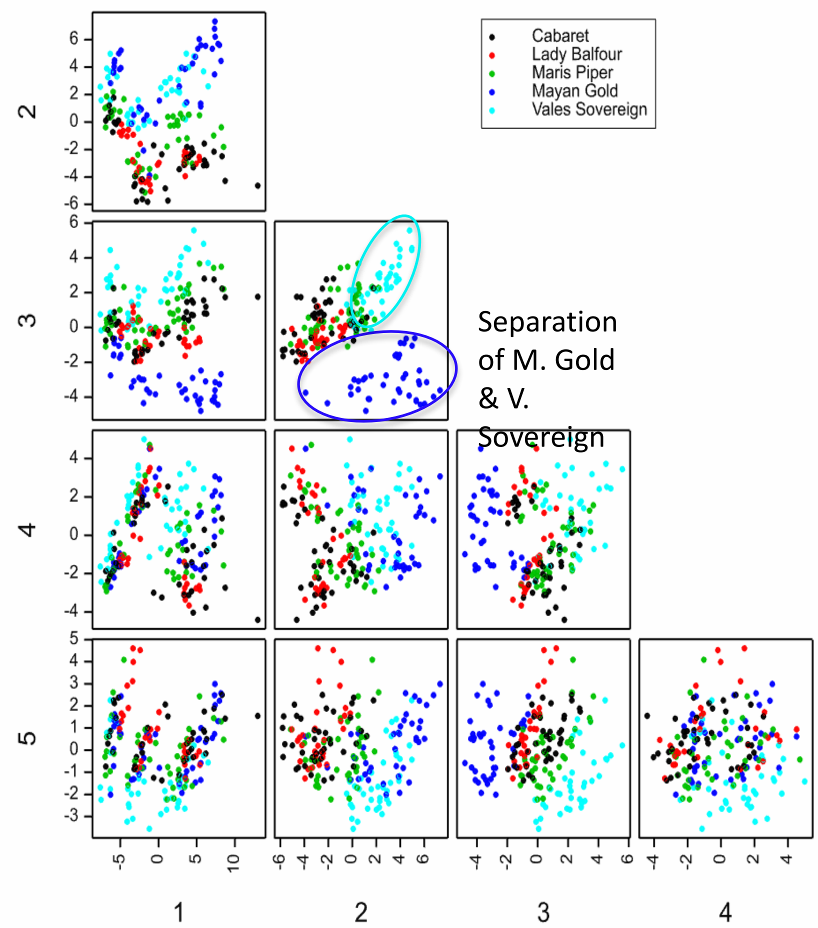
Conventional management:

- standard plough
- no compost
- 0 kg ha^{-1} N
- full recommended dose herbicide

Economics: Yield quality

- Potato: dry matter, total N, protein, sugars & starch, minerals, vitamin C, chlorogenic acid, carotenoids, polyphenol oxidase, LC-MS, GC-MS
- No effect of treatment on quality measures; differences between cultivars
- WOSR: oil content, fatty acid composition, total N, C & H, tocopherols, phytic acid, glucusinolate
- Cereals: dry matter, TGW, β-glucan content, sugar & starch content, total C, H & N, LC-MS, GC-MS P & N
- Beans: 60 bean weight, dry matter, sugar & starch content, total C, H & N, LC-MS, GC-MS P & NP
- Combinable crops: analysis in progress

Principle components analysis of GC-MS Non-Polar Metabolites (n = 53)

