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Integrating multifunctionality of agriculture in regional land use concepts

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1 Introduction

Because of high population density in Europe agriculture has not only the aim to produce food but also to contribute to the protection of cultural landscapes and the maintenance of ecological services. This multifunctionality often leads to conflicts between various actors and calls for the development of land use concepts that reduce such conflicts and formulate adequate priorities. However, land use concepts are often formulated ecology oriented neglecting socio-economic objectives such as the maintenance of incomes and employment. As a corollary the interests and, more importantly, the potential production responses of farmers to conservation requirements are often left out of the picture although these reactions may have a great bearing even on major ecological variables. From an overall welfare point of view such land use concepts may be “suboptimal”.

The present paper is aimed to illustrate, on the basis of an empirical study, how multi-criteria analysis can be used to transform a primarily ecology-oriented land use concept for an ecologically very sensitive region into a more integrative and comprehensive one that makes due allowance for socio-economic objectives and farmers’ response. As sample region we use the *Bayerisches Donauried*, a region which is dominated by floodplain zones and riverine fens and which is consequently of high value for nature conservation and agriculture.

Section 2 discusses the concrete problems of land use in the region under study. Section 3 presents the – primarily ecology-oriented – land use concept that was developed for the region by a group of scientists and experts some years ago (cf. Zettler et al., 1997). In section 4 we introduce the farmer as an economic actor and discuss three alternative responses of farmers to the stipulated conservation measures. Section 5 is dedicated to a multi-criteria evaluation of the three enlarged versions of the above-mentioned land use concept (“land use options”), and to the selection of the most promising one. The results are discussed in section 6, under the aspects of both methodology and future policy action.

2 Problems of land use in the *Bayerisches Donauried*

The region covers the Danube valley from the city of Neu-Ulm to that of Donauwörth. Its landscape is mainly characterized by the influence of the water which largely determines the possibilities of land use as well as the occurrence of species and habitats in the region. Thus at the beginning of the 19th century the Danube was a widely meandering river without a fixed riverbed and with numerous major and minor bayous. As the entire region was flooded regularly and was generally characterized by a high ground water level, agricultural use was almost exclusively restricted to grassland.

The reconstruction of the Danube considerably reduced the influence of the water in *Bayerisches Donauried* during the last two centuries (Zettler et al., 1997). The drawdown of the ground water table and the lesser occurrence of floods made possible an expansion of arable cultivation to 84 % of the total agriculturally used area (AUA) and an accompanying intensification of agricultural cultivation. While on the remaining grassland in most cases only low yields can be achieved the arable land is high yielding and is primarily used for forage cultivation. Particularly the cultivation of silage maize forms the basis of milk and beef production.

On the other hand the above-mentioned interferences had negative ecological effects so that today the quality and survival of valuable habitats as well as their function for the natural environment are in jeopardy (Zettler et al., 1997, S. 22). Yet even today the *Donauried* fulfills important ecological functions. For example, it is an internationally highly appreciated habitat of endangered species of the flora and fauna. It should be added that the region serves as a large surface retention zone with a great water storage capacity and can therefore make an important contribution to water retention in the case of floods.

Another non-agricultural function of the *Donauried* consists in the supply of drinking water. Particularly important is the withdrawal of an annual quantity of 21.5 million m^3 of ground water per year by the Water Authority Stuttgart (Zettler et al., 1997 p. 75). Last but not least the region is of central importance for local recreation.

3 The ecology oriented land use concept

This concept was developed by a group of researchers on the basis of a profound analysis of the region's ecological status and problems, and of in-depth discussions with experts, administrators and decision makers. The most important ecological objectives formulated in the expertise are (Zettler et al., 1997): the reestablishment of the natural floodplain dynamics, the protection of the remaining fen areas, and the improvement of the living conditions of meadow birds. To attain these objectives various conservation oriented measures and changes in agricultural land use practices are suggested. In fen areas and riverine forests the groundwater level is to be raised to 40 to 50 cm below the surface. In meadow bird areas the share of grassland is to be extended. At the same time living conditions of meadow birds are to be improved by subjecting farmers to legal requirements concerning mowing dates as well as site-specific water logging for certain periods. Remaining floodplain forests are to be supplemented via afforestation on farms. In addition, environment friendly farming according to the requirements of "good agricultural practice" is to be enforced in the whole area.

