Socio-Economic and Ecological Effects of Alternative Direct Payment Regimes on Different Swiss Alpine Regions

Christian FLURY
Nikolaus GOTSCH
Peter RIEDER

Cahiers d'économie et sociologie rurales, n° 57, 2000

Christian FLURY*, Nikolaus GOTSCH*, Peter RIEDER*

Effets socio-économiques et écologiques de systèmes alternatifs de paiements directs dans deux régions des Alpes suisses

Résumé – D'une région à l'autre, les niveaux de productivité de la terre, les besoins en moyens et techniques de production, ainsi que les coûts à produire diffèrent, ils sont fonction des caractéristiques topographiques, climatiques, environnementales, agronomiques et structurelles de la région et conduisent à des formes d'utilisation de la terre très variées. En outre, l'utilisation des terres offre des exemples évidents d'externalités environnementales et de nouveaux indicateurs couvrant une large diversité d'attributs et d'actifs environnementaux ont dû être élaborés afin de répondre à la demande des responsables régionaux de développement rural. Un modèle spatial de programmation linéaire est présenté dans cet article. Il porte sur deux régions des Alpes suisses et permet d'analyser les effets de différentes options de paiements directs sur l'utilisation de sols, notamment leurs conséquences sur le nombre de sols mis en jachère, selon leur situation topographique. L'étude démontre également que l'efficacité écologique peut être améliorée si les aspects régionaux et spatiaux sont pris en compte lors de l'élaboration des nouvelles mesures de politique agricole, et ce à un moindre coût pour le contribuable. Il apparaît enfin que la suppression des paiements directs actuels, qui visent au maintien du revenu agricole, pourrait être à l'origine d'un effondrement de l'agriculture dans les régions des Alpes suisses.

Mots-clés :
modélisation de l'utilisation des terres, programmation linéaire, analyse à critères multiples, politique agricole, paiements directs

Socio-economic and ecological effects of alternative direct payment regimes on different Swiss Alpine regions

Summary *– Differences in land productivity, input and technology requirements and production costs are functions of topographic, climatic, environmental, agronomic and infrastructural characteristics which lead to considerable variations in land-use intensity. Land-use also offers obvious examples of spatial environmental externalities. Policy-makers concerned with regional rural development face an increasing need for indicators which encompass a wide diversity of attributes and environmental assets in a spatial setting. In this paper, a spatial sectoral linear programming model is described and implemented for two Swiss Alpine regions. The effects of different policy assumptions for land-use payments are investigated. Special reference is made to the effects of varying types of direct payments on the amount of fallow land in various topographic situations. It can be shown that ecological effectiveness can be improved, at lower costs for the taxpayer, by giving due consideration to regional and spatial aspects when designing agricultural policy measures. At the same time, the results show that the elimination of the actual income-supporting direct payments (the so-called base payments) may cause a collapse of agriculture in Swiss mountain regions.*

Key-words :
land-use modelling, linear programming, multi-criteria analysis, agricultural policy, direct payments

* *Agricultural Economics, ETH Zentrum, CH-8092 Zurich, Switzerland*
e-mail : christian.flury@iaw.agrl.ethz.ch ; nikolaus.gotsch@iaw.agrl.ethz.ch ; peter. rieder@iaw.agrl.ethz.ch

POLICY-MAKERS and stakeholders concerned with regional rural land-use and development find themselves facing an ever-increasing need for instruments that can improve transparency in the policy debate and enhance understanding of opportunities and limitations for development (Bouman *et al.*, 1999). The complexity of land-use requires different approaches which combine the experience and methodological approaches of various disciplines. Different disciplinary contributions can be integrated with the help of multi-criteria analysis (MCA). MCA has evolved from being a mechanism for the selection of the best alternative from a set of competing options to become a range of decision aid techniques (Beinat and Nijkamp, 1998). A number of land-use models have been developed in the last decade based on a combination of methods of system analysis and multi-criteria or multi-objective decision models, respectively. The scenario-based programming approach is one method which is frequently applied. De Wit *et al.* (1988), for example, employ multiple goal programming for regional analysis and planning of regional agricultural development. This methodology permits scenarios to be drawn up, whereby biophysical, technical and economic information on potential or improved land-use strategies is combined with various objectives derived from different policy views. A common characteristic of such models is that they aim at the quantification of biophysical and economic trade-offs. Kruseman and Bade (1998), for instance, propose a bio-economic modelling framework for the assessment of the effectiveness of different agrarian policies to improve farm household income and soil fertility based on the functional combination of (1) an agricultural household model; (2) a multiple goal linear programming model; and (3) a partial equilibrium model. Cesaro (1995) uses a Weighted Goal Programming Model for the simulation of the consequences of alternative scenarios of CAP reform in a mountain area in north-eastern Italy on land-use patterns and the economic performance of the agricultural sector. Ridgley and Heil (1998) design buffer zones around protected areas (Mexico's Izta-Popo National Park) under different scenarios combining Lexicographic Goal Programming and Geographic Information System (GIS). Tiwari *et al.* (1999) apply Compromise Programming to determine trade-offs between ecological and economic goals in an irrigation project in the Northern Planes of Thailand. A GIS was used to integrate spatial aspects in the analysis. Bouman *et al.* (1999) and Zander and Kächele (1999) combine technical coefficient generators, a linear programming (LP) model and a GIS to quantify trade-offs among socio-economic, agronomic and environmental indicators at field level. The widespread use of GIS illustrates the fact that nowadays spatial aspects receive a considerable amount of attention in regional land-use planning.

Land-use also offers obvious examples of spatial environmental externalities, which in many cases may be biased in favour of specific environmentally non-benign activities (Beinat and Nijkamp, 1998). The negative effects of land exploitation are manifested in soil erosion, loss of habitats, increased vulnerability of soils and loss of natural amenities. On the other hand, appropriate land-use activities prevent the emergence of these negative externalities. There is no uni-dimensional denominator which can be used to assess and evaluate land-use changes and policies. There are many complex linkages between the economy, the social sphere and the environment in which land-use and space act as vehicles for transmitting externalities. Consequently, there is a need for a clear formulation of indicators encompassing a wide diversity of attributes and environmental assets in a spatial setting. This is particularly true when there is a wide degree of divergence between topographic, climatic, environmental, agronomic and infrastructural characteristics. To a large extent, differences in land productivity, input and technology requirements and production costs are functions of these characteristics and lead to considerable variations in land-use intensity: production sites with good access and high productivity are often exploited in an ecologically unsustainable way, in the sense that, for instance, an excessive amount of fertiliser is applied. In contrast, remote areas with high transportation costs, areas with difficult access for machines or low productivity may lay fallow.

