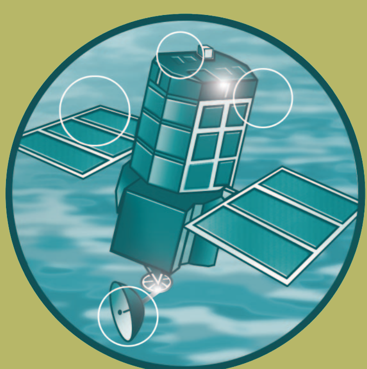
Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Review of impacts of rural land use and management on flood generation

Impact study report

Appendix D: Socio-economic dimensions of flood generation from agricultural land

R&D Technical Report FD2114/TR



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Appendix D: socio-economic dimensions of flood generation from agricultural land

R&D Technical Report FD2114/TR

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Statement of use
This report is aimed at those involved in land management. It provides the current position of knowledge and science with respect to land use management and its impact on flood generation. It will be of benefit to those seeking to reduce flood risk though specific land management practices, and those who wish to assess the impact of specific management practices on flood risk.

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Executive summary

FD2114/TR, the 'Impact Study Report', introduces the FD2114 project and gives a comprehensive review of the impacts of rural land use and management on flood generation. Project FD2114 is part of the Broad Scale Hydrology Modelling Programme (Calver and Wheater, 2001).

This report, which constitutes Appendix D of FD2114/TR, reviews the social and economic dimensions of the link between rural land use and flood generation using the Driver-Pressure-State-Impact-Response Framework. It considers policy interventions to reduce flood generation, adopting the perspectives of policy makers and land managers. The extent to which agri-environment schemes provide an opportunity to reduce the probability of runoff is also explored. The Appendix also explores possible long futures as these might affect the interrelationship between rural land use and the potential to generate floods.

The Appendix focuses on land use as it might affect runoff with potential to cause flooding. The impact of floods when they do occur, and therefore the justification for interventions to control runoff where this is a known contributor, is not dealt with in detail (although some mention is made of costs attributable to local muddy floods). The contribution of runoff control to the management of flood risk would require an assessment of flood damage and this goes beyond scope of the current enquiry. Suffice to say that there is greatest interest in controlling runoff, where to do so will reduce the risk of flooding to urban property. A further point of clarification is required. Although the focus is often on the potential of surface runoff to contribute to flood generation, the movement of soil water must not be overlooked, especially as much intensively farmed land has been artificially drained to increase the evacuation of excess water during and after rainfall events.

There is considerable evidence to show that the incentives provided by agricultural commodity markets and prices are the key driver for rural land use. These incentives are, however, strongly influenced by government agricultural policy that subsidises particular types of land use as a means of providing support to farmers and the rural economy. Public funding of improved drainage for agriculture was a key component of support for the sector between 1950 and 1980. Together with changing agricultural technologies and associated farming systems, these market and policy drivers have tended to increase the pressure on soil and water resources as farms have become larger, more intensive and more specialised. In particular, conversion of grassland to arable in lowland areas and increased animal stocking rates in upland areas have in some cases led to increased water erosion and runoff, thereby deteriorating the ‘state’ of soil and water resources.

Evidence suggests that where runoff and associated water erosion have contributed to flooding the resultant impacts have been greatest beyond the site (and in most case the farm) of origin, giving rise to significant ‘external’ costs borne by society at large. The on-farm costs of runoff are small compared to the potential gains from intensive land use. Thus there are few incentives to land managers to control runoff.

There is evidence that changes in land use have been associated with localised ‘muddy floods’, in some cases with farmers found liable for the damage caused to others. Although the Environment Agency estimate that land use on ‘hill slopes’ contributes £115m per year to flood damage, there is limited evidence to support this.

There are currently few policy interventions which explicitly address control runoff from rural land, although some features of agri-environment schemes include components which are likely to reduce runoff. Interventions which seek to reduce near-source drivers and pressures associated with land use change are likely to prove more effective and efficient than interventions to mitigate impacts, especially as the drivers themselves are defined by policy. This involves discouraging inappropriate land use and farming practices where these are clearly linked to increased runoff with potential to cause flooding.

Response themes to control runoff will reflect the dominant purpose of rural land, whether mainly farming for food production or a multi-functional approach to land management including contribution to biodiversity, hydrological processes and sustainable rural economies. This will influence the promotion of integrated rather than single purpose solutions to problems associated with land management.

The diffuse nature of rural land management and related flood generation suggest that, on its own, mandatory regulation would prove ineffective and inefficient, being difficult and costly to administer and enforce, and possibly insufficiently flexible to deal with local circumstances and practices.

Given the evident responsiveness of farmers to financial inducements, the best approach would appear to be a mix of economic and voluntary instruments, supported by advice and technical support. In cases where runoff has the potential to add significantly to flood risk, it may be necessary to regulate against particular practices. Such a ‘fit for purpose’ approach is compatible with the Environment Agency’s recent adoption of a diverse approach to environmental protection, much of it driven by a need to reduce the burden of regulation for all parties.

Experience of the adoption and diffusion of technology in the farming sector can help to design and promote appropriate soil and water conservation measures to reduce runoff from farmland. Proposals must offer relative advantage (including the advantage to farmers of the ability to demonstrate compliance with regulatory requirements), be practicable, and make a difference. It is important therefore that runoff control techniques are proven locally, are championed by opinion leaders, and supported through research and extension.

The criteria of effectiveness and efficiency require that policies to reduce flood generation from rural land adopt a risk-based approach at the catchment level. It will be important to be able to attribute particular land use and management practices to flood risk (defined in terms of probability and consequences) and from this determine the contribution of suitable and proportionate intervention measures. It is clear therefore that the links between land use and flooding at the catchment scale need to be assessed to inform a strategic approach, including choice of intervention measures and instruments.

It is apparent that although the existing state of knowledge can reasonably estimate the probability of runoff at farm level (and the efficacy of interventions to control this), it is not easy to connect this to flood risk at the sub-catchment and catchment scale. A catchment/coastal zone approach is required to capture the aggregated impact of interventions, especially of individually small measures such as on-farm runoff controls. Research is required to test and validate these linkages as a prerequisite for policy formulation.

Given the critical role of agricultural policy, it seems appropriate to include compliance with runoff control measures as a condition of support to farm incomes, especially those regimes which promote environmental protection. Agri-environment schemes, notably the Environmental Area Scheme and the Countryside Stewardship Scheme, are used by the Government in England and Wales to encourage the sustainable development of rural areas and to deliver public benefits associated with land management. Although at present these schemes do not contain specific components for the control of runoff from farmland flooding, there are a number of management options that may help to do so. These include payments to farmers to revert arable land to grassland, establish field margins and related boundary features, introduce buffer zones between farmed land and watercourses, retain stubble in fields during winter, and restrict animal stocking rates. New arrangements for 2005 are currently under review. They may include measures to reduce soil erosion and associated runoff on cultivated land with relatively light soils on hillslopes. There may be requirements to cultivate along contours, adopt direct drilling and avoid of crops such as maize that can increase the vulnerability of soils. Such targeted measures, together with the generic promotion of those mentioned earlier, could help to reduce runoff and the probability of flooding.

Proposals for the new Environmental Stewardship Scheme include reference to the protection of soils as a primary objective. A specific secondary objective is to contribute to the improvement of flood management. It is anticipated that this will be met through the adoption of particular land management options to help reduce runoff such as those mentioned above, together with options to temporarily store excess water such as on farm retention reservoirs and washlands. It remains to be seen how many of these options are adopted in the final scheme but it is likely that the majority will appear in some form.

With respect to long term futures, the Foresight scenarios suggest that the probability of runoff from rural land and hence the contribution to flood generation varies according to the type and orientation of farming systems. Under the ‘utilitarian’ World Markets and Provincial Enterprise scenarios, the probability of runoff increases in intensively farmed areas. Under the more ‘community’ oriented scenarios of Global Responsibility and Local Stewardship there is an embedded commitment to sustainable land management practiceswhich, amongst other things, reduce the probability of runoff.

Although there is a tendency in flood management to focus on surface water flows and flooding, in a rural context the role of groundwater is critical and needs explicit consideration in any strategy to manage the interface between rural land and flood generation. Furthermore, the potential contribution of artificial agricultural drainage systems (usually associated with intensive land use) to catchment runoff must not be overlooked.

A key influence on the justification for intervention is likely to be the management of flood risk to urban areas. The costs of interventions on rural land will be justified mainly against the benefits to urban flood alleviation, or the savings in defensive expenditure. Thus, the rationale for intervention in rural land management largely depends on the impact on urban flood risk, and much depends on catchment and event specific factors.

Key constraints to successful interventions are likely to be institutional rather than technical, including possible reluctance to adopt runoff control/storage measures by land managers, policy conflicts, and the fact that integrated solutions tend to be more complex to implement in the first instance. There will be need to demonstrate that intervention methods can make a difference, are practicable, and, in the case of farmers, can support livelihoods. There are uncertainties regarding the effectiveness of runoff control/storage measures under local conditions which will justify applied research to support the design of responses, as well as concerted action to promote adoption.

Contents

1. Overview

This Appendix explores the social and economic dimensions of rural land management as they affect flood generation. The main focus here is placed on the extent to which land use and land management practices influence the rapidity of the movement of rainwater from the land to a point of outfall into a watercourse from where it joins water from other parts of the catchment area. Movement from land to the watercourse is either through the soil profile or along the surface of the land. Flooding can arise when such flows exceed the capacity of the receiving channel. The focus here is on the likelihood that land management contributes to the generation of floods.

In most cases, land management practices which increase the proportion of rainwater moving quickly as surface runoff can increase the probability of flood generation at a local scale compared to land uses which absorb water into the soil profile or retain surface runoff in some way. This is not to say that soil water cannot contribute to flood generation, especially where light soils and/or artificial drainage result in relatively rapid movement of water through soils to a point of outfall into a receiving watercourse. For the most part, however, localised flooding is usually associated with surface runoff, where as at the catchment scale the rapid movement of water through soils facilitated by land drainage may also contribute to flood generation. The point at issue is whether land management practices, including actions such as surface and subsurface artificial drainage, have the potential to generate floods and whether changes in these practices could reduce this potential in situations where it might be beneficial to do so. The term runoff here is used to denote water than exits from agricultural land. Although the focus is usually on surface runoff as a source of local flooding, soil water also adds to runoff as it drains to surface channels. Thus land management practices which affect the rate of water movement through soils with the potential to generate flooding must also be included. The following discussion is set in this context.

A further point of definition is made. As noted in FD2114/TR, from a flood protection standpoint, flood risk is *"a combination of the probability that a critical peak discharge is exceeded, defined as Flood Hazard, and the consequent economic damage."* In the literature on social and economic dimensions of flooding, the term 'risk' is often used more loosely to denote a chance that some event will occur without reference to the degree of potential damage. The focus in this Appendix is on the potential for land use to contribute to an increased probability of flooding locally or at the catchment scale. Although some examples are given of damage costs, where the terms "flood risk", "risk of flooding" and "risk of runoff" are used, they usually simply denote probability of occurrence.

Following this overview, Section 2 uses the Driver-Pressure-State-Impact-Response Framework to explore those aspects of rural land use associated with flood generation. The potential link between flood generation and diffuse pollution is considered in Section 3. The possible measures and the range of policy instruments that might be used to alleviate the probability of runoff that could contribute to flooding associated with rural land management are discussed in Section 4, followed by a review in 5 of factors likely to influence farmer adoption of control measures.

