The challenge of competing goals: animal welfare, the environment, human health and the profitability of livestock production

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Abstract

Producing livestock for meat, milk, or other good requires the skillful combination of a wide variety of resources, such as land, labour, equipment and veterinary medicines. From an infinite number of potential combinations the challenge for farmers and farm managers is to select the 'best' solution, which is dynamic and may change in light of evolving governmental policies and market conditions.

Governmental policies include regulations which establish accepted minimum standards for issues that are of concern to the public, such as the welfare of farmed animals, environmental care and the protection of human health. Farmers must comply with these standards or face prosecution and any associated penalties. However, regulation is a blunt instrument and given practical constraints presented by operating in a natural environment some conflicts now exist between individual regulations. Furthermore conflict can occur between regulatory compliance and achieving an acceptable level of profitability. Regulations in combination may thus require farmers to risk breaching a minimum standard, where no course of action is expected to assure compliance and acceptable profit simultaneously or led to unexpected changes in livestock production where unacceptable levels of profitability are derived.

Using the example of sheep ectoparasite control in Scotland this paper describes some conflicts that currently arise and considers potential production consequences, highlighting challenges for producers and researchers.

1. Introduction

‘The challenge of competing goals' as presented here for livestock producers is to ensure that an acceptable balance is achieved between competing goals. In support of this, livestock researchers must find new ways of dealing with livestock problems that minimise some of the unacceptable outcomes of production. The challenge is in truth an existing one, but one which has not been adequately addressed as yet and may become greater with the widening of Europe due to an increase in the social, cultural, economic and environmental diversity amongst nation states. It requires us to look holistically at livestock production systems rather than focus on the detail, as livestock production along with other agricultural activity is multifunctional (OECD, 2001). That is, it generates multiple outputs that are inextricably linked. For example, calf production is linked to milk production and wool production is linked with sheepmeat production. These linkages extend to animal welfare, the environment and human health, factors that go much further than the farm gate and may not have a direct impact on the profitability of livestock production. For illustrative purposes we address the problem of external (ecto) parasites of sheep in a Scottish context. Ectoparasites are not a problem unique to Scotland or to sheep. There are competing goals due to the presence of negative linkages between the outputs from alternative control strategies.

2. The problem of sheep ectoparasites

There are six ectoparasites of importance to Scottish flocks. These are; scab (*Psoroptes communis ovis*), lice (mainly *Bovicola ovis*), keds (*Melophagus ovinus*), ticks (*Ixodes ricinus*), headfly (*Hydrotoea irritans*) and blowfly (*Lucilia sericata*) (Henderson, 1990; Cawley, 1995).

Each, in its own way, can cause serious reductions in livestock productivity such as reduced liveweight gains, reduced lambing rates and increased mortality in both lambs and adults. The irritation, pain and distress that ectoparasites can inflict upon host animals either directly, or, in the case of ticks, as a consequence of the infectious diseases they transmit can be severe. Scab mites set up an allergic reaction on the skin that causes extreme irritation. Affected stock will scratch themselves on any available object, their appetite is suppressed and mortality is common though typically from secondary infections, emaciation and dehydration (Bates, 1997; Bates, 1999; Corke et al., 1999; Parker et al., 1999). Sheep scab has been cited as the greatest threat to sheep health and welfare in Britain (Lewis, 1997). Blowfly lay their eggs on the fleece of host sheep. After hatching the maggots secrete an enzyme that liquefies the skin and flesh, providing a 'soup' on which they can feed. Again the pain and distress to affected stock is commonly severe and in England and Wales alone an estimated 12,000 sheep die from blowfly strike each year (French et al., 1995). Ticks affect hosts in yet another way, whilst they feed on the blood of host animals anaemia is rarely a problem. The major problems caused by tick infestations relate to their role as disease vectors. In Britain the three main diseases transmitted by ticks are louping-ill, tick-borne fever and tick pyaemia. Between them these infections cause fevers, meningo-encephalomyelitis, abscesses - typically in joints and impair the host's immune system. The control of these parasites has thus clear benefits for both animal productivity and welfare.

Where the costs of control are less than the prevented animal productivity losses then there will also be a gain to farm profitability.

Unfortunately however control is highly dependent upon the application of veterinary medicines (Milne, 2004). The majority of which can cause harm if they contaminate the environment and one of which in particular may harm human health. Improving animal productivity/profitability and welfare thus can conflict or compete with the environment and/or human health. What then is the best course of action? A number of the issues involved are highly emotive and ethical in nature. It is therefore necessary to have a transparent and easily understandable framework for examination of the problem such as can be offered by multi-criteria analysis.

