

## A CIWEM Conference

# The Land-use and Water Series Integrating Water and Soil Strategies *Translating Research into Action*

12 October, 2005

SOAS, London

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## Background

The interactions between land and water are attracting increasing interest from the perspectives of science, policy and practice. The water and land sectors have also been brought closer together by the creation of Defra, uniting Government policy responsibilities for both water and farming, and through the links increasingly being made between the Water Framework Directive and the reform of the Common Agricultural Policy.

However, the developing focus on the relationship between **land** and **water** at a catchment scale has often tended to overlook the critical role of **soil** at the interface. In reality the structure, properties, and management of soil are all key elements in meeting emerging EU and UK policy objectives.

A failure to understand the role of soils and their interactions with water in the environment means that society is missing opportunities to find cost-effective ways of mitigating problems and delivering benefits:

- **Soil and Diffuse Pollution:** Better soil management in water gathering grounds would reduce the costs of treating water to remove nitrate, pathogens and pesticides from drinking water.
- **Soil and flooding:** Managing soils to capture hold water upstream would reduce the impact of fluvial flooding on settlements downstream, reducing the need for investment in flood defences.
- **Soil, organic matter and fertilisers:** Making greater use of organic composts would enhance soil productivity and structure and sequester carbon that would otherwise contribute to climate change.
- **Soil, siltation and aquatic biodiversity:** By tackling soil erosion, better soil management would reduce the impact on game fisheries of siltation of spawning gravels.

While current practice in the water industry is highly focused on 'end of pipe treatment' this conference has been designed to show how soil management within the catchment can deliver significant environmental benefits. The conference will communicate recent research into soil management, focusing on soil-water interactions. It will be highly applied rather than theoretical and a wide range of projects and case studies will illustrate what needs to be done. For example, we need to:

- Persuade **policy-makers** that water companies need to be allowed to work closely with farmers to tackle drinking-water quality problems at source rather than by costly treatment
- Encourage **flood risk managers** to assess how improving soil structure in a catchment will mitigate peak flows and reduce the need for expensive flood defences
- Prompt **farmers** to invest in improving the organic matter content and structure of their soils
- Persuade **riparian land managers** that taking action to reduce siltation could pay a handsome future dividend in improved fisheries.

The conference is also relevant to many emerging themes in policy and practice, including Government proposals for 'Catchment-sensitive farming, the drafting of the Second Soil Action Plan for England, the Environment Agency's Soil Strategy, and the expected EU Soil Framework Directive, as well as the continuing implementation of the Water Framework Directive and of the reformed Common Agricultural Policy.

The conference **aims** to explore four of the main areas in which scientific findings, many of them new, need to be turned into practical action, to deliver a step change in managing soil-water interactions.

**The objectives** of the conference are to:

- Disseminate to a wider audience key recent research findings on the relationship between soil management and water quality, water flows, siltation and the processing of organic wastes.
- Show how these findings need to be translated into practical action for environmental gain at a catchment level, enabling a massive reduction in end-of-pipe treatment costs.
- Build links between many disparate projects which are tackling parts of the whole, in the interests of promoting concerted action.
- Deliver a conference outputs which set out an agenda for action.

## Programme

09.00 Registration and Coffee

09.45 Introduction and welcome to the Conference on behalf of CIWEM

**Robin Green** Wardell Armstrong LLP and CIWEM President

Session 1: Chairman **Brian Chambers** ADAS

09.50 Keynote presentation: Soil and Water strategies - developing concerted actions  
with the focus on delivery **Martin Froment** RDS

10.10 Catchment scale management of soil resources – the Parrett Catchment Project

**Jo Oborn** FWAG

10.30 Soil, land-use nutrients and water – experience from the Water4All project

**Kevin Hiscock** UEA

10.50 Erosion & siltation defining the problem & control strategies **Gavin Wood &**

**Jane Rickson** National Soil Resources Institute, Cranfield

11.10 The SOWAP (SOil and WAtEr Protection) project: the impacts of soil management on  
soil erosion and water quality **Ceris Jones** Agronomica & **Jeremy Biggs** Pond  
Conservation

11.30 Soil management effects on runoff, sediment and phosphorus loss in the Hampshire  
Avon catchment **Paul Withers** ADAS Catchment Management Group

11.50 Break 1 Buffet and refreshments

Session 2: Chairman: **Jonathan Abra**, Technical Director, Ewan Group plc

12.40 Organic manure management to the benefit of soil and water quality

**Brian Chambers** ADAS

13.00 Organic matter in soils: maintenance and application – research into practice

**Tim Evans** Tim Evans Environment

13.20 Is there a link between soil compaction and flooding? A review of the evidence.

**John Hollis** National Soil Resources Institute, Cranfield

13.40 Flooding and erosion – key issues and ways forward?

**John Boardman**, Environmental Change Institute, Oxford University

14.00 Setting out actions, organisations and priorities Participants to identify actions

14.10 Break 2 Sweet and refreshments

14.50 Discussion

Chairman: **Alan Woods**, New Game Plan & chairman CIWEM **ARC** panel

The discussion will be based around questions posed to the audience at the end of the second session (14.00) – they will be framed in such a way as to provide useful outputs to participants after the conference.

16.00 Close

## **Soil and Water strategies - developing concerted actions with the focus on delivery**

### **Martin Froment**

Rural Development Service, Room C504, Government Buildings, 98 Epsom Road, Guildford, Surrey, GU1 2LD

Tel No: 01483 404260 Fax No: 01483 403646 E-mail: [martin.a.froment@defra.gsi.gov.uk](mailto:martin.a.froment@defra.gsi.gov.uk)

Environmental scientists and policy makers have been taking a growing interest in soil and water in recent years. In simple terms they question the sustainability of current land management practices if we want to continue drawing upon the benefits that soil provides: clean water, flood control, food and timber, wildlife habitat and a pleasant place to live.

Scientists have highlighted the increasing pressure that society is placing on the soil resource and the consequences of poor soil management. Most commentators suggest that they are right and that something should be done. Soil issues are often linked to water and air, as well as land use, which adds a socio-economic dimension to managing environmental impact. Problem issues with soil and water impact on both rural and urban communities - but with agriculture managing three-quarters of the land surface in England, this industry has a key contribution to make in resolving the problem.

