Royal Agricultural Society of England

Practice with Science Group

The Current Status of Soil and Water Management in England

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Prepared for the
"Practice with Science" Group

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Professor Godwin's research has helped to improve the efficiency of food production and reduced the environmental impact of agriculture, through improved production systems, increased quantity and quality of food production, "the sustainability of soils" and the improvement of the environment. He has taught numerous courses in agricultural engineering, soil mechanics and soil and water management. In addition to developing masters' courses in agricultural engineering, precision farming and soil management he has developed and delivered many practically orientated short courses for manufacturers, advisors and farmers.

A member of the Institution of Agricultural Engineers for over 40 years, Prof Godwin served as President from 1994-1996 and was made an Honorary Fellow in 2000. He is also a Fellow of the Royal Academy of Engineering, an Associate of the Royal Agricultural Societies, Chairman of the Douglas Bomford Trust and a founding Trustee for the Claas Foundation.

Professor Gordon Spoor
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Brian Finney CBE is former Chief Mechanisation Adviser, ADAS, and Head of Specialist Services within ADAS. He is a past-President and Honorary Fellow of the Institution of Agricultural Engineers, an Honorary Fellow and until recently Honorary consulting Engineer to RASE. Since retirement from ADAS he has carried out consultancy and examining work for Cranfield University and other organisations, both in Britain and overseas.

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Dr Hann has worked extensively both in the UK and all over the world on projects relating to soil and water conservation engineering and management, soil erosion conservation measures, land drainage, habitat creation and restoration, sports field development, pipeline restoration and soil management in the built environment. His areas of expertise also extend to agricultural engineering, soil engineering and waste engineering for agronomically and environmentally acceptable application of rural and urban bio-solids to land.

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Executive Summary

Farmers in England, who manage 72% of the land, face the challenge of increasing yields while at the same time reducing inputs, improving soil health and generally enhancing the environment. The Royal Agricultural Society of England wishes to ascertain whether they will be able realistically to meet these demands in the fundamental area of soil and water management and engineering and has therefore raised the following questions:

- Is appropriate research in the pipeline to help?
- Will there be enough specialists to help?
- Is new information filtering through to farmers quickly and effectively?

The following key areas are considered:-

- Research;
- Education;
- Information availability to farmers;
- Awareness of policy makers and advisers to current situation.

The report, which focuses on the applied physical sciences and engineering to provide practical engineering and management solutions to soil and water problems, was prepared by taking a holistic view in drawing together the combined knowledge and experience of the authors, and seeking advice from other specialists, policy makers and practitioners.

The key conclusions of the report are:

Agricultural production in general and soil and water management in particular, face a considerable challenge in meeting the demands of i. increasing food production and security at both national and international level, ii. the demand for alternative fuels, iii. climate change, iv. soil protection, v. flood and pollution control and vi. the availability of water resources for crop and animal production combined with the diminishing supply of labour. The reduction in labour force will continue the drive for larger machines, increasing the average weight of the national fleet.

Currently due to various issues of both policy and economy linked to the retirement of key applied physicists and engineers, there is a much depleted professional body of specialists who can address the research, extension and training issues required to support the farming community and work with the environmental bodies. The career structure for new entrants to these professions is poorly defined, and this discourages entry. Immediate attention needs to be given to the provision of a small cohort of professionals that can supply the necessary expertise, whilst there is sufficient time for them to be mentored by those (now mostly retired) with a proven field record.

There is a considerable store of fundamental research information available and whilst there is a need for some further supplementation, the prime requirement is to use and develop this existing information, linking in with field experiences elsewhere, to address current problems. Future emphasis, therefore, needs to be given to applied research and development, conducted by personnel with a good understanding of agricultural and environmental needs who can “design” innovative

solutions to practical problems. These professionals need also to be encouraged to provide extension advice and practical training for farmers and agronomists.

The specialists require suitable academic backgrounds in engineering or applied physical science including soil science together with a good base and support structure (possibly at colleges or universities or within a Government Agency) and need to be in regular contact with farmers and farming problems.

This gives rise to the following recommendations:

- Alert DEFRA and other bodies to the problem and encourage DEFRA to move from its current largely environmental policy to one which also embraces production within the environmental framework. The commitment of DEFRA and its supporting agencies will be critical if the current situation is to be reversed.

- The RASE, working with other parties should attempt to raise £1 million/year for a 5 year period to stem the decline in available professionals. An additional £300,000 is required to train doctoral engineers and applied soil physicists over the same period. A further fund of £20,000 to £30,000 per year would also assist in supplemental funding of undergraduate and postgraduate students and their projects.

- Encourage the development of research, training and professional accreditation at the existing establishments, identified below, and attempt to generate an atmosphere of excellent communication between all parties.

    - Rothamsted, North Wyke Research and IBERS in basic and strategic research. With the exception of Rothamsted, however, there are no applied physicists and engineers at the other two centres, hence good linkages need to be formed with the other partners in the network;
    - Cranfield University in postgraduate teaching and basic and applied research;
    - Harper Adams University College in undergraduate education, training and applied research;
    - Reaseheath College providing Level 3 National Diploma graduates and acting as a feeder route to Harper Adams University College;
    - BASIS in the further development of accredited short courses;
    - Institution of Agricultural Engineers for professional accreditation.

- Give consideration and support to the establishment of one base, for a pilot scheme to provide a national centre for soil and water management and engineering. This centre would link applied research and development with teaching, extension and short course provision.

- Encourage universities and colleges offering agriculture and soil science programmes to include modules on soil and water management in their curriculum.

- Collaborate with the key groups to organise events, produce a journal (hardcopy and electronic) and develop an electronic library of soil and water management articles to promote good management practices and to provide a network for practitioners.

- Convene a conference for all interested parties, to include DEFRA and its agencies, farmers, charities, commercial businesses, practitioners, professional

- The Practice with Science Advisory Group should nominate a champion/facilitator to work with agri-business over a period of years to steer the new initiatives, and report to the Group as required.

Contents

1. Introduction

The Royal Agricultural Society of England has asked its new "Practice with Science" Advisory Group to advise it on year-round activity relating to the RASE's objective "to be the leading independent voice for agriculture and the rural economy", based upon its commitment to "Practice with Science". Chaired by Sir Don Curry, the Group has focussed on four early priority areas: - these are soil, water & energy; plant breeding; the environmental benefits of livestock; and public good. Underlying all the theme areas is the importance of investment in research and the need for an effective bridge between knowledge and practice. Because of the remit of the Royal Agricultural Society of England, this work focuses predominantly on England, but incorporates information from Wales, Scotland, Northern Ireland and areas further afield where appropriate.

This report focuses on the issues surrounding the national capability to provide practical solutions to physical problems in soil and water management within the field. Whilst focusing on the physical and engineering issues, nutrient aspects are not being ignored where they interact; for example, where bio-solids and other materials are used to supplement granular fertiliser and issues of application and materials handling have to be considered. Similarly, issues relating to the application of pesticides and herbicides are considered. For the purpose of clarification, the term "water" in this report relates to the water held within or passing through soil and hence includes field drainage and irrigation but not to the broader issues of the availability of water resources in general.

2. Purpose of the Report

Farmers in England, who manage 72% of the land, face the challenge of increasing yields while at the same time reducing inputs, improving soil health and generally enhancing the environment. The Royal Agricultural Society of England wishes to ascertain whether they will be able realistically to meet these demands. Hence it raises the following questions:

- Is appropriate research in the pipeline to help?
- Will there be enough specialists to help?
- Is new information filtering through to farmers quickly and effectively?

The report will address these issues by considering the following key areas:-

- Research
- Education
- Information availability to farmers
- Awareness of policy makers and advisers to current situation.

The report was prepared by the authors taking a holistic view in drawing together their combined knowledge and experience, and seeking advice from other specialists, policy makers and practitioners, as listed in the Acknowledgements, to whom grateful thanks are extended.

3. Current concerns and potential drivers of change

Recent months have seen a major change in the perception and role of agriculture which has been brought about by a series of major international issues. These issues relate to the growth and expectations of the world population, and the demand for food and fuel, interlinked with climate change. Specific aspects are highlighted below.

3.1 Food supply and security

Both the national and international population is increasing, with the national population currently estimated at increasing by 1 million every 3 years and more alarmingly the projected world population due to increase from the current 6.7 to 9 billion by 2050. In addition to which, many developing countries are changing their diets to a more western style. Recent statistics have shown that the available cereal/capita/year is now well down from its peak in the early 1980's and that the food self sufficiency ratio in the UK has been reduced from 75% in 1994 to a current 58%.

3.2 Biomass and Bio-fuel production

The recent fossil fuel energy issues have seen a major international demand for bio-fuel substitution. This is especially so in the USA, where so called surplus grain is being processed for domestic energy consumption, to offset the massive transfer of wealth to non-US oil producers in a climate of increasing international oil prices. In addition to this, former food producing land is currently being used for the production of bio-mass (e.g. short rotation willow coppice and miscanthus) for direct combustion or co-firing with other fuels. There is, therefore, a significant demand for land and a potential conflict between fuel and food, especially in the UK, a small island with a high population density.

3.3 Crop nutrition and the land application/utilization of "waste products"

Fertiliser prices have recently risen due to the need for gas in the production of nitrogen and the increased demand for phosphates and potassium in a market with finite resources. The use of organic materials, animal manures and bio-solids (processed sewage sludge) offers a partial solution. Farmers are now requesting rather than resisting sewage sludge from the water companies and most major supermarkets now accept produce from bio-solid treated land (Waitrose and Tesco are the exceptions).

3.4 Climate Change and Flood Risk Management

The practical issues related to climate change have been caused by concerns over shifting weather patterns which influence the distribution of rainfall. The scientific opinion is that the UK will experience less but higher intensity rainfall in the summer months and greater winter rainfall. Recent summer flooding issues call for a greater concentration of effort in the field management of soil water, its temporary storage and drainage.