2.1 A multi-criteria analysis of sheep ectoparasite control

Multi-criteria analysis (MCA) is a technique for the holistic analysis of decisions with multiple consequences or outcomes (DTLR, 2003). A performance matrix is prepared with columns for each of the decision criteria, such as animal welfare consequences. Rows are formed for each alternative option - in this case ectoparasite control strategies. Under each criteria the consequences or performance outcomes for each alternative are placed. These may be financial, descriptive or a relative score. The weight that should be placed on each criterion in the final decision choice can also be stated, and where a scoring system is used these values may be multiplied by the criterion weights to provide an overall score for each alternative. By using a scoring system there is no need to formulate financial values for any non-financial outcomes, such as environmental harm in the case of sheep ectoparasite control. (See (DTLR, 2003) for further explanation).

The multiple outputs i.e. four criteria, against which alternative sheep ectoparasite control strategies need evaluating as identified previously are farm profitability, animal welfare, environmental damage and human health harm. A scoring scale of 0 to –2 was used for all criteria in this analysis with 0 being minimum possible loss of profit, animal welfare, environmental damage or harm to human health and –2 being the maximum loss.

Farm profitability

The relative importance of farm profitability may be low to those with strong ethical views on animal welfare, the environment and/or human health. However it is important as farm businesses play a key role in many rural economies, both directly and indirectly, for example through creating and maintaining landscapes that are often central to local tourism. Adopting an ectoparasite control strategy that minimises costs and maximises output, that is, maximises profit, is therefore a desirable goal both for the individual farmer and for society as a whole. Improving farm efficiency and productivity has therefore been the main thrust of much scientific research.

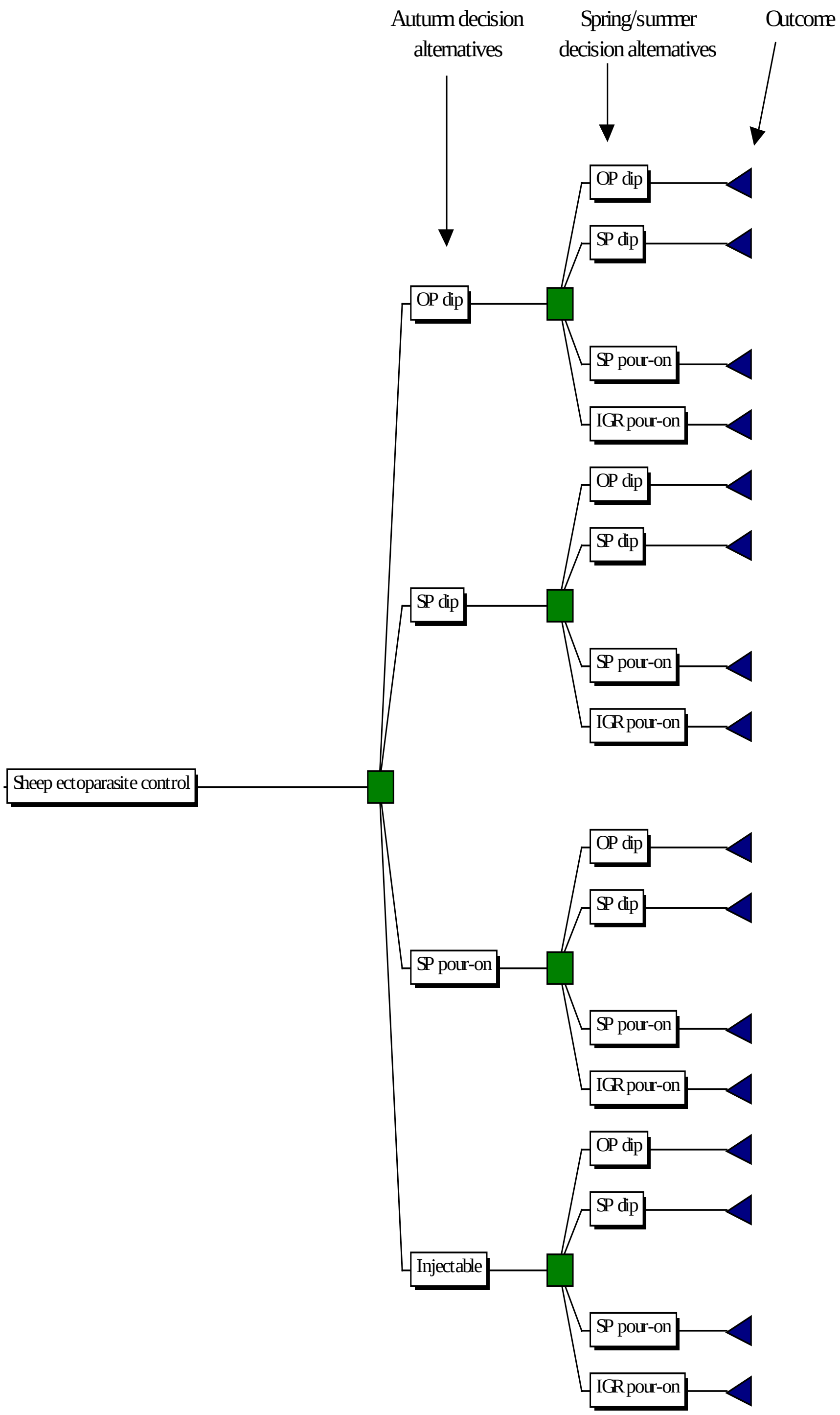
The costs of implementing control measures are relatively easy to quantify. However determining the profit maximising control strategy is difficult. The probability of any one parasite or combination of parasites affecting a flock is uncertain, as is the number of animals that may be affected within a flock. Furthermore the level of production losses will vary depending on the severity of the infestation/attack and stage of the production cycle. Assessing and incorporating risk is therefore a key element of evaluating alternative actions. A probability-weighted value of each control alternative can be estimated by constructing a decision tree (Hardaker et al., 1997). Figure 1 shows the 16 alternative control strategies evaluated in this paper. These are a simplification of the real situation and encompass just two treatment periods each year to coincide with the main times when ectoparasites affect

