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Securing UK Soil Health

2015 is the United Nations International Year of Soils. Soils underpin the global food system and regulate water, carbon and nitrogen cycles but are subject to pressures from population growth and climate change. In England & Wales, soil degradation costs around £1bn per year. This POSTnote outlines the evidence for measures that sustain soils and existing policies affecting soil health.

Overview

- Soils filter and store water, support agriculture and other plant and animal communities, and harbour a quarter of the world's biodiversity.
- Soil is a renewable resource but can be permanently degraded by pressures such as urbanisation or erosion. Degradation of peat soils releases CO_2 to the atmosphere.
- Arable soil health can be improved by appropriate cropping and organic matter inputs but poor management can lead to erosion, degradation of soil fertility and reductions in water-holding capacity.
- The evidence base for soil management has been challenging to develop because soils improve slowly. There is no UK-wide scheme for monitoring soil health.

Background

Soil performs several globally important functions:

- Around 95% of food production relies on soil.[1] The global nature of the food system makes soil health (or quality) an international concern.
- Soils are home to a quarter of the Earth's biodiversity; organisms such as bacteria, fungi, and earthworms. These support plant growth, and cycle carbon, nitrogen and other nutrients. Soil microbes are a source of antibiotics and may provide future drug discoveries.[2]
- Soils absorb and store water; their capacity to do so relies on good soil structure, which is maintained by soil organisms, organic matter and appropriate management.[3,4]
- Soils store three times as much carbon as is contained in the atmosphere; degradation of carbon-rich soils releases significant quantities of CO_2.[5]

The ability of soil to perform these functions is reduced when it is degraded (its quality is reduced) or eroded (its quantity is reduced). There may be trade-offs between the different functions of soil; for example, increasing food production can be detrimental to water quality (POSTnote 478), carbon storage and biodiversity.[6-8] Over half the world's agricultural land is subject to soil erosion (reduction in soil depth) and 12m hectares are abandoned each year because of soil degradation due to unsustainable farming practices.[9] Nutrient deficiencies in soil can directly affect human diet and health.[10] In 1982, the UN Food & Agriculture Organisation World Soil Charter called for governments to commit to "manage the land for long-term advantage rather than for short-term expediency". Since then, many reports have highlighted the problem of ongoing soil degradation and its implications for global food security.[11-13] Protecting soil presents an opportunity to address simultaneously several global challenges such as food security, climate change, water security, waste management and biodiversity loss.[12,13]

This note summarises the most common soil degradation processes globally, then focuses on soil degradation in the UK, management strategies to improve soil health, and the policies affecting UK soils. Agricultural land occupies 75% of the UK and 10% is urban and developed.[14]

Soil Degradation

Many processes of soil degradation are associated with food, forestry, textile and biofuel production, so pressures on soil may be exacerbated by the demands of rising population. Soil erosion is also likely to be aggravated in the future by heavier winter rainfall events[2] and there may also be indirect effects on soil associated with climate-induced changes in land use.[15,16]

Mechanisms of Soil Degradation

- **Sealing by infrastructure** – building and urbanisation often covers soil with water-impermeable surfaces. All functions are lost from sealed soil; for example, water run-off to surrounding land is increased (POSTnote 448). Agricultural land is often used for urban expansion.
- **Compaction** – the weight of farm machinery or livestock can compress soil which increases water run-off, reduces water holding capacity and makes it harder for plants to grow (POSTnote 484).[4,17] In arable soil, cultivation becomes more difficult so fuel costs and machinery wear increase. Compaction is more common under crops that are cultivated or harvested when soil is wet. Remediating deep compaction can be difficult and requires costly machinery. Vehicle compaction can be reduced by using satellite positioning to keep vehicles to fixed routes in fields (Controlled Traffic Farming; POSTnote 505).
- **Loss of organic matter (OM)** (Box 1) – cultivation and removal of crop residues can reduce the OM content of soil.[3,18,19] This impairs most soil functions, reduces fertility and water holding capacity and leaves soils vulnerable to erosion and compaction.[13,20] Soils such as peat contain large stores of carbon as OM, accumulated over millenia under waterlogged conditions. Draining these soils for agriculture or forestry can cause this carbon to be released to the atmosphere as CO_2.[5]
- **Erosion** – wind or water can physically remove soil, leading to sediment run-off to drainage channels (POSTnote 484) and reduced fertility.[6,9,17] Soils can become unproductive and eventually be lost entirely. Some crops (maize, sugar beet, potatoes) are more prone to soil erosion than others because they establish slowly (leaving soil bare for longer after planting) or require extensive disturbance of soil during cultivation.[21]
- **Contamination** – toxic elements, such as arsenic, can accumulate in soil often as a result of industrial activity. Contamination can damage biodiversity, make soil non-productive and pollute underlying groundwater. Methods to remediate severe contamination are expensive.
- **Salinisation** – irrigation water or coastal flooding that evaporates leaves salts, which can build up in soil to levels that reduce fertility or are toxic for plants, and is a major cause of desertification. Globally, a third of food is grown on irrigated land. Although expensive, salinisation can sometimes be alleviated using large volumes of purified water.
- **Acidification** – atmospheric pollutants produced by fossil fuel burning, industry and agriculture can increase the acidity of rain, which may alter soil chemistry and biology to reduce soil fertility. Draining wetlands, coniferous forestry and nitrogen fertilisers can contribute to the acidification of some soils.[22]

