Alpine Grassland at the Interface of Biology and Socioeconomics: Development of Interdisciplinary Models to Explain Differences in the Intensities of Use and Management

H. K. WYTRZENS

1. Introduction

Pastures and meadows are the most dominant form of agriculture in the Austrian Alps. Grassland management (and the livestock husbandry that goes with it) plays a key role in the ecology, botany, environmental protection and rural structure of mountain areas. There is, however, also an important socioeconomic dimension to this land use; grassland enterprises are a source of employment and income for farmers. These farmers add to the security of food supply and manage the landscape. This allows others to populate alpine valleys and provides the basic resource underpinning the tourist industry.

The following paper has two basic aims. First, it seeks to introduce economic and social components to the discussion about mountain grasslands. Second, it attempts to build bridges between economic and ecological aspects of grassland use. This leads to the key issue, which is to see how we can use an interdisciplinary model to explain the often very different intensities of grassland use and management. This focus on different land-use intensities reflects the importance for mountain areas of changes in these intensities. Both over and under-exploitation of grassland can lead to massive economic or ecological problems, ranging from soil and water pollution through to afforestation or abandonment of large areas of land (see ZANETTI 1999, 14).

The sustainable development of alpine landscapes and their primary production units requires a constant process of land-use optimisation that accounts for both economic and ecological perspectives. This is an extremely complex task (see RUBEN et al. 1998). Indeed, such an undertaking is impossible without some kind of workable model addressing the interactions between the various factors that help determine the intensity of use of grassland.

This paper can be considered a preliminary working report in this direction, as it describes the current position in the development of just such a model. The relevant stages in this development process are reflected in the structure of the paper and essentially involve finding the answers to the following questions:

❶ What exactly are we trying to explain through the use of a model? In other words, what do we understand by the terms usage intensity and management intensity?

❷ How can we measure usage and management intensity and what are the key factors leading to differences in these intensities?

❸ How can we combine all the individual determining factors within a single explanatory model? Which scientific disciplines can best contribute to a comprehensive understanding of the grassland system and how should such an interdisciplinary endeavour be organised?

The model being developed has two basic aims. It should help explain why the intensity of use and management of grassland varies so much.

It should also help identify promising intervention strategies which would allow us to guide the use and management of grassland towards those forms and intensities most desired by society.

2. Grassland usage intensity as the core subject of the research

We first need to clarify the nature of the phenomenon we are attempting to observe and explain; we need to define „grassland usage intensity“. We draw on various elements of environmental planning theory and the concept of multifunctional agriculture to generate a fairly specific and robust idea of what this complicated concept actually means.

As is clear from the literature (see WYTRZENS 1994, BRIEMLE and ELSÄSSER 1997; PEVETZ 1998), agriculture is not about food production alone. Instead, agriculture is now expected to simultaneously fulfil a range of other tasks, such as management of landscapes and ecosystems, waste recycling, and provision of spatial and recreational resources. This means that agricultural land is generally expected to serve different purposes simultaneously. In the language of environmental planners, the articulation or fulfilment of demands placed on land simply means the use of this land (see SPITZER 1975, 1987, 1991). In the context of this research, use or usage therefore means the appropriation or exploitation of land by individuals or society in order to satisfy objective or subjective needs. If pastures or meadows are subject to some individual or collective wish or need, then we can talk of „grassland use“.

A short, but comprehensive, definition of the term „grassland use“ is to describe it as any direct or indirect use of grassland in order to satisfy a need.