The extent to which existing agri-environment schemes and proposed changes in the EU Common Agricultural Policy affect flood generation are reviewed (6), especially as they determine land use and the detail of farming practice.

Section 7 takes a long-term view of rural land use and identifies the implications for flood generation under alternative future scenarios that vary in governance and social and economic motivation. As a result of differences in drivers affecting land use, the scenarios present different probabilities of runoff and flood generation and are likely to involve different policy responses.

A summary and conclusion is contained in Section 8. Key constraints to successful interventions to control flood generation in rural areas are likely to be institutional rather than technical, including barriers to the adoption of runoff control and interceptor storage measures by land managers, policy conflicts, and the fact that integrated solutions tend to be more complex to implement in the first instance. Changing priorities in the countryside, however, reflected in a reorientation of rural and agricultural policies, provide an opportunity to promote changes in land use and management practices that can help to reduce the probability of flood generation.

2. DPSIR framework for rural land use and flood generation

Figure 1 illustrates the broad anthropogenic context of flood generation on farmland using the Drivers-Pressures-State-Impacts-Response Framework. The selection of appropriate intervention measures to mitigate flooding rests on an understanding of this framework as it applies to rural land management. It is useful to consider the historic dimension of land use and how changes in management practices over time have given rise to concerns about flood generation.

2.1 Drivers

There are a number of key drivers of land use and farming practice. The incentives provided by agricultural commodity markets and prices are a critical determinant of land use management decisions. These incentives are shaped

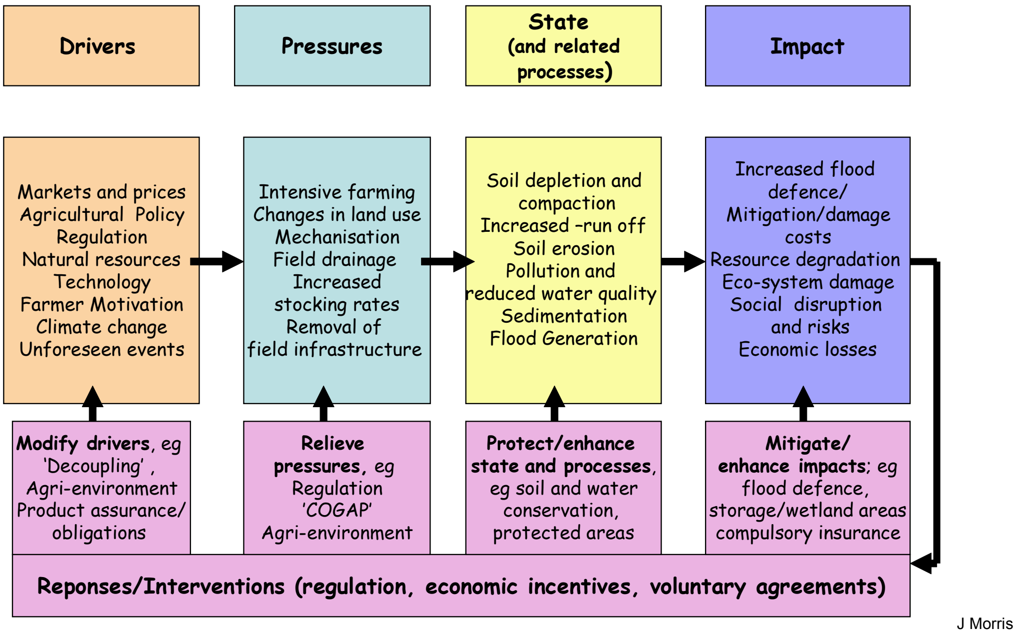

Figure 1 DPSIR Applied to Flood Generation from Agricultural Land

by the interventions contained within the EU Common Agricultural Policy (CAP) which variously support farm production, farm incomes and the rural economy (Boardman et al., 2003a; Falconer and Ward, 2000; Green 1986; Lundekvam et al., 2003; Morris et al., 2000; Sutherland, 2002). Changing agricultural technologies, partly influenced by a mix of factors within and external to the rural sector, also act as a driver for land use change (Bouma et al., 1998; Souchere et al., 2003). Existing regulatory regimes, as they define acceptable practices and permissible use, are key drivers (Selman 1988, 1989). More recently, agri-environment schemes such as the Environmentally Sensitive Area

Scheme and the Countryside Stewardship Scheme have attempted to modify drivers in favour of environmental protection and the provision of public goods using a mix of voluntary and economic measures (Lobley and Potter, 1998; Werner, 1993). The new ‘entry level’ stewardship scheme (Defra, 2003) attempts to promote good environmental practice on all farms in return for an annual payment per hectare. Of course land managers, especially those involving family businesses, interpret these drivers with respect to their own personal circumstances and preferences, including motivations for countryside conservation (Morris and Potter, 1995).

2.2 Pressures

The review of literature contained in other sections of this report has confirmed the link between agricultural policy drivers and the pressures on land and water resources generated by intensive agriculture, whether associated with changes in land use type such as the switch from grassland to arable, or the adoption of farming practices such as intensive mechanisation within a given land use type. Increased pressure on land, in response to market and policy drivers, has direct consequences for increased runoff (Environment Agency, 2002).

Indeed, evidence suggests that production oriented drivers on are so lodged in the minds of land managers that CAP reforms in the early 1990s to reduce output and relieve environmental pressures did little to reduce the tendency towards intensification (Winter and Gaskell 1998, Souchere et al., 2003). Subsequent attempts to extensify land use through measures to ‘decouple’ farm income from production have not alleviated the pressures on land and water resources in areas where the drivers to intensify are greatest. Furthermore, there is concern that a decline in commodity prices could in some cases encourage farmers to intensify or seek economies of large-scale production in order to protect income. Reduced real income could also reduce the scope for voluntary environmental measures (Potter, 1986).

2.3 State

The evidence presented in Section 3 of the main report confirmed the link between pressures and the state of rural catchments in terms of the probability of runoff, soil erosion and pollution. In many cases this has been associated with a depletion of rural infrastructure such as ditches, boundary walls and hedges, bio-diversity and landscape features, many of which has served to limit the probability of runoff and increase the temporary storage of potential flood water. There is well-documented evidence of soil erosion and flooding arising as a consequence of land use change and farming practices, but for the most part at a local scale (Boardman et al., 1996; Boardman et al., 2003a, b; Environment Agency, 2002, Evans, 1996)

2.4 Impacts

The greatest impacts of runoff from rural land in the UK occur beyond the site (and usually the beyond the farm) of origin. They also tend to be cumulative and long term in so much that they are often associated with soil erosion that can further exacerbate runoff. Impacts are also associated with sedimentation processes that can reduce the hydraulic capacity of the land drainage system at a local level and possibly at a catchment scale (although the evidence for the latter in the UK is limited). For the most part, farmers do not perceive runoff as a problem unless it is associated with damage to personal property, major soil erosion risk, or could result in claims by an injured third party (Bielders et al., 2003; Robinson and Blackman, 1990; Robinson, 1999).

Evans (1996) reviews the evidence of runoff events on farmers' fields associated with water erosion, citing impacts such as loss of crop yield, fertiliser loss, requirement to repeat cultivations or to re-establish crops, and damage to infrastructure. In some cases, runoff induced erosion accounted for between £30 and £50/ha (1990 prices) loss of output or lost value of input. However, erosion and associated rills and deposits tend to affect relatively small parts of fields (typically 10%) such that average costs per ha are small (typically £3 to £5 /ha) when spread across whole field areas. These damage costs are also small relative to the potential gain from remaining in or switching to arable cropping compared to a lower runoff grassland option. Gross margins (inclusive of area payments) for cereal cropping are currently about £500/ha compared to about £200/ha for grassland (Nix, 2003). Robinson and Blackman (1990) reporting water erosion and flooding on the South Downs estimated average on farm water erosion costs of between £18 and £35 /ha. They report that farm costs for one reported event were £13,000 compared to off-farm costs in excess of £400,000. A survey of 30 farmers in south east England (Robinson,1999) further confirmed that farmers were little concerned with the on-farm effects of water erosion risk, supporting the view that any long-term loss of productivity could be made good by general improvements in yields from improved crop varieties and agro-chemicals (Burnham and Mutter, 1993).

With respect to upland livestock production, Evans (1996) estimates that, in one area of the Peak District from about 1970 to 1986, sheep numbers increased by about 50%, while the area of eroded moor increased by 4% per year. Evans suggests that this probably only resulted in a reduction of 0.1 % in the number of sheep actually carried on the moor. In this respect, the benefits of avoiding erosion appear to outstrip the costs at farm level, at least in the short term. The situation is further complicated on moorland because farmers often share common grazing rights with others such that there is little incentive for individuals to adopt corrective action unless everyone agrees to do so. Land tenure critically affects the willingness of land managers to adopt soil and water conservation where this involves extra cost or reduced income now in return for uncertain benefits later.

At UK agricultural sectoral level, Evans (1996) suggests that 3.7% of the UK farmed area is potentially at risk of water erosion, of which probably 0.5% of the actual field areas are damaged in some way, equivalent to 0.02% of the cropped areas. Taking very broad estimates of the gross value of UK arable cropping (roughly £16,000m on 6.1 m ha in 2003), this suggests an output loss of about £1.22 m per year, or a loss of value added (after direct production costs) of about £0.9m/year. These ‘internal’ costs borne by the farming sector are relatively minor given many other uncertainties which determine the returns to farming, and are insignificant against the benefits to farmers of arable farming under the present agricultural support regimes.

Evans (1996) estimated the loss of farm revenue for all upland areas at about £55,000 (1990 prices) out of a total upland output of over £600m per year, less than 0.01%. Thus the incentives to adopt erosion-reducing behaviour and hence reduce runoff are relatively small, either locally or for the sector as a whole. Incentives may be greater, however, where uncontrolled runoff can lead to loss of riparian farmland as reported in parts of Wales (Newson, 1990).

The greatest impacts of runoff and related soil erosion, however, are off-site. As discussed elsewhere in this document, these relate to flood generation, deposition of soils on roads and into watercourses, and damage to property. The off-site, non-farm land, clean up and damage repair costs of ‘muddy floods’ varies accordingly to circumstances, but, quoting various sources, Evans (1996) reports costs of between £4,000 and £250,000 per event over the period 1968-1993. A mean estimate of off-site damage costs of about £100/km2 on land liable to water erosion was derived for 12 events in East Anglia. When applied to 25,000km2 of land considered at risk (Evans, 1996), this equates to about £2.5m/year, although it is recognised that costs could be higher in severe weather years. These costs excluded annual costs associated with disruption to traffic (£3.3m), road accident risk (£0.1m), footpath loss (£0.5m) and damage to watercourses (£7m). While these costs may underestimate the contribution of runoff during extreme events which can result in severe flooding of lowland rural and urban areas in major flood events at the catchment scale, there is limited information to link land use and management practices to enhanced flood risk during prolonged and severe precipitation and resultant flood events.

Other costs of catchment runoff and associated soil transport relate to water pollution, especially phosphate and pesticide pollution, discoloration of water, and impact on freshwater fisheries. In the absence of other information, Evans (1996) attributes 1% of identifiable costs of water pollution to erosion events, at between £3m and £30m/year depending on assumptions. Drawing together various estimates, Evans placed the total annual costs of erosion related events at between £24 m and £51m, and while there probably is a degree of double counting and overestimation in some of these estimates, they demonstrate two things: first, the costs of water erosion, for the most part associated with runoff from farm land which results in flooding and water pollution, are mainly felt off-farm; and second, the incentives for farmers to adopt water erosion and runoff control measures are limited.

