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Decision support for grazing management: evaluation of suitability and estimation of potential on alpine pastures for sheep and goats

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Abstract

In this paper a methodology for both a qualitative and quantitative assessment of suitability and potential of grazing areas based on GIS (Geographical Information Systems) is presented. In the past, the use of Alpine pastures during summer was an economical resource for farmers, which became neglected due to intensification of agriculture after World War II. Nowadays Alpine pastures are becoming important again, mainly because of new demand for typical, local products, but also because the extensive management on alpine pastures creates landscapes of high touristic value and high biodiversity. However, this requires new solutions for management of mountain pastures, or more generally, the development of innovative land management tools.

Keywords: cultural landscape, land management, remote sensing

Introduction

High pastures play a central role in the Alpine region; nevertheless they became neglected due to intensification of agriculture after World War II. On the other hand, the intrinsic extensive character of mountain pastures, its contribution to natural biodiversity and to landscape variability and amenity became more and more in line with the current public and social demands placed on agriculture in Europe. As an example, it is precisely the relation between livestock and pastures, which was used by the OECD (Organisation for Economic Cooperation and Development) as an example of multifunctionality, i.e. 'inputs, which may create no fixed, indirect linkage between commodity (milk) and non commodity outputs (pastoral landscape)' (OECD, 2003). Following this trend, sheep and goats are regaining their importance for at least two reasons: First, because in many areas cattle farming declined, which lead to an upward trend of small ruminant breeding. Second, goats and sheep are particularly suited for low-intensity farming and for multifunctional use of marginal resources. This would suggest that it is reasonable to abandon the usual residual approach in favour of small ruminants, i.e. giving them what is left after cattle needs have been met. In the frame of the project 'Alpine network for sheep and goats promotion for a sustainable territory development' – AlpiNET GHEEP - supported by the European Community Initiative Programme INTERREG IIIB Alpine Space, one target was therefore the development of innovative land management and production tools in order to pursue the strategic aim, the promotion of sheep and goat breeding in the whole Alpine area. One component, presented in this paper, was to develop an assessment of suitability and potential for designing and shaping future grazing strategies. This was realized with two approaches developed through interdisciplinary work: The first one is a qualitative approach ('...evaluation of suitability') and the second one is a quantitative approach based on the newly developed ENEALP software ('...estimation of potential'). The software program analyses

the energy flow on alpine pastures (ENE = energy, ALP = alpine) and gives an estimation on the number of animals that can be pastured.
The results of this study stem from a joint effort of four ALPINET GHEEP project partners: The Agricultural Research and Education Centre Raumberg - Gumpenstein (Austria), the Research Centre of the Agricultural Institute of San Michele all'Adige (Trento, Italy), the Breeders' Provincial Association of Belluno (Italy) and the Regional Agency for Rural Development Friuli Venezia Giulia (Italy).

Methodology

To reach the goal and to be able to cover all requirements – both the estimation of suitability and potential – two different, but complementing approaches were chosen: A more field oriented, qualitative one (expert system) and a strictly quantitative model-oriented one. The first can only characterize the qualitative suitability of specific alpine pastures for selected species of animals. The model-oriented approach is applicable on a wider, more general spatial scale and additionally enables a quantitative estimation of the energy content and forage potential, making an estimation of how many animals can be sustained by a certain area. The quantitative model is called 'Pasture Evaluation Model' (PEM) and is based on the combination of GIS-methods and expert knowledge of plant production. The original model was set up by Egger, Angermann, Aigner and Buchgraber in 2003. For the AlpiNET GHEEP Project it was adapted and complemented with remote sensing methods and better adaptation to local biotope types and yield functions to reach a purely quantitative approach (Blaschka *et al.*, 2007, Guggenberger *et al.*, 2007). The PEM is a multivariate data-model to estimate the quality and quantity of an alpine pasture. The basis of all calculations concerning the need of the animals is the assumption that for sustainable use, a pasture has to bring at least a yield of 8 Megajoule (MJ) metabolizeable energy (Steinwidder, 2002). The assessment of suitability analyses individual spatial entities under different aspects, which have to be determined in the field. The factors reflect the needs of the animals and have an alternating effect. For each factor, an ordinal score was developed and is assigned based mainly on expert's knowledge and experience of farmers. The scores are modelled after the 'Land Suitability Classes' of the Food and Agriculture Organisation (1976), see Table 1.

