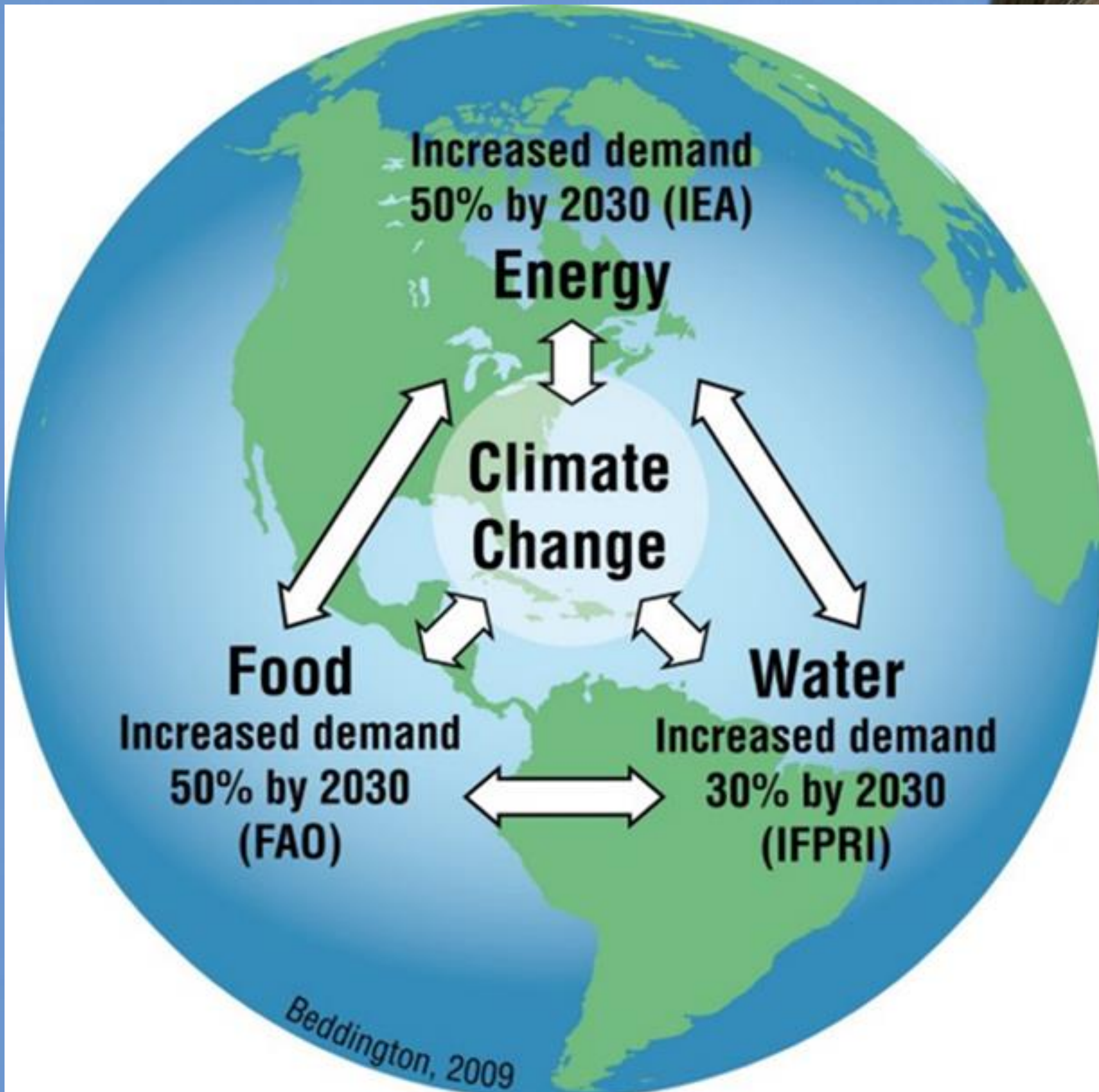
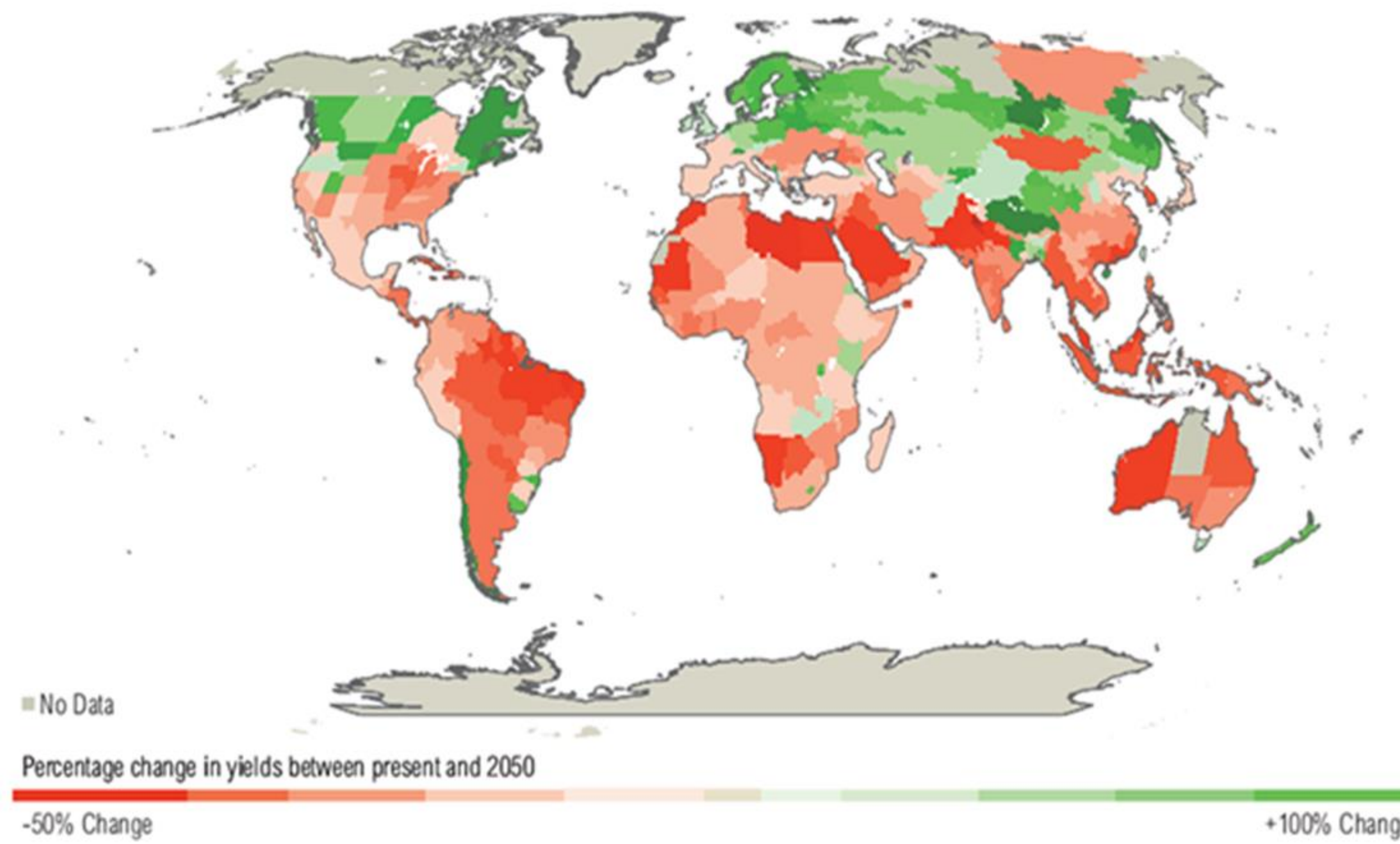
Managing agricultural landscapes sustainably: production, people, nature

Prof Sue Hartley
Director, York Environmental Sustainability Institute
University of York



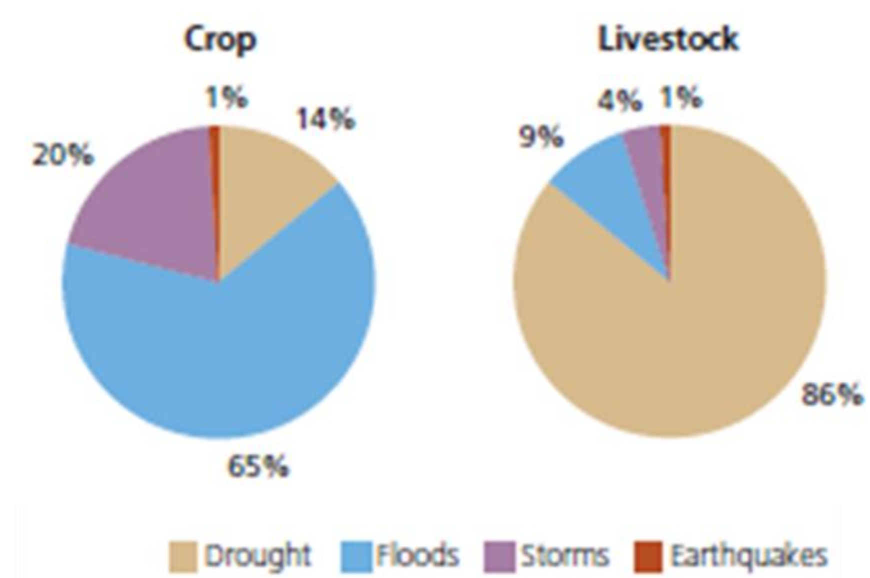
"Now, more than ever, we need to connect the dots between climate, poverty, energy, food and water. These issues can not be addressed in isolation."

Figure 2 | Climate Change is Projected to Impact Crop Yields (3° C World)



Source: World Bank. 2010. *World Development Report 2010*. Washington, DC: World Bank.

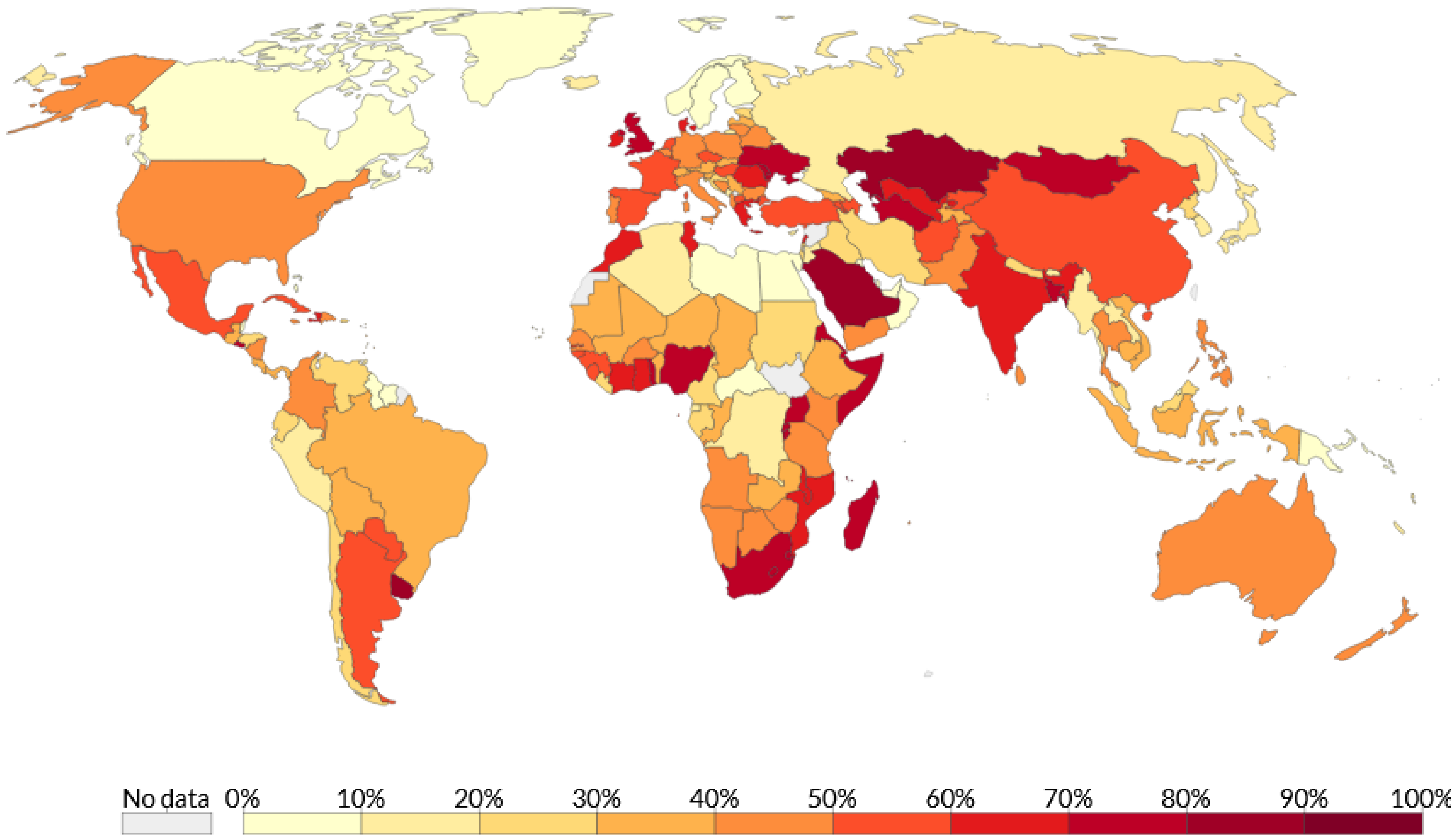
Damage and loss to agriculture sectors caused by specific types of abiotic hazard (2006–2016)



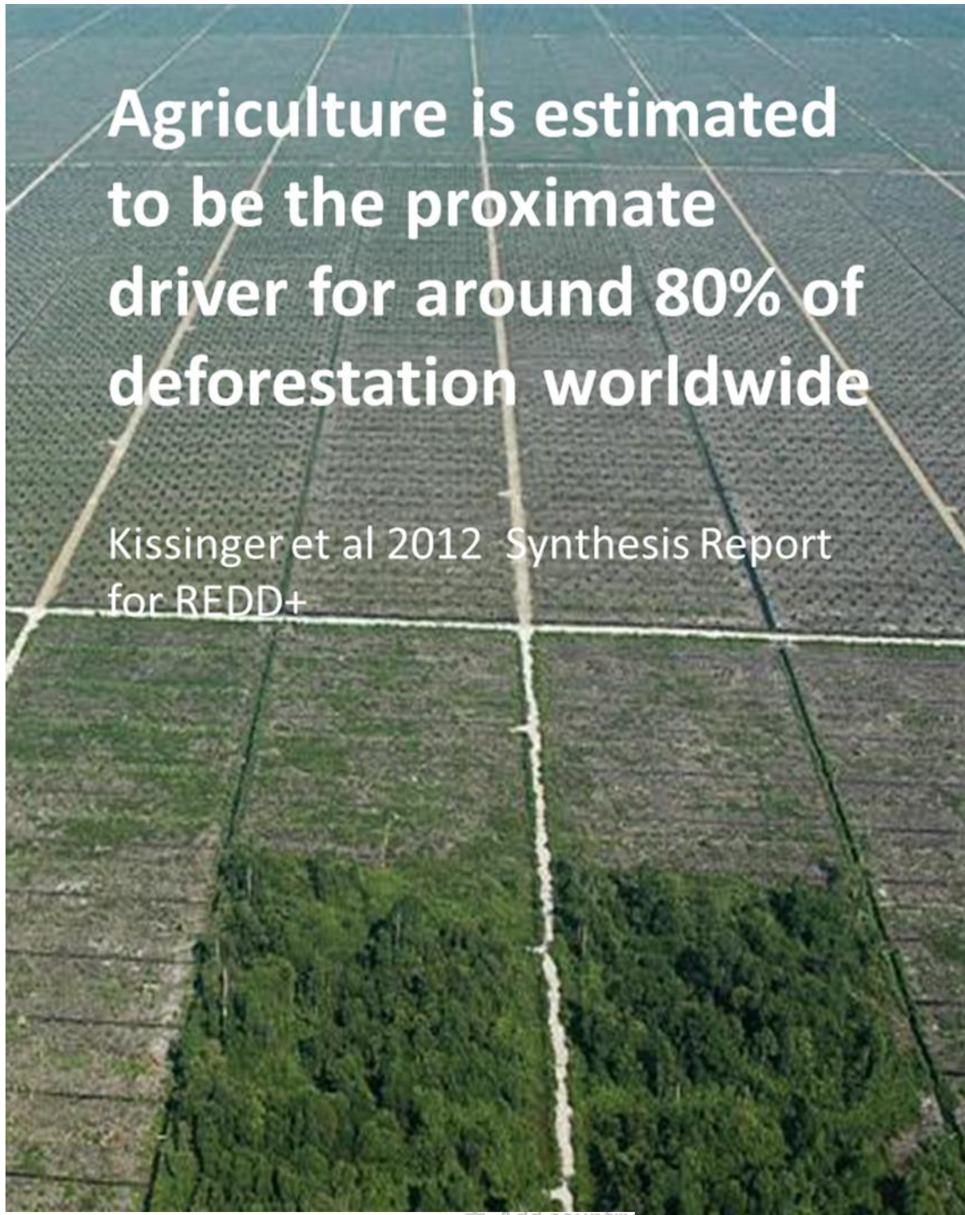
FAO. 2018e. *The impact of disasters and crises on agriculture and food security*. Rome. (available at http://www.fao.org/3/I8656EN/i8656en.pdf).

