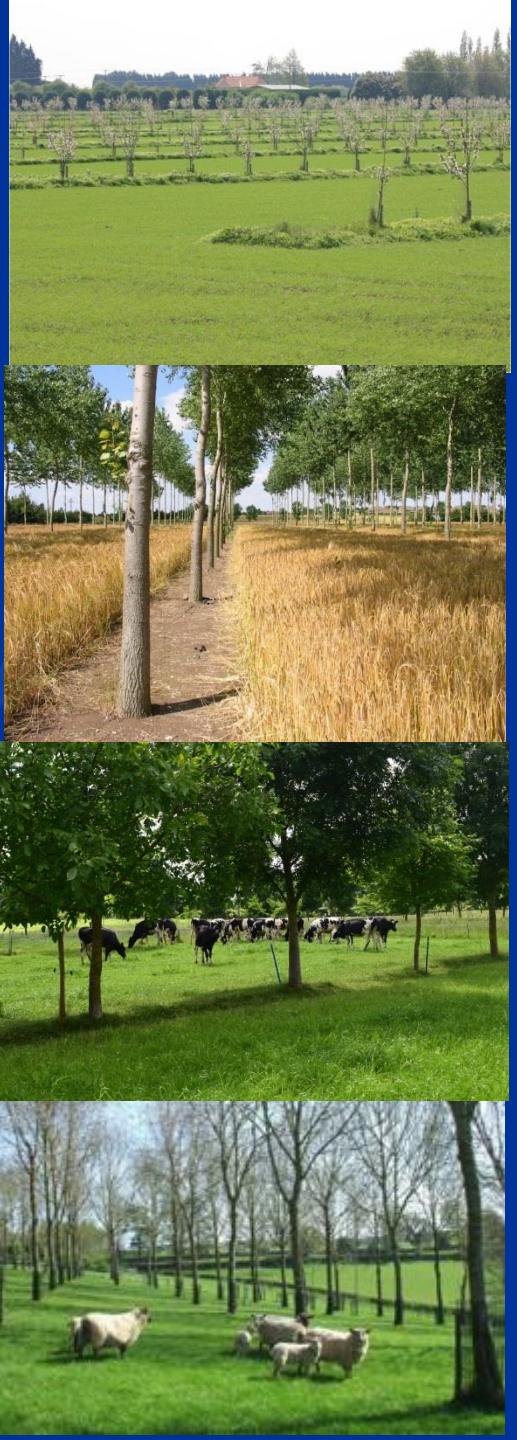
Agroforestry in the UK: "Non-market" benefits

Paul J. Burgess

School of Water, Energy and Environment, Cranfield University, Cranfield, MK43 0AL, UK

Presentation at Agroforestry 2017,
Cranfield University
22 June 2017



European Union's Seventh Framework Program for research, technological development and demonstration under grant agreement no 613520

Content

- Market and non-market stocks and flows on farms
- Environmental accounting
- Non-market benefits of agroforestry
- Implications for farmers and foresters

Market assets and outputs of a farm

Human capital
(knowledge & skills)