4 Alternative responses of farmers

As a consequence of these changes in land use, farmers would, above all, have (1) to transform arable land into grassland and (2) to pass over to a more extensive cultivation of existing grassland. In the first case they would suffer a net loss of production potential for the production of animal feed, in terms of feed energy (lower productivity of grassland). In the case of an extensification of grassland cultivation the result would also be a loss of feed energy. Clearly, in the region there will be no possibility to lease additional land to offset these losses, because the planned measures will affect almost all farmers. For the same reason it would not be possible for farmers to buy forage from their neighbours.

The ecology-oriented concept does not discuss farmers' production responses to these problems. In an economic analysis of the proposed measures Kantelhardt and Hoffmann (2001; compare also Hoffmann and Kantelhardt, 2003) derived mainly three production responses. A first option – probably preferred by nature conservationists – is the reduction of (1) the number of livestock. However, there are more imaginative responses. To compensate the losses mentioned above farmers could expand the production of (2) clover-grass or (3) silage maize, on the arable land which lies outside the areas designated for nature conservation purposes. It is apparent that the neglect of farmers' response to environmental requirements can counteract the overall ecological aim. These responses and the underlying socio-economic objectives have to be taken into account in the form of an "integrative" multi-criteria analysis.

5 Multi-criteria analysis of the land use options

In the following we will use a multi-criteria anlysis (MCA) to assess the major ecological and socio-economic effects of the following land use options:

(1) „Status Quo" (SQ): Continuation of the traditional mode of cultivation, without the measures defined in the ecology oriented land use concept.

(2) "Reduction of Livestock" (RL): Implementation of the measures defined in the ecology oriented land use concept, and reduction of the number of livestock.

(3) "Compensation by clover-grass" (CG): As under (2), but compensation of the loss of animal feed by expanding the cultivation of clover-grass.

(4) "Compensation by silage maize" (SM): As under (2), but compensation of the loss of animal feed by expanding the cultivation of clover-grass.

On the basis of this analysis an evaluation of the land use options will be carried out.

5.1 Evaluation Criteria

To evaluate the land use options we use the concept of „landscape functions". Landscape functions stand for the services, defined in the broad sense of the word, rendered to society by land use (Bastian and Schreiber, 1999, S. 38; De Groot, 1992 p. 13ff.). The land use functions used for the MCA and the indicators chosen to measure them are shown in the first two columns of Table 1.

Table 1: Land use options in *Bayerisches Donauried*: Scores regarding landscape functions

Landscape function	Indicator	Value of the indicator							
		absolute				standardized			
		Land use option				Land use option			
		SQ	RL	CG	SM	SQ	RL	CG	SM
„ECOLOGICAL"									
Water protection	Nitrogen use (t N) PSM-Einsatz (t active component)	2 825 21.5	2 589 19.7	2573 18.2	2604 19.2	0.00 0.00	0.94 0.54	1.00 1.00	0.88 0.68
Soil protection	Erosion potential (C-Faktor)	2 223	2 037	1 998	2 240	0.07	0.84	1.00	0.00
Protection of species and habitats	Intensive area * (1 000 ha)	22.0	19.1	19.1	19.1	0.00	1.00	1.00	1.00
Climate protection	Greenhouse potential (kt CO_2)	127.7	117.6	123.4	123.7	0.00	1.00	0.42	0.40
Protection of resources	Use of primary energy (TJ)	343.5	321.5	329.4	326.7	0.00	1.00	0.64	0.76
„ECONOMIC"									
Maintenance of jobs	Employment in agriculture (1000 labour hrs.)	927.5	885.9	938.0	932.4	0.80	0.00	1.00	0.89
Maintenance of agricultural income	Change in agricultural income (Mio. EUR)	22.0	20.2	20.5	21.1	1.00	0.00	0.16	0.48
Production of food	Value of production (Mio. EUR)	46.7	43.2	45.1	45.4	1.00	0.00	0.54	0.63
Reduction of public expenditure	Public payrents to farms (Mio. EUR)	11.2	10.4	10.6	10.9	0.00	1.00	0.78	0.32