3.5 Irrigation Water Management

Although irrigated agriculture accounts for only 1% of total UK water abstraction and 4% of the crop area, it accounts for 20% of the crop value. A third of all potatoes and a quarter of all fruit and vegetables are supplied by just 1000 agri-businesses in Eastern England. These businesses depend upon reliable water supplies to deliver continuous supplies of premium quality produce demanded by consumers. A recent study by Knox, Kay and Hammett (2007) to develop a water strategy for agriculture, reported that the way forward for improved irrigation water management included:

- *Working together*. Improving the dialogue between individual abstractors, the agri-food industry and regulator;
- *Making best use of available water*. Improving the security of on farm water supplies and ensuring its wise use;
- *Developing a knowledge base*. Improving water management knowledge and skills training within the agri-food industry.

However, increased competition for water, rising demands from other sectors, coupled with environmental protection and the longer-term threat of climate change, all threaten the sustainability of irrigated agriculture and the livelihoods it supports. It is essential that irrigation water management, therefore, receives priority support.

3.6 Land Drainage

Linked to the issues of climate change is the need to maintain good land drainage which, as shown in Table 1, has seen little reinvestment in recent years. The renewal of failing land drainage systems was buoyant when there was a government subsidy (up to mid 1980's) and this provided some 15 to 20 years leeway. Stansfield (1987) was suggesting that 50,000 ha of drainage were ceasing to function each year and that a further 2 million ha needed/would benefit from drainage. After this period, rather than a routine replacement of the older systems, falling commodity prices and farm incomes prevented anything but the most urgent investment. There is currently concern with respect to the possible impact of field drainage on peak flood flows.

3.7 Soil erosion control and sediment transport

This area has seen a concentrated effort by DEFRA with a number of initiatives, including Soil Management Plans, to address the joint problems of soil erosion and sediment transportation from fields into water courses and roadways and the associated issue of phosphate transfer. One underdeveloped area which offers considerable promise to both the environment and production agriculture in the future is the development of appropriate soil conservation measures more appropriate to efficient machinery operations.

3.8 Labour availability

The continuing decline in the total farm labour force, the ageing farmer population (average age now 58) and the increase in farm size all have important implications for machine design and size, and soil management in general. An appreciable proportion of land, particularly in Southern and Eastern England, is now farmed on behalf of owners by large scale operations which may work over a 50km radius. The result is a further trend towards larger entirely 'combinable' farms, larger and heavier machines, minimal cultivation, the emphasis on minimizing the number of hours' work

to establish a crop, and good mobility between sites. Many managers spend long hours driving machines during the peak periods, which must have implications on the time available for management, but also reinforces the need for the continuing development of driver assistance and partial or complete automation. The long term sustainability of some arable systems may call for the integration of livestock enterprises and the efficient use of manures and other organic materials, all labour-intensive projects. It is difficult to see how this could be achieved with the labour presently available on arable farms. Although due to physical size constraints, it is difficult to envisage a time when individual machine size will become larger than the current largest machines, the average size/weight of the national fleet will continue to increase.

3.9 Increasing machine weight and soil compaction

Current issues of labour costs and profitability have driven up machine capacity, size and weight. This is especially true in the area of harvesting machines, where not only has the machine to propel itself across the field, it also requires sufficient power to undertake key threshing/separating/cleaning tasks and to temporarily carry several tonnes of harvested product. Typically the larger combine harvester models weigh c.30 tonnes and sugar beet harvesters c.50 tonnes. The latter has also an operating season in late autumn and winter, when soil conditions may be at their most fragile. In an attempt to ensure that these machines are not prevented from operating by EU legislation, significant work has been undertaken to ensure that the larger section tyres fitted to them and rubber tracks do little or no more damage than earlier much lighter (5 -10 tonne) models. Had good engineering solutions not been found, the economic competitiveness of EU and UK agriculture could have been severely damaged. Applied research and development still remains to be undertaken in this area, especially in the further development of an effective low or zero ground pressure (controlled traffic) solution for a range of crops and cropping systems. The above enable shallower or no-till farming systems to be more effective and reduce the need for deeper soil loosening to improve root penetration, infiltration and soil hydraulic conductivity. This in turn reduces the size of tractors and the labour requirements.

3.10 Environmental Stewardship

Much has been made of this activity in recent years and many lessons have been learned about the preservation of flora and fauna in agricultural environments. It appears, however, to some, that the recommendations from this work have been implemented without the dual need for both production agriculture and environmental stewardship. Work is required in future to rectify this situation in a sustainable way. It would appear that the environmental focus of the past 10 to 15 years, enabled by a period in history of food surplus, requires revision to provide long and lasting benefits.

3.11 Management of Less Favoured Areas (LFA's)

There is a body of opinion that expects (as in earlier times of National crisis) that in order to provide additional food and fuel, increased output will be required from land with the LFA status. Fraser (2008) indicates this accounts for 45% of the agricultural area in the UK (and 80% of Wales), and reports that climate change could make the uplands more agriculturally productive. This could lead to the adoption of new crops and livestock breeds compensating for loss of lowland areas growing bio-energy crops. It would thus play a crucial role in ensuring food security without impacting unfavourably on the 70% of the UK's water supply which the uplands contribute.

3.12 Summary

This brief analysis indicates there is a major issue relating to soil and water management nationally where there is a need to feed the nation (world food stocks will be in short supply), provide as much energy as possible, accommodate climate change, be good stewards of the environment and conserve our precious soil resource. It is pertinent to remember that currently 72% of the land of England is under agricultural management and a further 9% in forestry, DEFRA (2008). This will probably require a greater intensity of farming in the more marginal areas with relatively fragile environments, where soil and water issues will need to be sensitively managed. The above concerns echo those recently published by the Commercial Farmers Group (Leaver (2008)) concerning the wider agricultural scene.

4. Requirements

Table 1 summarises the current status, ranging from fundamental research to training for farmers, of the main components of soil and water management, which are identified below.

- Drainage;
- soil erosion control;
- improved management of soil structure including tillage – traction – compaction – controlled traffic;
- waste to land;
- irrigation.

4.1 The table shows that currently there is little need for further basic research as most of the fundamental principles are well understood. It does, however, emphasise the need for applied research and development in each of the areas relevant to both arable and grassland conditions. Whilst there is need for continuing applied research and development in all of the above areas, probably the two most significant are related to in-field water management (drainage and soil erosion control), to reduce flooding and the issues related to the management of upland areas. All the pressures demand the highest levels of skill and innovative engineering in applied research, development and design to ensure their sustainability. A recent review paper by Thompson (2008) which focuses primarily on basic soil science research highlights the need for the following applied work:

- increasing the efficiency of management at the machine/soil and soil/plant interfaces;
- reducing indirect and direct energy consumption;
- increasing the environmental signature of production systems.

4.2 There is also a need for extended education and it is imperative that the principles of practical soil and water management, with field exercises, are given more emphasis in both university and college agriculture and soil science courses and the RASE may wish to promote this within the educational sector.

Table 1 gives a brief outline of the material that should be covered in each of the areas and a typical syllabus for a detailed integrated programme is given in Appendix 1. There would need to be differentiation in the detail of the material within scientific and engineering programmes, ensuring that soil science and physics, soil/plant/water relationships and soil mechanics are core prerequisites. The closure of undergraduate programmes at Silsoe has left a chasm in the national provision. Whilst postgraduate programmes should theoretically provide some substitution, many postgraduate students at MSc level do not have the background in mathematics and physical sciences to be the longer term providers of the “engineered” solutions required.

4.3 The combined area of extension and training requires more specialists. Although in a number of specific areas consultants are available, it is the training and development of these and their replacements in integrated soil and water management that must be provided for in future. Typical areas for farmer training are suggested which cover the agronomic, environmental and economic benefits through to the selection and maintenance of the system and its components.

Table1. Current status of key soil and water management issues

Subject	Position	Basic Research Need	Applied Research and Development Need	Education	Extension	Farmer Training Requirement
Drainage	Typically100,000ha/a in the 1970-1980's current estimate 5000ha/a Relying on the effectiveness of drainage installed about 30 years ago when in a period of 10 years almost I million ha were improved	Nil The fundamental principles are well understood	1. Relationship between good field drainage and flood risk, in lowland and upland conditions. 2. Soluble phosphate control in drainage water 3.Drainage economics	Syllabus ranging from soil physics to practical design & installation	From more than 500 giving advice on design to a current estimate of 20 Need for sound Impartial advice	1. Agronomic, economic and environmental benefits 2. Relationship with flow and flood control 3.Drain maintenance
Soil Erosion Control	The UK has little history of soil conservation structures/ measures to control water erosion Current need is to develop good conservation practice for farmed land to avoid run-off, soil loss, sediment & phosphate transfer	The fundamental principles are well understood However, there is a need to develop an effective design procedure to identify risk of soil erosion and the measures required for UK conditions	1. Practical adoption of internationally tested cost effective conservation measures e.g. grass waterways 2. Improved methods for controlling runoff from tramline wheel marks	Syllabus ranging from soil physics through soil examination todesign and layout of conservation measures	Some in the past through ADAS. Currently EA and Natural England via Catchment Sensitive Farming Officers. A further structure is needed to deliver the more detailed solutions	1. Agronomic, economic & environmental benefits 2. System selection and maintenance

Tillage, Compaction, Traction & Controlled traffic	Reduction in crop yields due to poor and weak soil structure are widespread in wet years. A great deal of work through research institutes, universities and Colleges and ADAS Much of this is no longer in place with the exception of Cranfield University	Nil The fundamental principles are well understood	1. Practical demonstration of improved soil management 2. Appropriate cultivation systems for "novel" crops on a range of soils. 3. Selection of tyre/ wheeling management systems, including controlled traffic	Syllabus ranging from soil mechanics /physics through soil examination to machine design and selection	Some still provided by agronomists Specialists needed to deliver the more complex solutions	1. Agronomic, economic & environmental benefits 2. Selection of the most appropriate system and equipment
Wasteto Land	An area which has been well researched and some continues through UK Water, ADAS and Universities	Nil The fundamental principles are well understood	1. Application techniques 2. Nutrient accumulation	Syllabus ranging from nutrient value basic pathology and risk assessment to the selection of application methods,	Available through agronomic consultants with further training	1. Agronomic, economic & environmental benefits 2. Selection of the most appropriate application methods
Irrigation	An area where the drive for high quality salads and field vegetables has maintained activity.	Nil The fundamental principles are well understood	Techniques for improving water use efficiency and precision, e.g. 1.precise and targeted specific application methods 2.appropriate soil moisture sensors 3. benefits of spatially variable application	Syllabus ranging from soil/plant/water relations to system design and layout	Available through a network of specialist consultants	1. Agronomic, economic & environmental benefits 2. Selection of the most appropriate application methods 3. Understanding water regulations

5. Synopsis of National Capability

Table 2 compares the national activity in research, education and extension of 1980 with the current position. 1980 was nominally selected as a base line to represent a period of "high agriculture" just prior to the peak in public funded R and D in 1983 when there were a comprehensive range of services available for soil and water management. After this time both funding and productivity started to decline (Leaver (2008)). Whilst there is no benefit in totalling the number of asterisks indicating personnel involvement, Table 2 clearly shows that there has been a very significant reduction in those involved in all three sectors of research, education and extension. The reasons for this are numerous and are linked to the general reduction in support for agriculture at both the government policy level and from the service providers. The latter are now much more commercially orientated, whether research stations, universities, colleges or advisers. This has occurred principally through a reduction in central support for their activities and the inability of farmers to pay as their incomes have declined.

