STRATEGIC EVIDENCE OF FUTURE CHANGE

Horizon Scanning evidence and analysis report (1)

Appendices C and D

Defra Partnership

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This document is a companion document to the main Horizon Scanning report for March 2015 produced by SAMI Consulting.

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Appendix C –

Comparative table of issues & factors

Comparitive table of issues/NEAPS, Cranfield 2013 key factors, SAMI selected stories

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	2. Food production, processing and distribution • Farm size and structure – consolidation or fragmentation	**Food –** • Informed consumers base food purchases on information that relates to their priorities and values	**Food –** • ***Story*: Rise of digital food chain – IT / big data and food security**

[1] As produced by Helen Doran, Natural England, 5 November 2014

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	• Livestock management (related methane emissions) and animal welfare • Choice of farming systems, crops and livestock • Organic farming, high productivity farming • Consumption of new types of food / crops • DIY food production, organic and local food production • Food security – global demand and supply patterns • New food production processes and technologies • Vegetarian vs. meat based diets • Diffusion of functional food (food with health or other benefits)	• Food waste reduction is being improved with industrial and homoe appliance technical advancement • Enhanced food used to combat widespread health issues • Food preservation advancements driven by emerging interests in eating living foods (eg, mould) **Agriculture, forestry, and rural communities –** • Food prices continue to rise driven by resource shortages, increasing demand and extreme weather events • Limited water availability likely to be a dominant factor in the determination of global food production • Changing cropping techniques are being adopted in response to changing weather patterns • Plant breeding breakthroughs have recently been made for key crops such as wheat. •	• ***Emerging*: Decline in nutritional quality of crops > C3 crops and climate** • ***Story*: Rise of 'smart farming' – IOT, drones, etc. allowing precision inputs and monitoring of outputs in ag and environmental management**
Composite threats to food security	**3. Land use and land management** • Role of agriculture in landscape management • Availability and quality of arable land (domestic and international) • Land grabs and agriculture colonialism (neo-food colonialism)	**Land –** • Future land use is likely to be driven by economy factors such as energy prices and competitive advantage • Smart design concepts embedded in urban expansion plans are becoming 'best	

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	• Land conflicts – energy crops versus food crops • Livestock versus crop production, food versus non-food crops	practice' for sustainable urbanisation • Incentives and international pledges of commitment aid the establishment of conservation areas	
	4. Oceans, marine life and fisheries • Sea food – consumption rates of fish, marine legislative framework • Marine biodiversity • Ocean as a carbon sink • Ocean acidification • Marine ecosystem management • Fish quotas and protected zones	**Oceans –** • Sea-level rise may be less severe than previously predicted • Ocean acidification is altering ecological interactions such as symbiosis and competition • Marine plastics pose potential toxicity to marine life calling for further research • Marine energy database, a collaborative resource that may facilitate sustainable marine development, created	
Continuing environmental change including climate change and natural hazards	**5. Climate, environment and biodiversity** • How 'environmental technologies' (e.g. coastal realignment, natural flood defences) can be used to address future social, economic and environmental issues (in particular climate change) • Biodiversity (habitats and species) protection and management (UK and global) • Coastal erosion and management • Role of protected land (areas of scientific interest, national parks, etc.) • Forests, woodlands, parks and waterways • Frequency and intensity of extreme weather events	**Climate –** • Changes to polar climate patterns having quicker impacts than anticipated • Innovative combinations of 'soft' and 'hard' marine defences increasingly used to combat coastal erosion • Non-traditional species conservation techniques taken seriously under climate change • New environmental role models may begin to actively use their influence for environmental good	• ***Story*: Acceleration of climate change impacts / failure of climate adaptation (no political momentum) / new understanding of speed of specific climate change impacts**

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	• Impact of climate change on biodiversity and ecosystems • Low carbon technologies • Alternative CO_2 capture – algae or chemical mineralization • Impact of climate change on human health • New tools, techniques and frameworks being developed to 'value' ecosystem services • Ecosystem service payments • EU legislation, incentive schemes		
Natural resource depletion	**6. Natural resources and waste management** • Sustainable consumption and production • Availability and accessibility of farming resources – water, fertilizer, raw materials, fuel • Water supply / demand – dependency of global food production • Erosion and rates of soil loss, soil quality • Water recycling, grey water systems and rainwater harvesting	**Natural resources, waste –** • Rising demand for water is set to redefine urban development and water management plans • Exploration of resources in challenging, environmentally sensitive regions • Plastic reduction through bans on plastic use and packaging solutions may address the unsustainability of future use • Combatting E-waste through technological innovation and a legislative framework for safe disposal •	
Potential rise in invasive species, pests and disease	• Impact of climate change on spread / likelihood of diseases and viruses, invasion of foreign species into domestic ecosystems • Disease surveillance, control and emergency response (blue tongue, bird flu) – endemic diseases as well as new, exotic diseases		

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
Innovative chemicals and materials	• New materials (smart materials) • Chemistry and chemicals – biopolymers, synthetic biology, green and sustainable chemistry		
Increasing pollution	• Air quality • Water quality and aquatic biodiversity • Contamination of soil / land • Environmental pollution		• ***Emerging*: Non-transport air pollution** • ***Emerging*: New risks and responses to water quality**
Economic growth and globalisation	**7. Economy and industry** • Shift towards low-carbon economy • Long term economic growth prospects • Growing importance of CSR • Rural economies • Chargeable services public bodies can levy for accessing their expertise/services/products • Changes to grant schemes BIG Lottery, Heritage Lottery, Landfill Tax, other green taxes • Peer to peer payments • Biodiversity offsets **8. Globalisation, politics and security** • Glocalisation – increased importance of the local and region specific adaptations of products and services – importance of local knowledge • Agriculture and food policy/security • Environmental policy • Bio security • Competitiveness and sustainability of rural businesses	**Economy –** • High investment in fossil fuel exploration is a deterrent to meeting agreed carbon emission targets • Economic growth through the promotion of innovations is being used as a strategy by many governments • The economy grows with widespread peer-to-peer exchange • Re-thinking the work-life balance with some countries investigating the potential benefits of adopting a four-day work week **Globalisation, politics** – • Vulnerability of the energy supply infrastructure considered a national security weak spot • Global demand for certain foods creating localised social deprivation • Legal rights for nature gaining support and may promote environmental protection	

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	• Development of rural infrastructures (communication, waste, education, health, energy, water, mobility, retail) • Agro-forestry and competitive timber production • Prices and volatility – e.g. global wheat and rice prices	• Combating corruption and illicit trade using novel analytical methods	
Changing governance at global and local scale	• CAP reform, EU strategy, WTO • Changes to existing local or regional institutions that we may see as a result of the localism agenda and where the decision making powers lie • How partnerships might change between private/public/NGO sector (at national, regional and local scale) in terms of land management to deliver environmental outcomes • Changes to how natural environment issues are dealt with at a local level (e.g. land use planning, green and blue space, local site and species protection) • Who the trusted voices are if not politicians –local leaders (community or religious)		• ***Emerging*: Citizen science > monitoring > whistleblowing > 'sousveillance'**
Population growth and demographic change	**9. Demographics and urbanisation** • Sustainable urban infrastructures • New forms of urban planning • Population growth and distribution • Age structure and distribution • Migration and skills available to UK PLC • Future of work – how, where and when we work • Green infrastructure and spaces for nature in	**Demographics and urbanisation –** • Walkable cities (custom-made or re-designed) emerge focussed on public transport and pedestrian infrastructure • Creative park design uses scarce urban space to better foster outdoor social interaction • Urban planning being used to discourage	

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	new urban development	crime through careful design of green space • Biologically active concrete facilitates urban greening on building surfaces	
Increasing energy demand	**10. Energy supply and demand** • Renewable energy and enabling technologies • Decentralised electricity generation (CHP, micro wind and solar) • Impact and diffusion of next generation biofuels (inc biogas and biomass) • Low carbon agriculture • Energy scavenging technologies • International energy infrastructure and distribution	**Energy supply and demand –** • Battery improvements leading to large-scale energy storage systems • Energy grid infrastructure developments likely to revolutionise international energy supply, demand, and transmission • Advances in the reduction and use of nuclear waste • Investigation of non-traditional energy sources, such as volcanoes, space and urban noise	• ***Emerging*: micro-generation / energy harvesting > more localised energy infrastructure**
Scientific and technological advances	**11. Science, technology and innovation** • Rural and urban infrastructures – water, sanitation, waste, energy, food supply, transport • Nano, bio, info tech and cognitive science (NBIC) conversion and unknown risks of nano- and biotech • Information technology – ongoing revolution, miniaturisation, diffusion and increased calculating power, Green IT • Mashups and convergence (interconnection of data flows) • Robotics and automation – private households and industry • New forms of tracing, controlling and managing livestock		• ***Story*: Bio-tech, gene editing, CRISPR** • ***Emerging*: AI/ES, eg for vets**

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	• Future impact and nature of GM and GMOs • New farming technology and management systems • New disease identification and response system (new methods of diagnostics, modelling) • Bio-pesticides / control species • New crops / types of crops grown • Types of livestock / forms of meat production (e.g. shift from cow meat to game or kangaroos – i.e. effect on emissions from livestock) • Urban agriculture and vertical farming – advanced hydroponic systems		
Changes in behaviour/values and ethical stances	**12. Consumer attitudes and behaviours** • Attitudes and behaviour related to climate change, environment and sustainability • Value-related consumption (e.g. organic and fair trade) • Local food production/consumption (locavores, seasonable consumption) • Attitudes towards technological change (e.g. Nanotechnology, GMOs) • Links between how information about the natural environment is presented and used and how this influences behaviour change (use of arts, promotion of natural heritage) • Values related to intrinsic worth of the natural environment • How people value the environment at different spatial scales (global to local) for different issues	**Consumers –** • Some consumer brands are demanding socially or environmentally meaningful actions of their consumers to increase brand respect • Online access to personal information raises concerns about public privacy and identity protection • Advances in social and physiological habit breaking techniques may help halt negative habits for health / environmental benefit • Crowd-funding, as a means of supporting innovative environmental, health and social initiatives, increases in popularity	

Strategic evidence priorities: Defra's Evidence Investment Strategy	Trends Defra scan against under their key factors[1]	Cranfield	SAMI / Futurescaper – Scan of Scans
	13. Health and wellbeing • Prevalence of lifestyle diseases such as obesity • Attitudes and behaviour related to health and food • Whole greenspace agenda linked to physical and mental health and wellbeing		

Appendix D

Expert recommendations on ‘areas of search’

Introduction

This is an Annex to the main report on the ‘Scan of Scans’, March 2015.

At this start-up phase of the scanning, the Expert Panel were requested to make recommendations on pointers for the most critical, potentially transformative *emerging* changes relevant to the Defra NEAPS (National Evidence Action Plans).

These were framed as future areas of search (i.e. 'scanning horizons'), in the wider field surrounding each of the topics. These are likely to be a) at the edges of known science & technology: b) new connections between social / technical / economic / political etc: c) new opportunities, unforeseen side effects etc.

Two main categories were suggested: ‘**General horizons of change & areas of search’** and **‘Possible emergent transformations & tipping points’.** Some reviewers have expanded on these, theme by theme.

This is a working document, which may be extended and enhanced through the life of the project, as new issues and scanning results become available. We anticipate that a suitable format will emerge, which helps to connect & complement the scanning results as managed through the Futurescaper system.