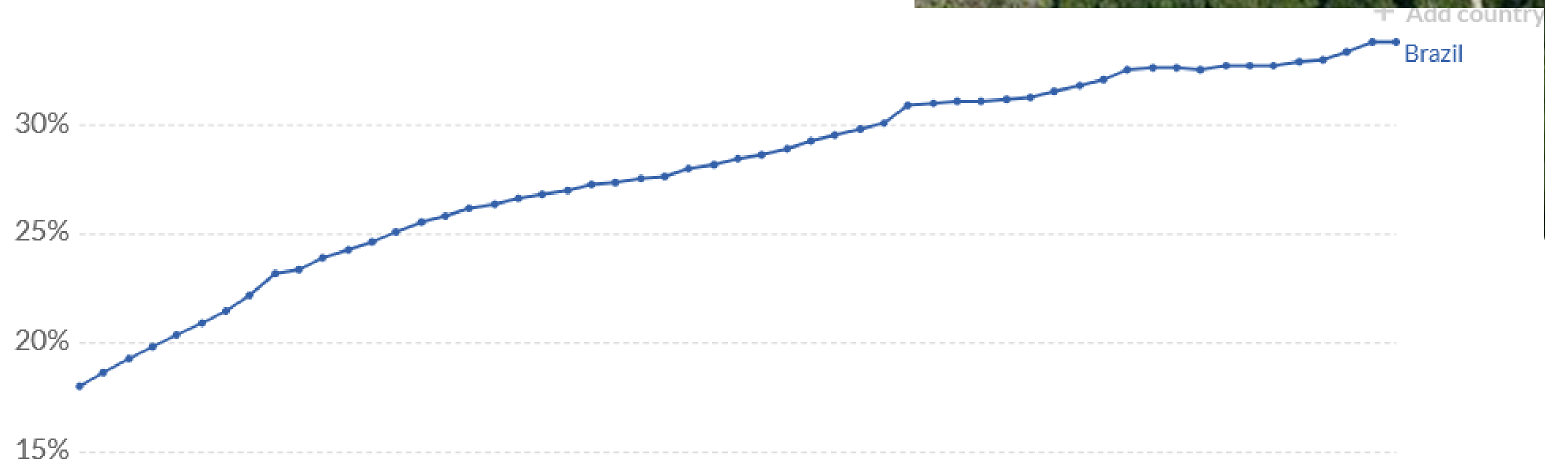
Share of land area used for agriculture, 2015

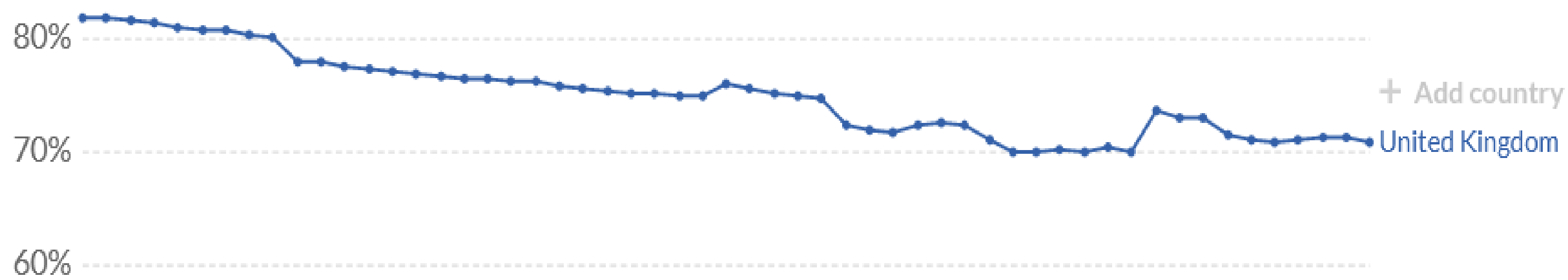
The share of land area used for agriculture, measured as a percentage of total land area. Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures.



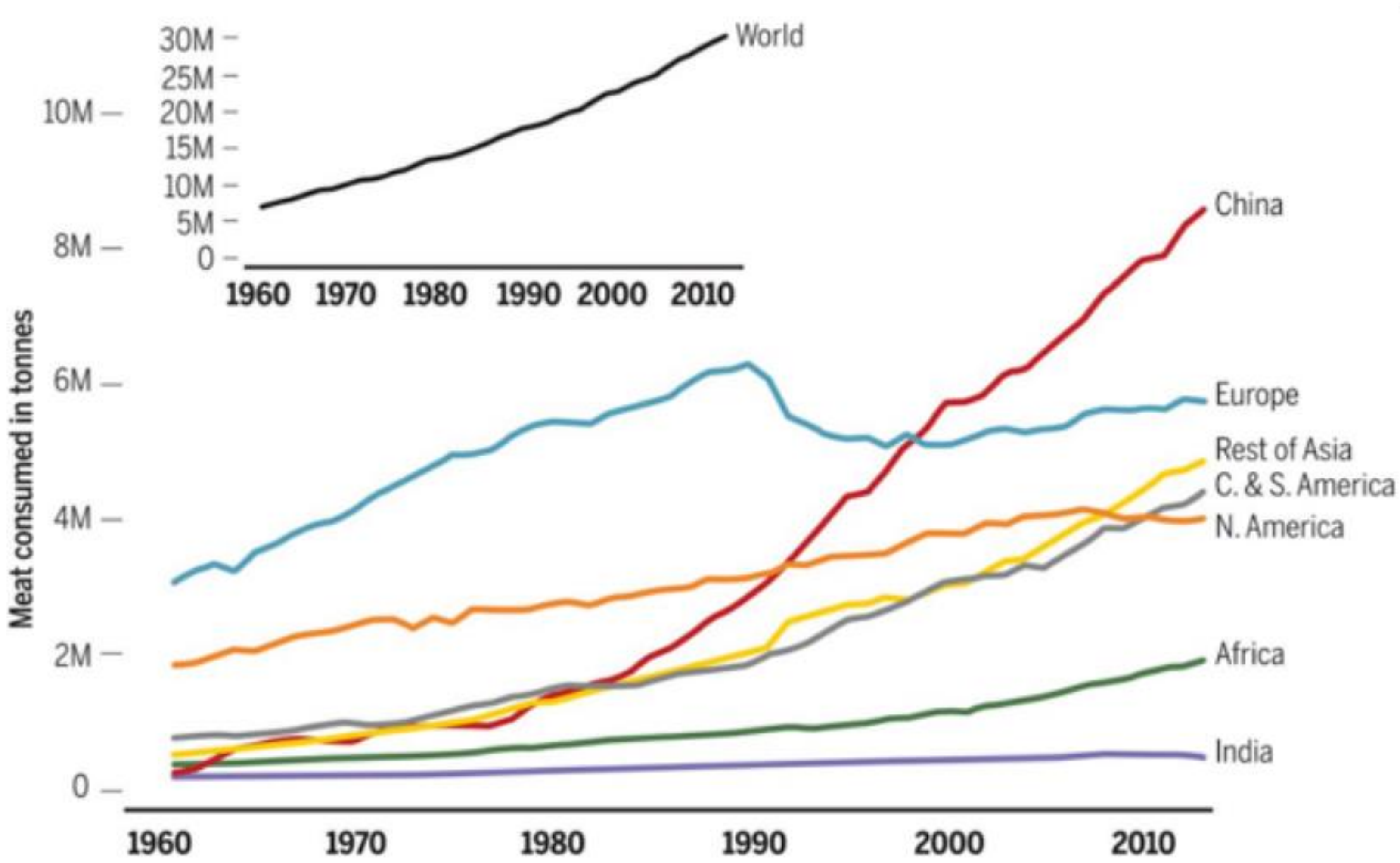
Source: World Bank





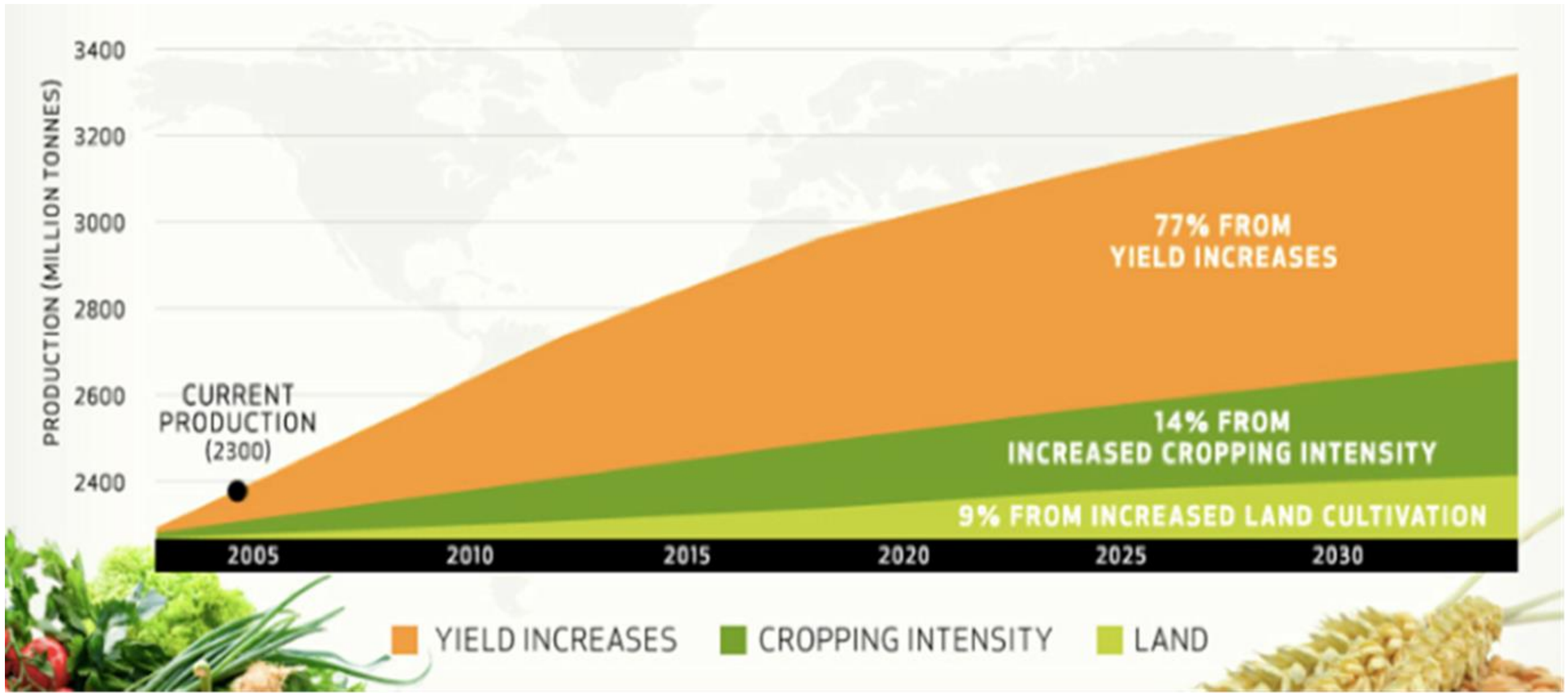


Change in agricultural land as %total area1960-2015



Total consumption of meat (in million metric tonnes)

Image: Science Magazine



The pace of improvement has slowed steadily...