5.1. Research (Fundamental and Applied)

The national capability in this area has been virtually eliminated from what 30 years ago was one of the most comprehensive capabilities in the world. The closure, amalgamation or size reduction of the Field Drainage Experimental Unit, Scottish Institute/Centre for Agricultural Engineering, ADAS Mechanisation, Newcastle University's Agricultural Engineering Department and the National Institute of Agricultural Engineering (Silsoe Research Institute), has significantly reduced the number of service providers to the establishments detailed below.

a) Rothamsted and North Wyke Research

SoilCIP (Cross Institute Programme) encompassing Rothamsted Research and North Wyke Research

Keith Goulding and David Chadwick report the SoilCIP brings together about £3M worth of ex-Core Strategic Grant research at Rothamsted and North Wyke into a new Institute Strategic Programme Grant for research into sustainable soil function on managed land. Of the c 70 staff in the SoilCIP, there are c 26 focusing on the interactions between soil and water.

At North Wyke Research, 18 of the staff focus on the agri-environmental aspects of waste to land, ammonia and GHG emissions, the reduction of diffuse pollution, manure loadings. They have just completed the revision of the Livestock Manures section of RB209. North Wyke receives core funding from BBSRC supported by contracts from DEFRA, EU and research councils (BBSRC responsive mode, NERC and ESRC, e.g. via the Rural Economy & Land Use programme).

At Rothamsted Research, the biogeochemistry, soil physics and modelling groups comprise 11 staff (4 alumni of Silsoe College, 3 of 4 in the soil physics group) with the major focus on soil/plant/water relationships under different soil stress conditions, nutrient cycling and modelling, and novel sensor development to monitor soil water status. In addition to the Rothamsted site, work is continuing at Woburn into tillage, irrigation, drought resistant varieties and the relationship between soil strength and crop growth.

Whilst this is a good size group and can cover many of the agronomic, environmental and biological aspects of the work, the majority of the staff are not

applied soil physicists and engineers and the closure of “sister institutes” and university departments which developed the applied soil physics and engineering aspects means that the staff are now working in isolation.

b) Cranfield University – School of Applied Sciences (incorporating Silsoe College and Soil Survey of England and Wales)

The continuing strength of Cranfield University shown in Table 2 is due to the current increase in the spread of activities combined with a number of recent appointments in areas related to soil bio-diversity and ecology. However, the recent retirement of key staff (with skills in soil conservation, drainage, applied soil physics and mechanics, land restoration, soil management, tillage, compaction and waste application to land) has resulted in a loss of those with a practical first hand experience of serving U K farming. This means that, in the short - medium term at least, the work may of necessity drift from the applied to the more fundamental and away from practical agriculture. However, within the past few weeks an advertisement has been released for a Professor of Agricultural Engineering with a focus on tillage and related topics.

The work at Cranfield in these applied/engineering areas in recent years has been driven by short term industrial and Charities funding. It has been achieved through PhD student projects and by stretching the boundaries of the sponsored projects e.g. the rolling resistance of aircraft tyres when landing on dirt runways. This has kept a stream of activity going and has and will produce a further supply of post doctoral graduates over the next 1 to 2 years.

Regrettably:

- Many of these post doctoral graduates will return to their home countries to pursue their careers;
- A number of well qualified UK/EU nationals have relatively recently moved to Australia and New Zealand where there is a better career structure;
- In the academic year 2006-7, Godwin and his immediate colleagues supervised 18 research students of whom only 2 were UK nationals and one of those was past retirement age. This illustrates a further problem of the lack of suitably qualified UK nationals prepared to work in an area where policy and the general state of agriculture have not been conducive to a viable long term career.

Cranfield provides national strength in the areas of soil erosion control and in broader soils related activities, in irrigation and water resources, aspects of waste application and off road traction (for 4x4 vehicles) .

c) ADAS

The role of ADAS has changed dramatically over the last two decades. In the early eighties it was a major contributor to research aimed at best practice for productive agriculture. Typical of this was the output from the Field Drainage Experimental Unit, assisting farmers with water table management. Similar work was being carried out on soil management/ cultivation systems by Soil Scientists and Agronomists. It was also very much involved with extension work with circa 1000 officers offering advice with soil and water specialist support.

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Currently ADAS conducts works in soil and water in two ways. Firstly, through Government funded research designed to quantify pollutants of water and air

derived from agriculture and to identify means by which farm management can be modified to minimise this pollution. This work is to assist compliance with EU Directives. The second activity, still considered by ADAS soil scientists, is to improve tools for technology transfer which are designed to minimise pollution of water and air (Fertiliser recommendations and Manure management are the two main areas).

ADAS no longer does a significant amount of advisory work or any R and D aimed at agricultural production, their work is directed towards minimising perceived damage to the environment due to agriculture or providing advice on soils to non agricultural industries. In part, this situation has developed because the privatised ADAS prices are higher than the agricultural industry has been able to afford.

ADAS continues to deliver independent research on environmental, livestock, arable, horticulture and food related topics from former Experimental Husbandry Farm premises (see Appendix 3), and elsewhere in 9 different English counties. However, there is little or no professional capacity in soil and water engineering and management.

d) Harper Adams University College (HAUC)

HAUC is currently initiating a limited amount of applied research and PhD provision, principally in traction related topics and the combustion properties of bio-energy and farm wastes funded by The Douglas Bomford Trust and the Claas Foundation. HAUC has plans to increase the activity in this area. Currently HAUC is working with Cranfield University in the area of irrigation as it influences fresh produce quality.

e) Institute of Biological, Environmental and Rural Sciences (IBERS)

This Institute with 300 staff and a £20m budget has resulted from the merger of IGER (The Institute of Grassland and Environmental Research) and Aberystwyth University. It will occupy two sites, both in Wales, with the aim of 'sustainable land use, climate change, security of food and water supply'. Principally the work will be associated with plant and animal breeding for the Less Favoured Areas. Currently there are no engineers, applied soil physicists or applied soil scientists on the staff.

f) University of Reading - Soil Science Department

The University continues to train PhD students; however, because of the nature of external funding, the balance of research has changed over the years from that focused predominantly on agricultural production to a much stronger focus on environmental problems. They continue to work in aspects related to UK agriculture including pesticide degradation, management of organic materials and the fate of contaminants in the food chain with close ties with Rothamsted, North Wyke and Forest Research. The Department offers soil related courses in their Environmental Science undergraduate degree programme and at postgraduate level offer a NERC supported Masters Degree on Soils and Environmental Pollution.

g) There are other groups and individuals at selected Universities (e.g. Lancaster and Exeter) working primarily in the soil environment area, which although important, is not the main thrust of this report. .

Table 2. Comparison of the National Capability in Soil and Water Management between 1980 and the current time for Research, Education and Extension

	1980 Activity	Staff	2008 Activity	Staff
Research				
ADAS EHF's	On farm experimentation in regional areas	*****	Retains R and D facilities on 9 sites in England and Wales	*****
ADAS - Mechanisation	Practical soil management	*	Last man left to join TAG and has now retired	0
ADAS - Soils	Practical soil management	***	Environmental management	**
Cranfield University (at Silsoe)	Soil dynamics, Cultivations, Drainage of heavy clay soil, Irrigation, Soil conservation	***	Transferred to Cranfield Campus. Soil conservation, bio-systems and eco-system services, Digital soil mapping, Soil sensors, Irrigation and water resources, Off-road traction, Soil dynamics	****
Harper Adams University College		*	Traction, waste management, bio energy for CHP. fresh produce conservation	**
IBERS/IGER			Merger of IGER and Aberystwyth University Management in upland LFA's principally in breeding programmes for plants and animals	No soil physicists
Letcombe Laboratory	Direct drilling and minimum tillage	***	Closed	0
MAFF- FDEU- Drainage	Drainage systems	**	Closed	0
Newcastle University	Soil dynamics	**	Closed Agricultural engineering 1990; 1 specialist in Irrigation remains	*
NIAE(Later AFRC Engineering and SRI)	Cultivations, Traction, Soil Dynamics, Soil Physics	***	Closed Soil physics moved to Rothamsted Research	0
North Wyke Research			Agri-environmental aspects of waste to land, ammonia and GHG emissions, the reduction of diffuse pollution, manure loadings	***
Rothamsted Research	Soil Physics	**	Soil Physics	*
SIAE	Compaction	**	Closed/amalgamated with SAC	*
Soil Survey of England and Wales	Soil survey and applied soil physics	*****	Merged with soil activity of Silsoe College in 2001 to form NSRI, now part of School of Applied Sciences, Cranfield University –see above	As above
Education				
Cranfield University (at Silsoe)	BSc Agricultural Engineering MSc Soil and Water Engineering	As above	Closed MSc Soil Management and Advanced Irrigation	As above
Farm Institutes and Colleges	Vocational programmes	****	Many closed agricultural programmes for other rural related skills	*
Harper Adams University College	HND Agricultural Engineering	As above	HND/BSc/BEng/MSc/MEng Agricultural Engineering and Off Road vehicles	As above
Newcastle University	BSc/MSc Agricultural Engineering/ Soil Science	**	Closed and Agricultural Engineering Department/Closed	*
Reading University	BSc Soil Science	***	Closed; postgraduate courses soils/environment are active	**
Reaseheath College			Would consider provision at Level 3 National Diploma	
Rycotewood College	OND/HND Ag Eng and Soil and Water option	*	Closed	0
Writtle College	HND Agricultural Engineering	*	Closed programme; 1 specialist in soil management remains	*

