Countermeasures:

ENVIRONMENTAL AND SOCIO-ECONOMIC RESPONSES - A LONG-TERM EVALUATION

ECONOMIC ASSSESSMENT OF COUNTERMEASURES

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Economic Assessment of Countermeasures

A Technical Deliverable of the CESER Project

Countermeasures – Environmental and Socio-Economic Responses

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Terms of Reference

This report forms the technical deliverable "Economic Assessment of Countermeasures" as part of the requirements of Work Packages 5 and 6 of the CESER project (Countermeasures – Environmental and Socio-Economic Responses).

The CESER Project is co-funded by the European Union's Fourth Framework, Nuclear Fission Safety Programme (DGXII). The main institutions participating in this project are the University of Stirling (UK), University of Bremen (Germany), Finnish Environment Institute (Finland), Nord-Trøndelag College (Norway) and University of Salzburg (Austria). The project runs from January 1997 until June 1999.

The overall aim of the project is the development of a decision support system to aid the long-term management of radioactively contaminated agricultural land. This is intended to help decision makers in selecting the most appropriate countermeasures for their specific circumstances by applying environmental, economic and social criteria alongside those of radiological effectiveness and practicability. To achieve this, the work programme is structured into the following objectives:

1. To identify the most significant environmental and agricultural impacts arising from application of countermeasures designed to reduce soil-plant-animal transfer of radionuclides.
2. To quantify through modelling, experiments and expert judgement the degree and duration of these environmental and agricultural impacts.
3. To evaluate the combined impacts of countermeasures including differential responses of radiocaesium and radiostrontium under different food production systems.
4. To predict the spatial patterns of side-effects on a regional and national basis through utilisation of geographical information systems and classify geographical areas according to their suitability for countermeasures.
5. To identify and assess consumer attitudes towards contaminated food products, the use of countermeasures in food production and their willingness to pay to avoid damages.
6. To compare the direct and indirect costs and benefits of countermeasures related to changes in economic output, environmental quality and human health.
7. To provide a decision support package, which can be used as a regional and national planning tool in the long-term evaluation of countermeasure suitability of land, incorporating both environmental and socio-economic impacts.

This technical deliverable specifically addresses objectives 6 and 7 of the work programme.

1. Introduction

Accidental releases of radioactivity into the environment can cause long-term contamination in agricultural food production systems. However, successful remediation may allow food production to continue. Decision makers have a wide choice of countermeasures that aim to reduce soil-plant-animal transfers of radionuclides. Criteria commonly applied in selecting countermeasures are radiological effectiveness, cost and practicability. Little consideration has been given to the risk of negative effects of remediation on the essential functions of ecosystems and agricultural productivity. To address this, the CESER project is seeking to quantify the potential environmental and agricultural impacts of countermeasures and to value these in economic terms. The work is focused on countermeasures applied in land-based food production systems contaminated with radiocaesium and radiostrontium.

Countermeasures are likely to generate a variety of costs, which may fall on the farmers and land managers, but may also fall on society. Social costs would arise from any adverse impacts on the environment or on farm profitability. To quantify these impacts, estimates have to be obtained for:

- Costs to farmers/land managers due to losses in profits resulting from necessary changes in their farming activities;
- Environmental costs due to impacts such as water pollution, soil erosion, land use change and effects on biodiversity.

Benefits of countermeasures include the value of the food that could otherwise not have been sold for consumption. Little is known about consumer attitudes towards contaminated and treated foods in this context. Related work carried out jointly by the Nord-Trøndelag College, Norway and the University of Stirling as part of the CESER project has sought to estimate the necessary price reductions if treated foods are to be sold to the public. These reductions clearly impact on the magnitude of benefits. Alternatively, the benefits of countermeasures can be considered in terms of reductions in risk, and in lives saved/illness averted.

The CESER project has developed a series of decision-aiding tools that can be used to assess the suitability of different countermeasures by applying environmental, economic and social criteria. The ‘Economic Assessment’ presented here, was intended as a separate component within Work Package 6. It is a significant achievement beyond the original work programme that some of the economic impacts of countermeasures have been integrated into the expert/decision support system (CeserDSS). This software package allows the assessment of countermeasure suitability for a range of Scottish farm types in relation to agricultural and environmental conditions. An economic assessment tool was added to the software based on the methodology presented in this report.

The general methodology of cost-benefit analysis is explained in Chapter 2. Chapter 3 discusses the collection of data for private costs to the Scottish farmer and for environmental costs (excluding landscape quality). Chapter 4 reports the results of the contingent valuation study undertaken to estimate landscape change costs and Chapter 5 briefly discusses benefit estimation. Chapter 6 shows how these economic cost and benefit estimates are incorporated into the Decision Support System. Chapter 7 summarises the work in terms of strengths, weaknesses and opportunities.

Figure 1 illustrates how the economic assessment of countermeasures is embedded in the overall structure of the CESER project.

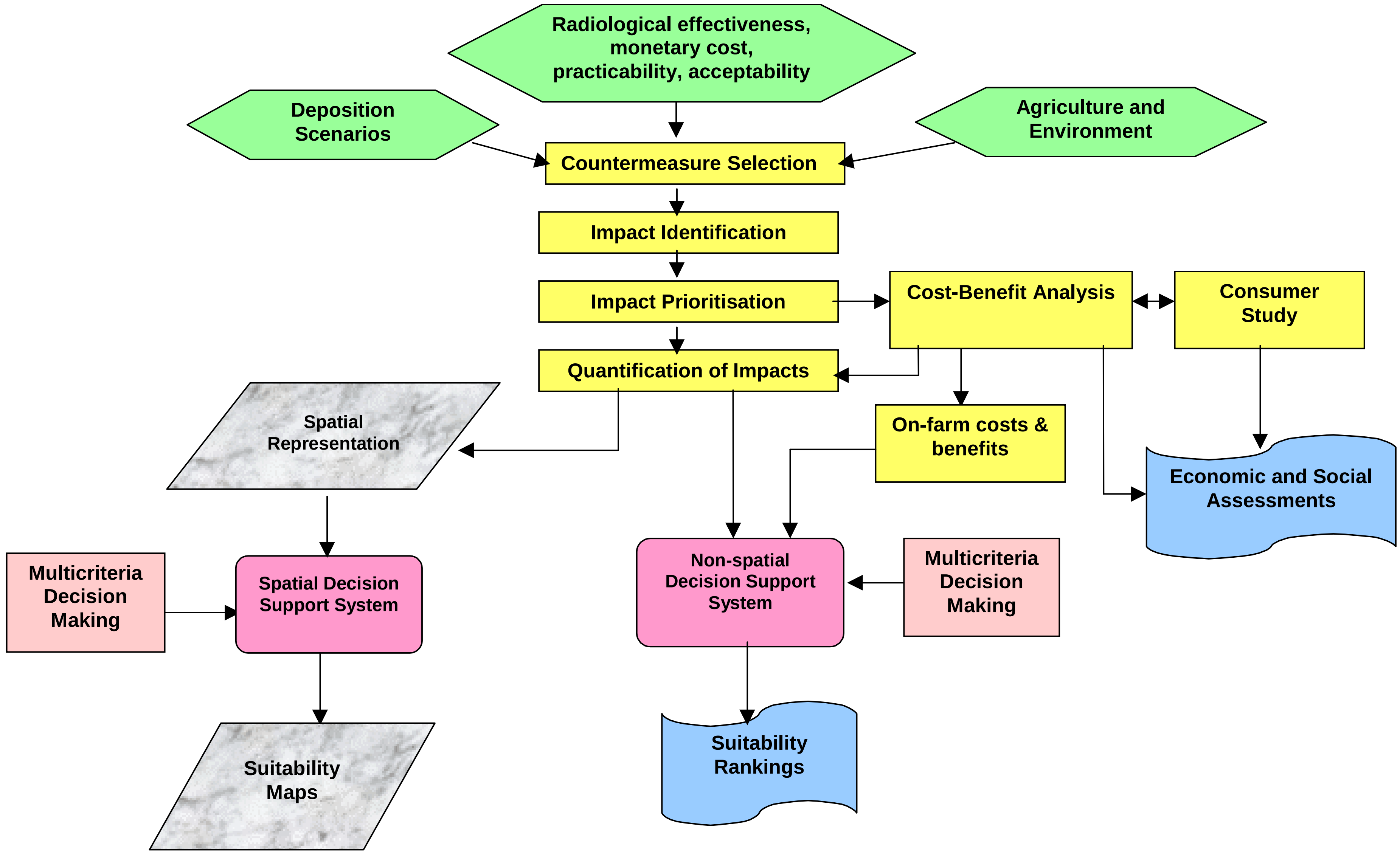


Figure 1. Overview of the CESER project.

2. The Methodological Basis: Cost-Benefit Analysis

There are two main requirements to delivering the economic objectives of the project: (i) a methodological basis, i.e. the Cost Benefit Analysis approach and (ii) data on benefits and costs of countermeasures. *Costs* include on-farm costs met by the farmer and environmental costs, both on- and off-farm. Estimates for some of these environmental costs can be obtained from the literature. For landscape impacts, original estimates were derived using the contingent valuation approach. Two methods of measuring the *benefits* can be identified: (i) the value of production saved (that is, avoided product wastage), and (ii) the value of avoided health damages. With respect to (i), allowance must be made for risk preferences on the part of consumers, as discussed in Grande (1998). With regard to (ii), information is required on predicted savings in exposure and the consequent reduction in risk to humans. Ideally, these reductions in exposure can be expressed in monetary terms using Willingness to Pay estimates for reduced risk, gathered from other studies.

Cost-benefit analysis (CBA) is generally understood to refer to the appraisal of projects or policies from the perspective of society as a whole, rather than from the perspective of those responsible for the decisions on the project. Historically, CBA was widely used for project appraisal (see Hanley and Spash 1994, Chapter 1), but has become increasingly used for policy appraisal too, in both the EU generally (Pearce, 1998) and the UK (Hanley, 1999). Since the 1970s, there has been a growing tendency to incorporate the environmental impacts of policies and projects into CBA, through the monetarisation of these impacts as either benefits or costs. Improvements in the techniques used for environmental valuation have facilitated this trend (Hanley and Spash, 1994).

There are five steps to a typical cost-benefit analysis (Common, 1988):

- Project definition and identification.
- Complete enumeration of the consequences of going ahead with the project.
- Aggregation over consequences at each period in the project's life to obtain time series for project costs and benefits.
- Aggregation of the costs and benefits over time to estimate the present net value of the project.
- Sensitivity analysis.

For countermeasures, changes in agricultural management activity and associated environmental changes were predicted as outputs from other parts of the project. The economist has to value these changes in monetary terms and aggregate them into overall costs and benefits. Selected countermeasures can then be compared on social cost-benefit grounds. Farm-level costs must be estimated as part of the CBA exercise. These can be used to compare countermeasures in terms of effects on farm income. This forms an important part of the Decision Support System (see Chapter 5).

Table 1 lists the countermeasures that are included in the CESER Decision Support System and for which direct and indirect costs and benefits are required. A detailed description of each countermeasure is given in Appendix I.

Table 1. Brief description of the countermeasures considered in the CESER Decision Support System.

Countermeasure	Description
Feed AFCF	Feed ammonium-iron-hexacyanoferrate to animals
Feed Calcium	Feed Calcium to dairy cows daily
Feed clean roughage	Animals fattened on uncontaminated roughage
Feed clean concentrate	Animals fattened on uncontaminated concentrate
Feed more concentrate	Animals fed an increased diet of concentrate
Intensify pasture use	Intensify use of improved land
Improve pasture	Improve rough grassland by cultivation and seeding.
Sell animals early	Animals sold after early weaning
Sell animals for fattening	Animals sold for fattening elsewhere
Cease animal/crop production	Cease existing production and leave land fallow
Deep plough	Plough to 50 cm depth
Skim & burial	Remove top 5 cm of soil and place at 50cm depth
K fertilization	Apply potassium fertiliser annually
Liming	Apply lime to soil every 2 years
Change to oil seed rape	Convert arable production to spring oil seed rape
Cease hunting	Cease hunting (stalking) of deer
Afforestation	Cease current practice and convert to coniferous forest

Note: Within the Decision Support System certain combinations of these countermeasures are also permitted.

3. Estimating Countermeasure Costs

A thorough review of the literature was undertaken to locate information on costs of countermeasures. Much of the data was restricted to direct costs for areas of the Former Soviet Union most affected by the Chernobyl accident (e.g. Hubert, *et al.*, 1996; Roed, *et al.*, 1996;). However, these costs cannot be directly transferred to Western Europe, given, for example, the considerable differences in labour costs, productivity, commodity prices and available technology. Published data on the direct costs of countermeasures is also often aggregated in a way which makes it difficult to identify individual cost elements (Strand *et al.*, 1997). No specific literature on the environmental costs of countermeasures was available. However, it was possible to draw parallels with other human activities giving rise to similar impacts.

3.1. On-farm Costs

For on-farm effects, two key publications have provided most of the cost and benefit data used in the economic assessment of countermeasures. These are: The Farm Management Handbook 1998/99 (SAC, 1998) and The Economic Report on Scottish Agriculture 1998 (SOAEFD, 1998). More detailed data relating to particular countermeasures was obtained through personal discussions with Scottish Agriculture College advisors and other experts. Table 2 shows five examples of the types of variables and data sources used in the calculation of on-farm costs for different countermeasures. In the CeserDSS, data for some of these variables has to be supplied by the user.

Table 2. Calculating farm level costs: Examples of variables and data sources.
(cm = countermeasure, normal = normal management)

Countermeasure	Cost element	Variables and Data Sources
Supply calcium daily to dairy cows	Cost of calcium	Number of cows – input by user Calcium fed per day (cm) – 500 grammes Calcium fed per day (normal) – input by user Price of calcium - £25/tonne (pers. comm. Franzefoss Bruk A/S)
Lime the soil (every 2 years)	Cost of lime	Area of application – input by user Spreading rate – 2 tonne/ha Price of lime - £30/tonne (SOAEFD, 1998 p13)
	Contractor cost	Area of application – input by user Work rate – £6/ha (SAC, 1998 p305 based on 2t/ha)
Afforestation (e.g. on livestock farms)	Loss of existing margin	Number of animals – input by user Margin per animal – varies by farm type (SAC, 1998)
	Animal disposal	Number of animals – input by user Average weight of animals – input by user Disposal to landfill - £25/t (Connell, pers comm.)
Administer AFCF	Cost of AFCF	Number of animals – input by user Price of AFCF – depends on form of application (Brynhildsen *et al.*, 1996; Hansen *et al.*, 1996) Treatment period – varies by farm type and scenario
Improve land (applies to rough grazing on upland/hill farms)	Additional labour	Area of improvement (ha) – input by user Labour rate - £6.1/hr (SAC, 1998 p307) Ploughing rate – 0.9 ha/hr (SAC, 1998 p301) Fertilising rate – 3 ha/hr (SAC, 1998 p301) Sowing rate – 1.3 ha/hr (SAC, 1998 p301)
	Seeding material	Cost of materials - £96/ha (SAC, 1998 p 111)

For all countermeasures a partial equilibrium budgeting model was adopted. This implies that countermeasures do not have impacts on, for example, input prices at the regional or national level. It also implies that impacts of any countermeasure on other aspects of farm activities are not taken account of, e.g. the impact of early weaning and sale of lambs on other farm enterprises. To take account of these wider effects, programming models for representative farm types would be needed. Finally, the approach taken makes no allowance for different levels of risk across countermeasures from the point of view of the farmer.