These types of spatial aspects are particularly pronounced in mountain regions where, for example, fallow land may generate negative external effects. Poncet (1971) reports that landslides are more likely to occur on mountain slopes where farming activities have been abandoned. Aulitzky (1974) identifies unmown slopes as catalysts for the start of avalanches, because the slip factor of unmown grass is much higher than that of grazed or mown slopes. Furthermore, abandonment induces turf-erosion as a result of creeping late winter snow frozen to overlong grass (Körner, 1999). The loss of species diversity which is to be expected when the cultivation of grassland is abandoned represents yet another negative external effect. Körner (2000) points out that, if correctly managed, agricultural land use near the tree-line contributes to biological richness of plants. Furthermore, Körner (1999) expects that in the future, it will probably be impossible to reverse post-abandonment shrub and tree invasions, hence resulting in a finite loss of species diversity.

According to Nijkamp and Vreeker (2000), there is a perceptible rise in interest in policy-relevant regional land-use and development analysis due to several factors: (1) a region is a properly demarcated area with some degree of homogeneity which allows for a more operational empirical investigation; (2) a region is usually also subject to properly regulated administrative competence and control, thus there is more scope for a relevant policy analysis; (3) and finally, the statistical data base at a regional level is often more appropriate for monitoring, analysing and modelling the economy and ecology of an area.

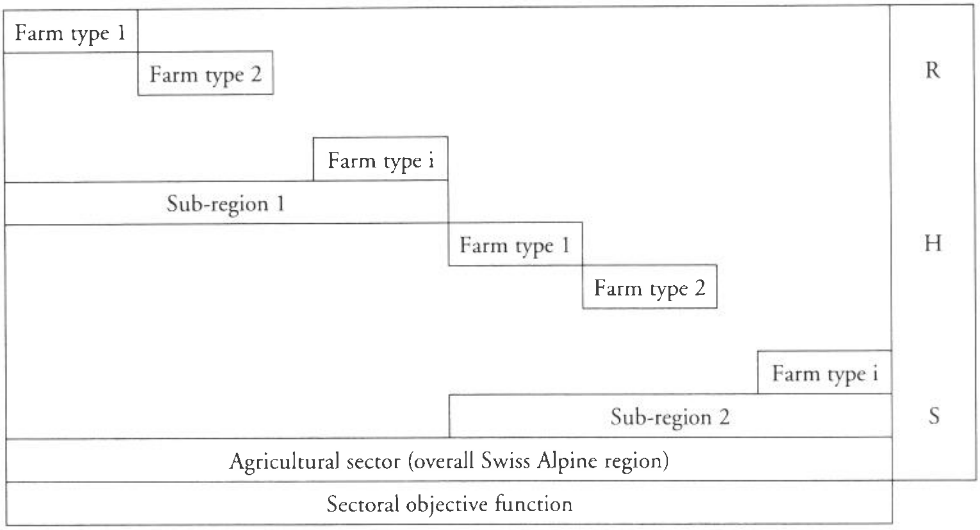
In this paper, a land-use model is described for two Swiss Alpine regions. It gives due consideration to the type of spatial and regional aspects described above. The purpose and structure of this sectoral linear programming model are described in the following section. The effects of different policy assumptions for direct payments are investigated in the results section. Special reference is made to the effects of different types of direct payments on the amount of fallow land in various topographic situations. Conclusions are drawn in the last section. One important result of the model calculations is that the ecological effectiveness (reduction of fallow land on steep slopes) can be improved by giving due consideration to regional and spatial aspects when designing agricultural policy measures with, at the same time, lower costs for the tax payer. At the same time, the results show that the elimination of the actual income-supporting direct payments (the so-called base payments) could well cause the collapse of agriculture in Swiss mountain regions.

PURPOSE AND DESCRIPTION OF THE MODEL AND THE DATABASE

The model described in this section is developed within the scope of the multidisciplinary research programme 'PRIMALP — Sustainable primary production in the Alpine region' at ETH Zurich (see *www.primalp.ethz.ch*). Production methods and policy concepts for sustainable land-use in agriculture and forestry in the Swiss Alpine region are developed via an association of engineering with natural sciences, social sciences and humanities (Gotsch *et al.*, 2000). A synthesis of the results is structured, formalised and communicated with the aid of a spatial linear programming model. The individual projects of the overall programme provide important contributions to the model. Model results and policy recommendations are communicated to the policy decision-makers.

The linear programming model is a sectoral model (see Figure 1) the objective of which is to maximise the sectoral revenue of agriculture in the overall Swiss Alpine region. This is achieved by the optimal allocation of scarce production factors among farm types in different sub-regions, giving due consideration to the restrictions of each level of aggregation (farm, sub-region, overall Swiss Alpine region). This means that the overall sectoral structure is optimised simultaneously in a way which results in a maximum payment of production factors according to the criterion of comparative cost advantage.

Figure 1. Overview of the structure and components of the linear programming model



		Activity									RHS farm level			RHS sub-regional level			
Level of aggregation	Constraint	Grassland	Arable farming	Cattle and sheep	Purchase of feeding concentrates	Purchase of mineral fertiliser	Purchase and sale of animals	To let and take land on lease	Purchase and sale of labour	Milk quota trade	Milk quota	Family labour	Farm land area	Market for animals	Summering pasture	Farm land area	Market for hired labour
	Land use	x	x					x					x				
	Crop rotation		x														
	Animal feeding	x	x	x	x												
Farm	Fertilisation	x	x	x		x											
	Cattle and sheep rearing			x			x										
	Milk production			x						x	x						
	Labour	x	x	x	x	x			x			x					
	Market for leased land							x									
Sub-region	Labour market								x								x
	Land use	x	x													x	
	Summering pasture			x											x		
Sector	Animal trade						x							x			

RHS: Right hand side.

Sub-regions are defined to conform with the legislation governing regional investment aid. Each sub-region belongs to one of six possible types of region which are defined on the basis of regional economic structure — contribution of the three sectors to overall sectoral income, commuter balance and according to their economic power (see Bätzing *et al.*, 1995). Within each sub-region, five farm types compete for the land available. Grassland is used for different types of cattle (dairy or nursing cows, beef or calf production, cattle rearing) and sheep. Various cropping activities are possible (maize, barley, potatoes, wheat). Full-time and part-time farms are included with two different types of barn each. Land can be used at two different levels of intensity.