Government policy makers have responded by doing what policy makers do: delivering policy statements, action plans, manipulating subsidy and support schemes, amending legislation and urging other policy makers and society to move forward. The last 3 years have seen policy makers launch Defra's Soil Action Plan, The Environment Agency's Soil Strategy, the Water Framework Directive, CAP reform and Cross-compliance, amendments to agri-environment schemes to give greater focus on resource protection and development of the EU Soil Thematic Strategy. No land manager can doubt that something has been going on.

So where are we? Consultation with industry has been a key element of Defra's approach, both to raise awareness of soil and water issues and to deliver positive and workable solutions to the challenges faced by the industry. There is broad agreement at a national level that we have a problem to resolve, that soil and water is important and that considering the scale of the problem its' resolution cannot be left to individual land managers/farmers or agencies acting alone, concerted and co-ordinated action will be needed.

The key task ahead is to deliver the necessary changes in farm practice at a regional and local level. Critical to our success is the active engagement and support of all stakeholders and land managers/farmers.

## Catchment Scale Management of Soil resources – The Parret Catchment Project

**Jo Oborn**

Environmental Agronomist, FWAG, County Hall, Taunton, Somerset, TA1 4DY  
Tel No: 01823 355427 E-mail: [jeoborn@somerset.gov.uk](mailto:jeoborn@somerset.gov.uk)

[www.parrettcatchment.info](http://www.parrettcatchment.info)

### Summary

The Parrett Catchment Project was set up in 2001 to address repeated, severe flooding and water quality issues over 1690 km<sup>2</sup> of Somerset. The project comprises of 27 organizations, with the objective to reduce the severity of future flooding incidents.

One of the main aims is to improve land use and land management in order to reduce run-off and flooding. As a result the Farming water initiative was set up. Using E.U. Interreg money to address land related problems; it has been possible to fund the following

- Interception Ponds
- New woodland sites on vulnerable areas
- Temporary flood storage
- Focused advice on Land use and Land management

Early in the project, high risk areas were identified along with the main causes. Following on by adopting a proactive approach with funding partners, it has been possible to implement changes and improve land management to reduce run-off and flooding. This has been delivered by improved soil management, sustainable cropping rotations, and changes to land use funded through agri environmental schemes.

## Soil, land-use nutrients and water – experience from the Water4all project

### Kevin Hiscock

University of East Anglia, School of Environmental Sciences, Norwich, NR4 7TJ  
Tel No: 01603 593104 Fax No: 01603 591327 E-mail: [k.hiscock@uea.ac.uk](mailto:k.hiscock@uea.ac.uk)

The EU-funded *Water4All* project involves the participation of four partner countries (Denmark, Germany, The Netherlands and the UK) with the aim of finding sustainable solutions to the problem of diffuse nitrate contamination of vulnerable soils and aquifers. Considerable experience exists in continental Europe in the adoption of measures for reducing soil nitrate leaching. Such measures range from the provision of advice on alternative farming practices, for example organic farming, to the wholesale change of land use, for example the conversion of arable land to broad-leaved woodland. These changes also result in other benefits for the countryside, including economic gains. The *Water4All* project completes in December 2005 and a major output has been the publication of a *Guidance Handbook* that contains detailed information on the ranges of measures applied in the four partner countries.

Further information is obtainable from [www.water4all.com](http://www.water4all.com).

## Erosion & siltation: defining the problem & control strategies

**R J Rickson, J H Duzant and G A Wood**

National Soil Resources Institute (NSRI), Cranfield University, Silsoe, Bedfordshire, MK45 4DT  
Tel No: 01525 863058 Fax No: 01525 863253 E-mail: j.rickson@cranfield.ac.uk

### Defining the problem

Soil erosion and surface runoff are associated with the movement of nutrients and contaminants at field and catchment scales. These processes have environmental and economic costs, including loss of soil resources, reduced carbon sequestration and increased flooding risk (EA, 2002). Efforts to alleviate these threats are driven by the EU 6<sup>th</sup> Environmental Action Programme, Thematic Strategy for Soil Protection, Water and Soil Framework Directives, and the DEFRA Agri-Environment and Environmental Stewardship Schemes. Whilst erosion control *principles* are understood well (Morgan, 2005), successful implementation of *practices* is more challenging.

### Control strategies

Erosion research must be oriented toward effective, practical and economically feasible solutions, to ensure successful adoption by land managers.

Two projects, based on sound science and practical application, are presented – “The strategic placement and design of buffering features for sediment and P in the landscape” (<http://www2.defra.gov.uk/research/>), and the EU LIFE / Syngenta project “Soil and water protection in Europe” (SOWAP) (<http://www.sowap.org/index.htm>). The former considers the design and effectiveness of field buffer strips in controlling soil, water and nutrients losses at varying scales, from individual plant species to buffer placement in the landscape. The latter project considers soil management practices in controlling soil, water, nutrient and pesticide losses.

### References

Environment Agency, 2002. Agriculture and natural resources: benefits, costs and potential solutions. Bristol.

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Morgan, R.P.C. 2005. Soil erosion and conservation. Blackwells.

## **The SOWAP (SOil and WAtEr Protection) project: the impacts of soil management on soil erosion and water quality**

### **Ceris Jones**

Agronomica, Potticks House, Bradford-on-Avon, Wiltshire, BA15 2PF  
Tel No: 01428 658691/07808 124540 Fax No: 01225 867600  
E-mail: [cjones@agronomica.org](mailto:cjones@agronomica.org)  
and

### **Jeremy Biggs**

Pond Conservation, C/o BMS Oxford Brookes University, Gypsy Lane,  
Oxford, OX3 0RP  
Tel No: 01865 483278 Fax No: 01865 483282 E-mail: [jbiggs@brookes.ac.uk](mailto:jbiggs@brookes.ac.uk)

SOWAP (**SOil and WAtEr Protection**) represents a collaborative attempt by industry, NGOs, academic institutions and farmers to address the environmental, economic and social concerns arising from the practice of conventional agriculture.

Working in the UK, Belgium, Hungary and the Czech Republic, SOWAP is investigating the effect of site-specific soil management, from conventional ploughing to conservation tillage, on a range of economic and environmental indicators. Understanding the contribution of soil management to diffuse water pollution by sediment, nutrients and pesticides is integral to the project.