The substantial costs of water erosion and off-site costs have been further confirmed in three recent assessments of the external costs of UK agriculture. Drawing on the sources previously revered to, Pretty el al., (2000) suggest an annual cost of £14 m of offsite damage caused by soil erosion by water.

Hartridge and Pearce (2001) estimate this to be £19 m per year. For their part, the Environment Agency (2002) suggests that 25% of major flood events over the period 1970 to 1990 were associated with runoff from hill slopes, and that 57% of these events have been linked to erosion and deposition. On this basis, but with limited hard evidence, the Agency concludes that 14% of flood damage costs in England and Wales are attributable to hill slope floods and to agriculture, equivalent to £115m per year.

Similar observations (quoted in Evans, 1996) regarding the relative magnitude of off-farm water runoff and erosion costs are reported for other countries, with costs of £350 to £1070 /km2 (1990 prices) for the USA (compared to UK equivalent £150- £450/km2).

Although beyond the scope of this study, a comprehensive coverage of evidence based flood damage costs and methods for estimation, including those for flooding on agricultural land, are contained in Penning Rowsell at al., (2003).

2.5 Responses

Responses by policy makers and regulators comprise interventions to reduce the negative or enhance the positive impacts of development. The overall purpose is to reduce the external environmental impacts and costs associated with runoff and water erosion. Responses which address the causes of unwanted impacts, namely high level drivers and pressures, are likely to be more effective, efficient and sustainable than those which attempt to mitigate impacts. Examples of responses, categorised according to the target components of the DPSI(R) framework are given in Table 1. They are also classified according to the use of regulatory, economic, voluntary and other instruments.

A range of interventions is available to reduce control runoff as shown in Table 2. These can be classified into two main groups associated with reducing catchment runoff *near to source* and reducing the impact of flooding *near to receptor*. However, it is recognised that these two groups are closely interrelated.

Table 1 Rural land management and flood generation: responses to address drivers, pressures, state and impacts

	RESPONSES AND INTERVENTIONS			
Drivers	**Regulation**	**Economic Instruments**	**Voluntary measures**	**Other**
Agricultural Commodity Markets and Prices Agricultural Policy notably CAP	Quotas and conditions on production. 'Modulation'	Reduced direct support (subsidies, area payments, headage payments) for agricultural production. Decoupling of production and income support. Tradable quota. Market incentives for wise use	Supply chain incentives requiring adoption of best practice, environmental audits, traceability,	Technical support and promotion of alternative enterprises and land use
Technological Change and related farming systems and organisation of farming sector	Regulation of particular inputs or practices associated with environmental damage	Taxes or subsidies associated with technology use, support for family farms	Voluntary restrictions on practices associated with erosion and runoff Farmer groups/learning schools for sustainable technology	Research and Technology Development, and Extension for integrated crop management systems, extensive farming , minimum tillage systems,
Regulation: land use and development regulation. Controls on farming practices. Environmental regulations. Water resource regulation.	Restrictions on land use and management practices in risk prone areas, IPPC type regulations. Licensing. Positive bias towards alternative land use. Animal welfare	Taxes and subsidies on particular land uses. Tradable permits	Land care management protocols Participatory process to encourage wise use	Technical assistance to support promotion of alternative land use

Table 1 continued

Pressures				
Intensive agriculture: grassland to arable conversion, intensive cultivations, increased stocking rates, managed drainage, increased scale of farming	Restrictions on land use and management practices, cropping systems, tillage systems, stocking rates, compliance requirements. BAT type requirements.	Incentives for integrated crop management, support regimes for extensive farming, agri-environment payments for flood water retention/storage. ESA/CSS type payment regimes Taxes/subsidies on selected practices	Codes of good agricultural practice. Voluntary soil and water management measures Voluntary membership of agri-environmental schemes. Farmer land care groups.	Research and extension to support sustainable farming systems, including erosion control and water retention measures.
State				
Increased runoff, soil erosion, pollution, reduced soil and natural storage, larger fields, reduced natural landscape features.	Regulation on land use and farming practices to reduce runoff in vulnerable areas. Designated protected areas for water retention and storage to reduce runoff at source.	Agri-environment schemes for arable reversion, adoption of best practices. Grants for soil and water conservation measures, to control runoff, retain water	Voluntary adoption of soil and water conservation measures, and related biodiversity enhancements, such as hedgerows/farm pond	Research and technical assistance and advice to control run processes environmental.
Impacts				
On-site: soil loss, reduced fertility, flooding. Offsite: flood risk, siltation, erosion, property damage and disruption, pollution.	Compulsory third party insurance. Compulsory mitigation/defence measures to avoid off site runoff. Designated retention/storage areas near receptor areas	Compensatory payments, mitigation expenditures. Penalties/fines Insurance.	Damage avoidance strategies by those at risk.	Warning systems to reduce flood damage. Flood defence schemes.

Reducing runoff near to source
Three main themes can be applied (Table 2):

- Changing the broad land use type;
- Changing current land management practices associated with a specific land use type;
- Adoption of catchment runoff control methods.

Management options in the first two themes are generic and could be implemented on a national or regional basis through high level policy responses such as modifications to incentive regimes contained in agricultural and agri-environmental policy. Options in the third theme, while drawing on the broad policy framework, are catchment specific and imply a strong and continuing local planning and support network, linked into initiatives such as catchment flood management plans.

Managing runoff in receptor areas (flood plains)
A range of management options are available (Table 2) which comprise:

- Enhancement of floodplain storage;
- 'River Restoration';
- Adoption of land uses tolerant to flooding;
- Flood defences for agricultural land;
- Management of erosion: sediment transport and deposition:

Table 2 also summarises the incentives, opportunities, limitations and constraints relating to the implementation of possible response measures. The strong influence of high level policy drivers on land use and any measures to modify land use in pursuit of catchment management objectives is apparent.

There has been limited review of the actual efficacy of interventions specifically to reduce runoff, but where there has been, findings have sometimes been mixed. For example, although the establishment of large-scale woodland in agricultural catchments can reduce runoff, large areas of set-aside may increase the chance of flood generation (Williams et al., 1995).

The new EU Directive on Environmental Liability (adopted in April 2004) may add further incentive for farmers to manage their environmental effects. The Directive aims to prevent or remedy environmental damage by requiring operators to bear the cost of remediation of damage or the cost of preventative measures: that is, it applies the polluter pay principle. A competent authority, presumably Defra or its appointee, will be charged with determining relevant standards of remediation or prevention and recovering costs form operators. Strict liability (regardless of whose fault it is) applies to those activities already subject to regulation such as storage of hazardous chemicals, whereas other activities not controlled by regulation (such as land use if this is not regulated) are subject to fault–based liability. It is apparent that in the case of flood generation, the Directive will require either a regulatory framework for land management practices or clear guidance on what is likely to constitute 'at fault'.

3. Flood generation and diffuse pollution

Runoff from farmed areas can be associated with diffuse pollution to surface and ground waters (Defra, 2003), and where this is the case there can be advantage of adopting an integrated approach.

There is particular concern at present with the probability of diffuse pollution from agricultural land. Reduced discharges to surface waters by industry and sewage treatment works mean that agriculture is now perceived to be 'the number one polluter of water in the country' (PCFFF, 2002), with increased calls to reduce this source of environmental risk. The application of the polluter pays principle, now embodied within the Water Framework Directive (CEC 2000; HCEFRAC, 2003a), led the House of Commons Committee on Environment, Food and Rural Affairs with an eye on agriculture, to declare that 'those responsible for diffuse pollution should pay for it' (HCEFRAC, 2003b). Agriculture will be required, perhaps as a condition of grant aid to the sector, to reduce pollution risk.

The extent to which interventions to control diffuse pollution contribute to the control of flood generation (and vice versa) depends on local conditions. Control of diffuse pollution from rural land requires modifications to land use, farming practices, the use of inputs and to pathways through which potential pollutions reach receiving waters (English Nature, 2002; Defra 2003). Indeed, interventions that influence runoff of polluted water for the purpose of controlling diffuse pollution may in some circumstances contribute to the alleviation flood generation and the mitigation of flood impacts. Defra (2003), in its Strategy for the Control of Diffuse Pollution of Water from Agriculture, recognises that land management practices associated with soil erosion and runoff, such as those which reduce soil cover or increase surface compaction, can give rise to diffuse pollution. In this context, Defra argues that measures to control runoff include what is generically referred to as 'flood control', and specific measures such as riparian land management, controlled drainage and barrier ditches. These and other methods to control pollution were screened in broad terms against criteria of effectiveness, practicability and cost from the point of view of pollution control, but they were not linked per se with flood management.

For its part, English Nature (2002) explored the suitability of diffuse pollution control measures for given farming and regional characteristics such as arable farming in the eastern counties and livestock farming in the west of England. Reference is made to land and soil management as this affects runoff, but not specifically with respect to flood risk. Recommendation were made on measures that could be adopted to address pollution control according to farm type, together with an assessment of likely costs of implementation and the order of grant aid that might be necessary to encourage adoption by farmers (English Nature, 2002). Alternative policy regimes for controlling diffuse pollution, including the choice of regulation and economic instruments, have also been reviewed (OXERA, 2003). There are common messages emerging from these studies, namely: there is considerable scope to reduce environmental risk through changes in farming practices; there is a need to enhance farmer understanding of pollution problems and the extent to which their action can make a difference; and, given the diffuse nature of the problem, a mix of economic and voluntary measures, supported by compliance requirements linked to grant aid, is likely to prove more cost effective than intensive regulation. These messages associated with diffuse pollution are relevant to the management of flood generation.

In summary, where flood risk and pollution are linked, and there is a commitment to mitigation, it makes sense to adopt an integrated approach. But it cannot be assumed that measures to address one will necessarily deliver benefits to the other.