Basic data

For both parts of the analysis, the first step is to acquire basic ecological data on the area, especially land cover, vegetation and climate. Vegetation has to be classified according to the so-called structural types defined in the „Pasture Evaluation Model' (PEM). These types compromise in this case typical biotopes found in the subalpine and alpine vegetation belt in the Alps: Rich pasture, rough pasture, tree pasture, tall herbs, shrub formations, bush formations, alnus sp. formations, tall conifer shrubs, wood, and finally unproductive areas.
To evaluate the suitability of the different vegetation types for sheep and goats grazing both bibliographic sources and the knowledge of experts was used. Since most of the studies published on grazing on open land of small ruminants, particularly goats, refer to Mediterranean environments, the experts' know how was very important to calibrate the qualitative model. Especially for the qualitative model productivity, water availability, slope, structural fragmentation and accessibility of the specific study area was assessed, either by GIS or field study. In general, the model is designed that additional parameters can easily be incorporated.

Table 1. Suitability scores assigned to the indicators (FAO, 1976, modified).

Land suitability class	Suitability score	Description
S1: Highly suitable	5	Land without significant limitations. Include the best 20-30% of suitable land as S1. It is not perfect, but the best which can be found
S2: Moderately suitable	4	Land that is clearly suitable, but has limitations that either reduce productivity or increase inputs needed to sustain productivity, compared to S1 land
S3: Marginally suitable	3	Land with significant limitations in regard to productivity/production costs
N1: Currently not suitable	2	Land with limitations to a sustainable use that can not be overcome at a currently reasonable cost
N2: Permanently not suitable	1	Land with limitations that can not be overcome
Not grazed	0	

Qualitative approach

The qualitative approach assesses individual spatial entities under different aspects, which have to be determined in the field. The factors with their assigned score reflect the needs of the animals and have an alternating effect. Overall, high points guarantee best conditions; poor conditions correspond to lower scores. The assessment can be done in parallel for different species, according to their demands: Cattle, especially dairy cows, have high demands, in contrary to sheep and goats. Wild animals can even get along in areas with the lowest scores.

The following usage classes were set:

- High: cattle, including diary cows, above 4.25 points.
- Medium: sheep and goats, between 3.25 and 4.25 points.
- Low: wild animals, below 3.25 points.

The obligatory criteria to calculate the suitability score of a certain pasture are:

- Vegetation type.
- Water availability.
- Slope.

Additionally, depending on data availability, based on the following criteria the results can be refined:

- Productivity analysis.
- Structural fragmentation of pastures.
- Accessibility.
- Sheep stocking rate estimation.

For the detailed scores for vegetation type, water availability and slope as examples, see Tables 2 to 4. The values calculated can be used to produce different thematic maps, or all together as mean make up the overall suitability score which then is used to produce a 'suitability map' (see results) for the pasture studied.

Table 2. The structural types as defined in the 'Pasture Evaluation Model' and used for classification of vegetation in both approaches. Also shown are the suitability scores used in the qualitative approach.

Structural type	Sheep	Goat
Rich pasture	5	5
Rough pasture	4	4
Tree pasture	3	3
Tall herbs	2	3
Shrub formations	2	3
Bush formations	2	3
Alnus spp. formations	2	4
Tall conifer shrubs	1	1
Wood	1	1
Unproductive	0	0

Table 3. Suitability scores for water availability.

Distance from water [km]	Suitability score
0.0-0.5	5
0.5-1.0	3
1.0-1.5	1
> 1.5	0

Table 4. Suitability scores for slope.