Extension				
ADAS	Soils, Drainage, Cultivations, Traction and Compaction, Management	*****	No direct one to one farm service; presentations based on applied research on solely the environmental aspects of soil and water management	**
BASIS		-	Accreditation of Soil and Water Management Short Course	*
Catchment Sensitive Farming (EA/NE)	Not formed	-	Management of selected catchments, limited soil and water advice, main focus on pollution abatement	****
Consultants (AICC c 220 members including TAG have 44% of professionals)			A number provide specialist advice, primarily on cultivation techniques	
Cranfield University (at Silsoe)	Short courses in Soil Management, Drainage and Irrigation	As above	Not economically viable	As above
FWAG		****	Soil and Manure Management Plans; advice on ELS's and HLS's	*****
Harper Adams University College		As above	BASIS Soil Management/ FACTS/EA Training	As above
MAFF Drainage officers	Drainage scheme design and installation control	*****	Closed	0
SAWMA/IAgrE (Soil & Water Specialist Group)	Farmers' meetings and workshops, publication of SAWMA Journal and short courses	*	Closed late 1980's merged with IAgrE who maintain a series of professional meetings and workshops	Volunteers
Soil Management Initiative	Not formed	-	Exists in name only	*
UK Irrigation Association	Professional and practitioner aspects of irrigation management	Volunteer	Professional and practitioner aspects of irrigation management	* part time

The above approximate full time equivalent numbers based upon expert advice, the exact numbers are not critical they are submitted to show the change in capability

* <5
** 5 -10
*** 10 - 20
**** 20 - 50
***** > 50

N.B. It is recognised that there could be other individuals involved and the authors apologise for any omissions; time and resources do not permit a detailed survey of the current and past situation.

5.2 Funding for research

In general during the past 30 years the shortage of funding from the Research Councils has meant that the focus of research has been to maintain a purer scientific thrust rather than address practical solutions to agricultural problems. During the 1980's the phrase "near market research" which prevented the funding of projects that were expected to be commercialised within 5 years, did some damage to the more practically focused research and development. This directive might well have worked in other sectors, but it caused a major problem for agriculture with its diverse base of relatively, by industrial standards, small farm businesses. This saw the end of most applied research grants to universities and was one factor reported in the closure of Silsoe Research Institute.

A meeting held at Babraham in the late 1980's debated the focus of the future mission of AFRC/BBSRC. The overwhelming conclusion was that work in the area of "transgenics" was scientifically more important than work in soil and water in preparation for issues related to climate change. Regrettably this led to the virtually total decline in funding for soil and water management topics

A recent research review for DEFRA Chaired by Pollock (2008) reveals that research work on energy, water and waste have not been well funded, as they appear not to have been the responsibility of a particular funding mechanism. The factors reported in Section 3 concerning the production value of soil are closely related to them and suffer the same problem. This is illustrated by the fact that there is not one soil and water project related to production agriculture in the current call for tenders released by DEFRA. The continuation of this policy will ultimately lead to the collapse of national capacity in this area.

The development of the levy board funding system has to an extent replaced the Research Council support for applied research, but the vision is often, of necessity, short term and soils research is often considered generic and not crop and hence levy board specific. The newly formed Agriculture and Horticulture Development Board plans to appoint a research director that will manage cross commodity issues.

The Universities have suffered from the distortion caused by the Research Assessment Exercise which has focused on the performance of the individual/ department/school with peer reviewed articles rather than more practical outputs, publications and extension presentations. The third stream strategy (for businesses and community activities) within the universities may bridge the gap, but the authors agree with Leaver (2008) that this will require a change of thinking within university departments. Until this is fully addressed, lack of funding within a particular project and tight University budgets make the dissemination of research results more difficult with time.

The following paragraph reported in the "Why Science Matters for Farming" by the NFU (2008) gives an overview of the dramatic reduction in funding:

In real terms, government science investment via MAFF fell by 45% between 1986 and 1998 (DTI/OST (1998)). In 2007 DEFRA funding of BBSRC institutes had dropped to £19 million from the real terms equivalent of £129 million in 1972, with further reductions expected. Overall, Defra's funding for sustainable agriculture will fall by a further 20% by 2010-11 on top of the 12% cut for 2006-07. The institutes hit hardest by this – the Institute for Animal Health, the Institute for Grassland and Environmental Research and Rothamsted Research - are also the ones of most relevance and importance to farming (House of Commons (2007)).

During the late 1990's MAFF ceased the funding of both taught and research postgraduate scholarships, which did maintain a corps of well qualified graduates entering the industry, albeit small.

The report for the Commercial Farmers Group by Leaver (2008) states that the problem is not in the remit of DEFRA which is "to promote a competitive and efficient farming and food sector which protects and enhances our countryside and wider environment and contributes to the health and prosperity of our communities" or of BBSRC whose mission statement includes a responsibility for "basic, strategic and applied research" and "to promote and support the exploitation of research outcomes" also to "provide trained scientists and engineers which meet the needs of users and beneficiaries... including agricultural (and other) industries". The problem lies in the need for these objectives to be fulfilled.

All of this calls for the formation of a much more robust integrated plan for the future and the lack of coordination between individual sources of funds needs to be reversed. The authors are in complete agreement with the conclusions by Leaver (2008) that the period of decline in UK agricultural productivity has been strongly influenced by the decline in public sector funding.

5.3 Education

Similar conditions exist in the education sector with a small amount of soil and water management (with little engineering) being taught within the few remaining vocational and undergraduate agriculture courses in the Universities and Colleges mentioned in Table 2. Soil and soil management modules are available within the agricultural, biological science and environmental science programmes, but there is little or no coverage of practical soil and water management. This is despite the availability of practically orientated text books, for example Schwab et al (1955), which has been available for over 50 years with frequent new editions This leaves the MSc programmes in Soil Management and Advanced Irrigation at Cranfield as the main provider; these programmes each graduate 6 -10 students per annum, the majority of whom are from overseas countries and are currently sub-optimal in terms of student numbers. The problem here is that as the farming population declines in number and the industry becomes more “corporate” in nature, there are fewer students from farming backgrounds that wish to pursue agricultural careers. The thought of an uncertain career, better career prospects elsewhere after a less demanding academic training, together with undergraduate debt and the lack of postgraduate scholarships, have all impacted on student numbers and the viability of courses.

The welcome fact is that Harper Adams University College is expecting to enrol circa 70 freshmen into their undergraduate Agricultural Engineering and Off Highway Engineering programmes in October 2008. HAUC is currently considering the introduction of a programme in Soil and Water Management, with a strong agricultural focus, as a logical complement and extension to their other agricultural courses. This could provide a good opportunity to replace the undergraduate provision from the former Silsoe College. This would be further strengthened if Reaseheath College could act as a feeder college to HAUC, to replace the loss from the closure of Rycotewood College to agricultural engineering and soil and water management at the Level 3 National Diploma. This requires the validation of additional modules in either their agriculture or agricultural engineering programmes, to enable the relatively small number of candidates that the market demands to have a nationally recognised qualification. The topic of soil and water management could be the foundation of the new range of courses in sustainable agriculture which are currently being planned at Harper Adams.

At the other end of the education spectrum there is obviously a strong link between education and research at the doctoral level and the fact that 3 of the 4 staff in soil physics at Rothamsted were Silsoe trained, indicates the importance of maintaining a viable soil and water physics/mechanics group within Cranfield University. The broader issues relating to Research Students were considered in Section 5.1.

5.4 Extension and Short Courses

a) Extension has also been decimated, principally due to the removal of the extension role of MAFF/ADAS for one - to - one on farm advice for soils, mechanisation and drainage design. Since the retirement of key specialists, little direct advice is now given, as there are no affordable means for farmers to seek help. Groups like TAG, LEAF, FWAG and independent crop consultants (such as members of AICC) provide advice on cultivation practices, some of which is conducted when undertaking other “paid for” roles, using information that they have gathered from their basic degrees, short courses and practical experience. These organisations suffer because there is, however, no corps of trained and experienced professionals for extending the full range of soil and water management research into practical farming solutions.

b) In 1980 Cranfield University at Silsoe initiated a series of practical Short Courses in conjunction with the Soil and Water Management Association (SAWMA), the first of these in irrigation was the catalyst for the formation of the UK Irrigation Association. This was soon followed by further programmes in both Soil Management (tillage, traction and compaction) and Drainage. Initially these courses attracted 25 delegates per course and often the next course was fully booked before the completion of the current programme. Interaction with the farmers, manufacturers, consultants and dealers on these programmes ensured that the team were always kept abreast of current and future challenges. The role of SAWMA, initiated by a strong farmer led group after the publication of the Strutt Report which followed the soil problems that arose during the wet harvest of 1968, cannot be overstated. SAWMA was administered by RASE and published a "Journal" , see Appendix 2 for typical contents, which provided excellent networking opportunities to attract a viable cohort of candidates for short courses. Unfortunately as agriculture receded in the late 1980's, SAWMA and its secretarial support was not considered viable by RASE and was closed. To overcome a complete loss, the membership was transferred to the Institution of Agricultural Engineers who established a Soil and Water Specialist Group. This Group is currently very active with often 30+ members at its events. At this time the Silsoe short courses also became non viable, unless a specific customer (e.g. United Agri Products) or a "farmer group" guaranteed a given number of attendees.