* area not used as extensive grassland
SQ = Status Quo. – RL = Reduction of livestock. – CG = Compensation by clover-grass. - SM = Compensation by silage maize.

The five “ecological” and four “economic” functions were selected mainly on the basis of the present land use in the region and the relevant land use objectives underlying the above-mentioned expertise. In addition, more global objectives such as climate protection were included. Evidently in the case of some landscape functions there is an inverse relationship between the extent to which the function is fulfilled, and the value of the indicator. This is true of all ecological landscape functions and of one of the “economic” ones, namely the „reduction of public expenditure“.

5.2 Scoring the land use options

The scores that the land use options obtain with respect to the fulfillment of the landscape functions were determined on the basis of comprehensive economic and material flow calculations. The latter are oriented at the chain of an ecobalance and comprise a definition of objectives, a life cycle inventory analysis (LCI) and an impact analysis of the agricultural production methods.[1] The resulting scores are shown in the middle part of Table 1.

The standardized scores (standardization from 0 to 1) can be seen in the right hand part of table 1. Whenever there is an inverse relationship between the score and the fulfillment of the landscape function (see above) the score is set to 0 for the highest degree of fulfillment, and to 1 for the lowest one.

5.3 Weighting the landscape functions

The weights to be given to the landscape functions are to reflect „the“ preferences of the major decision makers and stakeholders of the region. Usually preferences vary considerably from one group of interviewees to another. We organised written interviews of 25 focus persons. Among them, according to their own assessment of their major professional or other

[1] For a detailed account of these calculations cf. KANTELHARDT 2003.

involvement, 8 can be said to belong to the group “conservationists”, 8 to the group “promotors of regional development”, and 9 to the category “agriculturists”.

In the letter accompanying the interview, particular care was taken to make clear to the recipients that the weight to be allocated to a landscape function does not refer to the landscape function as such but to the difference between the highest and the lowest absolute score. The result of the interviews is given in table 2.

Table 2: Land use options in *Bayerisches Donauried*: weights for the landscape functions

Landscape function	group of interviewees			Ø of all interviewees	Ø of the three groups
	„Con-servationists“	„Agricul-turists“	„Promotors of regional development“		
"ECOLOGICAL"					
Water protection	0.14	0.07	0.16	0.12	0.12
Soil protection	0.13	0.06	0.09	0.09	0.09
Protection of species and habitats	0.19	0.04	0.15	0.12	0.13
Climate protection	0.06	0.05	0.08	0.07	0.07
Protection of resources	0.08	0.06	0.09	0.07	0.07
„ECONOMIC“					
Maintenance of jobs	0.09	0.18	0.09	0.12	0.12
Maintenance of agricultural income	0.14	0.31	0.10	0.19	0.19
Production of food	0.12	0.17	0.18	0.16	0.16
Reduction of public expenditure	0.06	0.06	0.07	0.06	0.06
TOTAL					
Sum Total	1.00	1.00	1.00	1.00	1.00
of which "Ecological“	0.59	0.28	0.56	0.47	0.48
"Economic"	0.41	0.72	0.44	0.53	0.52