Annual % change in crop yield

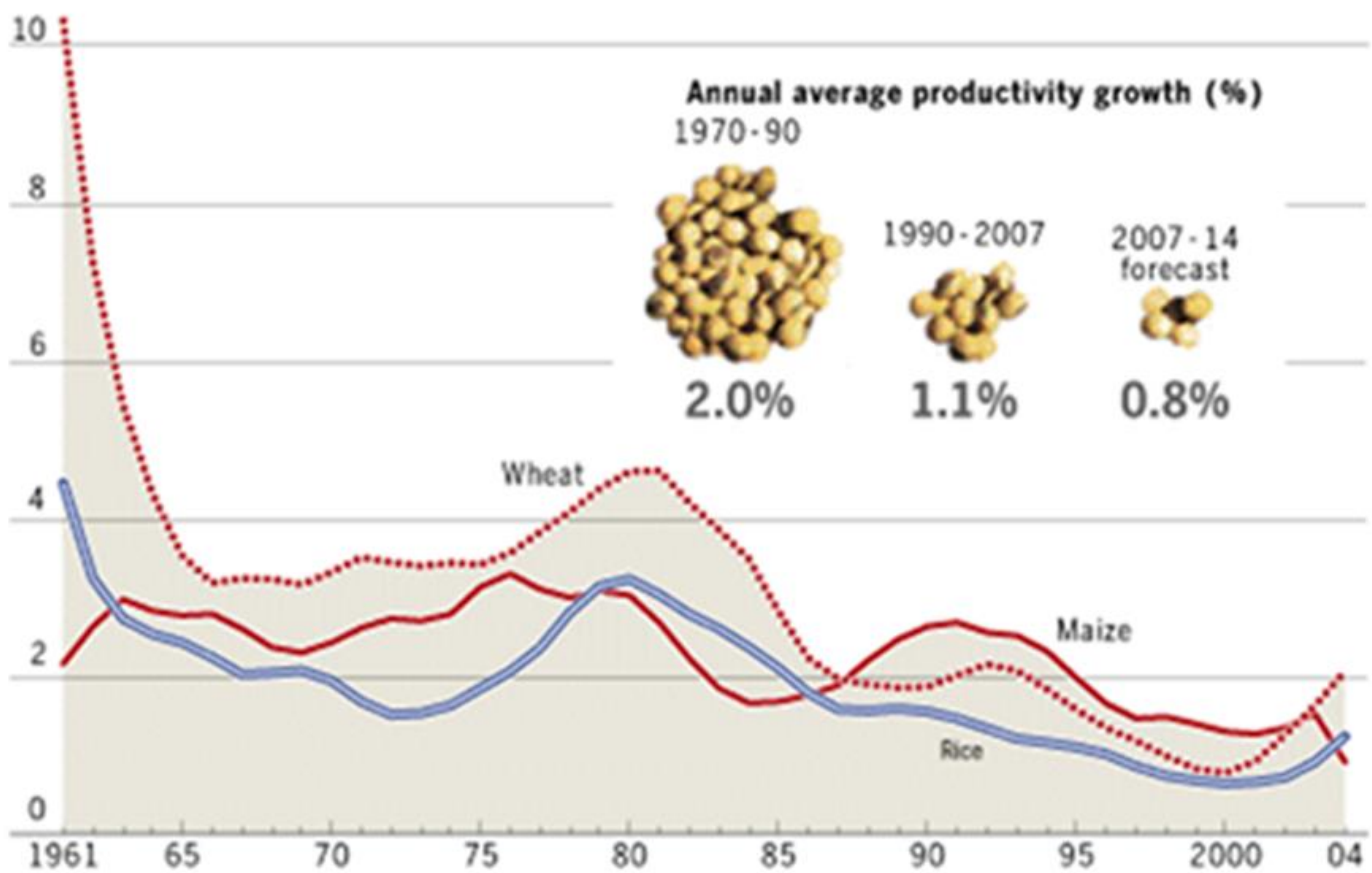
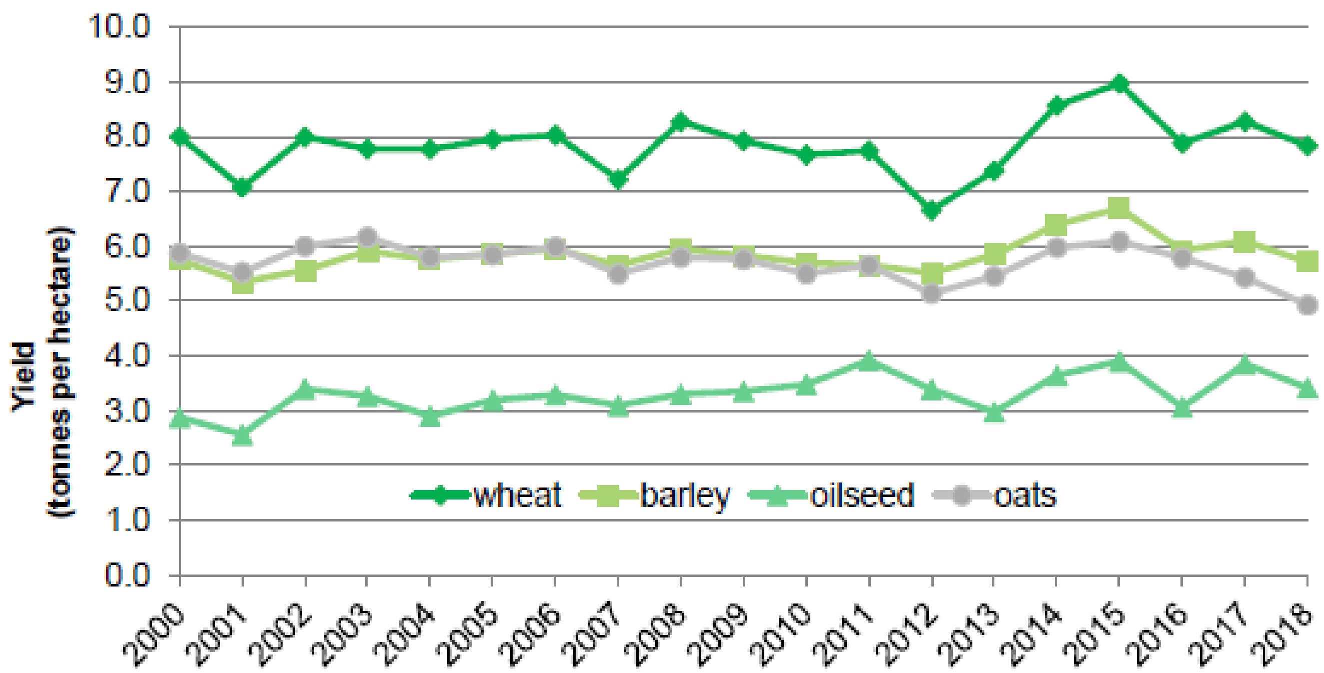
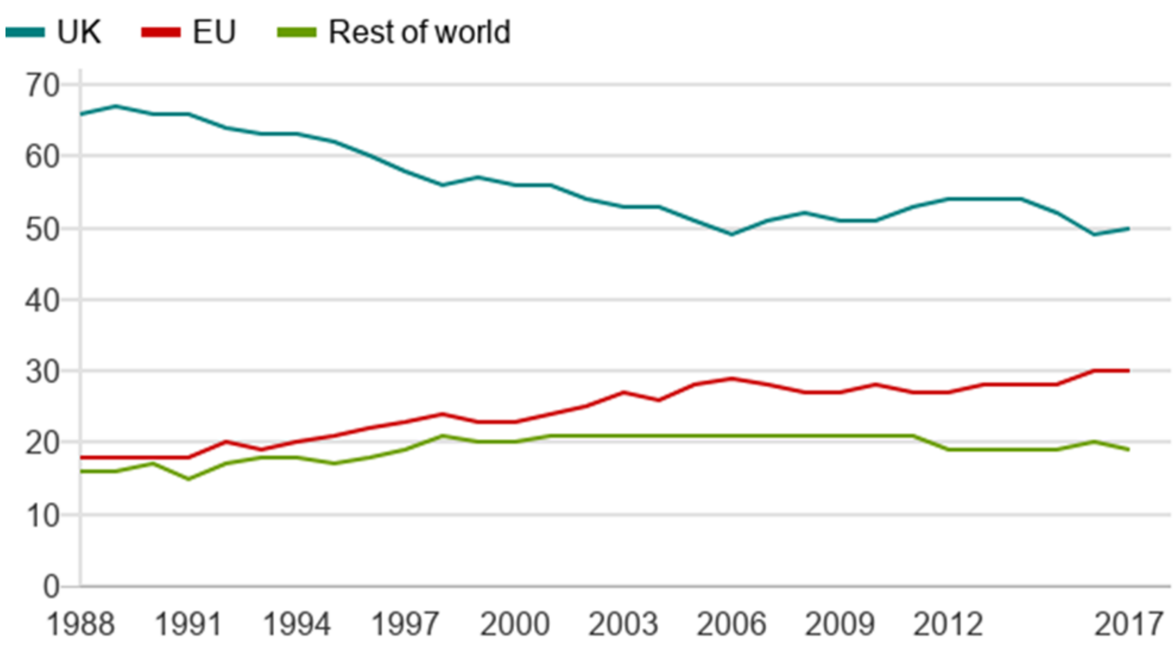


Figure 5: UK crop yields between 2000 and 2018



Where does the food we eat come from?

As a percentage of total UK consumption



Source: DEFRA

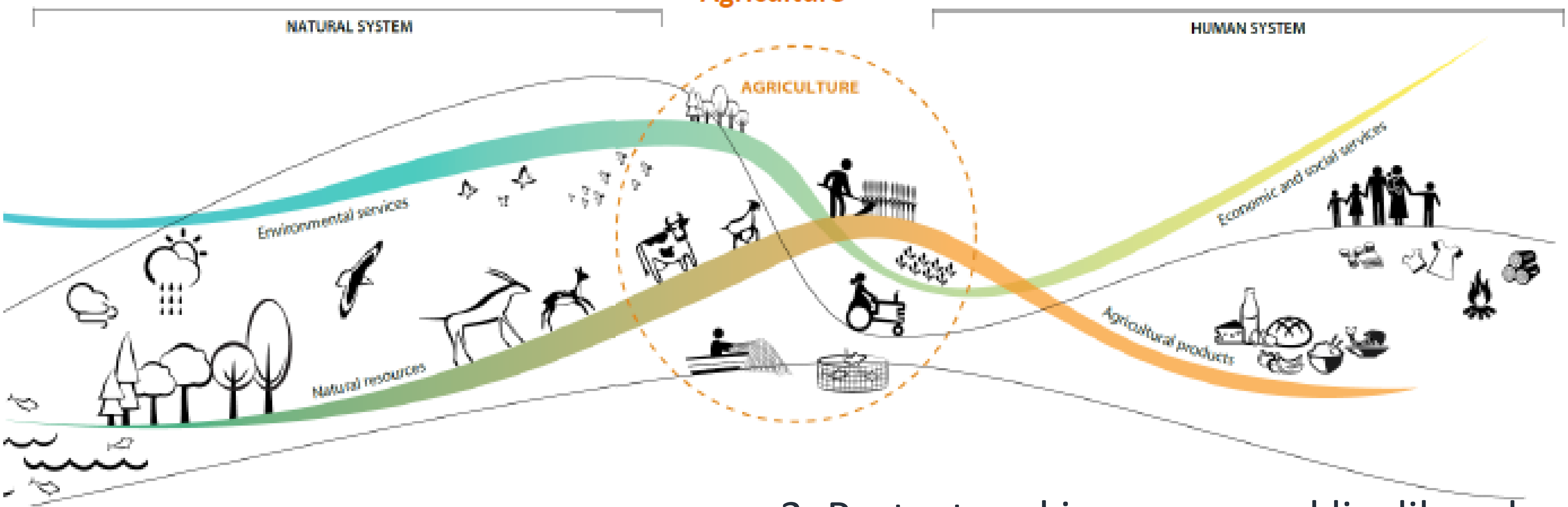
BBC

UK	EU
Farmland Butterfly Index has fallen by 27% since 1990.[a]	European Grassland Butterfly Index declined by almost 50% between 1990 and 2011.[f†‡]
Since 1970 the Farmland Bird Index has reduced by 57% of its value.[a†]	Between 1990 and 2014, across 26 EU Member States, there was a 31.5% decrease in populations of common farmland birds.[g‡]
Since 1980 the UK insect pollinator biodiversity indicator has shown long term decline, though recent short term stability. Both wild and honey bees have shown an overall decline since the 1960s.[b]	Evidence indicates that of the 1,965 European native bees 101 are Near Threatened; 24 Vulnerable; 46 Endangered; 7 Critically Endangered; with 1,101 being data deficient.[h]
2.2 million tonnes of topsoil are lost annually, resulting in carbon emissions that are 50% higher than those from the petroleum refining industry.[c]	11.4 % of the EU suffers from moderate to high levels soil erosion (more than 5 tonnes/ha/year), with a further 0.4% affected by extreme soil erosion (more than 50 tonnes/ha/year).[i]
Previously extensive native biogenic oyster reefs in the English channel and southern North Sea were almost completely extirpated in the 20th century.[d]	Only 5% of seabed habitats out of 702 in the MSFD initial assessment were in good status. 76% were of unknown status.[d]
Only 9 of 162 fisheries in English inshore waters (top 15 species) could be confirmed as sustainable. Most others were data deficient.[e]	Only 19 (20%) of 95 fish stocks assessed in European waters were sustainable - None in the Mediterranean, 19/54 (35.2%) in the NE Atlantic.[j]
Soil erosion, soil compaction and loss of organic soil costs farmers £246 million.[c]	It is estimated that there is a 0.43% loss of agricultural productivity annually across the EU due to soil erosion, which is estimated to cost €1.25 billion.[k]

Stewart et al People and Nature 2019

THE FIVE PRINCIPLES of sustainable food and agriculture

Innovation for Sustainable Food and Agriculture (FAO 2017)



3. Protect and improve rural livelihoods, equity, and social well-being

1. Improve efficiency in the use of resources

4. Enhance the resilience of people, communities & ecosystems to climate change & market volatility

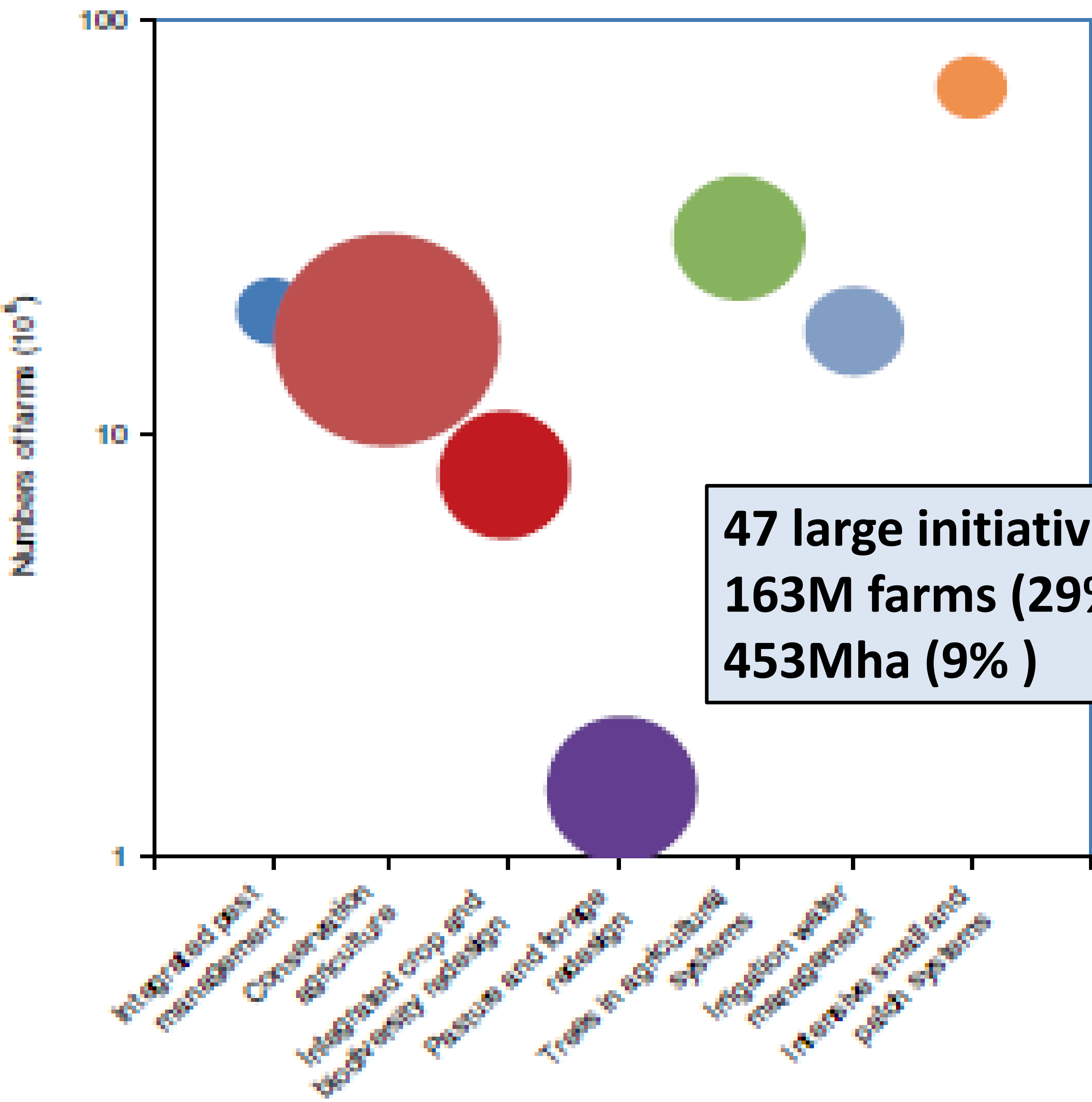
2. Conserve, protect and enhance natural resources

5. Promote responsible and effective governance mechanisms

nature sustainability
ANALYSIS
https://doi.org/10.1038/s41893-018-0114-0

Global assessment of agricultural system redesign for sustainable intensification

Jules Pretty[1*], Tim G. Benton[2], Zareen Pervez Bharucha[3], Lynn V. Dicks[4], Cornelia Butler Flora[5], H. Charles J. Godfray[6], Dave Goulson[7], Sue Hartley[8], Nic Lampkin[9], Carol Morris[10], Gary Pierzynski[11,18], P. V. Vara Prasad[12], John Reganold[13], Johan Rockström[14,19], Pete Smith[15], Peter Thorne[16] and Steve Wratten[17]

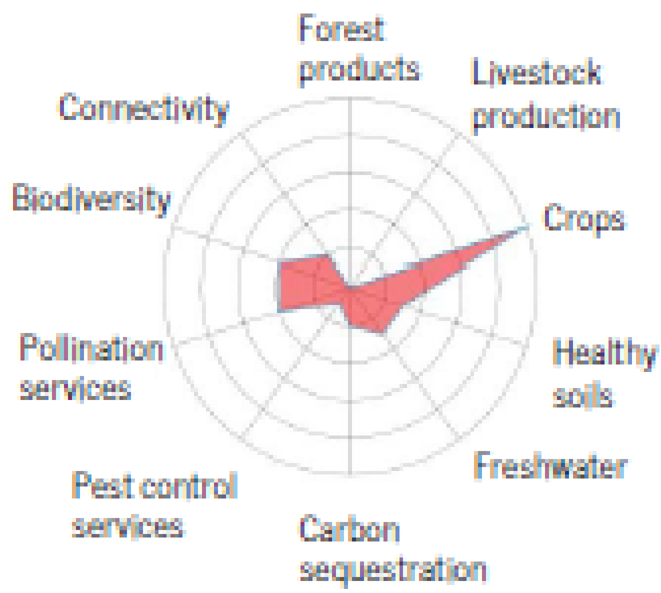


47 large initiatives
163M farms (29%)
453Mha (9%)

Redesign type	Illustrative redesign sub-types of intervention
1. Integrated pest management	Integrated pest management through farmer field schools
	Integrated plant and pest management
	Push–pull systems
2. Conservation agriculture	Conservation agriculture practices
	Zero- and low-tillage
	Soil conservation and soil erosion prevention
	Enhancement of soil health
3. Integrated crop and biodiversity redesign	Organic agriculture
	Rice–fish systems
	Systems of crop and rice intensification
	Zero-budget natural farming
	Science and technology backyard platforms
	Farmer wisdom networks
	Landcare and watershed management groups
4. Pasture and forage redesign	Mixed forage–crop systems
	Management intensive rotational grazing systems
	Agropastoral field schools
5. Trees in agricultural systems	Agroforestry
	Joint and collective forest management
	Leguminous fertilizer trees and shrubs
6. Irrigation water management	Water user associations
	Participatory irrigation management
	Watershed management
	Micro-irrigation technologies
7. Intensive small and patch scale systems	Community farms, allotments, backyard gardens, raised beds
	Vertical farms
	Group purchasing associations and artisanal small producers (in community-supported agriculture operations, tekei groups, guilds)
	Micro-credit groups for small-scale intensification
	Integrated aquaculture

Multifunctional landscapes ?