It is a well-known fact that human needs and wishes are extremely diverse. The result is that the type, number and inten-

Author: Univ.Doz. Dr. Hans Karl WYTRZENS, Institut für Agrarökonomie der Universität für Bodenkultur, Peter-Jordan-Straße 82, A-1190 WIEN

sity of demands placed on a particular unit of grassland can be very different, leading in turn to very heterogeneous combinations of uses on any one area. In order to bring clarity and structure to the complex of potential needs, the various uses to which grassland can be put must be categorised. The research can then focus on the most common types of use. Previous studies have shown that grassland is (of course) put to agricultural use, followed primarily by uses related to recreation, water management, environmental protection and hunting (see *Figure 1*). For each parcel of land, our central concept of „grassland usage intensity" should reflect the extent of the functions required of this parcel of land. The level of this intensity depends on the total number of demands placed on the land at any one time (i.e. the total number of simultaneous uses) and the extent of the „claim" made on the land by each individual use. (see SPITZER 1971, 36)

Agricultural management underpins the existence of grassland, so the intensity of this management is also calculated independent of total (multidisciplinary) usage intensity (see *Figure 1*). This agricultural management intensity acts as a key factor, creating a connection between the plant population and the socioeconomic system. It represents the degree of economic exploitation of pastures and meadows within the context of agriculture (see PISTRICH 1999, 8). The agricultural management intensity can thus be characterised in terms of enterprise management theory, as the ratio between two or more production factors in the context of a production process (see STOYKE 1995). In the case of grassland management intensity then, a relationship will generally be drawn between the labour and/or capital used for basic fodder production and the area of land used for this production (see WYTRZENS and MAYER 1998, 27).

This brief overview should have made it clear just what it is we are trying to explain scientifically.

3. Grassland management and usage intensities: measurement and influence

The aim is clearly to find explanations for the different grassland usage intensities observed in mountain regions. However, these explanations must also be capable of empirical confirmation. Accordingly, those methods allowing quantitative measurement of these uses (usage intensities) form the basis of the research. In other words, having defined the dependent variable „grassland usage intensity", we need to address the issue of its measurement.

Uses are quantified through a scoring model (see FLECK 1985). Given the current situation in alpine grassland, the following grassland uses are taken into account: water management, recreation, waste recycling, hunting and shooting, and military uses (see *Table 1*). Each different type of use is classified according to its intensity. This classification is based on the relevant degree of expression of specific intensity indicators (e.g. recreational use is classified according to the frequency of such activities as hiking, skiing, horse riding etc.). The degree of expression of each indicator is captured in a rating scale which is inevitably non-metric in nature.

All the indicator values for any one type of use are then combined using an intensity matrix (see *Figure 2*). This matrix is designed such that the intensity level (category) recorded for a particular use because of a high rating for some intensity indicator is not reduced by a lower value obtained for another intensity indicator relevant to that use.

The intensity levels calculated for each individual non-agricultural use are then added together to produce a single measure which reflects the degree of multiple use of the grassland in question.

The measurement of management intensity follows the same approach in principle, though it differs in the detail. This management intensity is expressed as an intensity factor, bi. This intensity factor is calculated using figures for the number of cuts and grazings (n), the amount of nitrogen applied each year (d), the number of mechanical treatments (p), pesticide use (l) oversowing (yes/no) (u) and grassland improvement (yes/no) (g). These individual numeric expressions are standardised, weighted and then summed to give the overall intensity factor. The variables „number of cuts and grazings" and „nitrogen application" are gi-