Scottish flocks. Five alternative medicines are included, though for epidemiological reasons at each treatment period only four of these are options. (The application of IGR is excluded from the autumn treatment choice as it only controls blowfly that are not active at this time. Macrocyclic lactones are excluded from the spring/summer treatment based on the following assumptions:

- that they only control scab,
- the main risk of scab introduction is through replacement stock in the autumn
- Regulations require scab to be controlled - so any infestation introduced in the autumn will have been eliminated by the spring/summer)

Whilst there is an option not to apply any medicine, this has been excluded on the basis that in the majority of cases this would be unacceptable on animal welfare grounds and could result in prosecution under animal welfare legislation.

Figure 1 Decision tree framework with 16 alternative control strategies.



It is assumed that the production cycle starts in the early autumn with the introduction of replacement stock and that this is the only entry point for the three obligate ectoparasites scab, lice and keds.

The probability weighted outcome (control costs plus disease losses) of each strategy were then estimated for two exemplar flocks, a hill flock of 1000 ewes and a lowground flock of 100 ewes. These flock types/sizes represent the two extremes of sheep production systems in Scotland. The spectrum of ectoparasites encountered by the two flocks was kept constant with the exception of ticks, which only affected the hill flock for epidemiological reasons. The probability that ticks and four other ectoparasites are encountered by these flock types is shown in Table 1.

Table 1. Probability of a parasite affecting a flock and the proportion of sheep affected

Parasite	**Flock probability**	**Animal probability**
Scab (all flocks)	0.1	As calculated by a Reed-Frost model (Abbey, 1952)
Lice (all flocks)	0.5	0.5
Keds (all flocks)	0	0.5*
Ticks: Hill flock Lowground flock	1 0	TBF 0.01 (autumn) 0.05 (spring) Tick pyaemia 0.05 (spring) Louping ill 0.01 (autumn)
Blowfly	0.8	0.1

These values, control costs and disease losses were estimated based on published literature, a primary survey conducted in 2000 (Milne, 2004) and expert opinion and included the costs of complying with applicable regulations. The probability weighted financial outcome is shown in Table 2. These outcomes were then allocated a score between 0 and –2 according to their relative values with 0 being the best and –2 the worst.