A Monoculture row-crop



"changes to a farming system that maintain/enhance specified kinds of agricultural provisioning while enhancing/maintaining delivery of specified range of other ESS over a specified area & time frame"

C Mixed cultivated, forest and range landscape

Trade-offs or Win-wins?

Kreman et al Science 2018

Win-win: more targeted pest control

Estimated crop yield losses worldwide (% of attainable yields)		
Crop	Without pest control	Using mechanical, biological and chemical control measures
Rice	77	37
Wheat	50	28
Potato	75	40

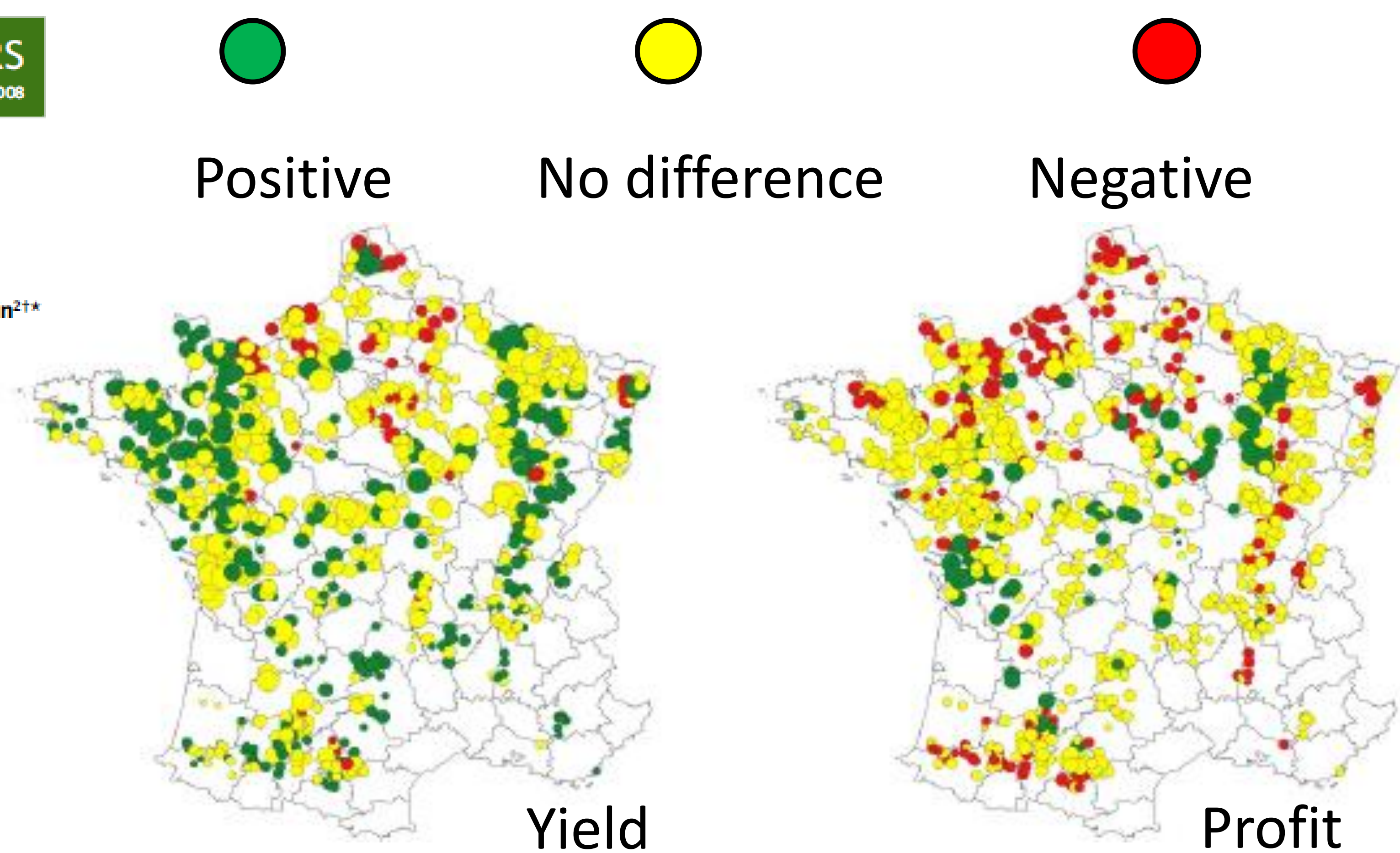
Crop protection prevents the loss of 22-40% of staple food production (Oerke, 2005)

76% of pesticide active ingredients have been removed from the EU market (Karabelas et al, 2009)

nature plants
LETTERS
PUBLISHED: 1 MARCH 2017 | VOLUME: 3 | ARTICLE NUMBER: 17008

Reducing pesticide use while preserving crop productivity and profitability on arable farms

Martin Lechenet[1,2*], Fabrice Dessaint[2], Guillaume Py[1], David Makowski[3†] and Nicolas Munier-Jolain[2†*]

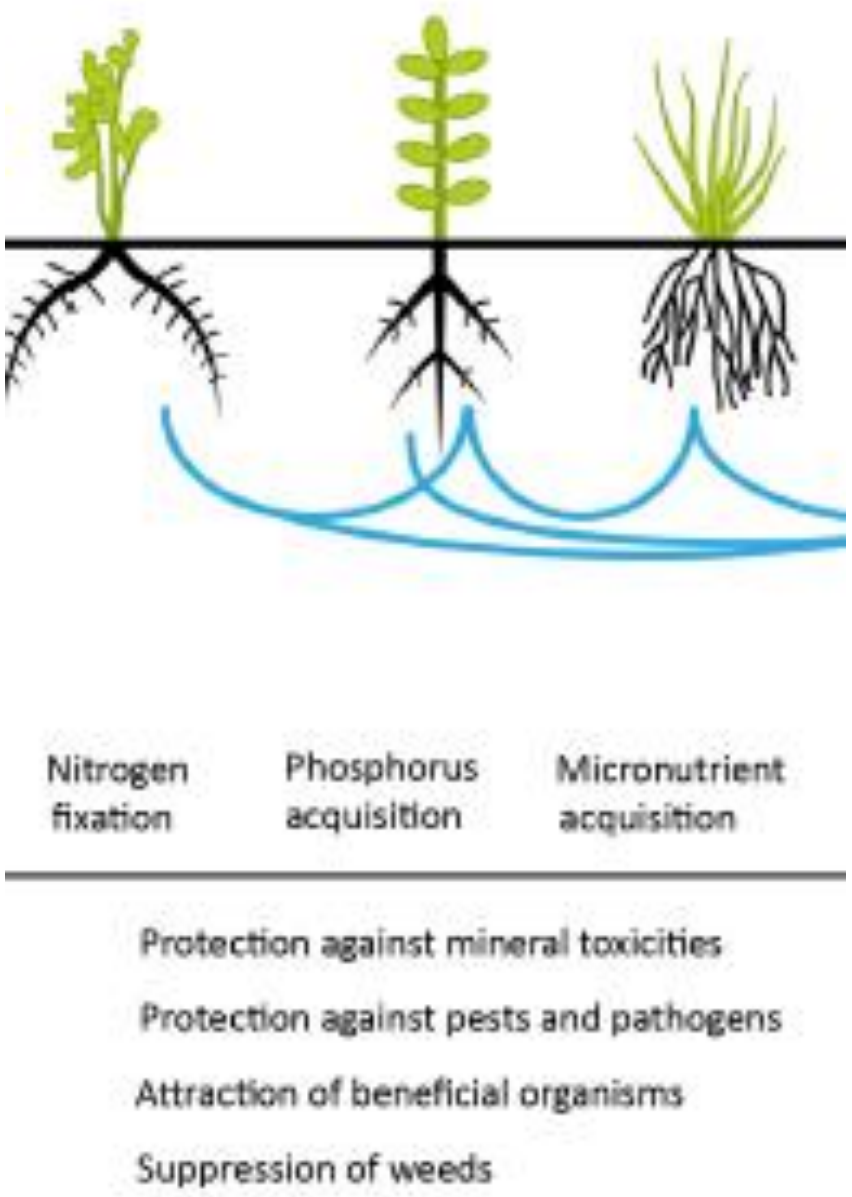


Pesticide use can be reduced by 42% with no negative effects on either yield or profit on 59% farms (n = 946)

Win-win: non-chemical pest control

Research review Brooker et al 2014

Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology



Meta analysis: 249 experiments on intercropping vs nematodes & soil-borne diseases; 43 focal crops, 20 intercrops, 7 nematode types, 9 pathogen types

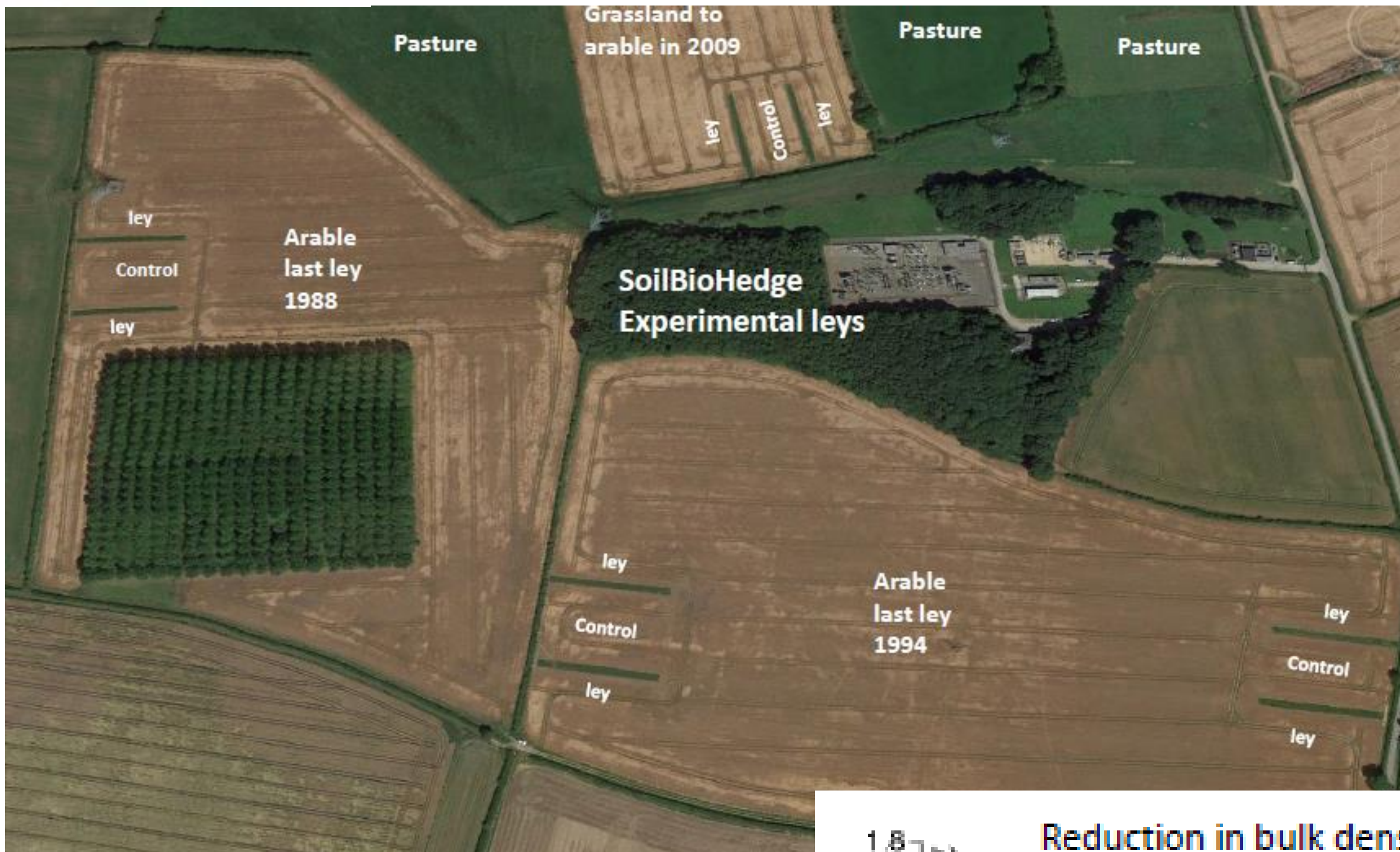
Soil-borne disease damage to primary crop reduced by 54%; nematode damage by 31%

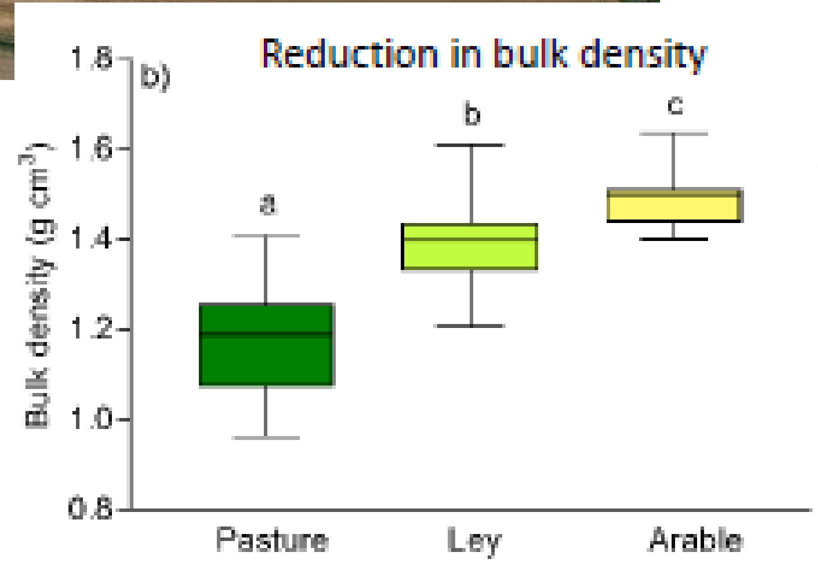
51% reduction in damage sufficient to obtain equivalent yields from intercropped fields to those from monocrop

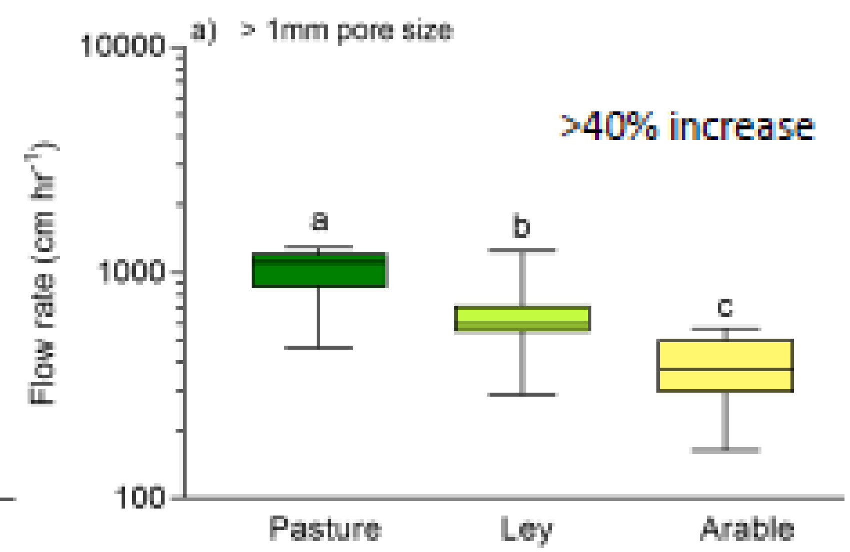
(unpublished data Chadfield, Hartley, Redeker)

Win-win: ley strips and soil health

Harnessing hedgerow soil biodiversity for restoration of arable soil quality and resilience to climatic extremes and land use changes.