List of reviewers:

Reviewers for each topic area are shown on the relevant pages.

(Adam Barker: Expertise in coastal planning & management: biodiversity, conservation, tourism policy etc.)

Lisa Boden (University of Glasgow): Expertise in veterinary epidemiology: member of EPIC- Centre of Expertise on Animal Disease Outbreaks

Paul Cunningham (Manchester Business School): Expertise in marine science & policy: general science policy & technology innovation systems.

Jeremy Carter: Expertise in climate change, adaptation & resilience: environmental futures, assessment, governance issues.

(Angela Connelly: Expertise on a multi-disciplinary basis including environmental governance, built environment, socio-cultural studies, risk and resilience.)

Federico Cugurullo: Expertise on sustainable urbanism & eco-cities, urban geography and sociology, with collaborations including United Nations (Cities Programme), Ove Arup etc.

Prof. Ian Douglas: Ian is Emeritus Professor of Geography at Manchester University, and has performed many roles for bodies including United Nations agencies, IPCC and RCUK.

Sally Gee (Cooperative Group): Interests in governance of sustainable technology & innovation, including food and farming, waste management, bio-fuels, industrial pollution control.

Nigel Lawson: Expertise in urban risk management, waste management, flooding & resilience, environmental technologies.

Joe Ravetz (Scientific Coordinator): Expertise in land-use planning, urban & rural development, resource flow analysis, ecological economics, foresight & futures, etc.

Craig Thomas: Expertise in energy / technology / environment interactions: risk assessment & science communications.

Dan Welch: Expertise in agri-food policy, ethical / CSR issues in consumption & production: science communications.

Reviewers are based at the University of Manchester unless otherwise stated. (Brackets shows- reviewers not available for this round).

1. FOOD PRODUCTION, PROCESSING AND DISTRIBUTION

(DW)

'General areas of search'

- - Continuing global food price rises, due to changing diets, commodity speculation, water scarcity, population growth, climate change
- - Improvement in crop yields through improvements in crop breeding techniques, farming techniques and technologies
- - Changes to retail market structure
- - Sustainability initiatives in food service industry and public sector food procurement
- - Improvements in before-farm-gate food waste arising due to better demand forecasting, changes in supermarket supply chain policies, and development of alternative markets
- - Advances in packaging technology leading to improved shelf life of foods
- - Advances in RFID and sensor technology improving wastage rates in fresh produce distribution
- - Invasive pests and plant diseases due to climate change effects on their territorial reach
- *Antibiotic resistant infections due to antibiotics used in meat source, especially chickens*
- *Interaction of public health & personal diet, with changing fashion, with food supply chains: e.g. decline of traditional 'British' cuisine.*
- *Off-shoring: continued growth in imports of niche foodstuffs: e.g. flowers, green salads*
- *'Re-shoring': emergence of UK production in overseas niche commodities e.g. wine*
- *Growth of industrial glass-house horticulture, coupled with renewable energy / water systems, coupled with precision inputs and robotic farming.*
- *Vulnerability of industrial farming to pests, invasive species, industrial corruption.*
- *Vulnerability of some arable farm businesses to possible restrictions on UK migration system.*

'Possible transformations'

- - Scaling up of artificially grown meat production
- - Scaling up non-traditional protein sources, such as insects, for human consumption and animal feed
- - 'Food sovereignty' movements in the developing world in the context of rising global food prices and food security may disrupt international trade
- - Possible backlash against large scale anaerobic digestion in UK (on grounds of unfair incentives, issues around food waste and food poverty, support for smaller farmers)

- - Scaling up of urban intensive indoor agriculture (vertical farms, indoor hydroponics) may have disruptive effects on grocery retailing or aspects of rural economy
- - Technological advances in supply chain traceability may have disruptive effects on grocery retailing (e.g. QR-coded products for 'provenance branding')
- - Bioengineered meat and dairy alternatives may disrupt existing markets, may mainstream vegan and vegetarian diets
- - Major financial crisis of dairy processors due to continuing squeeze in profitability may disrupt retailer and producer markets
- - 'Facilitative interactions' between climate change driven invasive fauna may cause sudden localised ecosystem changes with catastrophic effects on native species
- - Major disruptions to global wheat markets due to geographical spread of stem rust
- - New food safety scares: especially arsenic concentrations in rice and baby foods
- *Local urban farming may bring great social benefits and healthier diets (e.g. the 'incredible edible' movement as well as reducing food miles and impacts on CO_2 emissions.*

2. LAND USE AND LAND MANAGEMENT

(ID)

a) Agriculture land & landscape

'General areas of search'

- Constant theme of agriculture and soil stability: major concerns over soil for the future.
- Responses to EU policies and their future impacts: example of extensification in grassland management: unknown consequences of policy shifts:
- Extensification represents a sudden shift in selective stress, which will affect the size and composition of the soil microbial community.The response of soil microorganisms to changes in plant diversity can be unexpected, with individual plant species proving more important in determining microbial community development than plant diversity per se. The nutrient cycling response to changes in soil biota can also be unpredictable, because certain species mediate specific processes within nutrient cycles (Horrocks et al., 2014).

'Possible emergent transformations'

Agriculture depends on ecosystem supporting services, particularly soil biota and soil processes. These are scientifically understood, but the science is not always taken into account when decisions on agricultural policy are made.

Were warnings about future global food supplies under conditions of climate change and continuing population increase to be taken seriously, then intensive systems of food production are likely to be encouraged, at least on the best farmland, with a greater targeting of agri-environment measures on poorer land. Such an outcome would be likely to encourage further expansion of the largest and most efficient farm businesses whilst prompting the disappearance of small farms, their past presence indicated merely by life-style properties on part of their former land (Munton, 2009). This would have a major impact on landscape management.

- e.g. highly complex land ownership, leasing and operational linkage : divisibility and flexibility of the bundle of rights which constitute ownership have allowed holders to respond to urban pressures and farming difficulties with practices including short-term leasing, contracting, supplying life-style residential properties and accommodating increased environmental regulation.

- Two other aspects of ownership should be noted: many environmental membership organisations now (e.g. National Trust, RSPB) now own land (over 500,000 ha) but have a lobbying influence through memberships of around 1 million each that plays a larger role than the cumulative proportion of UK land that they own.

b) Future land use change factors

- Future land use change is likely to be driven by economic factors such as energy prices and competitive advantage.
- The planning framework and countryside protection lobby remain powerful: extensions of National parks may be called for (e.g. the recent creation of the South Downs National Park). Powerful urban lobbies will seek to protect valued landscapes close to cities, especially in S.E. England.
- Good farmland will be lost to national infrastructure projects (including airport extensions) but the government will still have a key role to play. The holding of land by major housing development companies needs scrutiny as the failure to develop land prevents its use for either housing or farming.
- Economic factors are not the sole driver, the political filter will come into play and major regional differences will occur according to powerful lobbies and the way politicians understand the values of pieces of the countryside.
- A better understanding of the perspective of farmers as the major supplier of landscape related public goods, and the general public as the major consumer of countryside amenities, will aid in the development of conservation policy that takes into consideration multiple perspectives.

c) Arable land (UK / international)

- **In the UK** agricultural land, both arable and pasture fell from 76% of the land area in 1980 to 71 % in 2012. 36% of the agricultural land is croppable (arable), or 25% of the total land area. The issue is not just a decline in the total but a decline in good quality arable land. Urban development continues to spread on to class 1 agricultural land, despite the goal of protecting such land in many strategic plans. Grades 1 and 2 together form about 21% of all farmland in England. Data on the loss of specific classes of agricultural land do not seem to be readily available, but clearly if crop production shifts from high quality to low quality land yields may be lower and thus costs per kilo higher.
- **Internationally:** Cities everywhere are expanding on to arable land, particularly in China (Shanghai is a prime example). A huge loss of rice field areas in Asia is posing problems of increased fertiliser us elsewhere. The whole global nitrogen and phosphorus questions are perturbed by this and there may be implicit tipping points.
- A “land grab” is defined by GRAIN* as a large-scale land purchase or lease made by foreign investors. According to GRAIN, since 2006, there have been 416 land grabs in 66 countries covering nearly 35 million hectares (86.5 million acres) (see: http://www.circleofblue.org/LAND.html).

- UK is one of the largest “land grabbers” see table below m (areas in hectares; note the UK itself is 24.36 million ha, thus the UK has “grabbed” land equivalent to 10% of its own total area): (source: http://www.landmatrix.org/en/get-the-idea/web-transnational-deals/)
- Economic colonisation through land deals could spark civil conflict causing rapidly rising food prices that lead to starvation in some places and much more increased food insecurity.
- Debate about land for biofuels and land for food is tied in with these objectives. Don’t forget cases of foreign investment for land in wealthy countries: for example China is developing phase 2 of the Ord River Irrigation scheme in northern Western Australia to grow sugar cane to sell in China.
- Many of these land grabs are not considering climate change impacts, particularly swings in the ENSO (El Nino-Southern Oscillation) system. There are both human conflict and biophysical hazards facing the land grabs.

d) Landuse & urbanization

- Smart design concepts embedded in urban expansion plans are becoming best practice for sustainable urbanisation
- There is an immense way to go on this: urban sprawl is occurring in the rapidly growing Asian and African cities. The way in which land such as old railway sidings and canal wharves have been developed for apartment buildings in London and Manchester is much smarter than suburban sprawl, what are the relative trends? Will urban areas outside London develop the high urban population densities of Kensington and Chelsea? High densities can support urban rapid transit commuter systems and get people out of cars. But will commuter passenger miles in electric/hybrid cars increase more quickly than on urban rapid transit?
- Secondly, urban agriculture needs factoring in. It may account for one-third of the food consumption in African cities and could be effective in the UK, not to the same extent, but taking the Incredible edible Todmorden example, it is a force for human well-being and environmentally effective. Smart watering techniques and innovative hydroponics could be a fruitful way of integrating food production in better cities (including use of green roofs). Imagine all the trading estate and warehouse areas having cabbages and lettuces growing on their roofs!
- Need to say what “smart” is really all about: not just new markets for Siemens and IBM technology!

e) Landuse conflicts:

Energy crops versus food crops

- **In the UK:** Less than 10,000 ha may remain in production for energy crops (perennial crops such as *Miscanthus* and short rotation coppice (SRC) willow, and novel species like switchgrass and reed canary grass) but potential could be

between 0.93 and 3.63 M ha. Domestic supplies of perennial energy crops often offer superior greenhouse gas (GHG) balances and more needs to be done to encourage the development of a domestic energy crop market. (see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48342/5138-domestic-energy-crops-potential-and-constraints-r.PDF).

- **Internationally:** are Western countries using the land in the developing world to grow energy instead of simply lowering their energy consumption and helping to ensure domestic food production abroad to reduce famine? Europe consumes a lot of soy and palm oil, neither of which is grown in Europe on a large scale. Brazil is a major supplier of soy, with palm oil coming often coming from Malaysia.
- The German biodiesel sector only used three percent soy and 1.6 percent palm oil in 2012. Rapeseed oil made up around 85 percent of production, and most of it comes from within Germany. Rapeseed plantations in Germany do not compete with food crops. Because only 40 percent of the plant is used for fuel production, the remaining 60 percent is still available as feedstock for farm animals. The share of rapeseed in protein-rich animal feed has risen from nine percent to around 25 percent since 2001. (see: http://www.renewablesinternational.net/energy-crops-versus-food-crops/150/515/62147/).
- While countries like the United States and Brazil generally make ethanol from sugarcane and corn to replace gasoline, Germany makes a diesel substitute from rapeseed. But only 40 percent of the plant is used in the process, with the remaining 60 percent being fed to animals.
- To be acceptable, biomass feedstock must be produced sustainably. Bioenergy from sustainably managed ecosystems could provide a renewable, carbon neutral source of energy through the world and there is a strong societal need to evaluate the sustainability of bioenergy, especially because of the significant increases in production mandated by many countries. (see: http://pub.epsilon.slu.se/5562/1/ladanai_et_al_110104.pdf).