3.2. Environmental Costs

A wide range of possible environmental and agricultural side-effects associated with countermeasures was identified through extensive literature study. The following list of key impacts was selected for inclusion in the Decision Support System:

- Erosion and Sedimentation
- Soil Organic Matter
- Soil Nutrient Transport to Water
- Soil Pollutant Transport to Water
- Animal Welfare
- Product Quality
- Product Quantity
- Ammonia Emissions
- Biodiversity
- Landscape Quality

Full descriptions of these impact criteria are available in Appendix II.

Some of these impacts were very difficult to value in monetary terms. For example, changes in biodiversity present important conceptual problems (such as what measure of diversity to use), although some estimates of the value of specific changes in biodiversity do exist in the economic literature (e.g. Edwards-Jones *et al.*, 1995, Loomis and White, 1996). For other impacts, such as mobilisation of soil pollutants, no values in the literature could be found. A further challenge was to obtain cost figures applicable at the farm scale for subsequent use in the DSS. Some side-effects, such as ammonia emissions, will have impacts beyond the boundaries of a farm. There are also problems associated with transferring costs to a set of circumstances for which they were not originally intended. Differences in environment, culture, economic development and technology can make a cost estimate derived in one country irrelevant to another. Where doubts existed over the transferability of costs, a precautionary approach was applied and the cost was not used.

A further restriction in costing environmental and agricultural impacts was that precise predictions of the magnitude of impact were not available in all cases (Salt *et al.*, 1999a).

3.2.1. Erosion and sedimentation

Erosion is the transport of soil by wind and water. In Scotland, water erosion is the most common form affecting agriculture (Arden-Clark and Evans, 1993). Wind erosion is limited to areas of sandy or peaty soils in level or gently rolling countryside during dry weather (MAFF, 1986). Many countermeasures involve modifications in farming practices that influence rates of soil erosion, especially if they involve changes in the frequency of ploughing.

Much of the literature divides erosional effects into on- and off-site impacts. On-site impacts, in the short-term can include changes in crop productivity, fertiliser loss and operational problems. Study of the long-term on-site damage from erosion is very limited. It has been estimated for an area in the south-east of Scotland that rates of soil loss up to 25 tonnes per hectare per year could be tolerated for more than 200 years before the land would suffer significant yield losses (Frost and Speirs, 1984). No significant reductions in chemical fertility on arable land are expected in the UK due to the regular addition of large volumes of fertiliser. It is the loss of chemical fertility following erosion that causes rapid yield reductions in other countries (Frost *et al*., 1990).

Several relationships between erosion and crop yield have been generated for specific crops but most of these are for crops not relevant to Scotland. A relationship for winter wheat suggests a yield loss cost from erosion of £3.80 per hectare (Evans, 1996). Another relationship suitable for Scotland is a percentage yield reduction of 0.007% for every tonne of soil lost per hectare (Evans, 1981). The timing of the erosion event has a crucial effect on the damage cost, but Frost *et al.* (1990) suggest that a maximum yield reduction of 2.5% applies to the UK. Account is taken of the fact that crops have a remarkable ability to compensate for loss of plants at an early stage in the growth cycle. Important considerations when assessing the effect of erosion are the initial soil depth and threshold effects. Frost and Speirs (1984) suggest no detectable reduction in cereal yields in the short term for soils greater than 1.2 m in depth.

The largest impact of soil erosion in the UK occurs outwith the farm (Armstrong *et al.*, 1990). Most of the cost associated with off-site effects results from the damage to houses, roads etc. and removal of sediment eroded from cropland. Some countermeasures will result in increased exposure of bare soil to winter rain, which could have costly consequences. Evans (1996) lists a range of costs from £1 per km^2 for removing eroded soil from roads in the Cambridgeshire fenlands, to over £400 per km^2 for cleaning out ditches in the East Anglian fens. The average of the twelve cost estimates cited was £96.4 per km^2. In Canada, Fox *et al.* (1995) indicate that off-site damage from sediment eroded from Ontario cropland causes damage ranging from $25-$100 per hectare of cropland per year. A similar estimate has been used by Pimental *et al.* (1995) of $50 per hectare of crop and pasture.

In the CESER project erosion is quantified as weight of soil lost per hectare. To convert these erosion estimates into costs, a monetary value per weight of soil is required. Ribaudo (1986) reports an off-site damage cost of £4.72 per tonne of eroded soil (converted to 1998 £ sterling using the retail price index, ONS 1999).

An important aim of the CESER project is to place a value on the environmental *change* brought about by the countermeasure. This requires that both negative *and* positive cost effects are considered. For instance, afforesting arable land or leaving it fallow will lead to a long-term *decrease* in erosion, whereas, converting dairy grassland to barley production will greatly *increase* erosion.

3.2.2. Soil organic matter

The effects of agricultural practices such as tillage or liming on soil organic matter are well documented in the literature (e.g. Whitmore *et al.,* 1992, Simard *et. al.,* 1994). Generally a high content of organic matter is regarded as positive as it improves soil fertility and water holding capacity. Countermeasures that accelerate mineralisation of organic matter, e.g. converting grassland to cereal production, improving rough grassland and liming, may diminish the soil humus reserves. Conversely, afforestation or leaving the land fallow, will increase the humus level, although this is a slow process. Costs associated with these changes in soil quality could not be identified explicitly due to lack of data.

3.2.3. Soil nutrient transport to water

Changes in the amount of nutrients, in particular nitrogen and phosphorus compounds, reaching a water course can have considerable effects on water quality. Countermeasures, such as afforestation or cessation of agricultural production, may result in drastic reductions in the nutrient inputs to water bodies. Significant increases may occur as a result of changes in stocking density, livestock feeding regimes and soil applications of manure and fertilisers. Countermeasures associated with increased erosion are also likely to increase phosphorus inputs to water bodies (Bärlund *et al.,*1998).

Increased loadings of N and P will fuel primary production of aquatic biomass, which in turn increases the amount of dead matter. This uses up oxygen during it's decomposition. Some fish and other organisms may die if the oxygen drops below their critical level. Plants adapted to nutrient rich conditions will thrive, outcompeting those adapted to nutrient poor conditions. This process is termed eutrophication (Harper, 1992). Increased eutrophication has a wide range of impacts such as: a) bad taste and odour of drinking water, b) growth of toxin-producing cyanobacteria, c) poor visual appearance, d) degraded ecosystem, and e) interference with fishing, bathing and other amenity uses. The disappearance of fish, such as Arctic Char (Loch Leven) and Vendace (Castle Loch) from Scotland is almost certainly due to nutrient enrichment (Bailey-Watts, 1990).

Some WTP studies have valued ecosystem protection against eutrophication. In France Le Goffe (1995) found local residents willing to pay FF215 and FF160 per household per year to be able to bathe safely and eat local shellfish, and to prevent asphyxiation of fish, respectively, in Brest harbour. A further example is from Magnussen (1992) who derived a WTP of FF1000 for a 50% reduction in nutrient levels in the North Sea. In America, Bockstael *et al.* (1989) quote a WTP equivalent to FF350 for water fit for swimming in Chesapeake Bay.

The Baltic Drainage Basin Project has used contingent valuation to assess the costs and benefits of reduced eutrophication of the Baltic Sea (Gren *et al.,* 1995). Assuming a 50% reduction in loadings, the costs of nitrogen and phosphorus reductions are approximately 32000 million SEK and 3500 million SEK per year, respectively. The nitrogen and phosphorus loads were 1095 thousand tonnes and 36 thousand tons per year, respectively. Based on a 50% reduction, the costs are £4.7 per kg of N and £15.2 per kg of P, respectively (1998 £ sterling).

3.2.4. Soil pollutant transport to water

Countermeasures may have an effect on the quantity of pollutants reaching water bodies. Conversion of grassland to cereal cultivation on dairy farms will necessitate greater use of pesticides and herbicides, which may reach watercourses through runoff and percolation. Afforestation and fallow on arable land will reduce inputs of these compounds to the aquatic environment. Afforestation may lead to substantial local changes in the iron, manganese and aluminum levels in water, as measured following afforestation of the Cray catchment in south Wales (Stretton, 1984). However, in this and other cases (Robinson, 1980; Leeks and Roberts, 1987) very little change was noticed at the outfall of the catchments since nearly all the product of change was kept on site. This side-effect has thus not been included in the DSS.

Many countermeasures affect the amount of organic matter in the soil, e.g through liming, ploughing and land use (see Section 3.2.2.). Soil pollutants including radionuclides may be mobilised when organic matter degrades, increasing the risk of transport to surface and groundwater. Contamination of groundwater can potentially have a costly effect on drinking water although in Scotland very little drinking water comes from this source, only 3% in 1990 (Scottish Office, 1993).

Estimates for the costs of all types of water pollution (including erosion and run-off) in Scotland have been derived from an index of river, canal and estuary water quality (Moffatt, Hanley and Wilson, 1999). These national estimates cannot be used to derive costs associated with water pollution resulting from specific countermeasures. The estimation of costs is not only hampered by lack of suitable data but also by the difficulties in predicting which polluting substances may be mobilised by a particular countermeasure at a given site. It is expected that impacts will be generally small compared to other impact criteria.

3.2.5. Animal welfare

Potential negative impacts of countermeasures on the welfare of livestock have been identified in association with early weaning and intensive indoor feeding. Provision of better quality grazing land could have positive effects. No data on the valuation of animal welfare has been found in the literature. However, the physical health and well being of livestock may have an effect on the quality of the final product and this would be reflected in the price achieved at market. As agricultural support measures impose a distortion on market prices for many types of crop and livestock, this would have to be corrected for in deriving estimates of social cost.

3.2.6. Product quality

The quality of crops is likely to decline as a result of deep ploughing. Changes in the feeding regime of animals may have a positive or negative effect on meat quality. Any cost effects on product quality will typically be reflected in the difference in market prices achieved with and without the countermeasure. In reality this is difficult to assess given annual fluctuations in prices and the difficulties of predicting the exact nature of the change in quality. In addition, people’s perception and trust in ‘treated’ foods will affect the price at which treated products can be sold. These impacts have been assessed for lamb and milk as part of the CESER project (Grande *et al.*, 1999). The findings suggest that a 62% discount would be required for treated milk (relative to untreated milk from outside the contaminated area), and a 31% cut in lamb prices.

3.2.7. Product quantity

Many countermeasures involve changes in the quantity of agricultural produce. These will be reflected in the increased or decreased income that is generated. Countermeasures with large impacts on product quantity were preferentially costed for inclusion in the economic part of the CeserDSS. These are typically related to significant changes in management practices. For example, leaving land fallow or afforesting result in the complete loss of agricultural production. Another example is the sale of store animals instead of finished animals, ready for slaughter. However, in some cases the degree of change in quantity resulting from a countermeasure was difficult to predict. In the case of dairy cattle, for example, the effect of calcium supplementation on milk yield was not quantified.

3.2.8. Ammonia emissions

In European countries intensive farming is the main source of ammonia emissions (Asman, 1992). The detrimental effects of ammonia relate to the input of excess nitrogen to ecosystems. Countermeasures involving changes in intensive livestock systems such as dairy and lowland beef, have the greatest impact on ammonia emissions. Some data on the costs associated with atmospheric nitrogen exist in the literature, with costs generally expressed in terms of emissions of nitrogen oxides. Tellus Institute (1991), Chernick and Caverhill (1989) and Pace University Centre for Environmental Legal Studies (1989) have estimated marginal damage costs for nitrogen oxides of £3460, £2451 and £1011 per tonne of nitrogen oxides(NO_x) respectively (all converted to 1998 £ sterling). These compare with a Swedish estimate of £3381 per tonne (SNRA, 1992).

Unfortunately, these cost figures include not only costs associated with ecosystem damage through excess nitrogen inputs but also the cost in human health effects due to inhalation of NO_x. Thus the figures cannot be transferred to ammonia, which has no known direct impact on human health. UK agricultural emissions of ammonia (NH_3 and NH_4^+) contribute as much to total N deposition throughout the country as NO_x emissions from industry and vehicles (DoE, 1994). Ammonia has a much shorter residence time in the atmosphere than NO_x and thus contributes less to the long-range transport of N. Nevertheless, approx. 34% of the estimated 230,000 tonnes of ammonia per year emitted in the UK during 1988-1992, are exported to the sea or to other countries (DoE, 1994). Given these problems, changes in ammonia emissions resulting from countermeasures could not be costed despite good impact predictions being available.

3.2.9. Biodiversity

Several contingent valuation exercises have been carried out to estimate willingness to pay for the preservation of rare, threatened and endangered species in the USA (e.g. Loomis and White, 1996). However, obtaining values for single species is not sufficient when attempting to value full biological diversity. The Convention on Biological Diversity, signed by 154 nations at the Rio Summit, defines biodiversity as:

> ‘The variability among living organisms from all sources, including *inter alia*, terrestrial, marine and other aquatic ecosystems, and all the ecological complexes of which these are a part: this includes diversity within species, between species and of ecosystems (UNEP, 1993).’

Countermeasures entailing changes in grazing pressure or in land use will affect the biodiversity on a farm. In order to assess the resulting complex shifts in species distribution and abundance, an index or set of indices of biodiversity change would be required. However, as Reid (1992) points out, there is no clear consensus on how biodiversity should be measured.

To some extent the difficulty in valuing biodiversity is illustrated by Edwards-Jones *et al.* (1995). The authors have attempted to construct a WTP demand curve for species richness for areas of upland Scotland. Their aim was to compare the relative importance of ecological goods as ascertained by contingent valuation models and standard ecological evaluation. CVM respondents were asked to value their WTP to maintain the level of species richness as it existed at the time and also to bid for 50% and 100% increases in species richness. Their results showed little difference across different landscape types for the sites in their current state or with increased species richness.

Given these reservations and the lack of good impact predictions, it was not feasible to place a cost on changes in biodiversity resulting from countermeasures.

3.2.10. Landscape quality

Several contingent valuation exercises have been undertaken to place a value on particular landscapes (e.g. Willis, 1995; Willis and Garrod, 1991). However, very few have been identified that achieve a valuation for the types of landscapes which will change due to countermeasures. The most drastic impacts on the landscape will result from afforestation, pasture improvement and cessation of agricultural production. Some recent work in Finland is perhaps the most applicable found so far (Tyrväinen and Väänänen, 1998). Here the authors have attempted to value afforestation in the context of its contribution to the quality of the housing environment.