Table 2. Probability weighted financial outcomes and relative scores

			1000-ewe hill flock		100-ewe lowground flock	
Strategy	**Autumn medicine**	**Spring/summer medicine**	**Expected value £**	**Farm profit score**	**Expected value £**	**Farm profit score**
1	OP dip	OP dip	-1438	0.00	-399	-0.90
2	OP dip	SP dip	-1818	-0.14	-437	-1.10
3	OP dip	SP pour-on	-1878	-0.16	-443	-1.13
4	OP dip	IGR pour-on	-4868	-1.27	-457	-1.20
5	SP dip	OP dip	-1852	-0.15	-439	-1.11
6	SP dip	SP dip	-2232	-0.29	-477	-1.31
7	SP dip	SP pour-on	-2292	-0.32	-483	-1.34
8	SP dip	IGR pour-on	-5282	-1.42	-497	-1.42
9	SP pour-on	OP dip	-2628	-0.44	-492	-1.39
10	SP pour-on	SP dip	-3008	-0.58	-530	-1.59
11	SP pour-on	SP pour-on	-2759	-0.49	-227	0.00
12	SP pour-on	IGR pour-on	-5749	-1.59	-241	-0.07
13	Injectable	OP dip	-3726	-0.85	-571	-1.80
14	Injectable	SP dip	-4106	-0.99	-609	-2.00
15	Injectable	SP pour-on	-3857	-0.89	-306	-0.41
16	Injectable	IGR pour-on	-6847	-2.00	-320	-0.49

(Milne, 2004).

Animal welfare benefits or losses

In Britain and other European countries public concern for the welfare of farmed livestock is increasing (Hughes, 1995; Harper et al., 1998; McGlone, 2001; Harper, 2002). Although this concern is not currently fully translated into consumer purchasing behaviour for high welfare goods and services (and its market value is therefore not established. There are a number of non-financial measures that can be used to estimate the animal welfare consequences of events, but none currently quantify the consequences of ectoparasites. A proxy measure is therefore necessary and disease losses were selected (Heath et al., 1987; Dwyer, 2003) for this purpose as an indicator of welfare and relative scores were again allocated from best to worst on a 0 to -2 scale.

Damage to the environment and nature

As noted earlier contamination of the environment by medicines used to control sheep ectoparasites can be damaging. Most of the medicines are nerve agents and can affect insect, aquatic and mammalian species amongst which are the target parasites. Water contamination can be particularly damaging and there are a number of regulations that specifically protect the aquatic environment, these are based on the precautionary principle. Dips pose a high risk as there are considerable volumes of waste liquor that need to be disposed of, typically by spreading on land after dilution. Of these synthetic pyrethroid (SP) dips are the more damaging being 100 times more harmful in the aquatic environment than organophosphate dips (Chatfield, 2001). Avermectin based medicines (which are injectable and control scab) are excreted in the dung of treated animals and are banned from use in some areas as a consequence. Thus even when used according to recommended guidelines, the control medicines can cause damage in the natural environment (Taylor, 1999; Chatfield, 2001). Data on the absolute and relative harm caused is however not available. Whilst safety information is available for each medicine this has not been converted into damage assessment in the field situation and may not be sufficient to differentiate the relative position of each medicine (Boxall et al., 2003; Milne, 2004). What is clear is the SP dips are potentially the most damaging, followed by OP dips and then avermectins. As the likelihood of pour-on products contaminating the environment is very low it has been assumed that these do not pose an environmental risk. The scores allocated for environmental harm are then assumed to be as shown in Table 3 for each treatment period.

Table 3. Assumed environmental scores for medicines

Veterinary medicine	**Environment score**
OP dip	-0.5
SP dip	-1
SP pour-on	0
IGR pour-on	0
Injectable	-0.25

As a consequence of the sequence of two treatments (autumn and spring/summer) the scoring range again thus runs from 0 to -2.

Damage to human health

There is a potential benefit to human health through the control of ticks as this parasite transmits Lyme's disease which is zoonotic (Joss et al., 2003). However as mentioned above these medicines are nerve agents and one in particular can affect the human nervous system. That medicine is organophosphate based dips. Over recent years the level of concern regarding and evidence of damage to human health from organophosphate products has grown. The effects include muscle twitching, cramps, vomiting, salivation and sweating, and in severe cases may cause failure of the muscles used for breathing. In addition chronic effects on cognitive skills have been detected (Swanston et al., 1990; Steenland, 1996; O'Malley, 1997). The effects are thus potentially serious. In Britain handlers of concentrated sheep dip were found to be at particular risk and this has led to the modification of packaging to minimise operator contact with OP dip in its concentrated form (MAFF, 1999a; MAFF, 1999b; Anon, 2000). For each application of an OP dip a score of -1 was thus given within the human health criterion and a score of 0 for all other medicine applications.