Catchment studies of the effects of conservation tillage on water quality and aquatic biota are comparing first order streams with catchments that are either conventionally or conservation tilled. A set of sites in woodland, which are not exposed to agricultural impacts, provide controls. Water quality and biological sampling has been undertaken bi-monthly since November 2004 and is scheduled to continue until the end of 2005. Biological data are still in the process of being analysed and are not discussed here. The present paper reports the results of water quality investigations over the first 6 months of the study.

To date, the study shows that, in winter, sediment loads in the conservation tilled streams are significantly lower than conventionally tilled streams, and similar to those seen in semi-natural woodland streams. Summer sediment levels are generally lower and not significantly different between sites. Nutrient levels are more varied: in winter, total phosphorus concentrations were lower in 'conventional' streams and slightly elevated in 'conservation tilled' streams; however, phosphorus levels in all of the study streams were quite low and at levels where only minor biological damage would be expected. There was no difference in nitrogen concentration between 'conservation tilled' and 'conventional' streams; both were significantly higher than the natural woodland background level. Preliminary implications of the results are discussed.

Demonstration and dissemination is of key importance to SOWAP and project information is freely available at [www.sowap.org](http://www.sowap.org)

## Soil management effects on runoff, sediment and phosphorus loss in the Hampshire Avon catchment

### Paul Withers

ADAS Catchment Management Group, Sunnyhill House, 1 Thistlebarrow Road, Salisbury  
Wilts SP1 3RU  
Tel/Fax No: 01722 417491 Mobile: 07880 783591 E-mail: [paul.withers@adas.co.uk](mailto:paul.withers@adas.co.uk)  
[www.adas.co.uk](http://www.adas.co.uk)

The impact of soil and crop management on runoff, and sediment and phosphorus (P) mobilisation, from field plots on three different soil types in the Hampshire Avon catchment were monitored over two successive winters as part of a campaign of demonstration events run by the Environment Agency. The Hampshire Avon is a priority catchment suffering from diffuse pollution and the demonstration events were organised to encourage farmers to adopt improved soil and crop management practices to reduce sediment and P loss in land runoff. The results showed that land management can have a large impact on runoff rates, and subsequent sediment and P movement on hill slopes, and that the causes and effects are soil type and site specific. For example, late drilling in one year increased overland flow rates on a Greensand soil prone to capping from ca. 2% to 13% of incoming rainfall, with consequences for increased flood risk. The mobilisation of SS and P in runoff was consistently less under reduced cultivations than when the soil was ploughed, and avoiding tramlines running parallel to the slope reduced runoff by between 25 and 40%. The data are being used to help calibrate and validate a decision support tool called PSYCHIC (**Phosphorus and Sediment Yield Characterisation In Catchments**) that facilitates the cost-effective targeting of a range of land management options to mitigate sediment and P loss in priority catchments with siltation and eutrophication problems.

Details of PSYCHIC can be found at [www.psychic-project.org.uk](http://www.psychic-project.org.uk).

## Organic manure management to the benefit of soil and water quality

### Brian Chambers

ADAS Gleadthorpe, Meden Vale, Mansfield, Notts, NG20 9PF

Tel No: 01623 844331 Fax No: 01623 844472 E-mail: brian.chambers@adas.co.uk

Approximately 90 million tonnes (fresh weight) of animal manure are collected annually from farm buildings and yards, and are subsequently applied to around one-third of the area of agricultural land in the UK (3.9 million hectares). Additionally, 0.52 million tonnes of sewage sludge (biosolids) dry solids are recycled to c.80,000 ha of agricultural land in the UK, and around 4 million tonnes (fresh weight) of industrial 'wastes' (including paper sludge, green waste compost and food processing 'wastes' etc). The application of organic manures provides a valuable means of replenishing soil organic matter (SOM) reserves and maintaining the inherent fertility of arable land; concerns have been expressed that SOM levels in some arable soils maybe reaching critically low levels and that crop production may not be sustainable in the long-term. Organic manure applications recycle c.10 million tonnes of organic matter (OM) to soils annually. Also, farm manure applications supply an estimated c.450,000 tonnes nitrogen (N), c.270,000 tonnes phosphate ( $P_2O_5$ ) and c.400,000 tonnes potash ( $K_2O$ ), and biosolids dressings c.18,000 tonnes N and 15,000 tonnes  $P_2O_5$  per annum. Their potential fertiliser value has been estimated at over £200 million per annum.

Recent research has quantified the medium-term effects of repeated farm manure additions on soil properties and has shown that manure OM inputs decrease topsoil strength and bulk density, and increase topsoil porosity and plant available water supply. Also, that manure OM inputs increase the size and activity of the soil microbial population, and potentially mineralisable N capacity of the soil. Overall, the measurements showed that repeated OM inputs changed a large number of soil properties, which in combination, produce important improvements in soil quality and fertility. However, it is essential to ensure that these applications do not result in elevated nutrient emissions to the water (e.g. nitrate, ammonium, phosphorus, faecal indicator organisms etc) and air (e.g. ammonia, nitrous oxide etc) environments. Nitrate leaching studies on free draining arable and grassland soils showed that losses were increased by the application of manures with a large readily available N content (i.e. slurries and poultry manures) during the autumn to early winter period. Moreover, it is important to ensure that strategies to reduce one form of N loss (e.g. nitrate losses by restricting autumn applications) do not result in enhanced losses of other nutrients to the water or air environments, so called '*pollution swapping*'. Recent studies on cracking clay soils have shown that moving slurry applications from autumn to spring is likely to increase phosphorus and ammonium losses in drainflow, due to 'by-pass' flow down cracks and fissures. Also, that ammonia emissions to air are likely to be higher from spring/summer slurry applications compared with autumn application timings.

The development of integrated manure management practices will be a key challenge in reducing the impacts of agriculture on diffuse water pollution. In particular, there is a need to improve farmer confidence in manures as a reliable source of plant available nutrients, and to develop manure management practices on cracking clay soils to ensure that strategies to reduce the loss of one pollutant do not exacerbate losses of other pollutants. Also, it is clear that an essential part of reducing the environmental impact of manure management systems will be investment in expanded manure storage facilities and improved manure spreading equipment.