Given the lack of applicable data in the literature, an original contingent valuation exercise was undertaken to place values on two types of Scottish landscape likely to be affected by countermeasures, - rough grassland and heather moorland. This is discussed in more detail in Section 3.3.

The findings on economic estimates of the environmental costs of countermeasures are summarised in Table 3.

Table 3. Summary of environmental cost estimates found in the literature.

Impact criteria	Costs	Source
Erosion and Sedimentation	crop yield - 0.007 % / t of crop up to a max of 2.5 % off site - £4.72 / t of soil	Evans (1981) Frost *et al.* (1990) Ribaudo (1986)
Soil Organic Matter	no costs found in the literature	
Soil Nutrient Transport to Water	£4.70/kg of N; £15.20/kg of P	Gren *et. al.* (1995)
Soil Pollutant Transport to Water	no costs found in the literature	
Animal Welfare	variation in market prices	
Product Quality	variation in market prices	
Product Quantity	variation in income	
Ammonia Emissions	no usable costs found in the literature	
Biodiversity	not possible to value	
Landscape Quality	original contingent valuation study	See Section 3.3.

3.3. A Contingent Valuation Study of the Impacts of Countermeasures on Landscapes

Changes in landscape quality may have significant effects on the utility value to consumers. When landscape changes are viewed as undesirable, they have an economic cost (and similarly, an economic benefit if they are viewed as desirable). It is unlikely that everyone has the same preferences for landscape, thus we need to use a method, which allows for this variability in estimating economic values. These values, in accordance with the general principles of CBA, are based on the consumers' Willingness to Pay (WTP) to either support a desirable change, or else prevent an undesirable one[1].

Suitable data was not available in the literature for the valuation of landscape changes resulting from countermeasures involving land use change. Two common types of landscape in Scotland that are likely to be significantly affected, are rough grassland and heather moorland. *Contingent valuation* was used to value shifts in the quality of these landscapes as a result of 1) pasture improvement and 2) afforestation.

In the contingent valuation method, consumers are asked to express their environmental

[1] Willingness to Accept Compensation is an alternative measure of preferences, not used here.

preferences directly in a hypothetical market. This might consist of asking people for either their maximum willingness to pay for an increase in quality (or to prevent the loss) of an environmental good or their willingness to accept compensation to forgo such an increase (accept the loss). As the willingness to pay value is contingent upon the particular hypothetical market described to the respondent, this approach became known as the contingent valuation method (CVM) (Hanley *et al.*, 1997). CVM has recently been approved by the US government for use in natural resource damage claims, and has a surprisingly long history of use in policy/project appraisal in the UK.

Hanley and Spash (1994) identify five stages in undertaking a CVM exercise: (1) setting up the hypothetical market, (2) obtaining bids, (3) estimating mean willingness to pay, (4) aggregating the data, and (5) estimating bid curves.

The aim of the survey undertaken as part of the CESER project was to elicit from respondents estimates of their willingness to pay to prevent changes to two landscape categories. The survey was limited to local residents living close to the selected areas where the countermeasures would be applied. The focus on local resident values (rather than, say, national values) should provide more conservative cost estimates. The two landscape categories were heather moorland and rough grassland. Within each of these categories respondents were asked to value their willingness to pay (WTP) to avoid some proportion of the landscape changing to either productive grassland or coniferous forest. These, combined with the payment vehicle used, are the hypothetical markets. Respondents who preferred the altered landscape were asked their WTP to bring about this change.

An information pack containing good quality colour photographs and text was selected as the most suitable means to describe the goods and the changes that could occur to them. To avoid ‘information overload’ the volume of text was kept to a minimum while ensuring that there was sufficient information for the respondent to understand the landscape change scenarios.

The information pack consists of four pages (an example for heather moorland is included in Appendix III). The first page describes the contents of the pack and outlines some of the important issues relating to the particular landscapes that could be lost. The second page contains a map showing the area that would be affected by the hypothetical landscape changes. On this map are concentric circles showing the distance from the area at 10-mile intervals. The aim of this map is to allow the respondent to relate the area that could be affected by the hypothetical landscape change to where they live. In the survey respondents are asked to give the distance they live from this area. The final two pages of the information pack show photographic images of the baseline and altered landscapes: one page for a change from heather moorland to productive grassland and the second page for a change to coniferous forest. Short captions describe the management practices that maintain that particular landscape and some of the typical animal species occurring. The baseline pictures were manipulated using the software package ADOBE PHOTOSHOP Version 4.0.

The design of the questionnaire was optimised through an iterative process. In addition to several dummy runs with colleagues from different disciplines, two focus group meetings were held. These identified a one-off payment to a specially created trust fund as the preferred payment mechanism. A household rather than individual payment request was used, which follows the general view in the literature that this is the most appropriate means by which payments should be gathered for use in cost benefit analysis (Quiggin, 1998). One version of the questionnaire (for the heather moorland area) is included in Appendix IV.

A total of 639 face-to-face interviews were conducted by a market research company (System Three) over three weeks in May 1998 in two areas of Scotland. This total comprised 318 questionnaires completed near the heather moorland area (approx. 30 miles south-west of Aberdeen) and 321 questionnaires completed near the rough grassland area (near Oban, north-west Scotland). The sample was representative of the Scottish population in terms of age and gender when compared to the latest published figures in the Annual Report of the Registrar General for Scotland (GROS, 1998. Table 2.1).

In estimating the value of a given habitat, it is important to recognise that some respondents might prefer an alternative. This requires inclusion of negative bids for the habitat of interest and positive bids for the alternative (MacMillan and Duff, 1998). WTP amounts given by those who wanted to protect the existing landscape were taken as positive bids, whilst WTP amounts given by those who preferred the new alternative were taken as negative values. The resulting net figure indicates a preference for the existing landscape if positive and the new landscape if negative

The results, summarised in Table 4, show that the respondents have a clear preference for heather moorland over both productive grassland and coniferous forestry. The negative WTP for the change from rough grassland to productive grassland indicates that the respondents prefer the latter landscape but prefer the former to forestry. This implies a dislike of forestry regardless of the existing landscape and a preference for heather moorland over productive grassland with the latter preferred to rough grassland. The lack in precision of these mean estimates (the 95% confidence intervals) may have been due respondents finding it difficult to express their preferences in a monetary form, within the context of the hypothetical markets established.

Table 4. Net WTP (mean, 95% confidence interval and standard deviation) to preserve the existing landscape in £ sterling.

	New landscape			
	Productive grassland		**Forestry**	
Heather moorland	Mean WTP	46.5	Mean WTP	9.0
	5% trimmed mean	8.1	5% trimmed mean	1.1
	95% confidence interval	-.9 – 93.9	95% confidence interval	-14.4 – 32.3
	standard deviation	365.1	standard deviation	170.2
Rough grassland	Mean WTP	-36.8	Mean WTP	28.9
	5% trimmed mean	-5.9	5% trimmed mean	8.4
	95% confidence interval	-90.5 – 17.0	95% confidence interval	0.6 – 57.2
	standard deviation	400.6	standard deviation	217.9

Data aggregation, to derive per hectare valuations for each landscape preference, has been achieved by multiplying the mean net WTP estimates by the relevant number of households. To estimate the number of households in each area, regression equations were constructed for WTP against distance for the two geographical areas. In each case the distance from the site at which WTP is predicted to go to zero was derived and the populations within that distance were found from census data.

For the heather moorland area the regression equation suggests that the population within a radius of 25 miles should be used. Using data from the 1991 census (GROS, 1993) the number of households in this circle, effectively the whole of Angus and Kincardine and Deeside regions, is approximately 48,000. A similar analysis for the rough grassland area suggests the relevant population lies within a radius of 30 miles. Within this area the number of households is approximately 17,000 (GROS, 1993).

In order to derive a 'per hectare' value for each landscape, the size of the area affected by the changes has to be considered. In both the heather moorland area (12 square miles, 32 km^2) and the rough grassland area (9 square miles, 24 km^2), respondents were asked to consider changes to a quarter and to half of the area. These equate to area changes of 800 and 1600 hectares, respectively, for the heather moorland and 600 and 1200 hectares, respectively, for the rough grassland. The 95%-trimmed mean WTP estimates of Table 4 were applied to the number of households and to the size of area affected by the countermeasure. This generated a set of WTP values per hectare for each landscape, as shown in Table 5. A scope test, i.e. checking how WTP varied with the size of the affected area, indicated that the average WTP valuations are the same regardless of the size of area. Therefore, the per-hectare figures shown in Table 5 are given as a range of values.

Table 5. Aggregated WTP per hectare to protect heather moorland and rough grassland from changes in landscape to either productive grassland or forestry.

	Change to productive grassland	Change to forestry
Heather moorland		
Trimmed mean (£/household)	8.1	1.1
Relevant population	48,000	48,000
Area (ha)	800 – 1600	800 – 1600
Implied landscape value £/ha	243 – 486	33 – 66
Rough grassland		
Trimmed mean (£/household)	-5.9	8.4
Relevant population	17,000	17,000
Area (ha)	600 – 1200	600 – 1200
Implied landscape £/ha	-(84 – 168)	119 – 238

The results of the Contingent Valuation survey have been used in the CeserDSS to provide environmental impact scores for the landscape changes assessed.

4. Estimating Countermeasure Benefits

Countermeasures may allow food production to continue in areas contaminated by radioactive fallout. The societal benefit of avoided loss of production is usually regarded as the value of the saleable product that could not have been sold for human consumption if the countermeasure had not been applied. However, if food has been subjected to a countermeasure, then consumers may require a reduction in price to be willing to consume the product. This relates to an increase in perceived risk from eating these foods. The study by Grande *et al.* (1999) suggests that consumers may be willing to pay more for foods from areas not affected by radioactive fallout. For milk and lamb meat this price difference is likely to be of the order of 62% and 31%, respectively.

At the farm level, the benefit of a countermeasure can be regarded as the maintained margin to the farm or, in the cases where the finished product only forms a part of the farm's output, the maintained income from the sale of the final product. In cases where a countermeasure results in a change in management practice, e.g. converting land to oilseed rape or afforestation, then the farm level benefit is counted as the gross margin of the new land use. Section 5.2. provides more detail on the methods by which on-farm benefits are calculated in the CeserDSS.

The benefits of countermeasures can also be considered in terms of avoided radiation dose and consequent risk of illness. The benefit of any averted dose can be assessed in terms of peoples' Willingness to pay (WTP) to avoid an increased risk of illness that could occur had the additional dose not been averted. The economics literature suggests that WTP is the preferred method of assessing such risk reduction benefits, rather than risk-income trade-offs, as it allows for variations in individual preferences. This approach requires that the radioactivity prevented from being transferred to foodstuffs is reliably predicted for each countermeasure and converted into a collective averted dose (expressed in person-Sieverts or person-Sv). WTP to avoid this additional dose can then be measured. Ideally, the conversion of avoided risk into the economic value of this risk reduction needs to be carried out using data on individual's WTP for specific undesirable health end points (such as days of sickness). This approach has not yet been applied to radiological countermeasures but empirical findings exist for other health risks, such as urban air pollution (Reed Johnson *et al*., 1997; Strand, 1985).

An alternative to the WTP approach is to use a Cost of Illness method, which values reductions in risks as reductions in personal and social costs of illness. This method, less favoured by economists as it breaks the link with preferences, involves comparing the additional radiation dose with a health detriment cost (also expressed in terms of person-Sv). A range of health detriment costs are cited in the literature, including an estimate used by the TEMAS project, of 18,000 ECU's per person-Sievert (Montero *et al.*, 1998). A value of US$100,000 (approx 80,000 ECU at 1997 exchange rate) per person Sievert, recommended as a maximum by the Nordic Radiation Protection Authority, was used by the RESTRAT project (cited in Hedeman Jensen, 1999). This approach was not adopted in the CESER project. Within the CeserDSS only on-farm benefits are costed.

5. Economic Assessment in the CESER Decision Support System

5.1. Brief Description of the CESER Decision Support System

The CESER Decision Support System – CeserDSS (Salt *et al.* 1999b) is a software package developed for typical Scottish agricultural systems, which enables assessments of:

- land suitability for countermeasures
- environmental and agricultural impacts, and
- on-farm costs and benefits.

The software is intended for application at the farm level, providing separate assessments for dairy, upland and lowland sheep, upland and lowland beef, and arable crop farms as well as enterprises involving management of red deer (Appendix V explains how to obtain the software). After selecting a farm type and a radionuclide deposition scenario (see Table 6), the user is invited to choose from a list of countermeasures that might be appropriate to their situation.

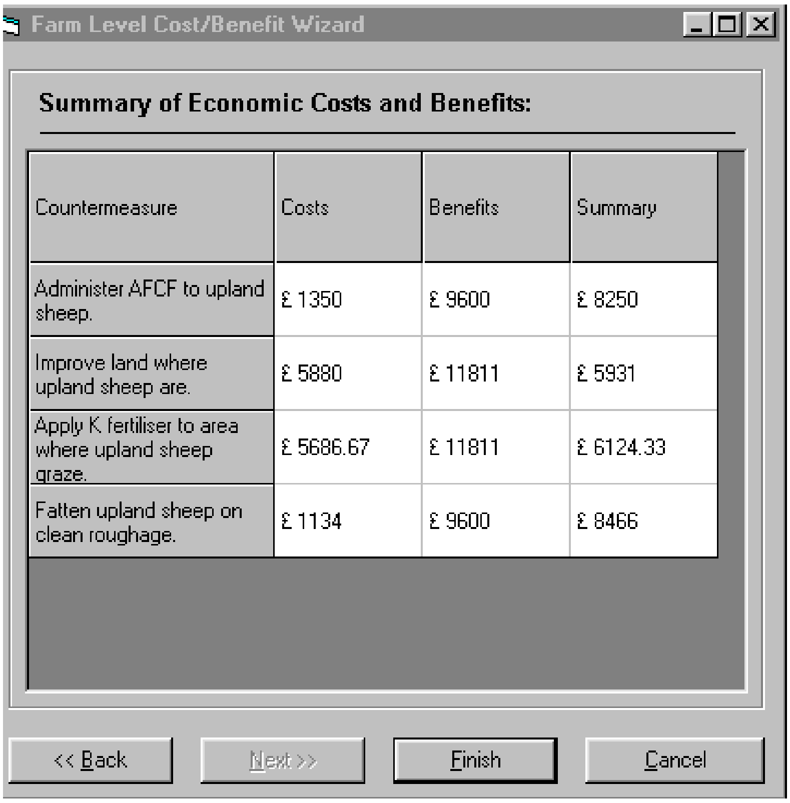
Table 6. Deposition scenarios in kilo-becquerels per square metre, for the most relevant radionuclides caesium-137, strontium-90 and alpha-plutonium.