c) In 2003 the Environment Agency, with inputs from NFU, FWAG and the Drainage District, funded a project at Cranfield University at Silsoe to evaluate the potential benefits of soil management on flood relief for the Parrett Catchment in Somerset and Dorset. Following the publication of the report (Godwin and Dresser (2003)) the need was recognised for the provision for a Continuing Professional Development accredited short course in soil and water management. BASIS was the obvious choice and this coincided with the launch of the Soil Management plans by DEFRA. Cranfield University at Silsoe developed such a course and trained approximately 100 practitioners in the first year with financial support from DEFRA. Subsequently Harper Adams University College and independent consultants have followed the outline syllabus prepared by Cranfield and BASIS and have continued to offer the course. Paul Singleton of BASIS reports that:

"323 candidates have now taken the course and there are firm bookings for 60 for the rest of 2008. We expect other courses to be booked and so hope that over 400 candidates will have taken the one week course and exam by the end of this year. We feel this is good for a relatively newly established course and exam.
You may know that we are working closely with the EA and now give one of the new 'Think Soils' books to each candidate taking the course. We have also mailed a copy of the book to every one of the candidates who have taken the course and the exam so far".

d) Dr André Carter reports that the UK Soil Management Initiative was set up in 1999 as an independent, non-profit-making limited company in response to a perceived lack of focus on soil management, lack of awareness of the problems associated with soil management, and lack of coordination of the efforts of those involved. Around twenty organizations, private, commercial, academic and government were involved.
The objectives of SMI were:

- To transfer technology to farmers;
- To promote agricultural and environmental policies supportive of sustainable soil management;

- To improve information exchange in the research, policy and practitioner communities;
- To research, develop, evaluate and promote soil management systems to improve crop production and protection of the environment.

SMI was part of the European Conservation Agriculture Federation (ECAF) with groups in France, Germany, Italy, Spain and Portugal, together with a further seven European countries in the process of joining and FAO participation.

In the year 2000 there was a brisk programme of workshops, field demonstrations, meetings, scientific publications, draft topic sheets, press releases and web site development. Further plans were made for workshops and demonstrations in 2001-2002, and for research projects over a longer period. In early 2007 an attempt was made to arrange a 'soils clinic' at the forthcoming Royal Show, sited with the Machinery Awards and the Tractor Village. Individuals were enthusiastic, but it proved impossible to raise the necessary funding. Now the SMI exists in name only. The failure of this project is attributable to lack of funding, notably the cessation of EU funding which was not replaced by DEFRA or any other UK group. The need for the work, and the ability of the people involved, has not been in doubt.

e) The Environment Agency web site states that:

"Through a joint initiative between Defra, Environment Agency and the Natural England partnership, dedicated advisers will soon be on hand to help farmers tackle the causes of water pollution. The £25 million two year catchment sensitive farming initiative focuses at local level and pulls together farmers, farm advisers, conservation bodies, water companies, and a wide range of other interests".

This scheme has now been funded through to 2010 (with some indication of funding for a further year) and focuses on environmental stewardship in selected catchments in England, with a new emphasis on strategic partnerships with joint funding and greater collaboration. There is a current need for further trained personnel to staff the expansion to a further 10 catchments. Currently very little of the staff time is spent in advising farmers on direct soil and water management issues. A redefinition of this initiative linked to aspects of production agriculture is worthy of consideration.

The Environment Agency has produced a resource called Think Soils and is currently updating its Best Farming Practices book.

f) FWAG provides consulting services in the area of soil management plans and specialises in helping farmers and landowners access additional funding for their farm businesses through a range of grant schemes e.g. Entry and Higher Level Schemes. There is no core funding for FWAG and hence the farmer directly or through a contract with a third party, finances the advice on nutrients, energy, soil and biodiversity.

g) LEAF provides guidance for farmers through publications, including the LEAF Audit, training pack, Green Box, their demonstration farms and Innovation Centres. They are in the process of changing their structure which will increase the amount of soil, water and biodiversity information supplied. They also run well attended events which feature resource management which are open to non-members.

h) A number of ex ADAS and MAFF Drainage Officers and others do provide consulting services in the area of soil and water management. Many of these however are also approaching retirement.

6. Estimation of Current and Future National Requirements

There is no foreseeable way to envisage the immediate replacement of the hundreds of professionals that were working in soil and water management in 1980, and neither is that necessary. What is required is the reversal of the current position where there are almost no applied soil and water engineers and applied soil scientists and soil physicists below retirement age to address practical agricultural problems. In order to take this forward a two stage approach is required:

6.1 The immediate future

The UK needs a small group to rescue and stabilize the present deteriorating position. The function of such a group would be:

- To provide an applied research and development base;
- To provide supervision for a series of PhD student projects;
- To provide undergraduate and college teaching to institutions who lack the necessary skills in house;
- To advise and to some extent staff short courses on soil management, to support BASIS, the Institution of Agricultural Engineers specialist soils group and any other technical or discussion groups with soil management advice or instruction;
- To provide on - farm consultancy;
- To provide advice and expertise to Government and Agency groups.

This could be achieved by a total of 10 professionals, at least 5 of those being based at one “centre for soil and water management and engineering”, specialising in applied research, development and postgraduate supervision. This would represent one soil and water management expert to every 24,000 farmers or salaried farm managers in England. The full economic cost would be approximately 10 times £100,000 or £1 million per year and should be funded via DEFRA and its agencies, the Regional Development Agencies, and the Higher Education Funding Council for England’s Strategic Development Fund. The latter should allow greater collaboration between Cranfield University and Harper Adams University College in the area of soil and water engineering.

In addition to this there needs to be a continual flow of funds to provide doctoral student support of say 4 per year at a cost of £25,000 per student per year to both help in the provision of solutions to the short term problems and provide the professionals for the longer term.

6.2 The longer term future

It is assumed that the group outlined above would produce, over a period of perhaps 5 years, a total cohort of several hundred much improved soil and water managers. These would include doctorate graduates, better educated undergraduates, and short-course trained agronomists, farmers, farm managers and others. The farming community in general would also have a greater awareness of soil management through demonstrations and publications. This cohort should be able to deal with any changing situation demanding soil management skills. Examples might be a move to controlled large scale surface and subsurface drainage, the former incorporating the need for a new approach to soil conservation, or new legislation relating to soil management. The need for a central lead group would continue.

The greatest challenge will be in finding and training appropriate staff to do this work. Two or three of the more junior positions could be filled by the cohort of current doctoral students graduating or about to graduate from Cranfield University, with the middle range and senior appointments from the few remaining experienced engineers, combined with the repatriation of UK nationals working overseas. The critical aspect is the availability of the recently retired professionals to be able to advise and mentor the staff in the foundation years.

7. Responses to Questions raised by the Practice with Science Group

7.1 ***Is the UK's soil and water management research capability "fit for purpose" and does it have a vision for the future of the science and the needs of a changing UK farming industry?***

It is apparent from Table 2 and Section 5 that the UK soil and water research base is not as it should be and that it has diminished catastrophically from its peak. This is compounded by the fact that many of the key applied soil science, soil physics and engineering researchers have now retired. There is little connection with agriculture and apparently no coordinated future vision for applied research. Recently "piece meal studies" have been conducted where researchers and academics "grab" whatever funds they can.

In July 2008 presentations by immediate post doctoral and doctoral students on waste application, tillage, traction and compaction work at Cranfield University at Silsoe, received much positive feedback from soil dynamics and soil and water research engineers at conferences in the USA, with comments saying that this work was virtually the only work happening internationally. Hence the state of soil and water research internationally is even less robust than the current UK position. There is, therefore, no comfort in the concept that you can "buy into" other nations' research, especially with soil and water topics which are very much local site and weather specific.

Currently, Cranfield University is advertising the position for a Professor of Agricultural Engineering, with skills in the area of tillage, traction and compaction, and precision farming. In addition staff and architects are working on plans to rebuild the world class facilities developed on the Silsoe Campus with new laboratories on the Cranfield Campus.

Where long term fundamental work is being conducted it tends to be rather "blue sky" and needs to be part of a coordinated overall strategy. In the recent past there has been a significant move to computer modelling because it is relatively inexpensive. These models can be very valuable in assisting in the full understanding of physical processes and as tools to help design solutions to field problems. These models need, however, to be validated with real data, and they cannot provide the total practical solution to applied research problems. They should be valuable tools to assist in the engineering design of new solutions.

The good news is that a significant amount of good science and engineering has already been conducted and it is the application of this that is required to meet the changing needs of UK agriculture. Hence, the future thrust must be from individuals and research programmes at the applied end of research, and linked strongly to development and extension.

7.2 ***What future soil R & D will be required to ensure the agricultural industry can meet the challenges of increasing output whilst reducing dependence on agro-chemicals, pesticides etc and improving the environment?***

The main thrust of this for the immediate future will be with applied research and development using the storehouse of fundamental knowledge, although some fundamental work will be required. The main topics for research were identified in Section 3, however, for completeness are highlighted below. The actual requirements will be dependent upon the needs of the market conditions and the general direction of agriculture.

Fundamental Research

To develop an effective design procedure to identify risk and the measures required to reduce runoff and control soil erosion under UK conditions.

Applied Research

- Relationship between good field drainage and flood risk, including the use of the soil for water storage and detention for both lowland and upland situations. Linking this to the management of uplands for increased production of food and fuel, whilst maintaining water supply and bio-diversity;

- Control of nitrates and soluble phosphates in drainage water;

- Drainage and soil management economics;

- Practical adoption of internationally well tried soil conservation measures to reduce runoff and erosion that do not restrict mechanised field operations e.g. grass waterways;

- Improved methods for controlling runoff from tramline wheel marks;

- Appropriate cultivation systems for “novel” crops for a range of soil types;

- Selection of tyre/wheeling management systems, including controlled traffic, to reduce compaction and the need for deeper tillage and tillage energy;

- Application techniques and nutrient accumulation for farm wastes, composts and bio- solids to reduce demand for fertilisers;

- Techniques for improving water use efficiency and precision such as:
  - Precise, specifically targeted water application methods;
  - Appropriate low cost soil moisture sensors for water control; and
  - The benefits of spatially variable application of water to accommodate variation in soil water holding capacities.