## Organic matter in soils: maintenance and application – research into practice

**Tim Evans, PhD, FCIWEM**

TIM EVANS ENVIRONMENT, Stonecroft, Park Lane, Ashted, Surrey, KT21 1EU

Tel/Fax No: 01767 679908 Mobile: 07813 113235 E-mail: [tim@timevansenvironment.com](mailto:tim@timevansenvironment.com)

### Introduction

The basic principles of soil science are well understood, e.g. [1], but perhaps not widely enough appreciated and therefore they are not applied universally. The thing that distinguishes soil from ground up rock is that soil is alive. Soil organic matter is the engine room that powers the life of soil.

Soil is a function of parent material, climate, time [of development], position in the landscape [hilltop, valley floor, etc.], vegetation and use. 19<sup>th</sup> century soil scientists in the UK were overwhelmed by the influence of parent material (geology) because UK soils are relatively young and geology changes over short distances. To an extent this attitude persists today. It was V. V. Dokuchaev (1846 – 1903) who demonstrated (to Russell [1]) the importance of the other factors, and changed western soil science. He had surveyed huge areas of Russian soils all formed in similar geological material but over wide variation of climate and time. Time, climate, vegetation etc. all affect soil organic matter.

To grow plants soil must provide a medium for rooting and permit uptake of oxygen, water and nutrients. Soil contains mineral particles that have been classified pragmatically by soil scientists into different ranges of particle size, i.e. sand, silt and clay. In a healthy soil these mineral particles are aggregated into larger structural units that are stabilised by organic matter, carbonates and oxides. The fissures between these structural units provide drainage and gaseous exchange and the pores within them and the films around them provide reserves of water and nutrients. The mineral particles may provide reserves of nutrients and control the movement of nutrients down the soil profile in drainage water e.g. by cation exchange.

These features are also very important for our water strategy. Soil has an essential filter function for water to sorb and degrade chemical and biological contaminants. Good soil structure is also essential to allow infiltration of rainwater and thus modulate flow to surface waters and the risk of flooding. Climate change has a major involvement with water strategy (both resources and drainage); soil is an important reservoir of carbon and provides a significant opportunity for carbon sequestration.

Soil organic matter is the glue that holds soil structure together and the waterproofing that protects it. It is also a very important component of cation exchange and a major reserve of plant nutrients, especially nitrogen.

### Restoration and Topsoil Manufacture

#### Introduction

Plants will grow quite happily without these reserves of nutrients, indeed crushed brick with liberal use of water soluble mineral fertiliser performed very well when Bloomfield *et al.* compared material sold as topsoil in NW England [2], but for a successful sustainable landscape, nutrient reserves are essential unless continuous feeding is planned. This was demonstrated by Coker *et al.* [3] at Smallford in Hertfordshire where wastewater biosolids (sewage sludge) were compared with mineral fertiliser. The site was a former gravel quarry

that had been landfilled and capped with calcareous clay textured material and sown with grass. The study showed that when organic matter was applied at 50 tDS/ha or more as biosolids a fertile soil was created that sustained plant growth. However when mineral fertiliser was used alone, plant growth stopped when fertiliser additions ceased, i.e. there was no residual value. Farmers and gardeners know intuitively the value of organic matter and the importance of maintaining soil in good heart.

The answer to why some reclamation projects are successes and others are failures almost invariably lies in the soil and site preparation and drainage. This may be because of the quality of the soil that was originally supplied, how it was handled, the design of the drainage scheme and slopes, or the aftercare programme. BS3882:1994 "Specification for topsoil" [4] was developed and written to answer these questions and contains verifiable specifications with standard methods of analysis and a code of practice for handling soil.

A good rule of thumb for successful restoration is that the topsoil should contain at least 1,500-2,000 kgN<sub>organic</sub>/ha [5]; above this threshold plants can obtain the 100 kgN/ha/year they need to grow, they then cycle organic matter and nutrients in leaf fall and soil develops. Even this is modest in comparison with good fertile soil that might contain 5,000-20,000 kgN<sub>organic</sub>/ha.

Temperate soils tend to a carbon: nitrogen ratio of about 12:1 – that's just how it is. The European Commission has identified loss of soil organic matter as one of the key threats to soil [6]; experts talk about 2%-3% organic matter being a critical limit below which soil becomes very vulnerable to erosion. 2% organic matter at a C:N of 12 equates to 2,300 kgN/ha in 20 cm of topsoil.

It is interesting that all of these figures for organic matter or nitrogen are in the same ballpark. This means the minimum for effective restoration of a soil-forming material with no organic matter (unlikely) is about 100 tDS/ha biosolids or farmyard manure or 150 tDS/ha compost. These are much higher rates than for agricultural use because you are trying to kick start a soil in contrast to maintaining a healthy one. They greatly exceed the nitrates directive [7] or code of good agricultural practice [8] limits (170-250 kgN/ha) so it's fortunate that restoration is outside their constraints, it is not [yet] agriculture. Follow their guidance and you are never going to achieve good restoration; it's a "no brainer".

In the context of the water strategy it is worth noting that the 1980s conventional thinking about the health risks of dietary nitrate is now looking decidedly flawed [9 and 0]; dietary nitrate has been shown to be protective against food poisoning.

Exogenous organic matter (EOM: biosolids, compost, manure, etc.) can provide the organic nitrogen and the organic matter needed to stabilise the structure of the soil. In the case of colliery spoil with a high potential acidity that addition of EOM will inhibit pyrite oxidation and buffer the pH, which reduces the rate of acidification.

Adding earthworms to low organic matter soil is a waste of time because they will simply die, but if the soil conditions are improved earthworms will colonise naturally. In about 1980 I conducted a replicated operational-scale field experiment (unpublished) measuring cereal yields related to agricultural rate biosolids application and earthworm activity. The site had been continuously cropped with cereals for 25 years. In two years the number of earthworms doubled in response to biosolids, the weight of each also doubled (i.e. quadruple the total mass) and deep burrowing species (*Allolobophora longa*) colonised the plots. It was too far for them to have migrated laterally so eggs must have been introduced in bird droppings.

### Practical Applications

The ability to manufacture topsoil that performs consistently and well using selected mineral material, for example some subsoils and selected screened C&D waste, and stabilised organic matter (biosolids and compost) has been proven since the late 1980s. This experience and other information informed writing the British Standard [4]. In the late 1980s Thamesgro Land Management was supplying approximately 200,000 tonnes topsoil per year manufactured to this specification to the London market. It was the basis of much high quality landscaping, for example the Eastern Gateway and Stockley Park.