Table 2 Management interventions and associated opportunities and constraints

Components	Interventions to control runoff or reduce impacts	Incentives and opportunities for implementation	Limitations and constraints to implementation
Managing Runoff through near source areas and pathways Near source and pathway areas Strong links to urban areas as a receptor Links to preference for managing impacts of floods with respect to choice of interventions, whether regulation, economic incentives (and penalties), voluntary measures, and funding of research, development and extension of intervention measures.	**Regulation or incentives for land use types** associated with runoff: heath land and moorland, forest and woodland , grassland, arable, set-aside, wetlands **Regulation or incentives for Land Management practices for given land use types** to control field runoff: heathland and moorland management and stocking regimes, woodland species and plantation management regimes, Grassland management regimes especially stocking rates, Arable: tillage techniques to reduce runoff, crop cover retention, wind breaks **Promotion, advice and incentives for adoption of generic catchment runoff control methods**: Soil conservation and structure improvement, contour ploughing, terracing, bunding, modifications to drainage intensity On farm water retention: vegetation buffers/traps, interceptor lagoons and reservoirs. Upland Wetlands to retain water	Very policy dependent: Agricultural support mechanisms, including production subsidies, agri-environment schemes, compliance requirement. Strong influence from habitat, water and soil policies and 'directives', with supporting policy instruments and funding mechanisms Sustainable land management practices can serve multiple policy objectives and be part of sustainable catchment management Land managers shown to be responsive to economic incentives: whether compensatory or penalty driven. Response dependent on attitudes to 'sustainable farming practices'. Potential to make significant local effect for relatively frequent flood events Land use, and land management practices can be regulated. Climate change could increase justification for winter runoff control	Very policy dependent, and policy may not be conducive to particular responses. Policy conflict. Responsibilities fragmented across institutions. Funding limited, fragmented or insecure Land use and practices may remain at discretion of land managers, choosing not to adopt. Land managers may not be convinced that practices are effective, feasible, or compatible with farming Effect on runoff may be localised, with limited effect at catchment scale for major flood events. The benefits of these actions are mainly off-farm, farmers unlikely to adopt unless compensated. Farmers do not perceive a problem for themselves or others, or that they are themselves responsible. Land tenure systems, such as short term tenancies, may constrain adoption of land improvement/runoff control measures. Climate change could increase potential for extensive arable cropping Scientific basis for advising locally relevant

			practices may be lacking. And extension services may not be available to promote best practice

Table 2 cont	Interventions to control runoff or reduce impacts	Incentives and opportunities for implementation	Limitations and constraints to implementation
Managing Runoff in Receptor Areas Near pathway and receptor areas Strong links to choice of engineering and other flood management interventions	**Projects and Management Interventions to Enhance Floodplain Storage**. On-line/off-line storage with varying degrees of hydraulic control Eg Set-back/realignment/removal/changes in levels of embankments, Decreased channel maintenance leading to increased vegetation and flooding of washlands, Changes in pumping regimes, Introduce hydrological compartments. Create scrapes, lowering the floodplains, Modify ditches and subsurface drainage systems. **'River Restoration'** including removal of hard structures, reinstatement of natural features, linked to managed flooding **Adoption of land uses tolerant to flooding**: woodland, reed beds, willows, carr and open water, wet grassland, extensive grassland, abandonment, **Flood Defences for Agricultural Land**: Embankments, Pumping schemes, Subsurface and arterial drainage, River channel works, River and drainage system maintenance, including vegetation control	As above, very policy dependent. Agricultural, agri-environment and biodiversity policies critically define objectives, incentives and actions, including choice of regulatory and economic instruments Flood management set in broader context of river/catchment management Push for catchment approach encourages holistic, integrated solutions. Floodplain storage and washland options can provide opportunity to integrate flood management, biodiversity and sustainable livelihoods. Provide a good opportunity for integrated policies at catchment scale. 'Farming floods' offers a diversification option for land managers with grants and allowances, with scope to meet water quantity and quality objectives. Priority setting according to comparative advantage of land areas: eg high protection to strategic agricultural assets.	As above, incentives may not be sufficient to encourage voluntary adoption. Policies may be counter-productive or in conflict, eg support to agriculture and support to agri-environment may give rise to different flood management responses in adjacent areas Responsibilities fragmented across institutions. Funding limited, fragmented or insecure Storage options may require farmers to work collectively, and this may not happen. Flood storage/washland options are often more complicated to prepare, appraise and fund than conventional flood defence solutions. Culture of 'flood defence' may act against alternative flood management strategies.

	Management of Erosion: bankside protection, including profiling, berms, vegetation, gabies and geo-textiles **Management of Sediment Transport and Deposition** : channel modifications/restoration, dredging/desilting, flow modifications, sediments traps, instream vegetation		

4. Policy instruments for reducing flood generation

Responses can draw on a range of policy instruments to reduce environmental risk. The use and suitability of alternative policy measures for the purpose of improving the sustainability of agriculture and rural land management in OECD countries has been reviewed by Defra (2002). Having derived various estimates of the external costs of agriculture, Pretty et al., (2000), Hartridge and Pearce (2001) and the Environment Agency (2002) make recommendations on actions that can be taken to reduce environmental damage and related costs, including those associated with soil erosion and off farm flooding. Policy instruments include:

- Regulatory measures comprising mandatory command and control methods which specify permissible inputs, practices and processes, and outputs. These might include restrictions on land use and farming practices which have proven links with runoff in high risk areas. Regulation may include adoption of specific mitigation measures such as contour ploughing or interceptor drains in high risk areas;

- Economic instruments involve the use of payments, charges, taxes, subsidies, or market instruments such as tradable permits to provide incentives to adopt or reject particular behaviour. Examples include payments to farmers to adopt runoff reducing land use such as arable reversion to grassland or to establish and maintain hedgerows, field boundaries and other features. Such arrangement are evident in current agri-environment schemes (Defra, 2002);

- Voluntary measures include the adoption by land managers of Codes of Good Agricultural Practice, membership of agri-environment schemes, and adoption of externally verified environmental management and auditing systems such as Linking Environment and Farming (LEAF);

- Other measures include actions by government associated with technology research and development, extension and training, and the promotion of improved soil and water management practices amongst land managers.

Table 1 above gives examples of the kind of policy instrument that can be used to address drivers, pressures, state characteristics and impacts. The choice of policy instrument depends on the objectives to be met, the severity of the risks involved, the need to ensure safe minimum standards, and the extent to which uncertainty requires a margin of precaution. The main criteria for choice of policy instruments (Turner et al., 1994; Tietenberg, 2003; Perman et al., 2003) are:

Effectiveness: Will they have the desired outcomes and make a difference? Will they to work reliably? Can risks be managed to acceptable levels?

Efficiency: Are they the best, most cost effective ways of meeting the objectives? Do they give best value for money for all concerned? Are they practical and economic to implement and administer?
Equity: Are the interventions fair, proportionate, targeted reasonably and obvious in their impact on those who are affected?

To date there has been a preference in rural land management towards a non-regulatory approach, with emphasis on a mix of voluntary measures (such agri-environment schemes), supported by economic incentives to farmers, with advice on improved environmental practices. Although there have been tight controls on non-agricultural development in rural areas, there has been limited direct regulation of agricultural land use and management practice (Selman 1988; Hidding 1993). However, it is acknowledged that the management of forestry land is subject to a mix of cross-compliance and direct regulation, much of it administered through the Forestry Commission. Afforestation, forest road construction and felling are subject to varying degrees of regulation, including strong links into the strategic planning framework. Where plantations are grant aided, compliance with codes of practice on Forest and Water Guidance is required. Aspects of this regulatory experience could be transferred into the general agricultural sector.

While mandatory regulations can be effective at delivering policy objectives, they are often perceived to be less efficient than economic instruments because they require intensive and expensive monitoring, are inflexible, apply standard compliance requirements irrespective of the costs of compliance or abatement, and do not provide incentives for environmental improvement beyond the regulatory standard (Turner et al., 1994; Gouldson and Murphy, 1998). In the case of agriculture, however, a combination of the diffuse nature of agricultural pollution and the sector's claim to be a special case has limited the use of the regulatory approach (at least until recent European Directives). There has been a tendency to promote voluntary measures in the form of Codes of Good Agricultural Practice (COGAP) (MAFF, 1995). These are also evident in various market driven commodity assurance schemes, including those led by supermarkets. 'Voluntary regulation' is potentially effective and efficient, but works best when set in a broad regulatory framework, linked to economic incentives whether fiscal or market based. The provision of training and advice to farmers, at one time a keystone of agricultural enhancement is also perceived to be a critical element in the promotion and take-up of good environmental management (Defra, 2002; Environment Agency, 2002; Mathieu and Joannon, 2003).

In the case of interventions made to reduce catchment runoff from rural land, it is critical that evidence clearly demonstrates a link between particular practices and flooding and other environmental damage. It is important that interventions target the offending practices and make a difference: that is they are effective. The review reported here suggests that although the link between land management and local, especially muddy floods can be made, this is not the case for infrequent catchment-scale flood events.

Under the banner of sustainable development, the guiding principle for environmental policy is ‘polluter pays’: making polluters responsible for the damage they cause, and thereby encouraging a change of behaviour (Tietenberg, 2003). In the case of agriculture, the situation is complicated because subsidies provided to support farm incomes encourage potentially polluting behaviour: a kind of policy ‘double-whammy’. Current policy is moving towards modification to the income support regimes by reducing the incentive to pollute, requiring compliance with good practice as a condition of farm income support, or offering direct incentives to provide environmental enhancement beyond compliance (that is the ‘provider-receives’). This ‘process-oriented’ approach to land management, which discourages practices associated with excessive water runoff and encourages those practices which retain waters that could generate flooding would seem to be a reasonable way forward. In many respects this is compatible with the trend towards a regulatory regime based on adoption of ‘best available techniques’ as a means of minimising pollution risk. The Integrated Pollution Control Regulation as it now applies to intensive pigs and poultry producers is an example of this (Pellini and Morris, 2002).

A key question arising is where the balance should lie between polluter pays and provider receives (Hodge, 2000). This often rests on prevailing entitlement and institutional norms: whether, for example, farmers have rights to use land as they wish even though this has uncompensated consequences for others (Wiebe and Meizen-Dick, 1998). Apart from the risk of local muddy floods where specific measures may be called for, the land-use/runoff/flood generation relationship is a diffuse one and potentially cumulative in so much as it is possible to speculate that water erosion of soils may successively reduce the ability of soils to retain moisture. It may also reduce downstream hydraulic capacity through changes in geomorphology which have required desilting of water courses to alleviate flood risk. In this respect the probability of flood generation in particular place at a particular time may be difficult to attribute to any particular land manager. Once again this suggests that generic compliance with good practice that can reduce flood generation should be promoted as part of income support regimes to farmers (assuming the latter continues). Indeed, the re-alignment of funds from production support to environmental incentives (‘modulation’), and the current piloting of the ‘broad and shallow’ entry-level agri-environmental scheme are indicative of this (Defra, 2003). In areas where potential contribution to flood generation is high and attributable to particular management practices there may be a call for more targeted compliance and enforcement.

5. Adoption of land management practices to control runoff

5.1 Motivation of land managers

There is much evidence which confirms that patterns of land use and farming practices are a direct response to the incentives provided by agricultural and more recently agri-environmental policy, modified by a complex of personal, family, farm business, and external contextual factors (Gasson 1988; Gasson and Potter, 1988; Moss, 1994). Response to policy incentives, modified by personal preferences, has been associated with water erosion risks and flooding (Robinson and Blackman, 1990; Robinson, 1999; Boardman et al., 2003a; Evans, 1996; Bielders et al., 2003; Verstraeten et al., 2003; Pretty et al., 2000).

With a view to reducing the pressures on rural landscapes and wildlife, the 1986 Agricultural Act introduced the Environmentally Sensitive Area (ESA) scheme, whereby farmers in selected geographical areas of biodiversity, landscape or historic importance can voluntarily agree to deliver increments of environmental protection or enhancement in return for financial reward over a specified period, usually 10 years. In 1991, the Countryside Commission introduced the Countryside Stewardship (CS) scheme which aimed to conserve and restore habitats and landscapes in the wider countryside, beyond those captured in the ESAs. The CS scheme focuses on environmental outputs in the form of target landscapes and habitats (rather than designated areas) achieved through locally defined management practices (Countryside Commission, 1993). It also is a discretionary scheme in that applications are screened for eligibility against environmental deliverables and value for money.