Financial capital

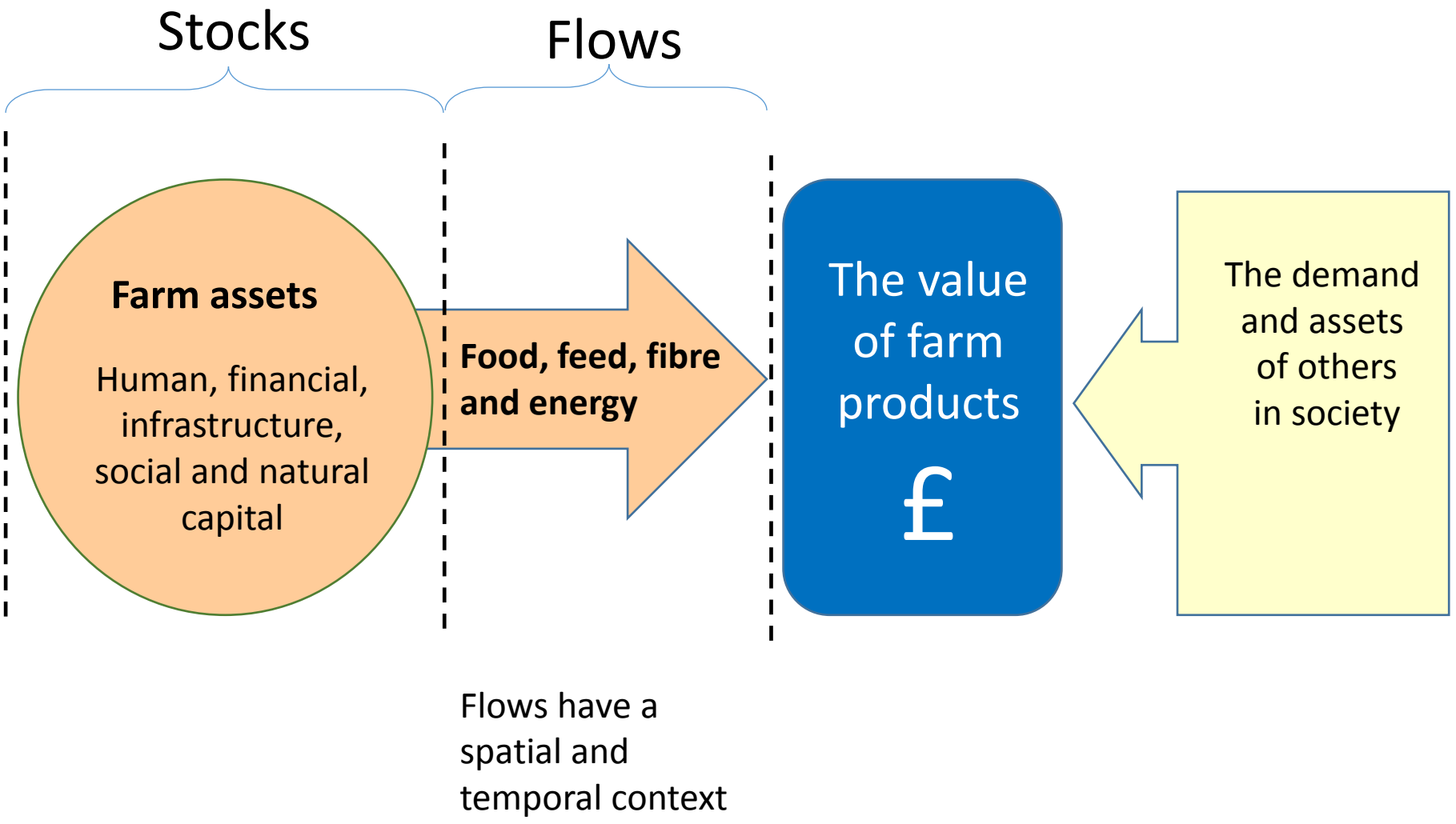
Infrastructure

Social capital
(e.g. trust, behaviour norms)

Natural capital
e.g. environmental assets

Marketable
food, feed, fibre and energy

Market stocks, flows, and values



Schematic adapted from Dickson et al. (2014) and Jones et al. (2016)

Indicative revenue flows of eight types of farm enterprise in the UK (£/ha/year)

Farm enterprise	Production
Eggs	2110
Chicken	1530
Pigs	1430
Dairy and dairy beef	1480
Arable	630
Sheep	250
Suckler beef	420
Woodland	50

Agricultural values from Chatterton et al. (2014); woodland values from Quine et al. (2011)
Agricultural values includes non-UK land use

Non-market outputs of a farm

Regulation of greenhouse gases (CO_2, N_2O, CH_4) and ammonia (NH_3)