Scenario	**^{137}Cs** kBq m^{-2}	**^{90}Sr** kBq m^{-2}	**alpha-Pu** kBq m^{-2}	**Situation**
Scenario 1	100	2	0.02	Chernobyl-like fallout on distant fields.
Scenario 2	100	100	0.02	Fallout with a higher Sr fraction on distant fields.
Scenario 3	1000	200	0.2	Fallout on fields close to site of nuclear release.
Scenario 4	5000	500	1	Fallout on fields very close to site of nuclear release.

The limitations of each of these countermeasures are then explored by querying the user about their farm environment and management regime to accurately determine whether the countermeasure is suitable. The decision support component of the software allows evaluation of the final list of countermeasures based on environmental and agricultural impact criteria by assessing them according to the user's own personal objectives. Using a Multicriteria Decision-Making Methodology called Ideal Point Analysis (Pitel, 1990), this component incorporates user-specified weighted criteria to the analysis and ranks the countermeasures from best to worst according to the environmental impact criteria.

The user then has the option of carrying out a detailed economic analysis of the final countermeasures. Ideally, this analysis would include both the direct costs of implementing the countermeasure and the indirect environmental costs. Within the CeserDSS the direct, or on-farm, monetary effects are shown in the section entitled “Farm Level Cost/Benefit Analysis Results” and the data used to derive these estimates is shown in the section called “Economic Information”. These sections will only show data once the “Farm Level Cost/Benefit Wizard” has been completed. The environmental costs of the countermeasures were not directly included in the CeserDSS. More research is required to produce cost estimates suitable for inclusion. However, the results of the Contingent Valuation study were used to set relative impact scores for changes in landscape quality.

On selecting the “Farm Level Cost/Benefit Wizard” from the “Run” menu (this can only be done once the “Countermeasure Selection Wizard” has been completed), the user will be presented with a list of countermeasures derived from the Selection Wizard. On clicking the ‘next’, button the user must answer a range of questions particular to each countermeasure and farm type. Once these have been completed the full list of economic variables will be shown in a table. These variables are used to derive the costs and benefits for each countermeasure and can be edited by the user if desired. The farm level costs and benefits are then calculated and displayed in a summary page that aggregates the costs and benefits into a net benefit or cost (see Figure 2). At each step the user can go back and edit any economic variables. When the user selects ‘Finish’ these results will be shown as a table in the section “Farm Level Cost/Benefit Analysis Results”. An overview of the entire countermeasure assessment process is given in Figure 3.



Countermeasure	Costs	Benefits	Summary
Administer AFCF to upland sheep.	£ 1350	£ 9600	£ 8250
Improve land where upland sheep are.	£ 5880	£ 11811	£ 5931
Apply K fertiliser to area where upland sheep graze.	£ 5686.67	£ 11811	£ 6124.33
Fatten upland sheep on clean roughage.	£ 1134	£ 9600	£ 8466

Figure 2. Example of CeserDSS output for an economic assessment on an upland farm finishing 300 lambs, with 20 ha of improvable land and 20 ha suitable for K fertilisation.

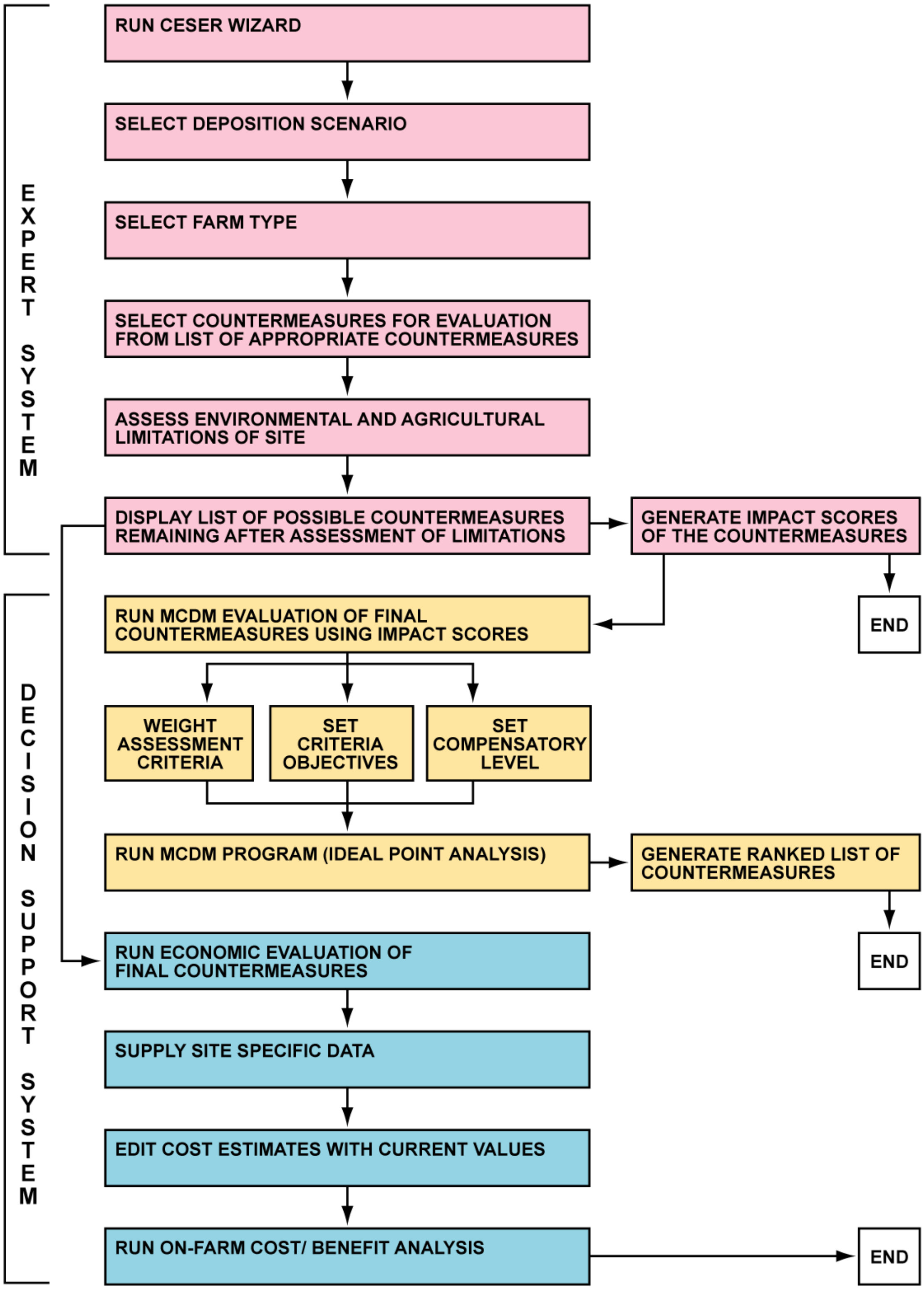


Figure 3. The countermeasure evaluation process in the CESER Decision Support System.

The following section describes the assumptions and calculations made in assessing on-farm costs and benefits of each of the countermeasures applied to each farm type within the CeserDSS.

5.2. Methodology and Assumptions for Quantifying On-farm Costs and Benefits

The descriptions of countermeasure cost and benefit assumptions and calculations have been grouped according to farm type. Each countermeasure is given a code used throughout the project. For each countermeasure the user has to answer questions about the farm being assessed. All other data required in the economic calculations is held as editable variables within the DSS. Descriptions of all variables and sources of data used in each calculation are provided.

The economic assessment package within the Decision Support System has been developed using typical management practices for Scotland supplied in the Farm Management Handbook (SAC, 1998). The costing methods are a compromise between excessive detail and oversimplification. However, by allowing the user to manipulate the variables used in the assessment it is possible to derive costs and benefits more applicable to a given situation. The costs and benefits are *only* calculated for the year in which the countermeasure is applied. Long-term comparisons between annually and less frequently applied countermeasures are currently not possible within the software.

5.2.1. Dairy production

DY1 – Administer AFCF
The on-farm costs of administering AFCF are calculated by multiplying the number of milking cows by an estimate of the daily AFCF cost and converting to an annual cost figure. The user is asked to enter the number of milking cows that are to be treated. A daily AFCF cost of £0.024 per cow per day is used (Brynhildsen *et al.,* 1996). No additional labour costs have been assumed. In addition, it is assumed that AFCF has no effect on the quality or quantity of the milk (Hansen, pers. comm.).

The benefit of administering AFCF is regarded as the maintenance of the milk margin. The typical milk yield in Scottish dairy herds, approximately 5900 litres per cow (SAC, Tweddle, pers. comm.), was rounded to 6000 litres per cow. Based on SAC (1998 p155) this equates to a margin of £0.113 per litre. Expressing the margin in this way allows the user to edit the yield per cow. The further the yield figure (input by the user) differs from the average, the less reliable the margin estimate becomes. However, in this case the user has the option to adjust the margin per litre.

DY2 – Supply calcium
The user input variables requested are the number of milking cows to be treated and the amount of Ca normally fed per cow per day. Any routinely supplied Ca is subtracted from the daily dose of the countermeasure (500 g of $CaCO_3$ per cow per day). The cost of the countermeasure is calculated by multiplying this difference by the calcium cost of £25 per tonne (price supplied by Franzefoss Bruk A/S, Norway) and converting to an annual cost. It is assumed that no additional labour costs are involved.

The benefit of this countermeasure is considered to be the maintenance of the milk margin, as calculated for DY1.

DY3 – Feed clean concentrate
The number of milking cows on the farm has to be specified by the user. The countermeasure costs are based on the additional use of concentrate. The following assumptions are made:

- price of dairy cow concentrate = £150 per tonne (SAC, 1998 p155).
- normal management: concentrate fed in summer / winter = 2 and 7.25 kg/day, respectively
- countermeasure: concentrate fed in summer / in winter = 8.2 and 9.5 kg/day, respectively

- summer grazing period = 175 days ; winter in-door period = 190 days.

The benefits are a) the maintenance of the milk margin (calculated as for DY1), b) reduced grassland and silage production and c) no need for barley in the winter diet. Grassland cost savings are based on grazing areas of 0.25 and 0.08 hectares per cow, respectively, for normal and countermeasure management, using a grassland production cost of £133 per hectare (SAC, 1998 p155). Silage cost savings are based on area requirements of 0.25 and 0.10 hectares per cow, respectively, for normal and countermeasure conditions. The area requirements can be edited by the user. The saving in barley is based on a normal dietary contribution of 3 kg per cow per day in winter.

DY4 – Exclude animal production
The user is required to provide data on the number of milking cows and their average weight. The costs of excluding animal production are the loss of gross margin (as calculated in DY1) and the cost of animal disposal in the first year. It is assumed that animals are disposed to landfill at a cost of £25 per tonne, including a £10 per tonne landfill tax (Connell, pers. comm.). No on-farm benefits are assumed for this countermeasure.

DY5 – Afforestation
The user must enter 3 variables: (i) the number of milking cows, (ii) the average weight of the cows and (iii) the area to be afforested. Afforestation will result in the loss of milk margin, as in DY1, and in the first year the cost of animal disposal, as in DY4.

The benefit of this countermeasure is the margin derived from afforestation. The cash flow estimates of SAC (1998 p465) have been used to generate a per hectare, per annum margin of £166 using an annual equivalent factor conversion of the net present value of a single rotation (Lumby 1991). This is multiplied by the area to be afforested.

DY6 – Feed concentrate grown on farm
The first step is to calculate the total barley feed requirement for the milking cows (as in DY3) and to convert this to a growing area based on the typical yield, input by the user. If the land available for conversion to barley production, as specified by the user, is insufficient then a ‘buying in’ requirement is calculated. Costs include additional ploughing and planting for the extra barley. These have been derived from SAC (1998 p305 and p15/17).

There are several economic benefits of this countermeasure: a) maintained milk margin (as calculated in DY1), b) reduced need to buy in concentrate, and c) reduced grassland and silage production. The reduction in concentrate is based on the normal summer and winter requirements, as shown in DY3. The saving in grassland and silage production is calculated by accounting for the extra area of land required for the home grown barley (taking into consideration the area of barley normally grown).

DY7 – Supply Ca and feed clean concentrate
This is a combination of DY2 and DY3.

5.2.2. Lowland sheep production

Lowland sheep production is assumed to involve breeding and fattening of lambs. The default variables for the cost and benefit calculations are for 'Lowground crossbred breeding ewes-finished lamb production off grass', as described in SAC (1998, p 212/213).

SL1 – Administer AFCF
The user is asked to enter the number of lambs finished on the farm. As for DY1, it is assumed that administering AFCF to sheep has no cost effect on the animal or animal products. For the AFCF

boli a cost of £4.50 per treatment per animal is used (Hansen *et al.*, 1996).

The only benefit of this countermeasure is the maintained income from finished lamb. Given that finished lamb production is only part of the total income of a typical lowland farm and that most other income (e.g wool, ewe sales, subsidies) will be unaffected, it is inappropriate to use the farms gross margin as a benefit estimate. An income figure based on the farm gate price of the finished lamb, £40 per lamb, (SAC, 1998 p213) is used instead. This will slightly overestimate the benefit as variable costs for the finished lambs have not been deducted. It has the advantage of making calculations in the DSS much simpler.

SL2 – Fatten on clean concentrate
The user has to specify the number of lambs finished on the farm. A sheep concentrate price of £90 (SAC, 1998 p213) is multiplied by the difference between countermeasure (1.0 kg/day) and normal (0.18 kg/day) use of concentrate. It is assumed that that the fattening period is 90 days and all concentrate is bought in. The user can alter the length of the fattening period. An additional cost may be the hiring of letting courts if there was insufficient housing for the lambs but in the CeserDSS fattening on clean concentrate is eliminated from the list of suitable countermeasures if housing is a limitation.

The main benefit of this countermeasure is the maintained income derived from the sale of the finished lambs (£40 each), as explained for SL1.

SL3 – Lime the soil
It is assumed that liming is carried out every two years at a rate of 2 tonnes per hectare and a price of £30 per tonne (SOAEFD, 1998 p13). An additional cost for contractor’s charges of £6 per hectare (SAC, 1998 p305) is included as it is assumed that lime-spreading equipment is not available on the farm. To calculate the cost of liming the user has to enter the area of land on which the countermeasure will be applied. This should agree with the area of land that is suitable for the countermeasure, as assessed in the Countermeasure Selection Wizard.

Liming would only be applied to suitable soils, which could occur on a small area of the farm. The user therefore has to estimate the percentage contribution that this land makes to the fattening of all lambs. A corresponding proportion of the maintained income is then used to calculate the benefit, as in SL1.

SL4 – Exclude animal production
The user has to input the number of ewes and the average weight. The costs of this countermeasure are the loss of gross margin and the disposal costs of the ewes, as discussed in DY4. Gross margin figures per 100 ewes are given in SAC (1998 p213). Disposal costs for lambs are excluded since they are not present on the farm all year round and their weight varies greatly over time.