In addition, the model includes indicators for the ecological, social and economic dimensions of sustainability and can therefore serve as a methodological device for the analysis and development of systems and concepts of sustainable agriculture in mountainous regions. According to Nijkamp and Vreeker (2000), the relevance of the same indicator varies at different spatial scales. Therefore, these indicators must be included at the relevant level of aggregation. Table 1 presents those indicators for the three sustainability dimensions and levels of aggregation which are discussed in this article. Each of these indicators is integrated in one of the structural components of the linear programming model – objective function, activities and restrictions.

Table 1. **Selected indicators included in the model at different levels of aggregation**

Indicator	Level of aggregation		
	Farm	Sub-region	Overall Swiss Alpine region
Ecological			
Agricultural land cultivated		x	x
Number of livestock units per hectare of agricultural land cultivated	x	x	
Social			
Number of farms		x	x
Number of standard labour units		x	x
Economic			
Sectoral revenue		x	x
Amount of direct payments granted for landscape cultivation		x	x

Further indicators are included in the model but not discussed here (for instance nutrient balances for nitrogen and phosphorus, the amount of organic and mineral fertiliser applied, greenhouse gas emissions (CO_2, CH_4) for the ecological dimension of sustainability, or farm revenue per worker for the social dimension of sustainability). The consideration of further indicators which may be of interest from a scientific and policy point of view is restricted. Only those indicators can be included that are available on a per-hectare scale for the entire Swiss Alpine area. The number of indicators included in the model is further restricted by the fact that a growing number of indicators complicates the interpretation of the results due to an increasing number of trade-offs among indicators to be considered.

The model includes the following spatial information from different geographic information systems and statistical databases:

• Agricultural land and forest land available in each sub-region subdivided into six altitude levels (<600 m, 600-1800 m in steps of 300 m, >1800 m above sea level) and four categories of slope (<16%, 16-32%, 32-51%, >51%) in a per-hectare grid (Bundesamt für Statistik, 1999).

• Distance of each hectare to the next road (Bundesamt für Landestopographie, 1999).

• Physical yields for each hectare and for different land-use activities (grassland, hay, silage, pasture) based on digital information of the cultivation suitability map (Bundesamt für Statistik, 1999) and on expert judgement obtained within the scope of specific sub-projects.

Input requirements (labour, mechanisation, fertiliser) are a function of land-use activity (grassland, hay, silage, pasture, crop production) and topographic situation (altitude, slope).

According to Day (1963), aggregation errors arise when aggregate economic variables, such as aggregate output supply or aggregate input demand, are studied without explicit reference to individual decision-making units. This author investigates the question of the degree of similarity which must exist between the component firm of a regional or typical firm aggregate in order to represent the aggregate of the individual decision problems without distortion. He identifies the conditions that must be fulfilled to prevent an aggregation error:

1. Technological homogeneity: proportional variation in the constraint matrix (which includes fixed, quasi-fixed, behavioural and policy bounds) of the individual firms that are represented by the aggregate;

2. Pecuniary proportionality: proportional variations in net return expectations of the individual firms that are represented by the aggregate;

3. Institutional proportionality: proportional variation of the resource endowment of the individual firms that are represented by the aggregate.

To minimise aggregation bias, Taylor and Howitt (1993) recommend, on the one hand, that as much regional detail should be incorporated into the model and associated analysis as time, resources and data allow. On the other hand, they advise against too much complexity which is detrimental to model complexity and increases the risk of modelling errors.

According to Day (1963), a "tolerable degree" of distortion of these restrictive conditions is acceptable for empirical purposes. The model structure described above attempts to reduce the risk of aggregation error in the following manner: pecuniary and institutional proportionality is approximated by including small sub-regions (see Table 2) with comparably homogenous economic and institutional environments. The distinction of production activities and model coefficients according to the topographic reality of sub-regions reduces the aggregation error by defining characteristic farms in "spatial categories" as described by Norton and Schiefer (1980, p. 249). The aggregation error is further reduced by distinguishing "farm size categories (labour-land-ratio grouping)" on the sub-regional level as suggested by the same authors.

The model is programmed in AMPL (Fourer *et al.*, 1993), an index-based programming language. With the help of this software, the basic structure of the database (indices and sets) is defined and the LP matrix is generated. The database is handled independently from the model with an input generator in the relational database software Microsoft Access 97 (Keusch, 2000). The optimisation is accomplished applying the CPLEX algorithm on a high performance parallel-scalar computer server. Further details on the structure of the model and technical information can be found in Flury (forthcoming).

Model results for two sub-regions are presented in the next section: Praettigau (henceforth 'Region 1') and the neighbouring Region Davos (hereafter 'Region 2'), both in the Swiss Alpine Canton of Grisons. Table 2 gives an overview on the actual structural characteristics of the two sub-regions. Region 1 has roughly five times more agricultural land than Region 2. Approximately the same ratio applies to the number of full-time farms and standard labour units. The relative share of part-time farms in total farms in Region 2 is half that of Region 1 (one sixth compared to one third). One reason for the higher share of full-time farms in Region 2 is the fact that the area has a long-standing tradition of tourism. This allowed part-time farms to be abandoned more easily within the scope of the usual sequence of generations. Another reason for the higher share of full-time farms in Region 2 is that the per- hectare milk quota is about four times higher than in Region 1. This ensures the economic basis for the survival of more full-time farms. In addition, these differences in milk quota influence the composition of the livestock: whereas approximately one quarter of the total livestock in Region 1 consists of cows for milk production, this share reaches more than seventy percent in Region 2. The majority of cattle in Region 1 serves for breeding and different fattening purposes (including suckler cows).

The share of agricultural employees in overall employment in Region 1 is more than five times higher than in Region 2. In addition, the last row of Table 2 shows that tourism plays an important role in Region 2 which is classified as a tourist region. In contrast, Region 1 shows an agrarian-touristic predominance.