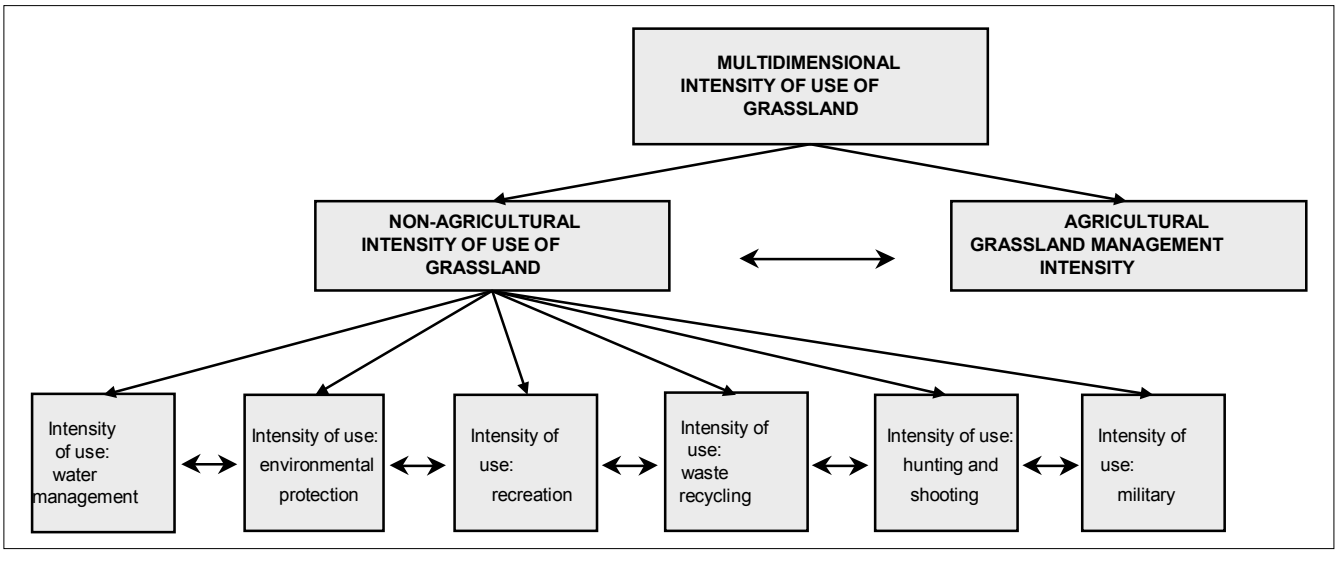

Figure 1: **Multidimensionality of use of grassland**

Table 1: **Intensity indicators used to measure the non-agriculture uses of grassland**

Type of use	**Intensity indicators**	*Answer category* never/rarely/ sometimes/often [0] / [1] / [2] / [3]	no/yes [0] / [3] /	none/very few/some/many [0] / [1] / [2] / [3]
environmental protection	• Management subject to environmental controls		x	
	• Landscape protection area		x	
	• National park			x
	• Prevalence of rare plant species			x
	• Prevalence of rare animal species			
water management	• Important for water supply		x	
	• Sensitive hydrological area		x	
	• Water protection area		x	
recreation	• Frequency of use for hiking	x		
	• Frequency of use for alpine skiing	x		
	• Frequency of use for cross-country skiing	x		
	• Frequency of use for paragliding	x		
	• Frequency of use for horse riding	x		
	• Frequency of use as a panoramic viewing area	x		
	• Frequency of flower picking activities			
	• Aesthetic value ("admired as a beautiful meadow/pasture")			
waste recycling	• Frequency of application of (composted) sewage sludge	x		
	• Frequency of application of composted organic waste			
hunting and shooting	• Frequency of use for hunting or shooting	x		
military use	• Frequency of use for military purposes	x		

ven a weighting of two, since partial statistical analysis showed that these two variables have a dominant influence on the degree of expression of the overall intensity factor. The variable „mechanical treatments" is also given a weighting of two, to account for the fact that this single variable actually represents several separate management practices, such as mechanical weed control, rolling etc. (see MAYER and WYTRZENS 1998).

Empirical measurements of both usage and management intensities on individual grassland parcels show that there is considerable variation in the extent of the demands placed on different areas of grassland (see PISTRICH et al. 1999).

Intensity level		Rating value for indicator y			
		0	1	2	3
Rating value for indicator x	0	0	I	II	III
	1	I	I	II	III
	2	II	II	II	III
	3	III	III	III	III

Figure 2: **Intensity matrix**

The key issue is therefore to identify which of the measured factors (variables) are most important in determining these relatively large differences in intensity. Theoretical considerations based on the available literature - and the results of our own pilot surveys - show that a wide range of factors play a role in determining the extent of grassland use.