Stockley Park, west of London (Figure 1) is a well known example of using organic amendment (in this case air-dried digested biosolids) to build topsoil to a defined specification [4]. Alan Tate, President of the Landscape Institute, presenting the Institute's Design Award in 1995, said Stockley Park is "regarded as the doyen of British Business Parks and a rare example of an entirely man-made landscape that provides a standard for the reclamation of other polluted and derelict land".



**Figure 1 Award winning Stockley Park, a landscaped business park that used biosolids to make the soil** (Tim Evans)

The site is more than 100 ha; it was a gravel quarry that had been filled with refuse since the 1940s. Before reclamation work started in the 1980s it was derelict and a source of groundwater pollution. 4.6 million m<sup>3</sup> of fill were excavated to expose 10 ha on which to build the campus-style business park. This fill was contoured over the rest of the site to make a rolling landscape that is mainly used as an 18-hole championship golf course designed by Robert Trent Jones and also lakes, running and riding tracks. The site would have needed more than 300,000 m<sup>3</sup> topsoil; there was none on site, so it was constructed *in situ* using suitably textured mineral material found during the excavations and 100,000 m<sup>3</sup> air-dried biosolids. More than 140,000 indigenous trees and shrubs were planted "the establishment of the woodland plantations has been phenomenal and is witnessed by the truly rapid growth rates and the very small number of failures, which is less than 5%. For a landfill site that is simply extraordinary" said Bernard Ede the landscape architect. He also said "the initial scepticism about heavy metals ... proved an unnecessary precaution".

In South-eastern Colorado there's another imaginative use of EOM for land restoration of the dunes from the 1930s "dust bowl" era; they are barren and the cause of air-quality and other problems.

Various attempts have been made over the years to establish vegetation to stop the sand blowing so soil formation can happen. Old tyres (to reduce wind speed at ground level) and manure (to add nutrients) were used to try to stabilise the dunes but with very limited success.

In the 1993 dewatered digested biosolids from New York City was being shipped westwards by train and it has produced the answer to vegetating and stabilising the dunes. Mike

Sharpe of Parker Ag Services, Colorado designed an imaginative strategy to trap the dunes without leaching N to the groundwater (Figure 2). He applied woodchips were at 25 t/ha and then the biosolids at 75 t/ha, which supplied 3000 kgN/ha. The woodchips were used as a source of carbon to trap the nitrogen from the biosolids in soil microbial biomass and prevent N-leaching. The two materials were incorporated by discing and then seed mixture comprising native and drought tolerant species was sown at just 5 kg/ha. The strategy worked, there has been no increase in nitrate in a borehole about 1 km from the site, the vegetation is healthy 10 years after application and the dunes have been stabilised.

Using organic resources to manufacture topsoil completes a cycle by taking wastes from the urban community, treating them; using them as constituents in manufacturing and finally returning the topsoil to sites in the urban area for their beautification, increase in biodiversity and substitution of primary raw material (i.e. avoiding excavating natural topsoil).

Use of exogenous organic matter is often a key constituent of successful restoration. Each scheme requires a tailored approach. If you treat it like dirt, that's what you will end up with. As Bernard Ede, Mike Sharpe and others have found if you apply basic soil science principles you can achieve good soils supporting sustained plant communities.

### Restoration Conclusions

It's not rocket science, actually it's Soil Science: successful land restoration does require choices and site specific designs. It won't work if you apply the rules for catchment sensitive farming slavishly though the founding principles are similar but they require thought and judicious application Farming

**Figure 2 Successful restoration in Colorado (left) the untreated dune with a buried fence line in the foreground, with 2 more below it (right) 10 years after the biosolids/woodchip treatment** (Mike Sharpe)



## Introduction

There has been settled farming in Europe, the Middle East, India and China for more than 4000 years. Farmers learnt that the only way to keep farming the same piece of land was by returning fertility to the soil by crop rotation, dung, manure and any other amendments. Even so, yields were only 20% of those achievable today; the crops were taking less out of the soil and they only needed to feed a smaller population of humans and animals.

Even into the first half of 20th century the stock of manure on a farm was part of its valuation when it was sold or its tenancy changed. It was a valuable asset rather than the almost liability that it has become on low-labour intensive livestock farms that buy in feed. The pursuit of plentiful, inexpensive food has resulted in larger and larger livestock operations, sometimes close to processing facilities, for example the concentration of milk production and dairy processing in the Chino Basin in California. The food is bought in from farms far distant from the livestock operations and the prices paid for the livestock outputs do not support the cost of returning the manure to the land that grew the feed. Smaller mixed farming systems cannot compete with the economies of scale of the mega units and as a consequence they consolidate into larger feed-production enterprises.

In the 19th century it was said that "the smoke from a factory chimney does not appear its cost curves", the same was true of the manure from concentrated animal feeding operations (CAFOs) until the laws of ecology [11] operated. After stormwater washed accumulated manure into water courses the inevitable legal instruments were enacted to force more sustainable management of manure and nutrient management plans, notably for nitrogen and phosphorus [12]. The cost of managing the manure returned to the cost curves; whether this will result in a restructuring and relocation of the industry remains to be seen, or whether it will make imported products more competitive. One effect of the legislation, and the need for renewable energy, has been an upsurge of interest in biogas production from manure and other organic residuals. In Europe livestock enterprises also increased in size for a variety of social and economic reasons; this impacted on groundwater and surface water quality and resulted in the Nitrates Directive and the Water Framework Directive ([7] and [13] respectively).

## Mixed farming at high elevation in Austria

Bernhard and Andrea Ebner farm south of the small market town of Dimbach in Upper Austria. They have been using lime-stabilised dewatered biosolids every year since 1994. Their 30 ha farm is 50km east of Linz; it is a typical of the Bohemian massif area. They raise cattle for milk and beef. The farm is half grass and half arable. The arable crops are maize, triticale, spring barley, oats and clover. By using limed biosolids every year in combination with the manure from their cattle the soil phosphate content has increased from



level A (deficient) to B-C (average to good). Soil pH has increasing from 5.1–6.2 (which would be too low for optimum crop yield) up to 5.5–6.7. Potassium and magnesium are now in the optimal range. The crop yields are significantly above the average for the area. The soil-structure is better than 9 years ago so it is easier to cultivate and less likely to erode. These soil improvements mean that the Ebners are able to grow maize without problems even though they are situated 650 m above sea-level and the annual rainfall is 800-900 mm.