Relative weights of each criterion

The relative weight that should be given to each criterion is not known. To explore possible preferences two alternative sets of weights are used.

- Case 1 demonstrates the situation where each criterion is given equal weight, based on the assumption that no information exists. This might be considered 'fair', and provides a baseline for comparison.

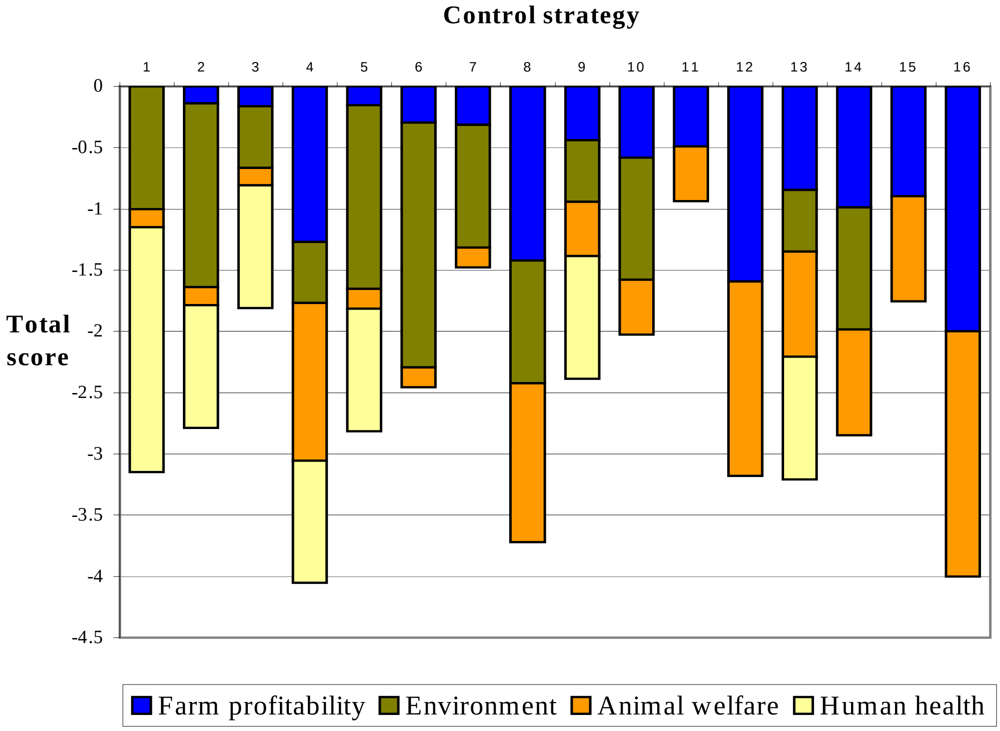
- In Case 2 human health and the environment are given a lower weighting than animal welfare and farm profitability, reflecting preferences 15-20 years ago in Britain as indicated by regulation. As there are no objective data to indicate the level of the lower weightings, a weight of 0.5 has been allocated to human health and the environment for investigative purposes. For this case the farm profitability values and scores were recalculated excluding the applicable regulatory compliance costs.

3. Results

Case 1: each criterion has an equal weighting

The MCA results for the hill flock of 1000 ewes, when each of the four criteria were given equal weighting, are shown graphically in Figure 2.

Figure 2. Case 1, total and individual criterion scores for a 1000-ewe hill flock, equal weighting for each consequence and the expected value outcome



Key

1. OP dip + OP dip
2. OP dip + SP dip
3. OP dip + SP pour-on
4. OP dip + IGR pour-on
5. SP dip + OP dip
6. SP dip + SP dip
7. SP Dip + SP Pour-on
8. SP Dip + IGR Pour-on
9. SP pour-on + OP Dip
10. SP pour-on + SP Dip
11. SP Pour-on + SP Pour-on
12. SP pour-on + IGR pour-on
13. Injectable + OP Dip
14. Injectable + SP Dip
15. Injectable + SP pour-on
16. Injectable + IGR pour-on

