Tipping points in lowland agricultural landscapes (TPAL)

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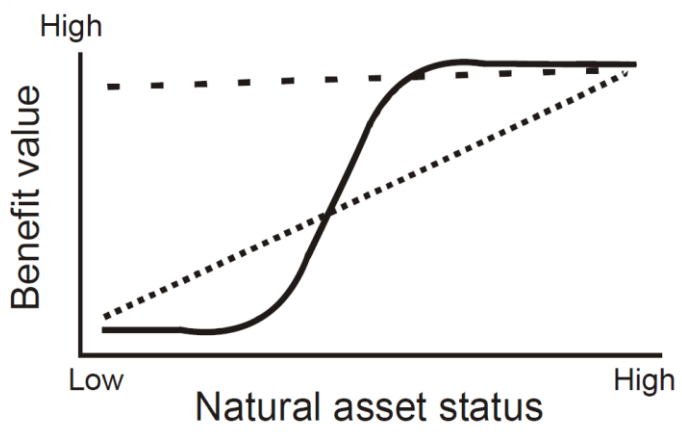
Overview

- A collaborative project between Bournemouth University (Adrian Newton, Stephen Watson, Paul Evans, Arne Loth) and CEH (James Bullock, Lucy Ridding, Morag McCracken)

- Undertaken as a contribution to the Valuing Nature Programme

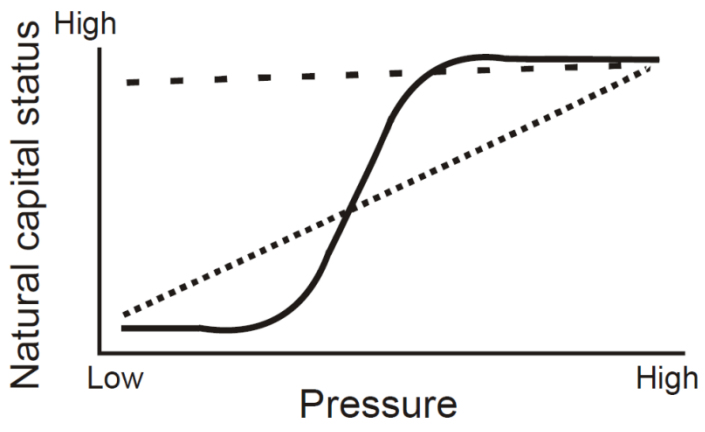
- Report available from VNP / CEH: https://valuing-nature.net/node/931

Analytical framework



Alternative forms of natural capital asset–benefit relationships, as hypothesized by Mace et al. (2015), *J. Appl. Ecol.*

The continuous line represent a threshold response (possible tipping point in benefit provision).



We hypothesized that the relationship between anthropogenic pressures and natural capital status might also demonstrate a threshold response (continuous line).

Analytical framework

Mace et al. (2015) identify three dimensions of asset status:

(i) *quantity* or 'amount' of the asset (i.e. its area, volume or mass);
(ii) *quality*, which refers to the condition of the asset; and
(iii) *spatial configuration*, which refers to its location and spatial distribution pattern.

Potentially, tipping points could be associated with each of these three dimensions, although this has not been examined systematically.

Consequently, we examined each of these three dimensions independently.

Aims and objectives

Overall aim: to examine the mechanisms and consequences of tipping points in lowland agricultural landscapes.

Specifically this research aimed to find out:

- How has the environment of Dorset changed in the recent past?
- How might it change in the near future?
- Is there any evidence for thresholds or tipping points in supply of ecosystem benefits?
- What are the implications of such change for human society, and specifically for economic growth and employment?

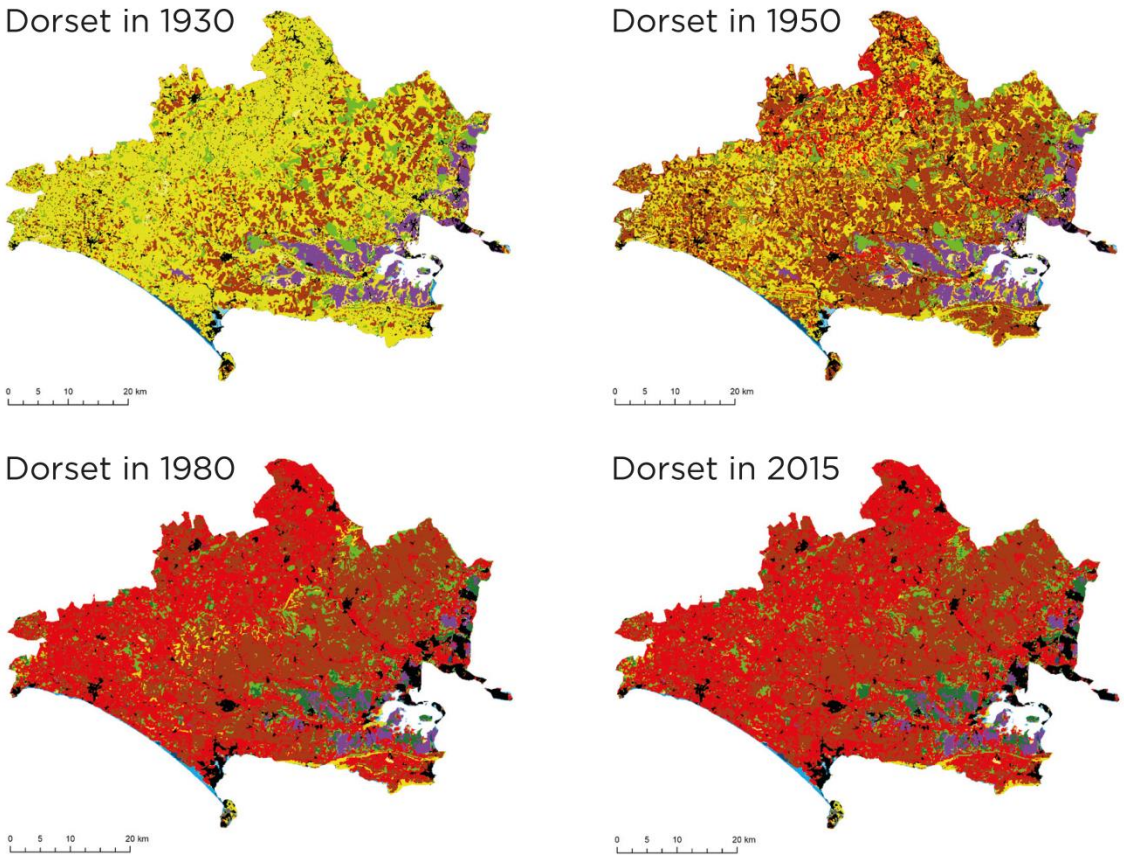
Approaches

We used three approaches to assess the occurrence of thresholds and tipping points, in the:

- *past* – using analysis of long-term data sets (WP1)
- *present* – using gradient analysis (WP2)
- *future* – using scenario development supported by agent based modelling (WP3)

Results WP 1: land cover change

- Maps produced of Dorset land cover indicating major changes since 1930 – see presentation by Lucy Ridding!