There are no benefits to the farm resulting from this countermeasure.

SL5 – Fatten on clean roughage
The animals are fed their usual diet except that contaminated roughage is replaced with uncontaminated hay. The user is asked to confirm that the existing supply of roughage is contaminated and has to enter the number of finishing lambs. The required feeding period is 60 days for Deposition Scenario 2 and 90 days for Scenario 3. A cost for hay of £60/t is used although it is recognised that the price varies by month, typically from £45-80 per tonne (SOAEFD, 1998). It is assumed that the feeding of any concentrate is unaltered.

As for SL1, the benefit of this countermeasure is taken as the maintained income derived from the sale of the finished lambs (£40 each).

SL6 – Afforestation
The costs of this countermeasure are the same as for SL4. The user has to specify the number of ewes, their average weight and the area to be afforested. The benefit is the gross margin gained from afforestation (£ 166 ha^{-1} $year^{-1}$), as explained for DY5.

SL7 - Administer AFCF and fatten on clean roughage
This is costed as a combination of SL1 and SL5.

SL9 – Apply K fertiliser
The user inputs required are the size of the area to be treated and the current annual rate of potassium application on that area. Application rates expressed as K_2O have to be divided by 1.2 to derive the weight of K. The current application rate can then be subtracted from the countermeasure application rate of 100 kg of K per hectare per year. A purchase cost (as K_2O or potash) of £220 per tonne (SOAEFD, 1998 p13) is assumed. Further costs arise through the additional labour required for the spreading. It is assumed that equipment for fertiliser spreading is available on the farm. A spreading rate of 3 hectares per hour and a labour rate of £6 per hour were applied. The area to be treated should agree with the area of land that is suitable for the countermeasure, as assessed in the Countermeasure Selection Wizard.

For the reason outlined in SL3 the benefit is regarded as the maintained income from the sale of the finished lambs in proportion to the feed contribution of the treated area.

5.2.3. Upland/hill sheep production

Upland/hill sheep management in Scotland can involve the production of finished lambs for slaughter as well as store lambs that are sold for fattening elsewhere (typically to lowland farms). To accommodate all common variations in management the CeserDSS would have required implementation of many options. A compromise is to calculate the costs and benefits for specific farming systems and then allow the user to edit the variables (e.g. gross margin and sale prices) to a figure appropriate to their management practice. The default figures within the DSS are based on management for 'upland crossbred breeding ewes/finished and store lamb production' as described in the Farm Management Handbook (SAC, 1998 p212/3). This assumes that per 100 ewes, 98 finished lambs and 50 store lambs are produced. An assessment of farms that only produce store lambs is possible if the number of store instead of finished lambs is entered and economic variables are edited accordingly.

SU1 - Administer AFCF
The costs and benefits are calculated as for SL1. Similar to lowland sheep farms, finished lamb production is only part of the total farm upland/hill income. An income figure based on the farm gate price of the finished lamb, £40 per lamb, (SAC, 1998 p213) is applied. If the farm only produces animals for fattening elsewhere (store lambs), then the user has to edit the price figure to reflect this, i.e.£34 per store lamb. This change would only affect the benefit estimate.

SU2 – Improve land
The user is queried on the availability of ploughing equipment and the size of the area to be treated. If a plough is available the costs consist of labour, seed, lime, fertiliser and sowing. If not, there are additional costs due to a ploughing contractor’s charges. All relevant costs are in SAC (1998 p111 and p305/7). It is assumed that no animals will be on the land during the sward establishment, imposing a further cost for the hire of grazing elsewhere for the first season. Typically, the charge for letting permanent pasture is £150 per hectare (SAC, 1998 p468).

The only benefit is considered to be the maintained gross margin from upland sheep production (£3937 per 100 ewes, SAC, 1998, p213), which is based on the number of ewes on the farm, as specified by the user. This assumes that the whole farm production benefits from the countermeasure. However, if only a very small part of the farm is improvable, the number of ewes entered could be reduced to reflect a smaller benefit. The gross margin estimate assumes that the farm finishes lambs for slaughter. If the farm sells animals for fattening elsewhere the gross margin estimate needs to be edited.

SU3 – Intensify use of improved land
The user enters the area of improved land to be treated and the total number of ewes on the farm. Reseeding is regarded as an additional cost in the first year only and will be carried out in the normal rotation in the following years. Assuming that a plough is available on the farm, the costs are for the seed and additional labour for the ploughing, fertilising and sowing. Fertiliser costs will vary as they depend on the grazing intensity on the improved land. A cost at the lower end of the range shown in SAC (1998) has been applied here, taking no account of the current fertilisation rate (a future improvement in the calculations would be to take account of the existing fertiliser application rates). The additional labour cost is based on the ploughing, fertilising and sowing work rates shown in SAC (1998, p301). As in SU2, it is assumed that no animals will be on the land during sward establishment, so a further cost is included for the hire of grazing elsewhere in the first year.

The benefit is the maintained gross margin from upland sheep production, as for SU2.

SU4 – Lime the soil
The cost and benefit calculations for this countermeasure are the same as those used for SL3.

SU5 – Apply K fertiliser
The calculations of SL9 are applied.

SU6 – Sell early for fattening
In this countermeasure the lambs are weaned early and immediately sold for finishing outside the contaminated area. Consequently the cost to the farm is dependent on how the animals are normally sold. If the animals are usually finished for slaughter then the cost is the difference between the prices for finished and weaned. If the animals are sold for fattening elsewhere the cost is the difference between the prices for store and weaned animals. No market price exists for weaned lambs so a price of £0.80 per kg is assumed (SAC, pers. comm.). The user enters the number and weight of the early weaned lambs. Store and finished prices are from SAC (1998 p213).

The benefit to the farm is the reduced variable cost for feed, veterinary services, etc. It is assumed that this is equivalent to half the variable costs given in SAC (1998 p213) for farms that normally sell for slaughter and a quarter for farms that normally sell for fattening elsewhere.

SU7 – Exclude animal production
The costs and benefits of this countermeasure are similar to SL4 with the number and weight of ewes specified by the user. Gross margin figures for upland sheep production are used (SAC 1998, p213). No on-farm economic benefit is assumed.

SU8 - Afforestation
The costs of SU7, i.e. the loss of gross margin and the sheep disposal cost in the first year, are applied. The benefit is the gross margin from afforestation and an estimate of £50 per hectare per year is calculated based on the figures of SAC (1998, p465). This includes a deduction due to certain grants not being available under upland /hill conditions.

SU9 – Fatten on clean roughage
The costs are similar to SL5. The animals are fed their usual fattening diet except that contaminated roughage is replaced with uncontaminated hay. The user is asked to confirm that the existing supply of roughage is contaminated and has to enter the number of finishing lambs. For Deposition Scenarios 1 and 2 the feeding period is 63 days and for Scenario 3 it is 105 days. The benefit of this

countermeasure is the maintained income derived from the sale of the finished lambs (£40/finished lamb, SAC 1998 p213).

SU10 Fatten on clean concentrate
The costing follows the approach used in SL2 assuming that the farm finishes lambs. The benefit of this countermeasure is the maintained income derived from the sale of the finished lambs, £40 each (SAC, 1998 p213).

SU11 – Sell for fattening
This is different to SU6 in that the lambs are sold for fattening after one grazing season. As a result the cost to the farm is the difference between the finished and store prices, i.e. £40 per finished lamb and £34 per store lamb (SAC, 1998 p213). The user enters the number of lambs normally finished.

As in SU6, the benefit to the farm is the reduced variable costs due to early sale. This is assumed to be equivalent to 25% of the variable costs, applied to the typical number of finishing lambs relative to the total number of ewes on the farm (SAC, 1998 p213).

SU12 – Administer AFCF and fatten on clean roughage
This is a combination of SU1 and SU9.

SU13 – Administer AFCF and sell for fattening
This is a combination of SU1 and SU11.

SU14 – Administer AFCF and intensify use of improved land
This is a combination of SU1 and SU3.

SU15 – Administer AFCF and apply K fertiliser
This is a combination of SU1 and SU5.

SU16 – Administer AFCF and improve land
This is a combination of SU1 and SU2.

5.2.4. Lowland beef production

In Scotland cattle are finished throughout the year, but in order to generate meaningful margin figures, production is usually divided into summer (outdoor) and winter (indoor) finishing cattle. For the cost assessment it is assumed that in a countermeasure situation all animals will be finished indoors. In the DSS it is assumed that beef farms breed and fatten calves using the management described in SAC (1998, p195) as '23-24 month beef from April/May born calves' for medium frame beef cross steers. If the user wishes to assess the costs for store cattle bought in for finishing or any other type of management, the gross margin and variable costs have to be edited accordingly.

BL1 – Administer AFCF
For winter finishing beef, direct administration of AFCF is preferred. The countermeasure for outdoor finished beef (AFCF in boli or feedblocks) is considerably more expensive and not very reliable. A minimum feeding period for winter finishing cattle of 40 days is required, but a period of 60 days is assumed, to allow a safety margin. The AFCF cost is £0.02 per animal per day (Brynhildsen *et al.,* 1996). The user has to specify the number of beef cattle finished on the farm each year. It is assumed that this countermeasure will not be applied to store cattle, grown for fattening elsewhere. Store animals, once sold, will undergo a finishing period much longer than the countermeasure feeding period and it is therefore more effective to apply the countermeasure on the farms that fatten the animals. However, if for political or other reasons, it was desirable to apply

the countermeasure prior to sale then the user can edit the appropriate variables within the CeserDSS to reflect this.

The benefit is the maintained beef gross margin, for medium frame beef cross steers (SAC, 1998 p195).

BL2 – Lime the soil
The cost calculations and assumptions for this countermeasure follow the methods described for SL3. The benefit is the maintained beef margin for medium frame beef cross steers (SAC, 1998 p195).

BL3 – Fatten on clean feed
The animals are fed their usual diet except that contaminated roughage is replaced with uncontaminated hay. The user is asked to confirm that the existing supply of roughage is contaminated and has to enter the number of beef cattle finished on the farm. The fattening period is taken as 40 days and a hay price of £60 per tonne is used (SOAEFD, 1998 p13). It is assumed that the animals are normally fed with bought-in (uncontaminated) concentrate and as a result there is no additional cost burden to the farm.

The benefit of this countermeasure is the maintained gross margin (see BL1).

BL4 - Afforestation
Afforestation results in the loss of the beef margin (see BL1) and will also incur animal disposal costs in the first year. The user has to supply information on the number and average weight of finished beef cattle. It is assumed that the animals will be disposed to landfill, at £25 per tonne, as in DY4. Disposal costs arising for other cattle, e.g. suckler cows, bulls, calves are currently not included in the software but can be easily calculated and added.

The benefit of this countermeasure is the margin derived from afforestation for which the user needs to input the area to be afforested. The net present value estimate of SAC (1998 p465) has been used and an annual equivalent factor conversion of this value has been used as the per annum margin (Lumby 1991).

BL5 – Exclude animal production
The costs are the same as for BL4 but there will be no economic benefit to the farm.

BL7 – Apply K fertiliser
The cost calculations and assumptions of SL9 are used, but the benefit calculation is assumed to be the maintained gross margin to the farm.

5.2.5. Upland/hill beef production

Upland/hill beef production is assumed to involve breeding of calves, either for fattening on the farm or sale as store cattle (see also comments in section 5.2.4.). In the DSS the default values are for beef farms that breed and fatten calves using the management described in SAC (1998, p195) as '23-24 month beef from April/May born calves' for medium frame beef cross steers. If the user wishes to assess the costs for store cattle sold to other farms or any other type of management, the gross margin and variable costs have to be edited accordingly. The appropriate number of store instead of finished animals should be specified.

BU1 – Administer AFCF
The user only needs to enter the number of finishing cattle on the farm. The cost of AFCF for upland beef production will vary with deposition scenario. For Scenarios 1 and 2, three boli per animal will be required (@£3.50 each) over 40 days. Scenario 3 requires AFCF to be administered

for a full year. As for SU1, the default variables used assume production of finished animals. However, should the user wish to apply this countermeasure to store animals that will be finished elsewhere, then the appropriate cost variables can be edited to reflect this.

The benefit is the maintained beef gross margin for medium frame beef cross steers (SAC, 1998 p195).

BU2 – Improve land
The costing method is as for SU2. The benefit is the maintained margin (as in BU1).

BU3 – Intensify use of improved land
The costs of this countermeasure are the same as for SU3 and the benefit is the maintained gross margin (as in BU1).

BU4 – Apply K fertiliser
The calculations of BL7 are used.

BU5 – Lime the soil
The cost and benefit calculations for this countermeasure are the same as those used in BL2.

BU6 – Sell for fattening
The cost used is the difference in farm gate price between finished and yearling beef cattle, for which the number of finishing cattle is entered by the user. The benefit is the reduced variable cost, approximately £125 per animal, assuming a 50% reduction in costs (SAC, 1998 p195).

BU7 – Exclude animal production
Excluding animal production means the total loss of beef margin (SAC, 1998 p195). In the first year there is also the cost of animal disposal, as explained in BL4. There are no on-farm benefits assumed for this countermeasure.

BU8 - Afforestation
The costs are as in BU7 but the benefit is the margin gained from afforestation. In an upland situation this is assumed to be £50 per hectare per year (based on the crop margins in SAC, 1998, p465) which includes a deduction for grants that do not apply to upland/hill situations.

BU9 – Fatten on clean feed
The cattle are fed uncontaminated roughage and concentrate during the last part of the fattening period, using the same proportions as in their normal diet. The user is asked to confirm that the existing roughage is contaminated. The calculations are based on the feeding period (40 days for Scenarios 1 and 2, 100 days for Scenario 3), daily feed requirement (5.9 kg/day DM hay) and price (hay £60/tonne). It is assumed that all concentrate is bought in and is uncontaminated.

The benefit is the maintained margin (as in BU1).

BU10 – Administer AFCF and improve land
This is a combination of BU1 and BU2 and is costed accordingly.

BU11 – Administer AFCF and intensify use of improved land
This is a combination of BU1 and BU3.

BU12 – Administer AFCF and apply K fertiliser
This is a combination of BU1 and BU4.

5.2.6. Management of red deer

In Scotland hunting of wild red deer generally takes place on large privately owned sporting estates in upland and hill areas. Income is derived from the sale of venison and fees for hunting. The number of red deer in Scotland is estimated at 300 000 (Red Deer Commission, 1989).

DE1 - Feed hay with AFCF during autumn/winter
It is assumed that AFCF is fed at a rate of 0.4g per animal per day (the same as for beef; specific data were not available) with the feeding period varying by scenario. A feeding period of 60 days is required for Scenarios 1 and 2, while for Scenario 3, AFCF feeding would be required for a full year. For all scenarios hay should be fed for a minimum of one month. A price of £60 per tonne of hay and a feeding rate of 1.2 kg DM per day (Clutton-Brock *et al.*, 1989) are assumed. The user needs to estimate the number of red deer stags and hinds present on the land/estate, the number of stags and hinds that will be killed by fee paying hunters, the number of deer shot in total and the estimated average weight of the stags and hinds shot. It is assumed that all carcasses are sold for venison.