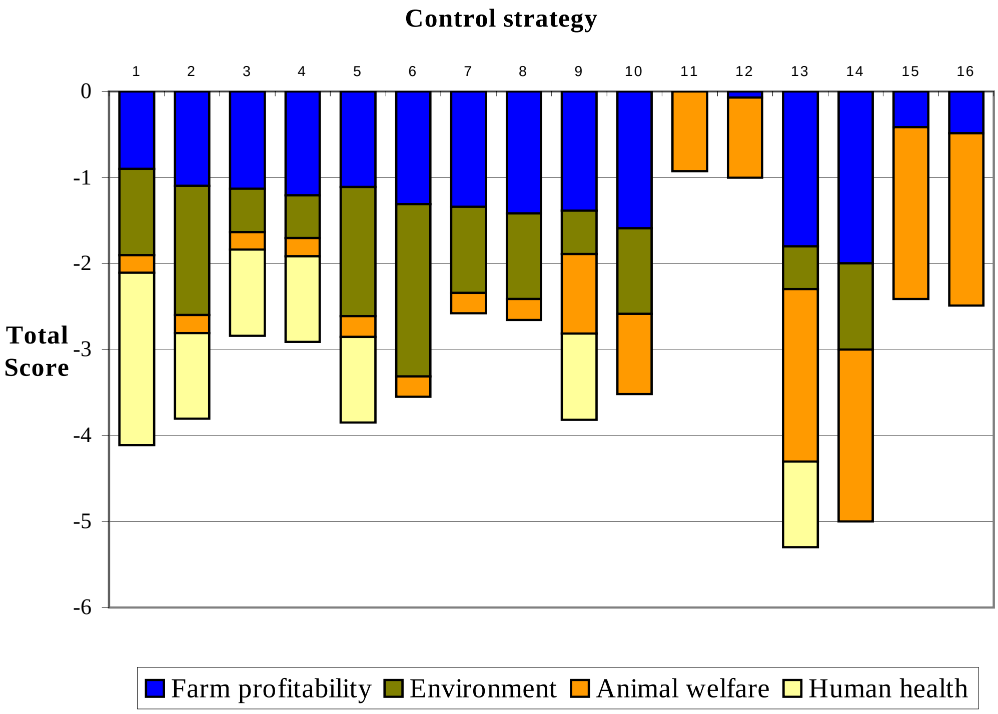
It can be seen from Figure 2 that the total score varies between control strategies. Control strategy 11 is the optimal[26], or 'best' strategy in this MCA, having a total score of –0.94, made up of undesirable consequences to both animal welfare and farm profitability. Strategy 4 is the worst strategy with a total score of -4.05, and incurs undesirable consequence for all four criteria. The profit-maximising solution for this flock type/size was Strategy 1 (OP dip in the autumn and spring/summer) and has a total score of –3.15. Whilst resulting in a more preferred animal welfare outcome than Strategy 11, it gives rise to greater undesirable outcomes for both human health and the environment. The best strategy for the livestock producer is thus in conflict with the overall optimal strategy and adopting Strategy 11 in preference to the profit-maximising strategy (Strategy 1), reduces farm profit by around £1321 (-£2759 minus -£1438, see Table 2).

The MCA results shown in Figure 2 also demonstrate that whilst control strategies can be equal in terms of the total score, and therefore total social benefits, they may consist of differing 'bundles' of goods. For example, Strategies 12 and 13 have similar total scores, but Strategy 12 incurs costs to farm profitability and animal welfare while Strategy 13 incurs costs across all four criteria. Additional farm profitability or animal welfare costs can thus be substituted for human health or environmental costs.

The results of the MCA for the lowground flock of 100 ewes, when each criterion is given an equal weighting are shown in Figure 3. The strategies are as in Figure 2.

[26] An optimal social outcome would be achieving the maximum social benefits from the combined aspects of sheep ectoparasite control.

Figure 3. Case 1, total and individual criterion scores for a lowground flock of 100 ewes, equal weighting for each consequence and the expected value outcome