The complex of determinants of usage and management intensity can be split into three distinct groups (see MAYER 1997). This division reflects the fact that grassland units belong to both ecological and socioeconomic systems:

- one group covers all those factors related to the biosphere, such as the prevailing vegetation ecology, pedology, climate and topography;
- a second group covers economic and social factors;
- the third group contains those factors which integrate both biotic / ecological and socioeconomic aspects. Examples include landscape, a healthy environment or the endangered status of plant and animal species.

The socioeconomic determinants impact at different levels (local, regional, international). The more important global or overlying socioeconomic determinants are:

- Macroeconomic situation (e.g. economic growth, market situation);
- Legislation (e.g. international trade agreements or environmental standards);
- Sociodemographics (e.g. population growth, top-heavy age distribution);
- Sociocultural factors (e.g. leisure and consumption habits, environmental awareness).

Key socioeconomic factors impacting at a regional or field level include:

- Degree of regional orientation towards tourism;
- Settlement density;
- Location and accessibility;
- Enterprise-level factors (land area, livestock numbers, milk quota, mountain farming zone etc.).

There are therefore a number of factors which impact on individual (or all) grassland uses, and whose importance varies from grassland parcel to grassland parcel. Their expression ultimately determines the level of intensity of each individual grassland use and the total demand placed on a grassland area.

4. Model structure and interdisciplinarity

The above sections have listed and grouped those factors of relevance to the usage intensity we are trying to explain. These lists and groups have two implications for the research:

❶ they give an indication of the basic configuration needed in a model that attempts to explain different grassland usage intensities, and

❷ they give an indication of the scientific disciplines required for the construction and differentiation of such a model.

The model clearly needs at least two main components, i.e. an ecological and a socioeconomic one (see *Figure*).

All ecological factors act as constraints, regardless of whether these factors are abiotic or biotic in nature. They determine which types or intensities of use are at all possible (see SCHEURER-LIETZ 1989, 20). In other words, these factors are the main determinants of the suitability of a particular grassland area for addressing particular needs or demands. Their importance is such that these factors may even preclude a particular grassland use (unfavourable pedological and climatic site conditions might, for example, preclude the use of the area as a water supply). At the same time, the actual uses made of grassland themselves impact on a range of ecological parameters, at least in the long term, with obvious implications for ecosystem functions and capacities (see OGLETHORPE and SANDERSON 1999). In appropriate circumstances, recreational activities such as skiing can cause changes in local plant species diversity, often limiting the ability of the grassland affected to meet the demands of environmental protection. Our research is not yet so advanced that we can properly model these dynamic interactions, but the ability to model these kinds of interdependencies remains a key objective.

The primary role of the ecological system in this research context is therefore the determination of potential usage. In a secondary role, the ecological system is itself changed by those uses that actually appear in practice. The socioeconomic system then acts on the basic potential determined by these natural conditions - socioeconomics determines which potential uses will be exploited by man (and to what extent). An effective explanatory model must contain elements which give plausibility to the diverse usage decisions faced by participants in the system. The socioeconomic component of the model therefore focuses on those factors which have the most influence on the relevant individual or collective behaviour or actions of both farmers and other users of grassland. The socioeconomic part of the model then represents the relationships between these determinants of behaviour or action and the various expressions of grassland use. Of course the model also has to take account of the probable existence of feedback mechanisms between economic determinants and both the type and intensity of actual grassland uses. A massive increase in grassland management intensity, for example, might exert downward pressure on meat and milk prices, which in turn might discourage input use in agriculture.

One of the challenges for model construction is clear from the above discussion, namely the proper treatment of cyclic relationships and inter-correlations between the numerous variables contributing to usage intensity. The coupling of the ecological and socioeconomic parts of the model is an equally difficult challenge (see DENT et al. 1995, JANSSEN and GOLDSWORTHY 1996). The various types of uses found on specific grassland units would seem to offer themselves as suitable candidates for such a connecting role. Grassland uses therefore act as central connecting points in the model presented here. At an organisational level, the individual grassland units form a common interface which all surveys must reference, regardless of whether these surveys are oriented toward the natural sciences or the social sciences. This interface is also the part of the model where the bridges between the different scientific disciplines participating in the research have to be built, in order to ensure the proper integration of the different contributions to the explanation of usage intensity.