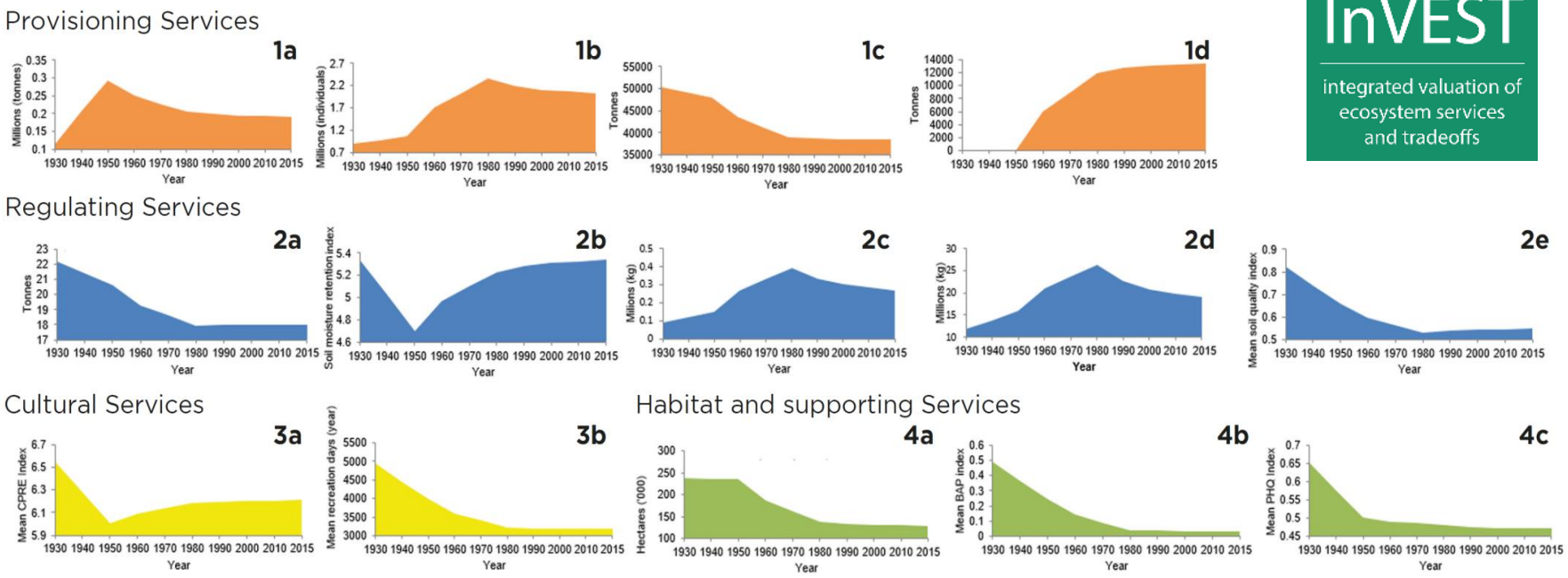
Key findings – WP 1 biodiversity

- Dorset's environment has been seriously degraded over the past 80 years. Measures of biodiversity value have undergone a substantial decline in this period, as illustrated by the 97% loss of neutral grassland and 70% loss of calcareous grassland.

- The condition of remaining semi-natural habitats has been reduced by nitrogen deposition and habitat fragmentation; for example the mean area of heathland patches has declined by 29% since 1978. These trends are primarily attributable to agricultural intensification and changing farming practices.