Slope [°]			
Sheep	Suitability score	Goat	Suitability score
0-20	5	0-20	4
21-45	3	21-40	5
> 45	1	41-50	3
		50-60	2
		> 60	1

Quantitative approach

The basis of the quantitative model is the abstract design of the Pasture Evaluation Model (PEM). It can be applied worldwide to every alpine-pasture-like area. Adaptation to local biotope types and derived structural types and yield functions, however, is an absolute necessity for a specific, local use. Following a purely model-oriented approach, the quantitative model of the ground-cover information is taken from the evaluation of a SPOT 5 satellite image (SIRIUS). The environmental factors determining the potential of a pasture have been converted into various formulas and functions. Examples are the duration of vegetation period or the average energy content of a specific forage type. The groundwork for this part was done in the basic work of Egger et al. (2003) and in the project 'Höhenprofil Johnsbach' (Gruber *et al.*, 1998), which is used for the local definition of yield functions in the eastern part of the Alps (Austria). The following results are calculated: Optimum forage- and energy yield (maximum theoretical volume), local forage- and energy yield (realistic volume), potential (balance from local need and yield)

At the trial sites of the 'Höhenprofil Johnsbach', alpine forage was manually harvested on site and conserved into hay without loss of residue. This was fed to male sheep in a digestion trial to define the exact usable energy content (in vitro digestibility, see GFE 1991, GFE 1998). The trial was repeated between 1994 and 1997.

For the calculation of annual precipitation and precipitation during the vegetation period, data for the whole Alpine region is available from the ALP-IMP project (see http://www.zamg.ac.at/ALP-IMP, last visit Sept. 24th, 2008). Cadastral data for core pastures, land-register borders and regional borders are obtained from the local agricultural administration.

The work flow for the model takes five steps to reach the results, explained in details as follows:

- Step 1. Estimation of land-cover classes by classifying vegetation and yield types. A conceptual model in the PEM for the estimation of energy quantum based on several Alpine pastures as examples was developed. Based on its realisation, the expert differentiation of various classes of ground cover has been given. This differentiation is roughly planned and summarises its members in the following biotope types: alpine pastures, dwarf-shrub heath land, bushes, pastures with trees, forests, infrastructure, vegetation-free areas, and water. Above all, the alpine pasture class is of great significance because it is a nutrition-rich sector. The alpine pastures are differentiated according to their vegetation types as rich pastures and rough pastures. Nine differing classes form the basis on which a near-natural or cultural landscape of the Alps can be characterized (the structural types, see methodology). For large areas, this work is done most efficiently with remote sensing in combination with a supervised classification (Schowengerdt 1997).
- Step 2. The nine structural types are abstracted in the second stage from their described character and given as a quantity regression. This is strongly coupled with the usability as animal forage and is thus known as a forage type. Those types show forage types of differing levels of quality, from very low growth (1,400 kg DM/ha, DM = Dry Matter) to very strong growth (3,800 kg DM/ha). This allocation is dynamically connected to the vegetation period within the most important classes and describes, for example, the alpine pasture structural type with the forage type as medium to very low growth in a second- degree polynomial ($y = (2.407 - 0.0814\ x + 0.0011\ x^2) * 100$, x = vegetation period). The vegetation period is derived from the altitude in differing climatic areas (Harflinger and Knees 1999). A similar model for the assessment of the energy content of the forage is used.
- Step 3. Basic GIS-methods, adjustment of yield using an expert system. The first assessment of dry matter yield and energy concentration leads to an „optimum energy yield'. This is a gross estimation that has to be adapted in a further step to local conditions. This adaptation requires an expert system, which comprises a series of local parameters and can calculate the volumes of concentration reductions (Harflinger and Knees, 1999). The local parameters comprise the annual precipitation during the vegetation period, altitude, slope inclination and exposition of each site, as well as the intensity of grazing (stock density). The expert system reduces the „optimum energy yield' to a realistic „local energy yield'.
- Step 4. Estimation of energy content by classifying vegetation and yield types. The PEM offers its users an ordered procedural structure and series of formulas and key features for calculating

the local energy yield. To support the expert basis connected with rich and rough pastures, it is complemented by the systematic trials of the 'Höhenprofil Johnsbach' (see the beginning of this chapter). Based on these trials, the energy content of a given vegetation type can by estimated, and is embodied in easily understandable and high-quality formulas.

- Step 5. Energy balance and quality control of the results using real animal grazing. A mass balance can be carried out if these parameters are put in relation to the requirements of energy and forage for the grazing animals. This data (and of the previous step) is the basis for the production of maps of pasture potential (see results for an example).