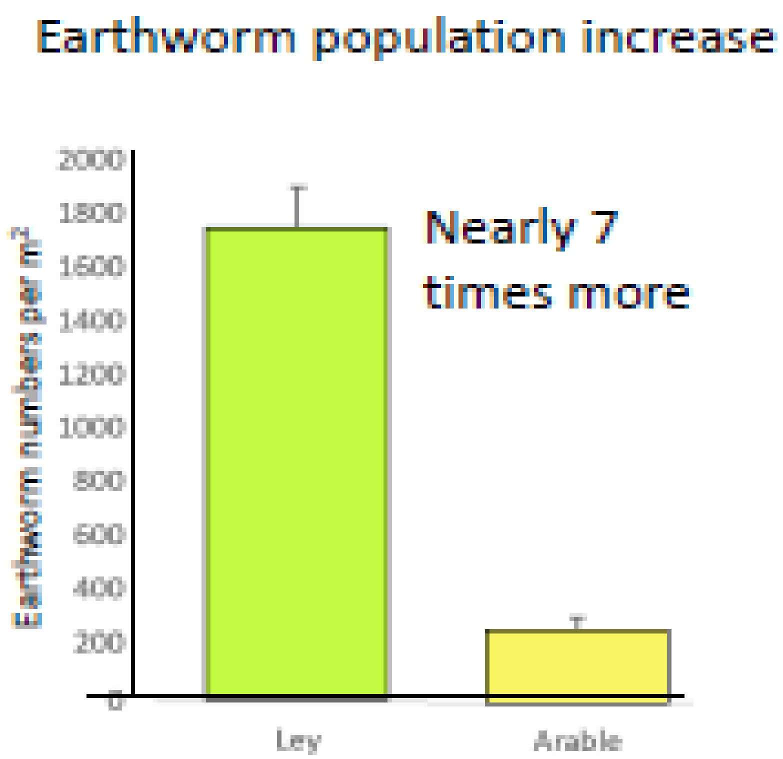


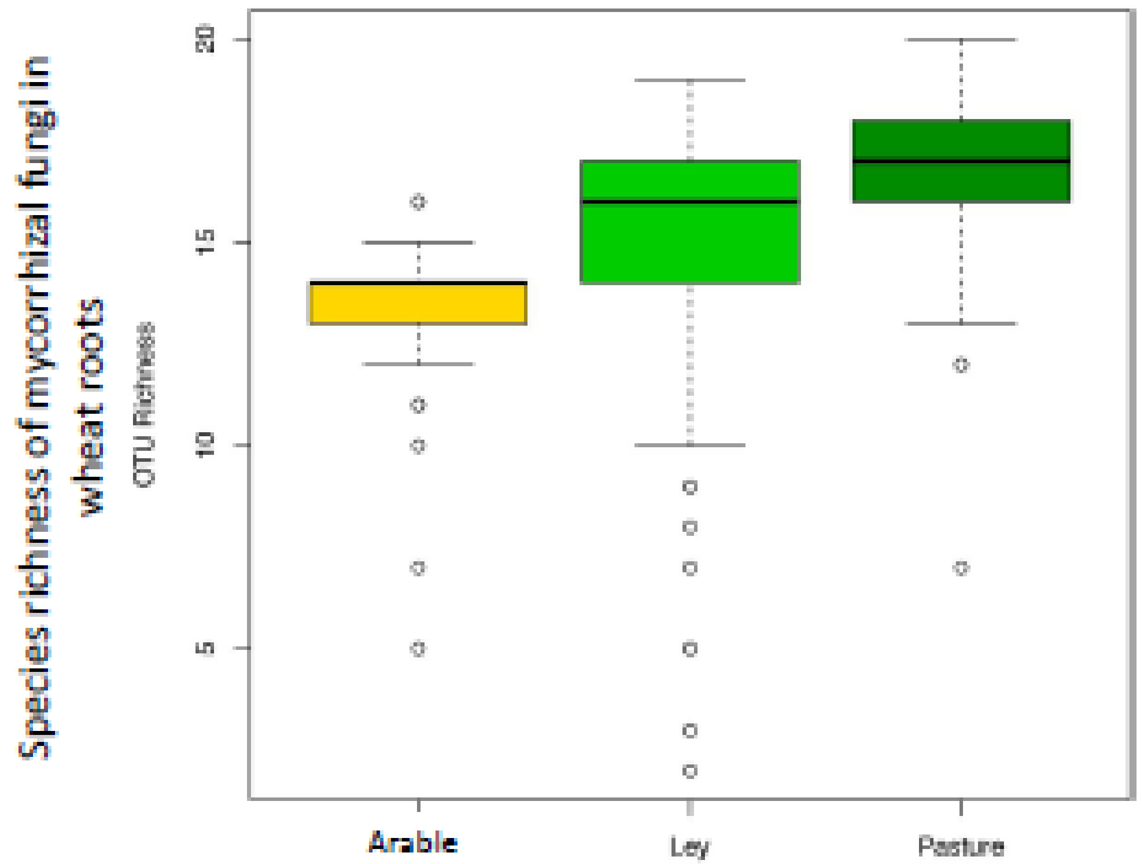




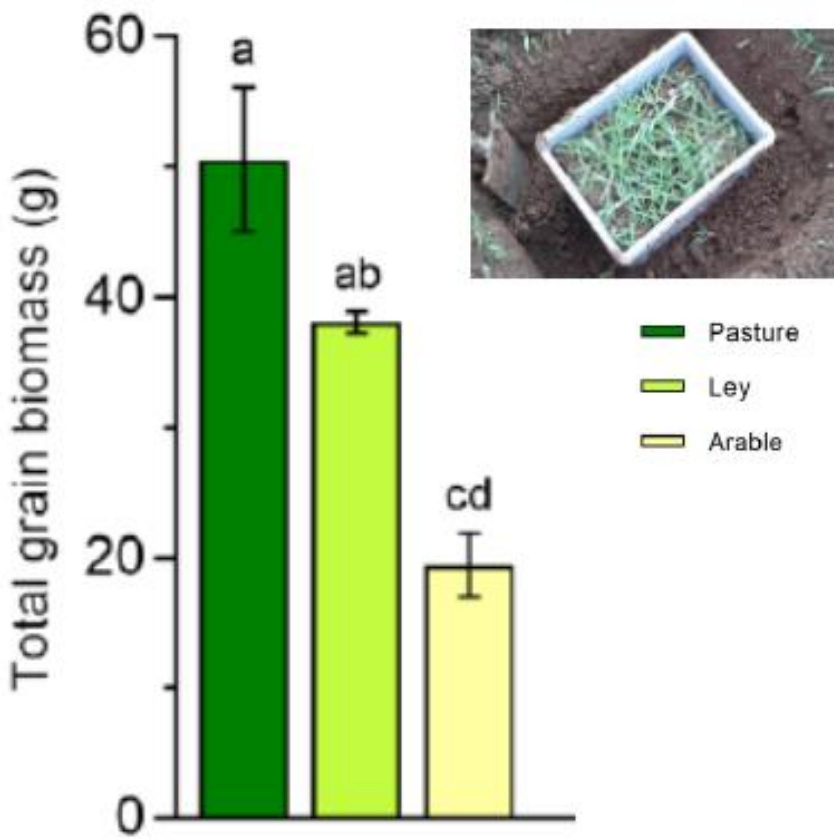
Unpublished data: Dr Despina Berdeni, Jonathan Leake, Joe Llanos, Steffi Tille

Leys rebuild soil biology and hydrological functioning

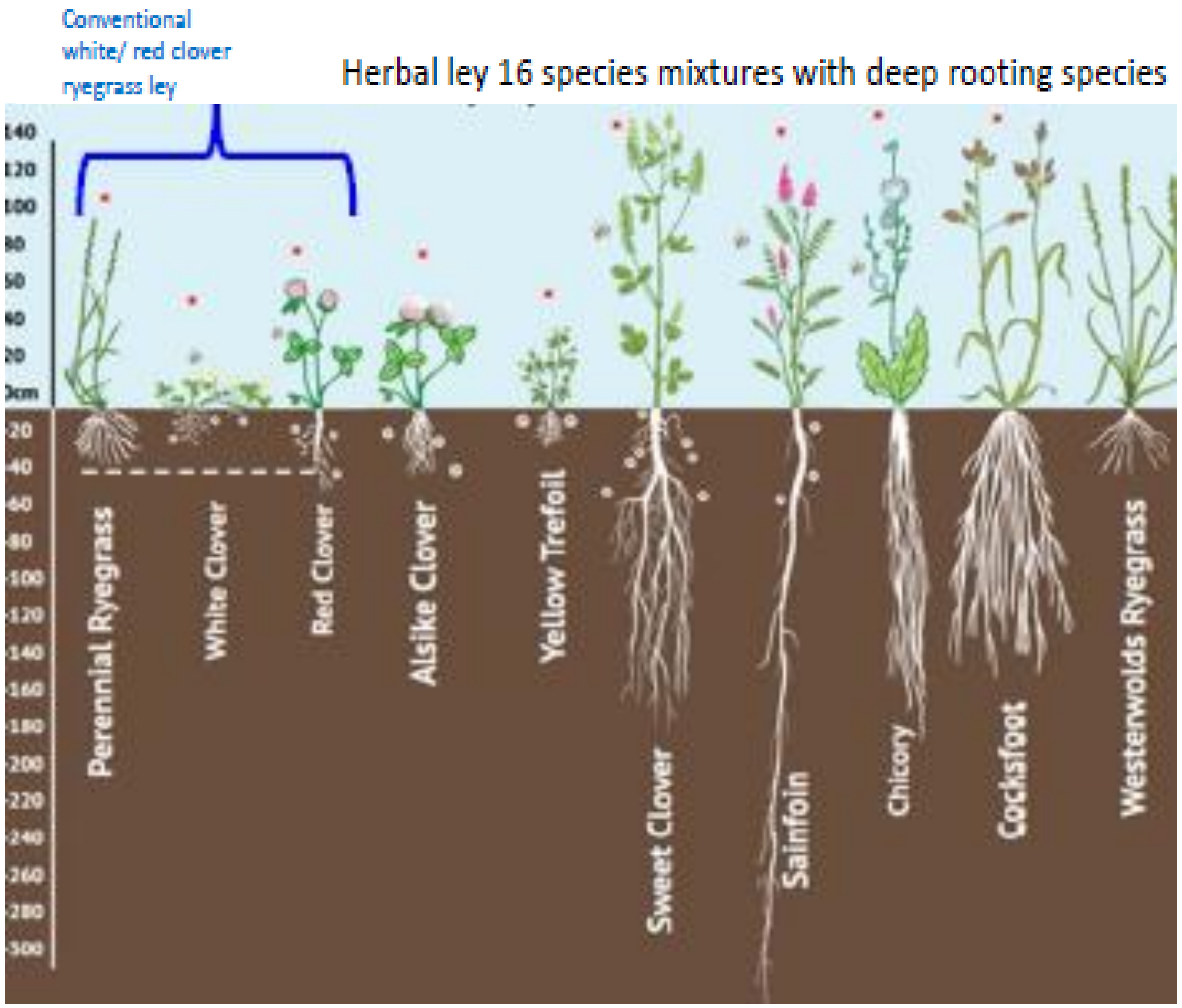




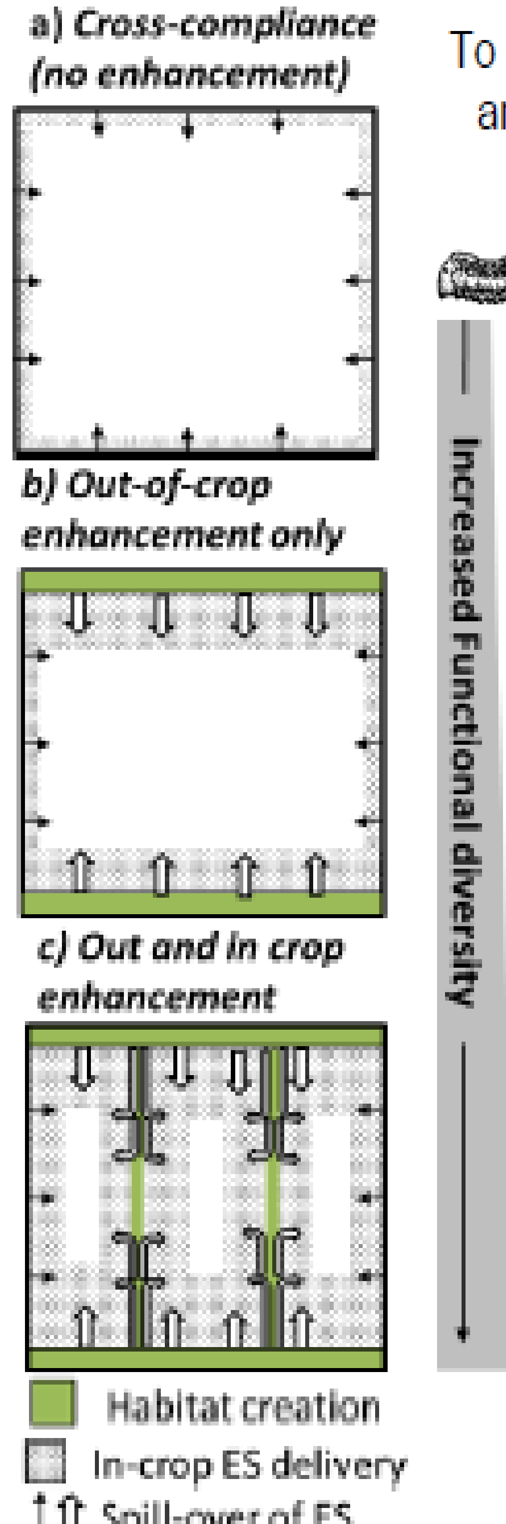
Unpublished results Dr Thorunn Helgason University of York



- Restore depleted population of earthworms and mycorrhizal fungi.
- Improve soil structure- reduced bulk density and increased water-stable macroaggregates - which improve soil carbon sequestration.
- Increased water storage capacity, macropores, drainage.
- Improved crop yields including increased crop resilience of crops to moderate drought and shallow flooding.
- Reduced requirement for N fertilizer in initial crops after ley.



Field scale treatments replicated on 15 arable farms



To support pest control, pollination and in field delivery of soil biota

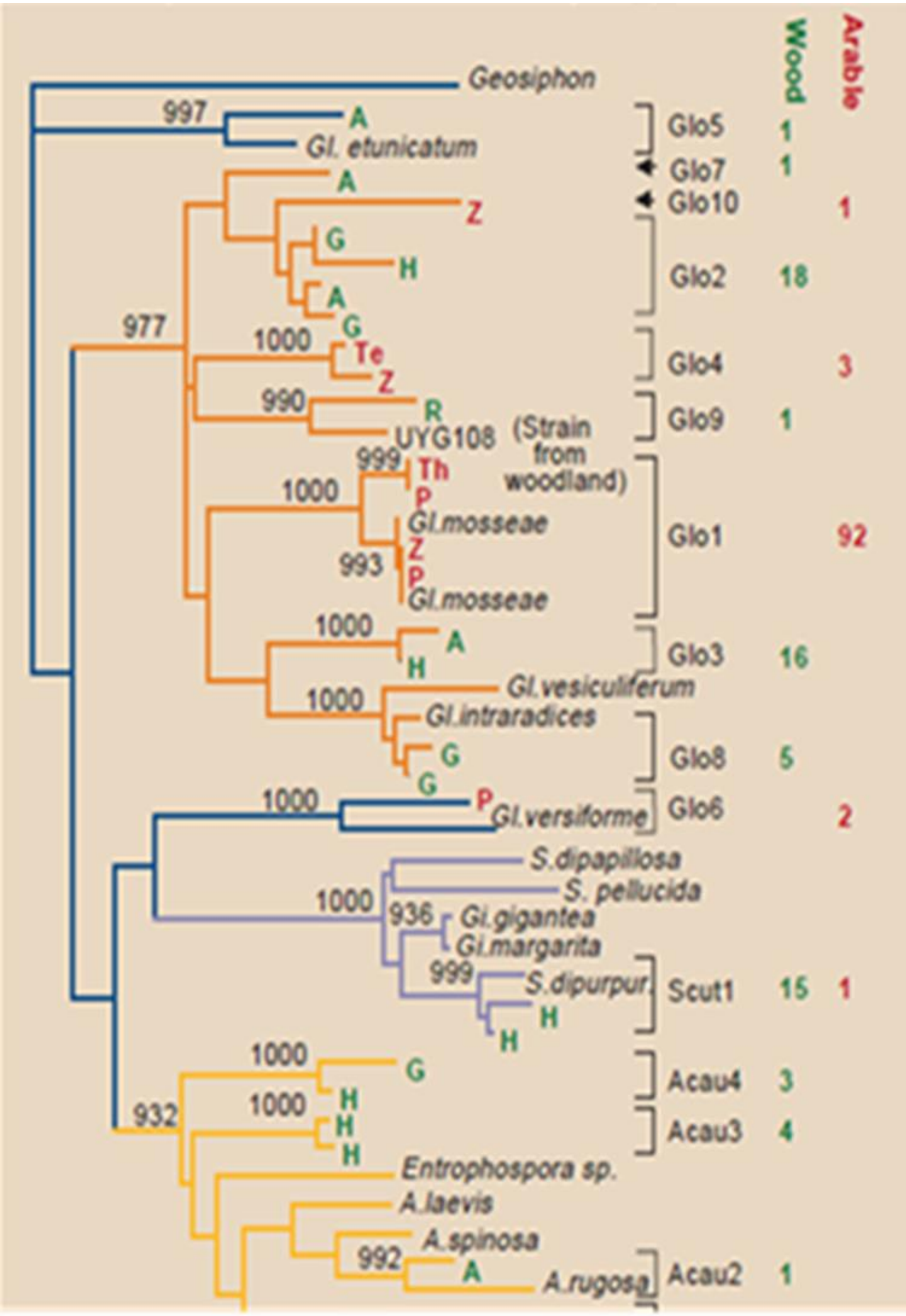
assist | Achieving Sustainable Agricultural Systems