The benefit of this countermeasure would normally be regarded as the maintained deer margin, but this has not been found in the literature. A simple estimate for the benefit is the maintenance of income from stalking (a UK term for hunting) and the sale of venison. Stalking income is calculated by multiplying the number of red deer stags and hinds killed, by the typical stalker's fees (taken as averages of fees found in stalking advertising material). The maintained venison income is derived from the average price paid by dealers (SNH, pers. comm.).

DE2 - Improve grassland on mineral soils and feed hay with AFCF during autumn/ winter
The calculation for the cost of feeding hay with AFCF is the same as above in DE1 and the cost of improving the grassland depends on the availability of ploughing equipment as described in SU2. No direct allowance has been made for the option of improving grassland in a less intensive way, i.e. by only applying fertiliser but not ploughing and reseeding. The benefit is the maintained income from the sale of venison and the fees from stalking (as described in DE1).

DE5 - Afforestation
For all other farm types the cost of this countermeasure has been the loss of current margin plus the animal disposal cost. It is highly unlikely that landowners would choose to incur costs by disposing of deer. It is therefore assumed that the animals will be left to migrate elsewhere and no disposal cost is included. Cost estimates in the form of gross margin figures for wild deer have not been found in the literature. In the same way as for the benefit calculations in DE1 and DE2 it is assumed that the cost of this countermeasure is the loss of income from both the sale of the culled deer and the fees generated from stalking.

The benefit is the margin derived from forestry, estimated to be £50 per hectare in an upland/hill situation (see BU8).

DE6 - Cease hunting
The cost of ceasing hunting will be the lost gross margin. However, as mentioned, this was not available in the open literature and the cost calculations of DE5 are therefore used. No economic benefit from this countermeasure is assumed.

5.2.7. Arable crop production

Only the crops most commonly produced in Scotland are considered in the Decision Support System, namely winter wheat, spring barley, winter barley, potatoes, swedes and winter oilseed rape, each crop being assessed separately. The area to be treated should always agree with the area of land that is suitable for the countermeasure, as assessed in the Countermeasure Selection Wizard.

CE1 - Deep plough
Two input variables are required from the user: the existing crop and the crop area. Deep ploughing is likely to have some effect on crop yield but this has not been quantified for the costing element in the DSS. However, the user can edit the margin per hectare variable to reflect any change in yield. Deep ploughing requires equipment that is unlikely to be available on most farms. Therefore contractors charges of £35 per hectare are assumed (SAC, 1998, p305) as a one-off cost.

The benefit is the maintained crop gross margin, which depends on the existing crop and yield. All crop margins are in SAC (1998, p.12-79).

CE2 - Skim and bury
Skim and bury ploughing requires special equipment and a contractor cost of £35 per hectare (as in CE1) is assumed. This countermeasure is likely to have a slight effect on crop yield but this loss has not been quantified within the DSS. The benefit is calculated in the same way as for CE1.

CE3 - Shallow plough and apply K fertiliser
The user is required to specify the existing crop, the crop area suitable for treatment and the current annual K fertiliser application rate (the user has to convert K_2O to K by dividing by 1.2). The costs for this countermeasure are the labour costs for ploughing and fertilising plus the cost of the additional K fertiliser. The labour cost is based on work rates of 0.9 ha/hr for ploughing, 3 ha/hr for fertilising, and skilled labour costing £6 per hour (SAC, 1998 p301/7). It is possible that the countermeasure ploughing could be timed to coincide with the normal ploughing operation, in which case the only cost is the additional fertiliser. The user can edit the variables accordingly.

The benefit is the maintained crop gross margin, which varies by crop.

CE4 - Shallow plough and apply lime
The costs for this countermeasure are the additional labour costs for ploughing, the contractor's cost for liming and the cost of the lime. These are based on a work rate of 0.9 ha/hr for ploughing, a liming contractor's cost of £6 per hectare (SAC, 1998 p301/7) and a lime price of £30 per tonne (SOAEFD, 1998 p13). The benefit is the maintained crop gross margin, which differs by crop type.

CE5 - Change crop type to winter sown oilseed rape
A change in the crop type means a loss of the existing crop margin but a gain of the new crop margin. All crop margins (per hectare) are from SAC (1998). The user needs to input the current crop and the area on which it is grown. No costs have been assumed for the conversion to a new crop type.

CE6 - Afforestation
The cost of afforestation is the loss of the existing crop gross margin. The benefit is the gain in forestry margin. A lowland forestry margin, as described in DY5, is used. The user is required to input the existing crop and the area on which it is grown.

CE7 - Leave fallow
Leaving land fallow means the total loss of crop margin (SAC, 1998) with no on-farm benefits.

CE10 - Shallow plough, apply K fertiliser and lime
This is a combination of CE3 and CE4 and is costed accordingly.

6. Limitations and Suggestions for Improvements

This final section sets out the strengths and weaknesses of the Economic Assessment of Countermeasures presented and outlines opportunities for improvements.

6.2. Strengths

All impacts of the countermeasures that are economically relevant are brought together in the methodological framework of cost-benefit analysis (CBA). This is advantageous in that it sets out impacts in a transparent and consistent way; it allows alternative countermeasures to be ranked in terms of their net social benefit; and it allows individual countermeasures to be judged in terms of their economic efficiency.

Many of the significant environmental impacts of countermeasures have been quantified in economic terms. Original per-hectare estimates for the net economic impact of landscape change due to countermeasures have been produced in a novel application of the contingent valuation method. Extremely comprehensive estimates of the farm-level costs of alternative countermeasures have been produced.

Through incorporation in the CeserDSS, on-farm costs and benefits can be easily evaluated by decision makers for a range of countermeasure options. The Cost-Benefit decision rule can also be compared with the multi-criteria analysis incorporated in the DSS.

6.2. Weaknesses

The CBA methodology represents a considerable simplification of the decision making situation. In reality, criteria other than social efficiency are likely to be important.

Cost estimates for many environmental impacts of countermeasures are lacking, e.g. changes in biodiversity, soil pollutants, soil organic matter and landscape quality other than those covered in the contingent valuation survey. A partial equilibrium budgeting approach was used in estimating farm-level costs. This does not allow for wider effects due to adjustments in management at the farm level, or for regional/national impacts of countermeasures on input and output prices. In costing the benefits of countermeasures, necessary price reductions, resulting from countermeasure effects on consumer confidence, were only estimated for milk and lamb.

6.3. Opportunities

There is no conceptual reason why, with additional resources, missing values for the environmental costs mentioned in Chapter 6.2. cannot be filled in through original empirical work.

In order to adjust predictions of farm-level costs for knock-on effects on the farm, the DSS could be linked to programming models of representative farm types using the Farm Accountancy Data Network information. This could incorporate different levels of relative risk if MOTAD-type (Minimizations of the Total Absolute Deviations) models were used. In order to adjust predictions of farm-level costs for changes in input and product prices, regional/national Computable General Equilibrium models could be utilised. Alternatively, elasticity estimates from existing models could be used.

The CeserDSS, or a modified version of it, is a very powerful tool for allowing people to explore countermeasure options using CBA. CBA is often criticised as being a “black box” technique, yet the DSS allows users to see exactly how benefits and costs stack up as countermeasure options and exogenous parameters (such as labour costs and crop prices) change. In this sense, the DSS can be seen both as a very useful educational tool and a means of promoting the use of environmental CBA in decision-aiding.

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Appendix I - Countermeasure Descriptions

Taken from Salt *et al.* (1999b)

Shallow ploughing
Shallow ploughing aims to bury the radionuclides that have been deposited on the soil surface, thus reducing root uptake by plants as well as external exposure and risk of inhalation from resuspension. Repeated shallow ploughing has no added benefit.

Performance and effectiveness
Soils are ploughed with a mouldboard plough to 25 cm depth. On arable land it is recommended in combination with application of lime or potassium. The contaminated crop should either be removed before ploughing or if the biomass is not too great it can be ploughed in. On permanent vegetation shallow ploughing is part of the following countermeasures: a) creating improved grassland, b) intensifying the use of existing grassland, and c) converting improved grassland to cereal cultivation to produce concentrate for feeding to dairy cows. The decontamination factor is assumed to be 2-4.

Side-effects
Shallow ploughing will increase the risk of erosion where bare soil surfaces occur or the density of plant cover is reduced. Soil organic matter will decrease on soils that have been previously undisturbed such as those under semi-natural or improved pasture. Both erosion and loss of organic matter can lead to loss of nutrients (e.g. nitrate and particulate phosphorus) and toxic micro-pollutants in runoff and leachate. These substances may reach ground or surface water leading to eutrophication or pollution with potential impacts on fisheries, recreation, drinking water abstraction and functioning of ecosystems. Ploughing in areas of semi-natural vegetation as part of pasture improvement could change the biodiversity if large areas were treated.

Deep ploughing
The aim of the countermeasure is to bury the contamination deeply by inverting the soil. This significantly reduces uptake by plant roots as well as external exposure to humans and risk of inhalation from resuspension.

Performance and effectiveness
The soil is ploughed once to 50 cm with implements such as forestry ploughs or other special ploughs. In the CeserDSS it is only recommended on arable land and is assumed to be followed by agricultural management as normal. The contaminated crop should either be removed before ploughing or, if the biomass is not too great it can be ploughed in. This type of ploughing may produce high ridges if the spacing is not narrow enough, and shallow mouldboard ploughing and other forms of tillage may be necessary to create an even surface. Ideally the spacing should be sufficiently narrow to invert the soil into the previous furrow. Poor structure of the subsoil brought to the surface may also necessitate further tillage e.g. harrowing and disking. A decontamination factor of 10 is assumed.

Side-effects
Side-effects on arable land will be loss of organic matter and of nutrients as the topsoil is buried. If after deep ploughing, fertilisation rates are kept at normal levels some nutrients may become deficient. Phosphorus losses in runoff are likely to decreases due to the lower P status of subsoils. It will take many years to build up organic matter and improve the soil structure. The quality and quantity of agricultural produce will be reduced. The impact on erosion will depend greatly on the nature of the subsoil which may be less or more erodible than the original to topsoil.

Skim and burial

This technique aims to bury the contamination by skimming off the top 5 cm of soil and burying it at depth. This significantly reduces uptake by plant roots as well as external exposure to humans and risk of inhalation from resuspension.

Performance and effectiveness

Using a specially designed skim and bury plough, the top 5 cm of soil including the contaminated surface layer are buried at 45-50 cm depth (Roed *et al*., 1996.). In the CeserDSS it is only recommended on arable land and is assumed to be followed by normal agricultural management. The contaminated crop should either be removed before ploughing or, if the biomass is not too great, it can be buried (e.g. grass turf) in the process. A decontamination factor of 10 or better is assumed. Availability of the equipment may limit application of the countermeasure.

Side-effects

Side-effects on arable land will be some loss of organic matter and of nutrients, as part of the topsoil is deeply buried. It is assumed that the nutrient status can be restored through fertilisation but it will take longer to restore the organic matter status. No significant changes in losses of phosphorus and nitrogen are expected. The quality and quantity of agricultural produce will be reduced, but to a much lesser extent than after deep ploughing.

Application of potassium

This countermeasure is designed to reduce the plant uptake of radiocaesium. Addition of potassium to soils with a low K status, significantly increases the pool of available potassium. This lowers the ratio of Cs to K in the soil solution and thus reduces radiocaesium uptake by plant roots.

Performance and effectiveness

Potassium fertiliser in granular form is applied annually at a rate of 100 kg/ha of K, either to the soil surface of grazed pastures or ploughed into the soil on arable land. A decontamination factor of 2.5 is assumed for suitable soils.

Side-effects

Side-effects include slightly enhanced mineralisation of organic matter and a change in the composition of the soil solution which may lead to leaching of nutrients and pollutants. This could cause deficiencies or toxicities, thereby reducing the quality of agricultural products and adversely affecting animal health. Potassium may promote plant growth on K limited soils but changes in biodiversity are unlikely.

Application of lime

This countermeasure is designed to reduce the plant uptake of radiostrontium. Addition of lime to soils with a low calcium status, significantly increases the pool of available calcium. This lowers the ratio of Sr to Ca in the soil solution and thus reduces radiostrontium uptake by plant roots.

Performance and effectiveness

Agricultural lime is applied bi-annually at a rate of 2t/ha of lime ($CaCO_3$) either to the soil surface of grazed pastures or ploughed into the soil on arable land. A decontamination factor of 2.5 is assumed for suitable soils.

Side- effects

Side-effects include enhanced mineralisation of organic matter and a change in the composition of the soil solution, which may lead to leaching of nutrients and pollutants. This could cause deficiencies or toxicities, thereby reducing the quality of agricultural products and adversely affecting animal health. Liming of acid soils may improve plant productivity and increase biodiversity.

Pasture improvement (upland sheep, beef, deer)
Rough grazing land may be converted to better quality pasture. The countermeasure relies on a combination of effects. Through ploughing all radionuclides are buried. Fertilisation promotes ‘growth dilution’ of radionuclides in plants. Improvable soils typically have a fairly high mineral content and thus lower soil-plant transfer of radiocaesium. Application of potassium and lime increases K/Cs and Ca/Sr ratios in the soil solution thus lowering relative plant uptake of radiocaesium and radiostrontium. Sown grass/clover swards have a lower potential for radiocaesium uptake compared to some of the indigenous plant species.

Performance and effectiveness
Small areas of rough grazing land on upland/hill farms are converted to better quality grassland by ploughing to 25 cm, fertilising (N-P-K), liming and sowing of a grass/clover mix. Nitrogen is applied as nitrate (NO_3^-) rather than ammonia (NH_4^+) to avoid mobilisation of radiocaesium. It may be necessary to deep plough to destroy an existing iron pan. Woody vegetation may need to be burnt off initially. Improved areas need to be maintained by annual fertilisation and periodic liming and reseeding (a 5 year interval is assumed). Livestock would be grazed on these areas in order to lower their radiocaesium and radiostrontium contamination prior to sale or slaughter. A decontamination factor of 4 or better is assumed.

In the management of red deer this countermeasure should be used preferably on mineral soils in valleys. It is recommended to be combined with feeding of AFCF treated hay. The effectiveness very much depends on how many deer will be attracted to these areas. This is most likely when natural feed sources are scarce e.g. in autumn and winter. By this time stags are in poor body condition and have little market value, while hinds are generally in better condition. Thus it is suggested that the countermeasure will work best for hinds and they should not be hunted until at least 1 month after the feeding has started.