Results WP 1: ecosystem services

- Land cover maps used to map ecosystem services using InVEST

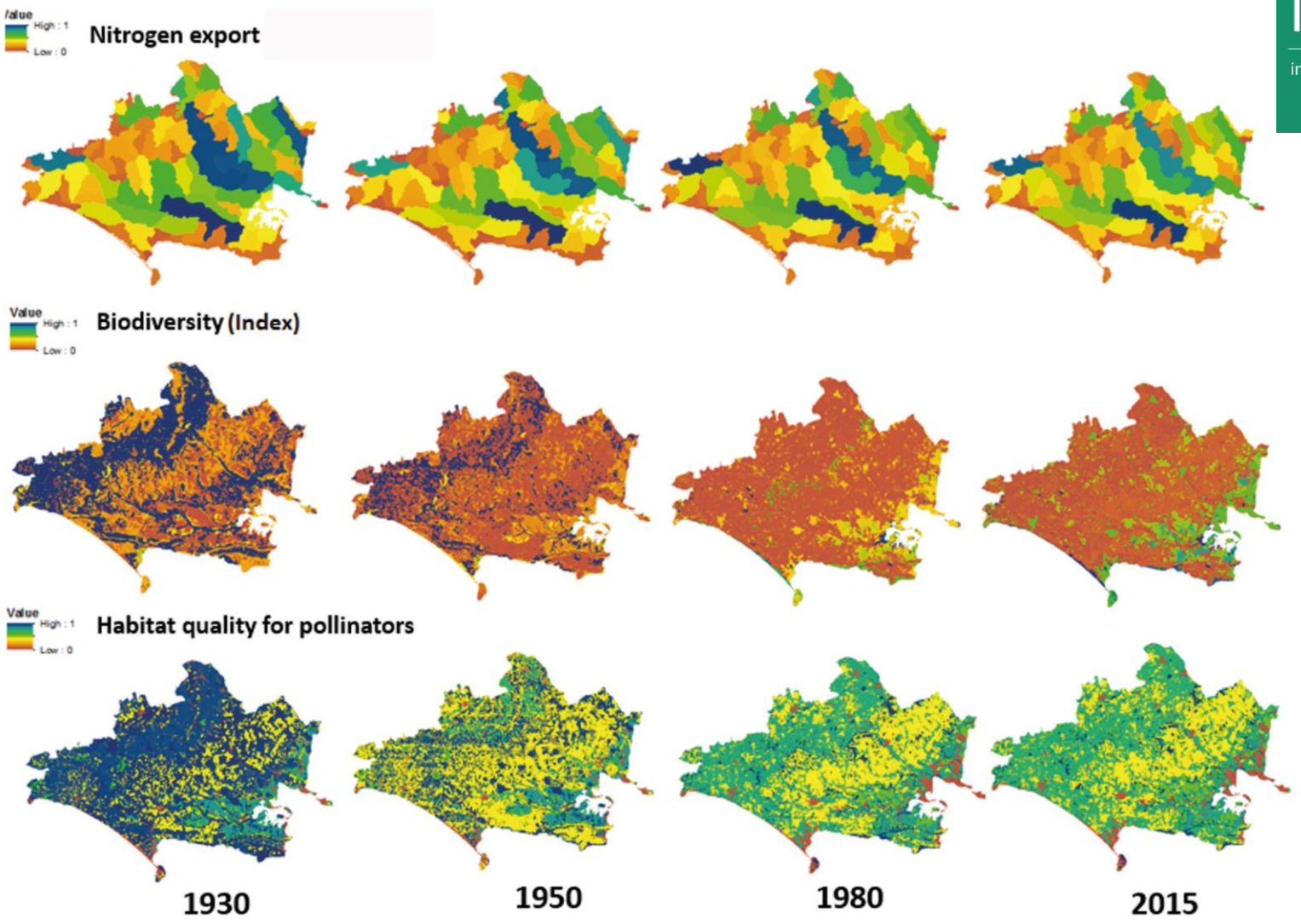


InVEST
integrated valuation of ecosystem services and tradeoffs

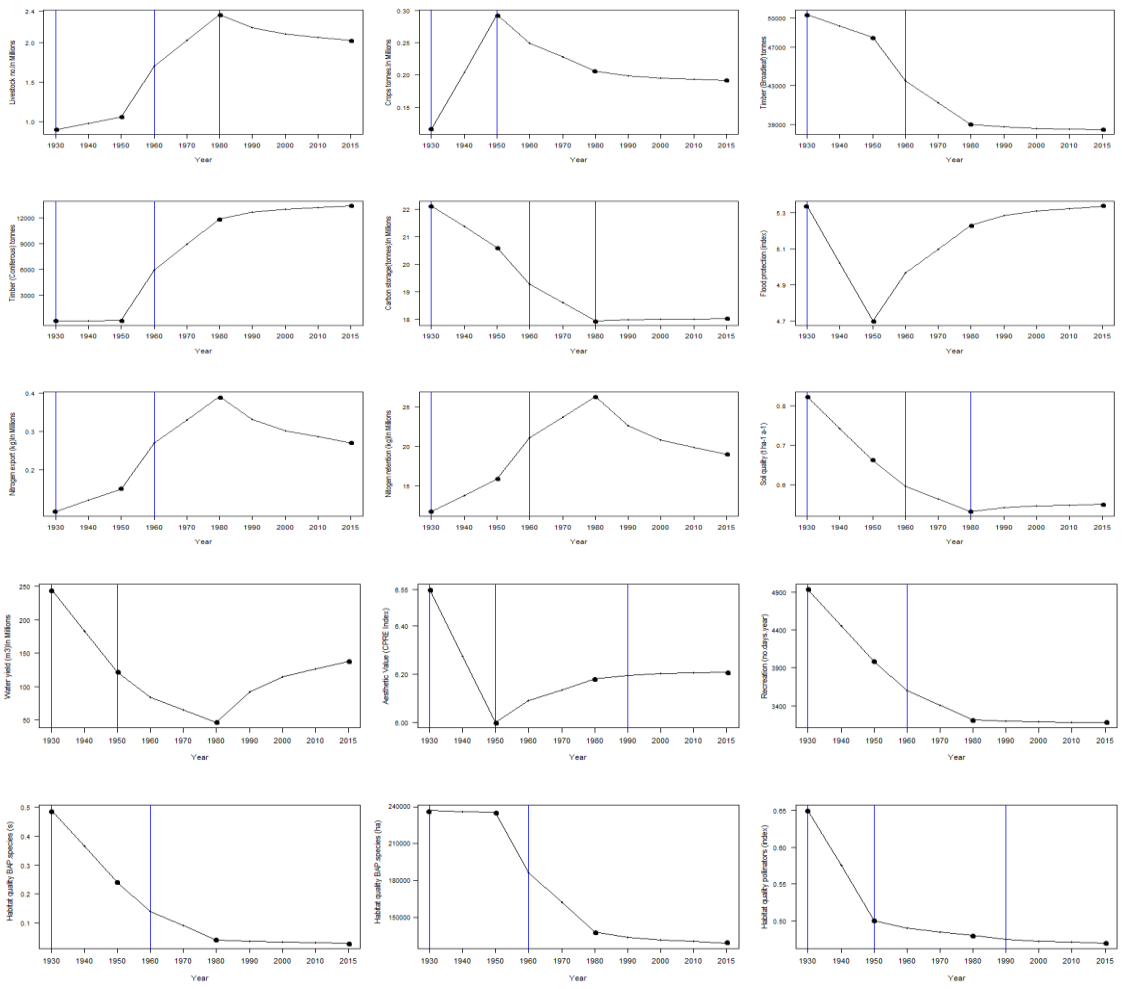
1a Food production (crops) **1b** Food production (livestock) **1c** Timber (broadleaved)
1d Timber (coniferous) **2a** Carbon sequestration and storage **2b** Flood protection **2c** Nutrient export
2d Nutrient retention **2e** Soil quality **3a** Aesthetic value **3b** Recreation value **4a** Habitat area (BAP species)
4b Habitat quality (BAP species) **4c** Habitat quality (for pollinators)

Results WP1: ecosystem services

InVEST
integrated valuation of ecosystem services and tradeoffs

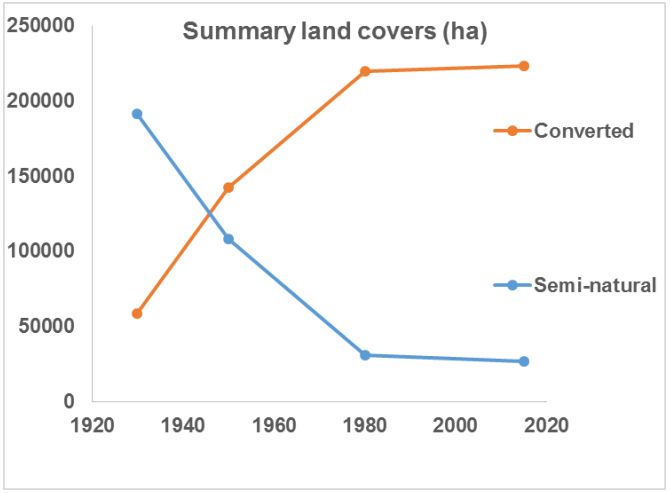


Trends in several aspects of NC



R Programming

- Breakpoint analysis
- Significant break-points ($p \leq 0.1$)



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NATURAL ENVIRONMENT RESEARCH COUNCIL

Key findings WP 1– ecosystem services

- Provision of most ecosystem services have declined significantly since the 1930's.