UK Soils

The UK has over 700 soil types, determined by variations in geology, climate, plant and animal ecology and land use. The UK's young soils (due to relatively recent glaciation) and mild climate mean that degradation is not currently as problematic as in some countries, but soil degradation costs are still significant (Box 2). For example, agricultural soils can be subject to erosion, compaction and loss of OM.[18] UK cereal yields are still among the highest in the world (6-7 tonnes per hectare)[26] but after many years of increasing yields, the last eight years have seen a wheat yield plateau (POSTnote 418).[27] In some areas cultivation has led to severe soil damage (Box 3). There are also thousands of potentially contaminated sites in the UK.[28] Salinisation may also become a problem in low lying parts of the UK in the future.

In England, 10% of soil is in urban areas and is subject to high levels of sealing.[14] Growth in housing will exacerbate this pressure. In Northern Ireland, building on agricultural and semi-natural land has increased. Conversion of semi-natural habitats to agricultural grassland, scrub or woodland is reducing biodiversity and there are over-grazing problems on heath and bog. Damage because of peat extraction is no longer widespread but still occurs.[29] Wales has 3% arable land and large areas of grassland grazing. The main issues are compaction on grassland caused by overgrazing, and the restoration of drained organic soils. Wales also has 1,300 former metal mining sites, some of which have polluted soils and rivers.[28] Scotland has large areas of upland carbon-rich soils, including extensive peatlands, which are particularly vulnerable to climate change impacts.[30]

Peat Soils

Peat Soils cover 10% of the UK land area but store around half (5bn tonnes) of the UK's soil carbon.[2] Upland peats occur in all the UK nations; they provide drinking water and their degradation can increase flood risk (POSTnote 396). Lowland peats such as the Fens of East England account for around a tenth of UK peat and having been drained for cultivation are some of the UK's most productive agricultural land (Box 3). Large areas of UK peat (as much as 80% by one estimate[5]) have been adversely affected by land-management activities including agricultural drainage and intensification of grazing, managed burning for grouse rearing, conifer afforestation and peat extraction.[35,36] Peat areas that are not Sites of Special Scientific Interest (about two thirds of UK peats) are generally not covered by restoration schemes and are at risk of further damage.[35]

Box 1. Soil Carbon and Organic Matter Amendment

Soil carbon content is usually defined by the amount of organic matter (which is around 50% carbon). Data from the Countryside Survey 1978-2007 show that arable agriculture tends to deplete soil carbon.[18] Adding organic matter (OM) to arable soil has many benefits, including:

- providing nutrients for plants and soil organisms, which improves natural soil functioning and reduces the need for synthetic fertiliser[23,24,25]
- improving the structure of soil, which makes it less vulnerable to erosion and better able to hold water and reduce flood risk[20]
- adding carbon, making better use of soil carbon storage capacity
- reducing soil density, which saves fuel during ploughing and reduces wear on agricultural implements.[23]

Regular addition of OM in combination with fertiliser inputs over several years results in improved yields and reduced farm costs. OM can be derived from plant material, food and industrial waste, compost, sewage sludge and animal manures. Regular application is as important as the type of organic material added.[23]