Human capital

Financial assets

Infrastructure

Social capital

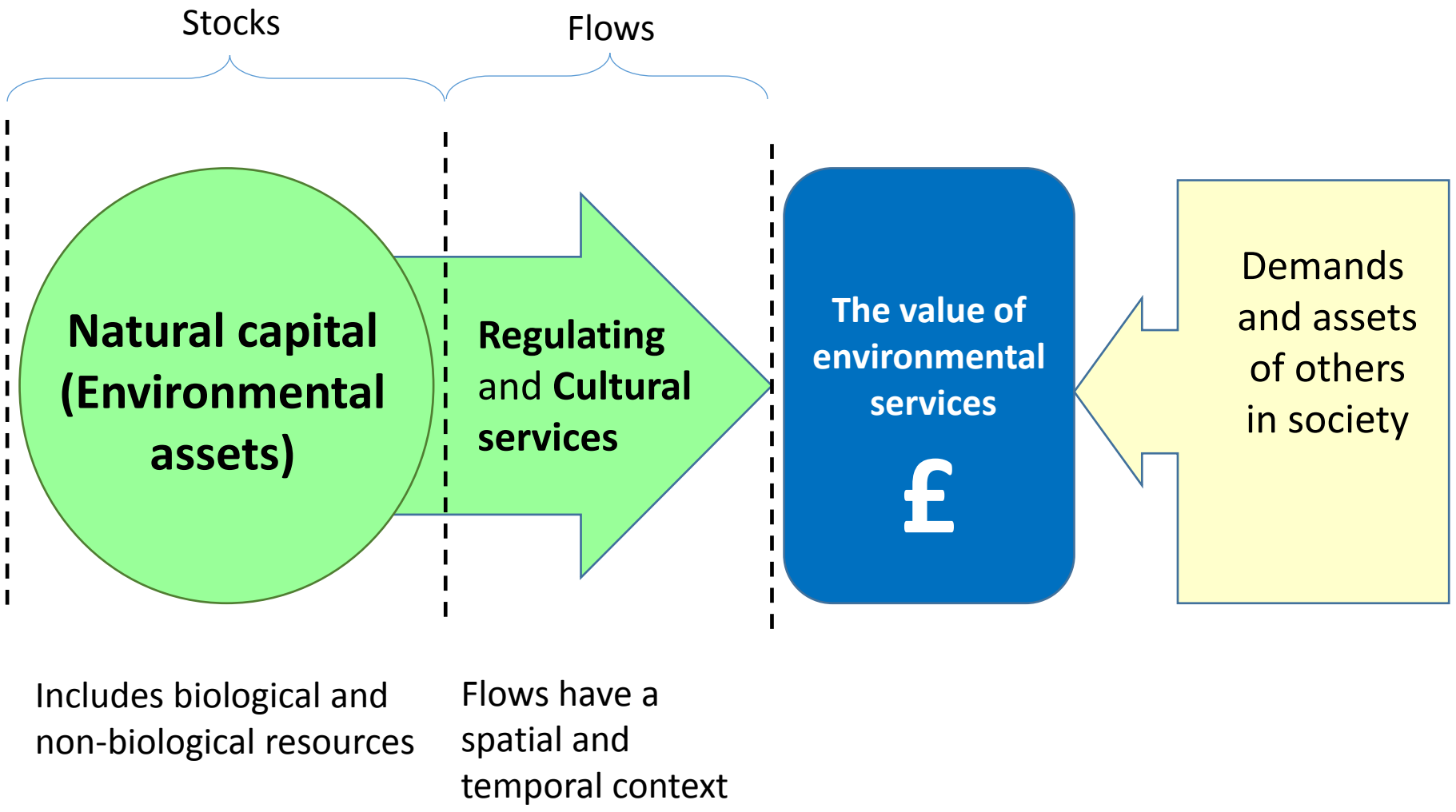
Natural capital
e.g. environmental assets

Marketable
food, feed, fibre and energy

Cultural services:
e.g. biodiversity, recreation, landscape

Regulation of pesticides; N leaching, eutrophication, soil erosion, faecal contamination, and cryptosporidium