Research into farmer participation in these schemes has provided insight into farmer motivation as well as responsiveness to environmental policy interventions. Different categories of adopters and non-adopters have been identified (Morris and Potter, 1995; Wilson, 1996; Lobley and Potter, 1998). For example, Morris and Potter (1995) surveyed 101 farmers in an ESA in South East England, of whom 55% were participants and 46% non-participants. They compiled a participation spectrum which classified respondents into active adopters (52% of adopters) strongly motivated by environmental commitment, passive adopters (48% of adopters) who take part mainly for financial reasons, conditional non-adopters (37% of non-adopters) who might consider participation if a particular constraining factor such as an aspect of scheme design were to be relieved, and resistant non adopters (63% of non adopters) who were adamant in their self-exclusion. The authors conclude that the sustainability of the ESA scheme, both in terms of achievement of purpose and funding feasibility, depends on the ability to convert a greater proportion of farmers into active adopters. Actions to push farmers along the participation spectrum included targeted promotional information campaigns for non-adopters, through advisory support and training for passive adopters, and the possibility of using active adopters as ‘demonstrators of good practice’. A comparison of the ESA and CSS schemes revealed that adopters of the ESA scheme were predominantly motivated by financial gain, whereas the CS Scheme adopters demonstrated predominantly conservation motives (Lobley and Potter, 1998). Such observations on farmer motivations and responsiveness are important when considering interventions to reduce flood generation. While a large cohort of farmers are active and voluntary conservationists (Burgess et al., 2000), financial inducements are clearly important for many farmers, and others may respond only if required to do so under a compliance regime.

The aforementioned studies question the sustainability of agro-environmental schemes that use financial inducements to engage otherwise disinterested farmers. They also raise a concern about selectivity by farmers resulting in policy 'deadweight': paying farmers for things they would do anyway, especially as agricultural policy reform reduces the gains associated with intensification (Froud, 1994). Countering this to some extent, Battershill and Gilg (1996), working amongst grassland farmers in the south west of England, argue that 'traditional', less intensive, and to some extent by default, more conservation-oriented farmers, are a suitable case for support. These at one time may have included a relatively large proportion of elderly farmers (Potter and Lobley, 1992), but perhaps less so now. Thus, agro-environmental schemes which secure 'good practices' on traditional farms may be just as valid as preventing 'bad practices' on conventional farms, especially when the former, and the rural economy of which they are an important part, are under particular pressure (Harrison-Mayfield et al., 1998).

Land tenure, property and entitlement rights are critical, influencing the way in which land managers respond to regulation or incentives, especially willingness to adopt long term solutions. Some responses may modify property rights, requiring compliance with specific conditions as part of entitlement to use (Hodge, 2000; Smith, 1996).

5.2 Adoption processes

The processes by which land managers adopt new land use practices, whether for agricultural or environmental enhancement, can be explained using the theory of adoption and diffusion of innovations (Rogers, 1995). An innovation is a product, process or way of doing things which is new to the adopter. For the purpose here, the innovation is the adoption of practices to reduce water runoff from land. According to this theoretical framework, prior conditions such as policy drivers or perceived needs shape the disposition of potential adopters towards the innovation. An innovation-decision process moves the decision maker from initial awareness to eventual adoption or rejection. This process is influenced by characteristics of the decision maker and of the innovation concerned, and by communication channels and agents of change.

The motivational characteristics of the land manager were referred to above. From a farmer's perspective, the 'innovation' itself, that is, the actions taken to reduce runoff, should have the following attributes:

- *Relative advantage* making the adopter better off;
- *Compatibility* with past experiences, existing values and needs, and practicable from a farming viewpoint,
- *Acceptable degree of complexity* in terms of ease of understanding and use, and avoidance of undue risk
- *Ability to try* innovations on a small scale in order to learn by experience and minimise risk; and
- *Ability to observe* the application and impacts of an innovation under relevant conditions thus demonstrating obvious benefits and value.

This innovation-decision algorithm has a well-established tradition in rural studies, especially explaining the adoption and diffusion of production-oriented agricultural technologies (Ryan and Goss, 1943; Morris and Hess, 1986; Napier et al., 1988). Rogers makes the point that the interest in applying diffusion research to agricultural production innovations in developed countries has been superseded by its application to environmental innovation.

There are of course, alternative models of innovation adoption that give different emphasis to various elements of the decision process. In the management of agricultural development, these include systems models, information models, learning and knowledge transfer models (reviewed by Garforth and Usher, 1997). The theory of reasoned action, popular in studies of consumer behaviour, has also been used to explain conservation attitudes and behaviour amongst farmers and others (Carr and Tait, 1991; Beedell and Rehman, 1999).

Although, the innovation- decision model is not without its critics (reviewed in Morris et al., 2000), it can provide a useful, versatile and accessible framework for understanding adopter behaviour. For example, the method was used to understand the resistance by arable farmers, a prime target for achieving controls of runoff from farm land, to adoption of Countryside Stewardship arable options, providing a basis for a strategy to encourage improved participation (Morris et al., 2000).

The innovation decision model offers a potentially useful framework to support the design and promotion of changes in land management practices to reduce catchment runoff. In particular it identifies the importance of prior conditions such as policy drivers, and of farmer characteristics and motivations as they determine willingness to adopt changes in practices. The framework also confirms the importance of land management techniques which are feasible from the adopters' perspective, and the role played by 'change agents' in the promotion of such techniques, whether advisors, farmer opinion leaders or 'partner organisations such as farming and conservation bodies (Winter et al., 1996).

6. Current agri-environment and CAP reform implications for flood generation in rural areas

Agri-environment schemes are one of the instruments available to Government to encourage the development of a better rural environment, in terms of biodiversity, landscape and historic quality. They form part of a wider suite of policy instruments to encourage the sustainable development of rural areas, with the aim of enhancing environmental, economic and community benefits in the long term. They are designed to implement the policy requirements of the EU's CAP Pillar II, which stresses the importance of building effective mechanisms for the delivery of public benefits through land management policy.

CAP reform is being carried out independently by the devolved governments of the Scottish Executive, and the Northern Ireland and the Welsh Assemblies. Most of the commentary below applies to the English case, and although the same principles and intention of reform apply generally, there are important differences in the interpretation and application of the reform agenda.

6.1 Background

The first Environmentally Sensitive Areas (ESAs) were introduced in England by MAFF (now Defra) in 1987, under the 1986 Agriculture Act. Since then, further ESAs have been introduced bringing the total in England to 22. These are defined areas in which, by encouraging environmentally friendly farming practices, the environmental resource is being maintained or enhanced. The Countryside Stewardship Scheme (CSS) was introduced by the Countryside Commission as a pilot national agri-environment scheme in 1991. Following an independent review in 1995, responsibility for the scheme transferred to MAFF in 1996. CSS is generally only available outside the ESA areas and is the main scheme in England targeted at the wider countryside. Agri-environment schemes now come under the England Rural Development Programme (ERDP).

As previously referred, ESAs and CSS are the two main agri-environmental interventions which provide financial incentives to farmers to adopt practices which protect or enhance biodiversity, landscape and historic qualities of rural land, in some cases providing additional incentives for public access. In the Welsh case, agri-environment schemes are administered through the Countryside Council for Wales on behalf of the Welsh Assembly, mainly in the form of the Tir Gofal programme which has very similar objectives to the English schemes. Most of the comments below are made with respect to the English case, but the same principles apply to the Welsh case.

6.2 Influence of the current schemes on flood generation

ESA schemes are geographically restricted to areas identified as being of especially high biodiversity, landscape or historic value, such as the South Downs and Dartmoor, and they are designed to encourage farming practices that enhance these characteristics. A main aim is to restore traditional farming practices and the associated environmental characteristics. These had declined under intensive agricultural production, typically intensification of grassland use and conversion to arable. Each ESA has one or more tiers of entry and each tier requires specific land management practices to be followed. The higher tiers involve higher payments but involve meeting more conditions, with the aim of achieving greater benefits. Management agreements are made for 10-year periods. By 2002 there were over 12,000 agreements covering in excess of 570 thousand hectares.

Each ESA has a series of environmental objectives that focus on desired outcomes and reflect the potential of the designated area. No two ESAs have exactly the same objectives but there is often a common theme running through ESAs with a similar landscape type, e.g. the river valleys, the uplands, the coastal marshes, etc. Each objective is largely associated with a specific tier or combination of tiers. It is safe to say that the control or management of flooding does not specifically appear in any ESA's objectives. However, a number of the changes in land management practices specified in order to achieve the environmental objectives could be associated with some of the more beneficial practices identified in Section 3.3 of Part A.

Broadly these could be summarised as:

- Arable reversion - reverting arable land to grassland;
- Retaining winter stubbles and growing spring cereals;
- Upland grazing management and stocking rate control;
- Boundary management and buffer strips;
- Grazing marsh, dyke and grazing management;
- River valley grazing management;
- Less intensive production;
- Raising and managing water levels to create wet grassland, wetlands or wet ditches and scrapes.

All ESAs have at least one of these in their list of options, but none has all of them.

It is suggested that grassland is likely to cause less runoff than arable land provided that it is properly managed. Therefore, arable reversion, which features in over half the ESAs, is seen as a positive action to reduce runoff potential. Similarly, over-wintering stubbles followed by spring cereals are seen as beneficial compared with the exposed soils associated with winter cereals. It has been suggested that higher stocking rates and long grazing seasons have led to increased potential for runoff, so the upland prescriptions that reduce stocking rates and limit grazing should have a beneficial effect. It has also been suggested that buffer strips, mainly introduced to enhance biodiversity and reduce pollution to watercourses may also reduce runoff. The benefits towards flood control that accrue from river and coastal grazing management, including ditch management for ecological gains, are less easy to define dependent upon the time of year, although managing grazing marsh and water meadows traditionally should increase the buffering capacity of the locality. The payment for less intensive land use and higher water levels, and provision of advice, reduces the financial impact of temporary flooding and potentially increases acceptance of this by the farmer.

The Countryside Stewardship Scheme applies throughout England and has identified 6 landscape types (which include chalk and limestone grassland and old meadows and pastures) and 5 landscape features (which include historic features and arable land) as priorities for intervention. Each county has set specific targets for its important landscape types and features. Priorities and objectives are set for these areas in agreement with partner organisations and agreements are made with land managers that offer the greatest potential benefit for the payments made. Farmers and landowners enter 10 year agreements to manage their land in an environmentally beneficial way. By 2002, almost 14,000 agreements had been entered into, with over 343,000 hectares in agreement, together with almost 33,000 km of arable margins.

As with ESAs, there are no specific options for the control of flooding, but as before, there are a number of management options that may bring benefits in reducing runoff. These are similar to those identified above and include:

- Arable reversion to grassland
- Creating and managing field margins in arable fields and intensive grassland
- Over-wintered stubbles
- Downland and upland grazing management and stocking rate control
- Regenerating heather on improved land
- Managing raised water level pastures and ditches

The arable options are a recent introduction to the scheme, but these are likely to be the most beneficial in terms of flood control. The rationale for other options is similar to that described above.

6.3 Other schemes in the England Rural Development Programme

There are several other schemes under the ERDP that, by definition, change the way that land is managed and thus have the potential for reducing the probability of flood generation. These include the Woodland Grant Scheme and the supplementary Farm Woodland Premium Scheme, the Energy Crops Scheme and the Organic Farming Scheme. The impacts that land managed under woodland and coppice might have on the reduction of flood risk are discussed in the Section 3 of Part A main Report and Appendix E, “Review of

Land Use Impact on Flood Runoff Studies in the UK”, and those under organic farming in the Appendix C, “Current State of Rural Land and Mitigation Measures”.

6.4 Future schemes

All current ‘Land-based Schemes’ are under review by Defra to determine their format and scope for the future. Proposals have already been put forward for a new Environmental Stewardship Scheme to replace the ESA and CSS schemes.