The model structures are presented here in qualitative, graphical form. This does not, however, imply that these structures are not yet capable of mathematical representation. A graphical presentation is preferred for a number of reasons:

❶ didactic considerations (a graphical visualisation provides more clarity and a better overview);

❷ a more mathematical approach would be beyond the scope of this paper;

❸ it reflects the current position of the research. Only a few parts of the outline model structure are supported by enough data to allow detailed mathematical representation based on an empirical justification.

Continuation and consolidation of the interdisciplinary cooperation characteristic of the work to date is needed, if the research is to move forward and continue to yield useful results (see ISERMEYER 1996). The material presented here already makes it clear which disciplines have contributed to the definition and description of model structure, and which still have a (or a further) contribution to make.

The continued involvement of experts in agricultural ecology, particularly agricultural botany, is required. Plant growth is not only the basis for livestock husbandry, but also a potential resource for other uses of grassland, such as environmental protection or hunting.

The involvement of geographers is equally important. Their job is to explain the connections and relationships between grassland and the surrounding rural structure.

Production technologists are also required. As intermediaries between the ecological and socioeconomic systems, they are in the best position to identify the technical potential of grassland units.

Finally, agricultural and environmental economists have an important role to play as well. They need to address the social and economic motives or stimuli behind the human action and behaviour which impacts on grassland. They also need to address the socioeconomic effects of changes in the grassland ecosystem.

The common goal of all the disciplines participating in this research should be to further develop the modelling approaches presented in brief here, in order to produce results that:

❶ offer new scientific and theoretical insights;

❷ have practical value, providing the decision-making basis for a more rational policy towards grassland areas.

5. Summary

In summary we can say:

❶ that grassland use and management involves the close integration of ecological and economic phenomena;

❷ this means that a team of experts drawn from a range of disciplines is needed, if grassland use and management is to be properly analysed;

❸ that the appearance of differences in usage and management intensities can

be traced back to often quite different causes;

❹ that a realistic explanatory model will therefore need a relatively complex structure

❺ that the model concept as it stands can only be considered a preliminary stage in an ongoing and consistent development process.

Preliminary work with individual components of the full interdisciplinary model (which is still under construction) already shows that there are indeed plausible and complex relationships between economic/ecological variables and the intensity of use/management of grassland. The next stage of the research is concentrating on adapting the existing partial models so that they can be integrated within a single model.

References

BRIEMLE, G. and M. ELSÄSSER, 1997: Die Funktionen des Grünlandes. In: Bericht über die Landwirtschaft. Band 75/1997.

DENT, J.B., G. EDWARDS-JONES and M.J. Mc GREGOR, 1995: Simulation of Ecological, Social and Economic Factors in Agricultural Systems. Agricultural Systems 49, 337-351.

FLECK, P., 1985: Zur Bewertung der Mehrfachnutzung des Landes. Gießen: Dissertation, Justus-Liebig-Universität.

ISERMEYER, F., 1996: Organisation von interdisziplinären Forschungsverbünden in der Agrarforschung. Arbeitsbericht 1/96 des Instituts für Betriebswirtschaft der Bundesforschungsanstalt für Landwirtschaft Braunschweig-Völkenrode. Braunschweig: Selbstverlag.

JANSSEN, W. and P. GOLDSWORTHY, 1996: Multidisciplinary Research for Natural Resource Management: Conceptual and Practical Implications. *Agricultural Systems* 51, 259-279.

MAYER, C., 1997: Bestimmungsgründe unterschiedlicher Bewirtschaftungsintensitäten im Grünland. Wien: Diplomarbeit, Universität für Bodenkultur.