funded by BBSRC NERC

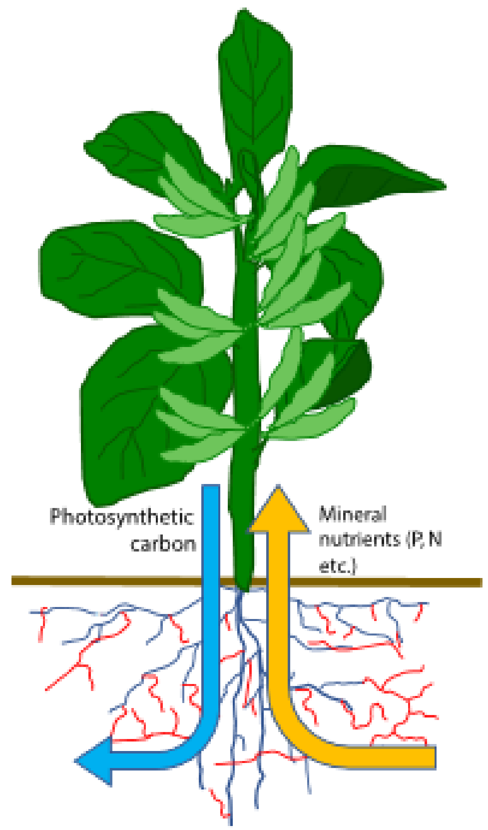
Centre for Ecology & Hydrology

Rothamsted Research

Contingent benefits



Helgason et al 1998



Journal of Ecology
BRITISH ECOLOGICAL SOCIETY
Journal of Ecology 2017, 105, 921–929
doi: 10.1111/1365-2745.12788

MINI-REVIEW: ECOLOGICAL SOLUTIONS TO GLOBAL FOOD SECURITY

Are mycorrhizal fungi our sustainable saviours? Considerations for achieving food security

Thomas J. Thirkell*, Michael D. Charters, Ashleigh J. Elliott, Steven M. Sait and Katie J. Field*

	Impact of AMF
Plant level	
Nutrient uptake	Enhanced nutrient uptake
	Reduced/no nutrient uptake effect
Biomass/yield	Enhanced yield
	Reduced/no yield effect
Defence	Enhanced defence
	Reduced/no defence effect
Drought tolerance	Enhanced drought tolerance
Metal/salinity tolerance	Enhanced metal/salinity tolerance
	Reduced/no metal/salinity effect
Agroecosystem level	
Soil C sequestration	Enhanced soil C sequestration
Soil structure/erosion	Enhanced soil structure
Water retention	Enhanced water retention
Nutrient leaching	Reduced nutrient leaching
Biodiversity/competition	Reduced weed competition/increased biodiversity
	Increased weed competition/reduced biodiversity

Garnett T and Godfray C (2012).
Sustainable intensification in agriculture. Navigating a course through competing food system priorities.

"There are major opportunities for improving environmental and productivity outputs simultaneously in agricultural systems with current low levels of production. However, trade-offs between yields and environmental outputs are more prevalent in high external input production systems"

Analysis of trade-offs in agricultural systems: current status and way forward

CJ Klapwijk[1,2], MT van Wijk[3], TS Rosenstock[4], PJA van Asten[2], PK Thornton[5] and KE Giller[1]

Current Opinion in Environmental Sustainability

Table 2

Strengths and weaknesses of the different approaches for analysing trade-offs in agricultural systems ('Act' is the actual or current state in the scientific literature, 'Pot' is the potential usefulness of a technique to assess a certain aspect of trade-off analyses)

	Research approach							
	Participatory		Empirical		Simulation		Optimization	
Aspect	Act	Pot	Act	Pot	Act	Pot	Act	Pot
Integration of interdisciplinary content	–	+	–	+	–	+	–	–
Assessment across different time horizons	–	+	–	–	+	+	+	+
Assessment across spatial scales and integration levels	–	+	–	+	+/–	+/–	+/–	+
Takes into account qualitative information	+	+	–	+	–	–	–	–
Appropriate representation of uncertainty	–	+	–	+	–	+	–	+
Identification of possibilities to alleviate the observed trade-offs	–	–	–	–	+	+	+	+
Ability to deal with real-life system complexity	+	+	+	+	–	–	–	–
Applicability to real-life decision-making	+	+	+	+	–	–	+/–	+/–

FCRN

OXFORD MARTIN SCHOOL

Garnett T and Godfray C (2012).
Sustainable intensification in agriculture. Navigating a course through competing food system priorities.

"***While there is a need for more scientific knowledge, it must be recognised that values shape stakeholders' different attitudes to the food system and their views on what the way forward should be. More deliberate exploration of these different values will help society obtain a deeper and shared understanding of what the challenge is and of what solutions might work***."

Sustainable intensification in agriculture: the richer shade of green. A review

Paul C. Struik[1] · Thomas W. Kuyper[2]

Agron. Sustain. Dev. (2017) 37: 39
DOI 10.1007/s13593-017-0445-7

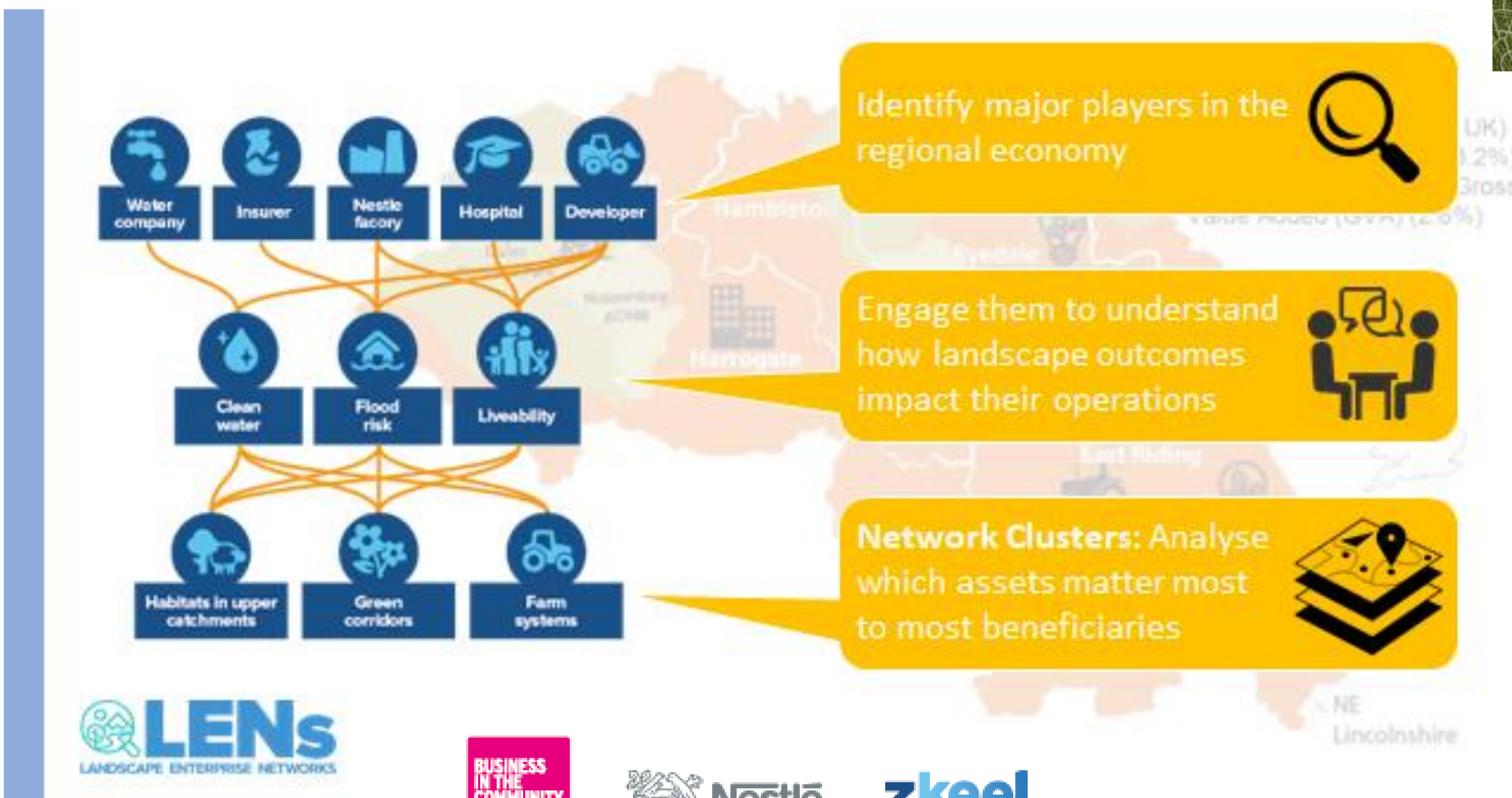
REVIEW ARTICLE

cecan
Centre for the Evaluation of Complexity Across the Nexus

"Society needs an agriculture that demonstrates resilience under future change, an agronomy that can cope with the diversity of trade-offs across different stakeholders, and a sustainability that is perceived as a dynamic process based on agreed values and shared knowledge, insight, and wisdom."

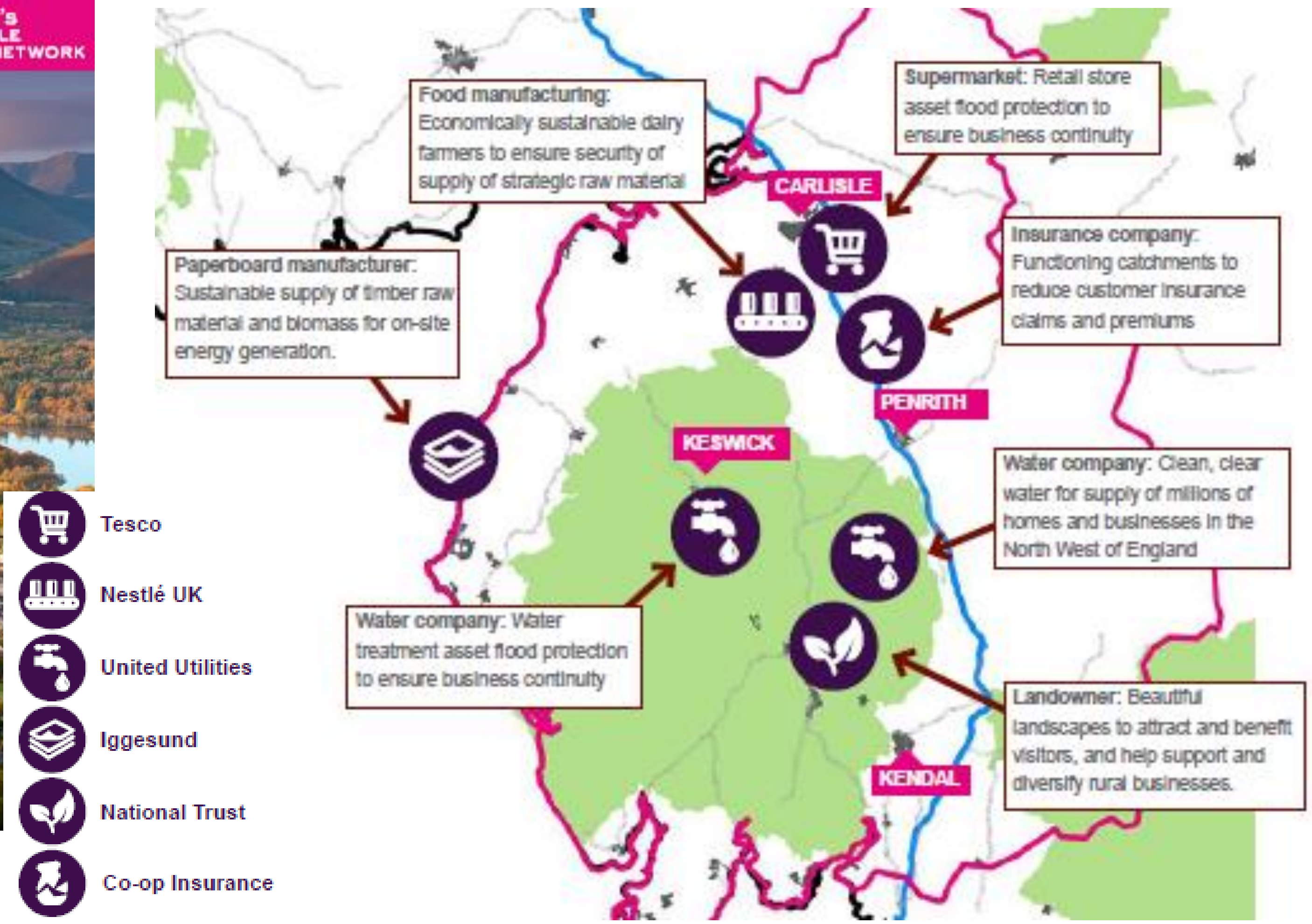
Figure 1. The stock of assets producing the flow of services that provide value to society

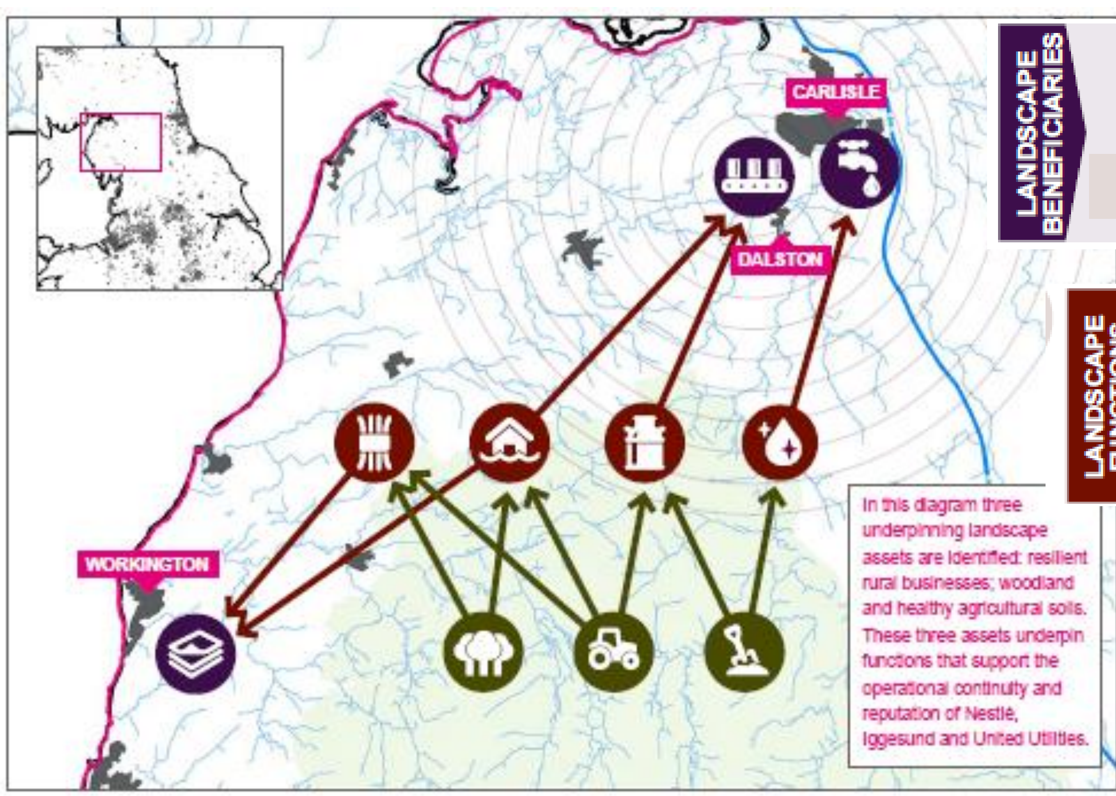
Source: Natural Capital Coalition https://naturalcapitalcoalition.org/natural-capital/