Side-effects
Scores in the DSS are based on small to medium sized areas being improved (less than 25% of the farm area). This limits the overall impact at the farm level. Side-effects are a combination of those described for shallow ploughing and for liming and K application with the additional risk of phosphorus and nitrogen losses. Positive effects on animal welfare as well as product quantity and quality are expected as more high quality grazing is provided. The impact on biodiversity may also be positive since a different habitat is introduced and grazing pressure on other land is slightly reduced. Based on the CESER contingent valuation study, the change in landscape quality was rated as negative if converting from heather moorland and positive if converting from rough grassland or blanket bog.

Pasture intensification (upland sheep, beef, deer)
Existing improved pasture on upland/hill farms may be managed more intensively to feed more livestock. The countermeasure is based on: a) dilution of radionuclides through enhanced plant growth, b) maximising the use of productive mineral soils which have lower radiocaesium transfer to plants, and c) less grazing on unimproved land where, due to the combination of soil type and vegetation, radiocaesium may be more plant available.

Performance and effectiveness
The application of fertiliser (NPK) and the stocking density are raised from the current to the highest recommended levels for upland/hill farms. These are 170 and 125 kg/ha of N and P (P_2O_5) respectively for mowing grass and 110 and 100 kg/ha of N and P (P_2O_5) respectively for grazing grass; 2 livestock units per ha.

Grassland productivity is maintained by regular ploughing, liming and reseeding, carried out approximately every 3 years. Nitrogen is applied as nitrate (NO_3^-) rather than ammonia (NH_4^+) to avoid mobilisation of radiocaesium. The decontamination factor for radiocaesium may be approx.

2 but depends on the specific circumstances. The effectiveness for radiostrontium is not known.

Side-effects
As the countermeasure is based on an intensification of already existing farm management, side-effects due to ploughing and application of lime/potassium are thought to be small. Higher application rates of phosphorus and nitrogen may increase the risk of eutrophication with potential impacts on fisheries, recreation, drinking water abstraction and functioning of ecosystems. Beneficial effects on product quality and quantity and animal welfare are expected due to increased intake of high quality grass by livestock.

Change to oilseed rape
The transfer of radiocaesium and radiostrontium into the food chain may be reduced on arable land by switching to an industrial food crop. Oilseed rape is used in the production of margarine and cooking fats. The processing removes a significant proportion of the radiocaesium contamination since it is not transferred to the oil/fat phase. The effectiveness for radiostrontium is uncertain.

Performance and effectiveness
Arable land where crops such as barley, wheat, potatoes or root crops are normally grown, can be used to produce winter oil seed rape. It is assumed that in the main arable areas of Scotland soil conditions are not a major limitation. However, it is recommended that oil seed rape is grown in rotation with other crops to prevent build-up of diseases. A market has to be found for the increased production. The reduction in contamination may be an order of magnitude or better, though detailed data is lacking.

Side-effects
Where the original crop was winter barley or winter wheat, erosion is expected to be reduced by introducing winter oilseed rape. For other crop changes the effects will vary with soil type, climate etc and no definite trends can be given. Changes in nutrient losses are also highly dependent on the previous crops. Large areas of oil seed rape are likely to lower the landscape quality since the crop is not popular in Scotland due to it's connection with allergies and it's unpleasant smell. Side-effects from conversion to spring oilseed rape would be similar though erosion may be slightly lower.

Afforestation
In areas where the deposition is too high to continue agricultural food production and the external dose to humans has to be kept to a minimum, afforestation may be appropriate.

Performance and effectiveness
Forestry is established using planting preparation without ploughing to minimise erosion (mounding). Coniferous trees are planted, ideally by machine rather than by hand. Annual herbicide application may be required for several years. No fertiliser is applied. Planting is restricted to fairly well drained sites to avoid. Poorly drained sites are not suitable as the necessary drainage could mobilise radionuclides through erosion and runoff. Species choice depends on climate, soil type, exposure and soil nutrient status. On fertile soils it would be possible to plant a wider range of trees including broadleaves. This option is currently not included in the DSS but the impact scores could be adjusted to allow it's assessment.

Side-effects
Over the long-term erosion and nutrient inputs to water bodies are reduced. However, the biodiversity of conifer monoculture is low compared to agricultural land and the change in landscape is generally perceived as negative. If a wider range of trees species is planted, biodiversity will be relatively higher and landscape change may be regarded more positively. It is possible to adjust the scores in the DSS accordingly.

AFCF supplementation
AFCF (ammonium-iron-hexacyanoferrate) is a prussian-blue type compound with very low toxicity. When fed to animals, it binds to radiocaesium making it less available for gut absorption. This reduces radiocaesium contamination in milk and meat. The Cs ion remains bound to the iron-hexacyanoferrate when excreted in faeces. AFCF should be continuously present in the digestive tract for maximum effectiveness and ideally added at a rate of 1 g per kg to mixed concentrate. AFCF has no effect on radiostrontium contamination of milk and meat.

Performance and effectiveness
Dairy cows require approximately 0.4 g AFCF per day. This can be given with the concentrate ration during milking at least twice per day. This countermeasure is expected to reduce the radiocaesium level in milk by 80-90%.

Beef cattle should ideally be given AFCF with concentrate or roughage at a rate of 0.4 g per day. Alternatively it is possible to supply the AFCF as boli or in feed blocks. This countermeasure has to be used for a minimum of 60 days prior to sale for slaughter. It is expected to reduce the radiocaesium level in meat by approx. 80 %.

Lambs during fattening as well as ewes during lactation can be treated with AFCF. All sheep that are regularly handled or fed supplementary feed should be given approx. 0.1 g AFCF per day with the feed. Free ranging sheep can be given AFCF in rumen dwelling boli, in salt licks or feed blocks containing AFCF. AFCF given daily in feed is expected to reduce the radiocaesium in meat by approx. 80%, while for the boli, feed blocks and salt licks the expected reduction is 50%.

In free ranging red deer it is recommended that AFCF is supplied in conjunction with feeding of hay. The effectiveness of the countermeasure will depend on whether animals use the feeding places. This is only likely when natural feed sources are scarce e.g. in autumn and winter. By this time stags are in poor body condition and have little market value, while hinds are generally in better condition. Thus it is suggested that the countermeasure will work best for hinds and they should not be hunted until at least 1 month after the feeding has started.

Side-effects
There are no known direct effects of AFCF on animal welfare or the quality and quantity of the agricultural products. Soil erosion will occur locally around feeding areas but this has not been included in the DSS. In experiments with animal manure it was found that radiocaesium bound to AFCF may leach faster in organic and possibly also sandy soils compared to CsCl. This has been included in the DSS.

Calcium supplementation (dairy cows)
Dairy cows can be supplemented with high levels of calcium to reduce radiostrontium transfer to milk. Increased levels of Ca compete with Sr, thus reducing the amount of Sr transferred to milk. Ca supplementation will not affect the transfer of radiocaesium to milk

Performance and effectiveness
This countermeasure is only recommended for dairy cows. A daily dose of 200 g per day is assumed to reduce the transfer of radiostrontium to milk by 40-60%. The higher efficiency will be observed where the present level of Ca in the diet is low (less than 60 g /d for dairy cows yielding ca. 20 L/d). The Ca must be given daily, ideally in two doses.

Side-effects
Side-effects on the animal are not expected if the following recommendations are followed: a) Ca should be given as $CaCO_3$ rather than $CaCl_2$, because of it's corrosive effect; b) the amount should not exceed 2% of the daily dry matter intake and c) the Ca:P should be between 1:1 and 2:1. However, Ca supplementation may need to be adjusted according to variations in feed (energy and

minerals) utilisation.

Fatten on clean concentrate (sheep)
This involves early weaning of lambs followed by fattening indoors on clean concentrate and sale for slaughter. The clean concentrate almost wholly replaces consumption of grass or other roughage.

Performance and efficiency
Lambs may be weaned at 4-5 weeks provided that they have access to palatable creep feed before weaning and they consume about 200 g/d of solid feed. The feeding must be managed to allow maximum intake of concentrated feed in the lambs, ie fresh dry feed given twice daily, clean feeding troughs and easily available fresh water. Care has to be taken to prevent diseases such as coccidiosis, urinary calculi and muscular dystrophy. The lambs will only consume milk and concentrated feeds. Radiocaesium and radiostrontium contaminated roughage is therefore not used for meat production, but only for breeding animals.

The lambs are expected to accumulate radiocaesium and radiostrontium from the ewe during the prenatal period and from milk during the nursing period. Assuming a feeding period of 90 days after weaning the countermeasure reduces the body burden measured at weaning by up to 88%. The efficiency for radiostrontium is uncertain. Feeding and housing facilities are required. This is likely to limit the application of this countermeasure on upland/hill farms.

Side-effects
As the lambs never graze, the grazing pressure on the vegetation and the need for fertilisers are reduced. This may have positive effects on water quality and biodiversity. However, the manure produced indoors has to be spread onto land. Thus no net reduction in nutrient losses from land is expected. The housing and intensive feeding of the lambs may be perceived as negative with respect to animal welfare but is likely to improve product quality.

Fatten on clean roughage (sheep)
This countermeasure aims to reduce the intake of radiocaesum and radiostrontium through feed, and thereby reduce the transfer of these isotopes to meat. This will also reduce the body content of already accumulated radiocaesium and/or radiostrontium.

Performance and effectiveness
This countermeasure is to be used during the fattening of lambs. The contaminated roughage in the diet, i.e. grass, silage or hay, is replaced with uncontaminated roughage without changing the composition of the diet. The feeding period varies between 60 and 105 days depending on the deposition scenario and farm type. A reduction of 80 to almost 100% in meat contamination is expected (assuming a biological half-life of 3 weeks). It may be cheaper to fatten on uncontaminated concentrate when roughage is more expensive due to higher transportation cost.

Side-effects
If roughage is bought in, an equivalent amount of grass on the farm is not needed. However, side-effects are likely to be small due to the limited period of feeding for lambs and the fact that the diet of the ewes is not changed.

Fatten on clean feed (beef)
Beef cattle are typically fattened on a combination of roughage (grass, silage, hay or straw) and concentrated feeds, mainly grain and protein sources. To reduce the daily intake of both radiocaesium and radiostrontium during the last part of the fattening period it is recommended that both uncontaminated roughage and concentrate are supplied.

Performance and effectiveness
Beef cattle (> 1 year old) are fed uncontaminated concentrate and silage in the same proportion as usual for 40-100 days as part of winter finishing indoors. Assuming an effective biological half-life of 19 days, the reduction in meat contamination is 75 to almost 100%.

Side-effects
Due to the short duration of the feeding period compared to the whole life span of the animal (approx 2 years), the side-effects resulting from less use of farm-grown roughage and concentrate are small. As the type of diet is not changed no effects on the animal are expected.

Feed clean concentrate (dairy cows)
Diets for dairy cows are usually a combination of roughage (grass, silage, hay or straw) and concentrated feeds, mainly grain and protein sources. To reduce the level of contamination in milk the diet has to be altered over the whole year. In many cases it is likely to be more cost effective and practical to replace part of the roughage with uncontaminated concentrate rather than with uncontaminated roughage. This countermeasure reduces the daily intake of both radiocaesium and radiostrontium.

Performance and effectiveness
Dairy cows are supplied with uncontaminated concentrate to cover 80% of their energy intake instead of the typical level of 20-30% currently supplied in Scotland. The concentrate should not account for more than 80% of the net energy of the total ration because of possible health hazards to the animals. At feeding levels exceeding 60% of net energy, the concentrate should be divided into at least 4 rations per day. As a result of this countermeasure a corresponding area of grassland will be left fallow. The effectiveness for Cs and Sr in milk is 60-80%.

Side-effects
Side-effects depend greatly on the current level of concentrate feeding and scores in the DSS are adjusted accordingly. Generally the land use change will lead to a decrease in erosion at the farm level and an increase in biodiversity through the introduction of fallow areas. The volume of faeces/manure will rise, increasing the need for land spreading and thus the risk of nitrogen and phosphorus losses to water bodies. Ammonia emissions and milk production will increase.

Feed concentrate grown on farm (dairy cows)
Diets for dairy cows are usually a combination of roughage (grass, silage, hay or straw) and concentrated feeds, mainly grain and protein sources. To reduce the overall contamination in the diet it is possible to replace a significant proportion of the home grown roughage with home grown barley concentrate. This countermeasure relies on the generally lower contamination in grain compared to grass per unit of energy supplied to the animal. It reduces the daily intake of both radiocaesium and radiostrontium.

Performance and effectiveness
Dairy cows are supplied with home grown concentrate up to 80% of their energy intake. The concentrate should not account for more than 80% of the net energy of the total ration because of possible health hazards to the animals. At feeding levels above 60% of net energy the concentrate should be divided into at least 4 rations per day. The countermeasure involves converting some existing grassland to barley cultivation and leaving a small area fallow. It is assumed that the source of concentrate already fed to cows remains the same, i.e. imported or home grown, but that additional concentrate required to raise the level to 80%, is home grown. The effectiveness depends on the level of contamination in the home grown concentrate.

Side-effects
Side-effects depend greatly on the current level of concentrate feeding and scores in the DSS are adjusted accordingly. Generally the land use change from grassland to barley will lead to an increase in erosion and a decrease in soil organic matter. Nutrient losses to water are expected to increase though this will depend on the intensity of the original grassland production. The volume of faeces/manure will rise, increasing the need for land spreading and thus the risk of nitrogen and phosphorus losses to water bodies. Ammonia emissions and milk production will increase. The change from intensive grassland only, to a mixture of barley fields, intensive grassland and some fallow will create a greater diversity of biological habitats.

Early sale for fattening (sheep)
Lambs from upland/hill farms are weaned early and sold to areas that either received less deposition or have less contaminated pastures due to soil type. This requires intensification in those areas receiving the additional lambs. If the upland/hill farm has facilities to fatten early weaned lambs indoors on concentrate, this option can be alternatively assessed in the DSS.

Performance and effectiveness
Lambs may be weaned at 4-5 weeks providing they have access to palatable creep feed before weaning and consume about 200 g/d of the solid feed. The feeding must be managed to allow maximum intake of concentrated feed, ie fresh dry feed given twice daily, clean feeding troughs and easily available fresh water. Care has to be taken to prevent diseases such as coccidiosis, urinary calculi and muscular dystrophy. The lambs will only consume milk and concentrated feeds. Radiocaesium and radiostrontium contaminated roughage is therefore not used for meat production, but only for breeding animals. The effectiveness of the countermeasure depends on the fattening regime at the farms buying the lambs.

Side-effects
Since the lambs never graze, the grazing pressure on the vegetation and the need for fertilisers is reduced, which may have positive effects on water quality and biodiversity on the farm selling the lambs. The opposite effects may occur on those farms receiving the additional lambs. This is not included in the DSS. The early weaning of the lambs may be perceived as a reduction in animal welfare. Product quantity is greatly reduced and the lambs will fetch a much lower price compared to older lambs.