The Government’s ‘Strategy for Sustainable Farming and Food’ proposed a new Entry Level Agri-environment Scheme open to all farmers, which would be available in 2005. This is currently being piloted in four areas of the country representative of distinct farming types. The precise management options that will be available are, as yet, not known but the options in the pilot give some clue to possible final structure. Once again, the options are largely targeted at environmental gains.

However, there is one option specifically designed to reduce soil erosion, which, because the measures are designed to reduce runoff, may help to reduce the probability of flooding. This option will only be available on cultivated fields at risk from soil erosion (sandy and loamy soils, particularly on slopes). A number of management measures may be included to reduce soil erosion on these vulnerable fields including:

- Avoiding vulnerable crops such as potatoes, maize and fodder brassicas;
- Using well placed buffer strips;
- Cultivating along field contours;
- Forming beetle banks along field contours;
- Establishing crops with minimum cultivations or direct drilling.

Additionally, a soil management plan might be prepared where at least 10% of fields are identified as being at risk from soil erosion. This would involve fully evaluating the potential for erosion and runoff for each field using published information and field guides, and preparing a plan setting out the steps that would be taken to minimise each of those risks. The plan will be updated annually to take account of experiences in the previous year.

Other options in the pilot with potential beneficial effects as identified earlier and available on all land include:

- Buffer strips and margins on arable land and intensive grassland
- Over-wintered stubbles
- Maintenance and management of permanent grassland

The Environmental Stewardship Scheme will comprise Entry Level options to replace the existing pilot, and Higher Level options. It is proposed that this scheme will have a number of tiers with options designed to meet the specific environmental objectives. One of the primary objectives of the scheme is the protection of natural resources, which includes soils. A specific secondary objective is to contribute to the improvement of flood management. It is anticipated that flood alleviation objectives will be met through the adoption of particular options that have the potential to increase water storage at the field and catchment level, including resource protection, wet woodland, wetland and inter-tidal options. There are also a number of less specific options that may contribute to the flood management objectives.

Examples of measures that could contribute to the overall flood alleviation objectives include:

- Land management options that improve soil structure and infiltration, through changes in cropping and tillage regimes and through the reduction in stocking rates in both upland and lowland areas;
- The restoration of hedges and ditch features and the restoration and creation (or re-creation) of moorland, heathland, bogs and wet woodlands;
- The restoration and re-creation of wetland habitat, which could provide additional floodwater storage and flood defence;
- Re-creating saltmarsh, saline lagoons and associated inter-tidal habitats that will contribute to sustainable coastal defences.

In addition, other options in the Higher Level Scheme that could contribute to flood alleviation include:

- Arable - grass margins, direct drilling, set-aside management, arable reversion and soil management strategy;
- Grassland - maintenance and restoration of wet grassland for birds, managing improved grassland to reduce erosion and runoff and stocking rate control;
- Woodland - creation and restoration.

It remains to be seen how many of these proposals are adopted in the final scheme but it is likely that the majority will appear in some form.

Whilst the above commentary focuses on the English case, a similar approach is being adopted in Wales, with arrangements that reflect local circumstances and priorities. The Tir Gofal Scheme was criticised for ‘not sufficiently encouraging improvement in basic soil, air and water resource management’ (Welsh Assembly, 2003), and proposals are now underway to address this in revisions to Tir Gofal, similar to those referred to above for England. Specific mention was made of the need to ensure that the programme ‘contributes to other policy objectives, such as…flood defence’.

6.5 CAP reform

Member states of the EU reached agreement on CAP reform on 26th June 2003. The principal points of this agreement with relevance to this study are:

- The links between farm subsidies and production will be broken - this ‘decoupling’ will remove the incentives for over production whilst at the same time reduce negative environmental impacts and reduce bureaucracy;
- The subsidy payments will be linked to ‘cross-compliance’ - the requirement will be to meet EU standards covering the environment, animal health and animal welfare. Farmers will also have to maintain land in good agricultural and environmental condition as defined by the Member States.

Modulation, the reduction of direct payments and transfer of monies to expenditure on Rural Development (so called Pillar 2) will start in 2005 (a year earlier than originally proposed). The level of modulation was also increased, starting at 3% in 2005 and rising to 5% by 2007, bringing about a greater switch of funding to agri-environment schemes and rural development. Defra (2004a) is consulting national bodies on the implementation of proposals where there are major areas of national discretion. Defra (2004b) has recently announced how it intends to implement the reforms in 2005.

What effect, if any, will these proposals have on potential runoff from agricultural land? A major redirection of funding will be towards agri-environment schemes under the ERDP. As reported above, these schemes are already being revised and updated, and the new Entry Level Scheme is being piloted and suggested options for a new Higher Level Environmental Stewardship Scheme are out for consultation. The benefits likely to arise from these have already been identified, but any increase in funding should ensure that the schemes are applied to a wider audience, thus increasing the effect. Additionally, set-aside will be retained and this may improve water retention as compared with a cereal crop over winter, and set-aside headlands may provide buffers to ditches, streams and rivers as discussed in Section 3 of Part A. Other benefits may accrue from a reduction in the intensity of some farming operations, possible affecting stocking rates, but further detail will be required on the way in which the proposals will be applied before any definitive outlooks can be predicted.

The CAP reforms, through a mixture of increased extensification of many farming enterprises, and increased cross compliance, should increase the incentive for wider participation in agri-environment schemes, reduce the environmental burden of farming and increase the contribution to positive environmental management. This changing policy framework will provide opportunities to promote and fund changes in land use and, along with appropriate flood management strategies and funding, could be used to target vulnerable catchments where it can be established that such interventions will make a difference and are worthwhile.

7. Long-term scenarios and implications for flood generation from rural land

Whereas the preceding review focuses on recent history and the current policy framework, it is recognised that the future could be very different. Although the DPSIR framework might apply, the characteristics and values contained within its components might be very different. One approach to long term planning is to generate 'scenarios' of possible future conditions and to interpret these for the purpose intended. This section considers the use of long term scenario building, or horizon planning, to explore the link between rural land use (as a pathway and a receptor for potential flood waters) and the management of flood risk. It draws on work carried out by the Office of Science and Technology's Foresight Programme (Dti, 2002) and the recent Foresight Flood and Coastal Defence Project (Evans et al., 2003). It also draws on a number of EU funded research projects concerned with land use and climate change (notably REGIS, ACCELERATE, ATEAM and MULINO).

7.1 Scenario building

Scenarios are not intended to predict the future (Dti, 2002). Rather, they are tools for thinking about the future, assuming that:

- The future is unlike the past, and is shaped by human choice and action;
- The future cannot be foreseen, but exploring the future can inform present decisions;
- There are many possible futures: scenarios map a 'possibility space';
- Scenario development involves a mix of rational analysis and subjective judgement.

Thus, scenarios are statements of what is possible; of prospective rather than predictive futures; propositions of what could be. They are often made up of a qualitative story-line and a set of quantitative indicators which describe a possible future outcome. The scenarios arise as a consequence of exploring the possible consequences of drivers of economic and social change, new trends and innovation, and of unexpected events.

The Foresight Programme (Berkout et al., 1998; Dti 1999, 2002) constructed four possible futures which are distinguished in terms of social values and governance (Figure 2).

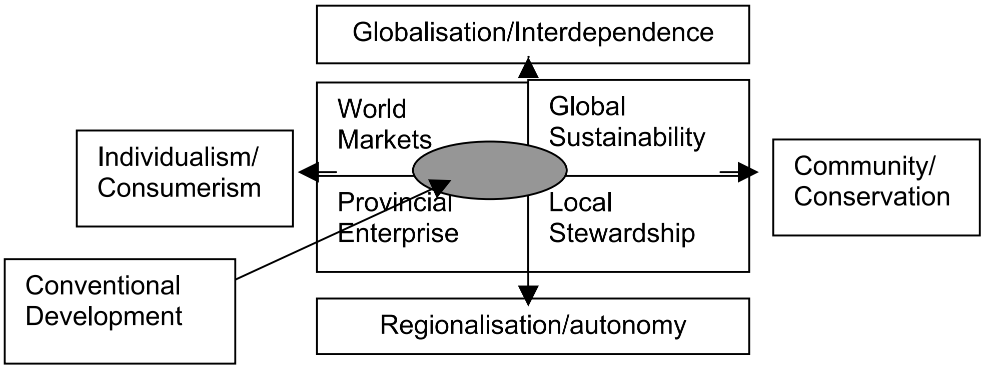

Figure 2 Possible Futures, based on Foresight (Dti,1999)

- World Markets are characterised by an emphasis on private consumption and a highly developed and integrated world trading system;

- Global Sustainability is characterised by more pronounced social and ecological values, which are evident in global institutions and trading systems. There is collective action to address social and environmental issues. Growth is slower but more equitably distributed compared to the World Markets scenario;

- Provincial Enterprise is characterised by emphasis on private consumption but with decisions made at national and regional level to reflect local priorities and interests. Although market values dominate, this is within national/regional boundaries;

- Local Stewardship is characterised by strong local or regional governments that emphasise social values, encouraging self-reliance, self sufficiency and conservation of natural resources and the environment.

The UKCIP02 study (Hulme et al., 2002) on climate change also linked these scenarios to possible trends in greenhouse emissions and associated climate change. The climate change signals are high under World market and Provincial Enterprise, and medium to low under Global Sustainability and Local Stewardship. The greater is the extent of climate change, the greater is the expected variation in storm intensity and the greater is the expected frequency and severity of flooding (although total precipitation may not vary greatly between scenarios).

7.2 Possible futures and likely future change agricultural scenarios

The generic scenarios in Figure 2 have been interpreted for the purpose of defining possible agricultural scenarios. As discussed in section 2 above, the main drivers that shape agriculture under the possible futures are:

- EU agricultural environmental and regional policy (especially CAP reform);

- Trade liberalisation and the role of WTO;
- Demand for and supply of agricultural commodities on world or national markets (as relevant) associated with population growth, economic prosperity and preferences;
- Technology development and applications;
- Priorities and interventions to deliver required economic, social and environmental objectives.

These drivers, many of which are interconnected, combine with the political, economic and social imperatives contained within the scenario types. In turn these generate the input (such as crop prices) and output parameters (such as land use) that give the scenarios their particular distinguishing characteristics.

Drawing on this framework, Table 3 summarises some of the key features of UK agriculture that might be associated with these futures. Land use (and the detail of farming systems, and the relative importance given to sustainable natural resource management and rural livelihoods) is likely to vary amongst the Foresight Scenarios and their rural sector characteristics. Summaries of possible land use, flood generation and impacts associated with each of these main agricultural scenarios are summarised for the 2050s and 2080s in Tables 4 to 7. The generation of flooding in rural areas will depend on the extent to which particular futures encourage land management practices known to be associated with flood generation or abatement. Similarly, the impact of flooding in receptor areas, and the responses to flood risk, will vary according to dominant land use and management practices that are scenario dependent.

For example, the World Markets scenario is characterised by outward looking, internationally competitive, large scale intensive farming. This is likely to exacerbate the probability of runoff and water soil-erosion in intensively farmed areas and catchments. It is likely, however, that arable production on marginal land will no longer be justified and some low grade land will be no longer be farmed. These changes could alleviate flood generation in some areas.

Under Global Sustainability, the market orientation of farming is moderated by a strong commitment to environmental protection, with a reinforcement of the agri-environment and compliance initiatives. Flood generation would generally reduce under this regime, and flood plains would be managed to provide natural storage.