MAYER, C. und H.K. WYTRZENS, 1998: Ausgewählte sozioökonomische Determinanten der Bewirtschaftungsintensität im Dauergrünland des Mittleren Ennstales ? Modellbildung und empirische Ergebnisse. In: „Effizienz und Wettbewerbsfähigkeit in der Agrarpolitik". Dokumentation der 8. ÖGA-Jahrestagung am 24. September 1998 (in Druck).

OGLETHORPE, D.R. and R.A. SANDERSON, 1999: An ecological-economic model for agri-environmental policy analysis. *Ecological Economics* 28, 245-266.

PEVETZ, W., 1998: Die Multifunktionalität der österreichischen Landwirtschaft. Schriftenreihe der Bundesanstalt für Agrarwirtschaft Nr. 82. Wien: Eigenverlag.

PISTRICH, K.H., C. MAYER und H.K. WYTRZENS 1999: Sozioökonomik der Grünlandnutzungsintensitäten. (im Druck).

PISTRICH, K.H., 1999: Einzelflächenbezogene Intensitätsunterschiede der Grünlandnutzung und –bewirtschaftung. Wien: Diplomarbeit Universität für Bodenkultur.

RUBEN, R., H. MOLL and A. KUYVENHOVEN, 1998: Integrating Agricultural Research and Policy Analysis: Analytical Framework and Policy Applications for Bio-economic Modelling. Agricultural Systems 58, 331-349.

SCHEURER-LIETZ, T., 1989*:* Die Verfügbarkeit landwirtschaftlicher Ressourcen im Berggebiet. Konzeption und Anwendung landwirtschaftlicher Nutzungsszenarien (Testgebiet Grindelwald). Schlußbericht zum Schweizerischen MAB-Programm Nr. 38/1989 im Rahmen des UNESCO-Programmes „Man and Biosphere". Bern.

SPITZER, H., 1971: Die Landnutzung in der Massenkonsumgesellschaft. In: Berichte zur Deutschen Landeskunde. Band 45, Heft 1. Bonn-Bad Godesberg.

SPITZER, H., 1975: Der ländliche Raum: Raumordnungsgemäße Bestimmung, Gliederung und Entwicklung. Veröffentlichung der ARL: Beiträge. Hannover: Vincentz.

SPITZER, H., 1987: Überlagerung von Freiflächennutzungen. In: ARL (Hrsg.): Flächenhaushaltspolitik – Ein Beitrag zum Bodenschutz. Forschungs- und Sitzungsberichte, Band 173. Hannover: Vincentz.

SPITZER, H., 1991: Raumnutzungslehre. Stuttgart: Verlag Eugen Ulmer.

STOYKE, C., 1995: Die Ökonomik einzelbetrieblicher Anpassungsmaßnahmen an Extensivierungsauflagen in der Pflanzenproduktion. Landwirtschaft und Umwelt: Schriften zur Umweltökonomik Bd. 11. Kiel: Wissenschaftsverlag Vauk.

WYTRZENS, H.K. 1994: Agrarplanung - Grundzüge der landwirtschaftlichen Raumplanung in Österreich. Wien, Köln, Weimar: Böhlau Verlag.

WYTRZENS, H.K., 1995: Grünland als Element der Agrarraumgestaltung. In: Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA) (Hrsg.): Kongreßband 1995 Garmisch-Partenkirchen. Grünland als Produktionsstandort und Landschaftselement und weitere Beiträge aus den Sitzungen der Fachgruppen. Darmstadt: VDLUFA-Verlag.

WYTRZENS, H.K. und C. MAYER, 1998: Unterschiedliche Nutzungs- und Bewirtschaftungsintensitäten im Grünland des Mittleren Ennstales und ihr sozioökonomischer Hintergrund. Forschungsbericht Band 3. Wien: Selbstverlag.

ZANETTI, G., 1999: Strukturwandel und Flächennutzungsänderungen in der österreichischen Landwirtschaft. ÖROK Schriftenreihe Nr. 145. Wien: Selbstverlag.