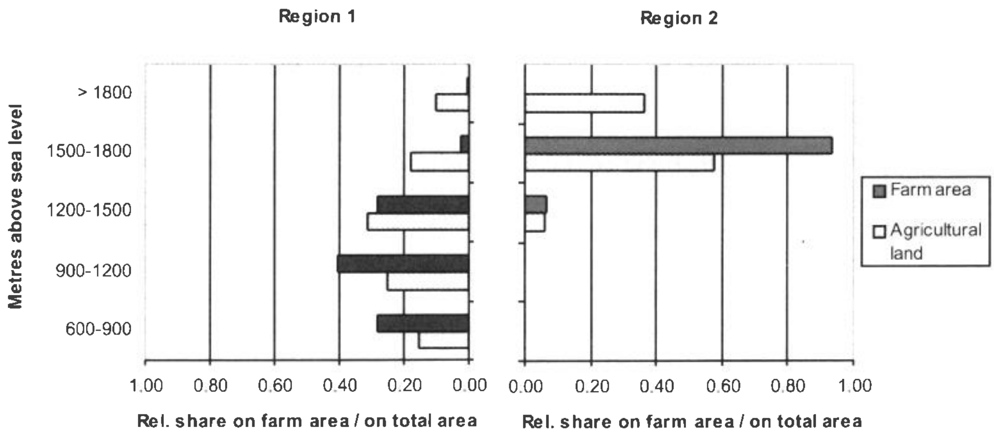
Table 2. **Structural data for the two sub-regions in 1996**

Characteristic	Region 1	Region 2
Agricultural land cultivated (hectares) [1)]	6 544	1 434
Total number of livestock [1)]	5 660	1 020
Number of livestock units per hectare of agricultural land cultivated	0.87	0.71
Number of farms [1)]	606	103
Number of full-time farms [1)]	405	86
Number of part-time farms [1)]	201	17
Number of standard labour units [a)], [1)]	1 060	201
Milk quota per hectare (kg) [2)]	800	3 150
Percentage of cows for milk production in total livestock [1)]	24	71
Percentage of other cattle livestock units in total livestock units [1)]	70	19
Percentage of sheep livestock units in total livestock units [1)]	6	10
Amount of direct payments granted for landscape cultivation (1000 CHF [b)]) [3)]	10 342	2 183
Percentage of employees in agriculture [1) and 4)]	22	4
Number of overnight stays per hectare of agricultural land [1) and 5)]	40	620

Sources: [1)] Bundesamt für Statistik (1996); [2)] Bundesamt für Landwirtschaft (1998); [3)] Personal communication, Mr. Marchion, Amt für Landwirtschaft Graubünden (22.9.00); [4)] Bundesamt für Statistik (1998); [5)] Bundesamt für Statistik (2000).
[a)] One standard labour unit corresponds to one full-time worker working on the farm during one year;
[b)] CHF: Swiss Francs.

The two regions differ not only from a structural and socio-economic point of view but also concerning their topographic and spatial characteristics, as shown in Figure 2. The figure depicts the relative share of agricultural land in the total area of agricultural land *(Agricultural land)* for each of the six altitudes above sea level and the relative share of agricultural land belonging to the farms located at that specific altitude in the total of agricultural land *(Farm area)*. A positive difference between the value for *Farm area* and *Agricultural land* at a specific altitude signifies that the area cultivated by all farms located at that specific altitude is larger than the area of agricultural land available at that same altitude. This means that these farms use land at other altitudes. For example, between 900-1200 m, 26 percent of the agricultural land available in Region 1 is located at that particular level, whereas farms located at that altitude use 41 percent of the total agricultural land available in Region 1. Hence, within the actual context of that specific region, 15 percent of the area used by the farms situated at that altitude is located at other levels. The model grants farms the possibility to use land at altitudes which do not correspond to their actual locations, whereby the additional costs for overcoming distances and differences in altitude are taken into account during the optimisation process. The figure reveals important differences concerning vertical extent in land-use between the two regions. The majority of the farms in Region 1 are located at an altitude of 600-1 500 metres and considerable resources have to be expended to overcome vertical distances of several levels of altitude. In contrast, more than 95 percent of the farms in Region 2 are located at one single altitude level (1 500-1 800 metres above sea level) and most transportation only involves one altitude level (from 1 500-1 800 metres to >1 800 m). These differences in the topographic setting between regions have important consequences for the design of efficient agricultural policy measures as will be shown in the next section.

Figure 2. Actual relative shares of farm area and agricultural land at different altitudes



RESULTS

The validity of the model is evaluated in the first subsection by comparing structural data for the sub-regions with base-run model results. The effects of a variation in two different types of direct payments on the development of the indicators listed in Table 1 are then discussed in the second subsection.

Validity of the model

The first column of Table 3 *(Actual)* shows the values for five of the six indicators listed in Table 1 for the two sub-regions in the year 1996. Information on the actual sectoral revenue as an economic indicator is not available on a regional basis. Values for this indicator are therefore not provided in Table 1. Relative values for these five variables (compared with *Actual*) resulting from model runs with different assumptions on opportunity costs for labour are shown in the second and third columns. Assuming no opportunity cost for labour *(Labour 0)* represents a short-term situation where farmers have no possibility to take up employment outside their farm business. In contrast, taking into account opportunity cost for labour (*Labour 10*, corresponding to ten Swiss Francs (CHF) per hour) reflects a longer time horizon. Farm labour becomes mobile and opportunity costs for labour are taken into account when labour allocation decisions are made. Prices, costs and policy measures correspond to the situation in 1999.

Comparison of the first and second columns of Table 3 shows that the model provides a reasonable reflection of the structural reality for the two sub-regions. All the agricultural land is cultivated. This is in keeping with the actual situation where no fallow land exists. Arable production is not practised in either region due to unfavourable climatic conditions. The reduction in livestock intensity by eight to eleven percent can be explained by the observation that nitrogen and phosphorus nutrient balances are more binding in the model than in reality. The number of farms remains constant. Labour use is seven percent lower in Region 1 and twenty percent lower in Region 2 which can be explained by the fact that labour is used more effectively in the model than in reality. An additional reason is the reduction in the number of labour-intensive dairy cows and the increase in labour-extensive nursing cows and beef production. A minor two percent increase can be observed in the amount of direct payments granted for landscape cultivation.

When opportunity costs for labour (last column of Table 3) are taken into account, plausible values are obtained for the structural variables both in direction and magnitude. Changes are more pronounced in Region 1 than in Region 2. Agricultural land cultivated decreases by over one quarter, to 73 percent, in Region 1 whereas no fallow land exists in Region 2. This is because of the structural and topographic differences between the two regions described in the preceding section. Region 1 exhibits an increase in the number of livestock units per hectare of cultivated land. This is due to the fact that, in the main, marginal land lies fallow and therefore the area remaining in production is used more intensively. There is no change in the number of livestock units per hectare in Region 2 because there is no fallow land in this region. When opportunity costs are taken into account there is a slight reduction in the number of farms to 94 percent in Region 2 and to 74 percent in Region 1. The reduction in cultivated area and livestock lowers labour requirements from 93 to 64 percent in Region 1. Since less land is cultivated in that region, the amount of direct payments granted for landscape cultivation decreases to 72 percent whereas there is no reduction of these payments in Region 2 because no fallow land exists. Differences in the amount of fallow land between the two regions can be explained by varying labour intensity: 9.0 hectares per standard labour unit are cultivated in Region 2 when no opportunity costs of labour are taken into account (Labour 0) compared with 9.6 hectares when these costs are considered (Labour 10). The corresponding figures for Region 1 are 6.9 hectares (Labour 0) and 7.3 hectares (Labour 10). There are three reasons for the lower labour intensity in Region 1 : higher per-hectare labour requirements for transportation due to greater vertical distances in that region compared to Region 2; higher labour requirements owing to higher average physical yields as a result of lower average altitude of fields in Region 1 ; a larger share of part-time farms in Region 1.