- Some services, such as soil quality and carbon storage, have declined continuously over this interval, with no sign of recovery.

- Others, such as mitigation of flood risk, have increased in recent years owing to changing land use, particularly the transition from arable to livestock farming that occurred over large areas after the 1950s.

Key findings WP 1– tipping points

- We detected a number of non-linear trends and thresholds, e.g. in provision of some ecosystem services

- True tipping points difficult to detect because of difficulty in identifying underlying feedback mechanisms

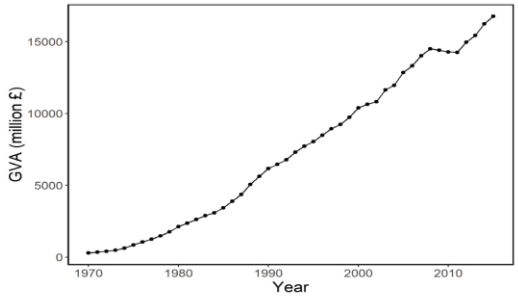
- Best evidence comes from local scale (e.g. clam fishery in Poole harbour)

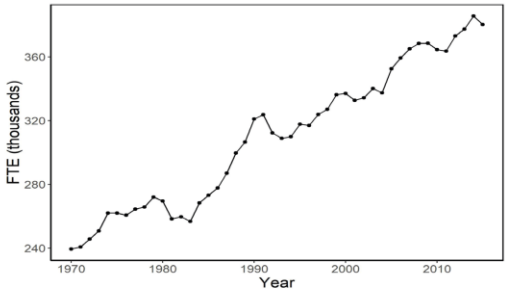
- If there are tipping points in agricultural landscapes, it is likely that we have already passed them, because of the magnitude in decline of natural capital since the 1930s

•Watson, Stephen CL, Francis GC Grandfield, Roger JH Herbert, and Adrian C. Newton. "Detecting ecological thresholds and tipping points in the natural capital assets of a protected coastal ecosystem." *Estuarine, Coastal and Shelf Science* 215 (2018): 112-123.

WP 3 : Links to the economy

- Results show a trade-off between natural capital and economic development





- GAMs (generalized additive models)

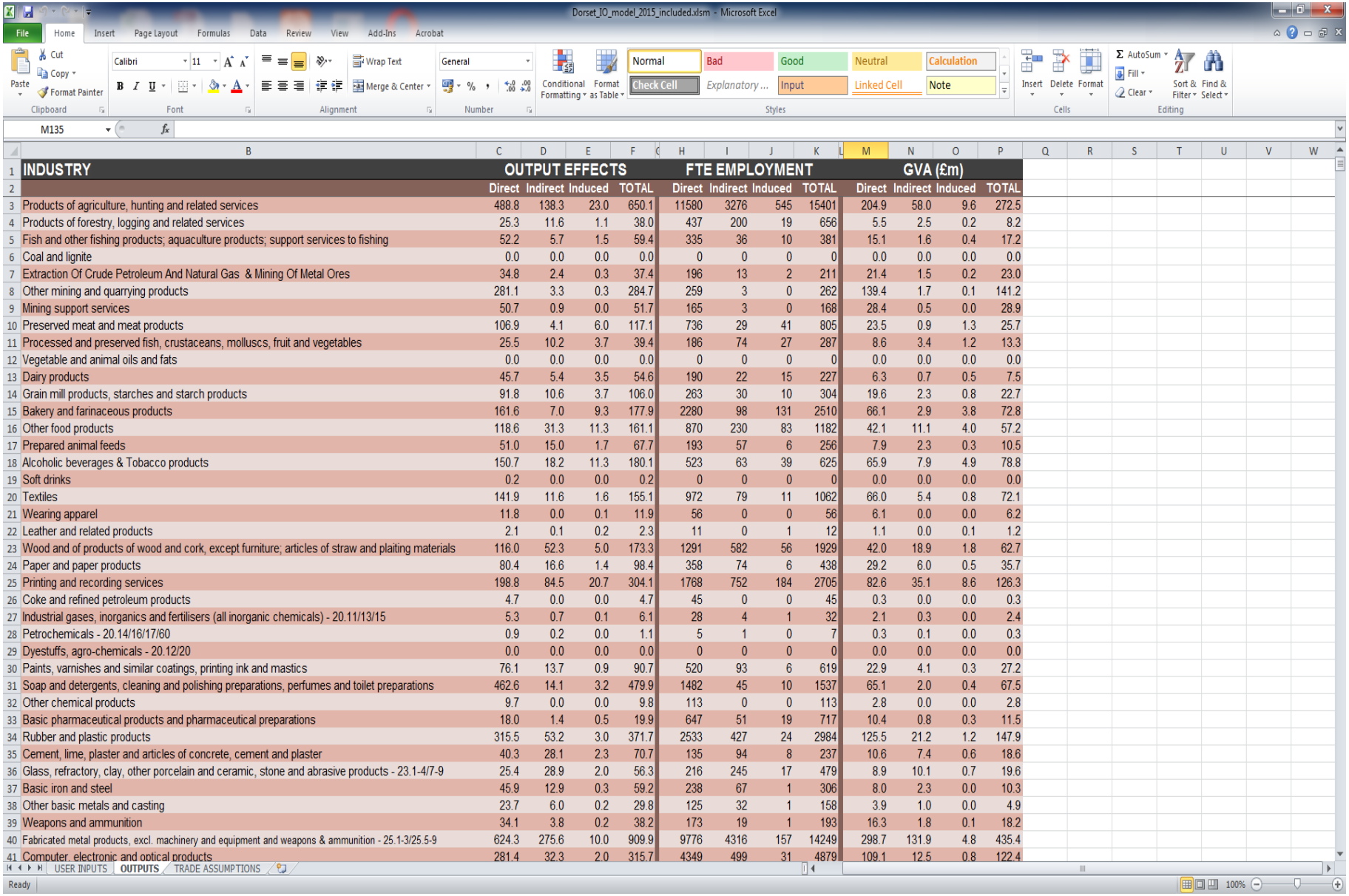
Significant (<0.05) interactions 1930- 2015 between:

Fertilizer inputs and 7 ES including biodiversity and nitrogen retention.
Pesticides and habitats for pollinators.
Total Factor Productivity of UK Agriculture and biodiversity
Mechanization and soil quality