It can be seen that the preferences of the “conservationists” and “promotors of regional development” are very similar to one another while at the same time diverging considerably from those of the “agriculturists”. While the „agriculturists“ consider the ecological landscape functions to be much less important than the economic ones, the “conservationists” and “promotors of regional development” value “Ecology” more highly than “Economy”. Out of the ecological landscape functions, the „agriculturists“ value the protection of species and habitats least whereas the two other groups accord to this landscape function the highest and second highest importance, respectively. It is interesting to note that the function “Reduction of public expenditure” plays a relatively unimportant role in the minds of all three groups. Probably the burden on the taxpayer is considered to be largely irrelevant because (1) payments to farms of *this* region are primarily financed by taxpayers of the *other* regions of the EU (principle of “financial solidarity”, or – in more critical terms - “externalization of costs”) and (2) a redistribution of income from the general taxpayer to the agricultural sector meets with wide acceptance.

To determine the „average“ weights, for each landscape function two alternative values were calculated: (1) the arithmetic mean of the weights given by all interviewees, and (2) the arithmetic mean of the 3 group weights. The result is given in table 2. Evidently, these averages do not differ much because of the similar size of the three groups. For the subsequent calculations the second value was selected.

5.4 Evaluation of land use options by means of the linear-additive model

Working with the linear-additive model the following utility function was used (cf. DTLR 2001):

$$U_i = \gamma_1 z_{i1} + \gamma_2 z_{i2} + \ldots + \gamma_n z_{in} = \sum_{j=1}^{n} \gamma_j z_{ij}$$

with $\gamma_1 + \gamma_2 + \ldots + \gamma_n = 1$,

where

U_i = total utility of land use option i

γ_j = weight of landscape function j

z_{ij} = standardized score of land use option i concerning landscape function j.

The land use option with the highest total utility U is considered to be „optimal“.

Basic solution

The result of these calculations – the *basic solution* - is shown in Table 3.

Table 3: Land use options in *Bayerisches Donauried*: Results of the Multi-criteria analysis

Landscape function	Weight	Utility values of option …			
		… SQ	… RL	… CG	…SM
"ECOLOGICAL"					
Water protection	0.12	0.00	0.09	0.12	0.09
Soil protection	0.09	0.01	0.08	0.09	0.00
Protection of species and habitats	0.13	0.00	0.13	0.13	0.13
Climate protection	0.07	0.00	0.07	0.03	0.03
Protection of resources	0.07	0.00	0.07	0.05	0.06
"ECONOMIC“					
Maintenance of jobs	0.12	0.10	0.00	0.12	0.11
Maintenance of agricultural income	0.19	0.19	0.00	0.03	0.09
Production of food	0.16	0.16	0.00	0.08	0.10
Reduction of public expenditure	0.06	0.00	0.06	0.05	0.02
TOTAL					
Sum Total	1.00	0.44*	0.49	0.69	0.62
of which "Ecological“	0.48	0.01	0.43	0.41	0.30
"Economic"	0.52	0.44	0.06	0.28	0.32

* Rounding error, SQ = Status Quo; RL = Reduction of livestock; CG = Compensation by clover-grass; SM = Compensation by silage maize.

Here the second column gives the above-mentioned weights, just for the reader’s information. The next columns, in the two upper parts of the table, show the land use options’ partial utility values (standardized score multiplied by the weight of the respective landscape function), and in the lower part give the total utility values, including the sub-aggregates for all ecological and all economic landscape functions. Clearly, on the basis of the given preference structure, option “clover-grass” has the highest total utility value, followed by “Silage maize”. A long way behind comes the reduction of the number of cattle. Least desirable is the continuation of the status quo.

Figure 1 serves to interpret this result. The diagonal lines are “iso total utility lines”. When farmers change from the traditional mode of cultivation to one of the three other options this will in every case lead to (a) a gain in aggregate utility from the ecological landscape functions and (b) a – less pronounced – loss of aggregate utility from the economic landscape functions. But the net effect is strongest when the mode of cultivation is changed to option “compensation by clover-grass”.