Table 3. **Relative changes in indicator values under different assumptions for labour opportunity costs in the two sub-regions (*Actual:* actual 1996 data; *Labour 0*: no opportunity costs for labour; *Labour 10*: opportunity costs for labour included)**

		Actual (absolute)	*Labour 0* (percent of *Actual*)	*Labour 10*
	Agricultural land cultivated (hectares)	6544	100	73
	Number of livestock units per hectare of agricultural land cultivated	0.87	89	102
Region 1	Number of farms	606	100	74
	Number of standard labour units	1060	93	64
	Amount of direct payments granted for landscape cultivation (1000 CHF [a])	10342	102	72
	Agricultural land cultivated (hectares)	1434	100	100
	Number of livestock units per hectare of agricultural land cultivated	0.71	92	92
Region 2	Number of farms	103	100	94
	Number of standard labour units	201	80	74
	Amount of direct payments granted for landscape cultivation (1000 CHF [a])	2183	102	102

[a] CHF: Swiss Francs

The effects of a variation in direct payments

All farmers in the Swiss Alpine area receive base payments of CHF 1200 per hectare. The motivation for these payments is, firstly, to ensure farmers'incomes in view of decreasing commodity prices and, secondly, to reduce the immediate structural pressure resulting from the commitment taken by the Swiss government to liberalise agricultural markets within the scope of the GATT Uruguay Round. The political motivation behind these base payments is therefore essentially transitional and is designed to prevent structural change from taking place too rapidly and causing an increase in fallow land and social hardship. In contrast, direct payments granted for the cultivation of steep slopes can be justified exclusively from the point of view of environmental policy: the cultivation of steep slopes has the character of a public good reducing the risk of avalanches and landslides through the prevention of fallow land.

The effects resulting from the elimination of base payments on the relative shares of fallow land at five different altitudes and on four categories of slope are discussed by comparing Figures 3 and 4. Opportunity costs of CHF 10/hour for labour are assumed in all the results discussed in this subsection. Figure 3 depicts the situation with base payments and slope payments. Slope payments correspond to actual slope payments amounting to CHF 370/hectare for slopes between 16-32 % and to CHF 510/hectare for the two steepest categories (32-51 % and >51 % of slope). As can be seen from the right-hand diagram of Figure 3, no fallow land exists in Region 2 when base payments are granted. This is due to lower transportation costs from fields to farms resulting from comparably shorter vertical transport distances (see Figure 2) and the more favourable structural conditions, in particular the availability of milk quotas. The left-hand diagram of Figure 3, depicting the situation in Region 1, shows that the higher the altitude, the greater the share of fallow land since physical yields decrease concurrently with increasing transportation costs at higher altitudes. In particular, the entire area above 1 800 metres altitude lies fallow. The entire area in the steepest category (>51 %) lies fallow in that region at altitudes above 900 metres even when base payments are granted. Mechanical harvesting of these steep slopes is not possible thus making their cultivation unprofitable when opportunity costs for labour are taken into account. Considerable amounts of fallow land exist at slopes <16 % in Region 1. In particular, the entire area above 1 500 metres with a slope <16 % is fallow land. This can be explained by the fact that no slope payments are granted for this slope category. Land use is uneconomic because physical yields are low at such high altitudes.

Figure 3. Relative shares of fallow land at different altitudes with base payments

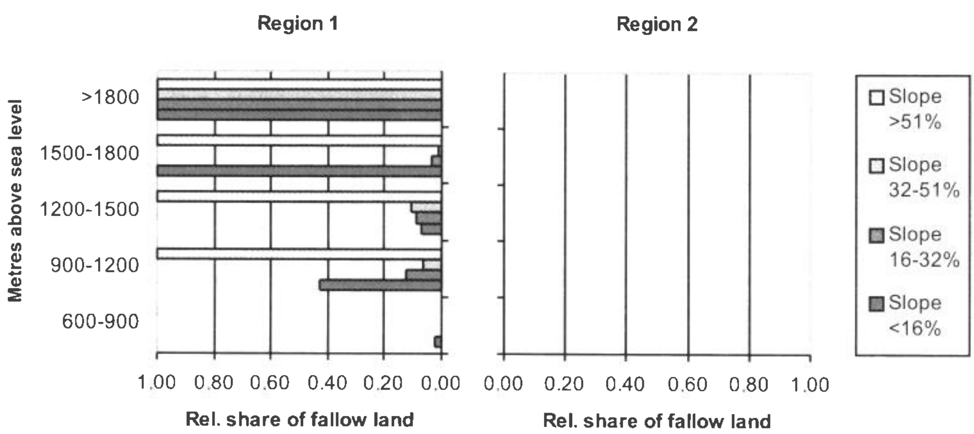
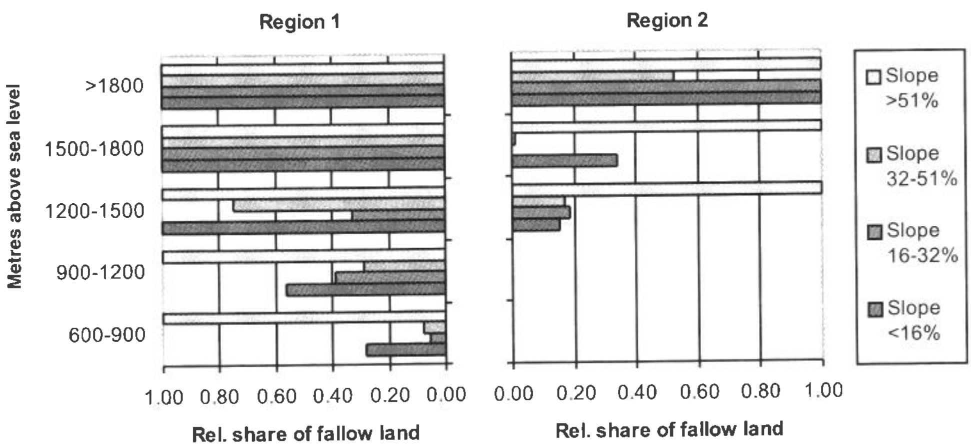