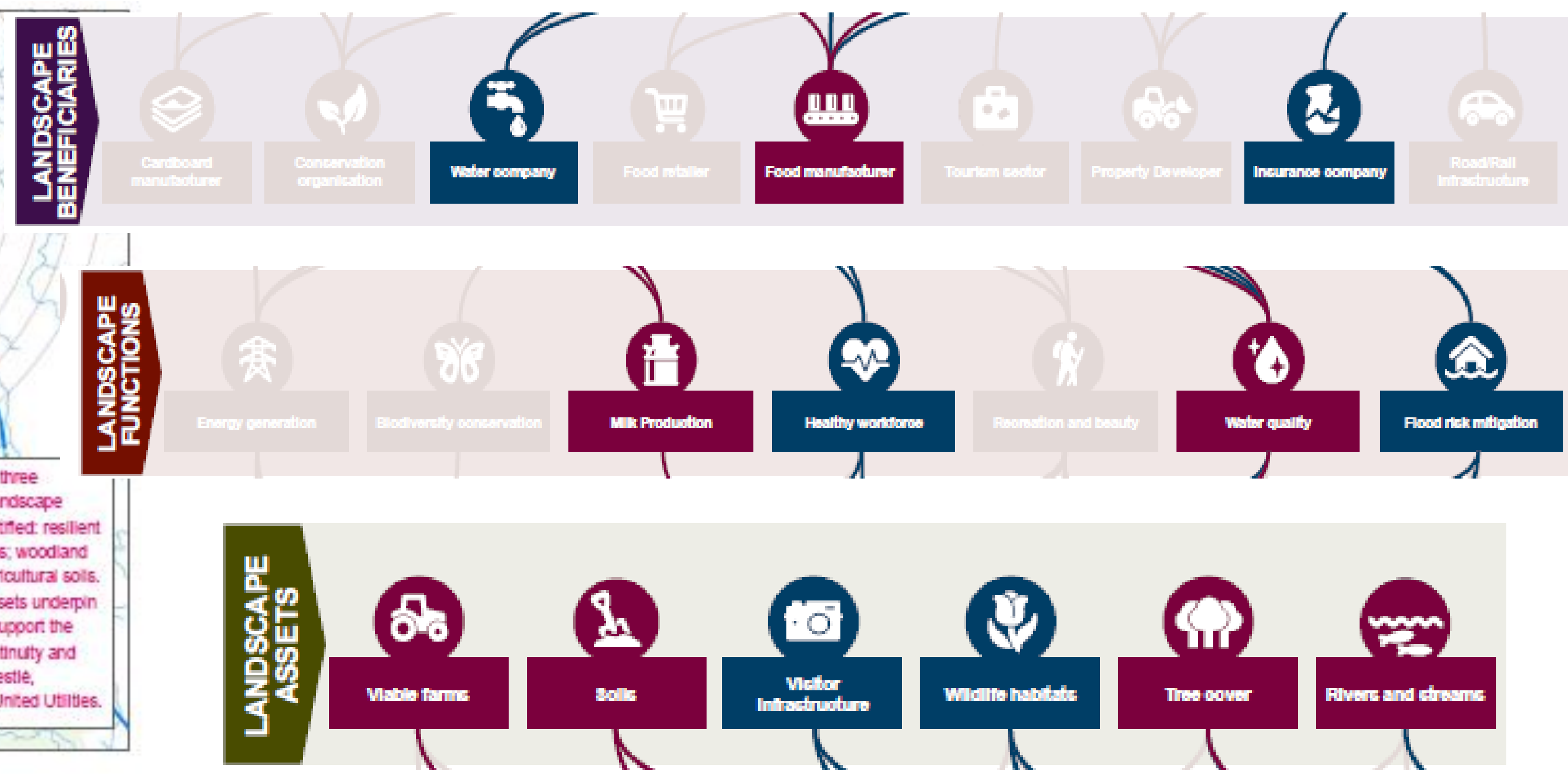


BUSINESS IN THE COMMUNITY Nestlé 3keel


BUSINESS IN THE COMMUNITY
Nestlé
3keel
THE PRINCE'S RESPONSIBLE BUSINESS NETWORK
Healthy Ecosystems Cumbria
A Landscape Enterprise Networks opportunity analysis
Making Landscapes work for Business and Society


Tesco
Nestlé UK
United Utilities
Iggesund
National Trust
Co-op Insurance
Food manufacturing: Economically sustainable dairy farmers to ensure security of supply of strategic raw material
Supermarket: Retail store asset flood protection to ensure business continuity
CARLISLE
Insurance company: Functioning catchments to reduce customer insurance claims and premiums
Paperboard manufacturer: Sustainable supply of timber raw material and biomass for on-site energy generation.
PENRITH
KESWICK
Water company: Clean, clear water for supply of millions of homes and businesses in the North West of England
Water company: Water treatment asset flood protection to ensure business continuity
Landowner: Beautiful landscapes to attract and benefit visitors, and help support and diversify rural businesses.
KENDAL


CARLISLE
DALSTON
WORKINGTON
In this diagram three underpinning landscape assets are identified: resilient rural businesses; woodland and healthy agricultural soils. These three assets underpin functions that support the operational continuity and reputation of Nestlé, Iggesund and United Utilities.


LANDSCAPE BENEFICIARIES
Cardboard manufacturer
Conservation organisation
Water company
Food retailer
Food manufacturer
Tourism sector
Property Developer
Insurance company
Road/Rail infrastructure
LANDSCAPE FUNCTIONS
Energy generation
Biodiversity conservation
Milk Production
Healthy workforce
Recreation and beauty
Water quality
Flood risk mitigation
LANDSCAPE ASSETS
Viable farms
Soils
Visitor infrastructure
Wildlife habitats
Tree cover
Rivers and streams

Farmer networks to drive change

Global Assessment of Social Capital for Sustainable Agriculture and Land Management

J Pretty, A L M Abubakar, S Attwood, R Bawden, H van den Berg, Z P Bharucha, J Dixon, C B Flora, K Gallagher, K Genskow, S E Hartley, J W Ketelaar, J K Kiara, V Kumar, Y L Lu, T MacMillan, A Maréchal, A Noble, P V V Prasad, E Rametsteiner, J Reganold, J I Ricks, J Rockström, O Saito, P Thorne, S L Wang, H Wittman, M Winter, P Y Yang

Farmer Clusters

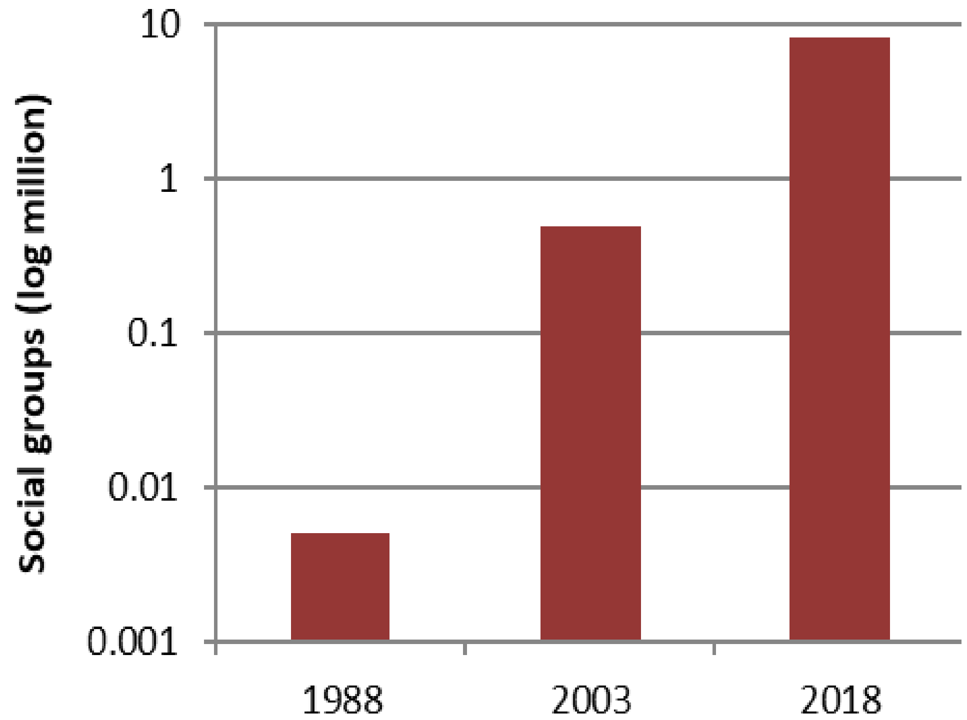
INNOVATIVE FARMERS

PART OF THE DUCHY FUTURE FARMING PROGRAMME

Table 1. Eight categories of social capital interventions for redesign of agriculture and land

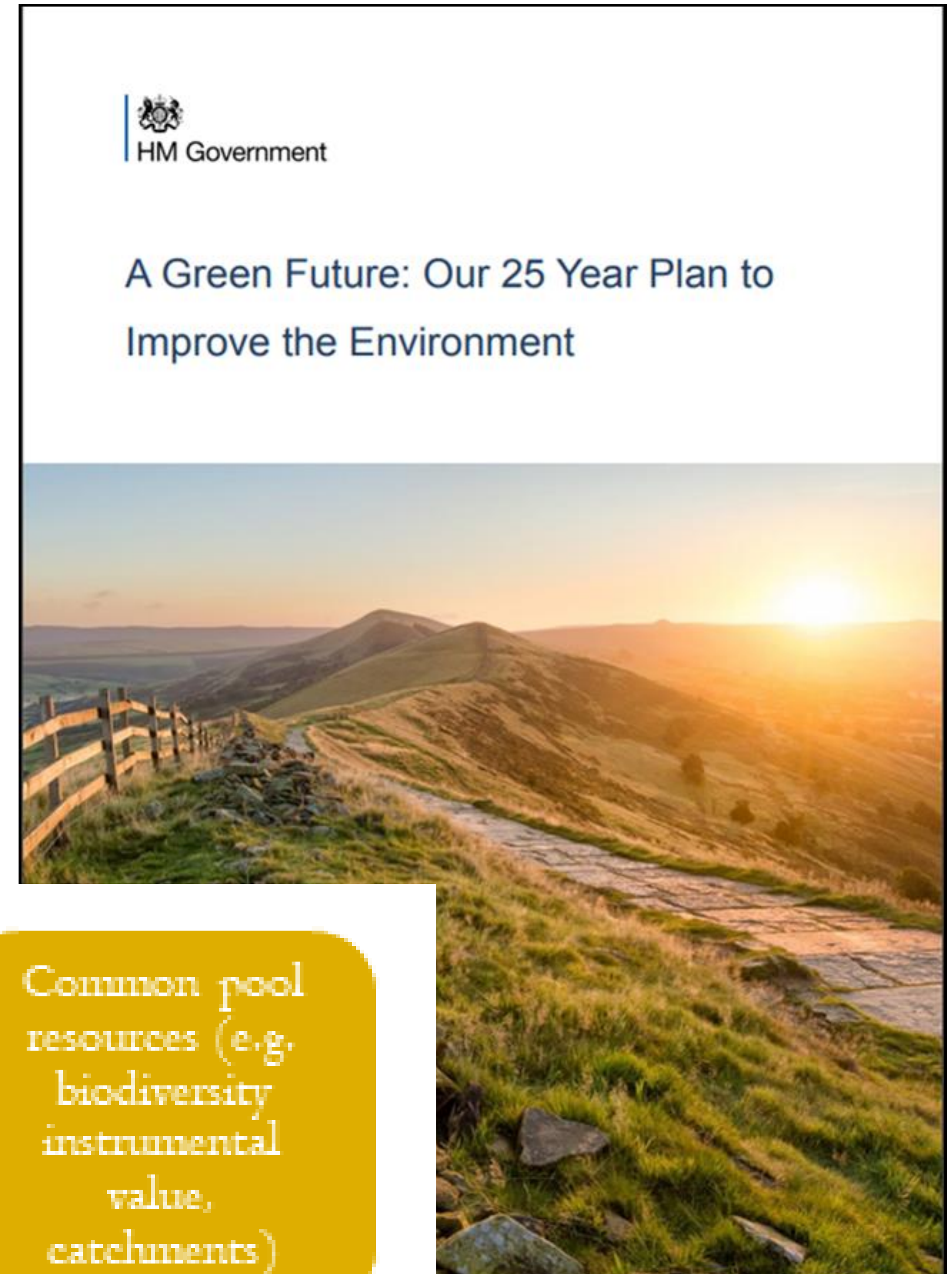
Redesign category	Intervention types
1. Integrated pest management	Farmer field school (FFS), push-pull systems of IPM, IPM clubs and FFS alumni groups
1. Forest management	Joint forest management (JFM), community based forestry (CBF), participatory forest management (PFM), agroforestry
1. Land management	Watershed and catchment management, conservation agriculture (CA), integrated biodiversity, farmer clusters
1. Water management	Participatory irrigation management (PIM), water user groups (WUGs), farmer water schools, farmer-led watersheds
1. Pasture and range management	Management intensive rotational grazing groups, veterinary groups, dairy groups, agropastoralist field schools
1. Supporting services	Microfinance groups, multifunctional farmer and non-farmer groups
1. Innovation platforms	Research platforms, co-production groups, science and technology backyard platforms, field science labs
1. Intensive integrated systems	Community supported agriculture groups, biogas-pig-vegetable groups, aquaculture

Figure 1: Cumulative number of social groups formed in agricultural and landscape redesign



We will:

- Embed an 'environmental net gain' principle for development, including housing and infrastructure.
- Improve the way we manage and incentivise land management, including designing and delivering a new environmental land management system.
- Improve soil health, and restore and protect peatlands – this will include developing a soil health index and ending the use of peat in horticulture.
- Expand woodland cover and make sure that existing woodlands are better managed to maximise the range of benefits they provide – this will include supporting the development of a new Northern Forest and appointment of a national Tree Champion to support our approach.
- Take action to reduce the risk of harm from flooding and coastal erosion including greater use of natural flood management solutions.



i. Designing and delivering a new environmental land management system

we will move to a system of paying farmers public money for public goods. The principal public good we want to invest in is environmental enhancement.

The Government will take steps to encourage private sector investment wherever possible, targeting public funds at projects that provide purely public goods.

OECD, 2013

Delivering win-wins: public money for public goods?

Environmental Land Management – Vision for the Future

- Cornerstone of land management policy
- Underpinned by natural capital principles
- Delivering, through land managers, the 25 YEP goals for:
  - Clean and plentiful water
  - Clean air
  - Thriving plants and wildlife
  - Reduction in and protection from environmental hazards
  - Adaptation to and mitigation of climate change
  - Beauty, heritage and engagement with the environment

But when we use a natural capital approach, we are more likely to take better and more efficient decisions that can support environmental enhancement and help deliver benefits such as reduced long-term flood risk, increases in wildlife, and a boost to long-term prosperity.

Objective	Result indicator
Species rich hay meadow	Species richness score based on presence of positive and negative indicator species.
Habitat for breeding waders	Score based on positive and negative habitat structural characteristics/features.
Provision of winter bird food	Score based on number of specified seed bearing plant species present.
Provision of pollen and nectar resources for pollinators	Score based on number of specified flowering plant species present and in 2nd year after establishment % cover of specified species.