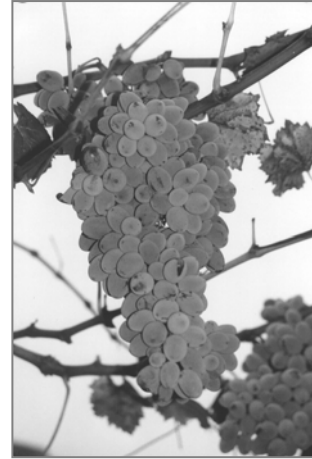
## Viticulture in France

Patrick Thubert runs 63 ha of vineyards designated as "Côtes du Roussillon" near Perpignan. He regularly uses composted biosolids that he spreads either before planting or on

established vines. "In our area, there is a huge deficit of organic matter in the soils and some of them are near desertification" he says. "The spreading of composted biosolids allows us to recreate a microbial life which has nearly disappeared because of the exclusive use of mineral fertilisers".

"The improvement of the soil structure has beneficial impact on the root development of the vines and limits erosion, especially during thundery episodes which are quite frequent in our region. Finally the increase of organic matter content also helps the growth of grass between the vine rows and regulates the water supply of vines better during the droughty season."

Other Mediterranean wine growers are (like Patrick Thubert) using more and more composted biosolids in order to produce quality wine.



### Arable Farming in Germany

Henry Grimm has a 180 ha family farm at Worpswede near Bremen. He grows maize, oilseed rape, wheat and sugar beet. "The land I farm has been owned by my family since 1756. For the last 15 years we have been using biosolids on approximately 100 ha. We save money using biosolids on our sandy soil instead of chemical fertiliser and at the same time we increase sustainable productivity." Henry Grimm says his farm, which is a family enterprise, benefits greatly from the use of biosolids from hanseWasser, Bremen; applying it to land improves soil properties and plant productivity, enhances moisture retention and reduces dependence on chemical fertilisers. Regular soil analysis and advice on application rates make sure that in the future his now 16-year old son can take over the farm.

Dr. Joachim Wendt, has a 105 ha farm at Oberboyen in Lower-Saxony and he is also one of hanseWasser's four consultants to other farmers. Like Henry Grimm, he grows maize, oilseed rape, wheat and sugar beet and uses biosolids on about 70 ha of the farm. "Lower-Saxony is very much an agricultural state – we have lots of farms here. I, myself, have used biosolids on my farm for the last 10 years and I am very convinced by the product. The biosolid material that the farmers in the area receive is high in nutrients and low in toxic agents. That was reason enough for me to also work part time as a consultant. For Lower-Saxony my prognosis is an increase in the use of biosolids – there already has been a dramatic increase over the last 5 years. Farmers understand that there is no other fertilising material that is as regularly analysed as biosolids – it is the ideal soil enhancement."

### Oregon USA

K&S Ranches in Oregon was started in 1914; it is a family business and has grown to more than 8,000 ha of rangeland by good progressive farming. The current farmer, Kent Madison, started using biosolids in about 1990. He has 3 full time employees sampling the soil and crops, applying the biosolids, maintaining the roads, loading areas and machinery. They use about 180,000 t dewatered digested biosolids each year mainly from the city of Portland. 0-8 cm soil samples show that the content of major and minor nutrients has increased. There is 3.2% organic matter in the treated soil compared with 1.3% in the untreated and the cation exchange capacity has increased by 50% which means that nutrients are not lost by leaching.

The important thing for K&S that the yield of grass has increased from 0.4 to 2.47 tDM/ha



and the crude protein from 5 kg/ha to 60 kg/ha, i.e. the grass has a better food value. There is a 7:1 conversion ratio of feed to beef from the treated grass compared with 15:1 from the untreated grass, which has less young growth. This translates into 255 kg beef per day from the treated grass compared with only 20 kg/day from the untreated because there is more forage and it is of better quality.

Kent Madison says "Using biosolids is good for the farm and it's good for the environment as well; there's more wildlife on our treated rangeland, as well as all the benefits to soil and crops."

## England

Maize silage provides essential winter food for farmer Nigel Powell's beef cattle in Hampshire but he farms on acid sandy soil "In a dry summer this sandy soil looks more like a desert than farmland and crops die back rapidly. But using biosolids ensures this does not happen and guarantees a worthwhile crop can be cut every year." Nigel had no hesitation about using biosolids when he took over the farm because he had been a contractor and had seen what it did for other farms. "Maize on treated land emerges rapidly and grows much faster than on untreated land. It stays healthier and no fungicide is needed. It stays greener longer. The overall yield is a bit better than maize grown just with bagged fertiliser but it has bigger cobs so the feed value is better. We must be saving at least £25 /ha [on reduced fertiliser] then we benefit from the extra yield and the feed value. But the biggest advantage for us is knowing that we will be able to harvest a reasonable crop whatever the season. This is very important on the drought-prone land."

Chris Ashley, who farms in Shropshire, said "When I came to this farm in 1958 there were terrible problems with wind erosion and blowing soil, it regularly blocked the roads and even the railway. Nobody else would take it on but I was keen to farm. We used to have livestock and the manure helped the soil but have had none since the foot and mouth of 1967. Wind blow was so bad I often had to drill sugar beet twice because the soil and seed were blown away the first time.



"I began using liquid digested biosolids more than 20 years ago. Recently we changed to dewatered digested cake. Normally we apply biosolids before cereals and sugar beet. Soon after we started we were able to grow wheat for the first time."

The soil is free-flowing sand. "Since using biosolids, the blowing problems have stopped, the soil has become less droughty and has taken on a darker colour and is generally more fertile. There has been no blowing for 15 years. Sometimes the water company would top-dress newly sown soil with liquid biosolids for me if it got very windy and this stopped blowing. We never need phosphate fertiliser because the soil levels are good and just use 50 kgN/ha, 130 kgK<sub>2</sub>O/ha and 1.7 litres/ha of manganese because the soil is manganese deficient. The amino-N of my sugar beet is always good, unlike my brother who uses chicken manure – his are very high." [Amino-N is a quality measure, it is related to the nitrogen fertilisation, if it is high it makes sugar processing more difficult.] Chris said of public reaction to his use of biosolids, "Sometimes people in the village ask why I use biosolids but then they come from miles around to buy my potatoes. We are very pleased with the results!"