Non-market stocks and flows



Schematic adapted from Dickson et al. 2014

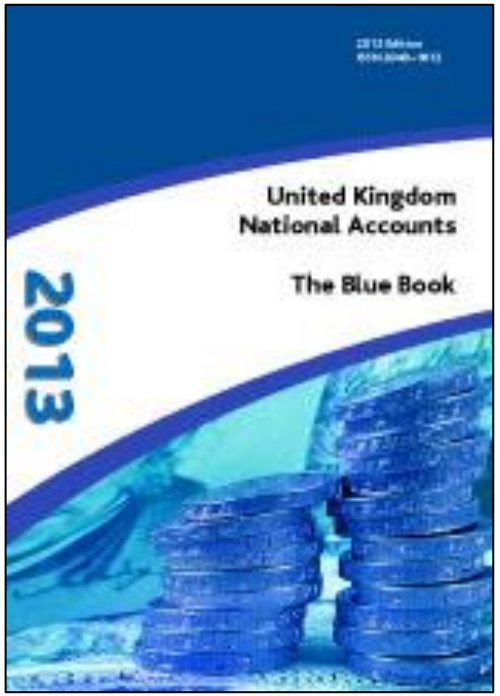
Indicative value of production revenue, regulating and cultural services of eight farm enterprises in the UK (£/ha/year)

Farm enterprise	Production	Regulating services	Cultural services	Net benefit
Eggs	2110	-340	20	1790
Chicken	1620	-330	20	1310
Pigs	1530	-390	20	1160
Dairy and dairy beef	1480	-470	50	1060
Arable	630	-340	30	320
Sheep	250	-100	120	270
Suckler beef	420	-290	100	230
Woodland	50	40	400	490

Agricultural values from Chatterton et al. (2014); woodland values from Quine et al. (2011)
Agricultural values include non-UK land use.

Environmental accounting

The UK Government includes environmental accounts in its National Accounts (The Blue Book).



The Blue Book

Across national governments there is now an internationally agreed System for Environmental-Economic Accounting (EC et al., 2012, 2013)

Environmental accounting includes stocks and flows

Natural capital assets	Example stock measurement	Example flow measurement
Soil	Soil depth (cm)	Soil erosion rate (t/ha/year)
Water quality	Groundwater quality (kg NO_3/m^3)	Rate of nitrate leaching (kg NO_3/ha/year)
Carbon	Carbon stocks (t/ha)	Carbon sequestration rate (t C/ha/year)
Air quality	Ammonia concentration in air (g NH_3/m^3)	Change in ammonia concentration (kg NH_3/ha/year)
Farmland bird numbers	Farmland bird index	Change in abundance
Recreation	Area of recreational sites (ha)	Visitor numbers (people/year)

Environmental accounting is based on quantifying stocks or flows in **physical units** and then to ascribe a monetary value per unit

As with financial accounting, a balance sheet can be maintained where the current balance equals the previous balance plus any flows or changes during the year

Stocks and flows vary with land use

Ecosystem service type	Ecosystem service	Arable	Dairy	Beef	Sheep	Wood land
Regulating stocks	Soil carbon (0-100 cm) (t/ha)	120	142	142	189	189
	Above-ground carbon (t/ha)	2.4	0.9	0.9	2	36.8
Regulating flows	**Water runoff contribution (m^3/ha/yr)**	169	150	150	150	101
	Methane emissions (kg CH_4/ha/yr)	-1.5	205	112	30	-3.5
	N_2O emissions (kg N_2O-N/ha/yr)d	10	10	8	2	0
	Ammonia emissions (kg NH_3-N/ha/yr)	7	36	29	4	0
	Nitrate losses (kg NO_3-N/ha/yr)	31	46	49	18	0
Cultural/ biodiversity stocks	Vegetation (species richness/200m^2)	11.8	14.7	14.7	21.1	21.5
	Bird food plants (species richness/200m^2)	6.6	9.1	9.1	11	9.6
Cultural flows	Conservation & heritage (0 low – 4 high)	3	3	3	4	4
	Sense of history and place	High*	High*	High*	Med*	Med*
	Spiritual benefits	Med*	Med*	Med*	High*	High*
	Recreation (proportion of visits %)	8	8	8	11	14
	Leisure/learning	Med	Med	Med	Med	High

Example stocks and flows for five land uses in Wales (Sources are stated in Hart et al. 2013)
Woodland is a deciduous wood; *: highly location specific
Highest positive values indicated in green and lowest in red.