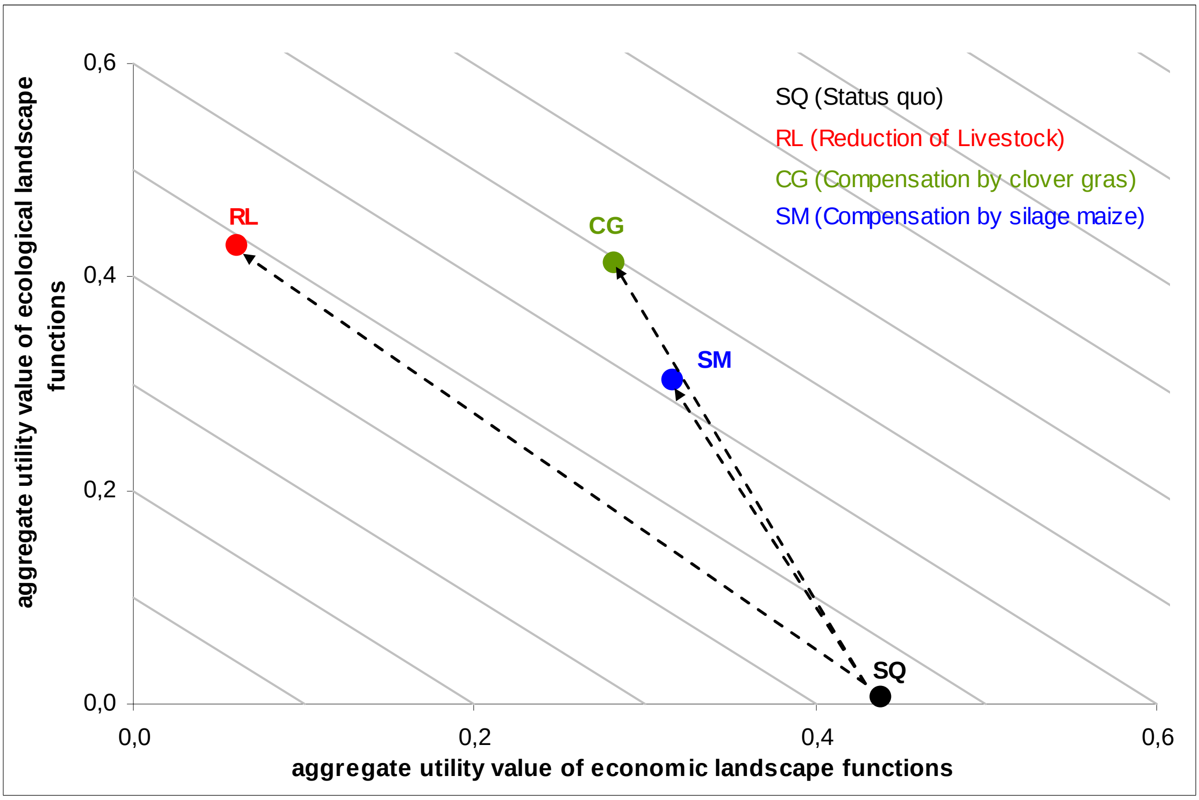

Figure 1: Results of the multi-criteria analysis, aggregated by classes of landscape functions

If we compare the three scenarios we notice two things. First, changing from “Reduction of livestock” to “Compensation by clover-grass” implies a considerable increase in the aggregate utility from the economic landscape functions (the rise in public expenditure being of little effect) while causing relatively little harm to aggregate ecological landscape functions (option “compensation by clover-grass” has lower scores regarding the protection of the atmosphere and of resources but higher ones concerning the protection of water and the soil). Second, changing further, from “Clover-grass” to “Silage maize”, would, of course, again benefit the economic objectives, but utility wise this would be more than offset by the harmful effects on the ecological ones.