Livestock versus crop production: food versus non-food

- UK milk industry crisis: falling prices: farmers moving out of dairy: threat to national food security?
- UK livestock numbers decreasing (but some effect of foot & mouth disease slaughtering in 2001 (see graphs at: http://www.ukagriculture.com/farming_today/livestock_data.cfm).
- More slight decline in cereal production. Year to year variations almost as great as apparent decline 1995-2010 (see table at: http://www.ukagriculture.com/statistics/farming_statistics.cfm?strsection=Total%20Cereals).

Emergent transformations:

- **For UK:** According to projections by the NFU, on current trends the UK will reach a tipping point in about 25 years, beyond which a majority of our food will have to be imported, unless governments take strong action to improve food production and protect consumers from a future of relying on food bought from abroad. (from:

http://www.theguardian.com/environment/2015/feb/24/uk-will-need-to-import-over-half-of-its-food-within-a-generation-farmers-warn).

- Need to look at individual animals, crops and agricultural products. Tipping point will be when global prices rise and locally grown food is insufficient
- **International:** Tipping points may arise as a product of contract growing: a common practice for companies, spreading from the US to countries like Brazil, which process crop items (such as corn) and for animal production (primarily the production of pigs and chickens). In a contract farming arrangement with crops, a corporation will sign a contract before the crop is planted which will specify how much finished product the company will buy and at what price. In animal production a corporation that owns livestock contracts with farmers to raise the animals to maturity. (see: http://www.sustainabletable.org/859/industrial-livestock-production).
- Supermarket contracts with farmers in Europe may work similarly. Is such a trend sustainable, particularly in relation to the soil and ecosystem services. It might be argued that continued fertiliser management and the recycling of organic waste back to fields would sustain the system. But at what cost to global carbon nitrogen and phosphorus cycles?

3. OCEANS, MARINE LIFE AND FISHERIES

(PC)

a) Interaction between climate change and oceanic flows

'General areas of search'

Scientific speculation exists concerning the potential link between climate change and the circulatory patterns of the major ocean currents. For example, the Gulf Stream forms part of the Ocean Conveyor Belt, a major current system that links all parts of the World's oceans. The Gulf Stream flows northwards from the Gulf of Mexico up the eastern seaboard of the United States, before it diverges into two main currents. One of these currents proceeds north past the Atlantic coast of Canada while the other heads northeast towards Greenland and northern Europe. The Gulf Stream transports warm water from the equatorial Pacific Ocean into the colder North Atlantic. It thus effectively warms up the eastern United States and northwestern Europe by about five degrees Centigrade. See:
http://environment.about.com/od/globalwarmingandweather/a/gulf_stream.htm

Much more extensive data is required on the nature of the Ocean Conveyor Belt and the present impact of climate change on northern Atlantic ice and the resultant cold water flows.

Melting sea ice can influence winter weather: changing the oscillation of the Jet Stream. As temperatures rise faster in the Arctic than at lower latitudes, this changes large-scale temperature and pressure gradients - which has consequences for northern hemisphere winter weather. Global warming has increased the loss of summer sea ice in the Arctic, which has altered atmospheric conditions in a manner that stacks the deck in favour of more severe winter outbreaks.The pressure change alters atmospheric circulations, including the jet stream - a stream of fast-flowing air in the atmosphere. It also makes the jet stream's path meander more, which allows cold Arctic air to reach further south, affecting the climate in the mid-latitudes. (ID).

At a broader level, the potential impact of climate change on other ocean circulation patterns, which are drivers of climate effects and play a role in ocean nutrient cycles (thereby underpinning major fishing industries) are also poorly understood. In addition, the impact of changes in ocean circulatory patterns may also have implications for migratory fish stocks (which follow food sources) and for marine mammals. However, the threat of a new ice age appears to be the most prominent concern with its major implications for agricultural and social systems in the Atlantic littoral.

‘Possible transformations’

One major concern is that global warming could lead to the rapid melting of the ice fields at the northern end of the Gulf Stream (around Greenland, for example) and that the massive volumes of cold water released by this process could divert, disrupt or even halt the Gulf Stream entirely. Such an outcome could stop or disrupt the whole Ocean Conveyor Belt system, thereby generating a new ice age for eastern Canada and north western Europe.

Furthermore, it is entirely unclear whether such a process would be governed by a negative feedback system whereby a partial disruption would lead to reduced temperature s which would restore the ice sheets and return to the status quo ante or whether the shift would be a straightforward switch and thus irreversible.

b) Remote ocean data monitoring systems

‘General areas of search’

Advances in a range of technologies relevant to ocean data monitoring offer significant opportunities for vast arrays of remotely operated or autonomous data collection instruments able to operate for long periods without maintenance or re-fuelling and which allow remote data collection. These include significant reductions in battery size and extension of battery life; miniaturised high-gain energy collection devices (solar, wave, current, etc.); low energy demand sensors; autonomous guidance and collision avoidance software; integrity of communications links and suitable bandwidths; satellite telemetry options, etc.

Marine agencies have long anticipated the ability to deploy ‘fleets’ of remotely operated or autonomous data monitoring devices, either as passive buoys or as mobile surface or underwater vehicles. However, recent projects (e.g. http://noc.ac.uk/news/demand-grows-new-generation-ocean-robots-developed-collaboration-noc) have started to see a coalescence of technological advances that could actually bring this into fruition.

‘Possible transformations’

The ability to mount a variety of sensors (temperature, current, chemical, radar, sonar, wavelength, etc.) and to operate these remotely or autonomously simultaneously across broad ranges of ocean, or in coastal zones where collision avoidance is critical, for substantial periods of time (months or years) would provide a significant boost to marine and environmental science. Coupled with improved systems for handling ‘big data’ (see Scan of Scans report), such systems could make a huge contribution to improving our understanding of a range of oceanic and coastal processes and how these interrelate.

In addition to marine research, such vehicles and system offer further potential in the marine security field. For example, surveillance of oil and gas installations against acts

of terrorism, patrolling remote shipping lanes as a piracy counter-measure. These systems raise issues regarding legislative frameworks, particularly for operations within (foreign) coastal jurisdictions.

c) Climate change and storm surges

'General areas of search'

One of the potential (and measurable) consequences of global warming is the rise in global sea levels. In itself, this is a cause for concern but when coupled with the increased prevalence of storm systems generated by the effect of rising global temperatures on meteorological systems, the heightened risk to littoral communities, economies and environments from storm surges assumes a greater significance.

Work by scientists at Climate Central, an independent climate research organization, which examined the future effects of sea level rise on storm surges, combined future global sea level rise with historic tide gauge water levels at 55 sites in the US seaboard. The main finding was that for around 1/3 of the areas considered, storm surges with a "once in a century" probability could become "once in a decade" events in future.

The implications of these findings for other coastal areas and for islands are significant, particularly for such areas located in the tropics and sub-tropics where the prevalence of major atmospheric events is already high and where there is a likelihood that such events may become more prevalent as global temperature continue to rise. Even in temperate regions (including the UK) the increasing occurrence of major storm events poses a heightened risk from storm surges (such as flooding and storm damage), and the risk of significant damage is likely to be higher. This in part is due to the fact that, in areas where storm surges are relatively frequent, societies have adapted land-use patterns accordingly (e.g. by building further in-shore) whereas, where such events have previously been rare, there is less recognition of the potential risks of occupying the costal fringe.

Particular attention is being paid to the Thames Barrier and potential flooding downstream as a result of a surge approaching 1953 dimensions. The issue of changing magnitude and frequency of surges is a key one for all British estuaries

'Possible transformations' :

There is therefore a need for a reconsideration of policy approaches to land use (such as planning) which attempt to anticipate changes in the frequency of extreme events,

or the severity of more frequent events, when evaluating risks from climate change and sea level rise. (See Tebaldi et al 2012).

d) Global 'cod wars'

The risks of overfishing are already well researched and documented. However, it is likely that growing populations (particularly in developing economies) will continue to put pressure on the use of fish stocks as an essential source of protein (given that it is a more 'efficient' source than land-based protein sources such as cattle). In addition, the perceived benefits of a fish rich diet in developed countries are driving an accompanying heightened demand for this food source. Lastly, fish protein is also a high demand protein source for land-based animal rearing, as well as for, paradoxically, aquaculture.

The ability of fishing fleets to travel immense distances to satisfy domestic demands has been shown to result in quasi-conflict situations in the past (the 'Cod War' between the UK and Iceland, disputes between UK fishermen and Spanish trawler fleets, incidents concerning Russian 'factory ships). However, there is a possibility that for a variety of reasons pressures on fish stocks will continue to rise. Apart from the documented potential impacts on global fish stocks, marine ecosystems, etc. there is a risk that potential conflict situations will increase as the rewards for poaching, incursions into coastal jurisdictions, in order to obtain increasingly dwindling stocks become relatively more attractive. See, for example: https://www.worldwildlife.org/stories/more-than-125-000-americans-urge-obama-administration-to-end-black-market-fishing

Major implications for the UK overseas territories and their marine zones and marine conservation areas as well as around the British Isles.

4. CLIMATE, ENVIRONMENT AND BIODIVERSITY

(JC)

'General areas of search'

- The role of habitats and ecosystems in climate change mitigation and adaptation. The positive role that habitats and ecosystems can have for climate change goals is increasingly been recognised and researched. Often, these can be relatively low cost approaches.
- The potential of current and projected future climate change impacts to influence the economic competitiveness of cities and urban areas, e.g. via insurance premiums, perceived investor risk, ability to raise capital.
- Major cities are increasingly standing out as a positive force for change on climate change mitigation and adaptation, through initiatives such as the C40 and the Rockefeller 100 Resilient Cities programme.
- The increasing frequency and intensity of extreme weather events, and research connecting these events to climate change, is becoming increasingly prominent.
- Large scale climate and earth system 'tipping points' with implications that are essentially unmanageable e.g. permafrost melting, Amazon dieback, ice sheet melt. In some cases these tipping points will intensify climate change (via increasing GHG levels) and in other cases will accelerate climate change impacts (e.g. sea level rise). The concept of tipping points has been around for several years, but the key issue now is monitoring their onset and understanding their consequences.
- Climate change impacts on critical infrastructure systems (water, electricity, transport, ICT) stand out as one of the key risk areas for nations such as the UK, where the risk from flooding is particularly prevalent in this respect. Related to this, the interoperability of infrastructure systems and the risk of climate change induced cascade effects stands out as a significant issue deserving of further attention.
- Resource motivated 'land grabs' by corporations and nation states are threatening ecosystems (and livelihoods), and potentially reducing their capacity to cope with environmental change.
- The prospects and impacts of environmental migration are increasing in likelihood and severity, and have the potential to impact on the UK.
- Threats to coastal ecosystems. Coastal ecosystems provide a crucial resource to people across the world, for example in the context of protection from storm surges and the provision of food (especially protein). They are being threatened by climate change, pollution, development and exploitation.
- Extreme weather events (especially floods, droughts and heat waves) threaten food production. This has and is likely to continue to create shortages that could impact on the UK in terms of food price and availability.