WP 3- Economic modelling

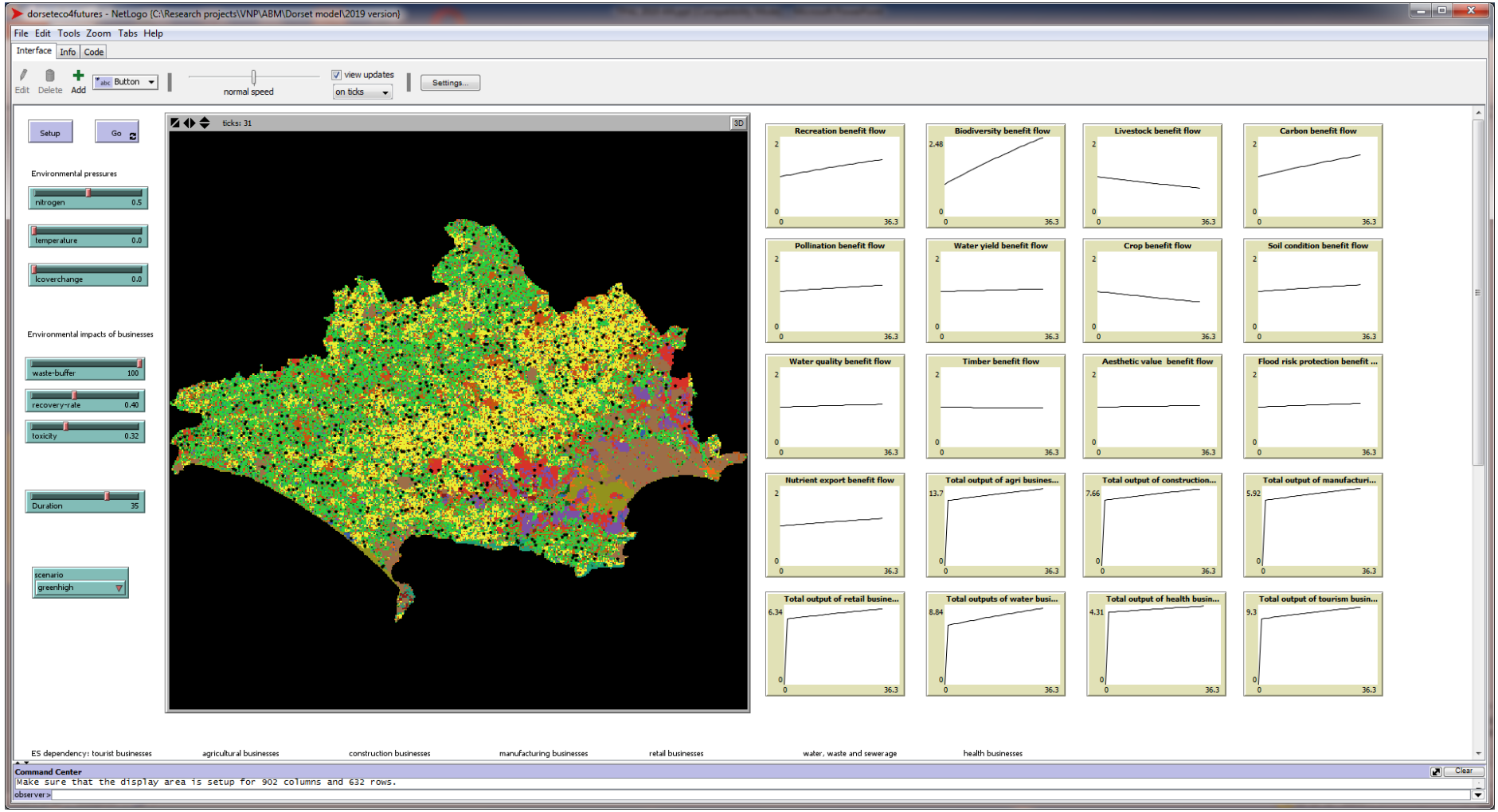
- Conventional input-output model developed for Dorset
- Based on ONS data, incorporates links between economic sectors
- However – it omits the environment!
- Agent-based economic model (DONC) also developed for Dorset
- Spatially explicit; incorporates land use change, natural capital condition and ecosystem services flows, plus links to economy