Box 2. Costs of Soil Degradation in England and Wales
A 2012 report for Defra estimated the annual costs of soil degradation in England and Wales at between £0.9 and £1.4 billion (Figure 1), 80% of which is due to compaction and loss of soil organic matter.[33] Most of these costs are borne not at the site of soil degradation but elsewhere. For example, the contribution of damaged soils to flooding events is estimated to be £233m per year, with the total annual cost of flooding estimated to be £1b (POSTnote 484). There are proven financial and environmental gains in protecting and improving soil health, in particular by improving the environmental performance of farming, restoring peatlands, and planting woodland.[34]

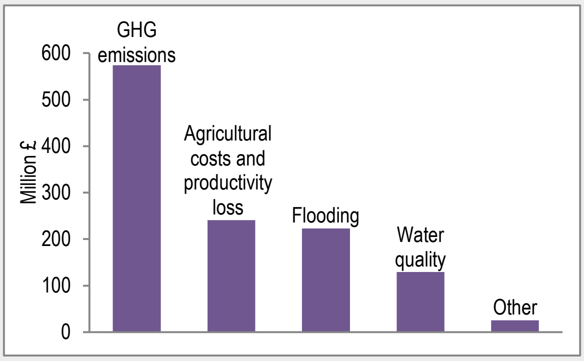

Figure 1. Annual costs of soil degradation in England & Wales.[33]

Improving Soil Health

Historically, there have been successful initiatives to improve soil condition, such as the US Government Soil Conservation Service formed to resolve the 'dust bowl' soil crisis of the 1930s. 'Terra Preta' soils in the Amazon Basin were improved thousands of years ago by adding charcoal and organic matter and are still exceptionally fertile.[37]

Soil Management Strategies

Soils vary on national, regional and field scales and optimum management practices will vary from place to place, depending on soil type, land use and climate. Possible measures include:

- **OM addition to agricultural land** confers benefits on most aspects of soil health (Box 1). Adding OM can increase soil carbon content for up to 20 years before it plateaus. It can be several years before benefits are apparent in crop yields or farm profits.[6,9,17,20,23-,25,38]
- **Cover crops** (or green manures), such as clover and vetch, protect soil from erosion and nutrient leaching over winter (POSTnote 478) and can be tailored to suppress weed growth and improve soil structure. They are then killed off or ploughed in, adding OM to the soil. Benefits to soil health vary with crop and weather and can take three or more years to become apparent.[38-40]
- **Longer crop rotation** and intercropping. Varied cropping permits soil recovery and may reduce pesticide requirement (POSTnote 501). The benefits of increasing rotation complexity depend on the crop species used.[41] Growing two or more crops alongside each other (intercropping) can suppress pests and weeds, covers the soil, protecting it from erosion and can increase nutrient supply to the main crop,[42] although mechanical harvesting can be difficult.
- **Non-inversion or reduced tillage** improves soil structure, can reduce erosion, cultivation time and fuel costs, and encourages earthworms. It does not necessarily sequester carbon (POSTnote 486),[6,41] and may not be suitable for organic farming because associated weed growth requires pesticide control. A flexible management approach to tillage, according to climate and crop, is most financially profitable.[38]
- **Tree planting in strategic areas** increases water infiltration and reduces erosion and run-off of sediment and water (POSTnote 396). Low density forestry can sometimes be effectively combined with animal grazing.[43] However, commercial forestry on upland carbon-rich soils such as peat can cause significant erosion.
- **Peat conservation** retains soil carbon stores and minimises CO_2 emissions to the atmosphere. Re-wetting areas previously drained for cultivation restores the plants (notably *Sphagnum* moss) and moisture conditions needed for peat formation, though this can have implications for methane emissions (POSTnote 454).