Sensitivity analyses

To obtain a more differentiated picture the model was also run for each of the three groups of interviewees separately. The result is as follows: The “conservationists” would clearly have the highest preference for option “Clover-grass”, and would consider option “Status Quo” to be by far the most undesirable one. The same goes for the “promotors of regional development”. In contrast, the “agriculturist” would rank the continuation of the traditional mode of cultivation highest; in their view, option “Reduction of livestock” would be by far the most unfavourable one.

The difference between the two views becomes somewhat clearer from Figure 2. From the conservation point of view moving from the traditional mode of cultivation to any of the other three options brings about positive ecological effects which “outweigh” the negative economic ones so that total utility increases. The reverse is true for the agricultural point of view which considers total utility to go down as a consequence of any change away from the Status Quo. From the latter standpoint option “Reduction of livestock” is particularly harmful because it is here that the – highly weighted – negative economic effects are most pronounced.

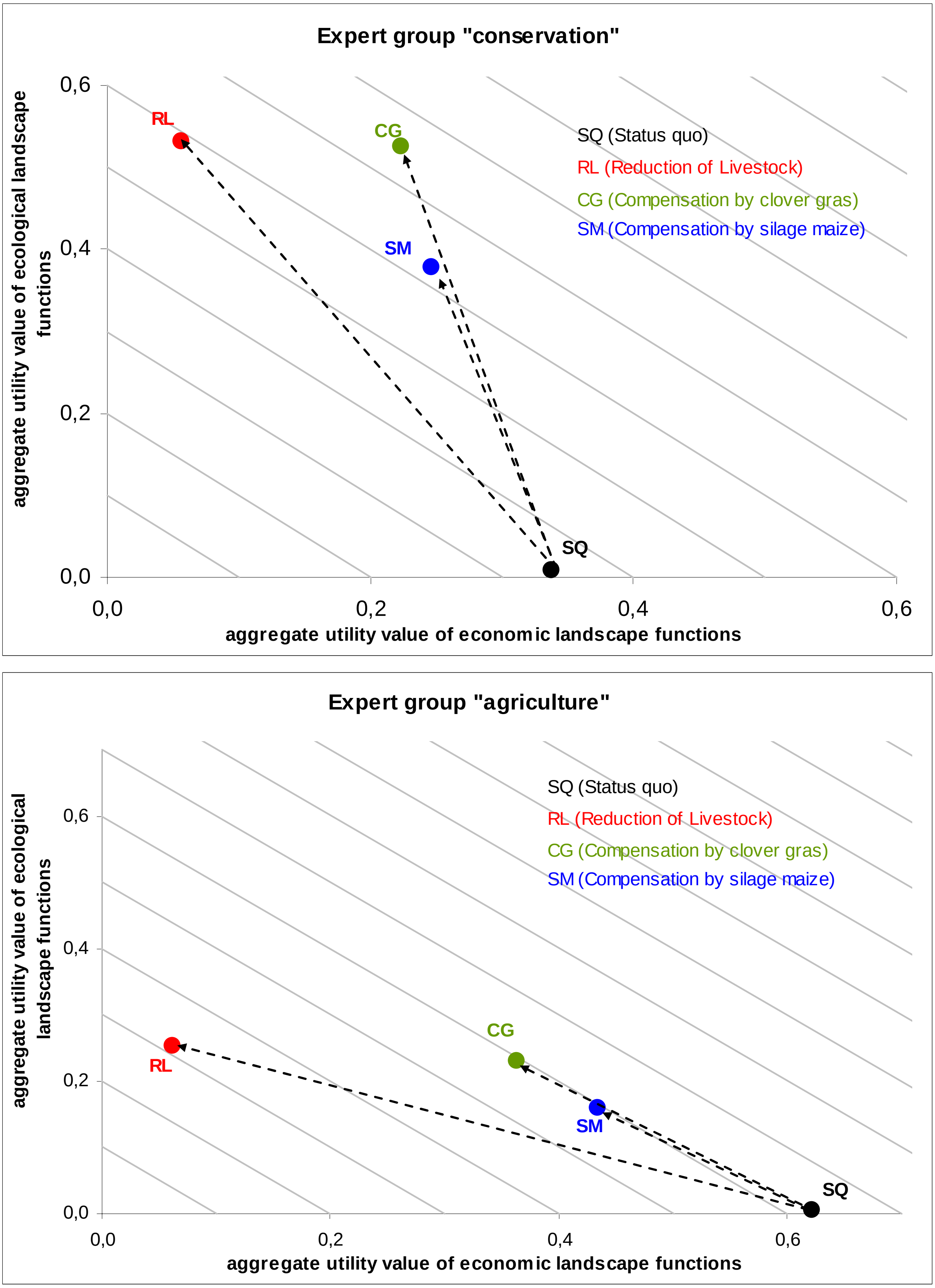

Figure 2: Results of the multi-criteria analysis for the experts groups "conservationists" and "agriculturists", aggregated by classes of landscape functions

From this it is clear that the results of the basic solution were largely determined by the weighting of the three groups' preference structures, which was 0.333/0.333/0.333 and lead to an aggregate weight of 0.48 for the ecological landscape functions (cf. Table 2). Doing a sensitivity analysis in which the weight of the "agricultural" preference structure is systematically raised (and postulating an equal weight for each of the two other groups) we obtain the results summarized in Table 4. Only when one accords the agricultural preference structure a weight of more than 0.9, which implies an aggregate weight of less than 0.31 for all ecological functions, will option "Status quo" become the "optimal" one. Thus the results are robust.

Table 4: Sensitivity analysis: Influence of the weight of group „agriculture" on the ranking of the land use options

Weight of group „Agriculturists" *	Rank of land use option …				Weight of the ecological landscape functions
	… SQ	… RL	… CG	… SM	
0.00	4	3	**1**	2	0.57
0.33	4	3	**1**	2	0.48
0.40	4	3	**1**	2	0.46
0.50	3	4	**1**	2	0.43
0.80	3	4	**1**	2	0.34
0.90	2	4	**1**	3	0.31
0.95	**1**	4	3	2	0.30
1.00	**1**	4	3	2	0.28