ENEALP – the software

The software ENEALP (download free of charge from http://www.raumberg-gumpenstein.at/cms/index.php?option=com_docman&task=doc_details&Itemid=&gid=2358) offers a user friendly input mask for the necessary parameters, and stores all results in a geo-database, which means, all data has a spatial reference. The single pixels are given in a relational tupple with clear X/Y coordinates and linked with all necessary information, above all with the identification given to each alpine meadow. The result is a relational database that permits all calculations of animal feeding (e.g. energy requirements of the animals per pasture). For an efficient use of the available resources with different species (for example cattle and sheep), the pixels representing the best energy yield, which are located at the lowest parts and are easily accessible are allocated to cattle, as this species is the most demanding (cf. qualitative approach). The middle range can only be used efficiently (without over-utilisation) with sheep. The parts with the lowest energy yield remain for wild animals. This distribution of resources is again transferred into a geo-dataset. Thus, a modern pasture management for a sustainable use of available pastures can be achieved, building the core for an innovative management of cultural landscapes.

Results

Both approaches were tested in the frame of the aforementioned AlpiNet GHEEP project. The study areas are situated in Italy, in the region of Friuli Venezia Giulia, in the Province of Trento and in the Province of Belluno. In Austria, the study area is located in the Niederen Tauern, Styria. As the scope of this paper focuses on the methodology, only one representative example for each approach is given.

Qualitative approach

For the qualitative approach, the results from the malga (Italian term for alpine pasture) Covel are presented. The pasture stretc.hes over an area of 350 ha, completely within the Stelvio National Park (province of Trento). During 2006, when the botanical relevees were made, 266 goats (partly in lactation) and 225 sheep were kept on the pasture. Two shepherds took care of the cattle, but controlled grazing is practiced only for the dairy goats. The total area is 350 ha, the altitude is between 1,520-2,560 m.a.s.l. The map resulting from the qualitative assessment can be seen in Figure 1.

Quantitative approach

The Austrian study area is situated in the south-western part of the district of Liezen in the Schladminger Tauern (Province of Styria, Geocentre: 13° 53' E, 47° 22' N), south of the river Enns between the towns Schladming and Irdning. The Southern border is formed by the crest of the Niederen Tauern, which are further subdivided in Wölzer (Eastern part of the study area) and the

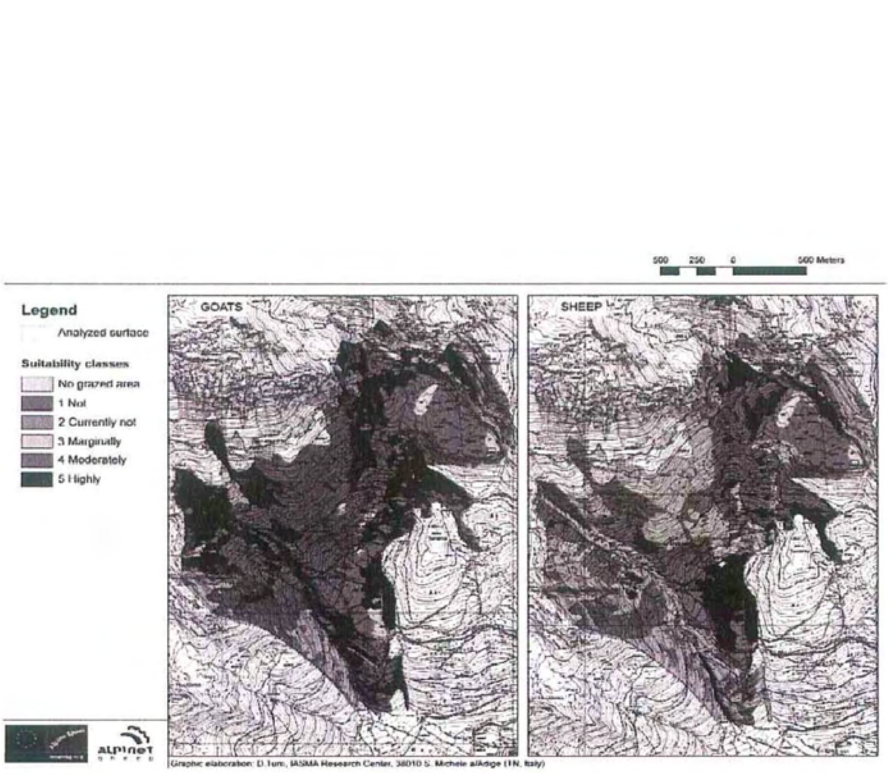

Figure 1. The suitability map of the malga Covel in the province of Trento, Italy.