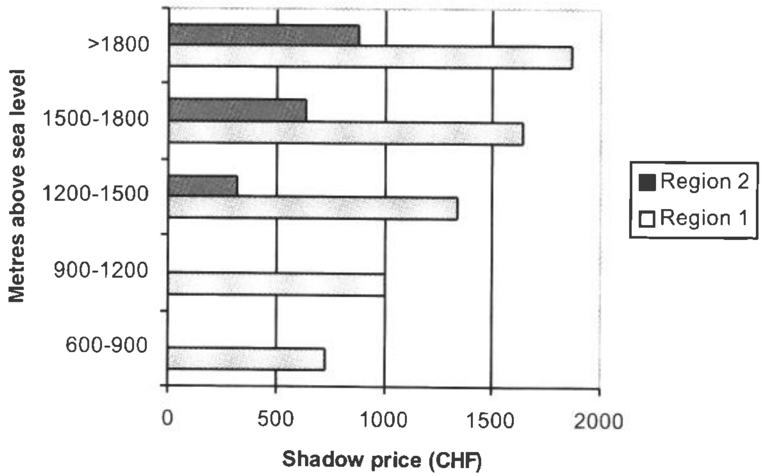
Figure 4 gives the same information as Figure 3 when slope payments only continue unchanged but base payments are no longer granted. Fallow land now also arises in Region 2, at all altitudes (there are no farms and no agricultural land below 1 200 metres above level in this region). The entire area above 1 500 metres altitude becomes fallow land in Region 1. The same applies to most of the area above 1 800 metres altitude in Region 2. The entire labour-intensive agricultural area in the steepest category (>51 %) lies fallow in both regions at all altitudes.

Figure 4. Relative shares of fallow land at different altitudes without base payments



Fallow land on very steep slopes is particularly hazardous from the point of view of avalanche and landslide prevention. The elimination of fallow land in these steep locations is a matter of public interest. Current slope payments amount to CHF 510 per hectare for the steepest category. Additional payments for the cultivation of steep land must be forthcoming to prevent this land from laying fallow when base payments are no longer granted. As can be seen from Figure 5, these additional slope payments vary from approximately CHF 700 per hectare at 600-900 metres above sea level to CHF 1 900 per hectare at >1 800 metres above sea level in Region 1. In Region 2, they vary from slightly over CHF 300 per hectare at 1 200-1 500 metres above sea to just under CHF 900 per hectare at >1 800 metres above sea level. Compensation requirements in Region 2 are lower compared with Region 1 as transportation costs from fields to farms are lower in the former. From these results, it can be concluded that significant differences in the optimal level of direct payments for the achievement of policy objectives exist between regions. The efficiency of policy measures can be enhanced significantly by giving due consideration to topographic and structural differences at regional levels.

Figure 5.
Efficient additional slope payments to prevent fallow land on steepest slopes at different altitudes



The effects of varying assumptions concerning direct payments on the indicators depicted in Table 1 are presented in Table 4. The first column *(Labour 10)* shows the absolute values for the relative figures presented in the last column of Table 3. The second column of Table 4 *(No base payment)* shows the results when base payments are no longer granted, as assumed in Figure 4. The significant increase in fallow land shown in Figure 4 is reflected in Table 4: agricultural land cultivated is approximately halved in Region 1 and reduced by over one third in Region 2 when base payments are no longer granted. In contrast, the number of livestock units per hectare of agricultural land increases because the area remaining in production is used more intensively. The elimination of base payments dramatically effects the social and economic indicators: The number of farms, the number of standard labour units and the sectoral revenue fall by one third (number of farms in Region 1) to approximately one half (sectoral revenue in Region 2). This means that the elimination of base payments causes a structural and economic collapse of agriculture in these two regions. One consequence is that the taxpayers'burden, in the form of direct payments, is reduced by at least 85 percent.

The last column of Table 4 *(Increasing slope payments)* shows the results when no base payments are granted, but additional slope payments for the steepest category of slopes (>51 %) according to Figure 5 are granted to prevent fallow land in that category of land. It can be seen from the last column of Table 4 that the relative share of agricultural land cultivated remains constant in both regions. However, there is no increase in the amount of fallow land in the ecologically sensitive steepest slope category, which is the specific purpose of these payments. The relative share of fallow land remains constant. The fallow land that is prevented in the steepest slope category thanks to supplementary slope payments for that category lies fallow now on less steep slopes (compare

Figures 4 and 6). The reason for this switch is that opportunity costs for labour are taken into account in these model simulations. This makes expansion in the cultivated area unprofitable and results in a decrease in the number of livestock units per hectare (second row of Table 4). The less pronounced reduction in Region 2 compared with Region 1 can be explained as follows:

Table 4. **Effects of varying assumptions concerning direct payments on selected indicators in the two sub-regions**

	Increasing slope payments	*Labour 10* (absolute)	*No base payment* (% *Labour 10*)	*Increasing slope payments* (% *Labour 10*)
	Agricultural land cultivated (hectares)	4743	53	53
	Number of livestock units per hectare of agricultural land cultivated	0.89	113	87
Region 1	Number of farms	450	67	67
	Number of standard labour units	654	57	57
	Sectoral revenue (1000 CHF [a)])	33730	61	64
	Amount of direct payments granted for landscape cultivation (1000 CHF [a)])	7446	13	27
	Agricultural land cultivated (hectares)	1434	63	63
	Number of livestock units per hectare of agricultural land cultivated	0.65	114	104
Region 2	Number of farms	97	62	62
	Number of standard labour units	149	62	62
	Sectoral revenue (1000 CHF [a)])	7690	52	52
	Amount of direct payments granted for landscape cultivation (1000 CHF [a)])	2227	15	19