Although not referred to earlier, further work is required in the area of precision farming concerning:

- The spatially variable application of fertiliser to target the inputs and to reduce residual nitrogen, and
- The reduction in the overall requirements for herbicides and pesticides.

The herbicide and pesticide research is currently being addressed by the Silsoe Spray Applications Group led by Professor Miller which is currently a part of The Arable Group (TAG). The Spray Applications Group is a unique national asset, providing quality research and advice on improving the effectiveness of agrochemical applications. Specific current and future topic areas include:

- Developing the fundamental relationship between application method and the formulation of active ingredients;
- Improving the targeting of spray applications, particularly drift control; and applying this in practice;
- Matching agrochemical applications to spatially variable targets;
- Improving product handling and traceability.

Currently the tenure of the Group's base at Silsoe and the location of this world leading facility are under discussion. Support from the RASE for the continuance of this activity would be particularly valuable.

7.3 ***Does the UK have access to the necessary soil and water management resources (including expertise), given a background of cuts in R & D capacity and expenditure?***

The answer to this question is best split into physical resources and expertise.

a) Physical Resources

Whilst there is some concern with these, the recent moves of the Soil Physics Group from Silsoe Research Institute to Rothamsted Research; and Silsoe College and Soil Survey and Land Research Centre to Cranfield University, have resulted in new build and refurbished state of the art soils laboratories respectively. The Rothamsted laboratory is equipped with growth rooms and high quality soil/plant/water physics equipment including x-ray soil particle size analyser, rainfall simulator and computer controlled tri-axial soil strength measuring apparatus.

The pending moves of the world class soil engineering and recently completed off road traction laboratories from Silsoe Campus to Cranfield campus will again result in new laboratories to house the equipment for tillage, traction and compaction, and erosion studies.

The long term tenure of Spray Applications Group laboratories currently at Wrest Park, Silsoe, a national gem, is currently being discussed with BBSRC. It is imperative that this world leading facility is transferred and then maintained and developed at the most appropriate and stable location for its future role.

The "Soil Hall" at Harper Adams University College is a valuable national resource for teaching and short courses. Further investment would increase its value for applied research and doctoral studies.

ADAS is maintaining a presence at a number of former Experimental Husbandry Farms to undertake applied research and development work at a range of locations across England and Wales, as given in Appendix 3.

b) Expertise

This is of much greater concern than the physical resources. In the short term there is probably adequate staff expertise in the environmental and biological sciences for

much of the research at centres such as North Wyke, IBERS and ADAS's former EHF's and elsewhere. However, as many of the key soil and water engineering researchers have now retired, there is a shortage of those with the practical skills to "engineer" sustainable solutions, hence leaving applied research poorly served.

The biggest challenge is in renewing the pool of professionals who can identify and conduct the applied research, deliver practically oriented teaching, provide extension advice and deliver short course training for farmers. These are not easy to find as they generally require a good knowledge of agriculture and have a sound science/engineering base. It is encouraging that a number of candidates with international reputations are expressing interest in the Cranfield professorship.

7.4 ***How can UK soil and water management capability be sustained, provided with more resources and integrated with capacity elsewhere in the EU and the world?***

- There needs to be change in national policy from being predominantly environment driven to production in an environmentally sensitive framework;

- Ensure that a greater proportion of those with sound agriculture, science and engineering backgrounds are engaged in the formulation of the strategy;

- Government/Defra/EA should "bite on the bullet" and source adequate applied work to ensure that the national capability for the production of food and fuel, whilst meeting environmental requirements, is optimised to reduce the UK dependence on international factors. The solutions to soil problems are site-specific and cannot be imported like farm equipment and food;

- The agricultural community needs to convince the former Levy boards and AHDB that soil is important to all and work to ensure that the proposed mechanism for integrated applied research and development flourishes;

- The UK's link to the EU and other parts of the world has been excellent; this is based on the parity of esteem between the international cadre of scientists and engineers involved in soil and water management. In order for this to continue the UK needs respected scientists and engineers to both share ideas and be capable of evaluating them to ensure they satisfy UK soil and weather conditions;

- It is recommended that RASE work with the Agriculture and Horticulture Development Board, Agri Food Charities Partnership and the individual Charities to create a postgraduate research scholarship fund for a minimum period of 5 years to enable the development of a cadre of good applied soil physicists and engineers for the longer term. This group between them should study applied problems, covering each of the key areas in soil and water management and engineering. The funding should be for UK/EU nationals (who pledge to work in the UK for a period) with a minimum of 4 graduates starting each year for 3 consecutive starts. These projects should have either or preferably both a commercial/agri-business and/or research station partner and operate rather like CASE Awards. These would be in addition to the 3 students at each of Cranfield University and Harper Adams University College that are currently funded by the Douglas Bomford Trust (either alone or with Chadacre and Morley Trusts and the Claas Foundation).

7.5 ***Are sufficient people being attracted to soil and water management and related areas as a career?***

The answer is a very definite "no". Experience suggests that there may be a sufficiently large group of individuals who would be attracted if there was a career structure and rather more job security.

The RASE should generate a fund in conjunction with other charities to provide "small top – up" grants for undergraduate engineers at Harper Adams in a similar manner to a number of equipment companies, and to fund soil and water projects.

The lack of postgraduate scholarships restricts the number of applicants and this must be addressed by Government agencies with help and input from a number of the agricultural charities and the AgriFood Charities Partnership (AFCP), see section 6.1.

7.6 ***Is there a career structure which will help to retain them in the discipline/in the UK?***

Currently there is no sensible career structure in the UK and in recent years it is probably only Cranfield University that has provided such a mechanism through an "academic" route. This has enabled the progress of a number of top quality masters students to post doctoral graduates and through to junior researchers and postgraduate teachers. Those staying in the UK are, however, few.

Nationally there needs to be a vision for a career structure available to encourage graduates at all levels to enter the profession. Initially this is most likely to be within the "Education" sector, but possibilities could exist in bodies such as the Environment Agency. The education sector can offer applied research, teaching and extension under one umbrella and permit progression from the junior academic/research grades to Professor and beyond, with further opportunities arising in the government, commercial and private sectors. All this needs to be heavily weighted to practical application of research findings into sensible on-farm development.

Within a body such as the Environment Agency, a section could be established which would allow the requirements of profitable production agriculture to be considered and developed alongside those of the environment. Initially it is envisaged a graduate's inputs and experience would be largely within extension, then progressing into policy and strategy matters within the remit of 'production within an environmental framework'.

Following the education route, one way forward to address this issue would be the reintroduction of the Scottish/US College system of practical developers/advisers alongside researchers and teachers to enable the profession to flourish. A system like this at a number of selected centres would enable a career structure to develop based upon applied research and development, extension and teaching.

Consideration should be given to the selection of one base for a pilot scheme and Harper Adams University College is one that would appear to have the key requirements, namely:

- A sound agricultural base;
- The only undergraduate agricultural engineering department in the country;
- A strong agronomy/plant sciences department;
- A keen interest to develop its activity in soil and water management;
- Opportunity for staff to be involved in training, teaching and applied research which would open up career opportunities for able people;
- A large cohort of undergraduate students to undertake projects;
- Through its old-students an excellent network of farmer contacts;
- A central location serving England and Wales, the latter providing a convenient link to IBERS and issues relating to the LFA's. Also close to Stoneleigh Park, where the RASE is keen to establish soil and water demonstration activity.

Other College (or Former ADAS EHF's) based units at say 3 other regional centres could develop with time to accommodate regional and catchment differences.

7.7 ***Is there sufficient capacity of the right quality in the education system to train the appropriate soil and water managers of the future?***

The answer to this question is "no and the existing capacity is diminishing quite rapidly". The major problem is that the experienced professionals have retired and their successors are not obvious because of the lack of mid-career professionals to take on leadership roles.

Currently Harper Adams University College, with its mission fundamentally aligned to the needs of practical agriculture, is moving to position itself centrally in national agricultural strategy. However, there is a need to recruit new blood to undertake the educational role and have much more direct engagement with farmers in soil and water management. It is critical that this is undertaken in the very near future so that the existing cadre of retirees can help mentor the incoming group. Currently Reaseheath College, in Cheshire, provides a progression of students from their First and National Diplomas into the HND/Foundation Degree and Degree programmes at HAUC in agricultural engineering. The Principal of Reaseheath College is open to further discussion on extending these to encompass aspects of soil and water management providing satisfactory accreditation procedures can be established.

7.8 ***Do farmers and contractors receive reliable information about soil and water management?***

In most cases the answer to this is “yes” but there are circumstances where both quality and reliability could be improved. The situation could deteriorate in future as the number of experienced providers approach or pass into retirement. This is further exacerbated by the lack of a centre of excellence from which farmers and advisers can obtain sound practical professional advice. There is little or no direct on-farm help unless farmers pay consultant fees and the availability of knowledgeable consultants is reducing. Those paying and attending the BASIS Soil and Water Management short course will receive good advice. Farmers have commented on the fact that they have no source of independent advice available to them.

If so, how and from where, and is there more that can be done?

Farmers generally obtain their information from the following sources, namely:

- Press articles, for example in the Farmers Weekly and Farmers Guardian. These are not structured and are published when the material is available;
- Privately retained agronomists (e.g. TAG and members of AICC);
- Courses such as the BASIS Soil and Water Management course;
- Speakers at Farmer Discussion Groups, although the supply is diminishing;
- Workshops and Conferences;
- Events such as “Tillage” and “Cereals”;
- Specialist publications sponsored and written by or for machinery companies, for example Simba, Vaderstaad and Claas. Usually these are well written but of necessity focus on the issues surrounding a particular range of products;
- Cranfield University for booklets on irrigation and water resources;
- Staff of FWAG, Natural England and the Environment Agency (via CSF Officers) provide some advice in the course of their other advisory duties. These, however, are generally focused on environmental issues and not on production. In future these two issues need to be more balanced;
- LEAF Audit and associated publications;
- Long course agricultural training programmes.