* Assumption: equal weight for each of the "Conservationists" and "Promotors of regional Development"; SQ = Status Quo. – RL = Reduction of livestock. – CG = Compensation by clover-grass. - SM = Compensation by silage maize.

6. Discussion and conclusions

The results of our study show that the production responses of farmers greatly influence the utility society obtains from land use. To take account of these production responses is of decisive importance for the success of land use concepts. This applies even in those cases where land use concepts are originally aimed to improve the ecological quality of land use and not the economic situation of the farmer; for farmers' responses have a great bearing on the achievement of ecological objectives. The analysis also shows that the development of appropriate land use concepts requires not only ecological but also socio-economic criteria. This also helps to assess the tradeoff between "ecology" and "economy". In our case study we find that the inclusion of socio-economic objectives and the resulting change in the land use option contribute to the maintenance of incomes and employment without overly harming the attainment of ecological objectives.

The multi-criteria analysis applied in our study seems to be an appropriate method to improve the quality of land use concepts. It should be added that the method could be improved with respect to the quality of ecological and socio-economic indicators reflecting the various land use functions. Furthermore it might be useful to include more qualitative indicators. This would also make it possible to integrate local actors more into the selection of land use functions and their indicators, possibly using repertory grid method (Fromm, 1995; for an application cf. Ahrens and Harth, 2004).

Finally, it should be stressed that to use multi-criteria analysis is not an end in itself but is to assist relevant actors in their decision making. In the land use context, firstly it serves to clarify the expectations of the various actors and thereby to objectify the local discussion. The first feed back we received from regional actors is very encouraging. Secondly and most importantly, it is an appropriate tool to help decision makers in designing a more integrated land use concept. Thirdly, it also generates suggestions concerning the potential support that private organisations and government bodies can give to farmers and other actors to contribute to the implementation of whatever will be the ultimate integrated land use concept.

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