Input-output economic model for Dorset



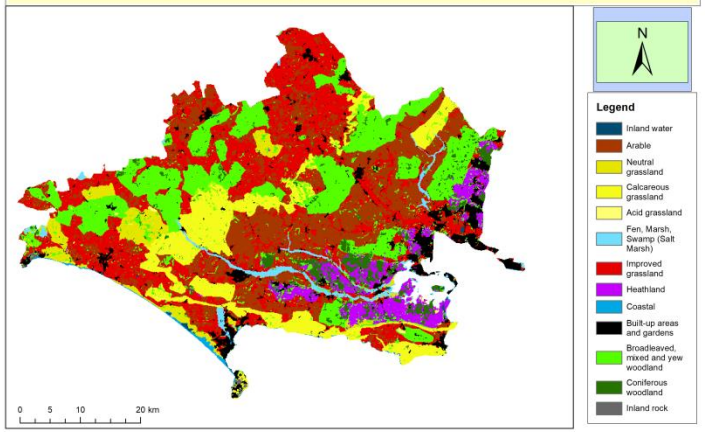
INDUSTRY	OUTPUT EFFECTS				FTE EMPLOYMENT				GVA (£m)			
	Direct	Indirect	Induced	TOTAL	Direct	Indirect	Induced	TOTAL	Direct	Indirect	Induced	TOTAL
Products of agriculture, hunting and related services	488.8	138.3	23.0	650.1	11580	3276	545	15401	204.9	58.0	9.6	272.5
Products of forestry, logging and related services	25.3	11.6	1.1	38.0	437	200	19	656	5.5	2.5	0.2	8.2
Fish and other fishing products; aquaculture products; support services to fishing	52.2	5.7	1.5	59.4	335	36	10	381	15.1	1.6	0.4	17.2
Coal and lignite	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0
Extraction Of Crude Petroleum And Natural Gas & Mining Of Metal Ores	34.8	2.4	0.3	37.4	196	13	2	211	21.4	1.5	0.2	23.0
Other mining and quarrying products	281.1	3.3	0.3	284.7	259	3	0	262	139.4	1.7	0.1	141.2
Mining support services	50.7	0.9	0.0	51.7	165	3	0	168	28.4	0.5	0.0	28.9
Preserved meat and meat products	106.9	4.1	6.0	117.1	736	29	41	805	23.5	0.9	1.3	25.7
Processed and preserved fish, crustaceans, molluscs, fruit and vegetables	25.5	10.2	3.7	39.4	186	74	27	287	8.6	3.4	1.2	13.3
Vegetable and animal oils and fats	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0
Dairy products	45.7	5.4	3.5	54.6	190	22	15	227	6.3	0.7	0.5	7.5
Grain mill products, starches and starch products	91.8	10.6	3.7	106.0	263	30	10	304	19.6	2.3	0.8	22.7
Bakery and farinaceous products	161.6	7.0	9.3	177.9	2280	98	131	2510	66.1	2.9	3.8	72.8
Other food products	118.6	31.3	11.3	161.1	870	230	83	1182	42.1	11.1	4.0	57.2
Prepared animal feeds	51.0	15.0	1.7	67.7	193	57	6	256	7.9	2.3	0.3	10.5
Alcoholic beverages & Tobacco products	150.7	18.2	11.3	180.1	523	63	39	625	65.9	7.9	4.9	78.8
Soft drinks	0.2	0.0	0.0	0.2	0	0	0	0	0.0	0.0	0.0	0.0
Textiles	141.9	11.6	1.6	155.1	972	79	11	1062	66.0	5.4	0.8	72.1
Wearing apparel	11.8	0.0	0.1	11.9	56	0	0	56	6.1	0.0	0.0	6.2
Leather and related products	2.1	0.1	0.2	2.3	11	0	1	12	1.1	0.0	0.1	1.2
Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	116.0	52.3	5.0	173.3	1291	582	56	1929	42.0	18.9	1.8	62.7
Paper and paper products	80.4	16.6	1.4	98.4	358	74	6	438	29.2	6.0	0.5	35.7
Printing and recording services	198.8	84.5	20.7	304.1	1768	752	184	2705	82.6	35.1	8.6	126.3
Coke and refined petroleum products	4.7	0.0	0.0	4.7	45	0	0	45	0.3	0.0	0.0	0.3
Industrial gases, inorganics and fertilisers (all inorganic chemicals) - 20.11/13/15	5.3	0.7	0.1	6.1	28	4	1	32	2.1	0.3	0.0	2.4
Petrochemicals - 20.14/16/17/60	0.9	0.2	0.0	1.1	5	1	0	7	0.3	0.1	0.0	0.3
Dyestuffs, agro-chemicals - 20.12/20	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0
Paints, varnishes and similar coatings, printing ink and mastics	76.1	13.7	0.9	90.7	520	93	6	619	22.9	4.1	0.3	27.2
Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	462.6	14.1	3.2	479.9	1482	45	10	1537	65.1	2.0	0.4	67.5
Other chemical products	9.7	0.0	0.0	9.8	113	0	0	113	2.8	0.0	0.0	2.8
Basic pharmaceutical products and pharmaceutical preparations	18.0	1.4	0.5	19.9	647	51	19	717	10.4	0.8	0.3	11.5
Rubber and plastic products	315.5	53.2	3.0	371.7	2533	427	24	2984	125.5	21.2	1.2	147.9
Cement, lime, plaster and articles of concrete, cement and plaster	40.3	28.1	2.3	70.7	135	94	8	237	10.6	7.4	0.6	18.6
Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products - 23.1-4/7-9	25.4	28.9	2.0	56.3	216	245	17	479	8.9	10.1	0.7	19.6
Basic iron and steel	45.9	12.9	0.3	59.2	238	67	1	306	8.0	2.3	0.0	10.3
Other basic metals and casting	23.7	6.0	0.2	29.8	125	32	1	158	3.9	1.0	0.0	4.9
Weapons and ammunition	34.1	3.8	0.2	38.2	173	19	1	193	16.3	1.8	0.1	18.2
Fabricated metal products, excl. machinery and equipment and weapons & ammunition - 25.1-3/25.5-9	624.3	275.6	10.0	909.9	9776	4316	157	14249	298.7	131.9	4.8	435.4
Computer, electronic and optical products	281.4	32.3	2.0	315.7	4349	499	31	4879	109.1	12.5	0.8	122.4

DONC: Agent-based model

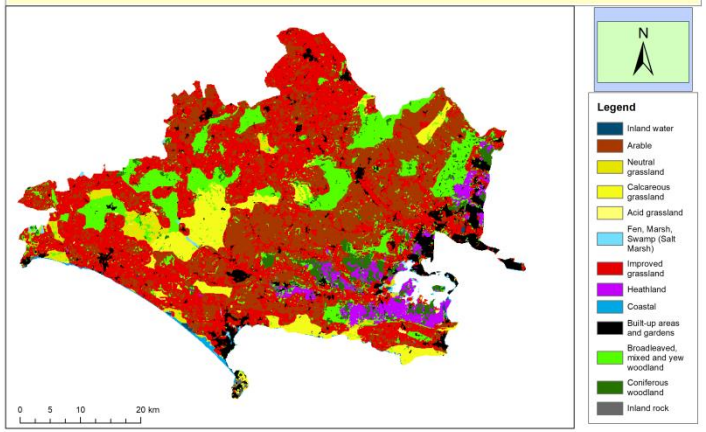


WP 3: future scenarios

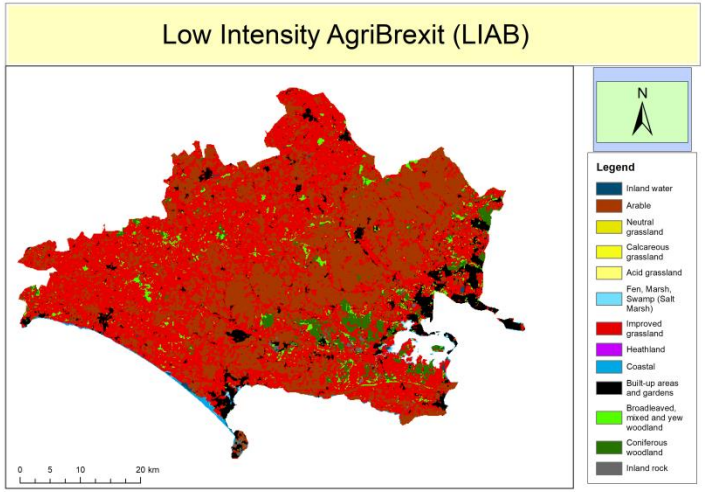
High Intensity GreenBrexit (HIGB)