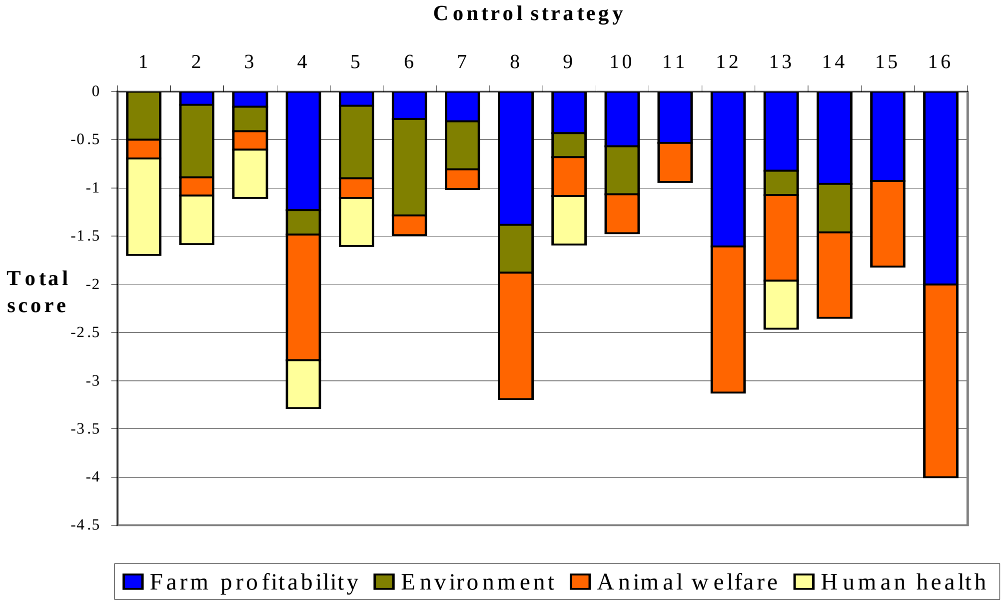
For the lowground flock, the profit-maximising control strategy is Strategy 11. This also generates the highest total score (-0.93) in the MCA and, in this Case, is therefore best from a social standpoint. The 'best' control strategies from both private (profit-maximising for the farm business) and social standpoints (overall optimal) therefore concur. However, greater animal welfare costs are incurred than necessary, e.g. those incurred in Strategy 11, demonstrating that animal welfare can be substituted for farm profit, as well as for human health and environmental protection.

Case 2: human health and the environment criteria allocated lower weights than animal welfare and farm profitability criteria

As Case 2 represents a situation similar to that prior to recent regulatory introductions, the farm profitability scores were revised to exclude applicable compliance costs. These revised scores, given in Appendix 1, will be used for the Case 2 MCA.

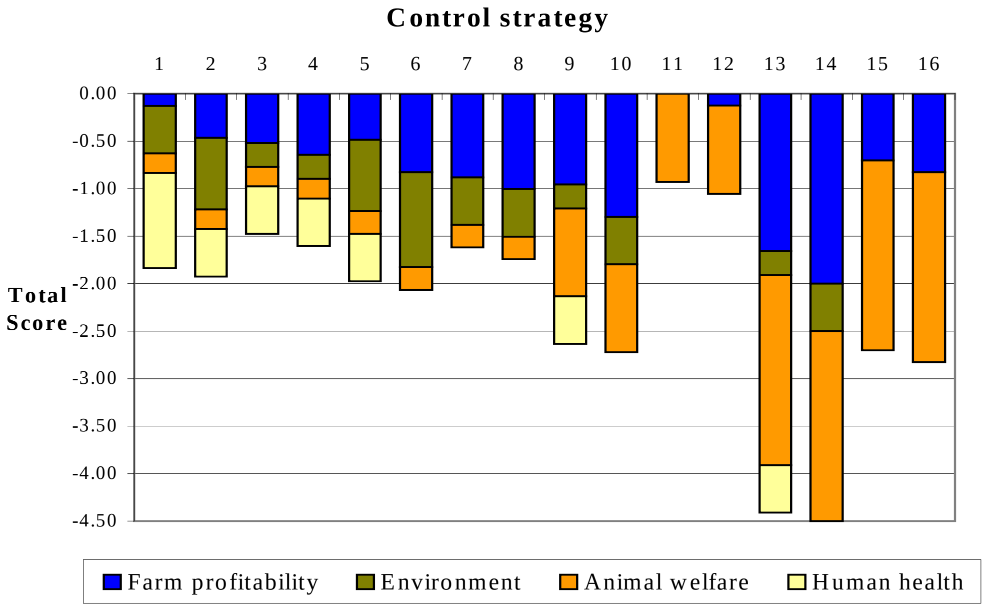
Figure 4 illustrates the Case 2 results of the MCA for a hill flock of 1000 ewes. The control strategy generating the highest total score remains Strategy 11, again this is not the profit-maximising control strategy, which is Strategy 1, highlighting a conflict between the 'best' control strategy from private and social standpoints.

Figure 4. Case 2, total and individual criterion scores for a 1000-ewe hill flock, unequal criterion weighting



The Case 2 results for a 100-ewe lowground flock are shown in Figure 5. The control strategy generating the highest total score remains the farm profit-maximising control strategy, Strategy 11. As for Case 1, there is concurrence between the 'best' control strategy from private and social standpoints, and the sole cost is to animal welfare.