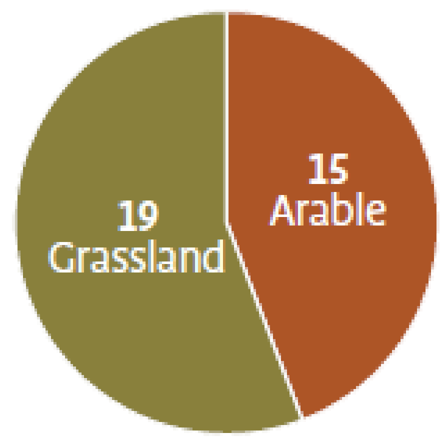
Piloting results-based payments for agri-environment schemes in England

Executive Summary

First published 9th October 2019

Natural England Joint Publication JP031

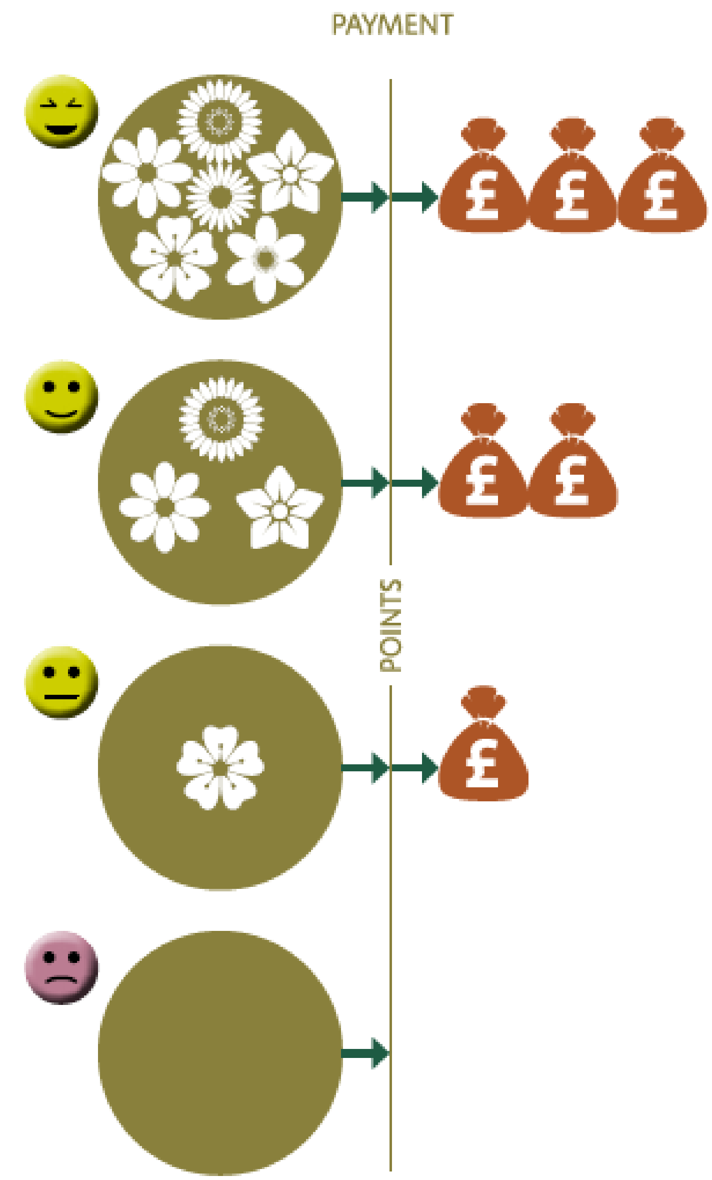
YORKSHIRE DALES
National Park Authority



Number of farms under agreement
(one grassland agreement holder left the pilot after the first year)

"The more that you put in, the more that you get out"

Participating farmer

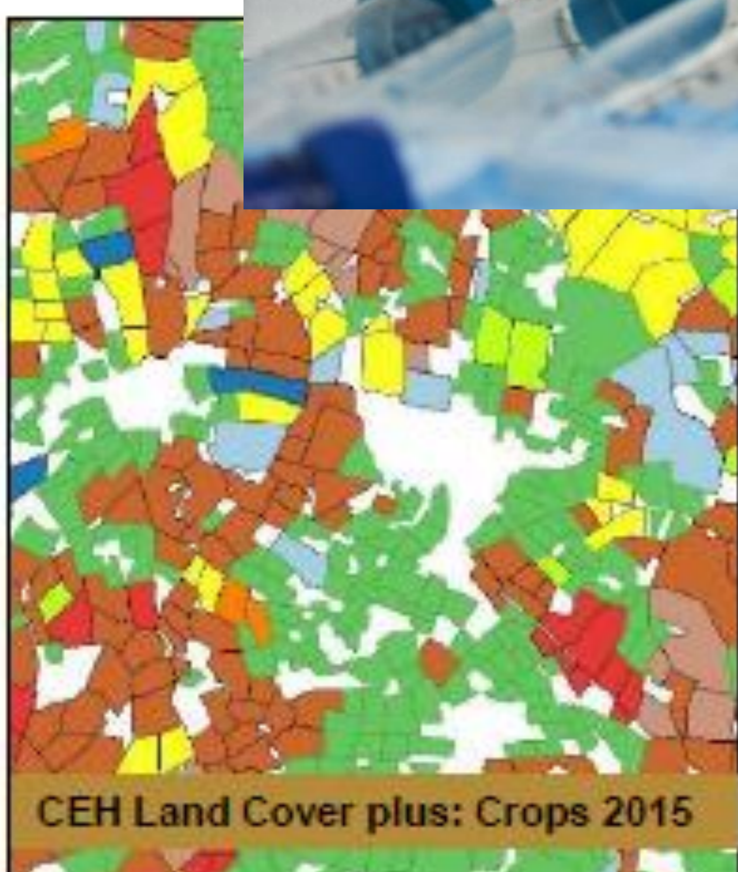


Measuring environmental change: outcome indicator framework for the 25 Year Environment Plan

Department for Environment Food & Rural Affairs

May 2019

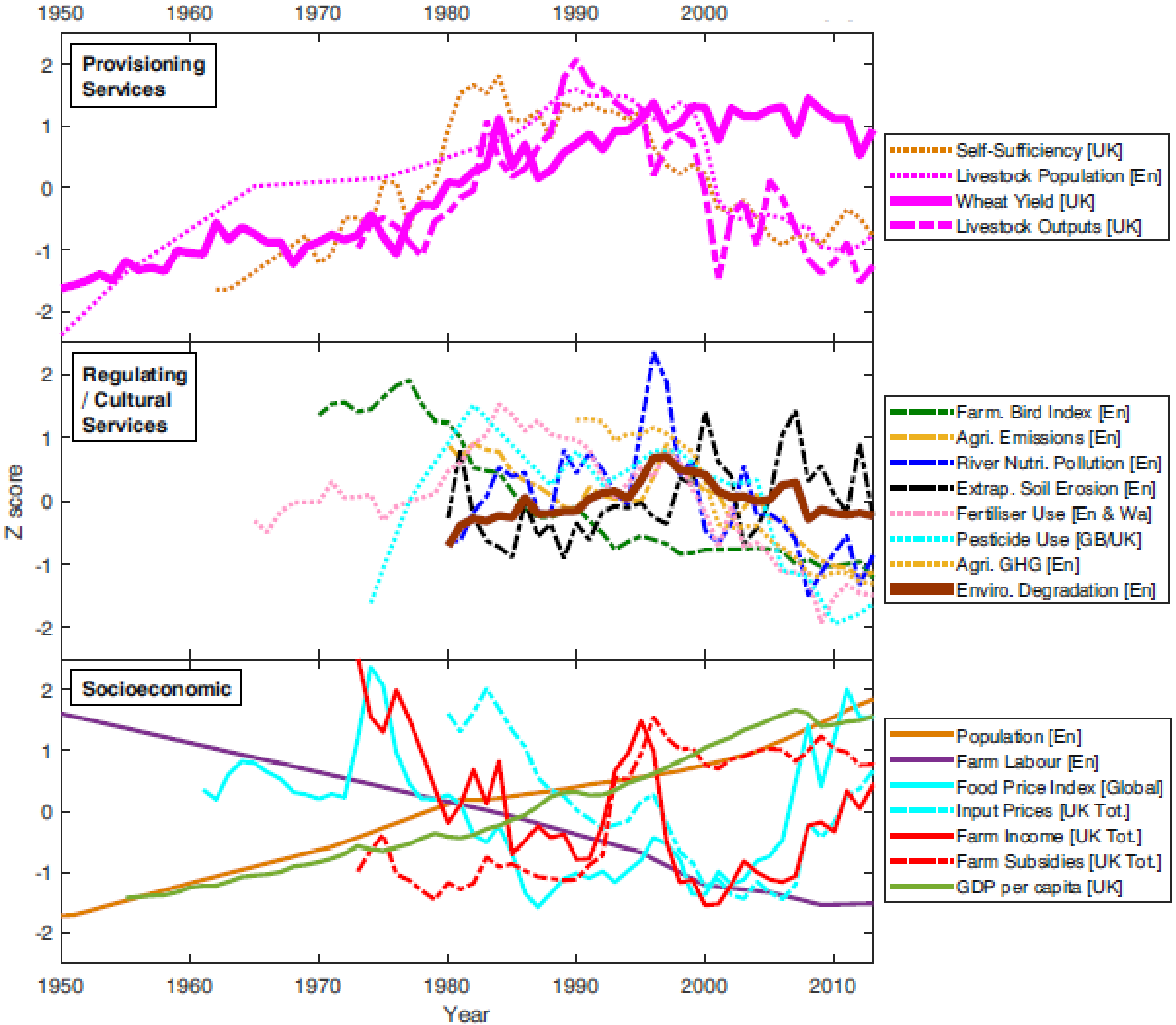
Arable farmer carrying out self-assessment in winter bird food © David Whiting



To what extent has sustainable intensification in England been achieved?

David I. Armstrong McKay [a,*], John A. Dearing [a], James G. Dyke [a], Guy M. Poppy [b], Les G. Firbank [c]

Science of the Total Environment 648 (2019) 1560–1569



What do we want from agricultural landscapes?

"In future, 100% of any public payment should be conditional on meeting higher standards of wildlife, soil & water" NT

"We shouldn't contemplate anything which undermines British farming's competitiveness or its ability to produce food" NFU

Thank you! https://www.york.ac.uk/yesi/

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• Sustainable intensification: Producing more from the same area of land while conserving resources, reducing negative environmental impacts and enhancing natural capital and the flow of environmental services.

• Ecological intensification: Increasing food production while reducing the use of external inputs and minimizing negative effects on the environment by capitalising on ecological processes and ecosystem services from plot to landscape scale.

• Agroecological intensification: Improving the performance of agriculture while minimizing environmental impacts and reducing dependency on external inputs through integration of ecological principles into farm and system management.

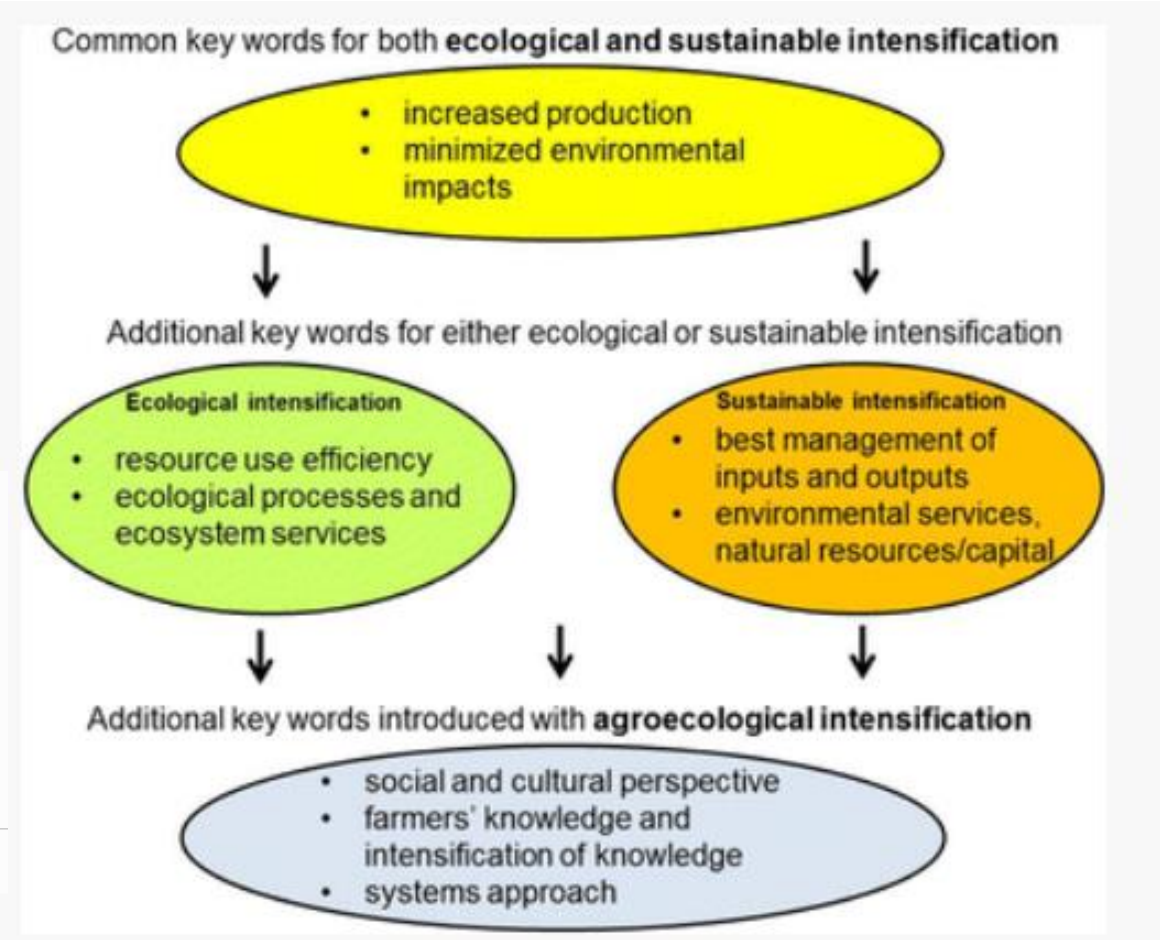
"agroecological intensification integrates ecological principles into agricultural management to reduce dependency on external inputs and increase the productive capacity of biotic and abiotic system components" Milder et al. (2012)

Agronomy for Sustainable Development
October 2015, Volume 35, Issue 4, pp 1283–1295 | Cite as

The blurred boundaries of ecological, sustainable, and agroecological intensification: a review

Authors Authors and affiliations

Alexander Wezel, Gizachew Soboksa, Shelby McClelland, Florian Delespesse, Apolline Boissau



Box 3: Concepts related to sustainable intensification

Ecological intensification: This phrase was coined by Cassman[32] in a 1999 paper on cereal production that anticipates many of the analyses of the last few years: "At issue, then, is whether further intensification of cereal production systems can be achieved that satisfy the anticipated increase in food demand while meeting acceptable standards of environmental quality. This goal can be described as an ecological intensification of agriculture." This concept is essentially synonymous with an environmentally oriented interpretation of sustainable intensification.

Agroecology: This has been defined as "the application of ecological concepts and principles to the design and management of sustainable agricultural ecosystems… This approach is based on enhancing the habitat both above ground and in the soil to produce strong and healthy plants by promoting beneficial organisms while adversely affecting crop pests (weeds, insects, diseases, and nematodes)[33]. However it can also been seen as a "scientific discipline, as a movement, and as a practice" – sometimes all three – and the way it is used varies by context[34].

Sustainable intensification in agriculture

Navigating a course through competing food system priorities

A report on a workshop

Tara Garnett[1] & H. Charles J. Godfray[2,3]

scientists and policy-makers alike. The big question is how t produce more food with much fewer resources. Sustainable intensification (i.e., increasing agricultural output while keepir the ecological footprint as small as possible) for some is an oxymoron, unless real progress can be made in ecological intensification, that is, increasing agricultural output by capitalizing on ecological processes in agro-ecosystems.

Box 1: Sustainable intensification: description, aspiration, or oxymoron? A selection of views

Key Policy concerns likely to influence the delivery of Public Goods across the agricultural, environment and rural system

Environment

- **Sustainability** (water, soil, environmental resilience)
- **Landscape Planning and Policy** (Habitat creation and protection
- **Health of the Environment** (animal, plant and tree health)
- **Wildlife** (biodiversity, pollinators)
- **Biosecurity** (AMR, disease risk)
- **Food production** (crop and livestock)

Social

- **Social capital** (community cohesion, resilience)
- **Population demographics** (rural/urban)
- **Wellbeing** (farmer, community physical and mental health)
- **Animal welfare**
- **Food safety**

Economic

- **Employment** (job creation, financial investment, tourism)
- **Labour** (availability, migration, skills)
- **Infrastructure** (digital and physical connectivity)
- **Business viability** (profitability, productivity, incomes)
- **Trade and regulation**
- **Land and housing** (prices, availability)

External Drivers

- Stakeholder views, capabilities, resistance
- Departmental resources, time, expertise
- Government funding commitments

CASE STUDY 2 - SHAPING FUTURE POLICY

Mapping the Future Agriculture, Environment and Rural System: Using Systems Mapping to embed complexity thinking in the design and development of post-Brexit policy across four domains: Animal Plant Health and Welfare; Environmental Land Management; Productivity, Risk and Resilience; and Rural Economies and Communities.

Goal: A whole system approach, putting policies into their real-world complex system context

Aims:

Embed and incorporate complexity at the early stages of designing new policy for the future agriculture, environment and rural system

Build capacity to incorporate complexity thinking into policy design and evaluation throughout the policy system

Stakeholders: Defra policy leads and policy analysts across four policy domains