The most critical aspect here is to ensure that there is a nucleus of professionals engaged in practical soil and water management who can “feed” all of the above with first hand or immediately second hand advice. Professionals with appropriate training and experience need to be present across the sector, from Government Agencies, through educational establishments to extension services. The potentially more senior grades should be encouraged to undertake a Masters degree or be recruited from such a programme. Provision needs to be made for studentships to support the studies and a path provided towards worthwhile careers afterwards.

Unfortunately since the withdrawal of Rycotewood College there is no vocational (equivalent to OND/C or HND/C) programme in the topic and soil and water issues are not always effectively covered in basic agricultural programmes. This latter situation could be rectified by extending the specialist work at Reaseheath and Harper Adams University College and encouraging other Universities and Colleges to introduce a syllabus similar to that given in Appendix 1, or as a minimum, give more attention to soil and water management than at present. If required the establishments could draw upon the expertise of the group suggested in Section 6.1.

Possibilities also exist to develop the BASIS course to provide more detailed information in specific areas.

7.9 ***Do they take notice of such information and implement "good practice"?***

From our experience in both lecturing to groups of farmers and talking to individual farmers over a period of 40+ years the answer to this is generally "yes", especially when they receive practical affordable solutions that fit within their farming system. The problem is, as mentioned before, the lack of providers. This was illustrated by a conversation with Caroline Drummond of LEAF, in June 2008 at Cereals, where she was saying that with the retirement of key individuals there was no one that she could recommend to her members to solve soil and water problems.

Caroline also states that "one of the key areas that drive farmers to change and make decisions is legislation, the GAEC is having a big impact on what farmers do - the other is the farm assurance schemes such as the Red Tractor and LEAF Marque for example. They make key recommendations to farmers against which they are inspected".

If not, what should be done and by whom to encourage this?

Ensure that there are a sufficient number of trained professionals available to undertake development work and provide advice. This work should be centrally coordinated either by DEFRA, one of its agencies, AHDB or the RASE acting for and supported by DEFRA coordinating an industry wide group. Such personnel would be the equivalent of the former 'Drainage Officers' of the past, but many fewer in number and broader in remit.

7.10 ***Are there specific knowledge transfer actions which the Royal Agricultural Society of England should consider taking?***

Yes: Possible actions include the following:

1. Work to encourage DEFRA to be more pro-active to embrace production alongside environmental issues.

2. Work with:

    - The Institution of Agricultural Engineers - Soil and Water Group;
    - Soil Management Initiative (SMI);
    - Research, education and extension providers (e.g. TAG and AICC);
    - Machinery companies and the Agricultural Engineers Association;
    - Soil consultants;
    - LEAF;
    - FWAG;
    - The Association of Drainage Authorities (arterial drainage systems);
    - The farming press;
    - NFU;
    - Local and national radio and television.

    To:

    i. Formulate an effective Soil and Water Management network to rekindle the aims of SMI and SAWMA and its Journal, (see Appendix 2 for a typical table of contents) with farmer groups. If funding permits, the revised Journal should be in both hard copy and electronic format. The RASE should also consider making available an electronic library of relevant soil and water management articles.

ii. Organise an event; integrating sections on drainage – irrigation – soil erosion control - tillage/compaction on an annual or biennial basis as a standalone activity and to discuss working with AEA to extend the remit of the "Tillage" event. Historically SAWMA would have a ½ day Technical Workshop ahead of the annual Farmers Weekly "Drainage Event". Have a display at "Cereals".

iii. Consider the formation of a series of county, regional or catchment based "Landcare" groups and/or Soil and Water Management Districts akin to the Australian/New Zealand and US models. The aim would be to stimulate soil and water related activity to enable profitable and efficient production together with good environmental management as reported by Palmer (2008). These groups function extremely well, but they need a good coordinator who is funded for their input. This might be possible through the Regional Development Agencies such as Yorkshire Forward who have shown strong leadership in this area.

3. Request that the Department for Children, Schools & Families ensures that agriculture and soil and water issues are included in school syllabi.

7.11 ***Are soil and water management issues understood and their importance taken into account sufficiently by policy makers?***

Having discussed this question with DEFRA it is fair to report that the key major national issues are well understood by the leading policy makers and where they require further assistance they refer to stakeholder and strategy forums which include ADAS, key universities, Rothamsted Research, Environment Agency and Natural England, consultants and the NFU. Certain issues, for example those concerning rising sea levels, are considered in future Foresight projects.

In recent years the official policy has been focused on the environmental issues associated with climate change and the decline in levels of soil carbon, erosion risks and the protection of soil and water from diffuse pollution. Discussion with DEFRA indicates that their proposed Soil Strategy does consider the anticipated national requirements to improve food security and to provide for the increase in production of bio fuels. Their proposed strategy also covers the issues of soil and water management in the "built" as well as the rural environment.

In order to manage policy in this area Defra developed a broad over arching First Soil Action Plan for England (2004-2006) and have followed this with a consultation document to develop a Soil Strategy for England (2008) which was released on 31 March 2008, with a deadline for responses of 23 June 2008. Responses are currently being analysed and the proposed Strategy revised. To quote the consultation draft of the proposed Strategy, its purpose "is to maximise the benefits that soils can bring to the economic and environmental well being of today's generation and future generations, and one of the key benefits listed is the production of food and fibre. This aim relates to DEFRA's wider aim for the populace to live within our environmental means and reflects the key principles of the UK Sustainable Development Strategy, which includes living within our environmental limits". In reviewing these documents it is noted that there are general references to issues such as compaction damage, soil carbon and organic matter levels, erosion and drainage and the need to be aware of environmental implications especially with the demands of climate change.

Overall the DEFRA policy is one of maintaining and improving the condition of soil and water nationally, which is critical for long term sustainability of the environment, agriculture and the population.

If the answer to the question above is "No", then how can soil and related issues be highlighted to policy makers and advisors?

The answer to the above question is not a categorical "***No***". It is sensed, however, that the practical agriculture community believe that in developing government policy there has been insufficient focus on the measures required to ensure food security whilst meeting the soil, water and environmental objectives. In reviewing the overall position, this deficiency appears to have arisen through a lack of connectivity between farmers, soil and water engineers, and soil specialists working closely with farmers and DEFRA, and has resulted in the absence of a robust 'advisory mechanism' for the key practical outputs discussed earlier. This is despite a Soils Advisory Forum with stakeholders from all these fields and they are involved in policy development and implementation. Bringing these parties still closer together and the provision of an advisory mechanism would appear vital when the agricultural industry manages 72% of the land area.

The RASE should discuss the findings of this report both internally and with DEFRA, Natural England, Environment Agency, NFU, CLA, and research and education bodies to raise ministerial awareness. This could be extended to a symposium based on this report, inviting other pre-eminent speakers, to call for change. The Society should also try to ensure the group advising the policy makers has full access to individuals capable of providing sound balanced advice on soil and water management aspects related to both production and environmental issues. It is not that there is a fundamental conflict – it is just that, at times, there appears to be; hence communication and dialogue need strengthening for the long term benefit of the industry and the environment.

It was disappointing when reviewing the list of respondents to the DEFRA Action Plan and Soil Strategy Consultation, that the RASE had not been able to contribute directly. It is suggested that in future the Fellows and Associates of the Royal Agricultural Societies be asked to provide expert opinion.

8. Conclusions and Recommendations

8.1 Conclusions

Agricultural production in general and soil and water management in particular, face a considerable challenge in meeting the demands of increasing food production and security at both national and international level, the demand for alternative fuels, climate change, soil protection, flood and pollution control and the availability of water resources for crop and animal production combined with the diminishing supply of labour. The effect of the latter will be to increase the average size of the field equipment.

The Environment Agency, Natural England and other Conservation bodies are becoming increasingly involved in soil and water issues at farm level. Their remit, however, is in environmental matters alone and the expertise within these bodies to understand the implications from the farm production point of view is minimal. There is, therefore, the need for specialists who can bring both aspects together, to ensure profitable farming whilst meeting environmental requirements.

Currently due to various issues of both policy and economy, there is a much depleted professional body of specialists who can address the research, extension and training issues required to support the farming community and work with the environmental bodies. Whilst many would argue that there is a shortage of professionals in soil science, soil ecology and the environment there are less than a handful in engineering and applied soil physics. The career structure for new entrants to the profession is also poorly defined, and this discourages entry. Immediate attention needs to be given to the provision of a small cohort of professionals that can supply the necessary expertise whilst there is sufficient time for them to be mentored by those (now mostly retired) with a proven record in the field.

There is a considerable store of fundamental research information available and whilst there is a need for some further supplementation, the prime requirement is to utilise and develop this existing information, linking in with field experiences elsewhere, to address current problems. Future emphasis, therefore, needs to be given to applied research and development, conducted by a cohort with a good understanding of agricultural and environmental needs who can “design” innovative solutions to practical problems.

The specialists required need a suitable academic background together with a good base and support structure (possibly at colleges or universities, or within a Government Agency) and to be in regular contact with farmers to discuss and help solve their problems.

The educational provision for both future specialist professionals and farmers in soil and water management is at a precarious level, the continuity of supply having been upset by the closure of the undergraduate and short course programmes at Silsoe. Harper Adams University College is, however, considering possibilities of extending its Higher National Diploma – Foundation Degree and undergraduate engineering programmes, to encompass a greater amount of soil and water management. It is recommended that this should be conducted in conjunction with Reaseheath College to provide a Level 3 National Diploma for technician training and as a feeder route for progression to Harper Adams. This development could be an important step in helping fill the void and should be strongly encouraged. Other universities and colleges running agricultural and soil science courses also need to be encouraged to include modules in applied soil and water management within their programmes.

Subject to there being a continual source of up-to-date information available, there are adequate low-cost opportunities for extension. The major outlets would be through the media, college and university teaching, clubs and societies, BASIS training and perhaps add-on displays at events such as 'Tillage'. There is, however, little prospect of the majority of farmers being able or willing to pay full-rate professional fees for one-to-one advice on the farm, at current commodity prices with rising input costs.