David Parker has a 400 ha mixed farm near Oxford and estimates using biosolids has trimmed £5000 off his annual fertiliser bill without compromising yields. "I have been able to cut back

sharply on the amount of bagged nitrogen top-dressing applied to grass, cereals and oilseed rape and have not had to buy any triple superphosphate."

A third of the farm is greensand and the rest is clay. There is a dairy herd, beef fattening and arable.

David, whose opinion is highly respected by his fellow farmers, said "I first used biosolids after seeing other farmers successfully using it. I am a chemist by training and knew of the potential risks from heavy metals and did not want to kill soil that my family has farmed for over 200 years. It was only when I was convinced it was risk-free that it was applied here."

"The effect of biosolids on winter barley was dramatic. There were twice as many strong tillers by Christmas ... there was nothing wrong with the non-biosolids crop [treated with farmyard manure, FYM] but when grown alongside ... it was made to look second rate ... [biosolids] yielded 0.5 t/ha more than the FYM-treated crop."

Peter King runs the 1,100 ha arable side of a mixed farming estate in Berkshire, that includes two dairy herds and three pig units. He has used dewatered digested biosolids for many years on the chalk hills with clay caps that he farms. He says "it is a valuable source of

nitrogen, phosphate and trace elements so provides enormous scope for cost-cutting". Peter found more tillering (shoots per plant) of wheat on treated land and therefore cuts back seed rate by 20% so that each plant can reach its full potential. Savings amount to £25-30 /ha for N, £20-25 /ha

for P<sub>2</sub>O<sub>5</sub> and £10-13 /ha for seed. Against this was a small increase in use of slug pellets and of growth regulator (to keep the crop standing up).



## Conclusions

It's often hard to quantify the benefits of organic matter because soil physics measuring techniques have difficulty picking up the effects, but plants know the difference and so do the farmers who grow them.

## Managing Risks

No discussion of biosolids would be complete without mentioning the hazards and how their risks are managed. EOMs contain everything that was in the original plant material (including when it has passed through an animal) they also contain anything that is environmentally ubiquitous. Measuring detectable quantities of these elements and compounds in EOMs is to be expected. Paracelsus wrote 500 years ago: "Dosis facit venenum." ("The dose makes the poison."). The relationship between dose and response (effect) is still one of the most fundamental concepts of toxicology (the science of poisons), but when we discuss environmental alarms and chemical health risks it is sometimes forgotten. The dose that is delivered to a receptor depends on the concentration in the EOM (source) and how much the matrix of the EOM controls the release of the substance, the chemistry of the soil to provide a pathway to the receptor and the uptake from the soil by the receptor. The UK Sludge use in agriculture regulations [14] were based on the results of field experiments and are being vindicated by a 9 site long-term field trial.

The idea persists that biosolids contain dangerously large concentrations of potentially toxic elements (PTEs) and persistent organic pollutants (POPs). This is far from the truth. By continuous work with industry the content of PTEs in biosolids has been reduced (**Error!**

**Reference source not found.**); the content of POPs has been managed by restricting the manufacture and marketing of those deemed necessary and by restricting emission from

combustion. Concentrations of substances like dioxins and furans have decreased substantially (**Error! Reference source not found.**). Surveys of biosolids and risk assessments based on the results have shown there is no need to monitor these routinely in biosolids.

Use of biosolids according to the Sludge Regulations gives an exemption from the Waste Management Licensing Regulations and the recent very regrettable "stealth tax" for the EA registering exemptions, except where the biosolids have to be stockpiled. The stealth tax for registration still applies when one is improving the environment by using biosolids or other EOMs for land restoration. Practically risk management means sampling and analysing the biosolids and ideally liaising with the source control team (variously called Trade Effluent, Catchment Control, or Pre-Treatment) to investigate and control any works where there are anomalous results. It also means analysing the soils prior to commencing a programme of application and then maintaining a balance sheet of the cumulative loading, which will trigger a re-sampling when the soil concentration is expected to have changed significantly. This re-sets the balance sheet, though the previous records of biosolids and loading would be maintained. The records are to be available for inspection by the regulator (EA, SEPA, etc.) at any reasonable time. The information must also be supplied to the person whose land is treated. In order that they can make best use of the nutrients, and use the optimum amount of complementary mineral fertiliser, it is best that this information is presented in agronomic terms about the fertiliser replacement value. It is therefore wise to include field trials of agronomic value in any significant EOM recycling programme; however there is also generic information if more product specific data are not available [15] and [16]. Optimum use of plant nutrients is an essential part of the water strategy.

### Conclusions

The water strategy and the soil strategy have crossovers. When wastewater is cleaned so that it is safe and beneficial to release back to the water environment we also have nutrient and organic rich residuals. The more the water is cleaned the more residuals are generated. Soil benefits from organic matter because it improves structure and makes soil more resistant to erosion, thus protecting water. SOM also improves the filtering capability of soil by increasing the CEC and stimulating the biomass, which protects recharge by percolating water. Enhances infiltration capacity (including increasing resistance to shatter and capping) modulates the release of rainwater to ditches, streams and rivers; this reduces the risk of flood surges. SOM decreases risk of soil erosion and thus reduces the risk of P-eutrophication (most P is lost as particulate-P associated with soil) and also reduces siltation of spawning grounds for fish. Brownfield development is a better alternative than greenfield development; one key to brownfield development is often the availability of topsoil to landscape it. By judiciously employing the principles of Soil Science we can manufacture topsoil that will support a self-sustaining healthy plant ecosystem. Climate change is a major threat to the water strategy; soil can sequester large amounts of carbon.

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14 The Sludge (Use in Agriculture) Regulations SI 1263, as amended by The Sludge (Use in Agriculture) (Amendments) Regulations 1990, SI 880. HMSO, London.