Box 3. Areas with Degraded Agricultural Soils
East Anglian Fens
Parts of the East Anglian fens have been drained to grow crops and the carbon-rich peat soil is being lost at rates of 1-2 cm a year. Since the mid-19th Century, 84% of East Anglian peat has been lost[21] and in some places, peat soils that were four metres deep have entirely disappeared.[31] Restoring the water-table level of some cultivated fens may provide more economic benefits than the existing agriculture.[2,21]

South-West England
Maize fields are particularly prone to soil compaction and erosion. Compaction reduces rain infiltration that increases water run-off, and eroded soil contributes to sediment in river and drainage channels. In South-West England, where serious flooding has occurred in recent years, maize cultivation has increased, 75% of maize sites suffer from soil compaction[4,21] and up to half of river sediment may be soil eroded from maize fields.[32]

Most good soil management practices will have a positive effect on more than one soil function (Box 1).[6,13] Organic farming certification requires good soil management practices (such as varied cropping and adding OM) and organically farmed soils often have higher carbon content, better structure and greater biological biomass and diversity.[44,45] However, yields are often lower than those achieved using artificial (fertiliser and pesticide) inputs.[46,47]

Farming and Soil Management

As in wider society, farmer awareness of soil health, soil functions and wider issues, such as climate change, varies.[48] In general, knowledge and understanding generates the confidence to undertake new practices,[49] but profit, ethics, experience, level of support and sense of community all contribute to farmer decision-making.[50,51] Good personal relationships with trusted advisers are likely to be key to encouraging uptake of good soil management in many cases,[51,52] (such as on remote farms or those without good access to internet-based information) but there is a lack of trained, field-experienced, trusted advisers.[49] Community partnerships to improve water quality at the level of river catchments (POSTnote 478) are a good model for distributing advice to farmers,[53,54] but are not nationwide. Around half of farmers have moved from traditional ploughing to reduced-tillage cultivation, which can save time and fuel costs as well as reducing soil compaction and erosion.[21] However, the cost of reduced-tillage equipment (such as seed drills and strip tillers) is likely to prohibit many from investing in new practices. The equipment needed to relieve compaction is also costly. The benefits of good soil management might not be immediate and those farmers on contracts or short tenancies may have little incentive to invest financially in safeguarding long-term soil health.

Food Labelling and Soil Management
UK food certification schemes that relate to soil management include Red Tractor, the LEAF marque and organic certification. Red Tractor is an industry-led assurance scheme that requires farmers to comply with CAP regulations (see below). Both LEAF and organic standards go further, requiring farmers to manage their soil to reduce erosion, enhance fertility and maintain good soil structure in a sustainable and environmentally sensitive way. Organic standards are defined by EU regulations; whereas LEAF marque requirements are defined by the LEAF charity to achieve sustainable farming systems with high environmental standards. Around 550,000 hectares (3.2% of UK farmland) is organic certified and 200,000 hectares is farmed to LEAF standards. There is no price premium on LEAF produce, as there is on organic.

Policy and Evidence
Like other natural assets that provide off-site, non-market benefits, the economic value of soil is not reflected in policy.[55,11] The evidence base for good soil management practices has been slow to accumulate because soils improve slowly and measuring their response needs long-term, controlled studies, of which there are few. Also, reductions in soil fertility can be compensated for by increasing the use of artificial fertilisers or irrigation.

Research, Data and Monitoring
Current Research Council-funded projects on sustainable agri-ecosystems and forecasting the response of soils to management and climate stress include a centre for doctoral training (£2.3m), and the SARISA (£5m), SARIC (£9m plus £1m from industry partners) and Soil Security (£8m) research programmes. UK soils data are held by various organisations in the devolved nations. Much is collated and accessible via the UK Soils Observatory,[56] but some are not publicly available because of privacy or licensing issues. Most available data relates to geological or chemical properties of soil. Data on the status of urban soils are lacking,[2] despite the role of soils in the benefits provided by urban green spaces (POSTnote 448).

The physical and chemical characteristics of UK soil were monitored 1978 to 2007 by the Countryside Survey (Defra funding is currently not in place to continue this survey) and are currently monitored by the Environmental Change Network (NERC funded). There is currently no UK-wide monitoring of changes in soil health. Most soil functions are dependent on living organisms so biological soil quality indicators (SQIs) are a useful measure of overall soil health. Because soils and their uses vary widely, a standardised method of measuring soil health requires a wide variety of indicators (of genetic, biochemical and functional diversity). Refining a suite of effective SQIs is an ongoing task.[57]