The Provincial Enterprise scenario reflects a change to a productivist focus for agriculture with a comprehensive regime of direct subsidies for production and a high level of protection from external competition. The probability of flood generation is high, and the off-farm costs borne by third parties are significant.

By comparison, Local Stewardship involves relatively extensive, small-scale farming, local area produce, and greater self-sufficiency in food, with a high level of environmental protection and enhancement. Nature conservation, including managed wetlands, is a key feature, with farmers, encouraged by a mix of regulation and payment schemes, providing environmental services, including possibly flood storage on washlands. Flood management decisions will be made at local level.

Thus, differences in drivers and governance amongst the possible futures have implications for the generation of flooding from rural land as well as the types of policies, interventions and coping strategies that might be required to mitigate associated risks.

Table 3 Future agricultural scenarios for England and Wales

	World Agricultural Markets	Global Sustainable Agriculture	Provincial Agriculture	Local Community Agriculture
Agricultural and rural policy	Abandonment of CAP. WTO led free trade in agricultural commodities. Limited interventions for social or environmental purposes. Increased global trade in agricultural commodities Rural diversification opportunities based on market potential.	Reformed CAP. WTO promoted liberalisation. Decoupled agricultural support. Retention of area payments. Promotion of sustainable agriculture, including agri-environment and animal welfare regimes Global rules seek ethical rural development. Multi-functional agriculture produces public goods.	Protectionist agricultural policies, involving input and commodity subsidies, deficiency payments and marketing/intervention regimes. Limited environmental and social concerns. Rural economy is based primarily on agriculture and food. Farming is the main agent of development	Protectionist and regional support policies justified in terms of social and environmental priorities and a commitment to self reliance and independence. Rural development emphasise conservation and community: a living/working countryside, balanced communities, sustainable livelihoods. Policy support for low input and extensive farming, including remote areas
Environmental policy	Limited restrictions on chemical use, other than market imposed. Limited interest in soil and water conservation unless affecting production. Environmental risk managed through economic instruments. Tradeable permits for water.	Comprehensive, integrated approach to prevention/minimisation of diffuse pollution from agriculture. Policy mix includes regulation, voluntary measures and economic instruments reflecting a commitment to 'stewardship' and biodiversity. Promotion of 'best available techniques'. Controls on water abstraction and use, with some trading.	Input intensive farming, limited controls on agro-chemicals and farming practices on environmental grounds. Relatively high probability r of soil damage, erosion and diffuse pollution, with regulation where these prejudice commercial interests.	Generally lower environmental risk but fragmented and selective regulation and control. Sustainable soil and water management embedded in farming culture, backstopped by strong regulatory and protective policies, e.g. to control soil erosion or water quality.
Food markets and prices	Market led, consumer driven, but with increased domination of major food retailers. . International procurement and market integration. Producer and consumer food prices fall for global products, with premia for niche products	Food supply chain accepts responsibility for promoting and responding to consumer concerns about safe, healthy and ethical foods. Consumer food prices rise due to quality assurance and compliance costs, providing incentives to producers	Supply driven food chain. Food industry, especially producers and processors define product offering and criteria for food quality Government supported supply side interventions maintain high producer prices, but cheap consumer food prices. Little pressure for farmers to be market oriented .	Distaste for global, processed foods. Greater connectivity between consumer and producer. Developed local area produce and markets. Highly differentiated foods are trading between regions. Local 'brands' emphasise environmental and social attributes. Farmer co-operative production, processing and marketing schemes to add value and raise prices.

Table 3 cont	World Agricultural Markets	Global Sustainable Agriculture	Provincial Agriculture	Local Community Agriculture
Farmer attitudes/ motivation	Polarisation into commercial, agribusiness (production oriented) and lifestyle, 'hobby' (conservation oriented) farmers. Biodiversity in farmed areas to suit commercial farming, or a commercial activity in itself.	Production oriented farmers tempered by increasing interest in conservation. Conservationists find expression in agri-environment schemes. Integration of farming and wildlife encouraged by policy	Commercially driven production focus, emphasis on output and production. Environmental motivations mainly commercially based and remedial.	Farmers as custodians of the countryside, embracing commitment to sustainable livelihoods. Strong conservation and community ethic. Varied income sources, on and off-farm.
Agricultural production and farming systems	Relatively low farmgate prices for 'bulk commodities' partially offset by low input prices resulting in moderately high input levels and yields. Commercially driven high technology systems, 'industrialised' agri-businesses, global in scope, reaping economies of scale. Marginal arable land abandoned. GMOs widely promoted and adopted. Important specialist niche producers focussing on targeted market segments for specialist foods, including organics and irrigated produce.. Intensive large scale feedlot livestock systems, but some extensive grazing on abandoned cropland. Hill and upland areas not farmed. Market driven welfare concerns.	Moderate farmgate prices for bulk commodities, high input prices and moderate regulation on inputs leads to moderate increases in agricultural productivity and production. Agri-environment contributes to global services. Diversification/multi-functionality important. Strong COGAP 'compliance' requirements resulting in relatively high costs. Large scale farms, but with policy to retain family farms through target support. Areas taken out of production for nature conservation. Selected adoption of GMOs, driven by environmental benefits. Limits on stocking rates, extensification incentives, strong welfare controls.	High, guaranteed farm gate prices and moderate input price encourage intensive farming systems with high crop and livestock yields. Broad based farming sector to provide self-sufficiency. Mixed arable and livestock farming systems, intensive lowland dairy and cattle, with beef and sheep maintained in disadvantaged areas. Vegetables and agro-industrial raw materials are growth sectors Moderate trend towards large farms but family farms remain viable. Patchy adoption of GMOs, driven by limited economic incentives, but little concern about side effects. Technology production oriented, but relatively low inducement to seek major efficiency gains by investment. Organics limited. Limited welfare concerns.	High farmgate commodity prices, moderate to high input prices, and strong ethical (and regulatory) framework encourage relatively low intensity farming, integrated with environmental management as a basis for sustainable agriculture and multi-functionality, Input levels and yields are relatively low, but area farmed increases. Agriculture is broad based and diverse, mixed arable and livestock systems are common. Arable farming exhibits high crop diversity and extended rotations. Retention of small scale, family based farming units, including support to remote upland and hill areas GMOs rejected. Non-differentiated organics widespread. Relatively extensive livestock systems, part of mixed farming systems. Emphasis on environment and welfare,

Table 4 Scenario 1: World Markets: Rural land management and flood generation and management

Change Land Use and Farming Practices		Comments
2050s	2080s	
Relative intensification of agriculture on Grade 1 and 2 land, Some marginal arable land reverts to grass and low grade land drops out of production, or put to alternative use. Reduced profitability per ha and lower land values reduces agricultural flood damage cost.	Further consolidation of general trend as for 2050s but with effects of climate change which are likely to move boundary of crops northwards, but not substantially affect receptor impacts.	Strong prospect of climate change, with implications for soil degradation and erosion Internationally competitive agriculture, WTO driven, large scale, specialist, less diverse, intensive farming. Zero farm subsidies, without protectionism. Limited agri-environment schemes, no set aside arrangements, but alternative land uses develop in response to market opportunities Commodity prices relatively low, offset by higher yields and reduction in prices of internationally traded inputs such as agri-chemicals. Increased use of precision farming methods and GMs as part of technologically advanced sector. GMOs could produce flood/wetness tolerant varieties. Intensification of management of high quality agricultural land leads to increased risks to soil structure and hence flood runoff generation, but recognition of adverse on-farm impacts (including soil erosion) could lead to improved management practices. Wetter winters drive investment in field drainage; this reduces the probability of flood generation on heavy clay soils and increases it on more permeable soils. Drier summers in South and East lead to increased use of irrigation, with increase probability of erosion Low agricultural value of poor quality land: abandonment of grade 5 and 5 ALC, possibly reducing runoff and offering 'market' opportunities for flood water retention /storage options, but without the environmentally driven pressures to maintain wetland habitats. Managed coastal retreat justified on economic grounds where compatible with protection of infrastructure or recreation opportunities. Flood defence driven by economic imperatives based on international prices and comparative advantage, with land managers paying directly for flood defence services, or selling floodwater storage services. Large areas of high-grade land in flood risk areas, such as the fens are likely to justify flood defence, funded by landowners. Low-grade land will probably not warrant protection, possibly leading to a market in flood storage services on previously farmed land. Flood damage costs on non-farmed land negligible. But possible market in 'wetlands' based on 'willingness to pay' for environmental goods.

Table 5 Scenario 2: Global sustainability: rural land management and flood generation and management

Change Land Use and Farming Practices		Comments
2050s	2080s	
Relative intensification of agriculture on Grade 1 and 2 land but commitment to sustainable land management practices to reduce flood runoff generation. Serious attempts to balance production with nature conservation. Extensification and diversification of land use on other grades, with flood water retention.	Further consolidation of general trend as for 2050s, but with some moderate effects of climate change which are likely to move boundary of crops northwards, with possible increased scope for winter flood storage schemes in floodplains	Relatively weak climate change signal. Internationally competitive agriculture, with interventions to meet social and environmental objectives, indicative of a mix of reformed CAP (Agenda 2000) plus application of WTO principles. Selected farm income support linked to wide spread compliance with good practice (such as integrated crop management), and targeted environmental enhancement. Relatively high yields in commercial sector supported by precision farming operating within constraints on use of cultivation, agro-chemicals and crop and livestock management practices which could generate damaging external impacts. Promotion of farm extensification and diversification for social and environmental purposes, recognising multi-functionality of agriculture. Strong emphasis on sustainable agricultural land management practices to protect soil structure and minimise adverse effects on runoff and erosion. Measures to enhance nature conservation also reduce flood runoff generation. Management of flood plain land seeks a compromise between protection of valuable agricultural production, protection of wetland habitats and flood storage and attenuation. Greater emphasis on wise use of land and water resources including floodplains. Large areas of high agricultural grade land likely to justify protection from flooding. Scope for sustainable integrated flood management and biodiversity in the form of managed washlands. This approach, applied at catchment level, will help reduce cost of flood damage in receptor areas by developing flood tolerant, wetland land uses.

Table 6 Scenario 3: National enterprise: rural land management and flood generation and management

Change Land Use and Farming Practices		**Comments**
2050s	**2080s**	
Agriculture is the dominant purpose and activity on all land grades. Relatively high agricultural profitability supported by subsidies. Production oriented, intensive agriculture increases the probability of run-off and erosion Limited attempts to address off-farm impacts. Lack of mitigation measures, including return of floodplain storage.	Further consolidation of general trend as for 2050s, but with effects of climate change which are likely to move boundaries of crops northwards, and increase risk of soil damage and runoff. .	Strong climate signal. National agricultural policy regime, similar to pre 1992 CAP reform situation with emphasis on self sufficiency through protectionism and direct production support and capital grants to farmers. Including those for land drainage. Moderate trend towards large farms, with mixed farming systems. Farm Commodity prices relatively high, but moderate yields increases with tendency to stagnate over longer term, with increased dependency on agri-chemical controls, and farming methods designed to overcome rather than work in balance with natural soil, water and ecological regimes. Technology development and investment commonly remediation driven. Agriculture is the dominant rural land use, including ‘reclamation’ and relatively intensive use of marginal land, with resultant risk of soil degradation and runoff. Little importance given to social and environmental issues unless this affects production. Investment in irrigated agriculture or field drainage are mainly driven to protect yields, without regard for environmental impacts, and defined by incentives of domestic markets and agricultural support. Continued degradation of soil structure due to agricultural management practices, increasing flood runoff, but lack of integrated environmental management so mitigation measures, including use of floodplains for flood storage and attenuation, will not occur. Flood defence for agriculture justified in terms of a ‘food from our own resources’ strategy, funded through public purse, similar to that which prevailed in 1960s to 1980s, including large scale regional schemes. When flooding does occur, damage costs are high.