Schladminger Tauern (western part). In this area (from East to West) the Sölk valley, the Untertal, the Obertal and the Preunegg Valley are found. For the area of the Kleinsölk Valley, an evaluation of the potential was performed: For manually selected pasture zones the potential and the possible number of sheep has been calculated: The region requires 2,300 sheep for grazing annually. But in a rotation process over several years, a herd of 700-800 animals can suffice to meet the need. The results are depicted in Figure 2.

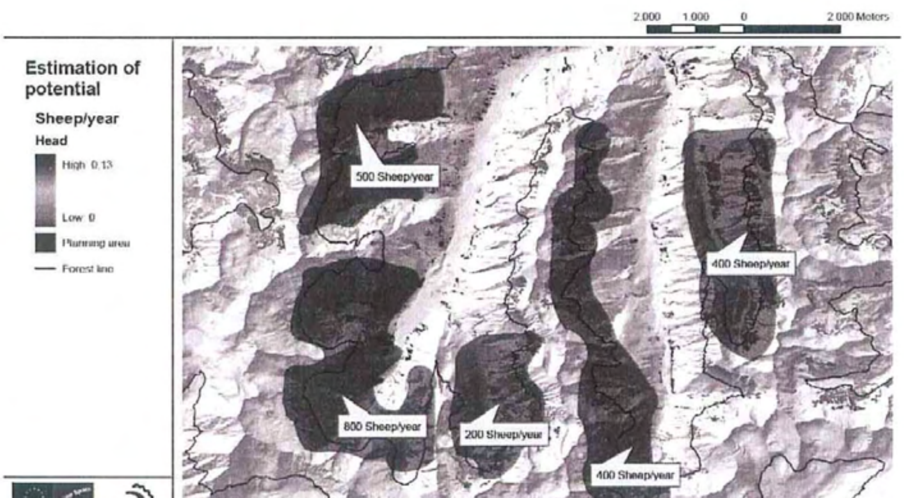

Figure 2. A planning case for the estimation of potential of sheep pasturing in the Niederen Tauern, Austria.

Discussion

This work is based on the application of information technologies, both in the field of Geographical Information Systems (GIS) and remote sensing, which allow studying a territory in a global way. The availability and the development of these technologies, which occurred in the last decade, allow integrating the experimental data based on field assessments, the management experience of experts and instrumental data obtained from cartography and satellite images. Yet the computing approach, although pragmatic, is incomplete if the knowledge and the local culture of the breeders are not considered. The sharing of information among breeders, administrators and technicians operating in the alpine area regions is a prerequisite for model qualifying and implementation. The first results represent a first step that could become a useful tool for territorial evaluations. Currently, a national follow-up project is under way, with local sheep breeders, where besides the promotion of sheep pasturing in the region, the model is further tested, especially to help re-use already abandoned areas or areas on the verge of being abandoned. The application of the model suggests future improvements, depending on the development of more accurate computing instruments and software, as well as enhancing the collection of experimental data about the vegetation and feeding behaviour of sheep and goats on alpine pastures. Further need of research was found in the classification of vegetation based on satellite images, which has been started to meet in the meantime. Another area with need for improvement is the mutual integration of both approaches: The qualitative approach can only characterize the suitability of specific alpine pastures for selected species of animals; the quantitative approach is applicable on a general spatial scale and enables an estimation of energy content and forage potential. So both approaches complement each other, both on data and spatial scale/level. In the realm of the quantitative part, the calculation of the cost-distance to the nearest water should be implemented differently, the current one brings sometimes inconsistencies in the results.
Additionally, the software ENEALP, which implements the model, is tightly coupled with expensive, closed source software and is only for a single workplace – no integration in an existing server-environment is possible at the moment. It is planned to re-implement the software based on existing free and open source programmes and libraries, following a distributed client-server architecture, which can easily be integrated in existing infrastructure.

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