Additional comments: (ID).

- Much attention to the million people+ cities, far less to places of less than 1 million in which some 60%+ of the world's urban people live. Big cities can afford considerable planning and environmental expertise, smaller towns and cities may have only a few experts to do all the work. Many of them however have good environmental outcomes, particularly where a local politician champions environment and sustainability. In the UK local governments tend to be much closer to uniformity of size of population than in many other parts of the world.
- The large-scale warming is expected to be accompanied by increased frequency and/or intensity of extreme events, such as heatwaves, heavy rainfall, storms and coastal flooding. There are also several possibilities that this large change could initiate nonlinear climate responses which lead to even more extreme and rapid (on the time-scale of decades) climate change, including the collapse of the ocean 'conveyor belt' circulation, the collapse of major ice sheets or the release of large amounts of methane in high latitudes leading to further global warming. (see http://classic.rsta.royalsocietypublishing.org/content/364/1845/2117.full.pdf+html
- Biotic invasions, change in species assemblages, and expansion and intensification of land use will also influence disturbance dynamics. What will happen when disturbance regimes change? How should society respond? What combinations of factors will cause surprises and qualitative shifts in ecosystems? The past may not predict the future, yet the lessons learned over the past few decades will become increasingly important as we anticipate responses of ecological systems to change. This applies to natural vegetation, agricultural systems, urban parks and gardens. Analogies can be made to manufacturing societal, cultural, economic and political systems
- Particular attention should be paid to coastal and floodplain power generation and distribution installations. The lessons of the 2007 Severn valley floods here and the Japanese tsunami impact ought to have been taken into account by now.
- War and civil conflict also prompt migration and lay waste large areas of productive farmland. In many countries land mines still make farming difficult and war and land mine injuries to farmers and their families reduces the productivity of farms. Land mine clearance and removal and an ending of war and conflict would greatly benefit everyone's environment and food security.
- The links between climate change and ecosystem change need attention: pest and diseases, invasive species, change in species composition and biodiversity, altered crop patterns (vineyards in the SE) changes in soils, less defined seasons, altered soil moisture regimes, all feed-back on natural vegetation , and planted crops, as well as grazing land. Patterns of recreation and holidays could change with resulting differing pressures on the coast and countryside..

Possible emergent transformations

- Breakdown of global climate change politics and negotiations. The Copenhagen summit acted as awake up call for many groups, with the realisation that global leaders either do not have the willingness or capacity to act decisively on climate change. If the forthcoming Paris summit produces a similar result, this could intensify efforts by other groups (including progressive cities, corporations

and others) to develop their own response. It could also lead to more direct climate activism.

- Fossil fuel divestment campaigns are becoming increasingly high profile, pushed forward by groups such as 350.org and recently the Guardian. The Rockefeller Foundation has recently noted that they have a 'moral obligation' to divest and have released shares in coal and tar sands companies. It the divestment campaign continues to build momentum this could have major implications for climate change (and related politics).
- The application of holistic systems focused environmental planning and management approaches, embedded within a more 'joined-up' governance framework, would have major implications for policy and action across a range of sectors in the UK from health, transport, energy, biodiversity……
- Lower oil prices over recent months are already having an impact on fossil fuel markets, for example with job losses in the oil sector and a scaling back of exploration plans. Similarly, fracking and tar sands oil in the US and Canada is looking increasingly uneconomical at these lower prices. Depending on whether the shift is made to dirtier fuels (particularly coal) or renewables, the associated implications for climate, environment and biodiversity will differ. With coal burning in the UK at the highest level for 25 years, this is not a positive sign in this respect.

Additional comments (ID):

- NGO and other social campaigns could alter public opinion about things like badger culls, hunting, GM crops, access to the countryside, mountain biking, off-road vehicles…all of which would affect responses and adaptation to climate change.
- Is the devolution of some financial controls, e.g. health and social care, to Greater Manchester heralding a step back to municipal socialism, when the city controlled water, power generation, gas and sewerage? What kinds and strategic levels of integration are required? Does the UK need a water grid?
- Is there still a place for carbon capture and storage: it seems to be one of the better engineering responses to carbon emissions. What benefits would enhanced nuclear power have for the environment and food security?
- The biggest tipping point would be if people all realised they could do something about climate change and its consequences by walking the children to school, walking to the shops and using public transport to get to work. This would probably alleviate emissions, improve health and road safety. As it is hundreds of millions of young Chinese, Indians and Brazilians are as anxious as the European counterparts to own and drive a car and as quickly as individual vehicle emissions are reduced, the total number of vehicles increases, with no fall in cumulative emissions. Individual responsibility for the environment need stressing and this should permeate education and household behaviour along with organisational and corporate responsibility.

5. NATURAL RESOURCES AND WASTE MANAGEMENT

(ID)

a) Sustainable consumption and production

'General areas of search':

- Cutting food waste and food losses during transport and storage are a priority.
- In the UK both household and retailer food waste (including food going to local composting and biodigestor schemes) remains a problem.
- High energy demand food production (e.g. greenhouse agriculture) needs evaluation
- Localising food production, including urban agriculture, should be a future concern in the UK
- The food-miles issue is a question of public choice; but also has implications for human welfare in the countries from which food is imported.
- An effective policy environment in tandem with powerful consumer awareness and engagement initiatives is vital if we are to see sustainability come fully to the forefront in citizens' consumption choices. Do we know where we are with changing attitudes to sustainable consumption?

'Possible transformations'

- Changes in planning regulations could affect farm land values and its future use.
- Global volatility in milk price: price wars by supermarkets force changes in the farming industry: causing some farmers to give up: acceleration in this could force a UK tipping point when our milk industry moves towards insufficiency.
- Alternative crops decisions as adaptation/response to climate change: selling farmland to develop vineyards in southern Britain.

b) Availability of farming resources

'General areas of search':

Demand for irrigation water, particularly in southern and eastern England, could rise by 20% by 2020. Building climate resilience in farming includes:

- Contingency planning for water shortages:

- Improving soil management with the objective of better managing soil fertility and moisture
- Field management to prevent excessive erosion and creation of ruts;
- Ensuring security of seed and crop storage facilities to deal with changes in moisture and temperature, as well as projected increases in pests (mice and rats);
- Improving fertiliser, herbicides and pesticide use to reduce wastage (e.g., scheduling, preventing/reducing non-effective applications, field inspections/monitoring and other management techniques); and
- Improving use of climate and weather forecasting in the timing of operations.

Catchment sensitive farming is likely to become increasingly significant.

Typical average annual fuel costs in the UK are £30/ha for arable land and £34/cow for dairy farms. Four key themes designed to reduce fuel consumption and emissions intensity:

• A - Better nutrient and fertilizer management;

• B - Better livestock management;

• C - Optimising renewable energy generation and encouraging fuel efficiency on farms;

• D - Better land management by locking in carbon in plants, trees and soils.

'Possible transformations':

Changes in water abstraction licencing could lead to sudden shifts in irrigation. In England, the onus is now on farmers to monitor their own patterns of water use by collating relevant information and using this to justify irrigation practices (see Knox et al 2012).

c) Water supply/demand & global food production

'General areas of search':

In the UK: Population growth in the last decade may continue and increase water demands, especially in the SE of England: the driest part of the UK. Groundwater (mainly in the chalk) could fluctuate more widely with drier summers and wetter winters: some winters may produce more groundwater flooding, summer summers, low groundwater levels and dried up streams.

Internationally: The dangers for food production come from higher demand for water from other sectors, the exhaustion of aquifers, changes in precipitation patterns, higher sea levels, and altered river flows caused by climate change. Incentives to encourage

greater efficiency of water use and the development of integrated water management plans need to be given high priority.

- Improving water governance through integrated water resources management is widely promoted as a critical need throughout the developing world.
- Planning and managing adaptation programs at the watershed scale need to take local
- vulnerability, and local culture and social organization into account.
- Need to have flexible options for storing water as practical, immediate, and cost-effective responses to existing variability and future climate-induced water scarcity. Much adaptation can be done on a small scale.
- Strengthening the capacity of women in managing water resources is clearly an opportunity for them to build resilience and adapt to climate change.

'Possible transformations':

Internationally: Tipping points are the critical points at which climate change will trigger negative impacts. For example, global warming can raise temperatures to a point where malaria emerges in regions hitherto unaffected. In these circumstances, water storage tanks that might previously have been suitable then become unsuitable unless they are adapted so that mosquitoes cannot breed in them. The rush to develop water harvesting and storage for climate change adaptation may increase health risks for already vulnerable people. Being aware of such tipping points is the first step towards averting unintended consequences.

d) Soil issues

'General areas of search':

- Soil erosion due to wind and rainfall already results in the annual loss of around 2.2 million tonnes of topsoil in the UK at a cost to British farmers of £9m a year in lost production (Defra 2009):
- Can we integrate non-crop habitat – trees, shelter belts, other habitat – in to farming systems in ways which can support production while also helping to reduce the risk of erosion?
- Socio economic factors, such as government subsidies, crop prices, factors leading to cultivation in risky situations on inappropriate soils, are the fundamental drivers of soil erosion: these change through time, leading to erosion in places where it has happened before. For example, the recent trend to poly-tunnel cultivation of strawberries, and potatoes on or near flood plains in the Wye and Lugg catchments, has led to damaging runoff affecting watercourses, roads and houses.
- Management change to reduce soil degradation erosion may include using bulky organic manures, applying inputs (fertilisers and agrochemicals), employing crop rotations, controlling farm traffic on fields, conservation tillage and taking a systems approach to farming. Their success will depend on individual farmer attitudes and relative costs and labour requirements.

‘Possible transformations’:

The erosion risks from climate change in the UK would seem to be associated with more summer thunderstorms affecting spring-planted crops and a continuing threat of erosion on winter cereals. Climate change may encourage a movement of arable farming into more upland areas: conversion of grazing land to arable runs the risk of erosion in wetter years (see Boardman, 2013) Higher temperatures will increase mineralisation (loss) of organic matter and result in increased CO_2 release, especially from organic soils, while mineralisation of wetter soils may result in an increase in methane emissions. Warmer, wetter soils are likely to result in increased N_2O emissions from nitrogen-fertilised soils, as these conditions favour denitrification (the conversion of nitrate to nitrogen gas).

Climate change is an overarching driver affecting numerous soil quality issues such as:

- a loss of organic matter because of higher decomposition rates (e.g. increased temperature, drying of wetlands);
- erosion as a result of more frequent extreme rainfall events;
- reduced trafficability as a result of periods of increased soil wetness;
- a reduction in soil fertility;
- increased and changing pest loads;
- a change of vegetation type and an increase in plant growth (both crops and natural vegetation).

e) Water systems

‘General areas of search’:

Public acceptability of recycled water is an issue: indirect potable reuse may be socially acceptable in the south-east of England, but public engagement and participation in future decision making about indirect potable reuse will be important for the success of any particular proposal. A SW USA study found that public acceptance of potable reuse is contingent on trust in the authorities who influence design of sociotechnical systems for water supply and reuse—including water and wastewater utilities, regulators, consultants, academics, and elected local officials.