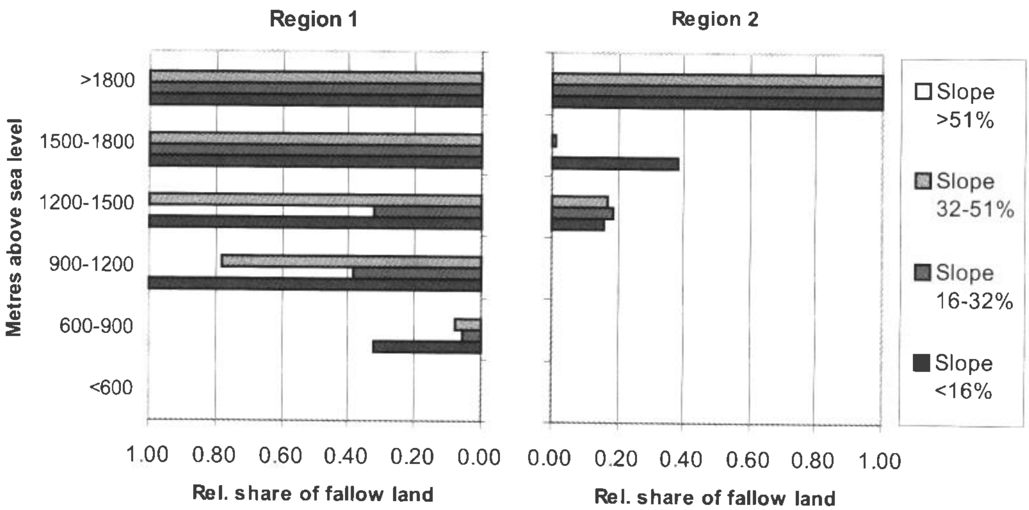
[a)] CHF: Swiss Francs

1. In Region 1, the area of agricultural land available in the steepest category (>51 %) amounts to 740 hectares which corresponds to 16 percent of the total area available. In Region 2, it only amounts to 120 hectares or nine percent of the total area available. Without base payments, all the land in the steepest category lies fallow in both regions (see Figure 4). With increased slope payments, all the land in the steepest category is cultivated (see Figure 6). However, due to technical, agronomic and topographic constraints, it can only be cultivated at a lower level of intensity. Consequently, the expansion of the cultivation of land in the steepest category takes place at the expense of areas that are cultivated more intensively when no additional slope payments are granted (compare Figures 4 and 6): land at 900-1200 metres altitude (in the slope categories <16 % and 32-51 %) lies newly fallow in Region 1, whereas in Region 2, land above 1800 metres altitude in the slope category 32-51 % lies newly fallow. Since Region 1 has relatively more land with a

higher level of physical yield per hectare than Region 2, the fodder basis is reduced more severely in the former than the latter resulting in a more drastic reduction in the number of livestock units per hectare in Region 1 (interregional roughage trade is not allowed in the model and the purchase of additional concentrates is not profitable).

2. When additional slope payments are paid, land which was formerly fallow in the steepest category is predominantly grazed by animals. When no such payments are forthcoming, these animals graze on summering pastures (alps) that do not form part of the farm area. The relative share of animals summered declines from 63 % when no base payments are paid to 52 % with increasing slope payments in Region 1. In contrast, only a minor reduction from 65 % to 61 % can be observed in Region 2. Hence, the more pronounced substitution of summering pastures by farm land in Region 1 results in a more distinct reduction in the number of livestock units per hectare in this region compared to Region 2 due to the restricted feeding basis per hectare.

Figure 6. **Relative shares of fallow land at different altitudes with increasing slope payments**



Further model runs investigate the sensitivity of labour use to increasing slope payments for all slope categories. In Region 1, a relatively small rise in these payments by ten percent suffices to increase the relative number of standard labour units from 57 to 62 percent (compare Table 4). The relative number of farms rises from 67 to 71 percent and the share of cultivated land from 53 to 58 percent. In Region 2, by way of contrast, additional labour input can only be promoted by providing stronger monetary incentives: an additional 50 percent increase in slope payments is necessary to generate higher labour input, which rises from 62 to 68 percent. The same relative increase in the number of farms takes place and the relative share of agricultural land cultivated rises from 63 to 70 percent. Differences in sensitivity towards changes in slope payments in these two regions are due mainly to the agronomic conditions, in particular the productivity of land. When base payments are no longer forthcoming, additional fallow land appears in Region 1 below 1 500 metres where even higher physical yields can be achieved (compare left-hand diagrams of Figures 3 and 4). On the other hand, in Region 2, only land with low yield potential lies fallow in addition to steepest slopes when base payments are cancelled. Higher slope payments must be granted to bring this land with low productivity potential back into cultivation.

The taxpayer finances the provision of this public good (reduction in fallow land) by approximately doubling the amount of direct payments in both regions. Only a minor proportion of these additional direct payments contributes to an increase in sectoral revenue which rises from 73 to 75 percent. A substantial share is absorbed by the remuneration of the additional (manual) labour needed for the cultivation of steep land.

CONCLUSIONS

Policy decision-makers and stakeholders face a growing need for tools which facilitate the assessment and evaluation of different policy options on a range of policy objectives. The complexity of this task demands an amalgamation of the experience and methodological approaches of different disciplines. Various disciplinary contributions are integrated with the help of multi-criteria models. There are many complex linkages between the economy, the social sphere and the environment in which land-use and space act as the vehicles for transmitting externalities. This is particularly true when there is a wide degree of divergence between the topographic, climatic, environmental, agronomic and infrastructural characteristics as exhibited by mountain regions such as the Swiss Alpine area. In this paper, a land use model is described for this area and implemented for two sub-regions. The effects of a range of policy assumptions for direct payments are investigated. Special reference is given to the consequences of alternative regimes of direct payments on the amount of fallow land in different topographic situations. One principal conclusion which can be drawn from the model calculations is that ecological effectiveness (reduction of fallow land on steep slopes) can be improved by giving due consideration to topographic aspects when designing agricultural policy measures with, at the same time, lower costs for the tax payer. At the same time the results show that an elimination of the actual income-supporting direct payments may cause a collapse of agriculture in Swiss mountain regions.

From the model calculations it can be further concluded that important trade-offs among different socio-economic and ecological indicators exist. These trade-offs vary considerably among regions according to their topographic conditions (and hence production costs, in particular transportation costs), the agronomic situation (yield potential as a function of altitude, slope and soil quality), the structural characteristics of the farms (for instance farm size and the quantity of milk quota available) and the regional socio-economic environment (providing, for instance, additional employment opportunities outside agriculture). Tailoring agricultural policy measures specifically to regional characteristics allows an improved exploitation of positive trade-offs among socio-economic and ecological indicators. The development and analysis of such policy concepts and the elaboration of suggestions for their implementation represents a broad field for future research.

REFERENCES

AULITZKY (H.), 1974 — Les régions menacées des Alpes et les mesures de prévention, Strasbourg, Conseil de l'Europe, (Also available in English: Endangered Alpine Regions and disaster prevention Measures).

BÄTZING (W.), MESSERLI (P.) and PERLIK (M.), 1995 — *Regionale Entwicklungstypen: Analyse und Gliederung des schweizerischen Berggebietes*, Bern, Bundesamt für Industrie, Gewerbe und Arbeit, Zentralstelle für regionale Wirtschaftsförderung.

BEINAT (E.) and NIJKAMP (P.), 1998 — Land-use management and the path towards sustainability, *in:* BEINAT (E.) and NIJKAMP (P.) (eds.), *Multicriteria Analysis for Land-Use Management*, pp. 1-13, Dordrecht, Boston, London, Kluwer Academic Publishers.