15 MANNER is a decision support system that can be used to accurately predict the fertiliser nitrogen value of organic manures on a field specific basis.  
<http://www.adas.co.uk/manner/index2.html>

16 PLANET, computerised version of Defra's 'Fertiliser Recommendations (RB209)' book - it gives recommendations for arable, horticultural or grassland crops in each field, each year, taking account of the crop nutrient requirement as well as the nutrients supplied from organic manures, soil and fertilisers. <http://www.planet4farmers.co.uk/welcome/index.html>

## Is there a link between soil compaction and flooding? A review of the evidence

### John Hollis

Principal Research Scientist, Soil Systems Group, National Soil Resources Institute,  
Cranfield University, Silsoe, Bedfordshire, MK45 4DT Tel No: 01525 863250  
Fax No: 01525 863253 E-mail: [j.hollis@cranfield.ac.uk](mailto:j.hollis@cranfield.ac.uk)

### Land Management and soil hydrology

Inherent soil physical characteristics constrain the mechanism and pathways by which excess precipitation moves from the land to surface waters. The Hydrology of Soil Types (HOST) Classification system (Boorman *et al*, 1995) groups soils into different categories according to these inherent characteristics and provides a direct link between the soil and catchment stream responses. Land management practices impact on soil physical characteristics and modify the hydrological response to rainfall. The impact of various land management practices on in-field or hill-slope runoff is well known and documented (O'Connell *et al*, 2004; Godwin & Dresser, 2003) and evidence of the extent of soil structural damage related to specific management practices is accumulating (see references below). Current government initiatives relating to good soil management and environmental stewardship (see links in references below) are designed to mitigate such structural damage with perceived additional benefits to water quality and reduced flood generation.

### Is there a link with flooding?

A recent comprehensive 'Review of the impacts of rural land use and management on flood generation' has been carried out (O'Connell *et al*, 2004: <http://www2.defra.gov.uk/research/>). Whereas there is good quantifiable evidence that a number of modern land management practices result in significantly increased in-field surface runoff and that specific mitigation practices significantly reduce such runoff it is at present unclear how much of this runoff is transferred to the surface water network or how it affects local stream response and flood frequency. When attempting to clarify this issue, it is important to distinguish between different types of flooding events within the landscape. Localised 'flash' or 'muddy' floods generated via surface runoff and channelling of flows through the landscape are very different to 'out of bank' flooding where large streams and rivers overflow into adjacent low-lying areas. There is good evidence from the UK, northern France, the Netherlands and Belgium that specific arable management practices result in localised and seasonal 'muddy floods' and that specific changes in management practices can reduce the frequency of these floods. However, although the two types of flood events are often linked, there is clear evidence that local flash or muddy floods are not always transferred to the surface water network in amounts large enough to cause 'out of bank' floods in the local stream valleys. Direct evidence that land management practices can affect 'out of bank' flooding would require systematic and targeted catchment level studies, which, at present, have not been carried out. This represents a significant knowledge gap that needs to be addressed.

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PALMER, R.C. (2005). Soil structural conditions in the Frome catchment during March 2004. NSRI research report No. YSR9145V for Environment Agency.

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**Links to Government Initiatives on soil and environmental stewardship**

Cross compliance:

Soil

<http://www.defra.gov.uk/farm/capreform/pubs/pdf/Soil-hb.pdf>

Habitats and Landcsape

<http://www.defra.gov.uk/farm/capreform/pubs/pdf/habitat-hb.pdf>

Agri-environment

Entry level handbook

<http://www.defra.gov.uk/erdp/pdfs/es/els-handbook.pdf>

Soil management plan as part of ELS

<http://www.defra.gov.uk/erdp/pdfs/es/guidance/soil-management-plan.pdf>

Farm environment record for ELS

<http://www.defra.gov.uk/erdp/pdfs/es/maps/example-els-fer.pdf>

## Flooding and erosion – key issues and ways forward?

### John Boardman

Reader in Geomorphology and Land Degradation, Environmental Change Institute,  
University of Oxford, South Parks Road, Oxford, OX1 3QY Tel No: 01865 285075/285183  
Fax No: 01865 275850 E-mail: John.Boardman@eci.ox.ac.uk

I confine my remarks to flooding as a result of runoff from agricultural land ('muddy floods') which affect property (Boardman et al., 2003; Boardman et al, in press). However, the fact that these phenomena are strongly controlled by land use (rather than extreme climatic events) should give us pause for thought with regard to major catchment flooding and the rush to blame 'climatic change'. This is an under-researched topic.

On the South Downs, we have much evidence that suggests that runoff from arable fields, carrying with it soil, is initiated by relatively frequent rainfall events of low magnitude: 30mm in 2 days. Larger events lead to more serious runoff and severe erosion (Boardman 1988). Grassed surfaces, or arable crops with more than ca. 30% crop cover, do not generate significant runoff, and any runoff occurring is clean water.

The association between winter cereal fields, muddy runoff and the risk of property damage has been understood since 1982 (Stammers and Boardman, 1984). Convincing the farming community, local authorities, MAFF/DEFRA, the public etc has taken rather longer but attitudes have now changed.

The case of flooding at Breaky Bottom vineyard on the South Downs illustrates the major importance of land use in generating runoff rather than excessive rainfall (Boardman and Robinson 1985, Boardman 1988, Boardman 2001).

Ways forward? The problem may cure itself due to significant changes in land use at key sites driven by new agri-environmental measures. But it may not!

On the South Downs a range of solutions have been tried: small dams, re-routing of runoff, conservation tillage and land use change.

It is clear that reliance on 'engineering solutions' will not work. Success has to be based on land use change at critical localities which reduce runoff from steep slopes, provide protection for valley bottom flow paths, and break-up large areas of winter cereal fields - a connectivity problem (Evans and Boardman 2003).

The challenge is in fact far greater in areas of high value crops e.g. on the Lower Greensand soils of the Rother Valley, West Sussex. Here, very significant incentives will have to be offered to farmers to move from potatoes, maize etc on vulnerable soils. It is very doubtful if current measures of encouraging shifts in drilling dates, and a coarser tillage will have any effect.

A more general point is that local authorities who have had to deal with the problems of property damage suffer from short-term institutional memory, lack of co-ordination with other local authorities, and a strong predisposition to resort to engineering solutions to flooding problems. This is excusable when short-term emergency solutions are needed, but there is little incentive for them to address the flooding problem over longer time scales.

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