- Membrane filtration on treated waste water is a proven, acceptable technique, as used in Singapore.
- Desalination may still be preferred by a majority of the public (e.g. from the London plant).
- Rainwater harvesting not well developed in UK compared with Germany: In 2011 an estimated 7,500 systems were installed in UK domestic and commercial properties in 2012, compared to the 50,000 systems installed in Germany each year.
- The method of charging for water, particularly in the domestic sector, is currently a barrier to the wider application of water conservation. There are two basic

approaches used to charge households for water, first, charges based on indirect measure of water usage, e.g. property value and second, based on volume of water used, e.g. metered supply. In properties which are not metered there is little incentive to conserve water. In 2010, about 30 per cent of all customers have a metered supply. This should increase in future, but how rapidly and how much water will it save?

'Possible transformations':

A severe drought may trigger individual, corporate and government action to improve water recycling (Just as floods in 2007 and subsequently have led to action on flood defences and adaptation).

Present rainwater harvesting (RWH) practice can have a high carbon cost, to avoid this a more integrated approach is needed and involves using and use RWH as both a water conservation measure and method of reducing runoff. (See: Fewkes, 2012)

Additional Comments (NL)

‘General areas of search’

- Having ‘exported’ much of our manufacturing processes to Asia we have also exported our pollution. Also, coal fired power stations still produce nearly 40% of the UKs electricity and we import approximately 85% of our coal usage. Changing economic and political circumstances could lead to the re-establishment of manufacturing in the UK and increased pollution.
- Pollution levels are closely linked to the sourcing, production and use of energy. ‘Green’ energy production is of course welcome but more study is required on the full life-cycle environmental/eco-toxicity (polluting) potential of some of these emerging technologies (batteries, concrete and steel for wind turbines, impact of tidal, tidal lagoon and wave power systems on the marine environment, etc. etc.).
- Buildings through their construction, use, renovation and demolition consume approximately 50% of final energy consumption and contribute almost 50% to CO2 emissions. This can be substantially reduced through retrofitting for energy efficiency.
- Pollution is linked to consumerism but online shopping can provide opportunities for parcel carriers to reduce the carbon footprint of home deliveries and provide an environmental advantage.
- Aquatic biodiversity is increasingly being compromised by litter and other pollutants.
- Impact of farming subsidies on land degradation due to the industrialisation of agriculture, increased use of fertilizers and pesticides and food waste need to be investigated.

‘Possible transformations’

- Urban planning needs to link housing with the production of goods and provision of services to reduce the need to commute. Internet and technology could increase home working. Local small-scale combined heat and power production (including greater use of thermal energy), waste to power plants and retrofitting building stock reduce energy requirements. Cycling facilities need to be integrated into urban transport planning and not just provided as an ‘add-on’. Policy initiatives are required.
- Brownfield and contaminated land is generally neither remediated nor used in advance of a development plan. National and local planning policy is required to ensure appropriate and sustainable re-development.
- Waste management policies to recognise waste as a resource and to include product design for end of life recycling and to reduce litter and fly-tipping.
- Increased environmental awareness within the community and the development of user-friendly monitoring technologies should also be enabled. Community based local stewardship and clean-up programmes are effective but are also an abrogation of local authority/state responsibilities towards the environment.

6. POTENTIAL RISE IN INVASIVE SPECIES, PESTS AND DISEASE

(LB)

'General areas of search'

- **Surveillance**
  - Decreasing infrastructure (ie fewer veterinary surveillance labs in UK)
  - Syndromic surveillance, early warning systems and crowd-sourcing approaches to early detection of disease in parallel with diminishing surveillance infrastructure.
  - Surveillance for BSE, TSEs in cattle and sheep – an industry desire for relaxation (specifically of TSE surveillance at abattoirs)
  - Recognition of importance of wildlife surveillance (particularly through phylogenetic sequencing data) and potential impact of disease on farmers (see potential conflicts for positive disease management and free-range status of birds in Avian Influenza; CSF and ASF between wild boar and free-range pigs; deer, badgers and TB).
  - Anti-microbial resistance surveillance and reduction targets for UK and impact on human and veterinary prescribing protocols. Look to other European industries for examples of how this has been managed (eg Denmark).
  - Residues/pesticides/other contaminants in food – may be more difficult to detect as new biotechnology/nanotechnology medicines and diagnostic tools become available; could have an impact on trade restrictions due to zero-tolerance approaches if there are differences between countries regarding access to these technologies.

- **Changes in disease prevalence in EU, USA-** associated with climate, trade or animal movements perceived to be a real threat to UK industry and impetus for continued contingency planning : increased circulation of specific threats to animal health and food security such as vector-borne diseases (BTV, Classical swine fever), new circulating strains of known viruses (Blue-tongue Virus BTV 6 – which is not vector borne) and emergent vector and non-vector borne diseases (Schmallenberg virus, African Horse Sickness, Porcine Epidemic Virus) . PED has a short time horizon – imminent arrival is likely with large-scale detrimental impact and potential to inadvertently reshape pig industry in UK if not brought under control quickly.

- Increased reliance on **farmer-led approaches** to disease control and eradication (see example of Bovine Viral Diarrhoea in Scotland) which require industry solidarity and knowledge networks. Beginning to see loss of industry memory/indigenous knowledge regarding 2001 outbreak FMD although it remains a top industry priority for contingency planning; farmers concerned over time to diagnosis and recognition of clinical signs; questions over the feasibility of FMD vaccination in future outbreaks;

- **Real-time animal traceability and digital food chain :** Electronic identification of livestock and horses and subsequent real-time location and movement databases is important for parameterisation of animal disease models as well as traceability of food/ deterrence of food fraud. ScotEID is at forefront of this.

'Possible transformations'

- Development of new genetically engineered vaccines – increased stability, differentiation between live virus and vaccinated animals – and working on effectiveness of multiple strains (see FMD vaccine development as an example).
- Development of pen-side testing techniques which are rapid and simple mobile tools which can be used outwith centralised laboratories. This will decrease transport time, and time to diagnosis, ultimately having a positive effect on herd health and husbandry costs.
    - Available technologies which are promising candidates for integration into pen-side tests include: high-speed real-time reverse transcriptase quantitative PCR (RT-qPCR), isothermal amplification techniques loop-mediated isothermal amplification (LAMP) and recombinase polymerase amplification (RPA)
    - Examples of pen-side tests under development include *inter alia*: Schmallenberg virus and Bovine Viral Diarrhoea (Aebischer et al. J. Clin. Microbiol. June 2014 vol. 52 no. 6 1883-1892); peste de petits ruminants (see Baron et al. Transbound Emerg Dis. 2014 Oct; 61(5): 390–396.). A BBSRC grant has been awarded to develop pen-side test for liver fluke in cattle and sheep (end date 2016).
- Technologies to enable remote animal husbandry and management techniques as well as surveillance
- Alternative sources of protein for animal feed sources (e.g. insects).
- Development of sophisticated phylodynamic models utilising genome sequencing to forensically detect origin and spread of infectious disease in disease outbreaks; used in conjunction with wildlife surveillance to detect spread of avian influenza in 2014 GB outbreak.

Additional comments (ID)

'General areas of search'

- For general review of past trends see: **Roy et al (2014)** The information portal website is: http://www.nonnativespecies.org/. The portal provides alerts with information about newly arrived invasive species such as the Quagga mussel: a highly invasive non-native freshwater mussel: can significantly alter whole ecosystems by filtering out large quantities of nutrients and is also a serious biofouling risk.

- ***Biosecurity*** is seen as the way to slow the spread of dangerous invasive species. E.g. The Killer shrimp *Dikerogammarus villosus*, is a non-native species poses a serious threat to aquatic wildlife. Biosecurity is responsibility of all water-space users, but difficult to police and enforce. What else can be done?
- EU legislation on invasive non-native species (INNS) came into force on 1 January 2015. This requires reporting new INNS by individual EU countries and thus better anticipation of movement of species across Europe. Ballast water in large ships remains an unresolved problem. Ships take in water at one port and discharge at another and thus can release non-native species into harbor waters. The UK currently has not taken a position on this issue and has not yet joined the International Maritime Organisation's Ballast Water Management Convention, which would work to reduce risk if ratified.
- Tree pests and diseases require constant vigilance and research into biological control agents (BCAs). Successful eradication using a BCA can be highly cost effective, but using the wrong BCA can result in major problems: such as that caused by the cane toad in Australia!
- An example of the complex pathways by which invasive species travel is provided by the Asian tiger mosquito. (Gould et al., 2010: Medlock et al., 2012: Madon et al. 2002: Medlock et al., 2012).

'Possible emergent transformations'

- The Asian hornet - *Vespa velutina* is in France and is expected to arrive in the UK soon, more details: http://www.nonnativespecies.org/alerts/index.cfm. The Forestry Commission warns of the following threats to trees that have not yet arrived in the UK: Citrus longhorn beetle; Eight-toothed European spruce bark beetle; Elm yellows phytoplasma; Emerald ash borer; Pinewood nematode; Pine processionary moth; Plane tree threats (see http://www.forestry.gov.uk/pestsanddiseases).
- The bigger picture is of forests, parks and gardens with several species affected by pests or disease. The impact on landscape quality and the availability of certain types of timber warrants attention.
- Future pathways of tree pest infestation and disease spread are difficult to predict. Varied outcomes are possible: e.g. Pautasso et al 2013)
- Predicted changes to climate in the UK, characterised by warming and wetter summers could provide perfect breeding grounds for a number of pest-borne diseases and it is likely that the range and activity of many ticks and mosquitoes will increase across the UK by the 2080s. The increased use of salt marshes to protect coastal regions and the heightened risk of flooding means the UK is becoming a more attractive habitat for mosquitoes, while the increasing proximity of animals that carry ticks to humans is another concern.

7. INNOVATIVE CHEMICALS AND MATERIALS

(SG)

General Areas of Search

- Advances in embryology and in-vitro fertilisation research: for example, the use of mitochondrial DNA from a third donor for creation of a viable embryo, transferred to agricultural sector for the generation of genetically improved livestock.

- Graphene: the discovery of a new material, an atom layer thick, that is electrically conductive, incredibly strong and flexible with multiple and diverse commercial applications.
    - Nanotech improvements of solar panels, resulting in reduced size and greater efficiency enabling micro-generation of energy across the rural landscape.
    - The use of carbon nanotubes to make lightweight composite materials, leading to an increased use of drones, for precision farming.

- Advances and diffusion of 3D printing, e.g.s:
    - Print tissues or drugs for veterinary practices.
    - Print tissues for the production of synthetic meat.
    - Print farming machinery parts, reducing wastage, reducing transportation emissions.

- Piezo electric:
    - Micro generation of electricity through kinetic energy, e.g. the movement of ivy in wind is converted into electricity.
    - Potential for capital intensive farming practices with zero energy consumption post production.

- Cell Tissue Culture and Bioengineering of meat alternatives/protein
    - Has environmental impacts, e.g. 45% less energy, 96% less GHG emissions and 99% less land used in production.

- Next Generation Sequencing:
    - A fundamentally different approach to sequencing technologies that has brought about major transformations and benefits for agriculture research.

    - This technique is highly specific enabling the sequencing of individual and/or multiple traits.
    - Allows identification of SNPs for identification of beneficial phenotypic traits.
    - Allows the sequencing of individual seeds prior to planting.
    - Has improved veterinary diagnostics, including the tracking of adaptations in pathological micro-organisms e.g. bird flu.
- SLIP (slippery liquid-infused porous surface): a germ repellent surface which bacteria cannot adhere to, can be used in animal husbandry or creating sterile conditions conducive to intensive farming.