EU Directives and the Common Agricultural Policy
There is no specific EU legislation on soils. Some EU Directives have indirectly addressed aspects of soil management. These include directives relating to water, nitrates and biodiversity that require reductions in agricultural run-off of soil and fertilisers to water (POSTnote 478). Consequently, in order to receive Basic Payment Scheme payments under CAP, UK farmers must maintain minimum soil cover (with vegetation, crop, cover crop, stubble or crop residue) and minimise erosion and compaction (by livestock and vehicle management and minimising machinery use on wet soil, although there are exemptions for meeting contractual deadlines). Requirements for maintaining soil organic matter extend only as far as not burning stubble. Arable farms must grow at least two different crops if over 10 hectares, and three if over 30 hectares.[58-61] Compliance with regulations must be enforced by inspection of at least 1% of farms per year.[62]

A proposed EU Soils Framework Directive was repeatedly blocked by some Member States including the UK (with Austria, Germany, France and the Netherlands) partly because it proposed a register of contaminated land, which would have been expensive to compile. However, while omitting contaminated land, the Scottish Soil Framework (2009) is similar to the proposed EU directive, aiming to create a framework for greater connectivity across existing policy realms relating to soils.[30] From 2016, the UK is required to report to the EU on the systems being developed to estimate greenhouse gas emissions from farmland, which must be in place by 2021 (EU Decision No 529/2013).

Soil Policy in England
In England, the 2009 ‘Safeguarding our soils, strategy for England’[63] has been superseded by the Natural Environment White Paper, which commits government to ensure soils are managed sustainably by 2030. The Climate Change Committee has stated that Defra “should take action to deliver its policy”.[21] Defra funding for contaminated land remediation is being phased out.[35] Other existing policies on soils include:
- the National Planning Policy Framework (2012), which states that development should preferentially be in areas of poorer quality agricultural soil[64]
- Defra’s 2013 Payment for Ecosystem Services (PES) action plan,[65] which identified peat soil restoration as an area of opportunity, and a pilot ‘UK Peatland Code’ (IUCN 2013), which aims to facilitate sponsorship of peat restoration.[66]
- A UK Government strategy aims to reduce horticultural use of peat to zero by 2030.[36]

New soil policies in agriculture could be delivered through existing mechanisms such as CAP payments and catchment sensitive farming schemes. Current Government policy is to develop a 25-year plan to “grow more, buy more and sell more British food”, which would require improvements in soil health.[67]

Endnotes

1. UN Food and Agriculture Organisation, 2015, *Healthy soils are the basis for healthy food production.*
2. Natural England, 2015, *Summary of Evidence: Soils.*

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Dr Helen Snell for researching this briefing, to the Natural Environment Research Council for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Jonathan Wentworth.