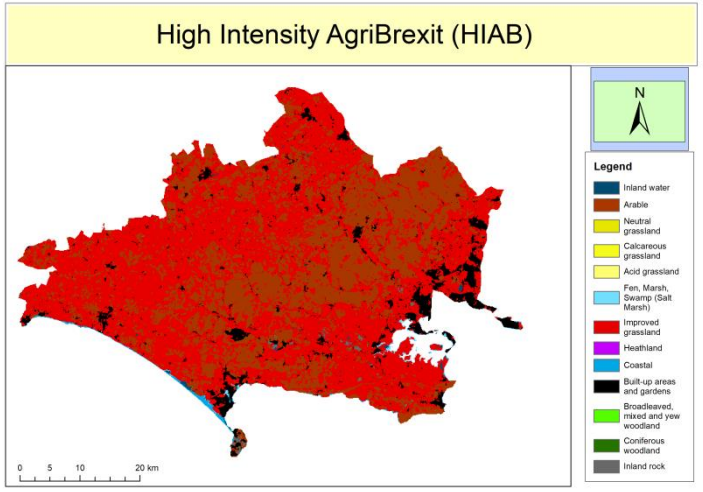
Low Intensity GreenBrexit (LIGB)



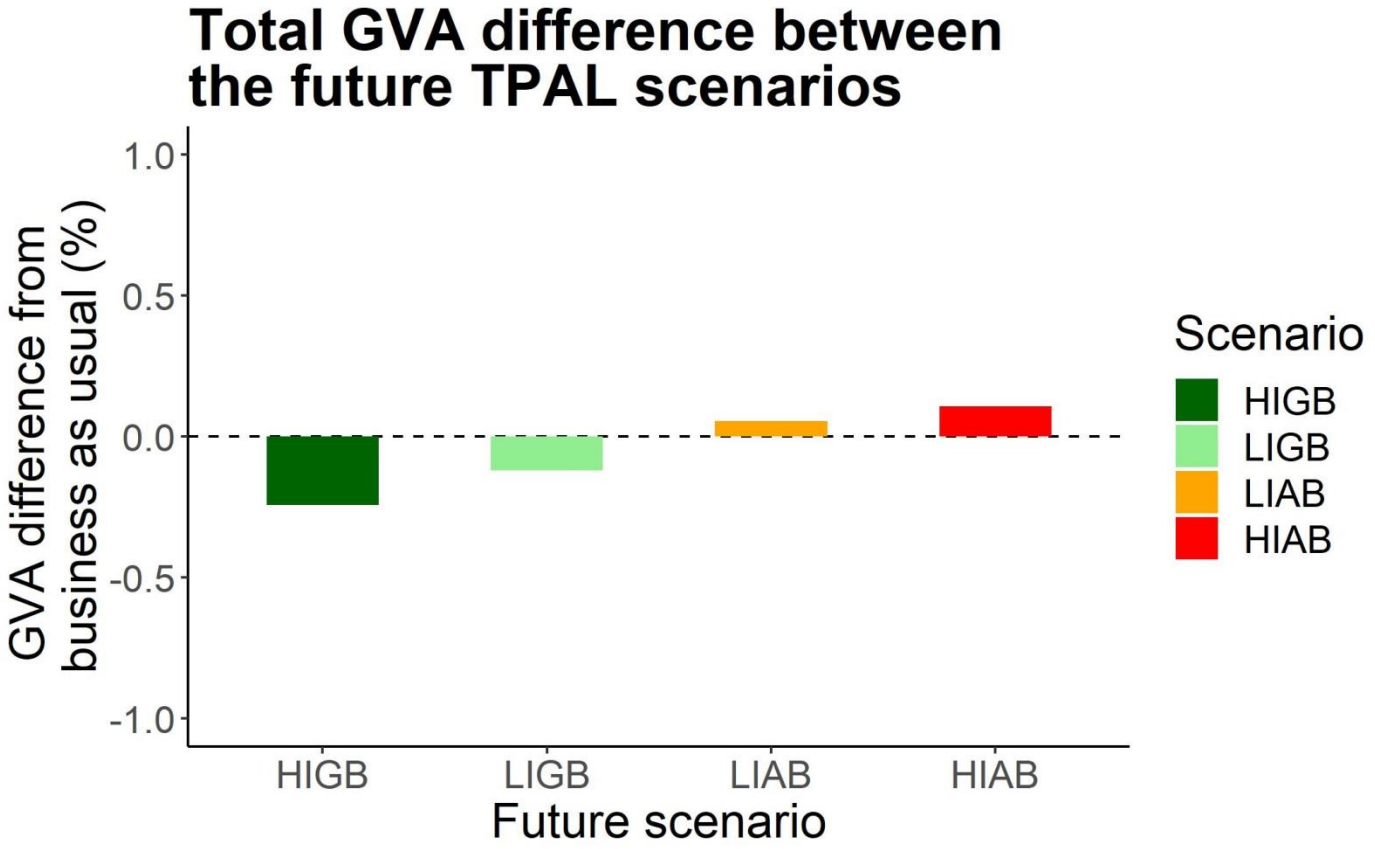
Low Intensity AgriBrexit (LIAB)



High Intensity AgriBrexit (HIAB)