- Informatics aided surgical procedures and diagnostics impacting on veterinary practices

Possible Transformations

Smart countryside

- Fibre optic connectivity:
    - Advances in farming are increasingly dependent on ICTS and connectivity is assumed to be universal. Yet, coverage is not 100%. What implications does this have for rural communities and agricultural producers?
    - Where connectivity exists is the infrastructure being fully realised? Is there a disconnect between food producers and environmental stewards skill sets and policy requirements to use electronic systems to, e.g. record crop production and calculate subsidies?
- Inadequate diffusion of sensors:
    - The lack of sufficient infrastructure for the realisation of Smart Countryside, or the rural realisation of the 'internet of things'.
- A centralised, uniform model of environmental stewardship:
    - Can a model of local service delivery, that is globally defined and controlled, be applied to environmental improvement? What are the implications for small holdings? How will patterns of environmental stewardship change in response to adoption of new technologies?

Micro generation of energy:

- Realised through the application of innovative materials, challenging a dominant model of centralised energy production and distribution, which has implications for the regulatory and policy regime, physical infrastructure including the GRID and requires changes in the division of labour between production and use, as well as culture and practices.

8. POLLUTION & ENVIRONMENTAL QUALITY

(ID)

a) Air quality

'Areas of search':

Significant attention to $PM_{2.5}$ is now being augmented by emphasis on PM_1, 100 nm or smaller particles that are able to enter the bloodstream directly.

Relative significance of UK emitted ozone and aerosol pollution and transboundary carried ozone and aerosol pollution is not known. Effects such as Saharan dust falling on the UK could become more frequent with climate change and northward spread of desertification.

'Possible transformations':

Both non-fossil fuel policies and fuel prices have expanded the use of wood stoves and biomass burners at many scales from power station to domestic users, creating more sources of particulate emissions. (see http://www.esru.strath.ac.uk/EandE/Web_sites/12-13/Domestic_flue_gas/background/market-study/uk-market.html#Ref)

Non transport air pollution

- The London Low-emission zone set out to achieve a reduction of PM_{10} by 0.17. Emissions from wood burning have increased it by an estimated 1.1 µg m^3. Changes in emissions sources are negating the effects of emissions reductions policies. Smoke control legislation may no longer be effective.
- Solid fuel organic aerosols are emitted throughout the year in London indicating that the negative effects on health and air quality, as well as climate, may have significant implications for air-quality policies and mitigation strategies.
- Boilers of all types, from domestic to industrial size, contribute to emissions and require regular maintenance: are current regulations up-to-date (see US EPA boiler emission regulations: http://www.epa.gov/airquality/combustion/docs/20121221_sum_overview_boiler_ciswi_fs.pdf

b) Water quality and aquatic biodiversity

'Areas of search':

Among household chemicals and personal care products, some preservatives exhibit toxicity, including estrogenic activity, are resistant to degradation and/or bioaccumulative and may present a hazard for the aquatic environment. Additionally, fragrances include compounds exhibiting estrogenic activity, and the inadequate toxicity data for these and the preservatives is worrying: monitoring such impacts may be difficult.

Anthropogenic trace compounds (ATCs), such as pharmaceuticals and pesticides, are specifically designed to act biologically with high potency, and may have profound effects on wildlife even at low nanogram per litre concentrations). Consequently, the potency of ATCs is a key risk factor for human and wildlife exposure as well as ecosystem functions. More information is needed about chronic impacts which might be much more severe than acute effects.

Monitoring of these ATCs, micro-plastics and other nanoparticles is difficult but becoming increasingly urgent.

'Possible transformations':

Micro-plastics (micro-beads) in personal care products are carried (from waste water treatment works and directly) into aquatic systems and affect the world's seas and oceans. Micro-plastics enter such organisms as fish, crustacean and plankton and thus potentially enter the human food chain whence human health may be affected.

Too many nanoparticles and ATCs could cause sudden changes in aquatic ecosystem states, with decline of keystone species for aquatic biodiversity.

Smart Countryside - Water quality monitoring:

- Issues of which parameters to monitor, continuously or at what interval, where, for how long, and by whom. "Perhaps the greatest scientific 'bang for the buck' lies in the development of inter-calibrated networks of water-quality sensors that provide information about water quality across the continuum from headwater streams to lakes, reservoirs, and ultimately coastal rivers and estuaries.
- The information provided by such a network would assist environmental and water quality managers as an early warning of problems, help assess long-term trends, and provide data to evaluate the effects of management and mitigation actions across multiple scales. However, standardized sensor measurement protocols, data collection strategies, and common quality control approaches will be

necessary to develop an inter-calibrated network of in situ optical sensors with different agencies and users".(from Pellerin et al 2014).

c) Contamination of soil/land

- General issue of the migration of contaminants through derelict land and the diffuse sources of mine water pollution in non-coal mine catchments
- Extensive work on PAHs in soils, but little on agricultural chemicals, especially farm pharmaceuticals and their impacts on soil biota.
- For Europe as a whole, loss of soil functions, land degradation and climate change remain major concerns. Looking ahead, climate change impacts on agricultural land are projected to intensify, and the underlying drivers of biodiversity loss are expected to persist.
- Risk of soil processes deteriorating to a tipping point after which they can no longer support crop yields.

d) Environmental pollution

- Threat to global agriculture, and thus UK food supplies, by high levels of ozone damaging ecosystems and reducing crop yields (by 7-12% for wheat and 3-5% for rice).
- Threat to intensive UK agriculture by increasing demand to build on green field, especially green belt land. As UK sourced food is declining as a proportion of UK food consumption, UK food security is falling.
- New chemical compounds are continually being developed and possibly posing risks to the environment and human and animal health. How can assessment of the impacts of these new compounds be improved?
- It is important that the combined effects of emerging contaminants and other contaminants are considered in the future. See: http://www.oecd.org/tad/sustainable-agriculture/49848768.pdf
- How will climate change affect the distribution and migration of contaminants?

9. ECONOMY AND POLITICS

(JR)

a) Economy and industry

General areas of search

- Growth of corporate CSR, ethical finance and general transparency changes the game for use of resources & management of environmental impacts
- Localization & downshifting cultures could begin to affect trends in resource use & global trade.
- Continued economic development in China & other emerging economies leads to 're-shoring' of manufacturing etc to UK & EU, with new types of industrial pollution etc.
- 'Bio-mimicry' principles of industrial design lead to large scale industrial symbiosis & production systems for biological materials such as algae, with requirements for water, energy, etc.
- Changing patterns of energy generation may create new industrial possibilities, but there may be new challenges in the management of materials, such as used batteries etc.
- Overall the push towards a 'circular economy' seems to be progressing but is likely to produce new opportunities with new challenges: e.g. partially re-used / recycled materials & components needing storage or processing or logistics at different points in the supply chain: new enterprises acting as inter-mediaries, trading in futures or 'material-as-service'.

Possible transformations:

- 'Internet of things' could transform the system of raw materials / production / distribution / consumption / recycle or waste.
- New social media & network technologies could enable community stewardship of ecosystems & their services to particular social groups.
- 3D printing & other distributed production methods could transform the system of industrial production & logistics, with new types of environmental risks & SME governance issues.
- Fair Trade and similar accreditations are expanding, but bring their own problems of trust, credibility, (i.e. who certifies the certifiers?).

b) Finance & market issues

- Growth of ethical finance and ethical financial markets may change the game for use of resources & management of environmental impacts.
- Ecosystems services markets and monetary valuations based on TEEB principles, e.g. Payment for Ecosystem Services, valuation of Ecosystems Approach etc. This might lead in the direction of financialization & privatization e.g. of forests: **OR** it might lead towards a better balance of economic & ecosystem priorities.
- International climate policy, e.g. REDD & carbon offsets, is increasingly a global financial commodity subject to fraud, corruption and speculation.
- Crowd-finance, peer to peer banking & other innovations, could enable the Ecosystems Markets & PES & similar schemes to go mainstream.
- Global carbon markets combine ETS and similar, but are vulnerable to speculation: the likelihood of a crash would have huge impacts making stocks worthless and encouraging growth of dirty fossil fuels.

c) Globalisation, politics and security

General areas of search

- Climate change could disrupt global food markets, with price volatility, leading to rapid increase in the UK's domestic food production, also including products previously imported, with effects on invasive species, pests, native ecological habitats etc.
- Geo-political tension could reinforce the dominance of the TNC food firms, with aggressive strategy towards domestic producers, land ownership etc.
- Legal rights of ecosystems etc are becoming recognized: and change the trends in CSR and their extraction of resources.
- Impact of valuation of ecosystems services could be on a global scale: land grabs & acquisitions, could combine with ecosystems & carbon markets, climate vulnerability, rapid urbanization and financialization of public assets.
- Economic change in Africa with a burgeoning population could create massive changes in food consumption within the continent affecting food exports from the continent (all depending on trends in conflict and corruption).
- Continued austerity politics in UK & EU is likely to lead towards rapid reduction & outsourcing of governance, e.g. most of Defra & partners' functions could be privatized on a cost-recovery basis where management is integrated to ecosystems markets.

Possible transformations:

- Satellite imaging / remote sensing could transform management of global commons, e.g. forestry / deforestation with Global Forest Watch,
- This could combine with the 'internet of things' to provide cradle to grave transparency on resources, products, processes and environmental impacts.

- But - this could then be vulnerable to more sophisticated and ICT-based forms of fraud, ‘phishing’, direct corruption, market manipulation etc. (as seen with carbon markets etc).
- NGO / Private sector schemes for geo-engineering (e.g. cloud seeding) could be problematic with unforeseen side effects, distributional questions and governance dilemmas
- Financial crisis in UN and similar bodies could lead to collapse in climate & CBD talks, leading to private sector / NGO rescue attempts.

10. CHANGING GOVERNANCE: GLOBAL & LOCAL

(JC)

a) Governance issues

'General areas of search'

- There is a disconnect between global environmental governance processes/frameworks and the environmental challenges they are established to address (e.g. climate change, biodiversity loss). This is in part due to the complexity characterising environmental challenges, but also because international organisations themselves suffer from fragmentation and inconsistencies.
- Landscape scale governance (e.g. based on river basins, landscape types) offers the potential to respond to environmental challenges at a workable and relevant scale. Administrative boundaries (districts, counties etc) do not provide an effective model for environmental planning and management due to the cross-boundary nature of related issues.
- The loss of spatial planning capacity and influence to positively influence the development and use of land to achieve environmental goals. In England and Wales, the role and ability of the planning system to contribute has been eroded via legislative and policy change and cuts to local authority budgets.
- Marginalisation of environmental issues within some local authorities. As a result of cuts to their budgets, there is a retreat to the delivery of statutory duties and objectives linked to high profile agendas (e.g. health, education) within local authorities. This is leading to certain environmental agendas being marginalised, including work on climate change.