Carbon stock in hedges

GoogleEarth image of a Hawthorn hedge, trimmed on three-year cycle, at Harnhill Manor Farm, Gloucestershire

Carbon storage from a PhD by Matthew Axe (2015)

	Field margin	2 m high Hedgerow
Above ground biomass (kg/m^2)	0.26	2.78
Below ground biomass (kg/m^2)	0.40	3.87
Soil organic carbon (0-30 cm) (kg/m^2)	8.51	9.87
Total carbon (kg/m^2)	9.17	16.52
Increase in carbon (kg/m^2)		**7.35**
Assume 100 ha farm with 1.5 m wide hedges and 8000 m of hedges (t C)		88.2
Value[a] of carbon stored in hedges (£)		**1470**

[a]Assumed values of C is £16.72 per tonne (Bateman et al. 2014), which is within the range (£11-37) quoted by Forestry Commission, 2016)

[b]: Mean field size of 12.5 ha

Carbon sequestration of hedges managed for woodfuel

Estimate of carbon sequestration from a blackthorn hedge managed on 15 year rotation for woodfuel (Crossland 2015)

	Below-ground C	Harvestable carbon in woodfuel
Carbon sequestration ($kg/m^2/year$)	0.053	0.470
C sequestration (100 ha farm with 8000 m (1.5 m wide) hedges (t C/year)	0.63	5.64
Value of carbon[a] (£/year)	**11**	**94**

[a]Assuming a carbon value of £16.72/t C (Bateman et al. 2014)

Carbon sequestration by parkland

Carbon sequestration by parkland (4% tree cover) over 14 years from tree planting (Upson et al. 2016)

	Pasture	Parkland	Wood
Tree biomass (t C/ha)	0.0	4.0	35.9
Soil organic carbon (t C/ha)	59.6	59.4	46.2
Total (t C/ha)	59.6	63.4	82.1
Change (t C/ha)		3.8	22.5
Value of change[a] (£/ha)		**63.5**	**376**
Net change (t C/ha/year)		0.29	1.60
Annual value of C sequestration[a] (£/ha/year)		**4.5**	**26.8**

[a]Assuming a value of £16.72/t C (Bateman et al. 2014)

Reducing downstream flooding

Modelled effect of trees in a 400 ha sub-catchment in Pontbren, Wales (Wheater et al., 2012)

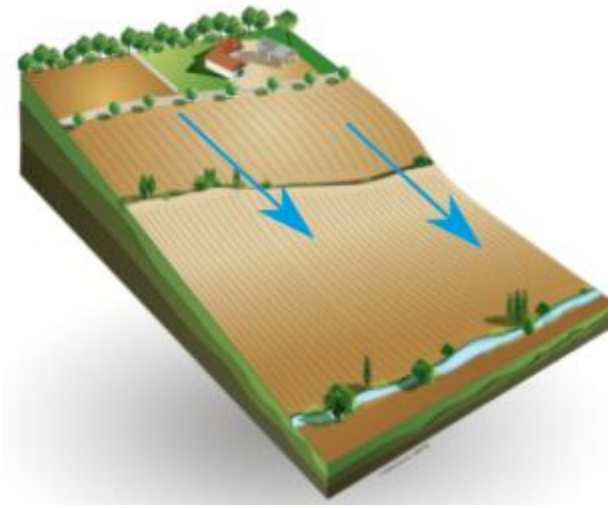
Management choice	Change in median flood peak
Remove all trees	+20%
Baseline situation	
Add tree shelterbelts	-20%
Afforestation	-60%