Table 7 Scenario 4: Local stewardship - rural land management and flood generation and management

Change Land Use and Farming Practices		Comments
2050s	2080s	
Diverse rural land use, working within the limits of available resources. Less intensive systems based on rotations and mixed crop and livestock systems Strong, cultural commitment to sustainable agriculture to protect soil quality, reduce runoff. Floodplain management to enhance flood storage and attenuation. The balance of priorities defined at local level, leading to variations in outcomes between locations.	Further consolidation of general trend as for 2050s, but with effects of climate change which are likely to move boundary of crops northwards. Land use has recognised multi-functions, and as a consequence sensitivity to flooding is reduced	Intermediate strength of climate change signal, which leads to wetter winters and increased runoff potential. CAP withdrawn and WTO does not apply. Introduction of regional/local/community rural and agricultural policy regimes which emphasise needs and priorities, self reliance and sufficiency, social and environmental objectives as defined at local level, and sustainable agricultural technologies. Characterised by local area produce, healthy foods, more organics, no GMOs, reduced agri-chemicals, lower input:output systems, offset by increase in farmed areas, tendency towards family and medium scale farms. Targeted support, with commitment through regulation and incentives to social and environmental objectives, promoting multi-functional sustainable agriculture, especially regarding environmental protection and enhancement. Diverse, sustainable agricultural management to protect soil structural quality. Some tensions between agricultural management and environmental management (e.g. field drainage, irrigation) resolved by strong integration of agricultural management and environmental protection at (small) catchment scale, with increased use of measures such as woodland buffer strips for habitat restoration, protection of water quality and flood runoff mitigation. Reduced levels of floodplain protection for agriculture and return to natural floodplain functions, reinforced by concerns to maintain wetland habitats, leading to increased flood storage and attenuation. Release of coastal land for managed retreat. Land uses are diverse, providing a basis for sustainable livelihoods, and land values rise. Flood management decisions made at regional, catchment and local level. Emphasis on sustainable flood management solutions that integrate multi-functions at catchment level flood plains, including agriculture, biodiversity, soil and water resources, tourism and recreation. Return of flood plains to natural condition and functions, encourages culture of flood management rather than defence, and reduces overall cost of flooding.

7.3 Likely responses to future change agricultural scenarios

Likely agricultural responses to future change are very scenario dependent, as each scenario affects policy objectives and choice of instruments. In particular, the scenarios reflect different relative ‘values’ and the balance of priority given to agriculture and biodiversity.

Under the ‘utilitarian’ World Market and Provincial Enterprise scenarios, there will be increased probability of runoff in intensively farmed areas. Land managers will adopt measures to mitigate on-farm effects where these are deemed financially advantageous, but will not take measures to mitigate off-farm effects unless subject to regulation or economic penalties. In the World Market scenario, mainly economic instruments will be used to correct for external effects which are deemed unacceptable. Under Provincial Enterprise, agricultural research and extension services would encourage farmers to adopt voluntary soil and water conservation measures to reduce agricultural land degradation.

Under the more ‘community’ oriented scenarios of Global Responsibility and Local Stewardship, responses will reflect a commitment to sustainable land management practices and approaches to flood management. Under these scenarios, farming will be required (and in principle farmers will be more willing) to comply with ‘good practice’ to control runoff. In the Global Sustainability future this will be tied to income support. The multi-functionality of rural land management will receive more recognition under these scenarios, with attempts to integrate farming, landscape, wildlife and amenity. The management of risks associated flood generation will be managed at catchment level in this broader context. In the lowlands, water storage in floodplains will be integrated with biodiversity and water resource objectives.

Responses to pressures in coastal and estuarine zones will vary amongst scenarios in much the same way. The World Market scenario would encourage abandonment of unproductive coastal areas, whereas Provincial Enterprise most likely would retain high levels of protection. Global Responsibility and Local Stewardship would seek integrated, potentially sustainable ‘managed’ solutions, the latter reflecting the particular interests of the local or regional community.

8. Summary and conclusions

This Appendix has: reviewed the social and economic dimensions of the link between rural land use and flood generation using the Driver-Pressure-State-Impact-Response Framework; considered policy interventions to reduce flood generation, adopting the perspectives of policy makers and land managers; and explored possible long futures as these might affect the interrelationship between rural land use and flood risk.

The incentives provided by agricultural commodity markets and prices are the key driver for rural land use. These incentives are, however, strongly influenced by Government agricultural policy that subsidises particular types of land use as a means of providing support to farmers and the rural economy. Together with changing agricultural technologies and associated farming systems, these market and policy drivers have tended to increase the pressure on soil and water resources as farms have become larger, more intensive and more specialised. In particular, conversion of grassland to arable in lowland areas and increased animal stocking rates in upland areas have in some cases led to increased water erosion and runoff, thereby deteriorating the ‘state’ of soil and water resources.

Evidence suggests that the greatest impact of runoff and associated water erosion is off-site, that is beyond the farm of origin, resulting in significant ‘external’ costs borne by society at large. The on-farm costs of runoff are small compared to the gains from intensive land use. Thus there are few incentives to land managers to control runoff. The possibility of legal liability under the new EU Directive on Environmental Liability could have a significant influence on land management practices where these do, or can potentially, give rise to flood damage and farmers can be shown to be ‘at fault’.

There is evidence that changes in land use have been associated with localised ‘muddy floods’, in some cases with farmers found liable for the damage caused to others. Although the Environment Agency estimates that land use on ‘hill slopes’ contributes £115m per year to flood damage, there is limited evidence to support this.

There are currently few policy interventions which explicitly address the control of runoff from rural land, although some features of agri-environment schemes include components which are likely to reduce runoff. Interventions which seek to reduce near-source drivers and pressures associated with land use change are likely to prove more effective and efficient than interventions to mitigate impacts, especially as the drivers themselves are policy driven. This involves discouraging inappropriate land use and farming practices where these are clearly linked to increased runoff and flood risk.

Response themes to control runoff will reflect the dominant purpose of rural land, whether mainly farming for food production or a multi-functional approach including contribution to biodiversity, hydrological processes and sustainable rural economies. This will influence the promotion of integrated rather than single purpose solutions to problems associated with land management.

The diffuse nature of rural land management and related flood generation suggest that, on its own, mandatory regulation would prove ineffective and inefficient, being difficult and costly to administer and enforce, and possibly insufficiently flexible to deal with local circumstances and practices.

Given the critical role of agricultural policy, it seems appropriate to include compliance with runoff control measures as a condition of support to farm incomes. The process of 'modulation', whereby farm income support is directed through agri-environment payments, can be used to 'incentivise' good practice. Defra's new entry-level stewardship scheme offers scope for this.

Given the evident responsiveness of farmers to financial inducements, the best approach would appear to be a mix of economic and voluntary instruments, supported by advice and technical support. In cases where risks are high, it may be necessary to regulate against particular practices. Such a 'fit for purpose' approach is compatible with the Environment Agency's recent adoption of a diverse approach to environmental protection, much of it driven by a need to reduce the burden of regulation for all parties.

Experience of the adoption and diffusion of technology in the farming sector can help to design and promote appropriate soil and water conservation measures to reduce runoff from farmland. Proposals must offer relative advantage (including the advantage to farmers of the ability to demonstrate compliance with regulatory requirements), be practicable, and make a difference. It is important therefore that runoff control techniques are proven locally, are championed by opinion leaders, and supported through research and extension.

The criteria of effectiveness and efficiency require that policies to reduce flood generation from rural land adopt a risk-based approach at the catchment level. It will be important to be able to attribute particular land use and management practices to flood risk (defined in terms of probability and consequences) and from this determine the contribution of suitable and proportionate intervention measures. It is clear therefore that the links between land use and flooding at the catchment scale need to be assessed to inform a strategic approach, including choice of intervention measures and instruments.

It is apparent that although the existing state of knowledge can reasonably estimate runoff probability at farm level (and the efficacy of interventions to control this), it is not easy to connect this to flood risk at the sub-catchment and catchment scale. A catchment/coastal zone approach is required to capture the aggregated impact of interventions, especially of individually small measures such as on-farm runoff controls. Research is required to test and validate these linkages as a prerequisite for policy formulation.

Given the critical role of agricultural policy, it seems appropriate to include compliance with runoff control measures as a condition of support to farm incomes, especially those regimes which promote environmental protection. Agri-environment schemes, notably the Environmental Area Scheme and the Countryside Stewardship Scheme, are used by the Government in England and

Wales, to encourage the sustainable development of rural areas and deliver public benefits associated with land management. Although at present these schemes do not contain specific components for the control of runoff from farmland flooding, there are a number of management options that may help to do so. These include payments to farmers to revert arable land to grassland, establish field margins and related boundary features, introduce buffer zones between farmed land and watercourses, retain stubble in fields during winter, and restrict animal stocking rates. New arrangements for 2005 are currently under review. They may include measures to reduce soil erosion and associated runoff on cultivated land with relatively light soils on hillslopes. There may be requirements to cultivate along contours, adopt direct drilling and avoid of crops such as maize which can increase the vulnerability of soils. Such targeted measures, together with the generic promotion of those mentioned earlier, could help to reduce runoff and the probability of flooding.

Proposals for the new Environmental Stewardship Scheme include reference to the protection of soils as a primary objective. A specific secondary objective is to contribute to the improvement of flood management. It is anticipated that this will be met through the adoption of particular land management options to help reduce runoff such as those mentioned above, together with options to temporarily store excess water such as on farm retention reservoirs and washlands. It remains to be seen how many of these options are adopted in the final scheme but it is likely that the majority will appear in some form.

With respect to long term futures, the Foresight scenarios suggest that the probability of runoff from rural land and hence the contribution to flood generation varies according to the type and orientation of farming systems. Under the ‘utilitarian’ World Market and Provincial Enterprise scenarios, the probability of runoff increases in intensively farmed areas. Under the more ‘community’ oriented scenarios of Global Responsibility and Local Stewardship there is an embedded commitment to sustainable land management practices that, amongst other things, reduce the probability of runoff.

Although there is a tendency in flood management to focus on surface water flows and flooding, in a rural context the role of groundwater is critical and needs explicit consideration in any strategies to manage the interface between rural land and flood generation.

A key influence on the justification for intervention is likely to be the management of flood risk to urban areas. The costs of interventions on rural land will be justified mainly against the benefits to urban flood alleviation, or the savings in defensive expenditure. Thus, the rationale for intervention in rural land management largely depends on the impact on urban flood risk, and much depends on catchment and event specific factors.

Key constraints to successful interventions are likely to be institutional rather than technical, including possible reluctance to adopt runoff control/storage measures by land managers, policy conflicts, and the fact that integrated solutions tend to be more complex to implement in the first instance. There will be need to demonstrate that intervention methods can make a difference, are practicable, and, in the case of farmers, can support livelihoods. There are uncertainties regarding the effectiveness of runoff control/storage measures under local conditions that will justify applied research to support the design of responses, as well as concerted action to promote adoption.

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