'Possible emergent transformations'

- There is a risk of a breakdown of the science-policy interface, following a shift to the political right, with implications for energy, environmental and climate change governance and policies.
- Rejection of austerity. As a counterpoint to a political shift to the right, a rejection of austerity focused governance could have an equally significant impact on environmental governance, particularly at the UK and EU scale.
- A decline/intensification of corporate capture of the political system would open/close governance opportunities for addressing environmental challenges (such as climate change).

b) National / local governance & current controversies

(JR)

Wider trends & megatrends in national and international governance – UK, EU and global – and some implications for Defra partnership remit:

- Loss of trust between citizens & politicians & government system: volatile political system, coalition politics, greater influence of financial & corporate sector,
- New sources of trust emerge: fringe parties (e.g. UKIP), celebrities & personalities, social media,
- Green Party puts environment / climate as top priority: may hold small balances of power, with larger balance of public opinion.
- New geo-political configurations in global environment /climate policy: e.g. Russia / Middle East / G20 / G77: rise of the NGOs and Foundations: rise of social media pressure groups.
- Digital transition affects every function of governance: data on citizens and organizations, production / consumption, environment / health impacts, and local ecosystems, can all be combined.

Wider trends in local governance in UK: with implications for Defra partnership remit:

- Financialization of public services & public assets: e.g. landscape maintenance, forest stewardship.
- Digital transition affects every function of governance: data on citizens and organizations, production / consumption, environment / health impacts, and local ecosystems, can all be combined.
- Functional pressure & financial need for partnership style working in all areas of environment / climate / food & rural affairs: local governance is likely to be more social network function.

Topical fault-lines and controversial splits in UK environment & food policy debate:

- Energy-environment issues: Fossil energy from fracking: Expansion of nuclear: Renewable energy from wind & other large scale sources
- Landscape and ecosystems services: ownership / stewardship of forests, wetlands, uplands & other common assets
- Flooding: demands for increased protection - VS unwillingness to pay for it via general taxation, leads towards variable cost-recovery models.
- Agri-food issues: GMOs in food chain: industrialization of production: rising water demand: campaign against tax-avoiding TNCs.
- Food-health issues: crisis of obesity leads to policy for health cost-recovery or variable tax rates on food: similar for substance abuse.

11. DEMOGRAPHICS, URBAN & RURAL ISSUES

(FC)

a) Urban issues

'General areas of search'

- Under the 'Smart City' banner, interconnected information and communications technologies (ICT) will shape the way urbanisation is understood and practiced.
- Current environmental, socio-political and economic challenges (climate change, food security, air pollution, water quality and energy, in particular) are largely caused by urbanisation. The Smart City (and, possibly in the future, the Smart Countryside) will either exacerbate these issues reaching the point of no return or mitigate/fix them
- The Smart City can monitor the environment (water quality and pollution, in particular) and grow in synergy with regional ecologies.
- The Internet of Things can make environmental, real-time data public. Smartphones can be connected to environmental sensors and citizens can actively be part of environmental monitoring.
- ICT, green infrastructure and urban design can transform cities into sources of food (urban gardens and building-integrated agriculture supported by real-time environmental data) and drastically improve food security
- Transport is not the only cause of air pollution, but its impact on air quality and climate change will continue to grow as cities will keep growing in size and number. Cities should be planned for 'access by proximity', so to reduce the need for transport systems, transport infrastructures, means of transport, fuel and energy.
- The emergence of clean-tech, green gated communities and privatized eco-friendly urban areas, indicates that the burdens of climate change and environmental degradation are not evenly distributed: a situation that challenges social cohesion, population health and political stability.
- Pressures for housing development will vary geographically and so will the scale and the socio-environmental impact of urbanization. The regions experiencing higher levels of housing growth will also experience a greater loss of eco-systems and, depending on the level of urban density, higher property prices and wider social exclusion/marginalization.

'Possible transformations'

- The rise of the 'Smart City' does not seem to be followed by the rise of the 'Smart Countryside', but this is likely to change as current cities will become bigger, new cities will be built and rural regions will be increasingly urbanized and connected (energetically, ecologically, economically and politically) to built environments.
- The Smart City could make citizens part of environmental politics via ICT and cloud systems sharing environmental data and enabling citizens' contribution to

environmental monitoring and, potentially, decision/policy making. Citizens could share their vision of the city and the region, online, and enhance democracy in urban politics and planning.

- The Smart City (automated systems, in particular) can potentially disrupt citizen participation. When the 'machine' provides key services (such as transport and energy consumption) with little or no human interaction, automation can generate apathy among citizens towards key environmental issues and hinder community development (a phenomenon already experienced in new, high-tech Asian and Middle-Eastern cities).
- Since current demographic trends indicate, in the UK, an aging population, cities should be designed and planned to be more accessible to elderly people.
- Studies show that clean, healthy environments and strong, cohesive communities are key to people's happiness. The Smart City can and should monitor levels of happiness via ICT, so that urban and regional development can maximise citizens' happiness.
- Current 'Cradle to Cradle' principles of design could be applied to urban/regional development to reduce the negative environmental, social and economic externalities of urbanization.

b) Rural issues

(JR)

There might be some perception that 'rural Britain' (in contrast to cities) is a rather quiet place where nothing much happens. ON the contrary, we would argue that the countryside is where all of the trends and transformations in this review can combine, and produce synergistic effects either positive or negative. Here is brief summary of 'areas of search leading to possible transformation': this uses the STEEP format (Ravetz, 2015):

Social

- Demographic change in rural settlements & farming communities with housing stress.
- split between overheating of in-migration areas: VS hollowing of out-migration.
- Occupational change in farming & land- based occupations: changing career structure etc
- Growth of horsiculture, hobby farming, eco-stewardship & low impact lifestyles.

Technological

- Smart countryside trends are behind 'smart cities' but may catch up (see 'governance' section).
- Precision farming, industrialized farming
- Digital-enabled ecosystems markets, crowd-funding, visitor participation etc.

Economic

- Consolidation, financialization and industrialization of mainstream farming:
- Displacement of farming by energy / industrial / pharmaceutical crops: leisure / tourism / ecological functions:
- Dependence of upland farming etc on CAP reform: farmers as landscape stewards with Pillar 2 type actions.
- Volatile global markets with implications volatile UK production
- Implications of dairy crisis for rural communities & economies:
- Land acquisitions by ultra-rich in certain parts of England: legacy of landownership in Scotland.

Environmental

- Implications for rural areas of climate change impacts: flood, drought, storm, heatwaves, sealevel rise, saline incursion.
- Implications for rural areas of invasive species, pests, malfunctions in food chain etc: (e.g. BSE showed the vulnerability not only of farming but of rural tourism).

Political

- Trends in local governance in UK, with implications for Defra partnership remit: reducing funds for local government.
- Financialization of public services & public assets: e.g. landscape maintenance, forest stewardship.
- Digital transition affects every function of governance: data on citizens, production / consumption, environment / health impacts, and local ecosystems, can all be combined.
- Functional pressure & financial need for partnership style working in all areas of environment / climate / food & rural affairs: local governance is likely to be more social network function.

Cultural

- Volatile changes in cultures, lifestyles, technology aids etc: implications for fluctuations in rural tourism, leisure:
- Similar implications for each of the ecosystem domains: e.g. uplands, lowlands, wetlands, coasts, forests:
- Urban fringe areas are particularly important as the most accessible location for most people. At present public funding for maintenance is cut, leading to various problems.

Urban

- Large parts of UK are not fully rural but more like ‘peri-urban’, ie. Low density beyond the urban fringe, but with rural economies and communities rapidly shifting towards urban.
- Rapid changes in some rural towns & villages: closure of shops & pubs: rationalization of public services & transport:
- Rise of social enterprise & cooperative economy, for shops, pubs, libraries etc.

12. ENERGY SUPPLY AND DEMAND

(CT)

General areas of search

Energy security: This is likely to significantly contribute to a national political agenda for the foreseeable future. As the UK increasingly moves towards being a gas importer, ensuring future energy security will be a contributing factor to the rural economy as new energy infrastructure is developed to meet the UK's energy needs.

Low carbon transition: The UK's continued commitment to a low carbon transition combined with energy security requirements means that energy will be a significant driver behind continued land use change, with impact on cross cutting issues for Defra in the UK in the coming decades.

Energy mix and distribution: While the general horizon of change is the low carbon transition, what is uncertain is the speed of development, mix of technologies and extent of land use change that the transition will encompass.

Energy landscape conflict: As new energy infrastructures develop (wind, solar, unconventional gas) across existing landscapes there can be opposition at proposed sites between local residents / businesses and the developers that can be based in the rural economy, biodiversity concerns or protection of food and farming interests. While these are primarily opposition to a local development they can also join up with similar local conflicts to form broader opposition movements that oppose national or even supranational development of a given energy technology. An example is recent opposition to unconventional shale gas development, both in the UK and abroad, in which local conflicts have become sites of interest for much broader opposition movements. As multiple low carbon energy technologies are now at a stage where they can be deployed *en masse* to further the low carbon transition, the primary potential obstacle to change is multi-scalar opposition to new infrastructure development.

Rural perspectives on energy developments: In an energy landscape conflict, it is easy for the concerns of rural residents, farming communities, industries and businesses to be overlooked in a broader polemical public discussion of pro / anti groups around a given technology. These rural groups often do not easily fit into a pro / anti debate and have local concerns which relate to their own human-environment vulnerabilities / relationship with the land. A difficult yet important horizon to scan is the rural perceptions and concerns about the significant changes to land use that will happen as part of the low carbon transition over the coming decades and their impact on concerns that include farming, the rural economy, local biodiversity and access to local resources. It is a difficult horizon because it isn't a primary focus of media, which prefers the simple and easy to relate pro / anti narrative already discussed.

Changes in energy vulnerability across rural populations: As energy supply moves towards a more distributed energy system and demand patterns shift there will be positive and negative impacts for communities living in rural areas and for local rural economies. A horizon of change that remains uncertain is how the low carbon transition will impact on the most vulnerable people in society who are defined as

‘energy vulnerable’. This could include the elderly, unemployed, local businesses and populations living in remote rural areas who may not benefit equally from future energy infrastructures.

Possible emergent transformations

Social change: public acceptance of / opposition towards ‘new’ energy technologies

‘Social change’ as an emergent transformation could lead to public acceptance of some new energy technologies as they develop across existing rural landscapes and become part of rural economies. For example, public acceptance of wind, solar and unconventional energy sources like shale gas and coal bed methane may occur in the future as their relative economic and environmental benefits are recognised. While a change towards social acceptance of a technology could speed infrastructure development of that technology, a change toward opposition and potentially protest at development sites could slow infrastructure development and create ‘energy landscape’ conflicts at proposed sites for development as local opposition groups protect existing landscapes from new energy developments.

At this stage it remains uncertain which technologies will be accepted and which opposed. It is also uncertain across which landscapes they will develop as part of a low carbon transition and the extent to which some landscapes (for example national parks) will be protected against new energy developments. Public perception of individual technologies will be a contributing factor in determining what the UK’s future energy mix and a low carbon transition will look like over the coming decades.

Together, shifts to our energy landscapes carry with them the potential to re-write the roles that energy plays in the make-up of our society and economy. In other words, shifting patterns in the production of and consumption of energy also constitute wider social and geographical changes which will impact on rural economies, systems of farming / food production and biodiversity and ecosystems, in ways that are as yet unclear.