3. European Commission, 2012, *The State of Soil in Europe,* JRC.
4. Palmer, R, and Smith, R, 2013, *Soil Use and Management*, 29 (4) pp. 567-575.
5. IUCN, 2011, *Commission of Inquiry on Peatlands*
6. Powlson, D, *et al*, 2011, *Food Policy* ,36 pp. 72-87.
7. Jones, D, 2013, *Journal of Applied Ecology*, 50 (4) pp. 851-862
8. Maskell, L, 2013, *Journal of Applied Ecology*, 50 (3), pp. 561-571.
9. Pimentel, D, 1995, *Science*, 267, no. 5201, pp. 1117-1123.
10. Yang, X, 2007, *Environmental Geochemistry and Health*, 29, 413-428
11. Koch, A, 2013, *Global Policy*, 4 (4) pp.434-441
12. Government Office for Science, 2011, *Foresight. The Future of Food and Farming. Final Project Report*.
13. Lal, R, 2010, *Food Security*, 2, pp. 169-177.
14. Khan, J, 2013, *Land Use in the UK.* Office for National Statistics.
15. Defra, 2005, *Audit of soils-related education and awareness initiatives.*
16. Nearing, M, 2004, *Journal of Soil & Water Conservation*, 59 (1) pp. 43-50.
17. Rickson, R, *et al*, 2015, *Food Security*, 7 (2) pp 351-364.
18. Countryside Survey, 2007*Soils Report from 2007.* CEH.
19. Chapman, S, 2013, *European Journal of Soil Science*, 64 (4) pp. 455-465.
20. Watts, C, and Dexter, A, 1997, *Soil & Tillage Research*, 42 pp. 253-275.
21. Committee on Climate Change, 2015, *Progress in Preparing for Climate Change - Report to Parliament.*
22. European Commission, *Agriculture and Acidification*.
23. WRAP, *DC-Agri project*.
24. Roig, N, *et al,* 2012, *Agriculture, Ecosystems and Environment*, 158 pp. 41-48.
25. Walsh, J, *et al*, 2012, *Journal of Plant Nutrition and Soil Science*, 175(6) pp. 840-845.
26. The World Bank, 2015, *Cereal yield (kg per hectare)*.
27. Knight, S, *et al*, 2012, *Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oilseed rape.* HGCA of the AHDB.
28. Environment Agency, 2004, *State of Soils in England & Wales*.
29. Northern Ireland Environment Agency, 2007, *Northern Ireland Countryside Survey 2007.*
30. The Scottish Government, 2009.*Scottish Soil Framework*:
31. Holman, I, 2009, *An estimate of peat reserves and loss in the East Anglian Fens; Commissioned by the RSPB.* Cranfield University.
32. Jaafar, M, 2010, *Soil erosion, diffuse source pollution and sediment problems associated with maize cultivation in England*. University of Exeter.
33. Defra, 2012, *Costs of Soil Degradation in England & Wales.*
34. Natural Capital Committee, 2015, *The State of Natural Capital.*
35. National Audit Office, 2014, *Environmental Protection.*
36. Defra, 2012, *Towards Sustainable Growing Media.*
37. Glaser, B, 2007, *Philosphical transactions of the Royal Society B*, 362(1478), pp 187–196
38. Stobart, R, and Morris, N, 2011, *Aspects of Applied Biology*, 113, pp. 15-24.
39. Stobart, R, and Morris, N, 2013, *Aspects of Applied Biology*, 121, pp. 43-50.
40. Stobart, R, and Morris N, 2014, *Aspects of Applied Biology*, 127, pp. 223-232.
41. West, T and Post, W, 2002, *Journal of the Soil Science Society of America*, 66 pp. 1930-1946.
42. Hauggaard-Neilsen, H *et al*, 2009, *Field Crops Research*, 113(1) pp. 64-71.
43. Sibbald, A 2001, *Agroforestry Systems*, 53 (1) pp. 39-53.
44. Gattinger, A, 2012, *Proceedings of the National Academy of Sciences*, 44, pp. 18226-18231.
45. Maeder, P *et al*, 2002, *Science*, 296 (5573) pp. 1694-1697
46. Martini, E, *et al*, 2004, *Field Crops Research*, 86, pp. 255-266.
47. Seufert, V, *et al*,. 2012, *Nature* 485, pp 229-232.
48. Hyland, J, *et al*, 2015, *Agriculture and Human Values*, in Press.
49. Kibblewhite, M, 2010, *A gap analysis on the future requirments of soil and water management in England.* Royal Agricultural Society of England.
50. Sautter, J, *et al*, 2011, Society & Natural Resources, 24 (2) pp. 133-147
51. Centre of Expertise for Waters, 2012, *Factors that affect uptake of natural flood management features by farmers in Scotland: A review.* James Hutton Institute.
52. NIAB, 2014, *An appraisal of research, best practice and communication approaches for the management of soil structure*.
53. *Demonstration Test Catchments*.
54. *Catchment Sensitive Farming*.
55. Defra, 2011,*The Natural Choice: Securing the value of nature.*
56. *UK Soil Observatory*
57. Defra, 2011, *Scoping Biological Indicators of Soil Quality Phase II.*
58. Defra, 2015, *Cross compliance in England: soil protection standards.*
59. Northern Ireland Government, 2015, *Cross Compliance*.
60. Welsh Government, 2015, *Cross Compliance.*
61. Scottish Government, 2015, *Cross Compliance*.
62. Defra, 2013, *Farm inspections - Guidance*.
63. Defra, 2009, *Safeguarding our Soils a Strategy for England.*
64. DCLG, 2012, *National Planning Policy Framework..*
65. Defra, 2013, *Payment for Ecosystem Services Action Plan.*
66. IUCN, 2013, *Draft UK Peatland Code*.
67. *Conservative Manifesto 2015.*