BOUMAN (B. A. M.), JANSEN (H. G. P.), SCHIPPER (R. A.), NIEUWENHUYSE (A.), HENGSDIJK (H.) and BOUMA (J.), 1999 — A framework for integrated biophysical and economic land use analysis at different scales, *Agriculture, Ecosystems and Environment*, 75, pp. 53-73.

BUNDESAMT FÜR LANDESTOPOGRAPHIE, (ed.), 1999 — *VECTOR25 Vektordatensätze*, Bern, Bundesamt für Landestopographie (*http:// www.swisstopo.ch/de/digital/VECTOR25/vec25.htm*).

BUNDESAMT FÜR LANDWIRTSCHAFT (ed.), 1998 — *Einzelbetriebliche Milchkontingentierungsdaten für das Milchjahr 1997/98*, Bern, Bundesamt für Landwirtschaft.

BUNDESAMT FÜR STATISTIK (ed.), 2000 — *Logiernächte in Hotel- und Kurbetrieben 1998*, Bern, Bundesamt für Statistik, Sektion Tourismus.

BUNDESAMT FÜR STATISTIK (ed.), 1999 — *GEOSTAT Benützerhandbuch*. Bern, Bundesamt für Statistik (*http://www.statistik.admin.ch/dienstle/elektron/downloads/hbd9902.pdf*).

BUNDESAMT FÜR STATISTIK (ed.), 1998 — *Betriebszählung 1995*, Bern, Bundesamt für Statistik, Sektion Erwerbsleben.

BUNDESAMT FÜR STATISTIK (ed.), 1996 — *Betriebsstrukturerhebung 1996*, Bern, Bundesamt für Statistik.

CESARO (L.), 1995 — CAP Reform and accompanying measures: A multicriteria model to evaluate effects on a mountain area in Northern Italy, *in:* ALBISU (L. M.) and ROMERO (C.) (eds), *Environmental and Land Use Issues: An Economic Perspective*, pp. 189-198, Kiel, Wissenschaftsverlag Vauk.

DAY (R. H.), 1963 — On aggregating linear programming models of production, *Journal of Farm Economics*, 45, pp. 797-813.

DE WIT (C. T.), VAN KEULEN (H.), SELIGMAN (N. G.) and SPHARIM (I.), 1988 — Application of interactive multiple goal programming techniques for analysis and planning of regional agricultural development, *Agricultural Systems*, 26, pp. 211-230.

FLURY (C.), forthcoming — *Nachhaltige Landwirtschaft im Alpenraum: Entwicklung von Nutzungsstrategien für den Kanton Graubünden auf der Basis eines Sektormodells*, Kiel, Wissenschaftsverlag Vauk (Schriftenreihe Nachhaltige Land- und Forstwirtschaft im Alpenraum).

FOURER (R.), GAY (D. M.) and KERNIGHAN (B. W.), 1993 — *AMPL: A Modeling Language For Mathematical Programming*, Ferncroft Village Danvers, Massachusetts, Body and Fraser Publishing Company.

GOTSCH (N.), FLURY (C.) and RIEDER (P.), 2000 — Polyproject 'PRIMALP — Sustainable agriculture and forestry in the Alpine region': Methodological concept and organisational needs of a transdisciplinary research project at ETH Zurich, *in:* SCHOLZ (R. W.), HÄBERLI (R.), BILL (A.) and WELTI (M.) (eds), *Transdisciplinarity: Joint Problem Solving among Science, Technology and Society*, pp. 280-85, Zurich, Haffmans Sachbuch Verlag (Workbook II: Contributions to the mutual learning sessions of the International Transdisciplinarity Conference, Zurich, February 27 - March 1, 2000).

KEUSCH (A.), 2000 — *Modellierung ressourcenökonomischer Fragestellungen am Beispiel der Erosion im Gebiet des Baldeggersees*, Zurich, ETH Zurich, Dissertation n° 13871, 269 p.

KÖRNER, (C.), 2000 — The Alpine life zone under global change, *Gayana-Botanica*, 57, pp. 1-17.

KÖRNER, (C.), 1999 — *Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems*, Berlin and Heidelberg, Springer Verlag.

KRUSEMAN (G.) and BADE (J.), 1998 — Agrarian policies for sustainable land use: Bio-economic modelling to assess the effectiveness of policy instruments, *Agricultural Systems*, 58, pp. 465-481.

NIJKAMP (P.) and VREEKER (R.), 2000 — Sustainability assessment of development scenarios: Methodology and application to Thailand, *Ecological Economics*, 3, pp. 7-27.

NORTON (R. D.) and SCHIEFER (G. W.), 1980 — Agricultural sector programming models: A review, *European Review of Agricultural Economics*, 7, pp. 280-26.

PONCET (M. A.), 1971 — Situation de la torrentialité dans les Alpes françaises – Problèmes nouveaux liés à l'évolution de l'économie régionale et du paysage végétal. Orientations nouvelles dans la lutte contre l'érosion torrentielle, *in*: GESELLSCHAFT FÜR VORBEUGENDE HOCHWASSERBEKÄMPFUNG (ed.), *Internationales Symposium "Interprevaent 1971" – Grenzen und Möglichkeiten der Vorbeugung vor Unwetterkatastrophen im alpinen Raum*, vol. 2, pp. 311-331, Klagenfurt, Gesellschaft für vorbeugende Hochwasserbekämpfung.

RIDGLEY (M. A.) and HEIL (G. W.), 1998 — Multicriterion planning of protected-area buffer zones: An application to Mexico's Izta-Popo national park, *in*: BEINAT (E.) and NIJKAMP (P.) (eds), *Multicriteria Analysis for Land-Use Management*, pp. 293-309, Dordrecht, Boston, London, Kluwer Academic Publishers.

TAYLOR (C. R.) and HOWITT (R.), 1993 — Aggregate evaluation concepts and models, *in*: CARLSN (G. A.), ZILBERMAN (D.) and MIRANOWSKI (J. A.) (eds), *Agricultural and Environmental Resource Economics*, pp. 142-174, New York and Oxford, Oxford University Press.

TIWARI (D. N.), LOOF (R.) and PAUDYAL (G. N.), 1999 — Environmental-economic decision-making in lowland irrigated agriculture using multi-criteria analysis techniques, *Agricultural Systems*, 60, pp. 99-112.

ZANDER (P.) and KÄCHELE (H.), 1999 — Modelling multiple objectives of land use for sustainable development, *Agricultural Systems*, 59, pp. 311-325.