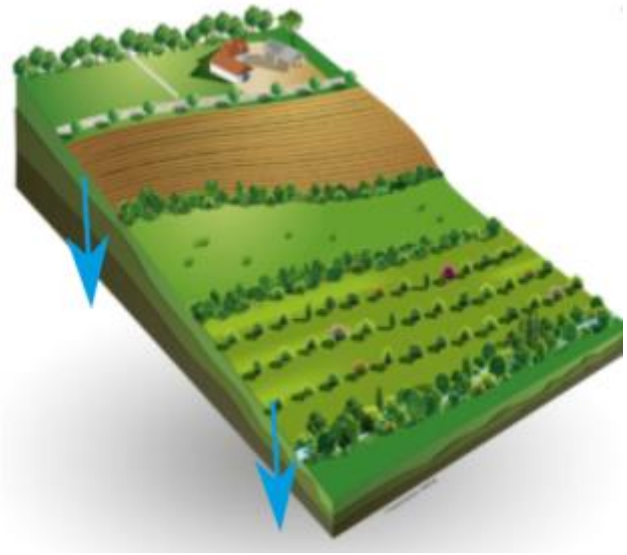
Ammonia reduction from poultry

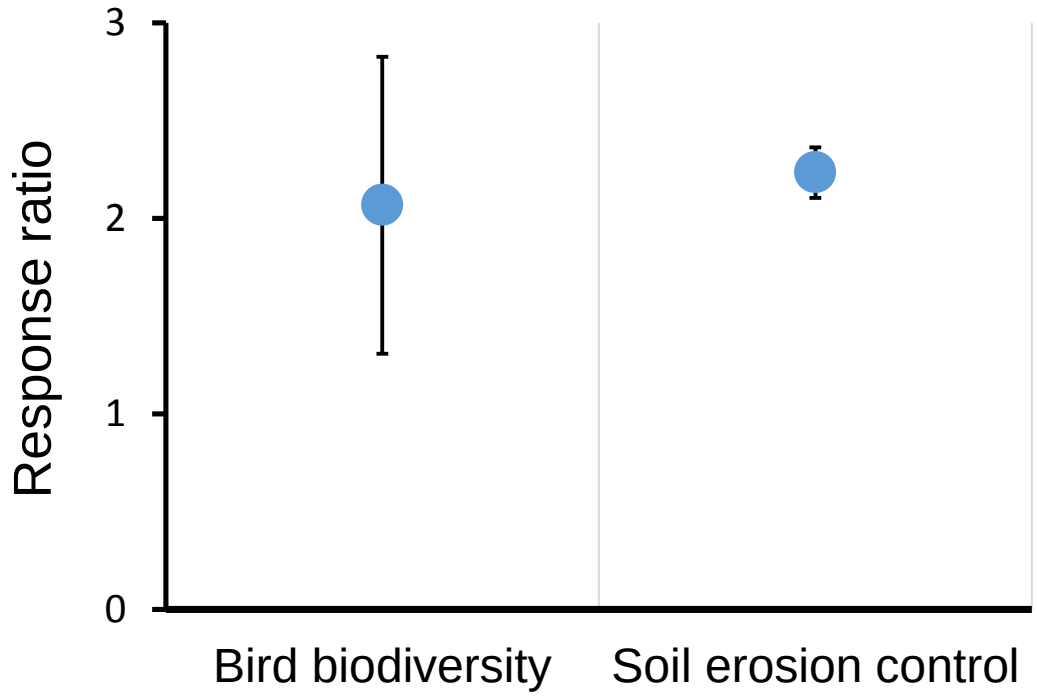
Plan view of Din Moss poultry unit in Fife

- Ammonia can damage human health and nitrogen-sensitive ecosystems
- Trees reduced downwind ammonia concentrations by 25-43% in two poultry systems (Bealey et al. 2015)
- Planting 0.5 ha of trees downwind of one poultry barn reduced the ammonia by 1.74 tonnes per hectare per year (Bealey et al. 2015).
- Assuming a social cost of ammonia of £1970 per tonne, this represents an annual societal benefit of **£3430 per hectare** of woodland

Biodiversity and soil conservation







Mean effect size (response ratios) of European agroforestry on bird biodiversity (n =16) and soil erosion control (n = 65) (relative to forestry or agriculture) (error bars show 95% confidence intervals) (Torralba et al. 2016)

Recreation

Bateman et al. (2014) calculated that planting a 100 ha open-access woodland in the UK would provide an annual benefit of £1.14 to £4.65 per person living within a 10 minute drive.

Assuming 100 ha planted close to a town with the population of Bedford (i.e. 80,000), then the recreational value would be **£912 to £3720/ha/year**

Societal value of open access parkland/woodland, particular close to population centres is large

Implications

Agroforestry can increase the **stock** of **natural capital** and improve the **flows** of **regulating and cultural ecosystem services.**

Environmental accounting can be used to value these stocks and services. Sometimes a company, e.g. a water supply company, may provide **payment for ecosystem services**.