The lack of funding for applied research, development, educational initiatives and all forms of extension poses a major problem to be addressed by the Royal Agricultural Society, Government and Government Agencies, the many agricultural charities, levy boards and commercial/agri-business companies. It may also be wise to consider Lottery funding, as the issue affects the whole nation. It is estimated that to stem the immediate decline, a minimum fund of one million pounds is required per year for a minimum 5 year period and that this be accompanied by further minimum funding for doctoral research programmes over the same period of £300,000. A further fund of £20,000 to £30,000 per year would also assist in supplemental funding of undergraduate and postgraduate students and their projects.

8.2 Recommendations

Alert DEFRA and other bodies to the problem and persuade DEFRA to move from its current largely environmental policy to one which also embraces production within the environmental framework. The commitment of DEFRA and its supporting agencies will be critical if the current situation is to be reversed.

The RASE working with other parties should attempt to raise £1 million/year for a 5 year period to stem the decline in available professionals and to raise the funds to train doctoral engineers and applied soil physicists over the same period.

Encourage the development of research, training and professional accreditation at the existing establishments, namely:

- Rothamsted, North Wyke Research and IBERS in basic and strategic research. With the exception of Rothamsted, however, there are no applied physicists and engineers at the other two centres, hence good linkages need to be formed with the other partners in the network;
- Cranfield University in postgraduate teaching and basic and applied research;
- Harper Adams University College in undergraduate education, training and applied research;
- Reaseheath College to provide Level 3 National Diploma graduates and act as a feeder route to Harper Adams University College;
- BASIS in the further development of accredited short courses for practitioners;
- Institution of Agricultural Engineers for professional accreditation (EngTech, I Eng, CEng and CEnv).

Create an atmosphere of excellent communication between all parties.

Give consideration and support to the establishment of one base for a pilot scheme to provide a national centre for soil and water management and engineering. This centre would link applied research and development with teaching, extension and short course provision. If the soil and water developments currently under consideration at Harper Adams University College proceed, this centre would appear

to be the most appropriate for such a base. Its particular attributes for such a pilot scheme are as follows:

- A sound agricultural base;
- The only undergraduate agricultural engineering department in the country;
- A strong agronomy/plant sciences department;
- A keen interest to extend its activity into soil and water management;
- A large cohort of undergraduate students to undertake projects;
- Would provide the opportunity for staff to be involved in training, teaching and applied research which would open up career opportunities for able people;
- Through its old-students an excellent network of farmer contacts;
- A central location serving England and Wales, the latter providing a convenient link to IBERS and issues relating to the LFA's. Also close to Stoneleigh Park, where the RASE is keen to establish soil and water demonstration activity.

Collaborate with the following key groups and other interested parties:

- Institution of Agricultural Engineers;
- Soil Management Initiative;
- Agricultural Engineers Association and members;
- NFU;
- LEAF;
- FWAG;
- Natural England;
- Environment Agency;
- The Irrigation Association;
- TAG.

To organise events, produce a journal (hardcopy and electronic) and develop an electronic library of soil and water management articles to promote good soil and water management practices and to provide a network for practitioners.

Provide support for the continued existence of the Silsoe Spray Applications Group as a national asset, to ensure that the best quality research and advice can be provided to improve the effectiveness of agrochemical applications.

Convene a conference for all interested parties, to include DEFRA and its agencies, farmers, charities, firms, practitioners, professional bodies and educational establishments, to consider potential future techniques which, with further development, would be both advantageous to profitable production and the environment. The objective would be to enthuse as wide a range of parties as possible into putting more effort and resources into improved soil and water management techniques. Link this with other groups e.g. NFU and the Commercial Farmers Group who share many of the same concerns.

The Practice with Science Advisory Group should nominate a champion/facilitator to work with agri-business over a period of years to steer the new initiatives, and report to the Group as required.

All parties consulted in the preparation of this report were thoroughly supportive of its aims and recommendations, especially the farming community, and a number said 'It's about time for farmers to speak up for themselves'.

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Appendix 1

Proposed syllabus for an integrated course in Soil and Water Management

Each of the lectures to embrace the necessary environmental implications, considerations and requirements

1 Introduction
2 Conditions for crop production
3 Role of drainage in agriculture
4 Surface drainage
5 Ditch design
6 Estimation of run-off
7 Piped systems, layout and spacing
8 Piped systems, pipe sizes
9 Installation and maintenance of schemes
10 Mole drainage techniques
11 Irrigation water, crop need, water holding capacity, scheduling
12 Storage needs, reservoir, bore holes and river extraction
13 Irrigation methods, system layout
14 Irrigation methods, operational considerations
15 Agricultural production systems and soil erosion
16 Principles of soil and water conservation
17 Practices of soil and water conservation
18 Wind erosion and its control
19 Erosion risk assessment and socio/economic constraints and benefits
20 Soil and Water Conservation
21 Optimising rainfall through cultural practice
22 Mechanization requirements
23 Preparation of soil tilth and packing states – overall requirements
24 Basic tillage tine mechanics: effect of depth/width ratio and rake angle
25 Principles of traction
26 Deep loosening principles and equipment
27 Inversion
28 Disintegration : Active secondary tillage
29 Re-arrangement and compaction : Passive secondary tillage
30 Mechanical weed control
31 Factors affecting soil compaction
32 Approaches to farm operational planning
33 Localization of loads, gantry, tramline and bed management systems
34 Improving subsoil fertility – nutrients
35 Residue management and straw incorporation
36 Farm waste effluent plans
37 Codes of Good Agricultural Practice
38 Injection and land spreading techniques
39 Economics of alternative land spreading methods
40 Integrated field methods and conservation systems for managing soil, water, plants and machines

Appendix 2

Sample contents from 'Soil and Water', the Journal of the Soil and Water Management Association Limited

Volume 9, No 1, 1981

Volume 15, Nos 1 & 2, Spring 1987

Minor news items – equipment, company news, awards, services	4 pages
Demands on soils increasing	John Hollis, Soil Survey of England and Wales, report on 13th Int Soil Sci Congress
The Hamble Series – Soil Assessment	M G Jarvis, Soil Survey of England & Wales
Field drainage 1940 – 1984 – A success! But where now?	Chris Stansfield, ADAS London
One pass tillage to avoid recompaction – recent work at Silsoe College	R J Godwin
Tillage – What now and what next? Report on the SAWMA 1987 Tillage Conference at Rothamsted (200 in attendance) Tillage: a series of notes. Gantry systems: reduced energy requirements, Faster, more intelligent tractors, High speed straw incorporation, Fuel economy and efficiency, Reduced energy requirements, Electronics for cultivation management Book reviews (3), research notes (3 items)	
A survey of water erosion	Robert Evans (Soil Erosion Research, Cambridge) & Dick Skinner (ADAS Soil Scientist, Cardiff)

Field meeting – a report on a SAWMA visit to Redesdale E H F, Northumberland

A report on the SAWMA Annual General Meeting hosted by Dowdeswell Engineering, Stockton, Warwickshire

Study your soil and keep down your costs – a report on a Soil Management Course at Silsoe

Appendix 3

Current status of former ADAS Experimental Husbandry Farms

ADAS continues to deliver independent research on environmental, livestock, arable, horticulture and food related topics from former Experimental Husbandry Farm premises and elsewhere in 9 different English counties.

Arthur Rickwood Farm (Black Fen, Cambridgeshire)
ADAS rents the site from Defra for work on high health status sheep, energy crops (particularly miscanthus), and horticultural research.

Boxworth (clay, Cambridge)
Farm sold to a private buyer. Defra retains ownership of all offices, laboratories and glasshouse, with 40ha of land and rents them to ADAS. Over 70 staff work from the site.

Drayton (heavy clay, Stratford on Avon)
ADAS managed on behalf of Defra. Ruminant, pig and poultry research for mainly corporate clients. Most of the farm is in short rotation willow coppice, with a small area of grass and arable for the Environmental Change Network programme.

Gleadthorpe (sand, Mansfield)
Farm sold to a private buyer. ADAS has a long lease on offices, laboratories and some buildings, plus long term trial areas. Mainly environmental research, over 30 staff. The poultry work has been moved to Drayton.

High Mowthorpe (chalk, Yorkshire)
Farm sold, but ADAS lease offices, glasshouses and laboratories and around 30ha for arable and livestock research. Some 20 staff work from the site.

Pwllpeiran (upland, Aberystwyth)
ADAS rents the site from the Welsh Assembly and continues hill and upland environmental and livestock research.

Redesdale (upland, Northumberland)
ADAS has given up the tenancy with the private landowner and withdrawn. Defra still owns, and has let to a tenant, the 20ha Dargues Farm on the same site.

Terrington (silt, King's Lynn)
The farm has been sold and all the offices and the pig unit vacated. The 5 arable staff have an office on a nearby farm and continue to look after 4000 arable trial plots in this 'high cereal disease pressure' area.

Rosemaund (Hereford)
The farm has been sold, but ADAS retains a lease on buildings and laboratories with 30ha for arable and livestock research. Some 25 staff work from the site.

The Royal Agricultural Society of England

Since 1840, the Royal Agricultural Society of England has played a leading role in the development of agriculture, the food chain it serves and the vibrant rural economy within which it operates. As the independent voice for the sector, the Society encourages innovation, the advancement of science, effective technology transfer and agricultural methods which are in tune with the environment and the highest ethical standards.

A thriving agricultural and land based industry relies upon the rapid uptake of scientific advance. The Society is committed to improving the profitability and competitiveness of rural businesses by providing the link between research and production. Our work includes:-

- Developing strong relationship with partners who work in science, technology and research;
- Sharing best practice and information to transfer the benefits of research to practical farming;
- Finding solutions to common problems both nationally and internationally;
- Promoting and demonstrating a rural low carbon agenda.

The Society's "Practice with Science" Advisory Group, chaired by Sir Don Curry, is tasked with advising the Society on year-round activity relating to the Society's objective "to be the leading independent voice for agriculture and the rural economy", based upon its commitment to "Practice with Science".

The report "The Current Status of Soil and Water Management in England" is the first report to be commissioned by the "Practice with Science" Group.

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