13. SCIENCE, TECHNOLOGY AND INNOVATION

(LB)

a) General science issues

'General areas of search'

- Remote sensing data using satellite systems for mapping, surveillance, prediction and control of animal, plant and human diseases
- Information technology- real-time animal movement and location testing
  - Ultra-high frequency versus low-frequency technologies and compatibility with existing technology (readers) and regulatory requirements for traceability
- Genomic research to improve breeding for disease resistance, improved feeds, and genetically engineered vaccines- 'personalisation' of animal and crop health delivery to farms.
- Nanotechnology – development of diagnostic tools or micro-tools which can penetrate and treat cells from the inside and associated intellectual property issues which may affect distribution and accessibility
- Dark data' may become an increasing concern for agriculture and animal health sectors – presenting opportunities for better data mining and intelligence but also risks – associated with data security, liability, opportunity costs.
- Genome biobanks may play an increasing role in future (see UK Biobank, Iceland example – deCODE genetics) – raises important ethical issues over the use of big (personal) data – opportunities and risks for the population – privacy, risk communication; sample ownership; commercialisation and patents resulting from data use and partnerships between commercial and government run businesses regarding data sharing with other scientists.
- Intellectual property case law development over self-replicating biotechnologies ((such as vectors, genetically modified organisms and information and computing technologies and computing technology – such as 3D printing)- see Bowman v. Monsanto Co., 133 S. Ct. (2013)

'Possible transformations'

- In animal health, the proposed introduction of bovine electronic identification system within the EU and the introduction of centralised equine database as a result of European legislation will make real possibilities to improve real-time traceability of animals prior to an outbreak.
- Impact of proposed EU Data Protection Regulation - knock on effects for data portability, - personalised medicine, cloud computing
- Availability of new technologies: 3D printing which may affect access, manufacture and distribution of pharmaceuticals/medicines –which may impact prescribing practices, quality, safety and distribution of generic medicines (see http://www.bbc.co.uk/news/technology-17760085)

b) Artificial intelligence / expert systems

Big data, learning algorithms and parallel computation are important . I agree with the comment regarding potential futures where one could foresee the farm to fork process as a digital one which may link with existing on farm databases, and centrally held data on animal movements. Data on companion animals and horses is very poor – something highlighted by the food scandal in GB a few years ago. I suspect coordinated large-scale animal health data collection and curation is a longer-term horizon objective at least in veterinary /animal health (10 years?). This will require efforts to stimulate farmer uptake and compliant use of technology (and whether they are early adopters or laggards). That itself is likely to be dependent on the structure of the industry (ie age, markets, solvency etc) and the infrastructure enabling internet access (not particularly good in some areas). Using smartphones or other mobile tech to collect data on animal health is not widespread– but I understand that this is an area that is currently being explored . There are certainly exemplar systems in African countries where this is the main mechanism for collection of surveillance data (something that may become important if surveillance facilities decline).

"Big data" is a term that has been identified as an emerging area in veterinary health, as in other sectors. However, there is also a realisation that the veterinary industry isn't yet dealing with truly "big data" (high velocity volume and variety). There is a fragmented landscape comprising multiple databases (across GB borders) – which record information at different resolutions and which don't talk to each other. Some data are recorded electronically but not available or used ("dark data"). Other important data are recorded on paper or not recorded at all. This probably has some opportunities (fragmented databases are more resilient to threats, hacking) – but more likely costs in terms of traceability and transparency.

14. CONSUMER ATTITUDES AND BEHAVIOURS

(DW)

General areas of search

- Consumer interest in provenance and sustainability of food: slow food movement; certification schemes; local food; farmers' markets etc.; including interest in technological advances in supply chain traceability (e.g. RFID technology) being articulated with smartphone and web developments

- Consumer support for alternative food networks such as: community-supported agriculture; urban-grown food distribution networks (e.g. Abundance); community gardens and institutional growing projects (e.g. schools, hospitals etc); temporary land leasing and sharing schemes (e.g Development Trusts Association; Landshare); local food coalitions

- Consumer support for food poverty & insecurity schemes: food banks and redistribution schemes

- Continuing interest in food waste at all stages of the food chain; pressure for local authority food waste collection and processing; neighbourhood food waste initiatives; support for on-site anaerobic digestion (including through novel funding platforms)

- Digitally-enabled 'collaborative consumption': linkages to alternative food networks

Consumer sensitivity to food health scares: "mad cow disease" "gluten allergy" "salmonella in eggs" can distort markets and also perhaps draw attention away from real threats such as resistant bacterial infections due to the use of antibiotics to make food animals grow faster.

Possible emergent transformations

- New food safety scares: food safety scare in certification labelling scheme produce

- Possible rapid consumer acceptance of artificially grown meat, or non-traditional protein sources, such as insects

- 'Food nationalism' consumer movements in the context of rising global food price and concerns over food security: first world 'food nationalism' may create political pressures, e.g. re CAG, against biofuels, or popular support for farmers vs supermarket supply chain policies

- Technological advances in supply chain traceability may have disruptive effects on consumer attitudes and behaviour towards existing certification schemes (e.g. QR-

coded products link to web platforms for ‘provenance’ branding, even web-enabled interaction with producer communities)

Social and health benefits of “grow your own” on allotments (with implications for land use policy) in and around buildings or as ‘incredible edible’ schemes may increase in acceptance and adoption.

15. HEALTH AND WELLBEING

(ID)

a) lifestyle diseases

As a low cost antidote for increasingly sedentary urban lifestyles, park-based physical activity could contribute to addressing the obesity and overweight epidemic for both adults and children (Maas et al., 2008) as well as risk of cardiovascular disease. Urban green space is not only a place for walking but also identified as a place that provided relaxation. Recent experimental work postulates a neurobiological link between stress, anxiety and depression (Bedimo-Rung, 2005) suggesting that contact with urban green space could play a role in addressing issues of mental ill-health. Work in Sheffield found that improved positive emotions and spiritual well-being may also have relevance in combating depression and anxiety and suggest a mechanistic path to account for the observation of decreased depression and anxiety when living near more green space. Clinically, more healthcare providers could consider writing “park” prescriptions emphasizing the variety of reasons for park use and the multiplicity of potential holistic health effects (Irvine et al., 2013).

Despite some evidence for an association between greenspace and obesity-related health indicators, findings are inconsistent and mixed across the studies (Lachowycz and Jones, 2011).

b) Attitudes and behaviour

General areas of search

Key points from 2011 NHS National Obesity Observatory Report:

- The majority of adults and children have an understanding of what constitutes a healthy diet. Eating lots of fruit and vegetables is the most frequently cited component of a healthy diet.
- Most adults consider healthy eating to be important and would like to improve their own eating habits and those of their children.
- Adults from lower income groups are more likely to cite cost as an important influence on their eating habits.
- The most frequently cited method of controlling weight is trying to eat less at mealtimes.

- The majority of adults report that they are either fairly or very physically active. Morbidly obese adults are significantly less likely than adults of a healthy weight to consider themselves physically active.
- Time is the most commonly cited barrier to participation in physical activity.
- The majority of children consider themselves to be about the right weight.
- Incentives may be successful in encouraging children to make healthier food choices at school.
- Interventions focusing on personal and social factors may be helpful in bringing about behaviour change.

Issues, particularly affecting children, are suggested by the Policy Studies Institute (2009).

- Intake of fresh fruit and vegetables – what does research tell us about how people understand the five-a-day message?
- Intake of salt – knowledge of guidance on salt intake and cooking practices
- Eating outside the home – is there a link with healthy eating?
- Economic outcomes of obesity
- Food safety practices among the general population or possibly among parents
- Perceptions of food poisoning – what do the general public believe to be the sources of food contamination?
- Attitudes and understanding of novel foods
- Attitudes to the intake of GM foods among specific subgroups of the population
- Parents' behaviour

A Canadian study found a relatively strong correlation between age and increased emphasis on healthy eating and nutrition, including more natural, higher quality and healthier foods. While some people have more time to devote to meal planning and preparation, for most it was a combined effort of food *avoidance* and food *adherence* that influenced premium food choices. At the same time, interest was not only with older individuals but in some cases there were some extremely health conscious younger participants; some older individuals did not appear to be overly concerned with what they ate.
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sis13265

Possible emergent transformations

- The most likely trend seems to be an increasing divergence between social groups who emphasise healthy eating and physical exercise and those who cannot afford healthy food and have little opportunity to exercise. As with other health issues: poverty is a key factor. This has implications for health services and for disability benefits. It also relates to school meals (which do seem to be getting far healthier).

- Tipping point will come as more and more obese people enter old age, costing the state more to look after and yet living longer, with the working population being a decreasing percentage of the total population. Migration (normally by people of working age who would pay taxes) would ease the problem, but add to pressures on the land and environment as a whole.

c) Whole greenspace agenda

General areas of search

As people have become more aware of the dangers of obesity, heart disease and high cholesterol levels in urban societies, the lists of the positive health and well-being aspect of activity and exercise, of the gentlest kind, in blue and green spaces in towns and cities have grown markedly (See Table 12.7 in Douglas and James, 2014). Many agencies actively promote the benefits of urban greenspace for improving mental and physical health and general well-being. However, the evidence is patchy and it is probably unwise to extrapolate general benefits from studies made in particular contexts. Bowler et al. (2010) concluded: "Policy makers should therefore be wary of translating the findings of studies which have been conducted only in specific settings, for defined indicators and subjects, into generalised statements of universal benefits".

The two central aims of the Natural England (2009) strategy *Our Natural Health Service* were to ensure that people live within 5 min walk of urban green space of at least 2 ha, and to ensure that GPs and community nurses are able to signpost people to approved walks or outside activities. The limited research that has been conducted suggests that use of parks for walking is shaped by common factors such as facilities, safety concerns and dog mess, but also differentiated factors by class, age, gender, disability and ethnicity (Carpenter, 2013). The social benefits are important, many people regarding the exercise walk in the park as a social occasion. Although many types of benefits have been studied, benefits to physical health, cognitive performance and psychological well-being have received much more attention than the social or spiritual benefits of interacting with nature, despite the potential for important consequences arising from the latter. The evidence for most benefits is correlational, and although there are several experimental studies, little as yet is known about the mechanisms that are important for delivering these benefits (Keninger et al., 2013). The many reviews of the literature of this topic stress the weak evidence base, but that should not stop further encouragement of outdoor exercise in greenspace. Realistic understanding of differing attitudes to the risks in outdoor urban recreation (Table 12.8 in Douglas and James, 2014) is needed to shape good policy.

d) Additional Comments:

(NL)

'General areas of search'

- TV, computers, iphones/pads/watches/glasses are increasingly promoting a virtual world at the expense of interaction with the actual world.
- Pedestrian only shopping precincts and the provision of local services within these areas will increase walking and cycling with corresponding health benefits. Urban planning needs to focus on discouraging the use of motorised travel at the expense of walking and cycling.
- The sell-off of outdoor sports facilities by schools along with a changing curriculum and staffing is reducing opportunities for active sport by younger people.
- Socio/economic factors are most likely to institute behavioural change. Strong link between obesity and financial security.
- The value of urban greenspace for health and well-being has increasingly been quantified. Much work on methodologies and toolkits for assessing ecosystem services provided by green infrastructure in urban areas has also been undertaken.

Possible emergent transformations

- Urban planners need to be better informed on the value of urban greenspaces and for health and wellbeing.
- Integrated urban planning could reduce the need for motorised transport.
- Food, drink, alcohol and entertainment industries should be more involved in preventing and managing lifestyle diseases and in the development of public health policies.
- More could be done in schools to promote a healthy lifestyle.
- Travel to school is increasingly dependent on motorised transport. The location of schools should be integrated with transport and greenspace planning to promote walking and cycling to school by young people.

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