Figure 5. Case 2, total and individual criterion scores for a 100-ewe lowground flock, unequal criterion weighting



The rank order of alternative control strategies, according to their total score calculated in the MCA, for the two potential social preferences encompassed by Case 1 and 2, as described above, are shown in Table 4. With the exception of strategy 15 (injectable + SP pour-on) the rank order is fairly stable for the hill flock. However for the lowground 100 ewe flock example other than for the best and worst strategies the rank orders are less stable. Thus for this flock situation the preference order for strategies are much more sensitive to the weighting given to the choice criteria.

Table 4. Rank order of alternative control strategies by flock type/size and Case

	Control strategy number				
	1000-ewe hill flock			**100-ewe lowground flock**	
Rank	**Case 1**	**Case 2**		**Case 1**	**Case 2**
1	11	11		11	11
2	7	7		12	12
3	15	3		15	3
4	3	10		16	4
5	10	6		7	7
6	9	2		8	8
7	6	9		3	1
8	2	5		4	2
9	5	1		10	5
10	14	15		6	6
11	1	14		2	9
12	12	13		9	15
13	13	12		5	10
14	8	8		1	16
15	16	4		14	13
16	4	16		13	14

The results of the MCA also show that the score given to alternative medicines is an important factor determining the most preferred strategies and rank order of strategies. This highlights the importance of having adequate scientific data on the real harmful consequences of the medicines i.e. not just potential hazard. In the absence of such data sub-optimal decisions may be made, incurring unnecessary costs to animal welfare, human health, the environment and/or farm profitability.

3.1 Discussion and conclusion

The MCA has shown that the best control strategy may differ by flock size. Furthermore it has shown how the 'bundle' of benefits can vary and that both the scores and weights given can influence the overall preference order for alternative control strategies. The private decisions of sheep farmers are the main way sheep ectoparasite control strategies are chosen. As shown in the analysis using arbitrary criterion weights, there is no guarantee that the optimal private and social benefit will concur when a more holistic assessment is made of the costs and benefits. An important element is achieving an optimal, or more socially acceptable, ectoparasite control strategy is a better understanding, ideally quantified relationships between different control strategies and their effects on animal welfare, the environment and human health. Decisions based on one element of a strategy are not sufficient. This fact has major institutional implications for improving the use of animal medicines if as argued a holistic approach is to be put in place. For example regulations designed to eradicate sheep scab and reliant primarily on timed application of OP dips in the short term produces unacceptable 'side-effects'. However, banning OP is shown to reduce animal welfare and farm profitability and many not necessarily improve the environmental outcome although human health may be protected. Of course new medicines that gave rise to fewer negative side effects may become available in the future but this does not affect the need for a holistic approach to livestock production.

In the absence of more certain estimates of the weights to be given to each societal goal (which may well vary by State and through time) a strategic examination is necessary to investigate and monitor the overall effects of institutional changes, and of policies such as taxes, subsidies, education and regulation. This also has far reaching institutional implications, not least of which is how to accommodate differences in the weights given to goals between member states and how to achieve the goals of a single market within the EU at the same time as 'fair' trade with exporters of similar products by third countries. Meanwhile, a more basic issue is how best to modify the behaviour of private individuals so as to actually achieve more acceptable overall societal preferences. Unless this can be done then regulation or other policy measure intended to change such behaviour may well produced unexpected results.

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4. APPENDIX 1

Revised farm profitability scores

Control strategy	1000-ewe hill flock		100-ewe lowground flock	
	Expected value	Farm profitability score	Expected value	Farm profitability score
1	-1281	0.00	-£241	-0.13
2	-1661	-0.14	-£279	-0.47
3	-1721	-0.16	-£285	-0.52
4	-4711	-1.23	-£299	-0.65
5	-1695	-0.15	-£282	-0.49
6	-2075	-0.29	-£320	-0.83
7	-2135	-0.31	-£326	-0.88
8	-5125	-1.38	-£340	-1.00
9	-2470	-0.43	-£334	-0.96
10	-2850	-0.56	-£372	-1.30
11	-2759	-0.53	-£227	0.00
12	-5749	-1.61	-£241	-0.12
13	-3569	-0.82	-£413	-1.66
14	-3949	-0.96	-£451	-2.00
15	-3857	-0.93	-£306	-0.70
16	-6847	-2.00	-£320	-0.83