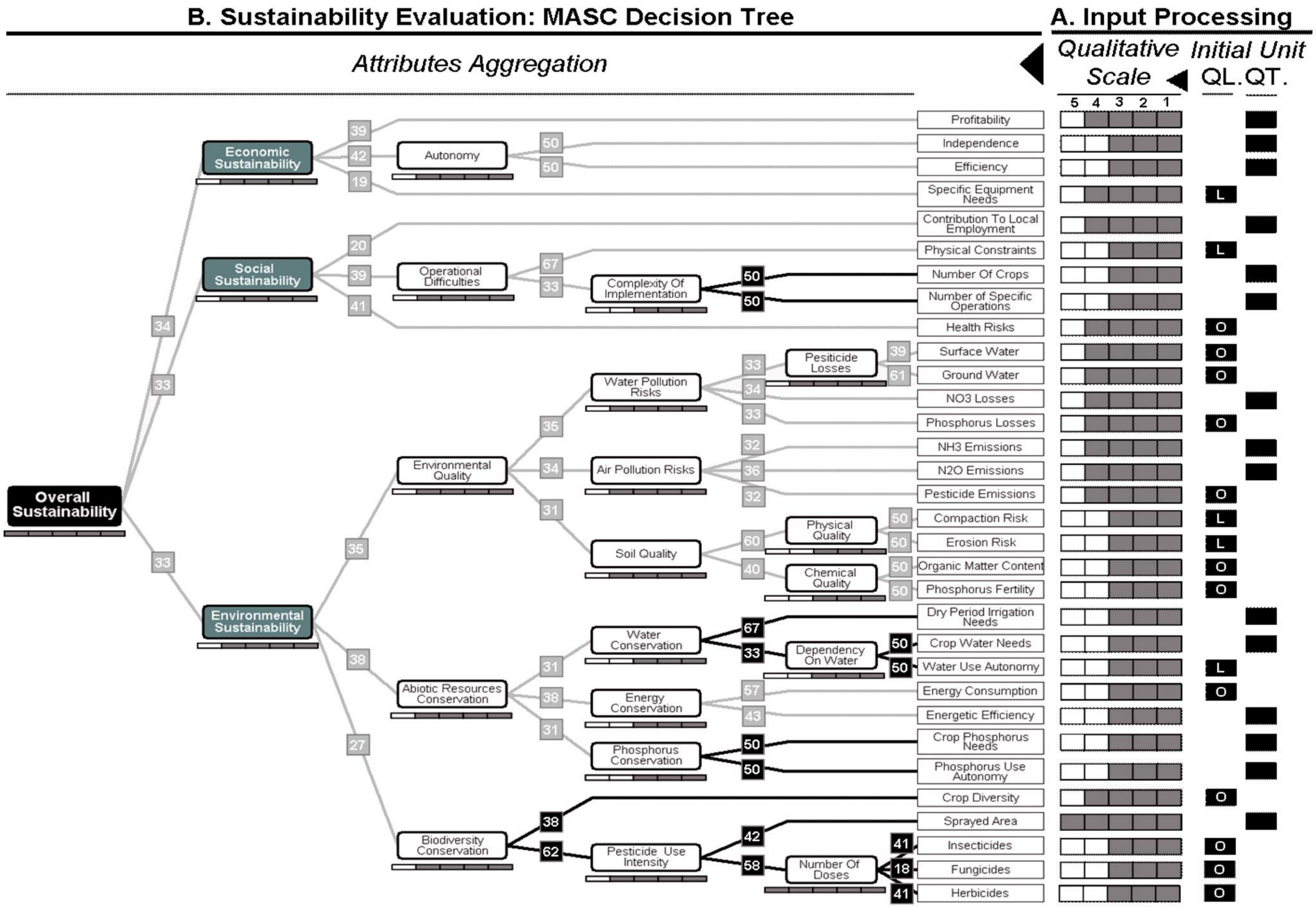


Contact: Lou Shepherd

Whole systems approach: trade-offs

- Nitrogen input for max yield vs. environmental pollution
- Complete weed control for eliminating competition vs. weed understorey for biodiversity & ecosystem services (IPM)
- Soil carbon for improving physical structure (e.g. for crop rooting) vs. carbon food resource for soil borne pathogens
- Insecticide control of crop pests vs. non target effects reducing natural enemy regulation of pest populations
- Short term profit vs. environmental health for long term sustainability

Systems Impact Assessment: DexIPM



Contact: Geoff Squire

Visitors and KE

- Networks and platforms: ENDURE, AnaEE, INRA, North Wyke Farm Platform, Rothamsted, SIRN
- Agronomy and industry groups: AICC, Danish Agronomy, Co-op Farms and now FarmCare, Agrinos, NFUS, Pepsico, Soil Essentials, Norwegian seed potato grower association, GWK Potato, Potato Council and AHDB
- Environmental organisations: LEAF, Soil Association, SEPA, SNH, BCT, GWCT
- Scottish Government policy advisors
- Scientific community: Zhejiang Academy Of Agricultural Sciences, AAB & CPNB meetings, Carbon Management Centre International Conference delegates meetings and site visits, Cornell University, Aberdeen University, SSCR events and visiting scientists to the institute

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- Nitrogen budgets and BNF: Euan James, Pete Iannetta, Mark Young
- Soil biophysics and hydrology: Blair Mackenzie, John Rowan, Marc Stutter
- Biodiversity and system function: Jenni Stockan, Cathy Hawes, Graham Begg, Ashley Gorman
- Dexi: Marion Demade, Geoff Squire
- Yield quality: Lou Shepherd, Derek Stewart