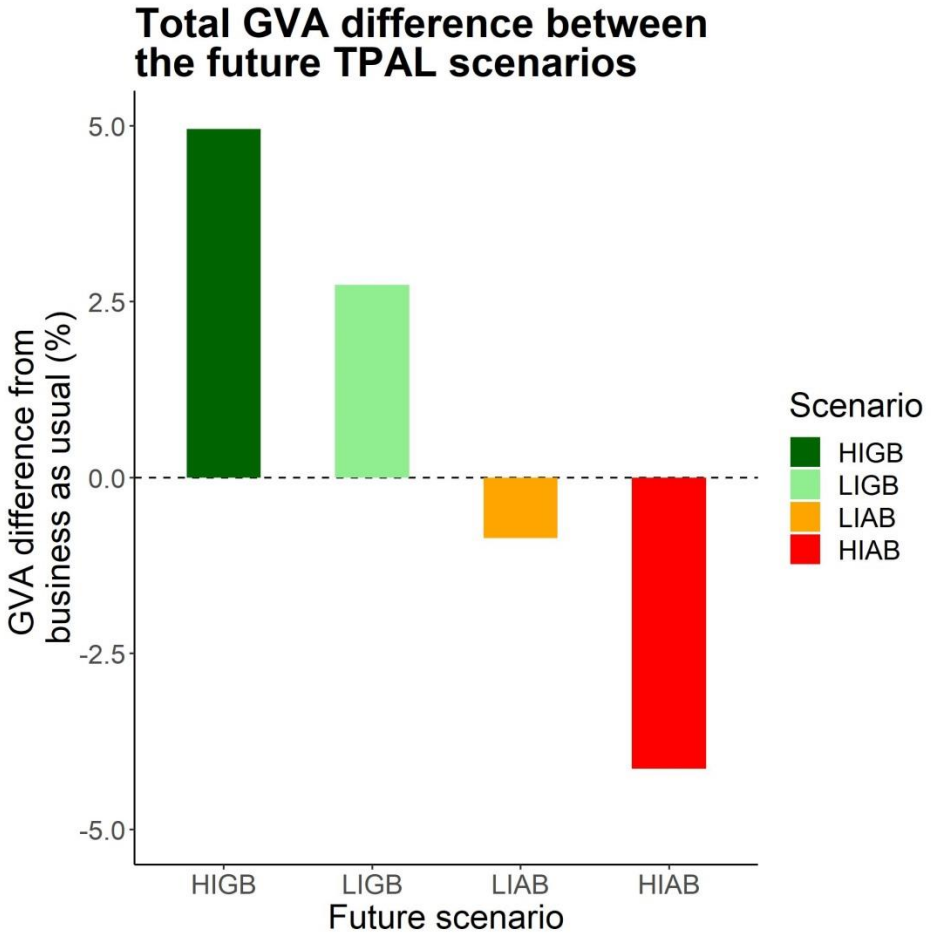


Economic impacts – ignoring value of ecosystem services



GVA = gross value added; a measure of the value of goods and services produced in an economy. GVA is output minus intermediate consumption

Economic impacts – including value of ecosystem services



Economic impacts of investing in natural capital can be much larger than investing in increased agricultural production

WP 3 Scenarios: Employment

- Changes in employment values obtained with the input-output model were very small, the total number of jobs increasing by 0.25% in the "Agribrexit" High Intensity scenario.

- Much larger values were obtained using the agent-based model, which incorporated ecosystem service flows. Here, the largest increase (of 8%) was obtained in the "Green Brexit" High Intensity scenario.

- This demonstrates how investment in natural capital can make a significant contribution to increasing employment.

Key findings – future economy

- Economic analyses indicate that the further intensification of agriculture would provide limited benefits to the local economy.

- Even if all remaining land in Dorset that is suitable for agriculture were converted to farmland, GVA would increase by ≤ 0.3%.

- However, investment in natural capital, aiming to improve the extent and condition of semi-natural ecosystems, could have a much greater impact on the economy, with GVA increases of up to 5% in the scenarios explored.

- Such investment could deliver an £0.8 billion increase in GVA and create more than 25,000 jobs.

Policy recommendations lowland agricultural systems

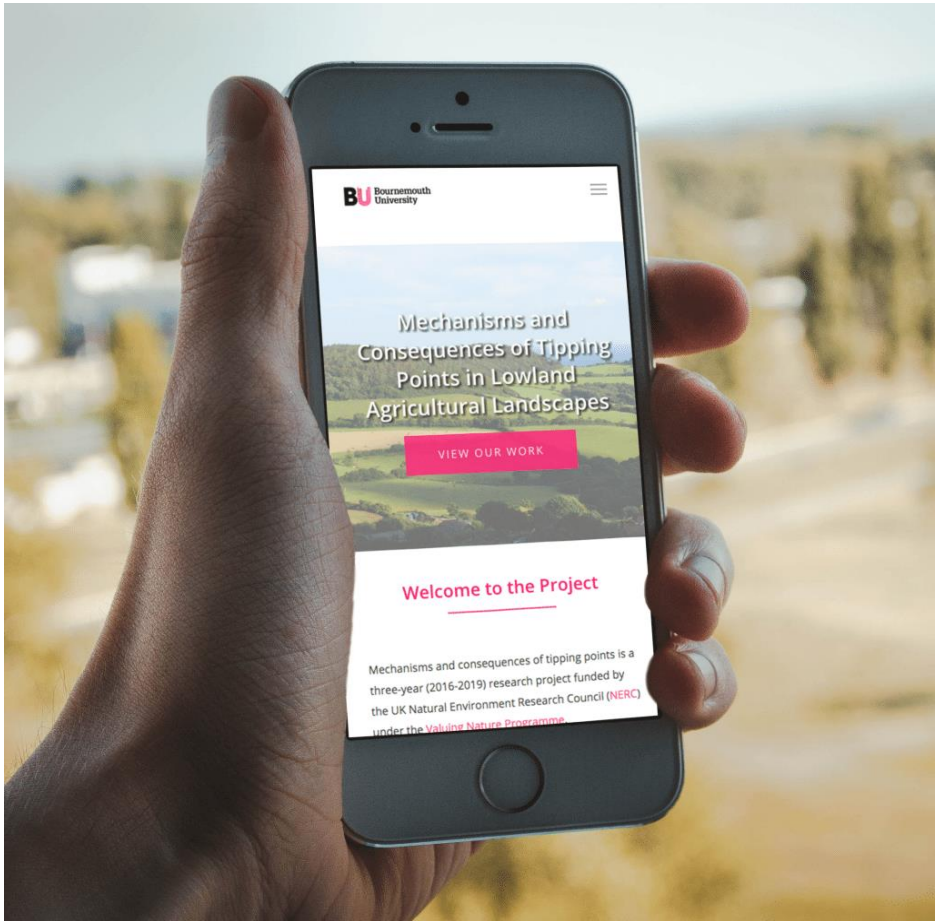
• Reduce nitrogen deposition. There is an urgent need to improve the condition of semi-natural ecosystems in agricultural landscapes such as Dorset. Initiatives designed to help farmers reduce nitrogen applications, such as the Code of Good Agricultural Practice for Reducing Ammonia Emissions should be strongly supported.

• Invest in natural capital, by enhancing ecosystem condition and by increasing the area of semi-natural habitats of high conservation value.

• Develop policies aimed at providing incentives for farmers to produce environmental goods and services. Evidence indicates that this would provide greater benefits to the economy than increased production of traditional agricultural products.

- Report available from VNP / CEH: https://valuing-nature.net/node/931

Thank you!



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VALUING NATURE PROGRAMME

Further TPAL reading:

- Watson, S. C., Grandfield, F. G., Herbert, R. J., & Newton, A. C. (2018). Detecting ecological thresholds and tipping points in the natural capital assets of a protected coastal ecosystem. *Estuarine, Coastal and Shelf Science*, *215*, 112-123.

- Watson, S.C.L and Newton, A., (2018). Dependency of Businesses on Flows of Ecosystem Services: A Case Study from the County of Dorset, UK. Sustainability, 10(5).

- **Loth, A. F., & Newton, A. C. (2018). Rewilding as a restoration strategy for lowland agricultural landscapes: Stakeholder-assisted multi-criteria analysis in Dorset, UK. *Journal for Nature Conservation*, *46*, 110-120.**