Because many benefits are widely distributed across society, **the UK government** should support agroforestry. Options include payments for:

- Agroforestry establishment/management
- Farm-level management plans for greenhouse gases
- Results e.g. for each net tonne of C sequestered or for each open-access hectare

References

Axe, M.S. (2015). Carbon measurement, prediction and enhancement of the agricultural hedgerow ecotone. Unpublished PhD thesis, Royal Agricultural University, Cirencester. 245 pp.

Bateman, I.J., Day, B.H. et al. (2014). UK National Ecosystem Assessment Follow-on. Work Package Report 3: Economic value of ecosystem services. UNEP-WCMC, LWEC, UK. http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=1n4oolhlksY%3d&tabid=82

Bealey, W.J., Braban, C.F., Theobald, M.R., Famulari, D., Tang, Y.S., Wheat, A., Grigorova, E., Leeson, S.R., Twigg, M.M., Dragosits, U., Dore, A.J., Sutton, M.A., Nemitz, E., Loubet, B., Robertson, A., Quinn, A.D., Williams, A., Sandars, D.L., Valatin, G., Perks, M., Watterson, D. (2015). Agroforestry Systems for Ammonia Abatement AC0201 Final Report.

Chatterton, J., Graves, A., Audsley, E., Morris, J., Williams, A. (2015). Using systems-based life cycle assessment to investigate the environmental and economic impacts and benefits of the livestock sector in the UK. Journal of Cleaner Production 86: 1-8.

Crossland, M. (2015). The Carbon Sequestration Potential of Hedges managed for Woodfuel. Report produced for www.twecom.eu project. Organic Research Centre.

Dickson, B., Blaney, R. Miles, L., Regan, E., van Soesbergen, A., Väänänen, E., Blyth, S., Harfoot, M. Martin, C.S., McOwen, C., Newbold, T., van Bochove, J. (2014). Towards a global map of natural capital: Key ecosystem assets. UNEP, Nairobi, Kenya.

Engel, S., Pagiola, S., Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. Ecological Economics 65: 663-674.

EC, FAI, IMF, OECD, UN, World Bank (2012). System of Environmental-Economic Accounting: Central Framework http://unstats.un.org/unsd/envaccounting/White_cover.pdf

EC, OECD, UN, World Bank (2013). System of Environmental-Economic Accounting 2012 Experimental Ecosystem accounting. http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf

References

Forestry Commission (2016) The Woodland Carbon Code. https://www.forestry.gov.uk/pdf/Woodland_Carbon_Code_Landowner_Leaflet_links_lowres.pdf/$file/Woodland_Carbon_Code_Landowner_Leaflet_links_lowres.pdf

Hart, K., Allen, B., Lindner, M., Keenleyside, C., Burgess, P.J., Eggers, J., Buckwell, A. (2013) . Land as an Environmental Resource, Report Prepared for DG Environment, Contract No ENV.B.1/ETU/2011/0029, Institute for European Environmental Policy, London.

Jones, L., Norton, L., Austin, Z., Brown, A.L., Donovand, D., Emmett, B.A., Grabowski, Z.J, Howard, D.C. , Jones, J.P.G., Kenter, J.O., Manley, W., Morris, C., Robinson, D.A., Short, C., Siriwardena, G.M., Stevens, C.J., Storkey, J., Waters, R.D., Willis, G.F. (2016). Stocks and flows of natural and human-derived capital in ecosystem services. Land Use Policy 52: 151–162

Quine, C., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A., Valatin, G. (2011). Woodlands. In: National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Torrlba, M., Fagerholm, N., Burgess, P.J., Moreno, G., Plieninger, T. (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agriculture, Ecosystems and Environment 230: 150-161.

United Nations (2013). http://unstats.un.org/unsd/envaccounting/seea.asp

Upson, M.A., Burgess, P.J., Morrison, J.I.L. (2016). Soil carbon changes after establishing woodland and agroforestry trees in a grazed pasture. Geoderma 283: 10-20.

Wheater, H.S., Ballard, C., Buygina, N., McIntyre, N., Jackson, B.M. (2012). Chapter 22 Modelling Environmental Change: Quantification of Impacts of Land Use and Land Management Change on UK Flood Risk In: System Identification, Environmental Modelling, and Control System Design (Eds: L. Wang, H. Garnier), Springer-Verlag London Limited.