Sell for fattening (sheep/beef)
On upland/hill farms that normally fatten animals it could be advantageous to sell lambs and calves for fattening on other farms. This would be the case if the roughage on the farm was too contaminated to be used for fattening but less contaminated feeds were available in other areas of the country. On many upland/hill farms the sale of store animals for fattening on lowland farms is part of normal practice, however, it is still regarded as a countermeasure since it would be combined with monitoring and slaughter restrictions.

Performance and effectiveness
It is recommended that calves suckle for at least 3-4 weeks before they are weaned and sold for fattening. The milk feeding period may be extended depending on normal farm management. Lambs are typically weaned at 8 weeks onto pasture and sold after one grazing season. The efficiency of this countermeasure depends on the fattening regime at the farm buying the animals. The market for live animals for fattening could limit the number of farms that can use this countermeasure.

Side-effects
By selling store animals instead of fattened animals the farmer reduces the level of production and thus income. There will be a reduction in the demand for grass/silage/hay production, which could

lower losses of nutrients to water, bodies and have some benefits in terms of biodiversity. Farms elsewhere buying in extra lambs will most likely have the opposite effects. This is not included in the DSS.

Exclude animal production/ leave land fallow

In situations where the deposition is too high to continue agricultural food production and the external dose to humans has to be kept to a minimum, it may be appropriate to leave the land unmanaged for many years.

Performance and effectiveness

All land is left unmanaged, ceasing tillage, fertilisation and harvesting. In animal production systems it is necessary to destroy the animals. Arable crops can be abandoned though it is not advisable to leave bare soil due to the risk of erosion and resuspension. Loss of agricultural output will have to be compensated for by increased production in other parts of the country or through imports.

Side-effects

In environmental terms this countermeasure can be regarded as beneficial. Erosion and nutrient losses to water bodies will decrease and soil organic matter will gradually build up. Effects on biodiversity are difficult to predict. Gains in some species will be accompanied by losses of others. If large areas of agricultural land are left fallow, biodiversity in the long term may be negatively affected if habitats become more uniform and shrubs and tress colonise. Trends will depend on the presence of wild ranging herbivores such as red deer. Landscape change was given a slightly negative score assuming that most people will not like the unmanaged appearance. This was partly based on results from the Contingent valuation study, which showed a preference for improved (bright green) compared to rough (green/brown) grassland. Social effects on the farming community will be serious.

Appendix II - Descriptions of the Impact Assessment Criteria Considered in the CeserDSS

Assessment criteria are used in the CeserDSS to characterise the environmental and agricultural impacts of countermeasure application. They were selected using a literature review and expert judgement. Once a comprehensive list of potential side effects of soil-plant-based and animal-based countermeasures had been compiled, the side-effects were prioritised to yield the following list of final assessment criteria:

Erosion and Sedimentation
Erosion is the loss of soil through water and wind induced transport. Sedimentation is the deposition of eroded soil in surface water bodies where detrimental effects on drinking water quality or biological habitats may occur.

Soil Organic Matter
The humus content of the topsoil.

Soil Nutrient Transport to Water
The transport of soil nutrients in dissolved or particulate form in runoff and percolate which may enter surface or ground water and cause eutrophication.

Soil Pollutant Transport to Water
The transport of soil pollutants such as heavy metals in dissolved or particulate form in runoff and percolate which may enter surface or ground water and cause water pollution.

Animal Welfare
The maintenance of animals in good health through humane handling, care and treatment. This entails a) freedom from thirst, hunger and malnutrition, b) provision of appropriate comfort and shelter, c) prevention, or rapid diagnosis and treatment, of injury, disease or infestation with parasites, d) freedom from distress and e) ability to display normal patterns of behaviour.

Product Quality
The quality of the agricultural product in terms of it’s saleability.

Product Quantity
The amount of food (milk, meat, grain, seed, root crop) produced for sale.

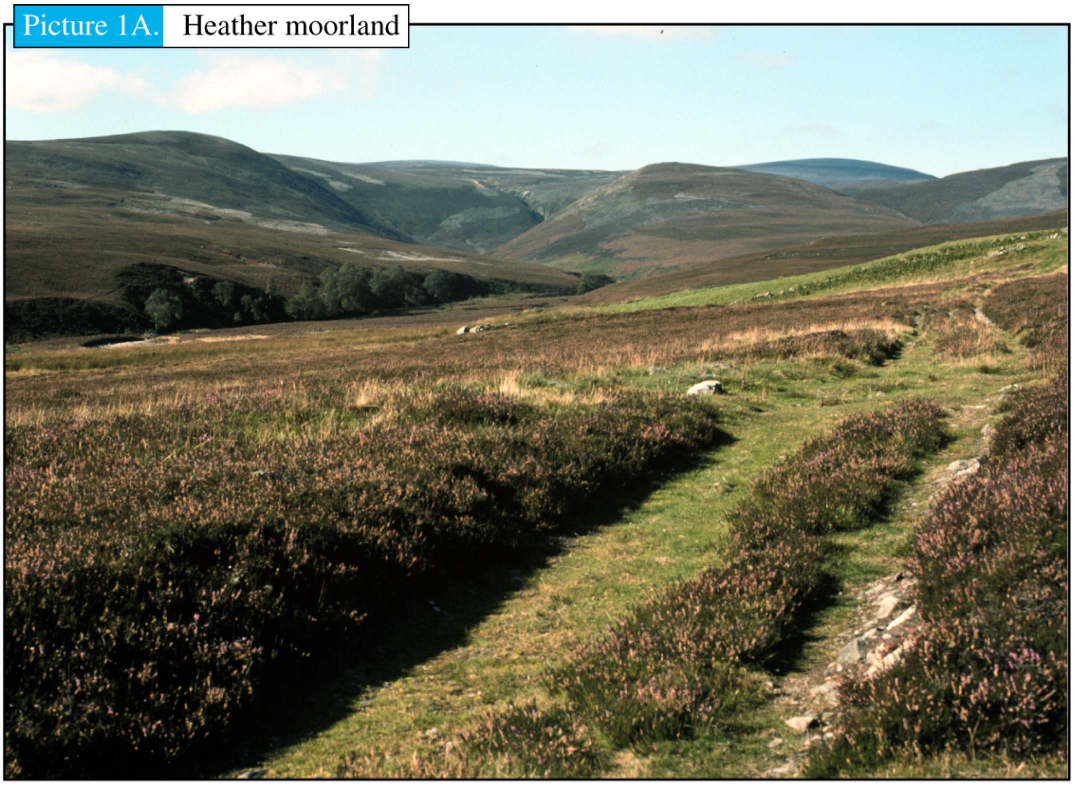
Ammonia Emissions
Emissions of ammonia due to volatilisation from nitrogen contained in animal faeces, urine or manure or in mineral fertilisers. The emissions from livestock occur during outdoor grazing and periods of housing, as well as during storage and land spreading of manures.

Biodiversity
The variability among living organisms and the ecological complexes of which they are part (Rio Conference 1992). In the context of the CeserDSS we have defined biodiversity as the ecological richness of a particular farm type which includes higher plant and animal diversity as well as rarity and distinctiveness of species and diversity of habitats/ecosystems.

Landscape Quality
The value of a landscape based on known and predicted preferences in Scottish people. Preference depends on cultural background, knowledge and educational level. Factors which may play a role are the perceived ‘naturalness’, diversity and fragility of an area and economic/recreational value.

Appendix III – Example of the Manipulated Images Used in the CESER Contingent Valuation Information Packs.

Picture 1A. Heather moorland



This kind of landscape is maintained by low levels of sheep and deer grazing and the burning of the heather. This promotes healthy heather for grouse and other birds, like Golden Plovers and Merlin.

Picture 1B. Change from heather moorland to more productive grassland

More productive grassland is created by regular ploughing, fertilising and seeding. This will support a higher number of sheep or cattle.

Picture 2A. Heather moorland

This kind of landscape is maintained by low levels of sheep and deer grazing and the burning of the heather. This promotes healthy heather for grouse and other birds, like Golden Plovers and Merlin.

Picture 2B. Change from heather moorland to forestry

Fast growing conifer trees such as Sitka Spruce are planted in straight lines. The trees are felled in 50-60 years time.

Appendix IV - Contingent Valuation Questionnaire Applied to a Heather Moorland Area.

1. I'd like to ask you how much importance you think the government should give to protecting the countryside and environment relative to other issues. I'd like you to look at the five issues shown on this card and rank them in order of importance from 1 for most important to 5 for least important.

Healthcare	…….
Funding for the arts	…….
Fighting crime	…….
Protecting the countryside and the environment	…….
Education	…….

2. This card shows some of the possible aims of government countryside policy. Again I'd like you to look at them and rank them from 1 for most important to 5 for least important.

Controlling pollution	…….
Protecting the landscape	…….
Protecting rare animals and plants	…….
Ensuring public access to the countryside	…….
Protecting historical sites	…….

Most of the land in the pictures is managed by farmers. Many farmers are under pressure from falling incomes, which might mean that they have to change the way they farm and this will affect the way the countryside looks. For example, they might have to increase the number of animals grazing the land or they might have to plant fast growing conifer trees onto rough grassland or heather moorland.

I would like to ask you some questions about such changes to an area of HEATHER MOORLAND shown on the map in the information pack.

The solid area in the centre of the map is the area we are talking about and, as you can see it is within (**READ OFF FROM RINGS ON MAP**) miles of where you live.

3. Distance respondents live from area.

Within 10 miles	……….
Between 10 and 20 miles	……….
Between 20 and 30 miles	……….
Between 30 and 40 miles	……….
Greater than 40 miles	……….

Within this area heather moorland covers approximately **12** square miles, that is about the size of Aberdeen. Imagine that the landscape changes may happen to <u>half</u> of this moorland area.

PART A

I'd like you to look at the first set of pictures in the Information Pack and for you to consider a possible change in landscape from heather moorland to more productive grassland.

4. Looking at the pictures in set 1, which of the following statements best describes your view?

   I would prefer to see the whole area remain as heather moorland. ______ **GO TO Q5**

   I would prefer to see half of the area change to more productive grassland. ______ **GO TO Q7**

5. Imagine that by paying money into a specially created trust fund you could help to protect this heather moorland. Only by people like you contributing to the fund could the heather moorland be protected. The more money donated the more likely the moorland could be safeguarded.

   a) Would you be willing to make a one-off donation to prevent the loss of half of this heather moorland? In thinking about your answer remember that you would have to reduce spending on something else and there might be other 'environmental good causes' which you would want to spend your money on.

   Yes ___ **If yes, go to Q5b**

   No ___ **If no, go to Q6**

   b) What is the largest amount that you would be willing to give? ____________

IF NOT WILLING TO GIVE AT 5a ASK

6. Could you tell me why you wouldn't be willing to pay anything? _________________
   ____

Now go to Part B

7. Changing the heather moorland to more productive grassland would be expensive. Imagine that by paying money into a specially created trust fund you could help to change this to more productive grassland. Only by people like you contributing to the fund could more productive grassland be created. The more money donated the more likely the change could occur.

   a) Would you be willing to make a one-off donation to help create more productive grassland in half of this area? In thinking about your answer remember that you would have to reduce spending on something else and there might be other 'environmental good causes' which you would want to spend your money on.

   Yes ___ **If yes, go to Q7b**

   No ___ **If no, go to Q8**

   b) What is the largest amount that you would be willing to give? ____________

IF NOT WILLING TO GIVE AT 7a ASK

8. Could you tell me why you wouldn't be willing to pay anything?________________
   ____

PART B

Now I'd like you to look at the two pictures in set 2 of the Information Pack and for you to consider a possible change of landscape from heather moorland to conifer forestry.

9. Looking at the pictures in set 2, which of the following statements best describes your view?

    I would prefer to see the whole area remain as heather moorland. ______ **GO TO Q10**

    I would prefer to see half of the area change to conifer forestry. ______ **GO TO Q12**

10. Imagine that by paying money into a specially created trust fund you could help to protect this heather moorland. Only by people like you contributing to the fund could the heather moorland be protected. The more money donated the more likely the moorland could be safeguarded.

    a) Would you be willing to make a one-off donation to prevent the loss of half of this heather moorland? In thinking about your answer remember that you would have to reduce spending on something else and there might be other 'environmental good causes' which you would want to spend your money on.

    Yes ___ **If yes, go to Q10b**

    No ___ **If no, go to Q11**

    b) What is the largest amount that you would be willing to give? ____________

IF NOT WILLING TO GIVE AT 10a ASK

11. Could you tell me why you wouldn't be willing to pay anything? __________________
    ____

Now go to Section 3

12. Changing the heather moorland to conifer forestry would be expensive. Imagine that by paying money into a specially created trust fund you could help to change this to conifer forestry. Only by people like you contributing to the fund could conifer forestry be created. The more money donated the more likely the change could occur.

    a) Would you be willing to make a one-off donation to help create conifer forestry in half of this area? In thinking about your answer remember that you would have to reduce spending on something else and there might be other 'environmental good causes' which you would want to spend your money on.

    Yes ___ **If yes, go to Q12b**

    No ___ **If no, go to Q13**

    b) What is the largest amount that you would be willing to give? ____________

IF NOT WILLING TO GIVE AT 12a ASK

13. Could you tell me why you wouldn't be willing to pay anything?__________________
    ____

Section 3: Other Information

To help us analyse the results of the survey we would now like to get some brief details about you and your household. Like all the information collected in this survey, this is completely confidential and anonymous.

14. a) Please could you tell me how many people aged 16 and over live here?______

    b) And how many under 16?_______

15. Looking at this card, could you please tell me which number reflects your households approximate income before tax?

    1) less than £5,000 ☐
    2) £5,000-£14,999 ☐
    3) £15,000-£24,999 ☐
    4) £25,000-£34,999 ☐
    5) £35,000-£44,999 ☐
    6) £45,000-£54,999 ☐
    7) £55,000-£64,999 ☐
    8) £65,000 and over ☐
    9) Undisclosed ☐

16. Can you tell me if you are a member of these following environmental groups/charities?

Greenpeace	☐	Friends of the Earth	☐
RSPB	☐	Scottish Wildlife Trust	☐
National Trust (for Scotland)	☐	WWF	☐
Royal Zoological Society	☐	Other (please specify)	☐
		..........…………...........	
I do not belong to any such group	☐		

17. Can you tell me which of the age bands on this card applies to you?

Less than 18	☐	36-45	☐	66-75	☐
18-25	☐	46-55	☐	76-84	☐
26-35	☐	56-65	☐	85 and over	☐

18. I will now read a list of outdoor activities. Please could you tell me whether you take part in these never, sometimes or often?

	Never	Sometimes (less than 6 times per year)	Often (more than 6 times per year)
Recreational Walking			
Mountain/hill walking			
Mountain biking			
Horse riding			
Water sports			
Camping			
Bird-watching			
Fishing			
Shooting			
Scenic Driving			
Other (please specify)			

19. And finally, do you have any further comments you would like to make?

____

____

Appendix V - The CeserDSS Software

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